

County	Yellowstone	Upstream River Mile	392.4
Classification	UA: Unconfined anabranching	Downstream River Mile	386
General Location	To Laurel	Length	6.40 mi (10.30 km)

Narrative Summary

Reach A17 is 7.6 miles long and is located just above Laurel. The reach is classified as Unconfined Anabranching (UA), which is characteristically one of the most dynamic reach types on the river. The river is flowing in the alluvial valley with minimal influences of the valley wall and through numerous forested islands. There are sites in Reach A17 where the river has migrated almost 1,000 feet since 1950.

Approximately 13 percent of the bankline in Reach A17 is armored by rock riprap, concrete riprap and flow deflectors. Between 2001 and 2011 the total length of rock riprap increased by about a half of a mile. At RM 387, a ~750 foot long stretch of flow deflectors on the left bank have been flanked, and by fall 2011 the river had migrated about 120 feet behind the flanked armor. The deflectors are still visible in the channel. In some places such as at RM 389.8, bank armor on both sides of the river narrows the corridor to about one channel width, or 1,000 feet.

Over a mile of side channels in Reach A17 were blocked prior to 1950. Two major channels were blocked on the north side of the river, one at the Buffalo Mirage Fishing Access Site at RM 391.5, and the other at Rm 389.5. These channels, as well as other secondary channels that were passively lost, host fairly dense concentrations of Russian olive. Similar to most reaches in Region A, the loss of side channels has been accompanied by an increase in the total river footprint, indicating that flow concentration into the main river channel has caused it to enlarge. Between 1950 and 2001, the size of the channel increased from 560 acres to 645 acres.

Land use in Reach A17 is primarily agricultural, although there are almost 600 acres of urban/exurban development in the reach as the river approaches the City of Laurel. Since 1950, there has been a reduction in flood irrigated acres of about 550 acres, and an increase in pivot irrigation from 0 acres in 1950 to 284 acres in 2011. A total of 383 acres of developed ground are in the mapped Channel Migration Zone; and about 11 percent of the CMZ has been isolated by physical features protecting those land uses.

At RM 388.5, a headgate diverts water into an old side channel that has been converted to a canal on the north side of the river. About ½ mile downstream, the canal is riprapped where it was recently threatened by rapid northward river migration. At this location, the river has migrated over 800 feet northward since 1950. The main channel of the river now flows along the riprapped canal embankment for about 750 feet.

There are corrals that are part of an animal handling facility within 600 feet of the north riverbank at RM 392.

Side channel loss and channel migration in Reach A17 has resulted in relatively high rates of riparian recruitment. Since 1950, there has been 330 acres of land that experience recruitment of new riparian vegetation. Most of that recruitment was in abandoned channels (200 acres) and about 27 acres of recruitment was direct result of channel migration.

Two ice jams have been recorded in Reach A17, in 1996 and 1997. Both occurred during the month of February, and were reported to have occurred at the Laurel Bridge.

There are over 200 acres of mapped wetland in the reach, with most of that emergent marshes and wet meadows. Many of these wetland areas occupy river swales on the floodplain north of the river, or abandoned channels in the active corridor.

Almost 22 acres of Russian olive has been mapped in the floodplain.

Reach A17 was sampled as part of the avian study. The average species richness in Reach A17 was 7.7, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. An average of 0.9 Cowbirds (a bird that parasitizes other bird's nests) were observed in cottonwood habitats during the field sampling visits. Reach A17 has lost about two thirds of its riparian forest considered at low risk of cowbird parasitism since 1950. At that time, there were about 28 acres of forest per valley mile considered to be isolated enough from agricultural infrastructure and urban/exurban development to be considered at low risk. By 2011, about 10 acres per valley mile considered low risk remained.

A total of three Potential Species of Concern (PSOCs) were observed in Reach A17 during the avian study, including the Black and White Warbler, Chimney Swift, and Ovenbird. One Species of Concern (SOC), the Bobolink, was also observed in Reach A17.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,900 cfs to 15,500 cfs, a drop of about 8 percent. 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 2,320 cfs to 1,780 cfs with human development, a reduction of 23 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 A17 include:

- Flanking of flow deflectors and accelerated erosion behind flanked structures
- Physical blockage of over a mile of side channel
- Russian olive colonization in abandoned side channels

- Emergent wetland development in abandoned side channels
- Ice jamming potentially associated with the Laurel Bridge

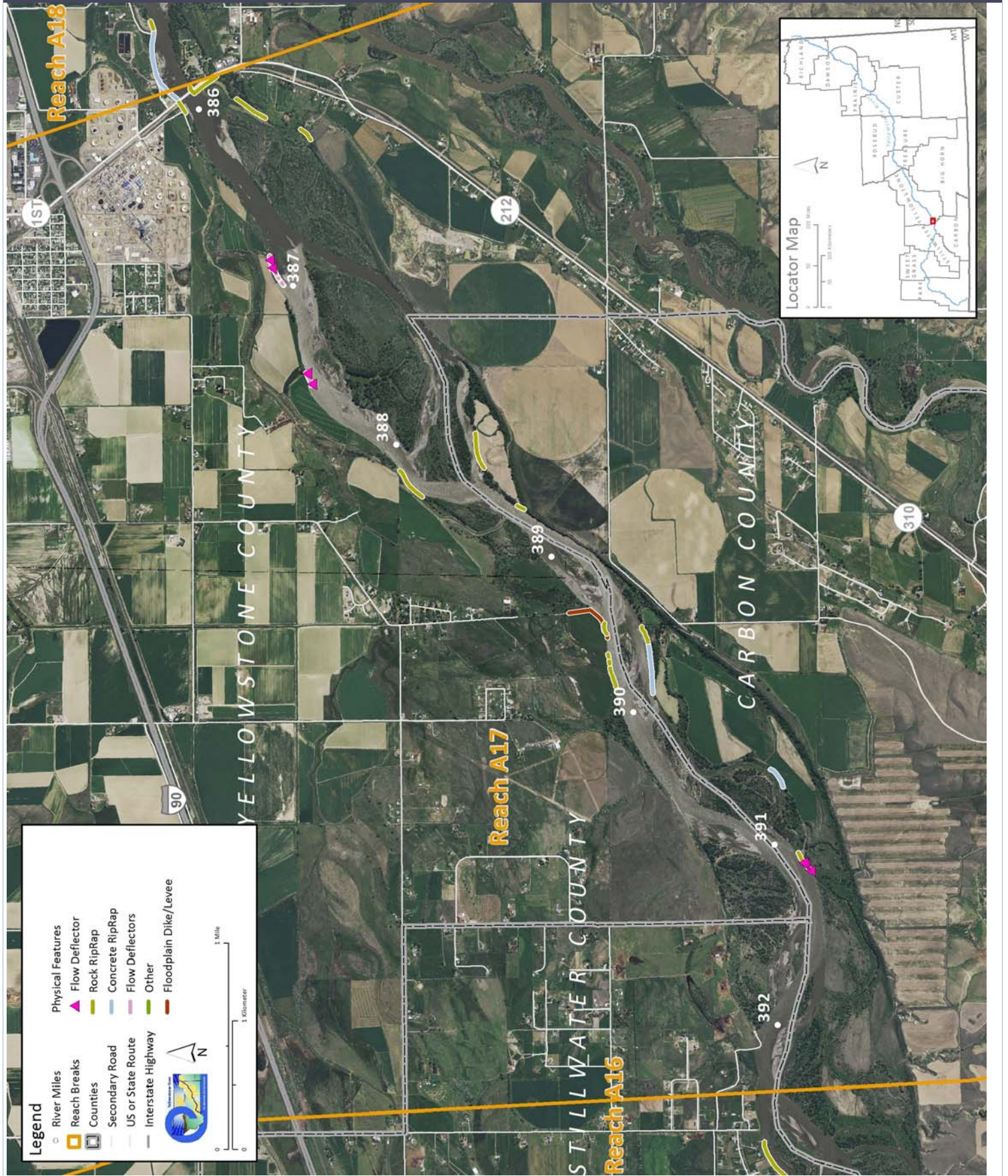
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A17 include:

- Bank armor removal (flanked flow deflectors), RM 387
- Side channel restoration at RM 391.5 and RM 389.5
- Nutrient management associated with corrals that are part of an animal handling facility at RM 392.
- Russian olive removal (22 acres)
- Wetland management/restoration due to extent of mapped wetland (200 acres)
- Irrigation diversion structure management at headgate on side channel at RM 388.5

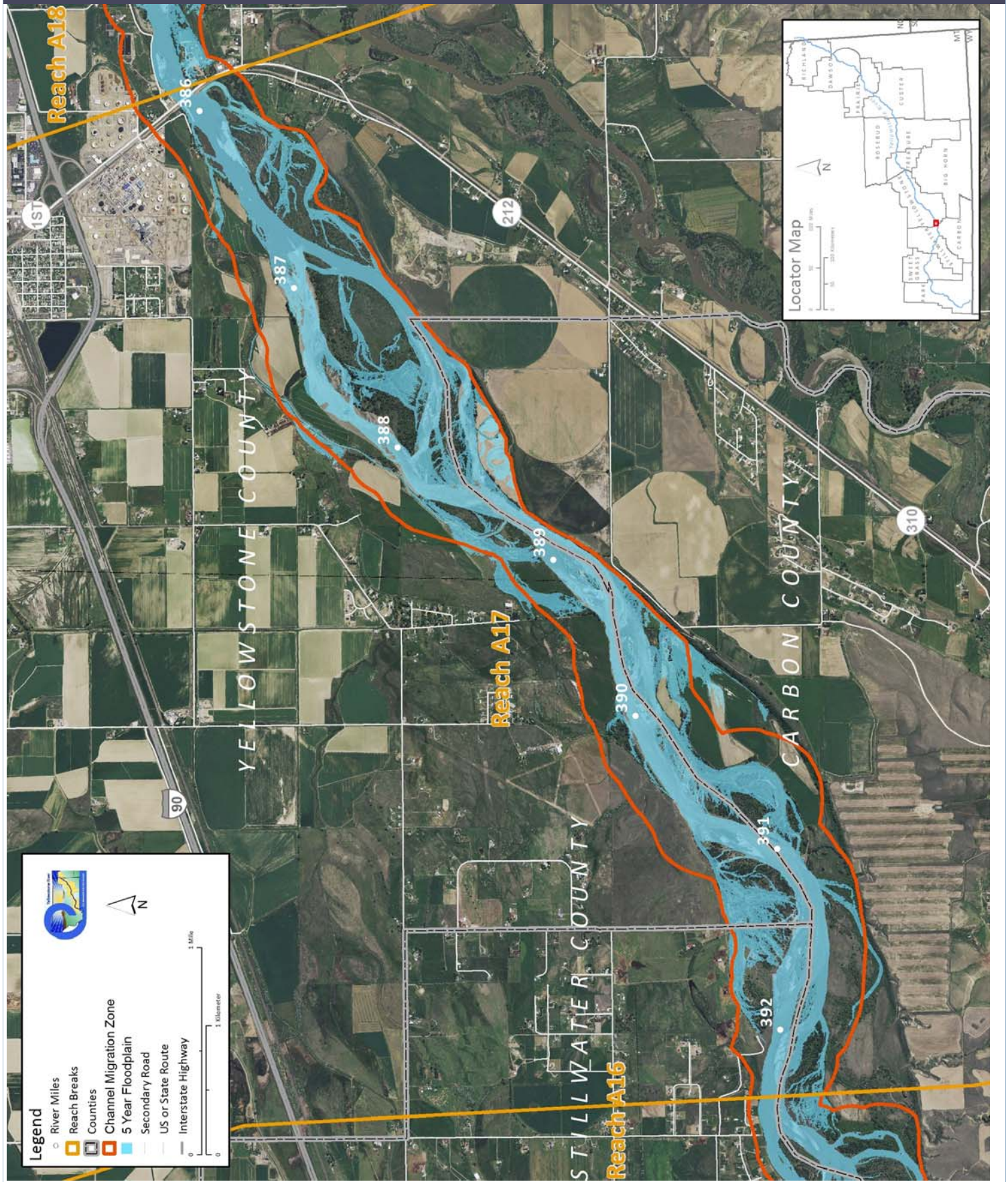
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	32,200	30,600	-5.0%			
100 Year (cfs)	58,600	57,600	-1.7%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	560.0	608.9	557.5	644.6	84.6	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	6,184	9.1%	2,584			
Concrete Riprap	2,205	3.2%	0			
Flow Deflectors	671	1.0%	-176			
Total	9,060	13.3%	2,407			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	7,639	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)	The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
Total Acres	195.3	180.6	-19.75 acres			
Acres/Year	7.5	7.2				
Acres/Year/Valley Mile	1.3	1.3				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	46.4	9%				
100 Year	89.9	7%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	245.6	11%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	4,530.2	4,110.3	Flood (Ac)	1,927.0	1,384.1	
Ag. Infrastructure (Ac)	68.6	118.5	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	59.1	292.3	Pivot (Ac)	0.0	283.8	
Urban (Ac)	95.4	203.9				
Transportation (Ac)	50.2	50.2				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	6.0	0.8	6.8	1.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	9.4	1.6	226.2			
Emergent	203.4	35.6				
Scrub/Shrub	13.4	2.3				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	21.8	6.7%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	27.7	64.2	9.7	-18.0		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	386
Classification	UA: Unconfined anabranching	Downstream River Mile	383.5
General Location	To Clarks Fork	Length	2.50 mi (4.02 km)

Narrative Summary

Reach A18 is 2.5 miles long and extends from Laurel to the mouth of the Clarks Fork River. The reach is classified as Unconfined Anabranching (UA), which is characteristically one of the most dynamic reach types on the river. The reach has one large island and even though it is fairly intensively armored through Laurel, there has been over 1,100 feet of southward channel migration since 1950 at one location about ½ mile downstream of the bridge.

Reach A18 is perhaps best known by the series of pipeline crossings below the Laurel Bridge. In 2011, floodwaters on the Yellowstone River peaked on July 2 at 70,600 cfs, which is an estimated 25-50 year flood event. On July 1, the day before the peak, a 12-inch diameter crude oil pipeline called the ExxonMobil Silvertip Pipeline, ruptured just downstream of the bridge in Reach A18. The pipeline was originally installed in a trench across the river that was 5-7 feet deep. The rupture spilled an estimated 50,000 gallons of oil into the Yellowstone River; the incident received national attention and millions of dollars were spent on cleanup. The Silvertip Pipeline and several others at this location have been replaced by HDD (Horizontal Directionally Drilled) lines.

The industrial land uses at Laurel coupled with the dynamic nature of the Yellowstone River in Reach A18 has resulted in the armoring of almost 40 percent of the river in this reach. That armor consists of rock riprap, concrete riprap, and flow deflectors. Almost all of the armor is located on the north bank where it protects the City of Laurel sewage treatment facility, as well as a canal that leaves the river at RM 385.7. There is one small section of concrete armor on the north bank, and it appears that the upper 300 feet of this armor has been flanked and now is visible in the middle of the river. Recent concerns over the main intake structure for the city's water supply sheds some light on the dynamics of the river, and potentially the influence of high density bank armor on channel stability. The 2011 flood evidently caused the river to downcut at the intake, perching the structure, such that there are current efforts in motion to relocate the intake several miles upstream. This downcutting may be related to the high density of armor between Laurel and Billings that effectively focuses flow into the main channel and can drive channel incision (downcutting). Reach conditions just downstream in Reach B1 support this hypothesis.

There are over three miles of mapped dikes in Reach A18. Dikes, levees, and transportation encroachment features have isolated about one half of the historic 100-year floodplain in the reach. Almost 17 percent of the 5-year floodplain has become isolated from the river. Most of the isolated 100-year floodplain area is south of the river, between the Yellowstone and Clarks Fork Rivers.

Land use in Reach A18 is primarily agricultural, although there are almost 380 acres of urban/exurban development in the reach as the river passes south of the City of Laurel. All of the irrigated land in Reach A18 is in flood irrigation. A total of 110 acres of developed ground are in the mapped Channel Migration Zone; and the over 90 percent of that is in urban/exurban land use. A total of 31 percent of the CMZ has become isolated by physical features.

Riparian mapping indicates that since 1950, about 67 acres in the reach were cleared to support irrigation and other land uses. There are about 18 acres of mapped Russian olive in the floodplain.

Since 1950, about 150 acres of land in Reach A18 was colonized by new riparian vegetation. There are over 140 acres of mapped emergent wetland in the reach, which consists primarily of emergent marshes and wet meadows.

Almost 18 acres of Russian olive has been mapped in the floodplain.

Reach A18 was sampled as part of the avian study. The average species richness in Reach A17 was 7.1, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for all sites evaluated is 8. On average, of 0.9 Cowbirds were observed in cottonwood habitats during the field sampling visits. Reach A18 has lost all of its riparian forest considered at low risk of cowbird parasitism since 1950. At that time, there were 3.4 acres of forest per valley mile considered to be isolated enough from agricultural infrastructure and urban/exurban development to be considered at low risk. By 2011, that had been reduced to zero.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 16,900 cfs to 15,500 cfs, a drop of about 8 percent. 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 2,780 cfs to 1,950 cfs with human development, a reduction of 30 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 A18 include:

- Flanking of concrete armor
- Pipeline rupture in highly armored reach
- Water intake perching in highly armored reach
- Russian olive colonization
- Emergent wetland development in abandoned side channels
- Floodplain isolation at confluence between Clarks Fork and Yellowstone River from transportation-related infrastructure

- Extensive CMZ encroachment in urbanized reach

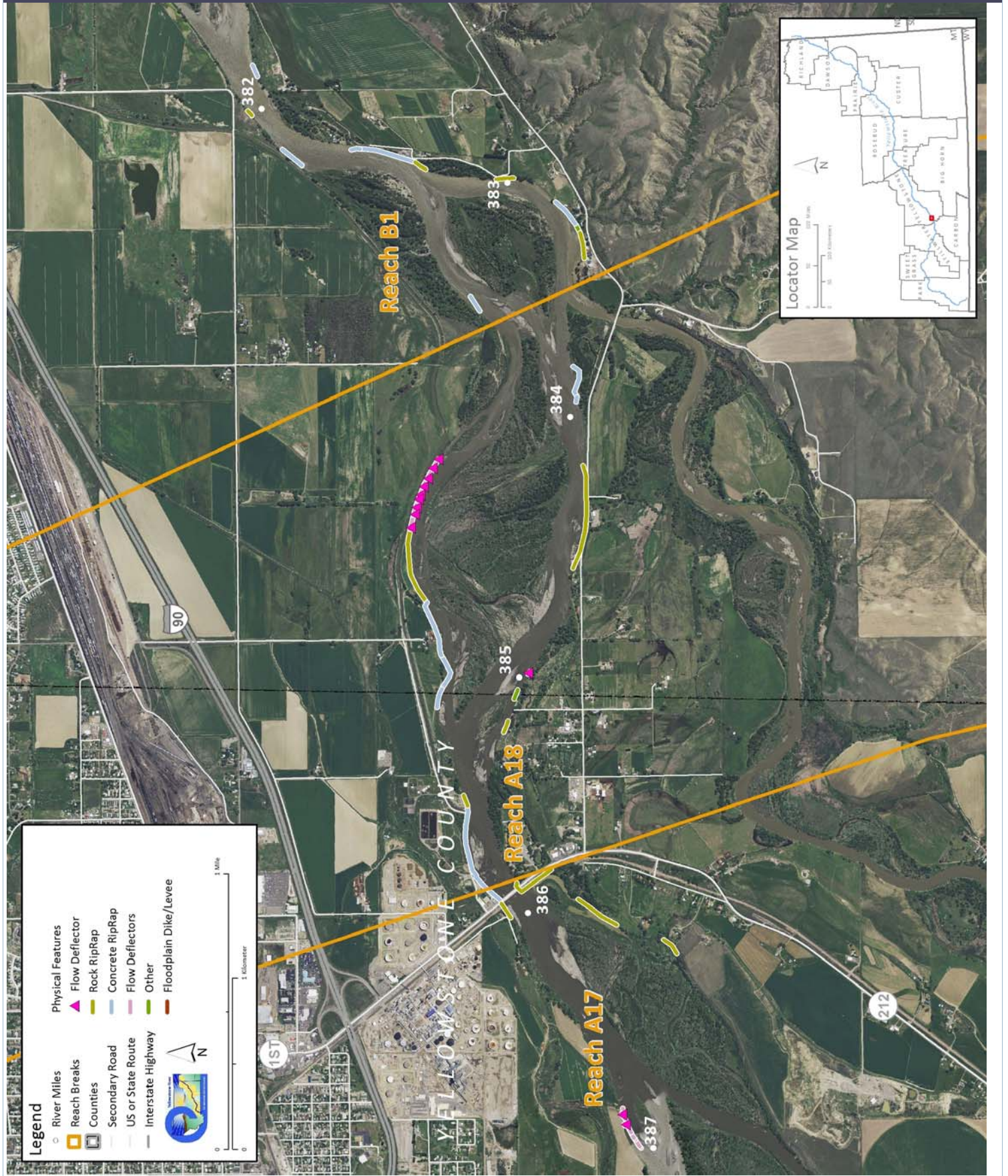
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A18 include:

- Irrigation diversion structure management at headgate on a canal at RM 385.7
- Flanked concrete armor removal RM 384
- Russian olive removal (18 acres)
- Floodplain restoration between lower Clarks Fork River and Yellowstone River
- Pipeline Management for several crossings at Laurel.

