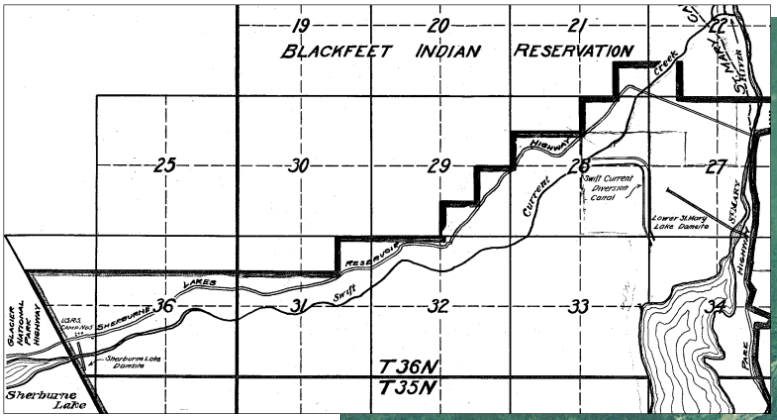
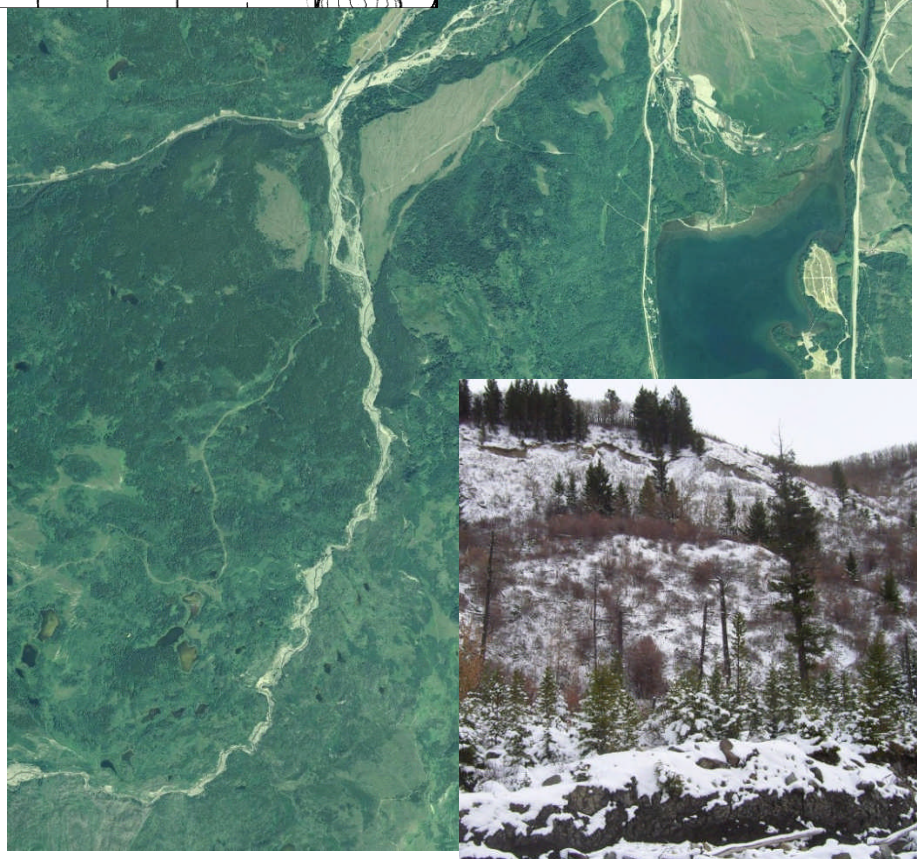
BOULDER / SWIFTCURRENT CREEK STABILIZATION PROJECT

Phase I Investigation

Final Report





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February, 2010

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1. Executive Summary

Swiftcurrent Creek drains an area of approximately 100 sq. miles in northwest Montana near the town of Babb, on the border of Glacier National Park and the Blackfeet Indian Reservation. Swiftcurrent Creek is tributary to the Saint Mary River, which flows north into Canada, emptying into the Saskatchewan River before ultimately making it to the Hudson Bay. Over geologic time, Swiftcurrent Creek has developed an alluvial fan at its confluence with the Saint Mary River. This fan is at least partially responsible for the formation of Lower Saint Mary Lake.

In 1914 the United States Bureau of Reclamation (BOR) began construction of Sherburne Dam, a 94 ft tall earth embankment dam, on Swiftcurrent Creek. Sherburne Dam provides storage of water for the off-reservation Milk River Irrigation Project by way of the Saint Mary Canal. Additionally, in the early 1900's, the BOR constructed a dike on the Swiftcurrent Creek alluvial fan which redirects flow towards and into Lower Saint Mary Lake.

The Blackfeet Tribe has expressed concerns for a number of years over problems that have arisen as a result of the construction of these facilities on reservation lands, including:

1. Flooding of Tribal property adjacent to Swiftcurrent Creek,
2. Sediment accumulation in Lower St. Mary Lake is causing a negative impact to the fishery,
3. BOR operation of Lake Sherburne is adversely affecting the quality of fish habitat from the dam to Lower St. Mary Lake.
4. Seepage is occurring from the St. Mary Canal which is damaging tribal lands.

In 1964 Swiftcurrent Creek experienced its flood of record, an event which has been estimated at a 250-year recurrence interval. Swiftcurrent Creek below Sherburne Dam has been in an unstable condition since this flood, and additional delivery of sediment to Lower Saint Mary Lake has occurred. To address these concerns, a cooperative data collection effort between the BOR, the Blackfeet Nation, the US Fish and Wildlife Service, and the US Geological Survey was undertaken to study stream channel characteristics, stream flows, sediment transport regimes, bank stability, and fish habitat. As part of this effort, a report was prepared by West Water Consultants, Inc. (WWC) titled "Design for Stabilization and Reconstruction of Swiftcurrent Creek and Boulder Creek near Babb, MT". This report was submitted in its draft form in 1998, with the intent that additional alternatives analysis and investigations would be completed prior to construction.

In the intervening years since submittal of this report, revised hydrologic flow estimation methods have been developed as well as advancements in the science of sediment transport, and the realization was made that, a review of the methodologies employed through the original study was warranted. DOWL HKM was tasked with reviewing this report and completing a reconnaissance evaluation of data needs and additional investigations; this current effort has been termed Phase I, and is intended to culminate in a plan which will provide the framework for future work and ultimate implementation of stabilization measures.

The following tasks were included as part of the Phase I Scope of Work.

1. Survey Review: to resurvey critical areas and collect sufficient data to draw general conclusions concerning channel stability in the intervening years since the 1995 data collection.
2. Channel Migration and Delta Growth Mapping: to investigate and document the presence of mass sediment sources to Swiftcurrent and Boulder Creeks as well as to document channel changes or changes in stability that have occurred.
3. Watershed Hydrology Review: to update the hydrology using current hydrologic methods to estimate instantaneous peak flows and the monthly timing of peak flows under both existing conditions (dam regulated) and natural conditions. The main purpose of this review was to gain a general understanding of the role that man-induced changes to hydrology play in the instability and other problems that are being experienced in the Swiftcurrent Creek watershed.
4. Sediment Transport Review: to review the sediment supply sources within the watershed as well as the primary findings of the WWC report, and to provide a reconnaissance investigation into the effects of Sherburne Reservoir operations on the sediment transport capacity of Swiftcurrent Creek.
5. Geomorphology Review: to review the geomorphic findings of the WWC report and the appropriateness of the reference reaches used.
6. Review of Potential Mitigation Measures: to evaluate the appropriateness of the restoration objectives, design alternatives, and design concepts presented in the WWC report and to indentify addition mitigation alternatives.

The following paragraphs provide a brief summary of the conclusions of the Phase I study:

Comparison of current Swiftcurrent Creek bed elevations and cross sections below the Swiftcurrent / Boulder confluence to previously surveyed data does not conclusively indicate a trend in either excessive aggradation or degradation, nor does it support the notion that the channel is trending from a single main thread channel to a braided stream. However, major shifts in alignment have occurred, indicating a dynamically changing environment. These shifts are the apparent result of sudden pulse movements of sediment which obstruct the active channel and cause reactivation of previously blocked or abandoned channels or the creation of new channels. The dynamically changing nature of the Boulder/Swiftcurrent system as well as the difficulty in stabilizing this system, as observed through the previous reconstruction experience, reinforces the need for a more comprehensive understanding of the sediment transport regime, the interrelated hydrology, and the geomorphology of the system.

The 1964 flood event was significant and had long-term impacts with lasting effects. The flooding that occurred in 1975 and in 1995 also appears to have significantly impacted the stream channel. Major shifts in the active channel location within the flood-prone area were documented. The Swiftcurrent and Boulder Creek basins are dynamic and portions of the streams have exhibited significant channel instability over time and are likely still in a period of instability. Before streamtypes can be applied or reference reaches identified, a better understanding of the stability or instability of the Swiftcurrent/ Boulder Creek system is needed and will be a focus of future evaluations.

The dike constructed by the BOR in the early 1900's redirects Swiftcurrent Creek along an alignment which now discharges into Lower St Mary Lake. The delta that occupies the mouth of Lower St Mary Lake is progressively advancing. This delta, estimated at 166 acres in 1953, was found to have expanded to an estimated 187 acres by 2005.

Preliminary investigations into Sherburne Dam operations reveal that current dam operations are affecting the Swiftcurrent Creek spring runoff hydrograph through: reducing peak flows, and altering the timing of the spring hydrograph. The cumulative effect of these changes is a dramatic shift in the shape of the hydrograph from what would otherwise be experienced under natural conditions. The impact of Sherburne Dam operations on peak flood flows is estimated to range from a reduction of about 900 cfs for the 2-year event, to a reduction of 3,200 cfs for the 100-year event.

Each of these changes to the runoff hydrograph affects the sediment transport capacity in Swiftcurrent Creek. Development of a sediment rating curve for Swiftcurrent Creek will allow additional investigation into the affects of regulation on sediment transport capacity. Further examination of the effects of Sherburne Dam and the potential to restore a more natural flow pattern should be completed prior to selection of any mitigation alternative. Additionally, a more refined flow analysis at the daily flow level is recommended, as more detailed data will be necessary for this sediment transport analysis.

Many potential mass sediment sources were identified in Swiftcurrent and Boulder Creeks. These sources appear capable of providing an unlimited supply of sediment to the stream. Stabilization at the source to limit additional erosion and sediment recruitment would need to be very extensive and would likely be very costly. The actively eroding sediment sources were observed to consist primarily of fine material with limited coarse sediment.

Several critical deficiencies exist in the WWC sediment transport analyses that limit the usefulness of the results, and cast doubt on the ability of these results to support the design recommendations. The most notable deficiencies are the error inherently introduced by the sampling methods used and the inability of the sediment rating relationships to provide estimates of sediment transport at flows higher than the 2-year recurrence interval flow. The WWC study also stops short of addressing all factors influencing the instability of Swiftcurrent Creek, most notably the altered hydrology resulting from Sherburne Dam operations. Review of the WWC sediment transport study supports the need for further sediment transport analyses prior to final design and/or implementation of mitigation measures.

Through the current review of the Swiftcurrent watershed hydrology as well as the review of the sediment transport analyses completed through the WWC study, deficiencies are apparent which affect the viability of the WWC conceptual design. The results of the Phase I reconnaissance investigation indicate that a more thorough understanding of the Swiftcurrent Creek system is necessary prior to implementation of any potential mitigation measures.

The following general list of work elements summarizes the recommendations of this Phase I evaluation, presented in order of logical occurrence; however, actual sequencing of tasks will likely vary.

1. Refinement of Project Purpose and Goals
2. Additional Data Gathering
3. Cultural Review
4. Hydrologic Data Collection
5. Additional Aerial Photography
6. Reference Reach Refinement
7. Topographic Mapping
8. Sediment Transport Analysis
9. Sherburne Dam Operations Analysis
10. Alternatives Analysis
11. NEPA Compliance
12. Final Design and Implementation Plan

2. Introduction

On June 17, 2009 a Stakeholders Meeting and a Work Group Meeting were held in Browning, MT to discuss the Swiftcurrent Creek and Boulder Creek Stabilization Project. The Work Group Meeting included a discussion on the need to review previous work efforts and studies. Specifically, the report prepared by West Water Consultants, Inc. (WWC) titled "Design for Stabilization and Reconstruction of Swiftcurrent Creek and Boulder Creek near Babb, MT" was identified for review. DOWL HKM was tasked with reviewing this report along with preparing a Phase I work plan for a reconnaissance evaluation of data needs and additional investigations to guide the ultimate implementation of stabilization measures. The Phase I Work Plan developed by DOWL HKM was reviewed and approved by the U.S. Bureau of Reclamation (BOR) and the Blackfeet Environmental Office (BEO) and work began in earnest in October 2009 in coordination with BOR and BEO staff. The purpose of this report is to present the methodologies and findings of the Phase I reconnaissance investigation and to present a framework for additional evaluations to be performed in the future.

A vicinity map of the Swiftcurrent Creek watershed is shown on Figure 1.

2.1. Scope of Work Summary

The primary goal of the Phase I work plan is to identify issues that need to be expanded upon in the future for successful implementation of a Boulder / Swiftcurrent Creek Stabilization Project. The following tasks were included as part of the Phase I Scope of Work.

7. Survey Review
8. Channel Migration and Delta Growth Mapping
9. Watershed Hydrology Review
10. Sediment Transport Review
11. Geomorphology Review
12. Review of Potential Mitigation Measures

The methodologies and findings for each of these tasks are presented in the following sections.

2.2. Background on Swiftcurrent Creek Watershed

2.2.1. Concerns of the Blackfeet Tribe

The Blackfeet Tribe has expressed concerns for a number of years about problems that have arisen as a result of the facilities constructed by the BOR on the Reservation. Four of these concerns were documented in letters exchanged between the BOR and the Blackfeet Tribe in 1991, including:

13. Flooding of Tribal property adjacent to Swiftcurrent Creek,
14. Sediment accumulation in Lower St. Mary Lake is causing a negative impact to the fishery,
15. BOR operation of Lake Sherburne is adversely affecting the quality of fish habitat from the dam to Lower St. Mary Lake.
16. Seepage is occurring from the St. Mary Canal which is damaging tribal lands.

Figure 1: General Vicinity Map

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December, 2009 ccvs

2.2.2. Previous Studies

To begin to address these concerns, a data collection effort was undertaken by several cooperating government agencies in 1995. Data collected included stream channel characteristics, streamflow, sediment transport, bank stability, and fish habitat. WestWater Consultants (WWC) was contracted to assist in the design and implementation of the data collection effort. WWC used the information collected to prepare a design for stabilization and reconstruction of the project area. WWC prepared a draft report in 1998 that summarized the data collected over a two year period and presented a design for reconstruction of Swiftcurrent and Boulder Creeks from their confluence to the county road bridge. As background information to illustrate its scope, the following excerpt from the WWC report has been included below:

> *Swiftcurrent Creek downstream from Sherburne Dam has been in an unstable condition since the flood of 1964, which has greatly increased the amount of sediment supplied to Lower Saint Mary Lake. The stream channel undergoes major changes in response to even frequent flood events and has been a concern to adjacent property owners. To address these concerns, a cooperative data collection effort was completed between the US Bureau of Reclamation (USBR), the Blackfeet Nation, US Fish and Wildlife Service, US Geological Survey and others in 1995 to study stream channel characteristics, streamflows, sediment transport regimes and bank stability, fish habitat and populations and other information.*
>
> *WWC and associate, Water Consulting, Inc. was contracted to assist in design and implementation of the data collection effort and to use the information to prepare a design for the stabilization and reconstruction of the project area.*

The study area of the WWC investigation was subdivided into six stream reaches (Reaches 1 through 6) for purposes of presenting the discussions.

2.2.3. Stream Reaches

For consistency, the stream reaches defined in the 1998 investigation are also adopted for this Phase 1 Study. Four additional stream reaches were added in order to discuss the upper basins of Swiftcurrent and Boulder Creeks. Stream reaches are presented on Figure 2. One stream reach (referred to as the Upper Reach of Swiftcurrent Creek) is located upstream of Reach 6 and includes Lake Sherburne, and the very upper section of Swiftcurrent Creek. Three reaches (Reach 7, Reach 8, and Upper Reach of Boulder Creek) were added above Reach 1 on Boulder Creek. The following table summarizes the general stream reach characteristics from upstream to downstream.

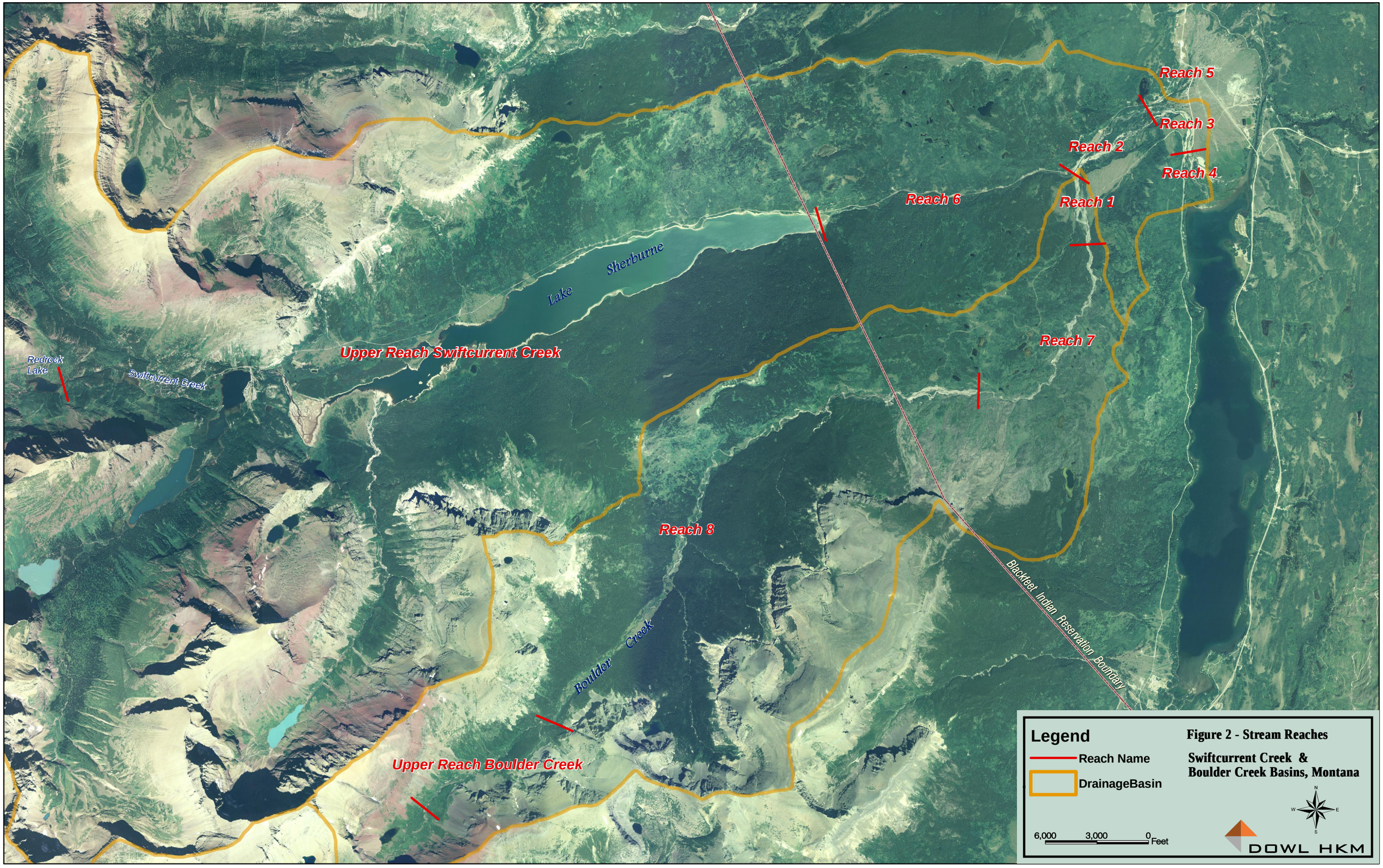

Figure 2 - Stream Reaches

Swiftcurrent Creek & Boulder Creek Basins, Montana

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Table 1 - Stream Reach Summary

Stream Reach	Creek	Length (miles)	Gradient (%)	Geologic Units Present Along Channel
Upper Reach of Boulder Creek	Boulder	2.0	4.1	Qgc
Reach 8	Boulder	8.6	1.4	Qlt and Qal
Reach 7	Boulder	2.9	3.0	Qlt and minor Qal
Reach 1	Boulder	0.9	2.7	Qlt and Qal
Upper Reach of Swiftcurrent Creek (Redrock Lake to Dam)	Swiftcurrent	10.0	0.4	Qgc upstream of Lake Sherburne; Qal and Qlt along Lake Sherburne
Reach 6 (Dam to confluence with Boulder Creek)	Swiftcurrent	3.3	0.8	Qlt and minor Qal
Reach 2 (from confluence with Boulder Creek downstream to ~Sta 172+03 to 103+91)	Swiftcurrent	1.3	1.4	Qlt and Qal
Reach 3 (~103+91 to 60+03)	Swiftcurrent	0.8	1.5	Qlt and Qal
Reach 4 (60+03 to lake)	Swiftcurrent	0.8	0.5	Qal
Reach 5 (1900's [original] channel to canal)	Swiftcurrent	1.4	1.3	Qal

2.2.4. Basin Geology

A generalized geologic map is presented in Figure 3. Several published maps (Cannon 1996, Carrara 1990, Earhart and others 1989, Mudge and Earhart, 1983, and Harrison et al. 1998) were referenced to create this map. Some geologic contacts between bedrock and surficial deposits were modified and active landslide and debris flow areas were mapped based on aerial photo review conducted by DOWL HKM. The following discussion applies to both Swiftcurrent and Boulder Creek basins but is referred to as the Swiftcurrent Creek basin. Bedrock is mapped as an undivided unit (BR) on the generalized geologic map (Figure 3); however, a brief discussion of individual bedrock units follows.

The Swiftcurrent Creek basin is located within an area of complex geologic structure. Generally speaking, tectonic forces thrusted sedimentary rocks upward from west to east. The major structural feature in the area, the Lewis and Clark Thrust Fault, brings older rocks (Proterozoic age) over younger rocks (Upper Cretaceous age) in the upper portions of basin (Harrison et al. 1998). The Akamina Syncline is another predominant structural feature in the basin. The upper Swiftcurrent Creek Basin drains this westward-dipping sequence (eastern limb of the Akamina Syncline) of argillite, quartzite, quartz arenite, dolomites, and stromatolitic limestones belonging to the Belt Supergroup (Harrison et al. 1998 and Earhart and others, 1989). The rock units present within the basin include: Snowslip (Ysn), Helena (Yh), Empire (Ye), Grinnell (Yg), Appekunny (Yap), and the Alytn (Ya) formations. A series of mafic lava flows is also present in the upper basin and is referred to as the Purcell Sill or Purcell Lava (Ypr). These bedrock units are very resistant to weathering and supply little sediment to the stream (Clark, 2000).

The Upper Cretaceous sedimentary rocks present within the basin include the Two Medicine formation (Ktm), Virgelle Sandstone and Telegraph Creek formation (Kvt), and Marias River Shale (Km). These units consist of mostly weak mudstones and sandstones. Very little of these Upper Cretaceous rocks are exposed in the Swiftcurrent and Boulder Creek Basins because they are overlain and obscured by Quaternary age unconsolidated deposits. Based on mapping by Mudge and Earhart (1983), the Virgelle Sandstone, Telegraph Creek and Marias River formations are present in the Swiftcurrent and Boulder

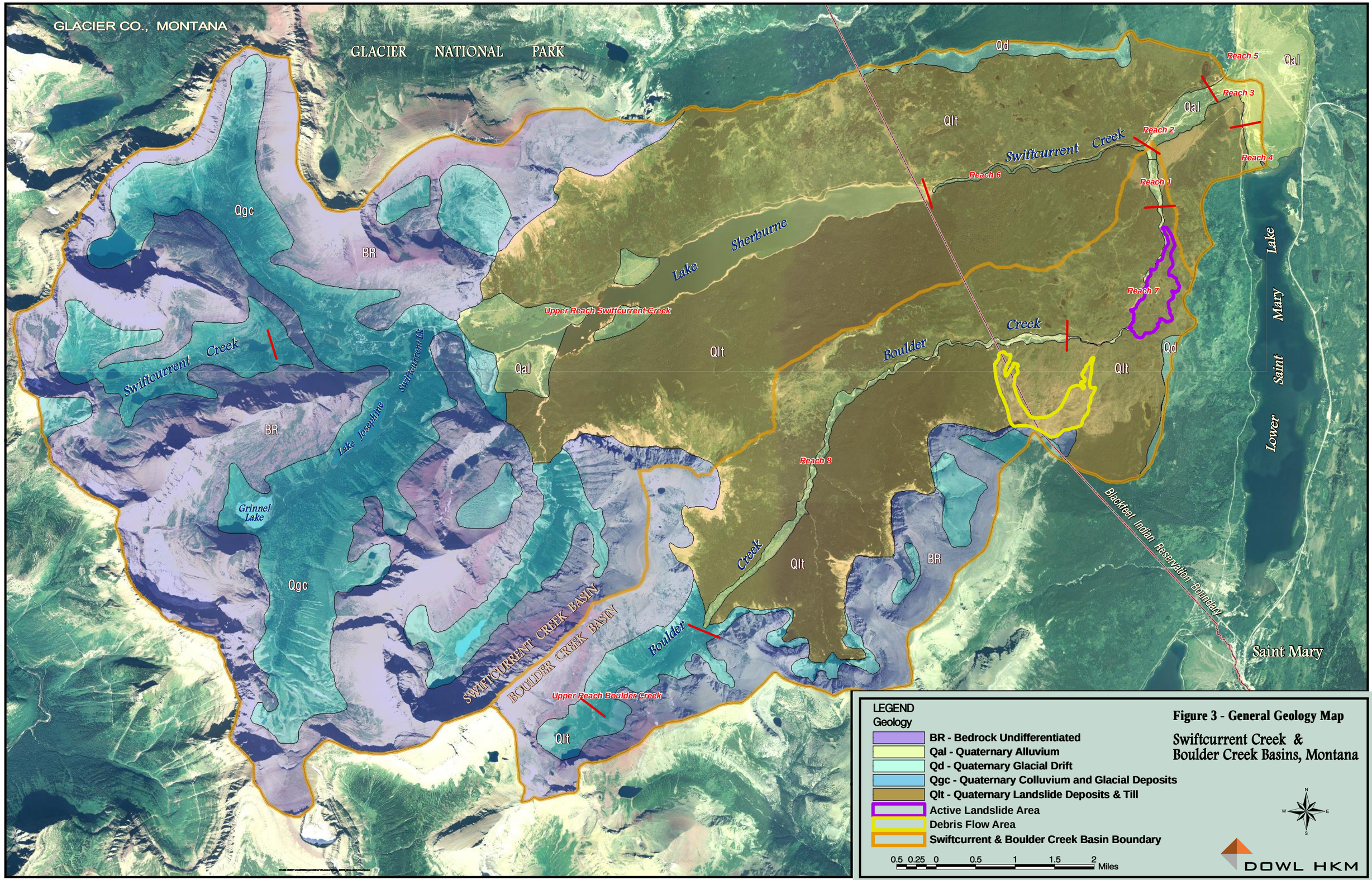


Figure 3 - General Geology Map

Swiftcurrent Creek & Boulder Creek Basins, Montana

Creek basins. The Two Medicine formation is only present north of Swiftcurrent Creek in the lower basin.

Erosion by ice associated with alpine glaciers has shaped these valleys and created numerous erosional features including U-shaped valleys, hanging valleys, cirques, arêtes, tarns, and horns and depositional features such as till, moraines, and terraces (Earhart and Others, 1989 and James, 1982).

The Quaternary deposits consist mainly of alluvium (Qal), landslide and till (Qlt), glacial drift (Qd), and undifferentiated glacial, fluvialglacial, and colluvial deposits (Qgc). The deglaciation of this area is thought to have been completed more than 10,000 years ago (Carrara 1993). After the glacial recession, Swiftcurrent and Boulder Creeks down-cut through the Quaternary deposits and transported significant amounts of sediment downstream to form the alluvial fan present at the mouth of the basin (Figure 3).

The alluvium (Qal), including alluvial fan and stream deposits, are described as unconsolidated gravel, sand, silt, and clay (Cannon, 1996). The Swiftcurrent Creek alluvial fan that created Lower Saint Mary Lake is reported to be a very thick deposit of alluvium (Cannon 1996). Recent growth of this delta area is discussed in Section 4.

The majority of the lower portion of the Swiftcurrent and Boulder Creek basins is mapped as undifferentiated Quaternary landslide and till deposits (Qlt). Glacial till typically consists of unsorted, sub-rounded to sub-angular boulder rubble containing minor amounts of sand, silt, and clay (Carrara 1990). The glacial till may be as thick as 50 feet (Cannon 1996). Landslide deposits mapped in this region include large rock slumps, slump-earth flows (debris flows), and rock block slides (Carrara 1990). The kind of clasts and grain size of the matrix vary depending on the bedrock units involved in the landslide (Carrara 1990). Carrara (1990) indicates that rock slumps are common along the eastern part of Glacier Park in areas underlain by Cretaceous sedimentary rocks, such as the lower portion of Swiftcurrent and Boulder Creek Basins. Based on aerial photo interpretation and field observations, portions of these landslide deposits have been re-activated in the lower Boulder Creek Basin. Discussion of these landslide deposits are provided in Sections 4.2 and 6.2.

Glacial drift (Qd), mapped along the basin divide in Swiftcurrent and Boulder Creek Basins, consists of mostly unsorted, sub-rounded to sub-angular gravel, cobbles, and boulders with minor amounts of sand, silt, and clay (Cannon 1996). The Quaternary deposits in the upper Swiftcurrent and Boulder Creek basins consist of various glacial and colluvial deposits (Qgc). Although some variation exists in the published geologic mapping, this unit includes colluvium, talus, till, rock glacier, solifluction, and other deposits.

Glaciation of these valleys and presence of landslides above the weak upper Cretaceous bedrock are predominant geomorphic features within the Swiftcurrent Creek basin.

2.2.5. Lake Sherburne Dam

Lake Sherburne Dam is a compacted earthfill structure which was originally constructed in 1914 to 1921. Prior to the construction of the dam, there were two existing lakes, Upper and Lower Lake Sherburne. The dam was constructed below the lower Lake, and has a total storage capacity of 68,080 acre-feet. The USBR website indicates that the reservoir water surface is controlled by operation of two 4' by 5' high-pressure gates, which permit a discharge of 2,100 cfs at the spillway overtopping elevation. The maximum discharge through the outlet works conduit is 4,200 cfs, which occurs at the maximum water surface elevation 21.2 ft above the spillway crest. In 1960, the original spillway was closed and replaced with an uncontrolled-overflow gloryhole spillway.

2.2.6. Flood History

The Swiftcurrent Creek Watershed has experienced six floods greater than the 25-year event from 1913 to 2008. The flood frequencies are based on records from the natural "Many Glacier" gage located above Lake Sherburne (Gage 05014500). The following list summarizes the flood date, peak flow, and flood frequency.

- June 13th 1937 – 2,250 cfs (~ 30-year event)
- June 8th 1964 – 6,700 cfs (~ 250-year event)
- June 20th 1975 – 3,310 cfs (~ 65-year event)
- June 7th 1995 – 3,150 cfs (~ 60-year event)
- November 13th 1999 – 1,750 (~ 25-year event)
- November 7th 2006 – 4,270 (~ 115-year event)

These peak flows occurred upstream of Lake Sherburne and are not impacted by the storage routing effects of the reservoir. The following list summarizes the corresponding peak discharges at Gage 05016000 below Sherburne Dam and illustrates the storage routing effects of Lake Sherburne.

- June 15th 1937 – 1,120 cfs (~ 2-year event)
- June 11th 1964 – 2,360 cfs (~ 25-year event)
- June 21st 1975 – 2,280 cfs (~ 25-year event)
- June 7th 1995 – 2,510 cfs (~ 30-year event)
- November 16th 1999 – 885 cfs (< 2-year event)
- November 7th 2006 – 0 cfs (fully stored inflow flood)

Recorded peak annual streamflows below Sherburne Dam have not exceeded the 2,510 cfs flood event which occurred in 1995. However, there have been 11 years in which the peak discharge below the dam was near the 25-year event.

2.2.7. Fire and Logging History

General information was obtained regarding two fires that have occurred within the Swiftcurrent Creek Basin. On August 31, 1936 the Heavens Peak Fire swept through the Swiftcurrent valley destroying many acres of forest and cabins that had been constructed in the upper basin. The Heavens Peak Fire burned over 14,000 acres, however, the extent of forest burned within the Swiftcurrent Creek basin is not well

documented. In August of 1984, the Napi Point (Peak) Fire destroyed at least 2,300 acres of forest and numerous homes and cabins located on the west side of Saint Mary Lake. Based on aerial photo review, the Napi Point Fire appears to have burned a significant portion of the lower basin of Boulder Creek to Saint Mary Lake.

No evidence of recent logging was observed in aerial photos, as would be expected, since most of the basin is within the boundaries of Glacier National Park.

3. Survey Review

3.1. Introduction

Over the late fall and winter of 1996, personnel from Druyvestein Johnson & Andrews Consulting Engineers and Land Surveyors (DJ&A) completed a survey of lower Boulder Creek and Swiftcurrent Creek for the U.S. Bureau of Reclamation (BOR). The limits of this survey include the lower one mile of Boulder Creek above the Swiftcurrent Creek confluence, and extend through the Swiftcurrent Creek alluvial fan formation to the point of discharge into Lower Saint Mary Lake. Survey data collected through this 1996 effort consists of channel cross sections as well as a detailed longitudinal profile of stream bed elevations and hydrographic characteristics. The results of this survey were subsequently used by WestWater Consultants, Inc. (WWC) in design of mitigation measures and preparation of their report titled "Design for Stabilization and Reconstruction of Swiftcurrent Creek and Boulder Creek near Babb, MT."

A review of the current channel conditions in comparison to the previous survey is desired to assess channel stability in the intervening years since conclusion of the WWC study. The intent of this re-survey is to document changes in channel geometry and aggradation or degradation trends within the system. Given how actively the channel continues to shift and migrate, an extensive re-survey of the stream channel at this early stage is not warranted, as this work will inevitably need to be redone for more detailed evaluations in the future and/or immediately prior to implementation and construction. The intent of the survey review is to resurvey critical areas and collect sufficient data to draw general conclusions concerning channel stability.

3.2. Data Collection

Field personnel from DOWL HKM and the Blackfeet Environmental Office (BEO) relocated previous survey monuments and re-surveyed select stream cross section and profile elevations on Boulder and Swiftcurrent Creeks during late October, 2009. The purpose of this survey is to provide a general understanding of how the channel has changed in the intervening years since the 1996 stream survey. A sampling of the cross-sections surveyed in 1996 were resurveyed to facilitate comparisons. Additionally, a sampling of elevations were collected along the thalweg profile to determine if a trend in aggradation or degradation is evident. Critical areas were identified by the BEO for resurvey, including: cross sections and profile in the vicinity of the Boulder/Swiftcurrent Creek confluence and the County Road Bridge, as well as resurvey of a cross section documenting the Swiftcurrent Creek channel location on the alluvial fan.

Control point coordinates and elevations from the original survey were obtained from the BOR. BOR drawings developed through reduction of the 1996 DJ&A survey indicate the horizontal coordinate system to be NAD 83. However, initial verification of this coordinate system revealed an apparent shift of several hundred feet from NAD 83 coordinates to the 1996 DJ&A survey data. Consequently, horizontal coordinates should be treated as a local coordinate system. Vertical coordinates are reported to be NGVD 29, based on the benchmark at the Chewing Blackbones Campground on Lower Saint Mary Lake.

3.3. Results

A set of exhibits showing a comparison of the 1996 and 2009 surveyed conditions is provided in Appendix A. Within these drawings, the "Main Channel Swiftcurrent Alignment" refers to the active channel at the time of the 1996 survey, while the "North Channel" refers to what was a dry channel at the time of the 1996 survey. This North Channel is currently the active channel.

Sheet G1, Appendix A, shows the locations of the 1996 surveyed cross sections, as well as the 2009 resurveyed sections (overlain in red). Four cross sections on lower Boulder Creek above the confluence were resurveyed, in addition to 3 sections on Swiftcurrent Creek immediately below the confluence, 5 sections above the County Road Bridge, and one section on the Swiftcurrent Creek alluvial fan. Sheets XS-1 through XS-7, show the resurveyed 2009 cross sectional geometry overlain on the original 1996 data. Cross sections are presented in order from the downstream end of the project to the upstream.

The following changes in channel cross-sections were observed through the review of the "Comparison of 1996 and 2009 Conditions" exhibits.

Table 2 – Summary of 1996 to 2009 Channel Changes

Location	Sheet Reference	Observations
Swiftcurrent Creek		
Cross Section 8+00 at CP16	XS-1	The channel is allowed to meander unconstrained on the alluvial fan below the county road bridge. A dramatic shift in channel location has occurred since the 1996 survey.
Cross Section 60+03 at CP5	XS-1	This cross section is located immediately upstream of the county road bridge. The current thalweg is approximately 1.17 ft lower than was surveyed in 1996. Additionally, the gravel bar at the center of the channel is smaller and lower in elevation to that surveyed in 1996.
Cross Section 66+55 at CP29	XS-1	This cross section appears to be within the extent of previous channel construction work.
Cross Section 78+44 at CP34	XS-2	This cross section appears to be within the extent of previous channel construction work.
Cross Section 83+88 at CP35	XS-3	This cross section appears to be within the extent of previous channel construction work. Blackfeet Environmental personnel indicate that reconstruction of this reach was completed after the 1996 survey, and the active channel was moved to the left (north) away from the Burns cemetery. The active channel has subsequently "jumped back" to the previous location near the toe of the Burns Cemetery hillside. Loss of material from this hillside is apparent from the 1996 survey to 2009. This erosion may have occurred after the 1996 survey and prior to placement of riprap during construction in 1998..
Cross Section 94+69 at CP36	XS-4	The current active channel occupies the same channel location as was surveyed in 1996, however, the thalweg elevation is roughly 1.2 ft lower than surveyed in 1996.
Cross Section 162+19 at CP28	XS-5	Minor aggradation within the 1996 active channel is evident within this section. This location appears to be approaching the lower extent of the sediment deposit which obstructed the "Main Channel Swiftcurrent Creek" alignment. Consistent with sections at CP4 and CP27, the active channel currently occupies the "North Channel" alignment. The current active channel is perched in the north channel approximately 3 ft higher than the previous 1996 channel elevation. The current thalweg is approximately 1 ft lower than the previous North Channel bed elevation.
Cross Section 165+83	XS-5	Similarly to the cross section at CP4, deposition is evident within the 1996 active channel, with the current active channel occupying the "North Channel" alignment. The current thalweg elevation is

Location	Sheet Reference	Observations
Swiftcurrent Creek		
at CP27		roughly equivalent to the 1996 surveyed North Channel bed elevation.
Cross Section 169+02 at CP4	XS-5	Deposition of sediment to an approximate depth of 3 ft within the 1996 active channel along the "Main Channel Swiftcurrent Creek" alignment has caused an obstruction and forced the stream to jump to the "North Channel" alignment. Additionally, deposition (~4 ft depth) within the North Channel alignment is evident and the current active channel location at this section has moved and is now immediately adjacent to the left bank. The resulting gravel bar adjacent to the current active channel is nearly identical in shape to the previous gravel bar, which is still visible in the cross section. The current thalweg elevation is roughly equal to both the 1996 active channel thalweg and North Channel bed elevation.
Boulder Creek		
Cross Section 1+15	XS-6	Surveyed floodplain topography and active channel location at this section looks nearly identical to that surveyed in 1996. However, the thalweg elevation has risen approximately 2.37 ft.
Cross Section 4+06	XS-6	The current active channel appears to have moved slightly to the east (towards right bank) in comparison to that surveyed in 1996. Although deposition along the left edge of the 1996 active channel is evident at this section, the current thalweg is approximately 2.13 ft lower than that surveyed in 1996.
Cross Section 11+54	XS-7	The current active channel occupies the same channel as was surveyed in 1996 along the left bank, however, the thalweg elevation is roughly 1.3 ft lower than surveyed in 1996.
Cross Section 19+49	XS-7	The stream is evidently very dynamic at this location. The active channel location has moved several times since the previous survey, including erosion and subsequent abandonment of a new stream channel 50 ft to the east (towards the right bank) of the 1996 active channel. The current active channel occupies a previous "dry channel" indicated on the 1996 survey approximately 90 ft to the west. Minor aggradation within the 1996 active channel is evident, while the elevation of the 1996 dry channel, which the current active channel occupies, has remained relatively unchanged.

3.4. Conclusions

The observations presented above support several general conclusions, as follows:

3.4.1. Aggradation/Degradation

A number of observed differences in channel geometry and bed elevations exist between the 1996 surveyed geometry and the 2009 resurveyed geometry. However, these differences reflect both increases in bed elevation in some locations and decreases in bed elevation in others. Although there have been significant changes in the channel alignment, a comparison of bed elevations does not conclusively indicate a trend in either excessive aggradation or degradation. It is noted, however, that below roughly cross-section 103+91 (Appendix A, Sheet G1), Swiftcurrent Creek emerges onto the alluvial fan and long-term aggradation can be expected. This is not reflected in the relatively short, 13-year time from 1996 to 2009.

3.4.2. Channel Geometry

The shape of the channel geometry at many cross-sections has experienced minor changes from 1996 to 2009, reflecting the instability of the system. However, these changes do not support the notion that the stream channel is trending from a single main channel to a braided stream. The cross section at STA 169+02 (Appendix A, Sheet XS-5) provides a good example of how the active channel has moved laterally across the floodplain, occupying several different locations, but persisting as a single primary channel and generally maintaining a very similar active channel geometry.

3.4.3. Lateral Instability

The Boulder/Swiftcurrent Creek System is a dynamically changing environment. Major shifts in the channel alignment have occurred in the 13 years since the original survey. Boulder Creek, in the vicinity of the cross section at STA 19+49 (Appendix A, Sheet XS-7), has occupied at least 3 distinct channels over a floodplain width of 180-ft. These shifts in channel alignment are not the result of lateral accretion, characterized by point bar deposition and meander bend erosion, but the apparent result of sudden pulse movements of sediment which obstruct the active channel and cause reactivation of previously blocked or abandoned channels or the creation of new channels. This is evidenced by the fact that the previous channels, now dry, remain in the floodplain and can be seen in cross section view.

Similarly, a sediment blockage at the divergence of the "Main Channel Swiftcurrent Creek" and the "North Channel" alignments near the Boulder/Swiftcurrent confluence has caused a sudden shift in the active channel and reoccupation of the North Channel alignment. This sediment blockage is partially visible in the cross section geometry for STA 169+02 (Appendix A, Sheet XS-5), and is indicated by the ~3 ft difference between the elevation in the 1996 active channel bed and the new geometry at approximate cross section STA 285. It is likely that this movement between these two distinct channels is a recurring cycle driven by the delivery of coarse bed load from Boulder creek as well as the occurrence, timing, and magnitude of Swiftcurrent Creek flood releases through Sherburne Dam.

3.4.4. Effectiveness of Stabilization Measures

Subsequent to the 1996 survey, Reach 3 of the WWC design was constructed in an attempt to protect the Burns Cemetery and the hillside it sits on, which was experiencing dramatic erosion. The channel was realigned towards the left bank, as can be seen in the difference (of the north side?) between the 1996 and 2009 surveyed geometry at STA 83+88 (Appendix A, Sheet XS-3). The new channel was armored with riprap and rootwads and controlled through rock vanes and vortex weirs. After this construction project, however, the channel reoccupied its previous course along the toe of the hillside below the Burns Cemetery. The results of the survey indicate apparent additional loss of hillside in comparison to the 1996 survey, although it is not known if this erosion was prior to or after reconstruction of Reach 3. Despite best efforts to control and/or influence the location of the channel, this shift back to the previous channel alignment illustrates the difficulty in achieving these objectives.

3.4.5. Summary of Conclusions

The dynamically changing nature of the Boulder/Swiftcurrent system as well as the difficulty in stabilizing this system, as observed through the previous reconstruction experience, reinforces the need for a more comprehensive understanding of the sediment transport regime, the interrelated hydrology, and the geomorphology of the system. This is reinforced by Tracie Sylte in her May 24, 2009 memo (included in Appendix E), where she stated, "The success of this project depends on collecting enough data and performing a thorough assessment to rigorously explore and discuss the benefits/costs, uncertainty, and reality of long-term efficacy of each alternative and the total stream system." The framework for collecting the additional survey required for a comprehensive analysis is presented in Section 9.

4. Channel Migration and Delta Growth Mapping

4.1. Methodology

The flood of record for Swiftcurrent Creek occurred in 1964. Several other flood events have also been recorded. An effort was made to obtain aerial photography that would bracket these events. The purpose of the aerial photography analysis is to investigate and document the presence of mass sediment sources to Swiftcurrent and Boulder Creeks as well as to document channel changes or changes in stability that have occurred.

Stereo pairs of aerial photos from 1953, 1966, 1990/1991, and 1995 and georeferenced orthophotos from 1995 and 2005 were the main source of data used for channel migration, delta growth mapping, and to delineate active landslide and debris flow areas. In addition to these primary aerial photograph sets, other years were obtained for this study that cover portions of the basin. Table 3 summarizes the aerial photographs obtained and reviewed.

Variability in accuracy exists in the interpretation of surficial features due to the scale, quality, and number of years of aerial photography used. Stereo pairs of aerial photos with original scales ranging from 1:20,000 to 1:40,000 or less, and stereo pairs of high resolution scanned images provide the most detailed information. Additionally, good detail was obtained from published orthorectified aerial photography from 1995 and 2005. The remaining photography reviewed including 2006 orthorectified aerial photography (2-meter resolution), high elevation, and medium resolution scanned aerial photography. Although these sources do not show enough detail to use in mapping surficial features, they provide general information for comparison from year to year.

Stereo pairs of aerial photos were interpreted using a Sokkisha MS-27 stereo scope. Select contact prints of aerial photos were scanned and then registered to the 2005 orthophotos using the georeferencing features in ArcGIS to remove positional inaccuracies in the various aerial photos. Mapping for each individual year was digitized in ArcGIS. The 2005 orthophotographs used as a photo base in this report are digital color MrSID images with a ground resolution of 1 meter and are registered to the State Plane Coordinate System North American Datum of 1983.

The results of the aerial photo mapping are presented on Figure 3 (General Geology), Figure 4 (Landslide and Debris Flow), Figure 5 (Delta Growth), Figure 6 (Early 1900's Swiftcurrent Creek Channels), and Exhibits 1a through 1f and Exhibit 2 in Appendix B (Channel Migration and Delta Growth mapping).

Table 3 -Summary of Aerial Photography Reviewed

Year	Date	Original Scale	Film Type	Source	Aerial Photo Coverage of Basin	Stereo Coverage of Basin
1953	8-30-53 and 9-1-53	1:20,000	Black and White Contact Prints	USDA	Reach 1-7, partial for Reach 8 and US and BC Basins	Reach 1-7, partial for Reach 8 and UBC Basin, none for US Basin
1963	5-21-63	<20,000	Black and White Contact Prints	BOR	Reach 3, 4, 5 Portions of Reach 1, 2, 6 and 7	Reach 3, 4, 5 Portions of Reach 1, 2, 6 and 7
1966	8-24-66	1:31,000 to 1:34,400	Black and White - High Resolution Digital to Contact Prints Black and White - Medium Resolution Digital Photos	USGS	Reach 1-8, partial for US and BC Basins All Reaches	Reach 1-7, partial for Reach 8, US and BC Basins All Reaches
1975	7-24-75	~20,000	Color – Contact Prints	BOR	Reach 1, 2, 3, 4, 5 Portions of Reach 6 and 7	Reach 1, 2, 3, 4, 5 Portions of Reach 6 and 7
1981	02-04-81	1:122,000	Black and White – Medium Resolution Digital Photos	USGS	Partial Cloud Cover	None
1982	9-6-82	~1:30,000	Black and White – Contact Prints	USDA		
1990/ 1991	9-7-90 12-17-91 8-26-91	1:40,000	Black and White Contact Prints	NAPP/ USDA	All Reaches except upper portion of US Creek Reach	All Reaches except upper portion of US and BC Basin Reaches
1993	10-2-93	<20,000	Color Infrared (CIR) Contact Prints	BOR	Reach 1, 2, 3, 4, and 5	Reach 3 and 4
1995	8-22-95	1:40,000	Black and White Contact Prints	NAPP/ USDA	Reach 1, 2, 3, 4, and 5, lower portion of Reach 6 and 7	Reach 1, 2, 3, 4, and 5, lower portion of Reach 6 and 7
1995	8-22 and 26-95	1:40,000	Black and White Digital Orthophoto Quarter Quadrangles (1-meter resolution)	NAIP/ NRIS	All Reaches	None
2005	7-31-05, 8-26 and 27-2005	1:40,000	Orthorectified Natural Color Digital Photos (1-meter resolution)	NAIP/ NRIS	All Reaches	None
2006	July/August 2006	1:40,000	Orthorectified Natural-Color Digital Photos – County Mosaics (2-meter resolution)	NAIP/ USDA	Lower half of basin	None

BOR – from Bureau of Reclamation files
NAPP – National Aerial Photography Program
USGS – United States Geological Survey
US – Upper Swiftcurrent
UBC – Upper Boulder Creek
BC – Boulder Creek
NRIS – Montana Natural Resource Information System
USDA – United States Department of Agriculture
NAIP – National Agriculture Imagery Program

4.2. Channel Migration History

The active channel location is represented by the mapped thalweg shown on Exhibits 1a through 1f in Appendix B. The amount of channel migration varies considerably within the Swiftcurrent and Boulder Creek basins and, in general, is driven by several factors, including: geology, gradient of the stream reach, and input of sediment and streamflow from tributaries. The following is a brief summary of channel migration observations by stream reach.

4.2.1. Upper Reach of Boulder Creek

The surficial deposits in the upper Boulder Creek basin are mostly colluvial and glacial in origin. The valley is a broad U-shaped glacial valley. No active landslides were observed in this reach, although avalanche/debris flow chutes and talus slopes are present along the channel sides that could deliver sediment and debris to the stream. A few debris chutes along the stream channel and portions of the channel look fresh and void of vegetation. No photos were obtained for this area prior to the 1964 flood, so comparisons of the channel before and after flooding cannot be made at this time. However, the stream channel in 1966 appears to be a stable single channel and no significant erosion of the channel sides or removal of vegetation is observed in the 1966 photos. Mapping indicates that the channel location is very similar in 1966, 1995, and 2005.

4.2.2. Reach 8

The geologic units mapped in Reach 8 are Quaternary landslide and till deposits on the valley sides and alluvium along the creek. In general, the upper third of Reach 8 is a broad open valley with a wide flood plain area. With the exception of a few avalanche/debris chutes in the very upper portion of the reach, most of the side slopes are heavily timbered with no obvious indications of recent erosion or instability. Although no photos were available for the upper third of Reach 8 prior to the 1964 flood, the stream channel in 1966 appears to be a stable single channel, and no significant erosion of the channel sides or removal of vegetation is observed in the 1966 photos. No significant channel changes are observed in the upper third of Reach 8 in the 1966, 1990/1991, or 2005 photos.

Erosion of channel sides and channel migration in the lower two-thirds of Reach 8 is visible in 1966 when compared to the channel condition in 1953, presumably as a result of the 1964 flooding. A single channel is present in the 1953 photos for the majority of Reach 8. The 1966 photos indicate sections of significant erosion, migration, and removal of vegetation particularly below major tributaries entering the stream channel from the south. Multiple channels are observed in a few areas, although a single channel is visible through most of this reach in 1953, 1966, and in more recent photography. Continued channel migration is observed in the lower two-thirds of Reach 8 in the 1966, 1990/1991, 1995, and 2005 photos but some re-vegetation is also visible in the 1995 and 2005 photography.

The valley in the lower two-thirds of Reach 8 is also fairly broad and open, with a wide floodplain. Most of the valley south of the creek is heavily timbered with no obvious indications of recent instability. The north side of the valley appears to be only partially timbered and may be so for many reasons, including: landslide movement, fire, or variability in soil conditions or geologic units underlying this area. A defined landslide scarp is visible along the northern margin of the basin in this reach above the partially

timbered area. This area is mapped as landslide deposits and may have been active in recent history, although no significant changes to the landslide are apparent in the aerial photos reviewed.

A re-activated portion of the landslide deposits exists on the south side of the channel in the very last mile of Reach 8 (Figure 4). The re-activated portion appears to be in the form of debris flow deposits that appear fresh and void of vegetation in 1966 when compared to the 1953 photos and which were possibly re-activated during the 1964 flood event. Some sediment from this debris flow reached the main channel through tributary drainages and erosion of the channel sides.

Significant channel migration, erosion of side slopes and side channels, and removal of vegetation can be observed in the 1966 photos in the last mile of Reach 8. Multiple channels exist in this section of stream in 1953, 1966, as well as in more recent photography, indicating that it was an area of relative channel instability even prior to the 1964 flooding. This is not surprising, given the active nature of the landslide/debris flows in this area.

4.2.3. Reach 7

The geologic units mapped in Reach 7 are Quaternary landslide and till deposits on the valley sides and minor alluvium along the creek. This reach has an incised channel and narrow floodplain area in the upper 1/4 of the reach along the debris flow area discussed above. Comparison of the 1953 and 1966 photos show no significant channel migration. In the photos reviewed from 1953, 1966, 1990/1991, and 2005, this section of Reach 7 appears to be a single channel.

The lower three-fourths of Reach 7 appears to have one main channel in all years of photos reviewed, however, smaller, active flowing side channels are visible. Multiple-channel flow likely occurred in this section during the 1964 flooding. The 1966 photos indicate sections of significant erosion, lateral migration, and removal of vegetation. Continued side channel erosion and no significant re-vegetation is observed in the 1990/1991, 1995, and 2005 photos.

Near the mid-section of Reach 7, an active landslide deposit was documented through the aerial photo interpretation and during the 2009 field visit. Active lobes of this landslide are visible in the 1953 photos, although the head scarp appears vegetated and perhaps less active. Some areas of the head scarp appear fresh and have less vegetation in the 1966, 1990/1991, and 2005 photos, indicating continued movement. This observation was verified during a field visit in October 2009 to this area. Several photos in Appendix D, particularly Field Site 9 Photo 22 and Field Site 13 Photo 26, show the active scarp along the upper portion of the landslide (south of Boulder creek), as well as active erosion at the toe of the landslide. Field Site 12 Photo 25 in Appendix D shows active erosion along the north side of the channel.

4.2.4. Reach 1

The geologic units mapped in Reach 1 are Quaternary landslide and till deposits on the valley sides and alluvium along the creek. Aerial photos from 1953 show a single main channel in Reach 1. Aerial photos from 1966 show a significant amount of vegetation removal, erosion of side channels, and channel migration within the floodplain along this reach. Multiple-channel flow may have occurred in this section during the 1964 flooding, however, one predominant channel is still visible in the 1966 photos.

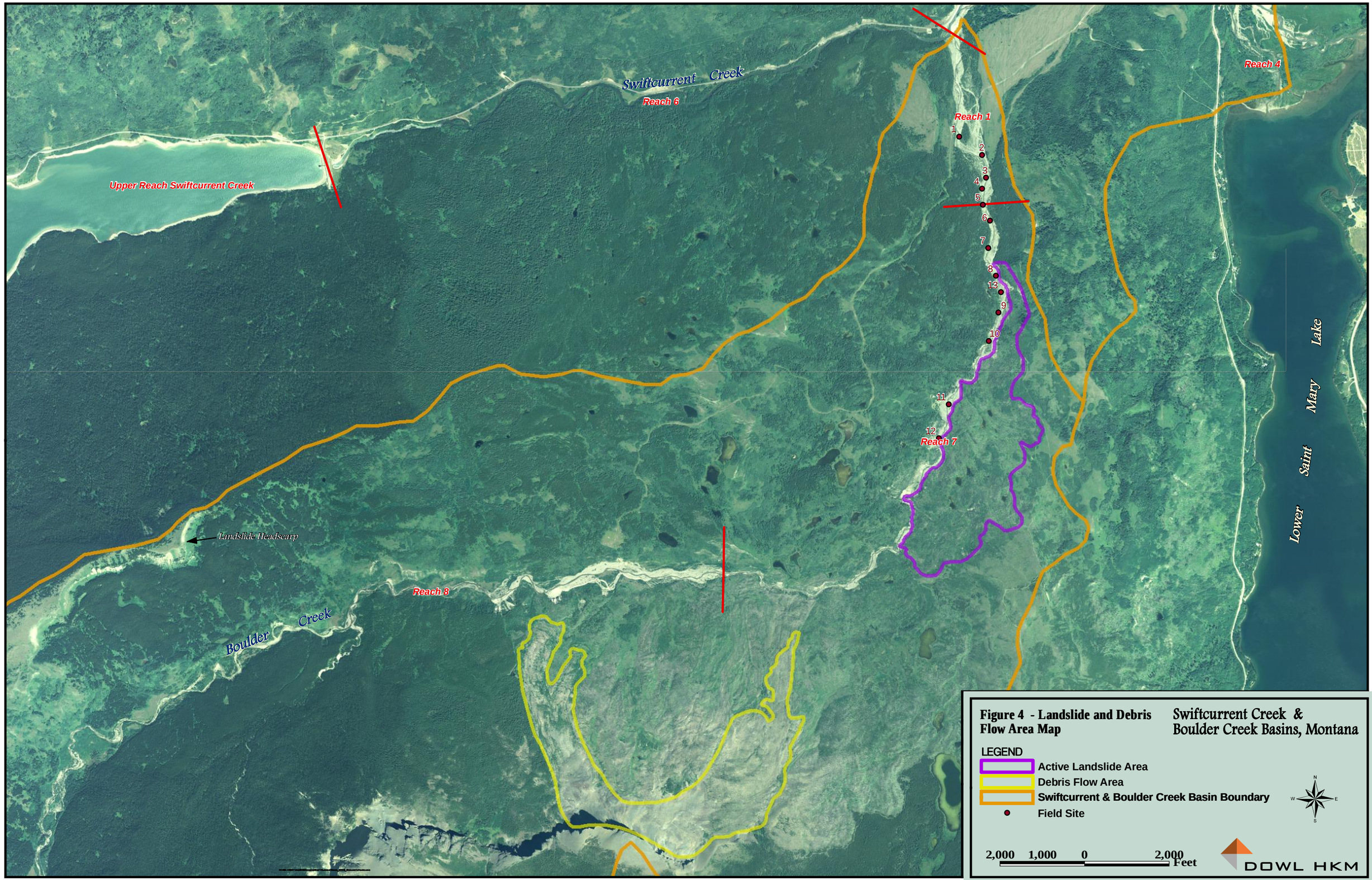


Figure 4 - Landslide and Debris Flow Area Map

Swiftcurrent Creek & Boulder Creek Basins, Montana

Additional erosion, migration, and removal of vegetation is apparent in the 1975 photos, presumably from the 1975 flooding but, as with the 1966 photos, the 1975 photos indicate multiple-channel flow during flooding but one predominant channel with flow is visible during lower flow periods. The 1998 WWC report indicates that this reach was starting to recover in the early 1990's, but that the flood of 1995 reversed that trend. Review of the 2005 photos indicates that since 1995, Reach 1 has apparently re-gained some stability, as indicated by the re-growth of vegetation within the floodplain and only minor channel migration.

4.2.5. Upper Reach of Swiftcurrent Creek

The surficial deposits in the upper Swiftcurrent Creek basin are mostly colluvial and glacial in origin. The valley is a broad U-shaped glacial valley. No active landslides were observed in this reach, although some relatively un-vegetated avalanche/debris flow chutes and talus slopes are present along the valley sides which could deliver sediment and debris to the stream. Lake Sherburne occupies the downstream 5.5 miles of the upper reach of Swiftcurrent Creek. No significant changes were observed in the upper reach in 1995 or 2005. No photos were obtained for this area prior to the 1964 flood so comparisons of the channel before and after flooding cannot be made at this time. Aerial photos obtained for the delta area above Lake Sherburne for 1966 indicate no significant changes in the channel in this area.

4.2.6. Reach 6

The geologic units mapped along Reach 6 are Quaternary landslide and till deposits on the valley sides and minor alluvium along the creek. The valley is relatively broad, and based on aerial photo review, no active landslides were observed in this reach and the valley sides appear well vegetated. The flood plain along Reach 6 is fairly narrow and vegetation is well established. No significant changes to the channel in Reach 6 were observed in the aerial photos reviewed. As indicated by the channel migration mapping, almost no change in channel location was observed (Appendix B, Exhibit 1e). This reach consists of a single channel with one short segment of side channel.

4.2.7. Reach 2

The geologic units mapped along Reach 2 are Quaternary landslide and till deposits on the valley sides and alluvium along the creek. Reach 2 is located at the mouth of the Swiftcurrent Creek valley. The valley in this area is relatively broad and open and the floodplain is widest in this section in comparison to upstream reaches and allows for significant channel migration. The 1953 channel was located along the north side of the floodplain (north channel). A culvert crossing located across the north channel is visible, and the apparent straightening of the channel in the vicinity of the crossing, as mentioned in the 1998 WWC report, is also visible. In 1966, Swiftcurrent Creek still occupies the north channel, the channel still has a straightened appearance, and the crossing is still intact. However in the area of the crossing, a few high-flow channels, probably occupied during the 1964 flooding, had developed in the center and southern portions of the floodplain and some removal of vegetation is visible. These channels converge into a single minor channel that appears to have some flow visible in the 1966 photos. This reach sustains significant erosion, migration, and vegetation removal prior to the 1975 aerial photos reviewed, presumably due to flooding that occurred in 1975. The crossing is no longer present at that time and the main flow has shifted to the south side of the floodplain and becomes braided in this reach, likely as a result of sediment influx from upstream. The 1982 and 1990/1991

aerial photos show that the main channel in Reach 2 is still located along the south side of the floodplain, but most of the flow is in a single channel with very minor secondary side channels. Erosion had diminished at that time, and re-vegetation of the floodplain is visible. The 1995 aerial photos show the main channel located along the south side of the floodplain. As mentioned in the 1998 WWC report, the flooding in 1995 (presumably in June of 1995), appeared to reverse this recovery trend and the channel again "jumped" back to the north channel. Aerial photos from 2005 show the main channel occupying the north side of the floodplain, but a significant secondary channel still exists along the south side. The flooding of 1975 appears to be the main destabilizing event in the reach.

4.2.8. Reach 3

The geologic unit mapped along Reach 3 is primarily Quaternary alluvial fan deposits. A dike was constructed in the early 1900's along the north bank, cutting off the channel (Reach 5) occupied in the early 1900's (referred to as the original channel in Decker, 1998). The channel is redirected in a relatively tight turn south. A bridge was constructed by the Bureau of Indian Affairs (BIA) at the downstream end of this reach sometime between 1963 and 1966. The floodplain in this reach is narrower than in Reach 2 due to confinement by the dikes. Some channel migration and bank erosion is observed in all years of photos reviewed and significant migration and erosion is visible in the 1975 photos, including at the BIA bridge, where the channel bypassed the structure and eroded a channel east of the bridge apparently during the 1975 flooding. The bridge crossing was re-constructed sometime between 1975 and 1981. Review of many years of aerial photos reveals that the channel in Reach 3 alternated, throughout recent history, between a single main channel and a main channel and a secondary channel. Review of aerial photos from 1953 and 1963 show some vegetation within the floodplain , however, none is visible in the 1966 aerial photos. This vegetation was apparently removed in the flooding of 1964 and had not re-established by 2005. A stream stabilization project was completed in 1997 by the BOR, in cooperation with the BEO, in an attempt to stabilize a portion of Reach 3 upstream from the BIA bridge. The project, which implemented the design developed by WWC, focused on a reach of Swiftcurrent Creek that was eroding the toe of a slope and jeopardizing Burns Cemetery.

4.2.9. Reach 4

Reach 4 is located on the alluvial fan of Swiftcurrent Creek, and includes the delta area discussed below (See Figure 5, Exhibit 1f, and Exhibit 2). This reach has experienced significant channel migration in the past 50 years. Prior to construction of the BIA bridge, the channel in 1953 was located along the western part of the floodplain and had one main channel visible in the upper portion of the reach. The 1966 photos also show a single main channel just below the bridge. This section is braided in the 1975 photos and flow is visible in at least three channels. After the bridge crossing was reestablished, this section is again occupying a single main channel as can be seen in the 1981, 1982 and 1990/1991 photos. In the lower section or delta portion of Reach 4, several channels are apparent and this channel section can be considered braided. The main channel flowed south from the bridge into Saint Mary Lake. This main channel migrated slowly eastward and, sometime between 1995 and 1997, the main channel switched to a secondary channel on the east side of the delta as reported in the 1998 WWC report. In 2005, the photos show the main channel occupying the east side of the delta, flowing into the lake near the mouth of the Saint Mary River.

