County	Rosebud	**Upstream River Mile**	208.1
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	195.9
General Location	Sheffield	**Length**	12.20 mi (19.63 km)
General Comments	Series of meander bends		

Narrative Summary

Reach C14 is 12.2 miles long and is located near Sheffield, which is about 15 miles upstream of Miles City. The reach straddles the Rosebud/Custer County Line. The reach is characterized by a dominant main thread that shows a distinct meandering pattern, with several islands persisting where meander bends have historically cut off. The river intermittently flows along the south valley wall. As a result it is classified as Partially Confined Meandering with Islands (PCM/I). In this section of river the valley bottom is consistently about 1.8 miles wide, and bound by Tertiary-age Fort Union Formation. The active meanderbelt of the Yellowstone River is about 3,000 feet wide.

The large meander features in Reach C14 have experienced significant migration since 1950 and also in recent years; one site at RM 204.5 migrated 977 feet southward between 1950 and 2001, and then over the next ten years continued to migrate another 400 feet so that it is now at the toe of the active rail line. At RM 200.5, the river has migrated 700 feet northward since 2001; eroding out irrigated lands and threatening structures.

As of 2011 there were about four miles of armor protecting 17 percent of the total bankline in Reach C14, including 15,087 feet of rock riprap and 6,300 feet of flow deflectors. Most of the rock riprap is protecting the rail line as it flows along the south bluff of Fort Union Formation, whereas flow deflectors are more commonly used to protect agricultural land. Between 2001 and 2011, about 3,000 feet of flow deflectors were evidently destroyed. Barbs can be seen in the river at RM 205.3R; the bank behind has since been partially armored with rock riprap. Another barb was flanked at RM 204.7L, and the river has migrated over 200 feet behind that structure towards the rail line. Another series of barbs were flanked at RM 203.6L and have since been replaced by rock riprap. Those flanked rock structures are visible on the 2011 air photos almost 200 feet out into the channel. At RM 200.8L, new riprap was built after older armor scoured out in 2011, which was followed by hundreds of feet of northward bank migration during the 2011 flood. Some of the new riprap appears to be trenched behind the bank. About 1,300 feet of rock riprap mapped in 2001 on the left bank at RM 196.9 has been flanked, and is now up to 70 feet out in the river.

Prior to 1950, about 3 miles of side channels were blocked in Reach C14. Chute channels formed through meander tabs have been blocked by small dikes such as at RM 198. Several historic anabranching channels appear to have been blocked prior to 1950 such as at RM 207.8. These areas provide excellent restoration/mitigation opportunities for side channel re-activation.

Similar to other reaches downstream of the Bighorn River confluence, the river channel has become smaller in Reach C14 since 1950. In 1950, the bankfull footprint was about 38 acres larger than it was in 2001, and riparian mapping shows about 208 acres of riparian encroachment into old channel areas. Floodplain turnover rates are also slightly lower; from 1950-1975 the average annual rate of floodplain turnover was 15.6 acres per year, and since 1975 it has been 12.5 acres per year.

Over two thousand acres of the 100-year floodplain has become isolated from the river due to flow alterations, agricultural development, and the abandoned railroad grade. In total, 40 percent of the entire historic 100-year floodplain has become isolated. Most of the isolation is associated with agricultural land development (29 percent of the historic floodplain), with another 10 percent of the isolation due to the abandoned rail grade. Isolation of the 5-year floodplain has been even more substantial; 2,321 acres or 59 percent of the 5-year floodplain has become isolated at that frequency event. Much of this isolated 5-year floodplain is on flood irrigated fields north of the river.

Bank armor on the north side of the river commonly narrows the natural meanderbelt of the river, which has resulted in large extents of the CMZ being restricted to migration. About 740 acres which represents 16 percent of the total CMZ has become restricted by physical features.

Four ice jams have been reported in the reach, including February of 1996, 1997, and 1998, and March of 2003. All of the ice jams in the 1990s were associated with lowland flooding.

One dump site was mapped on the left bank at RM 196.3.

Reach C14 has seen extensive riparian clearing since 1950s. Typically, riparian clearing for agriculture occurred prior to 1950 along the Yellowstone River. In this reach, however, 760 acres of riparian area were cleared since 1950, which represents 30 percent of the total 1950s riparian corridor. In several cases, this includes riparian clearing on large meander tabs. With this clearing, the reach has seen a substantial loss of forest area considered at low risk of cowbird parasitism. In 1950, the reach had 91.8 acres of such forest per valley mile and by 2001 that forest extent had dropped to 51.4 acres per valley mile.

Reach C14 has fairly extensive mapped wetland area; there are over 45 acres of mapped wetlands per valley mile, most of which is emergent marsh and wet meadow. A total of 22 acres of Russian olive were mapped in the reach, which reflects an abrupt reduction in Russian olive extent relative to upstream, where Reaches C10 through C13 have on the order of 200 acres of RO over similar valley distances.

Reach C14 was sampled as part of the fisheries study. A total of 36 species were sampled in the reach, including Sauger which has

been identified as Species of Concern by the Montana Natural Heritage Program.

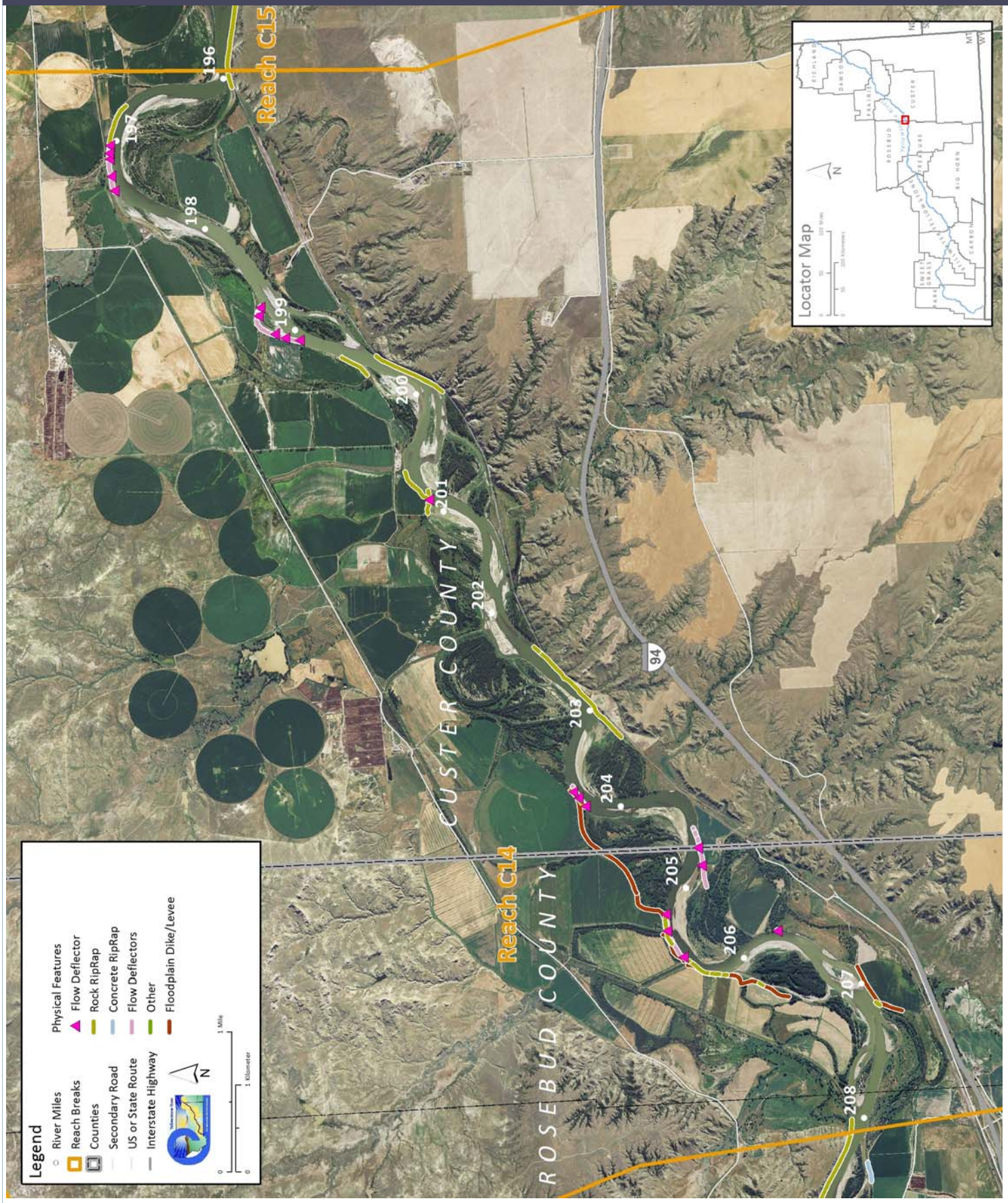
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 18 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 3,070 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,330 cfs under unregulated conditions to 3,390 cfs under regulated conditions, a reduction of 47 percent.

Fall and winter base flows have increased in Reach C14 by about 60 percent.

CEA-Related observations in Reach C14 include:
•Passive side channel abandonment due to flow alterations
•Flanking of barb structures on migrating meander bends
•Extensive floodplain isolation by agricultural dikes and abandoned railroad grade
•Pre-1950s blocking of side channels by agricultural dikes
•Armoring of bluff pool habitat against active railroad
•Floodplain isolation by the abandoned Milwaukee rail line on the north bank
•Post-1950s riparian clearing for irrigation development

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C14 include:
•Removal of flanked barb at RM 205.3
•Side channel reactivation at RM 208L
•CMZ Management due to extent of CMZ restriction (11 percent)
•Dump removal on left bank at RM 196.3L
•Russian olive removal

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): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	11.9	156.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		61,900	77,800	88,100	110,000	120,000	142,000	4,850	6,330
Regulated		47,300	61,700	70,900	90,500	98,600	118,000	3,070	3,390
% Change		-23.59%	-20.69%	-19.52%	-17.73%	-17.83%	-16.90%	-36.70%	-46.45%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	60,600	22,700	6,090
	Regulated	46,900	13,700	4,430
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	42,800	13,500	6,330
	Regulated	32,500	8,330	3,390
	% Change	**-24%**	**-38%**	**-46%**
Fall	Unregulated	9,140	5,550	2,300
	Regulated	10,500	6,890	3,640
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,950	2,020
	Regulated	12,300	6,030	3,260
	% Change	**5%**	**22%**	**61%**
Annual	Unregulated	45,500	7,940	2,790
	Regulated	34,100	7,390	3,630
	% Change	**-25%**	**-7%**	**30%**

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
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/7/96 - 8/7/96	B/W		6295000	39800
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2009	NAIP	7/15/2009	Color	1-meter pixels	6309000	26400
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2011	NAIP	7/15/2011	Color	1-meter pixels	6309000	58000
2013	NAIP	07/21/2013	color	1-meter pixels	6309000	
2013	NAIP	07/20/2013	color	1-meter pixels	6309000	

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	13,314	10.4%	15,087	11.7%	1,773
	Flow Deflectors	1,821	1.4%	1,638	1.3%	-184
	Between Flow Deflectors	7,431	5.8%	4,657	3.6%	-2,774
	Feature Type Totals	**22,567**	**17.6%**	**21,382**	**16.6%**	**-1,185**
Floodplain Control						
	Transportation Encroachment	4,433	3.5%	4,433	3.5%	0
	Floodplain Dike/Levee	14,808	11.5%	14,882	11.6%	73
	Feature Type Totals	**19,241**	**15.0%**	**19,315**	**15.0%**	**73**
	Reach Totals	**41,808**	**32.5%**	**40,697**	**31.7%**	**-1,111**

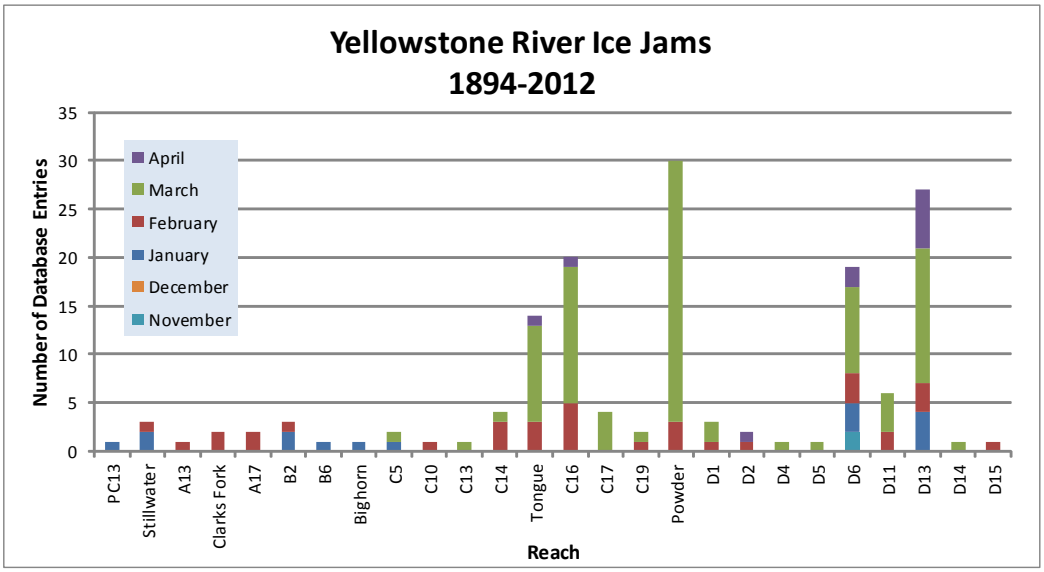
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Flow Deflectors/Between FDs	4,257	2,286	0	0	0	1,761	0	0
Rock RipRap	4,562	0	0	0	0	11,110	0	0
Totals	**8,820**	**2,286**	**0**	**0**	**0**	**12,871**	**0**	**0**

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.



Jam Date	Jam Type	River Mile	Damages
2/7/1996	Break-up	208	Flooding
2/20/1997	Freeze-up	208	Lowland flooding
2/3/1998	Break-up	208	Lowland flooding
3/15/2003	Break-up		?