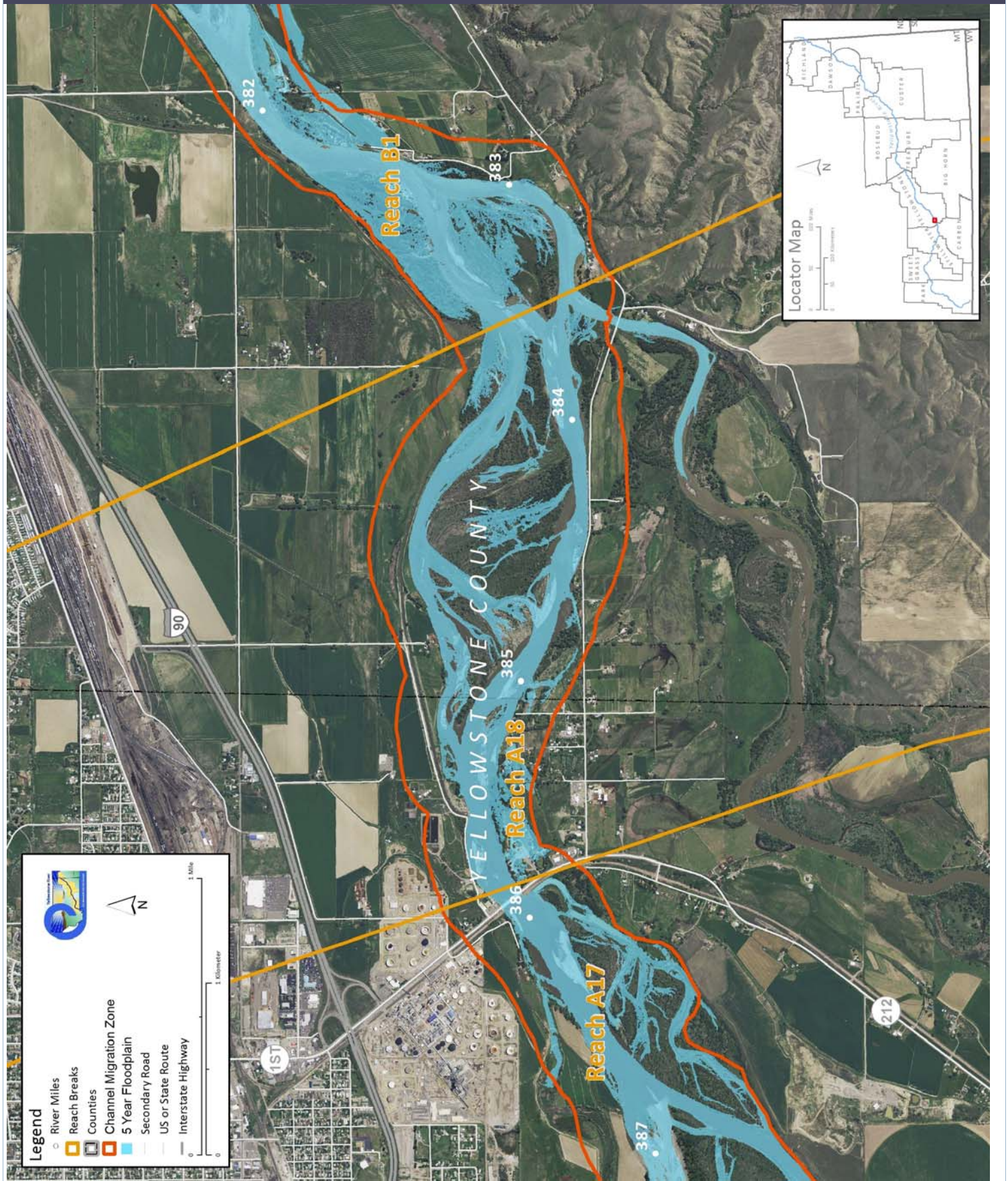
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Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	32,200	30,600	-5.0%			
100 Year (cfs)	58,600	57,600	-1.7%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	198.9	250.8	227.3	280.8	82.0	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	3,885	15.6%	220			
Concrete Riprap	3,782	15.2%	-736			
Flow Deflectors	1,525	6.1%	58			
Total	9,192	37.0%	-459			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	0	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)	The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
Total Acres	85.7	94.5	-57.18 acres			
Acres/Year	3.3	3.8				
Acres/Year/Valley Mile	1.6	1.8				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	15.0	17%				
100 Year	303.5	54%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	274.8	31%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	2,401.7	1,767.8	Flood (Ac)	945.9	893.5	
Ag. Infrastructure (Ac)	46.8	46.4	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	27.2	332.4	Pivot (Ac)	0.0	0.0	
Urban (Ac)	2.5	42.6				
Transportation (Ac)	22.8	23.0				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	39.9	27.3	67.2	9.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	15.8	7.7	188.7			
Emergent	139.7	68.2				
Scrub/Shrub	33.2	16.2				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	17.9	2.7%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	3.4	0.0	0.0	-3.4		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	383.5
Classification	UB: Unconfined braided	Downstream River Mile	368.3
General Location	Laurel to Billings	Length	15.20 mi (24.46 km)

Narrative Summary

Reach B1, located in Yellowstone County, extends from the mouth of the Clark Fork River to Billings. It is approximately 15.4 miles long, extending from RM 367.0 to 382.4. It is an Unconfined Braided (UB) reach type indicating minimal influence of the valley wall coupled by extensive open gravel bars and low flow channels. Human impacts in Reach B1 include early bridge construction and stream corridor narrowing, flow consolidation through diking and bank armoring, and loss of side channel due to physical blockages and apparent downcutting. Flow alterations in this reach have been substantial; the mean annual flood has dropped an estimated 17 percent due to human influences, and summer low flows have dropped by 42 percent.

In total there are 57,118 feet of bank armor in Reach B1, which equates to 10.82 miles of bank armor in a 15.4 mile long reach of river. Concrete riprap is the most prevalent type of armor, with about 5.5 miles present in 2011, even after the loss of 2,870 feet of concrete armor protection between 2001 and 2011. There are almost four miles of rock riprap, over 4,000 feet of which was constructed since 2001. There are also 7,616 feet of flow deflectors in the reach, and about 2,500 feet of those flow deflectors were built between 2001 and 2011. The most rapid expansion of armor occurred between 1950 and 1995, when the total length of bank protection expanded from 14,872 feet to 47,339 feet.

Numerous bank armor structures have been eroded out in Reach B1. Typically flanked, failed armor was identified at the following locations:

- RM 383L: 330 feet of flow deflectors totally lost
- RM 382.3R: lower 175 feet of concrete riprap flanked
- RM 281.5R: upper 400 feet of concrete riprap flanked: Idled crude oil pipeline is less than 200 feet behind this flanked armor
- RM 380.2R: lower 600 feet of concrete armor flanked
- RM 377.8: upper 540 feet of concrete armor flanked
- RM 373.8R: upper 300 feet and lower 270 feet of concrete armor flanked

The loss of side channel length through time has been extensive. Prior to 1950, almost a mile of side channels had been blocked on the south side of the river at RM 373.8 and at the South Billings Blvd Bridge at RM 371. Since 1950, another 14,800 feet have been blocked by dikes. One major blockage is located about 2 miles upstream of the Duck Creek Bridge at RM 381 and another near the gravel pit/trailer park complex at RM 373. Other side channels have been lost passively, without blockages. In total, Reach B1 has been characterized by a loss of seven miles of side channel length between 1950 and 2001, the majority of which occurred between 1976 and 1996.

A review of available data indicate that the loss of side channels in Reach B1 is both directly and indirectly related to bank stabilization within the reach. Between 1950 and 1976, a series of dikes were constructed upstream of South Billings Blvd to block the course of a primary channel, isolating several thousand feet of channel. Womack (2000) notes that “the greatest measureable change has occurred due to abandonment of secondary channels, primarily due to construction of dikes and secondarily due to channel armoring. A relatively short dike at the upstream end of a braided reach can have a disproportionate effect, because it may effectively eliminate miles of channel”. These blockages are associated with some of the braiding parameter reduction in Reach B1. However, the most loss of side channels occurred after 1976, when the dikes above South Billings Blvd. were already in place. Some of these channels were abandoned due to blockage by dikes, and other locations of channel abandonment and braiding parameter reduction show no apparent direct relationship to physical features.

The side channels that were passively abandoned in Reach B1 are commonly perched above the main Yellowstone River channel. This perching indicates that abandonment may be related to downcutting of the main channel. Womack (2000) noted that width to depth ratios decreased in heavily armored reaches due to flow consolidation in a single channel. Womack suggests that channel confinement and consolidation into fewer channels has resulted in downcutting and reduction in width to depth ratio. Flow alterations have also likely contributed to side channel abandonment.

Several bridges were constructed in Reach B1 prior to 1950. These bridges all constrict the natural meander corridor of the river and have been associated with channel downcutting. Womack (2000) showed seven feet of degradation immediately upstream of the South Billings Blvd Bridge.

The primary land use in the reach is non-irrigated agriculture although several thousand acres of agricultural land has been developed since 1950. In 2011, there were about 3,000 acres of land under flood irrigation and 240 acres under pivot in Reach B1. Between 1950 and 2011, the extent of urban/exurban land use expanded from 310 acres to over 2,000 acres. The development has extended into the Channel Migration Zone (CMZ). A total of 810 acres of CMZ are developed, with 242 acres of ground developed for urban/exurban use and 84 acres in pivot irrigation. Another 470 acres of land in the CMZ are under flood irrigation. As a consequence of extensive development in the CMZ, about 25 percent of the total CMZ footprint has become restricted due to armoring and dike construction.

There is one animal handling facility within 300 feet of the north riverbank just downstream of the Duck Creek Bridge at RM 377.7.

A total of 610 acres of the historic 100-year floodplain has become isolated from the river, which is 14 percent of the total 100-year floodplain footprint. Most of the 100-year floodplain isolation is due to transportation infrastructure. Similarly, about 13 percent of the 5-year floodplain (270 acres) has been isolated by transportation infrastructure. There are 184 acres of flood irrigated land in the 5-year floodplain, and 73 acres in pivot. Whereas most of the isolated 100-year floodplain area is behind the I-90 corridor in the city of Billings, most of the isolated 5-year area is in the stream corridor, which supports the interpretation that some downcutting in the reach has perched historic channels and floodplain area.

There are several pipeline crossings in Reach B1. At RM 382, two pipelines cross under the river; one is a natural gas pipeline owned by NW Energy LLC, and the other is an idled crude oil pipeline owned by Conoco Phillips. The idled crude oil pipeline follows the river close to the bank at RM 281.5R where concrete armor has been flanked. There are four pipelines at South Billings Blvd; the one of these pipelines that was built to carry crude oil has been idled under nitrogen. The other pipelines are all natural gas.

Over 400 acres of wetland have been mapped in the reach, with most of that (270 acres) emergent wetland marsh that is located primarily in the active stream corridor and in abandoned channels. A total of 42 acres of Russian olive have been mapped in the reach, and these trees are dispersed throughout the corridor.

Reach B1 was sampled as part of the avian study. The average species richness in Reach B1 was 8.0, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird Species of Concern (SOC), the Black-Billed Cuckoo, was identified in the reach. Three bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, including the Black and White Warbler, Chimney Swift, and Ovenbird. Since 1950, Reach B1 has lost all of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 3.5 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to zero.

Reach B1 was sampled as part of the fisheries study. A total of 31 fish species were sampled in the reach, and none of these species have been identified by the Montana Natural Heritage Program as Species of Concern (SOC).

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 22,800 cfs to 18,900 cfs, a drop of about 17 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,900 cfs to 2,000 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B1 include:

- Blockage of miles of side channel
- Extensive armoring with CMZ encroachment
- Passive loss of major side channels due to downcutting and flow alterations

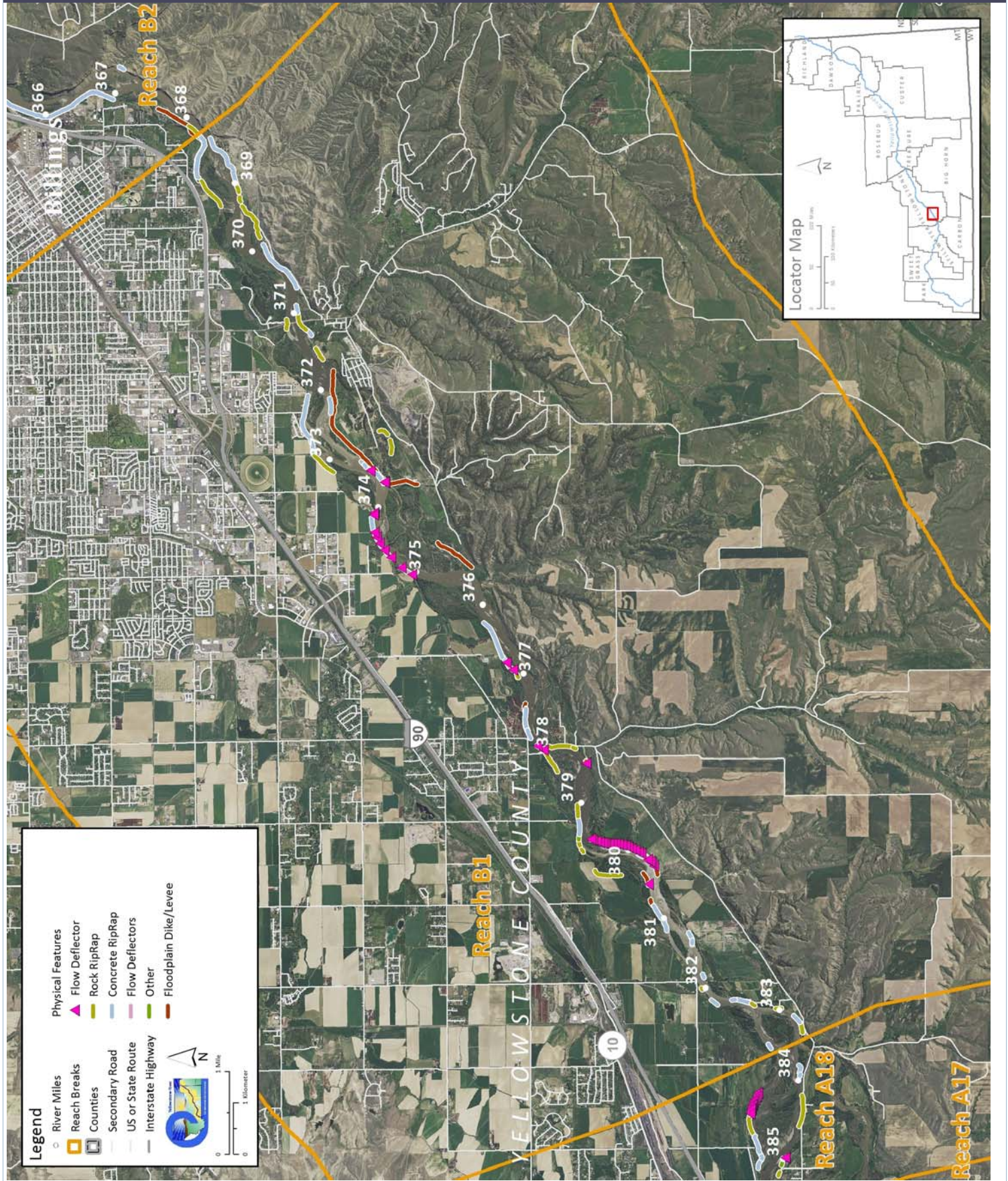
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B1 include:

- Side channel restoration at RM 381 and RM 373
- Pipeline crossing management – natural gas pipeline at RM 382
- Flanked armor removal at RM 383, RM 382.3, RM 281.5, RM 380.2, RM 377.8, and RM 373.8
- CMZ management due to extent of current CMZ restriction (25 percent)
- Russian olive removal
- Pipeline management at crossings and also where concrete armor has flanked where idled crude oil pipeline runs parallel to bank at RM 285.1R
- Nutrient management at corrals that are part of an animal handling facility within 300 feet of river at RM 377.7 just downstream of Duck Creek Bridge.

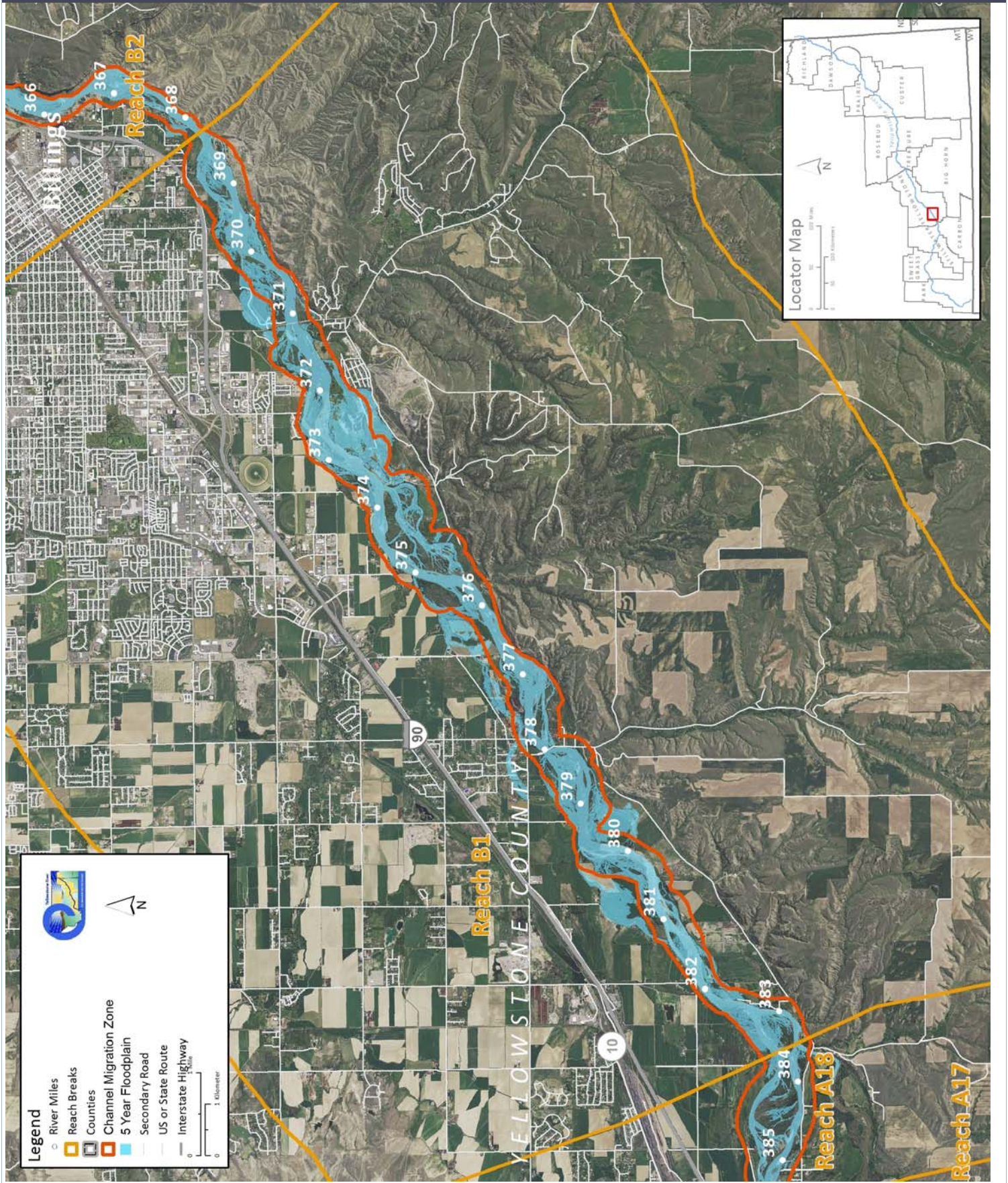
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	42,700	38,500	-9.8%			
100 Year (cfs)	76,200	73,700	-3.3%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	1,809.2	1,745.6	1,505.2	1,696.7	-112.5	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	20,753	12.9%	4,418			
Concrete Riprap	28,749	17.8%	-2,870			
Flow Deflectors	7,616	4.7%	2,553			
Total	57,118	35.5%	4,102			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	4,970	14,812				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)	The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
Total Acres	490.8	362.9	209.05 acres			
Acres/Year	18.9	14.5				
Acres/Year/Valley Mile	1.4	1.1				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	267.4	13%				
100 Year	610.6	14%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	1,285.4	25%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	9,453.9	7,931.3	Flood (Ac)	2,905.2	2,922.5	
Ag. Infrastructure (Ac)	221.2	354.2	Sprinkler (Ac)	0.0	26.1	
Exurban (Ac)	142.1	710.4	Pivot (Ac)	0.0	241.0	
Urban (Ac)	174.6	1,542.1				
Transportation (Ac)	102.1	151.0				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	57.0	119.4	176.4	8.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	81.4	6.2	421.6			
Emergent	269.3	20.4				
Scrub/Shrub	70.9	5.4				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	41.6	1.8%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	3.5	0.0	0.0	-3.5		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	368.3
Classification	PCB: Partially confined braided	Downstream River Mile	362.2
General Location	Billings	Length	6.10 mi (9.82 km)

Narrative Summary

Reach B2 is 6.1 miles long and located in Billings. The reach extends from the rimrock bluffs south of town, under the I-90 Bridge, to the refinery area at Lockwood. It is a Partially Confined Braided (PCB) reach type indicating some influence of the bluff line on the river coupled by extensive open gravel bars and low flow channels. Reach B2 is extensively urbanized, with floodplain dikes, industrial and urban/exurban development, pipeline crossings, and bridges throughout the reach. Flow alterations in this reach have been substantial; the mean annual flood has dropped an estimated 17 percent due to human influences, and summer low flows have dropped by 42 percent.

In total there are 21,700 feet of bank armor in Reach B2, which equates to 4.1 miles of bank armor in a 6 mile long reach of river. Concrete riprap is the most prevalent type of armor, with about three miles present in 2011. There is almost a mile of rock riprap and a few flow deflectors. There are also over three miles of floodplain dikes mapped in the reach.

