Lower Big Hole Irrigation Infrastructure Survey and Prioritization

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Executive Summary

This study provides an inventory of irrigation infrastructure along the lower 44.2 miles of the Big Hole River and prioritizes irrigation infrastructure improvement projects that will lead to improved irrigation efficiency and also benefit in-stream flows. A secondary component of this study is to evaluate the extent of floodplain and streambank alterations due to irrigation diversions, floodplain berms and riprap.

During this assessment, a total of 45 irrigation diversions were identified in the lower Big Hole River, with 34 diversions located on the mainstem of the lower Big Hole River and significant side channels. These 34 diversions are the primary focus of this assessment. This equates to 0.8 diversions per mile or 1 diversion every 1.25 miles. Diversions along the lower Big Hole River divert water through an extensive irrigation ditch network, of which 259 miles were mapped in GIS using color aerial imagery. In addition, a total of 8.0 miles of riprap and floodplain berms were identified within the study area, with streambank alterations covering 18% of the lower 44.2 miles of the Big Hole River, while accelerated streambank erosion was identified along 1.0 miles of the lower Big Hole River.

The results of this assessment were used to develop an irrigation infrastructure improvement priority matrix in which irrigation diversions were ranked based on existing conditions and the potential for improvement, with the goal of providing benefits for both irrigation water management and in-stream flows. Two of the 34 diversions identified on the lower Big Hole River and significant side channels in this study serve two separate ditches. Thus, there are a total of 36 diversions included within the priority matrix. Out of the 36 diversions assessed using the priority matrix, a total of 6 diversions were rated a very high priority, 12 diversions were rated a high priority, 11 diversions were rated a moderate priority and 3 diversions were rated a low priority. Due to a lack of data, four diversions on the mainstem of the lower Big Hole River were not assessed with the priority matrix.

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1.0 Introduction

A study of irrigation infrastructure was undertaken along the lower 44.2 miles of the Big Hole River to identify the condition of existing irrigation infrastructure and to assess the potential for irrigation infrastructure improvements that will increase both irrigation water management efficiency and in-stream flows, while allowing for the continuation of natural channel processes. A secondary component of this study was to evaluate the extent of floodplain and streambank alterations due to irrigation diversions, floodplain berms and riprap. The goals of this study are to:

1. Evaluate the potential for the improvement of irrigation infrastructure while also providing for increased in-stream flows.

2. Evaluate the extent of floodplain and streambank alterations due to irrigation diversions, floodplain berms and riprap.

To accomplish these goals, a detailed inventory and assessment of irrigation diversions and the extent of the irrigation ditch network was conducted, along with an assessment of the extent of riprap and floodplain berms. This data was used to develop an irrigation infrastructure improvement priority matrix in which each diversion was rated based on the following factors:

- Potential for improved water management efficiency
- Potential to benefit in-stream flows
- Existing and future diversion and ditch maintenance requirements
- Influence of diversions on sediment transport and natural channel processes
- Potential to maintain or improve fish habitat
- Level of reach scale impacts
- Ownership, interest level and willingness of responsible parties

2.0 Methods

To inventory and assess irrigation diversions along the lower Big Hole River, a review of the existing data was performed, followed by a "float survey" through the study area and interviews with irrigators. Irrigation diversions, riprap, floodplain berms, log revetments, barbs, accelerated streambank erosion, and fish habitat features were mapped using GPS during the "float survey", which was conducted along the entire lower Big Hole River between Maiden Rock Canyon and the High Road Bridge between November 3rd and November 16th. Once the "float survey" was completed, follow-up meetings with irrigators were conducted on November 27th and 28th and December 6th and 7th, with additional phone interviews conducted in December and February. A description of the methods employed in each phase of this study is provided in the following sections.

2.1 Existing Data Review

During the existing data review, streamflow data from the United States Geological Survey (USGS), Montana Department of Natural Resource Conservation (DNRC) and the Montana Department of Environmental Quality (DEQ) were assessed. Additional information regarding groundwater-surface water interactions was also reviewed from one study performed by the Montana Bureau of Mines and Geology (MBMG) within the project area.

2.2 GIS Analysis

Existing GIS data and color aerial imagery from 2005 (National Agricultural Imagery Program) was used to assess the location of irrigation diversions, the extent of the irrigation ditch network, channel encroachment by roads and structures, and water rights Points of Diversion (POD) and Places of Use (POU). GIS was also used to map the project area and to delineate the current channel margin of the Big Hole River, including side channels and sloughs.

2.2.1 Project Area

For this study, the project area was considered to be the Big Hole River valley bottom between the mouth of Maiden Rock Canyon and the confluence with the Jefferson River, which is referred to as the "Lower Big Hole River Valley" in this report. The delineated project boundary attempts to include all areas that Big Hole River water is used to support agricultural irrigation. Once the valley bottom and river channel were delineated, potential irrigation diversions were identified and maps were created for use during the field assessment portion of the study.

2.2.2 Irrigation Ditch Network

The irrigation ditch network was delineated in GIS using color aerial imagery from 2005. The irrigation ditch network developed through this process was then revised following the field assessment and discussions with irrigators. The irrigation ditch network developed during this assessment should be considered a working GIS layer for future assessments since it is not complete, especially in areas where many small ditches transect fields used for flood irrigation.

2.2.3 Road and Structure Encroachment

Encroachment of the river channel by roads and structures was identified using existing GIS data and color aerial imagery from 2005. Road encroachment was assessed using the Montana Department of Administration road layer (published 02/10/2007). Sections of road not included in this GIS data layer were delineated based on the 2005 color imagery. Structures identified in this assessment include houses and other buildings located within the study area. Structures were delineated using the 2005 color imagery by placing a point on the structure or in the center of a "group of structures", thus providing a general overview of floodplain development and channel encroachment. Encroachment by roads and structures was then assessed by identifying structures and sections of road that are within 150 feet and 300 feet of the Big Hole River channel margin.

2.2.4 Water Rights

An initial assessment of diversions on the mainstem of the Big Hole River was performed using the Montana DNRC Points of Diversion (POD) and Places of Use (POU) GIS data layers for the Big Hole 4th code HUC. The POD file was queried by source name (SRCNAME) using the "Big Hole River" and source type (SRCTYPE) using "surface water" to identify diversions that use surface water directly from the Big Hole River.

2.3 Field Data Collection

Field data collection consisted of two components: first, a "float survey" using a kayak was conducted between Maiden Rock Canyon and the High Road Bridge; and, second, site visits and phone interviews were conducted with irrigators. During the "float survey" and the follow-up site visits, information on diversion dams, headgates, and the irrigation ditch network was collected. In addition, the extent of riprap, floodplain berms, log revetments, barbs and accelerated bank erosion were assessed during the "float survey", with an emphasis on streambank alterations associated with irrigation infrastructure. Information on fish habitat and channel features was also collected in the field, with a focus on potential spawning habitat. For the purposes of this assessment, the following terms are defined:

Diversion Feature Types

Initial diversion = diversion dam or weir located upstream of the headgate that directs water down a side channel or diversion channel toward the headgate

Headgate, diversion = headgate associated in close proximity with some sort of diversion dam or weir that directs the flow toward the headgate

Headgate = headgate not associated with flow diversion structure in the immediate vicinity, generally located in a diversion channel, ditch or slough

Streambank Feature Types

Riprap = large angular rocks placed along the bank with the intention of protecting some sort of structure or infrastructure

Riprap, floodplain berm = large angular rocks placed along the bank at an elevation above the floodplain elevation, also applied when the feature only appears to be protecting the floodplain and not associated with any structures

Floodplain berm = gravels and cobbles (channel material) piled on the floodplain to reduce lateral channel migration

Log revetment = logs placed in manner similar to rock riprap

Barb = large angular rocks placed at a single point in channel, intended to deflect the flow away from the bank

Accelerated bank erosion = streambank erosion that appears to be related to irrigation infrastructure

Channel Feature Types

Habitat = habitat feature, primarily observed spawning gravels

2.3.1 Headgates and Diversion Dams

Headgates and diversion dams were mapped during the "float survey" using GPS. Color maps depicting the 2005 aerial imagery with potential diversions identified during the initial phase of this assessment were used in the field as a guide. At each diversion, digital photographs were taken and field notes were recorded. Ditch dimensions and the potential flow were also estimated. Due to the presence of multiple channels in several areas, it was only possible to assess one channel during the "float survey". When multiple channels were encountered, field maps were used to identify which channel should be floated to assess a diversion, though some diversions may have been missed. Additional discussions with irrigators were used to provide information on diversions that may have been missed during the "float survey".

2.3.2 Streambank Alterations

Riprap, floodplain berms, log revetments and barbs were mapped in the field using GPS and digital photographs. Following the "float survey", these streambank alterations were delineated in GIS using color aerial imagery, along with field recorded GPS points and site photos. This assessment technique quantified areas of large and extensive riprap, while areas with "smaller" riprap which may have become re-vegetated may not be accounted for in all circumstances. In addition, it is expected that there is a significant amount of riprap and floodplain berms that have been "abandoned" as the channel course shifted. In general, these features were not assessed, except when still connected to riprap that is adjacent to the channel. Thus, the amount of riprap identified in this assessment should be interpreted as the "minimum" amount. There is likely a much greater amount of "smaller" riprap and historic floodplain berms that were not quantified in this assessment, much of which may not be located along the active channel.

2.3.3 Accelerated Streambank Erosion

This assessment primarily focused on areas of accelerated bank erosion associated with irrigation infrastructure. These features were mapped in GIS using GPS data and digital photographs collected in the field. Naturally eroding banks can be expected in this river system and were not included in this assessment, nor were areas of accelerated bank erosion due to non-irrigation related causes in most instances.

2.3.4 Potential Spawning Sites

While a detailed assessment of fish habitat features was beyond the scope of this assessment, observed potential spawning sites were recorded. This was possible since the "float survey" was performed between November 3rd and November 16th, which coincides with the brown trout spawning period. Potential spawning sites were identified as cleared gravels and redds observed in the appropriate hydrologic areas, which tended to be at the downstream end of pools and glides and upstream of riffles. These sites were most often observed in braided channel areas, where the pool-glide-riffle sequences were most pronounced. Several side channels that are maintained as diversion channels also appeared to provide ideal spawning conditions.

3.0 Results

For the purpose of this assessment, the lower Big Hole River was broken into seven reaches based on the location of Montana Fish, Wildlife and Parks (FWP) Fishing Access Sites (FAS) (**Table 3-1)**. The results of this study will be presented within the context of these seven reaches in the following sections.

Table 3-1. Reach Descriptions.

Reach Name	Reach Number	Reach Length (miles)
Maiden Rock to Melrose/Salmon Fly	1	5.8
Melrose/Salmon Fly to Brown's Bridge	2	6.3
Brown's Bridge to Glen	3	7.3
Glen to Notch Bottom	4	7.2
Notch Bottom to Pennington Bridge	5	9.7
Pennington Bridge to High Road Bridge	6	6.2
High Road Bridge to Jefferson River	7	1.8
TOTAL		**44.2**

3.1 Existing Data Review

The results from the existing data review phase of this study are presented below. This information was used to guide the data collection phase of the study and to facilitate the development of the irrigation infrastructure improvement priority matrix.

3.1.1 Streamflow Data

Streamflow data collected by the USGS and Montana DNRC was assessed to provide an estimate of losses to streamflow due to irrigation withdrawals progressing downstream. Where available, streamflow data was reviewed for the July 1st through September 30th timeframe between 2001 and 2007. The complete streamflow dataset is presented in **Appendix A**.

Three USGS gaging stations were included in this assessment:

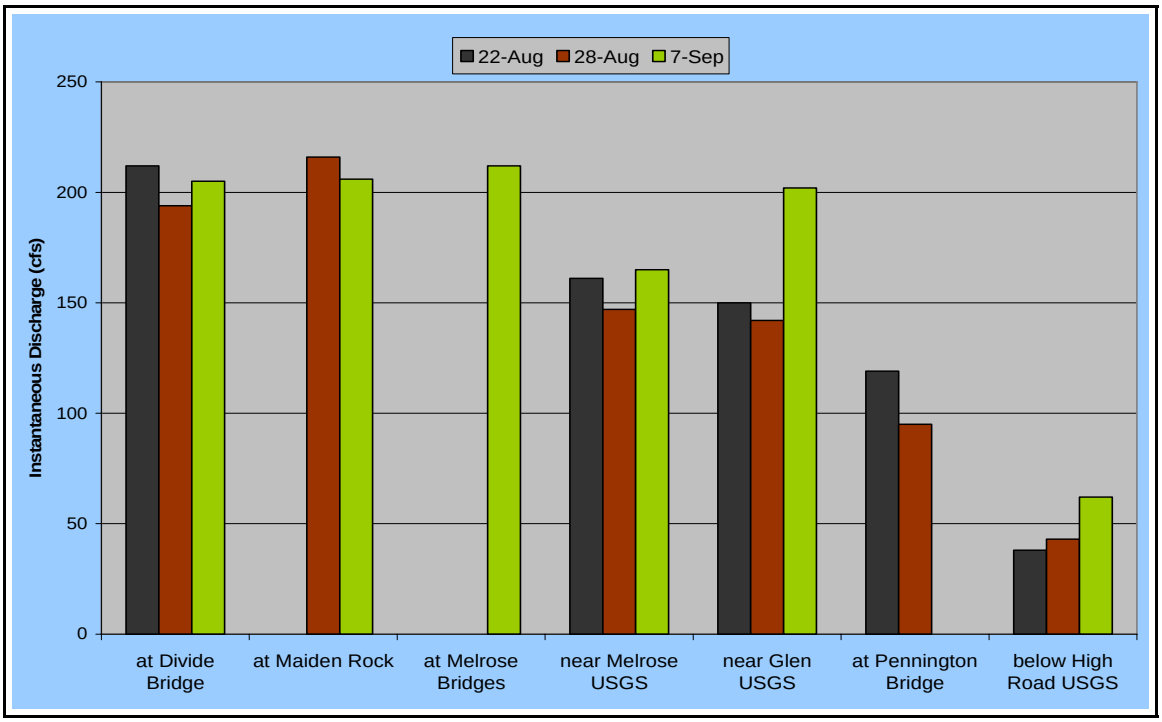
- near Melrose (06025500)
- near Glen (06026210)
- below Hamilton Ditch near Twin Bridges (06026420)

The USGS near Melrose gage is located just downstream of the Kalsta Bridge, which is approximately 7 miles downstream of the town of Melrose, while the USGS near Glen is located downstream of Notch Bottom, which is approximately 8 miles downstream of the town of Glen. The USGS below Hamilton Ditch near Twin Bridges gage is located downstream of the High Road Bridge. Streamflow data from the USGS near Melrose and near Glen gages was reviewed from 2001-2007, while the USGS below Hamilton Ditch gage came online in 2007, so only one

year of data collected by the USGS was available. Additional streamflow data recorded at the High Road Bridge was obtained from Montana DNRC, which maintained a measuring device at this site between 2001 and 2004, while the Jefferson River Watershed Council collected the data in 2005 and 2006. Montana DNRC also operated measuring devices at Divide Bridge and Pennington Bridge in 2007 and made synoptic flow measurements at several sites in August of 2007.

Streamflow measurements performed at the Divide Bridge, at the bridge in Maiden Rock Canyon, at the Melrose Bridge and at the USGS near Melrose gage downstream of the Kalsta Bridge suggest that streamflow remains relatively stable between the Divide Bridge and the Melrose Bridge and then decreases between the Melrose Bridge and the USGS near Melrose gage (**Figure 3-1**). Synoptic streamflow measurements at the Divide Bridge, the bridge in Maiden Rock Canyon, and the Melrose Bridge documented flows of 205, 206 and 212cfs, respectively, on September 7th, 2007. Synoptic streamflow measurements between the Melrose Bridge and the USGS near Melrose gage, recorded a decrease of 47cfs between the two sites on September 7th, 2007. During the summer of 2007, mean daily streamflow decreased by an average of 28cfs between the Divide Bridge and the USGS near Melrose gage (**Table 3-2**).

Figure 3-1. Lower Big Hole River Synoptic Streamflow Measurements, August 2007.



Data and figure provided courtesy of Dave Amman, Montana DNRC

Streamflow data from the USGS near Melrose gage located downstream of the Kalsta Bridge and at the USGS near Glen gage located downstream of Notch Bottom, indicate that streamflows tend to increase between these two sites. USGS gaging station data from 2001-2007 indicate that between July 1st and September 30th mean daily streamflows increased between these two sites in 5 out of the past 7 years, with an average increase in streamflow of 22cfs (**Table 3-2**). During the 2007 synoptic measurements, streamflows decreased slightly between the two sites during the two August monitoring events, but then increased during the September 7th monitoring event (**Figure 3-1**).

Table 3-2. Streamflow Gains and Losses (cfs), July 1-September 30, 2001-2007.

Reach	2001	2002	2003	2004	2005	2006	2007
Divide Bridge to Melrose							-28
Melrose to Glen	+26	+53	+51	+15	-4	-14	+29
Glen to Pennington Bridge							-38
Pennington Bridge to High Road Bridge							-84
Glen to High Road Bridge	-139	-181	-142	-147	-149	-139	-139
Divide Bridge to High Road Bridge							-119

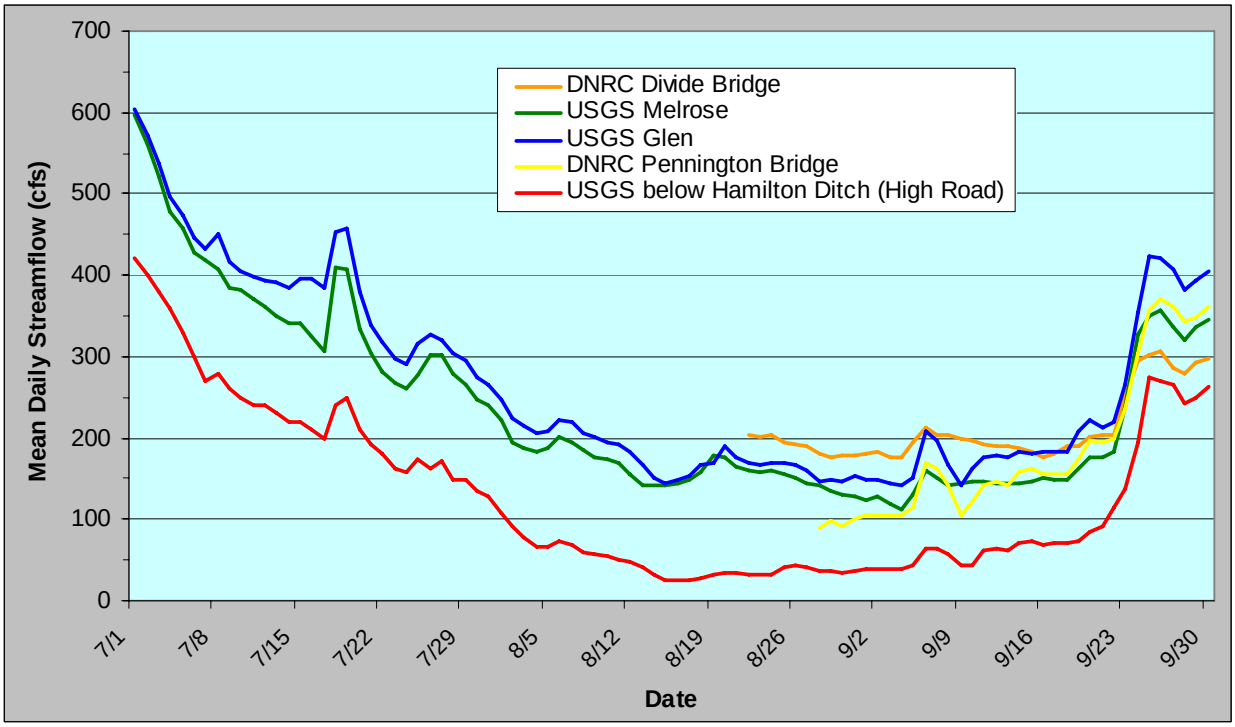
USGS near Melrose gage located downstream of Kalsta Bridge
USGS near Glen gage located downstream of Notch Bottom
USGS below Hamilton Ditch gage located downstream of High Road Bridge
Divide Bridge and Pennington Bridge monitored by Montana DNRC

Streamflow measurements between the USGS near Glen gage, which is located downstream of Notch Bottom, and Pennington Bridge indicate that streamflow decreases in this section of river. Downstream of the USGS near Glen gage, streamflow was observed to decrease during the 2007 synoptic measurements, with flows at Pennington Bridge 31cfs lower than at the Notch on August 22nd and 47cfs lower than at the Notch on August 28th (**Figure 3-2**). In the summer of 2007, mean daily streamflow decreased by an average of 38cfs between the USGS near Glen gage and Pennington Bridge (**Table 3-2**).

Streamflow measurements between Pennington Bridge and the USGS gage below Hamilton Ditch, which is downstream of the High Road Bridge, indicate that streamflow decreases in this section of river. During the 2007 synoptic measurements, streamflow between the two sites decreased by 81cfs on August 22nd and 52cfs on August 28th (**Figure 3-1**). In the summer of 2007, mean daily streamflow decreased by an average of 84cfs between Pennington Bridge and the USGS below Hamilton Ditch gage (**Table 3-2**).

Based on this assessment, streamflows appear to decrease between Maiden Rock Canyon and USGS near Melrose gage and then remain stable or slightly increase between the USGS near Melrose and the USGS near Glen gages (**Figure 3-2**). Downstream of the USGS near Glen gage, mean daily streamflows between 2001 and 2007 decreased by an average of 148cfs, while mean daily streamflow decreased by an average of 119cfs between the Divide Bridge and the High Road Bridge in 2007 (**Table 3-2**).

Figure 3-2. Mean Daily Streamflows, July 1-September 30, 2007.



3.1.2 Ditch Flow Data

In addition to Big Hole River streamflows, measured and estimated flows of several ditches performed by Montana DEQ as part of a temperature study in July of 2006 were also reviewed (Flynn et. al. 2008). Ditch flows are presented relative to USGS gaging stations and DNRC flow measuring sites as discussed in the previous section. Ditch flows utilized to model temperature are described within this section and **Table 3-3.** This data represents measurements and estimates from one week in late July of 2006 that were used to model the relationship between streamflow on water temperature. Additional ditch flow data is required to verify the accuracy of the flows presented in the following discussion.

There are several major diversions between the Divide Creek Bridge and the Melrose Bridge, including Upper McCauley, Lower McCauley and the Melrose Canal, along with an un-named diversion (D19) in Maiden Rock Canyon. There are also several smaller diversions. During temperature monitoring in 2006, Montana DEQ measured 20.7cfs at the Upper McCauley diversion and 16.7cfs at D19. Montana DEQ estimated 10.6cfs was diverted on July 26th at Lower McCauley and 6.5cfs was diverted at the Melrose Canal, for an estimate of approximately 17cfs between the two diversions based on measurements performed at the inlet and overflow of the diversion channel which feeds both of these diversions.

Major diversions between the Melrose Bridge and the USGS near Melrose gage include Pendergast-Spears-McCullough, Gallagher Ditch, Hagenbarth's Big Hole Ditch and Kalsta's. During temperature monitoring in 2006, approximately 21cfs were measured between the

Pendergast-Spears-McCullough and Gallagher ditches on July 27th, with 5.5cfs measured at the Pendergast-Spears-McCullough diversion and 15.7cfs measured in the Gallagher Ditch. It was estimated that 11.8cfs were diverted at Kalsta's and 20.7cfs were diverted at Hagenbarth's Big Hole Ditch.

Major diversions between the USGS near Melrose gage and the USGS near Glen gage include the Garrison/Kilwien diversion, along with Rafferty's Upper and Lower South Side ditches. There are also several smaller diversions. At the Garrison/Kilwien diversion, a flow of 35.3cfs was estimated. A flow of 6.2cfs was measured in Rafferty's Upper South Side ditch on July 29th, 2006, while a flow of 8.4cfs was measured in the Lower South Side ditch, for a combined flow of approximately 15cfs between these two ditches.

The Pageville Canal is the major diversion between the USGS near Glen gage and Pennington Bridge. A flow of 58.0cfs was measured in this diversion during temperature monitoring on July 30th, 2006. A portion of the water used in the Pageville Canal ends up in the Beaverhead River. Other substantial diversions within this reach include JS Ranch (Larson-Naranchich), the Sandy Ditch, and the Naranchich Ditch.