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	66,789	44,239	1.66	1950 to 1976:	16.56%
1976	61,868	58,008	1.94	1976 to 1995:	-7.30%
1995	64,341	51,220	1.80	1995 to 2001:	-22.77%
2001	64,232	24,859	1.39	1950 to 2001:	-16.56%
Change 1950 - 2001	**-2,557**	**-19,380**	**-0.28**		

Length of Side Channels Blocked

Pre-1950s (ft)	14,986
Post-1950s (ft)	0

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.)	27	0.5%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	1474	29.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	52	1.0%		
Abandoned Railroad	495	9.7%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	3039		2922	
Total Floodplain Area (Ac)	5088		5243	
Total Isolated (Ac)	**2049**	**40.3%**	**2321**	**59.1%**

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:	269	0	0	**269**

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
575	1,150	4,432	737	17%	306	0	0%

2011 Restricted Migration Area Summary

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).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	63	1.3%
RipRap/Flow Deflectors			
	Irrigated	250	5.3%
RipRap			
	Railroad	41	0.9%
	Non-Irrigated	45	1.0%
Flow Deflectors			
	Other Infrastructure	17	0.4%
	Non-Irrigated	77	1.6%
Dike/Levee			
	Irrigated	247	5.2%
	Totals	**739**	**15.6%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
1015.0	0.0	112.6	3.9	23.9

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	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	77	141	109	106	0.7%	1.3%	1.0%	0.9%
	Totals	**77**	**141**	**109**	**106**	**0.7%**	**1.3%**	**1.0%**	**0.9%**
Agricultural Land									
	Non-Irrigated	6,908	5,532	5,146	4,958	61.7%	49.4%	45.9%	44.3%
	Irrigated	2,517	3,507	3,982	4,058	22.5%	31.3%	35.5%	36.2%
	Totals	**9,425**	**9,040**	**9,128**	**9,017**	**84.1%**	**80.7%**	**81.5%**	**80.5%**
Channel									
	Channel	1,569	1,806	1,786	1,901	14.0%	16.1%	15.9%	17.0%
	Totals	**1,569**	**1,806**	**1,786**	**1,901**	**14.0%**	**16.1%**	**15.9%**	**17.0%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	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	0	6	6	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**0**	**6**	**6**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	35	47	47	47	0.3%	0.4%	0.4%	0.4%
	Interstate	0	66	66	66	0.0%	0.6%	0.6%	0.6%
	Railroad	95	101	58	58	0.9%	0.9%	0.5%	0.5%
	Totals	**131**	**214**	**171**	**171**	**1.2%**	**1.9%**	**1.5%**	**1.5%**
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	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	154	345	660	0.0%	1.7%	3.8%	7.3%	1.7%	2.1%	3.5%	7.3%
	Flood	2,517	3,353	3,637	3,398	26.7%	37.1%	39.8%	37.7%	10.4%	2.7%	-2.2%	11.0%
	Totals	**2,517**	**3,507**	**3,982**	**4,058**	**26.7%**	**38.8%**	**43.6%**	**45.0%**	**12.1%**	**4.8%**	**1.4%**	**18.3%**

Non-Irrigated

Multi-Use	6,439	5,123	4,666	4,531	68.3%	56.7%	51.1%	50.2%	-11.7%	-5.6%	-0.9%	-18.1%
Hay/Pasture	469	410	481	428	5.0%	4.5%	5.3%	4.7%	-0.4%	0.7%	-0.5%	-0.2%
Totals	**6,908**	**5,532**	**5,146**	**4,958**	**73.3%**	**61.2%**	**56.4%**	**55.0%**	**-12.1%**	**-4.8%**	**-1.4%**	**-18.3%**

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.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	0.5	1.6	0.3	1.1	1.9	2.5	2.8	5.3
Max	87.1	38.7	28.2	471.6	149.2	189.5	82.1	98.0	63.9
Average	17.9	7.4	9.5	58.3	34.3	37.1	29.0	24.0	22.7
Sum	554.6	376.6	218.7	1,632.8	1,133.0	1,112.4	464.0	359.6	317.1

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	412.8
Channel to Riparian (acres)	620.5
Riparian Encroachment (acres)	**207.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	642.4
1950s Floodplain Mapped as 2011 Channel (Ac)	130.2
Total Recruitment (1950s to 2011)(Ac)	**772.5**

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	48.6	292.7	121.6	0.0	**462.9**
Acres/Valley Mile	5.0	30.0	12.5	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	21.65	0.24%	0.57	0.94	3.05	0.36

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.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
☑	☑	Bigmouth buffalo	☑	☑	Flathead chub	☐	☐	Northern redbelly dace	☑	☑	Stonecat
☑	☑	Black bullhead	☑	☑	Freshwater drum	☐	☐	Pallid sturgeon	☐	☐	Sturgeon chub
☑	☑	Black crappie	☑	☑	Goldeye	☐	☑	Pumpkinseed	☑	☑	Sucker species
☐	☑	Blue sucker	☑	☑	Green sunfish	☐	☐	Rainbow trout	☑	☑	Sunfish species
☑	☑	Bluegill	☑	☑	Lake chub	☑	☑	River carpsucker	☐	☑	Walleye
☑	☑	Brook stickleback	☐	☑	Largemouth bass	☑	☑	Rock bass	☑	☑	Western silvery minnow
☐	☑	Brown trout	☑	☑	Longnose dace	☑	☑	Sand shiner	☐	☐	White bass
☑	☑	Burbot	☑	☑	Longnose sucker	☑	☑	Sauger	☑	☑	White crappie
☐	☐	Catfish species	☑	☑	Minnow species	☑	☑	Shorthead redhorse	☑	☑	White sucker
☑	☑	Channel catfish	☐	☐	Mottled sculpin	☐	☐	Shortnose gar	☐	☑	Yellow bullhead
☑	☑	Common carp	☑	☑	Mountain sucker	☑	☑	Shovelnose sturgeon	☐	☐	Yellow perch
☑	☑	Creek chub	☐	☑	Mountain whitefish	☐	☐	Sicklefin chub			
☑	☑	Emerald shiner	☑	☑	Northern pike	☑	☑	Smallmouth bass			
☑	☑	Fathead minnow	☑	☑	Northern plains killifish	☑	☑	Smallmouth buffalo			

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	281.9	215.6	12.1%
Rip Rap Bottom	278.9	168.1	9.4%
Rip Rap Margin	83.7	60.1	3.4%
Secondary Channel	67.4	95.2	5.3%
Secondary Channel (Seasonal)	182.6	143.0	8.0%
Channel Crossover	384.3	216.9	12.1%
Point Bar		146.2	8.2%
Side Bar		68.1	3.8%
Mid-channel Bar		75.6	4.2%
Island	507.2	507.2	28.4%
Dry Channel		90.0	5.0%

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.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

Yellowstone River Reach Narratives — Reach C15

County	Custer	**Upstream River Mile**	195.9
Classification	PCS: Partially confined straight	**Downstream River Mile**	192.3
General Location	Horton Siding	**Length**	3.60 mi (5.79 km)
General Comments	Very low riparian vegetation		

Narrative Summary

Reach C15 is located in Custer County at Horton Siding, about seven miles upstream of Miles City. It is 3.6 miles long and classified as a Partially Confined Straight (PCS) reach type, as the river has low sinuosity and flows along the south valley wall.

As of 2011 there were about 7,600 feet of armor protecting 19 percent of the total bankline in Reach C15, the vast majority of which is rock riprap protecting the rail line as it flows along the south bluff of Fort Union Formation. There are also minor amounts of flow deflectors (80 feet) and car bodies (150 feet) in the reach.

About 17 percent of the historic 100-year floodplain has become isolated. Isolation of the 5-year floodplain has been even more substantial; 298 acres or 61 percent of the 5-year floodplain has become isolated at that frequency event. Floodplain isolation appears to be mostly due to flow alterations, although there are 35 acres if isolated 100-year floodplain behind the abandoned Milwaukee rail line embankment.

Reach C15 has lost approximately 3,000 feet of side channel length since 1950; although there is no indication that side channels were intentionally blocked.

There has been about 1,200 acres of pivot irrigation development in Reach C15 since 1950, and most of that expansion has occurred since 2001. Pivot irrigation is more extensive than flood irrigation in this area, which is somewhat unusual in the Yellowstone River valley. About 10 percent (115 acres) of the land under pivot irrigation is within the Channel Migration Zone (CMZ) of the river, making it especially prone to threats of river erosion.

Reach C15 has seen relatively extensive riparian clearing since 1950s. Typically, riparian clearing for agriculture occurred prior to 1950 along the Yellowstone River. In this reach, however, 48 acres of riparian area were cleared since 1950, which represents 20 percent of the total 1950s riparian corridor. With this clearing, the reach has seen a substantial loss of forest area considered at low risk of cowbird parasitism. In 1950, the reach had 51.3 acres of such forest per valley mile and by 2001 that forest extent had dropped to 37.2 acres per valley mile.

A total of 8 acres of Russian olive have been mapped in Reach C15.

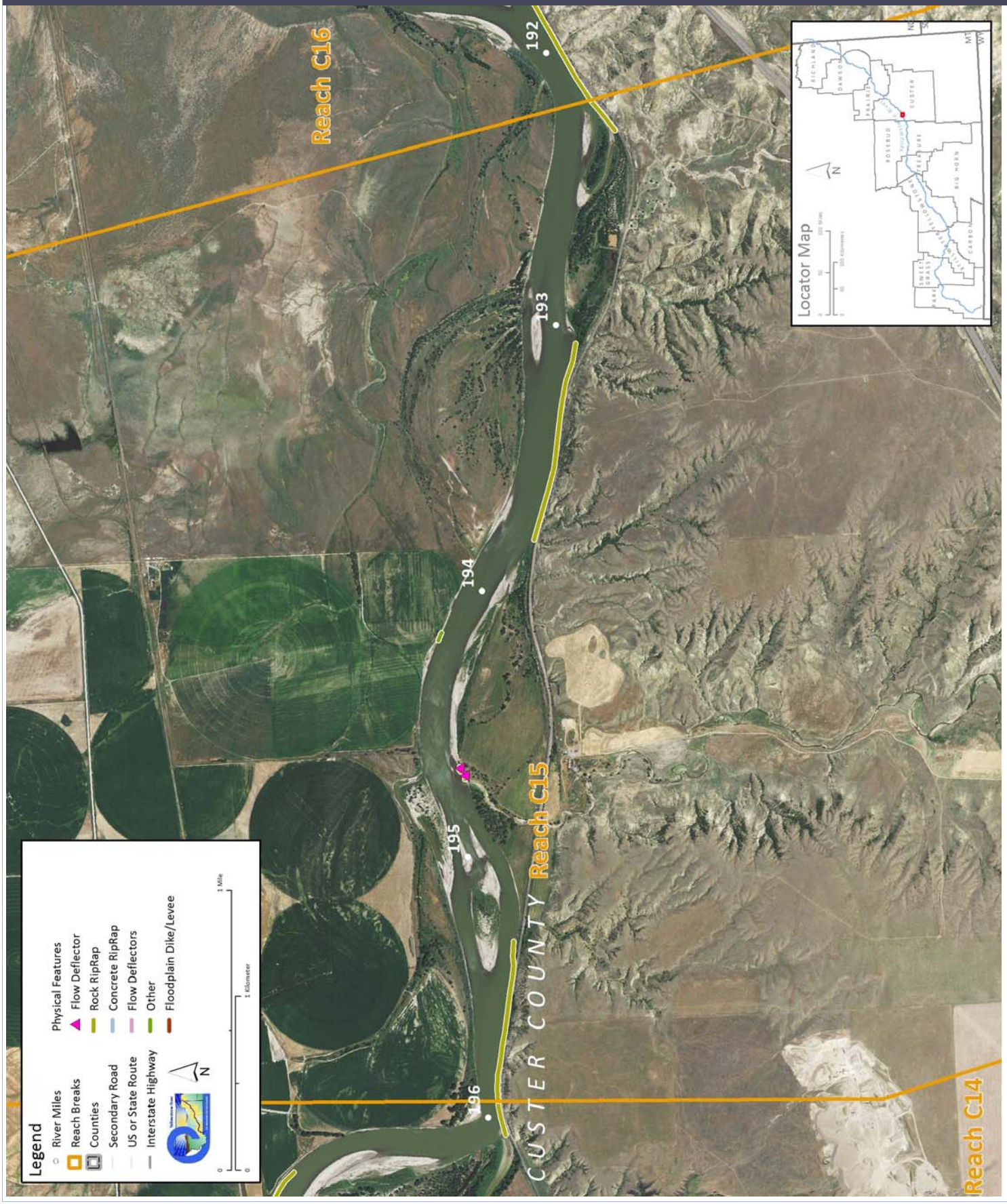
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 18 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 3,070 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,340 cfs under unregulated conditions to 3,390 cfs under regulated conditions, a reduction of 47 percent.

Fall and winter base flows have increased in Reach C15 by over 60 percent.

CEA-Related observations in Reach C15 include:
•Passive side channel abandonment due to flow alterations
•Extensive pivot irrigation development since 2001

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C15 include:
•Russian olive removal

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): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	8.3	168.5

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		62,000	77,800	88,100	110,000	120,000	142,000	4,850	6,340
Regulated		47,300	61,700	70,900	90,400	98,600	117,000	3,070	3,390
% Change		-23.71%	-20.69%	-19.52%	-17.82%	-17.83%	-17.61%	-36.70%	-46.53%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	60,700	22,700	6,090
	Regulated	46,900	13,700	4,430
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	42,800	13,500	6,340
	Regulated	32,600	8,330	3,390
	% Change	**-24%**	**-38%**	**-47%**
Fall	Unregulated	9,150	5,550	2,300
	Regulated	10,500	6,900	3,640
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,950	2,020
	Regulated	12,400	6,040	3,260
	% Change	**6%**	**22%**	**61%**
Annual	Unregulated	45,500	7,940	2,800
	Regulated	34,200	7,400	3,630
	% Change	**-25%**	**-7%**	**30%**

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
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7-Jul-96	B/W		6295000	39800
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

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	7,814	19.8%	7,578	19.2%	-235
	Flow Deflectors	0	0.0%	80	0.2%	80
	Car Bodies	152	0.4%	152	0.4%	0
	Feature Type Totals	**7,965**	**20.2%**	**7,810**	**19.8%**	**-155**
	Reach Totals	**7,965**	**20.2%**	**7,810**	**19.8%**	**-155**

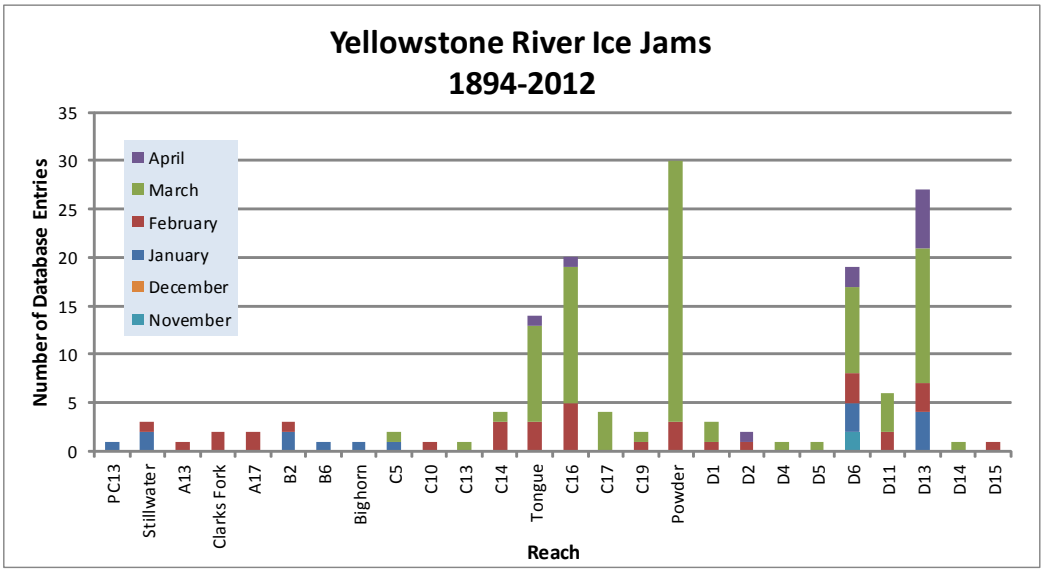
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Car Bodies	141	0	0	0	0	0	0	0
Rock RipRap	236	0	0	0	0	7,488	0	0
Totals	**377**	**0**	**0**	**0**	**0**	**7,488**	**0**	**0**