Since 1950, 6,566 feet of side channels have been blocked by dikes. These blocked side channels are in highly urbanized areas upstream of the I-90 Bridge and at the water treatment plant downstream.

The primary land use in the reach is urban/exurban development. A total of 620 acres of the historic 100-year floodplain has become isolated from the river, which is 41 percent of the total 100-year floodplain footprint. Most of the 100-year floodplain isolation is due to the Interstate Highway Embankment. Approximately 21 percent of the Channel Migration Zone has become restricted due to physical features, most of which are riprap installed to protect urban/industrial land uses.

A total of three ice jams have been recorded in Reach B2. One of these jams occurred in February of 1996, and the other two in January of 1997. They all resulted in flooding and the January 3 1997 jam caused some evacuations. The jams were reported as forming upstream of the I-90 Bridge.

There are numerous pipeline crossings in Reach B2. At RM 367 two pipelines cross under the river. One is a crude oil pipeline owned by Beartooth Pipeline that is HDD (Horizontal Directionally Drilled). The other is a petroleum product pipeline owned by Phillips 66 that as of Fall 2012 was trenched, and according to the addendum to the Yellowstone River Pipeline Risk Assessment, had 4 to 10 feet of cover. Further downstream, there are seven pipelines listed in the Pipeline Risk Assessment Report at RM 365. Several of these pipelines are trenched as a bundle, with a reported minimum of two feet of cover.

About 25 acres of Russian olive have been mapped in Reach B2.

Reach B2 was sampled as part of the fisheries study. A total of 31 fish species were sampled in the reach and one of those species was Sauger, which has been identified by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach B2 was sampled as part of the avian study. The average species richness in Reach B2 was 7.0, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, the Ovenbird and the Plumbeous Vireo.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 23,700 cfs to 19,700 cfs, a drop of about 17 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,910 cfs to 2,000 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B2 include:

- Extensive armoring with CMZ encroachment

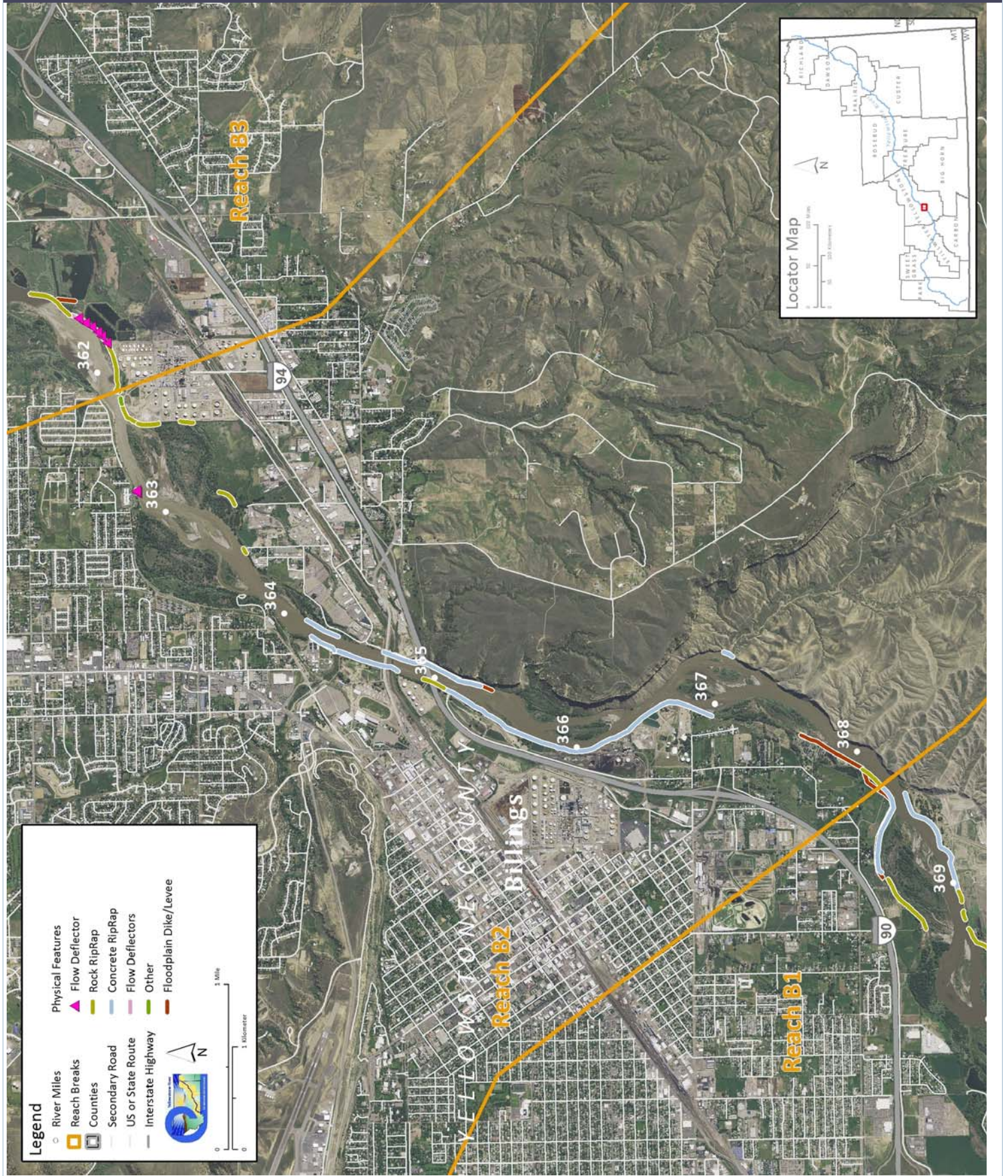
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B2 include:

- Pipeline crossing management
- Russian olive removal

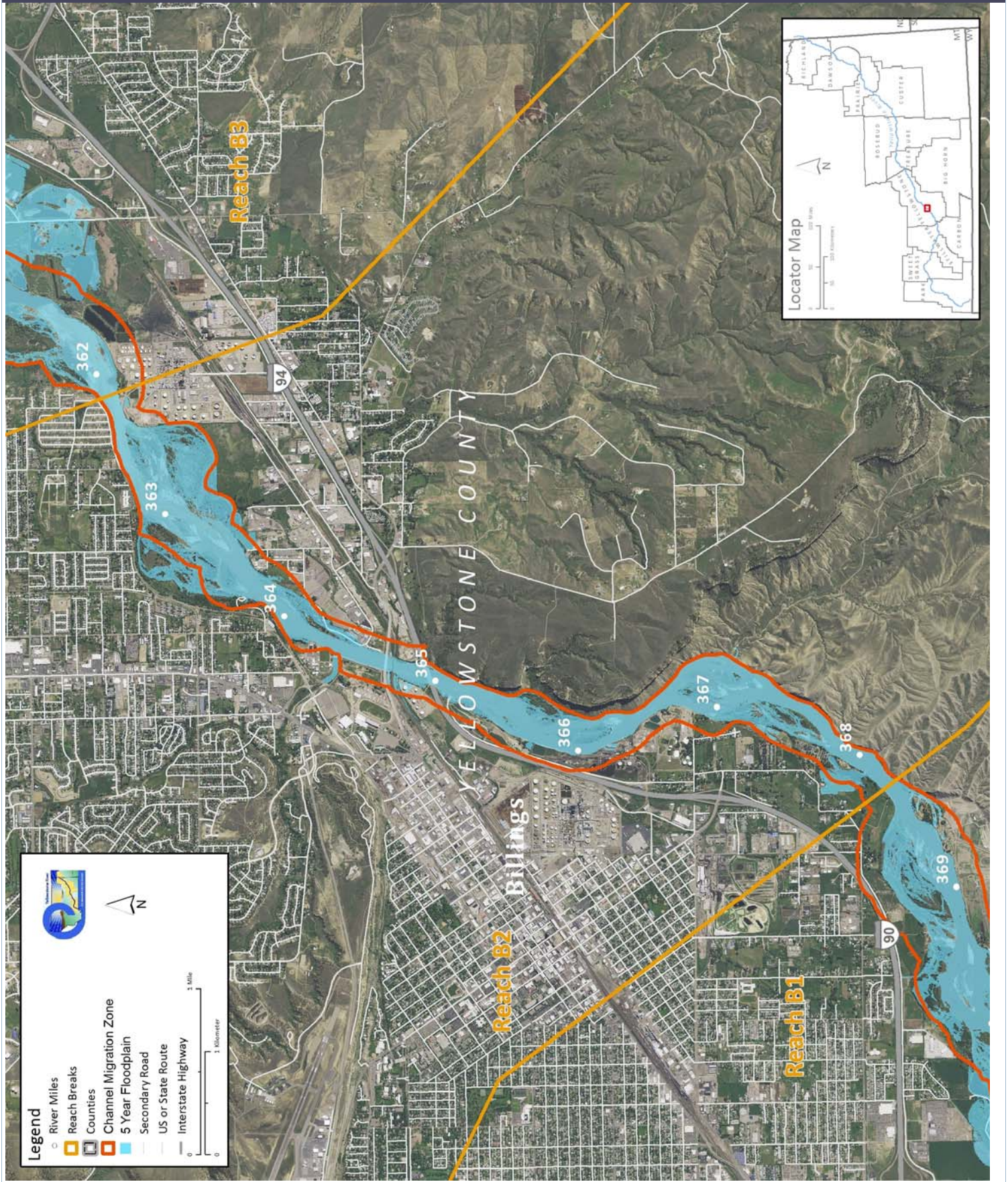
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	44,200	39,800	-10.0%			
100 Year (cfs)	78,600	76,000	-3.3%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	517.8	536.9	501.3	534.2	16.4	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	4,329	6.7%	828			
Concrete Riprap	17,283	26.8%	0			
Flow Deflectors	91	0.1%	91			
Total	21,702	33.7%	918			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	0	6,566				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)	The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
Total Acres	136.5	88.0	-37.22 acres			
Acres/Year	5.3	3.5				
Acres/Year/Valley Mile	0.9	0.6				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	58.1	15%				
100 Year	620.1	41%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	255.5	21%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	2,457.5	1,071.5	Flood (Ac)	469.3	0.0	
Ag. Infrastructure (Ac)	33.0	17.2	Sprinkler (Ac)	0.0	5.5	
Exurban (Ac)	318.3	0.0	Pivot (Ac)	0.0	0.0	
Urban (Ac)	760.2	2,495.1				
Transportation (Ac)	46.0	127.8				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	0.0	317.3	317.3	51.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	44.5	8.0	75.7			
Emergent	19.6	3.5				
Scrub/Shrub	11.6	2.1				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	24.6	3.2%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	5.0	1.9	4.0	-1.0		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	362.2
Classification	UB: Unconfined braided	Downstream River Mile	357.9
General Location	East Billings	Length	4.30 mi (6.92 km)

Narrative Summary

Reach B3 is 4.3 miles long and located in east Billings. The reach is characterized by the loss of several miles of side channel, extensive Russian olive infestation, and substantial flow alterations due to human influences.

In total there are about 13,500 feet of bank armor in Reach B3, which covers almost 30 percent of the bankline. Most of the armor is rock riprap, although there are over 3,000 feet of flow deflectors mapped in the reach, as well as over a mile of floodplain dikes.

Prior to 1950, 11,000 feet of side channels had been blocked in the reach, and since that time another 14,000 feet have been similarly blocked by small dikes. These ~4 miles of blocked channel are about equivalent in length to that of the main river. That said, as of 2001 there were still about 35,000 feet of active side channel in Reach B3.

Solid waste dumps were mapped on old side channels on the east floodplain areas at RM 361.5 and RM 360.6. There is one major headgate on the left bank of the river that feeds a heavily armored canal at RM 359.9.

Flow alterations and channel blockages have promoted the encroachment of riparian vegetation into old channel areas. Since 1950, almost 200 acres of riparian vegetation colonized previously un-vegetated side channels. Floodplain turnover rates have gone down since 1976 by about 2 acres per year, indicating slower rates of erosion.

Since 1950, predominantly agricultural land uses in Reach B3 have been converted to a mix of agriculture and urban/exurban development. About 1,000 acres of urban/exurban development has taken place since 1950. About 470 acres of ground continues to be flood irrigated in this area of east Billings. Approximately 16 percent of the Channel Migration Zone has become restricted due to physical features, all of which are bank armor installations designed to protect urban/industrial and agricultural land uses.

About 50 acres of Russian olive have been mapped in Reach B3. There are also fairly extensive mapped wetlands, with about 230 acres of total wetland area mapped, 95 acres of which are emergent wet meadows and marsh areas.

Reach B3 was sampled as part of the fisheries study. A total of 29 fish species were sampled in the reach, and none of those species have been identified by the Montana Natural Heritage Program as a Species of Concern (SOC).

Reach B3 was sampled as part of the avian study. The average species richness in this reach was 7.5, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) was also found, the Plumbeous Vireo.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 23,900 cfs to 19,800 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 44,500 cfs to 40,100 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,920 cfs to 2,010 cfs with human development, a reduction of 31 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,836 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B3 include:

- Riparian encroachment with flow alterations
- Extensive armoring with CMZ encroachment

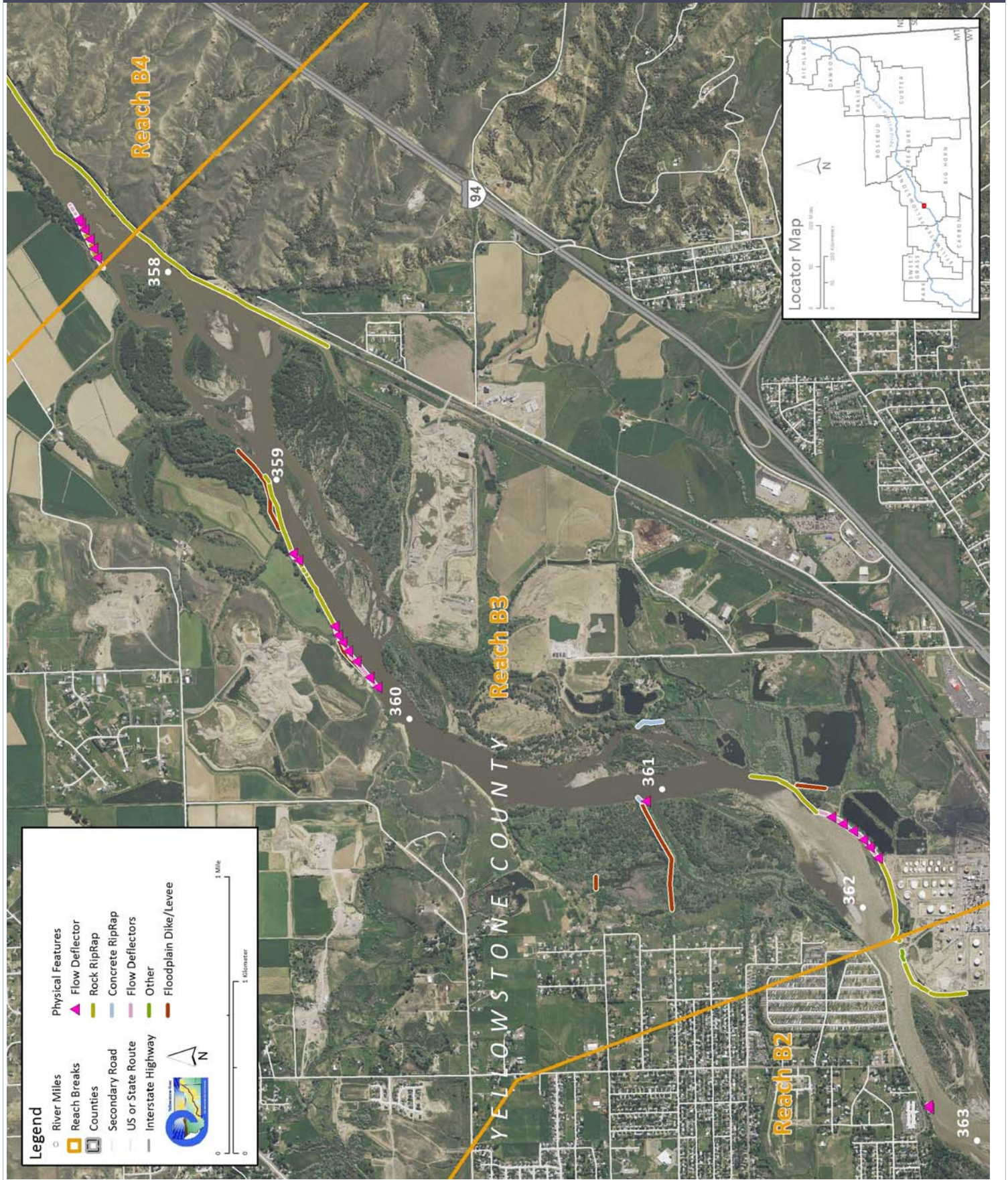
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B3 include:

- Side channel reactivation at RM 362.0, 360.5, 359.8 and RM 359.0
- Russian olive removal
- Solid waste dump removal RM 361.5 and RM 360.6
- Irrigation diversion structure management at RM 359.9.

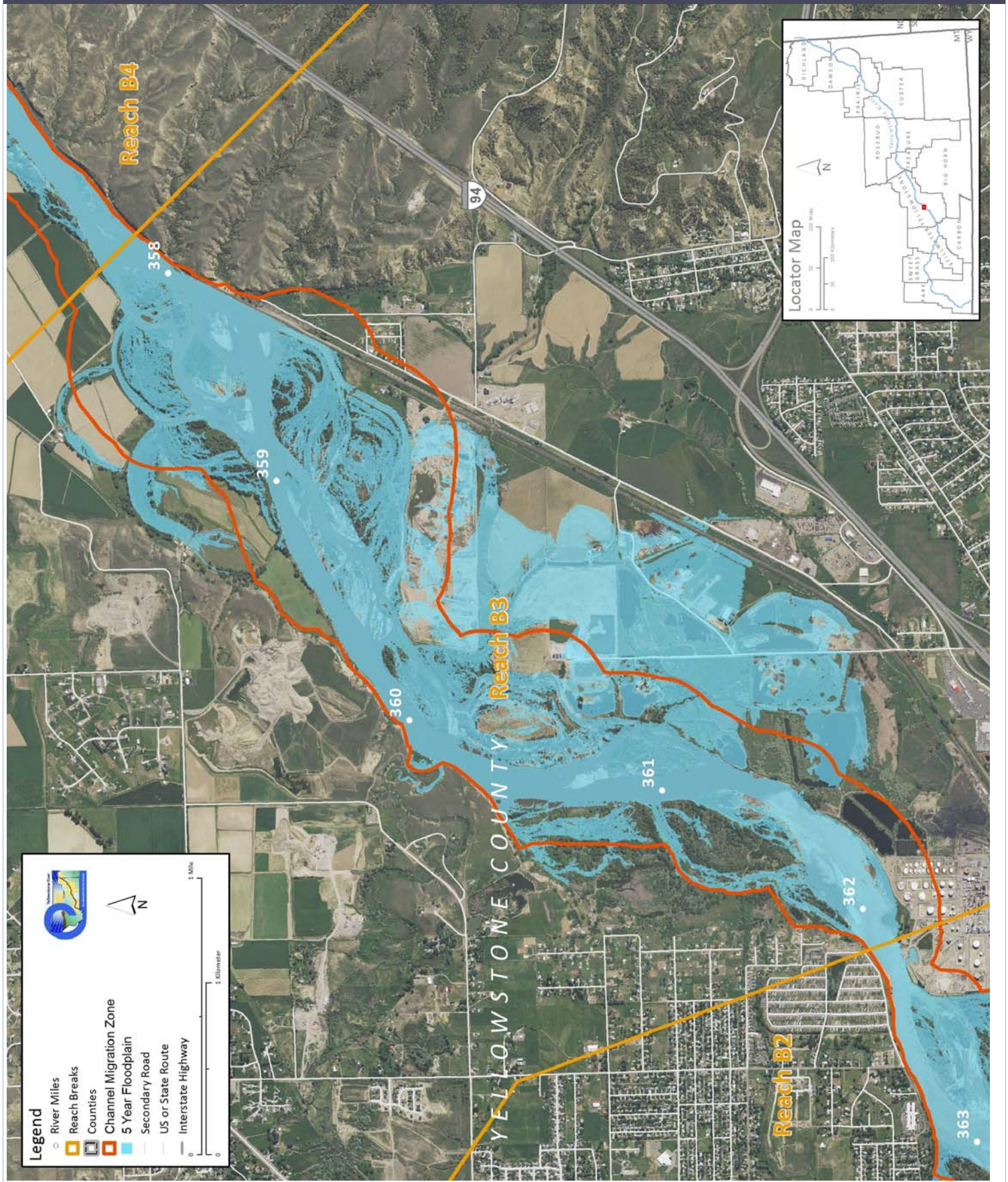
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	44,500	40,100	-9.9%			
100 Year (cfs)	79,200	76,600	-3.3%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	576.6	595.2	489.5	548.1	-28.5	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	10,047	21.7%	-252			
Concrete Riprap	592	1.3%	0			
Flow Deflectors	3,111	6.7%	42			
Total	13,750	29.7%	-209			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	11,002	13,693				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)		The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.	
Total Acres	184.6	127.0	57.31 acres			
Acres/Year	7.1	5.1				
Acres/Year/Valley Mile	1.9	1.3				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	154.8	14%				
100 Year	0.0	0%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	265.8	16%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	2,717.1	1,770.0	Flood (Ac)	420.2	472.5	
Ag. Infrastructure (Ac)	50.5	51.4	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	21.4	616.2	Pivot (Ac)	0.0	0.0	
Urban (Ac)	116.0	485.1				
Transportation (Ac)	21.2	20.4				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	29.6	166.2	195.8	21.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	95.8	25.3	231.2			
Emergent	94.9	25.0				
Scrub/Shrub	40.5	10.7				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	49.8	4.1%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	19.8	0.0	0.8	-19.1		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	357.9
Classification	PCS: Partially confined straight	Downstream River Mile	354
General Location	Upstream of Huntley	Length	3.90 mi (6.28 km)

Narrative Summary

Reach B4 is 3.9 miles long and located upstream of Huntley. It is classified as a Partially Confined Straight (PCS) reach type because within this area the river flows straight along the south valley wall with minimal meandering. The reach is characterized by the most extensive bank armoring of any reach on the river.

