County	Park	**Upstream River Mile**	564.8
Classification	CS: Confined straight	**Downstream River Mile**	560.2
General Location	Gardiner to Little Trail Cr.	**Length**	4.60 mi (7.40 km)

General Comments

Narrative Summary

Reach PC1 is the upstream-most reach of the project area, beginning at Gardiner Montana, and extending northward almost five miles to the Trail Creek confluence. Reach PC1 is confined/straight reach type and shows minimal impact in terms of flow alterations, bank armoring, and side channel loss. The bankfull area has remained essentially unchanged since 1950. Land use is dominated by non-irrigated agriculture, with some conversion of flood irrigation to sprinkler from 1950 to 2011. There are over 300 acres of urban/exurban development in the reach, dominated by the town of Gardiner. Although the development in Gardiner is very close to the river, it is located high on bluffs that are outside of the Channel Migration Zone (CMZ) and floodplain. The bluffs are composed of glacial outwash deposits that are very coarse and erosion resistant. The total CMZ area in Reach PC1 is only 115 acres, and there is essentially no riparian zone in this reach. This section of river is relatively steep, with steep boulder runs and associated wave trains that make it a popular stretch of river for recreational white water rafting. There is one boat ramp in the reach at RM 561.5, and the Queen of the Waters Fishing Access Site is located at RM 563.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located downstream of Reach PC1 at the Corwin Springs Bridge.

CEA-Related observations in Reach PC1 include:
•Urban/Exurban development at Gardiner

No reach-specific Practices have been identified for this reach.

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): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6191500	6186500
Location	Corwin Springs	Ystone Lake
Period of Record	1890-2012	1923-2012
Distance To (miles)	3.0	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	8,370	16,800	21,300	24,100	29,800	32,100	37,500	NA	1,760
Regulated	8,370	16,800	21,300	24,100	29,800	32,100	37,500	NA	1,680
% Change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	NA	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
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2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	08/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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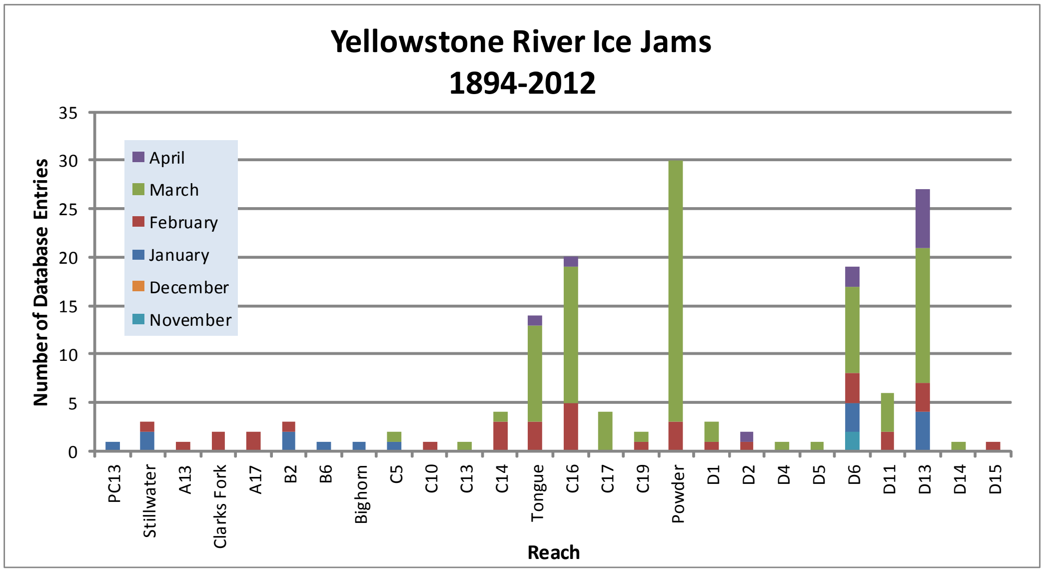
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

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	23,391		1.00	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	2,345,264		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**2,321,873**		**0.00**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
0	0	115	0	0%	0	0	0%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	0.0	0.0	1.4	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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	2	2	2	0	0.1%	0.1%	0.1%	0.0%
	Totals	**2**	**2**	**2**	**0**	**0.1%**	**0.1%**	**0.1%**	**0.0%**
Agricultural Land									
	Non-Irrigated	1,605	1,433	1,362	1,364	84.5%	75.4%	71.7%	71.8%
	Irrigated	42	35	36	36	2.2%	1.8%	1.9%	1.9%
	Totals	**1,648**	**1,468**	**1,398**	**1,399**	**86.7%**	**77.3%**	**73.6%**	**73.7%**
Channel									
	Channel	107	110	110	110	5.6%	5.8%	5.8%	5.8%
	Totals	**107**	**110**	**110**	**110**	**5.6%**	**5.8%**	**5.8%**	**5.8%**
ExUrban									
	ExUrban Other	0	6	6	6	0.0%	0.3%	0.3%	0.3%
	ExUrban Undeveloped	0	0	19	19	0.0%	0.0%	1.0%	1.0%
	ExUrban Industrial	31	107	107	107	1.7%	5.6%	5.6%	5.6%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	25	27	27	0.0%	1.3%	1.4%	1.4%
	Totals	**31**	**138**	**158**	**158**	**1.7%**	**7.2%**	**8.3%**	**8.3%**
Transportation									
	Public Road	60	58	58	58	3.2%	3.1%	3.1%	3.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**60**	**58**	**58**	**58**	**3.2%**	**3.1%**	**3.1%**	**3.1%**
Urban									
	Urban Other	1	27	27	27	0.1%	1.4%	1.4%	1.4%
	Urban Residential	16	30	77	77	0.9%	1.6%	4.0%	4.0%
	Urban Commercial	30	57	71	71	1.6%	3.0%	3.7%	3.7%
	Urban Undeveloped	4	10	0	0	0.2%	0.5%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**52**	**125**	**175**	**175**	**2.7%**	**6.6%**	**9.2%**	**9.2%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	36	36	0.0%	0.0%	2.6%	2.6%	0.0%	2.6%	0.0%	2.6%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	42	35	0	0	2.6%	2.4%	0.0%	0.0%	-0.2%	-2.4%	0.0%	-2.6%
	Totals	**42**	**35**	**36**	**36**	**2.6%**	**2.4%**	**2.6%**	**2.6%**	**-0.2%**	**0.2%**	**0.0%**	**0.0%**

Non-Irrigated													
	Multi-Use	1,605	1,433	1,362	1,364	97.4%	97.6%	97.4%	97.4%	0.2%	-0.2%	0.0%	0.0%
	Hay/Pasture	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Totals	**1,605**	**1,433**	**1,362**	**1,364**	**97.4%**	**97.6%**	**97.4%**	**97.4%**	**0.2%**	**-0.2%**	**0.0%**	**0.0%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.0	0.0	0.0	0.0	**0.0**
Acres/Valley Mile	0.0	0.0	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	0.05	0.28%	0.42	0.00	0.00	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Park	**Upstream River Mile**	560.2
Classification	CM: Confined meandering	**Downstream River Mile**	557.2
General Location	Devil's Slide area	**Length**	3.00 mi (4.83 km)

General Comments

Narrative Summary

Reach PC2 is located north of Gardiner near Devil's Slide. The reach is three miles long, and is confined by glacial terraces that taper in the northward direction as the river approaches Yankee Jim Canyon. This reach a contains over 3,000 feet of rock riprap, all of which is against the toe of the terrace where the river flows adjacent to Highway 89 on the east side of the river. About one third or 1,200 feet of that riprap was built since 2001, where older riprap was extended against the highway. The riprap covers 9.3 percent of the total bankline. Migration rates are very low, and the total CMZ acreage is 111 acres. Land use is dominated by non-irrigated agriculture, and irrigated agriculture has seen some conversion from flood to sprinkler and pivot. In 1950, there were 152 acres of land in PC2 under flood irrigation, and in 2011 there were none. Whereas there was no sprinkler or pivot irrigation in 1950, now there are 133 acres of sprinkler and 62 acres under flood irrigation. The Brogans Landing Fishing Access Site is located in the lower end of the reach.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located downstream of Reach PC2 at the Corwin Springs Bridge.

CEA-Related observations in Reach PC2 include:
•Urban/Exurban development at Gardiner

No reach-specific Practices have been identified for this reach.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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% Change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	NA	-4.55%

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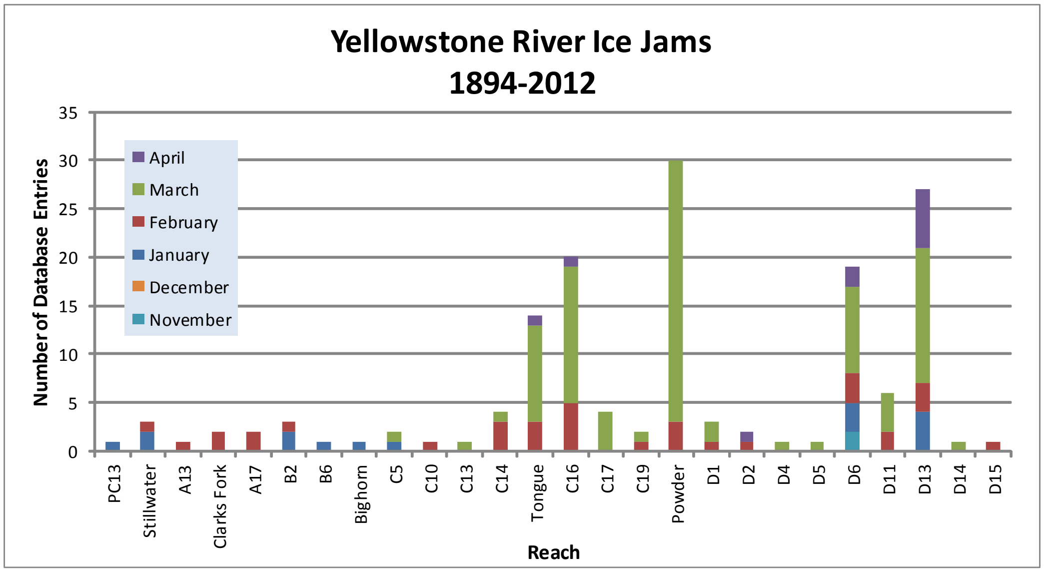
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

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	1,788	5.5%	3,043	9.3%	1,255
	Feature Type Totals	**1,788**	**5.5%**	**3,043**	**9.3%**	**1,255**
	Reach Totals	**1,788**	**5.5%**	**3,043**	**9.3%**	**1,255**

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.



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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	16,400		1.00	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	16,392		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**-9**		**0.00**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
0	0	111	0	0%	0	0	0%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
0.0	0.0	0.0	1.5	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	21	32	36	24	1.6%	2.4%	2.7%	1.8%
	Totals	**21**	**32**	**36**	**24**	**1.6%**	**2.4%**	**2.7%**	**1.8%**
Agricultural Land									
	Non-Irrigated	908	882	859	833	68.2%	66.2%	64.5%	62.5%
	Irrigated	251	223	156	194	18.8%	16.7%	11.7%	14.6%
	Totals	**1,159**	**1,105**	**1,015**	**1,027**	**87.0%**	**83.0%**	**76.2%**	**77.1%**
Channel									
	Channel	107	100	100	100	8.1%	7.5%	7.5%	7.5%
	Totals	**107**	**100**	**100**	**100**	**8.1%**	**7.5%**	**7.5%**	**7.5%**
ExUrban									
	ExUrban Other	0	16	16	16	0.0%	1.2%	1.2%	1.2%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	9	0	0	0.0%	0.7%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	9	34	129	129	0.7%	2.6%	9.7%	9.7%
	Totals	**9**	**59**	**145**	**145**	**0.7%**	**4.5%**	**10.9%**	**10.9%**
Transportation									
	Public Road	36	36	36	36	2.7%	2.7%	2.7%	2.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**36**	**36**	**36**	**36**	**2.7%**	**2.7%**	**2.7%**	**2.7%**
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	125	133	0.0%	0.0%	12.3%	12.9%	0.0%	12.3%	0.6%	12.9%
	Pivot	0	0	0	62	0.0%	0.0%	0.0%	6.0%	0.0%	0.0%	6.0%	6.0%
	Flood	251	223	31	0	21.6%	20.2%	3.1%	0.0%	-1.5%	-17.1%	-3.1%	-21.6%
	Totals	**251**	**223**	**156**	**194**	**21.6%**	**20.2%**	**15.4%**	**18.9%**	**-1.5%**	**-4.8%**	**3.5%**	**-2.7%**

Non-Irrigated												
Multi-Use	867	793	813	810	74.8%	71.8%	80.1%	78.8%	-3.0%	8.3%	-1.2%	4.0%
Hay/Pasture	41	89	46	23	3.5%	8.0%	4.5%	2.2%	4.5%	-3.5%	-2.3%	-1.3%
Totals	**908**	**882**	**859**	**833**	**78.4%**	**79.8%**	**84.6%**	**81.1%**	**1.5%**	**4.8%**	**-3.5%**	**2.7%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	0.0	2.5	2.4	0.0	**4.9**
Acres/Valley Mile	0.0	0.9	0.9	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	0.01	0.20%	0.25	0.00	0.01	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

Yellowstone River Reach Narratives

Reach PC3

County	Park	**Upstream River Mile**	557.2
Classification	CS: Confined straight	**Downstream River Mile**	546.8
General Location	Corwin Springs to Carbella; Yankee Jim Canyon	**Length**	10.40 mi (16.74 km)

General Comments

Narrative Summary

Reach PC3 is located north of Gardiner, extending from Corwin Springs to Carbella. This reach is highly confined and by glacial terraces on its upper end, and Archean-age gneiss on its lower end. As an Archean-age rock unit, the gneiss is over 2.5 billion years old. This bedrock confined section of river is known as Yankee Jim Canyon, which hosts a steep series of drops that create the most challenging whitewater section of the Yellowstone River outside of Yellowstone National Park. “Yankee Jim” George was a well-known character of the area; he came from the east in the late 1800s to settle on a newly built wagon road that extended from Bozeman to Mammoth Hot Springs in Yellowstone National Park. For 20 years Yankee Jim ran the National Park Toll Road. One hundred years later, Yankee Jim Canyon is highly popular as a recreational resource for both rafting and fishing. There are two boat ramps in the reach, located above and below the canyon. The Slip & Slide (RM 552) and Crystal Cross (RM 548) Fishing Access Sites provide river access but have no boat ramps.

Reach PC3 contains over three miles of bank armor, most of which is rock riprap that protects the highway at the entrance to Yankee Jim Canyon. Of those three miles, 700 feet was constructed since 2001. Channel migration is extremely localized in the reach, and is concentrated at the toe of an alluvial fan at the mouth of Cedar Creek that impinges on the river from the east.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler irrigation has increased. Even so, there has been a net loss of irrigated land of over 200 acres in the reach as exurban land uses have expanded.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs.

CEA-Related observations in Reach PC3 include:
•Conversion of flood irrigation to sprinkler
•Net loss of irrigated land

No reach-specific Practices have been identified for this reach.

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): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	40.2	0.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	8,800	17,600	22,300	25,200	31,100	33,500	39,100	1,230	1,760
Regulated	8,800	17,600	22,300	25,200	31,100	33,500	39,100	1,220	1,680
% Change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.81%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/27/2005	color	1-meter pixels	6192500	2250
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2009	NAIP	6/27/2009	Color	1-meter pixels	6192500	15200
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

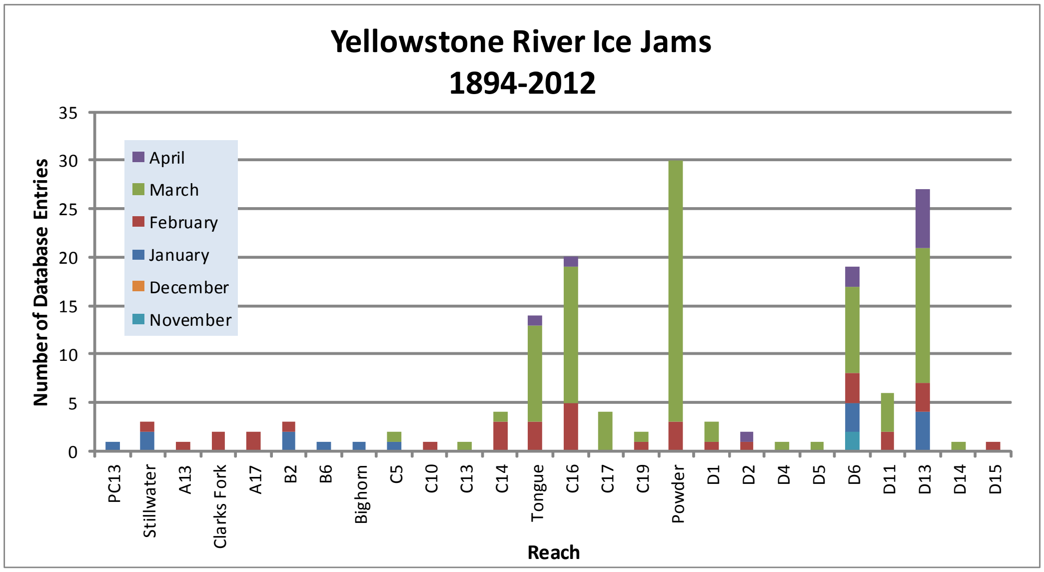
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	15,624	14.3%	16,335	15.0%	711
	Flow Deflectors	227	0.2%	227	0.2%	0
	Between Flow Deflectors	67	0.1%	67	0.1%	0
	Feature Type Totals	**15,917**	**14.6%**	**16,628**	**15.2%**	**711**
	Reach Totals	**15,917**	**14.6%**	**16,628**	**15.2%**	**711**

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	54,600		1.00	**1950 to 1976:**	
1976				**1976 to 1995:**	
1995				**1995 to 2001:**	
2001	54,596	1,677	1.03	**1950 to 2001:**	3.07%
Change 1950 - 2001	**-4**		**0.03**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
74	148	335	0	0%	0	0	0%

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
0.0	0.0	0.0	4.2	1.3

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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	21	32	36	24	0.5%	0.7%	0.8%	0.5%
	Totals	**21**	**32**	**36**	**24**	**0.5%**	**0.7%**	**0.8%**	**0.5%**
Agricultural Land									
	Non-Irrigated	908	882	859	833	20.1%	19.5%	19.0%	18.4%
	Irrigated	251	223	156	194	5.5%	4.9%	3.5%	4.3%
	Totals	**1,159**	**1,105**	**1,015**	**1,027**	**25.6%**	**24.4%**	**22.4%**	**22.7%**
Channel									
	Channel	107	100	100	100	2.4%	2.2%	2.2%	2.2%
	Totals	**107**	**100**	**100**	**100**	**2.4%**	**2.2%**	**2.2%**	**2.2%**
ExUrban									
	ExUrban Other	0	16	16	16	0.0%	0.4%	0.4%	0.4%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	9	0	0	0.0%	0.2%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	9	34	129	129	0.2%	0.8%	2.9%	2.9%
	Totals	**9**	**59**	**145**	**145**	**0.2%**	**1.3%**	**3.2%**	**3.2%**
Transportation									
	Public Road	36	36	36	36	0.8%	0.8%	0.8%	0.8%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**36**	**36**	**36**	**36**	**0.8%**	**0.8%**	**0.8%**	**0.8%**
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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	92	188	0.0%	0.0%	2.5%	5.1%	0.0%	2.5%	2.6%	5.1%
	Pivot	0	0	0	32	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.9%	0.9%
	Flood	635	535	272	184	15.6%	13.7%	7.4%	5.0%	-2.0%	-6.3%	-2.4%	-10.6%
	Totals	**635**	**535**	**364**	**404**	**15.6%**	**13.7%**	**9.9%**	**11.0%**	**-2.0%**	**-3.7%**	**1.1%**	**-4.6%**

Non-Irrigated													
	Multi-Use	3,400	3,299	3,113	3,116	83.6%	84.3%	84.7%	84.6%	0.7%	0.4%	-0.1%	1.0%
	Hay/Pasture	33	81	200	164	0.8%	2.1%	5.4%	4.4%	1.2%	3.4%	-1.0%	3.6%
	Totals	**3,433**	**3,380**	**3,313**	**3,280**	**84.4%**	**86.3%**	**90.1%**	**89.0%**	**2.0%**	**3.7%**	**-1.1%**	**4.6%**

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.

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	0.3	7.3	6.4	0.0	**14.0**
Acres/Valley Mile	0.0	0.7	0.6	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	0.02	0.15%	0.72	0.00	0.01	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Park	**Upstream River Mile**	546.8
Classification	CM: Confined meandering	**Downstream River Mile**	543.2
General Location	Carbella to Hwy 89 Br.	**Length**	3.60 mi (5.79 km)

General Comments

Narrative Summary

Reach PC4 extends from Carbella to the Highway 89 Bridge at Point of Rocks in the upper Paradise Valley. The reach is classified as confined meandering, indicating that it has some sinuosity, yet migration rates are low due to lateral confinement.

Flow deflectors and rock riprap cover about 800 feet of bankline in Reach PC4, which is about 2 percent of the total streambank length. All of this armor was in place prior to 2001.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased. Reach PC4 has seen a net expansion of about 150 acres of irrigated lands since 1950, with about half of the expansion into sprinkler irrigation and the other half into pivot.

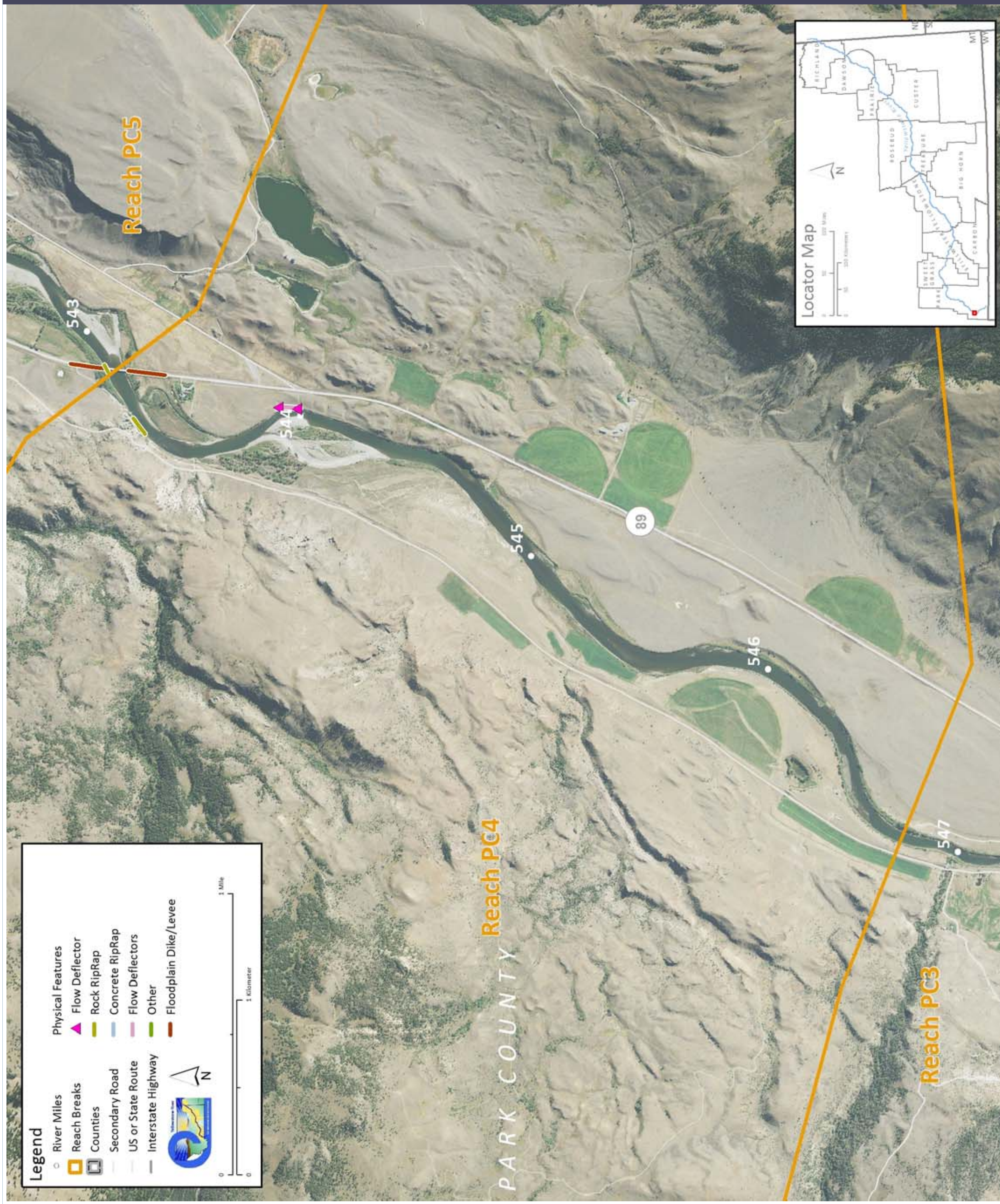
Reach PC4 marks the entrance of the Yellowstone River into the Paradise Valley. This is geomorphically indicated by the onset of point bar formation and sediment storage in the channel. One large bar deposit located about ¾ mile of the Highway 89 bridge has driven almost 300 feet of bank movement since 1950. As result, the Channel Migration Zone area in this reach has expanded relative to upstream, with an erosion buffer of 258 feet assigned to the alluvial edge of the river. Reach PC4 also has over 2,000 feet of active side channels.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located upstream of Reach PC4 at the Corwin Springs Bridge.

CEA-Related observations in Reach PC4 include:
•Increased bank migration and Channel Migration Zone area entering Paradise Valley
•Net expansion of irrigated lands

No reach-specific Practices have been identified for this reach.