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	19,497	5,895	1.30	1950 to 1976:	-12.15%
1976	19,522	2,815	1.14	1976 to 1995:	0.93%
1995	19,711	3,051	1.15	1995 to 2001:	-0.57%
2001	19,711	2,920	1.15	1950 to 2001:	-11.84%
Change 1950 - 2001	**214**	**-2,975**	**-0.15**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

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.)	122	12.5%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	12	1.2%		
Abandoned Railroad	35	3.6%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	805		560	
Total Floodplain Area (Ac)	973		859	
Total Isolated (Ac)	**168**	**17.3%**	**298**	**60.5%**

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:	4	0	0	**4**

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
180	360	720	14	2%	248	0	0%

2011 Restricted Migration Area Summary

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).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	16	1.6%
	Totals	**16**	**1.6%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
14.0	0.0	114.9	0.0	4.5

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	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	6	23	42	54	0.2%	0.5%	1.0%	1.3%
	Totals	**6**	**23**	**42**	**54**	**0.2%**	**0.5%**	**1.0%**	**1.3%**
Agricultural Land									
	Non-Irrigated	3,447	2,292	1,746	1,789	81.9%	54.5%	41.5%	42.5%
	Irrigated	324	1,471	2,002	1,941	7.7%	35.0%	47.6%	46.1%
	Totals	**3,771**	**3,763**	**3,748**	**3,729**	**89.6%**	**89.4%**	**89.1%**	**88.6%**
Channel									
	Channel	391	382	390	396	9.3%	9.1%	9.3%	9.4%
	Totals	**391**	**382**	**390**	**396**	**9.3%**	**9.1%**	**9.3%**	**9.4%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	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	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**0**	**0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	7	7	7	7	0.2%	0.2%	0.2%	0.2%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	33	34	22	22	0.8%	0.8%	0.5%	0.5%
	Totals	**40**	**41**	**29**	**29**	**1.0%**	**1.0%**	**0.7%**	**0.7%**
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	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	267	1,244	0.0%	0.0%	7.1%	33.4%	0.0%	7.1%	26.2%	33.4%
	Flood	324	1,471	1,735	696	8.6%	39.1%	46.3%	18.7%	30.5%	7.2%	-27.6%	10.1%
	Totals	**324**	**1,471**	**2,002**	**1,941**	**8.6%**	**39.1%**	**53.4%**	**52.0%**	**30.5%**	**14.3%**	**-1.4%**	**43.4%**

Non-Irrigated

Multi-Use	3,281	2,252	1,652	1,591	87.0%	59.9%	44.1%	42.7%	-27.2%	-15.8%	-1.4%	-44.4%
Hay/Pasture	165	39	94	198	4.4%	1.0%	2.5%	5.3%	-3.3%	1.5%	2.8%	0.9%
Totals	**3,447**	**2,292**	**1,746**	**1,789**	**91.4%**	**60.9%**	**46.6%**	**48.0%**	**-30.5%**	**-14.3%**	**1.4%**	**-43.4%**

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.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	2.2	1.0	4.8	8.2	0.4	2.7	1.7	7.4	0.5
Max	37.6	30.5	24.7	82.1	82.6	26.2	58.9	7.4	62.8
Average	12.4	9.7	11.3	31.5	16.4	8.3	17.5	7.4	11.0
Sum	74.5	87.2	90.7	189.2	196.3	57.9	87.5	7.4	121.5

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	30.5
Channel to Riparian (acres)	43.2
Riparian Encroachment (acres)	**12.7**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	54.8
1950s Floodplain Mapped as 2011 Channel (Ac)	16.9
Total Recruitment (1950s to 2011)(Ac)	**71.7**

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	7.0	25.5	14.4	0.0	**46.9**
Acres/Valley Mile	1.9	7.1	4.0	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	7.95	0.31%	0.70	0.02	1.03	0.19

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.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	105.0	79.0	20.3%
Rip Rap Margin	94.1	87.4	22.4%
Secondary Channel	28.3	26.7	6.8%
Secondary Channel (Seasonal)	15.3	19.4	5.0%
Channel Crossover	123.0	78.2	20.1%
Side Bar		44.4	11.4%
Mid-channel Bar		6.8	1.7%
Island	23.9	23.9	6.1%
Dry Channel		23.9	6.1%

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.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	192.3
Classification	PCM/I: Partially confined meandering/islands	**Downstream River Mile**	185
General Location	to Miles City	**Length**	7.30 mi (11.75 km)
General Comments	to Miles City		

Narrative Summary

Reach C16 is 7.32 miles long and is located just upstream of Miles City. The downstream limit of the reach is the mouth of the Tongue River at RM 185. The reach is characterized by a dominant main thread that shows a distinct meandering pattern, with several islands persisting where meander bends have historically cut off. The river intermittently flows along the valley wall. As a result it is classified as Partially Confined Meandering with Islands (PCM/I).

As of 2011 there were about two miles of armor protecting 14 percent of the total bankline in Reach C16, including 7,000 feet of rock riprap, 2,200 feet of concrete riprap, and 1,550 feet of flow deflectors. All of the concrete armor is protecting urban areas around the water treatment plant in Miles City. The flow deflectors protect non-irrigated agricultural land, and the rock riprap is protecting agricultural land (irrigated and non-irrigated), roads, and the rail line. A ~550 foot-long stretch of armor at RM 190.5R has been flanked since 2001, and erosion behind the armor now threatens a road; the river has locally eroded into the road embankment. There were also several miles of transportation encroachments and floodplain levees mapped in the reach.

About 13 percent (308 acres) of the 100-year floodplain has become isolated from the river in Reach C16, meaning it is no longer inundated at what was historically a 100-year flood event. Isolation can be due to flow changes and/or physical features that block overflows from reaching floodplain areas. Most of the 100-year floodplain isolation (185 acres) is due to the active rail line. Isolation of the 5-year floodplain has been even more substantial, with 62 percent (721 acres) of the historic 5-year floodplain no longer inundated at what was historically a 5-year flood event.

Three ice jams have been reported in the reach, including February of 2011, and March of 2003 and 2012. No damages were recorded in the ice jam database.

At RM 186.6 a steel trestle bridge built for the now abandoned Milwaukee Railroad crosses the river where it is about 1,000 feet wide. There are several very large barbs on the right bank of the river upstream of the bridge that extend about 100 feet off of the bank, and there is riprap directly under the structure.

About 210 acres which represents 9 percent of the total CMZ have become restricted by physical features. Areas that have become restricted to channel migration include the water treatment plant just upstream of the mouth of the Tongue River, behind the railroad grade at RM 191.5, and locally behind stretches of bank armor protecting irrigated and non-irrigated fields.

Mapped land uses in Reach C16 range from agricultural to urban to transportation infrastructure. The total acreage of flood irrigated land in the reach has dropped from 1,000 acres in 1950 to 830 acres in 2001; and during that time about 300 acres were developed for pivot. All of the pivot development occurred prior to 1976. Pivot irrigation has encroached into the active river corridor; approximately 27 acres of pivot-irrigated land is within the natural Channel Migration Zone (CMZ) of the river, making it especially susceptible to threats of river erosion. This pivot is at RM 190R, where a ~300 acre pivot field extends to within 150 feet of the river bank.

Reach C16 shows an increase in forest area considered to be at low risk of cowbird parasitism. In 1950, the reach had 54.5 acres of such forest per valley mile and by 2001 that forest extent had increased to 66.7 acres per valley mile.

A total of 170 acres of Russian olive were mapped in the reach, which is an abrupt increase relative to the two reaches upstream. The Russian olive is distributed throughout the riparian corridor but becomes more prolific in the downstream direction towards Miles City.

Reach C16 was sampled as part of the fisheries study. A total of 32 fish species were sampled in the reach, including Blue Sucker and Sauger, which have been identified as Species of Concern (SOC) by the Montana Natural Heritage Program.

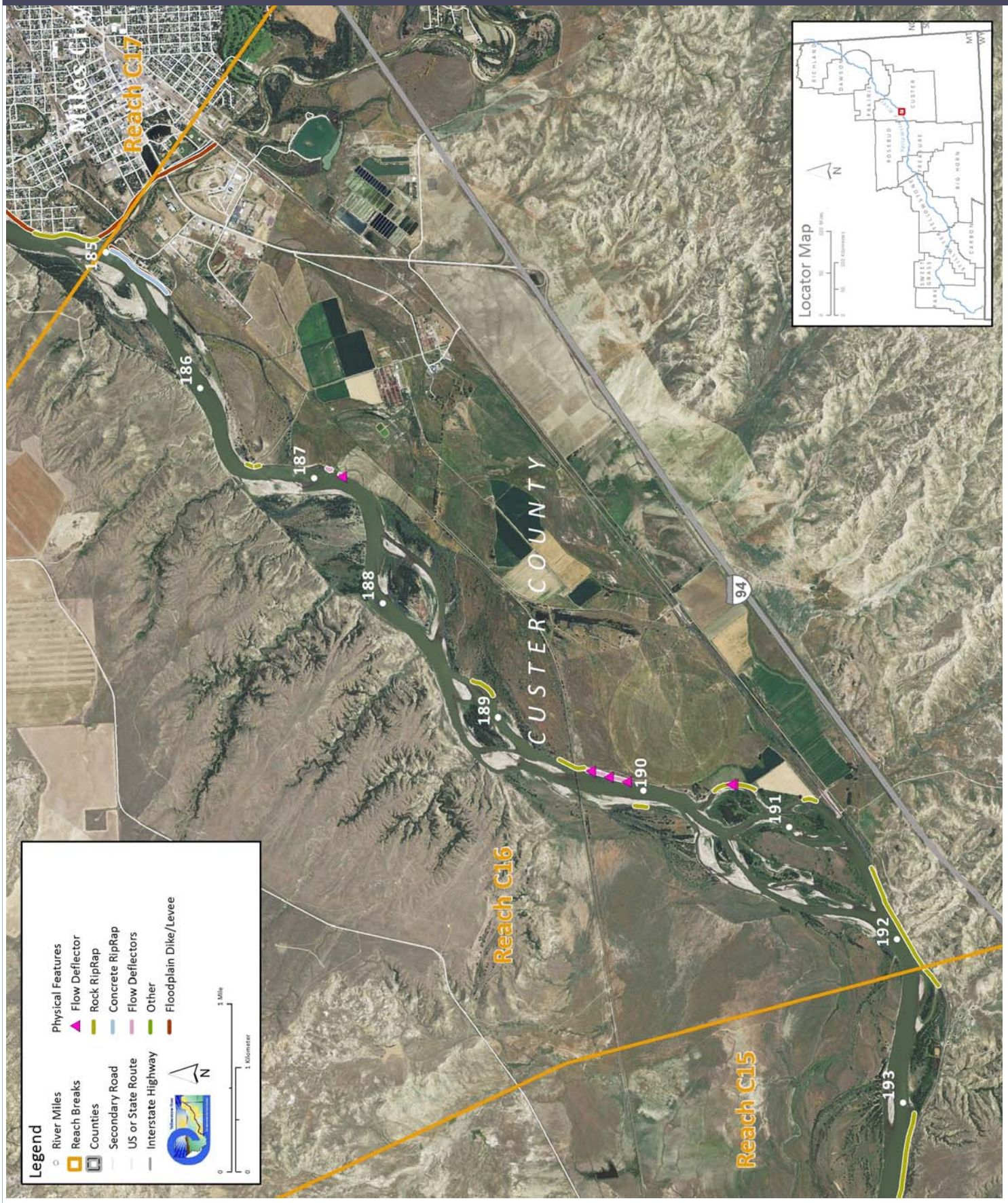
A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 18 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,850 cfs to 3,070 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,340 cfs under unregulated conditions to 3,390 cfs under regulated conditions, a reduction of 47 percent.

Fall and winter base flows have increased in Reach C16 by about 60 percent.

CEA-Related observations in Reach C16 include:
•Pivot irrigation encroachment into CMZ

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C16 include:
•Russian olive removal
•Removal of flanked rock riprap at RM 190.5R to prevent accelerated erosion behind

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): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6309000	6214500
Location	Miles City	Billings
Period of Record	1929-2015	1929-2015
Distance To (miles)	1.0	172.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		62,000	77,900	88,100	110,000	120,000	142,000	4,850	6,340
Regulated		47,300	61,700	70,900	90,400	98,500	117,000	3,070	3,390
% Change		-23.71%	-20.80%	-19.52%	-17.82%	-17.92%	-17.61%	-36.70%	-46.53%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	60,700	22,700	6,100
	Regulated	46,900	13,700	4,430
	% Change	**-23%**	**-40%**	**-27%**
Summer	Unregulated	42,800	13,500	6,340
	Regulated	32,600	8,340	3,390
	% Change	**-24%**	**-38%**	**-47%**
Fall	Unregulated	9,150	5,550	2,300
	Regulated	10,500	6,900	3,640
	% Change	**15%**	**24%**	**58%**
Winter	Unregulated	11,700	4,960	2,020
	Regulated	12,400	6,040	3,260
	% Change	**6%**	**22%**	**61%**
Annual	Unregulated	45,500	7,950	2,800
	Regulated	34,200	7,400	3,630
	% Change	**-25%**	**-7%**	**30%**

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
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/7/96 - 7/10/98	B/W		6295000	39800
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6295000	3500
2005	NAIP	08/05/2005	color	1-meter pixels	6309000	5620
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

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	6,789	8.9%	7,009	9.2%	221
	Flow Deflectors	601	0.8%	491	0.6%	-110
	Concrete RipRap	2,192	2.9%	2,192	2.9%	0
	Between Flow Deflectors	1,009	1.3%	1,064	1.4%	55
	Feature Type Totals	**10,590**	**13.9%**	**10,756**	**14.1%**	**166**
Floodplain Control						
	Transportation Encroachment	26,981	35.3%	26,981	35.3%	0
	Floodplain Dike/Levee	4,960	6.5%	4,960	6.5%	0
	Feature Type Totals	**31,940**	**41.8%**	**31,940**	**41.8%**	**0**
	Reach Totals	**42,531**	**55.7%**	**42,696**	**55.9%**	**166**

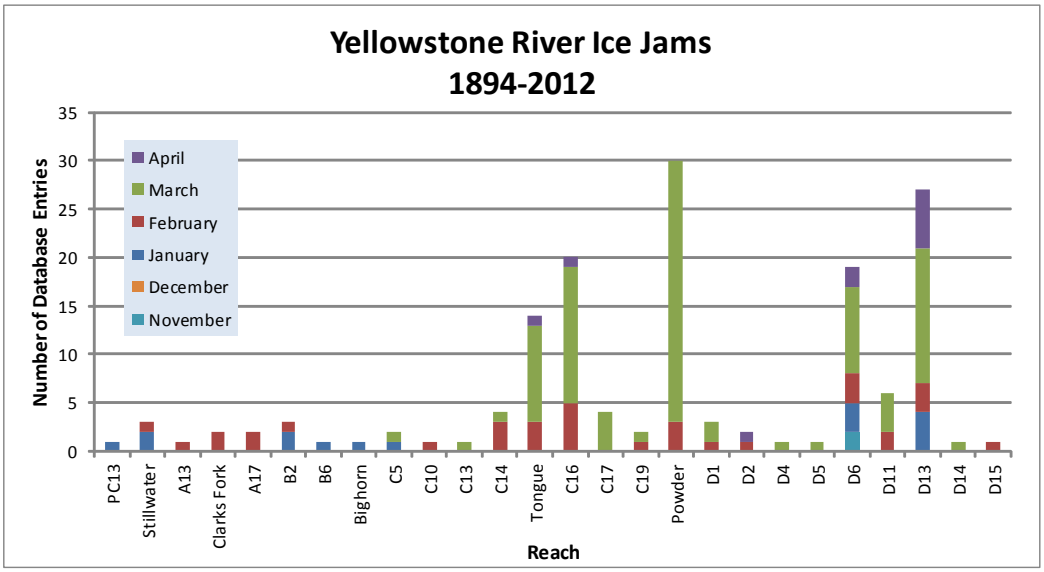
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	0	0	0	0	0	0	2,191	0
Flow Deflectors/Between FDs	0	1,610	0	0	0	0	0	0
Rock RipRap	1,735	380	0	295	0	5,120	0	0
Totals	**1,735**	**1,991**	**0**	**295**	**0**	**5,120**	**2,191**	**0**

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.