In total there are about 29,000 feet of bank protection in Reach B4, such that 74 percent of the bankline is armored. Most of the armor is rock riprap, although there are over 8,000 feet of concrete riprap mapped in the reach, as well as over 9,000 feet of floodplain dikes. Between 2001 and 2011, 500 feet of concrete riprap and 1,050 feet of flow deflectors were eroded out in the reach. The failed flow deflectors and concrete riprap have been largely replaced by rock riprap, although at the upstream end of the reach at RM 357.8, about 300 feet of flanked flow deflectors are in the river about 75 feet off of the left (north) bank.

The predominant land use in the reach is agriculture, with about 1,200 acres of land in flood irrigation in 2011. A total of 204 acres of developed land uses have encroached into the Channel Migration Zone (CMZ), including 193 acres of flood irrigation and 11 acres of transportation corridor. In order to protect these land uses, bank armor installations have isolated about one half of the river's CMZ.

Huntley Diversion Dam is located at RM 355.8. The structure diverts flow into the Huntley Main Canal, which follows the southern margin of the Yellowstone River floodplain. The diversion capacity of Huntley Dam is 600 cfs, and the project has the capacity to provide irrigation water to 30,000 acres of farm land. The crest length of the structure is 325 feet, and its structural height is 10.5 feet (http://www.usbr.gov/dataweb/dams/yellowstone_river_diversion.htm). The Huntley diversion structure was originally constructed as a temporary earthfill dam in 1931. In 1934, the temporary structure was modified to a concrete weir. In 1959, the dam underwent considerable rehabilitation due to undermining caused by settling and cracking of the concrete structure. As part of repairs required after recent flooding on the river, a fish passage channel was constructed around the north end of the dam. The structure is located at a point of split flow on the river, and blocks only the main channel. However, 2001 color infrared air photos of the site show that at low flows, the unblocked secondary channels are essentially dry and therefore incapable of passing fish.

Land has been developed in commonly flooded areas. About 280 acres of flood irrigated land is within the 5-year floodplain area.

There are corrals that are part of an animal handling facility adjacent to the north bank of the river at RM 355.

About 2.3 acres of Russian olive have been mapped in Reach B4.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 24,000 cfs to 19,900 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 44,700 cfs to 40,300 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 2,940 cfs to 2,010 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B4 include:

- Flanking of flow deflectors
- Repair of damaged flow deflectors with riprap

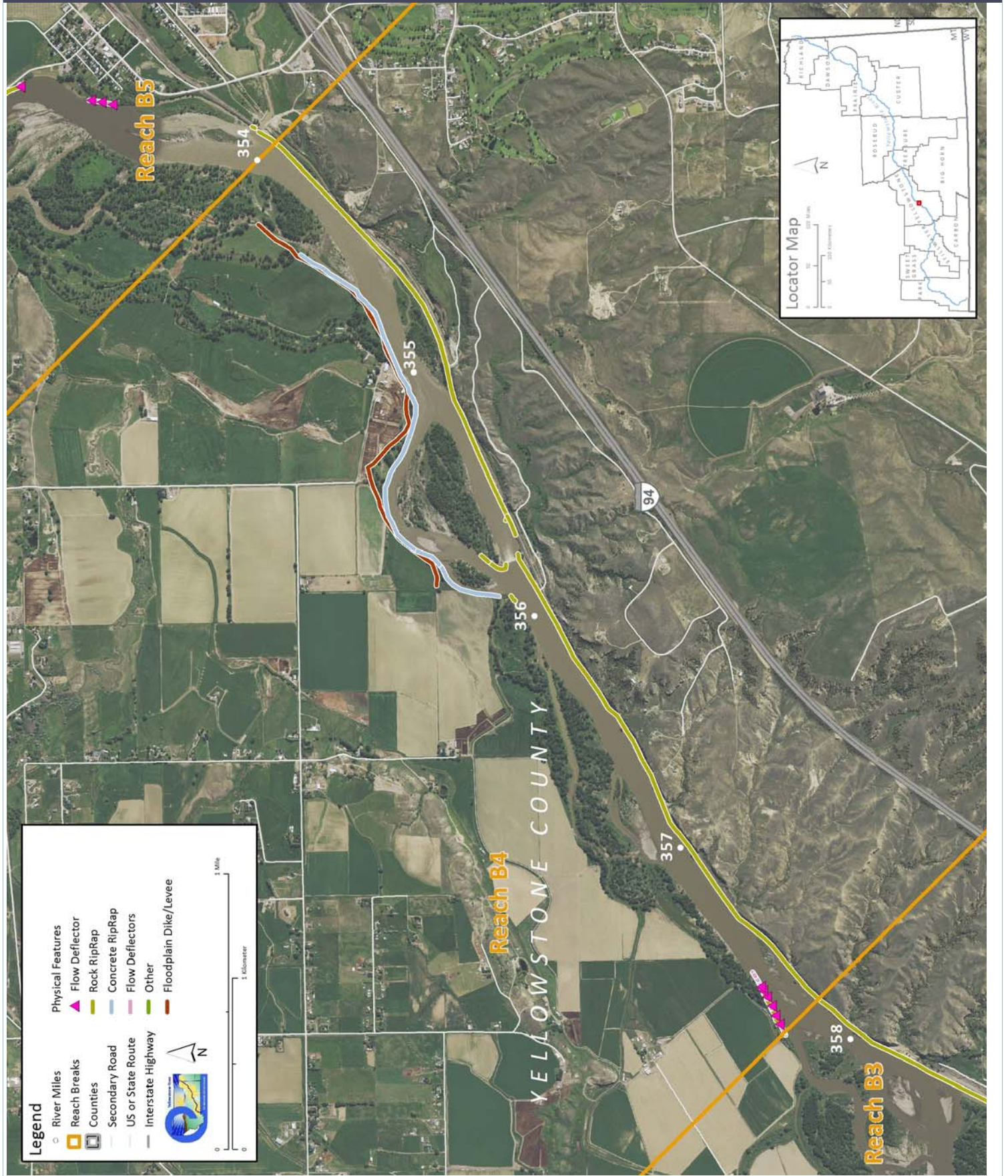
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B4 include:

- Flanked flow deflector removal at RM 357.8
- Nutrient management at corrals associated with animal handling facility at RM 355.
- Fish passage at Huntley Diversion Dam
- Watercraft passage at Huntley Diversion Dam
- Irrigation Diversion structure management at Huntley Diversion Dam

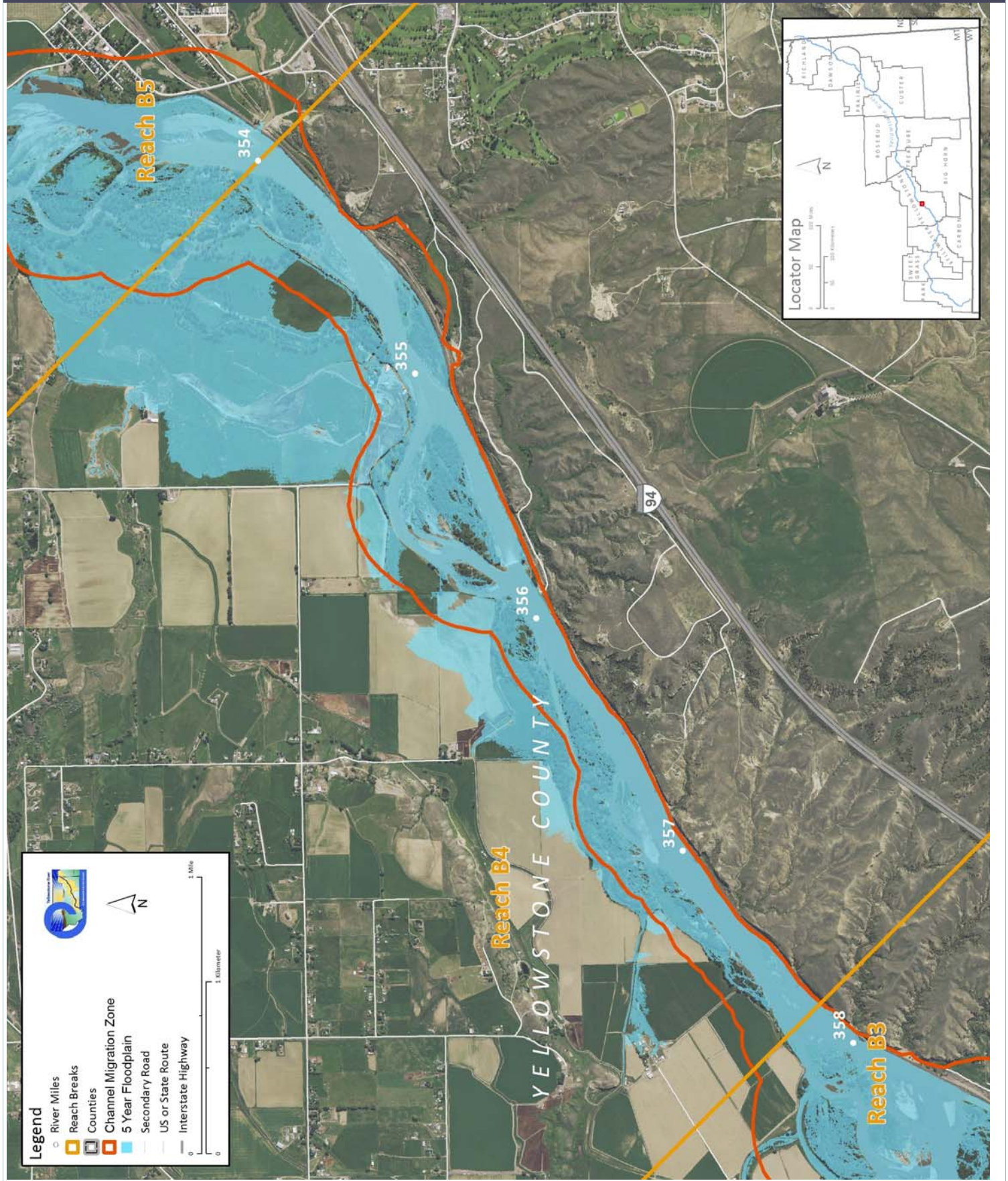
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Discharge					"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
	2 Year (cfs)	44,700	40,300	-9.8%			
	100 Year (cfs)	79,400	76,800	-3.3%			
Bankfull Channel Area (Ac)						Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.	
	1950	1976	1995	2001	1950-2001		
	322.4	315.6	315.7	360.6	38.2		
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.			
	Rock RipRap	20,729	52.1%	1,205			
	Concrete Riprap	8,331	20.9%	-502			
	Flow Deflectors	258	0.6%	-1,056			
	Total	29,318	73.7%	-353			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.				
	0	0					
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)		The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
	Total Acres	72.7	60.4	-14.25 acres			
	Acres/Year	2.8	2.4				
	Acres/Year/Valley Mile	0.8	0.7				
Open Bar Area					The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.		
	Point Bars	Bank Attached	Mid-Channel	Total			
	Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.				
	5 Year	131.5	14%				
	100 Year	28.9	2%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.				
	484.3	44%					
Land Use	1950	2011		1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
	Agricultural Land (Ac)	2,775.5	2,552.4	Flood (Ac)	727.6		1,161.5
	Ag. Infrastructure (Ac)	75.7	167.6	Sprinkler (Ac)	0.0		0.0
	Exurban (Ac)	0.0	40.9	Pivot (Ac)	0.0		0.0
	Urban (Ac)	0.0	0.0				
	Transportation (Ac)	21.8	59.4				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.		
	11.4	0.0	11.4	3.0%			
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres		Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
	Riverine	17.0	4.6	59.5			
	Emergent	34.3	9.2				
	Scrub/Shrub	8.1	2.2				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.				
	2.3	1.1%					
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.		
	0.5	0.0	0.0	-0.5			

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	354
Classification	UA: Unconfined anabranching	Downstream River Mile	346.7
General Location	Huntley: includes Spraklin Island	Length	7.30 mi (11.75 km)

Narrative Summary

Reach B5 is 7.4 miles long and is located near Huntley and Spraklin Island. The reach is an Unconfined Anabranching (UA) reach type, which indicates little influence by the valley wall coupled with relatively extensive forested islands and side channels. These reach types tend to be the most dynamic within the river corridor. Reach B5 flows northward through a wide valley section where the relatively erodible Bearpaw shale has retreated over geologic time, leaving an unusually broad river corridor. In Reach B5 the river crosses the valley from south to north, further contributing to the lack of confinement and allowance for channel migration.

About 12 percent of the bankline in Reach B5 is armored. In 2011, there was about a mile of concrete riprap, a half mile of rock riprap, and 1,500 feet of flow deflectors in the reach. Over the decade prior to that, however, 1,200 feet of concrete riprap and 1,150 feet of flow deflectors had eroded out, and 2,000 feet of rock riprap built, indicating a tendency for concrete and flow deflectors to fail coupled by an overall shift towards rock riprap bank protection between 2001 and 2011.

One of the most spectacular examples of barb failures on the Yellowstone River is in Reach B5, where about 1,300 feet of barbs on the left bank just downstream of the Huntley Bridge were flanked between 2001 and 2005. The river then migrated about 200 feet behind the barbs and the bank has since been armored with rock riprap. The flanked barbs remain visible in the middle of the river in 2011 imagery. Another barb was flanked on the left bank at RM 350, and is prominently exposed 65 feet off of the bank. In the lowermost end of the reach at RM 347, about 900 feet of concrete armor was flanked on the right bank, and the river is now up to 200 feet behind the armor, migrating rapidly to the east. This area has seen over 800 feet of river migration since 1950.

Prior to 1950, about 11,400 feet of side channels were blocked in the reach by small dikes. These channels are on both sides of the river just downstream of the Huntley Bridge at RM 352.5. Further downstream at RM 348 there are numerous older swales south of the river that are also blocked.

Land uses in the reach are primarily agricultural, with about 1,300 acres of flood irrigated land mapped as of 2011. There are also almost 600 acres of urban/exurban development. The Channel Migration Zone (CMZ) has been developed for multiple land uses; as of 2011, there were 389 acres of flood irrigation, 24 acres of urban/exurban land, and 10 acres of transportation infrastructure within the CMZ. About 14 percent of the total CMZ footprint has become restricted by bank armor and road prisms.

Trash dumps have been mapped on the left stream bank at RM 351.2, and up on the north bluff at RM 347.1. One large animal handling facility was mapped about 800 feet south of the river at RM 347.8.

About 55 acres of Russian olive have been mapped in Reach B5. The reach also hosts over 200 acres of mapped wetland areas, about 170 acres of which are emergent marshes and wet meadows.

Riparian recruitment in the reach has exceeded 500 acres since 1950; about half of that recruitment occurred in areas that were 1950s channel and the other half in areas that were eroded between 1950 and 2001.

Reach B5 was sampled as part of the avian study. The average species richness in this reach was 8.4, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. Two bird species identified by the Montana Natural Heritage Program as Potential Species of Concern (PSOC) were also found, the Plumbeous Vireo and the Ovenbird.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 25,600 cfs to 21,200 cfs, a drop of about 17 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 47,400 cfs to 42,600 cfs, which is a reduction of 10 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,000 cfs to 2,050 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

Because of the flow alterations, about 22 percent of the 5-year floodplain has become isolated in Reach B5.

CEA-Related observations in Reach B5 include:

- Flanking of flow deflectors and concrete riprap
- Blockage of over two miles of side channel pre-1950

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B5 include:

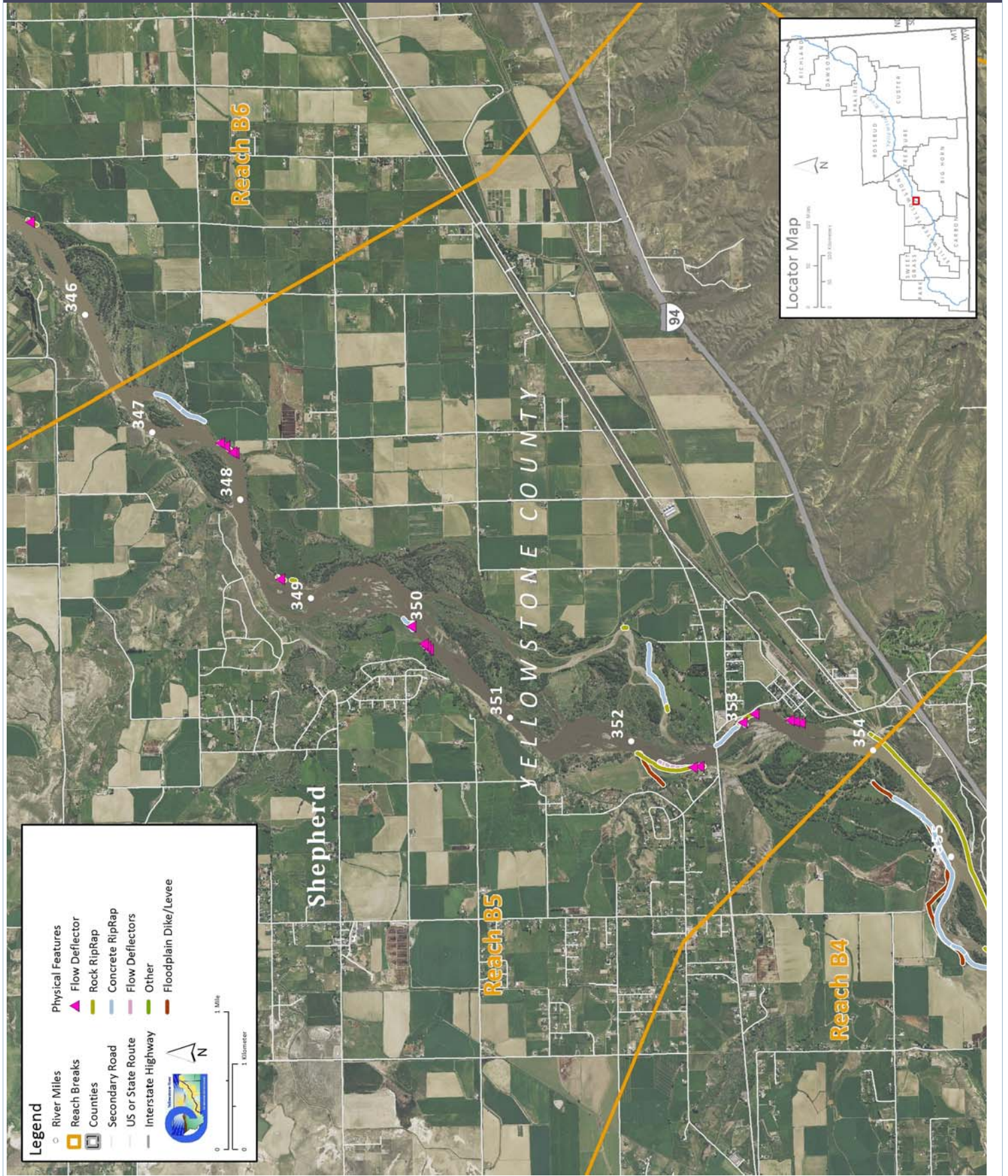
- Side channel restoration at RM 352.5
- Flanked flow deflector removal at RM 352.5 and 350.0
- CMZ management due to development within CMZ footprint
- Russian olive removal

- Nutrient management at animal handling facility at RM 347.8.
- Solid waste removal at RM 351.2L and 347.1L