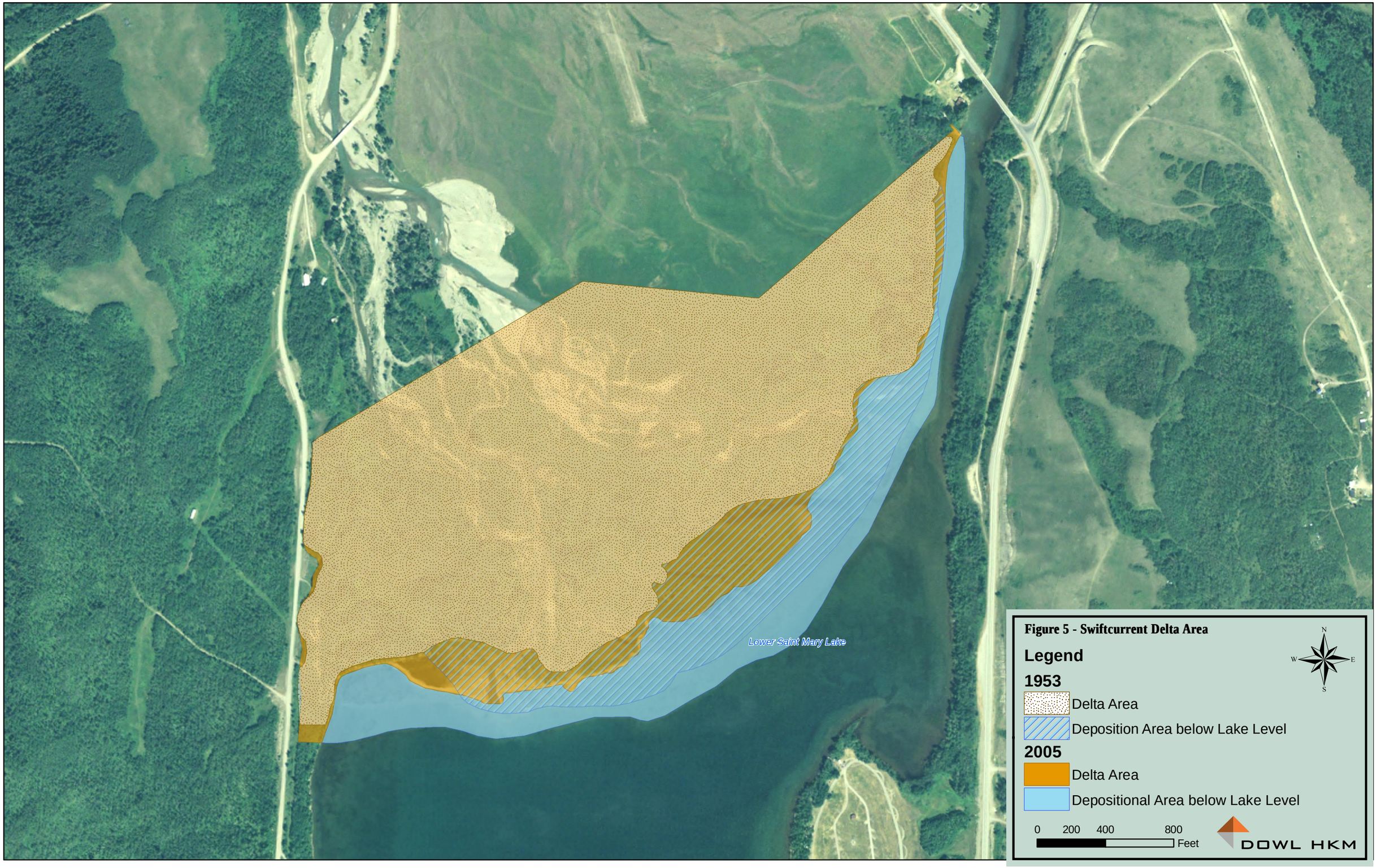


Figure 5 - Swiftcurrent Delta Area

4.2.10. Reach 5

Reach 5 is the channel documented in the early 1900's and was referred to as the "original channel" in the 1998 WWC report. Archive maps obtained by BOR from 1909, 1910, and 1913 show the location of the channel with respect to surveyed section boundaries. These maps were geo-referenced and the channels digitized in ArcGIS (Figure 6). There is some variation in the location mapped in each year, but the general vicinity is the same. Using the aerial photography obtained for this project, a general corridor delineating low areas that appear to have been previously occupied by the Swiftcurrent Creek channel is also shown on Figure 6.

4.3. Delta Growth Mapping

4.3.1. Methodology

Depositional characteristics for the existing delta area were mapped for the years 1953, 1966, 1996, and 2005. Features identified included areas of well established vegetation above the lake level, areas of active sediment deposition below lake level, and the "active channel area" which includes the active channel, sand bars, aquatic vegetation areas, and areas with partial vegetation.

Mean daily discharge and field gage height measurements from the USGS Gage 05017500 located on Saint Mary Lake directly across from the south end of the delta were reviewed to determine the approximate lake level on the days that aerial photographs used for delta growth mapping were taken. On these days, mean daily discharge ranged from 754 to 1060 cfs which corresponds to field gage heights of about 2.44 to 3.08 feet. This data indicates that lake levels varied by less than one foot (0.64 feet) on the dates of interest, and therefore, the impact of lake level fluctuation on the visible extents of the delta is most likely minimal.

4.3.2. Results

In general, the delta has continued to advance into the lake. Sediment has continued to accumulate above lake level at the mouth of the delta. Well established vegetation can be observed in 2005 where none had existed in previous years reviewed. Although somewhat subjective, it appears that the area of active sediment deposition below lake level has continued to migrate out into the lake. Several areas of well established vegetation observed in 1953 were removed, presumably during the 1964 flood event of record, and have sparse or no vegetation visible in the 1966 photos. Changes in the delta growth are visible but are modest from 1966 to 1995. Rough estimates based on this mapping indicate that the surface area of the delta has increased approximately 21 acres between 1953 and 2005.

Table 4 - Delta Growth Summary

Location	1953 Acres	2005 Acres
Delta above Lake	132.6	150.2
Sediment Accumulation below Lake Level	33.5	37.0
Total Acres	166	187

The extents of the delta through time are shown on Figure 5 and Exhibit 2 of Appendix B.

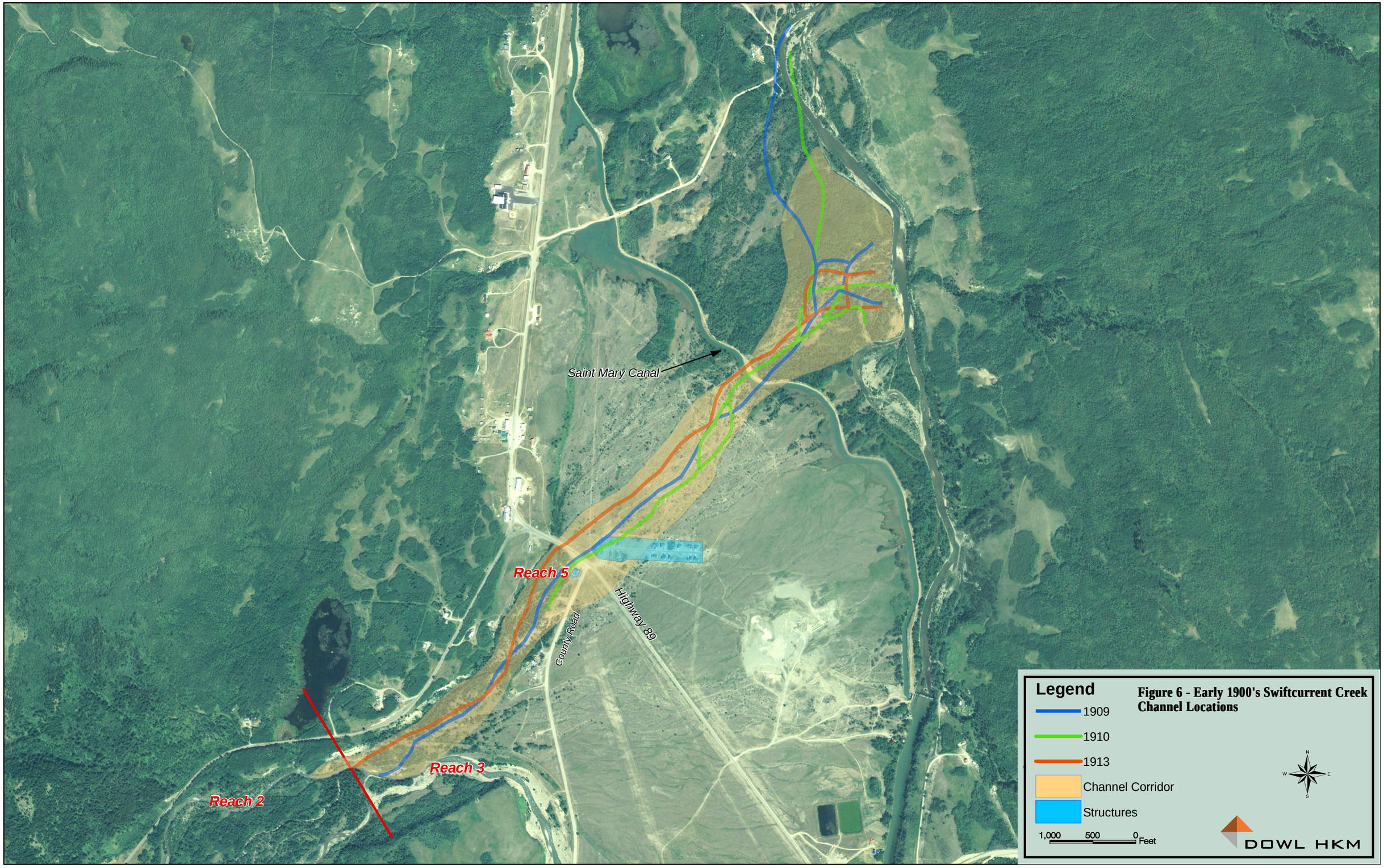


Figure 6 - Early 1900's Swiftcurrent Creek Channel Locations

4.4. Conclusions

The 1964 flood event was significant and had long-term impacts with lasting effects. The flooding that occurred in 1975 and in 1995 also appears to have significantly impacted the stream channel. Major shifts in the active channel location within the flood-prone area were documented. Based on the aerial photography reviewed, a single main channel persisted in most reaches of Swiftcurrent and Boulder Creeks. The presence of side channels was documented in aerial photography both prior to and after the 1964 and 1975 flooding, but only a few areas of true braiding in Reaches 2 and 4 were observed after the 1975 flooding. These braided reaches did not persist over time.

The Swiftcurrent and Boulder Creek basins are dynamic and portions of the streams have exhibited significant channel instability over time and are likely still in a period of instability. Applying streamtypes such as those from Rosgen to the stream reaches below the confluence of Swiftcurrent and Boulder Creeks may be premature, as additional work is first needed to better understand the stability of the upstream reaches of Boulder Creek. A better understanding of the stability or instability of the Swiftcurrent/ Boulder Creek system is needed and will be a focus of future evaluations, as described in Section 9.

The dike constructed by the BOR in the early 1900's redirects Swiftcurrent Creek from an alignment which discharged into the St Mary River along Reach 5 to a new alignment (Reach 3/Reach 4) which now discharges into Lower St Mary Lake. The delta that occupies the mouth of Lower St Mary Lake is progressively advancing. This delta which was estimated at 166 acres as of 1953 had expanded to an estimated 187 acres by 2005.

5. Watershed Hydrology Review

5.1. Introduction

The Phase I reconnaissance review of the Swiftcurrent Creek watershed hydrology utilized current hydrologic methods to estimate instantaneous peak flows and the monthly timing of peak flows under both existing conditions (dam regulated) and natural conditions. The main purpose of this review is to gain a general understanding of the role that man-induced changes to hydrology play in the instability and other problems that are being experienced in the Swiftcurrent Creek watershed. Watershed Characteristics

The Swiftcurrent Creek drainage basin area is roughly 100 sq. miles. The largest tributary to Swiftcurrent Creek is Boulder Creek, with a drainage basin of 26.7 sq. miles. Several lakes are present within the Swiftcurrent watershed, including the natural Swiftcurrent Lake and the manmade Lake Sherburne, created in the early 1900s with the construction of Sherburne Dam. Construction was begun on Sherburne Dam in 1914, and the first delivery of Milk River Project water from the reservoir occurred in 1919.

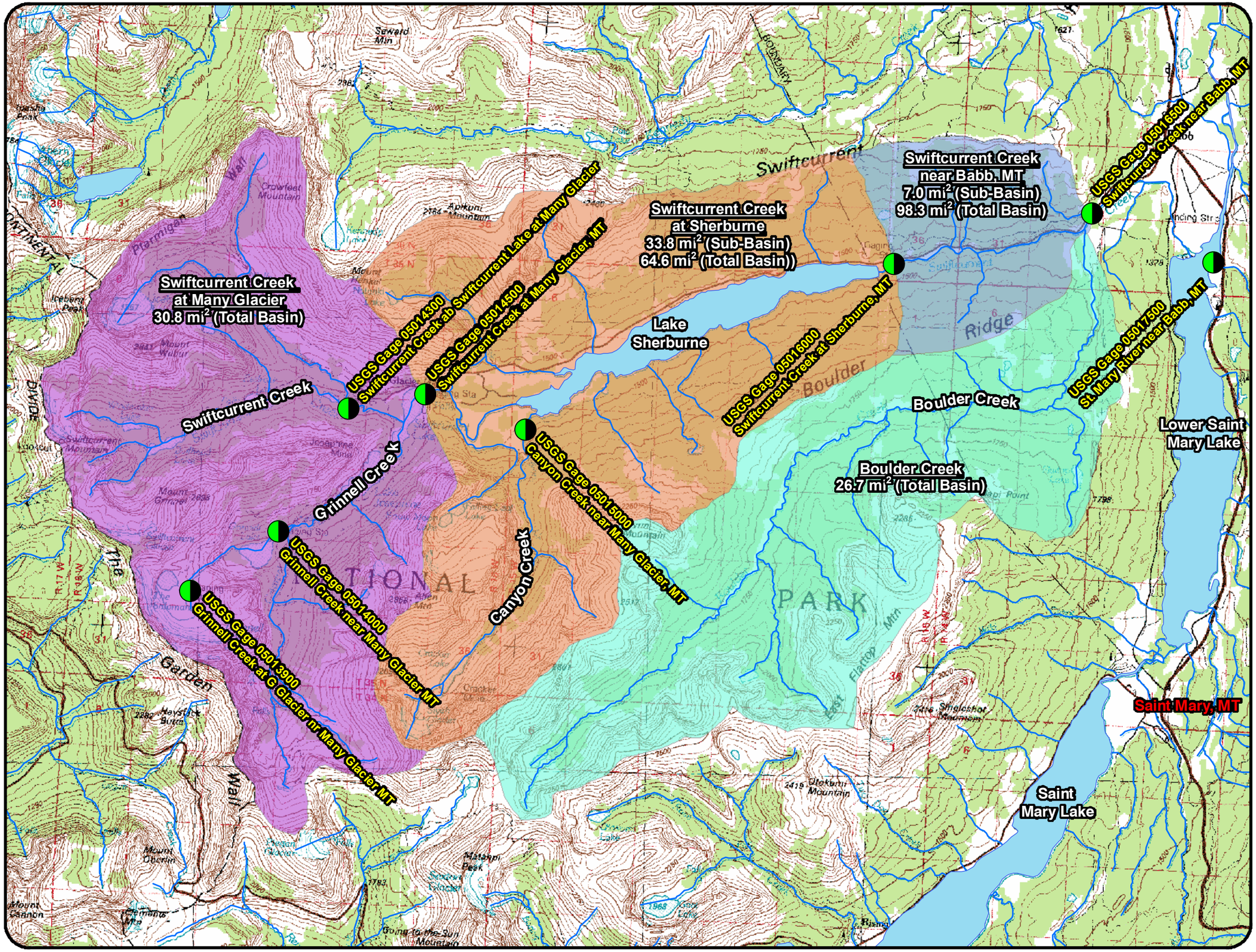
Swiftcurrent Creek below the confluence with Boulder Creek is very unstable and is therefore the key focus of the hydrology effort. Figure 7 provides an overview of the Swiftcurrent Creek watershed.

5.1.1. Streamflow Gages

Seven USGS streamflow gages have been operated within the Swiftcurrent Creek Watershed. USGS Gage 05014300 “Swiftcurrent Creek above Swiftcurrent Lake at Many Glacier” was installed in 2003 and provides a minimal period of record. USGS Gage 05014500 “Swiftcurrent Creek at Many Glacier, MT” referred to herein as the Many Glacier Gage is located on Swiftcurrent Creek just below Swiftcurrent Lake and has 96 years of record (1913-Present). This gage has a contributing drainage area of 30.8 sq. miles. USGS Gage 05016000 “Swiftcurrent Creek at Sherburne, MT”, referred to herein as the Sherburne Gage, is located just below Lake Sherburne Dam and has 96 years of record (1913 to Present). The drainage area above the Sherburne gage is 64.6 sq. miles. The most downstream gage on Swiftcurrent Creek was USGS Gage 05016500 “Swiftcurrent Creek near Babb, MT” located below the Boulder Creek confluence. This gage with a contributing drainage area of 98.3 sq. miles has only 8 years of record from 1902 to 1910. Two streamflows gages are located on Grinnell Creek and one on Canyon Creek, tributaries to Swiftcurrent Creek. The drainage areas of these three gages are relatively small in comparison to the Swiftcurrent Creek drainage (1.1 sq. miles, 3.3 sq. miles and 7.1 sq. miles). There are no streamflow gages located on Boulder Creek. The location of the USGS streamflow gages are shown on Figure 7.

Figure 7

Swiftcurrent Creek Watershed Overview



LEGEND

Drainage Basins

Name

- Boulder Creek
- Swiftcurrent Creek at Many Glacier, MT
- Swiftcurrent Creek at Sherburne, MT
- Swiftcurrent Creek near Babb, MT

USGS Gages

N W E S

1 inch equals 1.25 miles

0 0.5 1 2 Miles

DOWL HKM

5.1.2. Basin Characteristics

The drainage basins for the various subbasins of the Swiftcurrent watershed were delineated from digital USGS 24k topographic maps using ArcGIS 9.2. Drainage basin characteristics have been evaluated using ArcGIS or were obtained from the USGS Website. Table 5 summarizes the basin characteristics for these subbasins. Additional exhibits included in Appendix C show the basin delineations and other basin characteristics.

Table 5 - Swiftcurrent Creek Subbasin Characteristics

Drainage Area	Basin Area (Sq. Miles)	Mean Basin Elevation (ft)	Elevation above 6000 ft (%)	Basin Covered by Forest (%)	Mean Annual Precipitation (inches)
USGS Gage 05014500 Swiftcurrent Creek at Many Glacier	30.9	6,460	64.0	58.1	95.0
USGS Gage 05016000 Swiftcurrent Creek at Sherburne	64.6	6,390	62.0	63.0	85.0
Boulder Creek Basin	26.7	6,363	59.0	52.1	52.3
Swiftcurrent Creek near the Confluence with Boulder Creek	98.3	6,200	50.4	45.2	64.1

5.2. Previous Studies

The Swiftcurrent Creek Watershed has been an area of concern for many years, and previous studies have evaluated the hydrology of the Swiftcurrent Creek Watershed. One of those reports is the 1998 WWC report. The other report is USGS publication SIR 2009-5100 "Relation between Streamflow of Swiftcurrent Creek, Montana, and the Geometry of Passage for Bull Trout". The following section summarizes the hydrologic conclusion from both of these reports.

5.2.1. 1998 WWC Report

The hydrologic section of the WWC report presents a comparison of the natural hydrology of Swiftcurrent Creek to the existing regulated flows from Sherburne dam. The report also presents several methods for evaluating the design flows in Swiftcurrent Creek. These methods include measuring streamflows at three different locations during the 1996 water year, flood flow frequency analysis (performed by the USBR), and predictions based on bankfull flow estimates.

5.2.1.1. Streamflows in Water Year 1996

Streamflows were measured at three locations, including: the USGS Gage (05016000, Swiftcurrent Creek at Sherburne, MT), the USBR Cableway on Boulder Creek near the confluence with Swiftcurrent Creek, and the BIA road bridge located just downstream of the Boulder Creek Confluence. The report indicated that water year 1996 was average to slightly below average in terms of total runoff. Table 6 lists the range of flows measured at these three sites during the 1996 water year.

Table 6 - Range of Mean Daily Streamflows in Water Year 1996 (WWC, 1998)

Site Location	Minimum Flow Measurement (cfs)	Maximum Flow Measurement (cfs)
Swiftcurrent Creek at USGS Gage 05016000	1	815
Boulder Creek at the Confluence with Swiftcurrent Creek	30	353
Swiftcurrent Creek at the County Bridge	245	1104

The report indicates that the composite hydrograph of the USGS gage and the Boulder Creek flows fall below the measured streamflow downstream at the county road bridge for portions of the year, but during the highest flows periods, it exceeds the downstream flows. The disparity between these flows is rather large, and can possibly be explained by shifts in the bed elevation at the bridge causing errors in the discharge estimates.

5.2.1.2. Flood Flow Frequency Analysis

The flood flow frequency analysis completed by the USBR and published in the WWC study used USGS Water-Resource Investigation Report (WRIR) 86-4027, "Methods for estimating magnitude and frequency of floods in Montana, based on data through 1983." The analysis also uses the USGS Annual Peak Flow Frequency Analysis computer program on WATSTORE (WRC estimate) in arriving at flood flow frequencies for USGS Gage 05016000. The 1983 WRIR 86-4027 regional regression equations use three basin parameters including area, average annual precipitation, and a geographical factor. The geographical factor was not used because it introduced additional error into the estimate. The analysis includes the WRC estimate for both the USGS gage at Many Glacier (05014500) and at Sherburne (05016000) and combines these Swiftcurrent Creek flows with the regional regression estimates for the balance of the basin to predict regulated and natural flood flows. Table 7 summarizes the results of this previous analysis.

Table 7 – USBR Flood Frequency Analysis (WWC, 1998)

Location	2-Year (cfs)	10-Year (cfs)	50-Year (cfs)	100-Year (cfs)
Regulated Flood Flows				
Swiftcurrent Creek at Sherburne, (WRC Est.)	1,148	1,941	2,765	3,155
Swiftcurrent Creek between Sherburne and Babb	980	1,580	3,130	5,000
Swiftcurrent Creek near Babb	2,128	3,521	5,895	8,155
Naturalized Flood Flows				
Swiftcurrent Creek at Many Glacier, (WRC Est.)	660	1,879	4,193	5,752
Swiftcurrent Creek between Sherburne and Babb	2,180	2,840	5,220	8,360
Swiftcurrent Creek near Babb	3,000	3,890	7,100	11,200

In the intervening years since the WWC study, the USGS WRIR 86-4027 used in the peak flow analysis has been superseded by WRIR 03-4308, which includes additional period of record and revised regression equations.

5.2.1.3. Bankfull Flow Estimates

The bankfull discharge for both Boulder Creek and Swiftcurrent Creek are difficult to estimate because they are very unstable and typical field indicators are removed annually. These flows are often approximated by the 1.5-year event, and are primarily responsible for shaping and maintaining the stream channel geometry. The following bankfull flows are presented in the WWC report for the three streamflow measurement sites.

- Swiftcurrent Creek below the confluence with Boulder Creek – 1450 cfs
- Swiftcurrent Creek at the Bridge – 1600 cfs
- Boulder Creek at cableway – 550 cfs

5.2.2. USGS Scientific Investigation Report 2009-5100

This report primarily pertains to low-flow conditions of Swiftcurrent Creek, and presents two different methods for estimation of the natural streamflows within Swiftcurrent Creek. The first method includes the ratio of mean monthly discharge at USGS Gage 05015000 on Canon Creek (a tributary to Lake Sherburne) to mean monthly discharge at the upstream gage at Many Glacier (Gage No. 05014500). Similarly, the second method includes the ratio of the estimated annual discharge at seasonally operated gage 05016000 to annual discharge at the upstream Many Glacier gage. The conclusion presented in USGS SIR 2009-5100 from this analysis is that natural streamflows at the Sherburne gage (05016000) should be on the order of 1.4 to 1.5 times the streamflows at the Many Glacier gage (05014500).

5.3. Selection of a Regression Method

Several regression methods were evaluated in order to compare predicted flood flows for the drainage basins within the Swiftcurrent Creek Watershed. These regression methods include USGS regression equations and 9-gage regional regression equations based on various combinations of basin parameters (basin area (A), A & mean basin elevation (E), A & elevation above 6000 ft (E6000), A & area covered by forest (F), and A & average annual precipitation (P)).

5.3.1. USGS Regression Equations – Northwest Region

The Swiftcurrent Creek Basin lies completely within the Northwest Region of the USGS Water-Resources Investigations Report 03-4308. The applicable regression equations for the Northwest Region are:

$Q_2 = 0.128\ A^{0.918}\ P^{1.33}$ (standard error = 0.202)

$Q_{10} = 4.10\ A^{0.807}\ P^{0.720}$ (standard error = 0.161)

$Q_{50} = 31.2\ A^{0.733}\ P^{0.445}$ (standard error = 0.157)

$Q_{100} = 56.4\ A^{0.710}\ P^{0.403}$ (standard error = 0.168)

where: Q_T is the annual peak discharge, in cfs, for recurrence interval T, in yrs;
A is the drainage area, in mi^2; and
P is the average annual precipitation, in inches

5.3.2. Local Regression Analysis

Streamflow gages within a localized region of the Swiftcurrent Creek watershed were evaluated to identify gages with similar basin characteristics as Swiftcurrent Creek. Nine gages within a 90-mile radius of the project area were selected for the analysis. Table 8 shows the nine gages used for the regional regression analysis.

Table 8 - Gages Selected for Regional Regression Analysis

Station Name	Years of Record	A (mi^2)	E (ft)	E6000 (%)	F (%)	P (in)	Q2 (cfs)	Q10 (cfs)	Q50 (cfs)	Q100 (cfs)
Belly River at International Boundary	17	74.8	6180	58.0	51.3	79.0	1,500	1,900	3,800	6,000
Waterton River near International Boundary	17	61.0	6060	56.0	53.9	84.0	2,120	2,700	4,000	6,200
St. Mary River near Babb, Mont.	64	276.0	6170	53.0	66.0	71.0	3,550	6,180	9,290	10,900
Badger Creek near Browning	23	133.0	6020	51.0	59.3	39.0	1,800	3,000	7,000	11,000
North Fork Sun River near Augusta	30	258.0	6150	61.0	87.8	42.0	3,000	4,700	7,600	12,000
Twin Creek near Hungry Horse	11	47.0	5300	57.0	83.3	53.0	1,400	2,400	4,000	5,000
Swiftcurrent Creek at Many Glacier	86	30.9	6460	64.0	58.1	95.0	1,050	1,400	2,600	3,800
Middle Fork Flathead River at Essex	24	510.0	5900	46.0	87.0	52.0	9,500	15,000	24,000	30,000
Moccasin Creek near West Glacier	17	2.4	5620	41.0	81.0	57.0	113	280	530	675

The resulting regional regression equations from the various methods evaluated are summarized in the following sections.

5.3.3. Regression Based on Area

$Q_2 = 69.6\ A^{0.734}$ (standard error = 0.130)

$Q_{10} = 145\ A^{0.672}$ (standard error = 0.118)

$Q_{50} = 287\ A^{0.644}$ (standard error = 0.097)

$Q_{100} = 395\ A^{0.649}$ (standard error = 0.085)

where: Q_T is the annual peak discharge, in cfs, for recurrence interval T, in yrs;
A is the drainage area, in mi^2

5.3.4. Regression Based on Area and Mean Basin Elevation

$Q_2 = 220\ A^{0.743}\ (E/1000)^{-0.664}$ (standard error = 0.139)

$Q_{10} = 9{,}080\ A^{0.702}\ (E/1000)^{-2.39}$ (standard error = 0.109)

$Q_{50} = 8{,}200\ A^{0.668}\ (E/1000)^{-1.93}$ (standard error = 0.090)

$Q_{100} = 1{,}640\ A^{0.659}\ (E/1000)^{-0.820}$ (standard error = 0.089)

where: Q_T is the annual peak discharge, in cfs, for recurrence interval T, in yrs;
A is the drainage area, in mi^2; and
E is the mean basin elevation, in ft

5.3.5. Regression Based on Area and Elevation above 6000 feet

$Q_2 = 38.1\ A^{0.730}\ E6000^{0.156}$ (standard error = 0.140)

$Q_{10} = 3{,}810\ A^{0.696}\ E6000^{-0.846}$ (standard error = 0.115)

$Q_{50} = 8{,}370\ A^{0.668}\ E6000^{-0.873}$ (standard error = 0.086)

$Q_{100} = 1{,}890\ A^{0.660}\ E6000^{-0.406}$ (standard error = 0.087)

where: Q_T is the annual peak discharge, in cfs, for recurrence interval T, in yrs;
A is the drainage area, in mi^2; and
E6000 is the percentage of basin above 6000 ft, in %

5.3.6. Regression based on Area and Area Covered by Forest

$Q_2 = 99.1\ A^{0.735}\ F^{-0.084}$ (standard error = 0.140)

$Q_{10} = 15.4\ A^{0.668}\ F^{0.535}$ (standard error = 0.114)

$Q_{50} = 72.5\ A^{0.642}\ F^{0.328}$ (standard error = 0.098)

$Q_{100} = 351\ A^{0.648}\ F^{0.028}$ (standard error = 0.091)

where: Q_T is the annual peak discharge, in cfs, for recurrence interval T, in yrs;
A is the drainage area, in mi^2; and
F is the percentage of basin covered by forest, in %

5.3.7. Regression based on Area and Average Annual Precipitation

$Q_2 = 8.32\ A^{0.758}\ P^{0.492}$ (standard error = 0.119)

$Q_{10} = 109\ A^{0.676}\ P^{0.067}$ (standard error = 0.128)

$Q_{50} = 455\ A^{0.639}\ P^{-0.107}$ (standard error = 0.103)

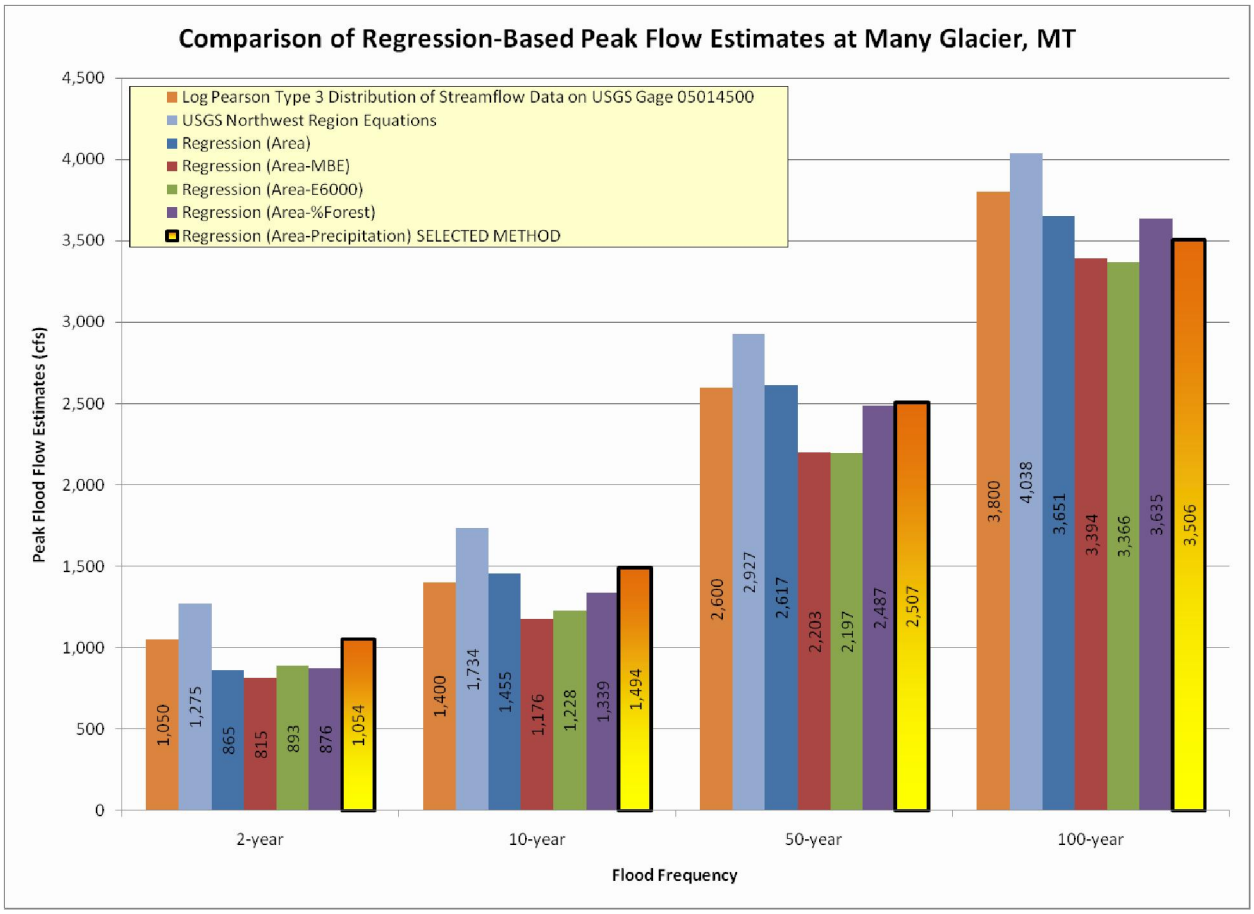
$Q_{100} = 611\ A^{0.644}\ P^{-0.101}$ (standard error = 0.090)

where: Q_T is the annual peak discharge, in cfs, for recurrence interval T, in yrs;
A is the drainage area, in mi^2; and
P is the average annual precipitation, in inches

5.3.8. Conclusion

The results from the various regression methods were compared to estimated flood flow frequencies based on stream gage data from the Many Glacier gage using the Log Pearson Type 3 distribution. These comparisons are shown on Figure 8 for the 2, 10, 50 and 100-year peak flood events. Further details of the various regression methods are provided in Appendix C.

Figure 8 - Comparison of Regression-Based Peak Flow Estimates



In comparison to flood flows developed based on USGS gage records, the USGS Northwest Region Regression equations over-predict flood flows for all events, while both the regional regression methods which utilize area & mean basin elevation and area & elevation above 6000 feet both under-predict flows. The other regional regression methods provide reasonable estimates in comparison to the recorded flood flows. The regional regression equations using basin area and mean annual precipitation compare reasonably well to estimates based on actual gage data over the full range of flood frequencies and are therefore selected for this Phase I analysis.

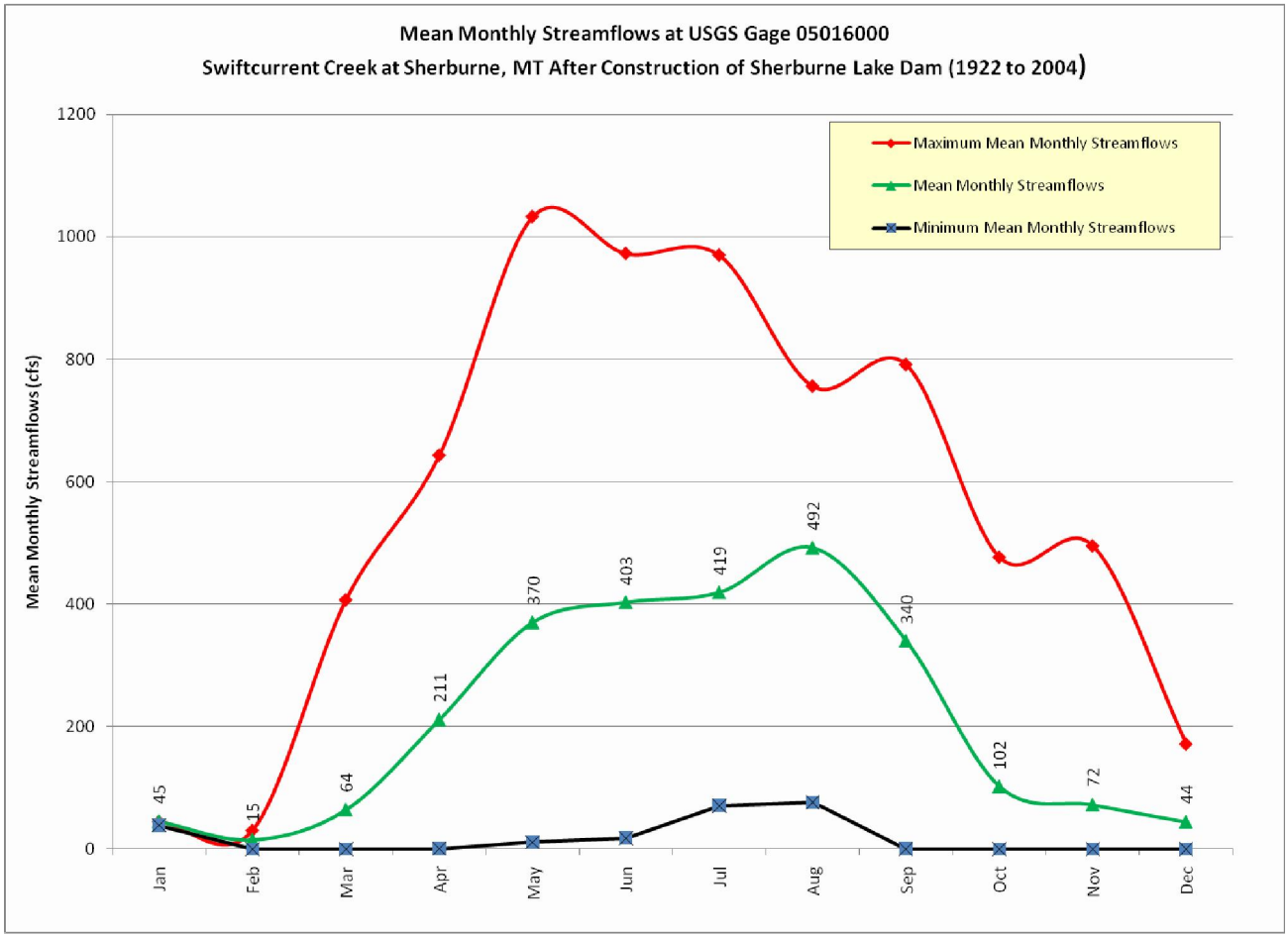
5.4. Existing Swiftcurrent Hydrology with Sherburne Dam

The following section presents the evaluation of the mean monthly streamflows and peak flood flows of Swiftcurrent Creek below Sherburne Dam under existing conditions (with regulation by Lake Sherburne).

5.4.1. Existing Mean Monthly Streamflows

Streamflow records are available from the Sherburne gage (05016000) beginning in 1913, approximately 3-years prior to construction of Sherburne Dam. Construction of the dam was completed in 1922. Figure 9 shows the mean monthly streamflows as well as the minimum and maximum flows for water years 1922 through 2004.

Figure 9 - Streamflows Below Lake Sherburne



Available streamflow records for Boulder Creek are limited to those collected as part of the 1998 WWC investigation. Additional Boulder Creek streamflow data will be required for a comprehensive understanding of the watershed hydrology. This will be addressed in the framework for future work presented in Section 9.

5.4.2. Existing Peak Flood Flows

The following flood frequency estimates were developed by the USGS using a log-Pearson Type 3 distribution of recorded annual peak discharges at the Sherburne gage.

- Q_2 = 1,140 cfs
- Q_{10} = 1,950 cfs
- Q_{50} = 2,790 cfs
- Q_{100} = 3,190 cfs

Boulder Creek flood flow estimates were estimated using the selected regional regression equation, and are summarized as follows:

- Q_2 = 703 cfs
- Q_{10} = 1,301 cfs
- Q_{50} = 2,434 cfs
- Q_{100} = 3,390 cfs

The peak flood flows for Swiftcurrent Creek and Boulder Creek can be added together as a very rough estimate of peak flood flows below the confluence. However, the operation of Sherburne Dam significantly shifts the timing of peak flows from that which would occur under natural conditions. The need for additional Boulder Creek flood flow records is addressed in the framework for future work presented in Section 9.

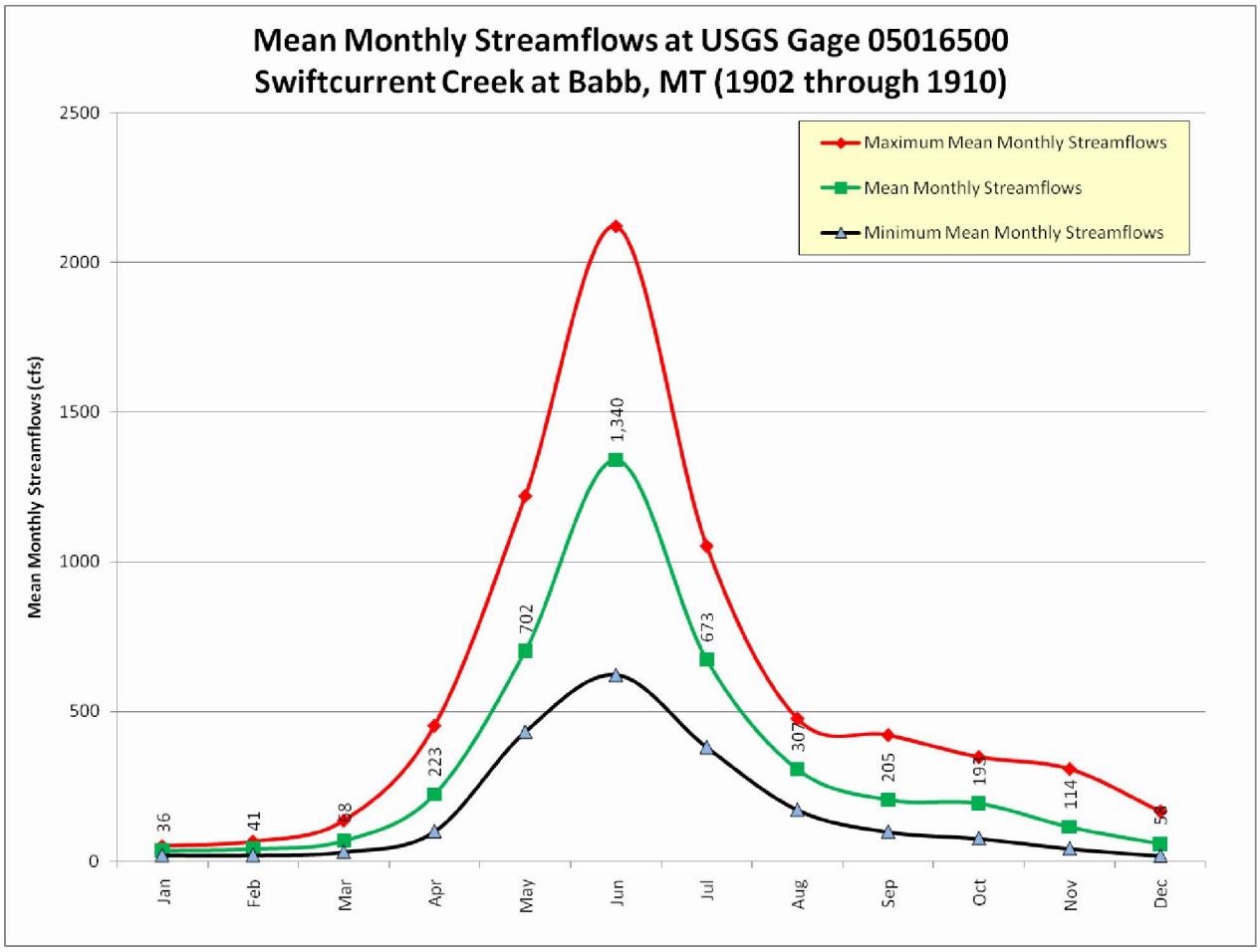
5.5. Natural Swiftcurrent Hydrology without Sherburne Dam

The natural Swiftcurrent Creek hydrology represents streamflows that would occur in the absence of Sherburne Dam. This section presents various methods used to assess natural flows.

5.5.1. Monthly Streamflows of Swiftcurrent Creek at Babb

The USGS gage on Swiftcurrent Creek at Babb, MT (05016500) was a natural streamflow gage, located just downstream of the confluence with Boulder Creek. This gage has a period of record of only 9 years from 1902 to 1910. The mean monthly streamflow recorded at this gage is shown in Figure 10.

Figure 10 - Mean Monthly Streamflows for USGS Gage 05016500

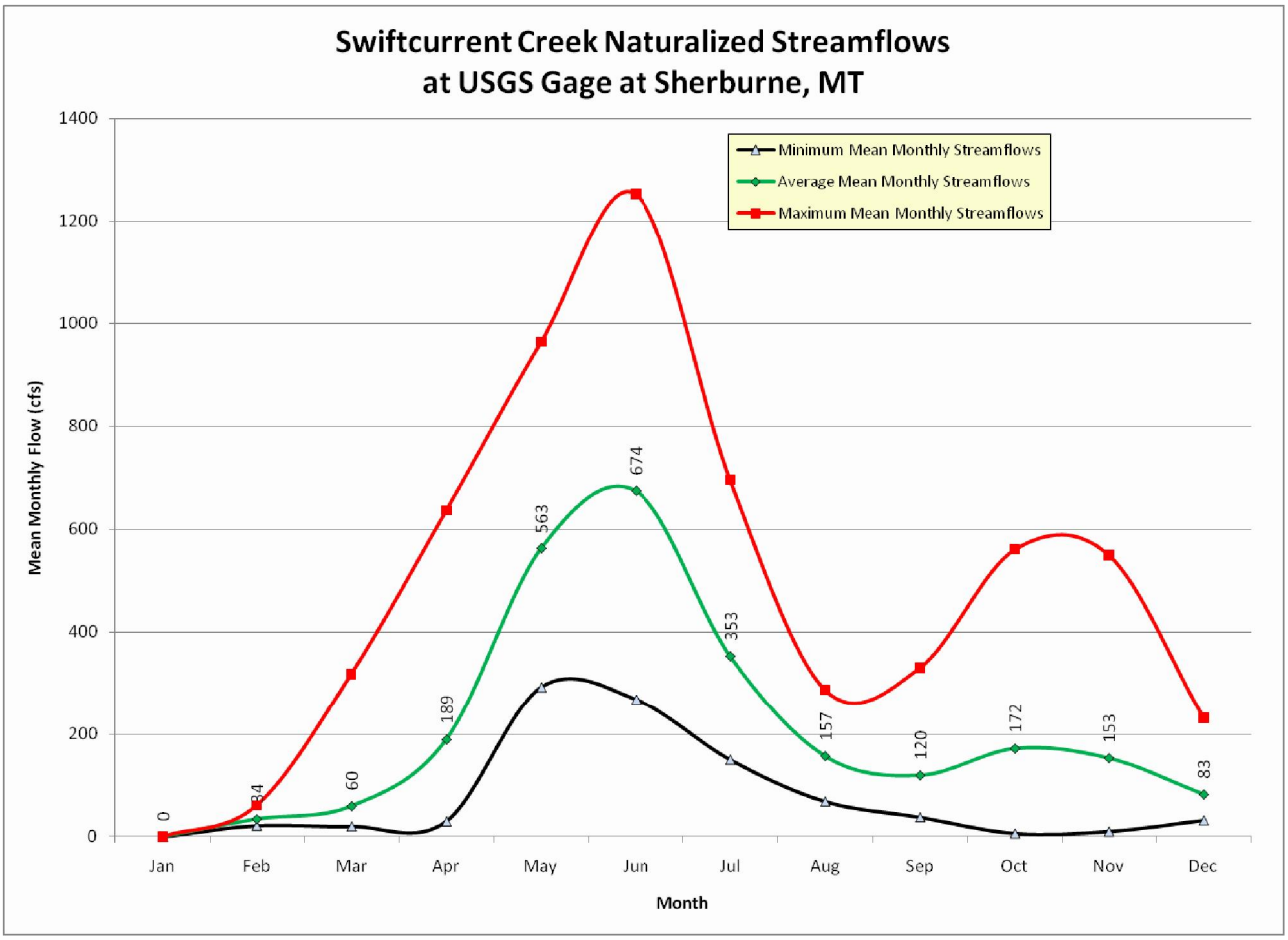


Although limited, records from this gage provide a representation of the shape of the hydrograph that would be expected under natural conditions.

5.5.2. Naturalizing Recorded Monthly Streamflows at Sherburne

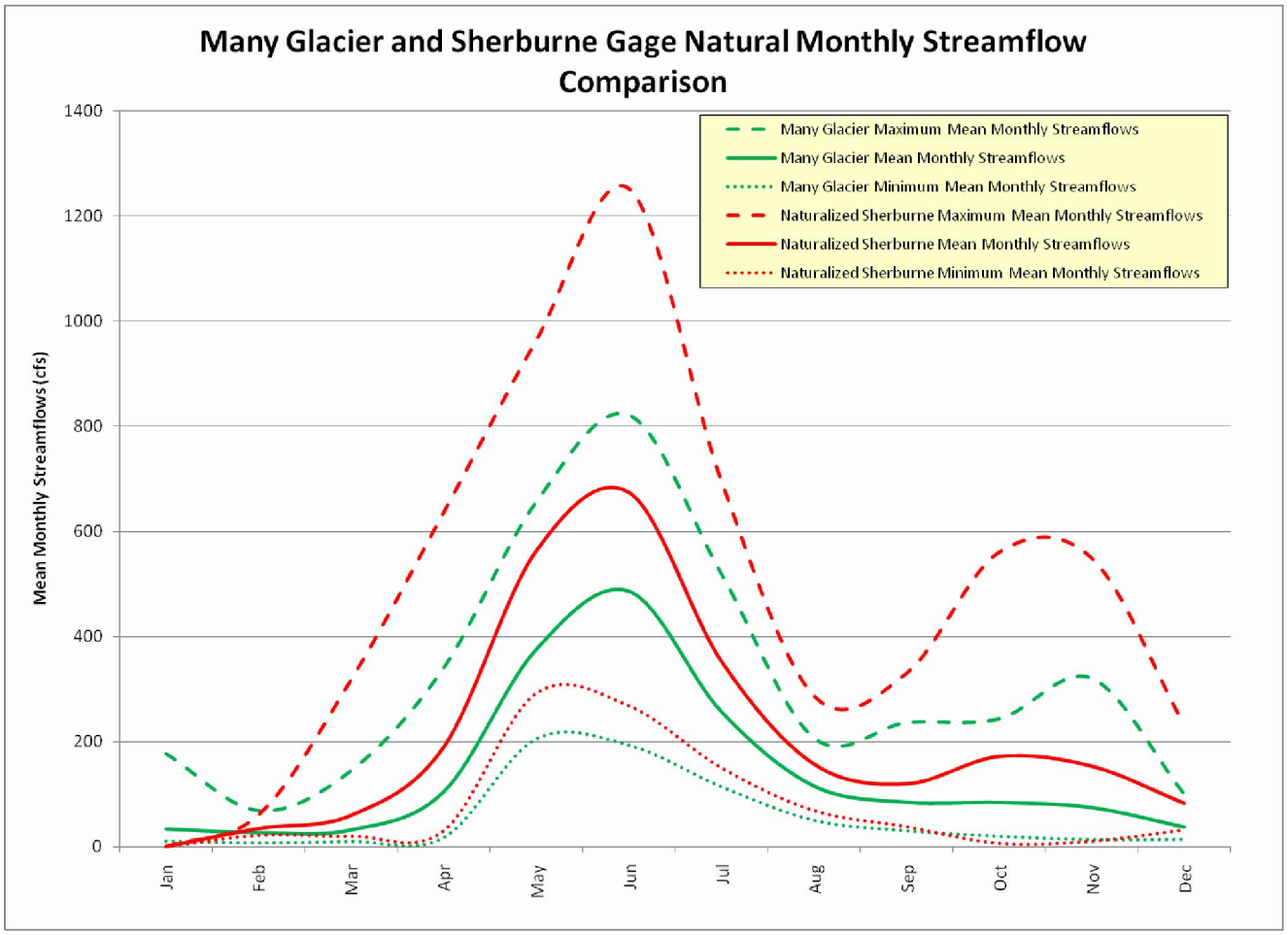
Streamflow at the Sherburne gage (USGS gage 05016000) is impacted by storage regulation and evaporation losses from Lake Sherburne. The streamflow record was naturalized to remove these effects using monthly storage contents data obtained from the USBR website, the reservoir stage-surface area relationship, and evaporation data. Naturalized streamflows were calculated by adding the recorded monthly streamflows to the monthly change in Lake Sherburne storage contents and the monthly reservoir evaporation. An average annual net lake evaporation of 10 inches was taken from the 1972 Missouri River Basin Study and was distributed through the year using data for Valier, MT. Figure 11 shows the naturalized streamflows for the Sherburne Gage.

Figure 11 - USGS Gage 05016000 Naturalized Streamflows



The shape of the resulting naturalized hydrograph was compared to that from recorded natural streamflows at the Many Glacier gage (USGS Gage 05014500) as a reasonableness check. Figure 12 shows the recorded natural streamflow hydrograph at Many Glacier in comparison to the naturalized hydrograph at Sherburne As shown, the shapes of the hydrographs are very similar, as should be expected.

Figure 12 - Many Glacier and Sherburne Gage Natural Monthly Streamflow Comparison



5.5.3. Gage Transfer of Naturalized Monthly Streamflow

A gage transfer of the naturalized streamflow at Sherburne was performed to estimate streamflows on Swiftcurrent Creek below the confluence with Boulder Creek. The USGS gage transfer equation published in USGS WRIR 03-4308 was used for this purpose.

$$Q_{UNGAGED} = Q_{GAGE}\left(\frac{DA_{UNGAGED}}{DA_{GAGE}}\right)^{exp}$$

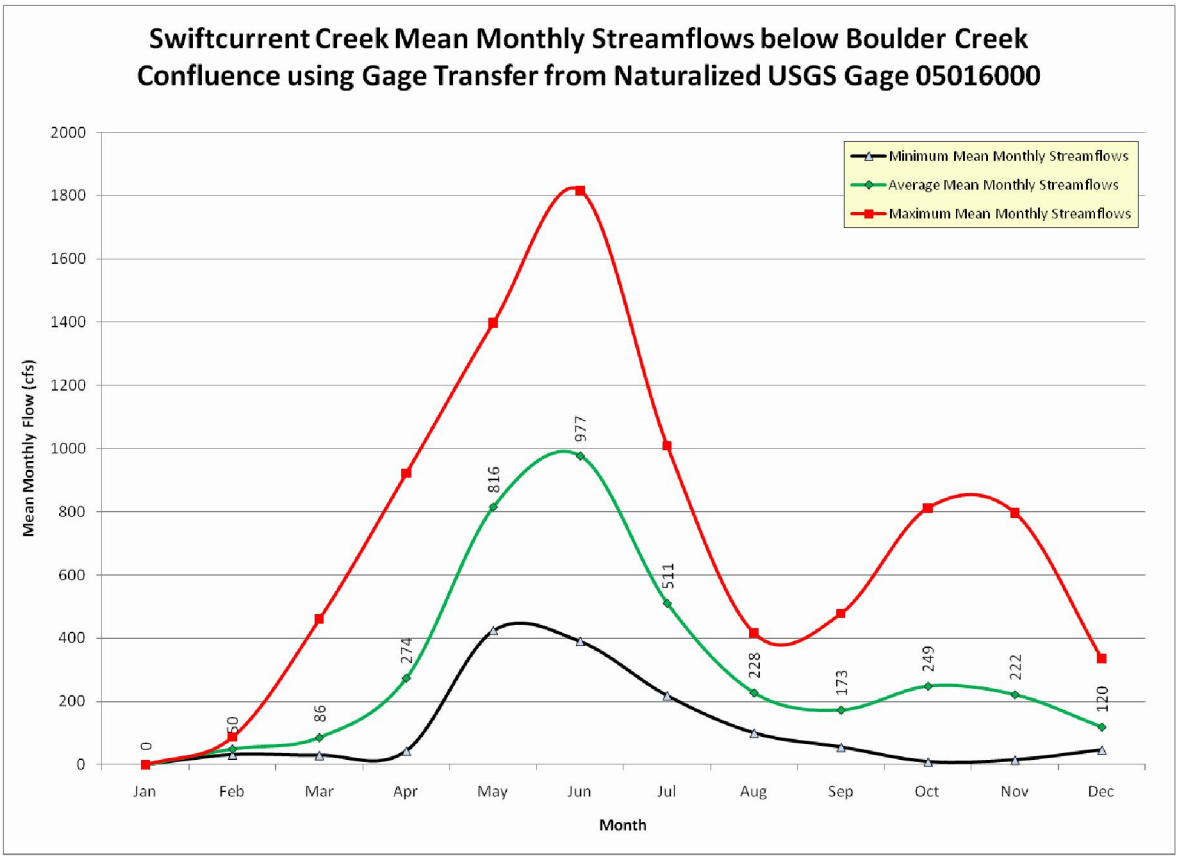
where:

$Q_{UNGAGED}$ is the streamflow of the site of interest, in cfs,
Q_{GAGE} is the streamflow at the gage site, in cfs,
DA_{GAGE} is the drainage area of gage site, in sq. miles,
$DA_{UNGAGED}$ is the drainage area at the site interest, in sq. miles, and
exp is a regression coefficient from USGS WRIR 03-4308 (Q_2 = 0.884)

The drainage areas at the Sherburne gage and at the confluence with Boulder Creek are 64.6 sq. miles and 98.3 sq. miles, respectively. The regression coefficient was taken from Table 13 in the USGS WRIR

03-4308 publication for the 2-year event in the Northwest Region. Figure 13 shows the estimated natural streamflow of Swiftcurrent Creek below the confluence with Boulder Creek.

Figure 13 - Naturalized Streamflows below Boulder Creek Confluence



5.5.4. Natural Peak Flood Flow Estimates

5.5.4.1. Regional Regression

The selected regional regression equations were used to estimate peak flood flows in the Swiftcurrent Creek Watershed. The drainage area and the mean annual precipitation below the Boulder Creek confluence are 98.3 sq. miles and 64.1 inches, respectively. The following flood frequency data summarize the predicted flood flows for Swiftcurrent Creek below the confluence of Boulder Creek.

- Q_2 = 2,089 cfs
- Q_{10} = 3,181 cfs
- Q_{50} = 5,478 cfs
- Q_{100} = 7,683 cfs

5.5.4.2. Gage Transfer Methods

The peak flood flows recorded at the Many Glacier gage were transferred downstream to the Sherburne Gage and then added to the regional regression estimates of peak flow from the remaining area of Swiftcurrent Creek and for Boulder Creek. In addition, a gage transfer from the Many Glacier gage directly to Swiftcurrent Creek below the confluence with Boulder Creek was also performed. This method should be used with caution, however, as the ratio of drainage areas from Many Glacier to the Boulder Creek confluence are outside of the typically accepted bounds (no more than a 50 percent increase in area).

$$Q_{UNGAGED} = Q_{GAGE}\left(\frac{DA_{UNGAGED}}{DA_{GAGE}}\right)^{exp}$$

where:

$Q_{UNGAGED}$ is the streamflow of the site of interest, in cfs,
Q_{GAGE} is the streamflow at the gage site, in cfs,
DA_{GAGE} is the drainage area of gage site, in sq. miles,
$DA_{UNGAGED}$ is the drainage area at the site interest, in sq. miles, and
exp is a regression coefficient from USGS WRIR 03-4308
(Q_2 = 0.884, Q_{10}=0.789, Q_{50}=0.722, and Q_{100}=0.700)

The results from the two gage transfer methods are summarized in Table 9.

Table 9 - Summary of Peak Flood Flows on Swiftcurrent at the Confluence with Boulder Creek

Peak Flow Method	Drainage Area of Gaged Site (sq. miles)	Drainage Area of Ungaged Site (sq. miles)	2-Year Flows (cfs)	10-Year Flows (cfs)	50-Year Flows (cfs)	100-Year Flows (cfs)
Gage Transfer To Sherburne Gage	30.9	64.4	2,010	2,499	4,418	6,354
Regional Regression on Incremental Area[1]	N/A	7.2	222	525	1,090	1,506
Regional Regression on Boulder Creek	N/A	26.7	703	1,301	2,434	3,390
Boulder Creek Regression Plus Sherburne Gage Transfer Plus Incremental Area Regression	N/A	98.3	2,935	4,325	7,942	11,250
Gage Transfer To Boulder Creek Confluence	30.9	98.3	2,921	3,489	5,996	8,543

[1] – Incremental Area consists of the drainage basin contributing to Swiftcurrent Creek below Lake Sherburne Dam to the confluence with Boulder Creek (P = 38 inches).

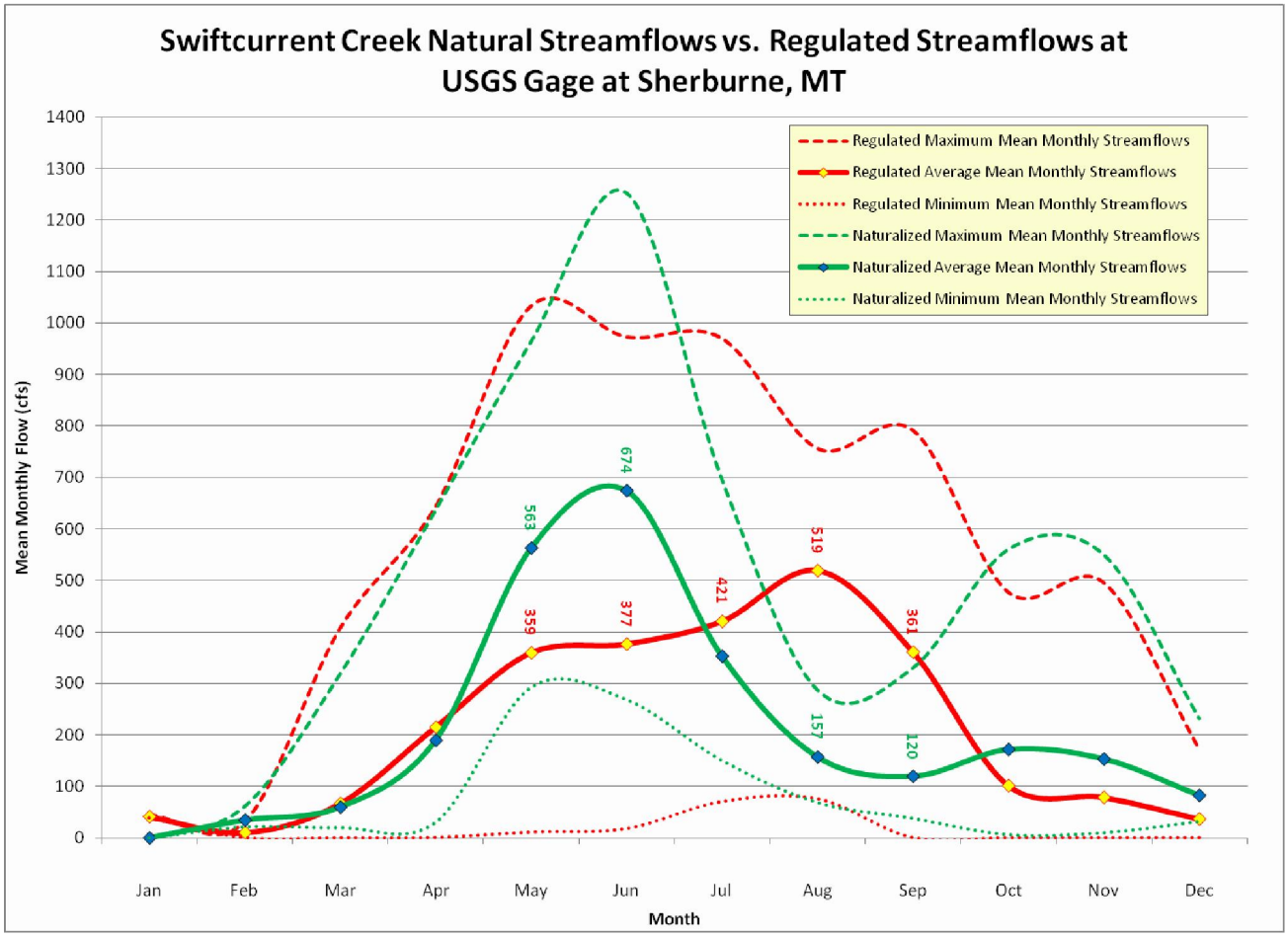
5.6. Comparison of Existing and Natural Hydrology

5.6.1. Mean Monthly Streamflows

A comparison of the existing and naturalized mean monthly streamflows of Swiftcurrent Creek at Sherburne was performed to assess the impacts of Sherburne Dam on Swiftcurrent Creek streamflows. Figure 14 provides a comparison of the average, maximum, and minimum streamflows under existing

conditions to those estimated to have existed under natural conditions, for the period 1922 through 2004.

Figure 14 - Existing vs. Natural Swiftcurrent Creek Streamflows



This chart illustrates a shift in the hydrograph shape. The average peak streamflows under natural conditions occur in June, whereas under the existing (regulated) condition, the peak typically occurs in August, a two month shift. The average peak monthly streamflow for existing conditions is approximately 155 cfs less than natural conditions. The maximum mean monthly streamflows are reduced by approximately 220 cfs in comparison to natural conditions.