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): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	36.6	10.4

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,560	19,100	24,000	27,100	33,400	36,000	41,900	1,240	1,760
Regulated	9,500	19,000	23,900	27,000	33,400	36,000	41,900	1,230	1,680
% Change	-0.63%	-0.52%	-0.42%	-0.37%	0.00%	0.00%	0.00%	-0.81%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/27/2005	color	1-meter pixels	6192500	2250
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	6/27/2009	Color	1-meter pixels	6192500	15200
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

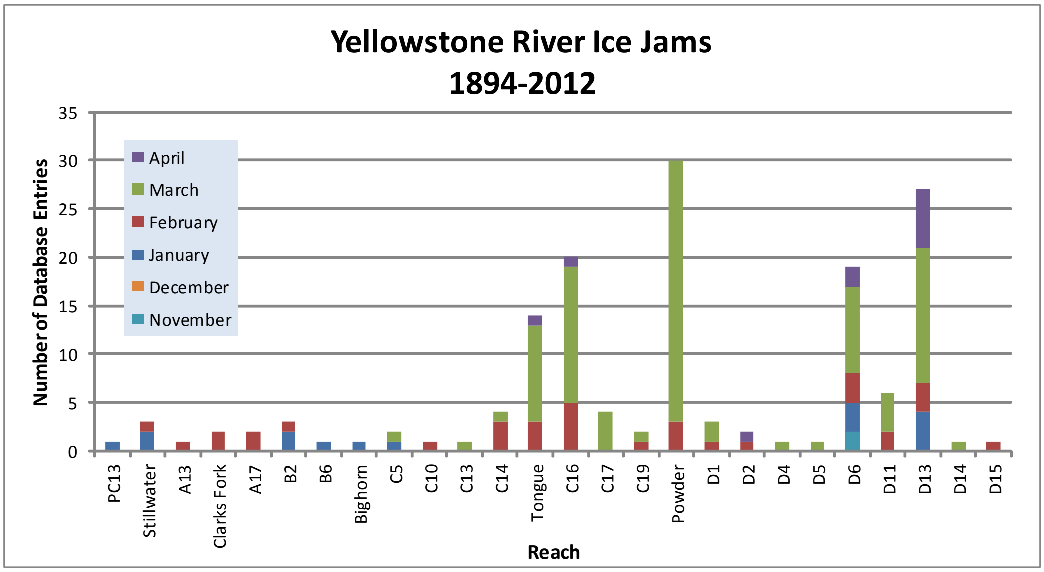
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	367	1.0%	367	1.0%	0
	Flow Deflectors	150	0.4%	147	0.4%	-3
	Between Flow Deflectors	283	0.7%	287	0.8%	4
	Feature Type Totals	**801**	**2.1%**	**801**	**2.1%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	918	2.4%	918	2.4%	0
	Feature Type Totals	**918**	**2.4%**	**918**	**2.4%**	**0**
	Reach Totals	**1,718**	**4.5%**	**1,718**	**4.5%**	**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	19,086	2,189	1.11	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	19,119	2,837	1.15	1950 to 2001:	3.02%
Change 1950 - 2001	**34**	**648**	**0.03**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
129	258	308	3	1%	0	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			
	Public Road	3	0.9%
	Totals	**3**	**0.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
5.5	0.8	0.9	3.4	0.8

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	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	8	2	4	4	0.5%	0.1%	0.2%	0.2%
	Totals	**8**	**2**	**4**	**4**	**0.5%**	**0.1%**	**0.2%**	**0.2%**
Agricultural Land									
	Non-Irrigated	1,408	1,294	1,392	1,253	83.1%	76.3%	82.1%	73.9%
	Irrigated	63	167	63	190	3.7%	9.8%	3.7%	11.2%
	Totals	**1,471**	**1,460**	**1,455**	**1,443**	**86.8%**	**86.2%**	**85.9%**	**85.1%**
Channel									
	Channel	186	179	180	181	11.0%	10.6%	10.6%	10.7%
	Totals	**186**	**179**	**180**	**181**	**11.0%**	**10.6%**	**10.6%**	**10.7%**
ExUrban									
	ExUrban Other	0	0	0	2	0.0%	0.0%	0.0%	0.1%
	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	9	13	22	0.0%	0.5%	0.7%	1.3%
	Totals	**0**	**9**	**13**	**23**	**0.0%**	**0.5%**	**0.7%**	**1.4%**
Transportation									
	Public Road	29	44	44	44	1.7%	2.6%	2.6%	2.6%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**29**	**44**	**44**	**44**	**1.7%**	**2.6%**	**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	39	85	0.0%	0.0%	2.7%	5.9%	0.0%	2.7%	3.2%	5.9%
	Pivot	0	0	24	97	0.0%	0.0%	1.6%	6.7%	0.0%	1.6%	5.1%	6.7%
	Flood	63	167	0	9	4.3%	11.4%	0.0%	0.6%	7.2%	-11.4%	0.6%	-3.7%
	Totals	**63**	**167**	**63**	**190**	**4.3%**	**11.4%**	**4.3%**	**13.2%**	**7.2%**	**-7.1%**	**8.8%**	**8.9%**

Non-Irrigated												
Multi-Use	1,341	1,287	1,354	1,236	91.1%	88.1%	93.1%	85.7%	-3.0%	5.0%	-7.4%	-5.5%
Hay/Pasture	68	7	37	17	4.6%	0.5%	2.6%	1.2%	-4.1%	2.1%	-1.4%	-3.4%
Totals	**1,408**	**1,294**	**1,392**	**1,253**	**95.7%**	**88.6%**	**95.7%**	**86.8%**	**-7.2%**	**7.1%**	**-8.8%**	**-8.9%**

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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	0.0	5.5	25.0	0.0	**30.5**
Acres/Valley Mile	0.0	1.7	7.6	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.

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	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.00	0.04%	0.10	0.00	0.02	0.07

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).

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County	Park	**Upstream River Mile**	543.2
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	539.4
General Location	Hwy 89 Br. to Big Creek	**Length**	3.80 mi (6.12 km)

General Comments

Narrative Summary

From the Highway 89 Bridge downstream to Big Creek, Reach PC5 is the first notably dynamic reach below Gardiner, with high rates of bank movement and a relatively high density of side channels and islands. In 2001, there were almost four miles of active side channel in the reach, although one 3,500-foot long channel on the west side of the river has been blocked by a dike. This dike does appear to have a culvert in it, keeping the channel somewhat accessible. In addition to side channel blockages, this reach has been impacted by over 5,000 feet of bank armor, most of which is rock riprap. One section of riprap that was about 150 feet long when constructed has been flanked and is now in the middle of the river. Since the rock was flanked, the river has migrated over 100 feet behind the old armor.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased. Reach PC5 has seen a net expansion of about 150 acres of irrigated lands since 1950, with most of the expansion into pivot. There has also been 100 acres of exurban development in Reach PC5 since 1950. There is one boat ramp at RM 542.5 at the Point of Rocks Fishing Access.

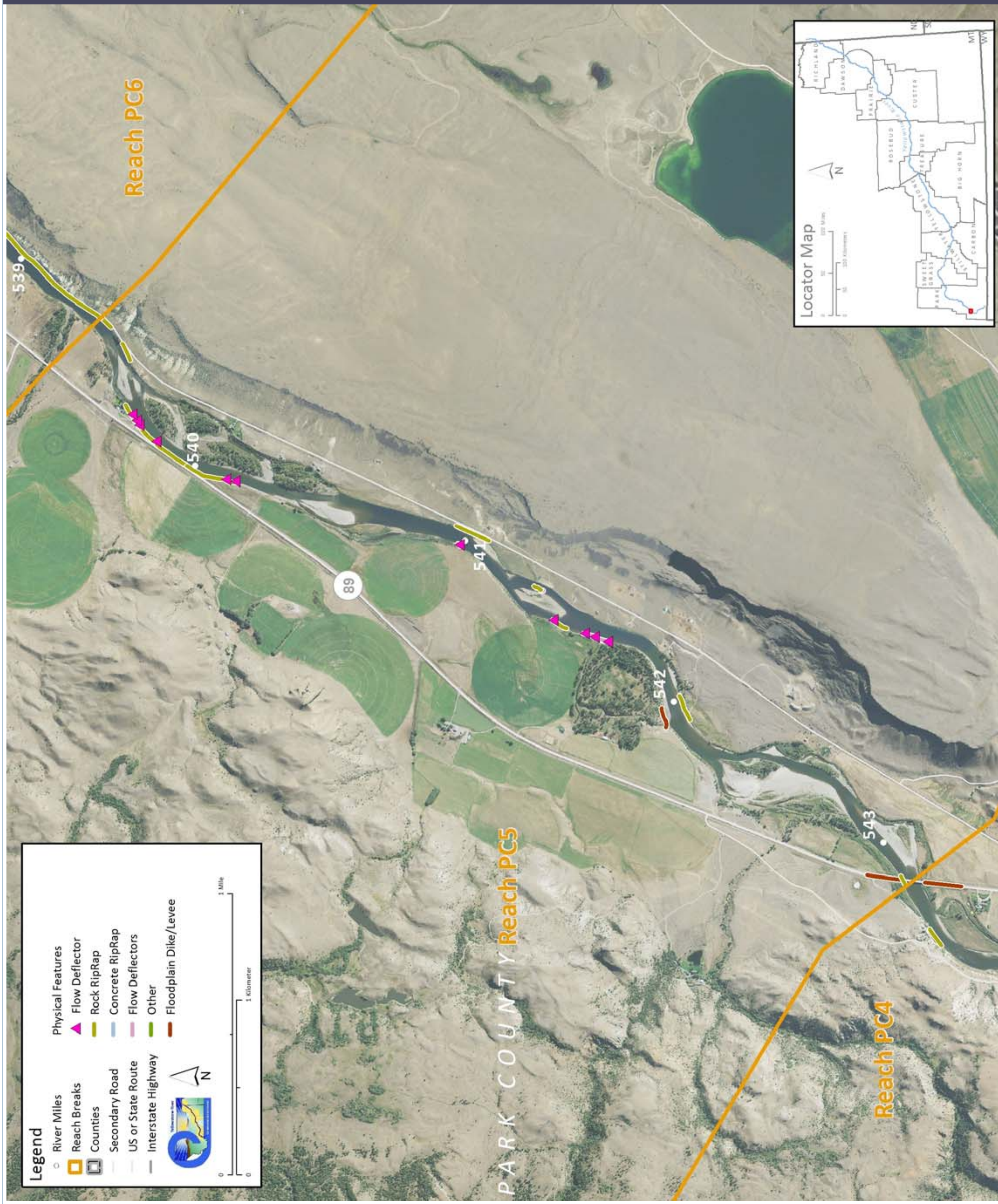
The influence of irrigation on streamflow is small but evident in Reach PC5. When gage data are extrapolated to reaches based on drainage area, Reach PC5 shows a 100 cfs reduction in the 2-year flood under developed conditions. This is a 0.5 percent reduction in the total flow of 19,000 cfs.

This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located upstream of Reach PC5 at the Corwin Springs Bridge.

CEA-Related observations in Reach PC5 include:
•Blockage of a 3,500feet-long side channel by a dike which may have a culvert
•Flanking of rock riprap and accelerated erosion behind
•Net expansion of irrigated lands

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC5 include:
•Side Channel Restoration at RM 542
•Removal of flanked bank armor at RM 541.4

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): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	1619500
Location	Livingston	
Period of Record	1929-2015	
Distance To (miles)	32.8	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,560	19,100	24,000	27,100	33,400	36,000	41,900	1,280	1,760
Regulated	9,500	19,000	23,900	27,000	33,400	36,000	41,900	1,260	1,680
% Change	-0.63%	-0.52%	-0.42%	-0.37%	0.00%	0.00%	0.00%	-1.56%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	6/27/2009	Color	1-meter pixels	6192500	15200
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	
2013	NAIP	08/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

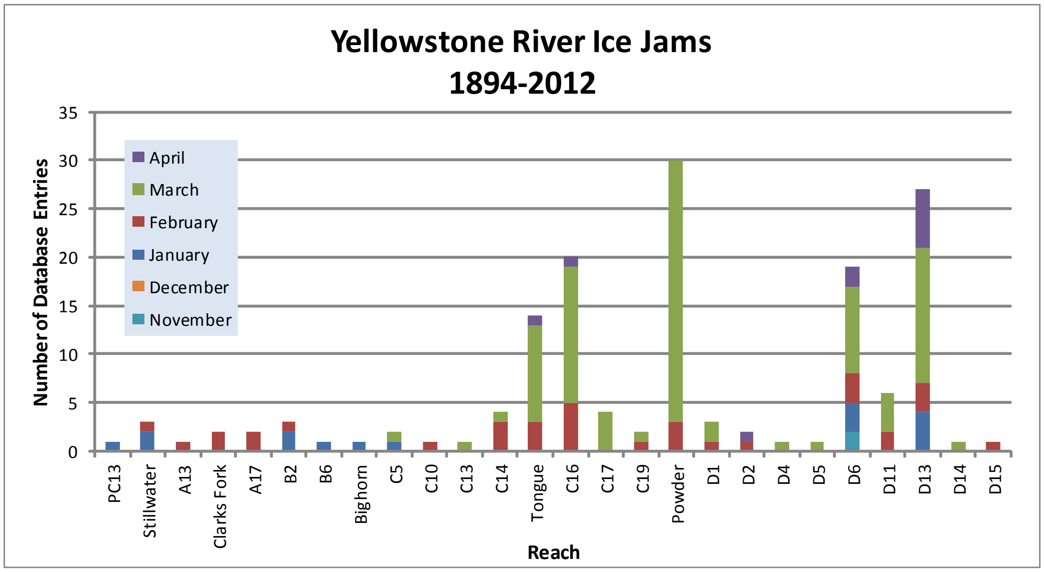
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,572	11.3%	4,372	10.8%	-201
	Flow Deflectors	707	1.8%	645	1.6%	-62
	Between Flow Deflectors	368	0.9%	348	0.9%	-20
	Feature Type Totals	**5,647**	**14.0%**	**5,365**	**13.3%**	**-282**
Floodplain Control						
	Floodplain Dike/Levee	1,023	2.5%	1,023	2.5%	0
	Feature Type Totals	**1,023**	**2.5%**	**1,023**	**2.5%**	**0**
	Reach Totals	**6,670**	**16.5%**	**6,388**	**15.8%**	**-282**

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	20,497	10,881	1.53	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	20,180	20,151	2.00	1950 to 2001:	30.55%
Change 1950 - 2001	**-317**	**9,270**	**0.47**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	3,503

HYDRAULICS

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

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

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

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
157	313	384	25	6%	0	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			
	Public Road	4	0.9%
RipRap/Flow Deflectors			
	Public Road	6	1.5%
	Irrigated	9	2.2%
RipRap			
	Exurban Residential	1	0.4%
Dike/Levee			
	Non-Irrigated	3	0.8%
	Totals	**22**	**5.8%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	3.2	2.4	20.1	2.7

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	0	10	26	14	0.0%	0.8%	2.0%	1.0%
	Totals	**0**	**10**	**26**	**14**	**0.0%**	**0.8%**	**2.0%**	**1.0%**
Agricultural Land									
	Non-Irrigated	806	895	781	557	61.3%	68.0%	59.3%	42.4%
	Irrigated	188	100	102	335	14.3%	7.6%	7.8%	25.5%
	Totals	**995**	**995**	**883**	**893**	**75.6%**	**75.6%**	**67.1%**	**67.8%**
Channel									
	Channel	287	252	253	258	21.8%	19.1%	19.3%	19.6%
	Totals	**287**	**252**	**253**	**258**	**21.8%**	**19.1%**	**19.3%**	**19.6%**
ExUrban									
	ExUrban Other	0	7	20	20	0.0%	0.6%	1.5%	1.5%
	ExUrban Undeveloped	0	0	6	14	0.0%	0.0%	0.5%	1.0%
	ExUrban Industrial	0	0	7	7	0.0%	0.0%	0.5%	0.5%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	3	71	62	0.0%	0.2%	5.4%	4.7%
	Totals	**0**	**11**	**104**	**102**	**0.0%**	**0.8%**	**7.9%**	**7.8%**
Transportation									
	Public Road	35	49	49	49	2.6%	3.7%	3.7%	3.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**35**	**49**	**49**	**49**	**2.6%**	**3.7%**	**3.7%**	**3.7%**
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	88	74	0.0%	0.0%	10.0%	8.3%	0.0%	10.0%	-1.7%	8.3%
	Pivot	0	0	0	222	0.0%	0.0%	0.0%	24.9%	0.0%	0.0%	24.9%	24.9%
	Flood	188	100	14	39	18.9%	10.1%	1.6%	4.3%	-8.9%	-8.5%	2.8%	-14.6%
	Totals	**188**	**100**	**102**	**335**	**18.9%**	**10.1%**	**11.6%**	**37.6%**	**-8.9%**	**1.5%**	**26.0%**	**18.6%**

Non-Irrigated												
Multi-Use	767	806	396	366	77.1%	81.0%	44.9%	41.0%	3.9%	-36.1%	-3.9%	-36.1%
Hay/Pasture	39	89	384	191	3.9%	8.9%	43.5%	21.4%	5.0%	34.6%	-22.1%	17.5%
Totals	**806**	**895**	**781**	**557**	**81.1%**	**89.9%**	**88.4%**	**62.4%**	**8.9%**	**-1.5%**	**-26.0%**	**-18.6%**

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.

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	0.0	26.4	34.0	0.0	**60.4**
Acres/Valley Mile	0.0	7.4	9.6	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.

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	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.11	0.06%	0.20	0.00	0.00	0.00

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County	Park	**Upstream River Mile**	539.4
Classification	CM: Confined meandering	**Downstream River Mile**	535
General Location	Big Creek to Six Mile Cr	**Length**	4.40 mi (7.08 km)

General Comments

Narrative Summary

Reach PC6 is 4.4 miles long, extending from the mouth of Big Creek to the mouth of Six Mile Creek. The reach has a fairly narrow riparian corridor and Channel Migration Zone (CMZ), indicating low rates of channel movement. Over two miles of the bankline in Reach PC6 are armored, by both rock riprap (7,371 feet) and flow deflectors (3,278 feet). Over 20 percent of the total bankline in this reach is armored, and all of that armor was in place in 2001. The armor protects both exurban and irrigated lands.

The amount of flood irrigated lands in Reach PC6 has dropped by one half since 1950 (200 acre reduction), and there has been commensurate development into pivot (85 acres) and sprinkler (93 acres) during that time. The overall footprint of agricultural lands within Reach PC6 has dropped by about 500 acres, with 450 of those acres converting to exurban development. About 11 acres of irrigated land in Reach PC6 are within the Channel Migration Zone. As the CMZ is quite narrow in this reach, it indicates that these irrigated lands extend essentially to the streambank. There is one boat ramp on the right bank at RM 536.8.

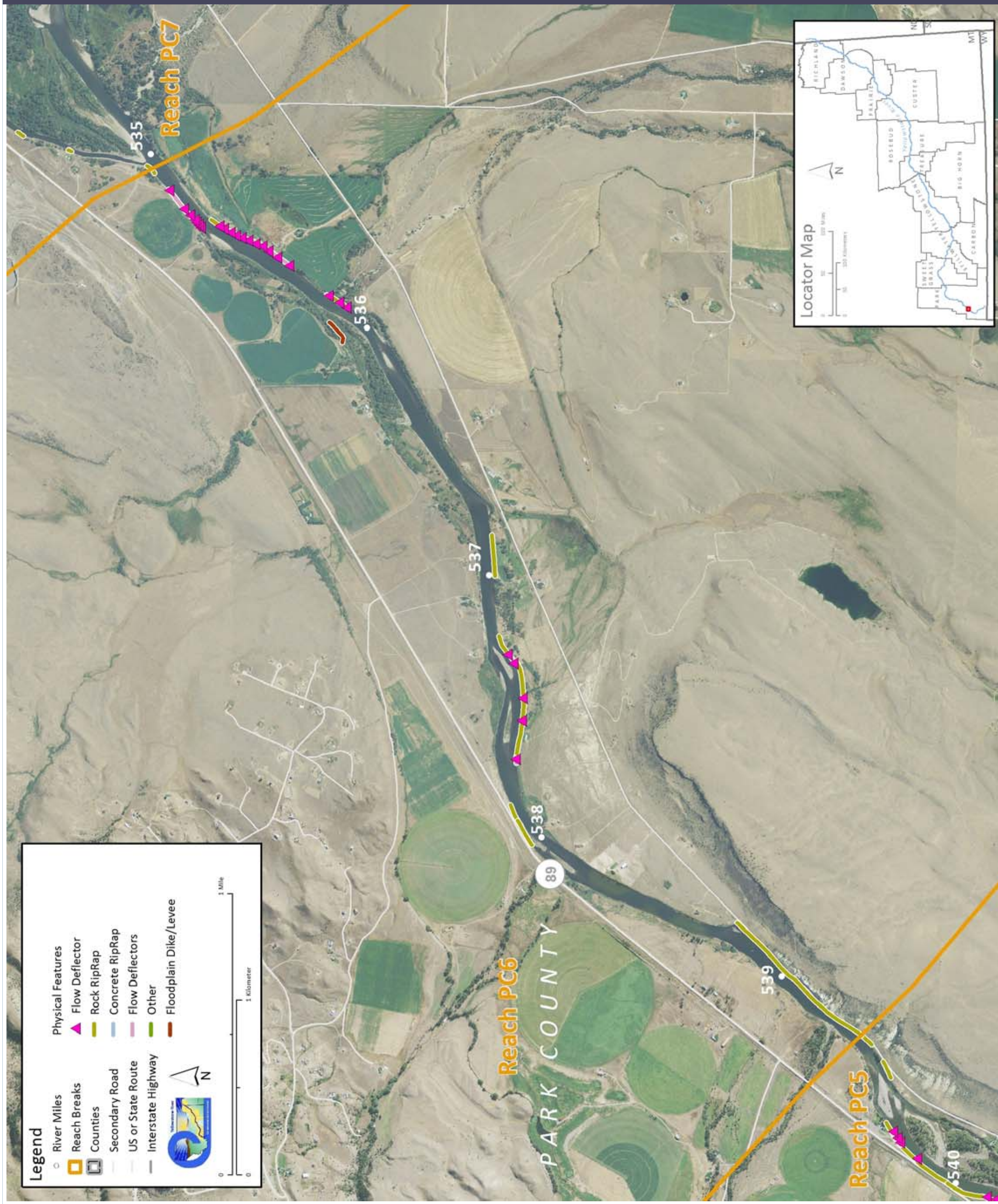
This area of the upper Yellowstone River basin experienced three severe floods in the last 20 years. The largest floods were in 1996 and 1997, when the 32,200 cfs peak flow measured at the Corwin Springs gage exceeded a 100-year flood for those two years in a row. The 1974 and 2011 floods were major as well, with both events exceeding 30,000 cfs. The Corwin Springs gage is located upstream of Reach PC6 at the Corwin Springs Bridge.

A hydrologic evaluation of flow depletions in the reach indicates that flow alterations over the last century have been minimal in this reach. Flow reductions due to human influences are estimated to be less than 2 percent for both high and low flows.

CEA-Related observations in Reach PC6 include:
•Conversion of agricultural land to exurban development
•Agricultural and exurban development close to the active channel within the CMZ

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC6 include:
•CMZ Management due to extensive encroachment of irrigated lands to edge of river.

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): Corwin Springs

Flood History

Year	Date	Flow on Date	Return Interval
1927	Jun 27	25,000	10-25 yr
1971	Jun 23	25,200	10-25 yr
1928	May 26	25,300	10-25 yr
1911	Jun 13	25,800	10-25 yr
2010	Jun 5	26,000	10-25 yr
2011	Jun 30	30,300	50-100 yr
1974	Jun 17	30,900	50-100 yr
1918	Jun 14	32,000	50-100 yr
1997	Jun 6	32,200	>100-yr
1996	Jun 10	32,200	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	28.4	17.8

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,560	19,100	24,000	27,100	33,400	36,000	41,900	1,310	1,760
Regulated	9,500	19,000	23,900	27,000	33,400	36,000	41,900	1,290	1,680
% Change	-0.63%	-0.52%	-0.42%	-0.37%	0.00%	0.00%	0.00%	-1.53%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2009	NAIP	6/27/2009	Color	1-meter pixels	6192500	15200
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	
2013	NAIP	08/15/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

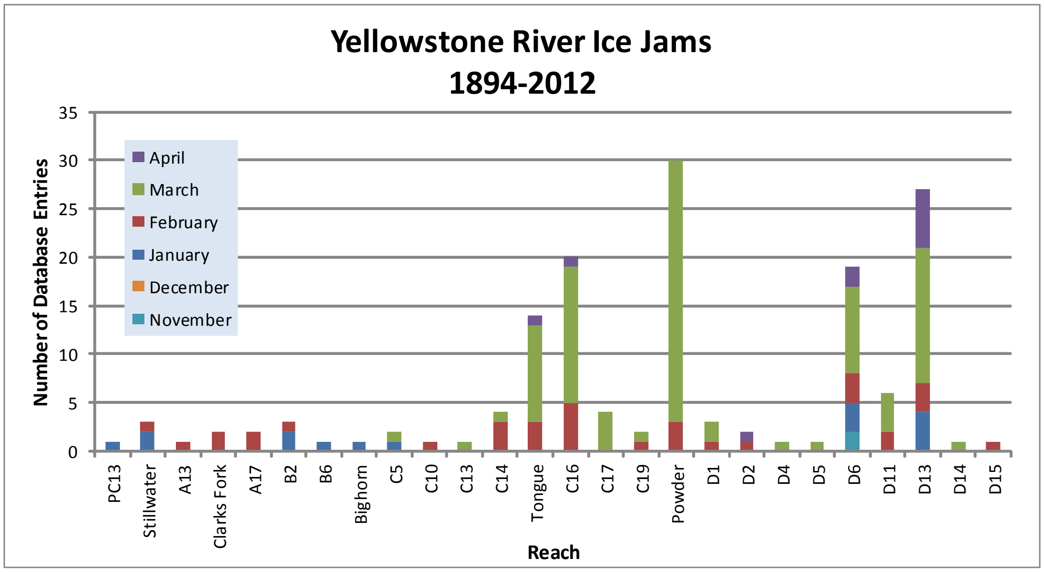
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,371	16.2%	7,371	16.2%	0
	Flow Deflectors	1,685	3.7%	1,685	3.7%	0
	Between Flow Deflectors	1,593	3.5%	1,593	3.5%	0
	Feature Type Totals	**10,649**	**23.4%**	**10,649**	**23.4%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	477	1.1%	477	1.1%	0
	Feature Type Totals	**477**	**1.1%**	**477**	**1.1%**	**0**
	Reach Totals	**11,126**	**24.5%**	**11,126**	**24.5%**	**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	22,711	4,503	1.20	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	22,709	4,579	1.20	1950 to 2001:	0.28%
Change 1950 - 2001	**-2**	**76**	**0.00**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
55	110	275	24	9%	12	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			
	Other Infrastructure	2	0.5%
	Exurban Residential	11	4.0%
RipRap			
	Public Road	2	0.8%
Flow Deflectors			
	Irrigated	8	2.7%
Dike/Levee			
	Non-Irrigated	1	0.4%
	Totals	**24**	**8.4%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
10.6	0.0	0.7	29.0	1.8

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	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	17	68	75	86	1.1%	4.4%	4.9%	5.6%
	Totals	**17**	**68**	**75**	**86**	**1.1%**	**4.4%**	**4.9%**	**5.6%**
Agricultural Land									
	Non-Irrigated	869	800	903	415	56.7%	52.2%	58.9%	27.1%
	Irrigated	409	430	205	355	26.7%	28.1%	13.4%	23.2%
	Totals	**1,278**	**1,230**	**1,107**	**770**	**83.4%**	**80.3%**	**72.3%**	**50.3%**
Channel									
	Channel	192	188	188	188	12.5%	12.3%	12.3%	12.3%
	Totals	**192**	**188**	**188**	**188**	**12.5%**	**12.3%**	**12.3%**	**12.3%**
ExUrban									
	ExUrban Other	0	0	0	3	0.0%	0.0%	0.0%	0.2%
	ExUrban Undeveloped	4	4	16	233	0.3%	0.3%	1.0%	15.2%
	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	104	211	0.0%	0.0%	6.8%	13.7%
	Totals	**4**	**4**	**120**	**446**	**0.3%**	**0.3%**	**7.8%**	**29.1%**
Transportation									
	Public Road	41	42	42	42	2.7%	2.7%	2.7%	2.7%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**41**	**42**	**42**	**42**	**2.7%**	**2.7%**	**2.7%**	**2.7%**
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	93	93	0.0%	0.0%	8.4%	12.0%	0.0%	8.4%	3.7%	12.0%
	Pivot	0	0	49	85	0.0%	0.0%	4.4%	11.0%	0.0%	4.4%	6.6%	11.0%
	Flood	409	430	63	178	32.0%	35.0%	5.7%	23.1%	3.0%	-29.3%	17.4%	-8.9%
	Totals	**409**	**430**	**205**	**355**	**32.0%**	**35.0%**	**18.5%**	**46.1%**	**3.0%**	**-16.5%**	**27.6%**	**14.1%**

Non-Irrigated

Multi-Use	849	761	571	272	66.4%	61.8%	51.6%	35.3%	-4.6%	-10.3%	-16.2%	-31.1%
Hay/Pasture	20	39	332	143	1.6%	3.2%	29.9%	18.6%	1.7%	26.7%	-11.4%	17.0%
Totals	**869**	**800**	**903**	**415**	**68.0%**	**65.0%**	**81.5%**	**53.9%**	**-3.0%**	**16.5%**	**-27.6%**	**-14.1%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.0	62.6	13.6	0.0	**77.2**
Acres/Valley Mile	0.2	15.3	3.3	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.01	0.15%	0.66	0.00	0.00	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Park	**Upstream River Mile**	535
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	529
General Location	Six Mile Cr to Grey Owl	**Length**	6.00 mi (9.66 km)

General Comments

Narrative Summary

Reach PC7 extends from the mouth of Six Mile Creek to the Grey Owl fishing access site. It is six miles long and is classified as a Partially Confined Anabranching (PCA) channel type. This indicates that the reach supports side channels and wooded islands, and intermittently flows along the edge of the stream corridor. The relatively complex reach type is evidenced by the relative broad Channel Migration Zone (CMZ) footprint, which is typically about 1500 to 2500 feet wide in this reach. In comparison, Reach PC6 just upstream has a CMZ that is typically about 500 feet wide. There are a total of 1,171 acres of stream corridor within the CMZ in Reach PC7. About 6 percent of that area has been restricted by bank armor.

