Yellowstone River Reach Narratives

Reach PC18

County	Park	**Upstream River Mile**	493.6
Classification	UA: Unconfined anabranching	**Downstream River Mile**	488.3
General Location	To below Mission Creek	**Length**	5.30 mi (8.53 km)

General Comments Reach PC18, located near Mission Creek in Park County, provides an example of both active (structure-related) and passive side channel loss, and also demonstrates CES data gaps in Park County.

Narrative Summary

Reach PC18 is located in Park County, downstream of Livingston at Mission Creek. It is 5.3 miles long, extending from RM 488.2 to RM 493.5. Reach PC 18 is an Unconfined Anabranching (UA) reach type. In the uppermost portion of the Reach (RM 492.5-493.5), the river flows along bluffs of the Fort Union Formation, which is made up of massive cliff-forming sedimentary rocks. The south side of the river consists primarily of young river deposits that form the modern valley bottom and low terraces. Sheep Mountain Fishing Access Site is located at RM 491.5. Just upstream of the fishing access site, the Middle Windsor Ditch diverts water off of a side channel.

In 2001, there was 9,650 feet of rock riprap in the reach and by 2011 that had expanded to 11,486 feet. Similarly, the extent of flow deflectors expanded from 1,710 feet to 3,370 feet from 2001 to 2011. Approximately 27 percent of the total bankline was armored in 2011. There is also one floodplain dike on the south floodplain near RM 492 that is about 3,400 feet long.

Over two miles of side channel have been blocked by dikes in Reach PC18. All of these lost side channels are located in the lower end of the reach below the mouth of Mission Creek. On the order of 3,370 feet were blocked prior to 1950, and about 8,000 feet since then.

Land uses in Reach PC18 are almost entirely agricultural, with historic flood irrigation converting to sprinkler and pivot, and some exurban development since 1950. There are still 302 acres of ground under flood irrigation in the reach. The major land use in the reach, however, is non-irrigated agriculture. There is one series of corrals associated with an animal holding facility that is within 200 feet of an abandoned channel at RM 490.3. Exurban Residential land use has expanded from zero acres in the1950s to 155 acres in 2011.

About 580 acres of wetlands have been mapped in Reach PC18, most of which are emergent marshes and wet meadows. Most of these wetlands are on the south side of the river in non-irrigated hay pastures or multi-use riparian bottoms.

Reach PC18 has 17 acres of Russian olive, which is the most of in any reach in Park County. This Russian olive is concentrated in one area on the south floodplain at RM 492.8; this area also has extensive mapped emergent wetlands.

This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,720 cfs to 1,560 cfs with human development, a reduction of 9.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC18 include:
•Blocked side channels that are thousands of feet long.
•Concentrated Russian olive infestation within mapped emergent wetland.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC18 include:
•Side channel restoration at RM 490R
•CMZ Management due to current restriction of 14 percent of the Channel Migration Zone
•Russian olive removal
•Nutrient management at corrals that are part of an animal handling facility at RM 490.3L
•Bank Stabilization Recommended due to the extent of armoring in the reach (27 percent armored banks)
•Irrigation diversion structure management at Middle Windsor Ditch diversion

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

Hydrologic data available for the Reach Narratives include data from representative gaging stations, modeling from the COE from the Big Horn river upstream, and modeling by the USGS for the Big Horn River to the Missouri River confluence. Gaging stations that best represent the watershed area within any reach are used to describe the flood history within the reach. Hydrology modeling results generated for all reaches provides unregulated and regulated flow values. Seasonal and annual flow duration data generated by the USGS are available for reaches C10 through D13.

Gage Representation (Gage-Based): Livingston

Flood History

Year	Date	Flow on Date	Return Interval
1971	Jun 23	29,200	10-25 yr
1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	123.9	13.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,400	22,400	28,100	31,700	38,900	41,800	48,500	1,720	1,760
Regulated	11,100	22,000	27,800	31,400	38,600	41,600	48,400	1,560	1,680
% Change	-2.63%	-1.79%	-1.07%	-0.95%	-0.77%	-0.48%	-0.21%	-9.30%	-4.55%

AERIAL PHOTOGRAPHY

A variety of aerial photographic sources provide the basis for much of the Cumulative Effects Assessment analysis. The table below lists the air photos compiled for the reach and the associated discharge at the most representative USGS gaging station.