The Big Hole Co-op Ditch is the major diversion between Pennington Bridge and the USGS below Hamilton Ditch gage. This ditch carried a flow of 77.6cfs when measured on July 30th during the 2006 temperature monitoring project. A portion of the water used in the Big Hole Co-op Ditch ends up in the Beaverhead River. Additional ditches in this reach estimated to carry between 5cfs and 10cfs in 2006 include the Orphan Home, Logan-Smith and Lott-Harvey ditches. The Hamilton Ranch ditch also has the capacity to carry a substantial amount of water.

Table 3-3. Ditch Flow Data Collected during the 2006 DEQ Temperature Study.

Site	Diversion Name	Ditch Flows used in Temperature Model (cfs)
DNRC Divide Bridge site		
DNRC Maiden Rock Canyon site		
D18	Upper McCauley	20.7
D19	Meriwether's	16.7
D20	Lower McCauley	10.6*
D21	Melrose Canal	6.5*
D24	Carpenter's	5.8
DNRC Melrose Bridge site		
D11a	Pendergast-Spears-McCullough	5.5
D11b	Gallagher Ditch	15.7
D12	Kalsta's	11.8*
D13	Hagenbarth's Main Ditch	20.7
USGS near Melrose gage		
D14	Hagenbarth's River Field Ditch	6.1
D15	Gainy's	2.5
D16	Garrison/Kilwien	35.3*
D26	Garrison's Wild Hay Ditch	4.0*
D27	Rafferty's Upper South Side	6.2
D28	Rafferty's Lower South Side	8.4
D37	Bryan Ditch	4.3
USGS near Glen gage		
D4	JS Ranch (Larson-Naranchich)	26.5
D2	Sandy Ditch	4.7
D3	Pageville Canal	58.0
D5	Naranchich	21.2*
DNRC Pennington Bridge site		
D6	Big Hole Co-op Ditch	77.6
D8	Orphan Home	9.5
D9	Logan-Smith	6.1*
D10	Lott-Harvey	9.6
D36	Hamilton ("Ranch") Ditch	1.7
USGS below Hamilton Ditch near Twin Bridges gage (High Road Bridge)		

*Estimated

3.1.3 Temperature Data

Montana DEQ assessed the existing thermal regime in the Big Hole River based on temperature and streamflow data collected in July of 2006 using the Heat Source v7.0 model. Areas of concern identified during this assessment include river km-50 near the USGS near Melrose gage and the entire lower 20-km of the river, which includes the area downstream of Notch Bottom. This study concluded that:

> *"Flow alteration is the most significant contributor to warming of the river, and subsequently, the most feasible alternative for returning the Big Hole River to a more natural thermal regime"* (MDEQ 2008).

This study also found that geologic controls in Maiden Rock Canyon and at Notch Bottom lead to a substantial amount of ground water accretion, leading to localized increases in streamflow.

3.1.4 Ground Water Data

Irrigation practices within the Big Hole watershed influence interactions between surface water and ground water in the basin. A study conducted by Montana Bureau of Mines and Geology found that most gains in aquifer storage occurred in May and June when 30,000 acre-feet were added to the aquifer in the lower basin, which the study defined as from Maiden Rock to Notch Bottom (Marvin and Voeller 2000). This study found that ground water storage was near its maximum by July and was relatively stable due to a dynamic equilibrium between irrigation recharge of the aquifer through leaky ditches and ground water discharge to surface water. Ground water storage was found to decline during August and September and most of this water was thought to be lost to evapotranspiration (the sum of evaporation and plant transpiration) rather than discharging to surface water. Once irrigation ceased, an average gain of 90cfs in streamflow was directly attributed to irrigation return flows in October and November between Maiden Rock Canyon and Notch Bottom (Marvin and Voeller 2000).

3.2 GIS Analysis

GIS analysis included the development of an irrigation ditch network, identification of road and structure encroachment, and a review of water rights.

3.2.1 Irrigation Ditch Network

A total of 37 irrigation ditches were identified and 259 miles of irrigation ditch were mapped along the lower Big Hole River (**Table 3-4**). This assessment suggests that the greatest potential to divert water for irrigation purposes exists in Reaches 3, 5, and 6, with the highest potential between Pennington Bridge and High Road Bridge. An overview of the irrigation ditch network in the lower Big Hole River Valley is provided in **Figure 3-3 (Appendix B)**.

Table 3-4. Irrigation Ditch Network.

Reach Name	Reach Number	Reach Length (miles)	Ditch Length (miles)	Ditch Length to Reach Length Ratio
Maiden Rock to Melrose/Salmon Fly	1	5.8	24.1	4.2
Melrose/Salmon Fly to Brown's Bridge	2	6.3	11.9	1.9
Brown's Bridge to Glen	3	7.3	53.0	7.3
Glen to Notch Bottom	4	7.2	15.9	2.2
Notch Bottom to Pennington Bridge	5	9.7	72.2	7.5
Pennington Bridge to High Road Bridge	6	6.2	70.0	11.3
High Road Bridge to Jefferson River	7	1.8	11.9	6.8
TOTAL		**44.2**	**259.0**	**5.9**

3.2.2 Road and Structure Encroachment

Road and structure encroachment was assessed to determine areas where natural channel processes are limited by existing structures and infrastructure. A total of 185.3 miles of road were identified in the lower Big Hole River valley, with 18.7 miles of roads within 150 feet of the river channel and 36.8 miles of road within 300 feet of the river channel (**Figure 3-4** in **Appendix B, Table 3-5)**. A total of 172 structures or "groups of structures" were identified in the Lower Big Hole River Valley. Of these, 23 structures were within 150 feet of the stream channel and 54 structures were within 300 feet of the river channel. This equates to one structure every 1.3 miles, though, in actuality, much of the structure encroachment occurs around the towns of Melrose and Glen. Of the 54 structures within 300 feet of the river channel, 6 (11%) were associated with riprap and floodplain berms mapped during this assessment. Based on this assessment, it appears that encroachment of the river channel by roads likely restricts lateral channel migration to a larger extent than structures at this time. Impacts due to roads are most apparent at bridge crossings which effectively restrict the floodprone area and prevent lateral channel migration.

Table 3-5. Road Encroachment.

Reach Name	Reach Number	Reach Length (miles)	Length of Road within 150 Feet (miles)	Length of Road within 300 Feet (miles)
Maiden Rock to Melrose/Salmon Fly	1	5.8	4.4	7.8
Melrose/Salmon Fly to Brown's Bridge	2	6.3	0.8	2.7
Brown's Bridge to Glen	3	7.3	4.1	7.6
Glen to Notch Bottom	4	7.2	3.6	6.4
Notch Bottom to Pennington Bridge	5	9.7	4.1	8.8
Pennington Bridge to High Road Bridge	6	6.2	1.4	3.1
High Road Bridge to Jefferson River	7	1.8	0.3	0.5
TOTAL		**44.2**	**18.7**	**36.8**

Table 3-6. Structure Encroachment.

Reach Name	Reach Number	Reach Length (miles)	Number of Structures within 150 Feet	Number of Structures within 300 Feet
Maiden Rock to Melrose/Salmon Fly	1	5.8	0	10
Melrose/Salmon Fly to Brown's Bridge	2	6.3	1	2
Brown's Bridge to Glen	3	7.3	15	25
Glen to Notch Bottom	4	7.2	0	4
Notch Bottom to Pennington Bridge	5	9.7	7	12
Pennington Bridge to High Road Bridge	6	6.2	0	1
High Road Bridge to Jefferson River	7	1.8	0	0
TOTAL		**44.2**	**23**	**54**

While providing an indicator of overall floodplain development densities, road and structure encroachment data was deemed unsuitable for use in the irrigation infrastructure improvement priority matrix.

3.2.3 Water Rights

Analysis of the Montana DNRC Points of Diversion GIS data layer indicates there are 257 claimed points of diversion along the lower 44.2 miles of the Big Hole River serving irrigation, stock and other purposes (**Table 3-7**). A total of 227 individual water rights claims and permits and a total of 66 distinct points of diversion were identified in the Points of Diversion GIS data layer, which maps water rights claims and permits based on the section-township-range legal land description. Based on this dataset, the number of claimed points of diversion per mile was calculated for use in the priority matrix. This assessment indicates that Reach 6 has the most claimed points of diversion per mile, with more than twice as many as any other reach. DNRC Points of Diversion that claim Big Hole River surface water as a source are presented in **Figure 3-3 (Appendix B)**.

Table 3-7. DNRC Points of Diversion.

Reach Name	Reach Number	Reach Length (miles)	Claimed Points of Diversion	Claimed Points of Diversion / Mile
Maiden Rock to Melrose/Salmon Fly	1	5.8	35	6.1
Melrose/Salmon Fly to Brown's Bridge	2	6.3	13	2.1
Brown's Bridge to Glen	3	7.3	30	4.1
Glen to Notch Bottom	4	7.2	23	3.2
Notch Bottom to Pennington Bridge	5	9.7	47	4.9
Pennington Bridge to High Road Bridge	6	6.2	108	17.4
High Road Bridge to Jefferson River	7	1.8	1	0.6
TOTAL		**44.2**	**257**	**5.8**

3.3 Field Data Assessment

The field data collection phase of this study involved a "float survey" to map irrigation diversions, riprap, floodplain berms, log revetments, barbs, accelerated streambank erosion, and fish habitat features using GPS. Once the "float survey" was completed, follow-up meetings with irrigators were conducted. Information collected during this phase of the study is provided by reach in the following sections, with accompanying reach scale maps in **Appendix B**. The seven reaches delineated in this study are based on Montana FWP Fishing Access Sites and also roughly correspond to various areas served by specific irrigation ditches.

A total of 45 irrigation diversions were identified in this study and 41 diversions were assessed. Four additional diversions were not assessed, but are known to exist (D40, D41, D44 and one unnumbered headgate on the Big Hole Ranch). Out of the 45 diversions identified during this assessment, 34 diversions are located along the mainstem of the Big Hole River and significant side channels, averaging 0.8 diversions per mile or 1 diversion every 1.25 miles (**Table 3-8**). These 34 diversions are the primary focus of this study. An additional 11 diversions located within ditches or along sloughs were also reviewed during this assessment, though these only represent a portion of the headgates within the ditch networks.

For the purpose of this assessment, diversions are numbered D1-D44 and diversion names were derived from interviews with irrigators (**Table 3-9**). Diversions were numbered based on the order they were encountered in. When the name of a diversion was in question, the primary irrigators name was used to identify the diversion. A detailed discussion of conditions at each individual diversion is provided in **Appendix C,** while irrigator contact information is presented in **Appendix D**. The database of "point features" mapped during this assessment, including diversions, barbs, and habitat features, is provided in **Appendix E**.

Table 3-8. Diversions, Streambank Alterations and Habitat Features.

Feature Type	Number	Total Length (Feet)	Total Length (Miles)
Diversions on mainstem and side channels	34		
Diversions in ditches and sloughs*	11		
Barbs	15		
Riprap	45	16,635	3.2
Riprap, floodplain berms	20	18,335	3.5
Floodplain berms	4	6,515	1.2
Log revetments	2	802	0.2
Accelerated bank erosion	9	5,126	1.0
Fish habitat (spawning sites)	14		

*There are likely more diversions in ditches not examined in this assessment.

A total of 71 sections of riprap were assessed, including floodplain berms and log revetments. Riprap was numbered R1-R71 (**Table 3-8**). Along the lower 44.2 miles of the Big Hole River, this assessment indicates that approximately 8.0 miles of streambank have been altered by the placement of riprap, floodplain berms and log revetments, covering approximately 18% of the study area. In addition, 1.0 miles of accelerated streambank erosion have been identified. A

total of 9 streambanks with accelerated erosion were assessed, covering 1.0 miles. The database of "line features" mapped during this assessment, including riprap, floodplain berms, log revetments, and accelerated bank erosion, is presented in **Appendix F**.

Table 3-9. Irrigation Diversions on the Big Hole River Mainstem Progressing Downstream.

Site	Diversion Name
Maiden Rock to Melrose/Salmon Fly	
D18	Upper McCauley
D19	Meriwether's
D20	Lower McCauley
D21	Melrose Canal
D22	Meriwether's
D44	Meriwether's (Buyan slough)
D23	Carpenter's
D24	Carpenter's
Melrose/Salmon Fly to Brown's Bridge	
D11a	Pendergast-Spears-McCullough
D11b	Gallagher Ditch
none	at Big Hole Ranch
Brown's Bridge to Glen	
D12	Kalsta's
D13	Hagenbarth's Big Hole Ditch
D14	Hagenbarth's River Field Ditch
D15	Gainy's
D39	Smith's
D40	Smith's
Glen to Notch Bottom	
D16	Gainy's
D17a	Garrison
D17b	Kilwien
D25	Glennon's (?)
D26	Garrison's Wild Hay Ditch
D27	Rafferty's Upper South Side
D28	Rafferty's Lower South Side
D37	Bryan Ditch
Notch Bottom to Pennington Bridge	
D4	JS Ranch (Larson-Naranchich)
D1	Copper's (Whitney Ditch)
D2	Sandy Ditch
D3	Pageville Canal
D5	Naranchich
Pennington Bridge to High Road Bridge	
D6	Big Hole Co-op Ditch
D8	Orphan Home
D9	Logan-Smith
D10	Lott-Harvey
High Road Bridge to Jefferson River	
D35	pump at Hamilton Ranch
D36	Hamilton Ranch Ditch

3.3.1 Maiden Rock to Melrose/Salmon Fly

The Maiden Rock to Melrose/Salmon Fly assessment reach is approximately 5.8 miles long (**Figure 3-5** in **Appendix B**). This reach starts in Maiden Rock Canyon at the uppermost diversion (Diversion 18) that is used to irrigate land in the valley downstream (south) of Maiden Rock Canyon. Diversion 19 is also located in the canyon, while Diversions 20 and 21 are located at the mouth of Maiden Rock Canyon. Diversions 22, 23 and 24 occur in succession between the mouth of Maiden Rock Canyon and Melrose, while Diversion 44 is located at the point of the island across from Diversion 22. Thus, a total of 8 diversions were assessed in this reach, all of which are used to irrigate lands between the mouth of Maiden Rock Canyon and Melrose, with the majority of the irrigation water supplied by Big Hole River used to irrigate the area along the east side of the river (**Table 3-10**). There is an average 1.4 diversions per mile in this reach. A detailed discussion of each diversion can be found in **Appendix C.**

Table 3-10. Maiden Rock to Melrose/Salmon Fly.

Feature Type	Number	Sites	Total Length (Feet)	Total Length (Miles)
Diversions on mainstem and side channels	8	D18, D19, D20, D21, D22, D23, D24, D44		
Riprap	6	R42, R44, R45, R46, R47, R67	1,321	0.25
Accelerated bank erosion	1	E3	467	0.09
Fish habitat (spawning sites)	3	H9, H10, H11		

*There are likely more diversions in ditches not examined in this assessment.

Six sections of riprap were identified in this reach covering approximately 1,321 feet (0.25 miles) and 4% of the reach (**Table 3-10**). In addition, the railroad runs along the river left bank in Maiden Rock Canyon and this bank has been altered by the railroad bed. Downstream of Maiden Rock Canyon, the Big Hole River is a multi-channel system flowing through a broad floodplain area. In general, sections of riprap in this reach are relatively short. The section of riprap (R45) along the river left bank downstream of Diversion 24 is leading to approximately 467 feet of accelerated bank erosion (E3) along the river right bank on the next bend downstream. The stream channel is becoming over-widened at this point due to the accelerated rate of streambank erosion.

Three potential spawning sites were identified within this reach, though there are likely more. Two of the sites were located in the multi-channel section of river downstream of the mouth of the canyon. The channel splits twice within this reach, with one split occurring along the Meriwether Ranch upstream of Diversion 22 and the second split occurring upstream of Melrose. These channels provide habitat complexity, though sections of riprap and channel over-widening reduce the habitat complexity. The river may also be in the process of abandoning the right channel at the first split, leading to a reduction in habitat during low streamflow. At the first channel split, the majority of the flow remains in the left channel, while the two channels are divided relatively evenly at the second split. The river right (western) channel was not assessed in either split, though the channel along the Meriwether Ranch (Buyan Slough or “County Line” slough) reportedly once supported extensive spawning.

3.3.2 Melrose/Salmon Fly to Brown's Bridge

The Melrose/Salmon Fly to Brown's Bridge assessment reach is approximately 6.3 miles long and extends between the two fishing access sites (**Figure 3-6** in **Appendix B**). One diversion (D11) along this reach was assessed, while a second diversion used by the Big Hole Ranch was not assessed. Diversion 11 is located in the left (east) channel downstream of Melrose. This diversion serves two ditches, which irrigate land to the east of the river. Two headgates within this ditch network were also assessed as well as a third headgate in a slough that carries return water from these ditches. There is an average of 0.3 diversions per mile in this reach. A detailed discussion of each diversion can be found in **Appendix C.**

Table 3-11. Melrose/Salmon Fly to Brown's Bridge.

Feature Type	Number	Sites	Total Length (Feet)	Total Length (Miles)
Diversions on mainstem and side channels	2	D11, unnumbered diversion at BHR		
Diversions in ditches and sloughs*	3	D29, D30, D31		
Riprap	2	R35, R33	479	0.09
Accelerated bank erosion	1	E5	185	0.04
Fish habitat (spawning sites)	3	H5, H6, H7		

*There are likely more diversions in ditches not examined in this assessment.

Only two sections of riprap were observed within this reach, totaling approximately 479 feet and 1% of the reach. Both sections of riprap were associated with the railroad along the river left bank of the left channel downstream of Melrose. The right channel was not assessed. Accelerated bank erosion was observed along the left bank downstream of Diversion 11, with an estimated length of 185 feet. Additional bank erosion was observed along the river left bank downstream of where the two channels converge, while a third large eroding bank was observed along river left in a field approximately 1.7 miles upstream of Brown's Bridge in the left channel where the channel splits around an island. The second and third eroding banks did not appear to be related to irrigation infrastructure and were not quantified in this assessment.

The left channel downstream of Melrose contained three potential spawning sites, including one site at the Salmon Fly FAS and one site just upstream of Diversion 11. The right channel was not observed, though it likely contains additional habitat potential. Downstream of the convergence of the two channels, the river is relatively straight, with a riffle and run dominated streambed that lacks habitat complexity.

3.3.3 Brown's Bridge to Glen

The Brown's Bridge to Glen assessment reach is approximately 7.3 miles long and extends between the two fishing access sites, with the Glen FAS located in the right (west) channel approximately 1.5 miles downstream of the town of Glen (**Figure 3-7** in **Appendix B**). The left (east) side channel was included in the next reach downstream since the diversions from this channel irrigate area between the Glen FAS and the Notch. A total of five diversions on the Big Hole River mainstem and side channels were assessed within this reach, while a sixth diversion

(D40) along the river right bank downstream of Glen was not assessed. Upstream of the I-15 crossing, Diversion 12 is located along the river left, while Diversion 13 obtains water from a diversion channel along river right. The initial point of diversion for Diversion 14 is located just downstream of the Kalsta Bridge on river right. Diversion 15 is located on the river left bank approximately 1 mile upstream of the town of Glen. Diversions 39 and 40 are located upstream and downstream of the town of Glen, respectively, and both diversions are located on side channels. Diversion 34 is located in the ditch fed by Diversion 12, while Diversion 42 is located at the mouth of Rock Creek in the ditch fed by Diversion 13. There is an average of 0.8 diversions per mile in this reach. A detailed discussion of each diversion can be found in **Appendix C.**

Table 3-12. Brown's Bridge to Glen.

Feature Type	Number	Sites	Total Length (Feet)	Total Length (Miles)
Diversions on mainstem and side channels	6	D12, D13, D14, D15, D39, D40		
Diversions in ditches and sloughs*	2	D34, D42		
Riprap	6	R34, R36, R37, R38, R39, R43	3,366	0.64
Floodplain berms	1	R68	2,458	0.47
Fish habitat (spawning sites)	3	H2, H3, H4		

*There are likely more diversions in ditches not examined in this assessment.

Six sections of riprap were identified, the majority of which is associated with I-15, which crosses the Big Hole River in this reach. There is approximately 3,366 feet (0.64 miles) of riprap, with an additional 2,458 feet (0.47 miles) of floodplain berm located at a bend approximately 1 mile downstream of the Kalsta Bridge. Thus, there is approximately 1.1 miles of streambank alterations within this reach, which amounts to 15% of the reach, much of which is associated with road encroachment.

Potential spawning habitat was observed at three locations. The diversion channel leading to D13 provided extensive habitat, as did the braided section of the Big Hole River mainstem along this diversion channel. Additional potential spawning habitat was observed in the mainstem of the Big Hole River upstream of the town of Glen.

3.3.4 Glen to Notch Bottom

The Glen to Notch Bottom assessment reach is approximately 7.3 miles long and extends between the two fishing access sites (**Figure 3-8** in **Appendix B**). The left (east) side channel upstream of the Glen FAS was included in this reach since the diversions from this channel irrigate the area between the Glen FAS and the Notch. There are a total of 7 diversions on the Big Hole River mainstem and side channels in this reach. In addition, three diversions in ditches and sloughs were identified and two were observed in the field. Diversions 16 and 17 utilize a single diversion channel along the left (east) side of the river. There are two headgates in diversion 17 leading into separate ditches (D17a and D17b). Diversion 25 is located in a side channel along river right, while Diversion 26 is located in a side channel along river left. Diversion 27 is located in a diversion channel on river right and Diversion 28 is also located along river right just upstream of the Notch and across from Diversion 38, which is located along

the river left bank at the lower end of Steven's Slough. Diversion 41 is located at the upper end of Steven's Slough and utilizes return flow from the ditch feed by D17a. Diversion 43 is located in the ditch feed by Diversion 28. There is an average of 1.0 diversions per mile in this reach. A detailed discussion of each diversion can be found in **Appendix C.**

Table 3-13. Glen to Notch Bottom.

Feature Type	Number	Sites	Total Length (Feet)	Total Length (Miles)
Diversions on mainstem and side channels	7	D16, D17, D25, D26, D27, D28, D37		
Diversions in ditches and sloughs*	3	D38, D41, D43		
Barbs	1	B15		
Riprap	13	R40, R41, R48, R50, R52, R53, R56, R59, R61, R62, R64, R65, R69	6,044	1.14
Riprap, floodplain berms	4	R49, R55, R57, R58	1,993	0.38
Floodplain berms	2	R60, R63	3,652	0.69
Accelerated bank erosion	2	E4, E8	1,415	0.27
Fish habitat (spawning sites)	4	H8, H12, H13, H14		

*There are likely more diversions in ditches not examined in this assessment.

Seventeen sections of riprap and riprap/floodplain berms were identified in this reach, covering approximately 1.52 miles of streambank. In addition, 0.69 miles of floodplain berms were identified. Thus, there is approximately 2.21 miles of streambank alterations within this reach, which amounts to 31% of the reach. Accelerated bank erosion was identified at two sites, covering 1,415 feet (0.27 miles). Streambank erosion at E4 was included in this assessment since a house was recently constructed near this eroding bank and the bank will likely require stabilization in the future. There was also one barb in this reach.

Potential spawning habitat was observed at three sites, with the upper site (H8) located downstream of Diversion 17 in the diversion channel. Sites H12 and H13 were located in a braided section of river downstream of R63. There is approximately one mile of dynamic braided channels that likely support additional spawning potential within this reach. Potential spawning sites (H14) were also observed in the diversion channel leading down to Diversion 27.

3.3.5 Notch Bottom to Pennington Bridge

The Notch Bottom to Pennington Bridge assessment reach is approximately 9.7 miles long and extends between the two fishing access sites (**Figure 3-9** in **Appendix B**). There are a total of 5 diversions within this reach. While the diversion channel leading to Diversion 5 was observed in the field, the actual point of diversion on the side channel was not observed. Progressing downstream, Diversion 4 is located on river left below the volcanic bluffs downstream of the Notch. Diversion 1 is located along river right. Diversion 2 is located at a geologic nickpoint at the outside of a bend on river left. Diversion 3 is located at the outside of a bend on river right, with the diversion channel for Diversion 5 located approximately 1,200 downstream on river left. In addition, Diversions 32 and 33 are located within the ditch fed by Diversion 3. There is an

average of 0.5 diversions per mile in this reach. A detailed discussion of each diversion can be found in **Appendix C.**

Table 3-14. Notch Bottom to Pennington Bridge.