Reach PC7 has over 8,800 feet of rock riprap and 550 feet of flow deflectors, which collectively armors about 15 percent of the total bankline. Of those 9,350 feet of armor, about 350 feet were constructed since 2001. Since 1950, one side channel that is 2,950 feet long was blocked by a dike at RM 532. This isolated channel is located just upstream of the Emigrant Bridge on the east floodplain, and has been identified as a potential side channel restoration area. In the upstream portion of the reach at RM 534, the Park Branch Canal diverts water from a long side channel that has been active since at least the 1950s.

Land use conversions in Reach PC7 have seen a reduction in flood irrigation that has been accompanied by about 67 acres of development of sprinkler and pivot irrigation systems. That said, this reach has experienced major exurban growth, from 0 acres in 1950 to 298 acres in 2011. Most of that growth reflects rural subdivision development on the glacial outwash terraces above the active stream corridor. There is one boat ramp on the right bank just above the Emigrant Bridge at the Emigrant Fishing Access Site, and just below the bridge, there is a ~72 acre fishing access site without boating facilities on the west side of the river (Emigrant West).

Reach PC7 contains over 200 acres of emergent wetlands, many of which appear to be associated with groundwater seepage from the base of the glacial terraces on the east side of the river, and ditch seepage on the west side of the river. These areas tend to be utilized as non-irrigated hay/pasture ground.

About 1.5 acres of Russian olive have been mapped in Reach PC7, which is a dramatic increase relative to upstream reaches.

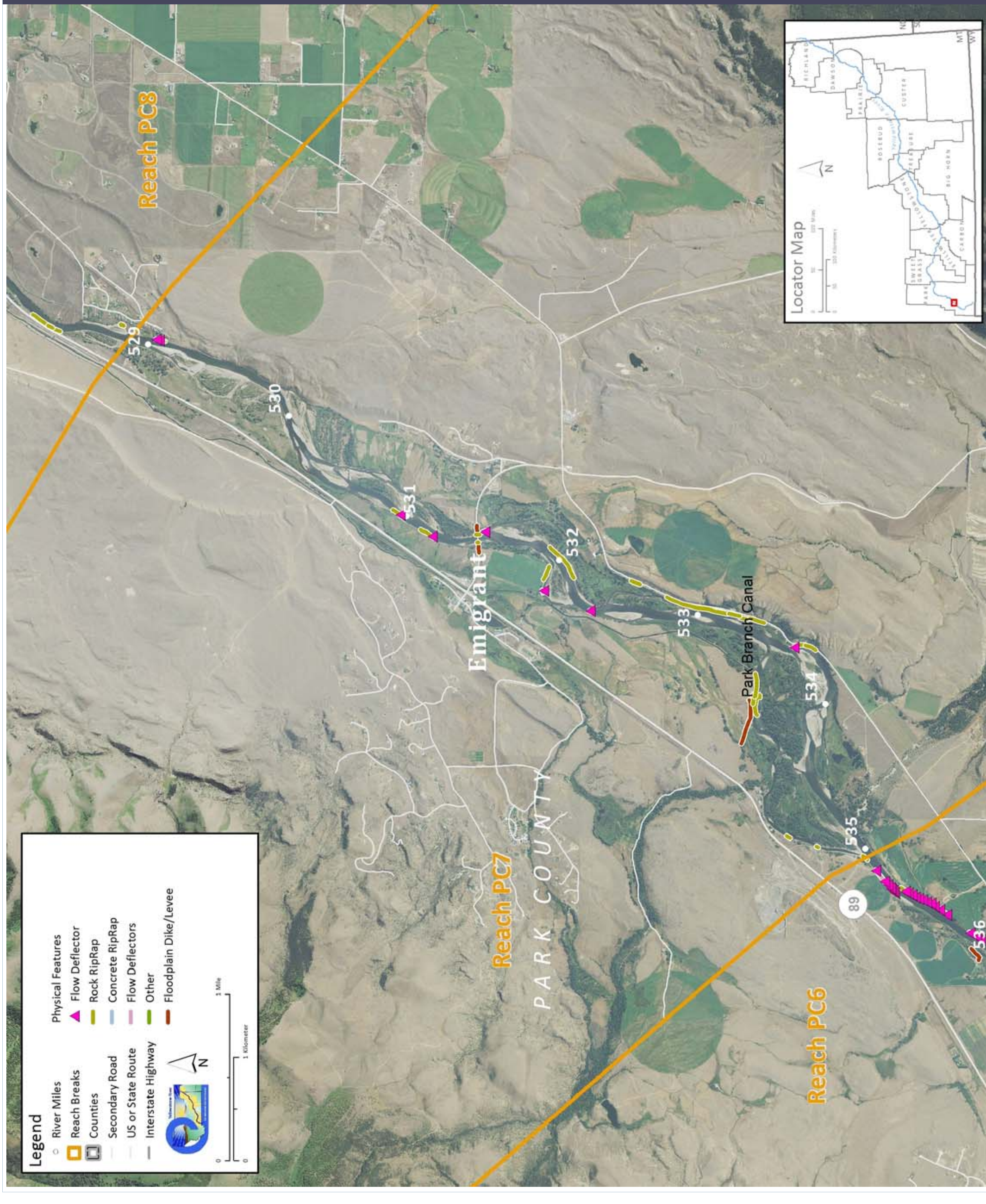
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,340 cfs to 1,320 cfs with human development, a reduction of 1.5 percent.

CEA-Related observations in Reach PC7 include:
•Conversion of agricultural land to exurban development
•Post-1950s side channel blockage with identified restoration potential
•Sharp increase in Russian olive extent relative to upstream reaches

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC7 include:
•Side Channel Restoration at RM 532R.
•Diversion Infrastructure Management at Park Branch Canal, RM 535.5
•Russian olive removal

PHYSICAL FEATURES MAP (2011)



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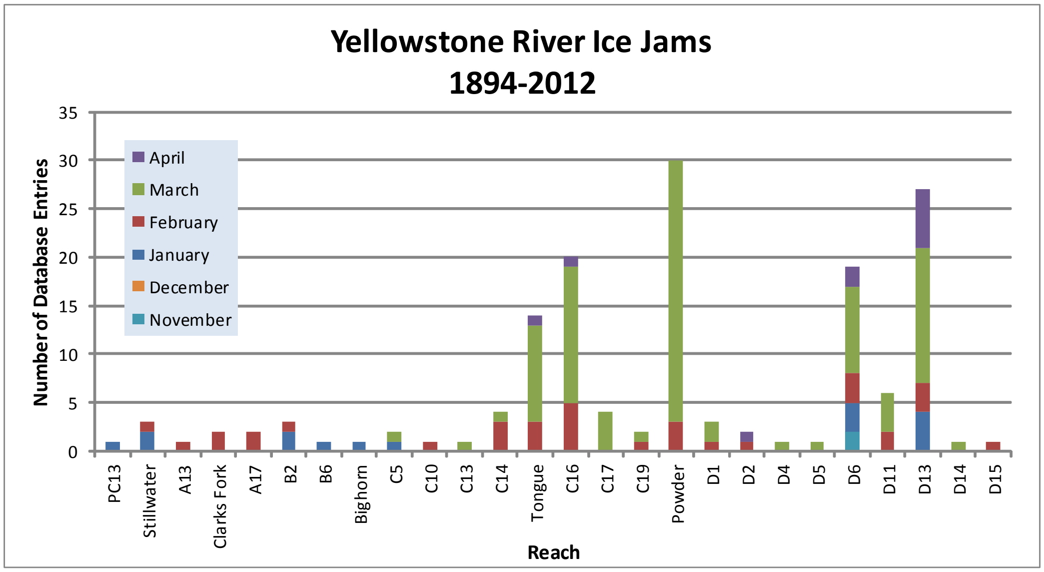
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

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	8,540	13.1%	8,841	13.6%	301
	Flow Deflectors	502	0.8%	556	0.9%	54
	Feature Type Totals	**9,042**	**13.9%**	**9,396**	**14.4%**	**355**
Floodplain Control						
	Floodplain Dike/Levee	2,005	3.1%	2,005	3.1%	0
	Feature Type Totals	**2,005**	**3.1%**	**2,005**	**3.1%**	**0**
	Reach Totals	**11,047**	**17.0%**	**11,401**	**17.5%**	**355**

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	34,130	29,472	1.86	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	32,556	41,507	2.27	1950 to 2001:	22.08%
Change 1950 - 2001	**-1,574**	**12,035**	**0.41**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	2,950

HYDRAULICS

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

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

Floodplain Isolation

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

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
194	388	1,171	74	6%	39	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			
	Public Road	0	0.0%
RipRap			
	Non-Irrigated	36	2.9%
	Irrigated	6	0.5%
	Exurban Undevelope	0	0.0%
	Exurban Residential	2	0.2%
	Canal	18	1.5%
Dike/Levee			
	Public Road	12	1.0%
	Totals	**74**	**6.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
10.0	11.6	0.0	16.0	3.5

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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011
Agricultural Infrastructure									
	Canal	33	33	33	33	1.2%	1.2%	1.2%	1.2%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	28	54	49	62	1.0%	2.0%	1.8%	2.3%
	Totals	**61**	**87**	**82**	**95**	**2.2%**	**3.2%**	**3.0%**	**3.5%**
Agricultural Land									
	Non-Irrigated	1,487	1,430	1,282	1,271	54.5%	52.4%	47.0%	46.6%
	Irrigated	415	315	265	237	15.2%	11.6%	9.7%	8.7%
	Totals	**1,902**	**1,746**	**1,547**	**1,509**	**69.7%**	**64.0%**	**56.7%**	**55.3%**
Channel									
	Channel	701	721	766	767	25.7%	26.5%	28.1%	28.1%
	Totals	**701**	**721**	**766**	**767**	**25.7%**	**26.5%**	**28.1%**	**28.1%**
ExUrban									
	ExUrban Other	0	1	3	3	0.0%	0.1%	0.1%	0.1%
	ExUrban Undeveloped	3	0	5	13	0.1%	0.0%	0.2%	0.5%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	21	30	30	0.0%	0.8%	1.1%	1.1%
	ExUrban Residential	22	94	236	251	0.8%	3.4%	8.7%	9.2%
	Totals	**25**	**116**	**274**	**298**	**0.9%**	**4.3%**	**10.0%**	**10.9%**
Transportation									
	Public Road	39	57	59	59	1.4%	2.1%	2.1%	2.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**39**	**57**	**59**	**59**	**1.4%**	**2.1%**	**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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	50	50	0.0%	0.0%	3.3%	3.3%	0.0%	3.3%	0.1%	3.3%
	Pivot	0	0	0	17	0.0%	0.0%	0.0%	1.1%	0.0%	0.0%	1.1%	1.1%
	Flood	415	315	214	170	21.8%	18.1%	13.9%	11.3%	-3.7%	-4.2%	-2.6%	-10.5%
	Totals	**415**	**315**	**265**	**237**	**21.8%**	**18.1%**	**17.1%**	**15.7%**	**-3.7%**	**-0.9%**	**-1.4%**	**-6.1%**

Non-Irrigated												
Multi-Use	928	1,373	1,116	1,088	48.8%	78.6%	72.1%	72.1%	29.8%	-6.5%	0.0%	23.3%
Hay/Pasture	559	57	167	184	29.4%	3.3%	10.8%	12.2%	-26.1%	7.5%	1.4%	-17.2%
Totals	**1,487**	**1,430**	**1,282**	**1,271**	**78.2%**	**81.9%**	**82.9%**	**84.3%**	**3.7%**	**0.9%**	**1.4%**	**6.1%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	12.1	203.9	112.5	0.0	**328.5**
Acres/Valley Mile	2.1	36.0	19.9	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	1.47	0.16%	0.81	0.15	0.14	0.02

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Park	**Upstream River Mile**	529
Classification	CM: Confined meandering	**Downstream River Mile**	516.3
General Location	Grey Owl to just below Mallard's Rest	**Length**	12.70 mi (20.44 km)

General Comments

Narrative Summary

Reach PC8 extends from the Grey Owl fishing access site to just below Mallard's Rest. It is almost 13 miles long and is classified as confined meandering, indicating that it has somewhat of a sinuous planform but is largely confined by older terraces or bedrock. This is a remarkably stable reach that shows little evidence of channel migration. Even though migration rates are low, approximately 8 percent of the bankline has been armored by 7,500 feet of rock riprap and 2,760 feet of flow deflectors. About 3,200 feet of that armor was constructed since 2001.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased proportionately. There has also been a major expansion of exurban land uses in the reach from 14 acres in 1950 to 1,433 acres in 2011. By comparison, 220 acres are in flood, 170 acres in sprinkler, and 1,014 acres in pivot irrigation. The relative expansion of pivot irrigation in this reach is large compared to the rest of the Paradise Valley. About 30 acres of irrigated land are located within the Channel Migration Zone, and 14 of those are under pivot. In one case (RM 519.5) a pivot occupies the entire core of a meander bend.

The popularity of recreational fishing in this reach is exemplified by the seven boat ramps identified in this 13 mile stretch of river. Fishing Access Sites in this reach include Grey Owl, Paradise, Lock Leven, and Mallard's Rest.

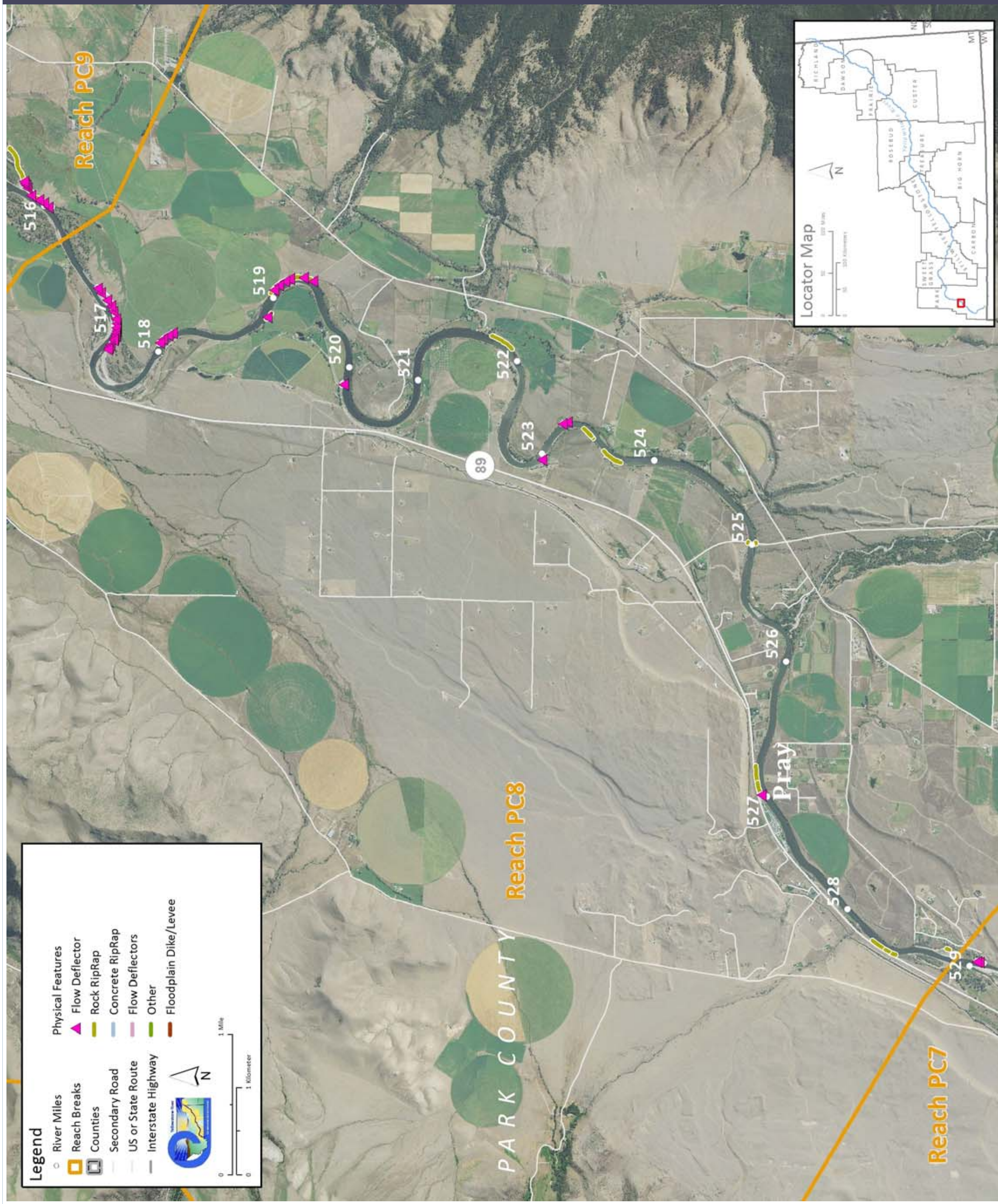
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,470 cfs to 1,430 cfs with human development, a reduction of 2.7 percent.

CEA-Related observations in Reach PC8 include:
•Major expansion from flood irrigation to pivot
•Conversion of agricultural land to exurban development
•Extensive armoring in naturally stable reach

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC8 include:
•Channel Migration Zone (CMZ) management

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6192500	1619500
Location	Livingston	
Period of Record	1929-2015	
Distance To (miles)	9.7	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,820	19,500	24,600	27,800	34,200	36,800	42,800	1,470	1,760
Regulated	9,760	19,400	24,500	27,700	34,100	36,800	42,800	1,430	1,680
% Change	-0.61%	-0.51%	-0.41%	-0.36%	-0.29%	0.00%	0.00%	-2.72%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/28/2005	color	1-meter pixels	6192500	2210
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2009	NAIP	7/22/2009	Color	1-meter pixels	6192500	6990
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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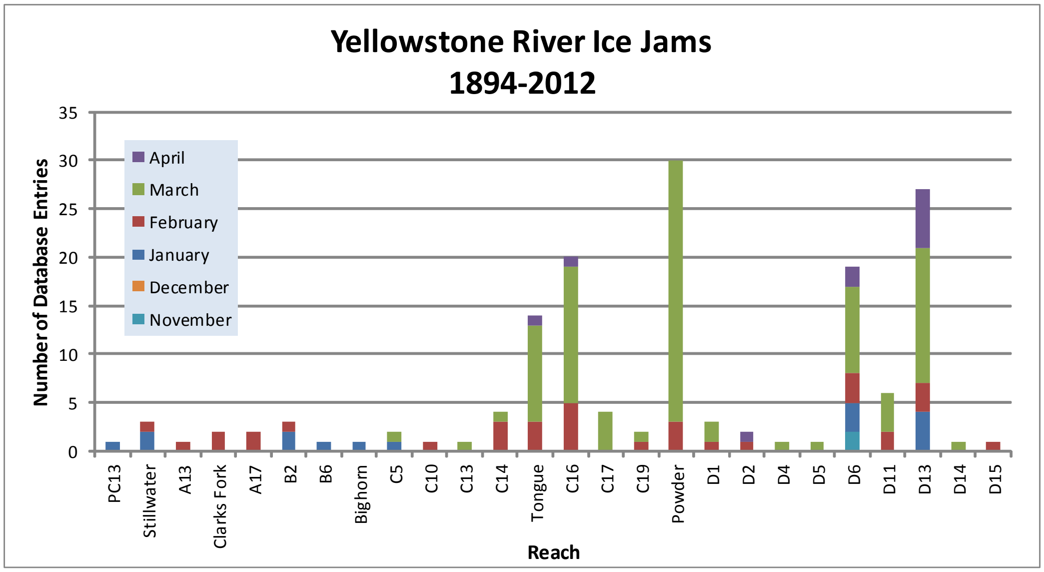
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

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	4,458	3.3%	7,494	5.6%	3,036
	Flow Deflectors	1,560	1.2%	1,603	1.2%	42
	Between Flow Deflectors	1,034	0.8%	1,155	0.9%	121
	Feature Type Totals	**7,052**	**5.3%**	**10,251**	**7.7%**	**3,199**
	Reach Totals	**7,052**	**5.3%**	**10,251**	**7.7%**	**3,199**

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.



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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	66,249	3,175	1.05	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	66,558	3,657	1.05	1950 to 2001:	0.67%
Change 1950 - 2001	**309**	**482**	**0.01**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
75	150	765	14	2%	39	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Non-Irrigated	2	0.2%
RipRap			
	Public Road	6	0.7%
Flow Deflectors			
	Non-Irrigated	4	0.5%
	Irrigated	2	0.3%
	Exurban Residential	1	0.1%
	Totals	**14**	**1.8%**

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

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
11.3	5.1	14.0	101.0	2.7

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	41	41	41	41	0.8%	0.8%	0.8%	0.8%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	32	60	61	59	0.6%	1.2%	1.2%	1.2%
	Totals	**73**	**101**	**102**	**100**	**1.5%**	**2.0%**	**2.1%**	**2.0%**
Agricultural Land									
	Non-Irrigated	2,966	3,114	1,985	1,432	59.9%	62.9%	40.1%	28.9%
	Irrigated	1,369	978	1,436	1,407	27.7%	19.8%	29.0%	28.4%
	Totals	**4,335**	**4,092**	**3,421**	**2,838**	**87.6%**	**82.7%**	**69.1%**	**57.3%**
Channel									
	Channel	511	493	510	511	10.3%	10.0%	10.3%	10.3%
	Totals	**511**	**493**	**510**	**511**	**10.3%**	**10.0%**	**10.3%**	**10.3%**
ExUrban									
	ExUrban Other	0	36	39	39	0.0%	0.7%	0.8%	0.8%
	ExUrban Undeveloped	0	0	68	416	0.0%	0.0%	1.4%	8.4%
	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	14	164	743	978	0.3%	3.3%	15.0%	19.8%
	Totals	**14**	**200**	**850**	**1,433**	**0.3%**	**4.0%**	**17.2%**	**29.0%**
Transportation									
	Public Road	17	63	64	64	0.3%	1.3%	1.3%	1.3%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**17**	**63**	**64**	**64**	**0.3%**	**1.3%**	**1.3%**	**1.3%**
Urban									
	Urban Other	0	2	2	3	0.0%	0.0%	0.0%	0.1%
	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**	**2**	**2**	**3**	**0.0%**	**0.0%**	**0.0%**	**0.1%**

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	110	171	0.0%	0.0%	3.2%	6.0%	0.0%	3.2%	2.8%	6.0%
	Pivot	0	0	760	1,014	0.0%	0.0%	22.2%	35.7%	0.0%	22.2%	13.5%	35.7%
	Flood	1,369	978	566	221	31.6%	23.9%	16.5%	7.8%	-7.7%	-7.4%	-8.8%	-23.8%
	Totals	**1,369**	**978**	**1,436**	**1,407**	**31.6%**	**23.9%**	**42.0%**	**49.6%**	**-7.7%**	**18.1%**	**7.6%**	**18.0%**

Non-Irrigated

Multi-Use	2,863	2,626	1,663	1,361	66.0%	64.2%	48.6%	48.0%	-1.9%	-15.6%	-0.6%	-18.1%
Hay/Pasture	103	488	322	70	2.4%	11.9%	9.4%	2.5%	9.6%	-2.5%	-6.9%	0.1%
Totals	**2,966**	**3,114**	**1,985**	**1,432**	**68.4%**	**76.1%**	**58.0%**	**50.4%**	**7.7%**	**-18.1%**	**-7.6%**	**-18.0%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	3.3	43.2	1.6	0.0	**48.1**
Acres/Valley Mile	0.3	4.5	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	0.67	0.28%	2.26	0.01	0.12	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Park	**Upstream River Mile**	516.3
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	514.6
General Location	To Pine Creek	**Length**	1.70 mi (2.74 km)

General Comments

Narrative Summary

Reach PC9 extends from just below Mallard's Rest to Pine Creek. It is a partially confined anabranching reach type, indicating that it has side channels and wooded islands with some valley wall influence. Reach PC9 is one of the shortest reaches in the CEA study at 1.7 miles. It is a short, fairly anomalous section of river that extends upstream from the mouth of Pine Creek and Pine Creek Bridge. This reach is anomalous because of its rates of change over the past 20 years. This includes sediment deposition, severe bank erosion and avulsions. The reach is located just upstream of a "pinch point" in the valley that is created by a glacial outwash terrace on the west bank and the Pine Creek outwash fan on the right bank. The Pine Creek Bridge was built on this pinch point, which is a stable bridge location. Because of the constriction at the bridge, however, sediment transport patterns appear interrupted which has caused sediment deposition and unstable channel dynamics upstream. Much of this erosion appears to have happened between 1991 and 2005, suggesting that the 1996 and 1997 floods drove substantial channel change.

Reach PC9 showed an increase in bankfull channel area of over 30 acres between 1950 and 2001, which may reflect the impact of the 1996/1997 floods on channel form. Air photos from as recently as 1991 show a broad expanse of forested islands, whereas the 2005 and 2011 imagery show extensive open bars and active bank erosion. In places, erosion into islands since 1991 has exceeded 500 feet. This has been accompanied by an increase in side channel length of almost 7,000 feet in the reach as islands have been eroded and dissected.

In 2011, almost 3,000 feet of rock riprap lined the banks in Reach PC9, as well as 677 feet of flow deflectors. This represents almost 20 percent of the total bankline in the reach.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased somewhat proportionately. Exurban land uses in the reach have expanded from 0 acres in 1950 to 82 acres in 2011, and all of that development is on the east side of the river just upstream of Pine Creek Bridge. The dominant land use remains agriculture, however, with 27 acres in flood irrigation, 142 acres in sprinkler, and 93 acres in pivot. Another 300 acres are in non-irrigated agriculture. There are almost 100 acres of emergent wetlands in Reach PC9, reflecting a large wet meadow complex on the southeast side of the river.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,520 cfs to 1,470 cfs with human development, a reduction of 3.9 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC9 include:
•Major post-1995 changes in channel geomorphology upstream of natural constriction point.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC9 include:
•Channel Migration Zone (CMZ) management

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	8.0	40.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,820	19,500	24,600	27,800	34,200	36,800	42,800	1,520	1,760
Regulated	9,760	19,400	24,500	27,700	34,100	36,800	42,800	1,470	1,680
% Change	-0.61%	-0.51%	-0.41%	-0.36%	-0.29%	0.00%	0.00%	-3.29%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

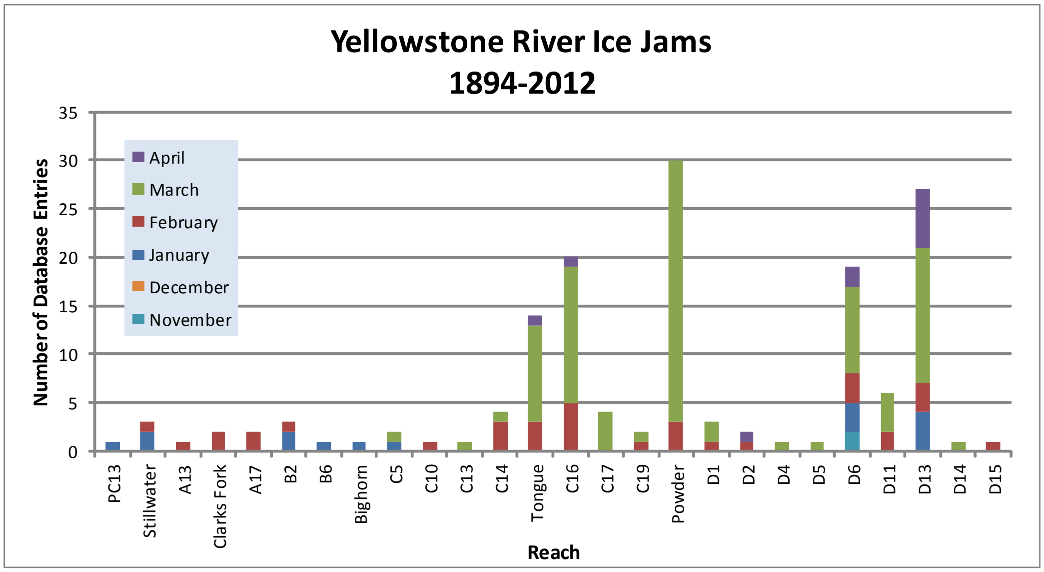
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,740	13.6%	2,894	14.4%	154
	Flow Deflectors	599	3.0%	599	3.0%	0
	Between Flow Deflectors	157	0.8%	79	0.4%	-79
	Feature Type Totals	**3,495**	**17.4%**	**3,571**	**17.7%**	**75**
	Reach Totals	**3,495**	**17.4%**	**3,571**	**17.7%**	**75**

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	11,280	10,502	1.93	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	10,061	17,176	2.71	1950 to 2001:	40.20%
Change 1950 - 2001	**-1,219**	**6,674**	**0.78**		

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.