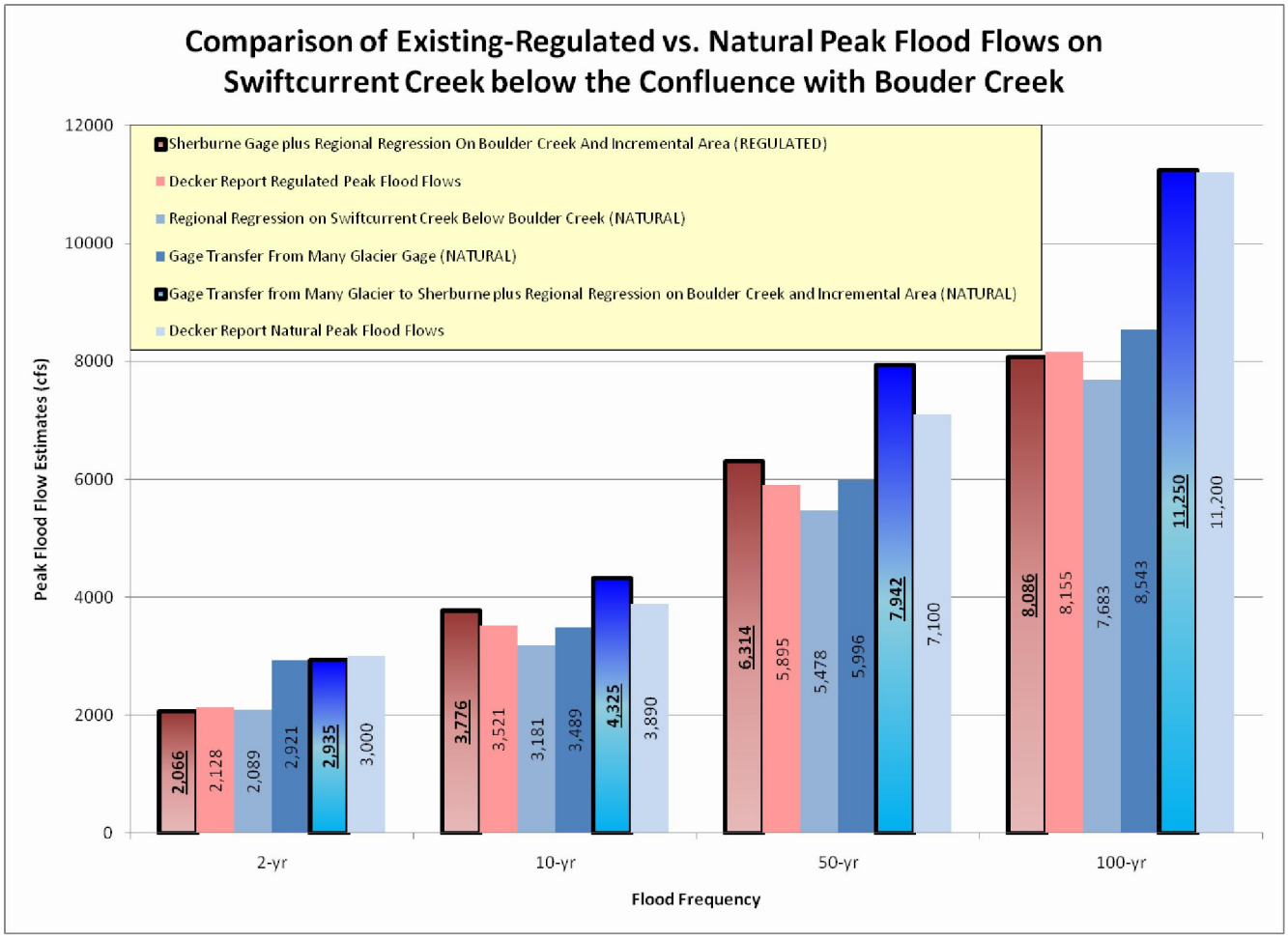
Under existing conditions, the dam releases streamflows above 250 cfs for approximately six months (April through September). Under natural conditions, the flow would only exceed 250 cfs for four months (April through July). This may induce additional transport of finer sediments. However, the capacity for transporting the coarser sediments may be significantly reduced due to the reduction in flood peaks.

A much more thorough evaluation of the impacts of the operations of Sherburne Dam on sediment transport in Swiftcurrent Creek is required. This will be addressed in the framework for future work presented in Section 9.

5.6.2. Peak Flood Flows

Figure 15 provides a comparison of the rough estimates of existing peak flood flows on Swiftcurrent Creek below the confluence with Boulder Creek to those that would exist under natural conditions. The peak flood flow estimates presented in the 1998 WWC report are also included. The methods selected as most reasonable for this comparison are highlighted.

Figure 15 - Existing vs. Natural Swiftcurrent Creek Flood Flows



The estimated natural and existing (regulated) peak flood flows using the updated hydrology are somewhat different from those presented in the 1998 WWC report. Since the completion of the 1998 report, a new USGS WRIR was published providing updated regression equations for estimating peak flood flows. These new equations were based on fifteen additional years of gage data. The impact of Sherburne Dam operations on natural flood flows is estimated to range from a reduction of about 900 cfs for the 2-year event to a reduction of 3,200 cfs for the 100-year event.

Further details of the hydrologic investigation are provided in Appendix C.

6. Sediment Transport Review

6.1. Introduction

An adequate understanding of sediment transport processes will be an essential part of the design of any rehabilitation or remediation efforts to be implemented on lower Boulder and Swiftcurrent Creeks. The transport of sediments from these drainages is responsible for several of the key symptoms that are viewed as undesirable in this system, specifically, the presence and recent growth of the delta in Lower Saint Mary Lake and the instability of the Swiftcurrent Creek channel.

The 1998 WWC study included an investigation of sediment transport to support the design of stabilization and reconstruction measures for lower Boulder and Swiftcurrent Creeks. The primary finding of this study is that, due to instability and stream braiding caused by the 1964 flood, Swiftcurrent Creek below the Boulder Creek confluence is not capable of transporting the sediment load delivered by the watershed. This finding is the driving influence behind the design recommendation to return the stream to a single-thread channel for the purpose of increasing the streams capacity to transport the sediment supply. This investigation, however, stopped short of providing a thorough review of all factors that have contributed to this condition.

The scope of the Phase I reconnaissance investigation completed through the current study includes a review of sediment supply sources within the watershed, a review of the primary findings of the WWC report, and a reconnaissance investigation into the effects of Sherburne Reservoir operations on the sediment transport capacity of Swiftcurrent Creek.

6.2. Sediment Supply Sources

Sediment transport can be categorized, based on the source of the sediments, as either wash load or as bed-material load. Wash load consists of clays, silts, and fine sands recruited into the stream from adjacent banks, hillsides, and/or up-basin erosion. Wash load sediments are found in only small amounts in the stream bed, while bed-material load consists of the sediments which dominate the stream bed, such as gravels, cobbles and boulders. (Wilcock et al., 2009)

The distinction between wash load and bed-material load is important, as it is related to the distinction between the two primary sediment transport concerns for Swiftcurrent Creek. It is likely that wash load is largely responsible for the recent growth of the Swiftcurrent Creek delta in Lower Saint Mary Lake, while bed-material load is the primary driving force of shifts in channel alignment and channel instability. A second important distinction is that the transport of bed-material load is predictable based on channel hydraulics and bed-material composition, whereas wash load transport is generally not predictable based on these factors, as wash load transport is dependent on the rate that fine sediments are supplied to the stream (Wilcock, 2007).

The distinction between wash load and bed-material load has clear implications in the context of the current Swiftcurrent Creek study. If the recent growth of the delta is, as suspected, due to wash load sediment transport, and the rate of wash load transport is not generally predictable; it follows that the rate of delta growth is also not predictable based on a sediment transport analysis. Growth rates,

however, can be estimated based on historical growth rates or through estimates of the rate of fine sediment supply to the system. Conversely, given that bed-material load is the driving factor behind channel change and channel instability, prediction of bed-material transport will need to be a focus of stabilization efforts.

6.2.1. Mapping

Review of aerial photography for the Boulder and Swiftcurrent Creek watersheds was completed to document and map the location of mass sediment sources, including landslides, debris flows, avalanche areas, and shallow slope failures immediately adjacent to the stream.

Figure 4 shows the active landslide and debris flow areas in Reaches 7 and 8 along Boulder Creek. Two relatively active debris flow deposits have been mapped in the lower portion of Reach 8 and upper portion of Reach 7. Material appears to be transported from higher up in the valley and deposited in lobes near the edge of the stream channel. These deposits appear fresh and void of vegetation in the 1966 photos, presumably re-activated during the 1964 flooding or the associated rainfall event. The debris flow deposits in Reach 8 appear to be over-riding and burying trees.

Downstream of these debris flow deposits, near the mid-section of Reach 7, an active landslide deposit was documented through aerial photo interpretation and also through the field investigations. Active lobes of this landslide are visible in the 1953 photos, although the head scarp appears vegetated and perhaps less active. Some areas of the head scarp appear fresh and have less vegetation in the 1966, 1990/1991, and 2005 photos, indicating continued movement. This observation was verified during a field visit in October 2009 to this area.

Approximately 50 percent of the Swiftcurrent Creek drainage consists of landslide and till deposits. In general, most of the features including the landslides, debris flows, and avalanche areas identified on the 2005 aerial photographs, were already present in 1953. Some reactivation of the debris flow was observed in the 1966 photos. The active landslide area in Reach 7 was also partially active in 1953 but additional movement and activation in the head scarp and toe area is observed in the 1966 and 1991 photos.

6.2.2. Field Investigations

In October of 2009, personnel from DOWL HKM and the Blackfeet Environmental Office conducted a field review of sediment sources within the Lower Boulder Creek drainage. The purpose of this investigation was to better understand the sources of sediment and the potential for remediation measures that would minimize sediment recruitment through stabilization at the source. The extent of field investigations included the lower 2.5 miles of lower Boulder Creek. Field photos taken during the field investigation are included in Appendix D along with a photo log. Each photo references the site location number as shown on Figure 4.

Field investigations revealed mass sediment sources on Boulder Creek immediately upstream of Reach 1. In this area, the stream meanders through the valley with massive erosion occurring at the outside of each meander bend (sites 1 through 6). The outside of each bend is characterized by vertically eroding faces (some in excess 30 ft high), each roughly 500 ft in length. Geologic mapping (Figure 3) indicates

that the eroding hillsides are quaternary landslide deposits and glacial till. These eroding meander bends are typical of the topography present throughout Reach 7. The exposed materials were observed to consist almost exclusively of fine sediments with some gravel deposits, although boulders on the valley floor indicate that larger material is likely also contained within these deposits. Stabilization of these erosion areas would be very difficult, as the mapping of the stream channel completed through the geomorphology section of this report indicates that the channel alignment is actively moving within the floodplain. There is little likelihood that stabilization or erosion protection measures installed along the meander bends would remain effective once the stream shifts.

Field photos of Sites 9 and 13 (photos 22 and 26, respectively in Appendix D) show the active scarp along the upper portion of the large landslide documented through the mapping (south of Boulder creek) as well as active erosion at the toe of the landslide. The field photo of Site 12 (photo 25 in Appendix D) shows active erosion along the north side of the Boulder Creek channel.

6.2.3. Conclusions

Many potential mass sediment sources were identified in Swiftcurrent and Boulder Creeks through mapping and field investigations, including stream erosion of adjacent hillsides, landslides, debris flows, avalanche areas, and shallow slope failures immediately adjacent to the stream. The vast majority of the sediment supply appears to be from Boulder Creek Reach 7 (see Figure 2 for reach designations).

The actively eroding sediment sources were observed to consist primarily of fine material with limited coarse sediment. The sources documented through the mapping and field investigations are capable of providing an unlimited supply of sediment to the stream. Stabilization at the source to limit additional erosion and sediment recruitment would need to be very extensive and would likely be very costly.

6.3. Review of WWC Sediment Transport Study

The goals of the sediment transport analysis completed through the WWC study were, “to determine total annual sediment discharges, energy requirements for the larger sized bedload sediment and to compare with estimated bank erosion rates to predict the proportion of the total sediment yield that is attributable to bank erosion.” Suspended sediment and bed load sediment sampling was completed and empirical sediment rating curves for both categories were developed from the results. The principle findings of the WWC study are that Swiftcurrent Creek, in its current geometry and under the current flow regime, is not capable of transporting the large sediment loads supplied by the watershed, a condition that is resulting in channel instability. The restoration objectives related to sediment transport for the design proposed in the WWC report include construction of a C3 or B3 channel that is “self maintaining and will accommodate floods without major changes in channel pattern or profile” as well as to “reduce bank erosion and sediment loads to Lower Saint Mary Lake, thereby slowing the rate of delta formation.”

A cursory review of the methodologies and analyses presented within the design report was completed. The results of this review are included in the following sections.

6.3.1. Sampling Methods

There are several important sources of error inherent to the sampling methodologies employed by WWC that should be considered. It is understood that funding and schedule constraints likely dictated these sampling methods.

The most obvious source of potential error is the sampler opening size. Sediment grain sizes near to or exceeding the opening size of the sampler cannot be collected, as acknowledged in the WWC report. The sampler used in the WWC analysis has a 3 inch opening (76 mm). In comparison to the WWC pebble count estimates of bed material size, 3 inches represents a size in the range of D45 to D70 for Boulder Creek and D55 to D75 for Swiftcurrent Creek below the confluence, where Dx indicates the particle size diameter for which x% of the bed material is less than or equal to. This comparison reveals that a significant percentage of the bed material potentially available for transport cannot be sampled through the methodologies employed. Furthermore, according to the WWC report, bar samples suggest that up to 30% of the bedload transported at the low flows observed during sampling may have exceeded the size capable of being sampled using this 3 inch sampler.

In addition to size classes greater than can be sampled by the hand-held sampler used, the WWC design report also indicates a higher proportion of smaller size classes transported in the bed load samples than collected in the bar samples. The possible explanation for this discrepancy provided in the report is the reduced sampling efficiency of the bar sample; as it is difficult to collect all of the grains in the size range of sand and smaller, particularly when obtaining underwater samples. Alternatively, this apparent discrepancy could also be an indication of poor sediment transport sampling efficiency at some grain sizes. The presence of a higher proportion of small grain sizes would be expected, given a low sampling efficiency of the larger grains, as they move less frequently at low flows and are harder to capture. Flows sufficient to move bed-material sediment generally occur during only a small fraction of the year, and even at flows where grains are actively transported, most of the grains on the bed surface are not moving most of the time (Wilcock, 2009). This makes it difficult to capture accurate sediment transport samples with the relatively short durations inherent to hand-held sampling methods, as one has to be consistently in the right place at the right time.

Due to the relatively short sampling durations and other sampling inefficiencies inherent to the methodology used, it is likely that the sediment transport rates estimated through the WWC study are an underestimate of the actual rate, and potentially a gross underestimation given the low flows experienced during sampling.

To overcome the difficulties in sampling bed-material load, Kristen Bunte (2001) provides the following sampling criteria to more accurately measure gravel and cobble movement at low flows: the sampler must have a sufficiently large entrance to allow cobbles to enter, be stationary to allow long sampling times, be capable of sampling relatively large volumes without adversely affecting sampling efficiency, keep flow resistance to a minimum, and be operable at wade-able flow depths and velocities. Alternative methods to hand-held sampling which meet these criteria include pit traps and net traps. However, these methods are not without drawbacks of their own, which include installation effort as well as inaccessibility and the fact that they can fill quickly at large flows (Wilcock, 2001).

6.3.2. Sediment Rating Curve

The results of the sediment transport sampling data were used in the WWC study to develop empirical sediment rating curves relating sediment yield to discharge for both suspended sediment and bed load, for the purpose of estimating total annual sediment yield.

Total suspended sediment loads in Boulder Creek are expected, based on the results of the sediment source analysis and the bed-material composition observed, to be dominated by wash load. Wash load transport is generally not predictable, as it is dependent on the rate that fine sediments are supplied to the stream (Wilcock, 2007). Although the suspended sediment rating curve developed through the WWC study may describe the erosion and suspended sediment yield at the time of the study, it cannot be relied upon as predictive tool for future suspended sediment transport.

One of the key challenges in development of an empirical bed-material sediment rating curve is the data collection intensity and effort required, as a large number of accurate sediment transport samples are needed over a wide range of flows to develop a meaningful empirical relationship. However, the sediment rating curves developed through the WWC study, due presumably to funding and time constraints, include a relatively small number of sediment samples (less than 10), all of which are at flows less than the 2-year peak discharge. The highest flows reported in the WWC report during sediment transport sampling are 300 cfs and 1100 cfs, respectively, for Boulder Creek and Swiftcurrent Creek. Since the resulting empirical relationship does not provide for extrapolation of data, even if the bed load sediment rating curve developed through the WWC study is accurate over the range of flows represented, it does not provide a means to estimate transport at flows outside of the range represented by the sediment transport sampling.

To be meaningful, a sediment transport rating curve must be capable of estimating sediment transport rates over the entire range of expected flows. Since sampling is often not practical at high flows, development of an entirely empirical rating curve is difficult. In general, the alternative to development of an empirical sediment rating curve is the utilization of one of several sediment transport formulas. However, this formula method is also not without challenges, as the formulas can be very sensitive to data input. Significant research in the area of sediment transport has occurred in the intervening years since the WWC study. In particular, to combat the logistical difficulties associated with both the entirely empirical method and the formula approach to sediment transport modeling, Wilcock (2001) recommends the use of a sediment transport formula calibrated by a small number of transport samples at small transport rates as a more practical alternative.

6.3.3. Conclusions

The principle finding of the WWC study is that Swiftcurrent Creek, in its current geometry and under the current flow regime, is not capable of transporting the large sediment loads supplied by the watershed. The WWC study further surmises that reconstruction to a C3 or B3 channel will accomplish the design objectives of creating a channel that is “self maintaining and will accommodate floods without major changes in channel pattern or profile,” as well as providing reduced “bank erosion and sediment loads to Lower St. Mary Lake, thereby slowing the rate of delta formation.”

Several critical deficiencies exist in the WWC sediment transport analyses that limit the usefulness of the results, and cast doubt on the ability of these results to support the design recommendations. The most notable deficiencies are the error inherently introduced by the sampling methods used and the inability of the sediment rating relationships to provide estimates of sediment transport at flows higher than the 2-year recurrence interval flow.

Additionally, understanding the distinction between reach instability caused by the deposition of bed-material within the active channel and the growth of the delta due to wash load sediment deposition is important in maintaining proper expectations for the results of mitigation measures. Simply improving the stream's ability to transport its sediment may reduce instability in one area, but at the cost of transferring the problem somewhere else. Addressing bed-material induced instability will likely not affect the recent growth of the Swiftcurrent Creek delta, as this issue is likely driven by wash load sediment transport.

The WWC study also stops short of addressing all factors influencing the instability of Swiftcurrent Creek. Although the general finding that Swiftcurrent Creek, in its current geometry and under the current flow regime, is not capable of transporting its large sediment load may be true, reconstructing the channel geometry is not the only mitigation alternative, and potentially not the most appropriate alternative. Stream channel change depends on both streamflow and sediment supply. Hydrologic analysis indicates that the current flow regime is significantly altered from the natural state. An examination of the effects of Sherburne Dam and the potential to restore a more natural flow pattern should be completed prior to selection of any mitigation alternative.

Review of the WWC sediment transport study supports the need for further sediment transport analyses prior to final design and/or implementation of mitigation measures. A bed-material sediment transport continuity analysis is recommended to assess the sediment transport capacity of upstream and downstream reaches, for the purpose of examining long-term reach stability. Additionally, development of a sediment rating curve based on a formula approach and calibrated with sediment transport samples is recommended.

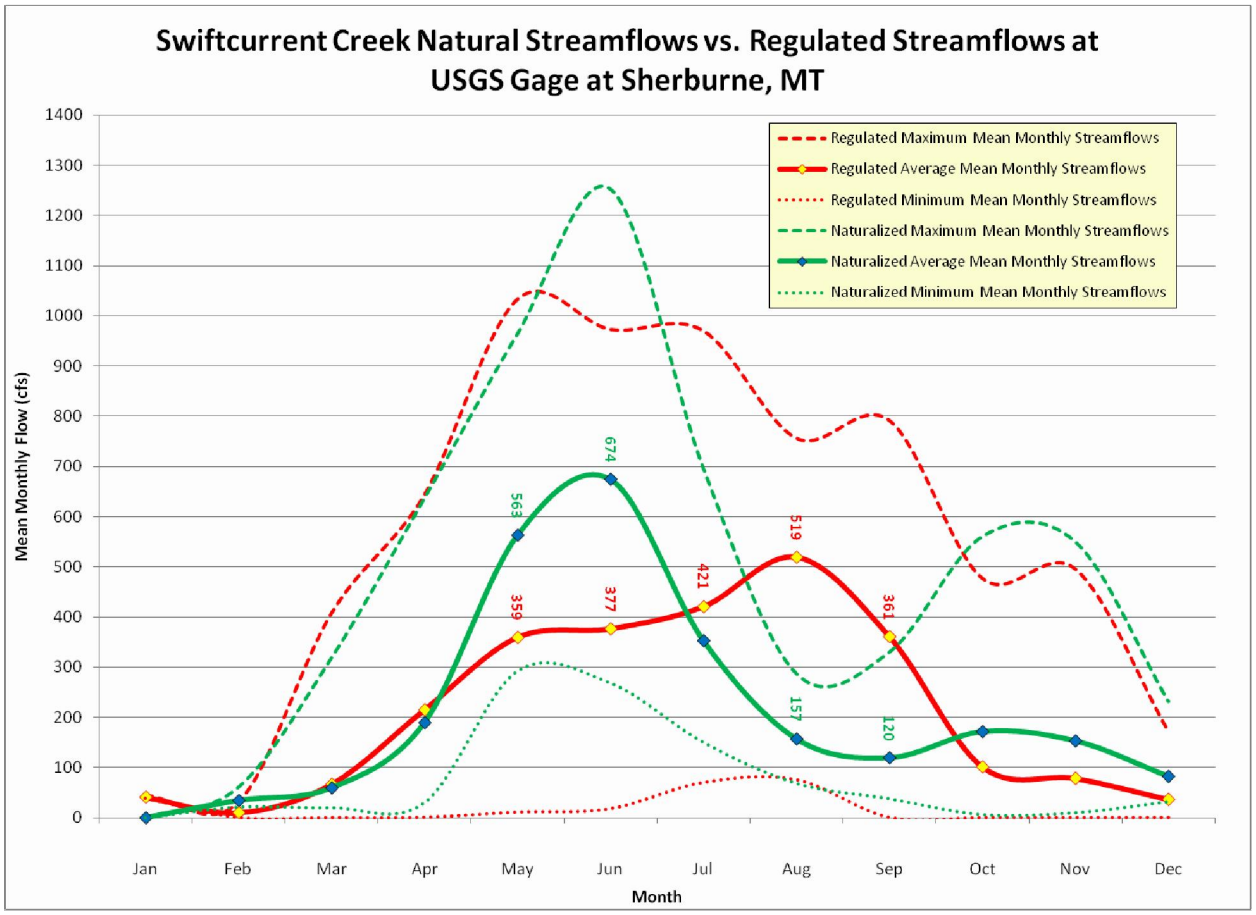
6.4. Sherburne Dam

As part of a watershed perspective to investigation of the sediment transport problems of Swiftcurrent Creek, a reconnaissance investigation into the effects of Sherburne Reservoir operations on the sediment transport capacity of Swiftcurrent Creek is needed.

Figure 16 (repeated from Section 5.7) illustrates the impacts of Sherburne Reservoir on the hydrology of Swiftcurrent Creek. Several observations can be made from a comparison of the existing and natural hydrographs. Not only does the reservoir reduce the maximum mean-monthly streamflows experienced on Swiftcurrent Creek, but the average regulated mean-monthly stream flow during the natural peak runoff period (May - June) is roughly equivalent to the minimum mean-monthly flow under natural conditions. In other words, when Boulder Creek can be expected to be moving bed load during an average June, dam releases from Sherburne are reducing the June mean-monthly peak flows to that which would naturally occur only in minimum flow years. In addition to lowering the peak flow, current

dam operations roughly double the duration of spring runoff, with actual timing of typical peak dam releases occurring in August, as compared to May or June under natural conditions. Delaying the timing of peak Swiftcurrent Creek flows is likely resulting in a significant lag between the natural Boulder Creek runoff hydrograph and the regulated hydrograph resulting from Sherburne Dam releases.

Figure 16 - Sherburne Dam Impacts to Natural Streamflows



Preliminary investigations reveal that current dam operations are affecting the Swiftcurrent Creek spring runoff hydrograph through: reducing peak flows, prolonging the duration of dam releases, and altering the timing of the spring hydrograph.

Each of these factors affects the sediment transport capacity in Swiftcurrent Creek. It is likely that a prolonged duration of high flow would lead to a net increase in the size of the armoring layer in Swiftcurrent Creek above the confluence, as the more easily transported smaller sized material would be transported out of the reach. The potential for replenishment of this material is limited by the presence of the reservoir. The loss of smaller gravel deposits may have biological implications for fish and other aquatic species. A reduction in peak flows eliminates the higher shear stresses that accompany higher flows and velocities. These higher shear stresses are needed to transport larger sized bed-material. Currently, high instability is experienced in Swiftcurrent Creek in the vicinity of the confluence with Boulder Creek. Boulder Creek appears to be the source of much of the coarse sediment

load to lower Swiftcurrent Creek. The reduction in peak flows is likely reducing the streams ability to transport the coarse sediment delivered from the Boulder Creek drainage, a condition that is likely exacerbated by the altered timing of Swiftcurrent peak flows which no longer coincide with those of Boulder Creek.

Development of a sediment rating curve for Swiftcurrent Creek will allow additional investigation into the affects of regulation on sediment transport capacity. Additionally, a more refined flow analysis at the daily flow level is recommended, as more detailed data will be necessary for this sediment transport analysis. The potential for revised reservoir operation procedures, specifically concerning dam releases, should be investigated as a means of achieving a more natural hydrograph in Swiftcurrent Creek.

7. Geomorphology Review

7.1. Review of Geomorphic Setting

As previously mentioned, certain types of landslides are common along the eastern part of Glacier Park in areas underlain by Cretaceous sedimentary rocks. A review of other basins that contain re-activated landslide deposits should be conducted including a review of the consequent sedimentation downstream of the landslide area. If allowed, a stream will naturally adjust to the influx of sediment to the system. The natural response of other streams to this particular situation would be very useful in the evaluation of stream stabilization alternatives for Swiftcurrent Creek. Divide Creek, for example, also sustained significant impacts to the channel during the 1964 flood event.

DOWL HKM's previous work regarding Divide Creek instability and excessive sediment deposition indicates numerous shallow failures along the stream channel within mapped landslide deposits. Divide Creek sustained significant fire damage during the 2006 Red Eagle Fire and may see an increase in sedimentation in the future as a result. The Divide Creek channel has similarly been confined in the area of the alluvial fan. For these reasons Divide Creek should be evaluated I as a likely candidate for containing appropriate reference reaches.

A comparison of Divide Creek or other streams identified as containing potential reference reaches should be made against those selected in the 1998 WWC study (Belly River and Otatso Creek) as part of the additional investigations to be completed in the future.

8. Review of Potential Mitigation Measures

Several primary restoration objectives were developed through the WWC study, and presented in the design report. Additionally, three mitigation alternatives were developed in an attempt to meet these objectives. Finally, a conceptual design was completed for one alternative, with the intent that additional data collection and feasibility analysis of the alternatives would be completed prior to final design or implementation of any mitigation measures. Refinement and expansion of these previously developed objectives and alternatives, as well as a review of the appropriateness of the conceptual designs is recommended prior to final selection of an implementation alternative.

8.2. Restoration Objectives

The following primary restoration objectives were presented in the WWC design report. Comments for each objective are included in bold.

- Convert the braided streams to single thread C3 or B3 channels that are self maintaining and will accommodate floods without major changes in channel pattern or profile. **The conclusion that eliminating braiding and constructing these specified channel types will provide the means to make the channel self maintaining is likely premature, as more detailed sediment transport analysis is necessary. Furthermore, including this item as a design objective inherently eliminates some alternatives that may be of value, such as incorporating a braided section which allows the stream to store sediment. This was also suggested by Traci Sylte in her memo dated 05/24/2009 (Appendix E). The over-arching design objective that should be preserved is the need to improve channel stability.**
- Use fluvial geomorphologic principles and bio-engineering techniques that will allow the river to adjust slowly over time and be representative of the natural river system. **Simplification of this objective by eliminating the reference to specific principles and techniques would likely improve clarity by shifting the focus from the techniques themselves to their purpose, which is to provide a system that is self sustaining and supports natural processes.**
- Improve fish habitat, particularly for bull trout, and improve the aesthetics of the river and adjacent riparian ecosystem. **This objective could be broken down into two distinct objectives; improve the quality of fish habitat, and improve the aesthetics of the river and adjacent riparian ecosystem.**
- Reduce bank erosion and sediment loads to Lower Saint Mary Lake, thereby slowing the rate of alluvial fan formation in the Lake. **This objective may not be entirely appropriate, as it specifies a solution rather than a desired objective or quality of the design. Due to the supply and size of the sediments which are likely primarily responsible for recent growth of the alluvial fan, the growth of the fan may be more appropriately addressed near the confluence with the lake rather than at the sediment source. Revision of the objective is recommended to focus on the desire to reduce the rate of delta [alluvial fan] growth.**

- Protect or reduce the effects of flooding on adjacent landowners and the Many Glacier Road. **The appropriateness of this objective should be further reviewed, as there is the potential that a viable alternative could increase flooding in some areas to improve floodplain connectivity to the stream.**
- Protect historic sites in the near vicinity, the county road bridge crossing on Swiftcurrent Creek, and the Burns Cemetery. **The appropriateness of this objective should be further reviewed, as there is the potential that removing or altering the county road bridge crossing could be part of a viable alternative to limit channel constraint or improve the streams ability to access as much of the alluvial fan as possible.**
- Minimize construction and maintenance costs. **Maximizing the benefit to cost ratio is likely a more appropriate objective than minimizing costs.**
- Maintain flexibility for USBR to control streamflows and releases from Sherburne Dam. **Although flexibility in operations is necessary to maintain efficient dam operations, revised dam operation practices which seek to provide more naturalized streamflows would likely provide benefit to the Swiftcurrent channel system and associated habitat and species. Revision of this objective should be considered to not only address the need to maintain operations flexibility, but also to improve the quality and timing of dam releases through more naturalized dam releases.**

8.3. Restoration Alternatives

Three design alternatives are presented in the WWC report, as follows:

1. Original Alternative – Reconstruction of Swiftcurrent Reach 3 to the county road bridge crossing and then continuing Reach 4 to the confluence with the Lake in one of the existing channels.
2. Alluvial Fan Growth Limitation Alternative – This alternative is a revision of the original alternative to help minimize sediment deposition within Lower Saint Mary Lake, and consists of reconstruction of Swiftcurrent Reach 3 to the county road bridge crossing and then reconstruction of Reach 4 to reroute flow to the outlet of the lake.
3. Historic Channel Alternative – Reconstruct Swiftcurrent Creek along the historic channel and breach the dike.

The historic alignment of Swiftcurrent Creek as it existed in the early 1900s is shown on Figure 6. The channel corridor surrounding the early 1900's channel(s) is largely unoccupied. However, infrastructure does exist within this corridor that would present significant challenges to restoring the stream to this historic corridor. Approximately 900 feet of Highway 89 and about 400 feet of a county road are located within the corridor. The channel would also cross about 700 feet of the Saint Mary Canal. No significant alteration or construction of structures within the channel corridor was observed in aerial photography reviewed from 1953 through 2006. The exceptions are one structure located just west of Highway 89 and the construction of a subdivision just east of the Highway (Figure 6). The northern half of this subdivision (approximately 6 homes) is located within the delineated channel corridor. Based on State of Montana Cadastral information accessed through the Natural Resources and Information System (NRIS) website, the vast majority of the property within the channel corridor is owned by the

Bureau of Reclamation, including the parcels where the structures are located. Two parcels on the very northern end of the corridor are owned by the Blackfeet Nation and a private landowner. This alternative should be evaluated in detail through the additional investigations to be completed in the future.

An additional conceptual alternative has been developed through the Phase I reconnaissance evaluation and is presented for consideration. This restoration concept, presented in Appendix E, consists of gravel harvesting to relieve the problems associated with downstream sediment deposition. As illustrated in Appendix E, the concept consists of collecting transported coarse sediments in a series of pits at strategic locations that are alternated between a "sediment interception cycle" and a "sediment harvesting cycle". The concept plan also allows for controlled aggradation on the existing alluvial fan to accommodate deposition of the finer wash load sediments at a more acceptable location. Although this concept presents the challenge of requiring a long-term commitment to operation and maintenance, it may warrant further evaluation.

8.4. Design Concepts

Through the current review of the Swiftcurrent watershed hydrology as well as the review of the sediment transport analyses completed through the WWC study, several critical deficiencies are apparent which affect the viability of the WWC conceptual design (specific deficiencies are discussed in detail in Section 4 and Section 5 of this report). The results of the Phase I reconnaissance investigation indicate that a more thorough understanding of the Swiftcurrent Creek system is necessary prior to implementation of any potential mitigation measures. Despite the shortcomings in the details of the WWC design, many of the design concepts upon which it is based are valid.

The following paragraph excerpt from the WWC report summarizes the design concepts.

> *In summary, a river restoration project needs to first determine the trend of the river and the correct potential streamtype to be designed to meet the geomorphological setting and the objectives of the proponents. The design must incorporate the proper channel dimensions, pattern and profile appropriate to the potential streamtype. In addition, the design must incorporate an adequate floodplain, grade control and bank stability to provide a stable river system that will maintain itself over time. It should also provide the type of riparian habitat to support all the desired resources.*

Although, the general design concepts used in the WWC study are sound, several refinements and additions are proposed as follows:

1. Sediment Transport – The transport of sediments from the Boulder and Swiftcurrent Creek drainages is responsible for several of the key symptoms that are viewed as undesirable in this system, specifically, the presence and recent growth of the Swiftcurrent Creek alluvial fan and the apparent instability of the Swiftcurrent Creek channel. Much of the success of any potential mitigation measure will hinge on the design's ability to transport the sediment supply and to deposit it in acceptable locations; as such, adequate sediment transport will be a critical design concept.

2. Sherburne Dam Operations – The Swiftcurrent Creek hydrology is significantly altered from its natural state. Naturalization of dam releases will likely play a critical role in maintaining adequate sediment transport capacity below the Boulder Creek confluence in addition to benefiting habitat and species.
3. Natural Stream Processes – A critical design concept is the ability of the mitigation measures to support natural stream processes. This concept is fundamental to insuring both long-term success and appropriate expectations. Several individual processes are addressed in items 3 and 4 below. These items were suggested by Traci Sylte in her memo dated May 24rd, 2009 (see Appendix E).
4. Allowing Stream Braiding – Incorporating areas where the stream can deposit and store sediments by allowing a local instability through inclusion of a braided section or sections may improve the overall stability of the project.
5. Alluvial Fan Utilization – The stream is currently constrained to a very small portion of the historic alluvial fan. Long-term efficacy of this project and reducing problems most likely depends on allowing the stream to utilize as much of the historic alluvial fan surface as possible.

9. Framework for Future Work

This framework for future work is intended to summarize the issues which need to be explored in more detail, prior to implementation of a Boulder / Swiftcurrent Creek Stabilization Project. The following general list of work elements is presented in order of logical occurrence; however, actual sequencing of tasks will likely vary. A detailed Scope of Work will need to be developed for each of these tasks as the work is contracted in the future.

1. Refinement of Project Purpose and Goals. Further development and refinement of the project purpose, goals, and objectives culminating in a written statement is necessary. Early development and documentation of these parameters is critical, especially given that this project will require the orchestration of a diverse team. Traci Sylte does a good job of further illustrating the need for these tasks in her memo (see Appendix E).

2. Additional Data Gathering. Additional data or reports pertinent to the project will be collected. This may include data developed by the BOR in completing the environmental assessment of modifications to the St Mary Canal, previous biological studies of the local fishery, or other information that may contribute to a complete understanding of the issues involved. The aerial photographs that have already been collected will be scanned and converted to a digital format for use by all team members.

3. Cultural Review. An inventory of cultural resources within the limits of the project area will be completed by the Blackfeet Tribal Historic Preservation Office. The results of this review will be used to identify culturally sensitive areas to be avoided or protected.

4. Hydrology.
    a. Establishment of a USGS stream flow gage on Boulder Creek is highly desirable to begin automated collection of stream discharges. Streamflows will be required to support sediment transport modeling.
    b. Development of long-term estimated mean daily flows for Boulder Creek will be necessary. The measured streamflow data collected for Boulder will be used to verify the reasonableness of the longer-term estimates of mean daily flows.

5. Aerial Photography. Updated aerial photography will provide a baseline for future work and also an additional reference concerning recent channel changes and alluvial fan growth.

6. Reference Reach Refinement. A more detailed analysis of similar streams and potential reference reaches with an emphasis on basin wide characteristics above the proposed reference reach will be necessary for use in the final design.

7. Topographic Mapping. The optimum time to obtain this data should be reviewed as the topography is very dynamic.

a. LIDAR Mapping of the project area will provide high quality topographic data for development and analysis of various alternatives.
b. A conventional survey of underwater topography and stream channel geometry will be necessary to supplement the LIDAR mapping in Phase II. Collection of conventional survey data may need to be updated prior to final design (Phase III).

8. Sediment Transport Analysis.
    a. Solicit Statements of Qualification from nationally recognized experts in the field of sediment transport modeling. Solicit Proposals from a short list of qualified experts and make a final selection based on proven capabilities and qualifications.
    b. With the assistance of the selected expert, develop the specific scope of work for the sediment transport analysis.
    c. Perform a final field verification of the general conclusions of the sediment source analysis, specifically the abundance and relative size of potential sediments.
    d. Implement a Sediment Sampling Plan. A significant amount of additional sediment transport sampling is anticipated to be needed to support credible sediment transport modeling.
    e. Analysis of sediment transport data, including development of sediment rating curves and a preliminary sediment continuity analysis
    f. Sediment Transport Modeling including verification against observed historic conditions.
    g. Employ Sediment Transport Model to evaluate potential remediation alternatives including an evaluation of costs and benefits. This would include evaluations of alternative hydrographs through modified operations of Sherburne Reservoir and modified stream gradients accompanying a restoration of Swiftcurrent Creek to its historic course.

9. Sherburne Dam Operations Analysis. The potential for revised reservoir operation procedures, specifically regarding the magnitude and timing of dam releases, should be evaluated in an effort to restore a more natural hydrograph to Swiftcurrent Creek. The use of a lake level regulating structure on Lower St. Mary Lake may provide some benefit in mitigating impacts to potential changes in Sherburne storage regulation.

10. Alternatives Analysis
    a. Final Refinement of Alternatives. Based on the results of other work tasks, a refinement of potentially viable alternatives is recommended. These alternatives would be advanced for more detailed analysis.
    b. Feasibility Analysis of Alternatives.
    c. Selection of a Preferred Alternative.

11. NEPA Compliance. The identified alternatives will need to be reviewed in accordance with the National Environmental Policy Act (NEPA).

12. Final Design and Implementation Plan.

10. References

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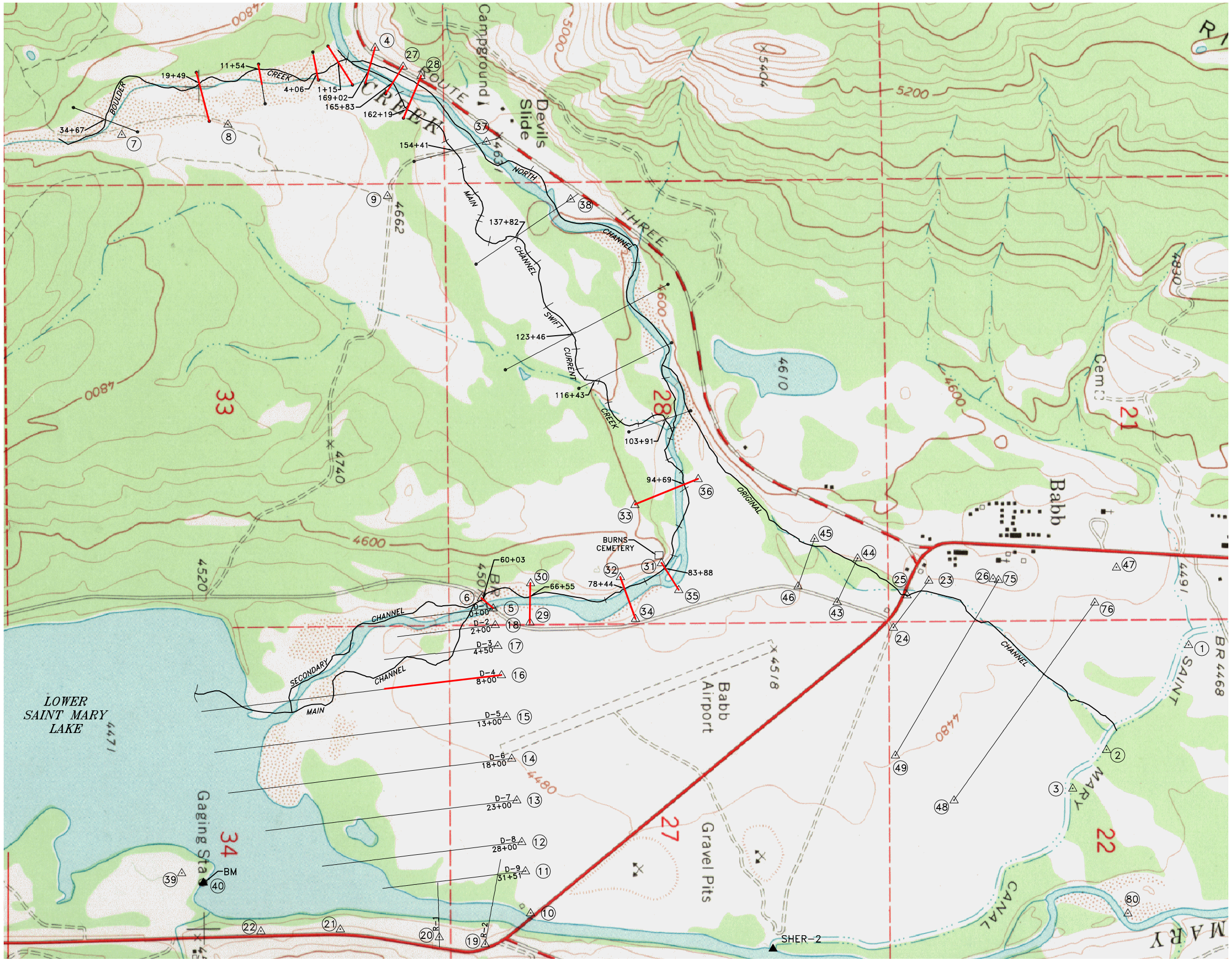
Appendix A

COMPARISON OF 1996 AND 2009 CONDITIONS



SHEET INDEX

SHT. NO.	DESCRIPTION
GENERAL	
G1	COVER SHEET, PROJECT LOCATION, SHEET INDEX
CHANNEL CROSS SECTIONS	
XS-1	SWIFTCURRENT CREEK D-4 STA 8+00, 60+03, AND 66+55
XS-2	SWIFTCURRENT CREEK STA 78+44
XS-3	SWIFTCURRENT CREEK STA 83+88
XS-4	SWIFTCURRENT CREEK STA 94+69
XS-5	SWIFTCURRENT CREEK STA 162+19, 165+83, AND 169+02
XS-6	BOULDER CREEK STA 1+15, AND 4+06
XS-7	BOULDER CREEK STA 11+54, AND 19+49
PLAN AND PROFILE	
PP-1	SWIFTCURRENT CREEK STA 16+00 - 44+00
PP-2	SWIFTCURRENT CREEK STA 71+50 - 99+50
PP-3	SWIFTCURRENT CREEK STA 155+50 - 173+54 (END)
PP-4	SWIFTCURRENT CREEK NORTH CHANNEL STA 44+00 - 69+10 (END)
PP-5	BOULDER CREEK STA 0+00 - 24+00

LEGEND:

- (10) △ – *PRIMARY CONTROL 2 1/2" ALUM. CAP*
- (40) ▲ – *PRIMARY CONTROL 3 3/4" B.C. BM*
- • – *SECONDARY CONTROL 2 1/2" ALUM. CAP*
- — – *LOCATION OF 2009 SURVEYED CROSS SECTION*

N

0 600 1200
scale feet

Prepared by :

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PROJ. NO. 4025.10301

Sheet No.
G1

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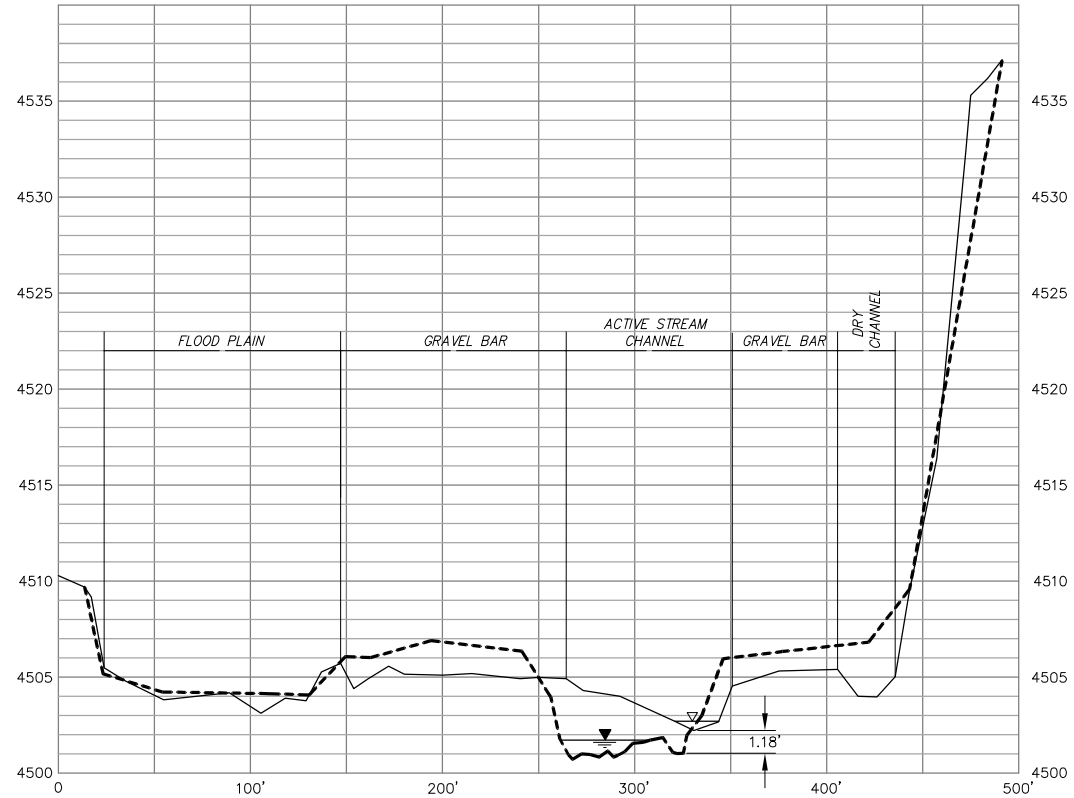
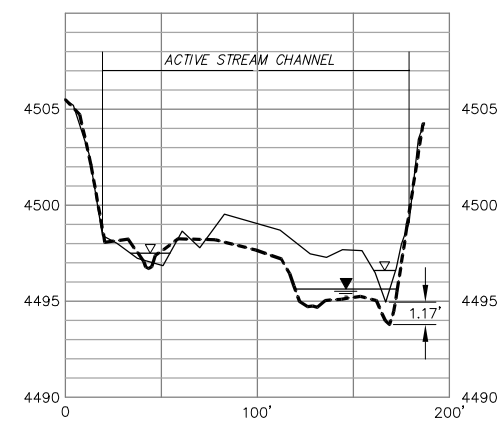


SWIFT CURRENT CREEK CROSS SECTION STA. 66+55 AT CP 29



SWIFT CURRENT CREEK CROSS SECTION STA. 60+03 AT CP 5

1996 NOTE : ICE BUILDUP, FORCING TWO CHANNELS AT DIFFERENT ELEVATIONS.

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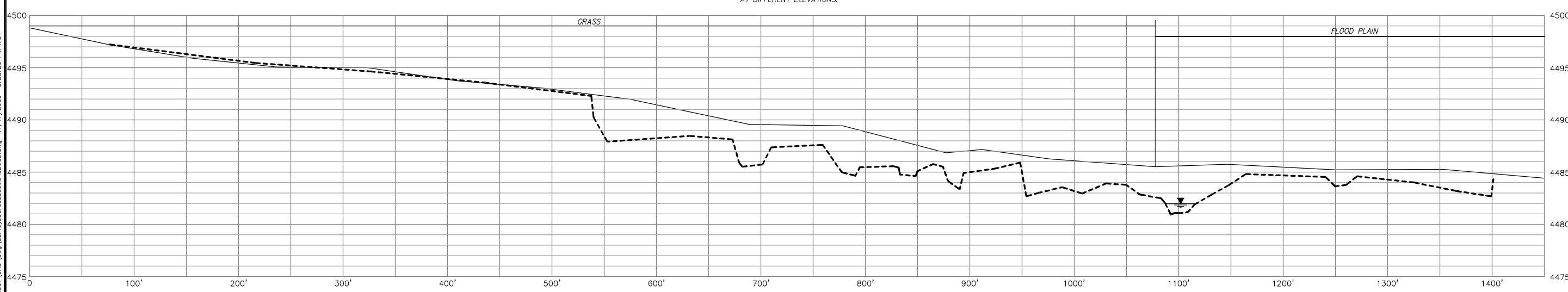
- 2009 SURVEYED GROUND SURFACE
- 1996 WATER SURFACE ELEVATION
- 2009 WATER SURFACE ELEVATION



SWIFT CURRENT CREEK CROSS SECTION D-4 STA. 8+00 AT CP 16

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COMPARISON OF 1996 AND 2009 CONDITIONS

SWIFTCURRENT CREEK CHANNEL CROSS SECTIONS

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Sheet No.
XS-1

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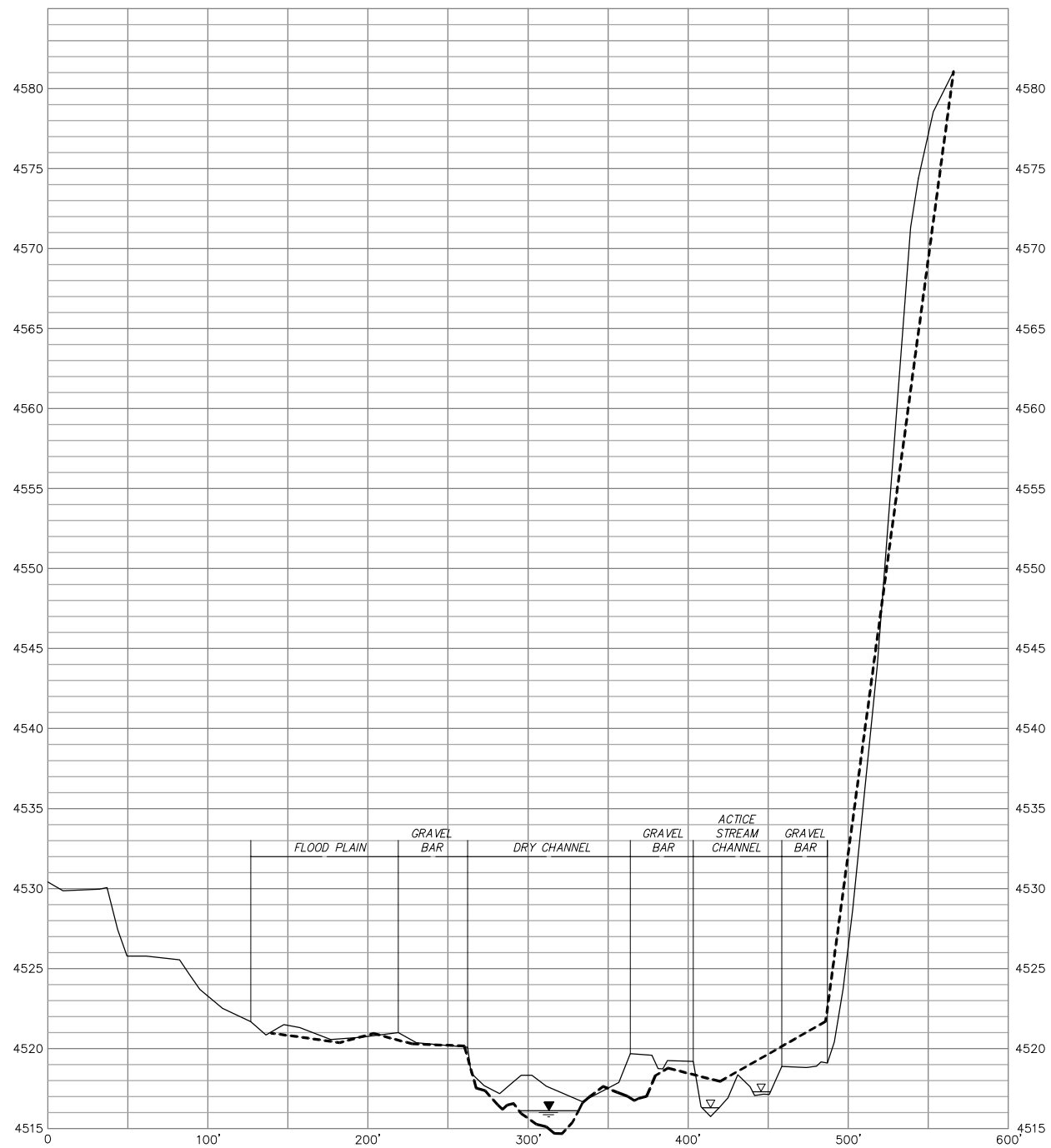

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COMPARISON OF 1996 AND 2009 CONDITIONS

SWIFTCURRENT CREEK
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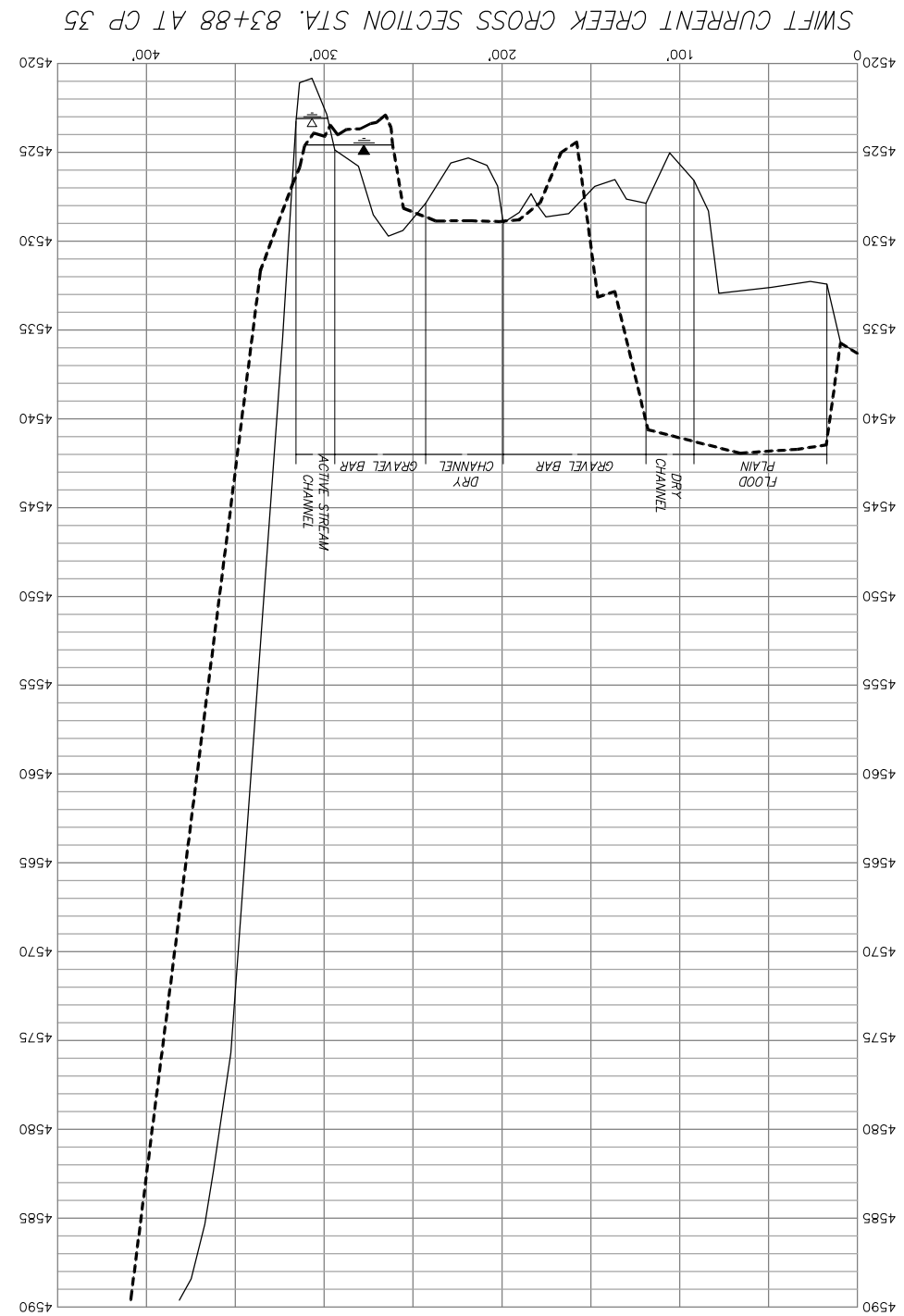

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- 1996 WATER SURFACE ELEVATION
- 2009 WATER SURFACE ELEVATION

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COMPARISON OF 1996 AND 2009 CONDITIONS

SWIFTCURRENT CREEK CHANNEL CROSS SECTIONS

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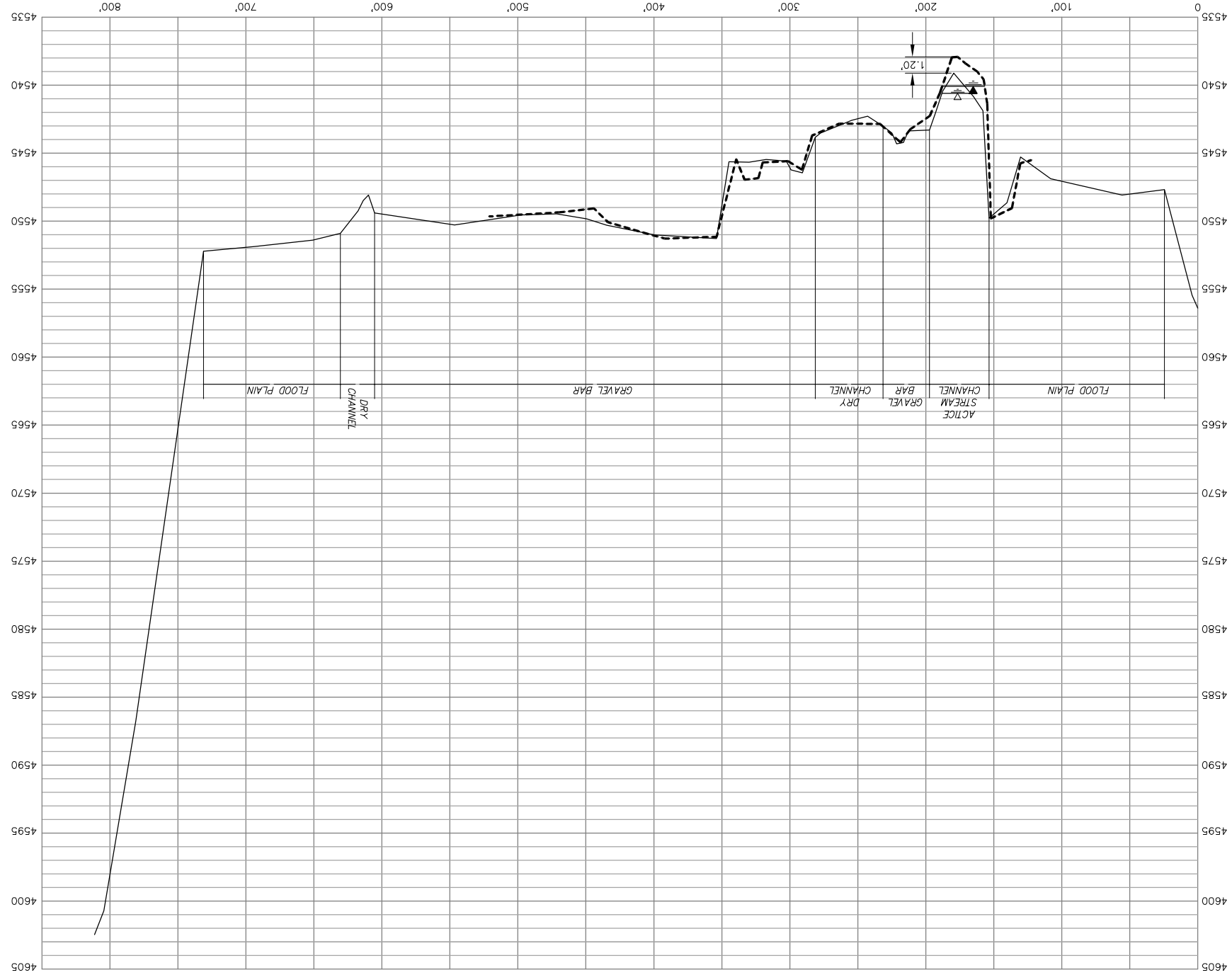

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SWIFTCURRENT CREEK CHANNEL CROSS SECTIONS

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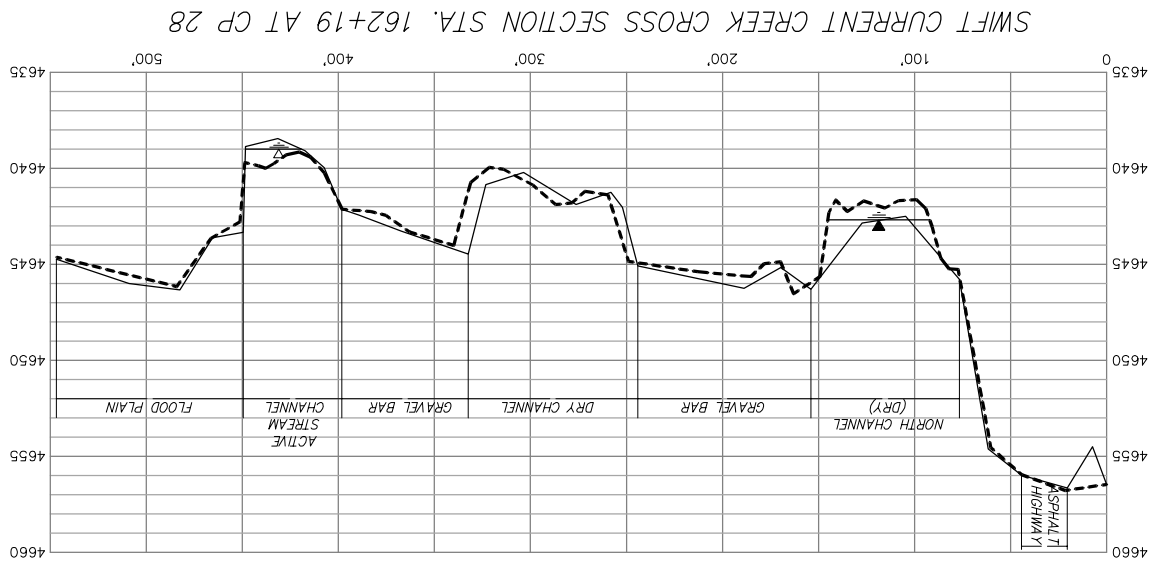

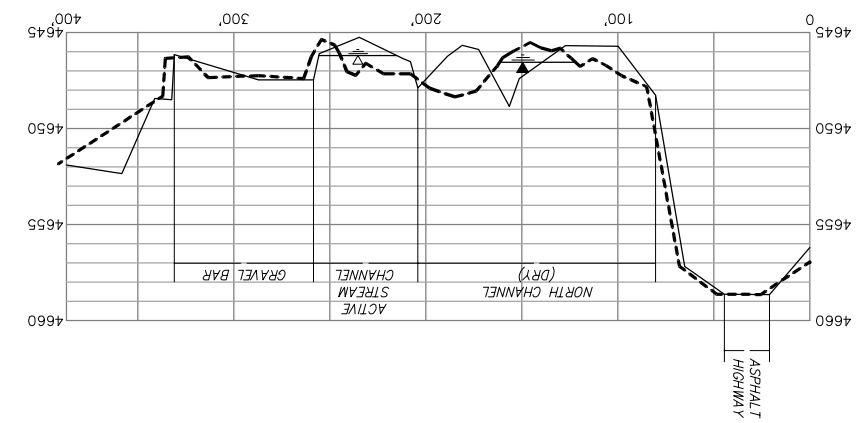

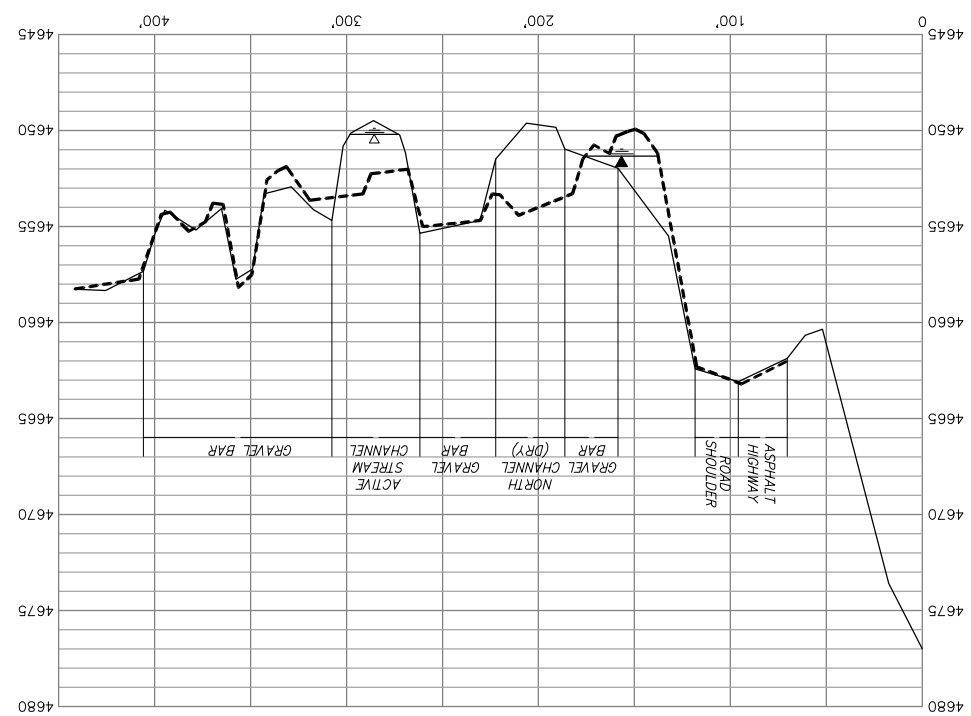

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- 2009 SURVEYED GROUND SURFACE
- 1996 WATER SURFACE ELEVATION
- 2009 WATER SURFACE ELEVATION