Feature Type	Number	Sites	Total Length (Feet)	Total Length (Miles)
Diversions on mainstem and side channels	5	D1, D2, D3, D4, D5 (primary headgate not assessed)		
Diversions in ditches and sloughs*	2	D32, D33		
Barbs	13	B1-B13		
Riprap	10	R2, R3, R4, R8, R11, R13, R20, R21, R22	3,098	0.59
Riprap, floodplain berms	8	R1, R5, R6, R7, R10, R15, R16, R66	5,947	1.13
Log revetments	2	R9, R14	802	0.15
Accelerated bank erosion	2	E1, E6	1,473	0.28
Fish habitat (spawning sites)	1	H1		

*There are likely more diversions in ditches not examined in this assessment.

A total of 18 sections of riprap and riprap/floodplain berms were identified in this reach, covering approximately 1.72 miles. In addition, log revetments have been used to stabilize two banks. Thus, there are approximately 1.87 miles of streambank alterations within this reach, which amounts to 19% of the reach. Accelerated bank erosion was observed at two sites, with E6 resulting from the diversion dam at Diversion 4 and E1 resulting from the diversion dam at E1.

Potential spawning habitat was identified in a braided section of the river. There are two channels in the lower 1.7 miles of this reach and the left (west) channel was observed to have a very dynamic stream channel, which likely leads to additional spawning potential. The right (east) channel upstream of Pennington Bridge was not assessed, though it also may have a similar character that would likely support additional spawning potential.

3.3.6 Pennington Bridge to High Road Bridge

The Pennington Bridge to High Road assessment reach is approximately 6.2 miles long and extends between the two fishing access sites (**Figure 3-10** in **Appendix B**). There are four mainstem diversions along this assessment reach. Diversion 6 is located along the right bank just downstream of the Pennington Bridge in the right channel, which carries most or all of the flow at low water. Diversion 8 is located along the river right bank in the main channel downstream of Nez Perce Creek. The main channel splits into two channels approximately 1.7 miles upstream of the High Road Bridge and both Diversion 9 and Diversion 10 are located along the river right bank in the right (east) channel. In addition to the mainstem diversions, Diversion 7 is located behind a floodplain berm in an area with ponded water. There is an average of 0.6 diversions per mile in this reach. A detailed discussion of each diversion can be found in **Appendix C.**

Table 3-15. Pennington Bridge to High Road Bridge.

Feature Type	Number	Sites	Total Length (Feet)	Total Length (Miles)
Diversions on mainstem and side channels	4	D6, D8, D9, D10		
Diversions in ditches and sloughs*	1	D7		
Barbs	1	B14		
Riprap	8	R18, R19, R24, R25, R26, R28, R30, R70	2,327	0.44
Riprap, floodplain berms	5	R17, R27, R29, R31, R32	6,682	1.27
Floodplain berms	1	R23	405	0.08
Accelerated bank erosion	3	E2, E7, E9	1,586	0.30

*There are likely more diversions in ditches not examined in this assessment.

A total of 13 sections of riprap and riprap/floodplain berms were identified in this reach, covering approximately 1.71 miles. In addition, one floodplain berm was identified in the left channel downstream of Pennington Bridge, though no other assessments of this channel were performed. Overall, there are approximately 1.79 miles of streambank alterations within this reach, which amounts to 29% of the reach. Riprap in the right channel within this reach is primarily located along the river right (eastern) bank and protects the broad floodplain between the Big Hole and Beaverhead rivers. This riprap appears to be forcing the river toward the west, where the valley is confined by the foothills. This is leading to a large eroding bank (E9) upstream of Nez Perce Creek as the Big Hole River cuts into the foothill bench. This bank is likely a large source of sediment to this reach during spring runoff. A second large eroding bank (E3) is located along the left bank as the river cuts into the foothill just upstream of the High Road Bridge crossing. Riprap on the right bank (R32) upstream is likely leading to this erosion.

3.3.7 High Road Bridge to Jefferson River

The High Road Bridge to the Jefferson River assessment reach is approximately 1.8 miles long and extends from the High Road FAS to where the Big Hole River and Beaverhead River combine to form the Jefferson River (**Figure 3-10** in **Appendix B**). Only the upper portion of this reach was assessed in the field, while the lower portion of the reach was assessed using color aerial imagery. Both Diversions 35 and 36 are fed by a diversion channel leading off to river left downstream of the High Road Bridge. Diversion 35 serves a pump, while Diversion 36 serves a large ditch network. There is an average of 1.1 diversions per mile in this reach. A detailed discussion of each diversion can be found in **Appendix C.**

Table 3-16. High Road Bridge to the Jefferson River.

Feature Type	Number	Sites	Total Length (Feet)	Total Length (Miles)
Diversions on mainstem and side channels	2	D35, D36		
Riprap, floodplain berms	3	R51, R54, R71	3,713	0.70

*There are likely more diversions in ditches not examined in this assessment.

Three sections of floodplain berms were identified within this reach, though only R71, which is along the river right bank downstream of the High Road Bridge was observed during the field assessment.

4.0 Irrigation Infrastructure Priority Matrix

A matrix of potential irrigation infrastructure improvement projects was developed to evaluate the potential for the improvement of irrigation infrastructure while also providing for increased in-stream flows. This matrix will be referred to as the "priority matrix" within this report. Utilizing data collected during this study, along with existing data, several parameters were included in the priority matrix under two main categories:

1. headgate and diversion dam factors
2. cumulative impact factors

In the priority matrix, there is a possible score of 35 points, with 20 possible points for headgate and diversion dam factors and 15 possible points for cumulative impact factors (**Tables 4-1** and **4-2**). Based on the total score, the priority of each diversion was rated based on the following scale:

25-35 Very High Priority
20-24 High Priority
15-19 Moderate Priority
<15 Low Priority

A total of 34 diversions were identified on the lower Big Hole River and significant side channels in this study. Two of these diversions serve two separate ditches: Diversion 11 and Diversion 17. Thus, there are a total of 36 diversions included within the priority matrix. Out of 36 diversions assessed using the priority matrix, a total of 6 diversions were rated a very high priority, 12 diversions were rated a high priority, 11 diversions were rated a moderate priority and 3 diversions were rated a low priority (**Table 4-3**). Due to a lack of data, four diversions on the mainstem of the lower Big Hole River were not assessed with the priority matrix, including: D5, D35, D40 and the unnumbered diversion on the Big Hole Ranch. The 11 headgates identified in ditches and sloughs were not included in the priority matrix.

4.1 Headgate and Diversion Dam Priority Matrix Factors

A total of eight factors were assessed for each individual headgate and diversion dam, including:

- headgate design
- headgate condition
- diversion dam maintenance requirements
- estimated potential flow
- presence of a Parshall flume
- influence on natural channel processes
- fish habitat associated with diversion
- ownership interest level

Headgate design was considered in the priority matrix since different designs vary in their efficiency, as well as in their ease of operation. The priority matrix assumes that metal "screw gates" are preferable to wooden "pin and plank" headgates since they can be more finely adjusted to regulate flow. Thus, "pin and plank" headgates were given a score of "3" and metal "screw gates" were given a score of "1".

Headgate condition was considered in the priority matrix to identify aging infrastructure that is in need of replacement. Headgates at or near the end of their operational lifespan were given a score of "2", while headgates in good condition were given a score of "0".

Diversion dam maintenance requirements were included in the priority matrix to evaluate potential problems with dam failure and sediment accumulation. The level of annual maintenance required was considered for this priority matrix parameter. Diversion dams requiring annual maintenance were given a score of "3", while diversion dams requiring maintenance semi-annually or less frequently were given a score of "1".

Estimated potential flow was included to provide an idea of the relative ditch size and its potential to decrease streamflow. Since this assessment was conducted after the irrigation season ended, flow estimates were based on ditch dimensions as estimated during field evaluation. A review of water rights based on the Montana DNRC points of diversion dataset, along with ditch flow measurements and estimates performed by Montana DEQ during the 2006 temperature study, also provided supporting information. In the priority matrix, a score of "3" was given to ditches with an estimated flow capacity of >25cfs. Ditches with lower flow capacity were given lower scores.

The presence of a **flow measuring device** was included in the priority matrix. A Parshall flume was identified as the preferred measuring device where conditions (i.e. slope) permit. Staff gages were not counted as flow measuring devices in the priority matrix, though a staff gage could be used in conjunction with a series of flow measurements to develop a rating curve, which would be a sufficient technique for flow measurement. Ditches with identified Parshall flumes were given a score of "0", while ditches lacking a Parshall flume were given a score of "3".

The **influence on natural channel processes** was included in the priority matrix to identify negative influences to lateral channel migration and sediment transport processes stemming from the location and construction of diversion structures. Possible negative impacts include an extensive amount of riprap, accelerated streambank erosion, channel over-widening, restrictions to natural lateral channel migration, and streambed aggradation or degradation due to an imbalance in sediment transport processes. While a detailed assessment of sediment transport processes was beyond the scope of this assessment, it was observed that diversion dams located in areas with relatively wide and flat floodplains that support multiple migrating channels tend to be the most difficult to maintain and have the most negative effect on natural channel processes. In the priority matrix, diversion dams that appeared to negatively influence natural channel migration and sediment transport processes were given a score of "2".

During the "float survey", **fish habitat associated with diversion structures** was identified. During this assessment, side channels that are used as diversion channels were often found to support potential spawning habitat. These areas are considered of extra importance to both the fishery and the irrigation system and were given a score of "2" in the priority matrix.

Ownership interest level was also considered in the priority matrix, since willingness of affected parties is a prerequisite for the successful implementation of projects. Ownership interest level was gauged during the irrigator interview process. When an irrigator expressed interest in a project, a score of "2" was assigned in the priority matrix. A list of potential projects identified during meetings with irrigators is presented in **Appendix G.**

Table 4-1. Headgate and Diversion Dam Factors Applied to the Priority Matrix.

Headgate and Diversion Dam Factors	Description	Score
Headgate Construction	wood "pin & plank"	3
	metal "screw gate" and wood	1
	metal "screw gate" and concrete	1
Headgate Condition	maintenance required or beneficial	2
	properly functioning	0
Diversion Dam Maintenance Requirements	annually	3
	semi-annually or less frequently	1
	unknown	0
Estimated Potential Flow	> 25 cfs	3
	10-25 cfs	2
	< 10 cfs	1
Flow Measuring Device (Parshall Flume)	absent	3
	unknown	1
	present	0
Influence on Natural Channel Processes	negative	2
	neutral / unknown	0
Fish Habitat Associated with Diversion Structures	observed	2
	not observed / unknown	0
Ownership Interest Level	interested / potential project identified	2
	potentially interested	1
	un-interested / unknown	0
Maximum Possible Headgate and Diversion Dam Score		**20**

4.2 Cumulative Impacts Priority Matrix Factors

The cumulative impact factors were selected to provide analysis of the amount of irrigation infrastructure development and the extent of streambank and channel alterations at the reach scale. A total of five factors were assessed to identify the cumulative effects of irrigation withdrawals and streambank and channel alterations at the reach scale, including:

- number of individual diversions per mile
- number claimed points of diversion per mile
- ditch length to reach length ratio
- percent of reach with streambank alterations
- analysis of streamflow gains and losses

The **number of individual diversions per mile** is based on diversions identified along the mainstem of the lower Big Hole River and significant side channels during this assessment. In the priority matrix, a score of "3" was assigned to diversions located in reaches with >1.0 individual diversions per mile. Diversions located in reaches with fewer individual diversions per mile were given lower scores.

The **number of claimed points of diversion per mile** is based on the Montana DNRC Points of Diversion GIS data layer and includes water rights claims and permits for both irrigation and stock water. In the priority matrix, a score or "3" was assigned to diversions located in reaches with >10 claimed points of diversion per mile. Diversions located in reaches with fewer claimed points of diversion per mile were given lower scores.

The **ditch length to reach length ratio** provides a measure of the extent of the irrigation network. Diversions located in reaches with a ditch length to reach length ratio of >10:1 were given a score of "3" in the priority matrix, while diversions in reaches with fewer miles of mapped ditch were given lower scores.

The **percent of reach with streambank alterations** provides a measure of restrictions to lateral channel migration. Diversions in reaches with streambank alterations along >20% of the total reach length were given a score of "3" in the priority matrix, while diversions in reaches with fewer streambank alterations were given lower scores.

The **analysis of streamflow gains and losses** provides an indicator of which reaches are most heavily utilized for irrigation purposes and where irrigation withdrawals may lead to critically low streamflows during the late-summer irrigation season. This analysis was based on streamflow measurements at USGS gaging stations as well as measurements performed by Montana DNRC. During this assessment, the section of river between Melrose Bridge and the USGS near Melrose gage, as well as the entire section of river downstream of the USGS near Glen gage, were identified as areas of significant irrigation withdrawals and decreased streamflows. Thus, these reaches were given a score of "3" in the priority matrix. The section of river between Maiden Rock Canyon and the Melrose Bridge was given a "2" since there are several large diversions, though streamflow measurements from 2007 suggest flows remain

relatively stable between these two sites. Between the USGS Melrose gage and the USGS Glen gage was given a score of "1" since streamflow was identified to increase between these two sites in 5 out of the past 7 years.

Cumulative impact priority matrix scores for each reach are provided in **Appendix H**.

Table 4-2. Cumulative Impact Factors Applied to Data Matrix.

Cumulative Impact Factors	Description	Score
Individual Diversions/Mile	> 1.0	3
	0.6-1.0	2
	0-0.5	1
Claimed Points of Diversion/Mile	> 10	3
	6-10	2
	0-5	1
Ditch Length to Reach Length Ratio	> 10:1	3
	5:1-10:1	2
	< 5:1	1
Percent of Reach with Streambank Alterations	> 20%	3
	11%-20%	2
	0%-10%	1
Streamflow Gain/Loss Analysis	Melrose Bridge to USGS Melrose gage, USGS Glen gage to Jefferson River	3
	Maiden Rock Canyon to Melrose Bridge	2
	USGS Melrose gage to USGS Glen gage	1
Maximum Possible Cumulative Impacts Score		**15**

Table 4-3. Priority Matrix.

Site	D18	D19	D20	D21	D22	D44	D23	D24	D11a	D11b	D12	D13	D14	D15	D39	D16
Diversion Name	Upper McCauley	Meriwether's	Lower McCauley	Melrose Canal	Meriwether's	Meriwether's (Buyan slough)	Carpenter's	Carpenter's	Pendergast - Spears - McCullough	Gallagher Ditch	Kalsta's	Hagenbarth's Big Hole Ditch	Hagenbarth's River Field Ditch	Gainy's	Smith's	Gainy's
Headgate and Diversion Dam Factors																
Headgate Construction	1	3	1	1	3	3	3	3	3	3	1	1	1	1	1	1
Headgate Condition	2	0	2	2	0	0	0	2	2	2	0	2	0	0	2	0
Diversion Dam Maintenance Requirements	0	1	3	3	3	3	3	3	3	3	1	3	1	1	1	3
Estimated Potential Flow (cfs)	2	2	3	3	1	1	1	1	3	3	2	3	1	1	1	1
Flume	1	0	3	3	3	3	0	0	3	3	0	0	3	1	3	1
Influence on Natural Channel Processes	0	2	0	0	2	2	2	2	0	0	0	0	0	2	0	2
Fish Habitat Associated with Diversion	0	0	0	0	0	0	0	0	2	2	0	2	0	0	0	0
Ownership Interest Level	0	2	2	0	2	2	0	2	2	2	2	2	2	0	2	0
Headgate and Diversion Dam Score	**6**	**10**	**14**	**12**	**14**	**14**	**9**	**13**	**18**	**18**	**6**	**13**	**8**	**6**	**10**	**8**
Cumulative Impact Factors																
Individual Diversions/Mile	3	3	3	3	3	3	3	3	1	1	2	2	2	2	2	2
Claimed Points of Diversion/Mile	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1
Ditch Length to Reach Length Ratio	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	1
Percent of Reach with Streambank Alterations	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3
Streamflow Gain/Loss Analysis	2	2	2	2	2	2	2	2	3	3	3	3	1	1	1	1
Cumulative Impact Score	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**7**	**7**	**10**	**10**	**8**	**8**	**8**	**8**
Total Score	**15**	**19**	**23**	**21**	**23**	**23**	**18**	**22**	**25**	**25**	**16**	**23**	**16**	**14**	**18**	**16**
Priority	Moderate	Moderate	High	High	High	High	Moderate	High	Very High	Very High	Moderate	High	Moderate	Low	Moderate	Moderate

Site	D17a	D17b	D25	D26	D27	D28	D37	D4	D1	D2	D3	D6	D8	D9	D10	D36
Diversion Name	Garrison	Kilwien	Glennon's (?)	Garrison's Wild Hay Ditch	Rafferty's Upper South Side	Rafferty's Lower South Side	Bryan Ditch	JS Ranch (Larson-Naranchich)	Copper's (Whitney Ditch)	Sandy Ditch	Pageville Canal	Big Hole Co-op Ditch	Orphan Home	Logan - Smith	Lott - Harvey	Hamilton Ranch Ditch
Headgate and Diversion Dam Factors																
Headgate Construction	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	1
Headgate Condition	0	0	0	0	2	2	0	0	2	0	0	2	2	2	2	0
Diversion Dam Maintenance Requirements	3	3	3	3	3	0	1	1	0	3	1	3	3	1	1	3
Estimated Potential Flow (cfs)	3	3	1	2	3	3	1	2	2	2	3	3	2	2	2	3
Flume	3	3	1	0	3	3	3	1	0	1	3	3	0	3	3	0
Influence on Natural Channel Processes	2	2	0	2	0	2	0	2	2	2	0	2	2	0	2	0
Fish Habitat Associated with Diversion	2	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Ownership Interest Level	2	2	0	2	2	2	0	0	1	2	1	2	2	2	2	2
Headgate and Diversion Dam Score	**16**	**16**	**6**	**10**	**16**	**13**	**6**	**7**	**8**	**11**	**9**	**16**	**14**	**13**	**15**	**9**
Cumulative Impact Factors																
Individual Diversions/Mile	2	2	2	2	2	2	2	1	1	1	1	2	2	2	2	3
Claimed Points of Diversion/Mile	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	1
Ditch Length to Reach Length Ratio	1	1	1	1	1	1	1	2	2	2	2	3	3	3	3	2
Percent of Reach with Streambank Alterations	3	3	3	3	3	3	3	2	2	2	2	3	3	3	3	3
Streamflow Gain/Loss Analysis	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3
Cumulative Impact Score	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**9**	**9**	**9**	**9**	**14**	**14**	**14**	**14**	**12**
Total Score	**24**	**24**	**14**	**18**	**24**	**21**	**14**	**16**	**17**	**20**	**18**	**30**	**28**	**27**	**29**	**21**
Priority	High	High	Low	Moderate	High	High	Low	Moderate	Moderate	High	Moderate	Very High	Very High	Very High	Very High	High

Note: The following diversions were combined for assessing the "Estimated Flow Potential" category: D20&D21, D11a&D11b, D17a&D17b, and D27&D28.

Table 4-4. Priority Matrix Ratings from Very High to Low.

Site	Diversion Name	Priority Matrix Score	Priority Matrix Rating
D6	Big Hole Co-op Ditch	30	Very High
D10	Lott - Harvey	29	Very High
D8	Orphan Home	28	Very High
D9	Logan - Smith	27	Very High
D11a	Pendergast - Spears - McCullough	25	Very High
D11b	Gallagher Ditch	25	Very High
D17a	Garrison	24	High
D17b	Kilwien	24	High
D27	Rafferty's Upper South Side	24	High
D20	Lower McCauley	23	High
D22	Meriwether's	23	High
D44	Meriwether's (Buyan slough)	23	High
D13	Hagenbarth's Big Hole Ditch	23	High
D24	Carpenter's	22	High
D21	Melrose Canal	21	High
D28	Rafferty's Lower South Side	21	High
D36	Hamilton Ranch Ditch	21	High
D2	Sandy Ditch	20	High
D19	Meriwether's	19	Moderate
D23	Carpenter's	18	Moderate
D39	Smith's	18	Moderate
D26	Garrison's Wild Hay Ditch	18	Moderate
D3	Pageville Canal	18	Moderate
D1	Copper's (Whitney Ditch)	17	Moderate
D12	Kalsta's	16	Moderate
D14	Hagenbarth's River Field Ditch	16	Moderate
D16	Gainy's	16	Moderate
D4	JS Ranch (Larson-Naranchich)	16	Moderate
D18	Upper McCauley	15	Moderate
D15	Gainy's	14	Low
D25	Glennon's (?)	14	Low
D37	Bryan Ditch	14	Low
D35	pump at Hamilton Ranch		unrated
D5	Naranchich		unrated
D40	Smith's		unrated
none	BHR		unrated

5.0 Discussion and Summary

The results of this inventory and assessment provide a foundation for selecting irrigation infrastructure improvement projects that benefit both agricultural users and water resources in the lower Big Hole River. The irrigation infrastructure improvement priority matrix developed during this assessment provides a tool for identifying potential projects based on the specific conditions at individual headgates and diversion dams as well as the cumulative effects of reach scale impacts. Addressing conditions at diversion dams and headgates identified in the priority matrix would facilitate improved irrigation water management, which, in-turn, may lead to increased in-stream flows, particularly during the critical mid-to-late summer time period when streamflows are low and water temperatures are warm.

Along the lower Big Hole River, 34 irrigation diversions were identified and 259 miles of irrigation ditch network were mapped. Extensive irrigation withdrawals lead to reduced streamflows throughout the project area, with an average decrease in mean daily streamflow of 119cfs between the Divide Bridge, which is upstream of the study area, and the High Road Bridge near the downstream end of the study area measured between August 22nd and September 30th 2007. Decreases in streamflow are most pronounced downstream of Notch Bottom, with streamflow data from 2001 through 2007 indicating that mean daily streamflows decrease by an average of 148cfs during the summer irrigation season downstream of the USGS near Glen gage. Based on this assessment, it is estimated that an average of 140cfs are withdrawn for agricultural purposes during the irrigation season between Notch Bottom and the confluence with the Jefferson River, with withdrawals decreasing to approximately 100cfs during extreme low flow periods.

The presence of diversion dams, riprap and floodplain berms have the potential to dramatically influence channel patterns within the lower Big Hole River. Diversion dams within the study area often extend well into the channel, which can lead to localized shifts in channel patterns. During this assessment, it was observed that diversion dams located in areas with relatively wide and flat floodplains that support multiple migrating channels tend to be the most difficult to maintain and have the most negative effect on channel processes. Due to the complex multi-channel meandering nature of the lower Big Hole River system, alterations to the channel bed and/or streambanks locally often lead to unexpected consequences upstream or downstream. Overall, this assessment identified 8.0 miles streambank alterations covering 18% of the lower 44.2 miles of the lower Big Hole River, while historic streambank alterations and floodplain berms that have since been abandoned by the active channel may be much more extensive.

5.1 Future Areas of Study

Due to the complex nature of the lower Big Hole River system, the following list of future areas of study is presented:

1. Obtain ditch flow measurements at ditches of interest throughout the irrigation season, both at the point of diversion and at the point of use. Perform a more detailed mapping of the largest diversion networks, including the locations of additional headgates within the ditch networks. Evaluate existing water rights claims and permits relative to current water use.

2. Place a seasonal gaging station at the Melrose bridges to evaluate changes in streamflow between the Divide Creek Bridge and the USGS near Melrose gaging station since synoptic measurements performed in 2007 indicated streamflows remain relatively stable between these three sites. Perform additional synoptic streamflow measurements throughout the study area and continue the seasonal gaging stations at the Divide Bridge and Pennington Bridge.

3. Quantify ditch loss and aquifer recharge between Notch Bottom and the confluence with the Jefferson River to compliment the study performed between Maiden Rock Canyon and Notch Bottom by MBMG.

4. Perform an assessment of ground water and surface water interactions throughout the study area, with an emphasis on ground water upwelling due to geological constrictions in Maiden Rock Canyon and at Notch Bottom as indicted in the 2008 temperature modeling report by Montana DEQ.

5. Assess the impact of diversion dams, riprap, and floodplain berms on channel bed morphology, lateral channel migration, streambed aggradation and degradation, and fish habitat through the use of sediment transport modeling and an assessment of historic channel migration patterns. Identify areas where multi-channel processes can be maintained and/or restored.

6. Perform additional floodplain berm mapping and flood hazard evaluation to determine the extent of floodplain berms and identify sites which may be obsolete and could be removed.

7. Perform additional fish habitat assessments, including identification of critical habitat during various life stages. Evaluate potential entrainment of fish in irrigation systems and monitor selected ditches for fish populations. Utilize this information to incorporate features that will minimize fish loss when designing and implementing headgate and diversion dam improvements.

8. Identify the potential to develop alternative stock water sources so that when the irrigation season ends, ditches can be closed.