Jam Date	Jam Type	River Mile	Damages
3/14/2003	Break-up		?
2/14/2011	Break-up		
3/7/2012	Break-up		

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	38,597	49,582	2.28	1950 to 1976:	-4.95%
1976	38,461	45,055	2.17	1976 to 1995:	-4.17%
1995	38,125	41,208	2.08	1995 to 2001:	0.92%
2001	38,194	42,010	2.10	1950 to 2001:	-8.08%
Change 1950 - 2001	**-403**	**-7,572**	**-0.18**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

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.)	53	2.2%		
Agriculture (generally relates to field boundaries)	42	1.7%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	14	0.6%		
Railroad	185	7.6%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	13	0.5%		
Total Not Isolated (Ac)	2139		1282	
Total Floodplain Area (Ac)	2447		2003	
Total Isolated (Ac)	**308**	**12.6%**	**721**	**62.0%**

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:	0	0	0	**0**

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
332	663	2,033	195	10%	214	0	0%

2011 Restricted Migration Area Summary

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).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	35	1.5%
	Public Road	18	0.8%
	Non-Irrigated	8	0.4%
RipRap			
	Urban Industrial	50	2.2%
	Railroad	7	0.3%
	Non-Irrigated	15	0.7%
	Irrigated	49	2.2%
Flow Deflectors			
	Non-Irrigated	30	1.3%
	Totals	**210**	**9.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
38.5	0.0	27.0	21.1	4.9

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	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	92	158	159	159	1.2%	2.0%	2.1%	2.1%
	Totals	**92**	**158**	**159**	**159**	**1.2%**	**2.0%**	**2.1%**	**2.1%**
Agricultural Land									
	Non-Irrigated	5,180	4,894	4,895	4,877	66.8%	63.1%	63.1%	62.9%
	Irrigated	1,004	1,199	1,131	1,131	12.9%	15.5%	14.6%	14.6%
	Totals	**6,184**	**6,093**	**6,026**	**6,008**	**79.8%**	**78.6%**	**77.7%**	**77.5%**
Channel									
	Channel	1,176	1,111	1,107	1,125	15.2%	14.3%	14.3%	14.5%
	Totals	**1,176**	**1,111**	**1,107**	**1,125**	**15.2%**	**14.3%**	**14.3%**	**14.5%**
ExUrban									
	ExUrban Other	74	0	0	0	1.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	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	4	4	4	0.0%	0.0%	0.0%	0.0%
	Totals	**74**	**4**	**4**	**4**	**1.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	54	16	10	10	0.7%	0.2%	0.1%	0.1%
	Interstate	0	48	48	48	0.0%	0.6%	0.6%	0.6%
	Railroad	63	63	32	32	0.8%	0.8%	0.4%	0.4%
	Totals	**118**	**128**	**91**	**91**	**1.5%**	**1.6%**	**1.2%**	**1.2%**
Urban									
	Urban Other	102	173	200	200	1.3%	2.2%	2.6%	2.6%
	Urban Residential	0	0	37	37	0.0%	0.0%	0.5%	0.5%
	Urban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Undeveloped	0	8	39	39	0.0%	0.1%	0.5%	0.5%
	Urban Industrial	6	78	90	90	0.1%	1.0%	1.2%	1.2%
	Totals	**108**	**259**	**366**	**366**	**1.4%**	**3.3%**	**4.7%**	**4.7%**

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	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	304	304	304	0.0%	5.0%	5.0%	5.1%	5.0%	0.1%	0.0%	5.1%
	Flood	1,004	895	827	827	16.2%	14.7%	13.7%	13.8%	-1.5%	-1.0%	0.0%	-2.5%
	Totals	**1,004**	**1,199**	**1,131**	**1,131**	**16.2%**	**19.7%**	**18.8%**	**18.8%**	**3.4%**	**-0.9%**	**0.1%**	**2.6%**

Non-Irrigated

Multi-Use	3,531	4,643	4,806	4,751	57.1%	76.2%	79.8%	79.1%	19.1%	3.5%	-0.7%	22.0%
Hay/Pasture	1,649	250	89	126	26.7%	4.1%	1.5%	2.1%	-22.6%	-2.6%	0.6%	-24.6%
Totals	**5,180**	**4,894**	**4,895**	**4,877**	**83.8%**	**80.3%**	**81.2%**	**81.2%**	**-3.4%**	**0.9%**	**-0.1%**	**-2.6%**

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.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.8	0.3	0.9	0.0	0.8	0.7	6.3	1.7	1.0
Max	84.1	74.1	29.0	61.8	68.9	71.3	62.0	81.1	84.9
Average	10.9	8.7	7.4	15.0	14.3	16.0	18.1	18.8	21.3
Sum	347.5	234.2	177.6	346.1	315.4	336.9	217.2	225.6	320.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	119.9
Channel to Riparian (acres)	174.4
Riparian Encroachment (acres)	**54.5**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	175.1
1950s Floodplain Mapped as 2011 Channel (Ac)	26.8
Total Recruitment (1950s to 2011)(Ac)	**201.9**

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	21.2	94.7	23.1	0.0	**139.1**
Acres/Valley Mile	3.2	14.3	3.5	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	170.16	3.72%	41.91	4.03	53.93	17.93

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.

Fish Species Observed in Reach/Region

Species of Concern

Reach	Region		Reach	Region		Reach	Region		Reach	Region	
☑	☑	Bigmouth buffalo	☑	☑	Flathead chub	☐	☐	Northern redbelly dace	☑	☑	Stonecat
☑	☑	Black bullhead	☑	☑	Freshwater drum	☐	☐	Pallid sturgeon	☐	☐	Sturgeon chub
☑	☑	Black crappie	☑	☑	Goldeye	☐	☑	Pumpkinseed	☑	☑	Sucker species
☑	☑	Blue sucker	☑	☑	Green sunfish	☐	☐	Rainbow trout	☐	☑	Sunfish species
☑	☑	Bluegill	☐	☑	Lake chub	☑	☑	River carpsucker	☐	☑	Walleye
☑	☑	Brook stickleback	☐	☑	Largemouth bass	☐	☑	Rock bass	☑	☑	Western silvery minnow
☐	☑	Brown trout	☑	☑	Longnose dace	☑	☑	Sand shiner	☐	☐	White bass
☑	☑	Burbot	☑	☑	Longnose sucker	☑	☑	Sauger	☑	☑	White crappie
☐	☐	Catfish species	☑	☑	Minnow species	☑	☑	Shorthead redhorse	☑	☑	White sucker
☑	☑	Channel catfish	☐	☐	Mottled sculpin	☐	☐	Shortnose gar	☐	☑	Yellow bullhead
☑	☑	Common carp	☑	☑	Mountain sucker	☑	☑	Shovelnose sturgeon	☐	☐	Yellow perch
☐	☑	Creek chub	☐	☑	Mountain whitefish	☐	☐	Sicklefin chub			
☑	☑	Emerald shiner	☐	☑	Northern pike	☑	☑	Smallmouth bass			
☑	☑	Fathead minnow	☑	☑	Northern plains killifish	☑	☑	Smallmouth buffalo			

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	234.3	102.3	9.2%
Rip Rap Bottom	58.7	44.9	4.1%
Rip Rap Margin	52.3	47.5	4.3%
Bluff Pool	97.8	86.3	7.8%
Terrace Pool	6.8		
Secondary Channel	88.3	114.0	10.3%
Secondary Channel (Seasonal)	109.6	87.6	7.9%
Channel Crossover	187.8	120.1	10.9%
Point Bar		24.5	2.2%
Side Bar		59.4	5.4%
Mid-channel Bar		59.1	5.3%
Island	269.2	266.2	24.1%
Dry Channel		93.1	8.4%
Confluence Area	1.6	1.6	0.1%

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.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	185
Classification	PCS: Partially confined straight	**Downstream River Mile**	180.5
General Location	Miles City; Tongue River confluence	**Length**	4.50 mi (7.24 km)
General Comments	Miles City; Tongue River		

Narrative Summary

Reach C17 is 4.5 miles long and is in Miles City. Through town the Yellowstone River is a Partially Confined Reach type as the river flows on the north edge of town against high bluffs of the Fort Union Formation.

As of 2011 there were just under two miles of armor protecting 21 percent of the total bankline in Reach C17, including 7,300 feet of rock riprap, 2,400 feet of concrete riprap, and less than a hundred feet of flow deflectors. Over 2,700 feet of rock riprap has been constructed in the reach since 2001. Most of the armor is on the right bank through town. The rock riprap is protecting either urban areas (2,540 feet) the railroad (2,040 feet), or agricultural lands (2,400 feet). The concrete riprap is all protecting agricultural land. Reach C17 also has over three miles of mapped floodplain dikes and levees, much of which is the Miles City Levee that is on the right bank of the river through town.

Prior to 1950, about 1,500 feet of side channel was blocked in Reach C17. This channel was actually the lowermost part of the Tongue River, which was re-routed to the Yellowstone and abandoned through what is now Miles City.

Ice jams have been a major issue in Miles City. The ice jam database records 24 ice jams in Reach C17 between 1934 and 2011. Most of the jams occurred in March, with a few in February and one in April in 1950. Damages associated with the jams include damages to the Miles City dike, damaged water gages, flooding, and evacuations.

The levees in Miles City coupled with flow alterations have isolated 683 acres, or 74 percent of the 100-year floodplain in the reach. Isolation of the 5-year floodplain has been similar; 286 acres or 78 percent of the 5-year floodplain has become isolated at that frequency event. Most of the 5-year floodplain isolation is along the historic Tongue River channel that has been cut off from the river.

Bank armor and levees on the south side of the river has narrowed the natural Channel Migration Zone of the river. About 540 acres which represents 40 percent of the total CMZ has become restricted by physical features.

One dump site was mapped on the right bank just below the Highway 59 Bridge at RM 184.

As an urban reach, the riparian corridor had already been largely impacted by 1950. Since then, however, almost 100 acres of additional riparian area has been cleared, representing 23 percent of the entire 1950s riparian footprint. With this clearing, the reach has seen a substantial loss of forest area considered at low risk of cowbird parasitism. In 1950, the reach had 9.1 acres of such forest per valley mile and by 2001 that forest extent had dropped to 0 acres per valley mile.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 19 percent and the 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,100 cfs to 3,180 cfs with human development, a reduction of 37 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,730 cfs under unregulated conditions to 3,530 cfs under regulated cond8itions, a reduction of 48 percent.

Fall and winter base flows have increased in Reach C17 by about 60 percent.

CEA-Related observations in Reach C17 include:
•Side channel blockage with urbanization
•Extensive armoring with urbanization

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C17 include:
•CMZ Management due to extent of CMZ restriction (41 percent)
•Dump removal on right bank at RM 184R
•Russian olive removal

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): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	149.7	-1.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,400	78,900	88,600	109,000	117,000	136,000	5,100	6,730
Regulated		48,200	62,700	71,300	88,000	94,400	108,000	3,180	3,530
% Change		-23.97%	-20.53%	-19.53%	-19.27%	-19.32%	-20.59%	-37.65%	-47.55%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,000	23,300	6,430
	Regulated	47,800	13,900	4,640
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,200	14,000	6,730
	Regulated	33,300	8,550	3,530
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,390	5,740	2,340
	Regulated	10,800	7,100	3,750
	% Change	**15%**	**24%**	**60%**
Winter	Unregulated	12,400	5,170	2,080
	Regulated	13,100	6,240	3,330
	% Change	**6%**	**21%**	**60%**
Annual	Unregulated	46,700	8,300	2,870
	Regulated	34,900	7,640	3,740
	% Change	**-25%**	**-8%**	**30%**

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
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/25/97 - 7/10/98	B/W		6309000	15400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	08/05/2005	color	1-meter pixels	6309000	5620
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

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	4,580	9.7%	7,294	15.5%	2,714
	Flow Deflectors	0	0.0%	92	0.2%	92
	Concrete RipRap	2,401	5.1%	2,398	5.1%	-3
	Feature Type Totals	**6,981**	**14.8%**	**9,784**	**20.8%**	**2,803**
Floodplain Control						
	Transportation Encroachment	4,563	9.7%	4,563	9.7%	0
	Floodplain Dike/Levee	19,101	40.6%	19,101	40.6%	0
	Feature Type Totals	**23,664**	**50.3%**	**23,664**	**50.3%**	**0**
	Reach Totals	**30,645**	**65.2%**	**33,448**	**71.1%**	**2,803**

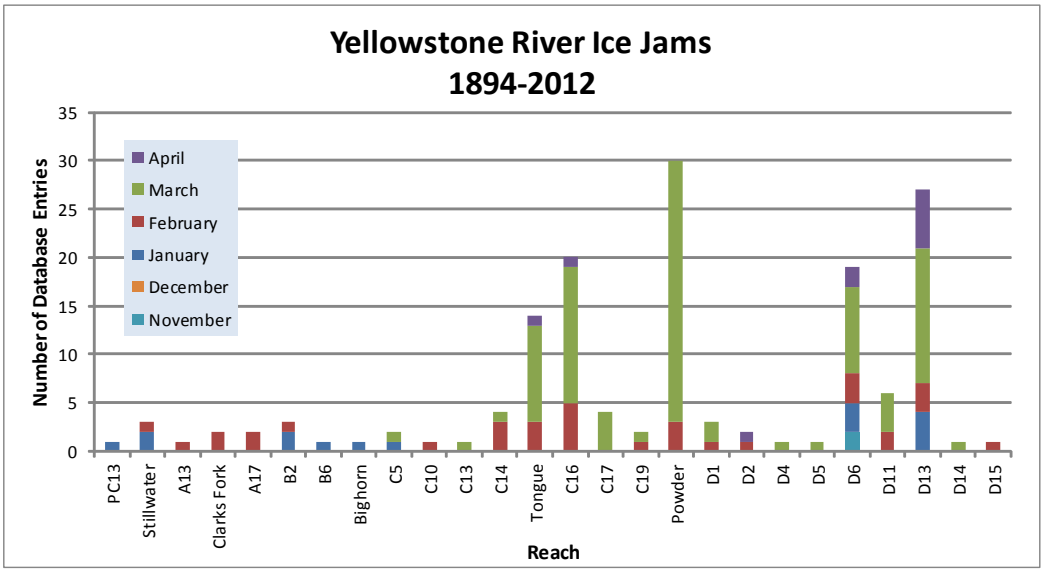
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Concrete RipRap	833	954	610	0	0	0	0	0
Rock RipRap	0	0	0	0	0	2,040	2,539	0
Totals	**833**	**954**	**610**	**0**	**0**	**2,040**	**2,539**	**0**

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.