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SWIFTCURRENT CREEK
CHANNEL CROSS SECTIONS

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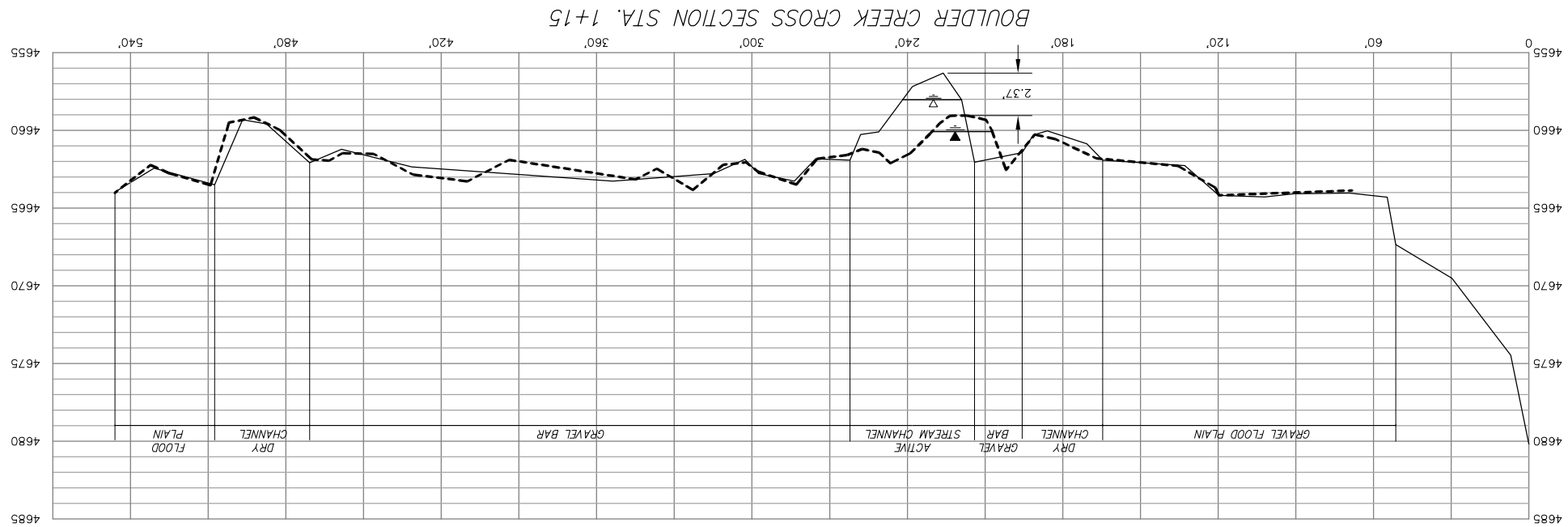

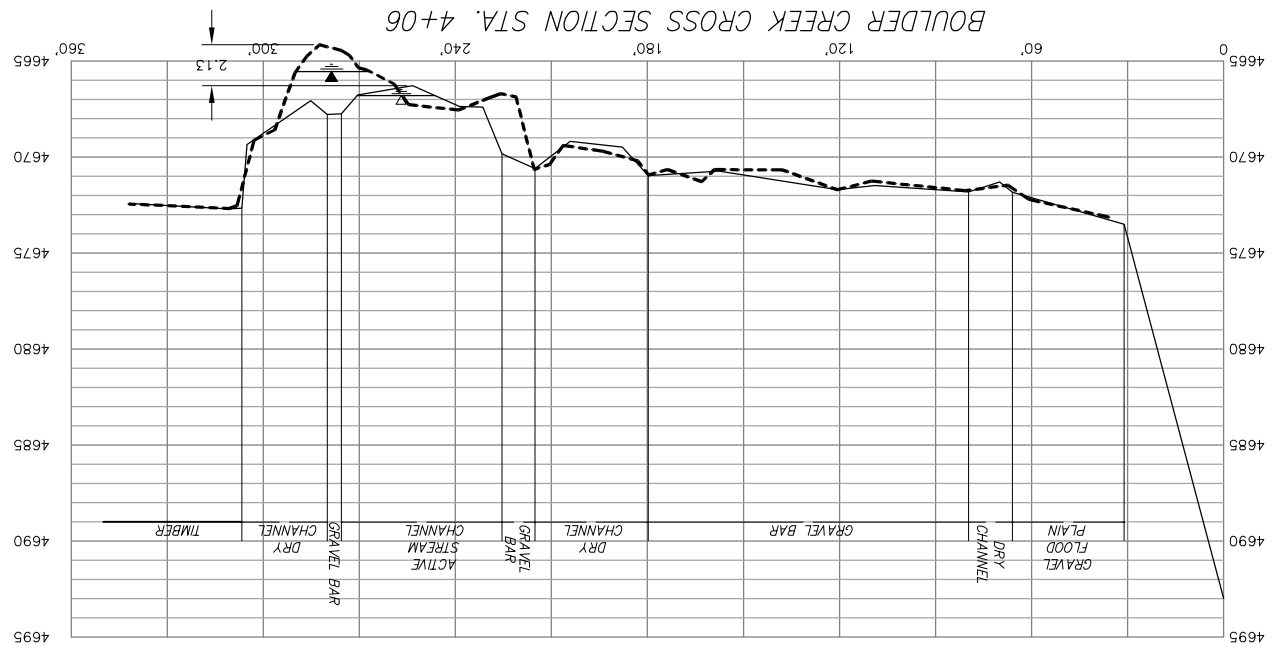

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- 2009 WATER SURFACE ELEVATION

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COMPARISON OF 1996 AND 2009 CONDITIONS

BOULDER CREEK CHANNEL CROSS SECTIONS

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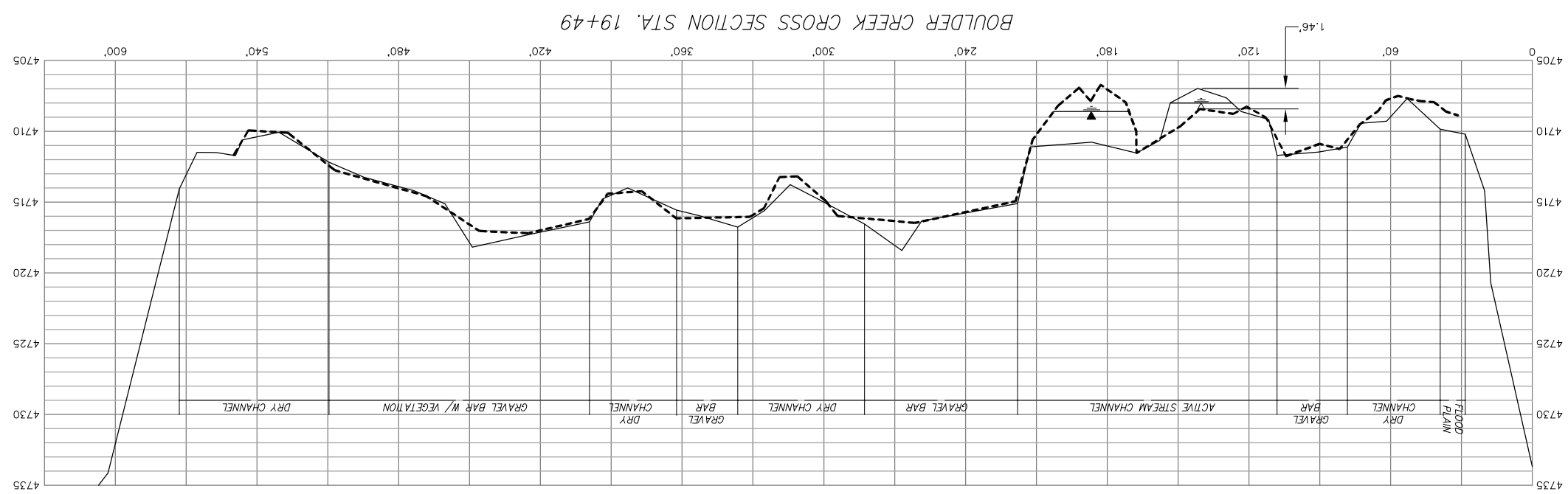

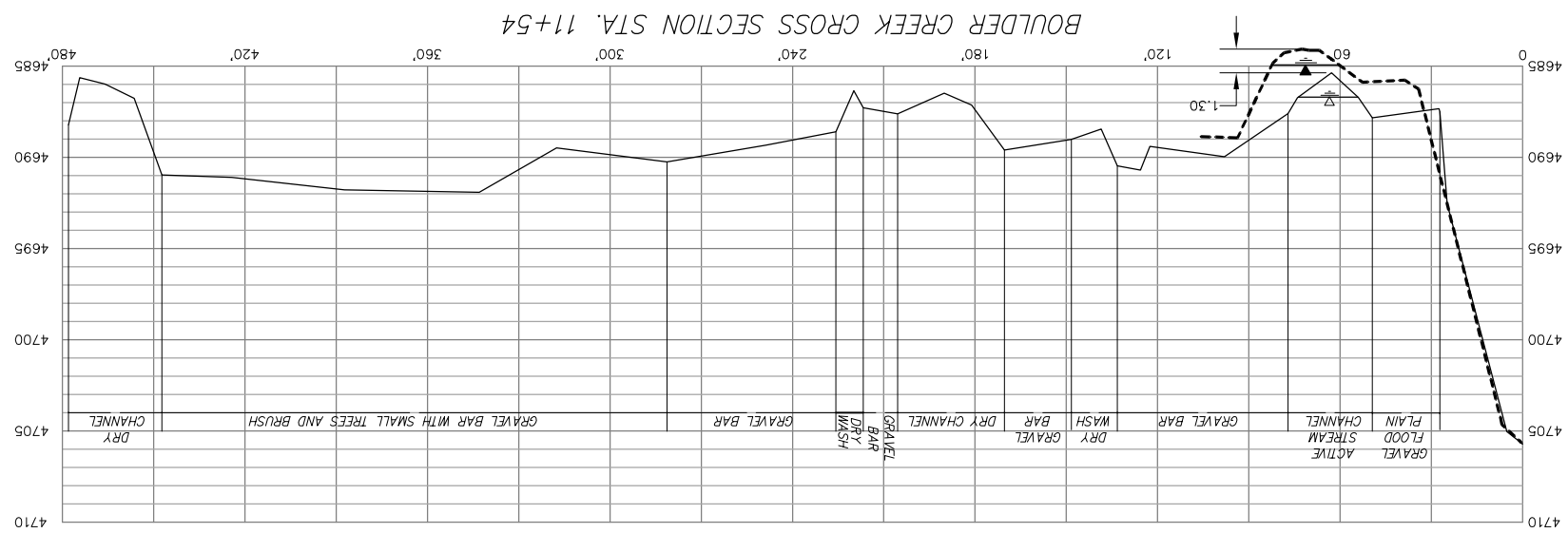

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COMPARISON OF 1996 AND 2009 CONDITIONS

BOULDER CREEK
CHANNEL CROSS SECTIONS

WARNING
0 ½ 1
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No.	Revision	By	Date

LEGEND

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- • EXTENDED CROSS SECTION END. SET 5/8"x24" REBAR WITH 2 1/2" ALUM. CAP MARKED BLKFT-USBOR.
- (7) PRIMARY CONTROL I.D. NUMBER. (TYP.)
- [637] CROSS SECTION END I.D. NUMBER. (TYP.)
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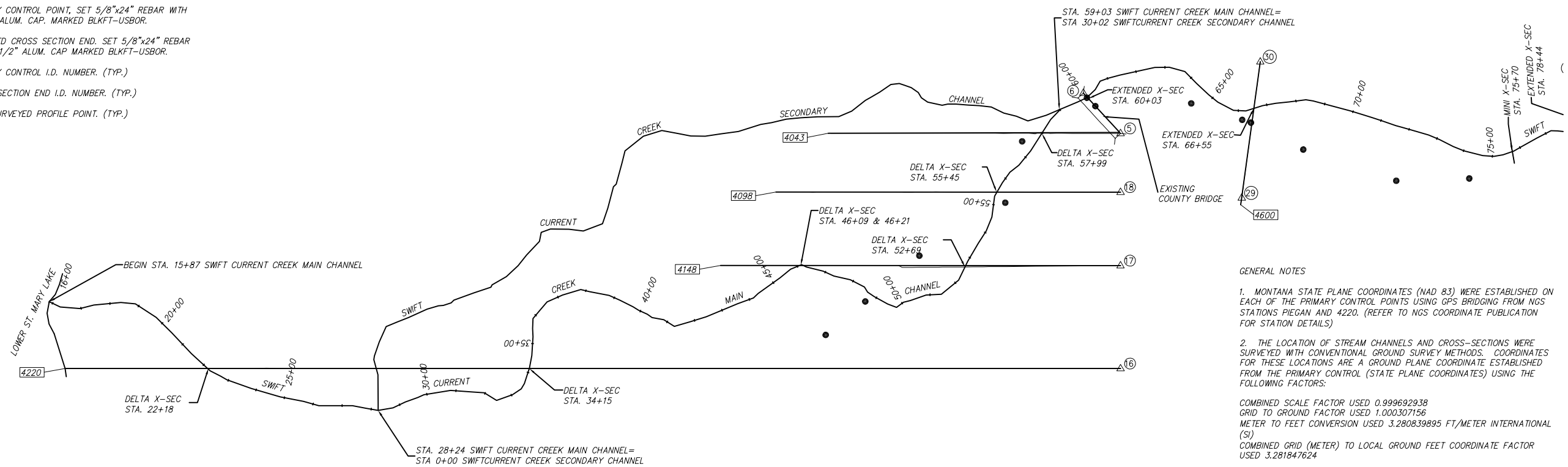

SWIFT CURRENT CREEK PLAN VIEW

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scale feet

GENERAL NOTES

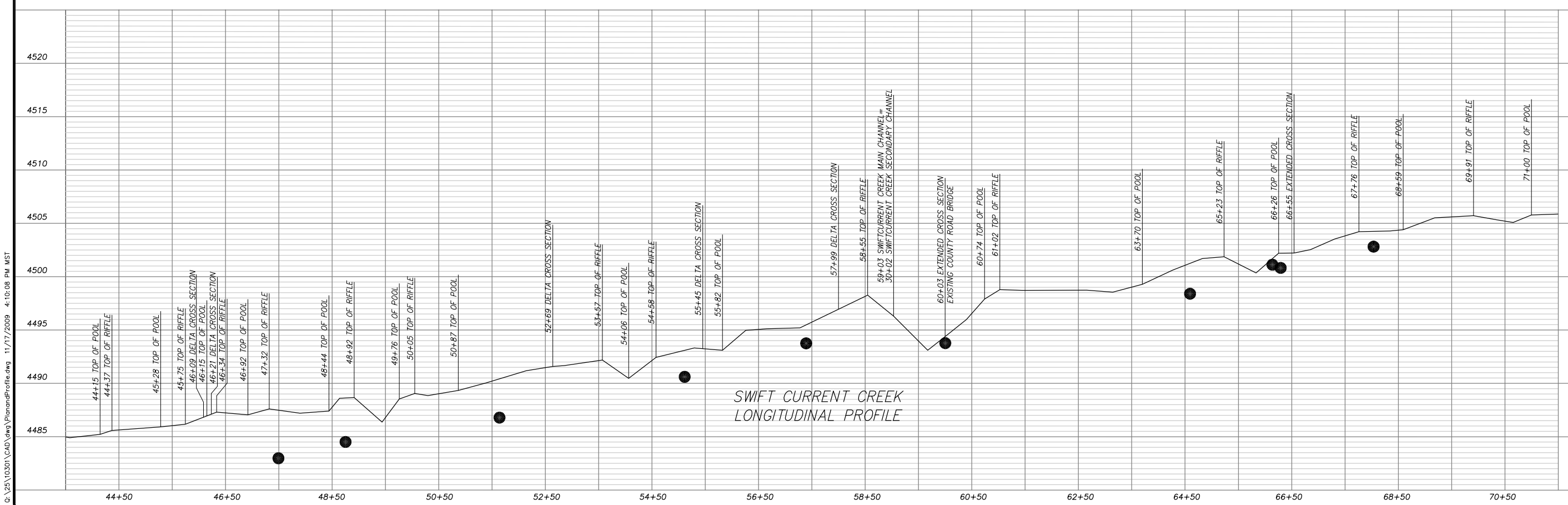
1. MONTANA STATE PLANE COORDINATES (NAD 83) WERE ESTABLISHED ON EACH OF THE PRIMARY CONTROL POINTS USING GPS BRIDGING FROM NGS STATIONS PIEGAN AND 4220. (REFER TO NGS COORDINATE PUBLICATION FOR STATION DETAILS)

2. THE LOCATION OF STREAM CHANNELS AND CROSS-SECTIONS WERE SURVEYED WITH CONVENTIONAL GROUND SURVEY METHODS. COORDINATES FOR THESE LOCATIONS ARE A GROUND PLANE COORDINATE ESTABLISHED FROM THE PRIMARY CONTROL (STATE PLANE COORDINATES) USING THE FOLLOWING FACTORS:

COMBINED SCALE FACTOR USED 0.99969293 8
GRID TO GROUND FACTOR USED 1.000307156
METER TO FEET CONVERSION USED 3.280839895 FT/METER INTERNATIONAL (SI)
COMBINED GRID (METER) TO LOCAL GROUND FEET COORDINATE FACTOR USED 3.281847624

3. BASIS OF BEARING IS FROM GPS OBSERVATION. THE ROTATION FROM GRID NORTH TO TRUE NORTH IS -2°52'38".

4. THE VERTICAL DATUM IS BASED ON A USGS ELEVATION ESTABLISHED AT THE GAGING STATION LOCATED AT THE CHEWING BLACKBONES CAMPGROUND ON THE LOWER ST. MARY LAKE. THE BM USED IS A BRASS CAP TABLET STAMPED RM NO. 1 LOCATED 15 FEET TO LEFT (N.W.) OF SHOREWARD SIDE OF GAGE HOUSE. ELEVATION 4,476.23 FT. NGVD OF 1929.



SWIFT CURRENT CREEK LONGITUDINAL PROFILE

No.	Revision	By	Date

WARNING
0 ½ 1
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COMPARISON OF 1996 AND 2009 CONDITIONS

SWIFTCURRENT CREEK PLAN AND PROFILE

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Sheet No.
PP-1

Project No. 4025.10301 ● PlanandProfile.dwg ● Date Nov. 2009 ● Designed ?? ● Drawn JTS ● Checked ?? ● Approved ??

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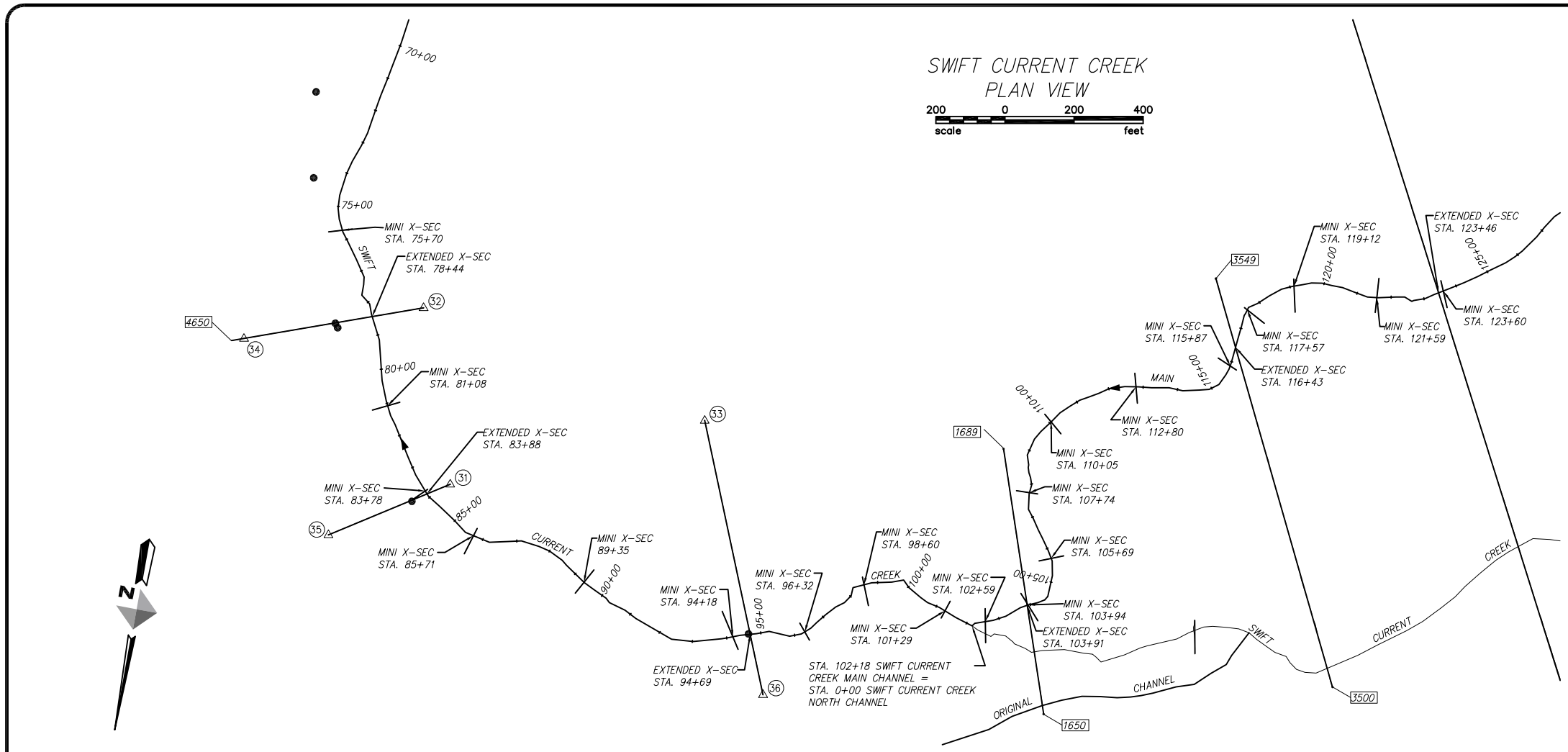

LEGEND

- △ PRIMARY CONTROL POINT, SET 5/8"x24" REBAR WITH 2 1/2" ALUM. CAP. MARKED BLKFT-USBOR.
- • EXTENDED CROSS SECTION END. SET 5/8"x24" REBAR WITH 2 1/2" ALUM. CAP MARKED BLKFT-USBOR.
- (7) PRIMARY CONTROL I.D. NUMBER. (TYP.)
- [637] CROSS SECTION END I.D. NUMBER. (TYP.)
- ● 2009 SURVEYED PROFILE POINT. (TYP.)

GENERAL NOTES

1. MONTANA STATE PLANE COORDINATES (NAD 83) WERE ESTABLISHED ON EACH OF THE PRIMARY CONTROL POINTS USING GPS BRIDGING FROM NGS STATIONS PIEGAN AND 4220. (REFER TO NGS COORDINATE PUBLICATION FOR STATION DETAILS)

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COMBINED SCALE FACTOR USED 0.999692938
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METER TO FEET CONVERSION USED 3.280839895 FT/METER INTERNATIONAL (SI)
COMBINED GRID (METER) TO LOCAL GROUND FEET COORDINATE FACTOR USED 3.281847624

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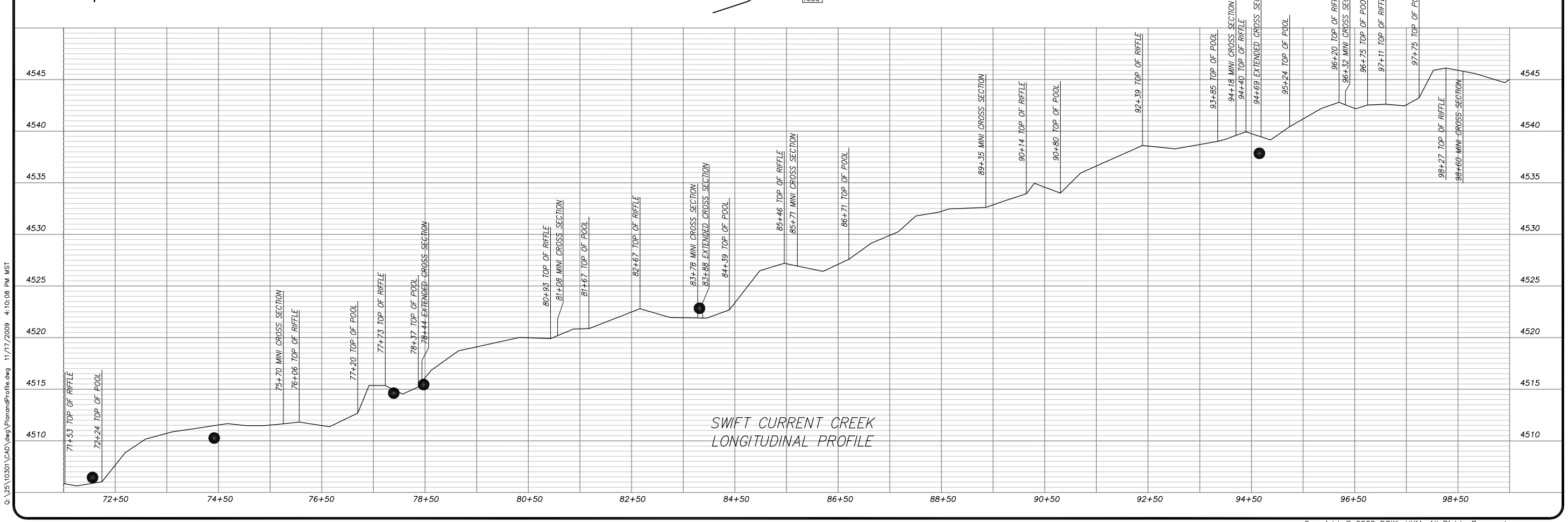
4. THE VERTICAL DATUM IS BASED ON A USGS ELEVATION ESTABLISHED AT THE GAGING STATION LOCATED AT THE CHEWING BLACKBONES CAMPGROUND ON THE LOWER ST. MARY LAKE. THE BM USED IS A BRASS CAP TABLET STAMPED RM NO. 1 LOCATED 15 FEET TO LEFT (N.W.) OF SHOREWARD SIDE OF GAGE HOUSE. ELEVATION 4,476.23 FT. NGVD OF 1929.



No.	Revision	By	Date

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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COMPARISON OF 1996 AND 2009 CONDITIONS

SWIFTCURRENT CREEK PLAN AND PROFILE

DOWL HKM
GRANITE TOWER BUILDING
222 N. 32ND ST., SUITE 700
P.O. BOX 31318
BILLINGS, MT 59107-1318
406-656-6399
406-656-6398 (FAX)
DOWLHKM.COM

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PP-2

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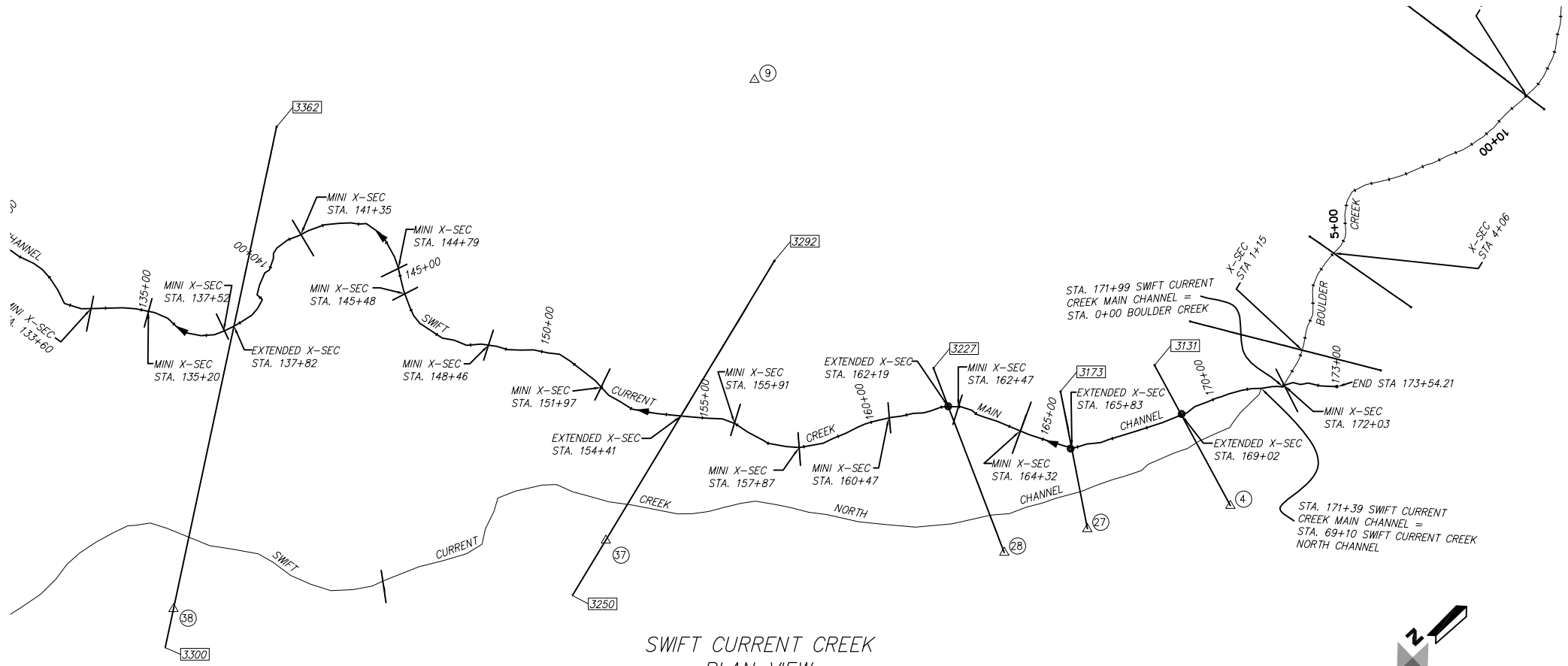

SWIFT CURRENT CREEK PLAN VIEW

200 0 200 400
scale feet

LEGEND

- △ PRIMARY CONTROL POINT, SET 5/8"x24" REBAR WITH 2 1/2" ALUM. CAP. MARKED BLKFT-USBOR.
- • EXTENDED CROSS SECTION END. SET 5/8"x24" REBAR WITH 2 1/2" ALUM. CAP MARKED BLKFT-USBOR.
- (7) PRIMARY CONTROL I.D. NUMBER. (TYP.)
- [637] CROSS SECTION END I.D. NUMBER. (TYP.)
- ● 2009 SURVEYED PROFILE POINT. (TYP.)

GENERAL NOTES

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COMBINED SCALE FACTOR USED 0.999692938
GRID TO GROUND FACTOR USED 1.000307156
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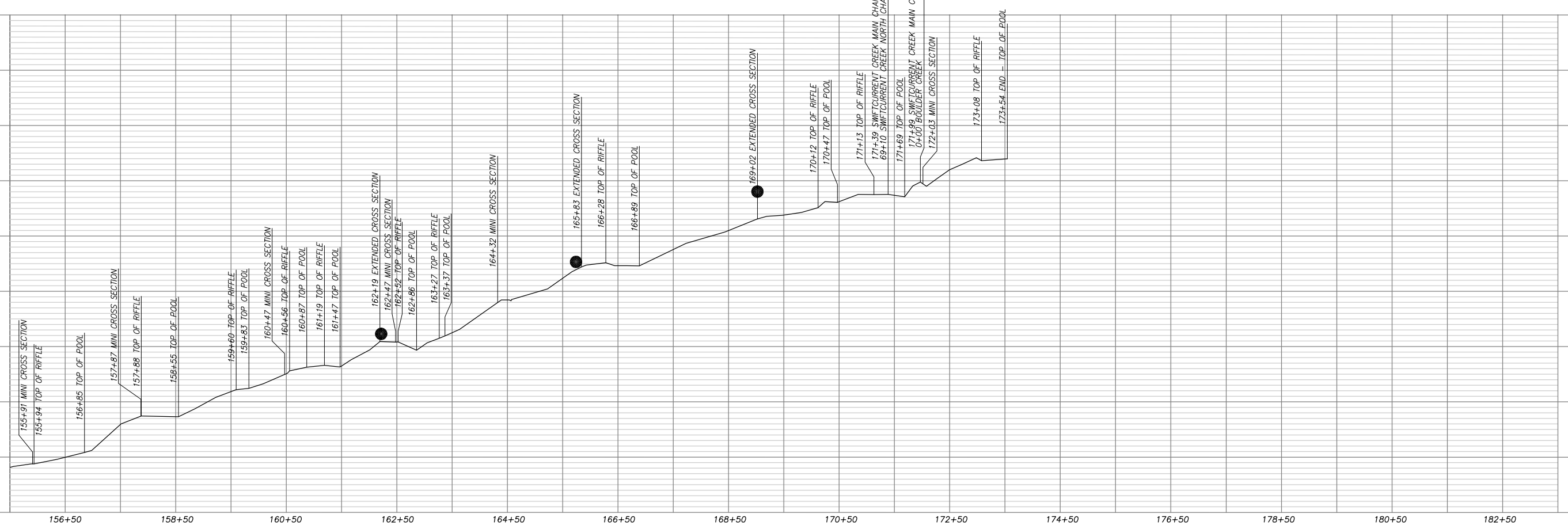

No.	Revision	By	Date

WARNING
0 ½ 1
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COMPARISON OF 1996 AND 2009 CONDITIONS

SWIFTCURRENT CREEK PLAN AND PROFILE

● Project No. 4025.10301 ● PlanandProfile.dwg ● Date Nov. 2009 ● Designed ?? ● Drawn JTS ● Checked ?? ● Approved ??

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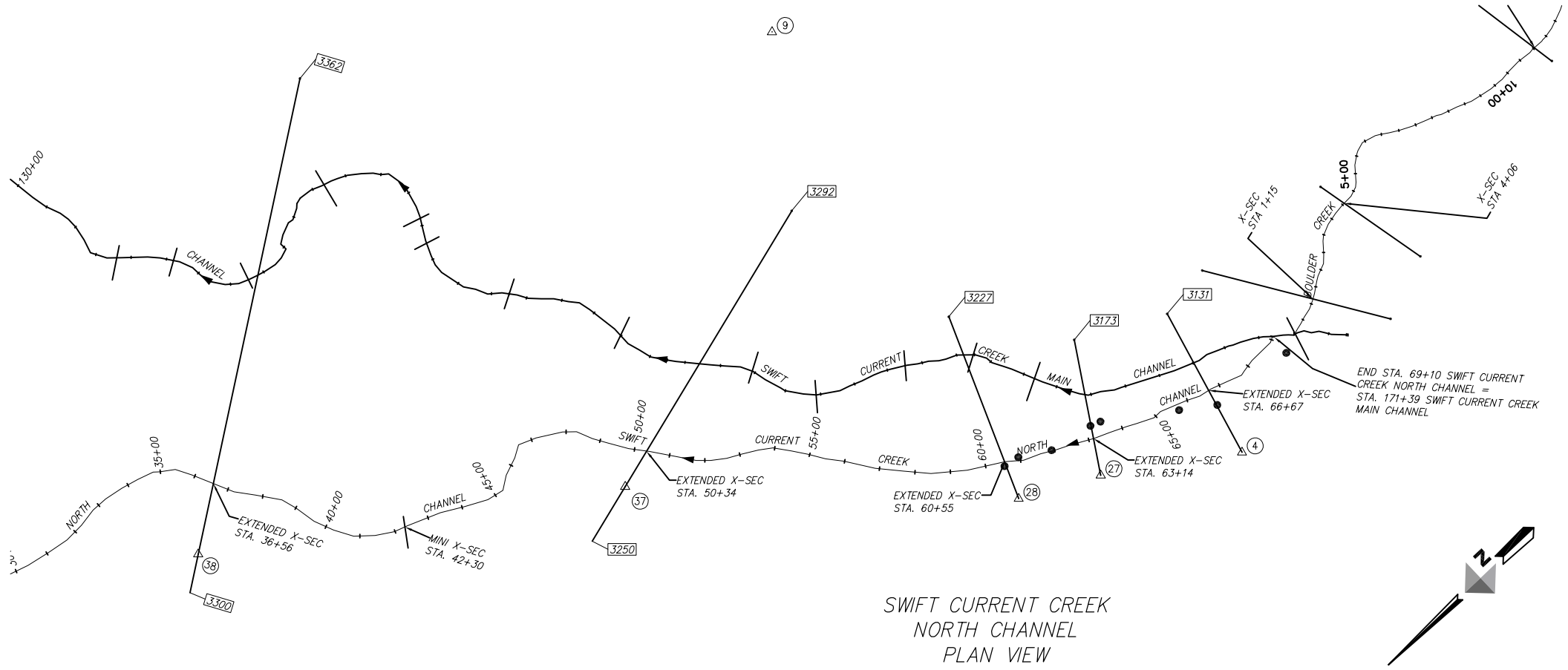

SWIFT CURRENT CREEK
NORTH CHANNEL
PLAN VIEW

200 0 200 400
scale feet

LEGEND

- △ PRIMARY CONTROL POINT, SET 5/8"x24" REBAR WITH 2 1/2" ALUM. CAP. MARKED BLKFT-USBOR.
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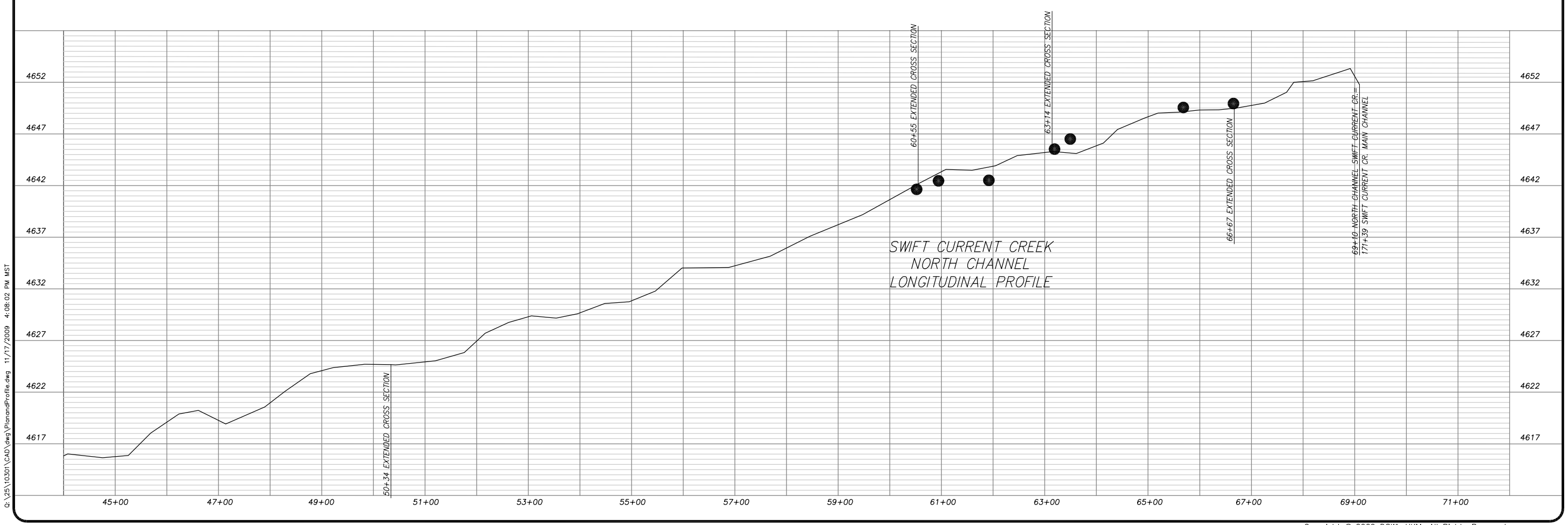

SWIFT CURRENT CREEK
NORTH CHANNEL
LONGITUDINAL PROFILE

No.	Revision	By	Date

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

● Project No. 4025.10301 ● PlanandProfile.dwg ● Date Nov. 2009 ● Designed ?? ● Drawn JTS ● Checked ?? ● Approved ??

COMPARISON OF 1996 AND 2009 CONDITIONS

SWIFTCURRENT CREEK NORTH CHANNEL PLAN AND PROFILE

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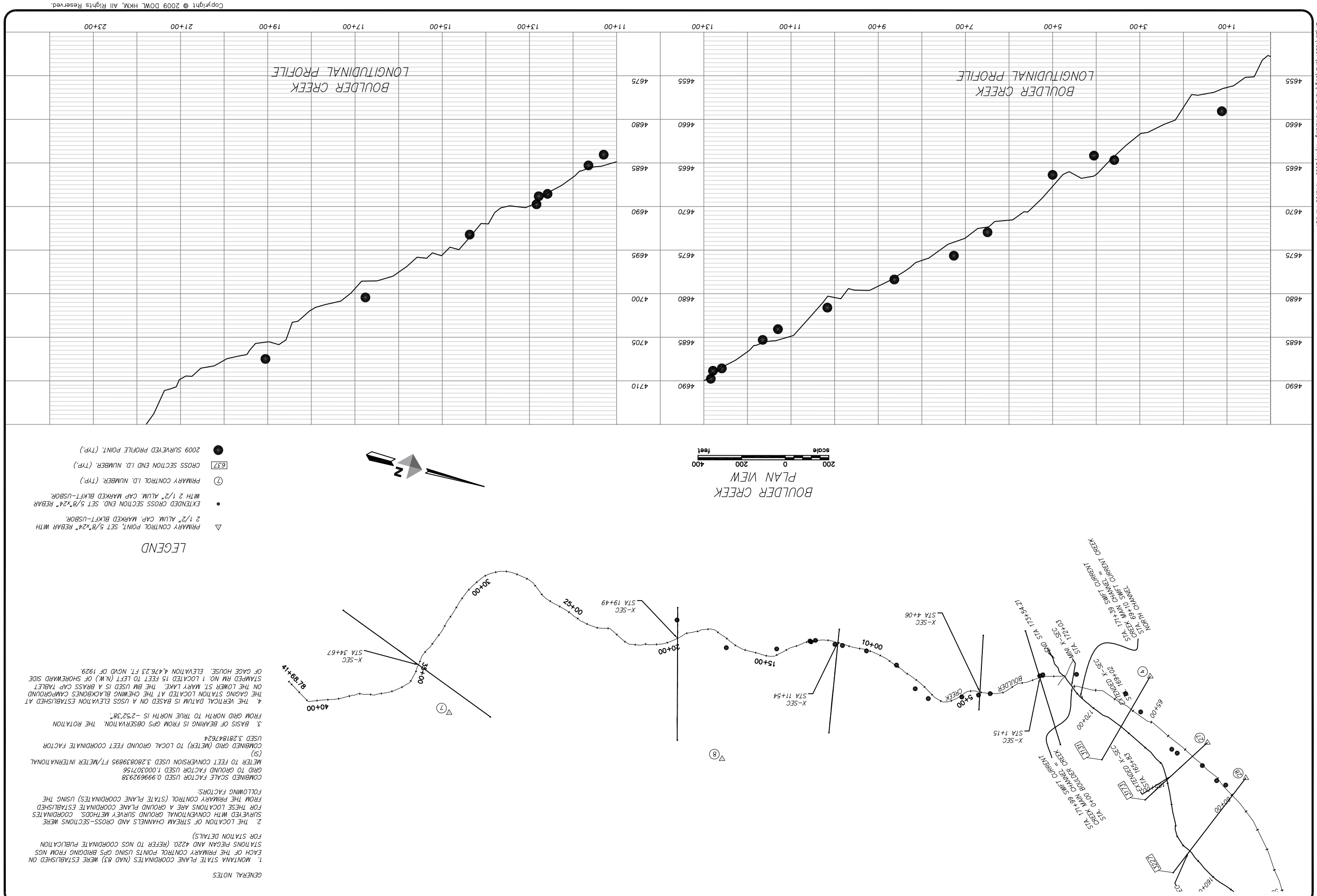
BOULDER CREEK
LONGITUDINAL PROFILE
BOULDER CREEK
LONGITUDINAL PROFILE
BOULDER CREEK
PLAN VIEW
scale
200 0 200 400
feet
N
LEGEND
PRIMARY CONTROL POINT, SET 5/8"x24" REBAR WITH 2 1/2" ALUM. CAP, MARKED BLKFT-USBOR.
EXTENDED CROSS SECTION END, SET 5/8"x24" REBAR WITH 2 1/2" ALUM. CAP MARKED BLKFT-USBOR.
PRIMARY CONTROL I.D. NUMBER. (TYP.)
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GRID TO GROUND FACTOR USED 1.00030715 6
METER TO FEET CONVERSION USED 3.280839895 FT/METER INTERNATIONAL (SI)
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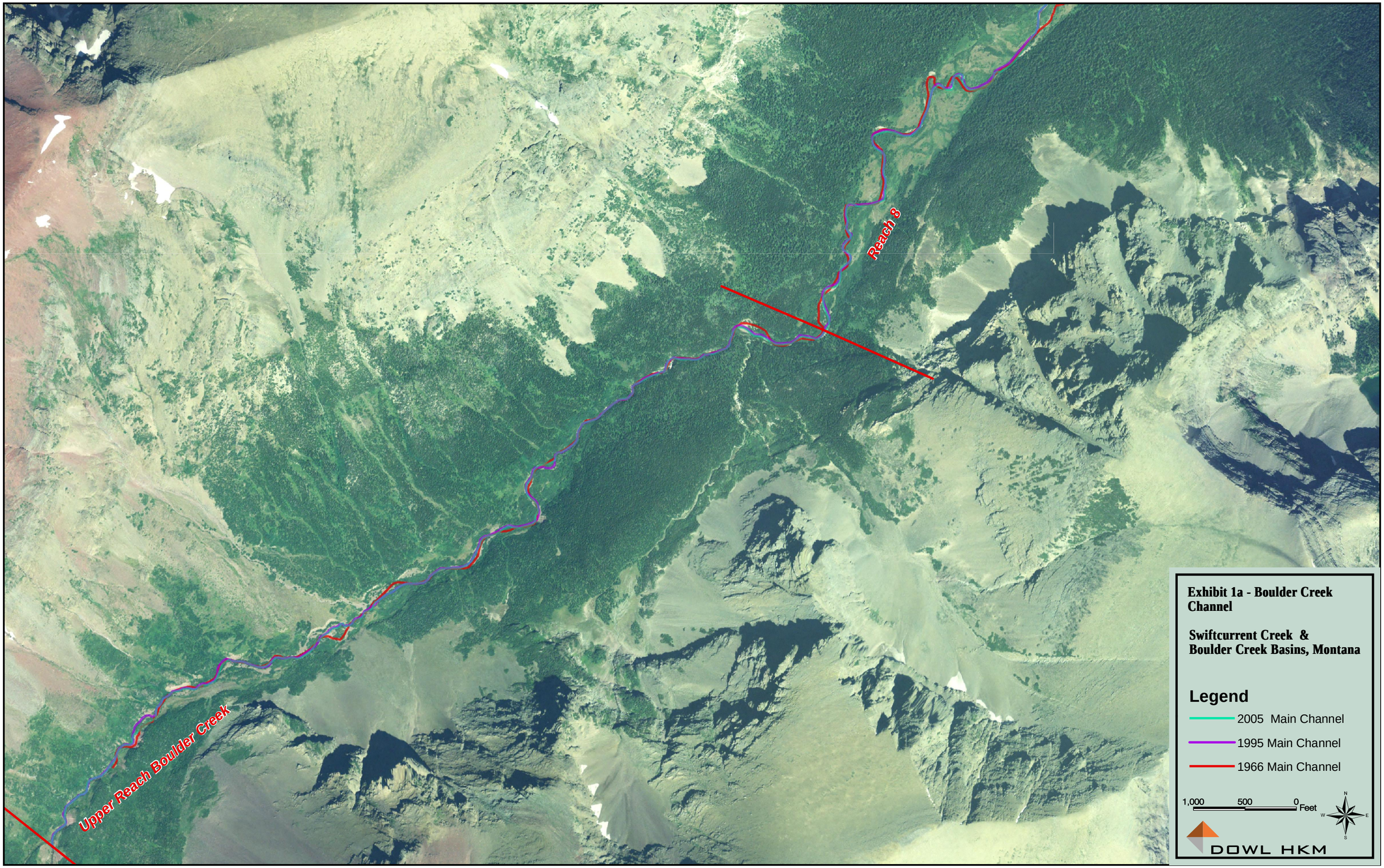
BOULDER
CREEK
STA 1+15
STA 11+54
STA 4+06
STA 34+67
STA 19+49
STA 173+42.1
STA 171+39 SWIFT CURRENT CREEK MAIN CHANNEL = STA 69+10 SWIFT CURRENT CREEK NORTH CHANNEL
STA 0+00 BOULDER CREEK
MIN. X-SEC STA. 172+03
EXTENDED X-SEC STA. 159+02
EXTENDED X-SEC STA. 165+83
41+68.78
40+00
35+00
30+00
25+00
20+00
15+00
10+00
5+00
0+00
60+00
65+00
70+00
160+00
X-SEC
X-SEC
X-SEC

Appendix B


Reach 8
Upper Reach Boulder Creek
Exhibit 1a - Boulder Creek Channel
Swiftcurrent Creek & Boulder Creek Basins, Montana
Legend
2005 Main Channel
1995 Main Channel
1966 Main Channel
1,000
500
0
Feet
N
W
E
S
DOWL HKM

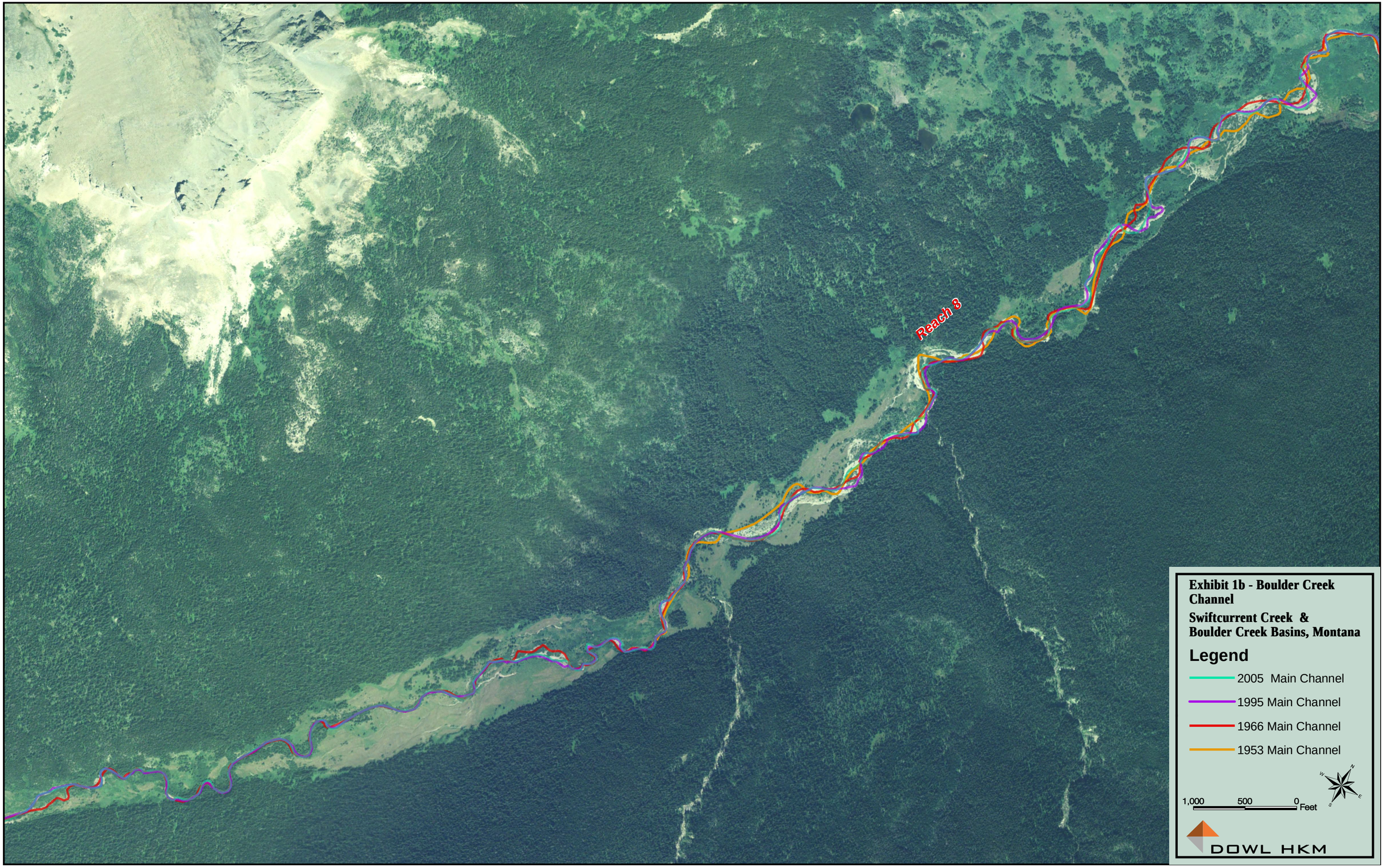
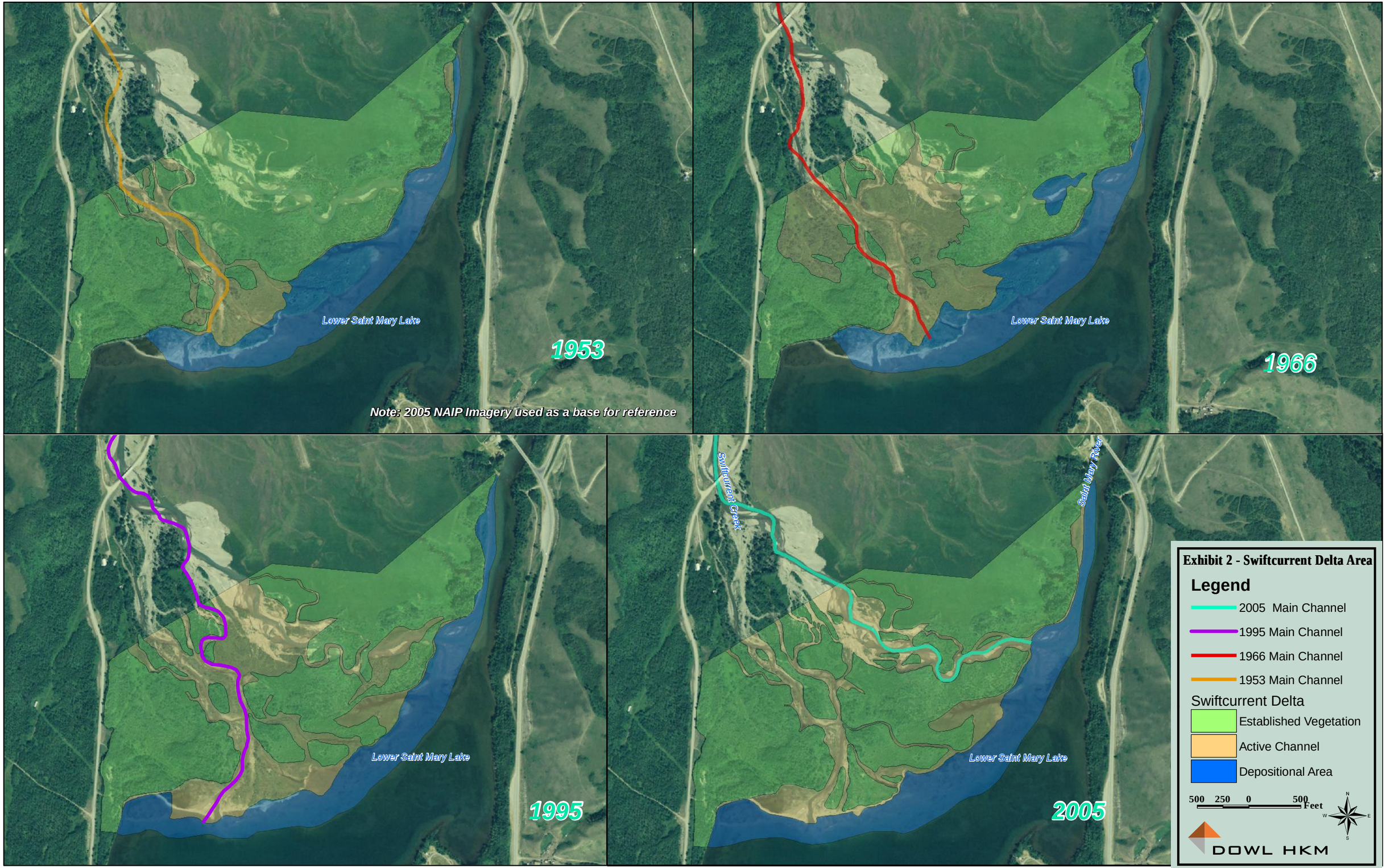

Reach 8
Exhibit 1b - Boulder Creek Channel
Swiftcurrent Creek & Boulder Creek Basins, Montana
Legend
2005 Main Channel
1995 Main Channel
1966 Main Channel
1953 Main Channel
1,000
500
0
Feet
DOWL HKM

Exhibit 1c- Boulder Creek Channel
Swiftcurrent Creek & Boulder Creek Basins, Montana
Legend
2005 Main Channel
1995 Main Channel
1966 Main Channel
1953 Main Channel
Debris Flow Area
1,000
500
0
Feet
N
W
E
S
DOWL HKM
Reach 8

Exhibit 1d- Boulder Creek Channel
Swiftcurrent Creek & Boulder Creek Basins, Montana
Legend
2005 Main Channel
1995 Main Channel
1966 Main Channel
1953 Main Channel
Debris Flow Area
Active Landslide Area
1,000
500
0
Feet
DOWL HKM
Reach 1
Reach 7
Reach 8

Reach 6
Exhibit 1e - Swiftcurrent Creek Channel
Swiftcurrent Creek & Boulder Creek Basins, Montana
Legend
2005 Main Channel
1995 Main Channel
1966 Main Channel
1953 Main Channel
1,000
500
0
Feet
N
W
E
S
DOWL HKM

Exhibit 1f- Swiftcurrent and Boulder Creek Channels
Legend
2005 Main Channel
1995 Main Channel
1966 Main Channel
1953 Main Channel
1,000
500
0
Feet
N
W
E
S
DOWL HKM
Reach 1
Reach 2
Reach 3
Reach 4
Reach 5
Reach 6


Lower Saint Mary Lake
1953
Note: 2005 NAIP Imagery used as a base for reference
Lower Saint Mary Lake
1966
Lower Saint Mary Lake
1995
Swiftcurrent Creek
Saint Mary River
Lower Saint Mary Lake
2005
Exhibit 2 - Swiftcurrent Delta Area
Legend
2005 Main Channel
1995 Main Channel
1966 Main Channel
1953 Main Channel
Swiftcurrent Delta
Established Vegetation
Active Channel
Depositional Area
500 250 0 500 Feet
N
W
E
S
DOWL HKM

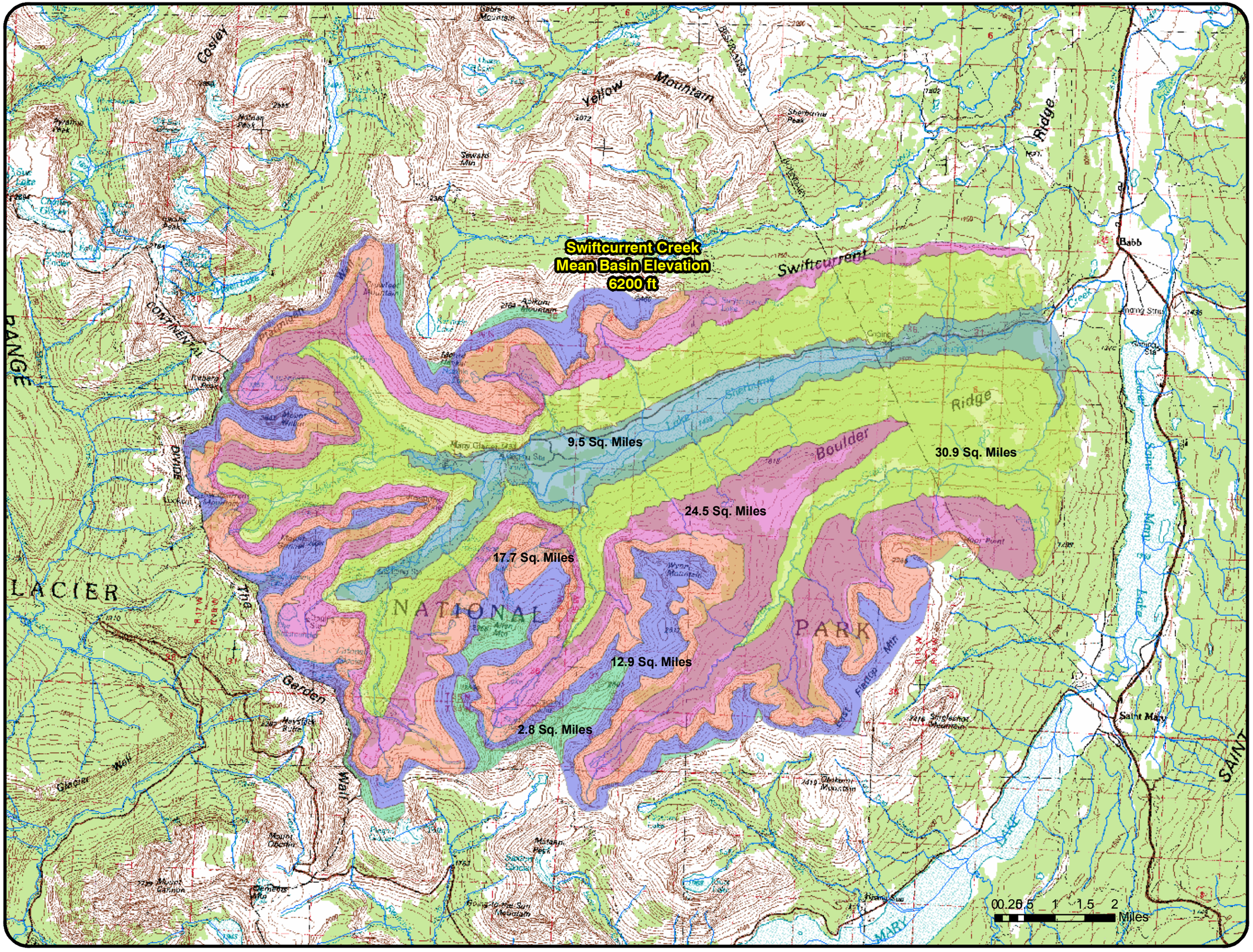
Appendix C

Basin Characteristics:	Swiftcurrent Creek at Many Glacier, MT	Swiftcurrent Creek at Sherburne, MT	Swiftcurrent Creek near Babb, MT	Boulder Creek at Confluence with Swiftcurrent Creek
Basin Area (sq. miles)	30.9	64.6	98.3	26.7
Mean Basin Elevation (ft)	6460	6390	6200	6363
Elevation above 6000 ft (%)	64	62	50.4	59
Storage of basin in lakes (%)	3.41	5.42	---	----
Basin in Forest (%)	58.1	63	45.2	52.1
Mean Annual Precipitation (in)	95	85	64.1	52.3
2-yr, 24-hour Precipitation Intensity (in/hr)	2.1	2.1	---	---
Mean minimum January Temp (F)	8	5	---	---
Width of Active Channel (ft)	45	54	---	---
Mean Depth for Active Channel (ft)	2	2.5	---	---
Width of Bankfull Channel (ft)	62	64	---	---
Mean Depth for Bankfull Channel (ft)	5	5	---	---
Main Channel Slope (ft/mile)	283	154	134	185
Total Stream Length (miles)	7.1	14.3	17.3	14.39
$Q_{1.25}$	885	841	1240	---
Q_2	1050	1140	2158	720
Q_5	1300	1610	2672	---
Q_{10}	1400	1950	2764	1102
Q_{25}	1700	2420	3494	---
Q_{50}	2600	2790	4990	1816
Q_{100}	3800	3190	7226	2428

Obtained From DOWL HKM Basin Delineation

Obtained from USGS Gage Data

Swiftcurrent Creek Mean Basin Elevation at the Boulder Creek Confluence



LEGEND

SwiftcurrentMBE Mean Elevation

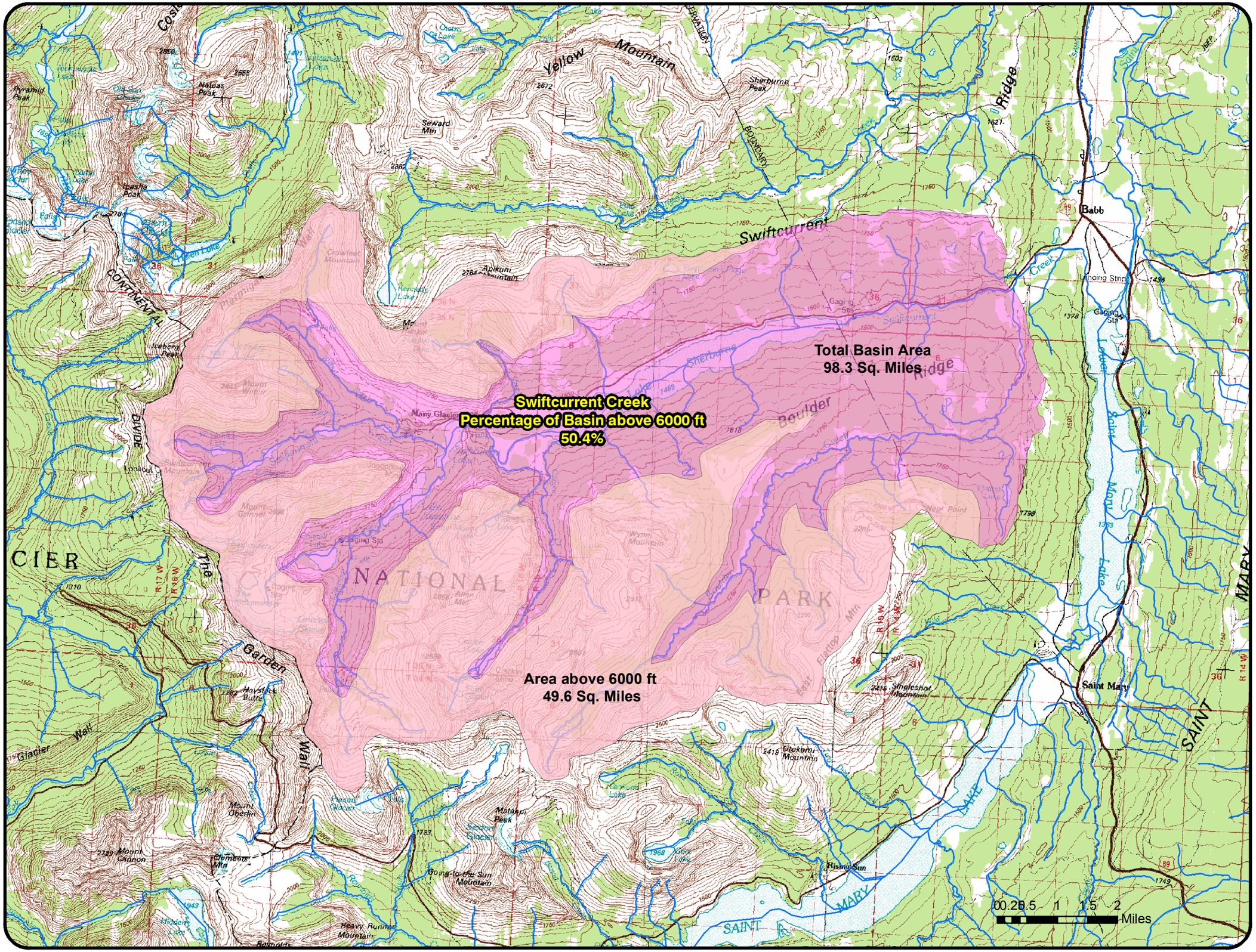
- 4839.23
- 5331.36
- 6151.57
- 6971.78
- 7792.00
- 8612