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

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
183	365	341	36	10%	26	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			
	Non-Irrigated	33	8.9%
RipRap			
	Public Road	1	0.4%
	Exurban Residential	3	0.8%
Flow Deflectors			
	Other Infrastructure	3	0.8%
	Totals	**40**	**11.0%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.9	2.7	0.0	11.3	0.6

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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	4	20	43	39	0.4%	2.0%	4.4%	4.1%
	Totals	**4**	**20**	**43**	**39**	**0.4%**	**2.0%**	**4.4%**	**4.1%**
Agricultural Land									
	Non-Irrigated	558	422	268	353	57.6%	43.6%	27.7%	36.4%
	Irrigated	198	296	358	263	20.4%	30.6%	36.9%	27.1%
	Totals	**757**	**718**	**627**	**615**	**78.1%**	**74.1%**	**64.6%**	**63.5%**
Channel									
	Channel	204	227	229	229	21.0%	23.4%	23.6%	23.6%
	Totals	**204**	**227**	**229**	**229**	**21.0%**	**23.4%**	**23.6%**	**23.6%**
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	67	82	0.0%	0.0%	6.9%	8.4%
	Totals	**0**	**0**	**67**	**82**	**0.0%**	**0.0%**	**6.9%**	**8.4%**
Transportation									
	Public Road	5	5	4	4	0.5%	0.5%	0.4%	0.4%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**5**	**5**	**4**	**4**	**0.5%**	**0.5%**	**0.4%**	**0.4%**
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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	211	142	0.0%	0.0%	33.6%	23.1%	0.0%	33.6%	-10.5%	23.1%
	Pivot	0	0	30	93	0.0%	0.0%	4.8%	15.2%	0.0%	4.8%	10.3%	15.2%
	Flood	198	296	117	27	26.2%	41.2%	18.7%	4.4%	15.0%	-22.5%	-14.4%	-21.8%
	Totals	**198**	**296**	**358**	**263**	**26.2%**	**41.2%**	**57.2%**	**42.7%**	**15.0%**	**15.9%**	**-14.5%**	**16.5%**

Non-Irrigated												
Multi-Use	557	403	206	145	73.7%	56.2%	32.8%	23.6%	-17.5%	-23.3%	-9.3%	-50.1%
Hay/Pasture	1	19	63	208	0.2%	2.6%	10.0%	33.8%	2.4%	7.4%	23.8%	33.6%
Totals	**558**	**422**	**268**	**353**	**73.8%**	**58.8%**	**42.8%**	**57.3%**	**-15.0%**	**-15.9%**	**14.5%**	**-16.5%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.1	94.8	17.7	0.0	**113.6**
Acres/Valley Mile	0.6	55.2	10.3	0.0	

RUSSIAN OLIVE

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

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

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

	Floodplain Area (Ac)	% of Floodplain	Other Area (Ac)	Inside RMA (Ac)	Inside '50s Channel (Ac)	Inside 50s Island (Ac)
Russian Olive in Reach	0.12	0.18%	0.65	0.00	0.01	0.01

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

Yellowstone River Reach Narratives

Reach PC10

County	Park	**Upstream River Mile**	514.6
Classification	PCM: Partially confined meandering	**Downstream River Mile**	511
General Location	To downstream of Deep Creek; Weeping wall, Jumpin	**Length**	3.60 mi (5.79 km)

General Comments

Narrative Summary

Reach PC10 is extends from the Pine Creek Bridge to below the mouth of Deep Creek. The reach is approximately 3.5 miles long, extending from RM 511.0 to RM 514.5. This is an especially unique section of the Yellowstone River where spring creeks that parallel the channel support a nationally recognized cold water fishery. The reach is also semi-confined by very coarse grained glacial alluvial terraces. Sediment recruitment from the terraces drives bar formation, resulting in locally rapid bank migration, and in some cases, threats to the spring creeks. This was exemplified during the 1996/1997 floods, when the river migrated tens of feet into high glacial terraces, delivering vast amounts of gravel to the channel. At one location near the Deep Creek confluence, a home on a ~30 foot high glacial terrace was undermined and deliberately burnt down to prevent its collapse into the river. Just downstream of this site, rapid point bar growth drove westward channel migration towards a prized spring creek, which created a real risk of Yellowstone River avulsion into that channel. Efforts to prevent an avulsion included sediment removal from the rapidly enlarging point bar, bank protection, and construction of a long floodplain dike between the spring creek and the river. This single bendway experienced approximately 750 feet of migration between 1948 and 1999, which translates to an average migration rate of 14.7 feet per year.

Approximately 14 percent of the bankline is armored, primarily by rock riprap (3,753 feet) and flow deflectors (1,197 feet). Between 2001 and 2011, the net length of bank armor increased by 1,037 feet, although 50 feet of flow deflectors were eroded out during that time. There are also over two miles of floodplain dikes in the reach, most of which run parallel to the river to isolate the spring creeks. Several thousand feet of side channels have been blocked in Reach PC10; one large channel that was blocked prior to 1950 extends downstream for several thousand feet into Reach PC11. There is a high concentration of emergent wetlands in these abandoned side channels.

The total bankfull channel area in Reach PC10 increased from 151 acres in 1950 to 191 acres in 2001, suggesting channel enlargement, either due to floods or flow concentrations in the main channel due to side channel loss and diking.

Land uses in Reach PC10 include irrigated ground, multi-use (non-irrigated and undeveloped), and exurban residential development. Whereas in 1950 there were 512 acres under flood irrigation, by 2011 that had been reduced to 17 acres. The expansion of irrigation during that time included 136 acres of sprinkler, and another 56 acres of pivot irrigation. Most of the land, over 900 acres, is used as non-irrigated agricultural land. There has also been about 180 acres of exurban development in Reach PC10, much of which is part of the Jumping Rainbow Ranch downstream of Deep Creek. Some of this development, such as the location of the house that was undermined in 1997, is in the Channel Migration Zone. In the upstream portion the reach, a gravel pit on a large point bar (RM 513.8) encroaches into the Channel Migration Zone. Because of the extensive levee construction in the reach to protect spring creeks, 38 percent of the CMZ has been restricted from the natural CMZ footprint. The reach is very popular for recreational boating and fishing; the Pine Creek Fishing Access Site is located just below the Pine Creek Bridge on the left bank.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,530 cfs to 1,480 cfs with human development, a reduction of 3.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC10 include:
•Extensive dike construction Floodplain dikes constructed to protect spring creek fisheries have narrowed the active meander corridor
•Exurban encroachment into the Channel Migration Zone (CMZ) has occurred on terrace surfaces
•Gravel pit and recreational pond development in a meander core may contribute to avulsion risk in the reach.
•Rapid dike construction and armoring following major flooding (1996/1997).
•Increase in primary channel length (sinuosity) with loss of side channels.
•Isolation of 38 percent of the CMZ, mostly avulsion hazard areas that support spring creeks.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC10 include:
•Selective side channel restoration at RM 511.5 (may be difficult to reactivate side channels without affecting developed spring creek fishery
•CMZ Management due to current restriction of 38 percent of the Channel Migration Zone

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6192500	6191500
Location	Livingston	Corwin Springs
Period of Record	1929-2015	1890-2012
Distance To (miles)	4.4	42.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,820	19,500	24,600	27,800	34,200	36,800	42,800	1,530	1,760
Regulated	9,760	19,400	24,500	27,700	34,100	36,800	42,800	1,480	1,680
% Change	-0.61%	-0.51%	-0.41%	-0.36%	-0.29%	0.00%	0.00%	-3.27%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

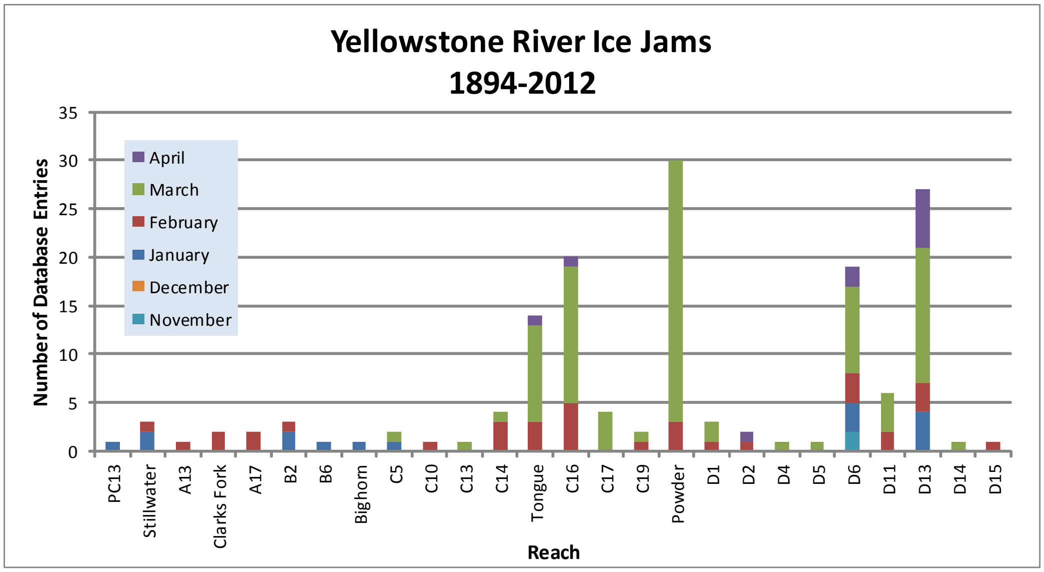
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	2,667	7.3%	3,754	10.3%	1,086
	Flow Deflectors	768	2.1%	674	1.8%	-94
	Between Flow Deflectors	478	1.3%	522	1.4%	44
	Feature Type Totals	**3,914**	**10.7%**	**4,950**	**13.5%**	**1,037**
Floodplain Control						
	Floodplain Dike/Levee	12,431	34.0%	12,431	34.0%	0
	Feature Type Totals	**12,431**	**34.0%**	**12,431**	**34.0%**	**0**
	Reach Totals	**16,344**	**44.7%**	**17,381**	**47.5%**	**1,037**

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	16,592	7,240	1.44	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	18,301	1,489	1.08	1950 to 2001:	-24.71%
Change 1950 - 2001	**1,710**	**-5,751**	**-0.35**		

Length of Side Channels Blocked

Pre-1950s (ft)	7,000
Post-1950s (ft)	1,454

HYDRAULICS

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

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

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

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
235	469	465	94	20%	201	159	79%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Flow Deflectors			
	Non-Irrigated	6	0.9%
Dike/Levee			
	Non-Irrigated	247	37.0%
	Totals	**253**	**37.9%**

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

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
0.0	27.5	0.0	19.9	0.3

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	49	62	55	2.0%	3.2%	4.1%	3.6%
	Totals	**31**	**49**	**62**	**55**	**2.0%**	**3.2%**	**4.1%**	**3.6%**
Agricultural Land									
	Non-Irrigated	817	864	895	852	53.6%	56.7%	58.7%	55.9%
	Irrigated	512	425	190	209	33.6%	27.9%	12.5%	13.7%
	Totals	**1,330**	**1,289**	**1,085**	**1,061**	**87.2%**	**84.5%**	**71.2%**	**69.6%**
Channel									
	Channel	163	186	214	229	10.7%	12.2%	14.0%	15.0%
	Totals	**163**	**186**	**214**	**229**	**10.7%**	**12.2%**	**14.0%**	**15.0%**
ExUrban									
	ExUrban Other	0	0	2	2	0.0%	0.0%	0.1%	0.1%
	ExUrban Undeveloped	0	0	72	0	0.0%	0.0%	4.7%	0.0%
	ExUrban Industrial	0	0	11	11	0.0%	0.0%	0.7%	0.7%
	ExUrban Commercial	0	0	16	16	0.0%	0.0%	1.0%	1.0%
	ExUrban Residential	0	0	62	150	0.0%	0.0%	4.1%	9.9%
	Totals	**0**	**0**	**163**	**179**	**0.0%**	**0.0%**	**10.7%**	**11.7%**
Transportation									
	Public Road	1	1	1	1	0.1%	0.1%	0.1%	0.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**1**	**1**	**1**	**1**	**0.1%**	**0.1%**	**0.1%**	**0.1%**
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	56	136	0.0%	0.0%	5.1%	12.8%	0.0%	5.1%	7.7%	12.8%
	Pivot	0	100	37	56	0.0%	7.8%	3.4%	5.3%	7.8%	-4.4%	1.9%	5.3%
	Flood	512	325	97	17	38.5%	25.2%	9.0%	1.6%	-13.3%	-16.2%	-7.4%	-36.9%
	Totals	**512**	**425**	**190**	**209**	**38.5%**	**33.0%**	**17.5%**	**19.7%**	**-5.6%**	**-15.5%**	**2.2%**	**-18.8%**

Non-Irrigated

Multi-Use	706	767	613	521	53.1%	59.5%	56.5%	49.1%	6.4%	-3.0%	-7.4%	-4.0%
Hay/Pasture	112	97	282	331	8.4%	7.5%	26.0%	31.2%	-0.9%	18.5%	5.2%	22.8%
Totals	**817**	**864**	**895**	**852**	**61.5%**	**67.0%**	**82.5%**	**80.3%**	**5.6%**	**15.5%**	**-2.2%**	**18.8%**

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.

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	22.5	165.1	49.1	0.0	**236.7**
Acres/Valley Mile	9.7	71.2	21.1	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	0.14	0.25%	1.46	0.02	0.01	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Park	**Upstream River Mile**	511
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	508.7
General Location	To near Suce Cr, Wineglass Mtn to west	**Length**	2.30 mi (3.70 km)

General Comments

Narrative Summary

Reach PC11 is located in the Paradise Valley downstream of Deep Creek, and consists of a Partially Confined Anabranching (PCA) reach type, reflected by multiple channels separated by wooded islands, and local abutment of the channel against low glacial terraces. Long floodplain dikes and bank armor installations have isolated natural migration and avulsion areas from the active channel corridor. These dikes and levees narrow the corridor significantly in the downstream direction; whereas in the upper portions of Reach PC11 the active corridor is approximately 2,000 feet wide, it is narrowed approximately 400 feet by floodplain dikes and bank armor at the downstream boundary of Reach PC11.

Some of the most significant impacts to Reach PC11 occurred prior to 1950. This includes the isolation of a major anabranching channel on the east side of the river that has been improved as a spring creek. The dike blocking this channel is located at its upper end in Reach PC10; within Reach PC11this channel is over a mile long.

Although many of the impacts to Reach PC11 occurred prior to 1950, one dike isolated a channel more recently. This 1/4 mile long channel to the west of the main river was blocked off between 1988 and 1991. Within Reach PC11, several channels that have historically been relatively connected to the active river are now largely isolated, forming spring creeks on each side of the river that run parallel to the river for miles. Continual improvements on these spring creeks are evident on the air photos, including original development efforts that included deepening and widening the relic Yellowstone River channels, and re-routing these channels to lengthen them as they parallel the main thread. On the west side of the river, a lengthened spring creek is separated from the river by over a mile of floodplain dike in Reach PC11 alone.

Approximately 35 percent of the bankline in Reach PC11 is armored by Rock Riprap (8,645 feet), and another 8 percent of the bank is protected by flow deflectors (2,047 feet). Approximately 6,900 feet of floodplain dikes protect the spring creek on the west side of the corridor from Yellowstone River overflows. Armor, dikes, and levees have isolated 26 percent of the natural Channel Migration Zone.

Since 1950 the main channel has increased length by approximately 10 percent or 1,200 feet. This trend is common in reaches where side channels have been lost and the main thread has more consolidated flow. The bankfull footprint has grown by 40 acres since 1950, which may reflect main channel expansion due to side channel loss.

Similar to other reaches in Park County, the extent of flood irrigation has dropped in the reach since 1950, and the amount of sprinkler and pivot irrigation has increased. The dominant land use remains agriculture, however, with 139 acres in flood irrigation, 102 acres in sprinkler, and 80 acres in pivot. Another 600 acres are in non-irrigated agriculture. There are almost 80 acres of emergent wetlands in Reach PC10, reflecting a large wet meadow complex across the river from the mouth of Deep Creek.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,550 cfs to 1,500 cfs with human development, a reduction of 3.2 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC11 include:
•Channel Migration Zone restrictions by floodplain dikes and bank armor causing simplification.
•Loss of side channel connectivity due to floodplain dikes and bank armor causing simplification.
•Increase in primary channel length with reduction in side channel length.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC11 include:
•Selective side channel restoration at RM 510L (may be difficult to reactivate side channels without affecting developed spring creek fishery
•CMZ Management due to current restriction of 26 percent of the Channel Migration Zone

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6192500	1619500
Location	Livingston	
Period of Record	1929-2015	
Distance To (miles)	2.1	

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	9,820	19,500	24,600	27,800	34,200	36,800	42,800	1,550	1,760
Regulated	9,760	19,400	24,500	27,700	34,100	36,800	42,800	1,500	1,680
% Change	-0.61%	-0.51%	-0.41%	-0.36%	-0.29%	0.00%	0.00%	-3.23%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

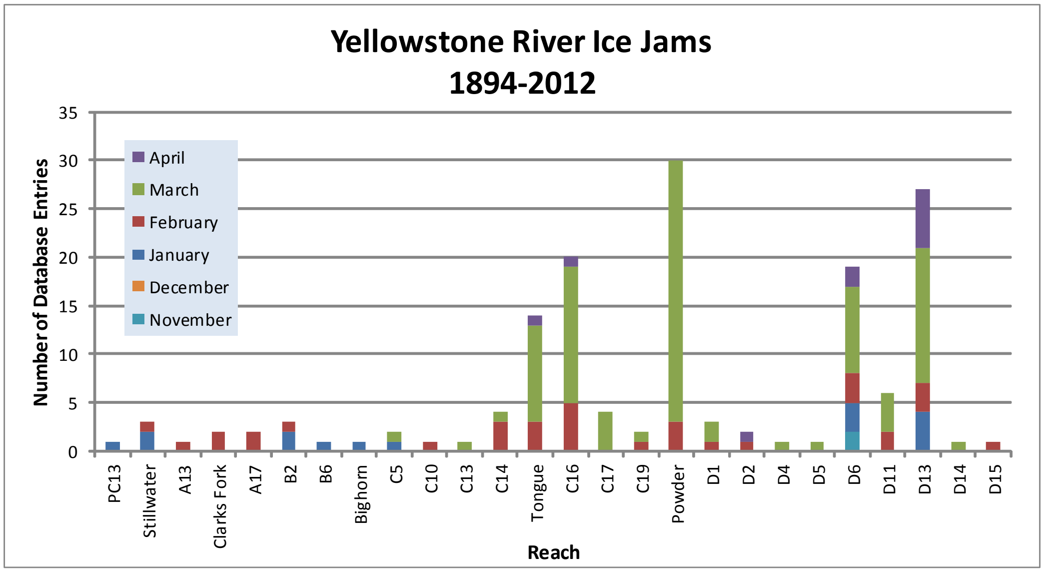
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	8,601	34.6%	8,645	34.8%	45
	Flow Deflectors	1,167	4.7%	1,149	4.6%	-17
	Between Flow Deflectors	1,118	4.5%	897	3.6%	-220
	Feature Type Totals	**10,885**	**43.8%**	**10,692**	**43.0%**	**-193**
Floodplain Control						
	Floodplain Dike/Levee	6,891	27.7%	6,879	27.7%	-12
	Feature Type Totals	**6,891**	**27.7%**	**6,879**	**27.7%**	**-12**
	Reach Totals	**17,775**	**71.5%**	**17,571**	**70.7%**	**-205**

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	11,289	12,686	2.12	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	12,432	7,832	1.63	1950 to 2001:	-23.25%
Change 1950 - 2001	**1,144**	**-4,854**	**-0.49**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	1,990

HYDRAULICS

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

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

Floodplain Isolation

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

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
211	422	475	104	22%	130	47	36%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap/Flow Deflectors			
	Non-Irrigated	106	17.6%
RipRap			
	Irrigated	21	3.4%
Flow Deflectors			
	Irrigated	23	3.9%
Dike/Levee			
	Non-Irrigated	4	0.7%
	Totals	**155**	**25.6%**

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

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
34.8	8.8	1.5	0.4	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	19	76	75	64	1.5%	6.1%	6.0%	5.2%
	Totals	**19**	**76**	**75**	**64**	**1.5%**	**6.1%**	**6.0%**	**5.2%**
Agricultural Land									
	Non-Irrigated	556	472	472	613	44.6%	37.9%	37.8%	49.2%
	Irrigated	501	447	392	320	40.2%	35.9%	31.4%	25.7%
	Totals	**1,057**	**919**	**863**	**934**	**84.8%**	**73.8%**	**69.3%**	**74.9%**
Channel									
	Channel	164	237	292	232	13.2%	19.0%	23.4%	18.6%
	Totals	**164**	**237**	**292**	**232**	**13.2%**	**19.0%**	**23.4%**	**18.6%**
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	2	2	0.0%	0.0%	0.2%	0.2%
	Totals	**0**	**0**	**2**	**2**	**0.0%**	**0.0%**	**0.2%**	**0.2%**
Transportation									
	Public Road	6	14	14	14	0.5%	1.1%	1.1%	1.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**6**	**14**	**14**	**14**	**0.5%**	**1.1%**	**1.1%**	**1.1%**
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	89	102	0.0%	0.0%	10.3%	10.9%	0.0%	10.3%	0.6%	10.9%
	Pivot	0	0	25	80	0.0%	0.0%	2.9%	8.5%	0.0%	2.9%	5.6%	8.5%
	Flood	501	447	278	138	47.4%	48.6%	32.2%	14.8%	1.2%	-16.4%	-17.4%	-32.6%
	Totals	**501**	**447**	**392**	**320**	**47.4%**	**48.6%**	**45.4%**	**34.3%**	**1.2%**	**-3.2%**	**-11.1%**	**-13.1%**

Non-Irrigated													
	Multi-Use	397	396	420	569	37.6%	43.1%	48.7%	60.9%	5.5%	5.6%	12.2%	23.3%
	Hay/Pasture	159	76	51	45	15.0%	8.3%	5.9%	4.8%	-6.7%	-2.4%	-1.1%	-10.2%
	Totals	**556**	**472**	**472**	**613**	**52.6%**	**51.4%**	**54.6%**	**65.7%**	**-1.2%**	**3.2%**	**11.1%**	**13.1%**

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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	27.5	75.5	55.0	0.0	**158.0**
Acres/Valley Mile	13.5	37.1	27.0	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	0.26	0.06%	0.13	0.06	0.05	0.00

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).

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County Park
Classification PCM: Partially confined meandering
General Location To Carters Bridge
Upstream River Mile 508.7
Downstream River Mile 506.7
Length 2.00 mi (3.22 km)
General Comments
Narrative Summary

Reach PC12 is located in the northernmost portion of the Paradise Valley, consisting of the two miles of river channel upstream of Carters Bridge. The reach is somewhat confined between terraces, Highway 89, and bedrock hillslopes. Carter's Bridge hosts a fishing access site and boat ramp.

Over its two mile length, the banks of Reach PC12 are armored by 7,267 feet of rock riprap and 4,106 feet of flow deflectors. Over 50 percent of the banks are armored. There are also about 8,700 feet of floodplain levees in Reach PC12. About 2,600 feet of this levee extent is the Highway 89 embankment which also forms the bankline as the river approaches the Livingston Ditch Diversion structure. A total of 39 percent of the Channel Migration Zone in this reach has been restricted by physical features such as bank armor and levees.

In 1950, there were 343 acres of land under flood irrigation in the reach. By 2000, that had dropped to about 90 acres, and sprinklers and pivots had expanded to 201 and 16 acres, respectfully. There was also about 51 acres of exurban development in the reach, all of which is just above Carter's Bridge on the west side of the river.

Over 100 acres of wetlands have been mapped in Reach PC12. These wetlands are located in isolated relic channels in the southwest floodplain, and in perched historic meander features in the northeast.