6.0 References

Marvin, R.K., and Voeller, T.L. 2000. Hydrology of the Big Hole Basin and an assessment of the affects of irrigation of the hydrologic budget. *Montana Bureau of Mines and Geology Open File Report 417*. Montana Bureau of Mines and Geology, Butte, Montana.

Flynn, K., Kron, D., Granger, M. 2007 Modeling Streamflow and Water Temperature in the Big Hole River, Montana-2006. TMDL Technical Report DMS 2008-01. Montana Department of Environmental Quality.

Appendix A

STREAMFLOW DATA

Lower Big Hole Irrigation Infrastructure Study

date	USGS Melrose streamflow (cfs)	USGS Glen streamflow (cfs)	High Road streamflow (cfs)	Difference between Melrose and Glen streamflow (cfs)	Difference between Glen and High Road streamflow (cfs)
7/1/01	652	720		68	
7/2/01	593	648		55	
7/3/01	543	594		51	
7/4/01	514	564	383	50	-181
7/5/01	517	580	396	63	-184
7/6/01	519	587	431	68	-156
7/7/01	500	569	430	69	-139
7/8/01	473	540	405	67	-135
7/9/01	439	507	367	68	-140
7/10/01	443	498	330	55	-168
7/11/01	438	500	341	62	-159
7/12/01	440	503	319	63	-184
7/13/01	443	523	361	80	-162
7/14/01	474	548	402	74	-146
7/15/01	480	559	451	79	-108
7/16/01	519	610	498	91	-112
7/17/01	567	657	596	90	-61
7/18/01	590	689	636	99	-53
7/19/01	578	683	636	105	-47
7/20/01	560	673	616	113	-57
7/21/01	530	638	568	108	-70
7/22/01	512	616	524	104	-92
7/23/01	472	568	463	96	-105
7/24/01	445	534	386	89	-148
7/25/01	400	472	327	72	-145
7/26/01	358	421	257	63	-164
7/27/01	328	382	205	54	-177
7/28/01	303	352	175	49	-177
7/29/01	288	334	160	46	-174
7/30/01	280	350	144	70	-206
7/31/01	306	376	141	70	-235
8/1/01	328	390	160	62	-230
8/2/01	321	373	171	52	-202
8/3/01	307	348	155	41	-193
8/4/01	294	325	145	31	-180
8/5/01	298	321	140	23	-181
8/6/01	289	307	133	18	-174
8/7/01	268	286	122	18	-164
8/8/01	246	249	106	3	-143
8/9/01	225	210	78	-15	-132
8/10/01	217	198	75	-19	-123
8/11/01	212	197	71	-15	-126
8/12/01	207	190	69	-17	-121
8/13/01	197	181	63	-16	-118
8/14/01	194	180	63	-14	-117
8/15/01	200	184	63	-16	-121
8/16/01	200	199	65	-1	-134
8/17/01	195	187	61	-8	-126
8/18/01	192	180	58	-12	-122
8/19/01	189	173	56	-16	-117
8/20/01	181	164	55	-17	-109
8/21/01	177	157	53	-20	-104
8/22/01	172	155	52	-17	-103
8/23/01	160	145	51	-15	-94
8/24/01	155	136	49	-19	-87
8/25/01	152	130	48	-22	-82
8/26/01	153	131	42	-22	-89
8/27/01	152	135	41	-17	-94
8/28/01	151	129	40	-22	-89
8/29/01	152	124	33	-28	-91
8/30/01	156	132	32	-24	-100
8/31/01	156	132	28	-24	-104
9/1/01	156	130	27	-26	-103
9/2/01	156	133	27	-23	-106
9/3/01	156	137	29	-19	-108
9/4/01	153	136	30	-17	-106
9/5/01	152	135	30	-17	-105
9/6/01	186	176	35	-10	-141
9/7/01	213	207	44	-6	-163
9/8/01	234	230	51	-4	-179
9/9/01	231	239	64	8	-175
9/10/01	225	236	64	11	-172
9/11/01	214	227	60	13	-167
9/12/01	208	222	58	14	-164
9/13/01	212	223	58	11	-165
9/14/01	212	233	61	21	-172
9/15/01	214	232	63	18	-169
9/16/01	209	230	64	21	-166
9/17/01	208	224	63	16	-161
9/18/01	207	233	64	26	-169
9/19/01	206	233	66	27	-167
9/20/01	206	218	64	12	-154
9/21/01	207	212	61	5	-151
9/22/01	201	201	62	0	-139
9/23/01	203	208	58	5	-150
9/24/01	201	217	60	16	-157
9/25/01	201	221	58	20	-163
9/26/01	200	218	57	18	-161
9/27/01	201	221	58	20	-163
9/28/01	203	213	64	10	-149
9/29/01	208	220	65	12	-155
9/30/01	205	238	78	33	-160

date	USGS Melrose streamflow (cfs)	USGS Glen streamflow (cfs)	High Road streamflow (cfs)	Difference between Melrose and Glen streamflow (cfs)	Difference between Glen and High Road streamflow (cfs)
7/1/02	1480	1580		100	
7/2/02	1280	1400		120	
7/3/02	1110	1240		130	
7/4/02	1060	1170		110	
7/5/02	962	1070		108	
7/6/02	893	983		90	
7/7/02	855	937		82	
7/8/02	881	943		62	
7/9/02	896	938		42	
7/10/02	826	871		45	
7/11/02	766	816		50	
7/12/02	703	761		58	
7/13/02	652	717		65	
7/14/02	615	681		66	
7/15/02	588	645		57	
7/16/02	676	711		35	
7/17/02	743	796		53	
7/18/02	684	752		68	
7/19/02	644	750		106	
7/20/02	629	741		112	
7/21/02	630	708		78	
7/22/02	590	649		59	
7/23/02	547	571		24	
7/24/02	516	544		28	
7/25/02	501	529		28	
7/26/02	508	562		54	
7/27/02	493	566		73	
7/28/02	509	583		74	
7/29/02	473	549		76	
7/30/02	427	490		63	
7/31/02	381	442		61	
8/1/02	331	377		46	
8/2/02	314	354	205	40	-149
8/3/02	296	334	156	38	-178
8/4/02	290	334	148	44	-186
8/5/02	298	348	160	50	-188
8/6/02	290	340	158	50	-182
8/7/02	288	329	152	41	-177
8/8/02	379	411	172	32	-239
8/9/02	426	478	227	52	-251
8/10/02	386	460	233	74	-227
8/11/02	338	403	214	65	-189
8/12/02	318	376	196	58	-180
8/13/02	304	367	184	63	-183
8/14/02	277	343	180	66	-163
8/15/02	254	294	166	40	-128
8/16/02	232	267	147	35	-120
8/17/02	214	247	115	33	-132
8/18/02	213	243	112	30	-131
8/19/02	207	238	99	31	-139
8/20/02	197	228	58	31	-170
8/21/02	208	233	46	25	-187
8/22/02	230	255	43	25	-212
8/23/02	234	264	54	30	-210
8/24/02	226	253	57	27	-196
8/25/02	236	256	57	20	-199
8/26/02	236	262	58	26	-204
8/27/02	256	284	64	28	-220
8/28/02	267	308	81	41	-227
8/29/02	270	328	93	58	-235
8/30/02	283	332	114	49	-218
8/31/02	276	332	121	56	-211
9/1/02	268	318	127	50	-191
9/2/02	261	309	127	48	-182
9/3/02	247	299	119	52	-180
9/4/02	240	276	107	36	-169
9/5/02	232	254	93	22	-161
9/6/02	234	264	91	30	-173
9/7/02	243	287	105	44	-182
9/8/02	267	307	125	40	-182
9/9/02	280	332	137	52	-195
9/10/02	291	346	147	55	-199
9/11/02	285	342	145	57	-197
9/12/02	284	349	144	65	-205
9/13/02	268	335	142	67	-193
9/14/02	260	321	136	61	-185
9/15/02	254	309	127	55	-182
9/16/02	244	290	115	46	-175
9/17/02	256	297	102	41	-195
9/18/02	278	336	149	58	-187
9/19/02	294	349	168	55	-181
9/20/02	289	344	177	55	-167
9/21/02	284	320	175	36	-145
9/22/02	285	308	165	23	-143
9/23/02	285	315	164	30	-151
9/24/02	290	325	170	35	-155
9/25/02	295	327	166	32	-161
9/26/02	301	339	182	38	-157
9/27/02	305	354	205	49	-149
9/28/02	318	371	220	53	-151
9/29/02	318	377	223	59	-154
9/30/02	314	376	223	62	-153

date	USGS Melrose streamflow (cfs)	USGS Glen streamflow (cfs)	High Road streamflow (cfs)	Difference between streamflow (cfs)	Difference between Glen streamflow (cfs)
7/1/03	882	1020		138	
7/2/03	803	944		141	
7/3/03	736	879		143	
7/4/03	682	827		145	
7/5/03	651	787		136	
7/6/03	606	733		127	
7/7/03	579	705		126	
7/8/03	549	672		123	
7/9/03	545	656		111	
7/10/03	513	619		106	
7/11/03	470	582		112	
7/12/03	443	542		99	
7/13/03	424	516		92	
7/14/03	408	498		90	
7/15/03	370	462		92	
7/16/03	362	439		77	
7/17/03	359	436		77	
7/18/03	336	417	217	81	-200
7/19/03	325	406	219	81	-187
7/20/03	314	394	216	80	-178
7/21/03	303	363	214	60	-149
7/22/03	300	306	189	6	-117
7/23/03	299	320	180	21	-140
7/24/03	281	299	174	18	-125
7/25/03	294	323	176	29	-147
7/26/03	333	425	215	92	-210
7/27/03	322	386	222	64	-164
7/28/03	320	368	212	48	-156
7/29/03	304	337	189	33	-148
7/30/03	289	320	164	31	-156
7/31/03	272	307	158	35	-149
8/1/03	250	292	159	42	-133
8/2/03	235	271	150	36	-121
8/3/03	233	258	143	25	-115
8/4/03	256	299	145	43	-154
8/5/03	252	296	147	44	-149
8/6/03	249	293	146	44	-147
8/7/03	259	289	138	30	-151
8/8/03	261	324	141	63	-183
8/9/03	243	303	145	60	-158
8/10/03	234	276	138	42	-138
8/11/03	230	271	133	41	-138
8/12/03	225	277	122	52	-155
8/13/03	212	260	107	48	-153
8/14/03	203	243	102	40	-141
8/15/03	189	222	98	33	-124
8/16/03	185	209	94	24	-115
8/17/03	189	218	91	29	-127
8/18/03	192	225	93	33	-132
8/19/03	188	217	90	29	-127
8/20/03	184	200	85	16	-115
8/21/03	184	201	83	17	-118
8/22/03	184	211	84	27	-127
8/23/03	203	223	85	20	-138
8/24/03	232	252	86	20	-166
8/25/03	222	265	90	43	-175
8/26/03	205	240	92	35	-148
8/27/03	205	239	91	34	-148
8/28/03	209	250	92	41	-158
8/29/03	207	250	95	43	-155
8/30/03	197	243	95	46	-148
8/31/03	190	236	92	46	-144
9/1/03	187	230	89	43	-141
9/2/03	181	225	85	44	-140
9/3/03	180	218	82	38	-136
9/4/03	179	221	82	42	-139
9/5/03	178	216	83	38	-133
9/6/03	177	215	83	38	-132
9/7/03	178	223	83	45	-140
9/8/03	181	226	82	45	-144
9/9/03	181	227	84	46	-143
9/10/03	184	225	86	41	-139
9/11/03	184	216	86	32	-130
9/12/03	188	191	83	3	-108
9/13/03	191	202	84	11	-118
9/14/03	194	209	87	15	-122
9/15/03	195	213	87	18	-126
9/16/03	197	217	89	20	-128
9/17/03	200	218	90	18	-128
9/18/03	212	241	94	29	-147
9/19/03	218	249	97	31	-152
9/20/03	223	251	97	28	-154
9/21/03	229	256	98	27	-158
9/22/03	234	259	105	25	-154
9/23/03	237	270	114	33	-156
9/24/03	239	274	121	35	-153
9/25/03	239	276	137	37	-139
9/26/03	236	273	144	37	-129
9/27/03	233	268	143	35	-125
9/28/03	225	259	142	34	-117
9/29/03	226	249	144	23	-105
9/30/03	223	229	144	6	-85

date	USGS Melrose streamflow (cfs)	USGS Glen streamflow (cfs)	High Road streamflow (cfs)	Difference between Melrose and Glen streamflow (cfs)	Difference between Glen and High Road streamflow (cfs)
7/1/04	1480	1410	1748	-70	338
7/2/04	1570	1540	2176	-30	636
7/3/04	1410	1420	2053	10	633
7/4/04	1330	1320	1755	-10	435
7/5/04	1270	1280	1620	10	340
7/6/04	1200	1220	1489	20	269
7/7/04	1060	1110	1234	50	124
7/8/04	938	1010	968	72	-42
7/9/04	819	903	795	84	-108
7/10/04	750	844	695	94	-149
7/11/04	699	794	629	95	-165
7/12/04	649	732	538	83	-194
7/13/04	594	675	478	81	-197
7/14/04	556	627	419	71	-208
7/15/04	526	575	374	49	-201
7/16/04	507	557	349	50	-208
7/17/04	492	532	327	40	-205
7/18/04	490	532	324	42	-208
7/19/04	535	560	339	25	-221
7/20/04	572	612	398	40	-214
7/21/04	660	691	457	31	-234
7/22/04	637	679	486	42	-193
7/23/04	560	627	439	67	-188
7/24/04	494	552	365	58	-187
7/25/04	464	494	302	30	-192
7/26/04	452	480	285	28	-195
7/27/04	421	441	258	20	-183
7/28/04	395	391	239	-4	-152
7/29/04	370	347	202	-23	-145
7/30/04	350	338	186	-12	-152
7/31/04	325	316	173	-9	-143
8/1/04	302	313	145	11	-168
8/2/04	293	301	148	8	-153
8/3/04	291	307	150	16	-157
8/4/04	294	305	151	11	-154
8/5/04	287	286	146	-1	-140
8/6/04	278	279	140	1	-139
8/7/04	260	263	129	3	-134
8/8/04	242	241	112	-1	-129
8/9/04	230	231	100	1	-131
8/10/04	218	218	86	0	-132
8/11/04	205	203	75	-2	-128
8/12/04	191	190	64	-1	-126
8/13/04	183	180	53	-3	-127
8/14/04	171	167	50	-4	-117
8/15/04	158	156	47	-2	-109
8/16/04	157	155	46	-2	-109
8/17/04	169	165	43	-4	-122
8/18/04	204	203	44	-1	-159
8/19/04	225	223	49	-2	-174
8/20/04	248	243	50	-5	-193
8/21/04	237	236	47	-1	-189
8/22/04	238	240	46	2	-194
8/23/04	282	276	54	-6	-222
8/24/04	326	299	58	-27	-241
8/25/04	340	327	67	-13	-260
8/26/04	360	340	77	-20	-263
8/27/04	381	362	84	-19	-278
8/28/04	371	362	88	-9	-274
8/29/04	355	346	84	-9	-262
8/30/04	331	330	79	-1	-251
8/31/04	296	292	69	-4	-223
9/1/04	281	270	61	-11	-209
9/2/04	275	267	55	-8	-212
9/3/04	286	278	58	-8	-220
9/4/04	287	281	59	-6	-222
9/5/04	292	269	57	-23	-212
9/6/04	314	277	56	-37	-221
9/7/04	290	276	59	-14	-217
9/8/04	273	262	57	-11	-205
9/9/04	261	257	55	-4	-202
9/10/04	258	252	53	-6	-199
9/11/04	245	246	53	1	-193
9/12/04	252	261	55	9	-206
9/13/04	292	310	66	18	-244
9/14/04	348	365	78	17	-287
9/15/04	364	388	93	24	-295
9/16/04	376	398	97	22	-301
9/17/04	376	404	104	28	-300
9/18/04	368	392	102	24	-290
9/19/04	398	421	111	23	-310
9/20/04	478	504	168	26	-336
9/21/04	535	589	330	54	-259
9/22/04	538	604	424	66	-180
9/23/04	518	570	414	52	-156
9/24/04	530	579	403	49	-176
9/25/04	522	570	411	48	-159
9/26/04	521	560	388	39	-172
9/27/04	514	543	412	29	-131
9/28/04	508	528	390	20	-138
9/29/04	504	520	382	16	-138
9/30/04	496	499	370	3	-129

flows above 1000 cfs at High Road not included since flow relationships developed for low flow conditions

date	USGS Melrose streamflow (cfs)	USGS Glen streamflow (cfs)	High Road streamflow (cfs)	Difference between Melrose and Glen streamflow (cfs)	Difference between Glen and High Road streamflow (cfs)
7/1/05	1810	1750		-60	
7/2/05	1590	1560		-30	
7/3/05	1370	1350		-20	
7/4/05	1200	1200		0	
7/5/05	1070	1090		20	
7/6/05	965	986		21	
7/7/05	883	896		13	
7/8/05	827	829	2512	2	1683
7/9/05	788	796	2547	8	1751
7/10/05	780	792	782	12	-10
7/11/05	789	794	689	5	-105
7/12/05	805	810	728	5	-82
7/13/05	767	783	756	16	-27
7/14/05	682	692	666	10	-26
7/15/05	622	623	597	1	-26
7/16/05	580	573	537	-7	-36
7/17/05	545	518	422	-27	-96
7/18/05	509	487	419	-22	-68
7/19/05	471	446	338	-25	-108
7/20/05	438	408	438	-30	30
7/21/05	405	381	210	-24	-171
7/22/05	393	354	173	-39	-181
7/23/05	394	341	164	-53	-177
7/24/05	381	332	158	-49	-174
7/25/05	376	339	154	-37	-185
7/26/05	378	355	156	-23	-199
7/27/05	359	332	138	-27	-194
7/28/05	318	304	125	-14	-179
7/29/05	319	286	120	-33	-166
7/30/05	294	277	109	-17	-168
7/31/05	275	262	99	-13	-163
8/1/05	281	263	91	-18	-172
8/2/05	306	288	88	-18	-200
8/3/05	310	312	98	2	-214
8/4/05	294	301	94	7	-207
8/5/05	279	290	91	11	-199
8/6/05	277	278	86	1	-192
8/7/05	268	271	83	3	-188
8/8/05	265	271	85	6	-186
8/9/05	276	266	86	-10	-180
8/10/05	299	285	88	-14	-197
8/11/05	315	308	99	-7	-209
8/12/05	311	311	101	0	-210
8/13/05	307	331	115	24	-216
8/14/05	299	320	112	21	-208
8/15/05	275	306	107	31	-199
8/16/05	261	277	95	16	-182
8/17/05	245	260	87	15	-173
8/18/05	223	236	80	13	-156
8/19/05	214	228	73	14	-155
8/20/05	206	217	68	11	-149
8/21/05	199	203	61	4	-142
8/22/05	189	191	57	2	-134
8/23/05	187	174	50	-13	-124
8/24/05	185	170	46	-15	-124
8/25/05	182	177	46	-5	-131
8/26/05	178	179	45	1	-134
8/27/05	177	177	45	0	-132
8/28/05	177	175	40	-2	-135
8/29/05	175	171	34	-4	-137
8/30/05	186	176		-10	
8/31/05	191	191		0	
9/1/05	187	190		3	
9/2/05	177	178		1	
9/3/05	174	170		-4	
9/4/05	169	166		-3	
9/5/05	173	168	26	-5	-142
9/6/05	176	169		-7	
9/7/05	174	167		-7	
9/8/05	171	168		-3	
9/9/05	170	170		0	
9/10/05	177	182		5	
9/11/05	192	192		0	
9/12/05	200	195		-5	
9/13/05	209	198		-11	
9/14/05	221	209		-12	
9/15/05	221	207		-14	
9/16/05	219	211		-8	
9/17/05	249	252		3	
9/18/05	280	286		6	
9/19/05	299	306		7	
9/20/05	319	313		-6	
9/21/05	320	313		-7	
9/22/05	309	301		-8	
9/23/05	310	306		-4	
9/24/05	324	342		18	
9/25/05	331	342		11	
9/26/05	336	352	172	16	-180
9/27/05	339	361	190	22	-171
9/28/05	341	362	167	21	-195
9/29/05	337	358	184	21	-174
9/30/05	329	346	180	17	-166

date	USGS Melrose streamflow (cfs)	USGS Glen streamflow (cfs)	High Road streamflow (cfs)	Difference between Melrose and Glen streamflow (cfs)	Difference between Glen and High Road streamflow (cfs)
7/1/06	1080	1010		-70	
7/2/06	1020	959		-61	
7/3/06	983	950		-33	
7/4/06	962	917		-45	
7/5/06	919	875		-44	
7/6/06	940	887		-53	
7/7/06	972	917		-55	
7/8/06	952	904		-48	
7/9/06	877	829	349	-48	-480
7/10/06	811	755	383	-56	-372
7/11/06	767	708	341	-59	-367
7/12/06	736	680	374	-56	-306
7/13/06	736	687	366	-49	-321
7/14/06	725	670	366	-55	-304
7/15/06	684	640	374	-44	-266
7/16/06	620	580	366	-40	-214
7/17/06	557	500	430	-57	-70
7/18/06	488	452		-36	
7/19/06	453	418		-35	
7/20/06	424	400		-24	
7/21/06	394	367		-27	
7/22/06	371	352		-19	
7/23/06	355	344		-11	
7/24/06	342	334	156	-8	-178
7/25/06	325	308	166	-17	-142
7/26/06	324	300	156	-24	-144
7/27/06	315	295	156	-20	-139
7/28/06	299	289	144	-10	-145
7/29/06	278	267	124	-11	-143
7/30/06	262	241	103	-21	-138
7/31/06	252	225	94	-27	-131
8/1/06	250	232		-18	
8/2/06	227	221		-6	
8/3/06	224	214		-10	
8/4/06	214	210		-4	
8/5/06	206	199		-7	
8/6/06	201	194		-7	
8/7/06	194	189	77	-5	-112
8/8/06	185	183	72	-2	-111
8/9/06	186	179	70	-7	-109
8/10/06	180	167	68	-13	-99
8/11/06	167	157	65	-10	-92
8/12/06	163	151	61	-12	-90
8/13/06	164	156	61	-8	-95
8/14/06	161	150	61	-11	-89
8/15/06	157	145	59	-12	-86
8/16/06	166	151	61	-15	-90
8/17/06	165	160	63	-5	-97
8/18/06	166	153	63	-13	-90
8/19/06	164	151	63	-13	-88
8/20/06	156	147	61	-9	-86
8/21/06	154	145	61	-9	-84
8/22/06	147	142	59	-5	-83
8/23/06	140	135	57	-5	-78
8/24/06	141	125	53	-16	-72
8/25/06	142	122	49	-20	-73
8/26/06	151	139	51	-12	-88
8/27/06	152	140	53	-12	-87
8/28/06	150	141	53	-9	-88
8/29/06	153	147	53	-6	-94
8/30/06	150	149	51	-1	-98
8/31/06	151	151	51	0	-100
9/1/06	152	157	53	5	-104
9/2/06	147	155	57	8	-98
9/3/06	139	137	55	-2	-82
9/4/06	141	139	51	-2	-88
9/5/06	140	146	53	6	-93
9/6/06	138	144	53	6	-91
9/7/06	136	130	46	-6	-84
9/8/06	135	130	41	-5	-89
9/9/06	137	137	42	0	-95
9/10/06	137	139	44	2	-95
9/11/06	138	134	44	-4	-90
9/12/06	138	136	44	-2	-92
9/13/06	142	135	42	-7	-93
9/14/06	148	141	41	-7	-100
9/15/06	173	171	46	-2	-125
9/16/06	188	186	55	-2	-131
9/17/06	197	202	63	5	-139
9/18/06	201	211	70	10	-141
9/19/06	207	224	72	17	-152
9/20/06	207	225	75	18	-150
9/21/06	248	245	85	-3	-160
9/22/06	277	287	103	10	-184
9/23/06	280	288	117	8	-171
9/24/06	282	296	124	14	-172
9/25/06	288	295	128	7	-167
9/26/06	292	300	128	8	-172
9/27/06	288	303	132	15	-171
9/28/06	285	315	144	30	-171
9/29/06	284	302	136	18	-166
9/30/06	277	302	113	25	-189