N W E S

1 inch equals 1.5 miles

DOWL HKM

Swiftcurrent Creek Elevation Above 6000 ft at the Boulder Creek Confluence



LEGEND

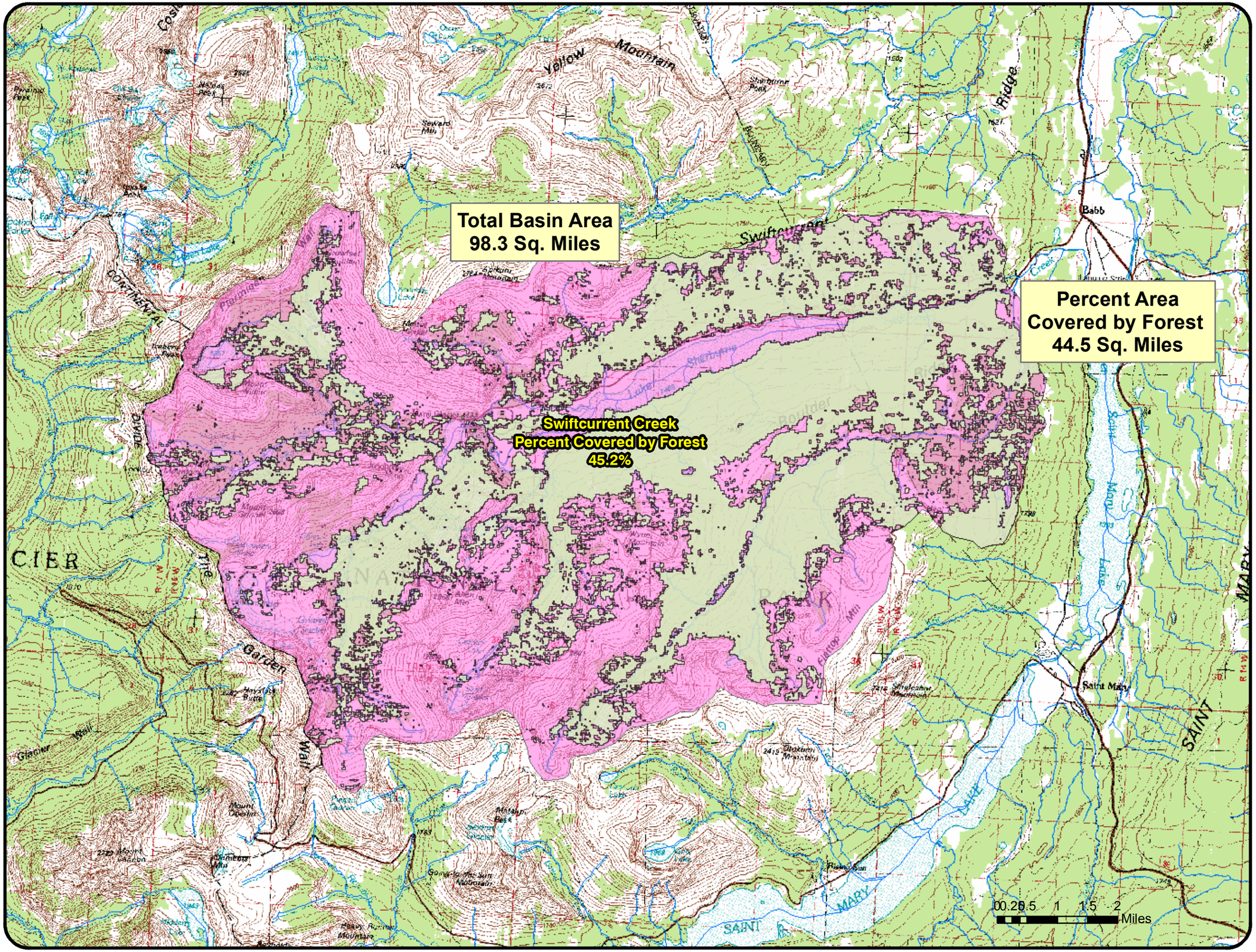
- Swiftcurrent_E6000
- Swiftcurrent@BoulderCrk

N
W E
S

1 inch equals 1.5 miles

DOWL HKM

Swiftcurrent Creek Percent Covered by Forest at the Boulder Creek Confluence



LEGEND

- Swiftcurrent Perc Forest
- Swiftcurrent@BoulderCrk

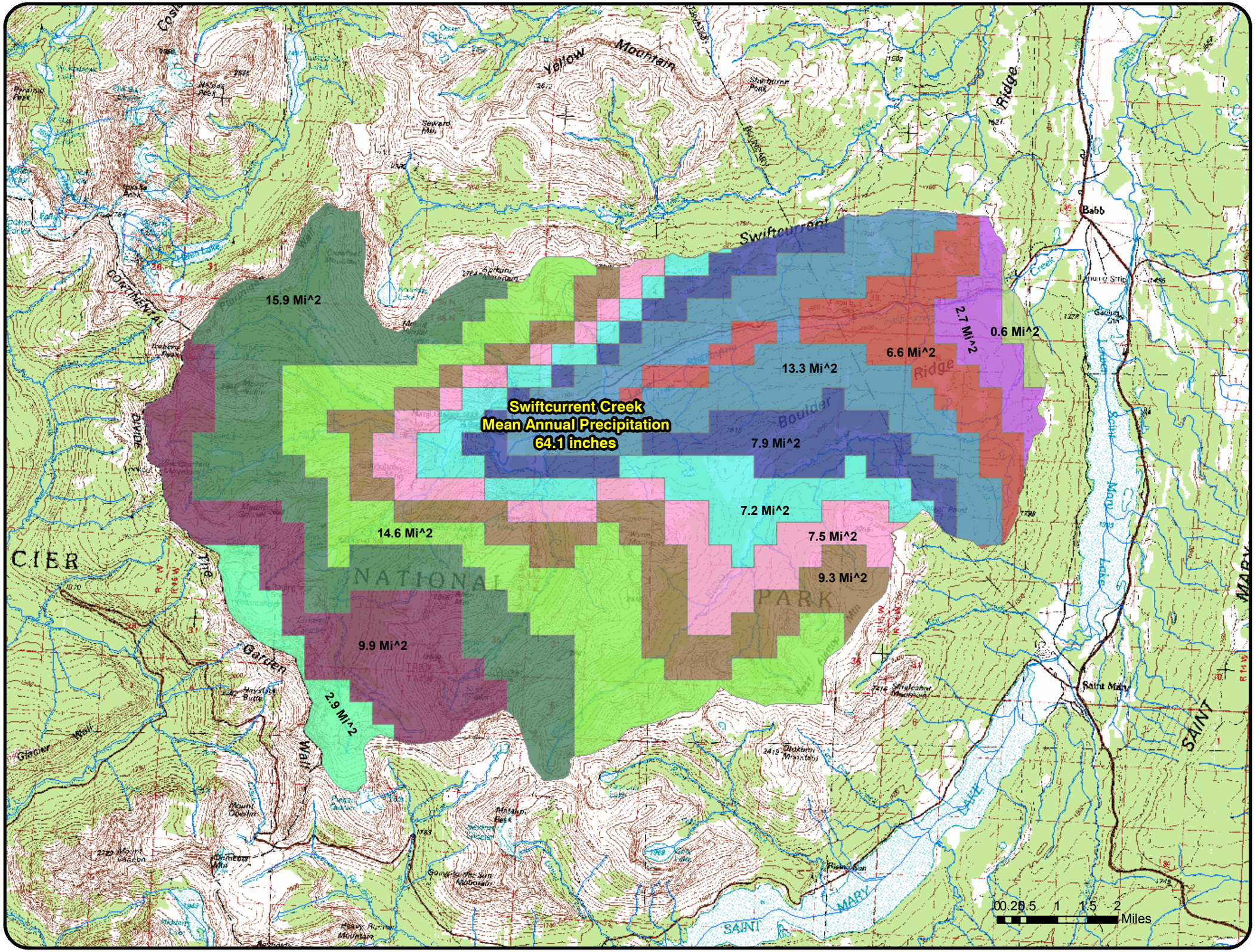
N
W E
S

1 inch equals 1.5 miles

BLACKFEET NATION

DOWL HKM

Swiftcurrent Creek Mean Annual Precipitation at the Boulder Creek Confluence



LEGEND

Mean Annual Precipiation Inches

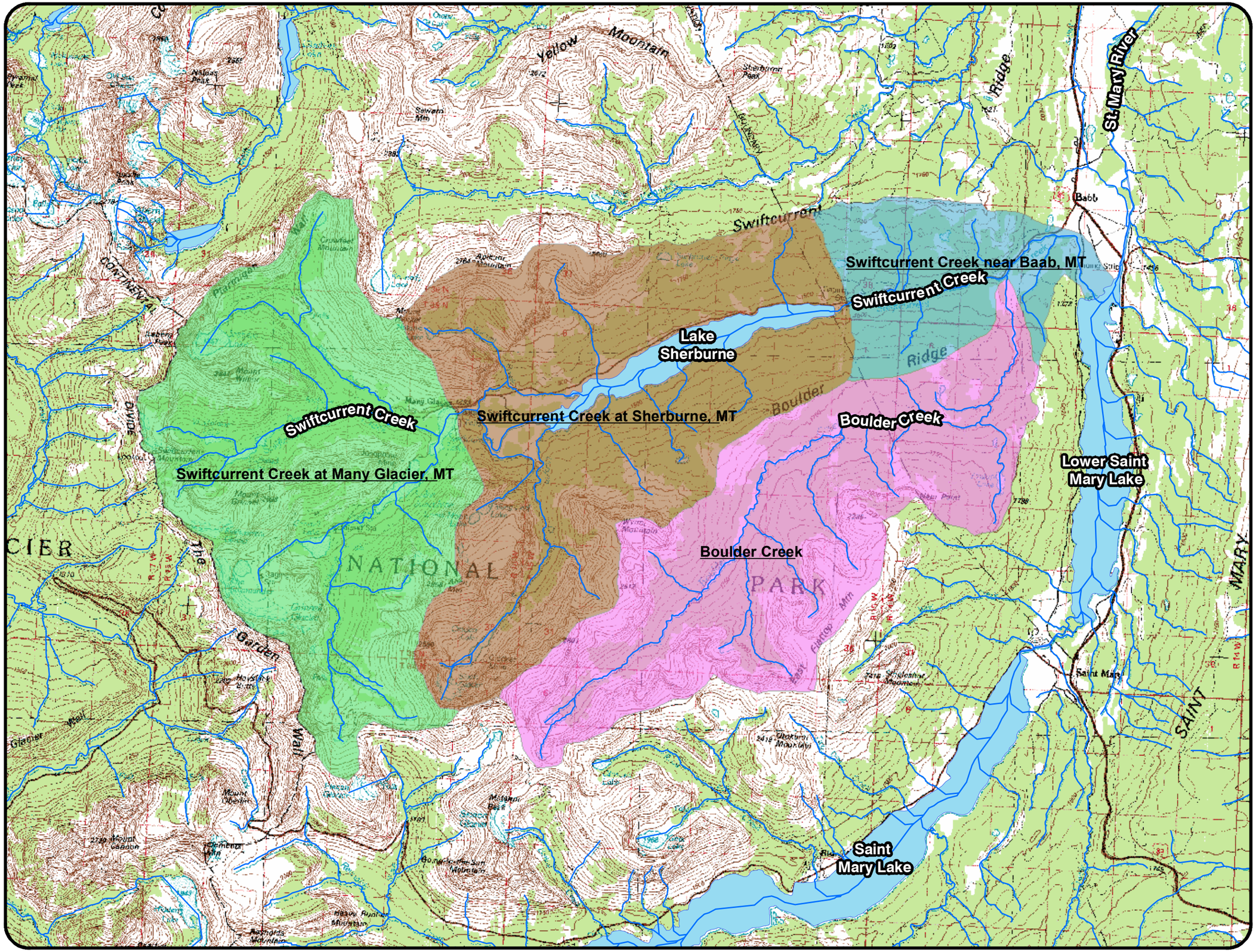
- 30
- 34
- 38
- 42
- 46
- 50
- 55
- 60
- 70
- 85
- 100
- 114

N W E S

1 inch equals 1.5 miles

DOWL HKM

Swiftcurrent Creek & Boulder Creek Drainage Basins



LEGEND

Drainage Basins

Name

- Boulder Creek
- Swiftcurrent Creek at Many Glacier, MT
- Swiftcurrent Creek at Sherburne, MT
- Swiftcurrent Creek near Babb, MT

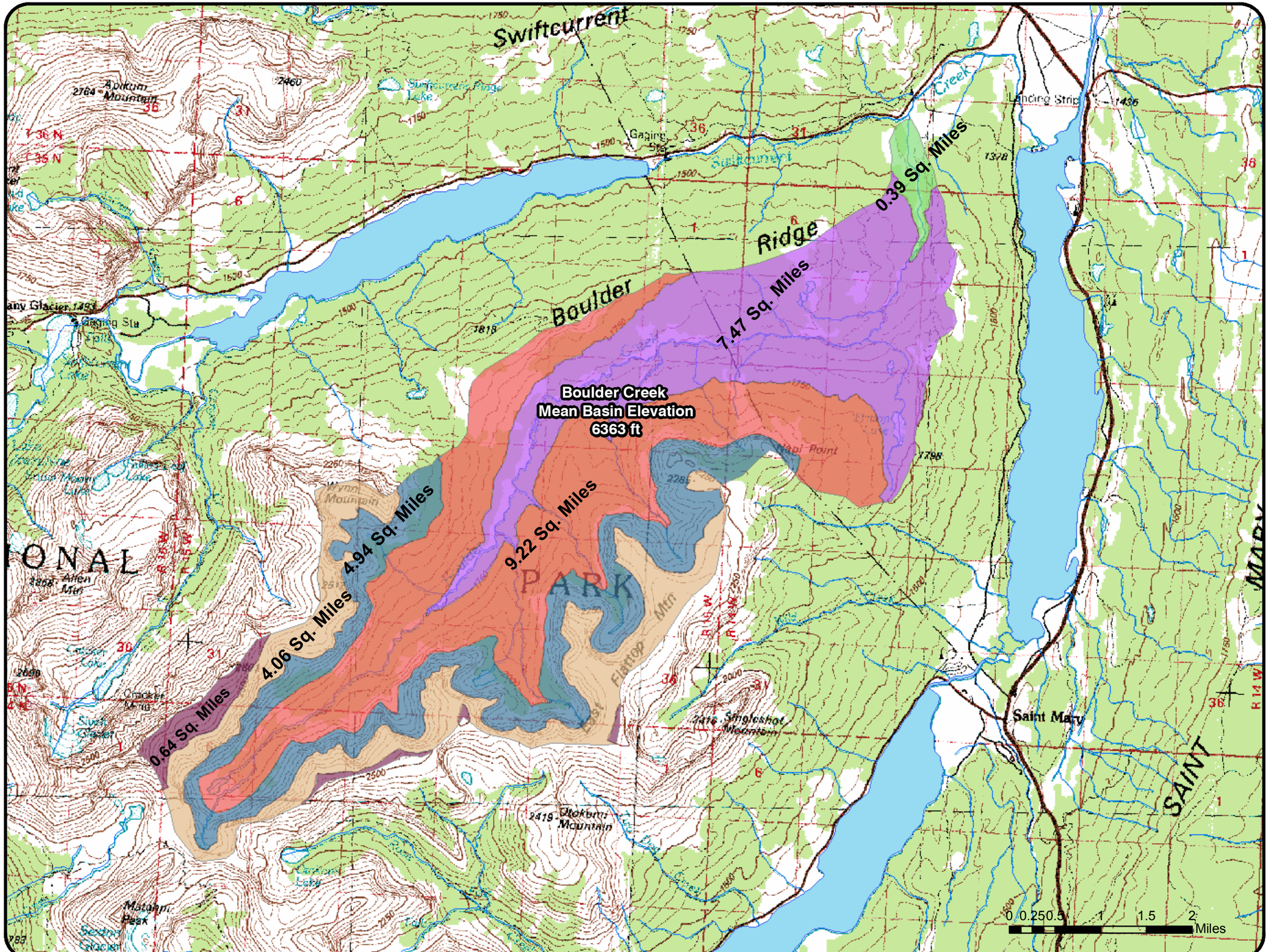
N W E S

1 inch equals 1.5 miles

0 0.5 1 2 Miles

DOWL HKM

Boulder Creek Mean Basin Elevation



LEGEND

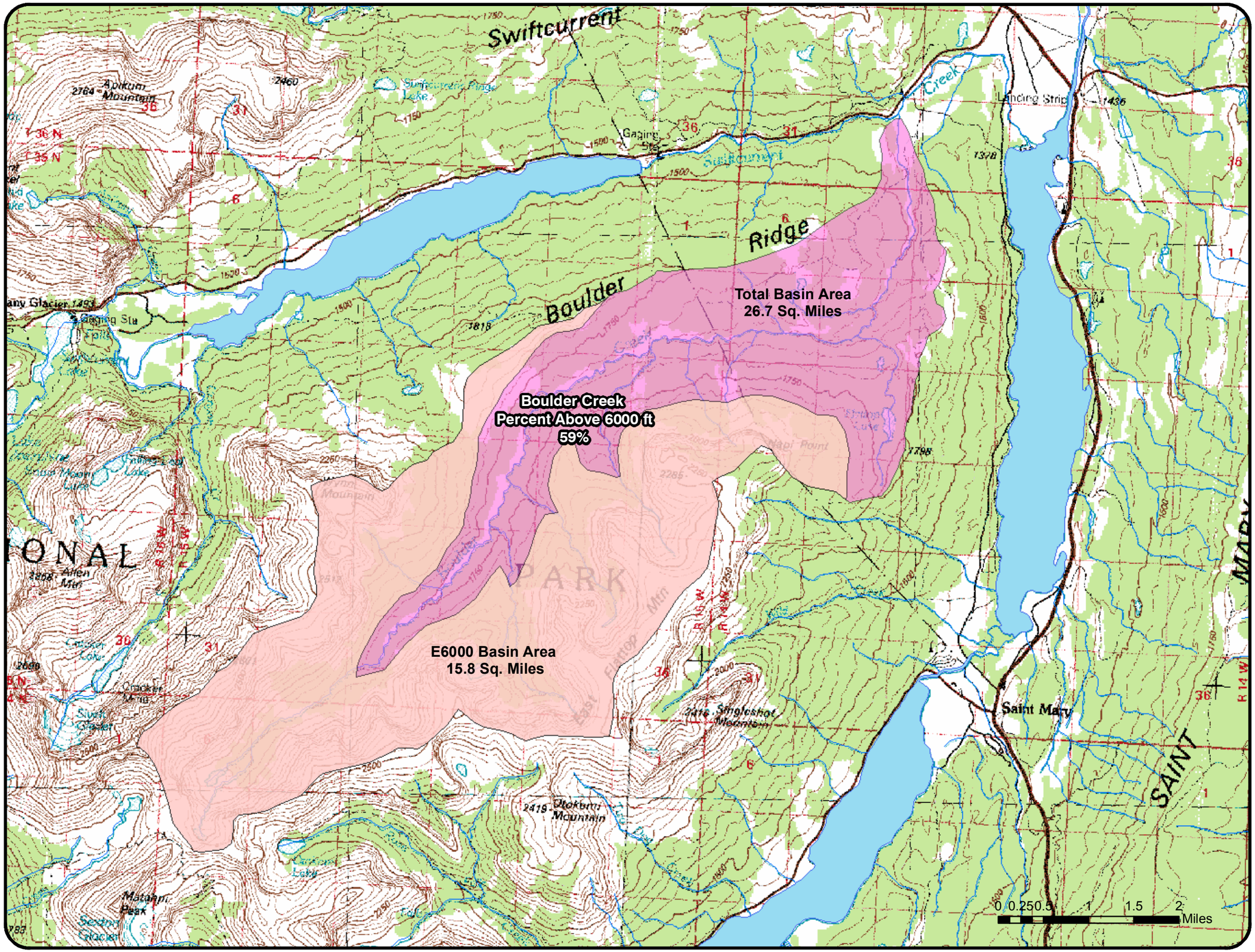
Mean Basin Elevation Elevation

- 4839.23
- 5331.36
- 6151.57
- 6971.78
- 7792.00
- 8612.00

N W E S

1 inch equals 1 miles

DOWL HKM



Boulder Creek Percentage Above 6000 ft

LEGEND

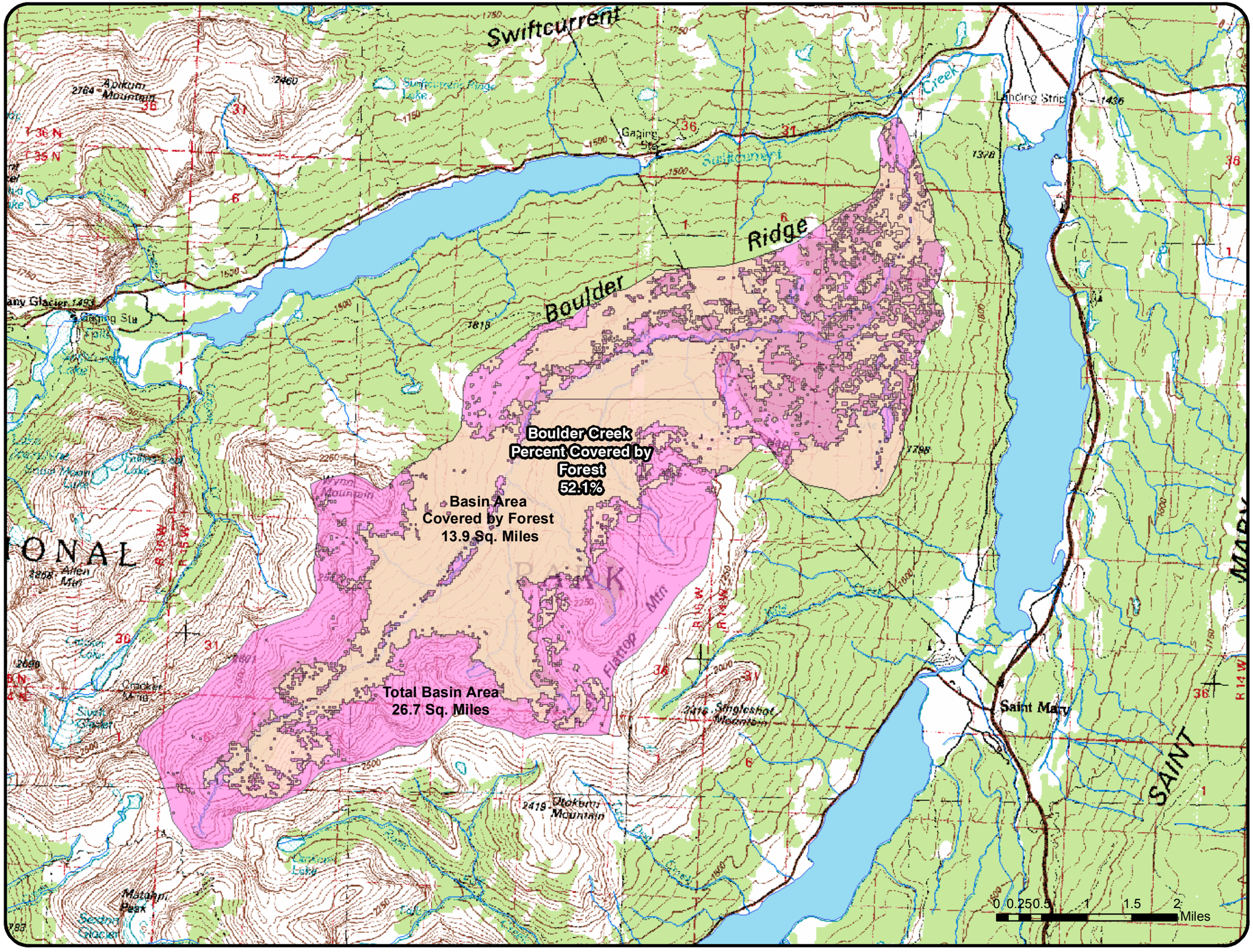
- Elevation Above 6000 ft
- Boulder Creek Basin

N
W E
S

1 inch equals 1 miles

DOWL HKM

Boulder Creek Percent Covered by Forest



LEGEND

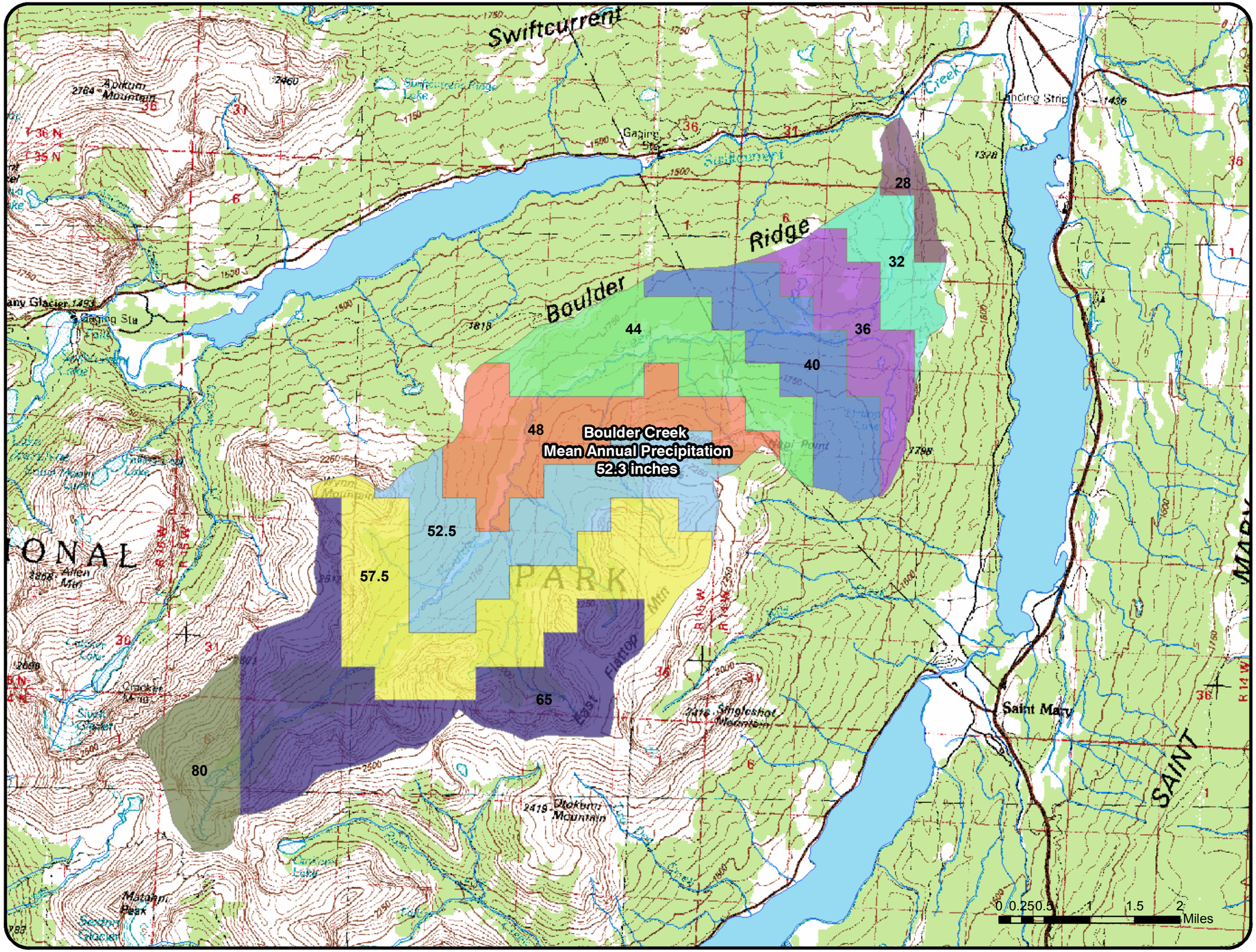
- Boulder Creek Forest
- Boulder Creek Basin

N W E S

1 inch equals 1 miles

DOWL HKM

Boulder Creek Mean Annual Precipitation



LEGEND

Mean Annual Precipitation

- 28
- 32
- 36
- 40
- 44
- 48
- 52.5
- 57.5
- 65
- 80

N W E S

1 inch equals 1 miles

DOWL HKM

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

05014500 Swiftcurrent Creek at Many Glacier, MT

Analysis at this site is based on a mixed-population procedure described by Interagency Advisory Committee on Water Data (1982).

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

--	--	--	--	--	1050	1300	1400	1700	2600	3800	5400	8700
99.5	99	95	90	80	50	20	10	4	2	1	0.5	0.2

Recorded Annual Peak Discharge:

05014500 Swiftcurrent Creek at Many Glacier, MT

```
Location.-- Lat 48 47'57", Long 113 39'21", Hydrologic Unit 10010002.
Drainage area.--   30.90 square miles.
Datum of gage.--    4876.78 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s	Date of Max. gage height	Maximum gage height (ft)

1913	May 28, 1913	4.25		1150	--	--
1914	June 4, 1914	3.40		690	--	--
1915	May 8, 1915	3.10		600	--	--
1916	June 17, 1916	4.75		1550	--	--
1917	June 9, 1917	4.20		1220	--	--
1918	June 10, 1918	4.30		1280	--	--
1919	May 28, 1919	4.00		1100	--	--
1920	June 16, 1920	3.86		1020	--	--
1921	May 26, 1921	3.97		1100	--	--
1922	May 20, 1922	3.54		868	--	--
1923	June 1, 1923	4.38		815	--	--
1924	May 16, 1924	4.00	_/1	771	--	--
1925	May 22, 1925	4.76		1040	--	--
1926	May 5, 1926	3.41		491	--	--
1927	June 8, 1927	4.91		1100	--	--
1928	May 23, 1928	4.92		1120	--	--
1929	May 24, 1929	4.24		884	--	--
1930	May 20, 1930	4.44		885	--	--
1931	May 17, 1931	4.61		1110	--	--
1932	May 22, 1932	5.05		1360	--	--
1933	June 17, 1933	5.00		1360	--	--
1934	June 7, 1934	4.87		1280	--	--
1935	May 23, 1935	4.49		1070	--	--
1936	May 16, 1936	4.43		1040	--	--
1937	June 13, 1937	6.89	_/1	2250	--	--
1938	May 27, 1938	4.61		1130	--	--
1939	May 30, 1939	4.76		1060	--	--
1940	May 12, 1940	3.88		695	--	--
1941	May 18, 1941	3.37		500	--	--
1942	June 6, 1942	4.65		1040	--	--
1943	June 18, 1943	5.46		1630	--	--
1944	May 17, 1944	3.38		506	--	--
1945	June 1, 1945	4.31		845	--	--
1946	May 29, 1946	4.20		798	--	--
1947	May 9, 1947	3.84		708	--	--
1948	June 4, 1948	5.02		1250	--	--
1949	May 28, 1949	4.02		758	--	--
1950	June 22, 1950	5.01		1210	--	--
1951	June 16, 1951	4.57		1010	--	--
1952	Oct. 2, 1951	4.14		811	--	--
1953	June 13, 1953	5.29		1320	--	--
1954	May 20, 1954	5.25		1280	--	--
1955	June 25, 1955	4.51		955	--	--
1956	May 21, 1956	4.84		1100	--	--
1957	May 8, 1957	4.11		821	--	--
1958	May 10, 1958	4.25		834	--	--
1959	June 6, 1959	4.62		1010	--	--
1960	June 17, 1960	4.53		968	--	--
1961	May 27, 1961	4.62		1010	--	--
1962	June 10, 1962	3.62		603	--	--
1963	June 10, 1963	4.19		825	--	--
1964	June 8, 1964	10.00		6700	--	--
1965	June 19, 1965	5.52		1390	--	--
1966	June 11, 1966	4.19		825	--	--
1967	May 23, 1967	4.78		1080	--	--
1968	Sept.19, 1968	4.57		985	--	--
1969	June 7, 1969	4.16		812	--	--
1970	June 13, 1970	4.87		1120	--	--
1971	May 28, 1971	4.57		985	--	--
1972	June 2, 1972	4.95		1150	--	--
1973	June 9, 1973	5.43		1370	--	--
1974	June 18, 1974	5.13		1230	--	--
1975	June 20, 1975	7.92		3310	--	--
1976	May 11, 1976	4.53		1010	--	--
1977	May 11, 1977	3.37		525	--	--
1978	June 6, 1978	4.46		947	--	--

```
 1979    June  6, 1979     4.66         1070                --          --
 1980    May  23, 1980     4.07          817                --          --
 1981    May   2, 1981     4.32          921                --          --
 1982    June 16, 1982     4.27          860                --          --
 1983    July 14, 1983     4.63         1040                --          --
 1984    May  31, 1984     5.01         1180                --          --
 1985    June  8, 1985     5.35         1340                --          --
 1986    May  29, 1986     4.61         1010                --          --
 1987    May   1, 1987     4.23          835                --          --
 1988    May  13, 1988     3.87          685                --          --
 1989    June 11, 1989     4.78         1080                --          --
 1990    Nov. 12, 1989     5.45         1390                --          --
 1991    May  19, 1991     5.68         1500                --          --
 1992    Apr. 30, 1992     4.25          852                --          --
 1993    May  14, 1993     3.89          693                --          --
 1994    May  13, 1994     3.91          710                --          --
 1995    June  7, 1995     7.72         3150                --          --
 1996    June  9, 1996     4.92         1140                --          --
 1997    June  1, 1997     5.58         1450                --          --
 1998    June 16, 1998     4.36          898                --          --

_/ Explanation of the footnotes used for Gage height data:
      1  Gage height affected by backwater.
```

Basin Characteristics:

Value	Abbrev	Explanation
283.0	SLOPE	Main channel slope, in ft per mile
7.1	LENGTH	Total stream length, miles
6460.0	ELEV	Mean basin elevation, ft above msl
64.0	EL6000	Percent of basin above 6,000 ft, msl
3.41	STORAGE	Percent of basin in lakes, ponds, and swamps
58.1	FOREST	Percent of basin in forest
4.5	SOIL_INF	Soil index, in inches
48.79916667	LAT_GAGE	Latitude of gage, in decimal degrees
113.65583333	LNG_GAGE	Longitude of gage, in decimal degrees
95.0	PRECIP	Mean annual precipitation, in inches
2.1	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
8.0	JANMIN	Mean minimum January temperature, in degrees F
45.0	WAC	Width of active channel, in feet
2.0	W2	Mean depth for active channel, in feet
62.0	WBF	Width of bankfull channel, in feet
5.0	W4	Mean depth of bankfull channel, in feet

Montana Flood-Frequency and Basin-Characteristic Data
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USGS 05014500 Swiftcurrent Creek at Many Glacier, MT												
YEAR	Monthly mean in cfs (Calculation Period: 1912-06-01 -> 2008-09-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1912						420	230	127	88	69		
1913					320	687	316	192	113	98	72	56
1914				133	368	360						
Mean Monthly Discharge Prior to Dam				133	344	489	273	159	100	83	72	56
1915					314	346	224	153	125	119	79	
1916			54	83	280	759	519	207	204	60	61	45
1917				33	346	613	402	144	94	81	56	70
1918	177	44	51	159	456	593	204	163	86	87	46	32
1919	42	36	33	126	430	347	169	107	58	36	42	44
1920	43	36	29			577	408	152	154	105		
1921	38					642	285	126	60	76		
Mean Monthly Discharge During Construction of Dam	75	38	42	100	365	554	316	150	112	81	57	48
1922					340	520	222	121	70	72		
1923					396	515	267	125	64	67		
1924				47	403	441	246	131	54	44		
1925					574	594	313	149	97	60		
1926					220	193	145	90	144	162		
1927					270	727	385	166	228	170		
1928					656	472	369	121	69	205		
1929					325	412	193	95	44	44		
1930					346	377	205	94	62	45		
1931					452	334	145	95	82	42		
1932					465	507	217	105	48	56		
1933					331	820	351	128	87	194		
1934				340	609	413	185	95	43	45		
1935					356	474	264	104	69			
1936					547	395	151	77	42	26		
1937					390	601	217	87	47	63		
1938				160	460	513	239	84	57	54		
1939					444	284	210	93	52	32		
1940			22	98	380	299	135	70	89	59		
1941			23	128	299	267	146	66	136	124		
1942			22	143	300	411	268	109	80	45		
1943			15	181	305	517	359	110	60	52		
1944			14	70	292	256	114	96	78	60		
1945			18	35	421	480	232	84	100	88	114	
1946			32	147	461	457	275	102	75	98		
1947				123	458	457	272	116	96	243		
1948			13	75	426	622	197	113	48	35		
1949			18	116	435	338	165	86	106	68	117	
1950				42	299	672	458	166	73	238		
1951				100	455	437	391	137	182	190		
1952					349	352	213	120	57	27		
1953					373	662	407	149	68	33		
1954				49	445	549	505	197	143	151	94	
1955					205	588	359	123	58	190		
1956					433	519	290	129	75	119		
1957			26	57	553	437	168	79	45	57		
1958			25	67	526	392	163	95	104	108	78	53
1959	65	34	21	119	305	616	325	133	235	200	68	43
1960	17	18	34	104	264	538	257	107	68	40	40	25
1961	20	38	31	90	432	596	190	91	63	118	41	23
1962	17	26	14	152	315	408	174	109	65	115	98	66
1963	26	61	26	70	344	549	272	91	64	47	48	30
1964	21	17	13	32	308	769	288	112	118	150	52	29
1965	24	27	23	94	321	580	276	125	84	90	68	36
1966	26	16	24	101	382	440	249	106	72	65	56	40
1967	27	32	20	26	369	597	356	126	60	64	96	33
1968	43	38	53	44	363	493	251	130	236	115	76	33
1969	28	17	12	133	359	441	215	82	59	86	53	25
1970	21	19	18	27	405	673	192	87	59	41	31	27
1971	31	39	19	100	467	565	356	168	71	67	46	25

1972	15	19	85	77	377	621	347	177	92	58	30	21
1973	27	16	15	46	325	454	178	89	64	55	143	42
1974	92	38	33	89	296	720	407	151	72	25	28	18
1975	14	11	10	17	243	822	440	148	114	107	106	96
1976	38	24	16	92	455	342	342	192	71	32	20	18
1977	15	15	13	105	264	263	136	129	134	54	56	36
1978	18	13	28	93	349	537	360	171	149	49	50	14
1979	10	12	32	50	426	440	188	81	51	29	20	34
1980	19	16	21	210	489	361	160	97	153	62	104	100
1981	57	34	33	134	462	459	276	106	54	32	30	30
1982	26	48	28	44	304	610	343	122	70	74	38	25
1983	28	23	40	83	322	381	317	119	62	35	102	26
1984	88	24	20	102	318	448	219	99	105	74	49	20
1985	12	7	10	128	418	408	170	100	174	167	137	18
1986	21	48	96	151	360	394	174	84	80	101	83	34
1987	19	19	66	179	407	266	200	104	52	20	13	32
1988	14	15	21	158	354	312	115	57	36	118	78	31
1989	26	17	36	143	334	527	240	148	114	80	218	63
1990	34	28	21	158	285	462	294	126	53	142	169	46
1991	28	28	25	109	452	636	377	136	51	28	36	24
1992	15	18	45	162	305	263	133	75	119	98	42	22
1993	15	12	27	75	384	322	247	114	82	46	26	21
1994	20	15	52	158	382	359	171	73	34	37	32	29
1995	35	68	72	65	309	634	275	137	51	183	215	98
1996	30	61	41	147	276	587	288	138	66	57	38	28
1997	37	25	54	97	435	608	281	137	103	111	54	20
1998	24	14	27	117	427	418	196	84	54	31	33	33
1999	28	21	31	102	279	528	350	179	61	135	237	58
2000	41	25	27	129	344	442	203	95	85	71	23	15
2001	11	11	13	57	321	302	118	59	33	26	74	28
2002	56	35	28	83	326	717	369	92	66	43	30	31
2003	26	31	47	162	329	442	173	70	33	45	46	28
2004	16	19	42	163	312	379	230	173	133	78	61	73
2005	101	42	34	87	278	383	139	65	54	220	75	39
2006	53	28	26	112	433	544	179	56	38	29	320	38
2007	26	19	144	112	341	341	144	50	30	81	53	41
2008	21	24	15	35	461	566	308	122	77			
Mean Monthly Discharge After Construction of Dam	34	27	32	105	376	487	257	116	85	84	75	37
Max Mean Monthly	177	68	144	340	656	822	519	207	236	243	320	100
Min Mean Monthly	10	7	10	17	205	193	114	50	30	20	13	14

USGS

Montana Flood-Frequency and Basin-Characteristic Data

Flood-frequency data are based on recorded annual peak discharges through 1998. Peak discharges for specified frequencies (exceedance probabilities) were determined by fitting a log-Pearson Type 3 probability distribution to base 10 logarithms of recorded annual peak discharges as described by the Interagency Advisory Committee on Water Data (1982, Guidelines for Determining Flood Flow Frequency--Bulletin 17-B of the Hydrology Subcommittee: U.S. Geological Survey, Office of Water Data Coordination). **Note: Data are provisional and user is responsible for assessment and interpretation of flood-frequency data.**

Most of the basin characteristic data were measured in the 1970s from the best-scale topographic maps available at the time. Some data, such as mean annual precipitation, soil index data, and mean January minimum temperatures, were compiled from maps prepared by other agencies. Channel widths were measured in the field by USGS personnel.

The flood-frequency and basin characteristics data were used in a new flood-frequency report just published by the USGS, entitled "Methods for estimating Flood Frequency in Montana Based on Data through Water Year 1998" (Water-Resources Investigations Report 03-4308). Information about the equations described in that report can be found at the following link.

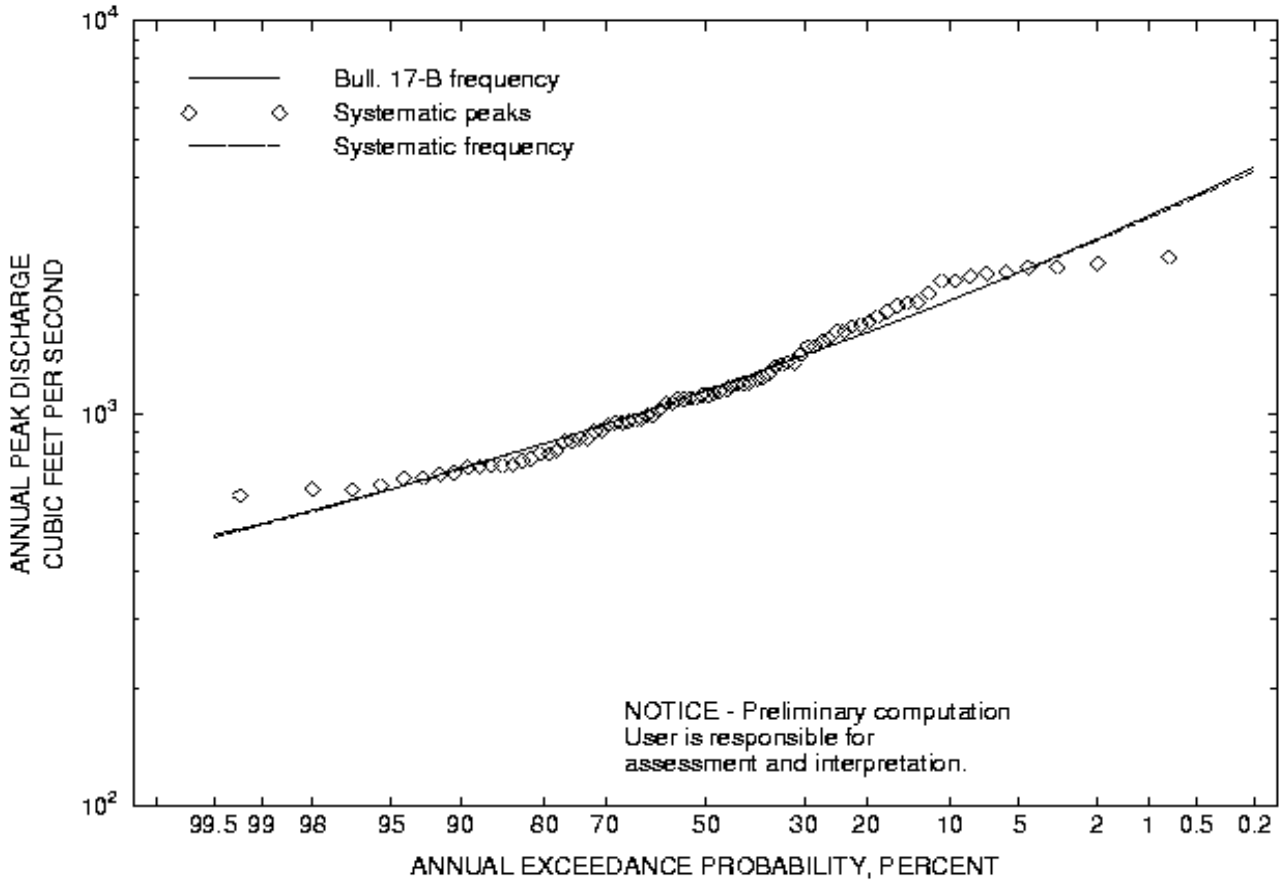
For more detailed information contact Charles Parrett:
Phone: 406-457-5928 or by e-mail.

05016000 Swiftcurrent Creek at Sherburne, MT

Flood-frequency analysis based on period of record since beginning of flow regulation.

Annual peak discharge, in cubic feet per second (top line), for indicated exceedance probability, in percent (bottom line):

491	526	645	725	841	1140	1610	1950	2420	2790	3190	3620	4240
99.5	99	95	90	80	50	20	10	4	2	1	0.5	0.2



NOTE: Systematic peaks are those that are recorded within the period of gaged record. The computed systematic flood-frequency curve is based only on the systematic peaks. The computed Bulletin 17-B flood-frequency curve often is different from the systematic flood-frequency curve because of differences between station skew and regional skew, low- or high-outlier adjustments, or the presence of one or more historical peaks outside the systematic record. Historical peaks also result in historical adjusted plotting positions (exceedance probabilities) for all peaks.

Recorded Annual Peak Discharge:

05016000 Swiftcurrent Creek at Sherburne, MT

```
Location.-- Lat 48 49'49", Long 113 30'59", Hydrologic Unit 10010002.
Drainage area.--   64.60 square miles.
Datum of gage.--    4730.26 ft above sea level.
```

Table of annual peak discharge data [--, no data]

Water year	Date	Gage height (ft)	Discharge ft3/s		Date of Max. gage height	Maximum gage height (ft)
1913	May 28, 1913	--	1850		--	--
1914	June 4, 1914	--	1090		--	--
1915	June 26, 1915	--	816		--	--
1916	June 17, 1916	--	2280		--	--
1917	June 10, 1917	--	1070		--	--
1918	May 5, 1918	--	1140		--	--
1919	May 29, 1919	--	950	_/5	--	--

1920	Aug. 3, 1920	--	1490	_/5	--	--
1921	May 28, 1921	6.10	1200	_/5	--	--
1922	June 7, 1922	6.10	1240	_/5	--	--
1923	June 11, 1923	5.31	864	_/5	--	--
1924	July 19, 1924	5.28	857	_/5	--	--
1925	June 18, 1925	6.25	1330	_/5	--	--
1926	Oct. 10, 1925	5.84	1120	_/5	--	--
1927	June 8, 1927	6.90	1670	_/5	--	--
1928	May 11, 1928	7.44	1830	_/5	--	--
1929	Oct. 14, 1928	6.50	1360	_/5	--	--
1930	June 12, 1930	5.64	937	_/5	--	--
1931	July 24, 1931	4.83	643	_/5	--	--
1932	May 31, 1932	7.00	1220	_/5	--	--
1933	June 2, 1933	5.88	1150	_/5	--	--
1934	June 7, 1934	6.98	1770	_/5	--	--
1935	Aug. 20, 1935	5.03	769	_/5	--	--
1936	Aug. 13, 1936	5.28	866	_/5	--	--
1937	June 15, 1937	5.82	1120	_/5	--	--
1938	May 29, 1938	5.42	954	_/5	--	--
1939	July 17, 1939	5.47	998	_/5	--	--
1940	July 26, 1940	5.02	760	_/5	--	--
1941	July 9, 1941	5.12	795	_/5	--	--
1942	June 5, 1942	6.67	1530	_/5	--	--
1943	June 21, 1943	7.14	1930	_/5	--	--
1944	Aug. 6, 1944	4.85	658	_/5	--	--
1945	June 4, 1945	5.35	910	_/5	--	--
1946	Sept. 3, 1946	4.87	689	_/5	--	--
1947	May 14, 1947	5.01	744	_/5	--	--
1948	June 17, 1948	6.38	1360	_/5	--	--
1949	Aug. 4, 1949	4.72	622	_/5	--	--
1950	June 24, 1950	5.84	1090	_/5	--	--
1951	June 16, 1951	6.69	1420	_/5	--	--
1952	Oct. 1, 1951	6.04	1100	_/5	--	--
1953	June 14, 1953	6.76	1270	_/5	--	--
1954	Sept.15, 1954	8.10	1920	_/5	--	--
1955	June 24, 1955	6.57	1180	_/5	--	--
1956	May 22, 1956	7.34	1630	_/5	--	--
1957	June 9, 1957	5.63	805	_/5	--	--
1958	June 19, 1958	6.15	1070	_/5	--	--
1959	Sept.30, 1959	6.35	1190	_/5	--	--
1960	July 28, 1960	8.30	2180	_/5	--	--
1961	June 30, 1961	6.47	1190	_/5	--	--
1962	Apr. 9, 1962	5.20	688	_/5	--	--
1963	Apr. 5, 1963	5.71	904	_/5	--	--
1964	June 11, 1964	8.37	2360	_/5	--	--
1965	May 16, 1965	6.54	1560	_/5	--	--
1966	Apr. 25, 1966	5.50	960	_/5	--	--
1967	May 10, 1967	6.71	1690	_/5	--	--
1968	Sept.19, 1968	6.08	1070	_/5	--	--
1969	June 25, 1969	7.63	2420	_/5	--	--
1970	July 8, 1970	7.67	2370	_/5	--	--
1971	May 14, 1971	7.45	2190	_/5	--	--
1972	May 18, 1972	7.28	2030	_/5	--	--
1973	Aug. 6, 1973	5.56	795	_/5	--	--
1974	June 17, 1974	7.13	1720	_/5	--	--
1975	June 21, 1975	7.75	2280	_/5	--	--
1976	May 12, 1976	5.89	964	_/5	--	--
1977	Oct. 1, 1976	5.54	737	_/5	--	--
1978	June 9, 1978	5.98	992	_/5	--	--
1979	May 27, 1979	7.27	1890	_/5	--	--
1980	Aug. 15, 1980	5.48	701	_/5	--	--
1981	July 15, 1981	7.77	2300	_/5	--	--
1982	May 22, 1982	7.12	1630	_/5	--	--
1983	Aug. 14, 1983	5.67	735	_/5	--	--
1984	July 25, 1984	5.63	734	_/5	--	--
1985	Oct. 8, 1984	6.26	1090	_/5	--	--

```
1986    May  29, 1986     7.04         1490    _/5         --          --
1987    Sept. 1, 1987     5.69          737    _/5         --          --
1988    Apr. 11, 1988     5.93          852    _/5         --          --
1989    Apr. 15, 1989     5.68          710    _/5         --          --
1990    July 13, 1990     8.00         2250    _/5         --          --
1991    June 22, 1991     7.11         1340    _/5         --          --
1992    Oct. 13, 1991     6.67         1130    _/5         --          --
1993    Aug. 10, 1993     5.74          643    _/5         --          --
1994    July 13, 1994     6.53          972    _/5         --          --
1995    June  7, 1995     8.63         2510    _/5         --          --
1996    July  5, 1996     6.79         1100    _/5         --          --
1997    June  4, 1997     6.67         1030    _/5         --          --
1998    Sept.14, 1998     6.85         1140    _/5         --          --


