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

## Narrative Summary

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

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

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

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

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

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

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

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

# Yellowstone River Reach Narratives — Reach PC21

**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 |
|---|---|---|---|
| 2 Year (cfs) | 22,400 | 22,000 | -1.8% |
| 100 Year (cfs) | 41,800 | 41,600 | -0.5% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

## Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 136.7 | 13.1 | | 148.9 | 12.2 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

## Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 6,270 | 26.2% | 169 |
| Concrete Riprap | 0 | 0.0% | 0 |
| Flow Deflectors | 123 | 0.5% | 62 |
| Total | **6,393** | **26.7%** | **232** |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

## Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 0 | 0 |

Numerous side channels have been blocked by small dikes.

## Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) |
|---|---|---|---|
| Total Acres | | | acres |
| Acres/Year | | | |
| Acres/Year/Valley Mile | | | |

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

## Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

## Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | | |
| 100 Year | | |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

## Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 64.9 | 19% |

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.

## Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 918.3 | 832.0 |
| Ag. Infrastructure (Ac) | 18.2 | 73.8 |
| Exurban (Ac) | 12.5 | 21.3 |
| Urban (Ac) | 0.0 | 0.0 |
| Transportation (Ac) | 38.1 | 58.3 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 148.2 | 69.8 |
| Sprinkler (Ac) | 0.0 | 9.3 |
| Pivot (Ac) | 0.0 | 256.5 |

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.

## 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.

## National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 1.9 | 1.0 |
| Emergent | 61.8 | 31.4 |
| Scrub/Shrub | 25.6 | 13.0 |

Total Wetland Acres: **89.3**

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).

## Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 0.2 | 0.2% |

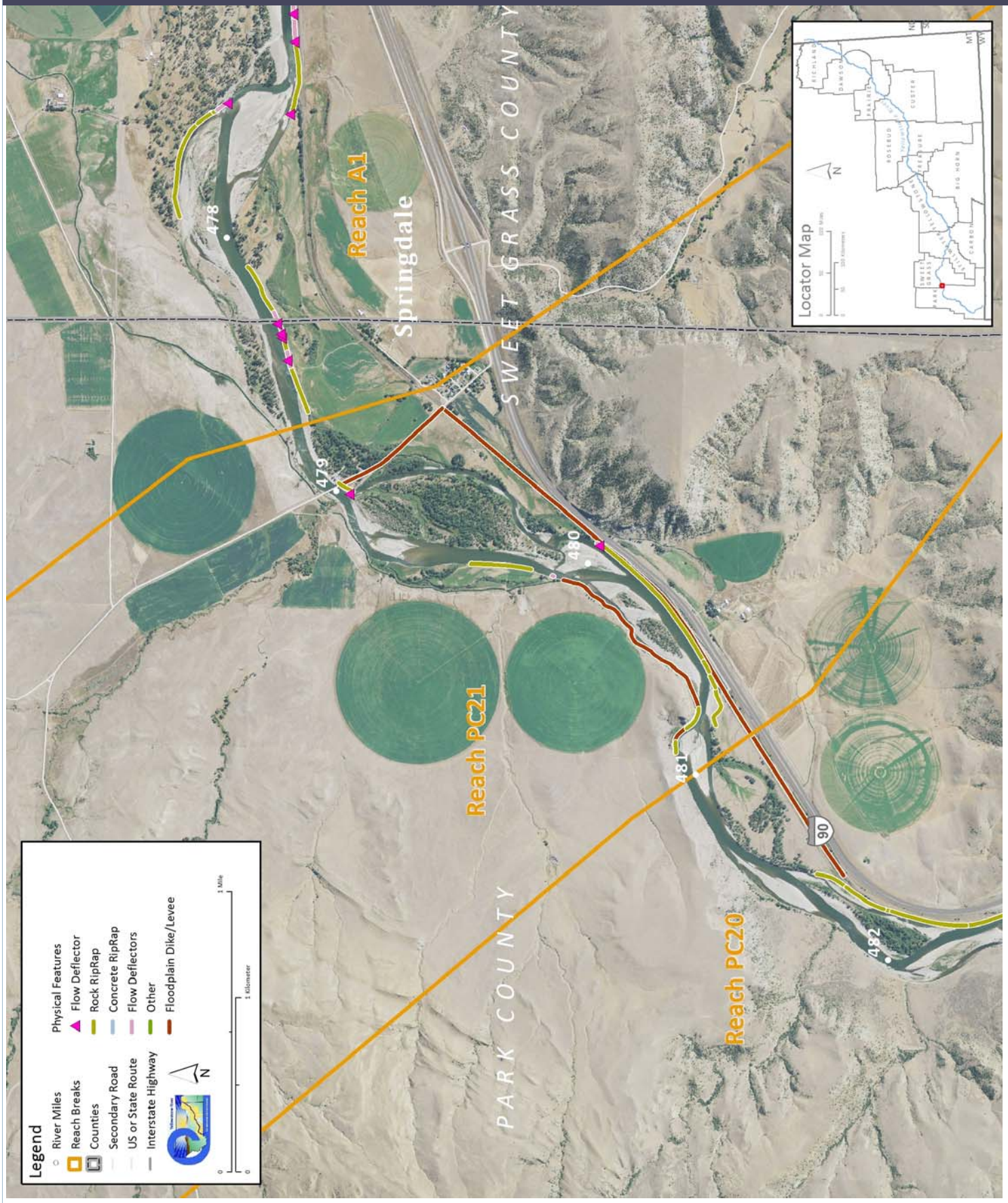
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

## Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

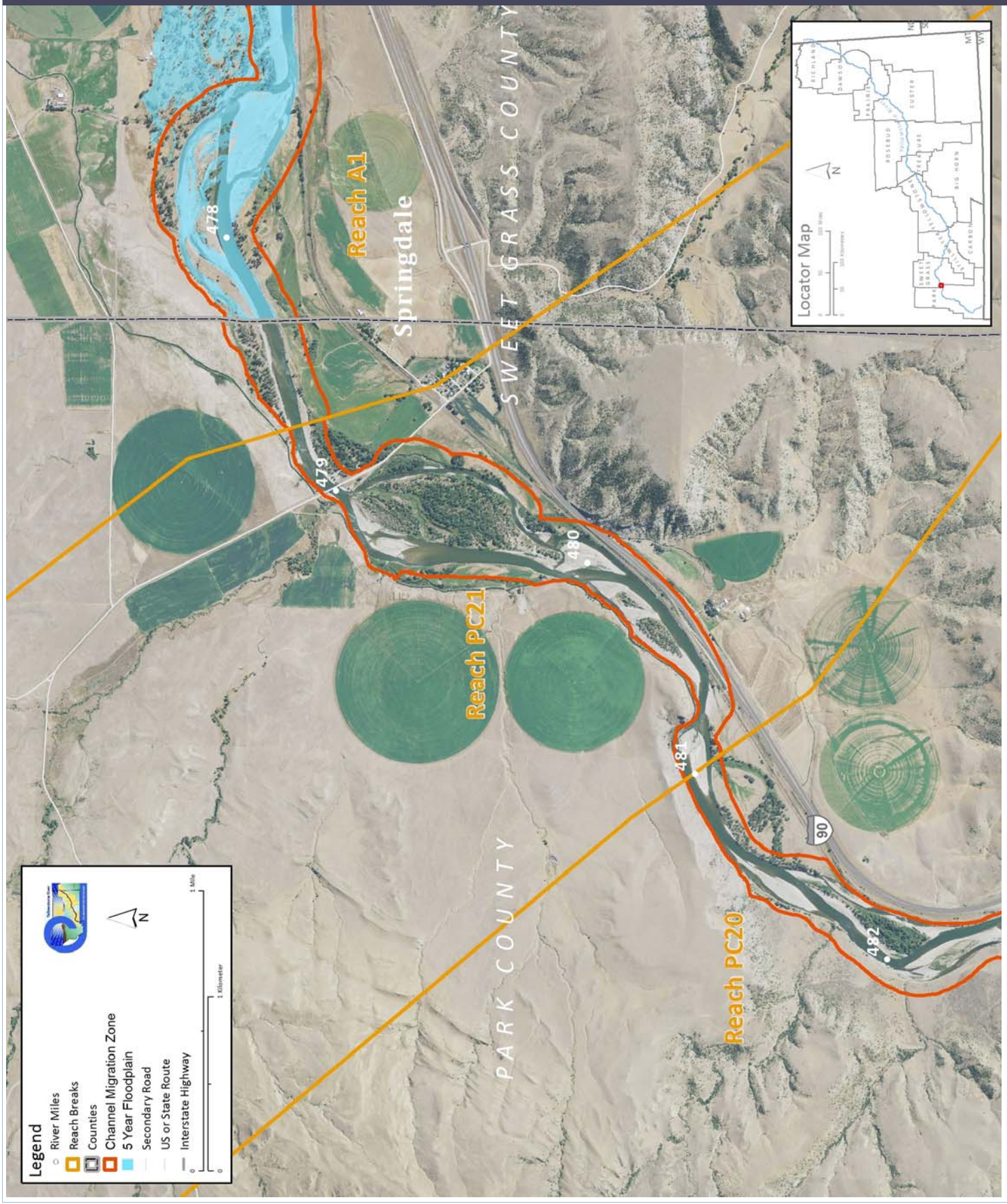
| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| | | | |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