Reach PC12 is located right next to the Livingston gage which is at Carters Bridge. This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011, the river peaked at 40,600 cfs, which is currently the flood of record at Livingston. This flood exceeded a 100-year event, with both the 1996/1997 events considered to have exceeded a 75-year flood.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,550 cfs to 1,500 cfs with human development, a reduction of 3.2 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC12 include:
•Narrowing of the CMZ to less than half of its natural width, mainly due to long levees that run parallel to the river to protect spring creeks.
•Loss of side channel connectivity due to floodplain dikes and bank armor causing simplification

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC12 include:
•Side channel restoration at RM 508L
•CMZ Management due to current restriction of 39 percent of the Channel Migration Zone
•Bank Stabilization Recommended Practices due to 55 percent of banks being armored in reach
•Irrigation diversion management at Livingston Ditch Diversion

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	142.3	-2.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,200	20,300	25,600	28,800	35,400	38,200	44,300	1,550	1,760
Regulated	10,100	20,200	25,500	28,700	35,300	38,100	44,200	1,500	1,680
% Change	-0.98%	-0.49%	-0.39%	-0.35%	-0.28%	-0.26%	-0.23%	-3.23%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/23/2009	Color	1-meter pixels	6192500	6770
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	
2013	NAIP	09/11/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

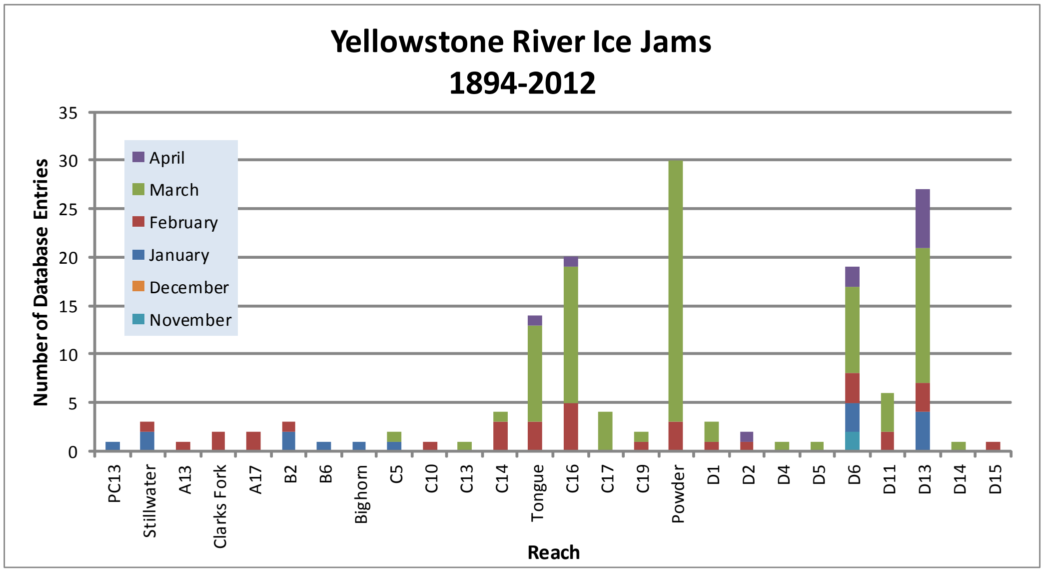
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	7,158	34.6%	7,267	35.1%	109
	Flow Deflectors	1,721	8.3%	1,772	8.6%	51
	Between Flow Deflectors	2,458	11.9%	2,334	11.3%	-124
	Feature Type Totals	**11,337**	**54.8%**	**11,373**	**55.0%**	**36**
Floodplain Control						
	Floodplain Dike/Levee	8,706	42.1%	8,706	42.1%	0
	Feature Type Totals	**8,706**	**42.1%**	**8,706**	**42.1%**	**0**
	Reach Totals	**20,043**	**96.9%**	**20,079**	**97.1%**	**36**

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	10,805	8,196	1.76	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	10,337	8,164	1.79	1950 to 2001:	1.78%
Change 1950 - 2001	**-468**	**-31**	**0.03**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
125	249	274	84	31%	126	72	57%

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			
	Exurban Other	6	1.6%
RipRap/Flow Deflectors			
	Public Road	10	2.5%
	Non-Irrigated	100	25.1%
	Irrigated	11	2.7%
Flow Deflectors			
	Public Road	1	0.4%
	Irrigated	24	6.0%
Dike/Levee			
	Public Road	3	0.8%
	Totals	**155**	**39.0%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
72.8	10.8	0.0	17.9	3.0

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	2	2	0.0%	0.0%	0.2%	0.2%
	Other Infrastructure	39	41	51	55	3.7%	3.9%	4.9%	5.2%
	Totals	**39**	**41**	**54**	**57**	**3.7%**	**3.9%**	**5.1%**	**5.4%**
Agricultural Land									
	Non-Irrigated	482	461	471	442	46.0%	44.0%	44.9%	42.2%
	Irrigated	343	334	285	307	32.7%	31.8%	27.1%	29.3%
	Totals	**825**	**795**	**755**	**749**	**78.7%**	**75.8%**	**72.0%**	**71.5%**
Channel									
	Channel	165	163	170	172	15.7%	15.5%	16.2%	16.4%
	Totals	**165**	**163**	**170**	**172**	**15.7%**	**15.5%**	**16.2%**	**16.4%**
ExUrban									
	ExUrban Other	0	0	3	3	0.0%	0.0%	0.3%	0.3%
	ExUrban Undeveloped	0	3	3	3	0.0%	0.3%	0.3%	0.3%
	ExUrban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	28	44	45	0.0%	2.6%	4.2%	4.3%
	Totals	**0**	**31**	**51**	**51**	**0.0%**	**2.9%**	**4.8%**	**4.8%**
Transportation									
	Public Road	19	19	19	19	1.8%	1.8%	1.8%	1.8%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**19**	**19**	**19**	**19**	**1.8%**	**1.8%**	**1.8%**	**1.8%**
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													
	Flood	343	334	172	89	41.6%	42.0%	22.8%	11.9%	0.4%	-19.2%	-10.9%	-29.7%
	Sprinkler	0	0	112	201	0.0%	0.0%	14.9%	26.9%	0.0%	14.9%	12.0%	26.9%
	Pivot	0	0	0	16	0.0%	0.0%	0.0%	2.1%	0.0%	0.0%	2.1%	2.1%
	Totals	**343**	**334**	**285**	**307**	**41.6%**	**42.0%**	**37.7%**	**40.9%**	**0.4%**	**-4.3%**	**3.3%**	**-0.6%**

Non-Irrigated

Multi-Use	417	416	443	438	50.6%	52.3%	58.7%	58.5%	1.8%	6.3%	-0.1%	8.0%
Hay/Pasture	65	45	28	4	7.9%	5.7%	3.7%	0.5%	-2.2%	-2.0%	-3.1%	-7.3%
Totals	**482**	**461**	**471**	**442**	**58.4%**	**58.0%**	**62.3%**	**59.1%**	**-0.4%**	**4.3%**	**-3.3%**	**0.6%**

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.

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	19.8	67.5	28.5	0.0	**115.8**
Acres/Valley Mile	10.8	36.8	15.6	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.

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County	Park	**Upstream River Mile**	506.7
Classification	PCB: Partially confined braided	**Downstream River Mile**	505
General Location	Through canyon upstream of Livingston	**Length**	1.70 mi (2.74 km)

General Comments

Narrative Summary

Reach PC13 flows through Allenspur Canyon, which is a notch carved through a limestone and sandstone ridge that runs perpendicular to the river. Within this notch, the river bottom is 1,000 to 1,800 feet wide, so that the river is not entirely confined. The reach is largely single thread with large point bars, and has several bank migration sites that have exceeded 200 feet of movement since 1950.

There are about 2,000 feet of bank armor in the reach, which covers about 13 percent of the total bankline. There is also about ½ mile of diking that is concentrated just downstream of Carters Bridge on the west floodplain.

Approaching Livingston, the primary modern land use is exurban, although historically the land was primarily used for agriculture. There are over 80 acres of exurban development in Reach PC13, most of which is on the west floodplain. Only 4 acres of land in the reach are irrigated. There is a ~13 acre fishing access site named Free River on an historic island that offers no boating facilities.

Reach PC13 experienced an ice jam-related flood in January of 2007 which flooded one house in the area.

Reach PC13 has seen a dramatic change in channel form since 1950, as it has shifted from a multi-thread anabranching reach type to a single channel with distinct meanders and open bars. In 1950, this reach had 6,600 feet of anabranching channels that flowed around wooded islands. Since then, the river has consolidated into a single thread and lost virtually all of its side channels. Those side channels were not blocked, but they were abandoned with flow consolidation into a single thread. The size of the channel (bankfull area) has increased by about 20 percent. One large meander in the reach is in the process of cutting off, as a prominent chute channel has formed against the east valley wall.

Numerous structures and a portion of the Highway 89 embankment are located within the CMZ in Reach PC13. A total of 8 percent of the CMZ has been restricted by physical features.

In the early 1960's, a dam was proposed for Allenspur Canyon but was ultimately defeated largely due to local resistance. Allen Spur Dam was proposed as a 380-foot tall dam with a 250,000 watt power plant that would have inundated the Paradise Valley up to 30 miles upstream.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,550 cfs to 1,500 cfs with human development, a reduction of 3.2 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC13 include:
•Transformation from a multi-thread, anabranching reach type to a single thread channel with open bars.
•Abandonment of over a mile of side channels since 1950 in a 1.7 mile long reach.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC13 include:
•CMZ Management due to development pressure in confined reach

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	140.6	-0.1

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,200	20,300	25,600	28,800	35,400	38,200	44,300	1,550	1,760
Regulated	10,100	20,200	25,500	28,700	35,300	38,100	44,200	1,500	1,680
% Change	-0.98%	-0.49%	-0.39%	-0.35%	-0.28%	-0.26%	-0.23%	-3.23%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	9/4/2011	Color	1-meter pixels	6192500	3960
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/26/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

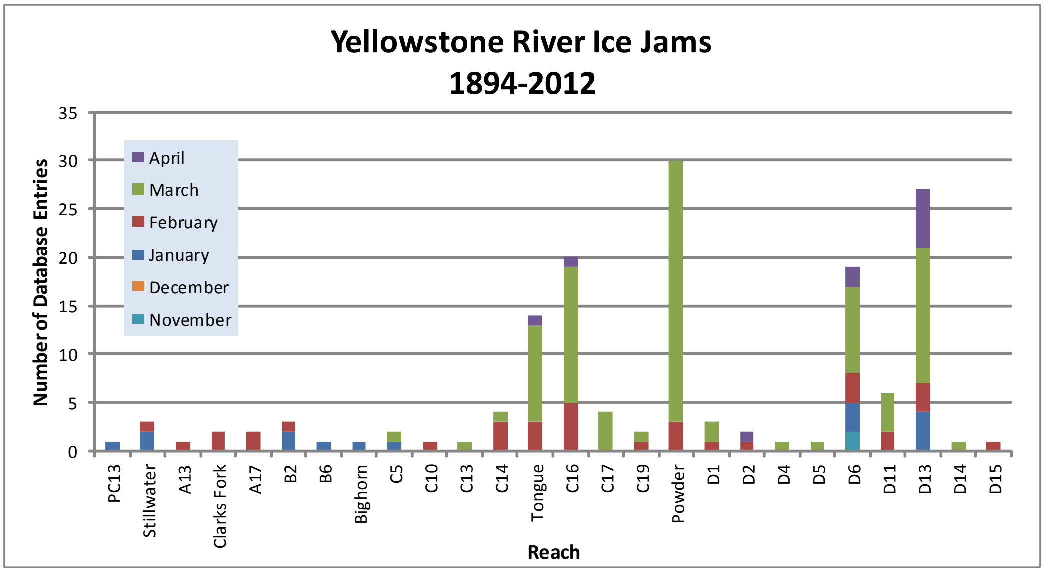
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	1,087	6.6%	1,240	7.6%	153
	Flow Deflectors	456	2.8%	394	2.4%	-62
	Between Flow Deflectors	620	3.8%	481	2.9%	-139
	Feature Type Totals	**2,164**	**13.2%**	**2,115**	**12.9%**	**-49**
Floodplain Control						
	Floodplain Dike/Levee	2,541	15.5%	2,541	15.5%	0
	Feature Type Totals	**2,541**	**15.5%**	**2,541**	**15.5%**	**0**
	Reach Totals	**4,705**	**28.7%**	**4,656**	**28.4%**	**-49**

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
1/17/2007	Released		1 house flooded

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	7,508	6,652	1.89	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	8,189		1.00	1950 to 2001:	-46.98%
Change 1950 - 2001	**682**		**-0.89**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
123	246	221	13	6%	15	6	41%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Exurban Other	10	4.4%
RipRap/Flow Deflectors			
	Exurban Residential	6	2.6%
Flow Deflectors			
	Non-Irrigated	3	1.3%
	Totals	**19**	**8.2%**

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

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation

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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	2	3	4	4	0.3%	0.6%	0.8%	0.8%
	Totals	**2**	**3**	**4**	**4**	**0.3%**	**0.6%**	**0.8%**	**0.8%**
Agricultural Land									
	Non-Irrigated	256	225	205	208	54.8%	48.3%	44.0%	44.6%
	Irrigated	36	0	11	4	7.7%	0.0%	2.4%	0.9%
	Totals	**292**	**225**	**217**	**212**	**62.5%**	**48.3%**	**46.4%**	**45.5%**
Channel									
	Channel	156	153	153	157	33.5%	32.9%	32.7%	33.6%
	Totals	**156**	**153**	**153**	**157**	**33.5%**	**32.9%**	**32.7%**	**33.6%**
ExUrban									
	ExUrban Other	2	2	2	2	0.3%	0.3%	0.5%	0.5%
	ExUrban Undeveloped	0	2	2	0	0.0%	0.5%	0.5%	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	3	70	78	80	0.7%	15.0%	16.6%	17.1%
	Totals	**5**	**74**	**82**	**82**	**1.1%**	**15.8%**	**17.6%**	**17.6%**
Transportation									
	Public Road	12	12	12	12	2.6%	2.5%	2.5%	2.5%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**12**	**12**	**12**	**12**	**2.6%**	**2.5%**	**2.5%**	**2.5%**
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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '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	36	0	11	4	12.3%	0.0%	5.2%	2.0%	-12.3%	5.2%	-3.2%	-10.3%
	Totals	**36**	**0**	**11**	**4**	**12.3%**	**0.0%**	**5.2%**	**2.0%**	**-12.3%**	**5.2%**	**-3.2%**	**-10.3%**

Non-Irrigated												
Multi-Use	214	200	192	189	73.2%	88.8%	88.7%	88.9%	15.6%	-0.1%	0.2%	15.7%
Hay/Pasture	42	25	13	19	14.4%	11.2%	6.0%	9.1%	-3.2%	-5.1%	3.0%	-5.3%
Totals	**256**	**225**	**205**	**208**	**87.7%**	**######**	**94.8%**	**98.0%**	**12.3%**	**-5.2%**	**3.2%**	**10.3%**

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.

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	0.5	8.4	3.3	0.0	**12.2**
Acres/Valley Mile	0.3	6.1	2.4	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	0.19	0.06%	0.02	0.00	0.03	0.03

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Park	**Upstream River Mile**	505
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	501.7
General Location	Through Interstate bridge crossing to Livingston	**Length**	3.30 mi (5.31 km)

General Comments

Narrative Summary

Reach PC14 is a 3.3 mile long river segment that extends from the mouth of Allenspur Canyon to Sacajawea Park in Livingston. The reach is heavily developed, with almost 600 acres of urban/exurban development in the land use mapping corridor, and another 45 acres developed on 9th Street Island and Siebeck Island. There are over three miles of bank armor in the reach, with about 17,000 feet of rock riprap and 1,600 feet of flow deflectors. This armor covers about 54 percent of the streambanks. Between 2001 and 2011, almost 400 feet of rock riprap located at the head of Siebeck Island was destroyed. There are also over three miles of floodplain dikes mapped in this reach. The physical features protect development on the west floodplain and on Siebeck Island, which is a ~100 acre island just upstream of the Interstate Bridge Physical features have isolated 39 percent of the natural channel migration zone in Reach PC14.

There have been extensive blockages of side channels in Reach PC14. Prior to 1950, about 8,600 feet of side channels were blocked by dikes, and since 1950 dikes have been built to block another mile of side channel.

About 100 acres of wetlands have been mapped in Reach PC14. About 20 of those wetland acres are on Siebeck Island.

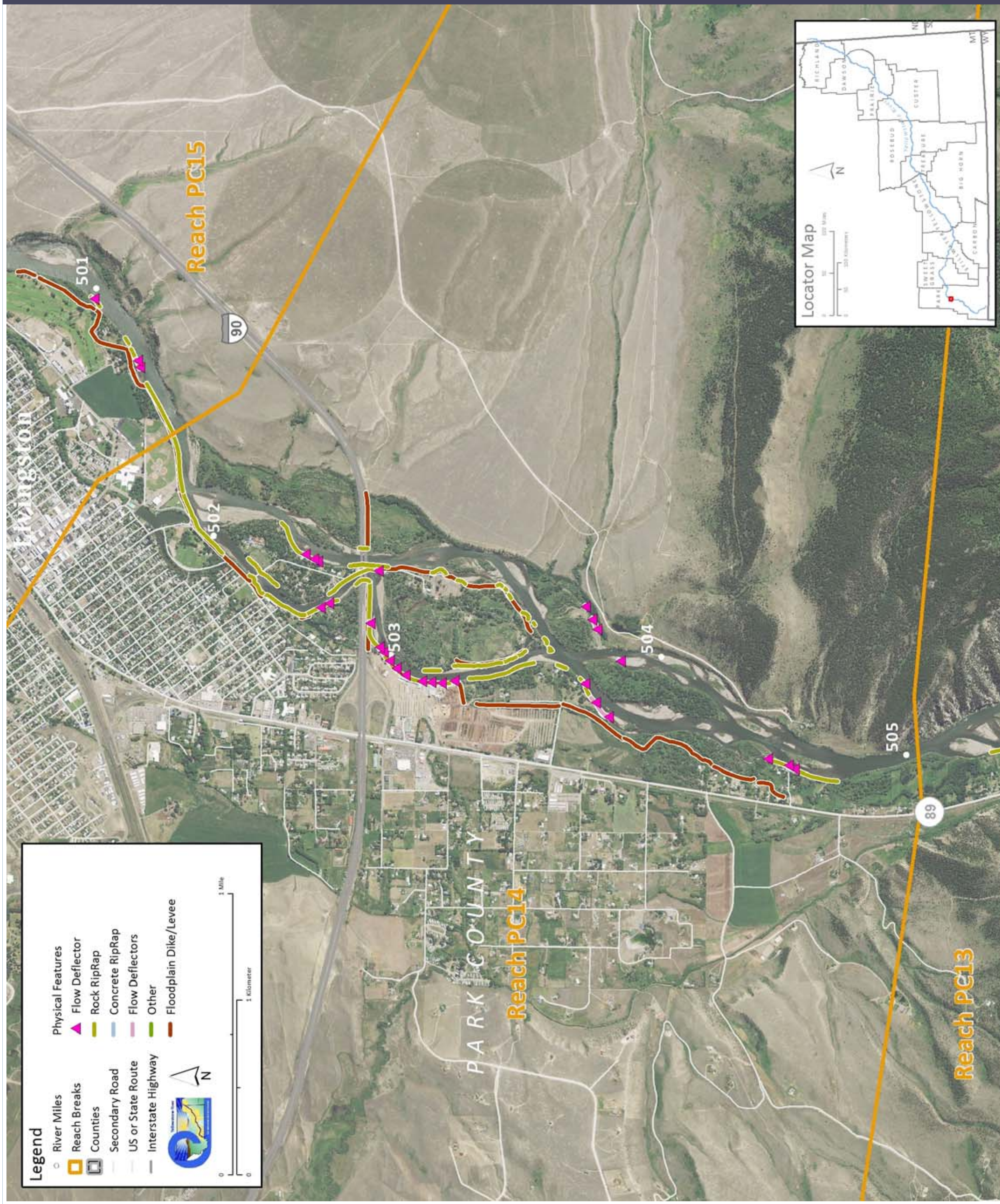
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,570 cfs to 1,510 cfs with human development, a reduction of 3.8 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC14 include:
•Physical features blocking over 13,000 feet of side channels.
•Riprap failure at head of Siebeck Island
•Extensive CMZ Restriction with floodplain development.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC14 include:
•Side channel restoration at RM 504.6L
•Bank armor removal at head of Siebeck Island at RM 503.8
•CMZ management due to 38 percent restriction of Channel Migration Zone
•Russian olive removal
•Bank Stabilization Recommended Practices due to extensive armoring in reach (51 percent of bankline)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	137.3	1.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,200	20,300	25,600	28,800	35,400	38,200	44,300	1,570	1,760
Regulated	10,100	20,200	25,500	28,700	35,300	38,100	44,200	1,510	1,680
% Change	-0.98%	-0.49%	-0.39%	-0.35%	-0.28%	-0.26%	-0.23%	-3.82%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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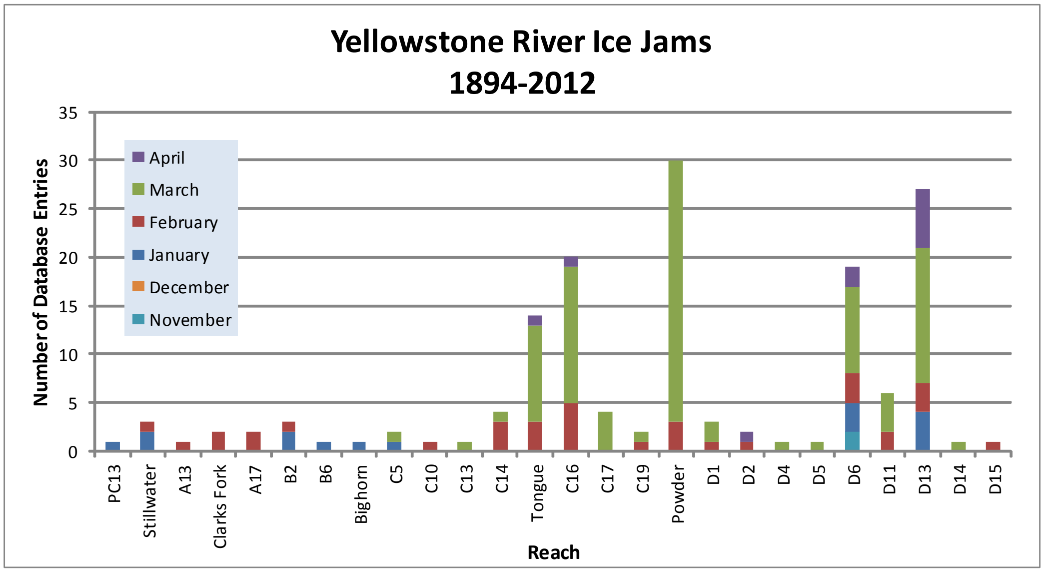
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

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	17,321	47.4%	16,932	46.4%	-390
	Gabions	0	0.0%	149	0.4%	149
	Flow Deflectors	961	2.6%	961	2.6%	0
	Between Flow Deflectors	629	1.7%	621	1.7%	-8
	Feature Type Totals	**18,911**	**51.8%**	**18,662**	**51.1%**	**-249**
Floodplain Control						
	Floodplain Dike/Levee	18,388	50.4%	17,937	49.1%	-451
	Feature Type Totals	**18,388**	**50.4%**	**17,937**	**49.1%**	**-451**
	Reach Totals	**37,299**	**102.2%**	**36,599**	**100.3%**	**-700**

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	18,451	26,163	2.42	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	18,253	18,762	2.03	1950 to 2001:	-16.13%
Change 1950 - 2001	**-198**	**-7,401**	**-0.39**		

Length of Side Channels Blocked

Pre-1950s (ft)	8,601
Post-1950s (ft)	5,546

HYDRAULICS

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

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

Floodplain Isolation

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

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
171	342	634	225	35%	63	44	69%

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			
	Urban Industrial	17	2.4%
	Interstate	5	0.6%
RipRap/Flow Deflectors			
	Urban Residential	6	0.8%
	Urban Industrial	15	2.2%
	Exurban Residential	19	2.8%
RipRap			
	Exurban Residential	15	2.1%
Flow Deflectors			
	Non-Irrigated	1	0.1%
Dike/Levee			
	Urban Other	66	9.5%
	Non-Irrigated	10	1.4%
	Exurban Residential	115	16.4%
	Totals	**268**	**38.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
0.0	4.0	0.0	135.2	9.2

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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	2	1	1	1	0.1%	0.1%	0.1%	0.1%
	Totals	**2**	**1**	**1**	**1**	**0.1%**	**0.1%**	**0.1%**	**0.1%**
Agricultural Land									
	Non-Irrigated	662	494	415	410	42.3%	31.6%	26.6%	26.3%
	Irrigated	150	26	34	34	9.6%	1.7%	2.2%	2.2%
	Totals	**811**	**520**	**449**	**444**	**51.9%**	**33.3%**	**28.7%**	**28.4%**
Channel									
	Channel	416	432	443	448	26.6%	27.6%	28.4%	28.7%
	Totals	**416**	**432**	**443**	**448**	**26.6%**	**27.6%**	**28.4%**	**28.7%**
ExUrban									
	ExUrban Other	9	0	0	0	0.5%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	15	4	4	0.0%	1.0%	0.2%	0.2%
	ExUrban Industrial	1	94	94	94	0.0%	6.0%	6.0%	6.0%
	ExUrban Commercial	0	19	28	28	0.0%	1.2%	1.8%	1.8%
	ExUrban Residential	28	85	140	140	1.8%	5.5%	9.0%	9.0%
	Totals	**37**	**214**	**266**	**266**	**2.4%**	**13.7%**	**17.1%**	**17.1%**
Transportation									
	Public Road	18	33	41	41	1.2%	2.1%	2.6%	2.6%
	Interstate	0	34	34	34	0.0%	2.2%	2.2%	2.2%
	Railroad	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**18**	**67**	**75**	**75**	**1.2%**	**4.3%**	**4.8%**	**4.8%**
Urban									
	Urban Other	49	61	61	61	3.2%	3.9%	3.9%	3.9%
	Urban Residential	183	226	226	226	11.7%	14.5%	14.5%	14.5%
	Urban Commercial	20	42	42	42	1.3%	2.7%	2.7%	2.7%
	Urban Undeveloped	25	0	0	0	1.6%	0.0%	0.0%	0.0%
	Urban Industrial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Totals	**277**	**328**	**328**	**328**	**17.7%**	**21.0%**	**21.0%**	**21.0%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	33	33	0.0%	0.0%	7.3%	7.4%	0.0%	7.3%	0.1%	7.4%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	150	26	1	1	18.4%	5.1%	0.2%	0.2%	-13.4%	-4.9%	0.0%	-18.3%
	Totals	**150**	**26**	**34**	**34**	**18.4%**	**5.1%**	**7.5%**	**7.6%**	**-13.4%**	**2.4%**	**0.1%**	**-10.9%**

Non-Irrigated												
Multi-Use	507	406	415	410	62.5%	78.1%	92.5%	92.4%	15.6%	14.4%	-0.1%	29.9%
Hay/Pasture	154	87	0	0	19.0%	16.8%	0.0%	0.0%	-2.2%	-16.8%	0.0%	-19.0%
Totals	**662**	**494**	**415**	**410**	**81.6%**	**94.9%**	**92.5%**	**92.4%**	**13.4%**	**-2.4%**	**-0.1%**	**10.9%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	15.3	26.4	51.2	0.0	**93.0**
Acres/Valley Mile	5.1	8.8	17.1	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	4.74	0.89%	3.68	1.92	0.45	1.36

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.

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.

County	Park	**Upstream River Mile**	501.7
Classification	PCS: Partially confined straight	**Downstream River Mile**	499.9
General Location	To Mayors Landing	**Length**	1.80 mi (2.90 km)

General Comments

Narrative Summary

Reach PC15 is a 1.83 mile long river segment that extends from Sacajawea Park to the KPRK Bridge (Hwy 89) in Livingston. Within the reach, the river largely flows along the east valley wall, with extensive development on the west side of the river. There are almost 463 acres of urban development in the land use mapping corridor within this reach. There is also over a mile of bank armor, almost all of which is on the left (west) bank of the river. This includes about 5,000 feet of rock riprap and 600 feet of flow deflectors, which drape about 29 percent of the bankline. There are also 9,000 feet of floodplain dikes mapped in this reach, and again, they are on the west side of the river. The physical features have restricted about one half of the river's natural Channel Migration Zone in Reach PC15.

The Vallis Ditch Diversion diverts water from a side channel on the east side of the river at RM 500.4. Across the river from the diversion, Mayor's Landing is a popular ~3 acre fishing access site with a boat ramp.

About 50 acres of wetlands have been mapped in Reach PC15, and most of these remain connected to the main channel. About 20 of those wetland acres are on Siebeck Island.