_/ Explanation of the footnotes used for Discharge data:
      5  Discharge affected to unknown degree by regulation or diversion.
```

Basin Characteristics:

Value	Abbrev	Explanation
154.0	SLOPE	Main channel slope, in ft per mile
14.3	LENGTH	Total stream length, miles
6390.0	ELEV	Mean basin elevation, ft above msl
62.0	EL6000	Percent of basin above 6,000 ft, msl
5.42	STORAGE	Percent of basin in lakes, ponds, and swamps
63.0	FOREST	Percent of basin in forest
--	SOIL_INF	Soil index, in inches
48.83027778	LAT_GAGE	Latitude of gage, in decimal degrees
113.51638889	LNG_GAGE	Longitude of gage, in decimal degrees
85.0	PRECIP	Mean annual precipitation, in inches
2.1	I24_2	Precipitation intensity for a 24-hour storm having a 2-year recurrence interval, in inches per hour
5.0	JANMIN	Mean minimum January temperature, in degrees F
54.0	WAC	Width of active channel, in feet
2.5	W2	Mean depth for active channel, in feet
64.0	WBF	Width of bankfull channel, in feet
5.0	W4	Mean depth of bankfull channel, in feet

Montana Flood-Frequency and Basin-Characteristic Data
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USGS 05016000 Swiftcurrent Creek at Sherburne, MT												
YEAR	Monthly mean in cfs (Calculation Period: 1912-07-01 -> 2004-10-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1912							374	175	120	93	92	62
1913					516	1074	430	274	116	133	91	62
1914				291	599	525	334	162	126		282	
Mean Monthly Discharge Prior to Dam				291	558	800	379	203	121	113	155	62
1915				244	403	473	316	203	173	175	127	63
1916	33	71	120	142	360	1020	687	257	210	50	86	31
1917	20	21	17	49	510	863	489	155	103	96	96	40
1918	157	0	91	221	425	725	244	171	106	101	61	42
1919	29	25	16	157	515	72	313	410	140	40	41	49
1920	40	33	22	69	490	702	415	380	221	187	99	84
1921	39	67	74	188	628	638	185	167	135	574	36	147
Mean Monthly Discharge During Construction of Dam	53	36	56	170	494	677	379	235	145	161	101	65
1922	39	24	21	59	408	670	159	389	232	84	57	42
1923	45	31	25	134	543	271	71	391	590	102		
1924					269	111	718	442	139	85		
1925					429	752	312	536	458	376		
1926				295	269	334	363	110	116	11		
1927				92	568	791	492	430	323	287		
1928					870	388	521	371	96	368		
1929				291	345	462	301	463	257	86		
1930					150	536	374	485	185	41		
1931				116	274	242	558	562	139	109		
1932					200	363	435	588	271	137		
1933					813	445	375	634	321	149		
1934				136	638	591	571	644	98	54		
1935					325	196	517	666	272	30		
1936					130	466	760	464	59	40	29	
1937					242	240	516	756	154	58		
1938				45	317	464	470	740	246	86		
1939				530	108	335	606	476	10	27	208	
1940				19	177	303	687	291	7	4	215	
1941				119	212	139	630	236	132	0		
1942				204	189	555	456	542	472	175	128	
1943				1	288	789	340	580	572	51		
1944				183	299	77	402	304	35	0		
1945				133	240	433	419	581	436	80		
1946				500	274	214	406	571	503	13		
1947			125	236	388	392	335	567	473	27		
1948				57	500	831	262	507	523	44		
1949				96	207	262	467	543	275	0		
1950			116	151	600	864	319	455	497	477	368	
1951			4	320	674	509	422	505	689	438	1	
1952		1	1	1	221	306	396	494	528	62	1	
1953			2	75	540	670	442	532	563	66	0	
1954			0	215	654	339	474	520	653	414	41	
1955			0		54	679	323	570	582	232	1	
1956			2	98	741	377	134	518	556	230		
1957			0	158	359	460	381	576	268	0		
1958			0	63	215	492	477	624	278	0		
1959			36	334	681	443	185	602	732	388	163	0
1960				53	364	286	377	678	399	0		
1961			8	464	203	217	479	662	379	107		
1962			0	456	376	68	487	521	63	0		
1963			14	644	382	18	402	677	405	17		
1964				322	293	602	276	555	508	278		
1965				3	432	566	223	599	547	233	86	0
1966		0	4	4	464	187	391	670	477	37		
1967			0	1	878	305	186	604	536	0		
1968			0	477	373	26	412	673	688	8	0	
1969			0	49	246	533	503	686	328	54		
1970			0	281	42	632	452	700	285	0	0	0
1971		0	0	1	599	566	357	512	769	106	0	
1972			1	1	1033	184	455	516	699	247	1	
1973		2	2	65	259	263	579	578	0	16		0

1974		2	39	515	331	460	546	645	578	0	0	0
1975		1	1	7	34	973	556	568	792	130		0
1976		0	0	68	526	311	381	617	727	95	0	
1977		0	0	59	445	463	179	158	111	1	0	
1978		0	0	21	432	423	533	594	608	207	117	2
1979		1	3	5	464	137	470	598	179	0	0	
1980			129	221	185	107	572	656	318	7		
1981		6	407	343	91	154	472	599	578	5		
1982				39	704	318	970					
1983			305	297	200	196	480	547				
1984			377	197	263	216	414	394	28	0		
1985			98	598	310	67	475	635	328	2		
1986			4	266	387	377	532	583	43	38		
1987			344	167	11	360	312	551	236	34		
1988			276	589	359	268	494	76	1	8		
1989			186	485	335	44	283	522	523	423		
1990			26	185	317	375	389	495	553	171		
1991		19	141	565	347	516	519	524	537	0		
1992		5	323	245	216	145	378	352	0	26		
1993			14	302	241	301	151	452	401	88		
1994			0	95	297	397	482	575	333	1		
1995			40	178	176	588	418	558	335	14		
1996			94	257	217	583	412	443	605	36		
1997			36	196	575	553	330	482	546	109	90	
1998			145	421	31	259	419	552	503	56		
1999			1	301	313	66	306	505	414	87	496	172
2000			155	372	327	144	373	512	213	48		
2001			1	175	335	166	511	175	39	11	5	
2002			69	346	306	468	446	540	574	128		
2003			3	278	222	99	545	539	143	78		
2004			13	444	218	217	155	596	395	1		
Mean Monthly Discharge After Construction of Dam	45	15	64	211	370	403	419	492	340	102	72	44
Max Mean Monthly Discharge	45	31	407	644	1033	973	970	756	792	477	496	172
Min Mean Monthly Discharge	39	0	0	1	11	18	71	76	0	0	0	0

USGS 05016500 Swiftcurrent Creek near Babb, MT												
YEAR	Monthly mean in cfs (Calculation Period: 1902-04-01 -> 1910-05-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1902				109	1219	995	1052	276	145	106	66	60
1903	50	46	50	100	465	1886	709	389	421	277	150	166
1904	50	40	40	280	749	900	519	293	151	76	42	24
1905	20	20	64	147	433	783	483	242	98	276	69	50
1906	30	30	31	299	500	623	381	220	151	347	308	58
1907	50	65	80	171	713	1507	912	387	387	157	61	41
1908	31	60	102	333	821	1940	547	172	118	208	89	18
1909	20	20	40	119	764	2120	783	476	170	97	125	45
1910	40	45	135	452	650							
Max Discharge	50	65	135	452	1219	2120	1052	476	421	347	308	166
Mean of Monthly Discharge	**36**	**41**	**68**	**223**	**702**	**1,340**	**673**	**307**	**205**	**193**	**114**	**58**
Minimum Discharge	20	20	31	100	433	623	381	172	98	76	42	18

USGS 05016500 Swiftcurrent Creek near Babb, MT												
Day of	Mean of daily Mean values for each day for 8 - 9 years of record in, cfs											
month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	36	41	63	70	417	1,440	864	528	251	183	152	71
2	36	41	65	66	427	1,480	882	487	242	191	140	78
3	36	41	71	70	417	1,520	1,090	424	232	205	128	70
4	36	41	71	73	413	1,480	1,370	411	219	228	124	66
5	36	41	72	75	461	1,420	1,250	356	215	226	123	59
6	36	41	72	83	468	1,410	1,090	325	204	220	118	65
7	36	41	73	90	450	1,480	1,030	312	203	200	113	72
8	36	41	76	105	461	1,510	953	306	200	200	113	68
9	36	41	76	118	507	1,550	800	302	192	172	107	59
10	36	41	76	137	542	1,440	732	318	203	171	107	59
11	36	41	80	148	570	1,420	698	308	199	174	109	57
12	36	41	73	167	588	1,390	683	302	203	179	107	57
13	36	41	73	181	614	1,400	635	302	194	170	104	57
14	36	41	67	182	670	1,290	641	298	171	172	110	57
15	36	41	67	193	751	1,260	587	283	165	196	111	57
16	36	41	67	191	826	1,240	575	275	165	172	117	57
17	36	41	63	199	830	1,210	533	263	163	172	128	57
18	36	41	63	205	818	1,210	508	261	166	170	122	57
19	36	41	63	239	752	1,250	476	265	169	158	115	54
20	36	41	63	295	765	1,340	453	278	173	168	117	53
21	36	41	63	298	969	1,370	425	281	177	197	117	53
22	36	41	63	292	876	1,330	396	267	174	183	122	51
23	36	41	63	317	893	1,310	399	259	209	175	117	51
24	36	41	63	329	819	1,260	413	253	240	176	111	51
25	36	41	63	395	789	1,210	404	255	297	203	107	52
26	36	41	64	432	792	1,270	451	257	298	217	107	51
27	36	41	65	437	852	1,210	436	261	248	236	96	51
28	36	41	65	453	853	1,230	458	269	194	235	90	51
29	36	50	65	435	941	1,260	547	267	195	225	90	51
30	36		66	428	1,020	1,130	540	265	191	214	89	51
31	36		66		1,200		560	269		192		51

Comparison of Annual Peak Discharges					
	Babb Gage	Many Glacier Gage		Sherburne Gage	
Year	cfs	Date	Flow (cfs)	Date	Flow (cfs)
1902	3240	---	---	---	---
1903	2630	---	---	---	---
1904	1350	---	---	---	---
1905	1260	---	---	---	---
1906	1030	---	---	---	---
1907	1840	---	---	---	---
1908	1940	---	---	---	---
1909	3360	---	---	---	---
1910	---	---	---	---	---
1911	---	---	---	---	---
1912	---	---	---	---	---
1913	---	5/28/1913	1150	5/28/1913	1850
1914	---	6/4/1914	690	6/4/1914	1090
1915	---	5/8/1915	600	6/26/1915	816
1916	---	6/17/1916	1550	6/17/1916	2280
1917	---	6/9/1917	1220	6/10/1917	1070
1918	---	6/10/1918	1280	5/5/1918	1140
1919	---	5/28/1919	1100	5/29/1919	950
1920	---	6/16/1920	1020	8/3/1920	1490
1921	---	5/26/1921	1100	5/28/1921	1200
1922	---	5/20/1922	868	6/7/1922	1240
1923	---	6/1/1923	815	6/11/1923	864
1924	---	5/16/1924	771	7/19/1924	857
1925	---	5/22/1925	1040	6/18/1925	1330
1926	---	5/5/1926	491	10/10/1925	1120
1927	---	6/8/1927	1100	6/8/1927	1670
1928	---	5/23/1928	1120	5/11/1928	1830
1929	---	5/24/1929	884	10/14/1928	1360
1930	---	5/20/1930	885	6/12/1930	937
1931	---	5/17/1931	1110	7/24/1931	643
1932	---	5/22/1932	1360	5/31/1932	1220
1933	---	6/17/1933	1360	6/2/1933	1150
1934	---	6/7/1934	1280	6/7/1934	1770
1935	---	5/23/1935	1070	8/20/1935	769
1936	---	5/16/1936	1040	8/13/1936	866
1937	---	6/13/1937	2250	6/15/1937	1120
1938	---	5/27/1938	1130	5/29/1938	954
1939	---	5/30/1939	1060	7/17/1939	998
1940	---	5/12/1940	695	7/26/1940	760
1941	---	5/18/1941	500	7/9/1941	795
1942	---	6/6/1942	1040	6/5/1942	1530
1943	---	6/18/1943	1630	6/21/1943	1930
1944	---	5/17/1944	506	8/6/1944	658
1945	---	6/1/1945	845	6/4/1945	910
1946	---	5/29/1946	798	9/3/1946	689
1947	---	5/9/1947	708	5/14/1947	744

Less than 2-year
Less than 5-year
Less than 10-year
Less than 25-year
Less than 50-year
Less than 100-year
Less than 500-year

1948	---	6/4/1948	1250	6/17/1948	1360
1949	---	5/28/1949	758	8/4/1949	622
1950	---	6/22/1950	1210	6/24/1950	1090
1951	---	6/16/1951	1010	6/16/1951	1420
1952	---	Oct. 2, 1951	811	10/1/1951	1100
1953	---	6/13/1953	1320	6/14/1953	1270
1954	---	5/20/1954	1280	9/15/1954	1920
1955	---	6/25/1955	955	6/24/1955	1180
1956	---	5/21/1956	1100	5/22/1956	1630
1957	---	5/8/1957	821	6/9/1957	805
1958	---	5/10/1958	834	6/19/1958	1070
1959	---	6/6/1959	1010	9/30/1959	1190
1960	---	6/17/1960	968	7/28/1960	2180
1961	---	5/27/1961	1010	6/30/1961	1190
1962	---	6/10/1962	603	4/9/1962	688
1963	---	6/10/1963	825	4/5/1963	904
1964	---	6/8/1964	6700	6/11/1964	2360
1965	---	6/19/1965	1390	5/16/1965	1560
1966	---	6/11/1966	825	4/25/1966	960
1967	---	5/23/1967	1080	5/10/1967	1690
1968	---	9/19/1968	985	9/19/1968	1070
1969	---	6/7/1969	812	6/25/1969	2420
1970	---	6/13/1970	1120	7/8/1970	2370
1971	---	5/28/1971	985	5/14/1971	2190
1972	---	6/2/1972	1150	5/18/1972	2030
1973	---	6/9/1973	1370	8/6/1973	795
1974	---	6/18/1974	1230	6/17/1974	1720
1975	---	6/20/1975	3310	6/21/1975	2280
1976	---	5/11/1976	1010	5/12/1976	964
1977	---	5/11/1977	525	10/1/1976	737
1978	---	6/6/1978	947	6/9/1978	992
1979	---	6/6/1979	1070	5/27/1979	1890
1980	---	5/23/1980	817	8/15/1980	701
1981	---	5/2/1981	921	7/15/1981	2300
1982	---	6/16/1982	860	5/22/1982	1630
1983	---	7/14/1983	1040	8/14/1983	735
1984	---	5/31/1984	1180	7/25/1984	734
1985	---	6/8/1985	1340	10/8/1984	1090
1986	---	5/29/1986	1010	5/29/1986	1490
1987	---	5/1/1987	835	9/1/1987	737
1988	---	5/13/1988	685	4/11/1988	852
1989	---	6/11/1989	1080	4/15/1989	710
1990	---	11/12/1989	1390	7/13/1990	2250
1991	---	5/19/1991	1500	6/22/1991	1340
1992	---	4/30/1992	852	10/13/1991	1130
1993	---	5/14/1993	693	8/10/1993	643
1994	---	5/13/1994	710	7/13/1994	972
1995	---	6/7/1995	3150	6/7/1995	2510
1996	---	6/9/1996	1140	7/5/1996	1100
1997	---	6/1/1997	1450	6/4/1997	1030
1998	---	6/16/1998	898	9/14/1998	1140

Criteria for selecting gages:

MBE	5200 ft - 7400 ft
E6000	30% - 70%
% Forest	35% - 90%
Precip	35 in - 95 in
YOR	greater than 10

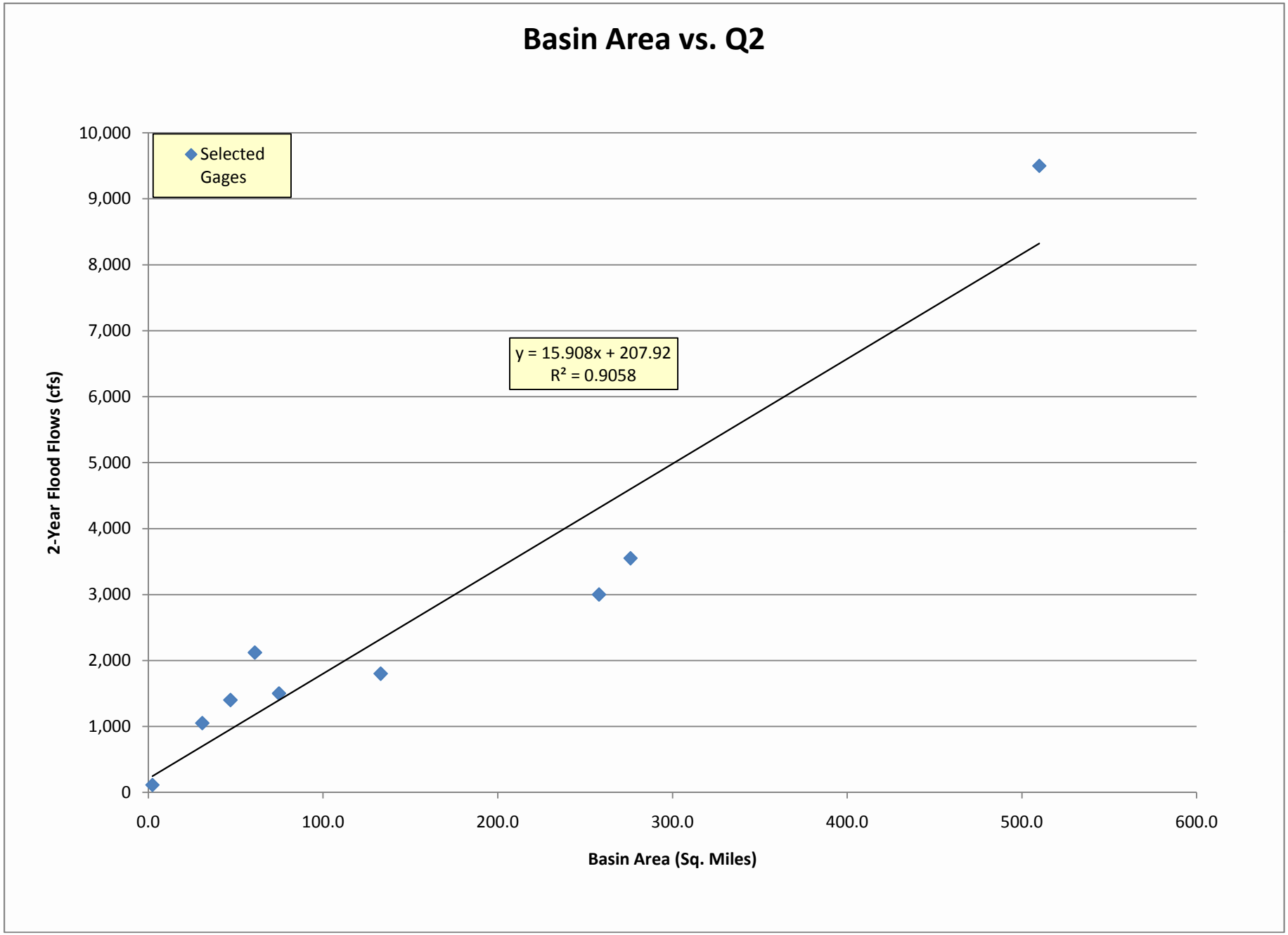
Boulder Creek	26.7	6363	59.0	52.1	52.3
Swiftcurrent Creek	98.3	6200	50.4	45.2	64.1

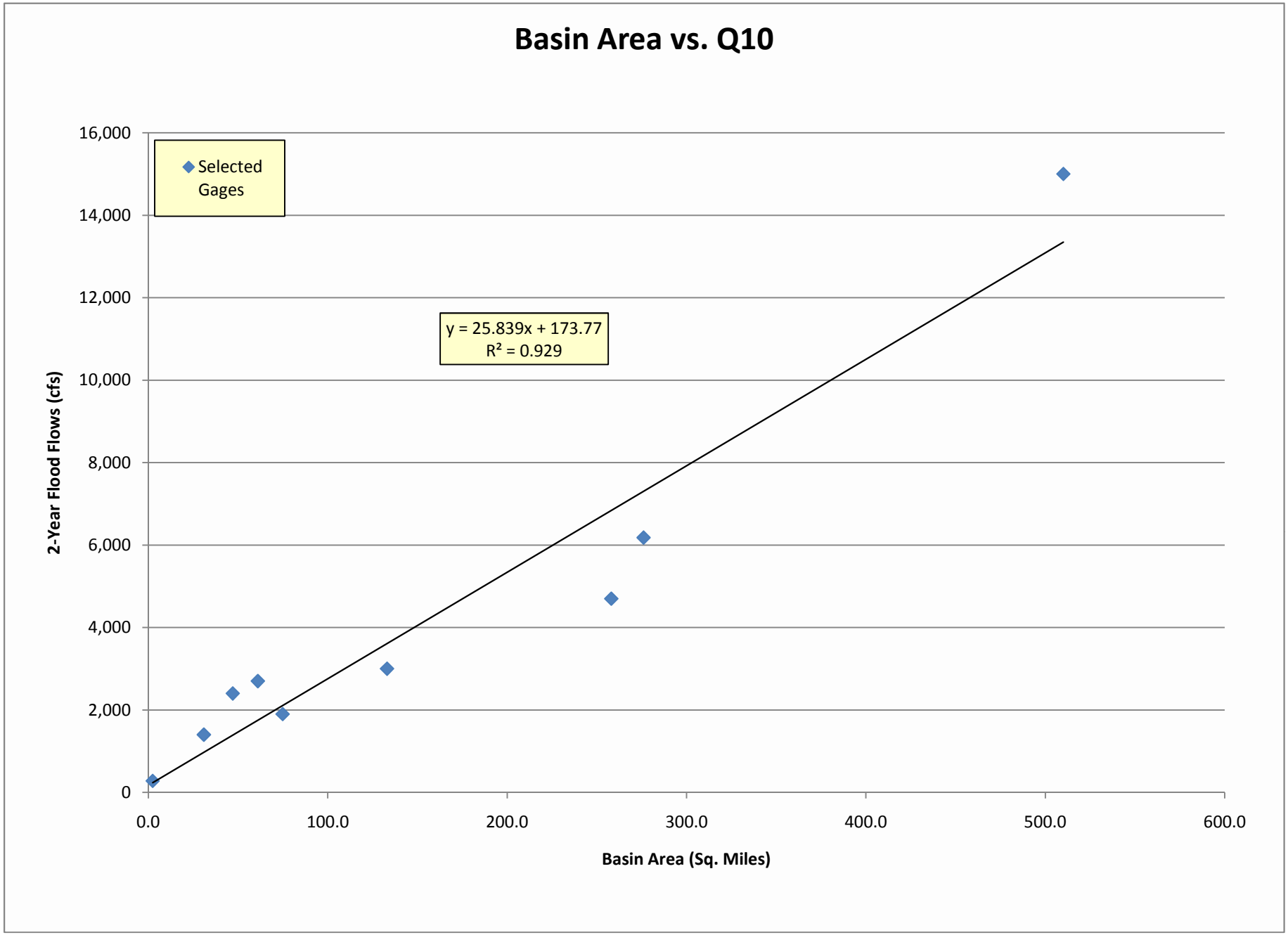
Representative Gages near the Swiftcurrent Creek Watershed

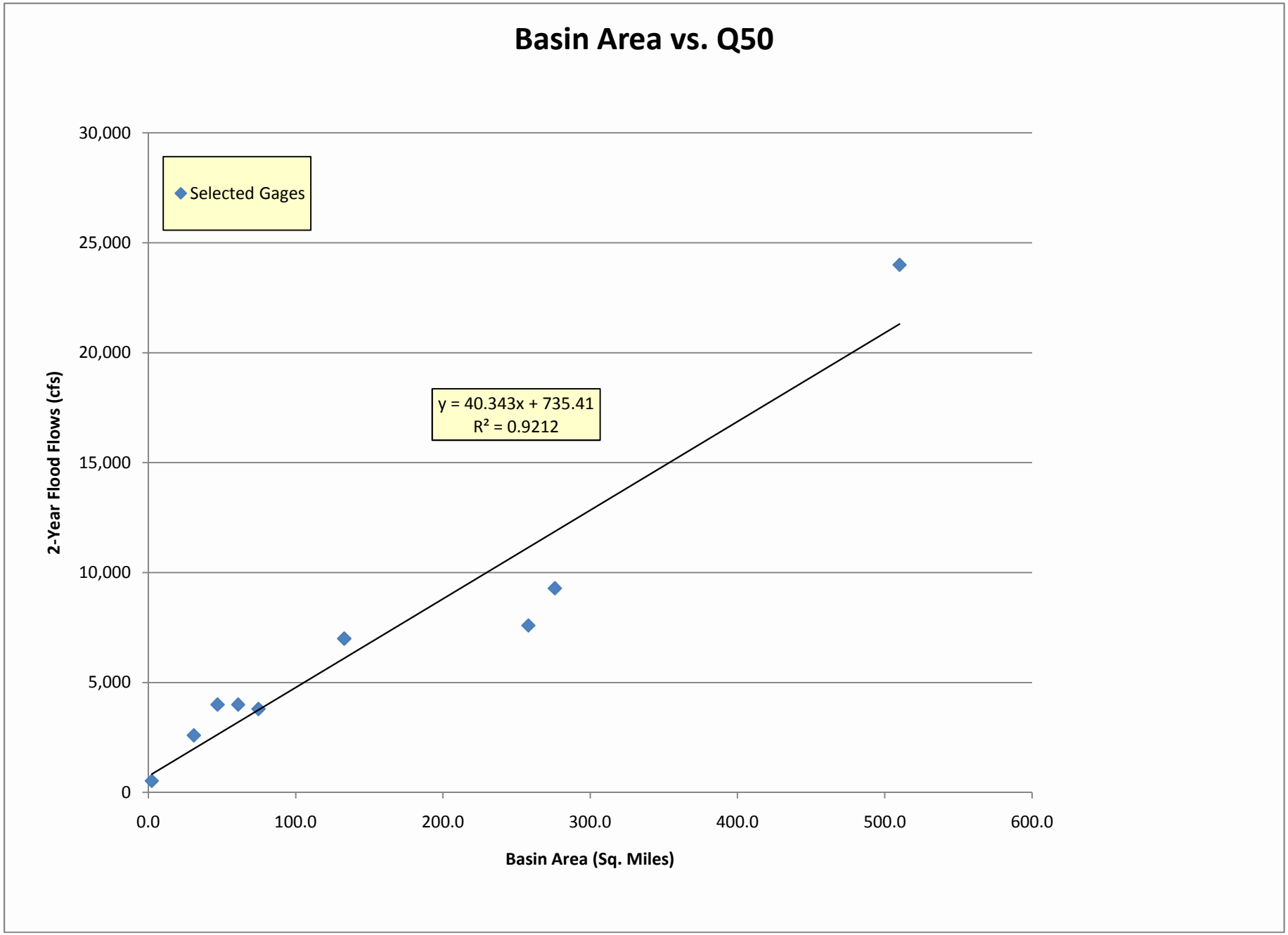
Number of Gages	Site Number	Station Number	Regression	Station Name	Region	YOR	A	E	E6000	F	P	Q2	Q5	Q10	Q25	Q50	Q100	Q200	Q500	Qmax
1	15	12302500	1	Granite Creek near Libby	West	23	23.6	5260	31.0	87.8	67.0	250	1,100	1,320	1,800	2,120	2,660	3,500	5,070	1,960
2	53	12338540	1	Monture Creek above Dunham Creek, near Ovando	West	14	64.7	6380	59.0	78.0	41.0	869	988	1,060	1,150	1,210	1,270	1,320	1,400	1,140
3	55	12338600	0	Monture Creek at Forest Service Boundary, near Ovando	West	19	105.0	6160	63.0	75.0	41.0	1,350	1,650	1,820	2,020	2,160	2,290	2,410	2,560	2,400
4	56	12338690	1	Monture Creek near Ovando	West	10	140.0	5910	54.0	75.0	35.0	1,550	1,920	2,130	2,370	2,540	2,690	2,830	3,000	2,120
5	65	12342950	1	Trapper Creek near Conner	West	18	28.5	6830	67.0	67.0	66.0	450	589	688	824	931	1,050	1,170	1,340	1,800
6	76	12350500	1	Kootenai Creek near Stevensville	West	22	28.9	6350	65.0	69.0	64.0	814	1,060	1,200	1,360	1,470	1,570	1,660	1,770	1,300
7	78	12351200	0	Bitterroot River near Florence	West	12	2354.0	5920	47.0	78.0	36.0	15,200	18,600	20,800	23,600	25,700	27,700	29,800	32,500	20,300
8	102	12369200	1	Swan River near Condon	West	20	69.1	5830	39.0	61.0	54.0	828	1,050	1,180	1,360	1,480	1,600	1,730	1,890	1,540
9	107	12370900	1	Teepee Creek near Polson	West	21	2.2	5460	45.0	89.0	51.0	10	20	30	47	65	88	117	168	44
10	108	12371100	1	Hell Roaring Creek near Polson	West	27	6.2	5210	37.0	90.0	48.0	30	62	89	130	165	203	245	306	104
11	131	5010000	1	Belly River at International Boundary	Northwest	17	74.8	6180	58.0	51.3	79.0	1,500	1,800	1,900	2,450	3,800	6,000	9,000	17,500	12,000
12	132	5011000	1	Belly River near Mountain View Alberta	Northwest	68	121.0	5920	46.0	59.8	65.0	2,100	2,800	3,200	4,600	6,500	9,100	13,000	21,000	16,400
13	133	5011500	1	Waterton River near International Boundary	Northwest	17	61.0	6060	56.0	53.9	84.0	2,120	2,450	2,700	3,000	4,000	6,200	9,600	18,000	12,400
14	134	5012500	1	Boundary Creek at International Boundary	Northwest	17	21.0	5610	33.0	70.6	75.0	530	650	720	910	1,600	2,500	4,300	8,600	5,930
15	135	5013000	1	Waterton River near Waterton Park, Alberta	Northwest	55	238.0	5910	48.0	58.6	68.0	4,500	5,500	6,300	7,600	10,500	15,000	21,000	33,000	25,700
16	138	5014500	1	Swiftcurrent Creek at Many Glacier	Northwest	86	30.9	6460	64.0	58.1	95.0	1,050	1,300	1,400	1,700	2,600	3,800	5,400	8,700	6,700
17	139	5016000	0	Swiftcurrent Creek at Sherburne	Northwest	80	64.6	6390	62.0	63.0	85.0	1,140	1,610	1,950	2,420	2,790	3,190	3,620	4,240	2,510
18	140	5017500	1	St. Mary River near Babb, Mont.	Northwest	64	276.0	6170	53.0	66.0	71.0	3,550	5,020	6,180	7,860	9,290	10,900	12,700	15,400	16,500
19	141	5020500	1	St. Mary River at International Boundary	Northwest	94	465.0	5790	39.0	57.0	59.0	3,710	6,380	8,910	13,200	17,400	22,700	29,300	40,600	40,000
20	143	6078500	1	North Fork Sun River near Augusta	Northwest	30	258.0	6150	61.0	87.8	42.0	3,000	4,000	4,700	6,000	7,600	12,000	19,000	33,000	51,100
21	145	6080000	1	Sun River near Augusta	Northwest	27	609.0	6330	70.0	85.5	42.0	6,300	10,000	13,500	18,000	24,000	32,000	42,000	60,000	59,700
22	149	6092000	1	Two Medicine River near Browning	Northwest	43	317.0	5600	36.9	42.0	36.0	3,400	5,000	6,500	9,200	13,000	20,000	32,000	60,000	100,000
23	150	6092500	1	Badger Creek near Browning	Northwest	23	133.0	6020	51.0	59.3	39.0	1,800	2,400	3,000	4,600	7,000	11,000	18,000	32,000	49,700
24	161	12356500	1	Bear Creek near Essex	Northwest	25	20.4	5770	32.2	74.4	47.0	400	630	830	1,250	1,700	2,400	3,400	5,600	1,840
25	162	12357000	1	Middle Fork Flathead River at Essex	Northwest	24	510.0	5900	46.0	87.0	52.0	9,500	13,000	15,000	19,500	24,000	30,000	36,000	49,000	75,300
26	163	12357300	1	Moccasin Creek near West Glacier	Northwest	17	2.4	5620	41.0	81.0	57.0	113	201	280	409	530	675	850	1,130	490
27	165	12358500	1	Middle Fork Flathead River near West Glacier	Northwest	55	1128.0	5800	44.0	84.7	59.0	20,000	26,000	30,000	35,000	41,000	49,000	61,000	85,000	140,000
28	166	12359000	1	South Fork Flathead River at Spotted Bear Ranger Station, near Hungry Horse	Northwest	18	958.0	6130	57.0	88.8	52.0	15,000	18,000	20,200	23,000	25,000	28,000	32,000	37,000	36,700
29	168	12359800	1	South Fork Flathead River above Twin Creek, near Hungry Horse	Northwest	31	1160.0	6090	56.9	89.2	52.0	19,000	24,000	26,200	30,000	32,000	36,000	41,000	50,000	50,900
30	169	12360000	1	Twin Creek near Hungry Horse	Northwest	11	47.0	5300	57.0	83.3	53.0	1,400	1,950	2,400	3,300	4,000	5,000	6,000	8,000	5,830
31	170	12361000	1	Sullivan Creek near Hungry Horse	Northwest	24	71.3	5510	38.0	80.0	35.0	1,900	2,400	2,700	3,100	3,500	4,100	5,000	7,000	5,020
32	172	12362500	0	South Fork Flathead River near Columbia Falls	Northwest Foothills	47	1663.0	5780	53.0	85.7	37.0	12,100	15,700	18,600	22,600	25,900	29,600	33,600	39,600	46,200

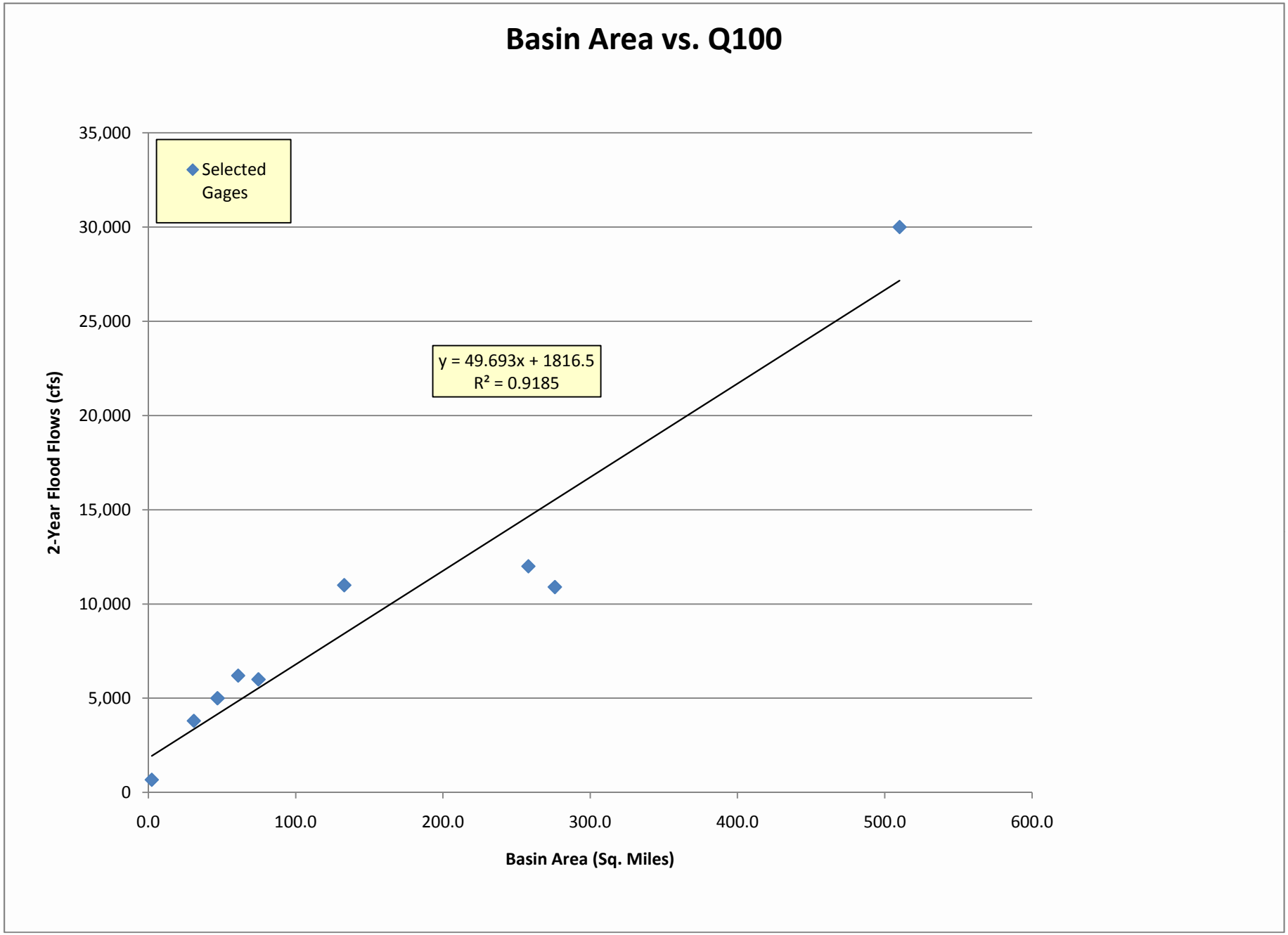
Regression Analysis														
Number of Gages	Station Number	Station Name	A	E	A	E6000	A	F	A	P	Q2	Q10	Q50	Q100
1	5010000	Belly River at International Boundary	74.8	6180	74.8	58.0	74.8	51.3	74.8	79.0	1,500	1,900	3,800	6,000
2	5011500	Waterton River near International Boundary	61.0	6060	61.0	56.0	61.0	53.9	61.0	84.0	2,120	2,700	4,000	6,200
3	5017500	St. Mary River near Babb, Mont.	276.0	6170	276.0	53.0	276.0	66.0	276.0	71.0	3,550	6,180	9,290	10,900
4	6092500	Badger Creek near Browning	133.0	6020	133.0	51.0	133.0	59.3	133.0	39.0	1,800	3,000	7,000	11,000
5	6078500	North Fork Sun River near Augusta	258.0	6150	258.0	61.0	258.0	87.8	258.0	42.0	3,000	4,700	7,600	12,000
6	12360000	Twin Creek near Hungry Horse	47.0	5300	47.0	57.0	47.0	83.3	47.0	53.0	1,400	2,400	4,000	5,000
7	5014500	Swiftcurrent Creek at Many Glacier	30.9	6460	30.9	64.0	30.9	58.1	30.9	95.0	1,050	1,400	2,600	3,800
8	12357000	Middle Fork Flathead River at Essex	510.0	5900	510.0	46.0	510.0	87.0	510.0	52.0	9,500	15,000	24,000	30,000
9	12357300	Moccasin Creek near West Glacier	2.4	5620	2.4	41.0	2.4	81.0	2.4	57.0	113	280	530	675

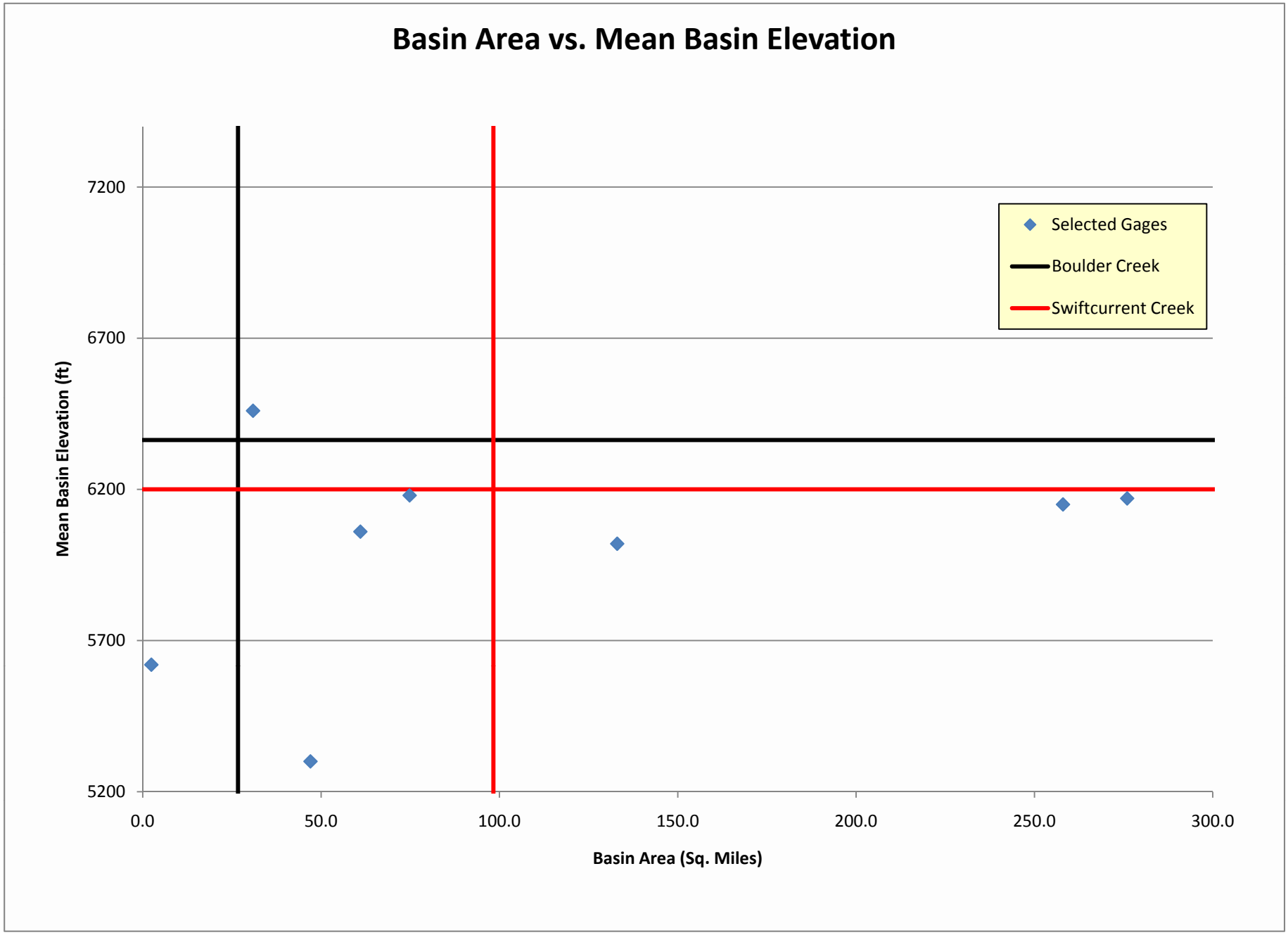
Log of Basin Characteristics														
Number of Gages	Station Number	Station Name	A	E/1000	A	E6000	A	F	A	P	Q2	Q10	Q50	Q100
1	5010000	Belly River at International Boundary	1.874	0.791	1.874	1.763	1.874	1.710	1.874	1.898	3.176	3.279	3.580	3.778
2	5011500	Waterton River near International Boundary	1.785	0.782	1.785	1.748	1.785	1.732	1.785	1.924	3.326	3.431	3.602	3.792
3	5017500	St. Mary River near Babb, Mont.	2.441	0.790	2.441	1.724	2.441	1.820	2.441	1.851	3.550	3.791	3.968	4.037
4	6092500	Badger Creek near Browning	2.124	0.780	2.124	1.708	2.124	1.773	2.124	1.591	3.255	3.477	3.845	4.041
5	6078500	North Fork Sun River near Augusta	2.412	0.789	2.412	1.785	2.412	1.943	2.412	1.623	3.477	3.672	3.881	4.079
6	12360000	Twin Creek near Hungry Horse	1.672	0.724	1.672	1.756	1.672	1.921	1.672	1.724	3.146	3.380	3.602	3.699
7	5014500	Swiftcurrent Creek at Many Glacier	1.490	0.810	1.490	1.806	1.490	1.764	1.490	1.978	3.021	3.146	3.415	3.580
8	12357000	Middle Fork Flathead River at Essex	2.708	0.771	2.708	1.663	2.708	1.940	2.708	1.716	3.978	4.176	4.380	4.477
9	12357300	Moccasin Creek near West Glacier	0.377	0.750	0.377	1.613	0.377	1.908	0.377	1.756	2.053	2.447	2.724	2.829

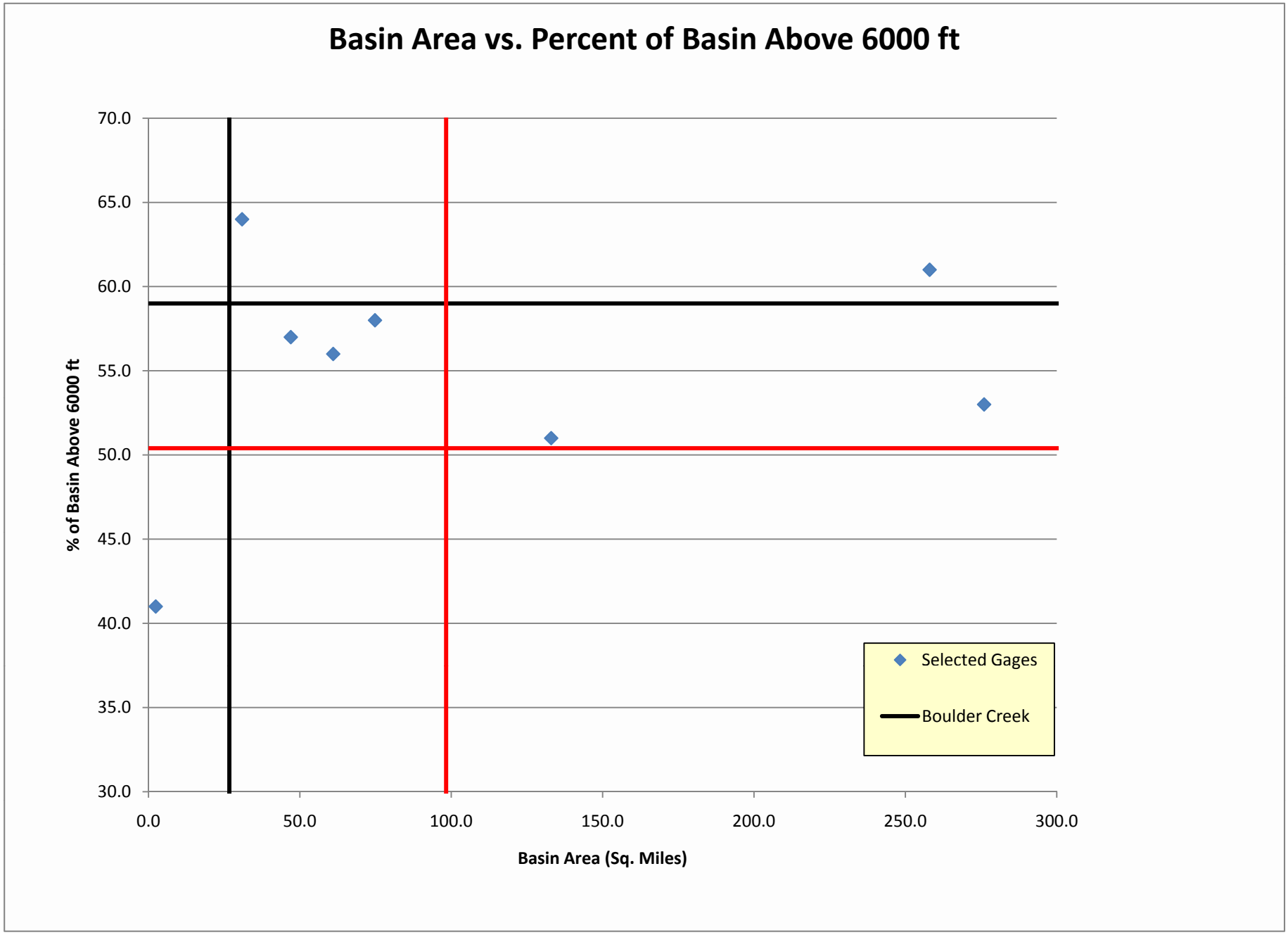

Basin Area vs. Q2
Selected Gages
y = 15.908x + 207.92
R² = 0.9058
2-Year Flood Flows (cfs)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Basin Area (Sq. Miles)

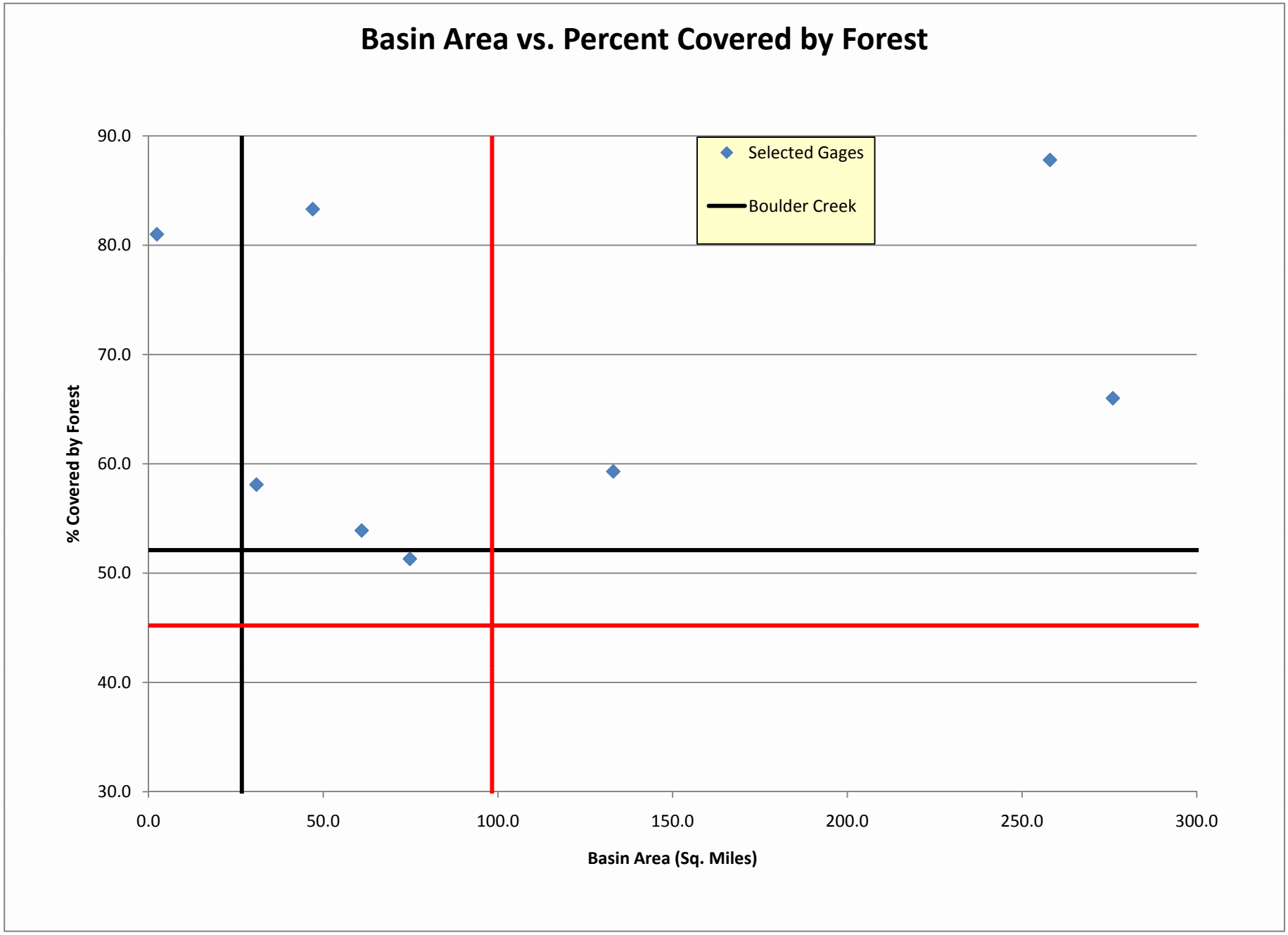

Basin Area vs. Q10
Selected Gages
y = 25.839x + 173.77
R² = 0.929
2-Year Flood Flows (cfs)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Basin Area (Sq. Miles)

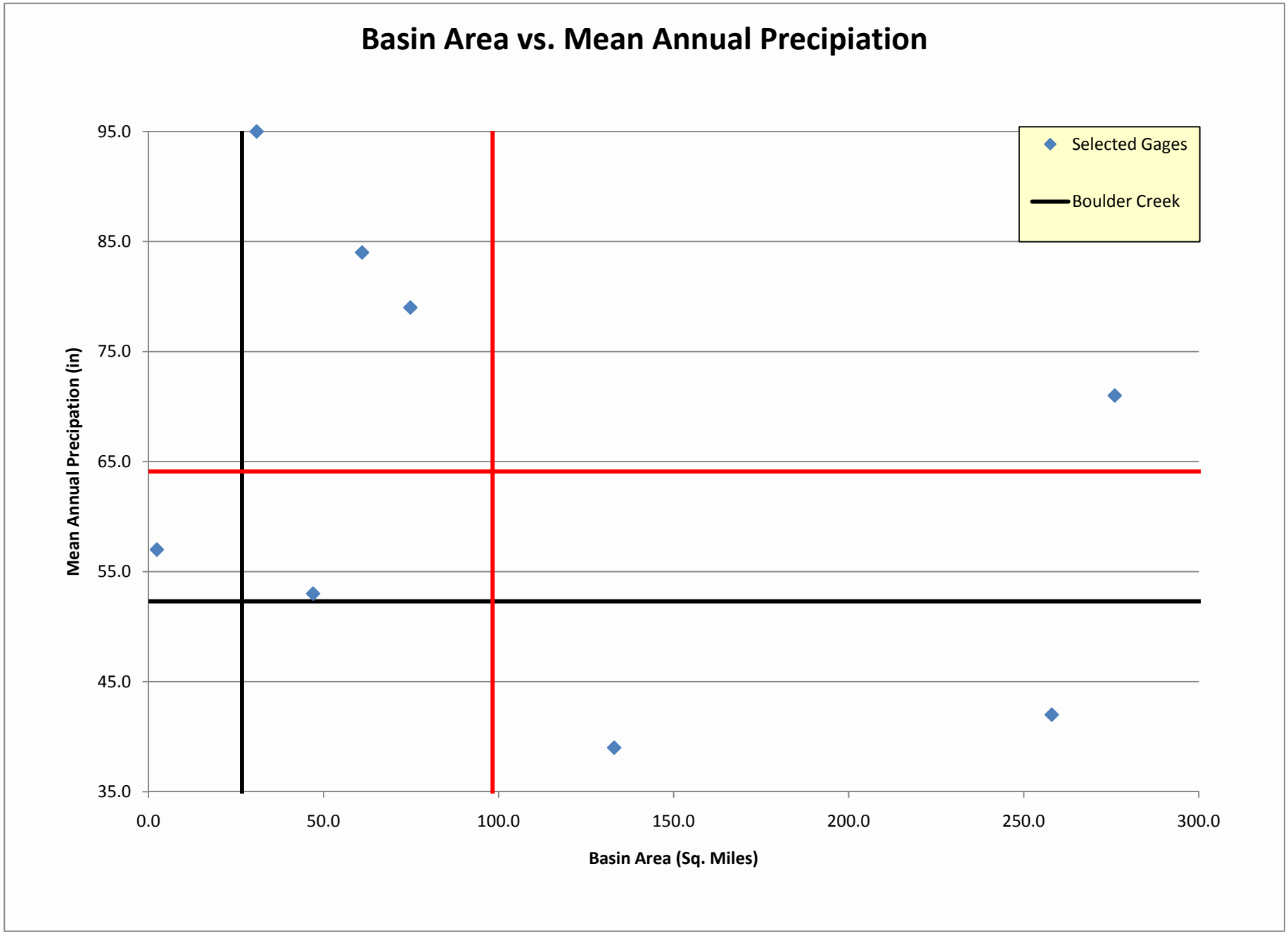

Basin Area vs. Q50
Selected Gages
y = 40.343x + 735.41
R² = 0.9212
2-Year Flood Flows (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Basin Area (Sq. Miles)


Basin Area vs. Q100
Selected Gages
y = 49.693x + 1816.5
R² = 0.9185
2-Year Flood Flows (cfs)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Basin Area (Sq. Miles)


Basin Area vs. Mean Basin Elevation
Mean Basin Elevation (ft)
7200
6700
6200
5700
5200
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Basin Area (Sq. Miles)
Selected Gages
Boulder Creek
Swiftcurrent Creek


Basin Area vs. Percent of Basin Above 6000 ft
% of Basin Above 6000 ft
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Basin Area (Sq. Miles)
Selected Gages
Boulder Creek


Basin Area vs. Percent Covered by Forest
Selected Gages
Boulder Creek
% Covered by Forest
90.0
80.0
70.0
60.0
50.0
40.0
30.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Basin Area (Sq. Miles)


Basin Area vs. Mean Annual Precipiation
Selected Gages
Boulder Creek
Mean Annual Precipation (in)
95.0
85.0
75.0
65.0
55.0
45.0
35.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Basin Area (Sq. Miles)

2-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.972479071
R Square	0.945715543
Adjusted R Squar	0.937960621
Standard Error	0.129737654
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.052651163	2.052651163	121.9503557	1.10836E-05
Residual	7	0.117823011	0.016831859		
Total	8	2.170474175			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.842834836	0.1320237	13.95836384	2.29205E-06	1.530648394	2.155021278	1.530648394	2.155021278
X Variable 1	0.734379262	0.066501106	11.0431135	1.10836E-05	0.577129134	0.89162939	0.577129134	0.89162939

10-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.972635565
R Square	0.946019942
Adjusted R Squar	0.938308505
Standard Error	0.118441567
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.720969889	1.720969889	122.6775186	1.08662E-05
Residual	7	0.098198833	0.014028405		
Total	8	1.819168722			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.160890234	0.12052857	17.92844828	4.14821E-07	1.875885454	2.445895014	1.875885454	2.445895014
X Variable 1	0.672433692	0.060710942	11.07598838	1.08662E-05	0.528875125	0.815992259	0.528875125	0.815992259

50-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.979919103
R Square	0.960241448
Adjusted R Squar	0.954561654
Standard Error	0.096660528
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.579596805	1.579596805	169.0627479	3.70483E-06
Residual	7	0.065402803	0.009343258		
Total	8	1.644999608			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.4579605	0.098363737	24.98848221	4.19307E-08	2.225367221	2.690553778	2.225367221	2.690553778
X Variable 1	0.644222595	0.049546387	13.00241316	3.70483E-06	0.527064007	0.761381184	0.527064007	0.761381184

100-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.984672869
R Square	0.969580659
Adjusted R Squar	0.965235039
Standard Error	0.084706429
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.600902657	1.600902657	223.1167528	1.44597E-06
Residual	7	0.050226254	0.007175179		
Total	8	1.65112891			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.596108284	0.086199001	30.11761456	1.14721E-08	2.392280037	2.799936532	2.392280037	2.799936532
X Variable 1	0.648552731	0.043418939	14.93709319	1.44597E-06	0.545883256	0.751222206	0.545883256	0.751222206

Regional Regression On Basin Area							
Flood Recurrence Interval	Regression Constant	Basin Area Exponent	R^2 Value	Standard Error	Equation	Estimated Boulder Creek Flows	Estimated Swiftcurrent Creek Flows
2-year	69.64	0.734	0.946	0.130	Q_2 = 69.64 A^0.734	777	2,024
10-year	144.84	0.672	0.946	0.118	Q_{10} = 144.84 A^0.672	1,319	3,168
50-year	287.05	0.644	0.960	0.097	Q_{50} = 287.05 A^0.644	2,382	5,516
100-year	394.56	0.649	0.970	0.085	Q_{100} = 394.56 A^0.649	3,321	7,734

2-year

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97296
R Square	0.946652
Adjusted R Squa	0.928869
Standard Error	0.138919
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.054684	1.027342	53.23462	0.000151828
Residual	6	0.11579	0.019298		
Total	8	2.170474			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	2.342521	1.546112	1.515104	0.180524	-1.440679448	6.125722	-1.44068	6.125722363
X Variable 1	0.742692	0.075674	9.814397	6.44E-05	0.557525191	0.927859	0.557525	0.927859164
X Variable 2	-0.66371	2.045011	-0.32455	0.75654	-5.667665659	4.340255	-5.66767	4.340255353

10-Year

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.980037
R Square	0.960472
Adjusted R Squa	0.947296
Standard Error	0.109474
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.747261	0.873631	72.89625	6.17594E-05
Residual	6	0.071907	0.011985		
Total	8	1.819169			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	3.957958	1.218406	3.248472	0.0175	0.976625722	6.939289	0.976626	6.939289317
X Variable 1	0.70233	0.059634	11.77728	2.26E-05	0.556410285	0.84825	0.55641	0.848250047
X Variable 2	-2.38694	1.61156	-1.48114	0.189075	-6.330286719	1.556403	-6.33029	1.556403385

50-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.985257
R Square	0.970731
Adjusted R Squa	0.960975
Standard Error	0.08958
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.596852	0.798426	99.49785	2.50738E-05
Residual	6	0.048147	0.008025		
Total	8	1.645			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	3.913825	0.996991	3.925638	0.007752	1.474276391	6.353374	1.474276	6.353373832
X Variable 1	0.668443	0.048797	13.69837	9.41E-06	0.54904017	0.787845	0.54904	0.787845297
X Variable 2	-1.93374	1.318699	-1.4664	0.1929	-5.160481612	1.292998	-5.16048	1.292998261

100-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.985628
R Square	0.971462
Adjusted R Squa	0.961949
Standard Error	0.088619
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.604009	0.802004	102.1225	2.32422E-05
Residual	6	0.04712	0.007853		
Total	8	1.651129			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	3.213791	0.986298	3.258437	0.017283	0.80040576	5.627177	0.800406	5.627176641
X Variable 1	0.658829	0.048274	13.64772	9.61E-06	0.540706649	0.776951	0.540707	0.776950677
X Variable 2	-0.82043	1.304556	-0.6289	0.55259	-4.012567196	2.371701	-4.01257	2.371701434

Flood Recurrence Interval	Regression Constant	Basin Area Exponent	Basin MBE Exponent	R^2 Value	Standard Error	Equation	Estimated Boulder Creek Flows	Estimated Swiftcurrent Creek Flows
2-year	220.05	0.743	-0.664	0.947	0.139	Q_2 = 220 A^0.743 E^-0.6637	739	1,979
10-year	9077.32	0.702	-2.387	0.960	0.109	Q_{10} = 9077 A^0.702 E^-2.3869	1,100	2,924
50-year	8200.21	0.668	-1.934	0.971	0.090	Q_{50} = 8200 A^0.668 E^-1.9337	2,057	5,170
100-year	1636.03	0.659	-0.820	0.971	0.089	Q_{100} = 1636 A^0.659 E^-0.8204	3,121	7,524

2-year

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.972635
R Square	0.946018
Adjusted R Squar	0.928025
Standard Error	0.139741
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	2.053309	1.026654	52.57455	0.000157
Residual	6	0.117166	0.019528		
Total	8	2.170474			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	1.580572	1.436358	1.100403	0.313334	-1.93407	5.095213	-1.934069	5.095212991
X Variable 1	0.730098	0.075334	9.691512	6.92E-05	0.545763	0.914433	0.545763	0.914432586
X Variable 2	0.156276	0.851684	0.18349	0.860457	-1.92772	2.24027	-1.927719	2.240270296

10-Year

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.97807
R Square	0.95662
Adjusted R Squar	0.942161
Standard Error	0.114684
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.740254	0.870127	66.15704	8.16E-05
Residual	6	0.078915	0.013152		
Total	8	1.819169			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	3.581254	1.178804	3.03804	0.02286	0.696825	6.465684	0.696825	6.465683525
X Variable 1	0.695622	0.061826	11.25136	2.95E-05	0.54434	0.846904	0.54434	0.846904021
X Variable 2	-0.84636	0.698968	-1.21087	0.271473	-2.55667	0.863955	-2.556671	0.863954793

50-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.986261
R Square	0.972712
Adjusted R Squar	0.963615
Standard Error	0.086496
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.60011	0.800055	106.9367	2.03E-05
Residual	6	0.044889	0.007482		
Total	8	1.645			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	3.922894	0.889068	4.412368	0.004508	1.747423	6.098364	1.747423	6.098363664
X Variable 1	0.668139	0.04663	14.32864	7.23E-06	0.55404	0.782237	0.55404	0.782237238
X Variable 2	-0.87292	0.52717	-1.65585	0.148831	-2.16285	0.417022	-2.162854	0.417022082

100-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.986034
R Square	0.972263
Adjusted R Squar	0.963017
Standard Error	0.087366
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.605332	0.802666	105.1591	2.13E-05
Residual	6	0.045797	0.007633		
Total	8	1.651129			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	3.276806	0.898012	3.648955	0.01072	1.079449	5.474162	1.079449	5.474162205
X Variable 1	0.659666	0.047099	14.00602	8.26E-06	0.544419	0.774912	0.544419	0.77491202
X Variable 2	-0.40561	0.532473	-0.76175	0.475078	-1.70853	0.897305	-1.708525	0.897305397

Flood Recurrence Interval	Regression Constant	Basin Area Exponent	Basin E6000 Exponent	R^2 Value	Standard Error	Equation	Estimated Boulder Creek Flows	Estimated Swiftcurrent Creek Flows
2-year	38.07	0.730	0.156	0.946	0.140	Q_2 = 38 A^0.73 E6000^0.156	792	2,002
10-year	3812.89	0.696	-0.846	0.957	0.115	Q_{10} = 3813 A^0.696 E6000^-0.846	1,188	3,361
50-year	8373.24	0.668	-0.873	0.973	0.086	Q_{50} = 8373 A^0.668 E6000^-0.873	2,139	5,863
100-year	1891.50	0.660	-0.406	0.972	0.087	Q_{100} = 1891 A^0.66 E6000^-0.406	3,159	7,956

2-year

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.972597
R Square	0.945946
Adjusted R Squa	0.927927
Standard Error	0.139835
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	2.053151	1.026575	52.49965	0.000158
Residual	6	0.117324	0.019554		
Total	8	2.170474			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	1.995897	0.968333	2.061168	0.084919	-0.37353	4.365323	-0.37353	4.365323205
X Variable 1	0.735048	0.071799	10.23755	5.07E-05	0.559362	0.910735	0.559362	0.910734651
X Variable 2	-0.08412	0.526392	-0.1598	0.87828	-1.37215	1.203916	-1.37215	1.203916334

10-Year

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.978317
R Square	0.957104
Adjusted R Squa	0.942806
Standard Error	0.114043
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.741134	0.870567	66.93689	7.89E-05
Residual	6	0.078035	0.013006		
Total	8	1.819169			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	1.188241	0.789725	1.504626	0.183123	-0.74415	3.120629	-0.74415	3.120628543
X Variable 1	0.668182	0.058556	11.41101	2.72E-05	0.524901	0.811463	0.524901	0.81146326
X Variable 2	0.534542	0.4293	1.245148	0.2595	-0.51592	1.585	-0.51592	1.585000484

50-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.982276
R Square	0.964866
Adjusted R Squa	0.953155
Standard Error	0.098145
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.587205	0.793602	82.3885	4.34E-05
Residual	6	0.057795	0.009632		
Total	8	1.645			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	1.860504	0.679635	2.737504	0.033848	0.197497	3.523511	0.197497	3.523511161
X Variable 1	0.641611	0.050393	12.73213	1.44E-05	0.518304	0.764918	0.518304	0.764918377
X Variable 2	0.328346	0.369454	0.888733	0.408361	-0.57568	1.232368	-0.57568	1.232367641

100-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.98469
R Square	0.969615
Adjusted R Squa	0.959486
Standard Error	0.091442
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.600959	0.800479	95.73163	2.81E-05
Residual	6	0.05017	0.008362		
Total	8	1.651129			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	2.544832	0.63322	4.018871	0.006968	0.995397	4.094266	0.995397	4.094266256
X Variable 1	0.648329	0.046952	13.80846	8.98E-06	0.533442	0.763215	0.533442	0.763214862
X Variable 2	0.02818	0.344223	0.081867	0.937416	-0.8141	0.870463	-0.8141	0.870463151

Flood Recurrence Interval	Regression Constant	Basin Area Exponent	Basin % Forest Exponent	R^2 Value	Standard Error	Equation	Estimated Boulder Creek Flows	Estimated Swiftcurrent Creek Flows
2-year	99.06	0.735	-0.084	0.946	0.140	Q_2 = 99 A^0.735 F^-0.084	794	2,096
10-year	15.43	0.668	0.535	0.957	0.114	Q_{10} = 15 A^0.668 F^0.535	1,146	2,537
50-year	72.53	0.642	0.328	0.965	0.098	Q_{50} = 73 A^0.642 F^0.328	2,185	4,813
100-year	350.62	0.648	0.028	0.970	0.091	Q_{100} = 351 A^0.648 F^0.028	3,297	7,644

2-year

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.980334
R Square	0.961055
Adjusted R Squa	0.948073
Standard Error	0.118694
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	2.085944	1.042972	74.0312	5.91E-05
Residual	6	0.08453	0.014088		
Total	8	2.170474			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	0.91998	0.612352	1.502372	0.183686	-0.57839	2.418351	-0.57839	2.418350804
X Variable 1	0.758399	0.062815	12.07358	1.96E-05	0.604697	0.912101	0.604697	0.912101348
X Variable 2	0.491876	0.319967	1.537268	0.175142	-0.29106	1.274808	-0.29106	1.274807886

10-Year

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.972809
R Square	0.946357
Adjusted R Squa	0.928476
Standard Error	0.127531
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.721584	0.860792	52.92559	0.000154
Residual	6	0.097585	0.016264		
Total	8	1.819169			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	2.035596	0.657943	3.093879	0.021282	0.425667	3.645524	0.425667	3.645523841
X Variable 1	0.675695	0.067491	10.01156	5.75E-05	0.510549	0.840841	0.510549	0.840840512
X Variable 2	0.066781	0.34379	0.19425	0.85239	-0.77444	0.908005	-0.77444	0.908004589

50-Year
SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.980406
R Square	0.961195
Adjusted R Squa	0.94826
Standard Error	0.103146
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.581166	0.790583	74.30991	5.84E-05
Residual	6	0.063834	0.010639		
Total	8	1.645			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	2.658289	0.532136	4.995511	0.002463	1.3562	3.960378	1.3562	3.960377683
X Variable 1	0.639008	0.054586	11.70641	2.34E-05	0.505441	0.772576	0.505441	0.772576133
X Variable 2	-0.10677	0.278053	-0.38401	0.714214	-0.78714	0.573597	-0.78714	0.57359668

100-Year
SUMMARY OUTPUT

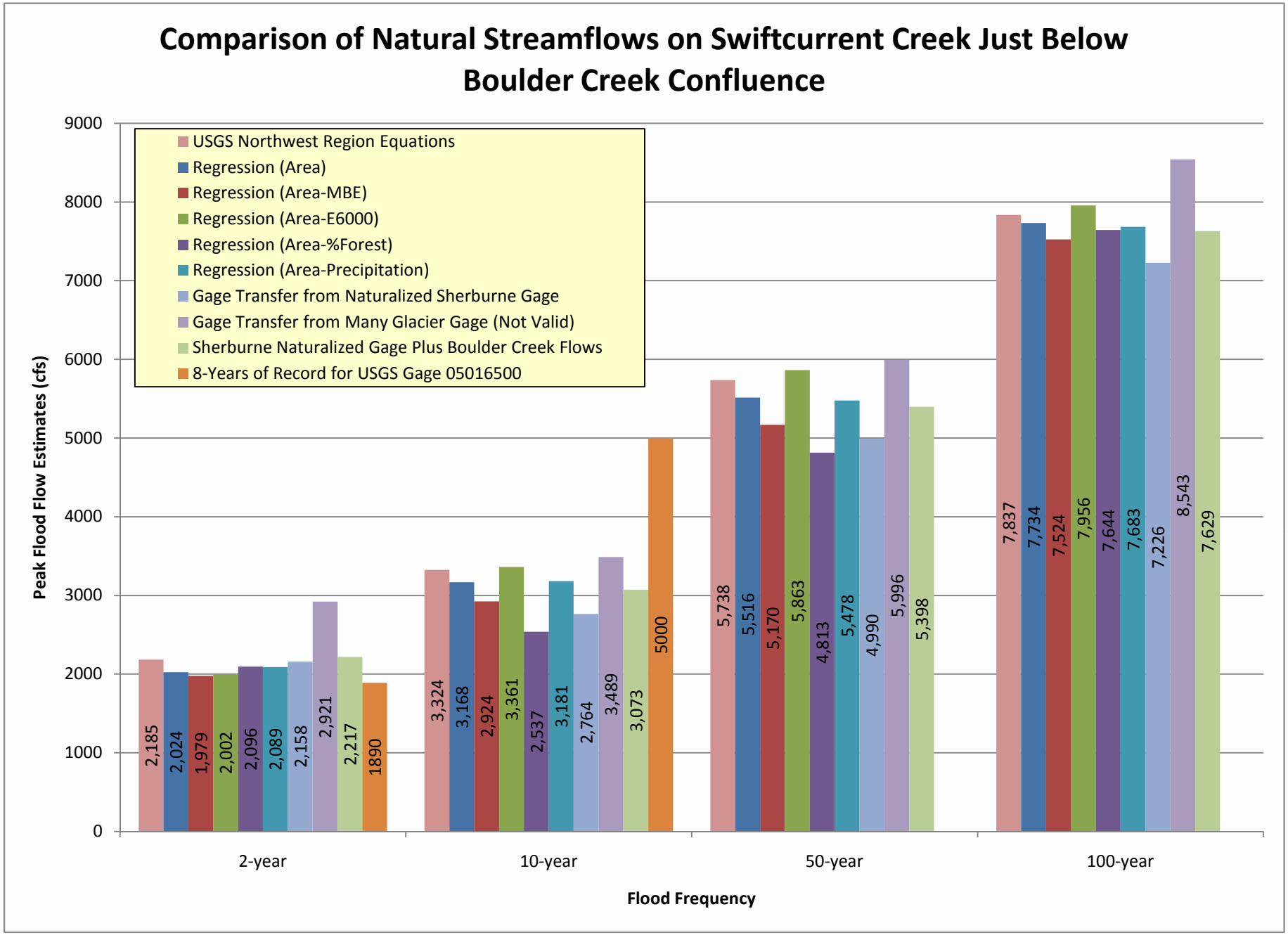
Regression Statistics	
Multiple R	0.985106
R Square	0.970434
Adjusted R Squa	0.960579
Standard Error	0.0902
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	1.602312	0.801156	98.46915	2.58E-05
Residual	6	0.048817	0.008136		
Total	8	1.651129			

	Coefficients	*andard Erro*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	2.785997	0.465351	5.986875	0.000976	1.647325	3.924669	1.647325	3.924669333
X Variable 1	0.64361	0.047735	13.48286	1.03E-05	0.526806	0.760415	0.526806	0.760414805
X Variable 2	-0.10121	0.243156	-0.41623	0.691718	-0.69619	0.493772	-0.69619	0.493772191

Flood Recurrence Interval	Regression Constant	Basin Area Exponent	Basin P Exponent	R^2 Value	Standard Error	Equation	Estimated Boulder Creek Flows	Estimated Swiftcurrent Creek Flows
2-year	8.32	0.758	0.492	0.961	0.119	Q_2 = 8.32 A^0.758 P^0.492	703	2,089
10-year	108.54	0.676	0.067	0.946	0.128	Q_{10} = 108.54 A^0.676 P^0.067	1,301	3,181
50-year	455.29	0.639	-0.107	0.961	0.103	Q_{50} = 455.29 A^0.639 P^-0.107	2,434	5,478
100-year	610.94	0.644	-0.101	0.970	0.090	Q_{100} = 610.94 A^0.644 P^-0.101	3,390	7,683


Comparison of Natural Streamflows on Swiftcurrent Creek Just Below Boulder Creek Confluence
USGS Northwest Region Equations
Regression (Area)
Regression (Area-MBE)
Regression (Area-E6000)
Regression (Area-%Forest)
Regression (Area-Precipitation)
Gage Transfer from Naturalized Sherburne Gage
Gage Transfer from Many Glacier Gage (Not Valid)
Sherburne Naturalized Gage Plus Boulder Creek Flows
8-Years of Record for USGS Gage 05016500
Peak Flood Flow Estimates (cfs)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2,185
2,024
1,979
2,002
2,096
2,089
2,158
2,921
2,217
1890
3,324
3,168
2,924
3,361
2,537
3,181
2,764
3,489
3,073
5000
5,738
5,516
5,170
5,863
4,813
5,478
4,990
5,996
5,398
7,837
7,734
7,524
7,956
7,644
7,683
7,226
8,543
7,629
2-year
10-year
50-year
100-year
Flood Frequency

USGS 05016000 Swiftcurrent Creek at Sherburne, MT												
YEAR	Monthly mean in cfs (Calculation Period: 1912-07-01 -> 2004-10-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1912							374	175	120	93	92	62
1913					516	1074	430	274	116	133	91	62
1914				291	599	525	334	162	126		282	
1915				244	403	473	316	203	173	175	127	63
1916	33	71	120	142	360	1020	687	257	210	50	86	31
1917	20	21	17	49	510	863	489	155	103	96	96	40
1918	157	0	91	221	425	725	244	171	106	101	61	42
1919	29	25	16	157	515	72	313	410	140	40	41	49
1920	40	33	22	69	490	702	415	380	221	187	99	84
1921	39	67	74	188	628	638	185	167	135	574	36	147
1922	39	24	21	59	408	670	159	389	232	84	57	42
1923	45	31	25	134	543	271	71	391	590	102		
1924					269	111	718	442	139	85		
1925					429	752	312	536	458	376		
1926				295	269	334	363	110	116	11		
1927				92	568	791	492	430	323	287		
1928					870	388	521	371	96	368		
1929				291	345	462	301	463	257	86		
1930					150	536	374	485	185	41		
1931				116	274	242	558	562	139	109		
1932					200	363	435	588	271	137		
1933					813	445	375	634	321	149		
1934				136	638	591	571	644	98	54		
1935					325	196	517	666	272	30		
1936					130	466	760	464	59	40	29	
1937					242	240	516	756	154	58		
1938				45	317	464	470	740	246	86		
1939				530	108	335	606	476	10	27	208	
1940				19	177	303	687	291	7	4	215	
1941				119	212	139	630	236	132	0		
1942				204	189	555	456	542	472	175	128	
1943				1	288	789	340	580	572	51		
1944				183	299	77	402	304	35	0		
1945				133	240	433	419	581	436	80		
1946				500	274	214	406	571	503	13		
1947			125	236	388	392	335	567	473	27		
1948				57	500	831	262	507	523	44		
1949				96	207	262	467	543	275	0		
1950			116	151	600	864	319	455	497	477	368	
1951			4	320	674	509	422	505	689	438	1	
1952		1	1	1	221	306	396	494	528	62	1	
1953			2	75	540	670	442	532	563	66	0	
1954			0	215	654	339	474	520	653	414	41	
1955			0		54	679	323	570	582	232	1	
1956			2	98	741	377	134	518	556	230		
1957			0	158	359	460	381	576	268	0		
1958			0	63	215	492	477	624	278	0		
1959			36	334	681	443	185	602	732	388	163	0
1960				53	364	286	377	678	399	0		
1961			8	464	203	217	479	662	379	107		
1962			0	456	376	68	487	521	63	0		
1963			14	644	382	18	402	677	405	17		
1964				322	293	602	276	555	508	278		
1965				3	432	566	223	599	547	233	86	0
1966		0	4	4	464	187	391	670	477	37		
1967			0	1	878	305	186	604	536	0		
1968			0	477	373	26	412	673	688	8	0	
1969			0	49	246	533	503	686	328	54		
1970			0	281	42	632	452	700	285	0	0	0
1971		0	0	1	599	566	357	512	769	106	0	
1972			1	1	1033	184	455	516	699	247	1	
1973		2	2	65	259	263	579	578	0	16		0
1974		2	39	515	331	460	546	645	578	0	0	0
1975		1	1	7	34	973	556	568	792	130		0
1976		0	0	68	526	311	381	617	727	95	0	

1977		0	0	59	445	463	179	158	111	1	0	
1978		0	0	21	432	423	533	594	608	207	117	2
1979		1	3	5	464	137	470	598	179	0	0	
1980			129	221	185	107	572	656	318	7		
1981		6	407	343	91	154	472	599	578	5		
1982				39	704	318	970					
1983			305	297	200	196	480	547				
1984			377	197	263	216	414	394	28	0		
1985			98	598	310	67	475	635	328	2		
1986			4	266	387	377	532	583	43	38		
1987			344	167	11	360	312	551	236	34		
1988			276	589	359	268	494	76	1	8		
1989			186	485	335	44	283	522	523	423		
1990			26	185	317	375	389	495	553	171		
1991		19	141	565	347	516	519	524	537	0		
1992		5	323	245	216	145	378	352	0	26		
1993			14	302	241	301	151	452	401	88		