date	DNRC Divide Bridge streamflow (cfs)	USGS Melrose streamflow (cfs)	USGS Glen streamflow (cfs)	DNRC Pennington Bridge streamflow (cfs)	USGS below Hamilton Ditch (High Road) streamflow (cfs)	Difference between Divide Bridge and Melrose streamflow (cfs)	Difference between Melrose and Glen streamflow (cfs)	Difference between Glen and Pennington Bridge streamflow (cfs)	Difference between Pennington Bridge and High Road streamflow (cfs)	Difference between Divide and High Road streamflow (cfs)	Difference between Glen and High Road streamflow (cfs)
7/1/2007		598	603		420		5				-183
7/2/2007		561	572		400		11				-172
7/3/2007		522	537		380		15				-157
7/4/2007		479	497		360		18				-137
7/5/2007		458	473		330		15				-143
7/6/2007		428	446		300		18				-146
7/7/2007		418	433		270		15				-163
7/8/2007		407	450		280		43				-170
7/9/2007		384	417		260		33				-157
7/10/2007		381	406		250		25				-156
7/11/2007		371	399		240		28				-159
7/12/2007		362	394		240		32				-154
7/13/2007		350	391		230		41				-161
7/14/2007		340	384		220		44				-164
7/15/2007		341	396		220		55				-176
7/16/2007		324	396		210		72				-186
7/17/2007		306	385		200		79				-185
7/18/2007		409	454		240		45				-214
7/19/2007		408	457		250		49				-207
7/20/2007		333	379		210		46				-169
7/21/2007		304	339		193		35				-146
7/22/2007		281	319		181		38				-138
7/23/2007		267	297		163		30				-134
7/24/2007		261	291		158		30				-133
7/25/2007		277	316		174		39				-142
7/26/2007		303	328		162		25				-166
7/27/2007		302	321		171		19				-150
7/28/2007		279	305		148		26				-157
7/29/2007		265	295		149		30				-146
7/30/2007		247	274		136		27				-138
7/31/2007		240	265		127		25				-138
8/1/2007		221	247		108		26				-139
8/2/2007		194	225		91		31				-134
8/3/2007		187	215		77		28				-138
8/4/2007		183	207		66		24				-141
8/5/2007		188	209		66		21				-143
8/6/2007		202	221		74		19				-147
8/7/2007		195	219		68		24				-151
8/8/2007		185	207		59		22				-148
8/9/2007		176	201		58		25				-143
8/10/2007		175	194		54		19				-140
8/11/2007		170	192		51		22				-141
8/12/2007		156	184		47		28				-137
8/13/2007		142	166		41		24				-125
8/14/2007		141	150		32		9				-118
8/15/2007		142	145		25		3				-120
8/16/2007		143	148		25		5				-123
8/17/2007		149	154		26		5				-128
8/18/2007		157	167		28		10				-139
8/19/2007		178	170		32		-8				-138
8/20/2007		177	191		34		14				-157
8/21/2007		165	176		35		11				-141
8/22/2007	203	161	169		32	-42	8			-171	-137
8/23/2007	202	157	168		32	-45	11			-170	-136
8/24/2007	203	160	169		31	-43	9			-172	-138
8/25/2007	194	155	169		41	-39	14			-153	-128
8/26/2007	191	152	167		44	-39	15			-147	-123
8/27/2007	189	143	160		42	-46	17			-147	-118
8/28/2007	181	141	147	89	37	-40	6	-58	-52	-144	-110
8/29/2007	176	135	148	98	36	-41	13	-50	-62	-140	-112
8/30/2007	179	130	147	91	35	-49	17	-56	-56	-144	-112
8/31/2007	179	127	154	101	37	-52	27	-53	-64	-142	-117
9/1/2007	181	124	149	105	39	-57	25	-44	-66	-142	-110
9/2/2007	183	127	148	106	40	-56	21	-42	-66	-143	-108
9/3/2007	175	120	145	104	39	-55	25	-41	-65	-136	-106
9/4/2007	176	113	142	104	40	-63	29	-38	-64	-136	-102
9/5/2007	195	130	150	113	43	-65	20	-37	-70	-152	-107
9/6/2007	212	160	209	170	65	-52	49	-39	-105	-147	-144
9/7/2007	203	151	197	162	63	-52	46	-35	-99	-140	-134
9/8/2007	203	141	168	143	57	-62	27	-25	-86	-146	-111
9/9/2007	199	145	142	104	43	-54	-3	-38	-61	-156	-99
9/10/2007	196	146	163	122	44	-50	17	-41	-78	-152	-119
9/11/2007	191	146	176	143	62	-45	30	-33	-81	-129	-114
9/12/2007	189	143	178	146	63	-46	35	-32	-83	-126	-115
9/13/2007	189	145	177	143	62	-44	32	-34	-81	-127	-115
9/14/2007	187	143	183	158	70	-44	40	-25	-88	-117	-113
9/15/2007	183	147	181	161	74	-36	34	-20	-87	-109	-107
9/16/2007	177	151	182	156	69	-26	31	-26	-87	-108	-113
9/17/2007	182	149	184	156	71	-33	35	-28	-85	-111	-113
9/18/2007	189	149	182	155	70	-40	33	-27	-85	-119	-112
9/19/2007	189	162	208	174	73	-27	46	-34	-101	-116	-135
9/20/2007	202	176	222	196	85	-26	46	-26	-111	-117	-137
9/21/2007	203	176	213	195	92	-27	37	-18	-103	-111	-121
9/22/2007	203	183	220	200	115	-20	37	-20	-85	-88	-105
9/23/2007	252	237	265	235	138	-15	28	-30	-97	-114	-127
9/24/2007	294	326	354	304	194	32	28	-50	-110	-100	-160
9/25/2007	303	349	424	356	274	46	75	-68	-82	-29	-150
9/26/2007	307	356	420	371	271	49	64	-49	-100	-36	-149
9/27/2007	286	337	407	362	265	51	70	-45	-97	-21	-142
9/28/2007	280	320	383	344	243	40	63	-39	-101	-37	-140
9/29/2007	292	336	393	349	250	44	57	-44	-99	-42	-143
9/30/2007	296	346	404	362	262	50	58	-42	-100	-34	-142

Appendix B

MAPS

Lower Big Hole Irrigation Infrastructure Study

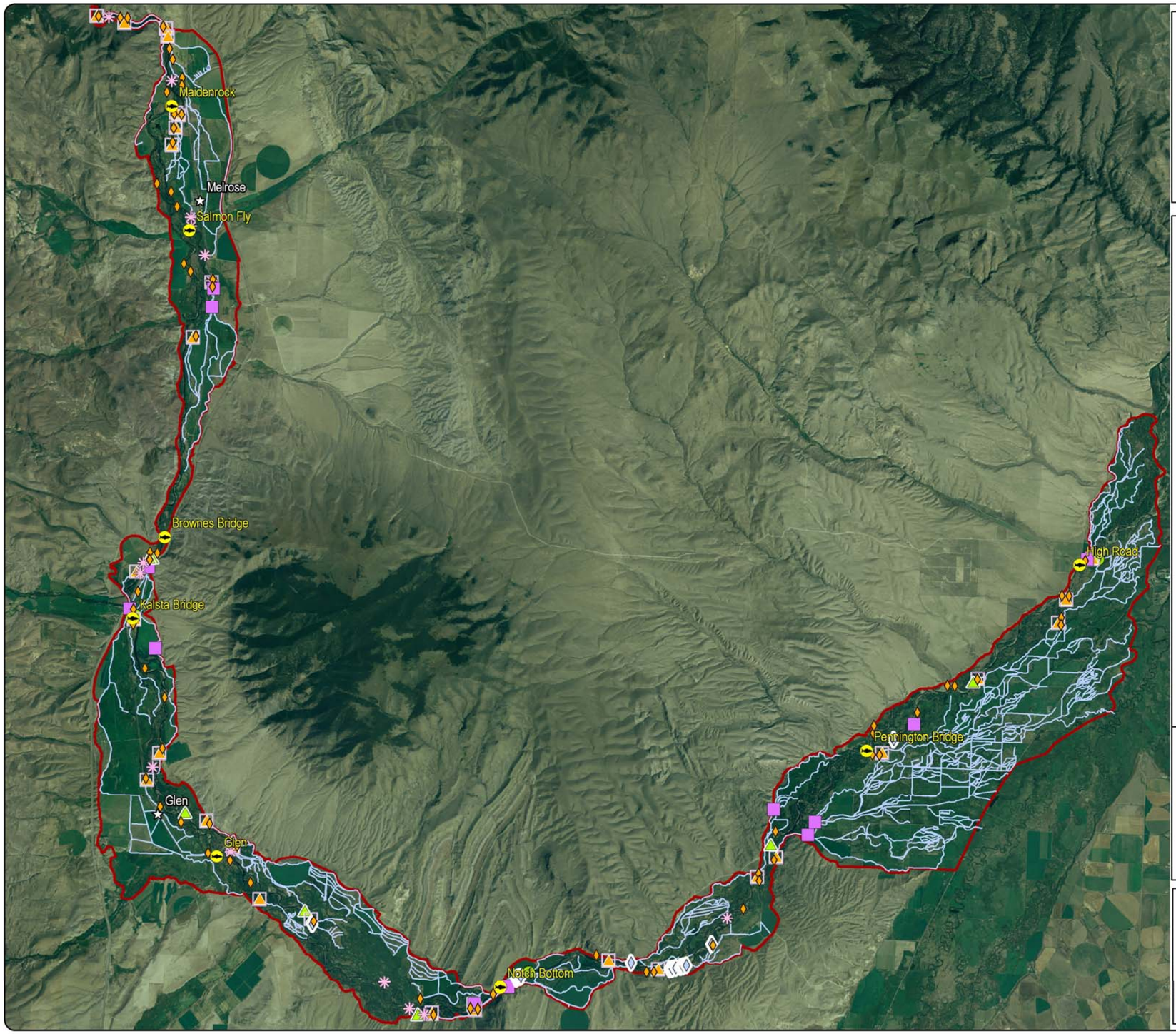


Figure 3-3
Overview of Water Rights and the Irrigation Ditch Network

LEGEND

- Lower Big Hole River Valley
- Irrigation Ditches
- Towns
- MFWP Access Points
- DNRC Water Rights
  Points of Diversion
  Surface WR for the Big Hole River
- USGS Stations

Field Assessment - Feature Type

- barb
- headgate in ditch
- headgate on mainstem
- initial diversion
- potential spawning site

N
W E
S

0 0.5 1 2 3 4 Miles

1:105,000

PBS&J

Date: February 2008
Location: Lower Big Hole River
Project Manager: J. Dunn
GIS: R. Schreiner

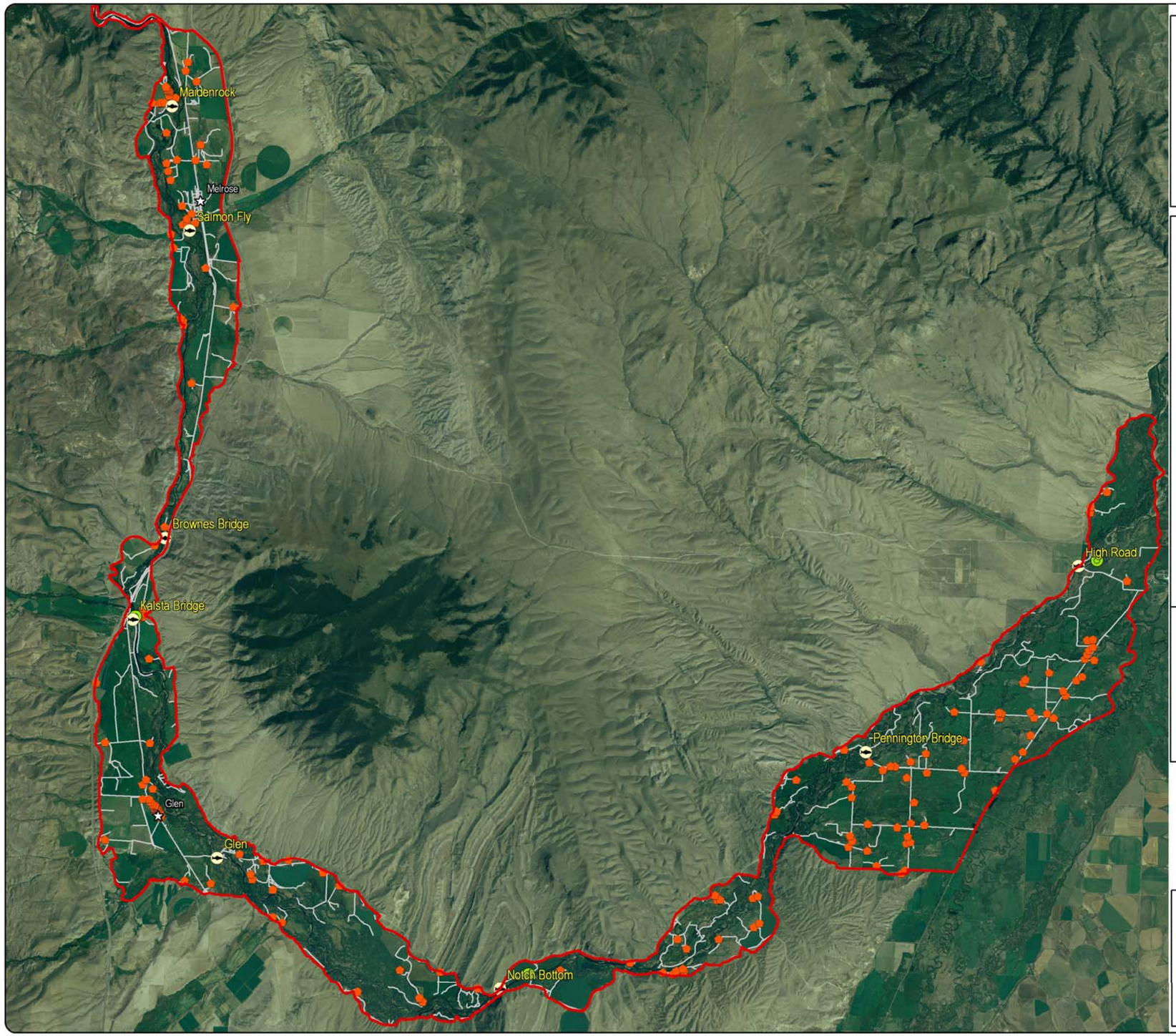


Figure 3-4
Roads and Structures in the Lower Big Hole River Valley

LEGEND

- Lower Big Hole River Valley
- Irrigation Ditches
- Towns
- MFWP Access Points
- DNRC Water Rights
  Points of Diversion
  Surface WR for the Big Hole River
- USGS Stations

N
W E
S

Miles
0 0.5 1 2 3 4

1:105,000

PBS&J

Date: February 2008
Location: Lower Big Hole River
Project Manager: J. Dunn
GIS: R. Schreiner

Figure 3-5 Reach 1 - Maiden Rock to Melrose/Salmon Fly

D18
H9
R42
D19
D20
D21
H10
Maidenrock
D44
D22
D23
D24
E3
R45
R46
R47
Melrose
H11
H5
Salmon Fly

LEGEND

- Lower Big Hole River Valley
- Towns
- MFWP Access Points
- USGS Gaging Stations

Streambank Alterations

- barb
- headgate in ditch
- headgate on mainstem
- initial diversion
- potential spawning site
- accelerated bank erosion
- floodplain berm
- log revetment
- riprap
- riprap, floodplain berm

Ditches

- D18, Upper McCauley
- D19, Meriwether
- D20, Lower McCauley
- D21, Melrose Canal
- D22, Meriwether
- D23, Carpenter
- D24, Carpenter
- D44, Meriwether (Buyan slough)

Miles
0 0.1 0.2 0.4
1:15,000

N

PBS&J

Figure 3-6 Reach 2 Melrose/Salmon Fly to Brown's Bridge

H11
H5
Salmon Fly
H6
R35
R33
H7
D11
E5
D29
D31
D30
Brownes Bridge

LEGEND

- Lower Big Hole River Valley
- Towns
- MFWP Access Points
- USGS Gaging Stations

Streambank Alterations

- barb
- headgate in ditch
- headgate on mainstem
- initial diversion
- potential spawning site
- accelerated bank erosion
- floodplain berm
- log revetment
- riprap
- riprap, floodplain berm

Ditches

- D11a, Pendergast-Spears-McCullough
- D11b, Gallagher
- D20, Lower McCauley
- D21, Melrose Canal
- D30, Garden