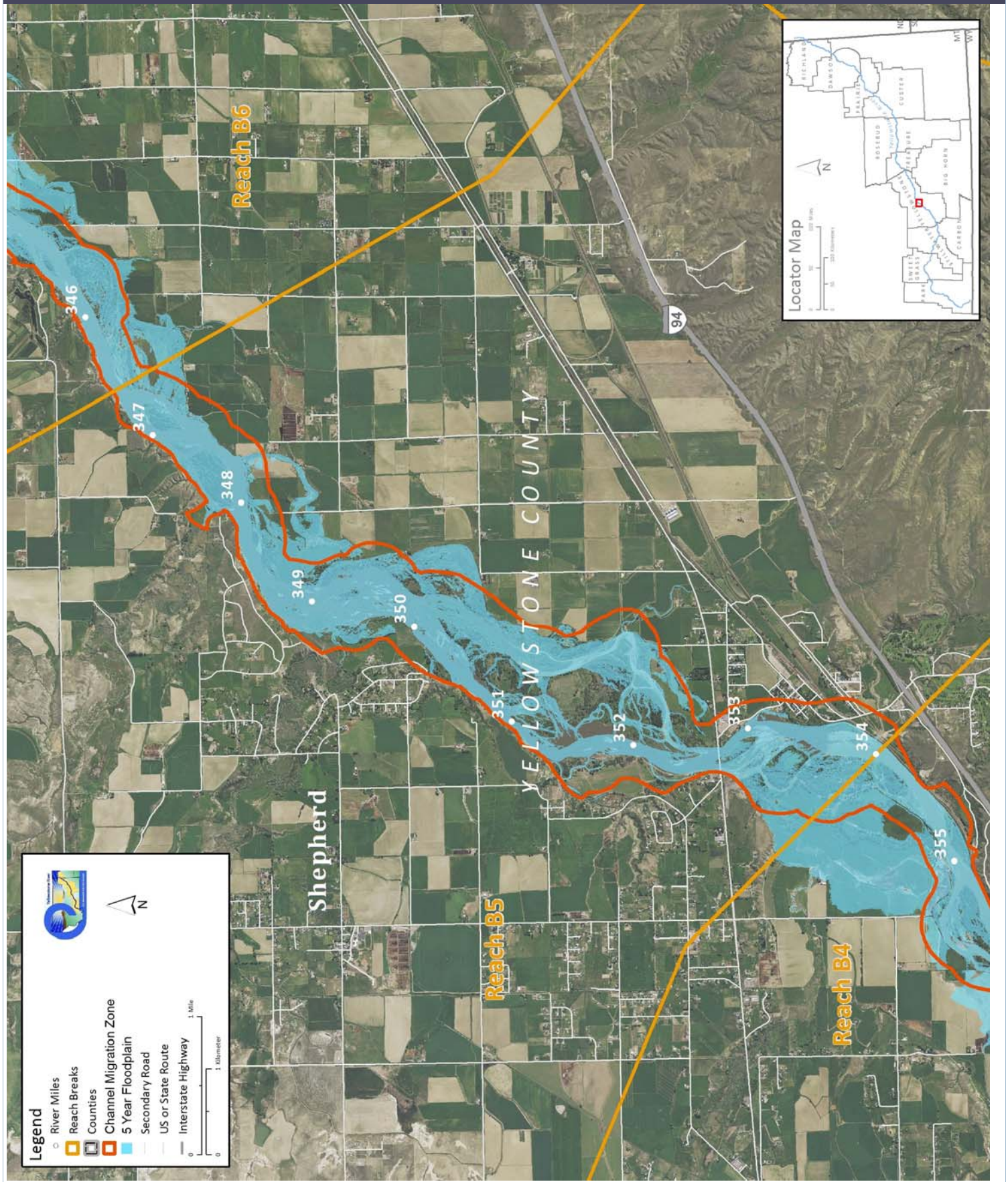
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	47,400	42,600	-10.1%			
100 Year (cfs)	84,000	81,200	-3.3%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	890.9	992.2	897.6	1,031.9	140.9	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	2,399	3.1%	1,847			
Concrete Riprap	5,361	6.8%	-1,218			
Flow Deflectors	1,550	2.0%	-1,153			
Total	9,310	11.9%	-523			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	11,393	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)	The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
Total Acres	312.0	278.7				
Acres/Year	12.0	11.1				
Acres/Year/Valley Mile	1.9	1.8	-56.24 acres			
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	253.4	22%				
100 Year	12.4	1%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	396.2	14%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	3,731.1	3,041.4	Flood (Ac)	920.7	1,271.2	
Ag. Infrastructure (Ac)	92.8	159.3	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	63.0	567.5	Pivot (Ac)	0.0	0.0	
Urban (Ac)	0.0	0.0				
Transportation (Ac)	45.0	48.6				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	65.9	22.2	88.1	7.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	17.7	2.8	239.8			
Emergent	169.8	27.1				
Scrub/Shrub	52.3	8.3				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	54.5	3.2%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	3.5	1.2	0.7	-2.8		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	346.7
Classification	PCB: Partially confined braided	Downstream River Mile	340.6
General Location	Ballantine	Length	6.10 mi (9.82 km)

Narrative Summary

Reach B6 is 6.1 miles long and is located Ballantine. The reach is a Partially Confined Braided (PCB) reach type, which indicates some valley wall influence coupled with relatively extensive unvegetated bars and low flow islands. Within Reach B6, the river flows closely along the north valley wall. The Gritty Stone fishing access site is located in the downstream end of the reach.

About 6.3 percent of the bankline in Reach B6 is armored, and the majority of that armor (2,300 feet) is concrete riprap. Since 2001, riprap has expanded by about 430 feet. Reach B6 also hosts almost 1,500 feet of car body riprap, which is fairly unusual in terms of extent on the Yellowstone River. The car bodies were put in place between 1950 and 1995, and their mapped location is at RM 341.7R, although they are difficult to see on the imagery.

Prior to 1950, a side channel that was about 1,350 feet long was blocked by a small dike at RM 343. Even though this side channel was blocked, there has been a net gain of over three miles of side channel since 1950.

Land uses in the reach are primarily agricultural, with about 1,862 acres of flood irrigated land mapped as of 2011. The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 237 acres of flood irrigated land in the CMZ, and about 9 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The modern 5-year floodplain contains over 200 acres of flood-irrigated ground.

There is one mapped animal handling facility in the reach at RM 345.5R. It is within 800 feet of the active river bank.

The 100-year floodplain has also been restricted; about 210 acres or 11.4 percent of the historic 100-year floodplain area has become isolated from the river by agricultural infrastructure.

Since 1950, there has been almost 250 acres of riparian recruitment in the reach, and most of that was in the 1950s channels that were abandoned.

One ice jam has been recorded in Reach B6. On January 3, 1997, an ice jam occurred at RM 345 that caused severe flooding and resulted in evacuations.

There are 49 acres of mapped Russian olive in the reach, and the mapping indicates that it has expanded on islands and in side channels. Riparian recruitment in the reach has exceeded 500 acres since 1950; about half of that recruitment occurred in areas that were 1950s channel and the other half in areas that were eroded between 1950 and 2001.

Reach B6 was sampled as part of the avian study. The average species richness in this reach was 8.25, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been substantial in this reach. The mean annual flood is estimated to have dropped from 26,000 cfs to 21,100 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped from 48,300 cfs to 43,000 cfs, which is a reduction of 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,000 cfs to 2,050 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

Because of the flow alterations, about 25 percent of the 5-year floodplain has become isolated in Reach B6. Much of that 5-year floodplain isolation is within old swales on the south side of the river. The 5-year flood discharge has dropped by 8.25 percent in this reach due to human influences, primarily irrigation.

CEA-Related observations in Reach B6 include:

- Gain in anabranching channel length
- Ice jamming
- Side channel blockage at RM 343.

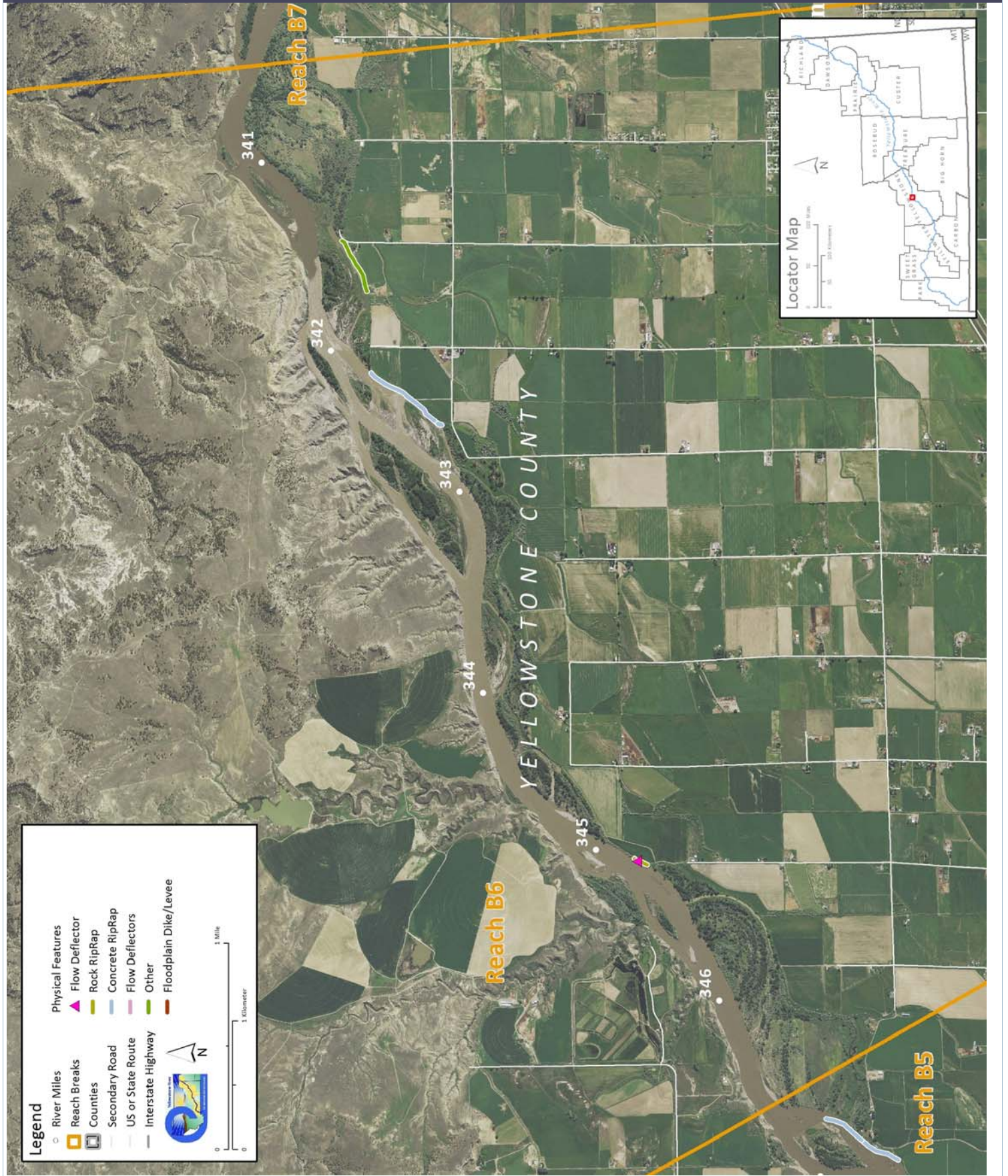
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B6 include:

- Russian olive removal
- Nutrient management at corrals associated with animal handling facility at RM 534.5R

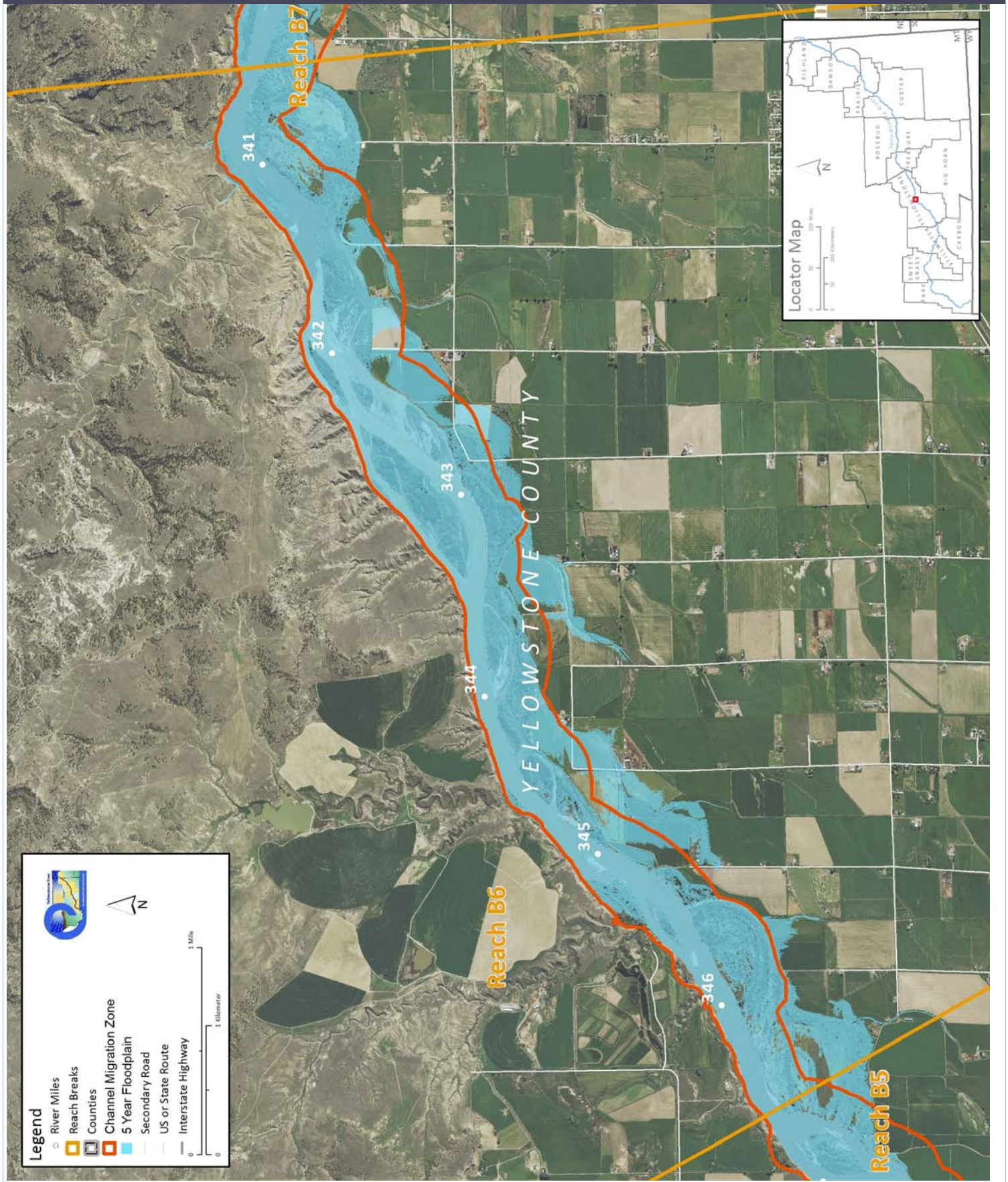
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	48,300	43,000	-11.0%			
100 Year (cfs)	85,300	82,200	-3.6%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	583.2	616.6	578.5	617.8	34.6	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	304	0.5%	304			
Concrete Riprap	2,275	3.5%	106			
Flow Deflectors	23	0.0%	23			
Total	2,602	4.0%	433			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	1,352	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)	The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
Total Acres	141.8	120.5	-36.52 acres			
Acres/Year	5.5	4.8				
Acres/Year/Valley Mile	1.0	0.9				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	343.9	25%				
100 Year	209.2	11%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	141.6	9%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	3,682.8	3,694.9	Flood (Ac)	1,317.8	1,862.1	
Ag. Infrastructure (Ac)	51.6	136.7	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	0.0	0.0	Pivot (Ac)	0.0	96.2	
Urban (Ac)	0.0	3.5				
Transportation (Ac)	16.6	17.1				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	1.9	1.0	2.8	0.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	2.9	0.5	112.4			
Emergent	71.5	12.7				
Scrub/Shrub	38.0	6.7				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	48.7	2.8%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	1.8	2.0	0.4	-1.4		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	340.6
Classification	UB: Unconfined braided	Downstream River Mile	331.8
General Location	To Pompey's Pillar	Length	8.80 mi (14.16 km)

Narrative Summary

Reach B7 is located just upstream of Pompey's Pillar. The Reach is almost nine miles long and is currently largely unconfined with a primary channel thread and numerous mid-channel bars and point bars. In the 1950's, the main channel flowed more closely along the north valley wall; southward migration since that time has reduced the influence of the valley wall on stream geomorphology. The valley is wide in this area, which is typical where the bounding rock units are made up of the relatively erodible Cretaceous-age Bearpaw shale.

Only 290 feet of the streambank in Reach B7 is armored, and no side channels have been blocked.

Land uses in the reach are primarily agricultural, with about 1,340 acres of flood irrigated land mapped as of 2011. The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 390 acres of flood irrigated land in the CMZ, and about 4 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The modern 5-year floodplain contains over 275 acres of flood-irrigated ground.

Reach B7 shows major southward migration of the river since 1950, with one area experiencing over 1,600 feet of migration over the past 60 years. The river has gained length, and the valley wall influence has become much less prevalent, as virtually all migration in this and adjacent reaches has been to the south. Since 1950 this section of river has lost almost 20,000 feet of anabranching channel length, and there is no strong indication that this loss is directly associated with floodplain dikes. Rather, it appears that significant lengths of anabranching channels were passively abandoned, which may be the consequence of a 19 percent reduction in the mean annual flood due to human influences.

South of the river over 600 acres of historic 100-year floodplain have been isolated from the river by the railroad. This includes a very broad area between the railroad and Interstate that will likely remain isolated since it is over 3,000 feet from the modern river. This area represents 22 percent of the total historic 100-year floodplain area.

The mouth of Arrow Creek is in Reach B7, and the lower portion of the creek has been captured by the river, shortening the tributary and likely driving downcutting upstream.

Reach B7 has 56 mapped acres of Russian olive that can be found in dense stands, however the extensive lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 640 acres of riparian recruitment in the reach. The acreage of recruitment has exceeded that of erosion of riparian areas by 131 acres. Additionally, there are 260 mapped wetlands in the reach, including 135 acres of wet meadows and marsh.

Reach B7 was sampled as part of the avian study. The average species richness in this reach was 8.8, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as a Potential Species of Concern (PSOC) was identified, the Dickcissel. Another species identified as a Species of Concern (SOC) was identified, the Red-headed Woodpecker.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 27,200 cfs to 22,100 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,010 cfs to 2,060 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

Because of the flow alterations, about 28 percent of the 5-year floodplain has become isolated in Reach B7. Much of that 5-year floodplain isolation is within irrigated fields on the south side of the river.

CEA-Related observations in Reach B7 include:

- Migration away from valley wall resulting in loss of bluff pool habitat.
- Passive abandonment of anabranching channels likely associated with reduced mean annual flows.
- Rapid channel migration through cleared, often flood irrigated fields.

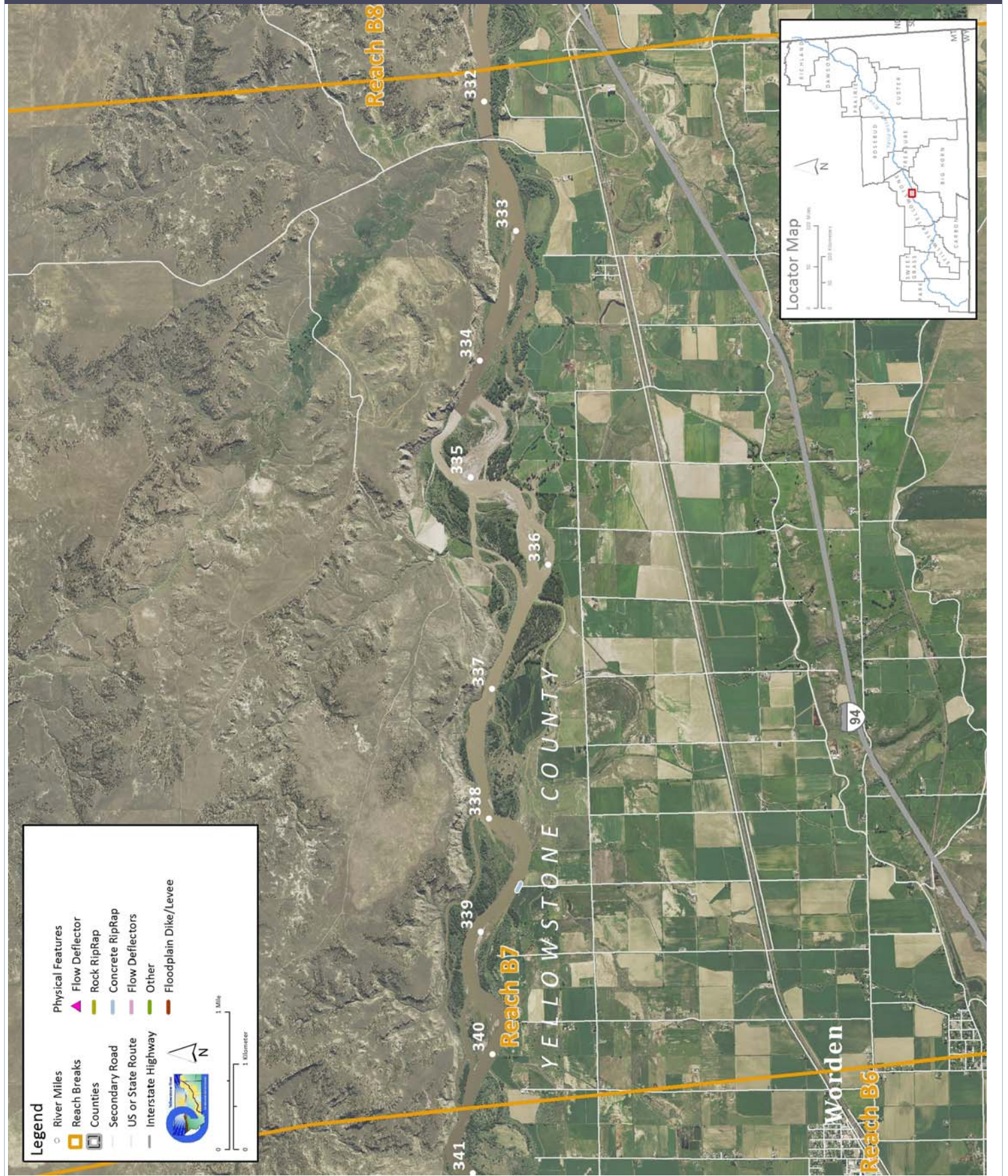
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B7 include:

- Russian olive removal

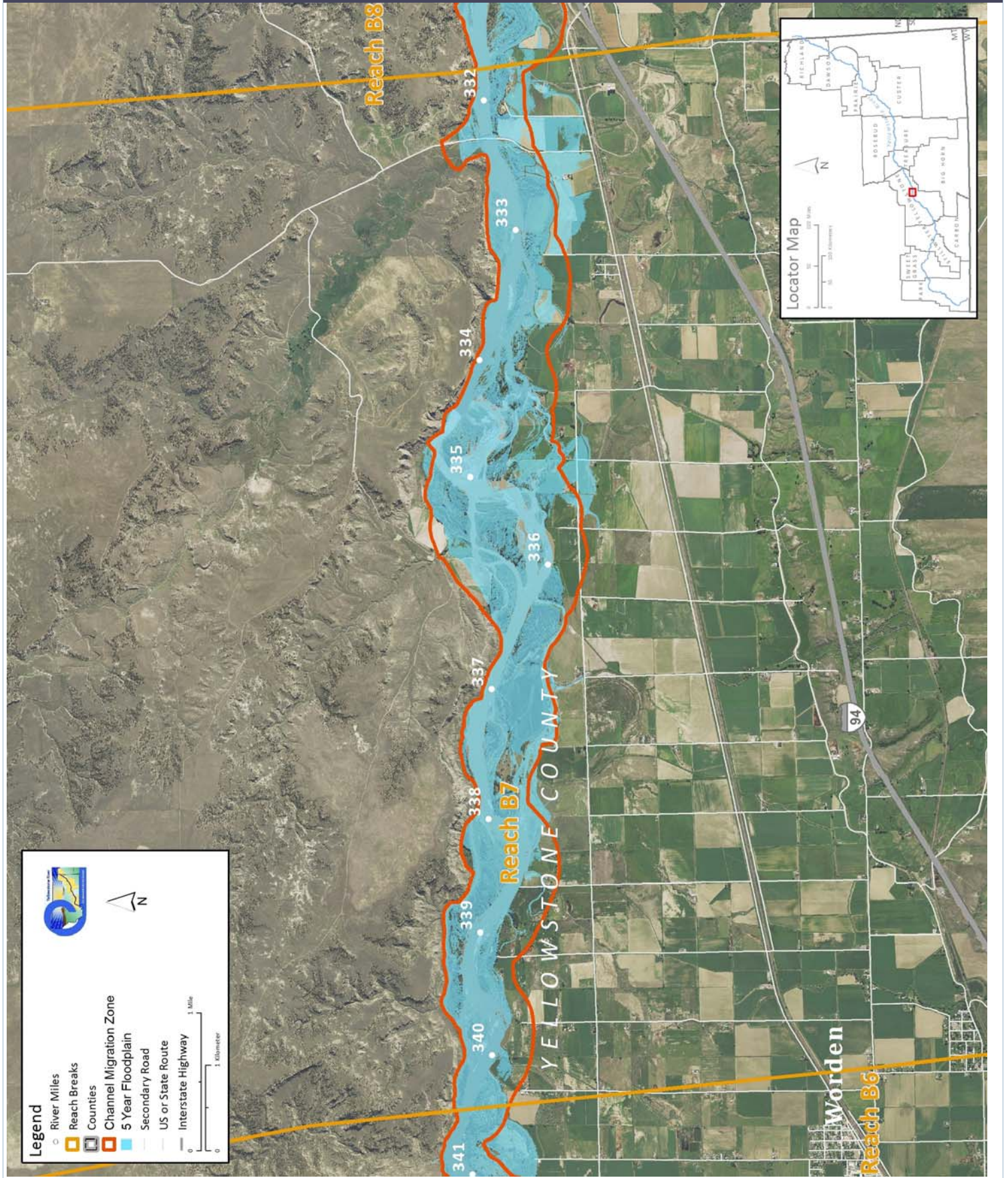
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Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	50,400	44,900	-10.9%			
100 Year (cfs)	88,800	85,600	-3.6%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	956.1	958.6	834.0	914.6	-41.5	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	0	0.0%	0			
Concrete Riprap	289	0.3%	0			
Flow Deflectors	0	0.0%	0			
Total	289	0.3%	0			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	0	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)	The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
Total Acres	319.9	255.1				
Acres/Year	12.3	10.2				
Acres/Year/Valley Mile	1.6	1.3	130.84 acres			
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	611.4	28%				
100 Year	699.0	22%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	124.7	4%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	4,646.5	4,391.6	Flood (Ac)	1,212.2	1,339.3	
Ag. Infrastructure (Ac)	60.6	187.9	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	0.0	58.4	Pivot (Ac)	0.0	0.0	
Urban (Ac)	0.0	0.0				
Transportation (Ac)	53.6	60.9				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	37.7	4.9	42.6	4.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	11.1	1.5	256.9			
Emergent	135.1	17.8				
Scrub/Shrub	110.7	14.6				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	55.7	2.2%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	9.2	3.0	6.4	-2.8		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	331.8
Classification	PCA: Partially confined anabranching	Downstream River Mile	322.7
General Location	Bull Mountain	Length	9.10 mi (14.65 km)

Narrative Summary

Reach B8 is located downstream of Pompey's Pillar. The Reach is 9.1 miles long and is partially confined by the valley wall with numerous forested islands. In the 1950's, the main channel flowed more closely along the north valley wall; southward migration since that time has reduced the influence of the valley wall on stream geomorphology. The valley is wide in this area, which is typical where the bounding rock units are made up of the relatively erodible Cretaceous-age Bearpaw shale.

Just over 3,000 feet of streambank are armored by rock riprap, which is about 3.3 percent of the total bankline. All of the bank armor in the reach is protecting the rail line on the south side of the river. High resolution imagery from fall 2011 indicates that at RM 328 about 570 feet of rock riprap has been flanked on the right bank against the rail line, and that the flanked rock is about 80 feet into the river off of the south bank. Currently, the river is within 100 feet of the rail line and migrating rapidly in that direction.

One side channel that is about 6,200 feet long at RM 326R was blocked prior to 1950.

Land uses in the reach are primarily agricultural, with about 1,240 acres of flood irrigated land mapped as of 2011. There are 124 acres of land in sprinkler and 86 under pivot. The modern 5-year floodplain contains about 250 acres of flood-irrigated ground.

One dump site was mapped on an old swale adjacent to a flood irrigated field at RM 326.5R.

The Channel Migration Zone (CMZ) has been developed for primarily flood irrigation; as of 2011, there were 457 acres of flood irrigated land in the CMZ, and about 7 percent of the total CMZ footprint has become restricted by bank armor and road prisms. The railroad has isolated almost 9 percent of the historic 100-year floodplain in the reach. About 22 percent of the 5-year floodplain has become isolated in Reach B8. Much of that 5-year floodplain isolation is due to transportation infrastructure on the south side of the river.

Similar to Reach B7 upstream, Reach B8 shows major southward migration of the river since 1950, with one area at RM 324.3 experiencing over 1,500 feet of migration over the past 60 years. This southward migration has threatened the rail line at RM 328R.

Overall, the migration rates and floodplain turnover rates have dropped since 1976 from 1.9 acres/valley mile/year from 1950 to 1976 to 1.5 acres/valley mile/year from 1976-2001.

Reach B8 has 91 mapped acres of Russian olive that can be found in dense stands, especially on forested islands. Even so, the extensive lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 600 acres of riparian recruitment in the reach, most of which was riparian colonization of old 1950's channel area. The acreage of recruitment has exceeded that of erosion of riparian areas by 51 acres. Additionally, there are 271 mapped wetlands in the reach, including 147 acres of wet meadows and marsh. The reach contains about 33 wetland acres per valley mile, which is a relatively high value for the Yellowstone River.

Reach B8 was sampled as part of the avian study. The average species richness in this reach was 7.8, which indicates the average number of species observed during site visits to the reach in cottonwood habitats. The average species richness for sites evaluated is 8. One bird species identified by the Montana Natural Heritage Program as a Potential Species of Concern was identified, the Plumbeous Vireo. Another species identified as a Species of Concern was identified, the Red-headed Woodpecker.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 28,000 cfs to 22,800 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,040 cfs to 2,070 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B8 include:

- Migration away from valley wall resulting in loss of bluff pool habitat.
- Blockage of one side channel at RM 326 sometime prior to 1950
- Transportation infrastructure –caused isolation of 5-year floodplain south of the river at RM 329.5

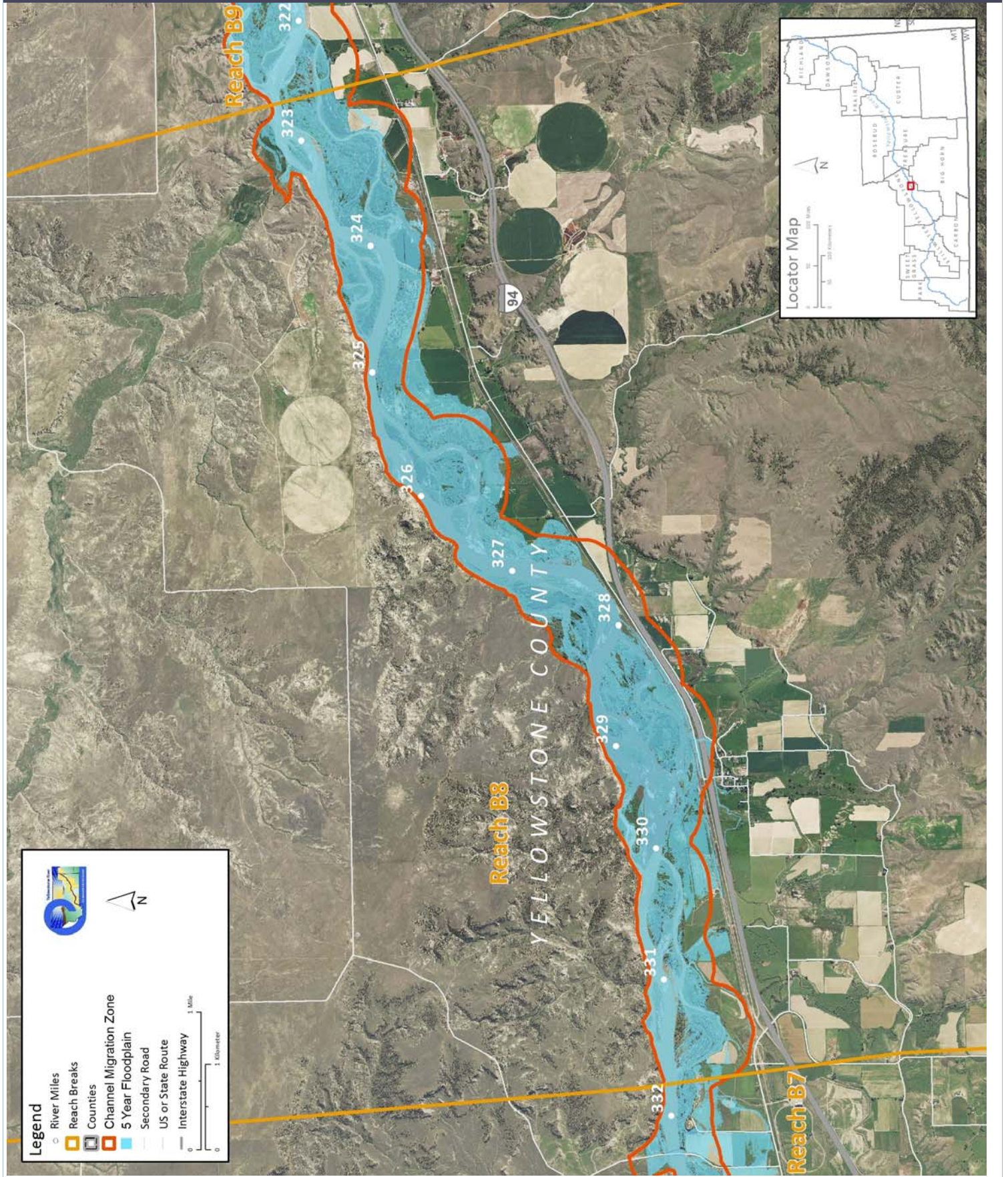
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B8 include:

- Side channel reactivation at RM 326
- Dump removal at RM 326.5R
- Flanked armor removal at RM 328R
- Russian olive removal

The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	51,700	46,100	-10.8%			
100 Year (cfs)	90,900	87,600	-3.6%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	1,051.1	1,093.5	1,003.0	1,089.4	38.3	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	3,208	3.3%	0			
Concrete Riprap	0	0.0%	0			
Flow Deflectors	0	0.0%	0			
Total	3,208	3.3%	0			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	6,209	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)		The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.	
Total Acres	391.0	291.8	50.51 acres			
Acres/Year	15.0	11.7				
Acres/Year/Valley Mile	1.9	1.5				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	442.3	22%				
100 Year	219.4	9%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	224.3	7%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	4,889.1	4,506.4	Flood (Ac)	1,269.7	1,238.8	
Ag. Infrastructure (Ac)	90.7	123.1	Sprinkler (Ac)	6.1	124.4	
Exurban (Ac)	43.0	77.4	Pivot (Ac)	0.0	85.9	
Urban (Ac)	0.0	0.0				
Transportation (Ac)	105.3	235.1				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	46.9	0.0	46.9	4.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	10.3	1.3	271.4			
Emergent	147.4	18.8				
Scrub/Shrub	113.7	14.5				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	91.2	3.2%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	8.5	7.5	8.4	0.0		

CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	322.7
Classification	UA: Unconfined anabranching	Downstream River Mile	318
General Location	Reed Creek	Length	4.70 mi (7.56 km)

Narrative Summary

Reach B9 is located in lower Yellowstone County near Reed Creek. The Reach is 4.7 miles long and is an Unconfined Anabranching (UA) reach type, indicating the presence of extensive forested islands with little valley wall influence on the main channel. This reach type is typically the most dynamic in the system due to a lack of confinement and extent of side channels.

About 7,300 feet of streambank are armored by rock riprap, which is about 15 percent of the total bankline. Most of the bank armor in the reach is protecting the rail line on the south side of the river, and most of it is located along the edge of a section of bluff line. Another section of armor is protecting a major power line crossing on the north bank at RM 321. Currently, two towers on the crossing are right on the edge of the river.

One side channel that is about 8,000 feet long at RM 321.5L was blocked prior to 1950. The lower end of this old channel still holds open water, but the upstream end has been graded into fields and also supports two major power line towers.

Land uses related to both irrigation and the railroad have encroached into the Channel Migration Zone (CMZ) in Reach B9. Overall, land uses in the reach are primarily agricultural, with about 508 acres of flood irrigated land mapped as of 2011. About half of that irrigated acreage is within the CMZ. There are 384 acres under pivot, about 75 of which are within the CMZ. The railroad has encroached into 101 acres of the CMZ and is primarily responsible for its isolation. In total, just under 10 percent of the CMZ has been restricted due to bank armor, and 7.3 percent of the restriction is due to the railroad, while 2.4 percent is associated with the protection of irrigated lands.

The modern 5-year floodplain contains about 76 acres of flood-irrigated ground, and 64 acres of ground under pivot.

Waco-Custer Diversion Dam is located at RM 320. The Waco-Custer ditch company was formed in the early 1900's, and the diversion dam was constructed shortly thereafter (<http://www.fws.gov/YellowstoneRiverCoordinator/Waco-custer.html>). The Waco-Custer diversion supports approximately 4,300 acres of irrigation, with a diversion capacity of 125 cfs. The structure is located approximately eight miles west of Custer, at River Mile 320. At the diversion, the Yellowstone River flows through two main channels, and the structure itself blocks only the right channel. The structure feeds the Waco-Custer Canal, which flows on the south floodplain surface of the Yellowstone River.

Migration rates in several locations in Reach B9 have exceeded an average of 10 feet per year since the mid-1950s. At Rm 322, the river migrated almost 200 feet between 2001 and 2011, which is double that average rate of 10 feet per year. That rapid recent migration has been through irrigated fields on the south side of the river. Lateral migration of the river has promoted extensive recruitment of new woody riparian habitat. Since the 1950s there has been about 210 acres of riparian recruitment in the reach, most of which was riparian colonization of old 1950's channel area. Additionally, there are 213 mapped wetlands in the reach, including 105 acres of emergent wetland types such as wet meadows and marsh. The reach contains about 53 wetland acres per valley mile, which is a relatively high value for the Yellowstone River.

Reach B9 has had a major loss of forest area that is considered at low risk of cowbird parasitism. In 19590, there were about 48 acres per valley mile of such forest, and that had been reduced by 2001 to 21 acres per valley mile.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,060 cfs to 2,080 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

About 23 percent of the 5-year floodplain has become isolated in Reach B9, and the vast majority of this isolation is on the south side of the river at RM 321 where the rail line has isolated an historic side channel. Much of that 5-year floodplain isolation is due to transportation infrastructure on the south side of the river. This isolated floodplain area still holds open water in a distinct swale.

CEA-Related observations in Reach B9 include:

- Blockage of one side channel at RM 321.5 sometime prior to 1950
- Railroad isolation of major channel remnant that supports open water.

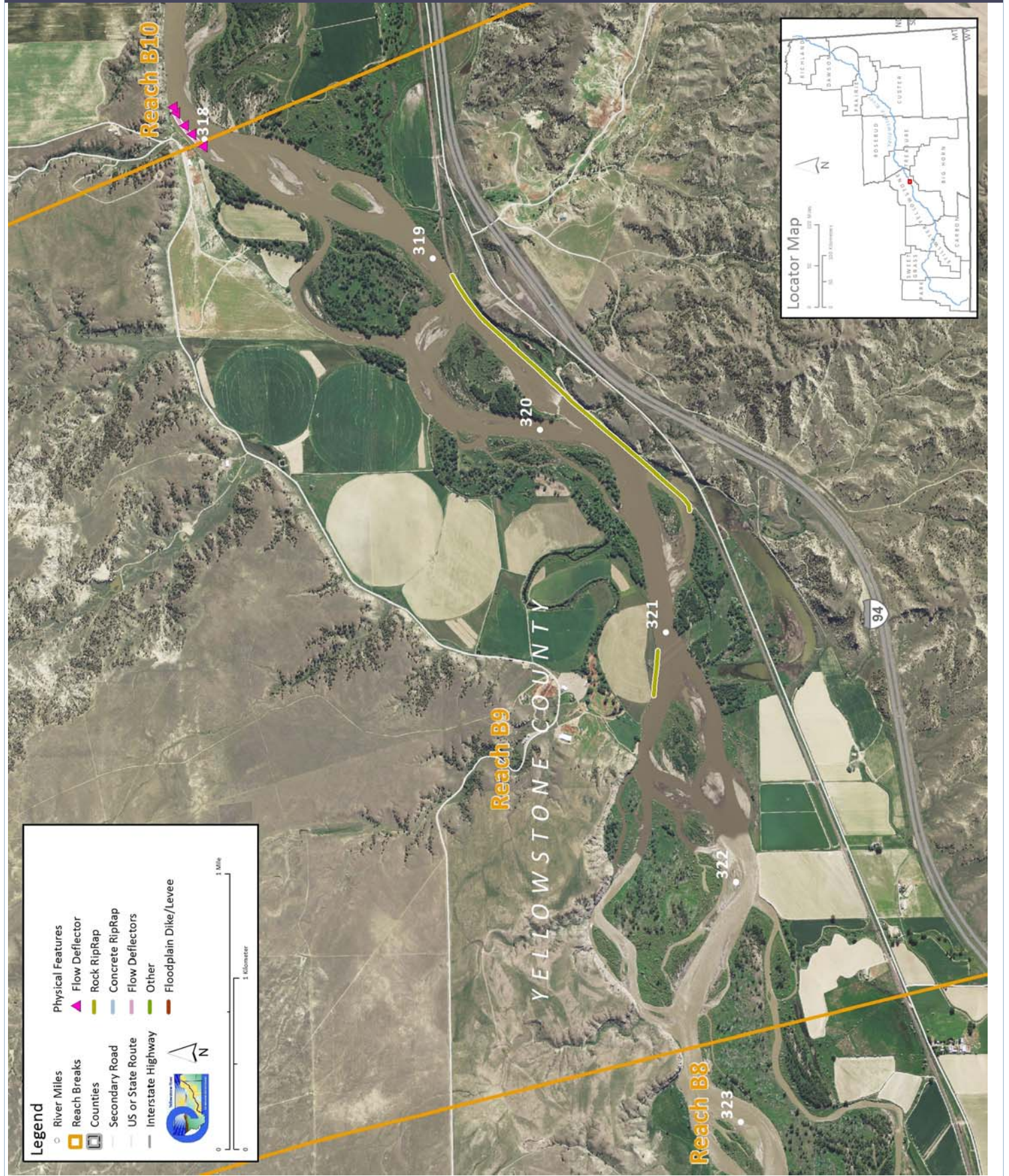
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B9 include:

- Side channel reactivation at RM 321.5—may be difficult due to power line
- CMZ management due to ~10 percent restriction of CMZ
- Russian olive removal
- Floodplain reconnection where active rail line has isolated historic channel remnant at RM 321R.
- Fish passage Practice at Waco Custer Diversion Dam (not complete blockage)
- Watercraft passage Practice at Waco Custer Diversion Dam (side channel passage exists)
- Irrigation Infrastructure management at Waco Custer Diversion Dam.