1994			0	95	297	397	482	575	333	1		
1995			40	178	176	588	418	558	335	14		
1996			94	257	217	583	412	443	605	36		
1997			36	196	575	553	330	482	546	109	90	
1998			145	421	31	259	419	552	503	56		
1999			1	301	313	66	306	505	414	87	496	172
2000			155	372	327	144	373	512	213	48		
2001			1	175	335	166	511	175	39	11	5	
2002			69	346	306	468	446	540	574	128		
2003			3	278	222	99	545	539	143	78		
2004			13	444	218	217	155	596	395	1		

Average Post-Dam	41	10	67	215	359	377	421	519	361	101	79	36

Average Pre-Dam	53	36	56	170	494	677	379	235	145	161	101	65

USGS 05016000 Swiftcurrent Creek at Sherburne, MT												
YEAR	Monthly Mean Volume (Acre Feet) (Calculation Period: 1912-07-01 -> 2004-10-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1912							22,984	10,736	7,158	5,743	5,474	3,812
1913					31,728	63,907	26,427	16,854	6,908	8,184	5,439	3,794
1914				17,292	36,837	31,240	20,531	9,930	7,474		16,780	
1915				14,543	24,749	28,134	19,412	12,482	10,306	10,742	7,581	3,874
1916	2,029	3,926	7,360	8,467	22,129	60,694	42,236	15,827	12,502	3,074	5,094	1,931
1917	1,211	1,188	1,033	2,928	31,359	51,346	30,092	9,512	6,135	5,909	5,718	2,472
1918	9,635	0	5,583	13,139	26,120	43,123	15,021	10,508	6,296	6,180	3,636	2,582
1919	1,765	1,372	953	9,348	31,678	4,302	19,252	25,222	8,319	2,429	2,458	2,994
1920	2,484	1,822	1,371	4,100	30,098	41,742	25,542	23,378	13,127	11,492	5,915	5,190
1921	2,416	3,693	4,519	11,169	38,620	37,970	11,344	10,293	8,033	35,318	2,166	9,045
1922	2,380	1,350	1,273	3,505	25,068	39,892	9,783	23,906	13,817	5,159	3,374	2,564
1923	2,767	1,727	1,543	7,985	33,375	16,126	4,353	24,054	35,131	6,266		
1924					16,534	6,611	44,148	27,171	8,289	5,208		
1925					26,378	44,747	19,153	32,939	27,253	23,107		
1926				17,548	16,546	19,874	22,338	6,776	6,885	670		
1927				5,451	34,900	47,056	30,221	26,434	19,226	17,641		
1928					53,494	23,082	32,004	22,781	5,712	22,652		
1929				17,328	21,182	27,473	18,495	28,450	15,304	5,300		
1930					9,192	31,888	22,966	29,821	11,014	2,509		
1931				6,897	16,817	14,394	34,329	34,568	8,295	6,696		
1932					12,298	21,594	26,766	36,155	16,114	8,412		
1933					49,959	26,473	23,052	38,983	19,071	9,180		
1934				8,110	39,248	35,155	35,128	39,598	5,843	3,290		
1935					19,983	11,663	31,777	40,975	16,161	1,857		
1936					7,981	27,717	46,731	28,549	3,511	2,484	1,738	
1937					14,886	14,269	31,734	46,503	9,158	3,591		
1938				2,654	19,492	27,628	28,905	45,470	14,614	5,313		
1939				31,525	6,647	19,922	37,243	29,256	613	1,654	12,347	
1940				1,131	10,859	18,054	42,254	17,905	440	242	12,764	
1941				7,081	13,017	8,277	38,713	14,536	7,837	7		
1942				12,121	11,627	33,019	28,008	33,308	28,056	10,736	7,617	
1943				61	17,678	46,925	20,912	35,687	34,042	3,124		
1944				10,871	18,379	4,582	24,730	18,668	2,106	12		
1945				7,890	14,782	25,741	25,776	35,700	25,938	4,944		
1946				29,734	16,854	12,710	24,989	35,079	29,907	769		
1947			7,655	14,031	23,876	23,296	20,611	34,851	28,122	1,672		
1948				3,392	30,744	49,454	16,128	31,156	31,127	2,687		
1949				5,712	12,728	15,584	28,733	33,412	16,370	9		
1950			7,139	8,997	36,868	51,382	19,639	27,995	29,562	29,330	21,868	
1951			246	19,041	41,436	30,276	25,960	31,051	40,980	26,950	83	
1952		56	49	77	13,558	18,214	24,361	30,375	31,388	3,788	39	
1953			92	4,463	33,203	39,886	27,178	32,718	33,483	4,058	28	
1954			0	12,793	40,182	20,184	29,170	31,974	38,856	25,456	2,422	
1955			6		3,308	40,380	19,873	35,054	34,649	14,241	76	
1956			98	5,855	45,568	22,433	8,264	31,863	33,108	14,111		
1957			25	9,378	22,056	27,360	23,421	35,423	15,923	5		
1958			19	3,731	13,226	29,246	29,336	38,374	16,512	4		
1959			2,201	19,857	41,867	26,372	11,344	36,997	43,569	23,876	9,669	6
1960				3,136	22,351	17,030	23,169	41,707	23,766	6		
1961			461	27,580	12,494	12,918	29,453	40,723	22,570	6,555		
1962			15	27,116	23,089	4,070	29,926	32,041	3,755	12		
1963			867	38,291	23,513	1,065	24,700	41,633	24,123	1,039		
1964				19,154	18,040	35,845	16,977	34,138	30,234	17,100		
1965				180	26,569	33,679	13,730	36,806	32,573	14,308	5,100	3
1966		7	218	230	28,549	11,133	24,048	41,209	28,354	2,250		
1967			24	32	53,980	18,125	11,418	37,151	31,912	13		
1968			21	28,395	22,923	1,571	25,321	41,406	40,909	501	6	
1969			5	2,886	15,120	31,692	30,910	42,156	19,505	3,296		
1970			6	16,733	2,558	37,619	27,774	43,066	16,941	13	5	12
1971		17	20	62	36,831	33,691	21,970	31,506	45,735	6,493	6	
1972			56	57	63,517	10,925	27,971	31,728	41,570	15,194	77	
1973		108	108	3,880	15,950	15,620	35,571	35,552	20	990		6
1974		114	2,367	30,639	20,322	27,384	33,560	39,641	34,370	1	1	18
1975		56	43	415	2,097	57,898	34,156	34,900	47,103	7,993		15
1976		23	30	4,052	32,324	18,482	23,445	37,907	43,260	5,811	4	
1977		5	5	3,523	27,368	27,527	11,000	9,733	6,623	34	14	
1978		4	15	1,220	26,538	25,164	32,742	36,536	36,196	12,709	6,962	123
1979		67	184	312	28,518	8,128	28,875	36,739	10,639	2	1	
1980			7,901	13,133	11,363	6,349	35,165	40,342	18,928	414		
1981		349	25,044	20,434	5,602	9,140	28,998	36,856	34,393	283		
1982				2,327	43,293	18,928	59,655					
1983			18,741	17,667	12,298	11,651	29,520	33,621				
1984			23,199	11,740	16,196	12,877	25,431	24,245	1,684	7		
1985			6,013	35,560	19,030	3,993	29,213	39,026	19,488	117		
1986			230	15,828	23,802	22,445	32,718	35,823	2,571	2,355		
1987			21,152	9,961	676	21,416	19,190	33,874	14,013	2,072		
1988			16,995	35,048	22,049	15,935	30,363	4,679	37	464		
1989			11,431	28,871	20,586	2,612	17,370	32,097	31,091	26,028		

1990			1,593	10,996	19,492	22,320	23,888	30,430	32,918	10,521		
1991		1,072	8,639	33,626	21,305	30,698	31,918	32,189	31,924	16		
1992		274	19,860	14,561	13,306	8,610	23,236	21,650	10	1,574		
1993			885	17,994	14,812	17,929	9,303	27,762	23,855	5,417		
1994			15	5,677	18,256	23,611	29,619	35,380	19,815	48		
1995			2,484	10,604	10,803	34,982	25,714	34,335	19,928	836		
1996			5,755	15,310	13,361	34,661	25,345	27,227	35,994	2,226		
1997			2,195	11,675	35,343	32,888	20,316	29,643	32,501	6,721	5,326	
1998			8,897	25,075	1,882	15,429	25,733	33,960	29,937	3,425		
1999			73	17,929	19,215	3,927	18,840	31,064	24,623	5,325	29,484	10,582
2000			9,543	22,118	20,076	8,580	22,935	31,469	12,645	2,927		
2001			52	10,395	20,580	9,872	31,432	10,779	2,333	658	292	
2002			4,236	20,571	18,803	27,830	27,411	33,222	34,138	7,877		
2003			162	16,548	13,644	5,897	33,498	33,166	8,533	4,821		
2004			775	26,432	13,429	12,924	9,500	36,653	23,516	61		
Total	24,687	17,229	241,486	1,016,174	2,090,966	2,206,467	2,394,389	2,785,026	1,839,273	564,589	179,562	49,023
Average	3,086	820	4,025	12,545	22,728	23,983	25,746	30,272	20,212	6,273	5,130	2,724

Contents in Sherburne Lake at the End of Each Month

YEAR	(Acre Feet)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1925	2,407	3,895	5,580	22,902	49,900	52,520	57,060	35,940	18,300	3,505	3,700	775
1926	5,032	5,860	7,815	14,630	16,000	12,060	9,962	7,890	5,790	9,701	1,090	3,830
1927	26,900	27,890	28,880	33,940	30,850	47,500	49,900	38,700	38,830	24,140	24,800	23,150
1928	26,900	26,900	26,900	29,100	34,780	50,200	50,050	38,440	37,040	36,800	25,800	23,700
1929	28,550	29,340	30,060	30,850	43,720	47,050	45,500	24,800	12,930	29,100	28,440	27,780
1930	18,880	22,100	25,400	28,770	50,350	52,360	46,340	24,690	17,800	11,580	12,300	15,530
1931	23,040	23,700	24,900	25,000	41,950	53,150	32,120	7,006	4,693	20,100	22,000	22,000
1932	8,416	9,334	10,290	11,260	37,660	53,150	44,000	17,700	5,372	5,580	6,572	7,444
1933	7,890	8,492	9,100	9,724	10,405	45,612	49,120	22,580	12,204	6,000	6,572	7,225
1934	20,200	20,200	20,200	39,805	53,195	53,015	34,492	3,353	910	20,380	20,300	20,300
1935	23,040	22,500	18,400	18,200	27,945	51,832	42,275	11,756	1,380	2,702	19,800	22,300
1936	6,572	7,152	7,740	31,442	53,945	56,852	23,568	910	0	3,616	4,492	5,884
1937	816	1,648	2,000	6,320	22,798	33,667	44,540	5,853	820	0	219	676
1938	8,796	10,372	11,820	24,635	47,500	60,080	49,540	11,636	2,230	2,348	820	4,559
1939	3,217	4,653	6,860	13,164	43,104	45,640	24,338	2,236	6,035	2,372	2,254	2,907
1940	9,680	11,237	13,700	21,000	42,041	47,020	15,422	1,928	9,256	7,386	3,192	7,572
1941	11,454	12,622	14,510	16,953	26,482	38,193	11,724	1,884	6,014	14,540	6,860	9,501
1942	35,589	37,184	38,830	40,156	56,900	60,539	55,572	31,224	10,511	16,220	21,410	33,073
1943	12,813	14,567	16,630	36,296	48,295	49,090	59,213	32,288	2,613	3,453	6,608	10,552
1944	9,913	10,356	12,408	8,347	13,240	28,671	13,011	2,131	6,529	4,298	6,759	8,652
1945	19,447	21,310	23,040	18,580	42,249	58,975	51,280	21,120	3,118	11,452	14,765	17,655
1946	18,350	20,300	24,250	10,676	34,372	58,941	54,320	26,966	3,687	4,445	13,896	16,899
1947	22,080	24,459	23,117	21,580	37,946	50,065	50,020	24,657	4,896	11,380	16,760	19,700
1948	32,776	34,252	35,849	35,420	48,100	54,305	54,820	32,644	5,243	23,535	24,261	30,894
1949	9,521	11,500	13,173	24,140	48,835	59,757	43,776	16,980	9,529	5,531	7,320	8,213
1950	33,928	36,272	37,907	34,084	30,630	41,326	59,825	45,365	21,410	15,575	25,290	31,202
1951	23,491	27,901	30,806	39,948	41,612	50,290	58,924	40,221	16,020	11,876	9,896	19,051
1952	16,971	18,450	19,630	28,539	46,900	58,278	51,976	32,180	6,234	6,875	11,316	14,441
1953	13,173	16,845	19,330	25,250	29,760	50,050	54,020	32,776	5,440	5,018	6,659	7,665
1954	15,970	18,330	21,410	14,135	20,340	47,350	59,247	43,958	16,150	5,066	10,126	13,020
1955	16,980	18,420	19,990	23,227	40,728	49,105	58,244	33,293	3,635	3,056	10,828	14,846
1956	19,042	20,680	22,842	25,150	23,766	45,035	61,015	39,818	12,930	4,345	4,896	16,350
1957	16,300	18,808	21,080	17,673	46,536	55,252	45,275	16,550	4,479	8,265	12,408	15,305
1958	18,430	21,080	23,689	26,614	57,972	62,060	47,020	16,360	8,198	9,946	14,504	16,836
1959	34,420	37,016	36,956	29,292	18,690	45,976	60,692	34,264	10,192	15,800	20,300	28,605
1960	15,431	17,160	21,430	28,770	31,460	57,236	53,735	21,470	3,947	2,975	8,788	13,216
1961	15,710	19,411	22,080	2,507	30,322	64,993	52,296	19,840	2,378	7,561	10,536	13,232
1962	15,359	18,120	19,940	8,183	13,784	41,339	26,284	3,505	5,881	7,320	10,980	13,360
1963	30,288	36,272	38,466	8,500	11,900	57,700	57,300	22,200	3,505	15,503	21,300	27,769
1964	15,305	16,998	18,500	2,301	15,503	54,095	59,995	32,996	11,804	6,601	10,996	13,496
1965	13,848	16,280	18,790	29,056	35,576	52,888	62,808	36,584	12,196	6,630	8,401	11,468
1966	11,324	12,939	15,170	25,750	33,007	61,852	58,907	25,811	2,186	5,304	5,594	8,857
1967	16,917	19,730	21,490	24,870	10,454	45,440	60,947	32,156	3,279	6,049	10,593	14,090
1968	24,624	28,066	33,337	10,626	21,070	60,301	55,620	25,811	3,099	9,009	16,989	20,190
1969	25,460	26,900	28,451	39,493	56,548	64,721	53,030	17,646	2,655	12,858	18,844	22,220
1970	16,170	17,800	19,483	4,505	43,286	64,517	52,616	17,304	5,846	7,488	11,876	14,090
1971	18,620	21,960	24,151	34,252	43,580	57,989	66,030	47,620	7,488	9,638	12,300	15,215
1972	15,980	18,380	27,868	36,644	18,090	62,140	64,772	47,710	14,423	7,079	11,508	13,976
1973	12,327	13,776	15,413	16,510	30,366	52,072	31,279	3,544	8,454	4,747	7,349	9,771
1974	35,381	37,172	54,320	19,582	30,927	65,384	64,500	36,704	7,913	11,972	23,073	27,065
1975	16,917	18,300	19,591	21,420	44,525	61,100	64,653	42,838	5,059	10,175	13,256	15,215
1976	30,476	33,040	34,684	40,975	50,005	59,672	63,924	43,398	8,720	6,817	15,910	25,921
1977	12,480	13,712	15,197	20,270	13,936	5,993	5,503	6,133	10,314	6,356	9,100	11,060
1978	25,770	27,175	30,228	38,934	46,060	65,775	61,032	38,245	14,495	14,891	19,564	23,678
1979	9,568	10,772	13,912	19,096	28,275	54,804	40,754	11,236	4,787	6,084	6,680	8,659
1980	14,672	16,446	10,241	14,826	43,219	65,958	44,000	12,856	6,084	7,364	8,926	12,712
1981	33,065	36,176	14,708	5,553	40,352	65,925	59,178	31,872	2,644	10,803	18,751	27,807
1982	14,632	18,126	20,790	22,805	7,983	39,503	6,695	15,976	21,382	7,367	9,940	12,609
1983	34,161	35,767	20,244	8,808	22,582	40,682	34,838	8,330	13,327	25,621	28,807	31,453
1984	34,932	35,190	13,824	10,228	17,790	40,909	34,010	16,800	23,795	16,119	24,125	26,472
1985	38,347	39,321	34,580	11,796	28,850	58,238	42,668	12,424	7,583	30,362	34,920	37,019
1986	38,408	43,647	53,753	51,895	60,017	68,371	50,067	20,496	25,085	21,979	32,859	35,341
1987	42,735	44,144	28,379	34,441	67,803	67,769	67,717	45,013	35,777	31,398	38,129	41,084
1988	40,417	42,058	28,018	9,709	18,947	27,844	6,773	6,639	9,670	35,200	36,120	38,905
1989	31,443	32,985	23,323	8,570	19,328	61,834	65,064	46,576	25,687	19,943	26,378	29,115
1990	37,000	39,760	40,769	45,515	52,027	67,015	67,135	47,357	18,795	6,744	26,624	33,077

1991	44,795	46,590	40,243	17,383	41,122	66,812	66,406	45,967	18,483	21,949	37,084	41,607
1992	28,215	29,258	12,819	10,417	21,739	34,000	22,190	5,927	15,347	20,986	24,354	26,656
1993	29,480	30,563	32,481	21,460	38,420	45,706	58,269	41,993	26,989	21,879	25,507	27,681
1994	32,745	34,290	39,638	48,995	62,919	67,597	52,129	23,262	5,981	26,037	28,565	30,709
1995	18,539	24,053	28,499	23,631	41,479	64,041	61,393	38,614	21,909	8,870	12,626	15,356
1996	33,410	39,747	39,136	38,699	51,792	66,542	64,849	48,031	17,041	36,120	30,957	29,981
1997	29,204	31,500	34,545	32,355	40,169	61,472	65,515	48,384	25,318	19,866	23,436	26,035
1998	30,934	32,401	25,825	11,374	46,646	67,238	58,839	32,630	6,702	27,920	27,097	28,675
1999	15,410	17,383	20,888	13,412	20,195	58,654	67,529	51,064	31,784	5,661	8,855	12,491
2000	24,897	27,065	19,914	10,917	19,462	44,617	37,539	12,996	5,975	37,443	28,204	21,969
2001	13,532	14,440	15,750	10,749	17,494	33,031	11,935	5,265	5,142	8,750	10,861	12,357
2002	19,709	22,589	21,687	11,250	26,171	64,339	66,105	40,873	11,436	6,999	12,279	15,966
2003	13,587	15,817	20,984	19,239	33,278	59,848	40,522	13,475	7,846	6,282	8,880	11,347
2004	16,487	18,151	21,786	10,179	24,277	41,636	51,411	30,734	18,631	8,154	11,122	13,741
2005	45,139	48,567	49,678	29,716	35,266	60,940	47,412	17,156	12,180	25,523	30,375	36,423
2006	43,628	46,320	26,699	17,745	35,832	66,473	54,272	26,372	7,652	28,522	34,670	38,484
2007	41,361	42,863	33,037	18,522	36,653	54,398	32,825	4,997	7,025	10,258	35,820	39,309
2008	23,059	24,983	25,776	8,434	32,707	66,078	61,772	38,421	35,249	13,556	17,641	21,103
2009	48,036	49,258	46,844	31,668	39,232	61,589	-----	-----	-----	39,476	43,823	46,161

Contents in Sherburne Lake at the Beginning of Each Month

YEAR	(Acre Feet)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1925		2,407	3,895	5,580	22,902	49,900	52,520	57,060	35,940	18,300	3,505	3,700
1926	775	5,032	5,860	7,815	14,630	16,000	12,060	9,962	7,890	5,790	9,701	1,090
1927	3,830	26,900	27,890	28,880	33,940	30,850	47,500	49,900	38,700	38,830	24,140	24,800
1928	23,150	26,900	26,900	26,900	29,100	34,780	50,200	50,050	38,440	37,040	36,800	25,800
1929	23,700	28,550	29,340	30,060	30,850	43,720	47,050	45,500	24,800	12,930	29,100	28,440
1930	27,780	18,880	22,100	25,400	28,770	50,350	52,360	46,340	24,690	17,800	11,580	12,300
1931	15,530	23,040	23,700	24,900	25,000	41,950	53,150	32,120	7,006	4,693	20,100	22,000
1932	22,000	8,416	9,334	10,290	11,260	37,660	53,150	44,000	17,700	5,372	5,580	6,572
1933	7,444	7,890	8,492	9,100	9,724	10,405	45,612	49,120	22,580	12,204	6,000	6,572
1934	7,225	20,200	20,200	20,200	39,805	53,195	53,015	34,492	3,353	910	20,380	20,300
1935	20,300	23,040	22,500	18,400	18,200	27,945	51,832	42,275	11,756	1,380	2,702	19,800
1936	22,300	6,572	7,152	7,740	31,442	53,945	56,852	23,568	910	0	3,616	4,492
1937	5,884	816	1,648	2,000	6,320	22,798	33,667	44,540	5,853	820	0	219
1938	676	8,796	10,372	11,820	24,635	47,500	60,080	49,540	11,636	2,230	2,348	820
1939	4,559	3,217	4,653	6,860	13,164	43,104	45,640	24,338	2,236	6,035	2,372	2,254
1940	2,907	9,680	11,237	13,700	21,000	42,041	47,020	15,422	1,928	9,256	7,386	3,192
1941	7,572	11,454	12,622	14,510	16,953	26,482	38,193	11,724	1,884	6,014	14,540	6,860
1942	9,501	35,589	37,184	38,830	40,156	56,900	60,539	55,572	31,224	10,511	16,220	21,410
1943	33,073	12,813	14,567	16,630	36,296	48,295	49,090	59,213	32,288	2,613	3,453	6,608
1944	10,552	9,913	10,356	12,408	8,347	13,240	28,671	13,011	2,131	6,529	4,298	6,759
1945	8,652	19,447	21,310	23,040	18,580	42,249	58,975	51,280	21,120	3,118	11,452	14,765
1946	17,655	18,350	20,300	24,250	10,676	34,372	58,941	54,320	26,966	3,687	4,445	13,896
1947	16,899	22,080	24,459	23,117	21,580	37,946	50,065	50,020	24,657	4,896	11,380	16,760
1948	19,700	32,776	34,252	35,849	35,420	48,100	54,305	54,820	32,644	5,243	23,535	24,261
1949	30,894	9,521	11,500	13,173	24,140	48,835	59,757	43,776	16,980	9,529	5,531	7,320
1950	8,213	33,928	36,272	37,907	34,084	30,630	41,326	59,825	45,365	21,410	15,575	25,290
1951	31,202	23,491	27,901	30,806	39,948	41,612	50,290	58,924	40,221	16,020	11,876	9,896
1952	19,051	16,971	18,450	19,630	28,539	46,900	58,278	51,976	32,180	6,234	6,875	11,316
1953	14,441	13,173	16,845	19,330	25,250	29,760	50,050	54,020	32,776	5,440	5,018	6,659
1954	7,665	15,970	18,330	21,410	14,135	20,340	47,350	59,247	43,958	16,150	5,066	10,126
1955	13,020	16,980	18,420	19,990	23,227	40,728	49,105	58,244	33,293	3,635	3,056	10,828
1956	14,846	19,042	20,680	22,842	25,150	23,766	45,035	61,015	39,818	12,930	4,345	4,896
1957	16,350	16,300	18,808	21,080	17,673	46,536	55,252	45,275	16,550	4,479	8,265	12,408
1958	15,305	18,430	21,080	23,689	26,614	57,972	62,060	47,020	16,360	8,198	9,946	14,504
1959	16,836	34,420	37,016	36,956	29,292	18,690	45,976	60,692	34,264	10,192	15,800	20,300
1960	28,605	15,431	17,160	21,430	28,770	31,460	57,236	53,735	21,470	3,947	2,975	8,788
1961	13,216	15,710	19,411	22,080	2,507	30,322	64,993	52,296	19,840	2,378	7,561	10,536
1962	13,232	15,359	18,120	19,940	8,183	13,784	41,339	26,284	3,505	5,881	7,320	10,980
1963	13,360	30,288	36,272	38,466	8,500	11,900	57,700	57,300	22,200	3,505	15,503	21,300
1964	27,769	15,305	16,998	18,500	2,301	15,503	54,095	59,995	32,996	11,804	6,601	10,996
1965	13,496	13,848	16,280	18,790	29,056	35,576	52,888	62,808	36,584	12,196	6,630	8,401
1966	11,468	11,324	12,939	15,170	25,750	33,007	61,852	58,907	25,811	2,186	5,304	5,594
1967	8,857	16,917	19,730	21,490	24,870	10,454	45,440	60,947	32,156	3,279	6,049	10,593
1968	14,090	24,624	28,066	33,337	10,626	21,070	60,301	55,620	25,811	3,099	9,009	16,989
1969	20,190	25,460	26,900	28,451	39,493	56,548	64,721	53,030	17,646	2,655	12,858	18,844
1970	22,220	16,170	17,800	19,483	4,505	43,286	64,517	52,616	17,304	5,846	7,488	11,876
1971	14,090	18,620	21,960	24,151	34,252	43,580	57,989	66,030	47,620	7,488	9,638	12,300
1972	15,215	15,980	18,380	27,868	36,644	18,090	62,140	64,772	47,710	14,423	7,079	11,508
1973	13,976	12,327	13,776	15,413	16,510	30,366	52,072	31,279	3,544	8,454	4,747	7,349
1974	9,771	35,381	37,172	54,320	19,582	30,927	65,384	64,500	36,704	7,913	11,972	23,073
1975	27,065	16,917	18,300	19,591	21,420	44,525	61,100	64,653	42,838	5,059	10,175	13,256
1976	15,215	30,476	33,040	34,684	40,975	50,005	59,672	63,924	43,398	8,720	6,817	15,910
1977	25,921	12,480	13,712	15,197	20,270	13,936	5,993	5,503	6,133	10,314	6,356	9,100
1978	11,060	25,770	27,175	30,228	38,934	46,060	65,775	61,032	38,245	14,495	14,891	19,564
1979	23,678	9,568	10,772	13,912	19,096	28,275	54,804	40,754	11,236	4,787	6,084	6,680
1980	8,659	14,672	16,446	10,241	14,826	43,219	65,958	44,000	12,856	6,084	7,364	8,926
1981	12,712	33,065	36,176	14,708	5,553	40,352	65,925	59,178	31,872	2,644	10,803	18,751
1982	27,807	14,632	18,126	20,790	22,805	7,983	39,503	6,695	15,976	21,382	7,367	9,940
1983	12,609	34,161	35,767	20,244	8,808	22,582	40,682	34,838	8,330	13,327	25,621	28,807
1984	31,453	34,932	35,190	13,824	10,228	17,790	40,909	34,010	16,800	23,795	16,119	24,125
1985	26,472	38,347	39,321	34,580	11,796	28,850	58,238	42,668	12,424	7,583	30,362	34,920
1986	37,019	38,408	43,647	53,753	51,895	60,017	68,371	50,067	20,496	25,085	21,979	32,859
1987	35,341	42,735	44,144	28,379	34,441	67,803	67,769	67,717	45,013	35,777	31,398	38,129
1988	41,084	40,417	42,058	28,018	9,709	18,947	27,844	6,773	6,639	9,670	35,200	36,120
1989	38,905	31,443	32,985	23,323	8,570	19,328	61,834	65,064	46,576	25,687	19,943	26,378
1990	29,115	37,000	39,760	40,769	45,515	52,027	67,015	67,135	47,357	18,795	6,744	26,624

1991	33,077	44,795	46,590	40,243	17,383	41,122	66,812	66,406	45,967	18,483	21,949	37,084
1992	41,607	28,215	29,258	12,819	10,417	21,739	34,000	22,190	5,927	15,347	20,986	24,354
1993	26,656	29,480	30,563	32,481	21,460	38,420	45,706	58,269	41,993	26,989	21,879	25,507
1994	27,681	32,745	34,290	39,638	48,995	62,919	67,597	52,129	23,262	5,981	26,037	28,565
1995	30,709	18,539	24,053	28,499	23,631	41,479	64,041	61,393	38,614	21,909	8,870	12,626
1996	15,356	33,410	39,747	39,136	38,699	51,792	66,542	64,849	48,031	17,041	36,120	30,957
1997	29,981	29,204	31,500	34,545	32,355	40,169	61,472	65,515	48,384	25,318	19,866	23,436
1998	26,035	30,934	32,401	25,825	11,374	46,646	67,238	58,839	32,630	6,702	27,920	27,097
1999	28,675	15,410	17,383	20,888	13,412	20,195	58,654	67,529	51,064	31,784	5,661	8,855
2000	12,491	24,897	27,065	19,914	10,917	19,462	44,617	37,539	12,996	5,975	37,443	28,204
2001	21,969	13,532	14,440	15,750	10,749	17,494	33,031	11,935	5,265	5,142	8,750	10,861
2002	12,357	19,709	22,589	21,687	11,250	26,171	64,339	66,105	40,873	11,436	6,999	12,279
2003	15,966	13,587	15,817	20,984	19,239	33,278	59,848	40,522	13,475	7,846	6,282	8,880
2004	11,347	16,487	18,151	21,786	10,179	24,277	41,636	51,411	30,734	18,631	8,154	11,122
2005	13,741	45,139	48,567	49,678	29,716	35,266	60,940	47,412	17,156	12,180	25,523	30,375
2006	36,423	43,628	46,320	26,699	17,745	35,832	66,473	54,272	26,372	7,652	28,522	34,670
2007	38,484	41,361	42,863	33,037	18,522	36,653	54,398	32,825	4,997	7,025	10,258	35,820
2008	39,309	23,059	24,983	25,776	8,434	32,707	66,078	61,772	38,421	35,249	13,556	17,641
2009	21,103	48,036	49,258	46,844	31,668	39,232	61,589	-----	-----	-----	39,476	43,823

Change in Contents in Sherburne Lake

YEAR	(Acre Feet)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1925		1,488	1,685	17,322	26,998	2,620	4,540	(21,120)	(17,640)	(14,795)	195	(2,925)
1926	4,257	828	1,955	6,815	1,370	(3,940)	(2,098)	(2,072)	(2,100)	3,911	(8,611)	2,740
1927	23,070	990	990	5,060	(3,090)	16,650	2,400	(11,200)	130	(14,690)	660	(1,650)
1928	3,750	0	0	2,200	5,680	15,420	(150)	(11,610)	(1,400)	(240)	(11,000)	(2,100)
1929	4,850	790	720	790	12,870	3,330	(1,550)	(20,700)	(11,870)	16,170	(660)	(660)
1930	(8,900)	3,220	3,300	3,370	21,580	2,010	(6,020)	(21,650)	(6,890)	(6,220)	720	3,230
1931	7,510	660	1,200	100	16,950	11,200	(21,030)	(25,114)	(2,313)	15,407	1,900	0
1932	(13,584)	918	956	970	26,400	15,490	(9,150)	(26,300)	(12,328)	208	992	872
1933	446	602	608	624	681	35,207	3,508	(26,540)	(10,376)	(6,204)	572	653
1934	12,975	0	0	19,605	13,390	(180)	(18,523)	(31,139)	(2,443)	19,470	(80)	0
1935	2,740	(540)	(4,100)	(200)	9,745	23,887	(9,557)	(30,519)	(10,376)	1,322	17,098	2,500
1936	(15,728)	580	588	23,702	22,503	2,907	(33,284)	(22,658)	(910)	3,616	876	1,392
1937	(5,068)	832	352	4,320	16,478	10,869	10,873	(38,687)	(5,033)	(820)	219	457
1938	8,120	1,576	1,448	12,815	22,865	12,580	(10,540)	(37,904)	(9,406)	118	(1,528)	3,739
1939	(1,342)	1,436	2,207	6,304	29,940	2,536	(21,302)	(22,102)	3,799	(3,663)	(118)	653
1940	6,773	1,557	2,463	7,300	21,041	4,979	(31,598)	(13,494)	7,328	(1,870)	(4,194)	4,380
1941	3,882	1,168	1,888	2,443	9,529	11,711	(26,469)	(9,840)	4,130	8,526	(7,680)	2,641
1942	26,088	1,595	1,646	1,326	16,744	3,639	(4,967)	(24,348)	(20,713)	5,709	5,190	11,663
1943	(20,260)	1,754	2,063	19,666	11,999	795	10,123	(26,925)	(29,675)	840	3,155	3,944
1944	(639)	443	2,052	(4,061)	4,893	15,431	(15,660)	(10,880)	4,398	(2,231)	2,461	1,893
1945	10,795	1,863	1,730	(4,460)	23,669	16,726	(7,695)	(30,160)	(18,002)	8,334	3,313	2,890
1946	695	1,950	3,950	(13,574)	23,696	24,569	(4,621)	(27,354)	(23,279)	758	9,451	3,003
1947	5,181	2,379	(1,342)	(1,537)	16,366	12,119	(45)	(25,363)	(19,761)	6,484	5,380	2,940
1948	13,076	1,476	1,597	(429)	12,680	6,205	515	(22,176)	(27,401)	18,292	726	6,633
1949	(21,373)	1,979	1,673	10,967	24,695	10,922	(15,981)	(26,796)	(7,451)	(3,998)	1,789	893
1950	25,715	2,344	1,635	(3,823)	(3,454)	10,696	18,499	(14,460)	(23,955)	(5,835)	9,715	5,912
1951	(7,711)	4,410	2,905	9,142	1,664	8,678	8,634	(18,703)	(24,201)	(4,144)	(1,980)	9,155
1952	(2,080)	1,479	1,180	8,909	18,361	11,378	(6,302)	(19,796)	(25,946)	641	4,441	3,125
1953	(1,268)	3,672	2,485	5,920	4,510	20,290	3,970	(21,244)	(27,336)	(422)	1,641	1,006
1954	8,305	2,360	3,080	(7,275)	6,205	27,010	11,897	(15,289)	(27,808)	(11,084)	5,060	2,894
1955	3,960	1,440	1,570	3,237	17,501	8,377	9,139	(24,951)	(29,658)	(579)	7,772	4,018
1956	4,196	1,638	2,162	2,308	(1,384)	21,269	15,980	(21,197)	(26,888)	(8,585)	551	11,454
1957	(50)	2,508	2,272	(3,407)	28,863	8,716	(9,977)	(28,725)	(12,071)	3,786	4,143	2,897
1958	3,125	2,650	2,609	2,925	31,358	4,088	(15,040)	(30,660)	(8,162)	1,748	4,558	2,332
1959	17,584	2,596	(60)	(7,664)	(10,602)	27,286	14,716	(26,428)	(24,072)	5,608	4,500	8,305
1960	(13,174)	1,729	4,270	7,340	2,690	25,776	(3,501)	(32,265)	(17,523)	(972)	5,813	4,428
1961	2,494	3,701	2,669	(19,573)	27,815	34,671	(12,697)	(32,456)	(17,462)	5,183	2,975	2,696
1962	2,127	2,761	1,820	(11,757)	5,601	27,555	(15,055)	(22,779)	2,376	1,439	3,660	2,380
1963	16,928	5,984	2,194	(29,966)	3,400	45,800	(400)	(35,100)	(18,695)	11,998	5,797	6,469
1964	(12,464)	1,693	1,502	(16,199)	13,202	38,592	5,900	(26,999)	(21,192)	(5,203)	4,395	2,500
1965	352	2,432	2,510	10,266	6,520	17,312	9,920	(26,224)	(24,388)	(5,566)	1,771	3,067
1966	(144)	1,615	2,231	10,580	7,257	28,845	(2,945)	(33,096)	(23,625)	3,118	290	3,263
1967	8,060	2,813	1,760	3,380	(14,416)	34,986	15,507	(28,791)	(28,877)	2,770	4,544	3,497
1968	10,534	3,442	5,271	(22,711)	10,444	39,231	(4,681)	(29,809)	(22,712)	5,910	7,980	3,201
1969	5,270	1,440	1,551	11,042	17,055	8,173	(11,691)	(35,384)	(14,991)	10,203	5,986	3,376
1970	(6,050)	1,630	1,683	(14,978)	38,781	21,231	(11,901)	(35,312)	(11,458)	1,642	4,388	2,214
1971	4,530	3,340	2,191	10,101	9,328	14,409	8,041	(18,410)	(40,132)	2,150	2,662	2,915
1972	765	2,400	9,488	8,776	(18,554)	44,050	2,632	(17,062)	(33,287)	(7,344)	4,429	2,468
1973	(1,649)	1,449	1,637	1,097	13,856	21,706	(20,793)	(27,735)	4,910	(3,707)	2,602	2,422
1974	25,610	1,791	17,148	(34,738)	11,345	34,457	(884)	(27,796)	(28,791)	4,059	11,101	3,992
1975	(10,148)	1,383	1,291	1,829	23,105	16,575	3,553	(21,815)	(37,779)	5,116	3,081	1,959
1976	15,261	2,564	1,644	6,291	9,030	9,667	4,252	(20,526)	(34,678)	(1,903)	9,093	10,011
1977	(13,441)	1,232	1,485	5,073	(6,334)	(7,943)	(490)	630	4,181	(3,958)	2,744	1,960
1978	14,710	1,405	3,053	8,706	7,126	19,715	(4,743)	(22,787)	(23,750)	396	4,673	4,114
1979	(14,110)	1,204	3,140	5,184	9,179	26,529	(14,050)	(29,518)	(6,449)	1,297	596	1,979
1980	6,013	1,774	(6,205)	4,585	28,393	22,739	(21,958)	(31,144)	(6,772)	1,280	1,562	3,786
1981	20,353	3,111	(21,468)	(9,155)	34,799	25,573	(6,747)	(27,306)	(29,228)	8,159	7,948	9,056
1982	(13,175)	3,494	2,664	2,015	(14,822)	31,520	(32,808)	9,281	5,406	(14,015)	2,573	2,669
1983	21,552	1,606	(15,523)	(11,436)	13,774	18,100	(5,844)	(26,508)	4,997	12,294	3,186	2,646
1984	3,479	258	(21,366)	(3,596)	7,562	23,119	(6,899)	(17,210)	6,995	(7,676)	8,006	2,347
1985	11,875	974	(4,741)	(22,784)	17,054	29,388	(15,570)	(30,244)	(4,841)	22,779	4,558	2,099
1986	1,389	5,239	10,106	(1,858)	8,122	8,354	(18,304)	(29,571)	4,589	(3,106)	10,880	2,482
1987	7,394	1,409	(15,765)	6,062	33,362	(34)	(52)	(22,704)	(9,236)	(4,379)	6,731	2,955
1988	(667)	1,641	(14,040)	(18,309)	9,238	8,897	(21,071)	(134)	3,031	25,530	920	2,785
1989	(7,462)	1,542	(9,662)	(14,753)	10,758	42,506	3,230	(18,488)	(20,889)	(5,744)	6,435	2,737
1990	7,885	2,760	1,009	4,746	6,512	14,988	120	(19,778)	(28,562)	(12,051)	19,880	6,453

1991	11,718	1,795	(6,347)	(22,860)	23,739	25,690	(406)	(20,439)	(27,484)	3,466	15,135	4,523
1992	(13,392)	1,043	(16,439)	(2,402)	11,322	12,261	(11,810)	(16,263)	9,420	5,639	3,368	2,302
1993	2,824	1,083	1,918	(11,021)	16,960	7,286	12,563	(16,276)	(15,004)	(5,110)	3,628	2,174
1994	5,064	1,545	5,348	9,357	13,924	4,678	(15,468)	(28,867)	(17,281)	20,056	2,528	2,144
1995	(12,170)	5,514	4,446	(4,868)	17,848	22,562	(2,648)	(22,779)	(16,705)	(13,039)	3,756	2,730
1996	18,054	6,337	(611)	(437)	13,093	14,750	(1,693)	(16,818)	(30,990)	19,079	(5,163)	(976)
1997	(777)	2,296	3,045	(2,190)	7,814	21,303	4,043	(17,131)	(23,066)	(5,452)	3,570	2,599
1998	4,899	1,467	(6,576)	(14,451)	35,272	20,592	(8,399)	(26,209)	(25,928)	21,218	(823)	1,578
1999	(13,265)	1,973	3,505	(7,476)	6,783	38,459	8,875	(16,465)	(19,280)	(26,123)	3,194	3,636
2000	12,406	2,168	(7,151)	(8,997)	8,545	25,155	(7,078)	(24,543)	(7,021)	31,468	(9,239)	(6,235)
2001	(8,437)	908	1,310	(5,001)	6,745	15,537	(21,096)	(6,670)	(123)	3,608	2,111	1,496
2002	7,352	2,880	(902)	(10,437)	14,921	38,168	1,766	(25,232)	(29,437)	(4,437)	5,280	3,687
2003	(2,379)	2,230	5,167	(1,745)	14,039	26,570	(19,326)	(27,047)	(5,629)	(1,564)	2,598	2,467
2004	5,140	1,664	3,635	(11,607)	14,098	17,359	9,775	(20,677)	(12,103)	(10,477)	2,968	2,619
2005	31,398	3,428	1,111	(19,962)	5,550	25,674	(13,528)	(30,256)	(4,976)	13,343	4,852	6,048
2006	7,205	2,692	(19,621)	(8,954)	18,087	30,641	(12,201)	(27,900)	(18,720)	20,870	6,148	3,814
2007	2,877	1,502	(9,826)	(14,515)	18,131	17,745	(21,573)	(27,828)	2,028	3,233	25,562	3,489
2008	(16,250)	1,924	793	(17,342)	24,273	33,371	(4,306)	(23,351)	(3,172)	(21,693)	4,085	3,462
2009	26,933	1,222	(2,414)	(15,176)	7,564	22,357					4,347	2,338

Lake Sherburne Storage/Surface Area Relationship		
Capacity (Acre-feet)	Area (Acres)	
0	0	0.1633
3,448	563	0.0320
10,390	785	0.0193
19,051	952	0.0150
29,389	1,107	0.0127
41,137	1,256	0.0178
55,130	1,505	0.0159
71,354	1,763	0.0111
90,012	1,970	0.0093
110,679	2,163	

Relationship obtained from previous work done in 1997 for Swiftcurrent Creek

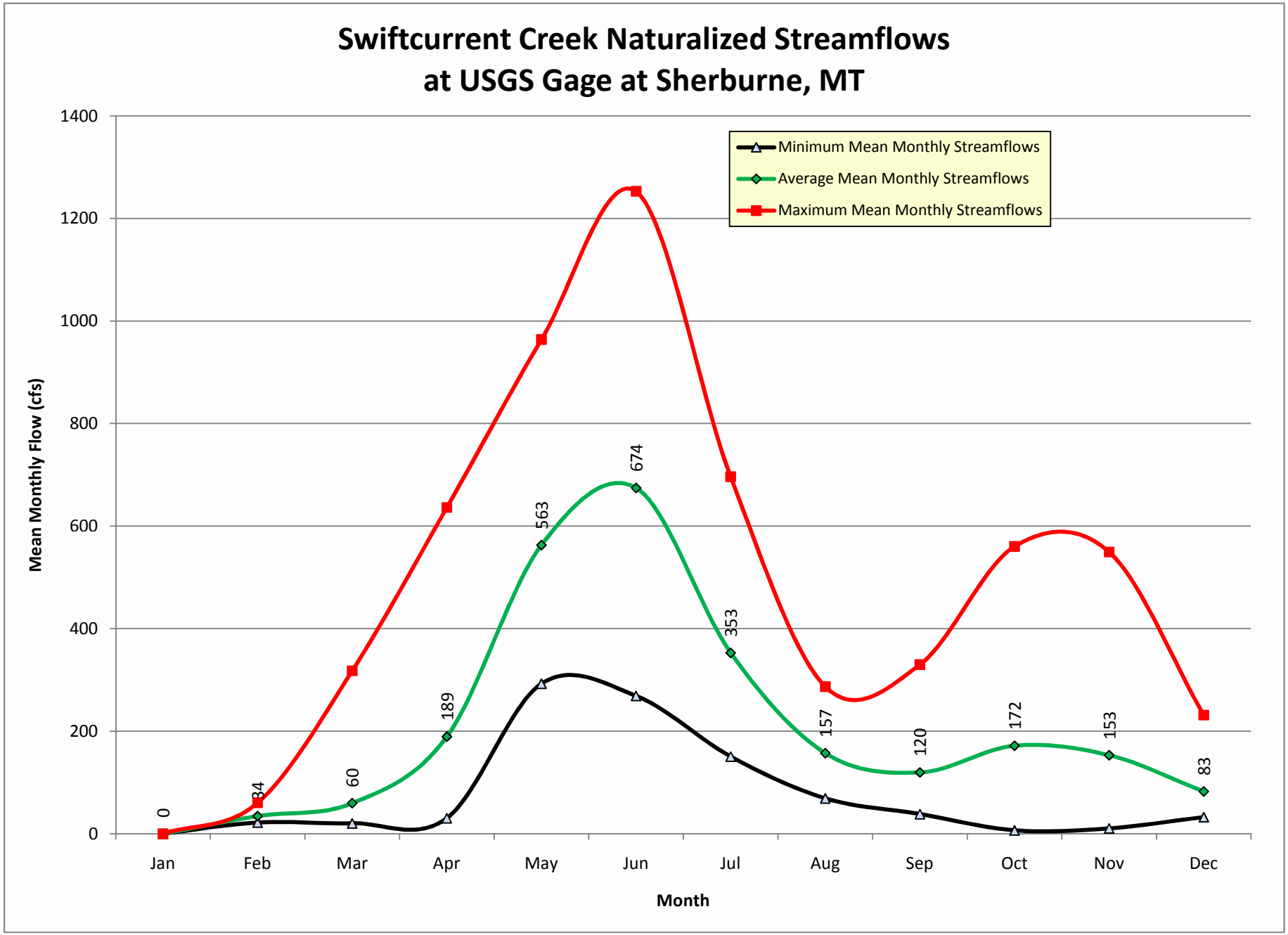
Water Surface Area at Lake Sherburne at the End of Each Month												
YEAR	Acres											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1925	0	393	577	631	1,010	1,412	1,459	1,536	1,190	938	565	571
1926	127	614	640	703	867	893	817	771	705	638	763	178
1927	575	1,070	1,085	1,099	1,165	1,126	1,369	1,412	1,225	1,227	1,028	1,038
1928	1,013	1,070	1,070	1,070	1,103	1,175	1,417	1,415	1,222	1,204	1,201	1,053
1929	1,022	1,094	1,106	1,116	1,126	1,302	1,361	1,334	1,038	834	1,103	1,093
1930	1,083	949	998	1,047	1,098	1,420	1,456	1,349	1,037	928	808	822
1931	884	1,012	1,022	1,040	1,041	1,270	1,470	1,142	677	603	968	996
1932	996	722	751	782	802	1,212	1,470	1,307	926	625	631	663
1933	691	705	724	744	764	785	1,336	1,398	1,005	820	645	663
1934	684	969	969	969	1,239	1,471	1,467	1,172	547	149	972	971
1935	971	1,012	1,004	939	936	1,085	1,446	1,276	811	225	441	963
1936	1,001	663	681	700	1,133	1,484	1,532	1,020	149	0	568	596
1937	641	133	269	327	655	1,008	1,161	1,317	640	134	0	36
1938	110	734	784	813	1,036	1,369	1,584	1,406	809	364	383	134
1939	599	525	602	672	838	1,291	1,336	1,031	365	646	387	368
1940	475	762	801	849	981	1,272	1,361	882	315	749	689	521
1941	695	806	828	864	912	1,063	1,219	811	308	645	865	672
1942	757	1,186	1,206	1,227	1,244	1,533	1,591	1,512	1,130	787	897	987
1943	1,154	832	866	905	1,195	1,383	1,398	1,570	1,144	427	563	664
1944	788	770	784	824	720	840	1,096	836	348	662	590	669
1945	729	958	986	1,012	943	1,276	1,566	1,436	983	509	805	869
1946	925	938	971	1,030	791	1,170	1,566	1,491	1,071	571	595	853
1947	911	997	1,033	1,013	990	1,216	1,415	1,414	1,036	609	804	908
1948	962	1,150	1,169	1,189	1,183	1,380	1,490	1,499	1,148	620	1,019	1,030
1949	1,126	757	806	839	1,028	1,393	1,579	1,303	912	757	630	687
1950	715	1,165	1,194	1,215	1,167	1,123	1,259	1,580	1,331	987	885	1,046
1951	1,130	1,019	1,085	1,125	1,241	1,264	1,419	1,565	1,244	894	814	769
1952	952	912	940	961	1,094	1,359	1,555	1,449	1,142	652	673	803
1953	863	839	909	956	1,045	1,112	1,415	1,485	1,150	627	613	666
1954	698	893	938	987	857	971	1,367	1,570	1,306	896	615	777
1955	836	912	940	966	1,015	1,251	1,398	1,555	1,157	569	499	793
1956	871	952	976	1,009	1,043	1,023	1,325	1,599	1,239	834	592	609
1957	900	899	947	982	925	1,352	1,507	1,330	904	596	717	824
1958	880	940	982	1,022	1,065	1,550	1,615	1,361	900	715	771	864
1959	909	1,171	1,204	1,203	1,106	945	1,342	1,593	1,169	779	889	971
1960	1,095	882	916	988	1,098	1,133	1,538	1,480	988	579	486	734
1961	839	888	957	997	409	1,119	1,662	1,455	964	388	695	788
1962	840	881	934	965	714	850	1,260	1,060	565	641	687	796
1963	842	1,118	1,194	1,222	725	814	1,546	1,540	999	565	884	986
1964	1,083	880	912	941	376	884	1,487	1,582	1,153	812	664	797
1965	845	852	899	947	1,102	1,185	1,465	1,627	1,198	820	665	721
1966	806	803	834	877	1,052	1,153	1,612	1,565	1,053	357	622	632
1967	736	911	962	989	1,039	786	1,333	1,598	1,142	535	646	789
1968	856	1,036	1,087	1,157	790	982	1,587	1,513	1,053	506	741	912
1969	969	1,048	1,070	1,093	1,235	1,528	1,658	1,468	925	434	833	948
1970	1,000	896	928	958	597	1,294	1,654	1,460	918	640	692	814
1971	856	944	996	1,028	1,169	1,299	1,550	1,678	1,371	692	761	822
1972	878	893	939	1,084	1,199	933	1,616	1,658	1,373	863	679	807
1973	854	822	850	882	903	1,119	1,451	1,131	566	723	605	688
1974	765	1,183	1,206	1,491	960	1,127	1,668	1,654	1,200	706	816	1,012
1975	1,072	911	938	960	988	1,316	1,600	1,656	1,286	615	778	840
1976	878	1,121	1,153	1,174	1,254	1,414	1,577	1,645	1,296	732	671	891
1977	1,055	825	849	878	970	853	644	629	649	783	656	744
1978	798	1,053	1,074	1,118	1,228	1,344	1,674	1,599	1,219	864	872	960
1979	1,021	759	792	853	953	1,090	1,499	1,251	801	606	647	666
1980	730	868	902	780	871	1,293	1,677	1,307	833	647	688	738
1981	830	1,154	1,193	868	630	1,246	1,677	1,569	1,138	432	793	946
1982	1,083	867	934	978	1,008	708	1,235	667	893	987	688	771
1983	828	1,168	1,188	970	734	1,005	1,250	1,176	719	842	1,051	1,098
1984	1,133	1,177	1,181	851	780	928	1,253	1,166	909	1,023	895	1,028
1985	1,063	1,221	1,233	1,173	812	1,099	1,554	1,283	824	695	1,119	1,177
1986	1,204	1,221	1,301	1,480	1,447	1,583	1,716	1,415	974	1,042	996	1,151
1987	1,182	1,284	1,310	1,092	1,171	1,707	1,706	1,705	1,325	1,188	1,132	1,218
1988	1,255	1,247	1,272	1,086	763	950	1,084	669	665	762	1,181	1,192
1989	1,228	1,133	1,153	1,016	727	956	1,612	1,663	1,353	1,051	965	1,062
1990	1,103	1,204	1,239	1,251	1,334	1,450	1,694	1,696	1,367	947	668	1,066
1991	1,154	1,321	1,353	1,245	920	1,256	1,691	1,684	1,342	941	995	1,205
1992	1,264	1,089	1,105	832	786	992	1,165	999	642	881	981	1,032
1993	1,066	1,108	1,122	1,146	988	1,222	1,337	1,555	1,271	1,071	994	1,049
1994	1,081	1,150	1,169	1,237	1,396	1,629	1,703	1,452	1,015	644	1,057	1,095
1995	1,124	942	1,027	1,094	1,021	1,262	1,647	1,605	1,224	995	736	828
1996	881	1,158	1,238	1,231	1,225	1,446	1,686	1,660	1,379	913	1,192	1,127
1997	1,115	1,104	1,134	1,172	1,145	1,244	1,606	1,670	1,385	1,046	964	1,018
1998	1,057	1,127	1,145	1,054	804	1,354	1,698	1,564	1,148	667	1,085	1,073
1999	1,096	882	920	980	843	969	1,561	1,702	1,433	1,137	634	736
2000	826	1,040	1,072	965	795	958	1,318	1,210	835	644	1,209	1,089
2001	996	846	863	888	792	922	1,153	815	621	617	733	794
2002	823	962	1,005	992	802	1,059	1,651	1,680	1,253	805	677	821
2003	893	847	890	981	955	1,156	1,580	1,248	844	704	654	737
2004	803	903	935	993	778	1,030	1,265	1,439	1,124	944	713	799
2005	850	1,327	1,388	1,408	1,111	1,182	1,597	1,368	915	820	1,049	1,120
2006	1,196	1,300	1,348	1,067	927	1,189	1,685	1,490	1,062	697	1,094	1,174
2007	1,222	1,260	1,287	1,153	942	1,199	1,492	1,151	613	677	781	1,189
2008	1,233	1,012	1,041	1,053	722	1,149	1,679	1,611	1,222	1,181	846	925
2009	983	1,379	1,401	1,358	1,136	1,232	1,608	---	---	---	1,235	1,304

Evaporation Losses in Lake Sherburne												
YEAR	Acre Feet											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Evaporation per Month in Inches											
	0.15	*0.20*	*0.30*	*0.60*	*1.05*	*0.70*	*2.00*	*1.95*	*1.35*	*1.10*	*0.40*	*0.20*
1925	0	7	14	32	88	82	243	250	134	86	19	10
1926	2	10	16	35	76	52	136	125	79	58	25	3
1927	7	18	27	55	102	66	228	229	138	112	34	17
1928	13	18	27	53	96	69	236	230	137	110	40	18
1929	13	18	28	56	98	76	227	217	117	76	37	18
1930	14	16	25	52	96	83	243	219	117	85	27	14
1931	11	17	26	52	91	74	245	186	76	55	32	17
1932	12	12	19	39	70	71	245	212	104	57	21	11
1933	9	12	18	37	67	46	223	227	113	75	21	11
1934	9	16	24	48	108	86	245	190	62	14	32	16
1935	12	17	25	47	82	63	241	207	91	21	15	16
1936	13	11	17	35	99	87	255	166	17	0	19	10
1937	8	2	7	16	57	59	194	214	72	12	0	1
1938	1	12	20	41	91	80	264	228	91	33	13	2
1939	7	9	15	34	73	75	223	168	41	59	13	6
1940	6	13	20	42	86	74	227	143	35	69	23	9
1941	9	13	21	43	80	62	203	132	35	59	29	11
1942	9	20	30	61	109	89	265	246	127	72	30	16
1943	14	14	22	45	105	81	233	255	129	39	19	11
1944	10	13	20	41	63	49	183	136	39	61	20	11
1945	9	16	25	51	83	74	261	233	111	47	27	14
1946	12	16	24	51	69	68	261	242	120	52	20	14
1947	11	17	26	51	87	71	236	230	117	56	27	15
1948	12	19	29	59	104	80	248	244	129	57	34	17
1949	14	13	20	42	90	81	263	212	103	69	21	11
1950	9	19	30	61	102	65	210	257	150	91	29	17
1951	14	17	27	56	109	74	236	254	140	82	27	13
1952	12	15	24	48	96	79	259	235	129	60	22	13
1953	11	14	23	48	91	65	236	241	129	57	20	11
1954	9	15	23	49	75	57	228	255	147	82	20	13
1955	10	15	23	48	89	73	233	253	130	52	17	13
1956	11	16	24	50	91	60	221	260	139	76	20	10
1957	11	15	24	49	81	79	251	216	102	55	24	14
1958	11	16	25	51	93	90	269	221	101	66	26	14
1959	11	20	30	60	97	55	224	259	131	71	30	16
1960	14	15	23	49	96	66	256	241	111	53	16	12
1961	10	15	24	50	36	65	277	236	108	36	23	13
1962	10	15	23	48	63	50	210	172	64	59	23	13
1963	11	19	30	61	63	47	258	250	112	52	29	16
1964	14	15	23	47	33	52	248	257	130	74	22	13
1965	11	14	22	47	96	69	244	264	135	75	22	12
1966	10	13	21	44	92	67	269	254	119	33	21	11
1967	9	15	24	49	91	46	222	260	128	49	22	13
1968	11	17	27	58	69	57	265	246	119	46	25	15
1969	12	17	27	55	108	89	276	238	104	40	28	16
1970	12	15	23	48	52	75	276	237	103	59	23	14
1971	11	16	25	51	102	76	258	273	154	63	25	14
1972	11	15	23	54	105	54	269	269	154	79	23	13
1973	11	14	21	44	79	65	242	184	64	66	20	11
1974	10	20	30	75	84	66	278	269	135	65	27	17
1975	13	15	23	48	86	77	267	269	145	56	26	14
1976	11	19	29	59	110	82	263	267	146	67	22	15
1977	13	14	21	44	85	50	107	102	73	72	22	12
1978	10	18	27	56	107	78	279	260	137	79	29	16
1979	13	13	20	43	83	64	250	203	90	56	22	11
1980	9	14	23	39	76	75	280	212	94	59	23	12
1981	10	19	30	43	55	73	279	255	128	40	26	16
1982	14	14	23	49	88	41	206	108	100	90	23	13
1983	10	19	30	48	64	59	208	191	81	77	35	18
1984	14	20	30	43	68	54	209	189	102	94	30	17
1985	13	20	31	59	71	64	259	209	93	64	37	20
1986	15	20	33	74	127	92	286	230	110	96	33	19
1987	15	21	33	55	102	100	284	277	149	109	38	20
1988	16	21	32	54	67	55	181	109	75	70	39	20
1989	15	19	29	51	64	56	269	270	152	96	32	18
1990	14	20	31	63	117	85	282	276	154	87	22	18
1991	14	22	34	62	80	73	282	274	151	86	33	20
1992	16	18	28	42	69	58	194	162	72	81	33	17
1993	13	18	28	57	86	71	223	253	143	98	33	17
1994	14	19	29	62	122	95	284	236	114	59	35	18
1995	14	16	26	55	89	74	274	261	138	91	25	14
1996	11	19	31	62	107	84	281	270	155	84	40	19
1997	14	18	28	59	100	73	268	271	156	96	32	17
1998	13	19	29	53	70	79	283	254	129	61	36	18
1999	14	15	23	49	74	57	260	277	161	104	21	12
2000	10	17	27	48	70	56	220	197	94	59	40	18
2001	12	14	22	44	69	54	192	132	70	57	24	13
2002	10	16	25	50	70	62	275	273	141	74	23	14
2003	11	14	22	49	84	67	263	203	95	65	22	12
2004	10	15	23	50	68	60	211	234	126	87	24	13
2005	11	22	35	70	97	69	266	222	103	75	35	19
2006	15	22	34	53	81	69	281	242	119	64	36	20