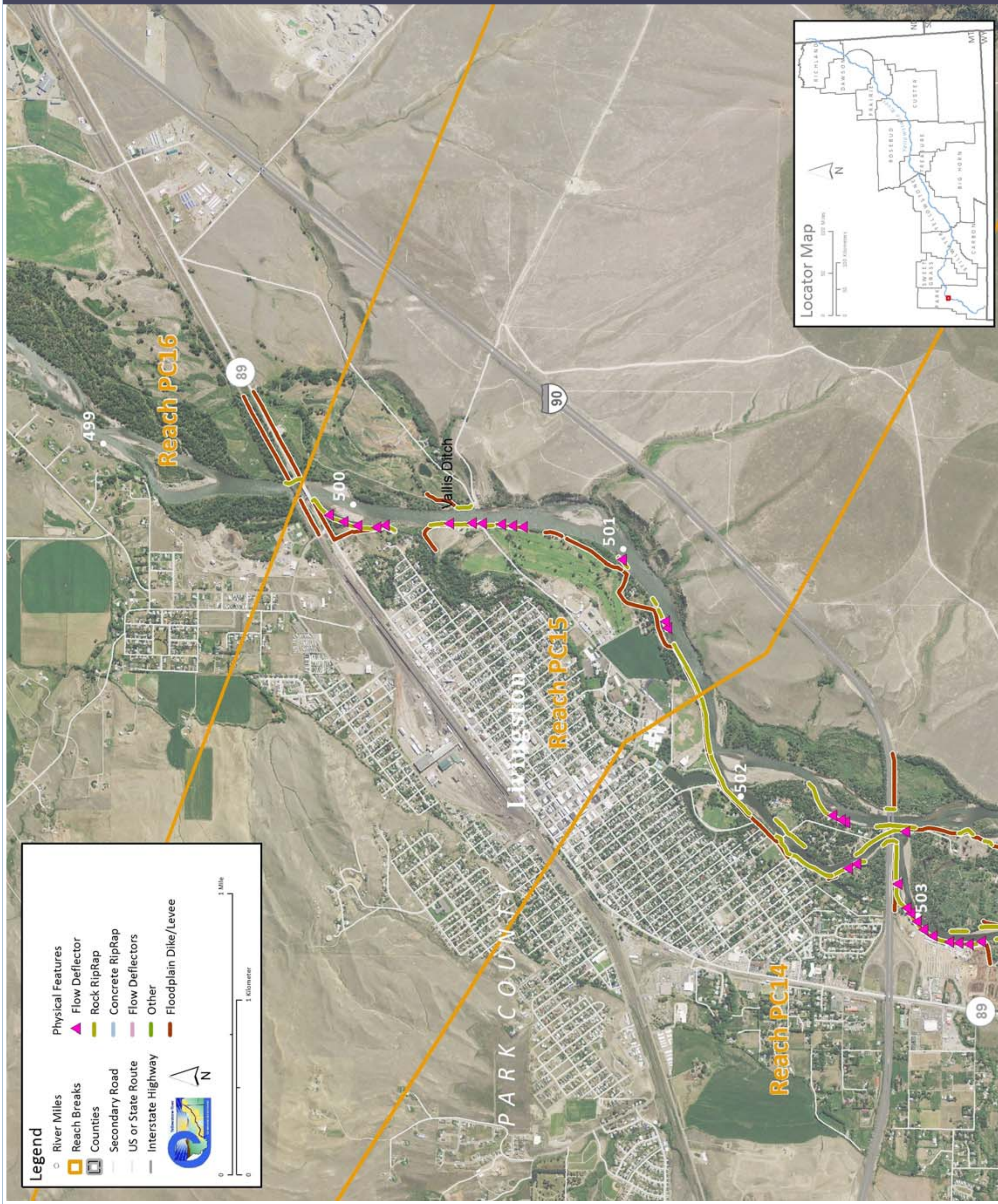
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,570 cfs to 1,510 cfs with human development, a reduction of 3.8 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC15 include:
•Physical features blocking over 13,000 feet of side channels.
•Extensive CMZ Restriction with floodplain development.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC15 include:
•CMZ Management due to current restriction of 53 percent of the Channel Migration Zone
•Channel Bank Stabilization Recommended Practices due to 29 percent of banks being armored in reach
•Irrigation diversion management at Vallis Ditch Diversion

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	135.5	4.9

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,200	20,300	25,600	28,800	35,400	38,200	44,300	1,570	1,760
Regulated	10,100	20,200	25,500	28,700	35,300	38,100	44,200	1,510	1,680
% Change	-0.98%	-0.49%	-0.39%	-0.35%	-0.28%	-0.26%	-0.23%	-3.82%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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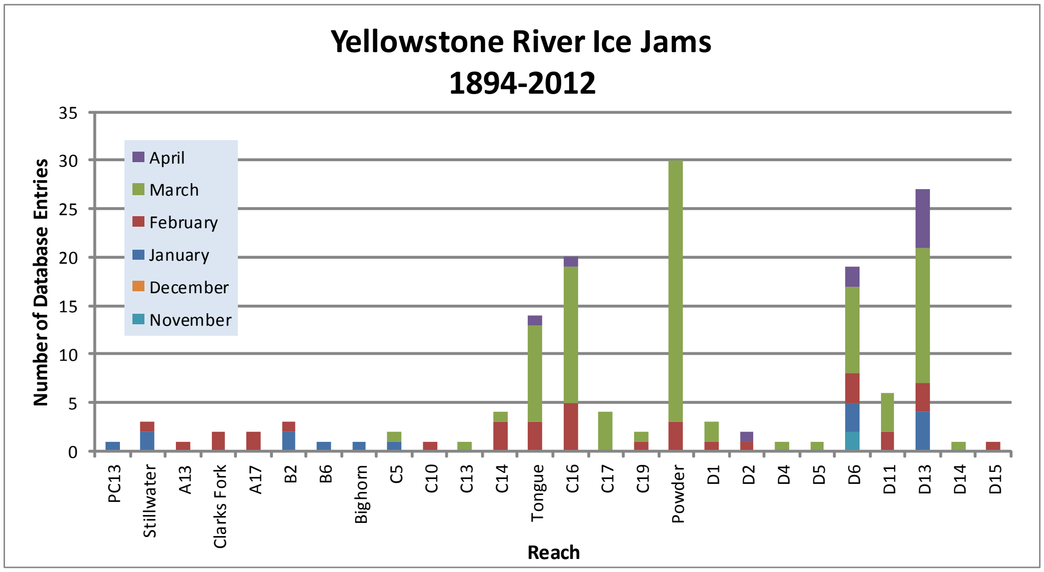
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

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	4,637	24.5%	4,880	25.8%	243
	Flow Deflectors	613	3.2%	613	3.2%	0
	Between Flow Deflectors	139	0.7%	0	0.0%	-139
	Feature Type Totals	**5,389**	**28.5%**	**5,493**	**29.1%**	**104**
Floodplain Control						
	Floodplain Dike/Levee	9,032	47.8%	9,032	47.8%	0
	Feature Type Totals	**9,032**	**47.8%**	**9,032**	**47.8%**	**0**
	Reach Totals	**14,421**	**76.3%**	**14,525**	**76.8%**	**104**

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.



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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	9,864	1,031	1.10	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	9,453		1.00	1950 to 2001:	-9.47%
Change 1950 - 2001	**-411**		**-0.10**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
79	158	150	36	24%	284	196	69%

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			
	Non-Irrigated	2	0.5%
Dike/Levee			
	Urban Other	230	53.0%
	Totals	**232**	**53.5%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.0	18.1	0.0	200.8	5.0

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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	7	13	26	26	0.6%	1.2%	2.4%	2.4%
	Totals	**7**	**13**	**26**	**26**	**0.6%**	**1.2%**	**2.4%**	**2.4%**
Agricultural Land									
	Non-Irrigated	504	413	310	350	48.1%	39.4%	29.5%	33.4%
	Irrigated	14	18	18	18	1.3%	1.7%	1.7%	1.7%
	Totals	**518**	**431**	**328**	**369**	**49.4%**	**41.1%**	**31.3%**	**35.2%**
Channel									
	Channel	91	97	109	106	8.7%	9.3%	10.4%	10.1%
	Totals	**91**	**97**	**109**	**106**	**8.7%**	**9.3%**	**10.4%**	**10.1%**
ExUrban									
	ExUrban Other	5	0	0	0	0.5%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	3	17	51	14	0.3%	1.6%	4.9%	1.3%
	ExUrban Commercial	0	0	0	20	0.0%	0.0%	0.0%	1.9%
	ExUrban Residential	0	4	17	17	0.0%	0.4%	1.6%	1.6%
	Totals	**8**	**21**	**69**	**51**	**0.7%**	**2.0%**	**6.5%**	**4.8%**
Transportation									
	Public Road	18	18	18	18	1.7%	1.7%	1.7%	1.7%
	Interstate	0	3	3	3	0.0%	0.3%	0.3%	0.3%
	Railroad	14	14	13	13	1.3%	1.3%	1.2%	1.2%
	Totals	**31**	**34**	**34**	**34**	**3.0%**	**3.3%**	**3.2%**	**3.2%**
Urban									
	Urban Other	21	86	123	123	2.0%	8.2%	11.7%	11.7%
	Urban Residential	205	236	246	246	19.6%	22.5%	23.5%	23.5%
	Urban Commercial	49	68	68	49	4.7%	6.5%	6.5%	4.7%
	Urban Undeveloped	78	17	0	0	7.4%	1.7%	0.0%	0.0%
	Urban Industrial	41	45	46	46	3.9%	4.3%	4.4%	4.4%
	Totals	**394**	**453**	**483**	**463**	**37.6%**	**43.2%**	**46.1%**	**44.2%**

Land Use Timeline - Tiers 3 and 4

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	18	18	0.0%	0.0%	5.5%	4.9%	0.0%	5.5%	-0.6%	4.9%
	Pivot	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Flood	14	18	0	0	2.6%	4.2%	0.0%	0.0%	1.6%	-4.2%	0.0%	-2.6%
	Totals	**14**	**18**	**18**	**18**	**2.6%**	**4.2%**	**5.5%**	**4.9%**	**1.6%**	**1.3%**	**-0.6%**	**2.3%**

Non-Irrigated												
Multi-Use	327	316	246	282	63.2%	73.3%	75.2%	76.4%	10.2%	1.8%	1.2%	13.2%
Hay/Pasture	177	97	63	69	34.2%	22.4%	19.3%	18.7%	-11.8%	-3.2%	-0.6%	-15.6%
Totals	**504**	**413**	**310**	**350**	**97.4%**	**95.8%**	**94.5%**	**95.1%**	**-1.6%**	**-1.3%**	**0.6%**	**-2.3%**

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.

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	2.8	36.7	10.9	0.0	**50.5**
Acres/Valley Mile	1.6	20.9	6.2	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	0.72	0.23%	0.49	0.34	0.07	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

Yellowstone River Reach Narratives

Reach PC16

County	Park	**Upstream River Mile**	499.9
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	495.6
General Location	To just upstream of Hwy 89 bridge	**Length**	4.30 mi (6.92 km)

General Comments

Narrative Summary

Reach PC16 is 4.3 miles long, extending from the KPRK Bridge (Hwy 89) in Livingston almost to the Highway 89 Bridge downstream. Within the reach, the river makes a large swing from a northerly trend to an easterly trend. The reach is dynamic, as multiple wooded islands, and intermittently flows along the north valley wall. In 2001, there were about 4.2 miles of side channels in the reach, indicating that there is as almost much side channel as main channel in this segment of the Yellowstone River. In some areas the river corridor is over 2,000 feet wide.

There are over 8,000 feet of bank armor in Reach PC16, about 6,500 feet of which is rock riprap. In 2011, there were 1,700 feet of flow deflectors in the reach, after about 200 feet had been destroyed between 2001 and 2011. These flow deflectors were on a large meander bend; they were flanked, and the river has migrated to the southeast about 200 feet beyond their original location. This erosion also damaged a large diversion structure. Bank armor covers about 18 percent of the total bankline. There are also 8,200 feet of mapped floodplain dikes in the reach. Prior to 1950, a 1,900-foot long channel was blocked at its upper end by the highway and Railroad Bridge approaches at the KPRK Bridge.

Land uses in Reach PC16 are mixed, including urban/exurban, irrigated agriculture, and non-irrigated agriculture. In 1950, over 660 acres were in flood irrigation and by 2011 that number had been reduced to 70 acres, with 173 acres being converted to sprinkler irrigation and 246 to pivot. Exurban development is most dense on the left (north) bank of the river, where the valley wall consists of erosion-resistant sandstone that is out of the Channel Migration Zone.

Over 200 acres of wetlands have been mapped in Reach PC16, most of which are emergent marshes and wet meadows. Most of these wetlands are in non-irrigated hay pastures.

There is one pipeline crossing in this reach. The crossing is near Rustad Lane, and is a natural gas line owned by NW Energy, LLC.

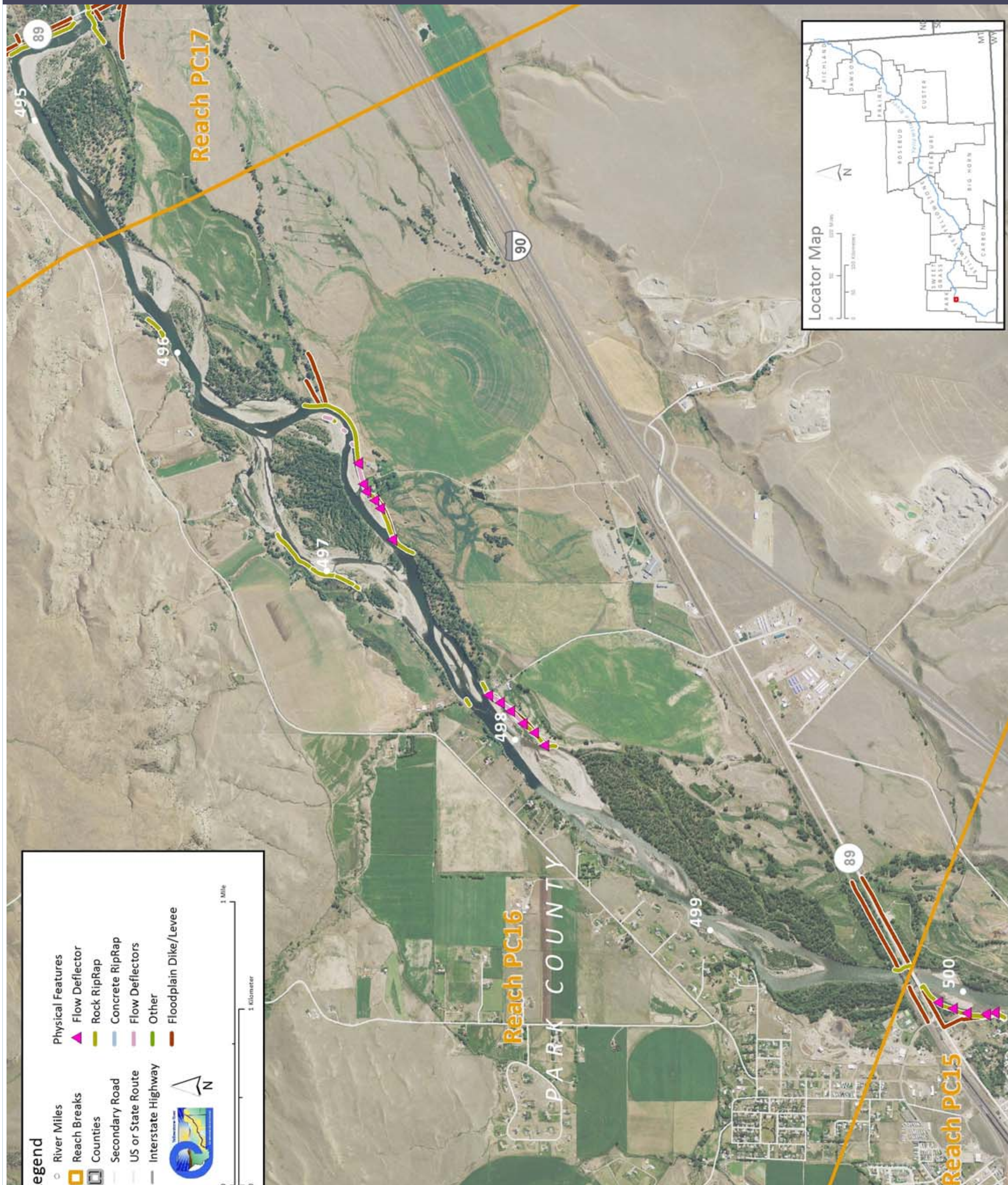
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,580 cfs to 1,510 cfs with human development, a reduction of 4.4 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC16 include:
•Flanking of flow deflectors and sever erosion behind.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC16 include:
•Side channel restoration below transportation embankment at RM 499.4L
•Flanked bank armor removal at RM 496.8
•CMZ Management due to current restriction of 14 percent of the Channel Migration Zone
•Pipeline Practices at natural gas crossing at RM 497.9 (natural gas may have special consideration in Practice)
•Irrigation diversion management at Vallis Ditch Diversion at RM 496.5

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	131.2	6.7

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,400	20,600	25,900	29,200	35,900	38,700	44,900	1,580	1,760
Regulated	10,300	20,500	25,800	29,100	35,800	38,600	44,800	1,510	1,680
% Change	-0.96%	-0.49%	-0.39%	-0.34%	-0.28%	-0.26%	-0.22%	-4.43%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	
2013	NAIP	06/28/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

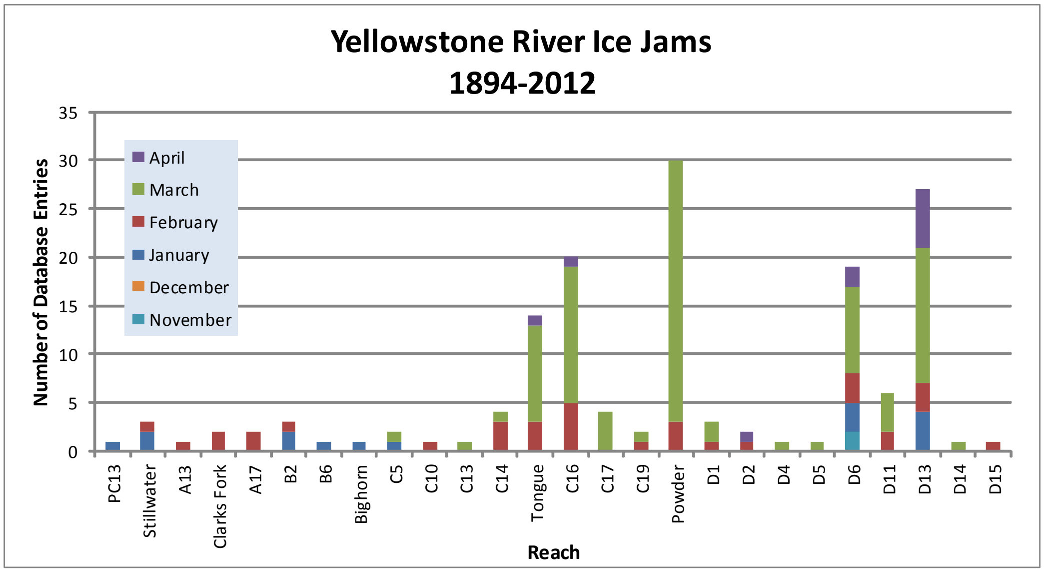
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	4,199	9.2%	6,475	14.2%	2,276
	Flow Deflectors	784	1.7%	759	1.7%	-25
	Between Flow Deflectors	1,126	2.5%	944	2.1%	-182
	Feature Type Totals	**6,109**	**13.4%**	**8,178**	**18.0%**	**2,069**
Floodplain Control						
	Floodplain Dike/Levee	8,196	18.0%	7,453	16.4%	-744
	Feature Type Totals	**8,196**	**18.0%**	**7,453**	**16.4%**	**-744**
	Reach Totals	**14,305**	**31.4%**	**15,631**	**34.3%**	**1,326**

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	23,645	25,912	2.10	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	22,759	22,182	1.97	1950 to 2001:	-5.78%
Change 1950 - 2001	**-887**	**-3,729**	**-0.12**		

Length of Side Channels Blocked

Pre-1950s (ft)	1,901
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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
212	423	759	52	7%	221	84	38%

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			
	Public Road	1	0.1%
	Non-Irrigated	89	9.0%
RipRap/Flow Deflectors			
	Non-Irrigated	18	1.9%
	Irrigated	15	1.5%
RipRap			
	Non-Irrigated	6	0.6%
	Irrigated	10	1.0%
	Totals	**140**	**14.3%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
0.1	18.1	8.2	12.6	5.4

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	47	130	182	156	1.9%	5.2%	7.3%	6.3%
	Totals	**47**	**130**	**182**	**156**	**1.9%**	**5.2%**	**7.3%**	**6.3%**
Agricultural Land									
	Non-Irrigated	1,299	956	824	1,042	52.3%	38.5%	33.2%	42.0%
	Irrigated	662	802	708	488	26.7%	32.3%	28.5%	19.7%
	Totals	**1,961**	**1,758**	**1,532**	**1,530**	**79.0%**	**70.8%**	**61.7%**	**61.6%**
Channel									
	Channel	433	388	463	485	17.4%	15.6%	18.6%	19.6%
	Totals	**433**	**388**	**463**	**485**	**17.4%**	**15.6%**	**18.6%**	**19.6%**
ExUrban									
	ExUrban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Undeveloped	0	17	0	0	0.0%	0.7%	0.0%	0.0%
	ExUrban Industrial	0	31	0	0	0.0%	1.3%	0.0%	0.0%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	1	100	203	208	0.0%	4.0%	8.2%	8.4%
	Totals	**1**	**149**	**203**	**208**	**0.0%**	**6.0%**	**8.2%**	**8.4%**
Transportation									
	Public Road	27	28	28	28	1.1%	1.1%	1.1%	1.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	5	5	5	5	0.2%	0.2%	0.2%	0.2%
	Totals	**32**	**33**	**33**	**33**	**1.3%**	**1.3%**	**1.3%**	**1.3%**
Urban									
	Urban Other	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Urban Residential	8	24	37	37	0.3%	1.0%	1.5%	1.5%
	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	33	33	0.0%	0.0%	1.3%	1.3%
	Totals	**8**	**24**	**69**	**69**	**0.3%**	**1.0%**	**2.8%**	**2.8%**

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	151	173	0.0%	0.0%	9.8%	11.3%	0.0%	9.8%	1.5%	11.3%
	Pivot	0	0	244	246	0.0%	0.0%	15.9%	16.1%	0.0%	15.9%	0.1%	16.1%
	Flood	662	802	314	70	33.8%	45.6%	20.5%	4.6%	11.8%	-25.1%	-15.9%	-29.2%
	Totals	**662**	**802**	**708**	**488**	**33.8%**	**45.6%**	**46.2%**	**31.9%**	**11.8%**	**0.6%**	**-14.3%**	**-1.8%**

Non-Irrigated												
Multi-Use	1,119	880	550	593	57.1%	50.0%	35.9%	38.7%	-7.0%	-14.1%	2.8%	-18.3%
Hay/Pasture	180	77	274	449	9.2%	4.4%	17.9%	29.3%	-4.8%	13.5%	11.5%	20.2%
Totals	**1,299**	**956**	**824**	**1,042**	**66.2%**	**54.4%**	**53.8%**	**68.1%**	**-11.8%**	**-0.6%**	**14.3%**	**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.

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	10.6	154.4	51.5	0.0	**216.5**
Acres/Valley Mile	2.7	39.4	13.1	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	0.84	0.12%	0.83	0.29	0.12	0.05

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Park	**Upstream River Mile**	495.6
Classification	PCB: Partially confined braided	**Downstream River Mile**	493.6
General Location	Through Hwy 89 bridge crossing to Shields River	**Length**	2.00 mi (3.22 km)

General Comments

Narrative Summary

Reach PC17 is 2.0 miles long, extending from just above the Highway 89 Bridge to just below the mouth of the Shields River. The reach is highly impacted by the two bridges that cross the river in the middle of the reach. One is the Highway 89 Bridge and the other is an abandoned railroad bridge that runs parallel to it just upstream.

There is over a mile of bank armor in Reach PC17, about 5,700 feet of which is rock riprap and another 130 feet is flow deflectors. About 28 percent of the total bankline, including those of side channels, is armored. Most of the armor is associated with the bridges.

About 25 percent of the Channel Migration Zone in Reach PC17 has been restricted by physical features. Much of this restriction takes place near the upper end of the reach, where the Highway 89 Bridge has restricted the natural CMZ from a width of 1800 feet down to 300 feet, isolating about 90 acres of ground downstream of the bridge approach. This constriction at the bridge has also caused extensive deposition upstream, and as a result the river currently flows parallel to the highway before “doglegging” through the bridge opening.

There are also 7,300 feet of mapped floodplain dikes in the reach. These dikes are all associated with the transportation prisms at the bridges. Construction of the bridges also resulted in the blockage of about 3,950 feet of side channel prior to 1950 on the north floodplain just downstream.

Land uses in Reach PC17 are almost entirely agricultural, with historic flood irrigation converting to sprinkler and pivot, and some exurban development. The major land use in the reach, however, is non-irrigated agriculture.

About 85 acres of wetlands have been mapped in Reach PC17, most of which are emergent marshes and wet meadows. Most of these wetlands are in non-irrigated hay pastures or multi-use riparian bottoms.