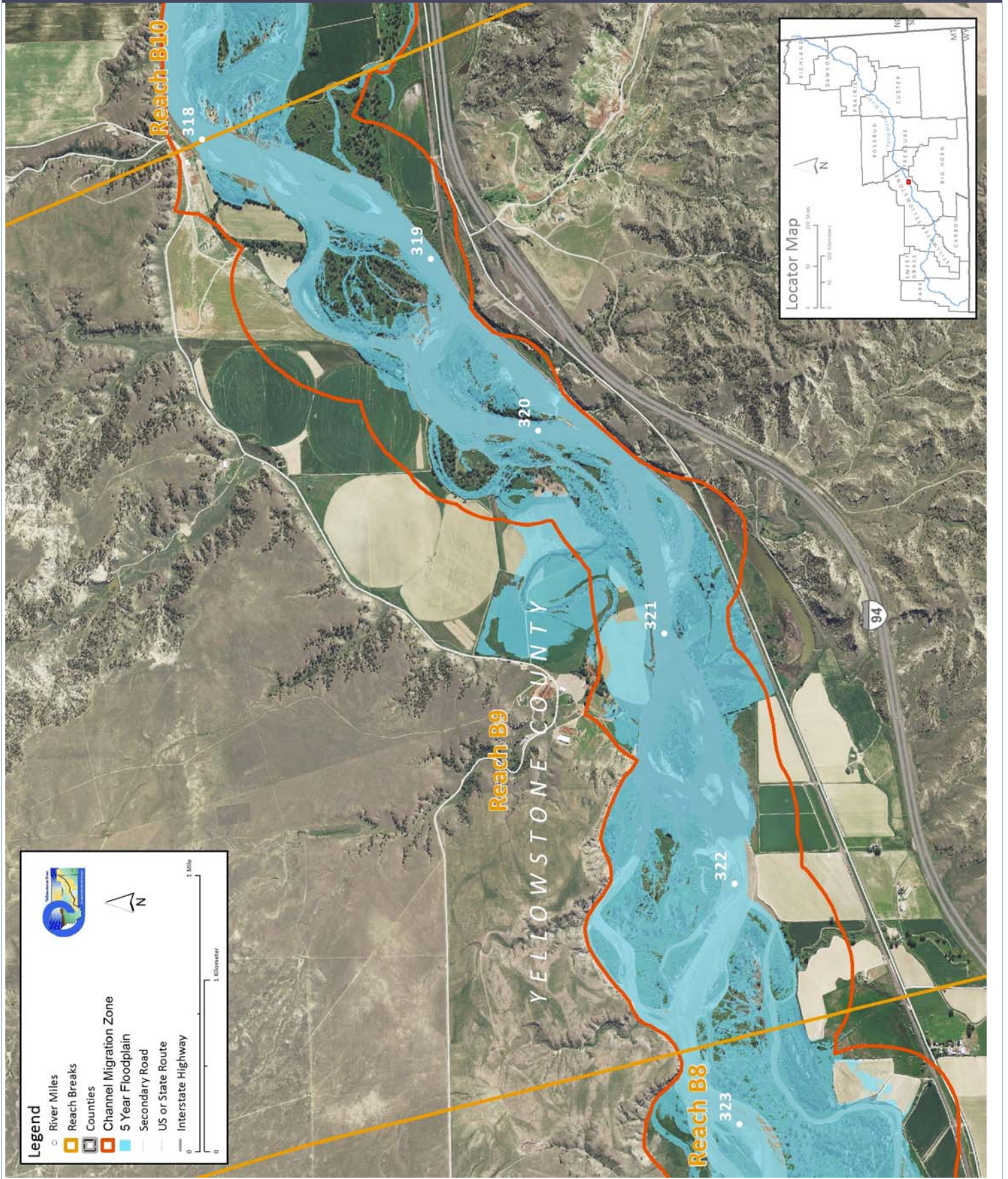
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	55,500	49,400	-11.0%			
100 Year (cfs)	97,200	93,600	-3.7%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	485.8	524.8	515.2	539.2	53.5	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	7,304	14.9%	0			
Concrete Riprap	0	0.0%	0			
Flow Deflectors	89	0.2%	0			
Total	7,393	15.1%	0			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	7,943	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)	The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.		
Total Acres	166.0	162.6				
Acres/Year	6.4	6.5				
Acres/Year/Valley Mile	1.6	1.7	6.4 acres			
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	175.0	23%				
100 Year	0.0	0%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	168.5	10%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	2,906.3	2,697.0	Flood (Ac)	656.7	507.8	
Ag. Infrastructure (Ac)	12.0	62.4	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	0.6	0.6	Pivot (Ac)	0.0	384.1	
Urban (Ac)	0.0	0.0				
Transportation (Ac)	61.4	153.2				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	4.9	0.5	5.4	1.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	24.3	6.2	212.5			
Emergent	104.6	26.9				
Scrub/Shrub	83.6	21.5				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	5.9	0.3%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	47.7	28.0	21.0	-26.7		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	318
Classification	PCM: Partially confined meandering	Downstream River Mile	310.8
General Location	Waco	Length	7.20 mi (11.59 km)

Narrative Summary

Reach B10 is located in lower Yellowstone County and contains the Captain Clark Fishing Access Site. The Reach is 7.2 miles long and is a Partially Confined Meandering reach type, (PCM), indicating the presence of a primary meandering channel thread with substantial valley wall influence on the river. The Captain Clark Fishing Access Site is located in the middle of the reach.

There are about 1,150 feet of rock riprap and 800 feet of flow deflectors in the reach, which collectively armor about 3 percent of the total bankline. About one half of the armor is protecting the active railroad, and the other half is protecting agricultural land. High resolution 2011 imagery shows the complete flanking of the mapped flow deflectors since 2001. The river has since eroded over 100 feet of bank behind the flanked barbs, eroding into a series of old corrals. The barbs are readily visible in the river.

One abandoned side channel that is about 3,300 feet long at RM 315R appears to be very old, however has several crossings that currently form plugs along its course. The channel is still within the 5-year floodplain, so the plugs have likely affected its function as a flood channel, and perhaps historically as a seasonal channel. This historic side channel is located landward (south) of the Fishing Access Site, which is on an old island. The lower end of this old channel supports a high density of Russian olive.

Reach B10 has lost almost 5.5 miles of side channel length since 1950. In the uppermost portion of the reach, the main river channel flipped from the south side of the corridor to the north sometime between 1976 and 2001, progressively abandoning a mile long channel and focusing the river into a single thread that flows along the north valley bluff line. This is where the flow deflectors described above have been flanked. This pattern has been common all through the reach; major secondary channels from the 1950s have been abandoned and the river has shifted to much more of a single thread meandering river. Some of the 1950's channels have potentially been blocked, and others appear to have been passively abandoned.

On the south side of the river at RM 312.5, the rail line currently isolates about 42 acres of historic 100-year floodplain. The river is currently against the rail line at this location, so that the separation between the river and the isolated remnant is only about 200 feet. This area is also adjacent to about 20 acres of mapped emergent wetland.

Overall, land uses in reach B10 are primarily agricultural, with about 860 acres of flood irrigated land mapped as of 2011. About one third of that irrigated acreage is within the CMZ. The railroad has encroached into 19 acres of the CMZ. In total, just under 7 percent of the CMZ has been restricted, and all of that restriction is due to bank armor protecting the rail line.

The modern 5-year floodplain contains about 72 acres of flood-irrigated ground. Reach B10 also supports almost 40 acres of mapped wetlands per valley mile, which is a relatively high density for the corridor.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,070 cfs to 2,090 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B10 include:

- Active and passive abandonment of over five miles of anabranching channel length since 1950
- Bank armor flanking associated with flow consolidation into single thread.

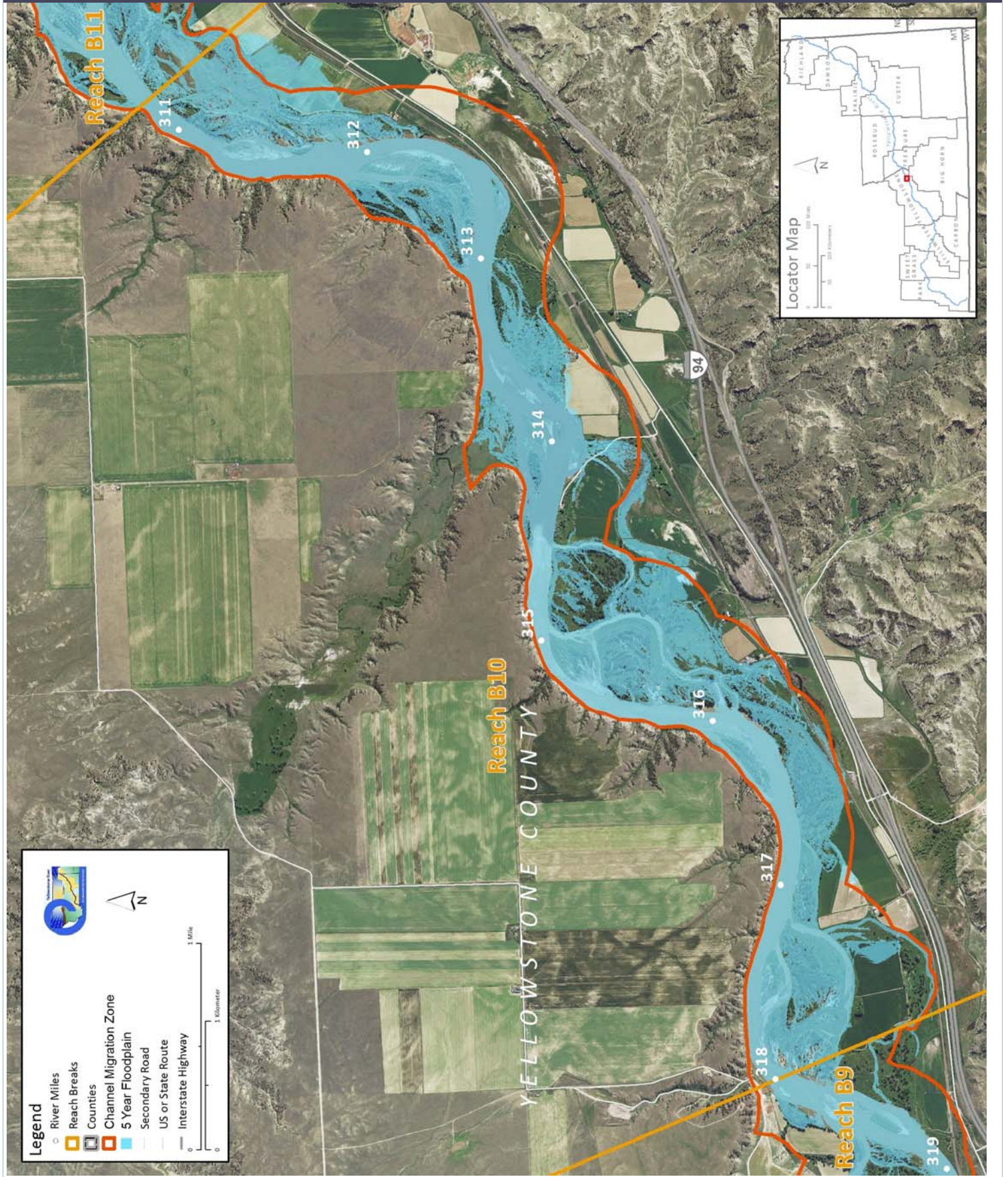
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B10 include:

- Removal of flanked flow deflectors at RM 318
- Side channel reactivation throughout reach
- Floodplain reconnection at Rm 312.5R
- Russian olive removal

The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	55,500	49,400	-11.0%			
100 Year (cfs)	97,200	93,600	-3.7%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	703.2	814.4	728.5	769.4	66.2	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	1,153	1.5%	0			
Concrete Riprap	0	0.0%	0			
Flow Deflectors	807	1.1%	0			
Total	1,960	2.6%	0			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	3,344	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)		The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.	
Total Acres	293.6	154.2	6.66 acres			
Acres/Year	11.3	6.2				
Acres/Year/Valley Mile	1.9	1.0				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	202.4	19%				
100 Year	111.7	7%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	163.7	7%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	4,202.4	4,263.9	Flood (Ac)	637.0	858.1	
Ag. Infrastructure (Ac)	43.9	58.2	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	0.0	8.2	Pivot (Ac)	0.0	0.0	
Urban (Ac)	0.0	0.0				
Transportation (Ac)	54.7	169.9				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	24.9	3.7	28.5	3.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	19.7	3.3	239.3			
Emergent	113.2	18.9				
Scrub/Shrub	106.4	17.8				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	38.8	1.5%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	6.3	6.2	8.4	2.2		

CHANNEL MIGRATION ZONE MAP



County	Yellowstone	Upstream River Mile	310.8
Classification	PCA: Partially confined anabranching	Downstream River Mile	302.7
General Location	To Custer Bridge	Length	8.10 mi (13.04 km)

Narrative Summary

Reach B11 is located in lower Yellowstone County. The Reach is 8.1 miles long and is a Partially Confined Anabranching reach type, (PCA), indicating the presence of forested islands with substantial valley wall influence on the river. Custer Bridge and the town of Bighorn are at the lower end of the reach.

There are about 2,600 feet of rock riprap and 1,200 feet of flow deflectors in the reach, which collectively armors about 4 percent of the total bankline. All of the armor is protecting agricultural land, both irrigated and non-irrigated. Most of the rock riprap was built between 1950 and 1976, whereas the flow deflectors were built between 1995 and 2001.

One side channel that is about 1,000 feet long at RM 305R appears to have been blocked as a seasonal channel by three different plugs that were all in place in 1950. Hydraulic modeling results show that under undeveloped conditions, the channel conveyed water at a 2-year discharge, but now it doesn't convey flow at the 5-year discharge. The blocked channel now has dense stands of Russian olive on its lower end.

Since 1950, the bankfull area of the channel has increased by about 60 acres in Reach B11 indicating some enlargement of the main channel between 1950 and 2001. This is interesting because there was also a net increase in riparian area due to erosional processes of about 75 acres, which may appear contradictory. In reviewing the GIS data, it is apparent that much of the channel migration in Reach B11 was through unvegetated farm fields such that the channel was able to enlarge, and the area created by the migration was then colonized by riparian vegetation, resulting in a net gain in riparian area, along with an increase in overall channel size. The total riparian recruitment acreage in the reach was 483 acres; 334 of those acres of recruitment were in 1950s channel areas, and 149 acres of eroded floodplain have been colonized by woody riparian species. The increase in riparian area is most evidenced by riparian shrub, which increased from 219 acres in 1950 to 462 acres in 2001. Reach B11 consequently has a robust riparian corridor with active recruitment associated with channel migration.

Reach B11 experienced a major avulsion between 1976 and 1002, when the river jumped about 1,600 feet to the northwest between RM 305 and RM 306, relocating into a relatively small developing side channel. The avulsed channel has since been migrating back to the southeast, creating a large sediment deposit downstream at RM 305 where the river corridor is tightly confined by the valley wall to the northwest and bank armored fields to the southeast. This section of river appears quite unstable.

Most of the floodplain isolation has been related to more frequent flooding; whereas 2 percent of the 100-year floodplain has become isolated due to human development, about 17 percent of the 5-year floodplain is no longer inundated at that frequency. Much of the loss of 5-year floodplain was in the blocked channel at RM 305R described above. The 100-year isolated floodplain is behind the active rail line and Interstate about 1,000 feet south of the river at RM 308.5R. Emergent wetlands have been mapped in this isolated floodplain area, which is about 21 acres in size. Hydraulic modeling indicates that this area would also be inundated at a 5-year event, making it a good potential candidate for restoring floodplain connectivity through the rail line and frontage road, or for simple wetland restoration.

The mapped land uses in Reach B11 indicate that flood irrigation is the dominant land use, with about 1,500 acres of ground in flood irrigation and 100 in pivot. The town of Bighorn contributes to about 70 acres of urban/exurban development, and the proximity of the rail line to the river corridor is evidenced by 191 acres of transportation footprint. The most common developed land use in the Channel Migration Zone (CMZ) is flood irrigation (431 acres). About 17 percent of the CMZ has been isolated due to physical features such as bank armor and floodplain dikes, and most of that is riprap protection against irrigated lands (11 percent of CMZ). Most of these restrictions are in the lower reach near the town of Bighorn.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,080 cfs to 2,100 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B11 include:

- Side channel blockage prior to 1950
- Channel instability caused by avulsion at RM 305

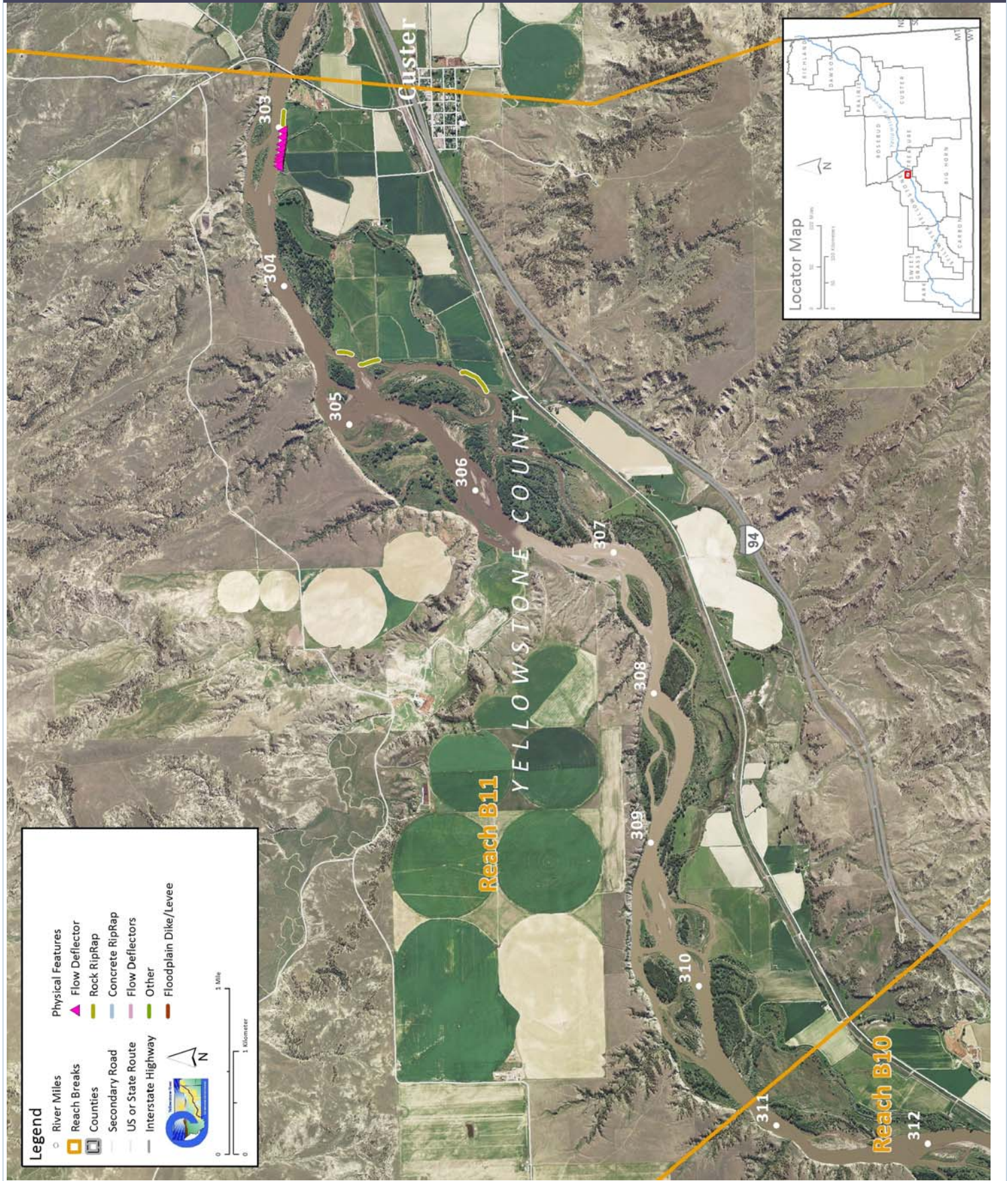
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B11 include:

- Side channel reactivation at RM 305R
- Floodplain reconnection at Rm 308.5R
- Russian olive removal
- Channel Migration Zone (CMZ) management due to extent of CMZ restricted (17 percent)

The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	55,500	49,400	-11.0%			
100 Year (cfs)	97,200	93,600	-3.7%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	916.2	948.6	928.3	976.4	60.2	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	2,570	3.0%	0			
Concrete Riprap	0	0.0%	0			
Flow Deflectors	1,169	1.4%	0			
Total	3,739	4.4%	0			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	1,002	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)		The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.	
Total Acres	252.0	259.1	74.5 acres			
Acres/Year	9.7	10.4				
Acres/Year/Valley Mile	1.3	1.4				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	206.3	17%				
100 Year	33.3	2%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	511.3	17%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	5,117.4	4,940.7	Flood (Ac)	1,189.9	1,490.7	
Ag. Infrastructure (Ac)	54.3	74.4	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	2.2	24.7	Pivot (Ac)	0.0	101.8	
Urban (Ac)	68.1	45.0				
Transportation (Ac)	88.0	191.3				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	9.9	0.2	10.1	1.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	17.6	2.4	221.4			
Emergent	160.7	21.8				
Scrub/Shrub	43.0	5.8				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	30.6	0.8%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	14.7	11.1	9.9	-4.8		

PHYSICAL FEATURES MAP (2011)



County	Yellowstone	Upstream River Mile	302.7
Classification	UA: Unconfined anabranching	Downstream River Mile	298.1
General Location	To Bighorn River confluence	Length	4.60 mi (7.40 km)

Narrative Summary

Reach B12 is located in lowermost Yellowstone County and extends to the mouth of the Bighorn River. The Reach is 4.6 miles long and is an Unconfined Anabranching reach type, (UA), indicating the presence of forested islands with minimal valley wall influence on the river. These reach types tend to be the most dynamic of all reach types, with typically high rates of bank migration.