Miles
0 0.15 0.3 0.6
1:22,000

N

PBS&J

Figure 3-7 Reach 3 - Browne's Bridge to Glen

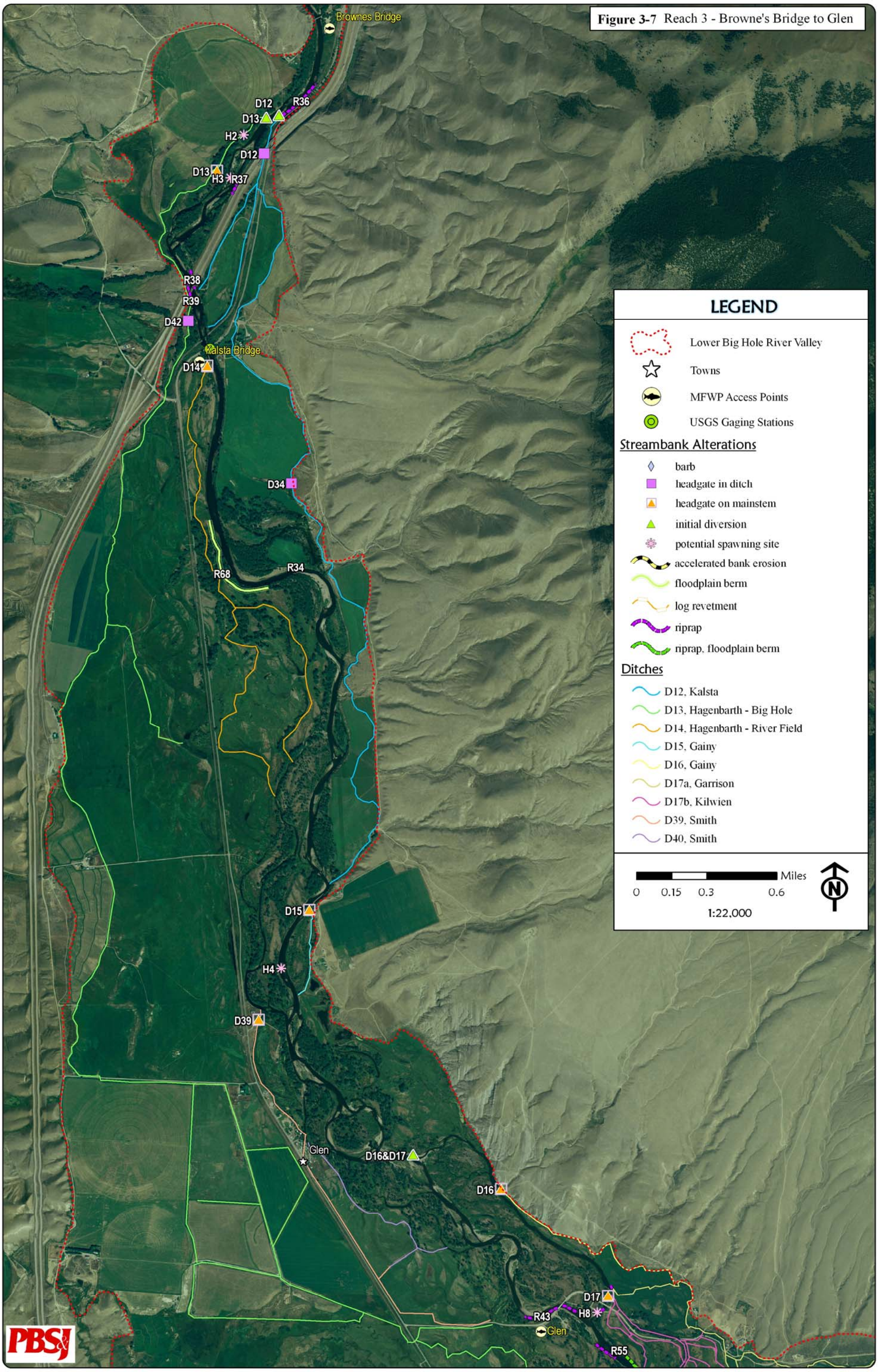


Figure 3-8 Reach 4 - Glen to Notch Bottom

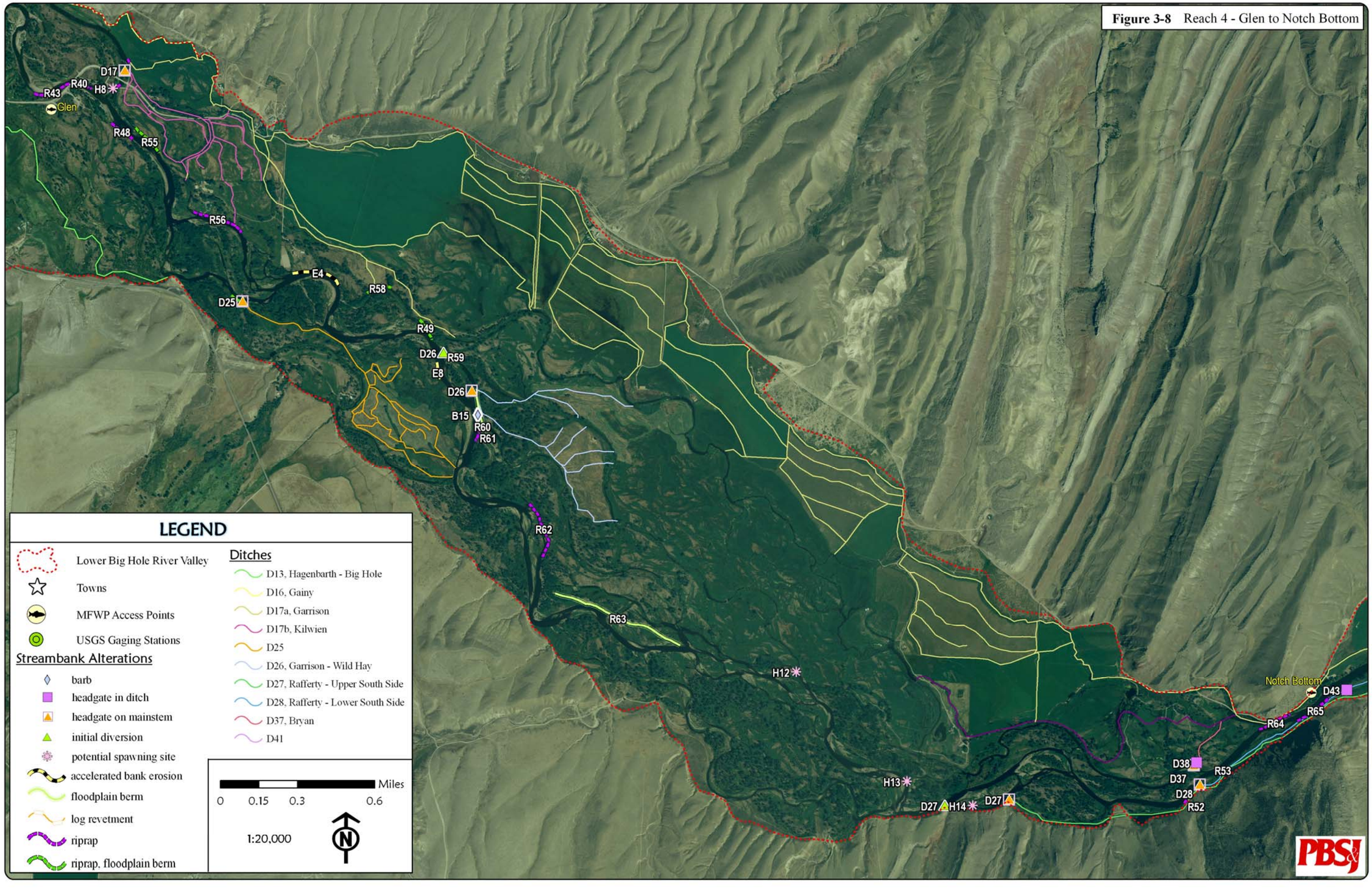


Figure 3-9 Reach 5 - Notch Bottom to Pennington Bridge

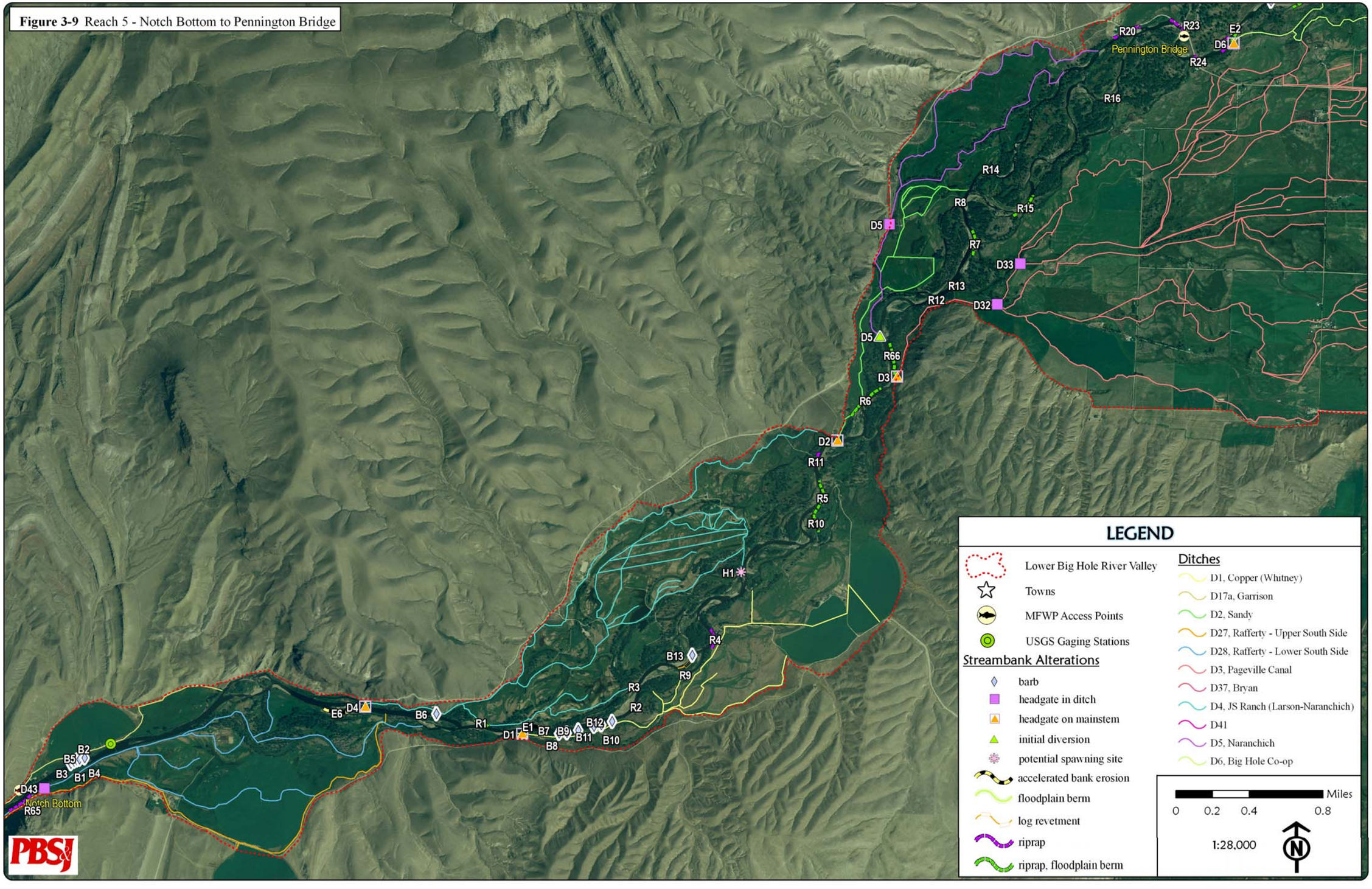
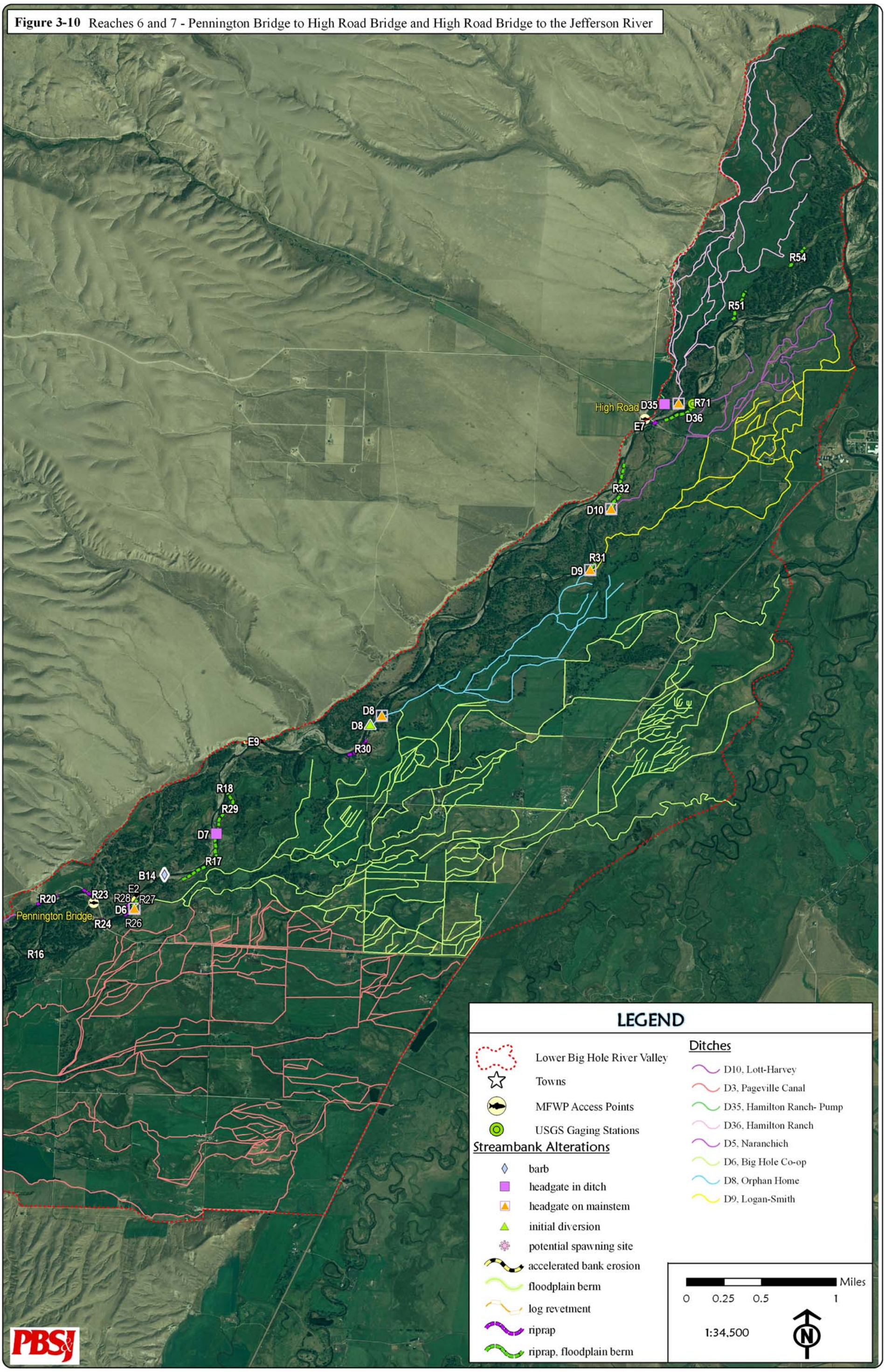


Figure 3-10 Reaches 6 and 7 - Pennington Bridge to High Road Bridge and High Road Bridge to the Jefferson River



Appendix C

DIVERSION DESCRIPTIONS

Lower Big Hole Irrigation Infrastructure Study

MAIDEN ROCK CANYON TO MELROSE/SALMON FLY FAS

Lower Big Hole Irrigation Infrastructure Study

Diversion 18 - Upper McCauley

Diversion 18 (Upper McCauley) is located on the river left bank at the inside of a meander bend in Maiden Rock canyon. The diversion weir is comprised primarily of large cobbles (channel materials) and boulders and extends most of the way across the channel. The weir does not appear to require regular maintenance and appears well-integrated into the natural channel morphology in this naturally confined section of river, though it may be a source of channel over-widening at the point of diversion. Channel confinement is provided by the canyon walls and the railroad on river left, while there is a terrace along river right. The channel bed material is large in this section of river. The diversion channel leads off to river left approximately 300 feet downstream to a headgate. There is a boulder check dam in the overflow channel that raises the water elevation at the headgate. The overflow water discharges through a vegetated gravel bar back into the Big Hole River. The headgate appears old and was comprised a metal “screw gate” in a wooden housing. After the initial diversion, the ditch is situated between the railroad track and the base of the canyon wall along the left side of the river. A portion of the ditch is transported in a pipe, which outlets back into a gravel and sand bottom ditch on river left at the mouth of the canyon. When the ditch enters the valley, it irrigates an area between the river and the interstate to the east of the Big Hole River at the mouth of Maiden Rock Canyon.

Diversion 19 – Meriwether's

Diversion 19 is located along the river right bank in a relatively straight section of Maiden Rock canyon. There is a very long cobble (channel materials) and boulder weir extending approximately 800 feet from the headgate. The diversion dam starts pulling water at the inside of the bend in a shallow riffle. The diversion dam includes a section of boulders that appears to be abandoned in the channel. The "pin and plank" headgate has two openings and the ditch has a gravel substrate. The ditch flows along the river right side of the canyon and irrigates an area downstream of the mouth of the canyon. There is reportedly a Parshall plume in this ditch.

Diversion 20 – Lower McCauley

Diversions 20 and 21 on the river left bank and are both fed by a large diversion weir located at the outside of a bend in the main channel at the mouth of Maiden Rock canyon. The diversion structure is located in a naturally confined area just before the canyon opens up. The floodplain berm along the railroad on river left also confines the channel. The large cobble (channel material) weir extends most of the way across the channel, where it transitions to boulders with a large boulder "anchoring" it at its farthest extent. This weir diverts water into two diversion channels along river left. The upper diversion (Diversion 20) and the lower diversion (Diversion 21) both serve ditches that run between the river and the railroad and are then directed under the railroad and frontage road where they irrigate the valley to the east of the Big Hole River upstream of Melrose, with the ditch fed by Diversion 20 located along the interstate.

Diversion 20 is a single metal "screw gate" in a wooden housing. Diversion water is partially regulated by a collapsible jack. The wooden housing for the headgate and the collapsible jack is nearing the end of it operational lifespan. This ditch had a sand and gravel bottom where observed, though both of these ditches reportedly have cobble bottoms in the valley. Return flow from both of these ditches reportedly occurs through Camp Creek, with some water passing under the Frontage road and used in the next field to the south.

Diversion 21 – Melrose Canal

Diversions 20 and 21 on the river left bank and are both fed by a large diversion weir located at the outside of a bend in the main channel at the mouth of Maiden Rock canyon. The diversion structure is located in a naturally confined area just before the canyon opens up. The floodplain berm along the railroad on river left also confines the channel. The large cobble (channel material) weir extends most of the way across the channel, where it transitions to boulders with a large boulder "anchoring" it at its farthest extent. This weir diverts water into two diversion channels along river left. The upper diversion (Diversion 20) and the lower diversion (Diversion 21) both serve ditches that run between the river and the railroad and are then directed under the railroad and frontage road where they irrigate the valley to the east of the Big Hole River upstream of Melrose.

Diversion 21 has 3 metal "screw gates" in a concrete housing, though only one headgate (most river right) appears functional. Water was ponded in the ditch below Diversion 21. The overflow channel at Diversion 21 is regulated by a large collapsible jack, which is reportedly difficult to operate when the water is high. Return flow from both of these ditches reportedly occurs through Camp Creek, with some water passing under the Frontage road and used in the next field to the south.

Diversion 22 – Meriwether's

Diversion 22 is located along the river left bank on the inside of a bend in the left channel just downstream of where the Big Hole River splits into two channels at the Meriwether Ranch. The left channel now carries the majority of the flow, though it was formerly known as "County Line Slough". The diversion structure is located in a relatively flat floodplain area and has the potential to dramatically influence channel form in what would naturally be a meandering gravel bed system. At this diversion, water is directed through a short diversion channel to the wooden "pin and plank" headgate. The cobble (channel material) and boulder diversion weir extends approximately a third of the way into the channel, where it meets a riffle. This ditch irrigates an area to the east of the Big Hole River upstream of Melrose.

There is a second un-assessed diversion on the right channel across from Diversion 22. This diversion (D44) is located along the left bank of the right channel (also called "Buyan Slough") near the upstream point of the island. Water from this ditch is used to irrigate the island.

Diversion 23 – Carpenter's

Diversion 23 is the more upstream of the two Carpenter's diversions. This diversion is located just upstream of the "Meriwether Bridge" on the river left bank at the outside of a bend. The diversion structure is located in a relatively flat floodplain area and has the potential to dramatically influence channel form in what would naturally be a meandering gravel-bar system. Water is directed to the wooden headgate via a cobble (channel material) and boulder weir that extends a third of the way into the channel. There is no diversion channel and the headgate is situated in the bank parallel to the flow. The "pin and plank" wooden headgate is adjusted by removing boards and was recently upgraded. The ditch had a gravel bottom and irrigates a relatively small area between the Big Hole River and the frontage road upstream of Melrose.

There is riprap upstream of the diversion along the river left bank. "The Meriwether Bridge" is located just downstream of the diversion.

Diversion 24 – Carpenter's

Diversion 24 is the more downstream of the two Carpenter's diversions. It is located on the river left bank at the outside of a bend. The diversion structure is located in a relatively flat floodplain area and has the potential to dramatically influence channel form in what would naturally be a meandering gravel-bar system. There is a large cobble (channel material) and boulder weir extending most of the way across the channel. This weir reportedly requires maintenance regularly. There is no diversion channel and the headgate is situated in the bank. The headgate is wooded "pin and plank" structure that is need of repair.

There is riprap downstream of the diversion on the river left bank, which is leading to bank erosion along the river right bank on the next meander bend downstream. The channel is becoming over-widened at this eroding bank.

At the time of this assessment, this diversion was scheduled for an upgrade, including a new headgate, modification of the diversion dam, and the addition of a Parshall flume.

MELROSE/SALMON FLY FAS TO BROWN'S BRIDGE FAS

Lower Big Hole Irrigation Infrastructure Study

Diversion 11a - Pendergast–Spears–McCullough

Diversions 11a and 11b are located along the river left bank at the outside of a bend in the left channel downstream of Melrose. The diversion structure was a small man-made island comprised of angular boulders and extended most of the way across the channel. There are two diversion channels, with a wooden headgate (Diversion 11a) on the more upstream channel and a gravel/cobble berm blocking the more downstream diversion channel (Diversion 11b), which prevents it from flowing during the winter. There is a second headgate (Diversion 29) in the Pendergast-Spears-McCullough ditch (11a) that directs water into the Gallagher ditch (11b). Return flow from the Gallagher ditch is directed back into a slough, which is then diverted at Diversion 30 into the Garden ditch.

The Diversion 11a headgate was wooden "pin and plank" structure in a wooden housing that was adjustable by adding/removing boards. There were two openings that could be adjusted. There was an overflow channel with a "collapsible jack" that could be adjusted to raise the water level reaching the headgate. This ditch irrigates an area between Melrose and Brown's Bridge. This ditch was originally located upstream of Melrose, but the diversion was moved after the construction of the railroad eliminated the upper portion of the ditch. It has a very low gradient and is slow and flat all the way.

There was riprap along the railroad track upstream of this diversion on river left leading to confinement along this side of the channel. There was bank erosion occurring downstream of the diversion dam along the river left bank.

Diversion 11b – Gallagher Ditch

Diversions 11a and 11b are located along the river left bank at the outside of a bend in the left channel downstream of Melrose. The diversion structure was a small man-made island comprised of angular boulders and extended most of the way across the channel. There are two diversion channels, with a wooden headgate (Diversion 11a) on the more upstream channel and a gravel/cobble berm blocking the more downstream diversion channel (Diversion 11b), which prevents it from flowing during the winter. There is a second headgate (Diversion 29) in the Pendergast-Spears-McCullough ditch (11a) that directs water into the Gallagher ditch (11b). Return flow from the Gallagher ditch is directed back into a slough, which is then diverted at Diversion 30 into the Garden ditch.

Diversion 11b currently lacks a headgate and is adjusted through manipulation of the gravel berm, which is angled out into the channel during the irrigation season. Additional water from the Pendergast-Spears-McCullough ditch (11a) enters the Gallagher ditch at Diversion 29. This ditch irrigates an area between Melrose and Brown's Bridge.

There was riprap along the railroad track upstream of this diversion on river left leading to confinement along this side of the channel. There was bank erosion occurring downstream of the diversion dam along the river left bank.

Diversion 29 – overflow from Pendergast-Spears-McCullough into Gallagher Ditch

Diversion 29 directs overflow water from the Pendergast-Spears-McCullough ditch (Diversion 11a) into the Gallagher Ditch (Diversion 11b). This diversion is located approximately 500 feet down the ditch from the main diversion on the Big Hole River.

The collapsible jack is nearing the end of its operation lifespan.

Diversion 30 – Garden Ditch

Return flow from the Gallagher Ditch (Diversion 11b) is directed into a slough at Diversion 31 and a portion of the water is then diverted into the Garden Ditch at Diversion 30. This ditch irrigates a relatively small area between the Big Hole River and the Frontage Road.

BROWN'S BRIDGE FAS TO GLEN FAS

Lower Big Hole Irrigation Infrastructure Study

Diversion 12 – Kalsta's

Diversion 12 is located at the outside of a bend on the river left bank underneath the most upstream I-15 over-pass. The diversion weir is made of large cobbles and small boulders and extends across the entire channel and has a "flow through" chute for boat passage. The headgate is located approximately 800 feet downstream the diversion channel. There are two metal "screw gates" in a concrete structure leading into a concrete ditch, which includes a staff gage. This diversion irrigates land above and below Kalsta Bridge along the east side of the Big Hole River.

There is railroad riprap upstream along the river left bank and the headgate is located among the interstate bridge pylons.

Diversion 34 – within Kalsta's Ditch

Diversion 34 is located approximately 1.7 miles down Kalsta's ditch (D12). At this diversion, the main ditch splits into two ditches. The right (west) ditch leads back to the river, flowing through a floodplain area feed by springs. The left (east) ditch flows approximately 2 more miles before returning to the river upstream of Diversion 15.

Diversion 13 – Hagenbarth's "Big Hole" Ditch

Diversion 13 is the located in a diversion channel along the river right bank. The diversion channel is formed by a semi-natural looking gravel bar on river right just downstream of Kalsta's diversion weir. The single wooden headgate is located approximately 1,500 feet down the diversion channel and there is a "blow-off" channel approximately 600 feet down the diversion channel. Water is directed toward the headgate by a gravel berm. This ditch irrigates land on the west side of the Big Hole River downstream of the interstate crossing and upstream of Glen. Flow in this ditch is regulated by a second headgate (Diversion 42) at the mouth of Rock Creek. Water from this ditch then flows into a network of ditches downstream of Glen.

Both headgates are scheduled to be replaced in the spring of 2008. At the upper headgate (Diversion 13), they plan to add a "collapsible jack" to replace the gravel berm currently used. At the second diversion (Diversion 42) where the ditch intercepts Rock Creek, they are also planning to replace the wooden headgate and replace the existing Parshall flume with a 6' Parshall flume.

Diversion 14 – Hagenbarth's "River Field" Ditch

Diversion 14 is located on the river right bank just downstream of the Kalsta Bridge. The diversion dam is comprised of cobbles (channel materials) and is angled directly upstream, but does not extend across a large portion of the channel. There is a deep scour hole below the Kalsta Bridge and sediment deposition downstream of this spot likely leads to gravel accumulations at the entrance of this ditch. There is a single metal headgate in a wooden structure. This gravel bottom ditch flood irrigates land between the Big Hole River and the frontage road.

Diversion 15 – Gainy's

Diversion 15 is located on the river left bank at the outside of a bend. There is a cobble and boulder weir extending out into the channel straight upstream approximately 350 feet from the headgate. This ditch is located where the river meets the foothills along river left, so it is somewhat naturally confined currently, though this is subject to lateral channel migration. The headgate is a metal "screw gate" in a wooden housing and there is an overflow channel with a "collapsible jack". Return flow from this ditch feeds a series of ponds located on the floodplain.

Diversion 39 – Smith's

Diversion 39 comes off a slough on river right and the initial point of diversion is located over a mile upstream. Overflow water from Hagenbarth's "River Field" ditch also feeds this slough. At the headgate, the diversion dam is made of gravel and cobble (channel materials), along with some wood. The single metal "screw gate" is situated in a wooden housing and is approximately 100 feet down a diversion channel. This gravel bottom ditch irrigates land downstream of Glen. There is a Pashall flume, though it reportedly may not function properly since the ditch is relatively flat.

GLEN FAS TO NOTCH BOTTOM FAS

Lower Big Hole Irrigation Infrastructure Study

Diversion 16 and 17 – Diversion Dam for Gainy's and Garrison/Kilwien

Diversion 16 – Gainy's

Diversions 16 and 17 are fed by a large diversion channel on the river left bank, with the initial point of diversion maintained by a gravel and cobble weir constructed out of channel materials in a riffle that is over-widened. Gravels have been piled up on both sides of the entrance to the side channel in an effort to maintain flow into the diversion channel. The initial diversion is located in relatively a broad and flat floodplain area with multiple channels.

Diversion 16 is located on river left bank and has a gravel, cobble and small boulder weir extending all the way across the channel. The diversion dam has also accumulated LWD closer to the headgate. The single headgate is made of metal and wood.

Diversion 17a – Garrison's (Buhrer-Garrison Ditch)

Diversions 16 and 17 are fed by a large diversion channel on the river left bank, with the initial point of diversion maintained by a gravel and cobble weir constructed out of channel materials in a riffle that is over-widened. Gravels have been piled up on both sides of the entrance to the side channel in an effort to maintain flow into the diversion channel. The initial diversion is located in relatively a broad and flat floodplain area with multiple channels.

Diversions 17a and 17b are located along the river left bank in diversion channel at the outside of a bend just upstream of the Burma Road bridge crossing. The floodplain is relatively low and flat, though the bridge downstream is well above the elevation of the floodplain. There is a large gravel and cobble (channel materials) berm across the entire channel, though a flow-through channel is created during the non-irrigation season to prevent the material from washing downstream during spring runoff.

Diversion 17 is comprised of two diversions and the headgates were replaced in 2006 with metal "screw gates". The river left headgate (17a) feeds the Garrison ditch, which runs several miles along the foothills and Burma road an primarily flood irrigates the valley bottom between the foothills and the river, with at least one field irrigated with sprinkler irrigation.

There is a short section of riprap upstream on river left, with additional riprap at the bridge downstream. There are staff gages on both headgates and the potential to add a Parshall flume to Garrison's diversion.

There is currently a design in place to improve this diversion dam. However, concerns have been raised that the river could overflow onto the floodplain here,

Diversion 17b – Kilwien's (Buhrer-Garrison Ditch)

Diversions 16 and 17 are fed by a large diversion channel on the river left bank, with the initial point of diversion maintained by a gravel and cobble weir constructed out of channel materials in a riffle that is over-widened. Gravels have been piled up on both sides of the entrance to the side channel in an effort to maintain flow into the diversion channel. The initial diversion is located in relatively a broad and flat floodplain area with multiple channels.

Diversions 17a and 17b are located along the river left bank in diversion channel at the outside of a bend just upstream of the Burma Road bridge crossing. The floodplain is relatively low and flat, though the bridge downstream is well above the elevation of the floodplain. There is a large gravel and cobble (channel materials) berm across the entire channel, though a flow-through channel is created during the non-irrigation season to prevent the material from washing downstream during spring runoff.

Diversion 17 is comprised of two diversions and the headgates were replaced in 2006 with metal "screw gates". The river right headgate (17b) feeds the Kilwien ditch.

There is a short section of riprap upstream on river left, with additional riprap at the bridge downstream. There are staff gages on both headgates. The Kilwien ditch is relatively flat.

Diversion 25

Diversion 25 is located along the river right bank in the right channel downstream of the Glen FAS. This is a large natural side channel. The diversion weir is made of cobble and gravels (channel materials). It appears that a portion of the diversion dam has washed out, leaving a plume of cobbles downstream. It is a metal "screw gate" in a metal housing surrounded by boulders (riprap) and cobbles.

Diversion 26 – Garrison's "Wild Hay" Ditch

Diversion 26 is located in a diversion channel to the river left of the main channel. The diversion channel reportedly used to be the main channel. The initial point of diversion is maintained by a gravel and cobble (channel materials) weir that extends approximately half way across the channel in a wide and shallow riffle. The diversion weir at the headgate extends across the entire side channel and is made of channel materials with a few boulders. There are two metal headgates in a wooden housing that was recently replaced. The headgate is housed in a large floodplain berm that extends downstream to an area with barbs and riprap.