Jam Date	Jam Type	River Mile	Damages
3/10/1934	NA	184	?
3/22/1939	NA	184	?
3/23/1941	NA	184	?
3/26/1943	NA	184	?
3/20/1944	NA	184	Flooding and evacuations
3/2/1946	Break-up	184	?
3/20/1947	Break-up	184	?
3/26/1949	NA	184	?
4/6/1950	NA	184	?
3/26/1951	NA	184	?
3/26/1956	NA	184	?
2/21/1958	NA	184	?
3/13/1959	NA	184	?
3/19/1960	NA	184	?
2/17/1962	NA	184	?
2/1/1971	Break-up	184	Levee threatened by erosion
3/1/1972	Break-up	184	Dike damage
3/8/1994	NA	184	Miles City dike damaged
2/8/1996	Break-up	184	Damaged water gauges
2/18/1997	NA	184	Flooding in low-lands, dike damaged
3/5/2009	Break-up		
3/16/2010	Break-up		
3/12/2011	Break-up		
3/13/2011			

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	23,304	16,353	1.70	1950 to 1976:	7.47%
1976	23,247	19,269	1.83	1976 to 1995:	-4.93%
1995	23,408	17,291	1.74	1995 to 2001:	-2.59%
2001	23,507	16,305	1.69	1950 to 2001:	-0.48%
Change 1950 - 2001	**202**	**-48**	**-0.01**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,466
Post-1950s (ft)	0

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.)	47	5.1%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	636	69.1%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	237		529	
Total Floodplain Area (Ac)	919		788	
Total Isolated (Ac)	**683**	**74.3%**	**259**	**77.9%**

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:	0	0	0	**0**

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
145	291	930	146	16%	407	394	97%

2011 Restricted Migration Area Summary

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).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	58	4.3%
Dike/Levee			
	Urban Residential	482	35.9%
	Totals	**540**	**40.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
64.1	0.0	0.0	294.4	2.6

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	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	31	60	63	65	0.8%	1.5%	1.6%	1.6%
	Totals	**31**	**60**	**63**	**65**	**0.8%**	**1.5%**	**1.6%**	**1.6%**
Agricultural Land									
	Non-Irrigated	1,186	1,056	983	930	29.3%	26.1%	24.3%	23.0%
	Irrigated	825	705	655	609	20.4%	17.4%	16.2%	15.0%
	Totals	**2,011**	**1,762**	**1,638**	**1,539**	**49.7%**	**43.5%**	**40.5%**	**38.0%**
Channel									
	Channel	713	710	691	694	17.6%	17.5%	17.1%	17.1%
	Totals	**713**	**710**	**691**	**694**	**17.6%**	**17.5%**	**17.1%**	**17.1%**
ExUrban									
	ExUrban Other	0	0	23	23	0.0%	0.0%	0.6%	0.6%
	ExUrban Undeveloped	0	0	7	7	0.0%	0.0%	0.2%	0.2%
	ExUrban Industrial	0	38	87	87	0.0%	0.9%	2.1%	2.1%
	ExUrban Commercial	16	16	17	17	0.4%	0.4%	0.4%	0.4%
	ExUrban Residential	15	212	250	344	0.4%	5.2%	6.2%	8.5%
	Totals	**30**	**266**	**384**	**477**	**0.7%**	**6.6%**	**9.5%**	**11.8%**
Transportation									
	Public Road	35	36	36	36	0.9%	0.9%	0.9%	0.9%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	52	52	25	25	1.3%	1.3%	0.6%	0.6%
	Totals	**87**	**87**	**61**	**61**	**2.1%**	**2.2%**	**1.5%**	**1.5%**
Urban									
	Urban Other	19	19	51	51	0.5%	0.5%	1.2%	1.2%
	Urban Residential	738	719	767	767	18.2%	17.8%	18.9%	18.9%
	Urban Commercial	164	164	165	165	4.0%	4.0%	4.1%	4.1%
	Urban Undeveloped	129	31	0	0	3.2%	0.8%	0.0%	0.0%
	Urban Industrial	128	233	230	230	3.2%	5.7%	5.7%	5.7%
	Totals	**1,177**	**1,165**	**1,212**	**1,212**	**29.1%**	**28.8%**	**29.9%**	**29.9%**

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	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	825	705	655	609	41.0%	40.0%	40.0%	39.6%	-1.0%	0.0%	-0.4%	-1.4%
	Totals	**825**	**705**	**655**	**609**	**41.0%**	**40.0%**	**40.0%**	**39.6%**	**-1.0%**	**0.0%**	**-0.4%**	**-1.4%**

Non-Irrigated

Multi-Use	1,139	935	873	781	56.6%	53.1%	53.3%	50.8%	-3.5%	0.2%	-2.5%	-5.9%
Hay/Pasture	47	121	111	149	2.4%	6.9%	6.7%	9.7%	4.5%	-0.1%	2.9%	7.3%
Totals	**1,186**	**1,056**	**983**	**930**	**59.0%**	**60.0%**	**60.0%**	**60.4%**	**1.0%**	**0.0%**	**0.4%**	**1.4%**

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.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	1.0	0.0	0.0	1.2	0.2	0.3	4.5	3.2	3.2
Max	14.7	13.0	10.4	83.0	49.5	38.0	90.5	76.8	66.6
Average	5.4	4.0	4.3	20.5	11.5	13.1	34.7	20.5	19.8
Sum	27.2	36.4	25.8	225.5	173.0	221.9	173.3	122.8	119.0

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	19.0
Channel to Riparian (acres)	69.1
Riparian Encroachment (acres)	**50.1**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	69.7
1950s Floodplain Mapped as 2011 Channel (Ac)	8.7
Total Recruitment (1950s to 2011)(Ac)	**78.4**

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	18.5	48.4	0.7	0.0	**67.6**
Acres/Valley Mile	4.6	12.0	0.2	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	66.49	2.63%	26.91	12.61	19.55	20.45

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.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	37.2	34.2	4.9%
Rip Rap Bottom	44.9	28.3	4.1%
Bluff Pool	196.2	173.0	25.0%
Secondary Channel	13.0	15.0	2.2%
Secondary Channel (Seasonal)	59.9	30.8	4.5%
Channel Crossover	102.2	91.2	13.2%
Point Bar		2.3	0.3%
Side Bar		29.7	4.3%
Mid-channel Bar		25.4	3.7%
Island	236.6	236.6	34.2%
Dry Channel		23.4	3.4%
Confluence Area	1.0	1.0	0.1%

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.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	180.5
Classification	PCS: Partially confined straight	**Downstream River Mile**	177.3
General Location	Downstream of Miles City	**Length**	3.20 mi (5.15 km)
General Comments	Channel follows left valley wall		

Narrative Summary

Reach C18 is 3.2 miles long and is located just downstream of Miles City. It is a Partially Confined Straight reach type, as the river flows over steep bedrock shelves that create a series of rapids between Miles City and a few miles above Kinsey Bridge. The river flows along the north bluff line through the whole reach, and has consistently maintained this course since at least 1950.

Reach C18 has no mapped bank armor which is indicative of the natural stability provided to this reach by erosion-resistant bedrock. The 2001 physical features inventory identified 1,742 feet of bedrock outcrop in the reach. A total of three discreet sets of rapids were mapped in the reach, all of which have been described as part of the Buffalo Shoals (RM 180, RM 179.9, and RM 178.2).

Between 1950 and 2001 there was about 26 net acres of riparian encroachment into the channel, and the bankfull channel area decreased by ~30 acres, indicating a diminishing river size over the last half-century. This trend is common below the mouth of the Bighorn River, where flow alterations have reduced peak flows and cause the active river channel to shrink. Consumptive water uses, primarily associated with irrigation, have contributed to the reduced flows.

Prior to 1950, a side channel that was just over 1,000 feet long appears to have been blocked at RM 179. There are currently several blockages across this old channel, including two roads that access a large gravel pit on the right bank of the river. This gravel pit at RM 178.4 is partly within the Channel Migration Zone (CMZ) of the river. Although the channel showed clear expression in the 1950s imagery, it is not very visible in the 2011 imagery, suggesting that restoring this feature may be difficult.

About 20 percent of the total 100-year floodplain has become isolated due to human development, and most of the isolation appears to be due to flow alterations rather than floodplain dikes. The 5-year floodplain is even more affected; 59 percent of the historic 5-year floodplain is no longer inundated at that frequency.

Land use is dominated by flood irrigation with additional gravel pit development (mapped as exurban industrial) and transportation infrastructure. There is one Fishing Access Site at Kinsey Bridge. There are two animal handling facilities north of the river that are within several hundred feet of the streambank; both are downstream of Kinsey Bridge, at RM 166.2 and RM 167.8.

There are 65 acres of Russian olive in the reach, most of which is on the south side of the river away from the bluff line to the north. Over half of the low-flow fish habitat in this reach is bluff pool, potentially making it important for fish with bluff pool habitat preferences.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,100 cfs to 3,180 cfs with human development, a reduction of 38 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,730 cfs under unregulated conditions to 3,530 cfs under regulated conditions, a reduction of 48 percent.

CEA-Related observations in Reach C18 include:
•Natural channel stability provided by bedrock
•Minimal bank armoring

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C18 include:
•Russian olive removal

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): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	146.5	3.5

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,400	78,900	88,600	109,000	117,000	136,000	5,100	6,730
Regulated		48,200	62,700	71,300	88,000	94,400	108,000	3,180	3,530
% Change		-23.97%	-20.53%	-19.53%	-19.27%	-19.32%	-20.59%	-37.65%	-47.55%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,000	23,300	6,430
	Regulated	47,800	13,900	4,640
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,200	14,000	6,730
	Regulated	33,300	8,550	3,530
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,390	5,740	2,340
	Regulated	10,800	7,100	3,750
	% Change	**15%**	**24%**	**60%**
Winter	Unregulated	12,400	5,170	2,080
	Regulated	13,100	6,240	3,330
	% Change	**6%**	**21%**	**60%**
Annual	Unregulated	46,700	8,300	2,870
	Regulated	34,900	7,640	3,740
	% Change	**-25%**	**-8%**	**30%**

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
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/25/97 - 6/13/96	B/W		6309000	15400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	08/05/2005	color	1-meter pixels	6309000	5620
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

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.

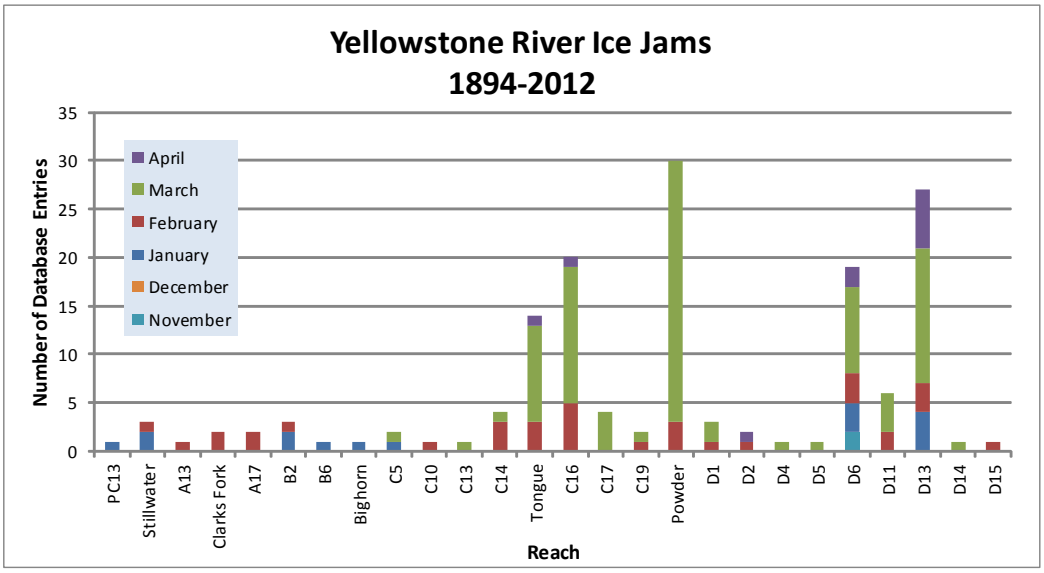
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Other In Channel						
	Bedrock Outcrop	1,742	5.1%	1,742	5.1%	0
	Feature Type Totals	**1,742**	**5.1%**	**1,742**	**5.1%**	**0**
	Reach Totals	**1,742**	**5.1%**	**1,742**	**5.1%**	**0**

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	16,929		1.00	1950 to 1976:	0.00%
1976	17,030		1.00	1976 to 1995:	27.63%
1995	17,048	4,711	1.28	1995 to 2001:	-21.65%
2001	17,106		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**177**		**0.00**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,052
Post-1950s (ft)	0

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.)	59	20.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	237		390	
Total Floodplain Area (Ac)	297		457	
Total Isolated (Ac)	**59**	**20.0%**	**67**	**59.5%**

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:	0	0	0	**0**

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
118	236	466	1	0%	45	0	0%

2011 Restricted Migration Area Summary

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).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Irrigated	1	0.3%
	Totals	**1**	**0.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
2.8	0.0	0.0	6.9	0.0