2007	15	21	32	58	82	70	249	187	69	62	26	20
2008	15	17	26	53	63	67	280	262	137	108	28	15
2009	12	23	35	68	99	72	268	---	---	---	41	22

Based on previous work done in 1997, Use evaporation numbers based on the Missouri River Basin Comprehensive Framwork Study (1971)

YEAR	Adjusted Mean Monthly Volume Acre-feet											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1925					53,465	47,449	23,936	12,068	9,747	8,398		
1926				24,398	17,992	15,986	20,377	4,829	4,864	4,640		
1927				10,566	31,912	63,772	32,849	15,463	19,494	3,063		
1928					59,271	38,570	32,091	11,401	4,450	22,522		
1929				18,173	34,151	30,879	17,172	7,967	3,551	21,547		
1930					30,868	33,981	17,188	8,391	4,241			
1931				7,049	33,858	25,668	13,543	9,640	6,058	22,158		
1932					38,768	37,155	17,861	10,067	3,890	8,677		
1933					50,706	61,726	26,782	12,670	8,808	3,051		
1934				27,764	52,746	35,061	16,849	8,649	3,462	22,773		
1935					29,810	35,613	22,461	10,664	5,877	3,200		
1936					30,583	30,711	13,702	6,056	2,617	6,100	2,632	
1937					31,421	25,197	42,800	8,030	4,197	2,783		
1938				15,510	42,447	40,288	18,629	7,794	5,299	5,464		
1939				37,863	36,660	22,533	16,164	7,321	4,453		12,242	
1940				8,473	31,986	23,107	10,883	4,555	7,803		8,593	
1941				9,567	22,626	20,050	12,447	4,827	12,001	8,592		
1942				13,508	28,480	36,747	23,306	9,206	7,470	16,517	12,836	
1943				19,773	29,781	47,801	31,268	9,018	4,496	4,003		
1944				6,852	23,335	20,062	9,253	7,923	6,544			
1945				3,481	38,533	42,542	18,342	5,773	8,046	13,324		
1946				16,212	40,619	37,347	20,628	7,967	6,748	1,579		
1947			6,339	12,545	40,328	35,486	20,801	9,718	8,477	8,212		
1948				3,022	43,527	55,739	16,892	9,223	3,855	21,036		
1949				16,721	37,513	26,587	13,015	6,828	9,021			
1950			8,804	5,235	33,516	62,143	38,348	13,792	5,756	23,585	31,612	
1951			3,178	28,240	43,209	39,027	34,831	12,603	16,919	22,888		
1952		1,550	1,253	9,034	32,015	29,671	18,319	10,814	5,571	4,488	4,503	
1953			2,600	10,431	37,805	60,240	31,383	11,715	6,276	3,694	1,689	
1954			3,103	5,568	46,462	47,250	41,294	16,940	11,195	14,454	7,502	
1955			1,600		20,898	48,829	29,245	10,356	5,121	13,714	7,865	
1956			2,285	8,214	44,276	43,762	24,465	10,926	6,360	5,603		
1957			2,320	6,020	51,000	36,155	13,695	6,914	3,954	3,845		
1958			2,653	6,707	44,677	33,425	14,565	7,936	8,452	1,818		
1959			2,171	12,253	31,362	53,713	26,284	10,828	19,628	29,555	14,199	8,327
1960				10,525	25,137	42,872	19,924	9,683	6,354			
1961			3,154	8,057	40,345	47,655	17,033	8,504	5,216	11,773		
1962			1,858	15,407	28,752	31,675	15,081	9,435	6,194	1,510		
1963			3,091	8,386	26,976	46,913	24,557	6,783	5,540	13,089		
1964				3,002	31,275	74,489	23,124	7,396	9,172	11,971		
1965				10,493	33,185	51,060	23,894	10,847	8,319	8,817	6,893	3,082
1966		1,635	2,470	10,854	35,898	40,045	21,371	8,367	4,847	5,401		
1967			1,808	3,461	39,655	53,157	27,147	8,619	3,164	2,832		
1968			5,319	5,742	33,436	40,859	20,904	11,843	18,316	6,458	8,011	
1969			1,583	13,983	32,283	39,954	19,495	7,010	4,619	13,538		
1970			1,712	1,802	41,391	58,925	16,149	7,991	5,586	1,714	4,416	2,239
1971		3,372	2,236	10,214	46,261	48,176	30,269	13,369	5,757	8,707	2,693	
1972			9,568	8,887	45,068	55,029	30,872	14,935	8,437	7,929	4,529	
1973		1,571	1,766	5,021	29,885	37,391	15,019	8,001	4,993			2,440
1974		1,925	19,545		31,751	61,907	32,954	12,114	5,714	4,124	11,129	4,027
1975		1,454	1,357	2,292	25,288	74,549	37,976	13,355	9,469	13,166		1,988
1976		2,606	1,703	10,402	41,464	28,231	27,960	17,648	8,727	3,975	9,120	
1977		1,251	1,511	8,640	21,119	19,633	10,618	10,466	10,877		2,780	
1978		1,427	3,095	9,982	33,772	44,958	28,278	14,009	12,584	13,185	11,664	4,253
1979		1,283	3,344	5,539	37,780	34,721	15,074	7,424	4,280	1,355	619	
1980			1,719	17,757	39,832	29,164	13,486	9,410	12,250	1,754		
1981		3,480	3,606	11,322	40,456	34,786	22,530	9,805	5,293	8,482		
1982				4,391	28,560	50,490	27,053					
1983			3,248	6,279	26,136	29,810	23,885	7,305				
1984			1,863	8,187	23,826	36,050	18,741	7,224	8,781			
1985			1,303	12,834	36,155	33,445	13,902	8,991	14,739	22,960		
1986			10,368	14,044	32,051	30,891	14,699	6,482	7,269			
1987			5,419	16,078	34,141	21,481	19,423	11,447	4,926			
1988			2,987	16,793	31,354	24,888	9,472	4,654	3,142	26,063		
1989			1,797	14,169	31,408	45,174	20,869	13,879	10,354	20,380		
1990			2,632	15,805	26,120	37,393	24,290	10,928	4,509			
1991		2,889	2,326	10,828	45,125	56,461	31,794	12,023	4,591	3,569		
1992		1,336	3,449	12,200	24,697	20,929	11,620	5,549	9,502	7,294		
1993			2,831	7,030	31,859	25,286	22,089	11,738	8,994	405		
1994			5,393	15,096	32,302	28,384	14,434	6,749	2,648	20,163		
1995			6,956	5,790	28,741	57,618	23,341	11,816	3,361			
1996			5,175	14,935	26,561	49,495	23,933	10,678	5,159	21,389		
1997			5,268	9,543	43,257	54,263	24,626	12,784	9,591	1,364	8,928	
1998			2,350	10,677	37,224	36,100	17,616	8,005	4,138	24,704		
1999			3,601	10,502	26,072	42,443	27,975	14,875	5,504		32,699	14,230
2000			2,419	13,169	28,690	33,791	16,077	7,123	5,718	34,454		
2001			1,384	5,439	27,394	25,463	10,529	4,241	2,279	4,322	2,428	
2002			3,360	10,183	33,794	66,060	29,452	8,263	4,841	3,513		
2003			5,351	14,852	27,767	32,534	14,436	6,322	2,999	3,321		
2004			4,433	14,874	27,595	30,343	19,486	16,210	11,539			
2005												
2006												
2007												
2008												
2009												

Adjust Mean Monthly Flows												
YEAR	cfs											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1925					870	797	389	196	164	137		
1926				410	293	269	331	79	82	75		
1927				178	519	1072	534	251	328	50		
1928					964	648	522	185	75	366		
1929				305	555	519	279	130	60	350		
1930					502	571	280	136	71			
1931				118	551	431	220	157	102	360		
1932					630	624	290	164	65	141		
1933					825	1037	436	206	148	50		
1934				467	858	589	274	141	58	370		
1935					485	598	365	173	99	52		
1936					497	516	223	98	44	99	44	
1937					511	423	696	131	71	45		
1938				261	690	677	303	127	89	89		
1939				636	596	379	263	119	75		206	
1940				142	520	388	177	74	131		144	
1941				161	368	337	202	79	202	140		
1942				227	463	618	379	150	126	269	216	
1943				332	484	803	509	147	76	65		
1944				115	380	337	150	129	110			
1945				58	627	715	298	94	135	217		
1946				272	661	628	335	130	113	26		
1947			103	211	656	596	338	158	142	134		
1948				51	708	937	275	150	65	342		
1949				281	610	447	212	111	152			
1950			143	88	545	1044	624	224	97	384	531	
1951			52	475	703	656	566	205	284	372		
1952		27	20	152	521	499	298	176	94	73	76	
1953			42	175	615	1012	510	191	105	60	28	
1954			50	94	756	794	672	275	188	235	126	
1955			26		340	821	476	168	86	223	132	
1956			37	138	720	735	398	178	107	91		
1957			38	101	829	608	223	112	66	63		
1958			43	113	727	562	237	129	142	30		
1959			35	206	510	903	427	176	330	481	239	135
1960				177	409	720	324	157	107			
1961			51	135	656	801	277	138	88	191		
1962			30	259	468	532	245	153	104	25		
1963			50	141	439	788	399	110	93	213		
1964				50	509	1252	376	120	154	195		
1965				176	540	858	389	176	140	143	116	50
1966		28	40	182	584	673	348	136	81	88		
1967			29	58	645	893	442	140	53	46		
1968			87	97	544	687	340	193	308	105	135	
1969			26	235	525	671	317	114	78	220		
1970			28	30	673	990	263	130	94	28	74	36
1971		59	36	172	752	810	492	217	97	142	45	
1972			156	149	733	925	502	243	142	129	76	
1973		27	29	84	486	628	244	130	84			40
1974		33	318		516	1040	536	197	96	67	187	65
1975		25	22	39	411	1253	618	217	159	214		32
1976		45	28	175	674	474	455	287	147	65	153	
1977		22	25	145	343	330	173	170	183		47	
1978		25	50	168	549	756	460	228	211	214	196	69
1979		22	54	93	614	584	245	121	72	22	10	
1980			28	298	648	490	219	153	206	29		
1981		60	59	190	658	585	366	159	89	138		
1982				74	464	849	440					
1983			53	106	425	501	388	119				
1984			30	138	387	606	305	117	148			
1985			21	216	588	562	226	146	248	373		
1986			169	236	521	519	239	105	122			
1987			88	270	555	361	316	186	83			
1988			49	282	510	418	154	76	53	424		
1989			29	238	511	759	339	226	174	331		
1990			43	266	425	628	395	178	76			
1991		50	38	182	734	949	517	196	77	58		
1992		23	56	205	402	352	189	90	160	119		
1993			46	118	518	425	359	191	151	7		
1994			88	254	525	477	235	110	45	328		
1995			113	97	467	968	380	192	56			
1996			84	251	432	832	389	174	87	348		
1997			86	160	704	912	401	208	161	22	150	
1998			38	179	605	607	287	130	70	402		
1999			59	176	424	713	455	242	92		550	231
2000			39	221	467	568	261	116	96	560		
2001			23	91	446	428	171	69	38	70	41	
2002			55	171	550	1110	479	134	81	57		
2003			87	250	452	547	235	103	50	54		
2004			72	250	449	510	317	264	194			
2005												
2006												
2007												
2008												
2009												
Average	---	34	60	189	563	674	353	157	120	172	153	83
MIN		22	20	30	293	269	150	69	38	7	10	32
MAX		60	318	636	964	1253	696	287	330	560	550	231


Swiftcurrent Creek Naturalized Streamflows
at USGS Gage at Sherburne, MT
Minimum Mean Monthly Streamflows
Average Mean Monthly Streamflows
Maximum Mean Monthly Streamflows
Mean Monthly Flow (cfs)
1400
1200
1000
800
600
400
200
0
0
34
60
189
563
674
353
157
120
172
153
83
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

Appendix D

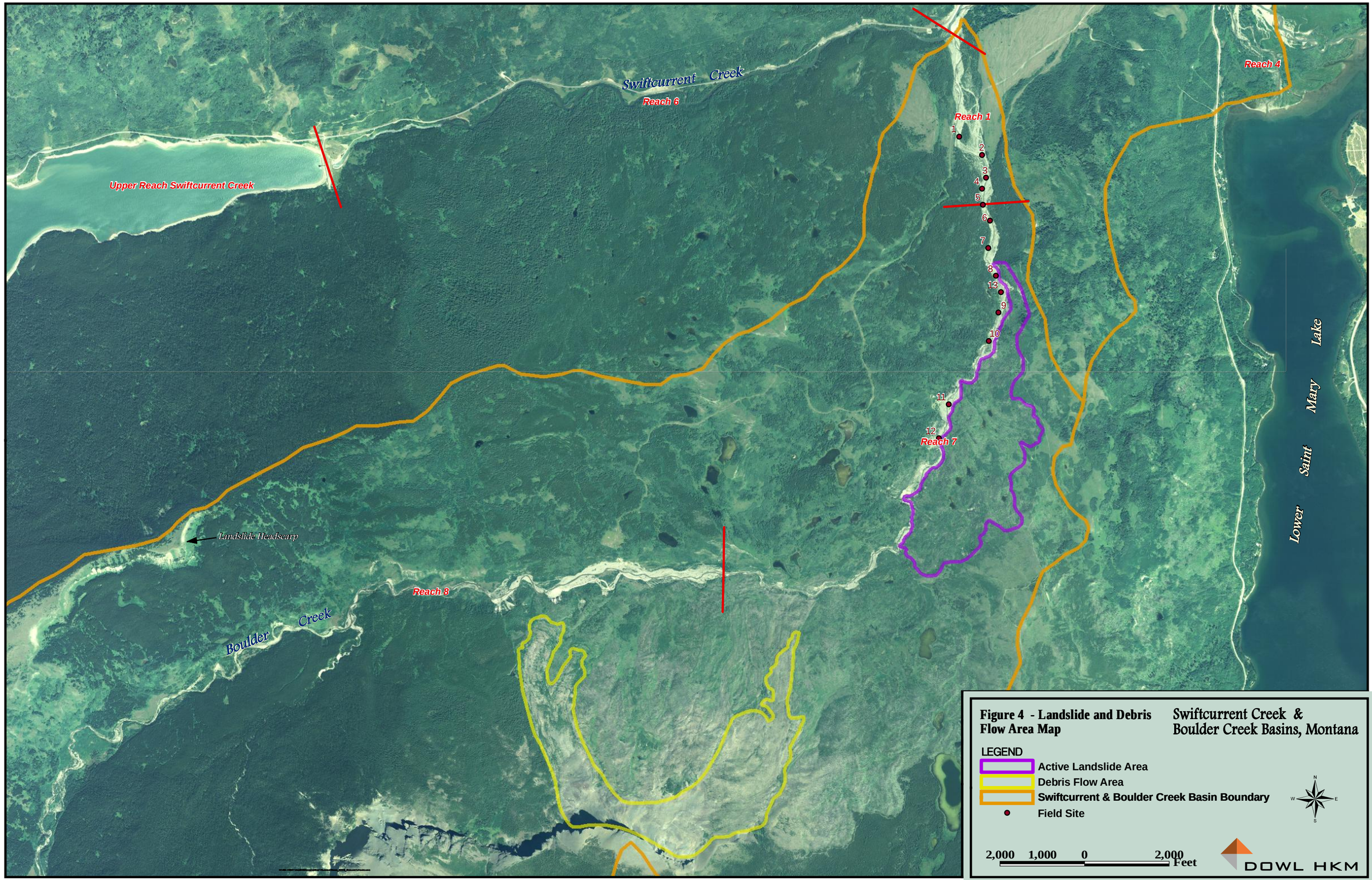


Figure 4 - Landslide and Debris Flow Area Map

Swiftcurrent Creek & Boulder Creek Basins, Montana

Appendix D - Field Site and Photo Summary

Field Site	X_Coord	Y_Coord	Description
1	319518	5411644	Erosion left bank (photos 1-3)
2	319682	5411512	End erosion right bank. Large boulders. Massive vertical exposed face 30+ ft high. (photos 4-7)
3	319712	5411348	Begin erosion right bank. (photos 8-9)
4	319682	5411269	End left bank erosion. Tree recruitment evident likely due to wind, as indicated by snapped trunks. (photos 10-11)
5	319690	5411153	Begin left bank erosion.
6	319740	5411039	Right bank erosion. (photos 12-13)
7	319727	5410842	Log debris jam. (photo 16)
8	319782	5410644	Approximate downstream limit of Napi Point Fire - 1984. (photos 20-21) Note photos 17-19 taken just downstream of point 8.
9	319801	5410379	Apparent partial large landslide (?) high above stream valley, as indicated by vertical exposed headscarp along hillside. (photo 22)
10	319731	5410174	Apparent hillisde movement left bank slumping into valley note trees in photo. (photo 23)
11	319443	5409719	Apparent landslide left bank. (photo 24)
12	319371	5409475	Apparent landslide left bank. (photo 25)
13	319819	5410525	Apparent landslide right bank. Big slide old trees bent mid way up trunk. Vertical 30 ft drop at top of hillside. (photo 26)

Field Site 1 Photo 1

Field Site 1 Photo 2

Field Site 1 Photo 3

Field Site 2 Photo 4

Field Site 2 Photo 5

Field Site 2 Photo 6

Field Site 2 Photo 7

Field Site 3 Photo 8

Field Site 3 Photo 9

Field Site 4 Photo 10

Field Site 4 Photo 11

Field Site 6 Photo 12

Field Site 6 Photo 13

Field Site 7 Photo 16

Between Field Site 7 and 8 Photo 17

Between Field Site 7 and 8 Photo 18

Between Field Site 7 and 8 Photo 19

Field Site 8 Photo 20

Field Site 8 Photo 21

Field Site 9 Photo 22

Field Site 10 Photo 23

Field Site 11 Photo 24

Field Site 12 Photo 25

Field Site 13 Photo 26

Appendix E

Memorandum

To: Gerald Wagner
Director, Blackfeet Environmental Office
Blackfeet Nation
P.O. Box 2029
Browning, MT 59417

From: Traci Sylte, P.E.
Watermark Consulting, LLC
8180 Double Tree Ln
Missoula, MT 59904

Date: May 24, 2009

Re: Review Comments and Edited Work Plan for the June 1998 Design for Stabilization and Reconstruction of Swiftcurrent Creek and Boulder Creek near Babb, MT (Decker Report)

Please find the following comments summarizing my review of the Decker Report. Also included is an edited work plan, as requested.

As an overall comment, Gary Decker is one of the best nationally in the field of stream rehabilitation and restoration - you have done well to employ him. The industry and knowledge of environmental river engineering and restoring riparian processes is changing rapidly and many new techniques and approaches have developed in recent years. The 1998 Decker Report presents a sound design based on what was known at the time; however, the design can be improved by incorporating new techniques and approaches. Additional data collection and assessment is also necessary. With additional evaluation, addressing the comments herein, a new or modified design that incorporates, reinforces, or perhaps changes the older design is highly recommended.

I commend the Blackfeet Tribe for your intention of rehabilitating these streams. I am honored to be a reviewer of this report and hope that you find my words helpful. Thank you for the

opportunity. Please excuse perhaps a little rambling, spelling, and grammatical error, as it is not the emphasis of my time and efforts here. I'm impressed with the knowledge, thought, and foresight, offered in your work plan – you will see that many of my comments simply reinforce your own expertise and review. Finally, please keep in mind that I'm only familiar with information disclosed in the report, the photos you've sent, and viewing the site through Google Earth – some of my questions may be quickly and easily answered by better knowledge of the site or actually seeing the streams first hand.

REVIEW COMMENTS

Organization, content, logic: The overall organization and logic are very good. Content is good, but should be expanded, as comments and work plan below suggest.

Project purpose, scope, goals, and objectives: I suggest reworking Section A.1 and C.1 to further develop the project purpose and need, the scope, limiting factors and constraints, and foremost, very specific goal and objective statements. Ideally, objectives are written with measurable metrics and performance measures to fulfill the goal (Objectives can and should be a work in progress as additional knowledge becomes available.) It is critical to clearly state the expected short- and long-term project functions, as well as the expected degree of accepted and expected variance. This section is paramount for the following: 1) assures that all stake-holders have the same vision and expectations; 2) provides a framework to evaluate the design comprehensiveness; 3) provides measures to evaluate project performance; 4) somewhat dismantles any future critical comment or cynicism that is outside any agreed upon project scope and expectations; and 5) provides a clear framework and linkage to monitoring.

Make sure to disclose uncertainty and possibility of gross system adjustments such as flooding after wildfire relative to the design's ability to reasonably accommodate, or not.

The Milltown Dam Stream Restoration Project and Kootenai River Master Plan are both recommended references for this section.

<u>Questions that should be answered or the discussed in further detail</u>

The following bulleted items (no order of significance) are questions that should be addressed by additional thought, investigation and perhaps data collection. The findings associated with these questions are very relevant to the design efficacy and ultimate project success.

1. **Alternatives:** The report discusses three alternatives:

   1) Original Alternative – Use existing channels and reconstruct only Reach 3: Swiftcurrent Creek Reach to Bridge
   2) Use existing channels and reconstruct both Reach 3 and 4: Swiftcurrent to Bridge and downstream to St. Mary's Lake Outlet
   3) Historic Channel Alternative – Utilize historic channels and breach dike

   However, only Alternative 1 has been developed. The success of this project depends on collecting enough data and performing a thorough assessment to rigorously explore and discuss the benefits/cost, uncertainty, and reality of long-term efficacy of each alternative and the total stream system. The most difficult, but possibly best solution for the long-term may be Alternative 3. It would be wisest to fully explore this before any decisions are made. Also, keep in mind that Alternative 3 may not have to be "all or nothing" in regard to utilizing all of the historic alluvial fan. Additional assessment could explore the possibility of utilizing a portion of the historic fan, and, new set-back levees could be employed, if certain infrastructures absolutely most be accommodated.

   - Does the existing levee section and the gross confinement of the alluvial fan and stream corridor absolutely have to be accepted? How do conditions downstream of the County bridge affect the upstream design? Success of the entire project relies on critical decisions made downstream of the bridge as well, despite the lack of adequate channel and possible major modification to stream and land management.

   - What is the feasibility and cost of allowing Swiftcurrent Creek to have more access to it's historic alluvial fan – maybe not all of it because of infrastructure, but could some of the levees be changed and additional road crossings be installed? This is expensive and with questionable feasibility, no doubt, but cost/benefit of providing greater alluvial space and levee system should at least be an alternative for comparison and evaluation of risk, maintenance and rehabilitation costs. I fully realize that this would take big changes to the airport and perhaps other infrastructure, but how serious is the Tribe at reducing risk and addressing long-term cost management?

   - Where is the best confluence… upstream or downstream of the St Mary River diversion, outlet of the lake? Would moving the St. Mary River diversion provide

large benefits and risk reduction to the overall system? If so, how feasible is it and what is the cost/benefit?

- Streams along the Front are still in the process of reaching equilibrium and appear to be naturally experiencing aggradation/incision processes. Alluvial fans and allowing the stream to braid in these systems, and therefore deposit sediment, is critical. Reducing sediment from bank erosion is also critical, but bedload incoming from the watershed still appears high regardless of bank erosion. Where will it deposit? Can there be a section of stream that is allowed to be braided, allowed to be functioning as an alluvial fan? What reach or portion of reach is the best for allowance of braiding? Can sediment transport be maintained upstream of this section? Designing a section of stream that is allowed to braid and deposit sediment in the widest possible floodplain may be a critical design consideration and component.

- None of the alternatives address Reach 6. It may be the lowest priority, but it would be good to discuss needs if any and why or why not to include.

2. **Sherburne Lake/Reservoir Operations**: Boulder Creek is roughly twice the gradient of Swiftcurrent Creek Reaches 3 and 4 and is producing most of the bedload (3.1% vs. 1.7% and 1.3%, respectively). Consequently, Boulder Creek has much greater stream power to transport sediment. The ability of Swiftcurrent Creek to function in a more stable manner most likely depends on maximizing flow from Reach 6 (Swiftcurrent downstream of the Dam) and assuring that the timing of the runoff peak flow of Reach 6 coincides with the runoff peak flow of Boulder Creek Reach 1.

    - How much storage is in Sherburne Lake and what is the retention timing to full pool and release in the spring? What does the hydrograph of the Sherburne Dam look like? What is the time of peak release compared to the timing of peak flow in Boulder Creek? Easy for me to ask – is the dam necessary? Can it be removed or modified to help remedy the downstream problems if flow timing is an issue?

    - Does the timing of release from Sherburne Dam reduce the amount of flow in Swiftcurrent Creek at a time when additional flow is necessary to transport sediment incoming from Boulder Creek?

    - With a natural hydrograph before the Sherburne Dam, was Swift Current Creek braided or aggrading? We may not know, but simulations can be modeled to help answer this question.

3. **Sediment Load and Transport**: New sediment transport models should be used to build upon the existing sediment load and transport assessment. If time and budget allows, additional bedload sampling using a 6-inch Helly Smith sampler is recommended. With the new models and hopefully updated suspended sediment and bedload data, answer the following:

    - What is the current sediment load and transport capacity by reach of Boulder Creek and Swiftcurrent Creek? How does the design accommodate this load?

    - What is the origin of sediment supply? How much is derived from upstream watershed processes and how much is coming from bank erosion.

4. **Reach 6:** Are there clear water scour issues on Swiftcurrent Creek downstream of the dam before the Boulder Creek confluence? If so, how does this affect sediment load, bank erosion, and stream stability issues? The report speaks to this section changing and being relatively stable, "able to accommodate" floods, but clear-water scour conditions should be reviewed if sediment was transported through the system prior to the Dam. If there was a lake prior to the dam, and therefore incoming watershed sediment did not exit the lake, clear-water scour and subsequent stream adjustment is not an issue. The report mentions that there was aggradation following the 1995 flood in this reach. Where did the sediment originate that caused the aggradation – must have been bank derived and how much is this an issue now?

5. **Reference Stream Issues**: Where are the reference reaches in Otatso Creek and the Belly River? Much of Otatso Creek appears more confined than the problematic sections of Boulder and Swiftcurrent Creek. By viewing Otatso Creek using Google Earth, where Otatso Creek becomes apparently similarly unconfined, it too has sediment transport and stream instability issues. Some assurance that longitudinal valley location, confinement, and sediment load for the reference streams is similar to Swiftcurrent and Boulder Creek. Selecting reference streams based on reach stability is fundamental, but in these systems watershed-derived (as opposed to altered bank sources) sediment load and transport capacity needs to be similar too.

    - Why isn't Divide Creek a reference stream? The Divide watershed seems similar. How are the subject streams different than Divide Creek? Point here is, how much natural instability and aggradation is inherent in these systems. Important to make sure the design can actually accommodate natural watershed and channel dynamics in these glacial watersheds. Make sure that Otatso Creek and Belly River are chosen

not just for their stability, but for similarities in watershed and morphologic characteristics, particularly sediment load and transport capacity.

- How did Otatso Creek and Belly River react after the ’64 flood? If they reacted differently, then why? If their conditions or trajectories are different than the subject streams and they have changed differently than our subject streams, then why? Speak to the specific morphologies and land management practices that have/have not occurred in the reference streams relative to what has occurred in the subject streams.

- If Otatso Creek and the Belly River are good reference streams and inherently more stable or have more desirable conditions, then what are the reasons for departure from Swiftcurrent and Boulder Creek? Why is it more stable/desirable? Is it morphology? Is it land management? Are the watersheds and sediment supply truly the same? Does the design address the critical element that brings Swiftcurrent and Boulder Creek conditions nearer to their reference?

6. **Delta Study**: Performing more in depth analysis of the Swiftcurrent Creek delta into St. Mary’s Lake would be good to improve understanding of sediment load and deposition dynamics. This will help to improve the understanding, although I wonder if the rigor and cost to perform a volumetric study that will be accurate is worth the information gained, provided all other issues and questions herein are addressed.

7. **Historic Photos**: Has the search for the 1938 or 1940’s photos been exhaustive? If these photos of this era are available, they should be obtained and evaluated without question.

8. **Land Management**: How much does historic and current land management cause or exacerbate stream instability. Discuss this further. What is the relative influence and significance of remedy of the following:
    - Undersized bridges and lack of additional crossing structures – the roads are essentially dams across this broad alluvial fan and floodplain. How much is backwater influence and confinement affecting streams. What are the solutions and costs? Are new bridges or road alignments necessary?
    - Cattle Grazing – often is very influential in lack of critical vegetation necessary to stabilize streams. How much is this an issue? If it is, then how much is the Tribe willing to change management? A historic account of canopy cover and relative density in the stream corridor through time would be helpful if land management has affected riparian vegetation necessary for stability.
    - Levee Section

- Channel straightening
- Other?

9. **Surface/Groundwater & Bankfull Determination**: Hydrologic and hydraulic analysis are appropriate, but additional refinement is necessary. What are the surface water gain/loss relationships along the stream? Hydrologic calculations are based on larger scale relationships, which are accurate, but may be missing reach specific issues, particularly lower on the alluvial fan where there actually may be less flow with greater drainage area. Channel sizing with less flow while needing to maintain sediment transport is difficult. What is the connection and distances of seasonal connection to the water table/ground water? What consequences in channel design parameters, transport capacity, and riparian vegetation does this issue have?

   New regional data and equations have been developed as well. These should be employed to verify and perhaps update the 1998 equations and values.

10. **Design Concepts**: The existing design concepts (Section C.3) should be updated to explore and discuss the following:
    - Allowing a braided section where the majority of bedload will deposit
    - Allowing side channels and maximizing channel complexity while maintaining sediment transport
    - Short-term versus long-term functions and expectations
    - Using new or updated bank protection and grade control measures
    - Importance of riparian vegetation and floodplain design and function
    - Monitoring and adaptive management plan
    - Revegetation and weed control plan if weeds are or may be an issue

11. **Design Parameters**: appears solid, but could be reworked to include the following to substantiate/verify:
    - If Otatso Creek is a reference, why no values here? Report displays Belly River and mentions Teton data, but not this creek, why? If Teton is a reference then where is the data displayed? – I may have missed it.
    - Why no riffle or pool gradient for Swiftcurrent Reach 2? Could it be designed like Boulder Reach 1 to be (I'm assuming) riffle dominated? If so, I can see this for Reach 1 and it's gradient, but the gradient such as that on Reach 2 typically is dominated

by pool/riffle transitions and therefore, more than just average slope values. This needs clarification.

- Belly River is quite a bit more sinuous with tight radius of curvatures. I question this reference stream and would like to see more reference data from other streams and for more than one flight year (The design relies heavily on 1958 dynamics of the subject stream, which may be the best data available – however, I'm not sure how the other reference streams are used. Would be good to expand the rational here and conduct additional verification if possible)
- As mentioned above, make sure that the discharge is actually increasing for Reach 3-5. Often these streams lose water on the fan. This may affect base flow conditions much more than bankfull – need to develop this a bit further and disclose rational.

12. **Pattern – Plan View Location**:

- The pattern needs to be designed and field verified for the entire stream length in order to make the best informed decision.
- Reach 5: As mentioned, the stream is accessing only a very small portion of the historic alluvial fan surface – this is a major issue. Long-term efficacy of this project and reducing problems most likely depends on allowing the stream to utilize as much of the historic alluvial fan surface as possible. Depending on sediment transport and deposition relations and locations (and where the channel is allowed to braid/deposit sediment), it may be possible to actually allow Swiftcurrent Creek two or three major stream crossings (one primary with secondary flood relief or allowance of channel change, or, maybe the design is single channel through the best road crossing point and allowed to braid below the crossing… all this should be flushed out with site survey and rigorous sediment transport modeling) through the County Road, modifying or moving the airstrip, and building set-back levees.
- Reach 3: The way that the levee and County Road constricts alignment is problematic to say the least. It would be good to fully explore allowing the stream to flow through the road without the substantial bend and straight section leading into the bridge (this links with the discussion above for Reach 5). Does the lower section of Reach 3 really fit design values? I didn't explore the appendices to search for this detail, but my bet is that gradient and sediment transport values are very marginal at best in this section…. Lots of red flags here.
- Reach 2 and 3: Question all along here is where is the sediment going to deposit? Really need a very rigorous evaluation of sediment transport capacity in these reaches. Can sediment be transported with reasonable ease and certainty to the

other side of the County Road? If not, what are the options depending on where it is predicted to deposit?

- The report states that the proper cross-section design is not accommodated by the bridge. So, not only is the road and bridge causing alignment and therefore sediment transport capacity problems, the undersized nature and limited freeboard is a major issue. Bridge replacement or major modifications appear necessary for long-term project success. Bridges and backwater have failed many a good stream reconstruction project. If the bridge is causing problems, it needs to be replaced or the project may be majorly compromised or fail.

13. **Specifications for Materials**: be sure to have an updated design incorporate new structures and techniques that were incorporated on the Jocko River and Milltown Restoration projects (e.g. cobble patches, engineered debris jams, floodplain topography, etc.)

    I agree with the sequencing, specifications on the materials, etc. Should look into having less vortex rock weirs and more cobble patches for grade control. (Jocko and Milltown examples)

    Riprap: whenever riprap is necessary it can be designed to accommodate stream function and aquatic habitat much better than what we have historically engineered. Assure the riprap banks are irregular in plan form and have protrusion of large rock mixed in with the typical rock distribution (anchored well with the majority of mass buried). Idea is to have roughness through protrusion at multiple vertical stages, as well as laterally along the bank (little scallops like nature does) (this dissipates energy much better and provides flow separation or zero velocity zones for multiple aquatic species and life stages). Also, only extend riprap in elevation as high as what is being designed to be protected (e.g. 100 year flood elevation, bankfull elevation, some infracture, etc.). Then, heavily vegetate above the riprap.

14. **Revegetation and Floodplain construction**: in the past we've grossly under-designed revegetation, floodplain construction/topography and floodplain roughness elements). We learned that revegetation and management of the floodplain and vegetation is just as paramount to success as the channel work. I strongly recommend hiring GEUM Consulting (Decker knows this firm well) and have them provide you with, and help you manage, a revegetation plan…I'm seeing that the most successful projects have up to 50% or more of the total project cost in revegetation expenses and out-year management of the vegetation

(watering, weed management). For your environment, I recommend considering collecting your own seed and grow your own planting stock in addition to transplants.

Discussed above is surface to ground water interaction. It is critical to understand base flow water table elevations for successful planting and to design the species and planting method.

15. **Quantity Estimates and Project Layout**: Since 1998, a lot has changed in our ability to map the terrain. New methods provide multiple design, quantity evaluation, and layout benefits. I recommend performing a Lidar flight over all the reaches (1-5). Many of the questions for cost/benefits of utilizing various portions of Reach 5 (and all others) could be evaluated relatively quickly and accurately if Lidar imagery and consequent elevations where developed.

16. **Costs**: You will certainly want to have updated cost estimates. Although there may be some thought or question on paying for additional design work when there was a sound design in 1998, I recommend the viewpoint that the 1998 design as having set a great foundation and layout for this additional effort. I highly recommend not cutting out any of the recommendations or hardships of possibly employing Reach 5 and moving infrastructures for long-term success. "Incrementalism" or taking sequenced, "baby steps", will work. If funding is an issue, as it always is, phase the project and year by year work towards a system that will serve the land and people well for the long-term.

EDITED WORKPLAN

I wrote all of the above comments with only scanning your work plan a month or so ago - I didn't want any of your comments and evaluations to bias my review. I am impressed to see a lot of similarities in thought.

1) **Survey Update:** I agree that a resurvey is necessary. See above for efficiencies with Lidar technology. This is recommended in addition to some degree of traditional channel-specific surveying.

2) **Channel Migration and Delta Growth Mapping –** I agree. Answering the other questions of sediment origin (bank erosion vs. upper watershed) and how much will a successful restoration project arrest bank erosion will help as well. It will be good to evaluate and understand the past, but also predict the future – there is a high supply of natural sediment. It is best to understand how much, at what rate and load it is supplied, and to have set

expectations for where and how to accommodate the inevitable deposition (albeit hopefully minimized to the extent possible by a healthy floodplain and proper stream function).

3) **Watershed Hydrology Review –** I agree and have outlined specifics above.

4) **Sediment Transport Review -** I agree. Keep in mind that somewhere along channel, even with a properly functioning stream, sediment will deposit. Use the best of technology to predict and then decide where you want it.

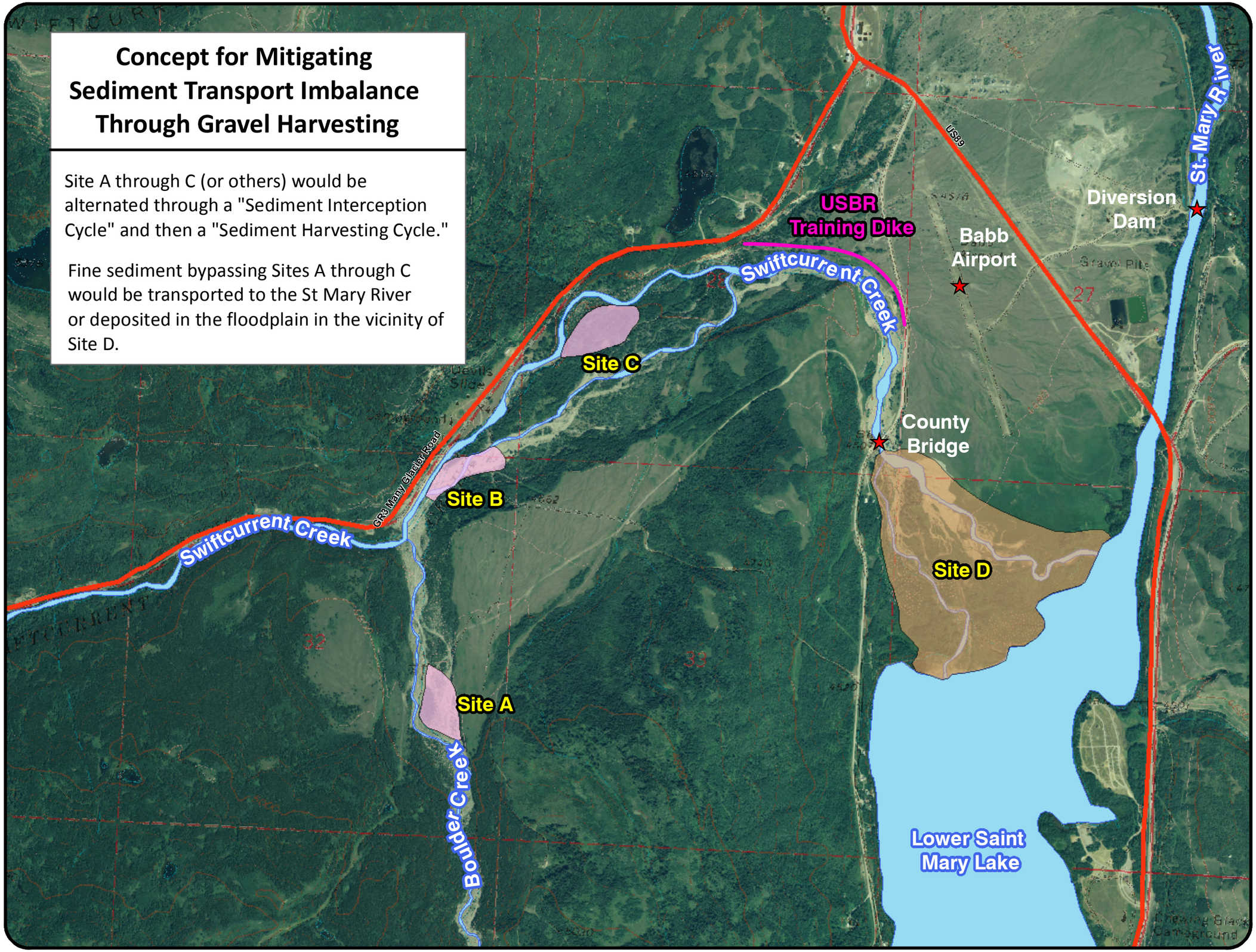
5) **Geomorphology Review –** I agree as I've discussed above.

6) **Review of Potential Mitigation Measures –** I agree. The term "harvesting of sediment" is intriguing. What exactly does this mean? I've discussed this with others on this and other projects. Rosgen spoke of a bedload collection system that he designed; it work briefly, but was soon overwhelmed because maintenance of hauling the bedload away was too consuming (in theory a very well-designed vortex system may work, but would be very experimental as well as expensive and a major commitment). Sediment collection basins have proven not to work as maintenance is always and issue and whether instream or off-stream sediment basins cause stream instability – and they always fill up and fail. My opinion is what I've said above; it's best to let Mother Nature harvest the sediment by allowing a natural area for deposition if at all possible and keep the watershed, stream, and floodplain vegetation as healthy as possible to minimize sediment production. There may be other ways to contend with harvesting sediment, but I'm unaware of them – tough problem.

Concept for Mitigating Sediment Transport Imbalance Through Gravel Harvesting

Site A through C (or others) would be alternated through a "Sediment Interception Cycle" and then a "Sediment Harvesting Cycle."

Fine sediment bypassing Sites A through C would be transported to the St Mary River or deposited in the floodplain in the vicinity of Site D.



SWIFTCURRENT CREEK STABILIZATION

Conceptual Gravel Harvesting & Aluvial Fan Stabilization

LEGEND

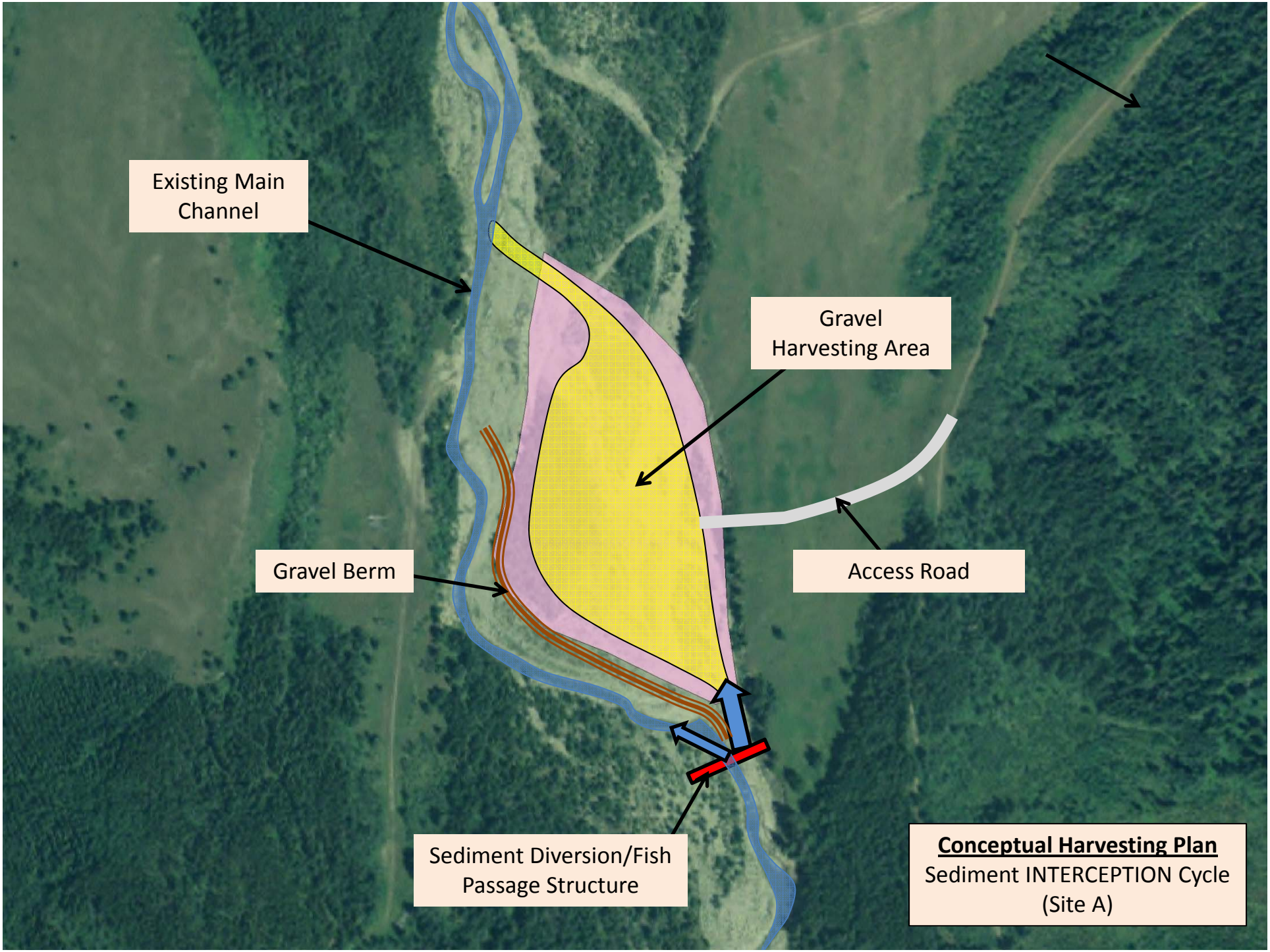
- Alluvial Fan Stabilization
- Gravel Harvesting Sites

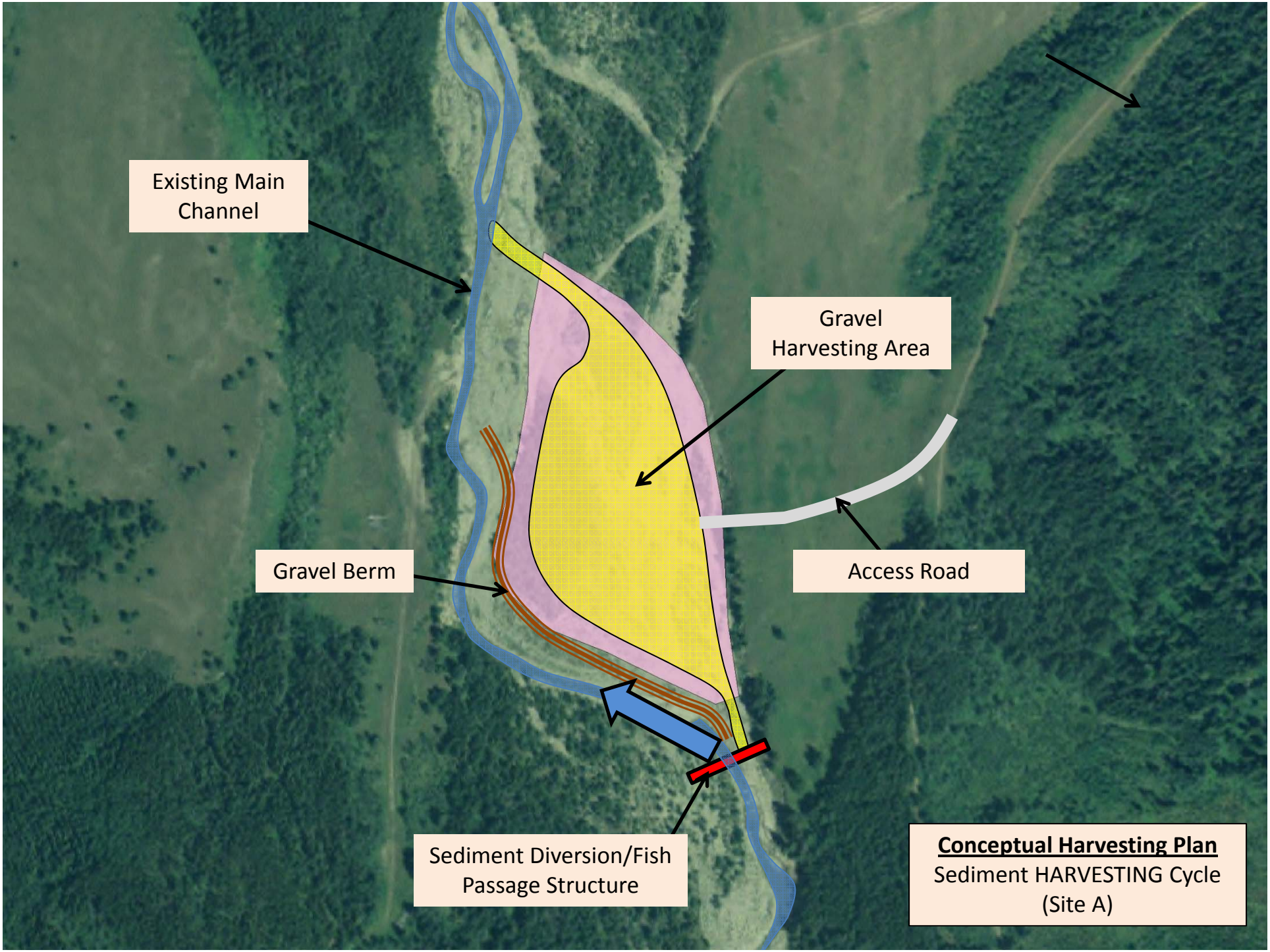
N
W E
S

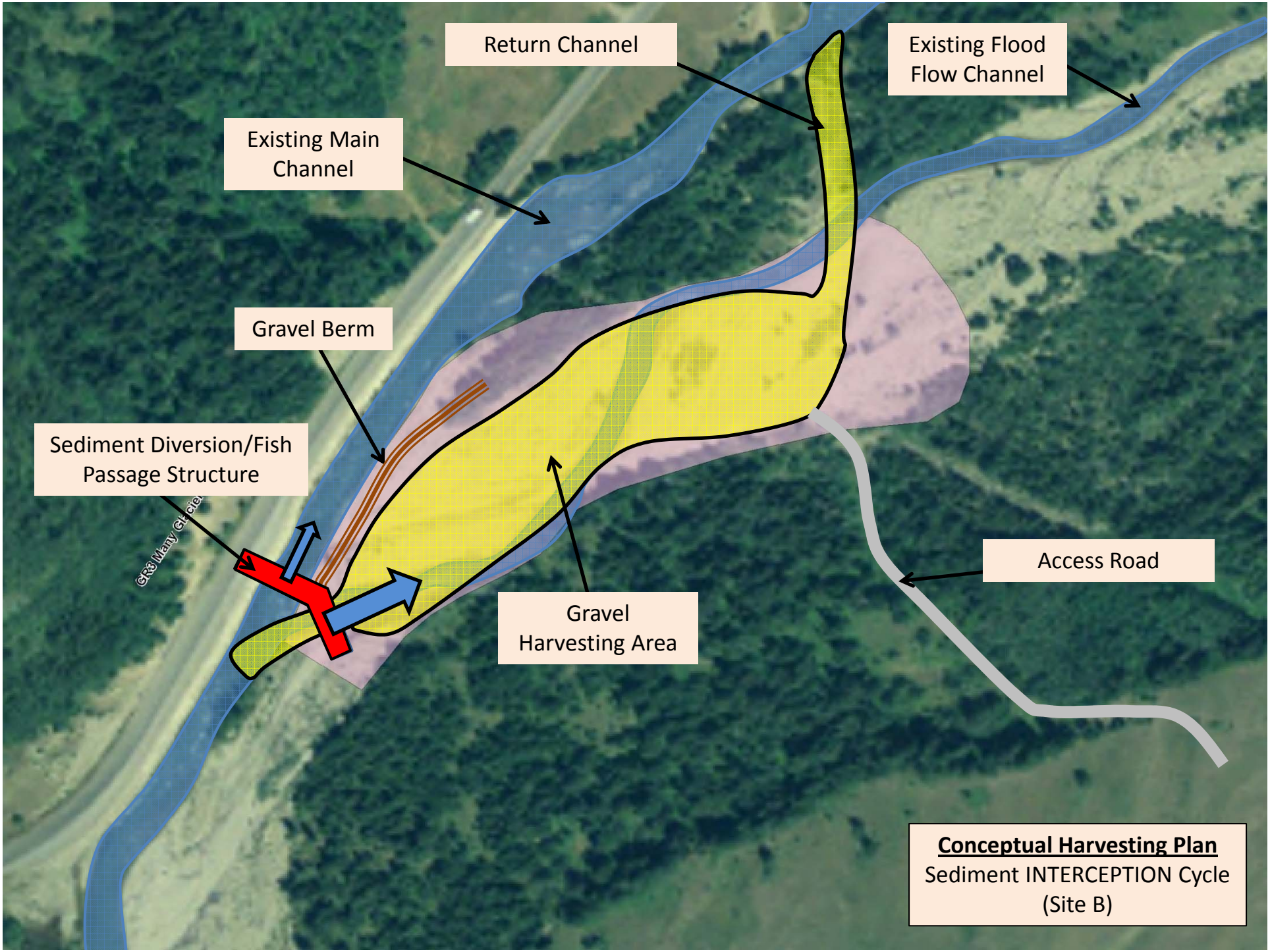
1 inch equals 1,250 feet

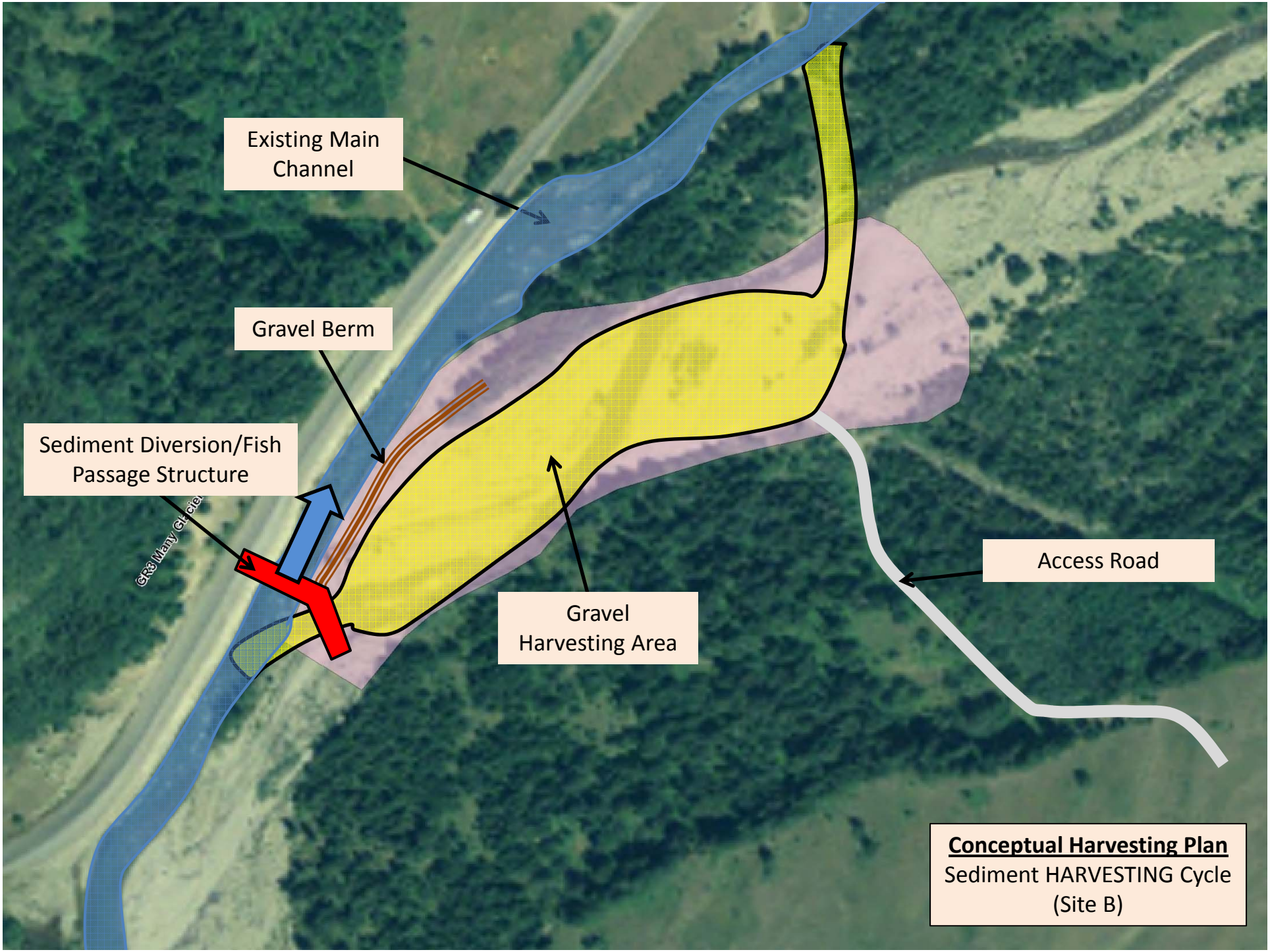
0 500 1,000 2,000 Feet

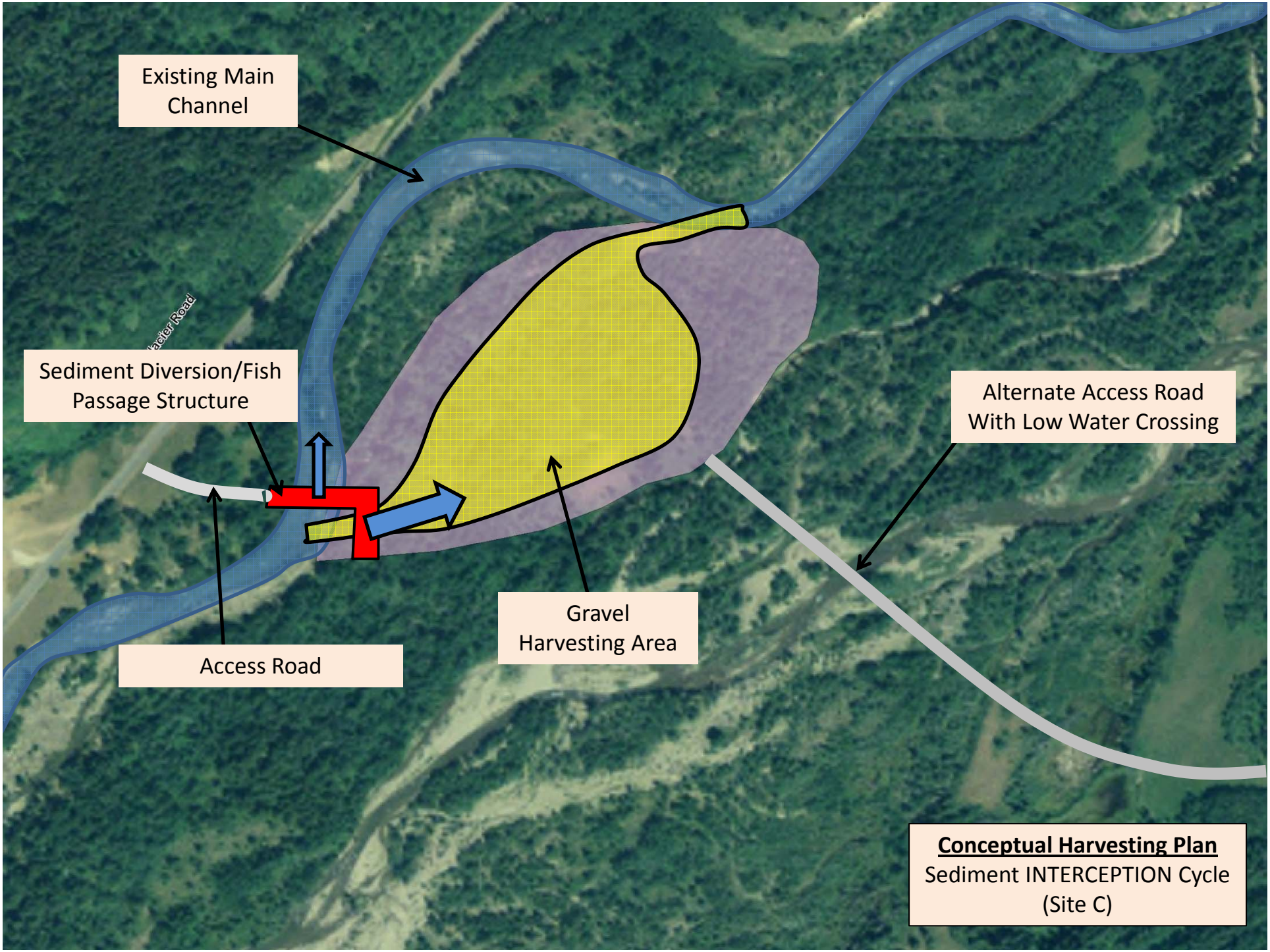
DOWL HKM

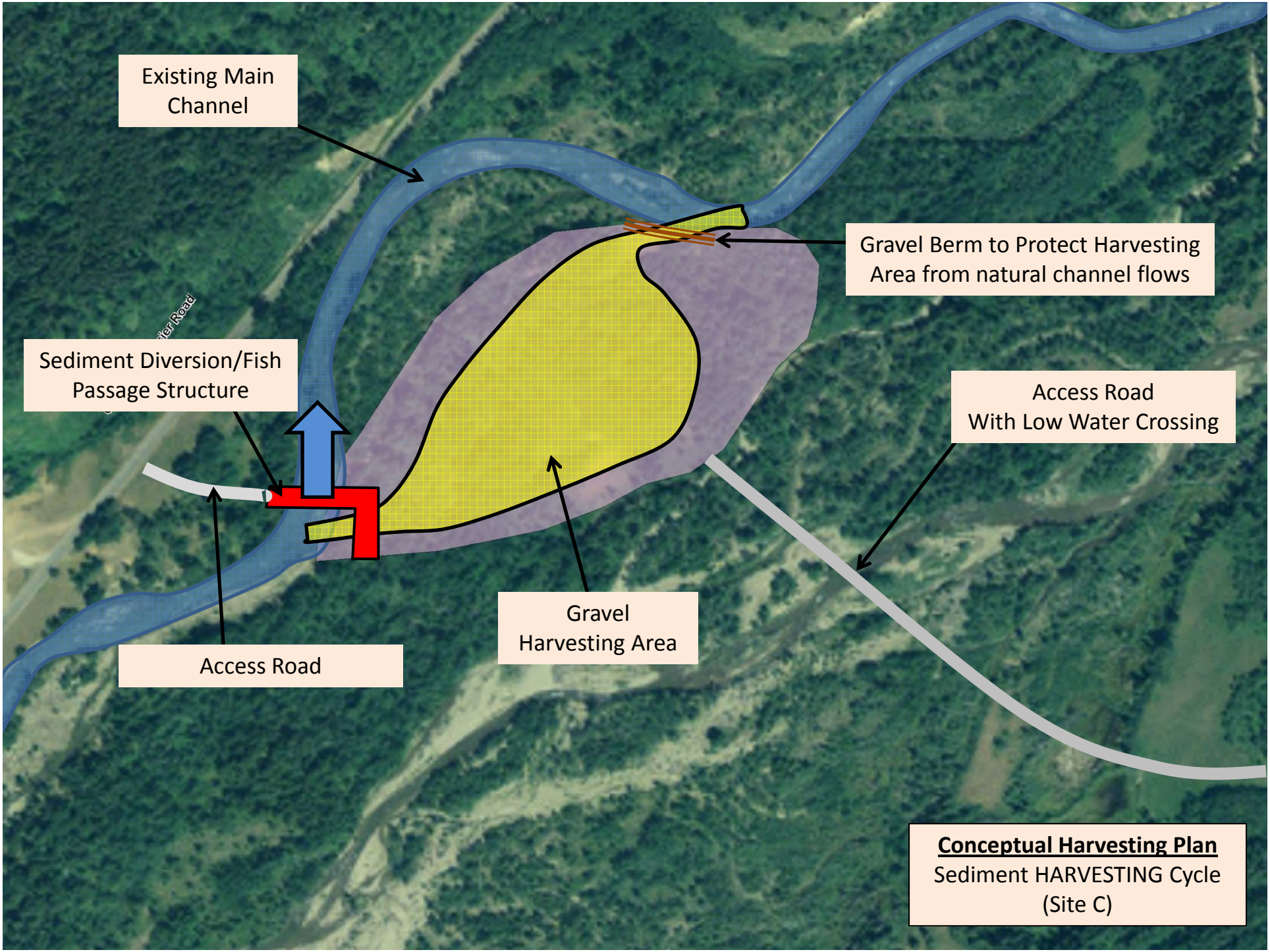

Existing Main Channel
Gravel Harvesting Area
Gravel Berm
Access Road
Sediment Diversion/Fish Passage Structure
Conceptual Harvesting Plan
Sediment INTERCEPTION Cycle
(Site A)

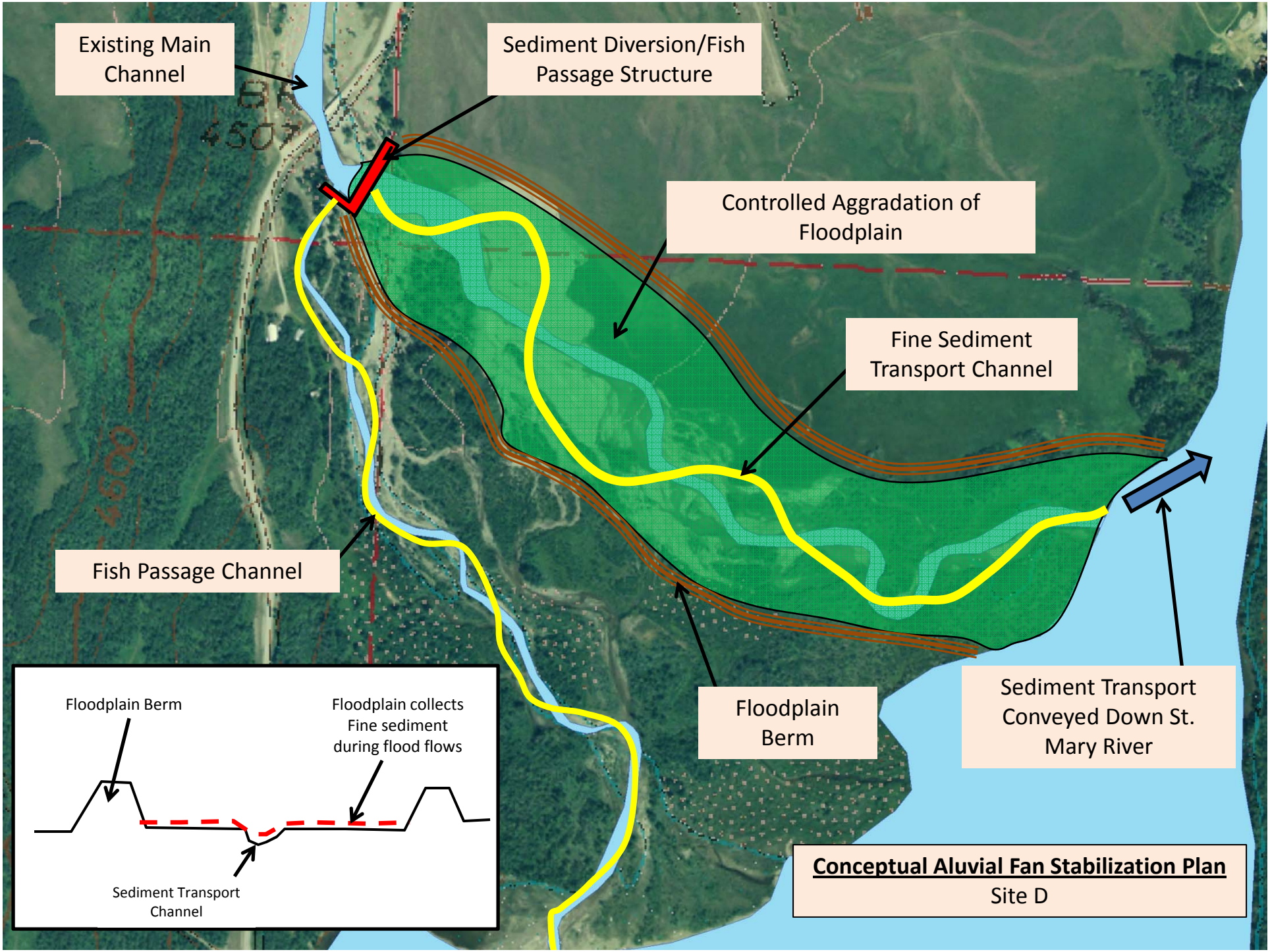

Existing Main Channel
Gravel Harvesting Area
Gravel Berm
Access Road
Sediment Diversion/Fish Passage Structure
Conceptual Harvesting Plan
Sediment HARVESTING Cycle
(Site A)


Return Channel
Existing Flood Flow Channel
Existing Main Channel
Gravel Berm
Sediment Diversion/Fish Passage Structure
Access Road
Gravel Harvesting Area
Conceptual Harvesting Plan
Sediment INTERCEPTION Cycle
(Site B)


Existing Main Channel
Gravel Berm
Sediment Diversion/Fish Passage Structure
Gravel Harvesting Area
Access Road
Conceptual Harvesting Plan
Sediment HARVESTING Cycle
(Site B)


Existing Main Channel
Sediment Diversion/Fish Passage Structure
Alternate Access Road With Low Water Crossing
Gravel Harvesting Area
Access Road
Conceptual Harvesting Plan
Sediment INTERCEPTION Cycle
(Site C)


Existing Main Channel
Gravel Berm to Protect Harvesting Area from natural channel flows
Sediment Diversion/Fish Passage Structure
Access Road With Low Water Crossing
Gravel Harvesting Area
Access Road
Conceptual Harvesting Plan
Sediment HARVESTING Cycle
(Site C)


Existing Main Channel
Sediment Diversion/Fish Passage Structure
Controlled Aggradation of Floodplain
Fine Sediment Transport Channel
Fish Passage Channel
Floodplain Berm
Sediment Transport Conveyed Down St. Mary River
Floodplain Berm
Floodplain collects Fine sediment during flood flows
Sediment Transport Channel
Conceptual Aluvial Fan Stabilization Plan
Site D