There are about 7,800 feet of rock riprap in the reach, which collectively armors about 16 percent of the total bankline. Most of the armor (7,700 feet) is protecting the rail line, with the remainder protecting non-irrigated agricultural land. At two locations (RM 301.5 and RM 299), the river is flowing along bank armor that is right on the railroad prism. One segment of bank armor right at the Bighorn River confluence is actively flanking and will likely be eroded out shortly. Most of the rock riprap was in place in 1950. About 3 miles of transportation encroachment due to the railroad was mapped in the reach.

No blocked side channels have been mapped in Reach B12.

Floodplain turnover rates have dropped in this reach, from 1.9 acres/year/valley mile between 1950 and 1976 to 1.3 acres/year/valley mile between 1976 and 2001. Between 1950 and 2001, there was a total of 214 acres of riparian recruitment in the reach, most of which was colonization of area that was channel in 1950.

Whereas 9 percent of the 100-year floodplain has become isolated due to human development, about 21 percent of the 5-year floodplain is no longer inundated at that frequency. All of the 100-year floodplain isolation is due to the railroad. These areas are very proximal to the river at RM 299 and 302, and could potentially be considered for floodplain and/or wetland restoration.

Land use is dominated by agriculture, with 137 acres of pivot irrigation development since 1950. Almost 50 of those acres of pivot are within the Channel Migration Zone (CMZ). Almost 9 percent of the Channel Migration Zone (CMZ) has been restricted, and the vast majority of that restriction is due to rock riprap protection of the railroad (8 percent).

Reach B12 supports 144 acres of wetland, which at over 35 acres per valley mile is a relatively high concentration of wetlands on the river. There are also 33 acres of mapped Russian olive.

Contrary to most other Reaches, Reach B11 has seen an increase in forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 33 acres per valley mile of such forest, and that number increased to 36 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 30,200 cfs to 24,500 cfs, a drop of about 19 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 11 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 3,090 cfs to 2,100 cfs with human development, a reduction of 32 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 3,846 cfs under unregulated conditions to 2,227 cfs under regulated conditions at the Billings gage, a reduction of 42 percent.

CEA-Related observations in Reach B12 include:

- Active flanking of bank armor at mouth of Bighorn River
- Channel instability caused by avulsion at RM 305

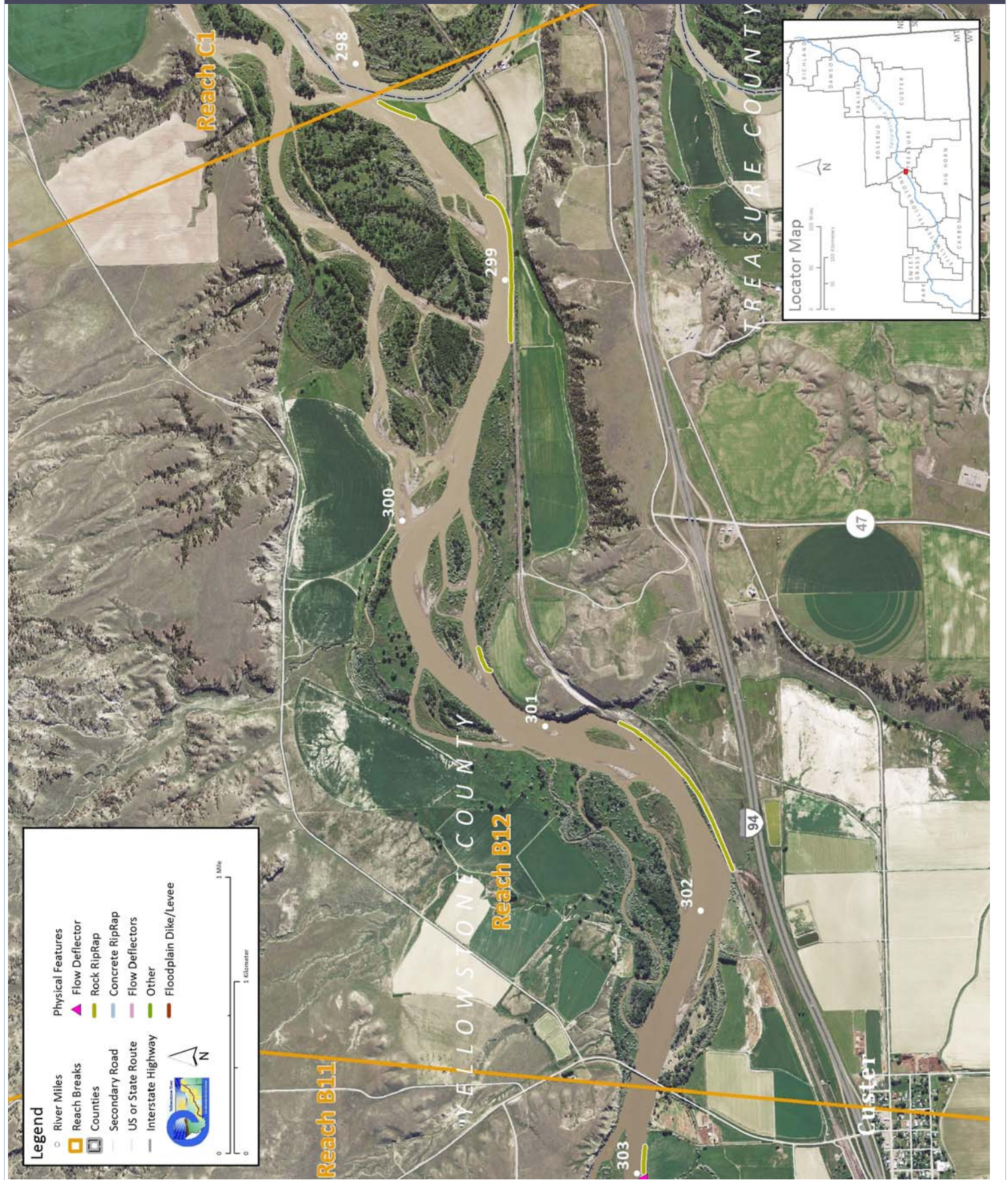
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach B12 include:

- Bank armor maintenance where active flanking is occurring at mouth of Bighorn River at RM 298.3R
- Russian olive removal

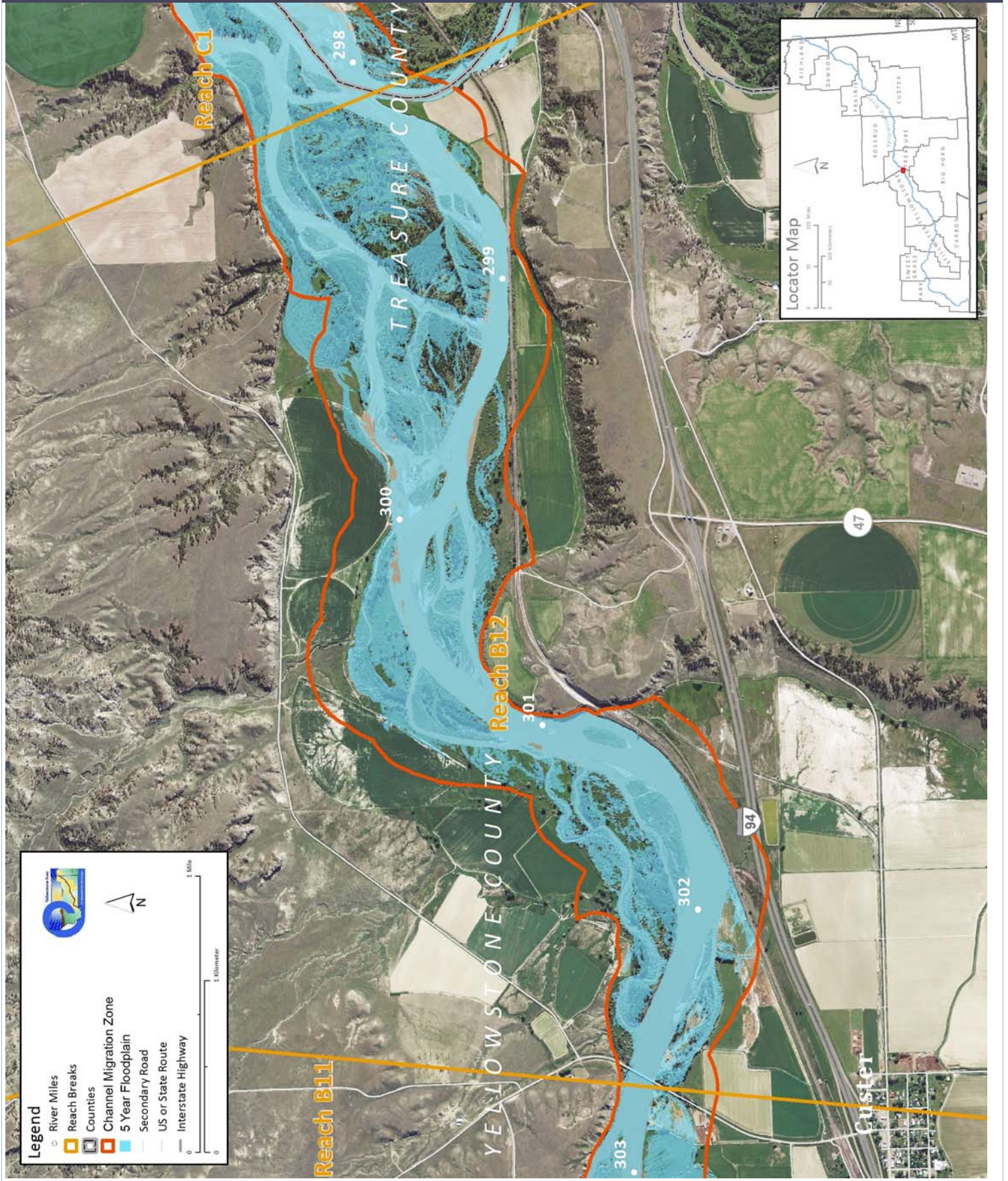
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	55,500	49,400	-11.0%			
100 Year (cfs)	97,200	93,600	-3.7%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	526.7	605.1	528.2	552.8	26.1	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	7,778	16.2%	0			
Concrete Riprap	0	0.0%	0			
Flow Deflectors	0	0.0%	0			
Total	7,778	16.2%	0			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	0	0				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)		The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.	
Total Acres	190.0	119.1	67.61 acres			
Acres/Year	7.3	4.8				
Acres/Year/Valley Mile	1.9	1.3				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)						
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	141.9	21%				
100 Year	89.6	9%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	146.9	9%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	2,985.1	2,805.0	Flood (Ac)	498.4	556.0	
Ag. Infrastructure (Ac)	10.9	42.9	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	0.0	0.0	Pivot (Ac)	0.0	136.8	
Urban (Ac)	14.6	14.6				
Transportation (Ac)	60.1	130.2				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
		0.6	0.6	0.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres		Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).	
Riverine	5.6	1.5	144.3			
Emergent	104.4	27.8				
Scrub/Shrub	34.3	9.1				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	32.5	1.6%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	33.0	42.0	36.1	3.1		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



County	Treasure	Upstream River Mile	298.1
Classification	UA: Unconfined anabranching	Downstream River Mile	292.3
General Location	From Bighorn confluence	Length	5.80 mi (9.33 km)

Narrative Summary

Reach C1 is located just downstream of the Bighorn River confluence. The Reach is 5.8 miles long and is an Unconfined Anabranching reach type, (UA), indicating the presence of forested islands with minimal valley wall influence on the river. These reach types tend to be the most dynamic of all reach types, with typically high rates of bank migration. At RM 296.5 for example, the river has migrated over 250 feet to the southeast between 2001 and 2011, indicating an average migration rate of over 25 feet per year.

There are about 2,300 feet of rock riprap in the reach, which collectively armors about 4 percent of the total bankline. About 1,000 feet of armor is protecting the rail line and another 500 feet is protecting agricultural ground. The remainder is protecting the Rancher's Ditch Diversion Structure at RM 295.5.

The Rancher's Ditch diversion dam is located approximately 2.5 miles downstream of the Bighorn River confluence. The dam was constructed in the early part of the 20th century and feeds a canal that flows on the north side of the river. There is a large, vegetated island in the Yellowstone River at the point of diversion, and diversion dams block channels on both sides of the island. The 2011 imagery shows that the south channel is becoming progressively abandoned, so that most flow goes over the main diversion structure on the north channel.

Since 1950, there have been over 7,000 feet of side channel blocked by floodplain dikes in the reach. These channels are on the lower end of the reach on the left (northwest) bank at RM 293. Even though side channels have been blocked, there has been a net gain of side channel length in the reach; since 1950, the total anabranching channel length has increased by 3,800 feet.

Since 1950, Reach C1 has experienced over 300 acres of new riparian recruitment, with most of that colonization occurring in old 1950s channel area. In balancing the amount of riparian area eroded out to the colonization acreage, there has still been a net gain of 118 acres of riparian area associated with channel movement. This reflects erosion of non-wooded lands and colonization of resulting open bar surfaces by woody vegetation, as well as the fact that the channel has gotten smaller since 1950; the bankfull area dropped by almost 50 acres (6 percent) between 1950 and 2001.

Whereas 8 percent of the 100-year floodplain has become isolated due to human development, about 47 percent (633 acres) of the 5-year floodplain is no longer inundated at that frequency. About 80 acres of historic 100-year floodplain area has become isolated by the railroad, and another 42 acres due to flow alterations. The loss of 5-year floodplain shows the strong imprint of flow alterations below the mouth of the Bighorn River and of development of those areas that are less frequently inundated; about 216 acres of currently flood irrigated floodplain areas are in the historic 5-year floodplain footprint.

Land use is dominated by agriculture, with 1,212 acres of pivot irrigation development since 1950. About 15 of those acres of pivot are within the Channel Migration Zone (CMZ). Approximately 7 percent of the Channel Migration Zone (CMZ) has been restricted, with about half of the restrictions due to riprap along the railroad, and the other half due to floodplain dikes protecting irrigated lands.

There are several corrals associated with an animal handling facility at RM 296.8R. The river is migrating in the direction of these corrals and is currently about 600 feet from the facility.

Reach C1 supports over 40 acres per valley mile of mapped wetland, which is a relatively high wetland density for the river. There are also over 100 acres of Russian olive mapped in the reach, occupying 2.6 percent of the total floodplain area.

Reach C1 has seen a substantial loss in forested area that is at low risk of cowbird parasitism since 1950. At that time, there were 48 acres per valley mile of such forest, and that number decreased to 20 acres per valley mile by 2001.

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been major in this reach. The mean annual flood is estimated to have dropped from 60,800 cfs to 47,100 cfs, a drop of about 23 percent. The 2-year flood, which strongly influences overall channel form, has dropped by 20 percent. Low flows have also been impacted; severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 4,600 cfs to 2,950 cfs with human development, a reduction of 36 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 6,150 cfs under unregulated conditions to 3,320 cfs under regulated conditions at Reach C10 downstream where the analysis begins, a reduction of 46 percent.

CEA-Related observations in Reach C1 include:

- Blocking of over a mile of side channel by floodplain dikes

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach C1 include:

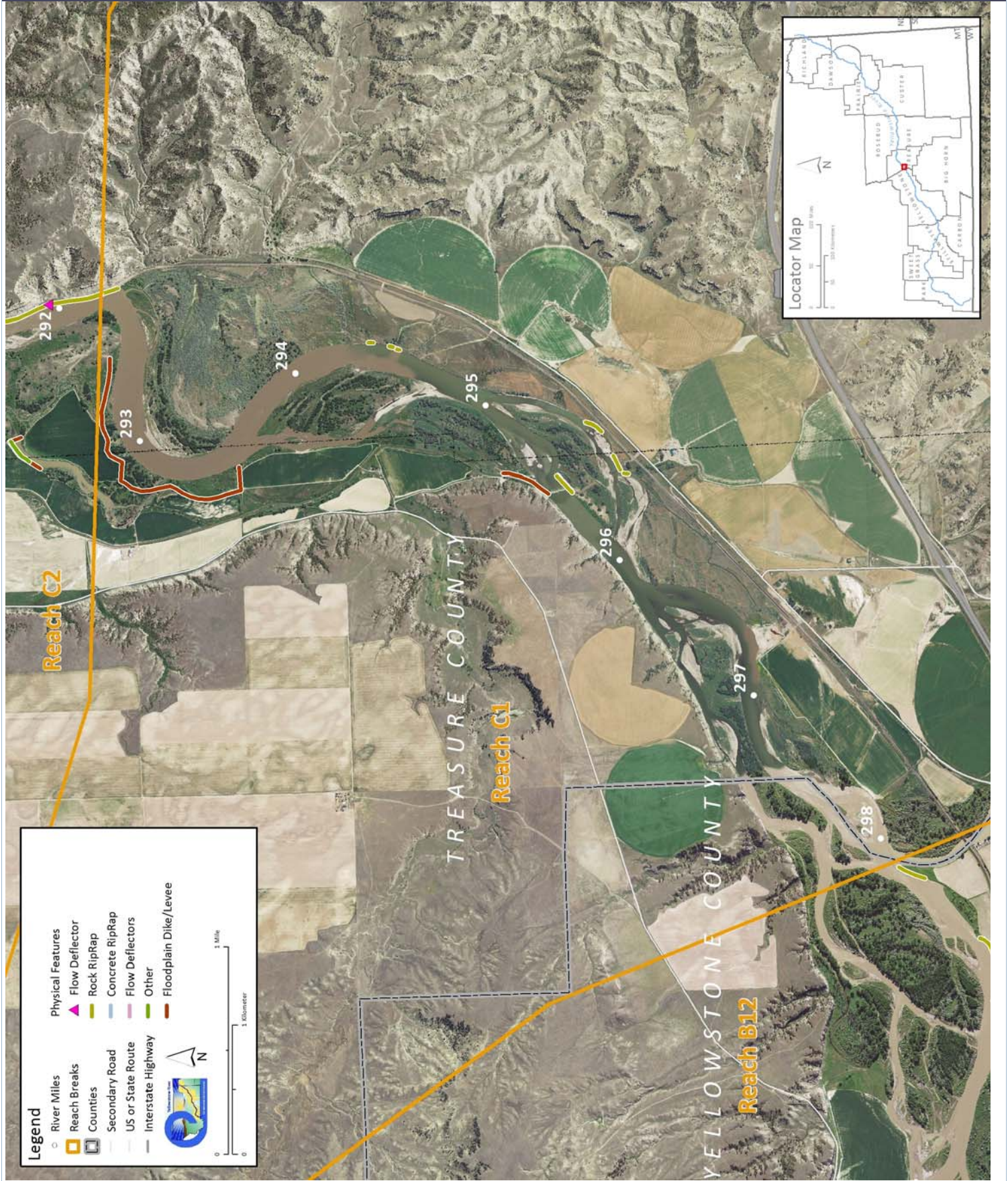
- Fish Passage at Ranchers Ditch Diversion: Structures block two channels at the diversion.
- Watercraft Passage at Ranchers Ditch Diversion
- Irrigation Infrastructure Management at Ranchers Ditch Diversion
- Side channel reactivation at RM 293
- Nutrient management at corrals associated with animal handling facility at RM 296.8R

- Russian olive removal

The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated from a large dataset that is presented in more detail in the full reach narrative report.

Discharge	Undev.	Developed	% Change	"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.		
2 Year (cfs)	60,800	47,100	-22.5%			
100 Year (cfs)	119,000	99,900	-16.1%			
Bankfull Channel Area (Ac)	1950	1976	1995	2001	1950-2001	Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood.
	775.2	765.3	696.4	728.8	-46.4	
Physical Features	2011 Length (ft)	% of Bankline	2001-2011 Change	There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.		
Rock RipRap	2,306	3.7%	406			
Concrete Riprap	0	0.0%	0			
Flow Deflectors	0	0.0%	0			
Total	2,306	3.7%	406			
Length of Side Channels Blocked (ft)	Pre-1950s	Post-1950s	Numerous side channels have been blocked by small dikes.			
	0	7,171				
Floodplain Turnover	1950 - 1976	1976 - 2001	1950-2001 In-channel riparian encroachment (negative number indicates retreat)		The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat.	
Total Acres	131.9	116.5	118.18 acres			
Acres/Year	5.1	4.7				
Acres/Year/Valley Mile	1.1	1.0				
Open Bar Area	Point Bars	Bank Attached	Mid-Channel	Total	The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns.	
Change in Area '50 - '01 (Ac)	27.4	54.2	1.9	83.5		
Floodplain Isolation	Acres	% of FP	Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.			
5 Year	633.4	46%				
100 Year	152.2	8%				
Restricted Migration Area	Acres	% of CMZ	Channel Migration Zone restrictions refer to the area and percent of the CMZ that has been isolated by features such as bank armor, dikes, levees, and transportation embankments.			
	113.0	6%				
Land Use	1950	2011	1950	2011	Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land.	
Agricultural Land (Ac)	4,744.8	4,661.6	Flood (Ac)	1,894.6	963.6	
Ag. Infrastructure (Ac)	50.9	40.2	Sprinkler (Ac)	0.0	0.0	
Exurban (Ac)	0.0	4.8	Pivot (Ac)	0.0	1,212.0	
Urban (Ac)	0.0	0.0				
Transportation (Ac)	85.4	154.3				
1950s Riparian Vegetation Converted to a Developed Land Use (ac)	To Irrigated	To Other Use	Total Rip. Converted	% of 1950s Rip.	Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.	
	31.9	5.7	37.5	5.0%		
National Wetlands Inventory	Acres	Acres per Valley Mi	Total Wetland Acres	Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation).		
Riverine	2.4	0.5	197.1			
Emergent	121.5	25.8				
Scrub/Shrub	73.2	15.5				
Russian Olive (2001) (Appx. 100-yr Floodplain)	Acres	%	Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.			
	104.5	2.6%				
Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)	1950	1976	2001	Change 1950-2011	Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.	
	48.3	20.7	19.9	-28.4		

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP