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	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	29	55	81	85	1.1%	2.0%	2.9%	3.1%
	Totals	**29**	**55**	**81**	**85**	**1.1%**	**2.0%**	**2.9%**	**3.1%**
Agricultural Land									
	Non-Irrigated	1,071	938	924	985	38.5%	33.7%	33.2%	35.4%
	Irrigated	1,319	1,369	1,370	1,305	47.4%	49.2%	49.3%	46.9%
	Totals	**2,391**	**2,307**	**2,294**	**2,290**	**86.0%**	**82.9%**	**82.5%**	**82.3%**
Channel									
	Channel	336	362	354	349	12.1%	13.0%	12.7%	12.5%
	Totals	**336**	**362**	**354**	**349**	**12.1%**	**13.0%**	**12.7%**	**12.5%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	18	18	23	0.0%	0.6%	0.6%	0.8%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	4	18	18	18	0.1%	0.7%	0.7%	0.7%
	Totals	**4**	**36**	**36**	**42**	**0.1%**	**1.3%**	**1.3%**	**1.5%**
Transportation									
	Public Road	12	12	12	12	0.4%	0.4%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	9	9	4	4	0.3%	0.3%	0.2%	0.2%
	Totals	**21**	**21**	**16**	**16**	**0.8%**	**0.8%**	**0.6%**	**0.6%**
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	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	1,319	1,369	1,370	1,305	55.2%	59.3%	59.7%	57.0%	4.2%	0.4%	-2.7%	1.8%
	Totals	**1,319**	**1,369**	**1,370**	**1,305**	**55.2%**	**59.3%**	**59.7%**	**57.0%**	**4.2%**	**0.4%**	**-2.7%**	**1.8%**

Non-Irrigated

Multi-Use	1,071	933	914	930	44.8%	40.4%	39.8%	40.6%	-4.4%	-0.6%	0.8%	-4.2%
Hay/Pasture	0	5	10	55	0.0%	0.2%	0.4%	2.4%	0.2%	0.2%	2.0%	2.4%
Totals	**1,071**	**938**	**924**	**985**	**44.8%**	**40.7%**	**40.3%**	**43.0%**	**-4.2%**	**-0.4%**	**2.7%**	**-1.8%**

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.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.5	0.2	0.4	0.6	0.8	1.2	10.8	11.8	8.1
Max	15.4	29.8	30.9	205.1	75.1	38.5	10.8	12.4	18.4
Average	7.7	8.2	12.5	69.1	12.9	13.3	10.8	12.1	12.7
Sum	54.0	73.7	87.3	207.2	102.8	119.5	10.8	24.2	38.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	14.0
Channel to Riparian (acres)	40.0
Riparian Encroachment (acres)	**26.0**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	40.4
1950s Floodplain Mapped as 2011 Channel (Ac)	16.8
Total Recruitment (1950s to 2011)(Ac)	**57.2**

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	5.7	21.8	0.0	0.0	**27.5**
Acres/Valley Mile	1.8	7.0	0.0	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	65.37	5.05%	23.84	0.00	12.16	1.29

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.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	41.4	24.1	6.8%
Bluff Pool	262.4	186.4	52.7%
Secondary Channel (Seasonal)	13.9	10.8	3.1%
Channel Crossover	24.7	45.7	12.9%
Point Bar		13.9	3.9%
Side Bar		40.9	11.6%
Mid-channel Bar		0.4	0.1%
Island	11.1	11.1	3.1%
Dry Channel		20.3	5.7%

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.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	177.3
Classification	CS: Confined straight	**Downstream River Mile**	166.2
General Location	Kinsey Bridge	**Length**	11.10 mi (17.86 km)
General Comments	Confined		

Narrative Summary

Reach C19 is 11.1 miles long and is located downstream of Miles City at Kinsey Bridge. It is a Confined Straight reach type, as the river flows over steep bedrock shelves that create a series of rapids between Miles City and a few miles below Kinsey Bridge.

There are approximately 4,000 feet of rock riprap in the reach, about one third of which was built since 2001. All of the armor is protecting the rail line on the south side of the river. By 1950 over three miles of side channels had been blocked off by small floodplain dikes in Reach C19. These old side channels are on both sides of the river just upstream of Kinsey Bridge. Bank migration rates are very low in the reach, and as a result the Channel Migration Zone (CMZ) is unusually narrow.

The Kinsey Main Canal diversion and pump station are located on the left bank at RM 175. The site consists of a rock diversion that extends about 200 feet into the river at an upstream angle to deflect flows into an excavated approach channel and pumping station. Kinsey Bridge is located at RM 172.1 and consists of a Steel multi-beam structure that was built in 1907 for the Milwaukee Railroad, but now supports County Road 62. It is just over 1,000 feet long and has four spans.

The 2001 physical features inventory also identified 7,200 feet of bedrock outcrop in the reach. A total of five discreet sets of rapids were mapped in the reach, including Buffalo Shoals (RM 176 and RM 177), Matthew Rapids (RM 174.5), and two unnamed rapids upstream and downstream of Kinsey Bridge at RM 172.5 and RM 171, respectively.

On the downstream end of the reach, an 8-inch Cenex pipeline that carries petroleum products flows parallel to the river on the landward side of the active BNSF rail line. The pipeline is about 400 feet away from the active riverbank at RM 166.5, but the fact that the rail line sits between the pipeline and the river suggests that its risk of exposure is low.

Between 1950 and 2001 there was about 89 net acres of riparian encroachment into the channel, and the bankfull channel area decreased by ~100 acres, indicating a diminishing river size over the last half-century. This trend is common below the mouth of the Bighorn River, where flow alterations have reduced peak flows and cause the active river channel to shrink. Consumptive water uses, primarily associated with irrigation, have contributed to the reduced flows.

About 13 percent of the total 100-year floodplain has become isolated due to human development, and most of the isolation appears to be due to flow alterations rather than floodplain dikes. The 5-year floodplain is even more affected; 55 percent of the historic 5-year floodplain is no longer inundated at that frequency.

Two ice jams have been reported in Reach C19; one in March of 1994 at RM 168 and the other in February of 1997 at RM 174. No damages were reported.

Land use is dominated by agriculture (~4,700 acres), with 326 acres of pivot irrigation development since 1950. There is one Fishing Access Site at Kinsey Bridge. There are two animal handling facilities north of the river that are within several hundred feet of the streambank; both are downstream of Kinsey Bridge, at RM 166.2 and RM 167.8.

There are 254 acres of Russian olive in the reach, most of which is on the north side of the river away from the bluff line to the south. Russian olive comprises almost 30 percent of all of the mapped shrubs in the reach. There are notably high concentrations of Russian olive in one of the abandoned side channels that is located on the left bank just downstream from the Kinsey Main Canal diversion.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,080 cfs to 3,150 cfs with human development, a reduction of 38 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,740 cfs under unregulated conditions to 3,510 cfs under regulated conditions, a reduction of 48 percent.

CEA-Related observations in Reach C19 include:
•Side channel blockages pre-1950
•Russian olive colonization, especially in blocked side channels
•Armoring needs by the railroad on the south bluff line
•Low natural rates of bank movement in reach with extensive bedrock exposure and rapids

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C19 include:
•Side channel reactivation at RM 175L and RM 174R
•Russian olive removal
•Nutrient management at animal handling facilities at RM 166.2L and RM 167.8L

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): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	135.4	6.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,700	79,500	89,400	110,000	119,000	138,000	5,080	6,740
Regulated		48,500	63,300	72,100	89,400	96,100	110,000	3,150	3,510
% Change		-23.86%	-20.38%	-19.35%	-18.73%	-19.24%	-20.29%	-37.99%	-47.92%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,300	23,400	6,460
	Regulated	48,000	14,000	4,660
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,400	14,000	6,740
	Regulated	33,400	8,570	3,510
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,410	5,750	2,320
	Regulated	10,800	7,120	3,740
	% Change	**15%**	**24%**	**61%**
Winter	Unregulated	12,500	5,180	2,080
	Regulated	13,200	6,250	3,340
	% Change	**6%**	**21%**	**61%**
Annual	Unregulated	46,900	8,330	2,870
	Regulated	35,000	7,660	3,740
	% Change	**-25%**	**-8%**	**30%**

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
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	8/1/96 - 8/25/97	B/W		6309000	15400
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	08/05/2005	color	1-meter pixels	6309000	5620
2005	NAIP	08/04/2005	color	1-meter pixels	6309000	5550
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

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	2,569	2.2%	4,043	3.4%	1,475
	Feature Type Totals	**2,569**	**2.2%**	**4,043**	**3.4%**	**1,475**
Other In Channel						
	Bedrock Outcrop	7,237	6.2%	7,237	6.2%	0
	Feature Type Totals	**7,237**	**6.2%**	**7,237**	**6.2%**	**0**
	Reach Totals	**9,806**	**8.3%**	**11,280**	**9.6%**	**1,475**

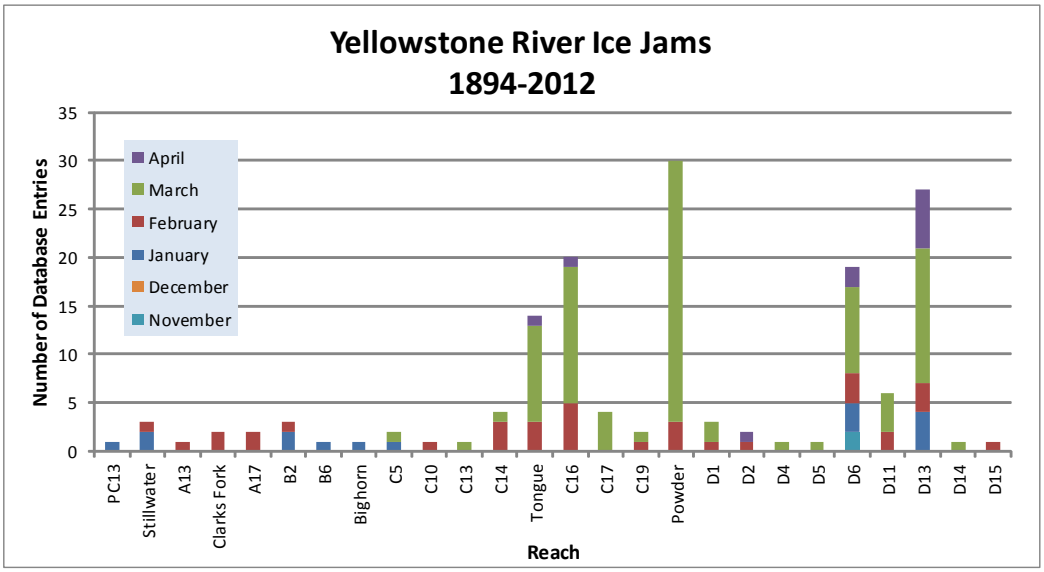
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	0	0	2,568	0	0
Totals	**0**	**0**	**0**	**0**	**0**	**2,568**	**0**	**0**

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.



Jam Date	Jam Type	River Mile	Damages
3/5/1994	NA	168	?
2/19/1997	NA	174	?

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	58,436	4,394	1.08	1950 to 1976:	4.37%
1976	58,444	7,142	1.12	1976 to 1995:	0.97%
1995	58,737	7,818	1.13	1995 to 2001:	5.77%
2001	58,737	11,656	1.20	1950 to 2001:	11.46%
Change 1950 - 2001	**301**	**7,262**	**0.12**		

Length of Side Channels Blocked

Pre-1950s (ft)	17,355
Post-1950s (ft)	0

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.)	86	13.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	573		1254	
Total Floodplain Area (Ac)	659		1370	
Total Isolated (Ac)	**86**	**13.0%**	**116**	**54.7%**

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:	0	0	0	**0**

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
93	186	1,670	3	0%	467	0	0%

2011 Restricted Migration Area Summary

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).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Railroad	3	0.1%
	Totals	**3**	**0.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
53.5	0.0	0.0	1.8	5.1

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	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	179	283	371	363	1.6%	2.5%	3.2%	3.2%
	Totals	**179**	**283**	**371**	**363**	**1.6%**	**2.5%**	**3.2%**	**3.2%**
Agricultural Land									
	Non-Irrigated	5,367	5,300	5,058	5,141	47.0%	46.4%	44.3%	45.0%
	Irrigated	4,385	4,374	4,544	4,451	38.4%	38.3%	39.8%	38.9%
	Totals	**9,753**	**9,674**	**9,601**	**9,592**	**85.3%**	**84.7%**	**84.0%**	**83.9%**
Channel									
	Channel	1,284	1,242	1,193	1,210	11.2%	10.9%	10.4%	10.6%
	Totals	**1,284**	**1,242**	**1,193**	**1,210**	**11.2%**	**10.9%**	**10.4%**	**10.6%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	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	0	12	12	0.0%	0.0%	0.1%	0.1%
	Totals	**0**	**0**	**12**	**12**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	84	100	131	131	0.7%	0.9%	1.1%	1.1%
	Interstate	0	0	56	56	0.0%	0.0%	0.5%	0.5%
	Railroad	129	129	65	65	1.1%	1.1%	0.6%	0.6%
	Totals	**213**	**229**	**252**	**252**	**1.9%**	**2.0%**	**2.2%**	**2.2%**
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	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	171	326	0.0%	0.0%	1.8%	3.4%	0.0%	1.8%	1.6%	3.4%
	Flood	4,385	4,374	4,373	4,125	45.0%	45.2%	45.5%	43.0%	0.2%	0.3%	-2.5%	-2.0%
	Totals	**4,385**	**4,374**	**4,544**	**4,451**	**45.0%**	**45.2%**	**47.3%**	**46.4%**	**0.2%**	**2.1%**	**-0.9%**	**1.4%**

Non-Irrigated

Multi-Use	4,461	5,138	4,972	5,026	45.7%	53.1%	51.8%	52.4%	7.4%	-1.3%	0.6%	6.7%
Hay/Pasture	906	162	85	115	9.3%	1.7%	0.9%	1.2%	-7.6%	-0.8%	0.3%	-8.1%
Totals	**5,367**	**5,300**	**5,058**	**5,141**	**55.0%**	**54.8%**	**52.7%**	**53.6%**	**-0.2%**	**-2.1%**	**0.9%**	**-1.4%**

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.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.0	0.5	0.9	1.2	0.9	0.5	0.7	1.2	2.3
Max	85.1	143.2	157.7	57.0	12.1	10.7	51.6	20.4	11.4
Average	11.7	14.8	16.9	23.2	5.1	3.9	11.1	5.0	6.8
Sum	408.9	489.7	573.5	139.5	56.1	78.8	165.9	55.2	61.4

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	17.9
Channel to Riparian (acres)	106.8
Riparian Encroachment (acres)	**88.9**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	159.2
1950s Floodplain Mapped as 2011 Channel (Ac)	22.6
Total Recruitment (1950s to 2011)(Ac)	**181.8**

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	16.1	165.2	12.2	0.0	**193.5**
Acres/Valley Mile	1.5	15.4	1.1	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	254.13	4.98%	128.46	0.73	24.24	1.27

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.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	381.7	350.0	29.3%
Rip Rap Margin	109.0	97.2	8.1%
Bluff Pool	212.0	144.5	12.1%
Secondary Channel	25.2	25.2	2.1%
Secondary Channel (Seasonal)	50.1	49.1	4.1%
Channel Crossover	376.7	265.0	22.2%
Point Bar		50.5	4.2%
Side Bar		100.2	8.4%
Mid-channel Bar		31.2	2.6%
Island	38.1	38.1	3.2%
Dry Channel		41.8	3.5%

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.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

Yellowstone River Reach Narratives — Reach C20

County	Custer	**Upstream River Mile**	166.2
Classification	CS: Confined straight	**Downstream River Mile**	158.7
General Location	Shirley	**Length**	7.50 mi (12.07 km)
General Comments	Confined		

Narrative Summary

Reach C20 is 7.5 miles long and is located in lowermost Custer County at Shirley. The Bonfield Fishing Access Site is located at RM 161 on the left bank. It is a Confined Straight reach type, as the river flows through the confining geology of the Fort Union Formation sandstones. Small tributaries that enter Reach C20 include Hay Creek (RM 165), Harris Creek (RM 164), Cabin and Cottonwood Creeks (RM 162) and Saugus Creek (RM 160.2). Bank migration rates are very low in the reach, and as a result the Channel Migration Zone (CMZ) is unusually narrow.