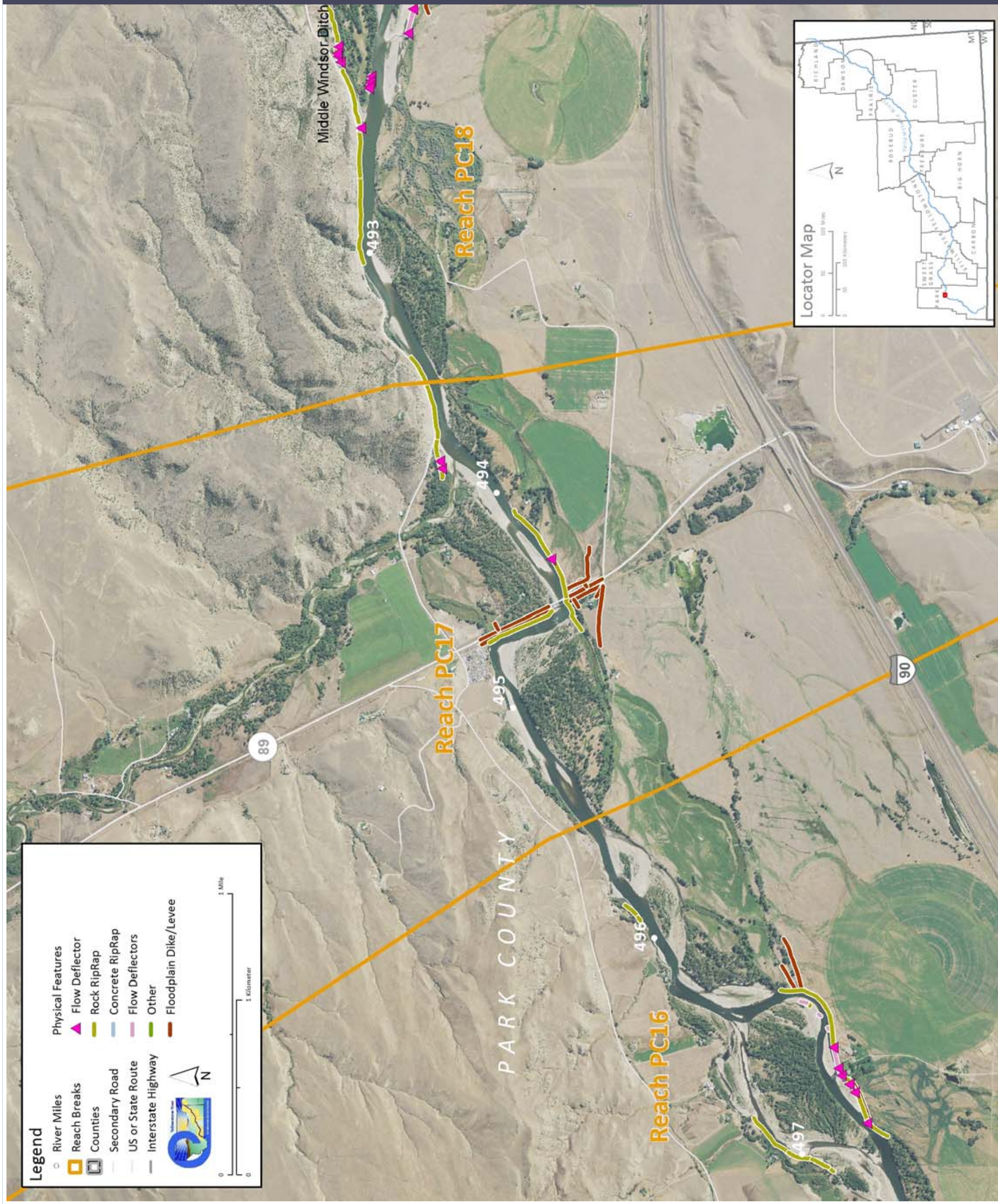
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

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

CEA-Related observations in Reach PC17 include:
•Constriction of CMZ at bridge and poor river alignment to structure.
•Side channel blockage by transportation embankment.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC17 include:
•Floodplain restoration/connectivity below transportation embankment at RM 494.5
•Side channel restoration below transportation embankment at RM 494.5
•CMZ Management due to current restriction of 25 percent of the Channel Migration Zone
•Bank Stabilization Recommended Practices due to the extent of armoring in the reach (28 percent armored banks)

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	129.2	11.0

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	10,400	20,600	25,900	29,200	35,900	38,700	44,900	1,720	1,760
Regulated	10,300	20,500	25,800	29,100	35,800	38,600	44,800	1,560	1,680
% Change	-0.96%	-0.49%	-0.39%	-0.34%	-0.28%	-0.26%	-0.22%	-9.30%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

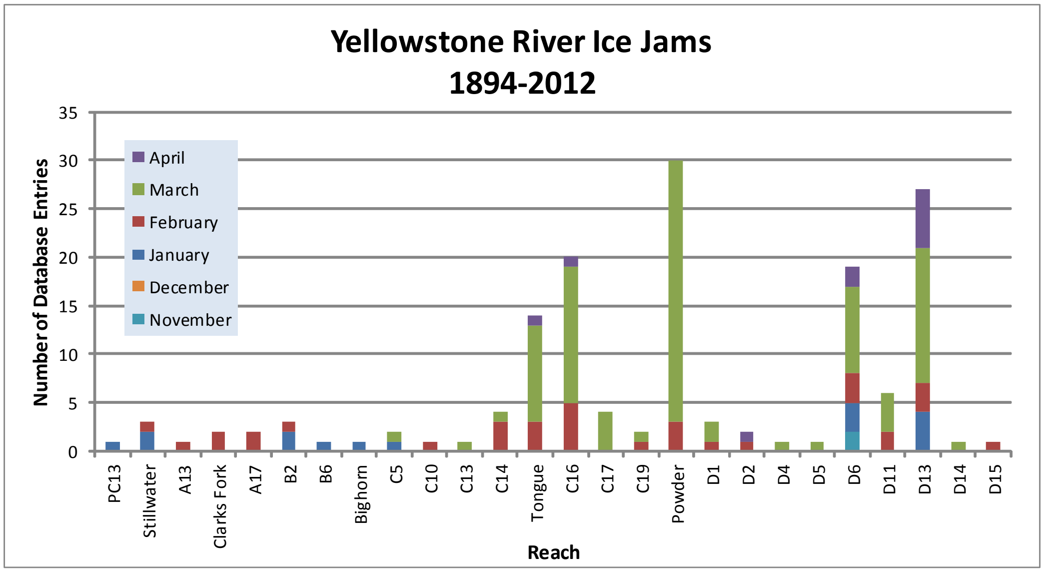
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	5,760	27.6%	5,704	27.3%	-56
	Flow Deflectors	78	0.4%	134	0.6%	56
	Feature Type Totals	**5,838**	**28.0%**	**5,838**	**28.0%**	**0**
Floodplain Control						
	Floodplain Dike/Levee	7,290	34.9%	7,290	34.9%	0
	Feature Type Totals	**7,290**	**34.9%**	**7,290**	**34.9%**	**0**
	Reach Totals	**13,128**	**62.9%**	**13,128**	**62.9%**	**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	10,030	2,384	1.24	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	10,430	2,345	1.22	1950 to 2001:	-1.04%
Change 1950 - 2001	**400**	**-39**	**-0.01**		

Length of Side Channels Blocked

Pre-1950s (ft)	3,948
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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
112	223	209	25	12%	213	81	38%

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			
	Non-Irrigated	90	21.2%
RipRap/Flow Deflectors			
	Public Road	2	0.4%
RipRap			
	Railroad	4	1.0%
	Non-Irrigated	10	2.4%
	Totals	**106**	**25.1%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
18.3	0.0	0.0	4.8	2.3

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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	11	31	38	44	1.1%	3.2%	3.9%	4.5%
	Totals	**11**	**31**	**38**	**44**	**1.1%**	**3.2%**	**3.9%**	**4.5%**
Agricultural Land									
	Non-Irrigated	462	521	493	611	47.6%	53.6%	50.8%	62.9%
	Irrigated	384	255	255	125	39.5%	26.3%	26.2%	12.9%
	Totals	**846**	**776**	**748**	**736**	**87.1%**	**79.8%**	**77.0%**	**75.8%**
Channel									
	Channel	96	126	131	132	9.9%	13.0%	13.5%	13.6%
	Totals	**96**	**126**	**131**	**132**	**9.9%**	**13.0%**	**13.5%**	**13.6%**
ExUrban									
	ExUrban Other	0	9	10	10	0.0%	1.0%	1.0%	1.0%
	ExUrban Undeveloped	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Industrial	0	8	8	8	0.0%	0.8%	0.8%	0.8%
	ExUrban Commercial	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	ExUrban Residential	0	1	17	22	0.0%	0.1%	1.8%	2.2%
	Totals	**0**	**19**	**35**	**40**	**0.0%**	**1.9%**	**3.6%**	**4.1%**
Transportation									
	Public Road	11	20	20	20	1.2%	2.1%	2.1%	2.1%
	Interstate	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Railroad	7	0	0	0	0.7%	0.0%	0.0%	0.0%
	Totals	**18**	**20**	**20**	**20**	**1.9%**	**2.1%**	**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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	40	60	0.0%	0.0%	5.4%	8.2%	0.0%	5.4%	2.9%	8.2%
	Pivot	0	0	0	47	0.0%	0.0%	0.0%	6.3%	0.0%	0.0%	6.3%	6.3%
	Flood	384	255	215	18	45.4%	32.9%	28.7%	2.5%	-12.5%	-4.2%	-26.2%	-42.9%
	Totals	**384**	**255**	**255**	**125**	**45.4%**	**32.9%**	**34.1%**	**17.0%**	**-12.5%**	**1.2%**	**-17.0%**	**-28.3%**

Non-Irrigated													
	Multi-Use	441	446	463	478	52.1%	57.4%	61.9%	64.9%	5.3%	4.5%	3.0%	12.8%
	Hay/Pasture	21	75	30	133	2.5%	9.7%	4.0%	18.1%	7.1%	-5.7%	14.0%	15.5%
	Totals	**462**	**521**	**493**	**611**	**54.6%**	**67.1%**	**65.9%**	**83.0%**	**12.5%**	**-1.2%**	**17.0%**	**28.3%**

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.

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	2.0	65.1	19.0	0.0	**86.1**
Acres/Valley Mile	1.2	37.9	11.0	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	0.27	0.07%	0.09	0.01	0.00	0.00

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

Yellowstone River Reach Narratives — Reach PC18

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

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

Narrative Summary

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

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

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

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

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

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

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

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

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

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

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

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

Discharge

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

AERIAL PHOTOGRAPHY

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

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

PHYSICAL FEATURES

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

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

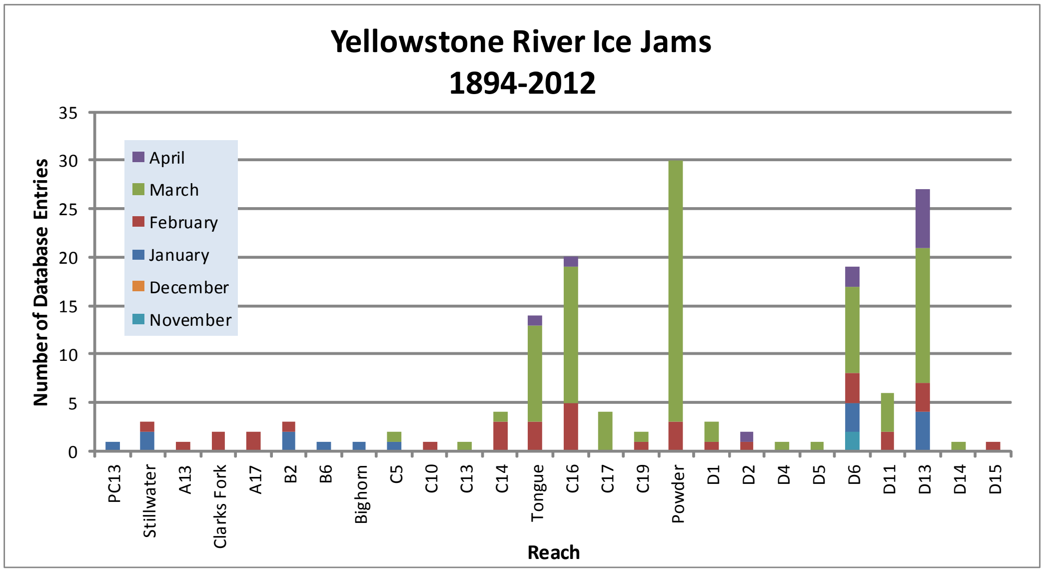
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

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

ICE JAMS

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



GEOMORPHIC

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

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

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

Braiding (Bankfull)

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

Length of Side Channels Blocked

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

HYDRAULICS

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

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

Floodplain Isolation

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

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

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

CHANNEL MIGRATION ZONE

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

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

2011 Restricted Migration Area Summary

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			
	Non-Irrigated	5	0.4%
	Irrigated	113	8.3%
RipRap			
	Irrigated	35	2.6%
	Exurban Residential	7	0.5%
	Canal	21	1.6%
Flow Deflectors			
	Other Infrastructure	3	0.2%
	Totals	**185**	**13.5%**

Land Uses within the CMZ (Acres)

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

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

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

Land Use Timeline - Tiers 3 and 4

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

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

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

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

RUSSIAN OLIVE

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

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

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

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

FISHERIES SUMMARY

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

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

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

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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.

County	Park	**Upstream River Mile**	488.3
Classification	CS: Confined straight	**Downstream River Mile**	485.4
General Location	To near Locke Cr	**Length**	2.90 mi (4.67 km)

General Comments

Narrative Summary

Reach PC19 is located in Park County, downstream of Livingston near Locke Creek. It is 2.9 miles long, and is a Confined Straight (CS) reach type indicating that it is highly confined between the valley wall to the north, and by the railroad/Interstate corridor to the south. The transportation corridor has isolated on the order of 40acres of historic floodplain from the river. These broad fields south of the river that are historic floodplain areas are now irrigated. The primary land use in the reach is agriculture, with about 200 acres each of flood, pivot, and sprinkler irrigation. More than half of the agricultural land is non-irrigated (~750 acres). In 1950, the transportation corridor footprint consumed about 50 acres in the reach, and that area was doubled with the construction of the Interstate in the late 1960s.

The stability of the reach is indicated by the fact that less than 3 percent of the bankline is armored. That 805 feet of armor was all constructed on the right bank sometime since 2001 where the river flows within a few hundred feet of the rail line. There are no side channels in the reach and the CMZ is relatively narrow.

Although the corridor confined and relatively narrow, there are about 50 acres of wetlands mapped in Reach PC19. These wetlands are consistently along low areas of the active riverbanks that support emergent and scrub/shrub wetland types. Only 0.03 acres of Russian olive was mapped in the reach.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,730 cfs to 1,560 cfs with human development, a reduction of 9.8 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC19 include:
•Corridor confinement by transportation infrastructure.
•Agricultural development and irrigation of historic floodplain area that has become isolated from the river by transportation infrastructure.

No reach-specific Practices were identified for Reach PC19.

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	121.0	18.3

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,400	22,400	28,100	31,700	38,900	41,800	48,500	1,730	1,760
Regulated	11,100	22,000	27,800	31,400	38,600	41,600	48,400	1,560	1,680
% Change	-2.63%	-1.79%	-1.07%	-0.95%	-0.77%	-0.48%	-0.21%	-9.83%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

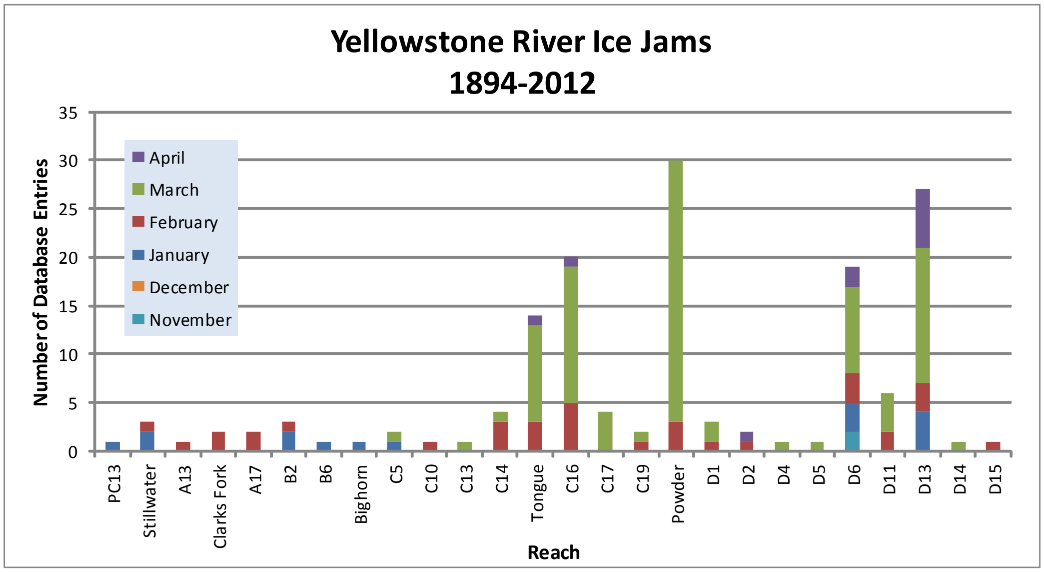
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	0	0.0%	805	2.8%	805
	Feature Type Totals		**0.0%**	**805**	**2.8%**	
	Reach Totals		**0.0%**	**805**	**2.8%**	

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	14,505		1.00	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	14,533		1.00	1950 to 2001:	0.00%
Change 1950 - 2001	**28**		**0.00**		

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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
19	38	153	0	0%	0	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			
	Non-Irrigated	2	1.4%
	Totals	**2**	**1.4%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
4.1	0.0	2.0	0.0	0.8

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	9	16	19	22	0.5%	1.0%	1.1%	1.3%
	Totals	**9**	**16**	**19**	**22**	**0.5%**	**1.0%**	**1.1%**	**1.3%**
Agricultural Land									
	Non-Irrigated	837	885	842	797	49.4%	52.2%	49.7%	47.0%
	Irrigated	686	613	611	654	40.5%	36.2%	36.1%	38.6%
	Totals	**1,522**	**1,498**	**1,453**	**1,450**	**89.8%**	**88.4%**	**85.7%**	**85.6%**
Channel									
	Channel	116	119	119	119	6.9%	7.0%	7.0%	7.0%
	Totals	**116**	**119**	**119**	**119**	**6.9%**	**7.0%**	**7.0%**	**7.0%**
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	1	0	0	0.0%	0.1%	0.0%	0.0%
	Totals	**0**	**1**	**0**	**0**	**0.0%**	**0.1%**	**0.0%**	**0.0%**
Transportation									
	Public Road	31	45	15	15	1.8%	2.7%	0.9%	0.9%
	Interstate	0	0	72	72	0.0%	0.0%	4.3%	4.3%
	Railroad	16	16	16	16	0.9%	0.9%	0.9%	0.9%
	Totals	**47**	**61**	**103**	**103**	**2.8%**	**3.6%**	**6.1%**	**6.1%**
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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	201	201	0.0%	0.0%	13.9%	13.9%	0.0%	13.9%	0.0%	13.9%
	Pivot	0	0	26	241	0.0%	0.0%	1.8%	16.6%	0.0%	1.8%	14.8%	16.6%
	Flood	686	613	383	211	45.0%	40.9%	26.4%	14.6%	-4.1%	-14.5%	-11.8%	-30.5%
	Totals	**686**	**613**	**611**	**654**	**45.0%**	**40.9%**	**42.1%**	**45.1%**	**-4.1%**	**1.1%**	**3.0%**	**0.0%**

Non-Irrigated												
Multi-Use	663	742	733	727	43.6%	49.5%	50.4%	50.1%	6.0%	0.9%	-0.3%	6.5%
Hay/Pasture	173	143	109	70	11.4%	9.6%	7.5%	4.8%	-1.8%	-2.0%	-2.7%	-6.6%
Totals	**837**	**885**	**842**	**797**	**55.0%**	**59.1%**	**57.9%**	**54.9%**	**4.1%**	**-1.1%**	**-3.0%**	**0.0%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	2.2	40.7	8.9	0.0	**51.9**
Acres/Valley Mile	0.8	15.2	3.3	0.0	

RUSSIAN OLIVE

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

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County	Park	**Upstream River Mile**	485.4
Classification	PCS: Partially confined straight	**Downstream River Mile**	481
General Location	East End	**Length**	4.40 mi (7.08 km)

General Comments

Narrative Summary

Reach PC20 is 4.4 miles long and flows through a narrow canyon known as East End just above Springdale. The reach is Partially Confined Straight (PCS); the river flows through a canyon that provides some curvature however that sinuosity is created by the canyon itself and does not reflect river meandering. Within Reach PC20, the river is closely bound by both the railroad line and Interstate. In places, the transportation infrastructure has been cut into the valley wall; in other areas it encroaches into the historic river floodplain. As a result, numerous slivers of historic floodplain area have become isolated from the river through the canyon, and most of these isolated floodplain areas are currently irrigated. Within the floor of the canyon, the river does show come migration, side channel formation, and habitat complexity, although those dynamics are relatively suppressed due to the natural and human-induced confinement.

Because of the moderately dynamic nature of the river and the encroachment by transportation infrastructure, there are over two miles of bank armor in Reach PC20, and about 1,100 feet of that armor was constructed since 2001. All of the armor is on the right bank of the river where the channel is against the railroad line. Over a quarter of the banks are armored.

The primary land use in Reach PC20 is non-irrigated agriculture, although there are 79 acres of ground under sprinkler irrigation, and 115 acres under pivot. All of the irrigation is well out of the Channel Migration Zone (CMZ).

Over 100 acres of wetlands have been mapped in Reach PC20 and there is some minor Russian olive present. All of the wetlands are in the active river corridor, on low surfaces that host emergent and scrub/shrub wetland types.

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

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CEA-Related observations in Reach PC20 include:
•Corridor confinement by transportation infrastructure.
•Agricultural development and irrigation of historic floodplain area that has become isolated from the river by transportation infrastructure.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC20 include:
•CMZ Management due to current restriction of 11 percent of the Channel Migration Zone
•Bank Stabilization Recommended due to 27 percent of banks being armored in reach

PHYSICAL FEATURES MAP (2011)

HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

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1902	Jun 11	30,100	10-25 yr
1943	Jun 20	30,600	10-25 yr
1974	Jun 17	36,300	50-100 yr
1996	Jun 10	37,100	50-100 yr
1997	Jun 6	38,000	50-100 yr
2011	Jun 30	40,600	>100-yr

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	116.6	21.2

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,400	22,400	28,100	31,700	38,900	41,800	48,500	1,730	1,760
Regulated	11,100	22,000	27,800	31,400	38,600	41,600	48,400	1,570	1,680
% Change	-2.63%	-1.79%	-1.07%	-0.95%	-0.77%	-0.48%	-0.21%	-9.25%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1948	DNR		B/W			
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

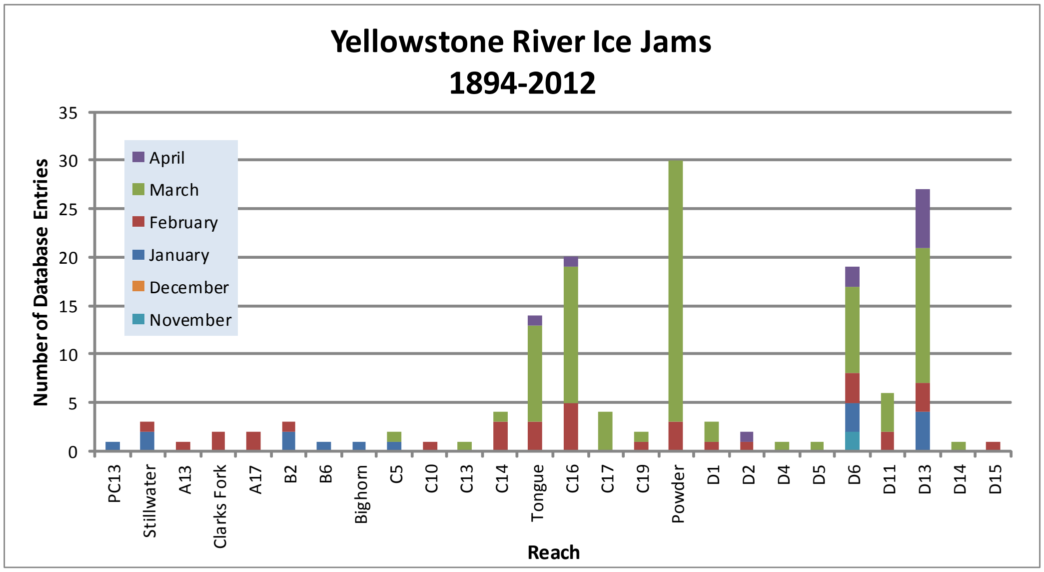
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	11,665	24.6%	12,764	27.0%	1,099
	Flow Deflectors	0	0.0%	56	0.1%	56
	Feature Type Totals	**11,665**	**24.6%**	**12,820**	**27.1%**	**1,155**
Floodplain Control						
	Floodplain Dike/Levee	3,181	6.7%	3,181	6.7%	0
	Feature Type Totals	**3,181**	**6.7%**	**3,181**	**6.7%**	**0**
	Reach Totals	**14,846**	**31.4%**	**16,001**	**33.8%**	**1,155**

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	23,758	10,972	1.46	1950 to 1976:	
1976				1976 to 1995:	
1995				1995 to 2001:	
2001	23,666	15,234	1.64	1950 to 2001:	12.44%
Change 1950 - 2001	**-92**	**4,262**	**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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
142	284	539	57	11%	43	0	0%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
RipRap			
	Railroad	59	10.1%
	Non-Irrigated	8	1.4%
	Totals	**67**	**11.5%**

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

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation

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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 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	27	33	60	72	1.1%	1.3%	2.4%	2.8%
	Totals	**27**	**33**	**60**	**72**	**1.1%**	**1.3%**	**2.4%**	**2.8%**
Agricultural Land									
	Non-Irrigated	2,032	1,987	1,819	1,784	79.5%	77.7%	71.2%	69.8%
	Irrigated	133	117	193	203	5.2%	4.6%	7.6%	8.0%
	Totals	**2,166**	**2,104**	**2,012**	**1,987**	**84.7%**	**82.3%**	**78.7%**	**77.8%**
Channel									
	Channel	281	312	333	346	11.0%	12.2%	13.0%	13.5%
	Totals	**281**	**312**	**333**	**346**	**11.0%**	**12.2%**	**13.0%**	**13.5%**
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	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	54	0	13	13	2.1%	0.0%	0.5%	0.5%
	Interstate	0	81	112	112	0.0%	3.2%	4.4%	4.4%
	Railroad	28	26	26	26	1.1%	1.0%	1.0%	1.0%
	Totals	**82**	**107**	**151**	**151**	**3.2%**	**4.2%**	**5.9%**	**5.9%**
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

Feature Class	Feature Type	Acres 1950	Acres 1976	Acres 2001	Acres 2011	% of Reach Area 1950	% of Reach Area 1976	% of Reach Area 2001	% of Reach Area 2011	Change Between Years (% of Agricultural Land) '50-76	'76-01	'01-11	'50-11
Irrigated													
	Sprinkler	0	0	79	79	0.0%	0.0%	3.9%	4.0%	0.0%	3.9%	0.0%	4.0%
	Pivot	0	0	105	115	0.0%	0.0%	5.2%	5.8%	0.0%	5.2%	0.6%	5.8%
	Flood	133	117	9	9	6.2%	5.6%	0.5%	0.5%	-0.6%	-5.1%	0.0%	-5.7%
	Totals	**133**	**117**	**193**	**203**	**6.2%**	**5.6%**	**9.6%**	**10.2%**	**-0.6%**	**4.0%**	**0.6%**	**4.1%**

Non-Irrigated												
Multi-Use	1,998	1,934	1,788	1,766	92.2%	91.9%	88.8%	88.9%	-0.3%	-3.1%	0.0%	-3.4%
Hay/Pasture	34	53	31	18	1.6%	2.5%	1.5%	0.9%	0.9%	-1.0%	-0.6%	-0.7%
Totals	**2,032**	**1,987**	**1,819**	**1,784**	**93.8%**	**94.4%**	**90.4%**	**89.8%**	**0.6%**	**-4.0%**	**-0.6%**	**-4.1%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.0	64.3	45.8	0.0	**111.1**
Acres/Valley Mile	0.3	15.8	11.2	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	0.22	0.05%	0.12	0.01	0.02	0.04

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

Yellowstone River Reach Narratives — Reach PC21

County	Park	**Upstream River Mile**	481
Classification	PCA: Partially confined anabranching	**Downstream River Mile**	478.8
General Location	To Springdale	**Length**	2.20 mi (3.54 km)

General Comments

Narrative Summary

Reach PC21 is the downstream-most reach in Park County, emerging from a narrow canyon just above Springdale. The reach is 2.2 miles long, and is classified as Partially Confined Anabranching, reflecting some influence of the valley wall on channel form coupled by islands and side channels. At the upstream end of the reach, the Hunters Hot Springs Canal Diversion diverts water along the left bank of the river where it flows along the valley wall. This canal carries water about 11 miles down the river valley.

Reach PC21 is fairly heavily armored, with over a mile of bank armor in the reach, and most of that is rock riprap. Most of the armor is on the right bank against the railroad line, but there is also armor protecting the Hunters Hot Springs Canal Diversion as well as hayfields along the left bank. In the lower end of the reach the left bank is a high terrace that has bedrock exposed at its toe.

The primary land use in Reach PC21 is non-irrigated agriculture, although there are 266 acres of ground under pivot irrigation. All of the pivot irrigation is well out of the Channel Migration Zone (CMZ). The Springdale Bridge Fishing Access Site is located in at the downstream end of the reach at Springdale Bridge. The bridge narrows the CMZ width from about 2,500 feet upstream to 1,000 feet downstream of the structure. Just upstream of the bridge, there are remnants of an older bridge, including a large pier in the river. Bedrock is exposed in the riverbed just upstream of the bridge.

About 90 acres of wetlands have been mapped in Reach PC21 and about 18 of those acres consist of emergent wetlands in low historic floodplain area that has been isolated from the river by the railroad and interstate. Although the Russian olive mapping shows 0.2 acres of RO in the reach, some of that had been eroded out by the river by fall 2011.