There is riprap in the side channel and the headgate is located in a large floodplain berm created using gravel and cobble channel materials. There is bank erosion downstream along the river right bank in this over-widened area.

Diversion 27 – Rafferty's "Upper South Side" Ditch

Diversion 27 is located along the river right bank in a side channel to the river right. The original inlet to this diversion has been abandoned and the river eroded away part of the original ditch. The existing point of diversion looks like a natural gravel bar. At the headgate, there is a diversion dam extending across the entire channel. This diversion dam is made primarily of channel materials, with some smaller angular boulders. There are two metal "screw gates" in a wooden housing that were situated parallel ("askew") to the flow. The cobble bottom ditch flows along the base of the foothill and through the Notch, irrigating an area downstream of the Notch.

Diversion 28 – Rafferty's "Lower South Side" Ditch

Diversion 28 is located along the river right bank in the main channel. There is a large cobble and boulder weir extending well upstream and across most of the channel. The single metal "screw gate" is in a wooden housing. The ditch parallels the "Upper South Side" ditch and runs along the river. This ditch carries floodwater during high flows and is regulated by a second headgate where it departs from the river.

Diversion 37 – Bryan Ditch

Diversion 37 comes off a river left side channel across from where Rafferty's "Lower South Side" ditch (D27) comes off on river right. There are two headgates in a row, with a created "spring creek" flowing in-between. The ditch then leads down into a ponded area that also has return flow water from Garrison's diversion (D17a). This ditch irrigates an area downstream of the Notch.

NOTCH BOTTOM FAS TO PENNINGTON BRIDGE FAS

Lower Big Hole Irrigation Infrastructure Study

Diversion 4 – JS Ranch (Larson-Naranchich Ditch)

Diversion 4 is located along the river left bank downstream of Notch Bottom. A diversion channel has been created on river left to direct water toward the headgate. The diversion channel consists of a large vegetated berm with a natural looking gravel bar directing flow from the main channel. The headgate is a metal "screw gate" in a concrete housing and is located approximately 1,500 feet downstream of the initial point of diversion. There is a "collapsible jack" to increase the elevation of the water at the headgate. This ditch irrigates fields to the north of the Big Hole River.

This diversion is leading to bank erosion along the river right bank downstream, along with channel over-widening.

Diversion 1 – Cooper's (Whitney Ditch)

Diversion 1 is located at the outside of a meander bend along the river right bank. There is a vegetated cobble and boulder weir that extends approximately half way across the channel. The weir is vegetated with willows and has captured woody debris. There are two metal "screw gates" in a wooden structure that were fully opened at the time of the site visit.

There was streambank erosion along the river left bank downstream of the diversion dam. There is a Parshall flume in the ditch. Additional irrigation water is supplied to this area by a pump, which withdrawals water from a natural side channel approximately 2 miles downstream.

Diversion 2 – Sandy Ditch

Diversion 2 is located along the river left bank at a bend. There is a geologic nick-point confining the left side of the channel here. The diversion dam is angled upstream and is comprised of boulders. It was rebuilt recently. There is a single metal "screw gate" within a cement structure that situated parallel to the main flow of the river.

This diversion weir may be leading to upstream aggradation as gravel settles out on the bar along river right. There is a high amount of stream power at this sharp bend. Floods and ice reportedly move the rocks comprising the diversion dam.

Diversion 3 – Pageville Canal

Diversion 3 is located at the outside of a bend on the river right bank. The ditch appears to utilize what was historically a side channel and is associated with a geologic nick-point that naturally confines the left side of the channel. The diversion dam is comprised of large boulders that were used to fill a deep hole. Since the placement of these boulders, the channel bed has aggraded and the diversion structure now appears assimilated into the streambed. There are 3 metal "screw gates" in a single concrete structure at the initial point of diversion, though the ditch reportedly fills with 2 of the headgates. This ditch splits into 3 ditches at a second diversion (D32) slightly less than a mile downstream of the initial diversion, with the most westerly of the ditches continuing on as the Pageville Canal. The main split (D32) is a concrete structure with metal headgates that sends the majority of the flow to the north through the main ditch, off which the Redfield ditch splits shortly thereafter at Diversion 33.

The Pageville Canal irrigates an area of 3000-4000 acres and serves 20 irrigators between the Big Hole and Beaverhead River. Most of this area is flood irrigated, though there is some sprinkler irrigation, with sprinkler irrigation concentrated at the southern end of the area near the foothills. Waste water goes into the Beaverhead River, California Slough and Owsley Slough.

There is riprap downstream of the headgate along the river right bank. The ditch has a staff gages at the initial point of diversion (D3) as well as at the first split (D32).

Diversion 32 – Pageville Canal splits into 3 ditches

The Pageville Canal (D3) splits into 3 ditches at a second diversion (D32) slightly less than a mile downstream of the initial diversion and headgate, with the most westerly of the ditches continuing on as the Pageville Canal. The main split (D32) is a concrete structure with metal headgates that sends the majority of the flow to the north through the main ditch, off which the Redfield ditch splits shortly thereafter at Diversion 33.

There are staff gages at the initial point of diversion (D3) as well as at the first split (D32).

Diversion 5 – Naranchich

The initial point of diversion consisted of a natural looking gravel bar that diverts flow into a diversion channel to the left of the mainstem slightly downstream of where the Pageville Canal (D3) comes off of river right. The diversion dam in the diversion channel leading to this ditch was not observed in the field and the two "Diversion 5" headgates recorded here are located within the ditch network. There are two metal "screw gates" in a rock and wood housing that supports a driveway and fence and creates a small pond upstream. This ditch runs along Burma Road, irrigating land between the river and road.

PENNINGTON BRIDGE FAS TO HIGH ROAD FAS

Lower Big Hole Irrigation Infrastructure Study

Diversion 6 – Big Hole Co-op Ditch

Diversion 6 is located along the river right bank downstream of the more southerly Pennington Bridge crossing. This is a very large diversion structure utilizing boulders that extend across the entire channel with a chute in the center for floater passage over an approximately 3-foot drop. The headgate is a single mechanism metal unit that is housed in a metal and rock structure. While it opens manually, a backhoe is currently required to "push" the headgate closed. Due to this issue, it is currently difficult to regulate during critical low flow periods.

The Big Hole Co-op ditch breaks into the Owsley Slough the Schoolhouse Slough and irrigates a large area between the Big Hole and the Beaverhead downstream of the Pennington Road primarily through flood irrigation. This cobble bottom ditch serves 22 irrigators and approximately 4,000 irrigated acres. This ditch discharges into the Beaverhead River, though water returns to the ditch as it moves through the network, so it is used by downstream irrigators.

The floodplain is relatively low here and has been built up around the headgate with a floodplain berm. There is riprap upstream on river right and downstream for a short distance on river left, with a floodplain berm downstream of the headgate on river right and accelerated streambank erosion occurring along river left downstream below the riprap. There is also a deep scour hole downstream of the dam.

There is currently a design for improvement of this diversion underway. There is a large Parshall flume, though it has been removed from the ditch since it ponded water in the ditch, making it more difficult to withdrawal water from the river.

Diversion 8 – Orphan Home

Diversion 8 is located on the river right bank in a relatively straight section of river downstream of a bend where riprap protects a low spot in the floodplain. The initial point of diversion is located in a relatively flat floodplain area and the headgate is located approximately 600 feet down the diversion channel. The initial diversion consists of a gravel berm extend well into the channel in this over-widened and shallow riffle. At the headgate, a small gravel berm has been built up to divert water toward the headgate, which is situated parallel to the flow. The headgate is comprised of wooden boards in a metal structure constructed from an old boiler pipe. There is a floodplain berm along the diversion channel that extends downstream of the headgate.

There is riprap in the channel upstream of the diversion dam suggesting channel migration. There is also a large eroding foothill terrace on river left approximately 1 mile upstream of this site and just upstream of Nez Perce Creek, which is likely leading to increased sediment loads within this section of river. Nez Perce Creek may also be a source of sediment.

This cobble bottom ditch is relatively steep. There is a Parshall flume in the ditch.

Diversion 9 – Hamilton Ranch Logan-Smith Ditch

Diversion 9 is located in the right channel at the outside of a bend on the river right bank, which appears to have less than half the flow. The diversion is located in a relatively flat floodplain area. A gravel berm comprise of channel substrate extends into a riffle deflects flow toward the headgate. It is a wooden "pin and plank" headgate with two openings. The system in place for raising and lower the headgate is reportedly difficult to operate.

This ditch is relatively steep downstream of the headgate.

Diversion 9 – Hamilton Ranch Lott-Harvey Ditch

Diversion 10 is located on the river right bank in the right channel upstream of a large floodplain berm. The diversion is located in a relatively flat floodplain area. The diversion structure includes boulders that create a vegetated peninsula, which leads to a small barb with cobbles extending into the channel. The channel reportedly used to lead directly to the headgate, but now only a slough leads down to it and the channel has migrated to the left. The short diversion channel leads to a wooden "pin and plank" headgate with two openings, while the ditch has a gravel/cobble substrate. The headgate is situated parallel to the flow.

The floodplain berm downstream of this diversion leads to bank erosion along the terrace on river left upstream of the High Road FAS.

HIGH ROAD FAS TO THE JEFFERSON RIVER

Lower Big Hole Irrigation Infrastructure Study

Diversion 36 – Hamilton "Ranch" Ditch, also known as "Hamilton" Ditch

The initial diversion dam serves both Diversions 35 and 36. This diversion dam extends out from the river left bank just upstream of the High Road Bridge. The diversion dam is situated just upstream of the bridge pylon and an eroding bank upstream reportedly deposits sediment at the inlet of the diversion channel. Annual maintenance is reportedly required to keep the inlet of the diversion channel free from grave. Diversion 35 is located upstream of Diversion 36 and serves a pump.

At Diversion 36, a large "collapsible jack" in the side channel directs water into the ditch, with the first headgate located approximately 600 feet down the ditch. This headgate is a metal "screw gate" in a wooden structure and there is a Parshall flume downstream and a "collapsible jack" diverting water down the other channel. There is reportedly a second diversion structure in this network that is similar. This cobble ditch irrigates approximately 1,000-2,000 acres of the Hamilton Ranch to the west of the confluence of the Big Hole and Jefferson rivers.

Bank erosion along the left bank upstream of the diversion dam likely results from the large floodplain berm on river right that starts downstream of Diversion 9.

Appendix D

IRRIGATOR CONTACT INFORMATION

Lower Big Hole Irrigation Infrastructure Study

Site	Diversion Name	Diversion Owner/Manager	Diversion Owned/Manager Contact Information	Property/Access Diversion Located On	Property/Access Contact Information
D18	upper McCauley	Eighorn, Gneiting	Joel & Luke Eighorn, 835-2082; Bob Gneiting, 835,3551; Paul Geiting, 835-3282	Eighorn Limited Partenship (where ditch exits canyon)	Eighorn Fencing, 835-2081, 835-2082
D19	Meriwether's	Meriwether Ranch	Meriwether Ranch, 835-2174; Chris Ellingson 835-2179	cadastral data missing, likely public access available	Teri Walsh, Manager, 835-2207
D20	lower McCauley	Pendergast, Smith, Kearns,	Tom Pendergast 835-3272; Tom Kearns; Don Smith, 835-3291	access through Eighorn Limited Partenship, same road as for D18	Eighorn Fencing, 835-2081, 835-2082
D21	Melrose Canal	Carpenter, Kearns, Dupuis, Meriwether Ranch	Myles Carpenter 835-2291; Tom Kearns	access through Eighorn Limited Partenship, same road as for D18	Eighorn Fencing, 835-2081, 835-2082
D22	Meriwether's	Meriwether Ranch	Meriwether Ranch, 835-2174; Chris Ellingson 835-2179	diversion headgate on Meriwether Ranch Land & Cattle	Teri Walsh, Manager, 835-2207
D44	Meriwether's	Meriwether Ranch	Meriwether Ranch, 835-2174; Chris Ellingson 835-2179	diversion headgate on Meriwether Ranch Land & Cattle	Teri Walsh, Manager, 835-2207
D23	Carpenter's	Carpenter	Dale Carpenter, 835-2761	diversion headgate on Meriwether Ranch Land & Cattle	Teri Walsh, Manager, 835-2207
D24	Carpenter's	Carpenter	Dale Carpenter, 835-2761	diversion headgate on Meriwether Ranch Land & Cattle	Teri Walsh, Manager, 835-2207
D11	Pendergast-Spears-McCullough	Spears, Pendergast, Kearns	Tom Pendergast, 835-3272; Owen Spears, 835-2952; Tom Kearns	diversion headgate on Pendergast Ranch Inc	Tom Pendergast, 835-3272
D12	Kalsta's	Kalsta, Gainy	Erik Kalsta, 835-2138	Kalsta Ranch Co	Erik Kalsta, 835-2138
D13	Hagenbarth's Big Hole ditch	Hagenbarth	Hagenbarth Livestock, 683-2163; Jim Hagenbarth, 490-2121	diversion headgate on Bradley Limited Partnership	
D14	Hagenbarth's River Field ditch	Hagenbarth	Hagenbarth Livestock, 683-2163; Jim Hagenbarth, 490-2121	headgate located on MFWP Kalsta Bridge FAS	
D15	Gainy's	Gainy	Harvey Gainy	Gainy Foundation	Harvey Gainy
D39	Smith's	Smith	Randy Smith, 925-1545	Hagenbarth	Hagenbarth Livestock, 683-2163; Jim Hagenbarth, 490-2121
D40	Smith's	Smith	Randy Smith, 925-1545		
D16	Gainy's	Gainy	Harvey Gainy	Hagenbarth	
D17	Garrision / Kilwien	Garrison, Kilwien	Bill Garrison, 835-2501; Mark Anderson, 835-2103 (lease from Kilwien)	Kalsta Ranch Co	Erik Kalsta, 835-2138
D25	Glennon?			Kilwien Property LLC	
D26	Garrison's Wild Hay Ditch	Garrison Ranches Inc.	Bill Garrison, 835-2501	Garrison Ranches Inc.	Bill Garrison, 835-2501
D27	Rafferty's Upper South Side Ditch	Rafferty	Mark Rafferty, 835-3251	access through Rafferty property	Mark Rafferty, 835-3251
D28	Rafferty's Lower South Side Ditch	Rafferty	Mark Rafferty, 835-3251	access through Rafferty property	Mark Rafferty, 835-3251
D37	Bryan Ditch	Rafferty	Mark Rafferty, 835-3251	headgate on William C. Childrey property	Bill Childrey, 835-2093
D4	J&S Ranch (Larson-Naranchich)	J&SG Investements Inc.	Bob Smith, 684-5282	State Land below the Notch	
D1	Copper's (Whitney Ditch)	Cooper	Cam Copper, 684-5534	diversion headgate on Marjorie Ann Riettini propert	
D2	Sandy Ditch	Robert V. Adams Revocable Trust	Gene Collins 684-5272	access through Patricia Shannon property	
D3	Pageville Canal	Pageville Canal Co.	Gary Geim 684-5767; Duke Novich, President	access through Geim property	Gary Geim 684-5767
D5	Naranchich	Robert V. Adams Revocable Trust	Gene Collins 684-5272	Robert Adams Revocable Trust	Gene Collins 684-5272
D6	Big Hole Ditch	Ashcraft	Dave Ashcraft, 684-5762, President; Dick Marshall, Vice-President	diversion headgate on Kalbas Enterprises Inc	
D8	Orphan's Home	Legacy Land and Livestock LLC	Dave Ashcroft 684-5762	Legacy Land and Livestock LLC	Kieth Fairbanks
D9	Logan-Smith	Trishman	George Trischman 684-5719	Hamilton Ranches Partnership	George Trischman 684-5719
D10	Lott-Harvey	Trishman	George Trischman 684-5719	Hamilton Ranches Partnership	George Trischman 684-5719
D35	pump at Hamilton	Trishman	George Trischman 684-5719	Hamilton Ranches Partnership	George Trischman 684-5719
D36	Ranch	Trishman	George Trischman 684-5719	Hamilton Ranches Partnership	George Trischman 684-5719

Appendix E

POINT FEATURE DATABASE

Lower Big Hole Irrigation Infrastructure Study

NORTHING (LAT)	EASTING (LONG)	SITE	FEAT_TYPE	FEAT_LOCAT	BANK	DESCRIPT	DIVRS_NAME	DIVRS_COND	DITCH_MAIN	MEASURE	IRRIG_MGMT	DATE_	PHOTO_NUM	REACH_NAME	REACH_NUM
45.67740	-112.72409	D18	headgate, diversion	main channel	left	1 metal headgate, cobble and boulder weir, part of ditch in pip	Upper McCauley	fair	good	no	unknown	11/10/2007	5-12, 56-58	Maiden Rock to Melrose/Salmon Fly	1
45.67719	-112.71982	H9	spawning site	main channel		spawning in glide in mainstem, 14-inch trout observed						11/10/2007	15	Maiden Rock to Melrose/Salmon Fly	1
45.67602	-112.71406	D19	headgate, diversion	main channel	right	wooden headgate, cobble and boulder weir extends well upstream	Meriwether's	fair	good	no	diversion weir extends well upstream	11/10/2007	17-23	Maiden Rock to Melrose/Salmon Fly	1
45.67501	-112.69918	D20	headgate, diversion	main channel	left	1 metal headgate, cobble and boulder weir used by D20 and D21	Lower McCauley	fair	good	no	there is a gravel berm in the ditch	11/10/2007	27-30,36-37,41,43-	Maiden Rock to Melrose/Salmon Fly	1
45.67306	-112.69850	D21	headgate, diversion	main channel	left	3 metal headgates, cobble and boulder weir used by D20 and D21	Melrose Canal	poor	fair	unknown	2 headgates appear broken	11/10/2007	27-35,42,49-55	Maiden Rock to Melrose/Salmon Fly	1
45.65335	-112.69334	D22	headgate, diversion	main channel	left	wooden headgate, cobble and boulder weir	Meriwether's	fair	good	no	weir possibly influences flow into the "County Line" side channel	11/10/2007	59-67	Maiden Rock to Melrose/Salmon Fly	1
45.65005	-112.69426	D23	headgate, diversion	main channel	left	wooden headgate, cobble and boulder weir	Carpenter's	fair	good	no	headgate elevation issues	11/10/2007	68-73	Maiden Rock to Melrose/Salmon Fly	1
45.64570	-112.69541	D24	headgate, diversion	main channel	left	wooden headgate, cobble and boulder weir	Carpenter's	poor	good	no	headgate elevation issues, weir maintenance, erosion downstream	11/10/2007	75-83	Maiden Rock to Melrose/Salmon Fly	1
45.66191	-112.69651	H10	spawning site	main channel		spawning in braided section						11/10/2007		Maiden Rock to Melrose/Salmon Fly	1
45.62766	-112.68760	H11	spawning site	left channel		spawning						11/10/2007		Maiden Rock to Melrose/Salmon Fly	1
45.65391	-112.69437	D44	headgate, diversion	side channel	left	headgate in right channel, irrigates island, metal deflector	Meriwether's	unknown	unknown	unknown	slough being abandonded, difficult to get water at low flows	11/27/2007		Maiden Rock to Melrose/Salmon Fly	1
45.61141	-112.67915	D11	headgate, diversion	left channel	left	wooden headgate, boulder weir, second channel blocked, spawning	Pendergast-Spears-McCulloug	fair	good	no	two diversion channels, gravel weir needs to be re-built regularly	11/8/2007	5-18	Melrose/Salmon Fly to Brown's Bridge	2
45.59733	-112.68504	D30	headgate, diversion	side channel	left	wooden headgate, gravel weir, slough	Garden Ditch	fair	good	yes		11/27/2007	57-60	Melrose/Salmon Fly to Brown's Bridge	2
45.62542	-112.68737	H5	spawning site	left channel		spawning in riffle						11/8/2007	1	Melrose/Salmon Fly to Browns Bridge	2
45.61815	-112.68210	H6	spawning site	left channel		spawing in glide above riffle						11/8/2007	2	Melrose/Salmon Fly to Browns Bridge	2
45.61182	-112.67927	H7	spawning site	left channel		spawning above/below D11						11/8/2007	5,7-10,17-18	Melrose/Salmon Fly to Browns Bridge	2
45.60985	-112.67850	D29	headgate	ditch		headgate and blow-off						11/27/2007	48-52	Melrose/Salmon Fly to Browns Bridge	2
45.60516	-112.67884	D31	headgate	ditch		headgate, overflow into slough						11/27/2007	53-56	Melrose/Salmon Fly to Browns Bridge	2
45.54121	-112.69645	D12	initial diversion	main channel	left	rock weir extending across entire channel with flow through chu	Kalsta's					11/8/2007	28-33	Brown's Bridge to Glen	3
45.53882	-112.69763	D12	headgate	main channel	left	2 metal headgates in concrete structure, concrete ditch	Kalsta's	good	good	no	moss since runs past August	11/27/2007	77-83	Brown's Bridge to Glen	3
45.54105	-112.69758	D13	initial diversion	main channel	right	gravel bar, diversion channel	Hagenbarth's Big Hole ditch					11/8/2007	31	Browns Bridge to Glen	3
45.53764	-112.70172	D13	headgate, diversion	side channel	right	wooden headgate, cobble weir	Hagenbarth's Big Hole ditch	poor	good	flume	headgate and weir scheduled to be replaced in spring 2008	12/7/2007	49-54	Brown's Bridge to Glen	3
45.52554	-112.70188	D14	headgate, diversion	main channel	right	1 metal headgate, cobble weir below Kalsta bridge	Hagenbarth's River Field di	good	good	no	gravel weir needs to be re-built regularly	11/8/2007	51-58	Brown's Bridge to Glen	3
45.49215	-112.69094	D15	headgate, diversion	main channel	left	1 metal headgate, cobble and boulder weir	Gainy's	good	good	unknown	unknown, serves ponds	11/8/2007	62-69	Brown's Bridge to Glen	3
45.48849	-112.69320	H4	spawning site	main channel		spawning observed along vegetated bank						11/8/2007	70-71	Brown's Bridge to Glen	3
45.48526	-112.69500	D39	headgate, diversion	side channel	right	1 metal headgate, cobble weir at silos	Smith's	fair	good	flume	flumes may read inaccurately due to ponded water in low gradient ditch	12/7/2007	55-63	Brown's Bridge to Glen	3
45.53993	-112.69948	H2	spawning site	side channel		spawning in diversion channel						11/8/2007	34-36	Browns Bridge to Glen	3
45.53724	-112.70050	H3	spawning site	main channel		spawning in braids, LWD						11/8/2007	39-43	Browns Bridge to Glen	3
45.51849	-112.69405	D34	headgate	ditch		headgate in ditch along bench		fair	fair	no	loss of water suspected in lower 4 miles	11/27/2007	74-76	Browns Bridge to Glen	3
45.52828	-112.70370	D42	headgate	ditch		headgate at Rock Creek						12/7/2007	47-48	Browns Bridge to Glen	3
45.47726	-112.68093	D16&D17	initial diversion	main channel	left	cobbel and gravel weir, converted side channel for D16 and D17						11/8/2007	74-84	Glen to Notch Bottom	4
45.47539	-112.67307	D16	headgate, diversion	left channel	left	1 metal headgate, cobble and gravel weir with LWD	Gainy's	poor	fair	no	main channel diversion being abandonded, side channel diversion float ba	11/8/2007	85-94	Glen to Notch Bottom	4
45.46904	-112.66330	D17	headgate, diversion	left channel	left	3 metal headgates in 2 diversions, cobble and gravel weir	Garrison/Kilwien	poor	good	no	main channel diversion being abandonded, side channel diversion failing,	11/8/2007	95-108	Glen to Notch Bottom	4
45.45626	-112.65312	D25	headgate, diversion	right channe	right	1 metal headgate, cobble and boulder weir	Glennon?	fair	good	no	diversion weir partially washed out	11/16/2007	7-19	Glen to Notch Bottom	4
45.45380	-112.63691	D26	initial diversion	main channel	left	gravel and cobble weir, serves D26 downstream in diversion chan	Garrison's Wild Hay ditch					11/16/2007	30-35	Glen to Notch Bottom	4
45.45171	-112.63451	D26	headgate, diversion	side channel	left	2 metal headgates, gravel and cobble weir across entire side ch	Garrison's Wild Hay ditch	fair	fair	no	diversion weir partially washed out, ditch relatively wide	11/16/2007	36-38,40,46-51	Glen to Notch Bottom	4
45.45038	-112.63397	B15	barb	main channel	left	barb with riprap downstream, second portion on opposite side of						11/16/2007	39,42-43	Glen to Notch Bottom	4
45.43656	-112.60770	H12	spawning site	left channel		spawning in braided section						11/16/2007	71-72	Glen to Notch Bottom	4
45.42934	-112.59540	D27	initial diversion	main channel	right	diversion channel, upper diversion inlet abandonded	Rafferty's Upper South Side					11/16/2007	73-75	Glen to Notch Bottom	4
45.42981	-112.59027	D27	headgate, diversion	side channel	right	2 metal headgates, cobble and boulder weir across entire side c	Rafferty's Upper South Side	fair	fair	no	leaky ditch	11/16/2007	76-83,93-94,102-10	Glen to Notch Bottom	4
45.43107	-112.57506	D28	headgate, diversion	right channe	right	1 metal headgate, boulder weir	Rafferty's Lower South Side	fair	fair		ditch adjactent to channel margin, very low berm at the Notch	11/16/2007	96-101,104-106	Glen to Notch Bottom	4
45.43215	-112.57559	D37	headgate, diversion	left channel	left	1 metal headgate, with 2nd headgate in ditch, gravel weir	Bryan Ditch	fair	fair	no	ditch flows through ponded area	12/7/2007	77-83	Glen to Notch Bottom	4
45.46800	-112.66419	H8	spawning site	left channel		spawning in riffle						11/3/2007	9	Glen to Notch Bottom	4
45.43061	-112.59849	H13	spawning site	main channel		spawning at outside bend						11/16/2007		Glen to Notch Bottom	4
45.42940	-112.59317	H14	spawning site	side channel		spawning, D27 diversion						11/16/2007		Glen to Notch Bottom	4
45.43675	-112.56363	D43	headgate	ditch		headgate in ditch						12/6/2007		Glen to Notch Bottom	4
45.43230	-112.57542	D38	headgate	ditch		headgate in ditch, spring cr						12/7/2007	81-82	Glen to Notch Bottom	4
45.44255	-112.51039	D1	headgate, diversion	main channel	right	2 metal headgates, cobble and boulder weir extending into chann	Copper's (Whitney)	fair	fair	flume	lack of water at low flow	11/3/2007	17-22 (12/6:40-46)	Notch Bottom to Pennington Bridge	5
45.45598	-112.48663	H1	spawning site	main channel		above riffle formed by LWD and gravel bar						11/3/2007	41-42	Notch Bottom to Pennington Bridge	5
45.46665	-112.47639	D2	headgate, diversion	main channel	left	1 metal headgate, boulder weir extending into channel	Sandy Ditch	good	good	no	elevated above channel, lack of water at low flow	11/3/2007	57-65	Notch Bottom to Pennington Bridge	5
45.47188	-112.46999	D3	headgate, diversion	main channel	right	3 metal headgates, submerged boulder weir extends across channe	Pageville Canal	good	good	staff gage	no	11/3/2007	70-78	Notch Bottom to Pennington Bridge	5
45.44420	-112.52806	D4	headgate, diversion	side channel	left	diversion channel with headgate and 2-foot drop to main channel	JS Ranch	good	good	no	no	11/3/2007	91-94,97-99	Notch Bottom to Pennington Bridge	5
45.47501	-112.47211	D5	initial diversion	main channel	left	gravel bar, diversion channel						11/3/2007		Notch Bottom to Pennington Bridge	5
45.48389	-112.47153	D5	headgate	ditch	left	main diversion not assessed, D5 in ditch, 2 headgates, ponds at	Naranchich	good	good	no	ponded water in portions of ditch	11/3/2007	115-116	Notch Bottom to Pennington Bridge	5
45.43880	-112.56079	B1	barb	main channel	left	protecting irrigated field						11/3/2007		Notch Bottom to Pennington Bridge	5
45.43898	-112.56042	B2	barb	main channel	left	protecting irrigated field						11/3/2007		Notch Bottom to Pennington Bridge	5
45.43909	-112.56013	B3	barb	main channel	left	protecting irrigated field						11/3/2007		Notch Bottom to Pennington Bridge	5
45.43917	-112.55983	B4	barb	main channel	left	protecting irrigated field						11/3/2007		Notch Bottom to Pennington Bridge	5
45.43929	-112.55925	B5	barb	main channel	left	protecting irrigated field						11/3/2007		Notch Bottom to Pennington Bridge	5
45.44386	-112.52012	B6	barb	main channel	left	protecting ditch						11/3/2007		Notch Bottom to Pennington Bridge	5
45.44268	-112.50630	B7	barb	main channel	right	protecting houses						11/3/2007	23-25	Notch Bottom to Pennington Bridge	5
45.44275	-112.50544	B8	barb	main channel	right	protecting houses						11/3/2007	23-25	Notch Bottom to Pennington Bridge	5
45.44301	-112.50416	B9	barb	main channel	right	protecting houses						11/3/2007	23-25	Notch Bottom to Pennington Bridge	5
45.44333	-112.50243	B10	barb	main channel	right	protecting houses						11/3/2007	23-25	Notch Bottom to Pennington Bridge	5
45.44350	-112.50162	B11	barb	main channel	right	protecting houses						11/3/2007	23-25	Notch Bottom to Pennington Bridge	5
45.44380	-112.50041	B12	barb	main channel	right	protecting houses						11/3/2007	23-25	Notch Bottom to Pennington Bridge	5
45.44926	-112.49173	B13	barb	main channel	center	protecting head of island						11/3/2007	33-34	Notch Bottom to Pennington Bridge	5
45.47789	-112.45910	D32	headgate	ditch		3 metal headgates, splits into 3 ditches		good	good	staff gage		11/28/2007	109-112	Notch Bottom to Pennington Bridge	5
45.48114	-112.45672	D33	headgate	ditch		splits into 2 ditches from 2 "pin and plank" headgates		fair	good	no		11/28/2007		Notch Bottom to Pennington Bridge	5
45.49920	-112.43372	D6	headgate, diversion	main channel	right	large headgate, boulder weir across entire channel with chute	Big Hole Co-op Ditch	fair	good	no	large weir across channel, backhoe required to close headgate	11/7/2007	3-29	Pennington Bridge to High Road Bridge	6
45.50264	-112.42973	B14	barb	main channel	left	below D6						11/7/2007	31	Pennington Bridge to High Road Bridge	6
45.50677	-112.42283	D7	headgate	ditch	right	pond with metal headgate, protected by large berm		poor	unknown	unknown	ponding, floodplain berm	11/7/2007	47-48	Pennington Bridge to High Road Bridge	6
45.51881	-112.40062	D8	headgate, diversion	side channel	right	wooden headgate, appears to lack closing mechanism	Orphan's Home	poor	good	flume	headgate difficult to close, shallow riffle at diversion	11/7/2007	69-76	Pennington Bridge to High Road Bridge	6
45.51789	-112.40221	D8	initial diversion	main channel	right	cobble weir across riffle						11/7/2007	68,77-80	Pennington Bridge to High Road Bridge	6
45.53363	-112.37267	D9	headgate, diversion	right channe	right	wooden headgate, appears to lack closing mechanism	Logan-Smith	poor	fair	no	headgate difficult to close	11/7/2007	81-86	Pennington Bridge to High Road Bridge	6
45.53959	-112.37010	D10	headgate, diversion	right channe	right	wooden headgate, appears to lack closing mechanism, boulder wei	Lott-Harvey	poor	fair	no	headgate difficult to close, channel migrating away from headgate	11/7/2007	89-98	Pennington Bridge to High Road Bridge	6
45.55007	-112.36133	D36	headgate, diversion	left channel	left	2 metal headgates, collapsible jack in side channel, weir in ma	Hamilton Ranch ditch	good	good	flume	main channel diversion fills with gravel at the inlet due to eroding ban	12/6/2007	1-15,19-30	High Road Bridge to Jefferson River	7
45.54996	-112.36326	D35	headgate	side channel	left	1 headgate, serves pump						11/27/2007	24	High Road Bridge to Jefferson River	7