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
1948	NA		DNR B/W			
1954	NA		DNR B/W			
1965	NA		DNR B/W			
1973	NA		DNR B/W			
1976	NA		DNR B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2005	USDA FSA		NAIP Color			
2007	Wolpert??		Color			
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

Several efforts to capture the types and extents of physical features in the corridor have been generated by the CEA study. The 2001 Physical Features Inventory was performed through helicopter/video Rapid Aerial Assessment by the NRCS (NRCS, 2001) and did not include Park County. This inventory includes point and linear features that represent bank armor, irrigation structures, transportation encroachments, and areas of accelerated erosion. Bank armor mapped in the 2001 inventory only reflects features on the active channel margin, and thus excludes off-channel features on historic side channels. Some floodplain restriction features such as dikes and levees in the 2001 Physical Features Inventory may extend well beyond the active channel. In 2013, the 2001 inventory was revised to include Park County. At that time, some attribute inconsistencies in the original data were addressed. This dataset was then updated to reflect conditions in the 2011 NAIP imagery.

For Stillwater, Yellowstone and Dawson Counties, a Physical Features Timeline was generated that includes additional mapping based on aerial photography and assigns approximate dates of feature construction based on observed presence/absence in historic imagery between the 1950s and 2005 (DTM and AGI, 2008). The Physical Features Timeline contains features that were not mapped in the 2001 inventory (e.g. bank armor abandoned in floodplain areas by 2001). As such the total bank armor extent in the 2005 data is commonly greater than that identified in 2001 or 2013.

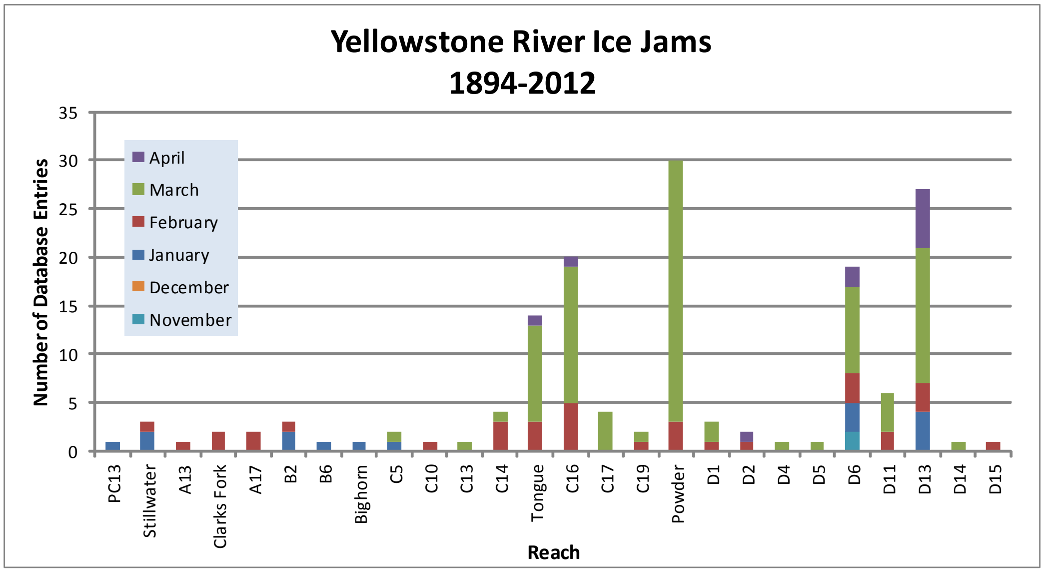
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	9,650	17.3%	11,486	20.6%	1,836
	Flow Deflectors	1,170	2.1%	1,352	2.4%	182
	Between Flow Deflectors	544	1.0%	2,110	3.8%	1,566
	Feature Type Totals	**11,364**	**20.4%**	**14,949**	**26.8%**	**3,584**
Floodplain Control						
	Floodplain Dike/Levee	3,339	6.0%	3,319	6.0%	-19
	Feature Type Totals	**3,339**	**6.0%**	**3,319**	**6.0%**	**-19**
	Reach Totals	**14,703**	**26.4%**	**18,268**	**32.8%**	**3,565**

ICE JAMS

Ice jam data were obtained from the National Ice Jam Database maintained by the Ice Engineering Group at Army Corps of Engineers Cold Regions Research and Engineering Laboratory (https://rsgis.crrel.usace.army.mil/icejam/). From this database, Yellowstone River ice jams are summarized by reach in the Yellowstone River Historic Events Timeline (DTM and AGI, 2008b). The basic information for each ice jam is presented as a list of events. The graph represents the number of database entries for a reach. Note that a single jam event may have multiple entries.