There is just over a mile of bank armor in the reach that covers about 8 percent of the total bankline. As of 2011 there was 6,059 feet of rock riprap in reach C20, and 1,650 feet of that armor was built between 2001 and 2011. Most of the rock riprap is protecting the abandoned Milwaukee Rail line on the north side of the river where it runs in the edge of the bluff line. The new armor is protecting the Shirley Pump Station at RM 165.3R. There are also 131 feet of flow deflectors across the river from the Bonfield Fishing Access Site.

Between 1950 and 2001 there was about 50 net acres of riparian encroachment into the channel, and the bankfull channel area decreased by ~58 acres, indicating a diminishing river size over the last half-century. This trend is common below the mouth of the Bighorn River, where flow alterations have reduced peak flows and cause the active river channel to shrink. Consumptive water uses, primarily associated with irrigation, have contributed to the reduced flows.

About 13 percent of the total 100-year floodplain has become isolated due to human development, and most of the isolation appears to be due to flow alterations rather than floodplain dikes. The 5-year floodplain is even more affected; 55 percent of the historic 5-year floodplain is no longer inundated at that frequency.

Land use is dominated by agriculture (~6,200 acres), with 327 acres of pivot irrigation development since 1950. Irrigated fields extend to the active streambank through much of the reach.

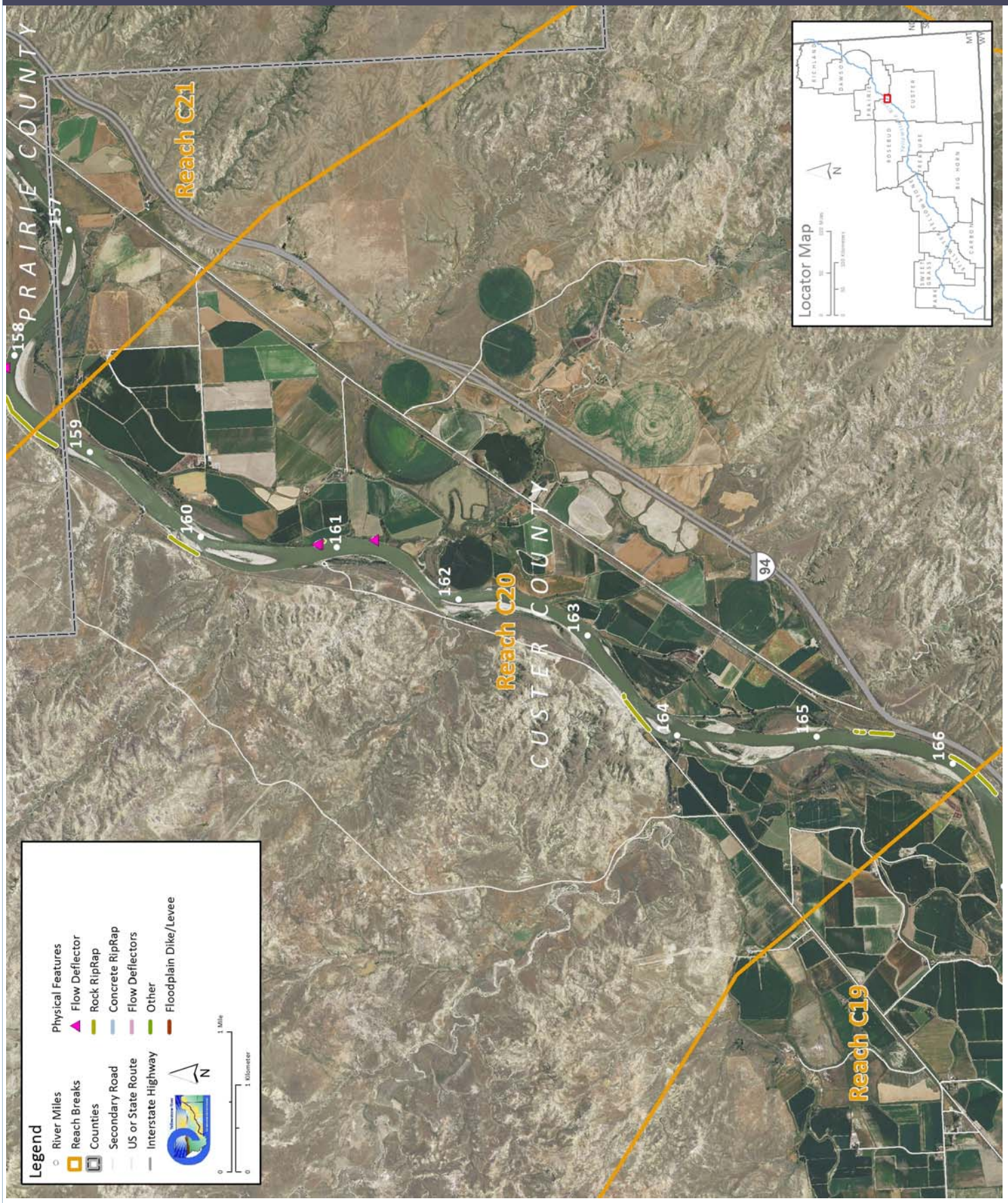
There are 84 acres of Russian olive in the reach. The Russian olive is concentrated on tributaries and in riparian areas colonizing old river swales, mostly in the upstream portion of the reach.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The magnitude of 100-year flood has dropped by 19 percent due to flow alterations associated with human development. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,080 cfs to 3,150 cfs with human development, a reduction of 38 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,750 cfs under unregulated conditions to 3,510 cfs under regulated conditions, a reduction of 48 percent.

CEA-Related observations in Reach C20 include:
•Irrigated land encroachment in reach stabilized by bedrock
•Bank armor on abandoned rail line on northern bluff

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C20 include:
•Russian olive removal

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): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	127.9	17.8

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,800	79,600	89,500	110,000	119,000	139,000	5,080	6,750
Regulated		48,600	63,400	72,300	89,700	96,400	111,000	3,150	3,510
% Change		-23.82%	-20.35%	-19.22%	-18.45%	-18.99%	-20.14%	-37.99%	-48.00%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,400	23,400	6,460
	Regulated	48,100	14,000	4,670
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,400	14,100	6,750
	Regulated	33,400	8,570	3,510
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,410	5,750	2,320
	Regulated	10,800	7,120	3,740
	% Change	**15%**	**24%**	**61%**
Winter	Unregulated	12,500	5,180	2,080
	Regulated	13,200	6,260	3,340
	% Change	**6%**	**21%**	**61%**
Annual	Unregulated	46,900	8,340	2,870
	Regulated	35,100	7,660	3,730
	% Change	**-25%**	**-8%**	**30%**

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
1950	USGS-EROS	26-Aug-49	B/W	1:14,800	6309000	3620
1976	USCOE	29-Sep-76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	7/9/96 - 8/1/96	B/W		6309000	35000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

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	4,410	5.5%	6,059	7.6%	1,650
	Flow Deflectors	0	0.0%	76	0.1%	76
	Between Flow Deflectors	0	0.0%	55	0.1%	55
	Feature Type Totals	**4,410**	**5.5%**	**6,191**	**7.8%**	**1,781**
	Reach Totals	**4,410**	**5.5%**	**6,191**	**7.8%**	**1,781**

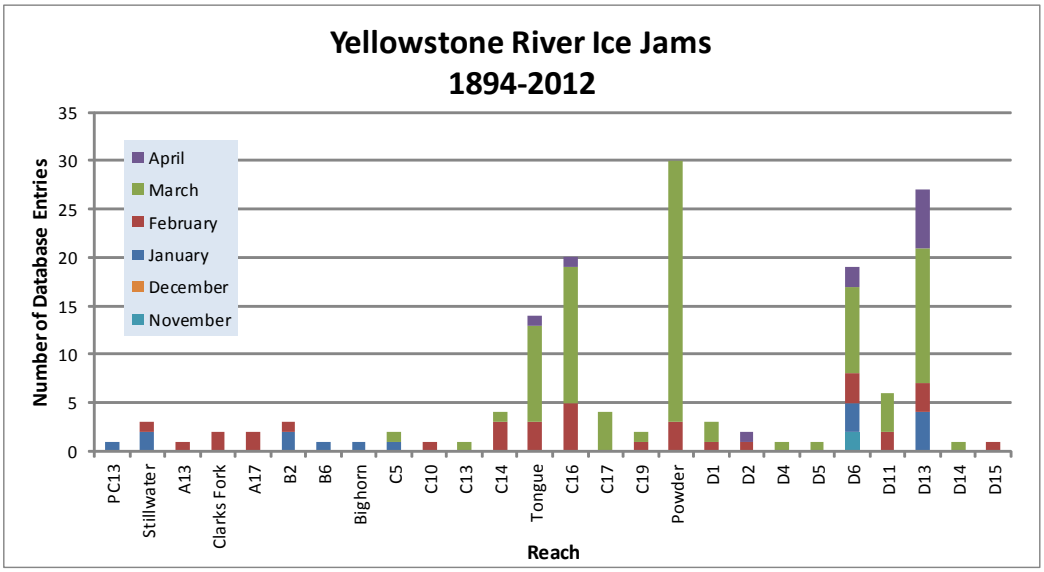
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	0	0	3,414	0	0
Totals	**0**	**0**	**0**	**0**	**0**	**3,414**	**0**	**0**

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	40,718	3,954	1.10	1950 to 1976:	6.78%
1976	40,017	6,863	1.17	1976 to 1995:	-4.31%
1995	39,899	4,828	1.12	1995 to 2001:	0.00%
2001	39,899	4,828	1.12	1950 to 2001:	2.18%
Change 1950 - 2001	**-819**	**874**	**0.02**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

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.)	48	12.6%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	336		818	
Total Floodplain Area (Ac)	385		914	
Total Isolated (Ac)	**48**	**12.6%**	**95**	**55.2%**

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:	1	0	0	**1**

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
83	166	1,071	0	0%	59	0	0%

2011 Restricted Migration Area Summary

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).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Irrigated	2	0.1%
	Totals	**2**	**0.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
28.4	0.0	3.1	1.9	1.2

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	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	43	120	168	158	0.6%	1.7%	2.4%	2.2%
	Totals	**43**	**120**	**168**	**158**	**0.6%**	**1.7%**	**2.4%**	**2.2%**
Agricultural Land									
	Non-Irrigated	3,391	3,066	3,057	2,955	47.6%	43.1%	42.9%	41.5%
	Irrigated	2,725	2,924	2,947	3,041	38.3%	41.1%	41.4%	42.7%
	Totals	**6,116**	**5,990**	**6,004**	**5,996**	**85.9%**	**84.1%**	**84.3%**	**84.2%**
Channel									
	Channel	849	812	762	781	11.9%	11.4%	10.7%	11.0%
	Totals	**849**	**812**	**762**	**781**	**11.9%**	**11.4%**	**10.7%**	**11.0%**
ExUrban									
	ExUrban Other	0	0	2	2	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	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	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**2**	**2**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Transportation									
	Public Road	45	34	60	60	0.6%	0.5%	0.8%	0.8%
	Interstate	0	95	95	95	0.0%	1.3%	1.3%	1.3%
	Railroad	68	70	29	29	1.0%	1.0%	0.4%	0.4%
	Totals	**113**	**200**	**184**	**184**	**1.6%**	**2.8%**	**2.6%**	**2.6%**
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	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	0	0	327	0.0%	0.0%	0.0%	5.5%	0.0%	0.0%	5.5%	5.5%
	Flood	2,725	2,924	2,946	2,714	44.6%	48.8%	49.1%	45.3%	4.3%	0.3%	-3.8%	0.7%
	Totals	**2,725**	**2,924**	**2,947**	**3,041**	**44.6%**	**48.8%**	**49.1%**	**50.7%**	**4.3%**	**0.3%**	**1.6%**	**6.2%**

Non-Irrigated

Multi-Use	3,327	2,864	2,848	2,775	54.4%	47.8%	47.4%	46.3%	-6.6%	-0.4%	-1.2%	-8.1%
Hay/Pasture	64	203	209	180	1.1%	3.4%	3.5%	3.0%	2.3%	0.1%	-0.5%	1.9%
Totals	**3,391**	**3,066**	**3,057**	**2,955**	**55.4%**	**51.2%**	**50.9%**	**49.3%**	**-4.3%**	**-0.3%**	**-1.6%**	**-6.2%**

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.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.3	1.6	0.8	0.2	1.6	1.3	1.4	1.1	1.4
Max	28.8	91.1	99.8	26.7	20.4	30.3	18.3	37.4	54.6
Average	6.9	12.9	11.4	6.3	7.3	5.8	6.1	11.1	18.0
Sum	137.6	206.4	193.5	43.9	58.6	69.1	42.4	77.8	89.8

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	22.8
Channel to Riparian (acres)	73.1
Riparian Encroachment (acres)	**50.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	110.0
1950s Floodplain Mapped as 2011 Channel (Ac)	17.9
Total Recruitment (1950s to 2011)(Ac)	**127.9**

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	5.7	49.2	1.6	0.0	**56.5**
Acres/Valley Mile	0.8	6.7	0.2	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	83.74	1.99%	6.56	0.00	11.92	2.85

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.

Low Flow Fisheries Habitat Mapping

	2001 (Acres)		
Habitat	Bankfull	Low Flow	% of Low Flow
Scour Pool	337.4	189.3	24.8%
Rip Rap Margin	142.9	96.4	12.7%
Terrace Pool	62.7	61.4	8.1%
Secondary Channel		13.6	1.8%
Secondary Channel (Seasonal)	41.5	52.9	6.9%
Channel Crossover	156.1	122.0	16.0%
Point Bar		52.7	6.9%
Side Bar		58.1	7.6%
Mid-channel Bar		44.1	5.8%
Island	31.7	31.7	4.2%
Dry Channel		39.9	5.2%

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.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.