Appendix F

LINE FEATURE DATABASE

Lower Big Hole Irrigation Infrastructure Study

SITE	FEAT_TYPE	FEAT_LOCAT	BANK	DESCRIPT	DATE_	PHOTO_NUM	FIELD	REACH_NAME	REACH_NUM	LENGTH_FEET
R42	riprap	main channel	right	old rock protecting road	11/10/07	13	yes	Maiden Rock to Melrose/Salmon Fly	1	194
R44	riprap	main channel	left	old rock protecting railroad	11/10/07	14	yes	Maiden Rock to Melrose/Salmon Fly	1	73
R45	riprap	main channel	left	cobble and rock below D24	11/10/07	84-87	yes	Maiden Rock to Melrose/Salmon Fly	1	712
E3	accelerated bank erosion	main channel	right	below riprap below D24	11/10/07	88-92	yes	Maiden Rock to Melrose/Salmon Fly	1	467
R46	riprap	main channel	left	rock protecting house	11/10/07	93-94	yes	Maiden Rock to Melrose/Salmon Fly	1	152
R47	riprap	main channel	left	rock, location estimated	11/10/07	95	yes	Maiden Rock to Melrose/Salmon Fly	1	128
R67	riprap	main channel	left	small rock above D23	11/27/07	85-86	yes	Maiden Rock to Melrose/Salmon Fly	1	62
R35	riprap	left channel	left	gravel berm along railroad	11/8/07	2	yes	Melrose/Salmon Fly to Browns Bridge	2	190
R33	riprap	left channel	left	rock protecting railroad	11/8/07	3-4	yes	Melrose/Salmon Fly to Browns Bridge	2	289
E5	accelerated bank erosion	left channel	left	downstream of D11	11/27/07	43	yes	Melrose/Salmon Fly to Browns Bridge	2	185
R36	riprap	main channel	left	rock protecting railroad	11/8/07	26-27,29	yes	Browns Bridge to Glen	3	1037
R37	riprap	main channel	left	rock protecting I-15	11/8/07	44-45	yes	Browns Bridge to Glen	3	441
R38	riprap	main channel	left	rock protecting I-15 bridge	11/8/07	47-48	yes	Browns Bridge to Glen	3	439
R39	riprap	main channel	right	rock protecting I-15 bridge	11/8/07	49-50	yes	Browns Bridge to Glen	3	303
R34	riprap	main channel	left	rock protecting field	11/8/07	59	yes	Browns Bridge to Glen	3	339
R43	riprap	right channel	right	rock protecting Glen bridge	11/3/07	4-5	yes	Browns Bridge to Glen	3	807
R68	floodplain berm	main channel	right	gravel berm, with road	12/7/07	70-72	yes	Browns Bridge to Glen	3	2458
R40	riprap	right channel	left	rock protecting houses	11/3/07	6	yes	Glen to Notch Bottom	4	387
R41	riprap	left channel	left	rock protecting field	11/3/07	9	yes	Glen to Notch Bottom	4	101
R48	riprap	main channel	right	rock, bend below Glen bridge	11/16/07	1-3	yes	Glen to Notch Bottom	4	555
R55	riprap, floodplain berm	main channel	left	rock, structures downstream	11/16/07	4-5	yes	Glen to Notch Bottom	4	716
R56	riprap	left channel	left	potential, not observed			no	Glen to Notch Bottom	4	1096
R57	riprap, floodplain berm	right channel	right	cobble berm above D25	11/16/07	7,11-12	yes	Glen to Notch Bottom	4	255
E4	accelerated bank erosion	main channel	left	new house close to bank	11/16/07	20-26	yes	Glen to Notch Bottom	4	1060
R58	riprap, floodplain berm	side channel	left	potential rock floodplain berm			no	Glen to Notch Bottom	4	535
R59	riprap	side channel	left	rock, channel for D26	11/16/07	33	yes	Glen to Notch Bottom	4	71
R49	riprap, floodplain berm	main channel	left	rock, influence Stevens Slough	11/16/07	27-29	yes	Glen to Notch Bottom	4	486
R60	floodplain berm	main channel	left	cobble, set back from channel	11/16/07	38,45-46,48,51	yes	Glen to Notch Bottom	4	832
R61	riprap	main channel	left	rock, B14 and R60 upstream	11/16/07	39,41,44	yes	Glen to Notch Bottom	4	390
R62	riprap	left channel	left	rock, overwide braided section	11/16/07	52-57	yes	Glen to Notch Bottom	4	1269
R63	floodplain berm	main channel	left	cobble, portion eroding	11/16/07	60-63,69-70	yes	Glen to Notch Bottom	4	2819
R52	riprap	right channel	right	rock protecting ditch, road	11/16/07	92,95	yes	Glen to Notch Bottom	4	194
R53	riprap	main channel	right	rock protecting ditch	11/16/07	107	yes	Glen to Notch Bottom	4	113
R64	riprap	main channel	left	rock protecting ditch, road	11/16/07	108,116	yes	Glen to Notch Bottom	4	725
R65	riprap	main channel	right	rock protecting ditch	11/16/07	110-112	yes	Glen to Notch Bottom	4	827
R69	riprap	left channel	left	rock, above D17	11/8/07	100-101	yes	Glen to Notch Bottom	4	86
E8	accelerated bank erosion	main channel	right	downstream of D26 inlet	11/16/07	32,34-35	yes	Glen to Notch Bottom	4	355
R50	riprap	left channel	left	upstream of D37	12/7/07	80	yes	Glen to Notch Bottom	4	228
R2	riprap	main channel	right	rock and wire	11/3/07	26-28	yes	Notch Bottom to Pennington Bridge	5	78
R3	riprap	main channel	left	rock protecting gravel road	11/3/07	29-32	yes	Notch Bottom to Pennington Bridge	5	244
R9	log revetment	main channel	right	stacked logs and rock	11/3/07	33,35,37	yes	Notch Bottom to Pennington Bridge	5	595
R4	riprap	main channel	right	rock protecting house	11/3/07	33,34,38-40	yes	Notch Bottom to Pennington Bridge	5	588
R5	riprap, floodplain berm	main channel	right	rock berm protecting structure	11/3/07	44-47	yes	Notch Bottom to Pennington Bridge	5	1032
R10	riprap, floodplain berm	floodplain	right	possible extension of berm R5			no	Notch Bottom to Pennington Bridge	5	543
R11	riprap	main channel	left	rock protecting house	11/3/07	48-50	yes	Notch Bottom to Pennington Bridge	5	462
R6	riprap, floodplain berm	main channel	left	rock protecting ditch, field	11/3/07	67-69	yes	Notch Bottom to Pennington Bridge	5	1205
R12	riprap	main channel	right	rock, estimate location	11/3/07		yes	Notch Bottom to Pennington Bridge	5	112
R13	riprap	main channel	right	rock, estimate location	11/3/07		yes	Notch Bottom to Pennington Bridge	5	123
R7	riprap, floodplain berm	main channel	right	rock with decadent cottonwoods	11/3/07	79-81	yes	Notch Bottom to Pennington Bridge	5	747
R8	riprap	main channel	left	rock	11/3/07	82	yes	Notch Bottom to Pennington Bridge	5	109
R14	log revetment	left channel	left	wired log structures	11/3/07	83-84	yes	Notch Bottom to Pennington Bridge	5	207
R15	riprap, floodplain berm	right channel	right	potential rock floodplain berm			no	Notch Bottom to Pennington Bridge	5	851
R16	riprap, floodplain berm	right channel	right	potential rock floodplain berm			no	Notch Bottom to Pennington Bridge	5	190
R1	riprap, floodplain berm	main channel	left	rock protecting ditch	11/3/07	11-13	yes	Notch Bottom to Pennington Bridge	5	438
E1	accelerated bank erosion	main channel	left	downstream of D1	12/6/07	40-41	yes	Notch Bottom to Pennington Bridge	5	636
R20	riprap	main channel	left	rock protecting house, road	11/7/07	115,122-123	yes	Notch Bottom to Pennington Bridge	5	848
R21	riprap	main channel	left	rock protecting road, bridge	11/7/07	116,124	yes	Notch Bottom to Pennington Bridge	5	362
R22	riprap	main channel	left	rock protecting road, bridge	11/7/07	116, 110	yes	Notch Bottom to Pennington Bridge	5	173
R66	riprap, floodplain berm	main channel	right	rock, vegetated	11/3/07	70	yes	Notch Bottom to Pennington Bridge	5	941
E6	accelerated bank erosion	main channel	right	downstream of D4 inlet	12/6/7	84-87	yes	Notch Bottom to Pennington Bridge	5	837
R23	floodplain berm	side channel	right	gravel removed, deepen channel	11/7/07	111-113,121	yes	Pennington Bridge to High Road	6	405
R24	riprap	main channel	right	rock protecting bridge	11/7/07	107	yes	Pennington Bridge to High Road	6	233
R25	riprap	main channel	left	pipe, rock protecting bridge	11/7/07	105-106	yes	Pennington Bridge to High Road	6	95
R26	riprap	main channel	right	rock protecting D6	11/7/07	1-3,10	yes	Pennington Bridge to High Road	6	331
R27	riprap, floodplain berm	main channel	right	rock downstream of D6	11/7/07	4,21,30	yes	Pennington Bridge to High Road	6	306
R28	riprap	main channel	left	rock protecting D6	11/7/07	9,12,15,25	yes	Pennington Bridge to High Road	6	420
E2	accelerated bank erosion	main channel	left	erosion downstream of D6	11/7/07	13-15,20-21	yes	Pennington Bridge to High Road	6	389
R17	riprap, floodplain berm	main channel	right	large rock berm	11/7/07	32-44	yes	Pennington Bridge to High Road	6	2710
R18	riprap	main channel	right	rock protecting house	11/7/07	49	yes	Pennington Bridge to High Road	6	175
R29	riprap, floodplain berm	main channel	right	possible extension of berm R17			no	Pennington Bridge to High Road	6	1259
R19	riprap	main channel	right	rock protection house	11/7/07	61-65	yes	Pennington Bridge to High Road	6	421
R30	riprap	main channel	right	possible extension of R19			no	Pennington Bridge to High Road	6	489
R31	riprap, floodplain berm	right channel	right	rock with decadent cottonwoods	11/7/07	87	yes	Pennington Bridge to High Road	6	665
R32	riprap, floodplain berm	right channel	right	large rock berm	11/7/07	98-104	yes	Pennington Bridge to High Road	6	1742
E7	accelerated bank erosion	main channel	left	due to upstream riprap	12/6/07	16-17,30	yes	Pennington Bridge to High Road	6	484
R70	riprap	main channel	right	at High Road bridge	12/6/07	14,27	yes	Pennington Bridge to High Road	6	164
E9	accelerated bank erosion	main channel	left	possibly due to berms upstream	11/7/07	50,52,58,60	yes	Pennington Bridge to High Road	6	713
R71	riprap, floodplain berm	main channel	right	rock, protecting field	12/6/07	21-22,28,31-32	yes	High Road to Jefferson River	7	1607
R51	riprap, floodplain berm	side channel	left	potential, not observed			no	High Road to Jefferson River	7	1238
R54	riprap, floodplain berm	side channel	left	potential, not observed			no	High Road to Jefferson River	7	869

Appendix G

POTENTIAL PROJECTS

Lower Big Hole Irrigation Infrastructure Study

Diversion Number	Diversion Name	Potential Project	Irrigator/Contact
D20	lower McCauley	replace headgate and collapsible jack	Pendergast, Kearns, Smith
D20	lower McCauley	add Parshall flume	Pendergast, Kearns, Smith
D22	Meriwether's	relocate point of diversion	Ellingson
D44	Meriwether's	re-activate flow in west channel	Ellingson
D11A	Pendergast-Spears-McCullough	replace "pin and plank" headgate with metal screw headgate	Pendergast, Spears, Kearns
D11B	Pendergast-Spears-McCullough	install headgate in second diversion channel and build weir	Pendergast, Spears, Kearns
D11	Pendergast-Spears-McCullough	stabilize eroding bank downstream	Pendergast, Spears, Kearns
D29	Pendergast-Spears-McCullough	replace headgate and collapsible jack	Pendergast, Spears, Kearns
D12	Kalsta's	close off lower 4 miles of ditch and use pumps for fields	Kasta, Gainy
D17a	Garrison/Kilwien	adding Parshall flume to Garrison ditch	Garrison
D16, D17a/b	Gainy's, Garrison/Kilwien	anchor initial point of diversion	Gainy, Garrison, Kilwien, Anderson
D27	Rafferty's Upper South Side	replace headgate	Rafferty
D28	Rafferty's Lower South Side	clear vegetation from left wall of diversion along main channel	Rafferty
D4	JS Ranch (Larson-Naranchich)	stabilize bank downstream on river right	Rafferty
D2	Sandy Ditch	reduce hydrologic impact of diversion dam, improve irrigation withdrawl	Adams, Collins
D6	Big Hole Co-op	replace headgate and reduce drop created by diversion dam	Ashcraft
D8	Orphan Home	replace headgate and deepen diversion channel, remove rocks in mainstem	Ashcraft
D9	Logan-Smith	replace headgate	Trischman
D9	Logan-Smith	add Parshall flume	Trischman
D10	Lott-Harvey	replace headgate	Trischman
D10	Lott-Harvey	add Parshall flume	Trischman
D36	Hamilton Ranch Ditch	improve diversion dam	Trischman
D36	Hamilton Ranch Ditch	stabilize large eroding bank upstream	Trischman

Appendix H

CUMULATIVE IMPACTS PRIORITY MATRIX SCORES

Lower Big Hole Irrigation Infrastructure Study

Individual Diversions/Mile					
Reach Name	**Reach Number**	**Reach Length (miles)**	**Number of Diversions**	**Diversions / Mile**	**Matrix Score**
Maiden Rock to Melrose/Salmon Fly	1	5.8	8	1.4	3
Melrose/Salmon Fly to Brown's Bridge	2	6.3	2	0.3	1
Brown's Bridge to Glen	3	7.3	6	0.8	2
Glen to Notch Bottom	4	7.2	7	1.0	2
Notch Bottom to Pennington Bridge	5	9.7	5	0.5	1
Pennington Bridge to High Road Bridge	6	6.2	4	0.6	2
High Road Bridge to Jefferson River	7	1.8	2	1.1	3
		44.2	**34**	**0.8**	

Claimed Points of Diversion/Mile					
Reach Name	**Reach Number**	**Reach Length (miles)**	**Claimed Points of Diversion**	**Claimed Points of Diversion / Mile**	**Matrix Score**
Maiden Rock to Melrose/Salmon Fly	1	5.8	35	6.1	2
Melrose/Salmon Fly to Brown's Bridge	2	6.3	13	2.1	1
Brown's Bridge to Glen	3	7.3	30	4.1	1
Glen to Notch Bottom	4	7.2	23	3.2	1
Notch Bottom to Pennington Bridge	5	9.7	47	4.9	1
Pennington Bridge to High Road Bridge	6	6.2	108	17.4	3
High Road Bridge to Jefferson River	7	1.8	1	0.6	1
TOTAL		**44.2**	**257**	**5.8**	

Ditch Length to Reach Length Ratio					
Reach Name	**Reach Number**	**Reach Length (miles)**	**Ditch Length (miles)**	**Ditch Length to Reach Length Ratio**	**Matrix Score**
Maiden Rock to Melrose/Salmon Fly	1	5.8	24.1	4:1	1
Melrose/Salmon Fly to Brown's Bridge	2	6.3	11.9	2:1	1
Brown's Bridge to Glen	3	7.3	53.0	7:1	2
Glen to Notch Bottom	4	7.2	15.9	2:1	1
Notch Bottom to Pennington Bridge	5	9.7	72.2	8:1	2
Pennington Bridge to High Road Bridge	6	6.2	70.0	11:1	3
High Road Bridge to Jefferson River	7	1.8	11.9	7:1	2
TOTAL		**44.2**	**259.0**	**6:1**	

Percent of reach with Streambank Alterations					
Reach Name	**Reach Number**	**Reach Length (miles)**	**Length of Streambank Alterations**	**Percent of Reach with Streambank Alterations**	**Matrix Score**
Maiden Rock to Melrose/Salmon Fly	1	5.8	0.3	4%	1
Melrose/Salmon Fly to Brown's Bridge	2	6.3	0.09	1%	1
Brown's Bridge to Glen	3	7.3	1.1	15%	2
Glen to Notch Bottom	4	7.2	2.2	31%	3
Notch Bottom to Pennington Bridge	5	9.7	1.9	19%	2
Pennington Bridge to High Road Bridge	6	6.2	1.8	29%	3
High Road Bridge to Jefferson River	7	1.8	0.7	40%	3
		44.2	**8.0**	18%	