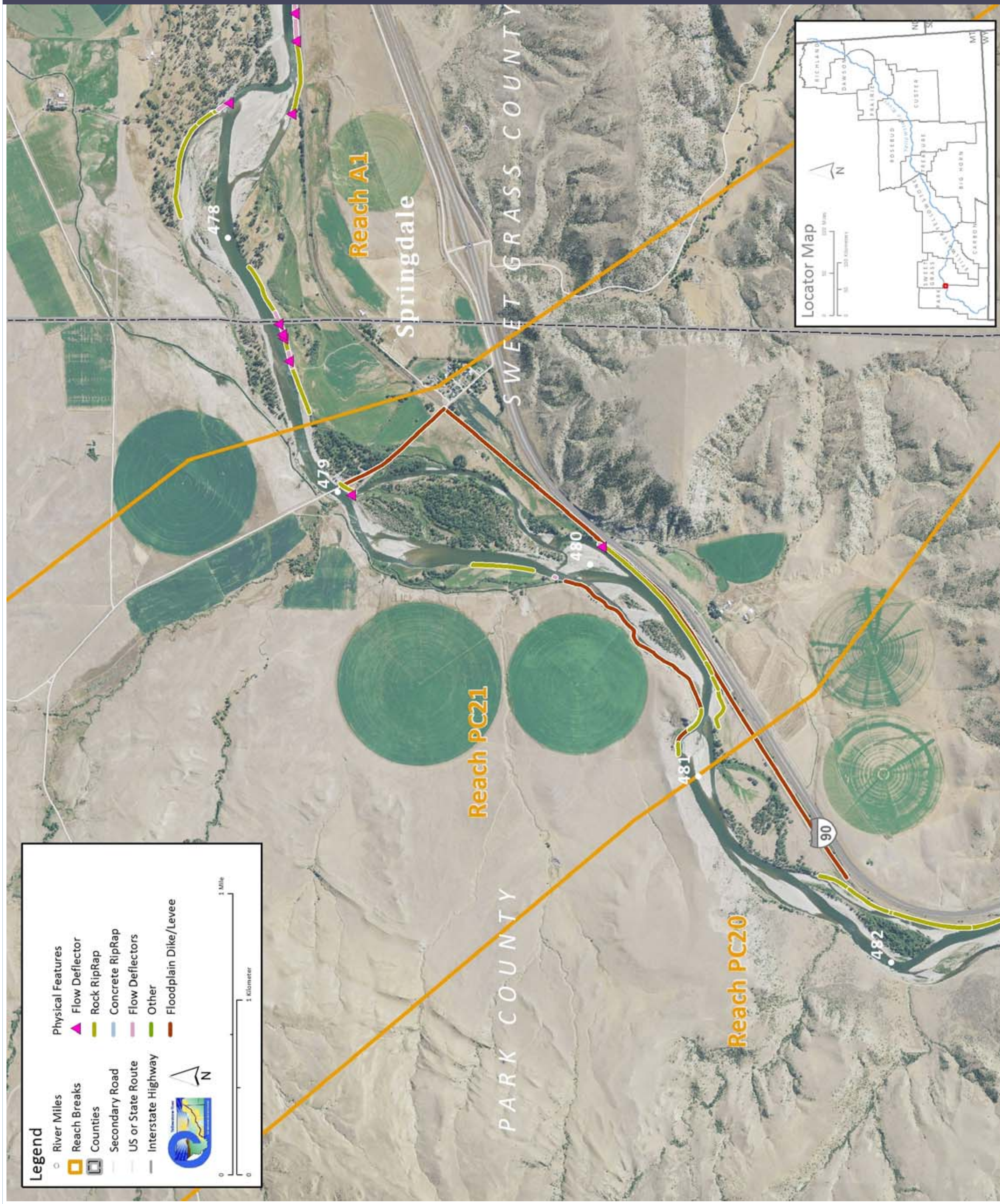
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been relatively small in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,730 cfs to 1,570 cfs with human development, a reduction of 9.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach PC21 include:
•Corridor confinement by transportation infrastructure.
•Emergent wetlands located in isolated floodplain area.
•Narrowing of CMZ by Springdale Bridge.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC21 include:
•CMZ Management due to current restriction of 19 percent of the Channel Migration Zone
•Bank Stabilization Recommended Practices due to 27 percent of banks being armored in reach
•Irrigation diversion structure management at Hunters Hot Springs Canal diversion.

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	114.4	25.6

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,400	22,400	28,100	31,700	38,900	41,800	48,500	1,730	1,760
Regulated	11,100	22,000	27,800	31,400	38,600	41,600	48,400	1,570	1,680
% Change	-2.63%	-1.79%	-1.07%	-0.95%	-0.77%	-0.48%	-0.21%	-9.25%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
2005	NAIP	08/26/2005	color	1-meter pixels	6192500	2320
2005	NAIP	08/25/2005	color	1-meter pixels	6192500	2390
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

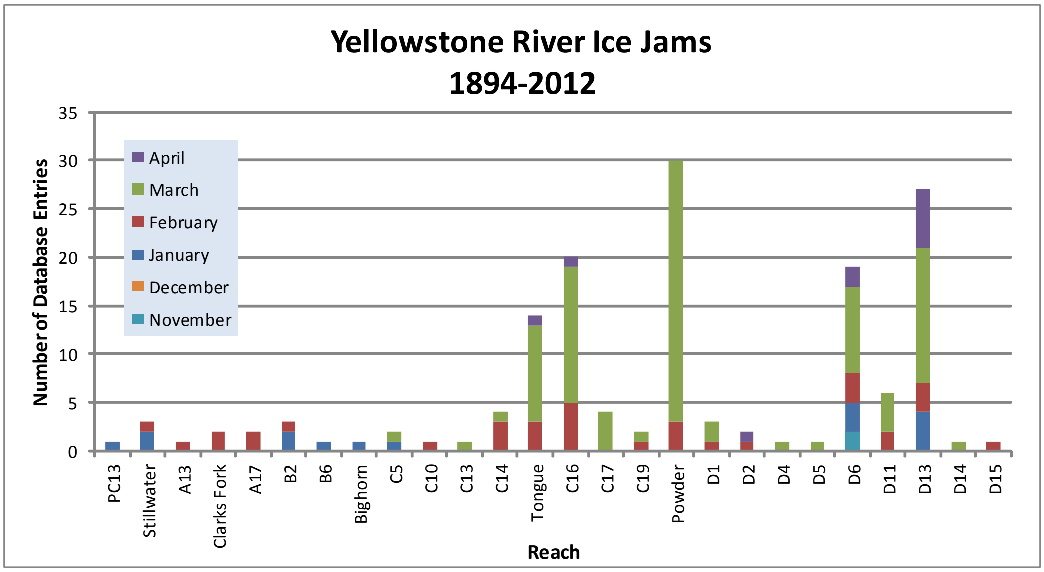
Note: As the goal for each physical features mapping effort were different, with differing mapping extents, there will be descrepancies between total feature lengths (e.g. length of rock riprap) in each data set.

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	6,101	25.5%	6,270	26.2%	169
	Flow Deflectors	60	0.3%	123	0.5%	62
	Feature Type Totals	**6,161**	**25.7%**	**6,393**	**26.7%**	**232**
Floodplain Control						
	Floodplain Dike/Levee	15,601	65.1%	15,612	65.1%	12
	Feature Type Totals	**15,601**	**65.1%**	**15,612**	**65.1%**	**12**
	Reach Totals	**21,762**	**90.8%**	**22,005**	**91.8%**	**244**

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	11,658	14,314	2.23	1950 to 1976:	
1976	1,552			1976 to 1995:	
1995				1995 to 2001:	
2001	11,983	14,978	2.25	1950 to 2001:	1.00%
Change 1950 - 2001	**325**	**664**	**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.)				
Agriculture (generally relates to field boundaries)				
Agriculture (isloated by canal or large ditch)				
Levee/Riprap (protecting agricultural lands)				
Levee/Riprap (protecting urban, industrial, etc.)				
Railroad				
Abandoned Railroad				
Transportation (Interstate and other roads)				
Total Not Isolated (Ac)				
Total Floodplain Area (Ac)				
Total Isolated (Ac)				

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

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

CHANNEL MIGRATION ZONE

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

Mean 50-Yr Migration Distance (ft)	Erosion Buffer (ft)	Total CMZ Acreage	Restricted CMZ Acreage	% Restricted Migration Area	Total AHZ Acreage	Restricted AHZ Acreage	% Restricted Avulsion Area
131	261	328	56	17%	11	9	82%

2011 Restricted Migration Area Summary

Reason for Restriction	Land Use Protected	RMA Acres	Percent of CMZ
Road/Railroad Prism			
	Public Road	25	7.3%
RipRap			
	Railroad	30	8.7%
	Irrigated	11	3.1%
	Totals	**65**	**19.2%**

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

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans- portation
9.5	0.0	0.0	6.7	22.9

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	18	20	20	20	1.5%	1.6%	1.6%	1.6%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	0	17	28	54	0.0%	1.4%	2.3%	4.4%
	Totals	**18**	**37**	**48**	**74**	**1.5%**	**3.0%**	**3.9%**	**6.0%**
Agricultural Land									
	Non-Irrigated	770	623	555	496	63.0%	51.0%	45.4%	40.6%
	Irrigated	148	264	291	336	12.1%	21.6%	23.8%	27.5%
	Totals	**918**	**887**	**846**	**832**	**75.1%**	**72.6%**	**69.2%**	**68.1%**
Channel									
	Channel	235	231	249	237	19.3%	18.9%	20.4%	19.4%
	Totals	**235**	**231**	**249**	**237**	**19.3%**	**18.9%**	**20.4%**	**19.4%**
ExUrban									
	ExUrban Other	0	0	7	7	0.0%	0.0%	0.5%	0.5%
	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	13	13	15	15	1.0%	1.0%	1.2%	1.2%
	Totals	**13**	**13**	**21**	**21**	**1.0%**	**1.0%**	**1.7%**	**1.7%**
Transportation									
	Public Road	28	3	6	6	2.3%	0.2%	0.5%	0.5%
	Interstate	0	43	43	43	0.0%	3.6%	3.6%	3.6%
	Railroad	10	9	9	9	0.8%	0.7%	0.7%	0.7%
	Totals	**38**	**55**	**58**	**58**	**3.1%**	**4.5%**	**4.8%**	**4.8%**
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	9	9	0.0%	0.0%	1.1%	1.1%	0.0%	1.1%	0.0%	1.1%
	Pivot	0	155	224	257	0.0%	17.5%	26.5%	30.8%	17.5%	9.0%	4.4%	30.8%
	Flood	148	109	58	70	16.1%	12.3%	6.8%	8.4%	-3.8%	-5.5%	1.6%	-7.7%
	Totals	**148**	**264**	**291**	**336**	**16.1%**	**29.8%**	**34.4%**	**40.3%**	**13.6%**	**4.6%**	**5.9%**	**24.2%**

Non-Irrigated												
Multi-Use	540	518	506	477	58.8%	58.4%	59.8%	57.3%	-0.4%	1.4%	-2.5%	-1.5%
Hay/Pasture	230	105	49	20	25.1%	11.9%	5.8%	2.4%	-13.2%	-6.0%	-3.5%	-22.7%
Totals	**770**	**623**	**555**	**496**	**83.9%**	**70.2%**	**65.6%**	**59.7%**	**-13.6%**	**-4.6%**	**-5.9%**	**-24.2%**

RIPARIAN

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

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

WETLANDS

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

	Riverine	Emergent	Scrub/Shrub	Forested	Total
Mapped Acres	1.9	61.8	25.6	0.0	**89.3**
Acres/Valley Mile	1.0	31.4	13.0	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	0.17	0.23%	1.07	0.03	0.02	0.06

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

County	Sweet Grass	**Upstream River Mile**	478.8
Classification	PCB: Partially confined braided	**Downstream River Mile**	475.4
General Location	Springdale	**Length**	3.40 mi (5.47 km)
General Comments	Springdale: Low primary sinuosity; large open bar area; extensive armoring		

Narrative Summary

Reach A1 is located just downstream of the Springdale Bridge in western-most Sweet Grass County. It is a Partially Confined Braided (PCB) reach type, indicating some influence of the valley wall on river geomorphology, as well as abundant un-vegetated mid-channel bars. The reach is 3.4 miles long. This reach is most prominently characterized by a large meander located at RM 478 that has been very dynamic over recent years. The meander bend has repeatedly migrated to the north and then cut off, leaving broad open gravel bars and a wide active channel corridor. The bendway has been heavily armored on its apex, and partially armored on its downstream limb. With all of the changes at this meander, there has been a net gain of total channel area in the reach of about 50 acres since 1950.

There are about 6,800 feet of rock riprap in the reach, over 1,500 feet of which was constructed since 2001. Several flow deflectors have been eroded out in Reach A1 since 2001. About 25 percent of the bankline was armored as of 2011. There are also over 6,800 feet of mapped transportation encroachment in the river corridor, most of which is the rail line that follows the south bank.

Although the rail line runs along the edge of the river, it is situated on higher terraces and as such has not isolated any 100-year historic floodplain area. However, about 9 percent of the total Channel Migration Zone (CMZ) footprint has become restricted, and these restrictions are due to armoring against both the rail line and irrigated fields. This demonstrates how terraces that may be out of the 100-year floodplain can still be prone to erosion and thus within the CMZ.

The primary land use in the reach is non-irrigated agriculture (~1,100 acres), although there are about 650 acres under some form of irrigation. Pivot irrigation has expanded from 0 acres in 1950 to 302 acres in 2011. Similarly, sprinkler irrigation has expanded from 0 to 250 acres during the same time frame, and the extent of flood irrigated lands dropped from 803 to 123 acres over those 61 years. About 46 acres of land under sprinkler and 10 acres of land under pivot are located within the CMZ.

About 120 acres of wetland have been mapped in the reach, with most of that (84 acres) emergent wetland marsh that is located primarily in the active stream corridor. About 20 acres of wetland have been isolated from the corridor by the rail line near RM 477.8. About 0.7 acres of Russian olive have been mapped in the reach, and these trees are dispersed throughout the corridor.

Hydraulic modeling of the reach shows an extensive network of floodplain channels on the floodplain in Reach A1 that creates some avulsion risk north of the river. Much of the armoring on the large meander at RM 478 has reduced the risk of an avulsion and potential bypass of the Prather Mayborn Westfall Ditch Diversion. In addition, one of the overflow channels has been allowed to activate, which has reduced the potential for additional avulsions. The strategic allowance of channel migration and secondary channel activation has prevented the creation of a severe pinch point at RM 477.4 that may have created long-term instability in the reach.

A large dike at RM 476.7 blocks a ~3,000-foot long side channel and focuses the river towards the south bank and the Prather Mayborn Westfall Ditch Diversion. Although the dike blocks the head of the channel, it is still seasonally accessed by other overflow points from the main river.

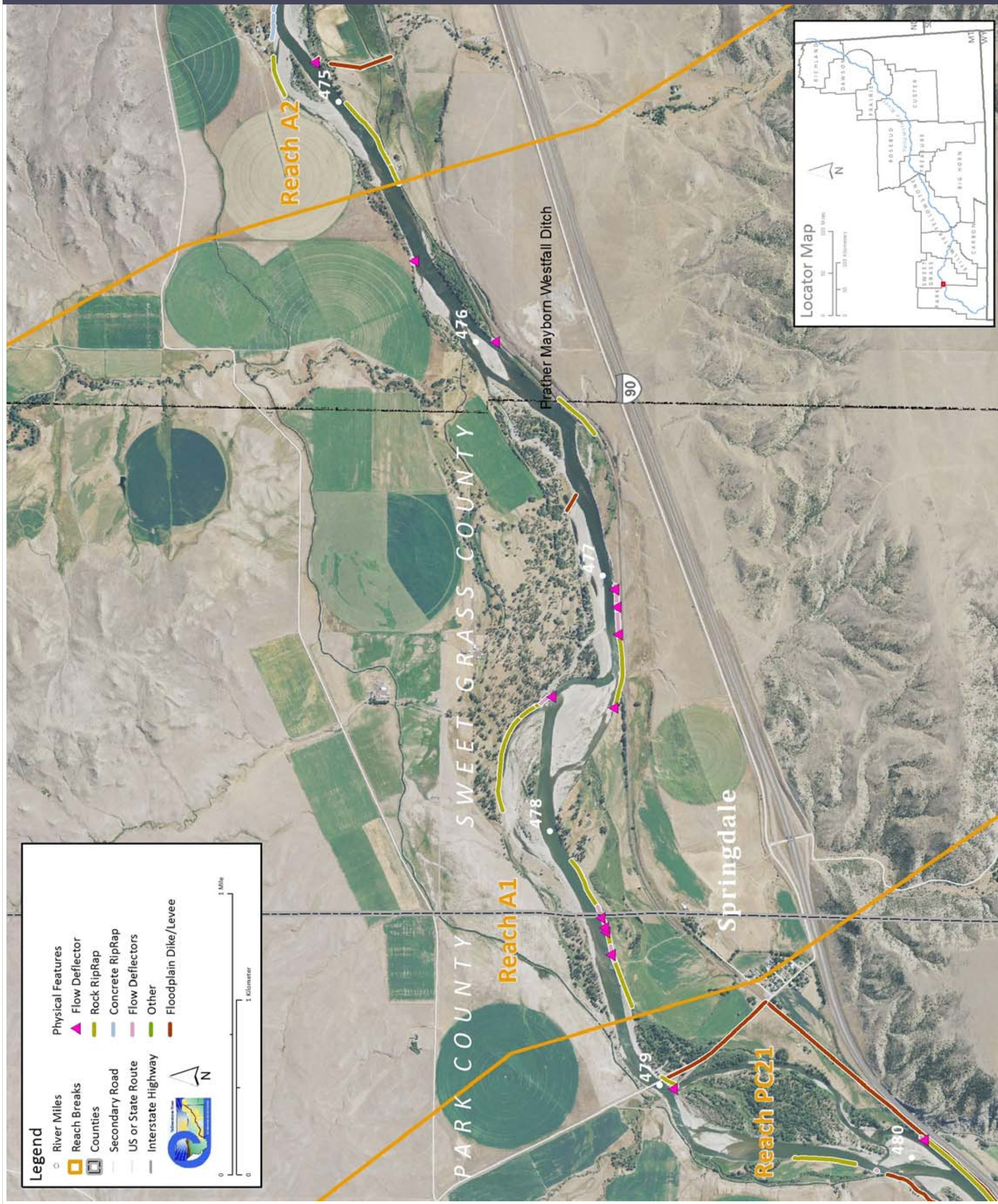
This area of the upper Yellowstone River has seen three severe floods in the last 20 years. The 1996 and 1997 floods were very damaging, early-June events that peaked at 37,100 and 38,000 cfs, respectively. At the time, these were considered to be sequential 100-year floods. Then in late June of 2011,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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,750 cfs to 1,570 cfs with human development, a reduction of 10.3 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A1 include:
•Strategic allowance of side channel activation to reduce overall avulsion risk
•Isolation of emergent wetlands by transportation infrastructure
•Blockage of a 3,000-foot long side channel to focus flows to a diversion structure.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A1 include:
•CMZ management due to level of restriction and avulsion risks on north floodplain
•Bank Stabilization Recommended Practices due to current extent of bank armoring (25 percent of total bankline)
•Irrigation diversion structure management at Prather Mayborn Westfall
•Wetland management/restoration due to high wetland concentrations

PHYSICAL FEATURES MAP (2011)



HYDROLOGIC SUMMARY

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

Gage Representation (Gage-Based): Livingston

Flood History

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

	Downstream Gage	Upstream Gage
Gage No	6214500	6192500
Location	Billings	Livingston
Period of Record	1929-2015	1929-2015
Distance To (miles)	111.0	27.8

Discharge

	1.01 Yr	2 Yr	5 Yr	10 Yr	50 Yr	100 Yr	500 Yr	7Q10 Summer	95% Sum. Duration
Unregulated	11,900	23,300	29,200	32,900	40,300	43,400	50,300	1,750	1,760
Regulated	11,500	22,900	28,800	32,500	40,000	43,200	50,100	1,570	1,680
% Change	-3.36%	-1.72%	-1.37%	-1.22%	-0.74%	-0.46%	-0.40%	-10.29%	-4.55%

AERIAL PHOTOGRAPHY

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

	Source	Acquisition Date	Type	Scale	Gage	Discharge
1950	USGS-EROS	5-Jul-48	B/W	1:23,600	6192500	9810
1976	USCOE	28-Sep-76	B/W	1:24,000	6192500	2560
1995	USGS-DOQ	23-Aug-97	B/W	1:24,000	6192500	4840
2001	NRCS	August 2-8, 2001	CIR	1:24,000	6192500	2000
2005	NAIP	08/25/2005	color	1-meter pixels	6192500	2390
2007	Woolpert	29-Jun-05	Color	1:	6192500	
2009	NAIP	7/16/2009	Color	1-meter pixels	6192500	8450
2011	NAIP	8/24/2011	Color	1-meter pixels	6192500	5170
2013	NAIP	08/31/2013	color	1-meter pixels	6192500	

PHYSICAL FEATURES

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

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

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

2001 and 2011 Physical Features Bankline Inventories

Feature Class	Feature Type	2001 Length (ft)	% of Bankline	2011 Length (ft)	% of Bankline	2001-2011 Change
Stream Stabilization						
	Rock RipRap	5,160	14.5%	6,839	19.2%	1,678
	Flow Deflectors	1,406	3.9%	573	1.6%	-832
	Between Flow Deflectors	995	2.8%	1,518	4.3%	523
	Feature Type Totals	**7,561**	**21.2%**	**8,930**	**25.1%**	**1,370**
Floodplain Control						
	Transportation Encroachment	6,845	19.2%	6,845	19.2%	0
	Floodplain Dike/Levee	331	0.9%	331	0.9%	0
	Feature Type Totals	**7,176**	**20.1%**	**7,176**	**20.1%**	**0**
	Reach Totals	**14,737**	**41.3%**	**16,107**	**45.2%**	**1,370**

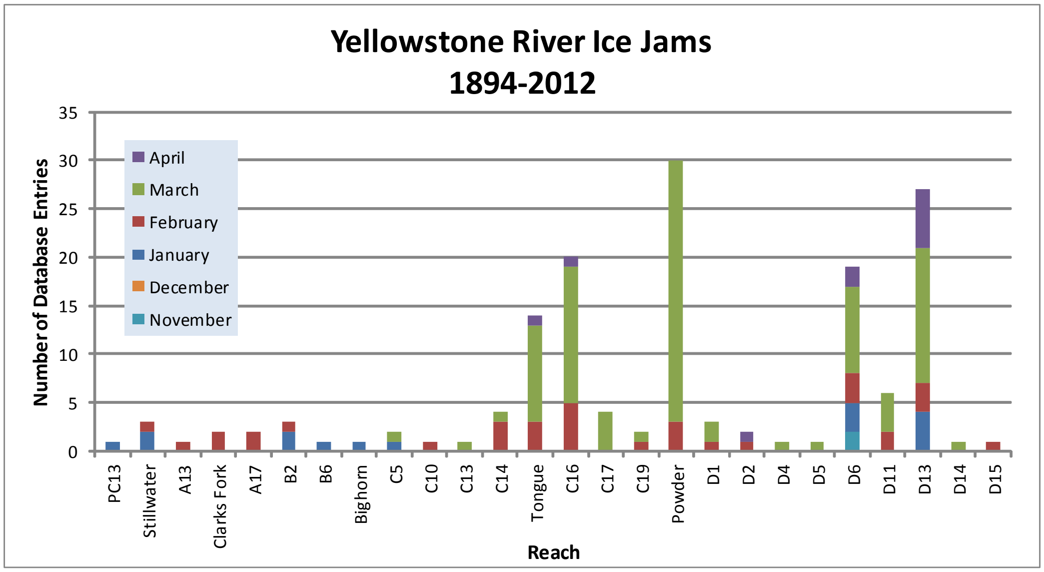
Intent of Bank Protection: 2001

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	0	522	0	0	0	895	0	0
Totals	**0**	**522**	**0**	**0**	**0**	**895**	**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.



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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	18,968	6,571	1.35	1950 to 1976:	9.83%
1976	18,838	9,020	1.48	1976 to 1995:	25.57%
1995	17,553	15,040	1.86	1995 to 2001:	-9.38%
2001	17,825	12,169	1.68	1950 to 2001:	24.97%
Change 1950 - 2001	**-1,143**	**5,598**	**0.34**		

Length of Side Channels Blocked

Pre-1950s (ft)	0
Post-1950s (ft)	2,970

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	0	0.0%		
Abandoned Railroad	0	0.0%		
Transportation (Interstate and other roads)	0	0.0%		
Total Not Isolated (Ac)	344		422	
Total Floodplain Area (Ac)	344		435	
Total Isolated (Ac)	**0**	**0.0%**	**13**	**7.4%**

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	5	0	**5**

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
190	379	582	82	14%	157	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	2	0.3%
RipRap/Flow Deflectors			
	Railroad	28	3.8%
	Irrigated	30	4.0%
RipRap			
	Railroad	6	0.8%
	Totals	**66**	**8.9%**

Land Uses within the CMZ (Acres)

Flood Irrigation	Sprinkler Irrigation	Pivot Irrigation	Urban/ ExUrban	Trans-portation
15.7	46.1	10.0	0.0	9.8

LAND USE

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

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

Land Use Timeline - Tiers 2 and 3

		Acres				% of Reach Area			
Feature Class	Feature Type	1950	1976	2001	2011	1950	1976	2001	2011
Agricultural Infrastructure									
	Canal	16	16	16	16	0.7%	0.7%	0.7%	0.7%
	Agricultural Roads	0	0	0	0	0.0%	0.0%	0.0%	0.0%
	Other Infrastructure	36	33	65	93	1.5%	1.4%	2.8%	4.0%
	Totals	**52**	**50**	**81**	**109**	**2.2%**	**2.1%**	**3.5%**	**4.7%**
Agricultural Land									
	Non-Irrigated	1,189	1,207	1,152	1,112	51.3%	52.1%	49.7%	47.9%
	Irrigated	803	766	700	678	34.7%	33.1%	30.2%	29.3%
	Totals	**1,993**	**1,973**	**1,852**	**1,790**	**86.0%**	**85.1%**	**79.9%**	**77.2%**
Channel									
	Channel	220	243	298	332	9.5%	10.5%	12.9%	14.3%
	Totals	**220**	**243**	**298**	**332**	**9.5%**	**10.5%**	**12.9%**	**14.3%**
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	5	5	5	5	0.2%	0.2%	0.2%	0.2%
	Totals	**5**	**5**	**5**	**5**	**0.2%**	**0.2%**	**0.2%**	**0.2%**
Transportation									
	Public Road	28	28	14	14	1.2%	1.2%	0.6%	0.6%
	Interstate	0	0	48	48	0.0%	0.0%	2.1%	2.1%
	Railroad	20	20	20	20	0.8%	0.8%	0.8%	0.8%
	Totals	**48**	**48**	**82**	**82**	**2.1%**	**2.1%**	**3.5%**	**3.5%**
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	260	254	0.0%	0.0%	14.0%	14.2%	0.0%	14.0%	0.2%	14.2%
	Pivot	0	0	287	302	0.0%	0.0%	15.5%	16.9%	0.0%	15.5%	1.4%	16.9%
	Flood	803	766	153	123	40.3%	38.8%	8.3%	6.8%	-1.5%	-30.6%	-1.4%	-33.5%
	Totals	**803**	**766**	**700**	**678**	**40.3%**	**38.8%**	**37.8%**	**37.9%**	**-1.5%**	**-1.1%**	**0.1%**	**-2.4%**

Non-Irrigated													
Multi-Use	1,119	1,059	1,100	1,046	56.2%	53.7%	59.4%	58.5%	-2.5%	5.7%	-0.9%	2.3%
Hay/Pasture	70	147	52	65	3.5%	7.5%	2.8%	3.6%	3.9%	-4.6%	0.8%	0.1%
Totals	**1,189**	**1,207**	**1,152**	**1,112**	**59.7%**	**61.2%**	**62.2%**	**62.1%**	**1.5%**	**1.1%**	**-0.1%**	**2.4%**

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	0.9	0.3	0.0	0.8	0.3	0.4	14.7	16.0	6.2
Max	20.0	11.9	5.3	219.1	149.9	171.1	14.7	29.8	26.6
Average	8.3	3.6	2.6	39.0	28.0	23.4	14.7	24.2	18.9
Sum	49.7	21.7	20.7	312.2	223.7	233.7	14.7	72.6	56.8

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)	71.8
Channel to Riparian (acres)	26.4
Riparian Encroachment (acres)	**-45.5**

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	7.4	84.3	38.0	0.0	**129.8**
Acres/Valley Mile	2.3	26.0	11.7	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	0.67	0.18%	1.19	0.03	0.03	0.01

FISHERIES SUMMARY

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

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

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

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

AVIAN

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

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 A

In the study segment, Laurel to Springdale, three themes emerge as dominant across the four interest groups. One theme focuses on the changing riverbank profile as more and more residential homes are built on the river's edge. The second theme focuses on the river as a powerful and dynamic physical entity. The third is about the changing social profiles of their communities and how those changes influence user practices.