County	Custer	**Upstream River Mile**	158.7
Classification	CM: Confined meandering	**Downstream River Mile**	149.2
General Location	To Powder River confluence	**Length**	9.50 mi (15.29 km)
General Comments	To Powder River; confined		

Narrative Summary

Reach C21 is 9.5 miles long and extends from River Mile (RM) 158.7 downstream to the mouth of the Powder River at RM 149.2. It is a Confined Meandering (CM) reach type, as the river flows down a sinuous course that is highly confined by Fort Union Formation sandstones and younger erosion–resistant terraces.

Reach C21 has just over 4,000 feet of rock riprap and 71 feet of mapped flow deflectors, which collectively armor 4.1 percent of the total stream bank. About one half of the armor is protecting road embankments, and the other half is protecting the railroad.

Bear Rapids forms two distinct shoals as bedrock shelves in the river between RM 153 and RM 154 near the mouth of Camp Creek.

Between 1950 and 2001 there was about 53 net acres of riparian encroachment into the channel, and the bankfull channel area decreased by ~58 acres, indicating a diminishing river size over the last half-century. This trend is common below the mouth of the Bighorn River, where flow alterations have reduced peak flows and cause the active river channel to shrink. Consumptive water uses, primarily associated with irrigation, have contributed to the reduced flows.

Land use is dominated by agriculture with 164 acres of the ~7,000 acre mapping footprint occupied by transportation-related land uses. There is one ~0.6 acre series of corrals near the mouth of Mack Creek at RM 157.2R that are within 200 feet of the river. There are also several acres of corrals within 300 feet of the river on the left bank at RM 154.9L. At RM 153.3R there is another much larger series of corrals that are within 500 feet of Camp Creek.

There are 49 acres of Russian olive in the reach, which appears to dominate riparian areas.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The 100-year flood has dropped by 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 24 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 5,080 cfs to 3,140 cfs with human development, a reduction of 38 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,730 cfs under unregulated conditions to 3,510 cfs under regulated conditions, a reduction of 48 percent.

CEA-Related observations in Reach C21 include:
•Natural channel stability provided by bedrock
•Minimal bank armoring

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C21 include:
•Russian olive removal
•Nutrient management at corrals at RM 157.2R and RM 153.2R, and 154.9L

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): Miles City

Flood History

Year	Date	Flow on Date	Return Interval
1974	Jun 22	75,400	10-25 yr
1997	Jun 15	83,300	10-25 yr
1943	Jun 26	83,700	10-25 yr
2011	May 24	85,400	10-25 yr
1944	Jun 19	96,300	50-100 yr
1978	May 22	102,000	50-100 yr

	Downstream Gage	Upstream Gage
Gage No	6329500	6309000
Location	Sidney	Miles City
Period of Record	1911-2015	1929-2015
Distance To (miles)	118.4	25.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated		63,900	79,700	89,700	111,000	119,000	139,000	5,080	6,750
Regulated		48,600	63,500	72,500	90,000	96,800	111,000	3,140	3,510
% Change		-23.94%	-20.33%	-19.18%	-18.92%	-18.66%	-20.14%	-38.19%	-48.00%

Flow Duration

Streamflow, in ft3/s, which was equaled or exceeded for indicated percent of time

Note that these statistics are only available from Reach C10 downstream. See the USGS report for detailed information.

Season		5%	50%	95%
Spring	Unregulated	62,400	23,400	6,470
	Regulated	48,100	14,000	4,670
	% Change	**-23%**	**-40%**	**-28%**
Summer	Unregulated	44,400	14,100	6,750
	Regulated	33,400	8,580	3,510
	% Change	**-25%**	**-39%**	**-48%**
Fall	Unregulated	9,420	5,760	2,320
	Regulated	10,800	7,130	3,740
	% Change	**15%**	**24%**	**61%**
Winter	Unregulated	12,600	5,180	2,080
	Regulated	13,300	6,260	3,340
	% Change	**6%**	**21%**	**61%**
Annual	Unregulated	46,900	8,350	2,870
	Regulated	35,100	7,670	3,730
	% Change	**-25%**	**-8%**	**30%**

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
1950	USGS-EROS	???	B/W	1:14,800	6309000	
1976	USCOE	9/29/1976 - 10/9/76	B/W	1:24,000	6309000	9520
1995	USGS DOQQ	9-Jul-96	B/W		6309000	35000
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6309000	3500
2005	NAIP	08/04/2005	color	1-meter pixels	6309000	5550
2005	NAIP	07/08/2005	color	1-meter pixels	6309000	18800
2007	Woolpert	10/15/2007 - 11/2/0007	Color			
2009	NAIP	8/11/2009	Color	1-meter pixels	6309000	12900
2009	NAIP	7/17/2009	Color	1-meter pixels	6309000	23300
2011	USCOE	October 2012	color	1-ft pixel	6309000	8100
2011	NAIP	7/16/2011	Color	1-meter pixels	6309000	57900
2013	NAIP	07/19/2013	color	1-meter pixels	6309000	

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	4,066	4.1%	4,025	4.0%	-41
	Flow Deflectors	0	0.0%	71	0.1%	71
	Feature Type Totals	**4,066**	**4.1%**	**4,096**	**4.1%**	**30**
Other In Channel						
	Bedrock Outcrop	2,854	2.9%	2,854	2.9%	0
	Feature Type Totals	**2,854**	**2.9%**	**2,854**	**2.9%**	**0**
	Reach Totals	**6,919**	**6.9%**	**6,949**	**6.9%**	**30**

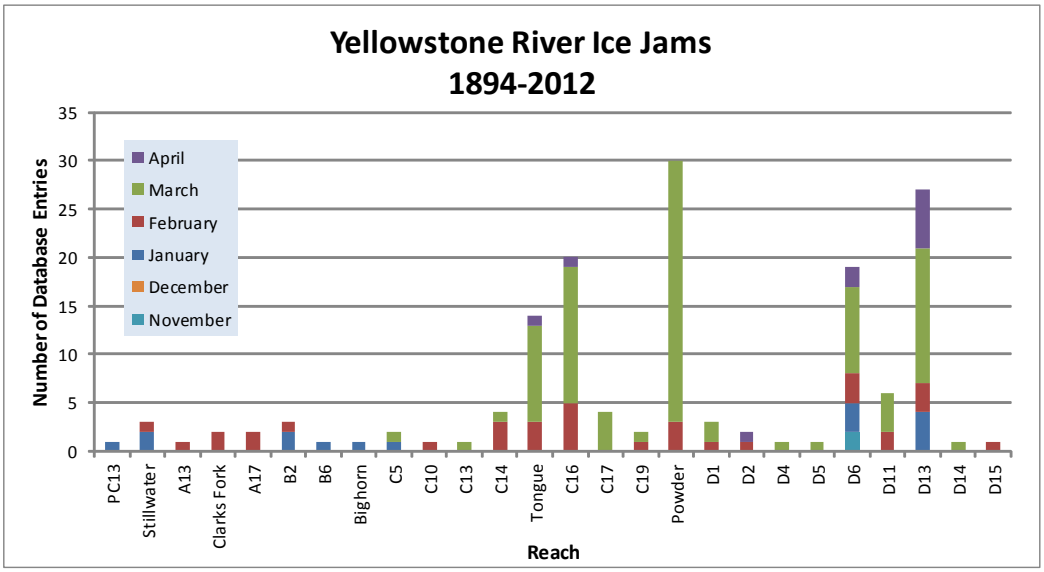
Intent of Bank Protection: 2001

The 2001 bank protection features were assessed for the 'intent' of what they protect.

Feature Type	Irrigated	Non-Irrig.	Ag. Infrastr.	Road	Interstate	Railroad	Urban	Exurban
Rock RipRap	0	0	0	2,378	0	2,676	0	0
Totals	**0**	**0**	**0**	**2,378**	**0**	**2,676**	**0**	**0**

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	50,040	3,028	1.06	1950 to 1976:	14.55%
1976	50,142	10,774	1.21	1976 to 1995:	2.48%
1995	50,158	12,286	1.24	1995 to 2001:	-9.91%
2001	50,035	6,080	1.12	1950 to 2001:	5.75%
Change 1950 - 2001	**-5**	**3,052**	**0.06**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	0

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.)	0	0.0%		
Agriculture (generally relates to field boundaries)	0	0.0%		
Agriculture (isloated by canal or large ditch)	0	0.0%		
Levee/Riprap (protecting agricultural lands)	0	0.0%		
Levee/Riprap (protecting urban, industrial, etc.)	0	0.0%		
Railroad	13	2.6%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	469		1090	
Total Floodplain Area (Ac)	481		1185	
Total Isolated (Ac)	**13**	**2.6%**	**95**	**35.3%**

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:	0	0	0	**0**

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
85	169	1,395	2	0%	56	0	0%

2011 Restricted Migration Area Summary

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).

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	2	0.2%
	Totals	**2**	**0.2%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
9.3	0.0	0.0	0.0	4.9

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	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	35	95	100	100	0.5%	1.2%	1.3%	1.3%
	Totals	**35**	**95**	**100**	**100**	**0.5%**	**1.2%**	**1.3%**	**1.3%**
Agricultural Land									
	Non-Irrigated	4,830	4,332	4,818	4,611	61.9%	55.6%	61.8%	59.1%
	Irrigated	1,799	2,165	1,737	1,916	23.1%	27.8%	22.3%	24.6%
	Totals	**6,629**	**6,497**	**6,556**	**6,527**	**85.0%**	**83.3%**	**84.1%**	**83.7%**
Channel									
	Channel	1,032	1,026	967	996	13.2%	13.2%	12.4%	12.8%
	Totals	**1,032**	**1,026**	**967**	**996**	**13.2%**	**13.2%**	**12.4%**	**12.8%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	0	11	11	0.0%	0.0%	0.1%	0.1%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**0**	**0**	**11**	**11**	**0.0%**	**0.0%**	**0.1%**	**0.1%**
Transportation									
	Public Road	28	32	57	57	0.4%	0.4%	0.7%	0.7%
	Interstate	0	76	76	76	0.0%	1.0%	1.0%	1.0%
	Railroad	72	72	31	31	0.9%	0.9%	0.4%	0.4%
	Totals	**100**	**180**	**164**	**164**	**1.3%**	**2.3%**	**2.1%**	**2.1%**
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	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Pivot	0	488	0	0	0.0%	7.5%	0.0%	0.0%	7.5%	-7.5%	0.0%	0.0%
	Flood	1,799	1,676	1,737	1,916	27.1%	25.8%	26.5%	29.4%	-1.3%	0.7%	2.9%	2.2%
	Totals	**1,799**	**2,165**	**1,737**	**1,916**	**27.1%**	**33.3%**	**26.5%**	**29.4%**	**6.2%**	**-6.8%**	**2.9%**	**2.2%**

Non-Irrigated

Multi-Use	4,746	4,193	4,077	4,066	71.6%	64.5%	62.2%	62.3%	-7.0%	-2.3%	0.1%	-9.3%
Hay/Pasture	84	139	741	545	1.3%	2.1%	11.3%	8.4%	0.9%	9.2%	-2.9%	7.1%
Totals	**4,830**	**4,332**	**4,818**	**4,611**	**72.9%**	**66.7%**	**73.5%**	**70.6%**	**-6.2%**	**6.8%**	**-2.9%**	**-2.2%**

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.

Riparian Mapping

	Shrub (Acres)			Closed Timber (Acres)			Open Timber (Acres)		
Statistic	1950	1976	2001	1950	1976	2001	1950	1976	2001
Min	0.6	0.7	0.1	1.5	1.5	1.9	2.4	2.4	1.5
Max	15.6	34.3	64.9	12.6	10.8	16.0	29.0	12.2	28.5
Average	4.9	7.7	6.4	5.2	4.6	5.9	8.2	4.9	8.9
Sum	113.4	246.8	199.7	57.3	36.8	47.5	73.4	19.5	98.2

Riparian Turnover

Conversion of riparian areas to channel, or from channel to riparian between the 1950's and 2001 data set.

Riparian to Channel (acres)	33.4
Channel to Riparian (acres)	86.8
Riparian Encroachment (acres)	**53.3**

Riparian Recruitment

Creation of riparian areas between 1950s and 2001.

1950s Channel Mapped as 2011 Riparian (Ac)	119.4
1950s Floodplain Mapped as 2011 Channel (Ac)	9.7
Total Recruitment (1950s to 2011)(Ac)	**129.2**

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	7.7	61.4	10.5	0.0	**79.6**
Acres/Valley Mile	0.9	7.2	1.2	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	48.62	0.84%	2.39	0.00	8.70	0.30

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.

Low Flow Fisheries Habitat Mapping

Habitat	2001 (Acres) Bankfull	Low Flow	% of Low Flow
Scour Pool	73.5	87.7	9.1%
Rip Rap Bottom	78.2	53.3	5.5%
Rip Rap Margin	62.6	7.6	0.8%
Terrace Pool	384.5	227.9	23.6%
Secondary Channel	27.3	28.8	3.0%
Secondary Channel (Seasonal)	47.7	91.3	9.4%
Channel Crossover	226.7	187.1	19.3%
Point Bar		55.1	5.7%
Side Bar		30.3	3.1%
Mid-channel Bar		95.0	9.8%
Island	53.7	53.7	5.6%
Dry Channel		44.7	4.6%
Confluence Area	4.0	4.5	0.5%

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.

CULTURAL INVENTORY SUMMARY

The Yellowstone River Cultural Inventory - 2006 documents the variety and intensity of different perspectives and values held by people who share the Yellowstone River. Between May and November of 2006, a total of 313 individuals participated in the study. They represented agricultural, civic, recreational, or residential interest groups. Also, individuals from the Crow and the Northern Cheyenne tribes were included.
There are three particular goals associated with the investigation. The first goal is to document how the people of the Yellowstone River describe the physical character of the river and how they think the physical processes, such as floods and erosion, should be managed. Within this goal, efforts have been made to document participants' views regarding the many different bank stabilization techniques employed by landowners. The second goal is to document the degree to which the riparian zone associated with the river is recognized and valued by the participants. The third goal is to document concerns regarding the management of the river's resources. Special attention is given to the ways in which residents from diverse geographical settings and diverse interest groups view river management and uses. The results illustrate the commonalities of thought and the complexities of concerns expressed by those who share the resources of the Yellowstone River.

Summary of Cultural Views in Region C

In the study segment, Powder River to Big Horn River, three conversations emerged across the four interest groups. The first conversation focuses on the "familiar way of life." The conversation exposes a local identity that is tied to agriculture and to traditional forms of recreation, such as hunting and fishing. When asked if the familiar management practices are sufficient in terms of sharing the river's resources, some locals express concerns. The second conversation explicitly acknowledges that the demand for recreational access to the river's resources is in its infancy in terms of representing a problem. The third conversation focuses on controlling the river with rip-rap and dikes.