GEOMORPHIC

The geomorphology data presented below consist of measured changes in Braiding Parameter since 1950 and blocked side channels. Braiding parameter is a measure of the total length of side channels relative to that of the main channel. The braiding parameter is calculated as the sum of anabranching and primary channel lengths divided by the primary channel length. Secondary channels within the bankfull margins are a function of flow stage and hence were not included in the braiding parameter calculation. If a reach has a braiding parameter of 3, then the total bankfull channel length is three times that of the main channel. The mean braiding parameter measured for all 88 reaches is 1.8.

Blocked side channels that were either plugged with a small dike or cutoff by larger features such as a levee or road prism were identified for the pre and post-1950s eras.

Additional geomorphic parameters are discussed in more detail in the study report and appendices.

Braiding (Bankfull)

	Primary Chan. Length (ft)	Anab. Ch. Length (ft)	Bankfull Braiding Parameter		% Change in Braiding
1950	27,144	39,797	2.47	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	27,886	27,224	1.98	1950 to 2001:	-19.86%
Change 1950 - 2001	**742**	**-12,573**	**-0.49**		

Length of Side Channels Blocked

Pre-1950s (ft)	3,369
Post-1950s (ft)	7,999

HYDRAULICS

Available hydraulic information includes county-based HEC-RAS modeling efforts by the Army Corps of Engineers with the exclusion of Park County. Floodplain modeling was performed for four conditions representing a developed and undeveloped floodplain, and unregulated and regulated flows for the 1.5, 2, 5, 10, 20, 50, 100, 200, and 500-year events. Park County has limited FEMA hydraulic modeling and was not included in the analysis.

The results of HEC-RAS modeling for the 5 and 100-year flood events were assessed to compare the extents of inundated area for the pristine (undeveloped floodplain, unregulated flows) and developed (developed floodplain, regulated flows) conditions. The data sets provided for each flow condition were unioned in the GIS to identify areas where the inundated extent differed. These area areas of human-caused floodplain isolation due to either flow alterations or physical features such as levees. For the 100-year flood event, isolated areas greater than 5 acres were attributed with the interpreted reason for isolation (railroad, levee, etc.). The resulting values are presented as acres and percent of the pristine floodplain that has been isolated. The pristine floodplain is defined as the total floodplain footprint minus the area of the mapped 2001 bankfull channel (mapped islands were included in the floodplain area).

Floodplain Isolation	100-Year		5-Year	
	Isolated Acres	% of Floodplain	Isolated Acres	% of Floodplain
Non-Structural (hydrology, geomorphic, etc.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

The 5-year floodplain is a good allegory for the extent of the riparian zone. Thus, irrigated areas within the 5-year floodplain tend to represent riparian zones that have been converted to agrigulture and may result in additional bank protection to protect the agricultural production and irrigation infrastructure.

	Flood	Sprinkler	Pivot	Total
Irrigated Acres within the 5 Year Flooplain:				

CHANNEL MIGRATION ZONE

A series of Channel Migration Maps were developed for the Yellowstone River from Gardiner to its mouth in McKenzie County, North Dakota (Thatcher, Swindell, and Boyd, 2009). These maps and their accompanying report can be accessed from the YRCDC Website. The channel migration zone (CMZ) developed for the Yellowstone River is defined as a composite area made up of the existing channel, the historic channel since 1950 (Historic Migration Zone, or HMZ), and an Erosion Buffer that encompasses areas prone to channel erosion over the next 100 years. Areas within this CMZ that have been isolated by constructed features such as armor or floodplain dikes are attributed as "Restricted Migration Areas" (RMA). Beyond the CMZ boundaries, outlying areas that pose risks of channel avulsion are identified as "Avulsion Potential Zones".

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
266	532	1,087	117	11%	277	53	19%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Non-Irrigated	5	0.4%
	Irrigated	113	8.3%
RipRap			
	Irrigated	35	2.6%
	Exurban Residential	7	0.5%
	Canal	21	1.6%
Flow Deflectors			
	Other Infrastructure	3	0.2%
	Totals	**185**	**13.5%**

Note that these data reflect the observed conditions in the 2011 aerial photography (NAIP for Park and Sweet Grass Counties, COE for the rest of the river).

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
43.8	0.0	13.5	31.1	1.8

LAND USE

Land uses were mapped from aerial photography Gardiner to the confluence of the Missouri River in North Dakota for four time periods: 1950s, 1976, 2001, and 2011. Mapping was performed at approximately 1:6,000 to ensure consistent mapping across all data sets. Typically, if a feature could not be easily mapped at the target mapping scale, it was not separated out from the adjacent land use.

A four-tiered system was used to allow analysis at a variety of levels. Tier 1 breaks land use into Agricultural and Non-Agricultural uses. Tier two subdivided uses into productive Agricultural Land and Infrastructure for the Agricultural land, and Urban, Exurban and Transportation categories for the Non-Agricultural land. Tier three further breaks down land uses into more refined categories such as Irrigated or Non-Irrigated and Residential, Commercial, or Industrial. Finally, Tier 4 focuses primarily on the productive agricultural lands, identifying the type of irrigation (Pivot, Sprinkler or Flood).

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	23	23	23	23	0.6%	0.6%	0.6%	0.6%
	Agricultural Roads	0	0	6	6	0.0%	0.0%	0.2%	0.2%
	Other Infrastructure	64	92	131	142	1.7%	2.4%	3.5%	3.7%
	Totals	**86**	**115**	**160**	**171**	**2.3%**	**3.0%**	**4.2%**	**4.5%**
Agricultural Land									
	Non-Irrigated	1,728	1,663	1,671	1,885	45.6%	43.8%	44.1%	49.7%
	Irrigated	1,365	1,351	1,124	843	36.0%	35.6%	29.6%	22.2%
	Totals	**3,093**	**3,014**	**2,795**	**2,728**	**81.6%**	**79.5%**	**73.7%**	**71.9%**
Channel									
	Channel	530	528	565	583	14.0%	13.9%	14.9%	15.4%
	Totals	**530**	**528**	**565**	**583**	**14.0%**	**13.9%**	**14.9%**	**15.4%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	12	12	0.0%	0.0%	0.3%	0.3%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	23	104	143	0.0%	0.6%	2.7%	3.8%
	Totals	**0**	**23**	**116**	**155**	**0.0%**	**0.6%**	**3.1%**	**4.1%**
Transportation									
	Public Road	62	24	47	47	1.6%	0.6%	1.2%	1.2%
	Interstate	0	67	88	88	0.0%	1.8%	2.3%	2.3%
	Railroad	21	21	21	21	0.6%	0.6%	0.6%	0.6%
	Totals	**84**	**112**	**155**	**155**	**2.2%**	**3.0%**	**4.1%**	**4.1%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Land Use Timeline - Tiers 3 and 4

		Acres				% of Reach Area				Change Between Years (% of Agricultural Land)			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011	'50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	91	128	0.0%	0.0%	3.2%	4.7%	0.0%	3.2%	1.5%	4.7%
	Pivot	0	0	275	412	0.0%	0.0%	9.8%	15.1%	0.0%	9.8%	5.3%	15.1%
	Flood	1,365	1,351	759	303	44.1%	44.8%	27.1%	11.1%	0.7%	-17.7%	-16.0%	-33.0%
	Totals	**1,365**	**1,351**	**1,124**	**843**	**44.1%**	**44.8%**	**40.2%**	**30.9%**	**0.7%**	**-4.6%**	**-9.3%**	**-13.2%**

Non-Irrigated

Multi-Use	1,487	1,399	1,459	1,410	48.1%	46.4%	52.2%	51.7%	-1.7%	5.8%	-0.5%	3.6%
Hay/Pasture	241	264	212	475	7.8%	8.8%	7.6%	17.4%	1.0%	-1.2%	9.8%	9.6%
Totals	**1,728**	**1,663**	**1,671**	**1,885**	**55.9%**	**55.2%**	**59.8%**	**69.1%**	**-0.7%**	**4.6%**	**9.3%**	**13.2%**

RIPARIAN

Riparian mapping data are derived from the Yellowstone River Riparian Vegetation Mapping study (DTM/AGI 2008). This study coarsely mapped the riparian vegetation communities using 1950's, 1976-1977, and 2001 aerial imagery in a GIS environment. The polygons are digitized at a scale of approximately 1:7,500, with a minimum mapping unit of approximately 10 acres. The goal of the delineation was to capture areas of similar vegetation structure as they appeared on the aerial imagery, while maintaining a consistent scale.

The "Riparian Turnover" values quantify the total area within the active channel area that converted from either woody vegetation to open bar or water, or from open bar or water to woody vegetation. A comparison of these values allows some consideration of overall riparian encroachment into the river corridor from 1950 to 2001.

WETLANDS

Wetland areas were mapped to National Wetland Inventory standards by the Montana Natural Heritage Program. Palustrine wetlands within the mapped 100-year inundation boundary were extracted and summarized into four categories: Riverine (Unconsolidated Bottom - UB, Aquatic Bed - AB, and Unconsolidated Shore - US), Emergent - EM, Scrub-Shrub - SS, and Forested - FO.

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	6.5	504.8	68.1	0.0	**579.4**
Acres/Valley Mile	1.4	105.6	14.3	0.0	

RUSSIAN OLIVE

Russian olive is considered an invasive species and its presence in the Yellowstone River corridor is fairly recent. As such, its spread can be used as a general indicator of invasive plants within the corridor. It has the added benefit of being easily identified in multi-spectral aerial photography, making it possible to inventory large areas using remote techniques.

In 2011, Natural Resources Conservation Service (NRCS) in Bozeman, MT conducted an inventory of Russian olive locations in the Yellowstone River watershed. This study utilized the Feature Analyst extension within ArcGIS to interpret multi-spectral 2008 NAIP imagery for the presence of Russian olive. The resulting analysis was converted from raster format to a polygon ESRI shape file for distribution and further analysis within a GIS environment.

This work scope was tasked with integrating the resulting Russian olive inventory into the Yellowstone River Conservation Districts Council (YRCDC) Cumulative Effects Assessment (CEA) GIS and associated reach-based database. Additionally, analysis of Russian olive within the corridor was conducted to characterize its distribution in throughout the corridor and its association with other corridor data sets.

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	16.66	0.79%	1.63	0.33	0.14	0.32

FISHERIES SUMMARY

Fisheries data available for the Reach Narratives include low-flow and high-flow habitat mapping of 2001 conditions for 406 miles of river, extending from the mouth upstream to a point approximately 8 miles upstream of Park City. Habitat mapping was performed remotely on the 2001 CIR aerial photography utilizing habitat classifications developed by Montana Fish, Wildlife, and Parks (DTM 2009). Historic habitat mapping using the 1950's imagery is limited to Reach B1 (high-flow) and D9 (low and high-flow).

Fisheries field sampling data have been provided by Ann Marie Reinhold (MSU). In this study, the Yellowstone River from Park City to Sidney was divided into five segments. Within each segment, fish were sampled in reaches modified by riprap ("treatment reaches") and relatively unmodified reaches ("control reaches"). Fish sampling was conducted during summer and autumn of 2009, 2010, and 2011. Boat electrofishing, trammel nets, mini-fyke nets and bag seines were used to collect data from river bends.

Fish presence data is only presented for those reaches that were sampled.

The Low Flow Habitat Mapping followed schema deveoped by Montana Fish Wildlife and Parks to identify key habitat units for certain aquatic species.

AVIAN

Birds were sampled in 2006 and 2007 by Danielle Jones of Montana State University. Point count methods were used at 304 randomly chosen sites in 21 braided or anabranching reaches. Each site was visited multiple times within a season, and sites were visited in both years. Birds were sampled in grassland, shrubland, and cottonwood forest habitats. Additional bird data was collected by Amy Cilimburg of Montana Audubon in summer 2012. High priority areas for data collection were identified with the assistance of the YRCDC Technical Advisory Committee. The Audubon methodology recorded data for a wider variety of bird species relative to the MSU study, including raptors and waterfowl.