# Yellowstone River Reach Narratives — Reach A1

| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 478.8 |
| **Classification** | PCB: Partially confined braided | **Downstream River Mile** | 475.4 |
| **General Location** | Springdale | **Length** | 3.40 mi (5.47 km) |

## Narrative Summary

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

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

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

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

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

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

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

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

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

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

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

# Yellowstone River Reach Narratives — Reach A1

**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 |
|---|---|---|---|
| 2 Year (cfs) | 23,300 | 22,900 | -1.7% |
| 100 Year (cfs) | 43,400 | 43,200 | -0.5% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

## Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 189.9 | 216.9 | 242.7 | 256.3 | 66.4 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

## Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 6,838 | 19.2% | 1,678 |
| Concrete Riprap | 0 | 0.0% | 0 |
| Flow Deflectors | 2,092 | 5.9% | -309 |
| Total | **8,930** | **25.1%** | **1,369** |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

## Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 0 | 2,970 |

Numerous side channels have been blocked by small dikes.

## Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 |
|---|---|---|
| Total Acres | 44.0 | 62.6 |
| Acres/Year | 1.7 | 2.5 |
| Acres/Year/Valley Mile | 0.5 | 0.8 |

1950-2001 In-channel riparian encroachment (negative number indicates retreat)

-45.46 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

## Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

## Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | 13.2 | 7% |
| 100 Year | 0.0 | 0% |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

## Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 65.8 | 9% |

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.

## Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 1,992.8 | 1,789.8 |
| Ag. Infrastructure (Ac) | 52.1 | 109.4 |
| Exurban (Ac) | 5.4 | 5.4 |
| Urban (Ac) | 0.0 | 0.0 |
| Transportation (Ac) | 47.6 | 81.5 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 803.4 | 122.6 |
| Sprinkler (Ac) | 0.0 | 254.2 |
| Pivot (Ac) | 0.0 | 301.6 |

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.

## 1950s Riparian Vegetation Converted to a Developed Land Use (ac)

| To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. |
|---|---|---|---|
| 3.7 | 0.0 | 3.7 | 1.0% |

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

## National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 7.4 | 2.3 |
| Emergent | 84.3 | 26.0 |
| Scrub/Shrub | 38.0 | 11.7 |

Total Wetland Acres: **129.8**

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).

## Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 0.7 | 0.2% |

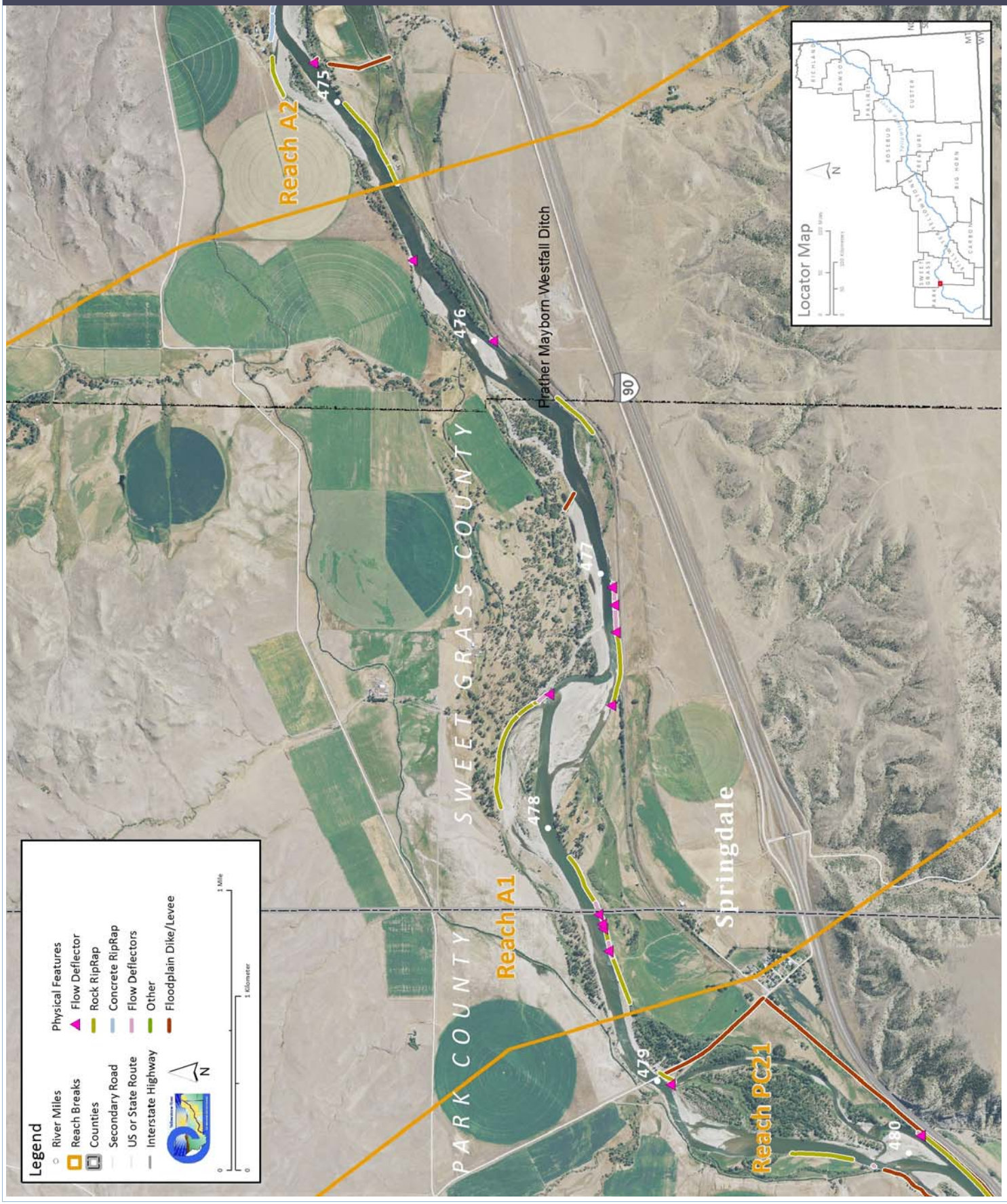
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

## Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

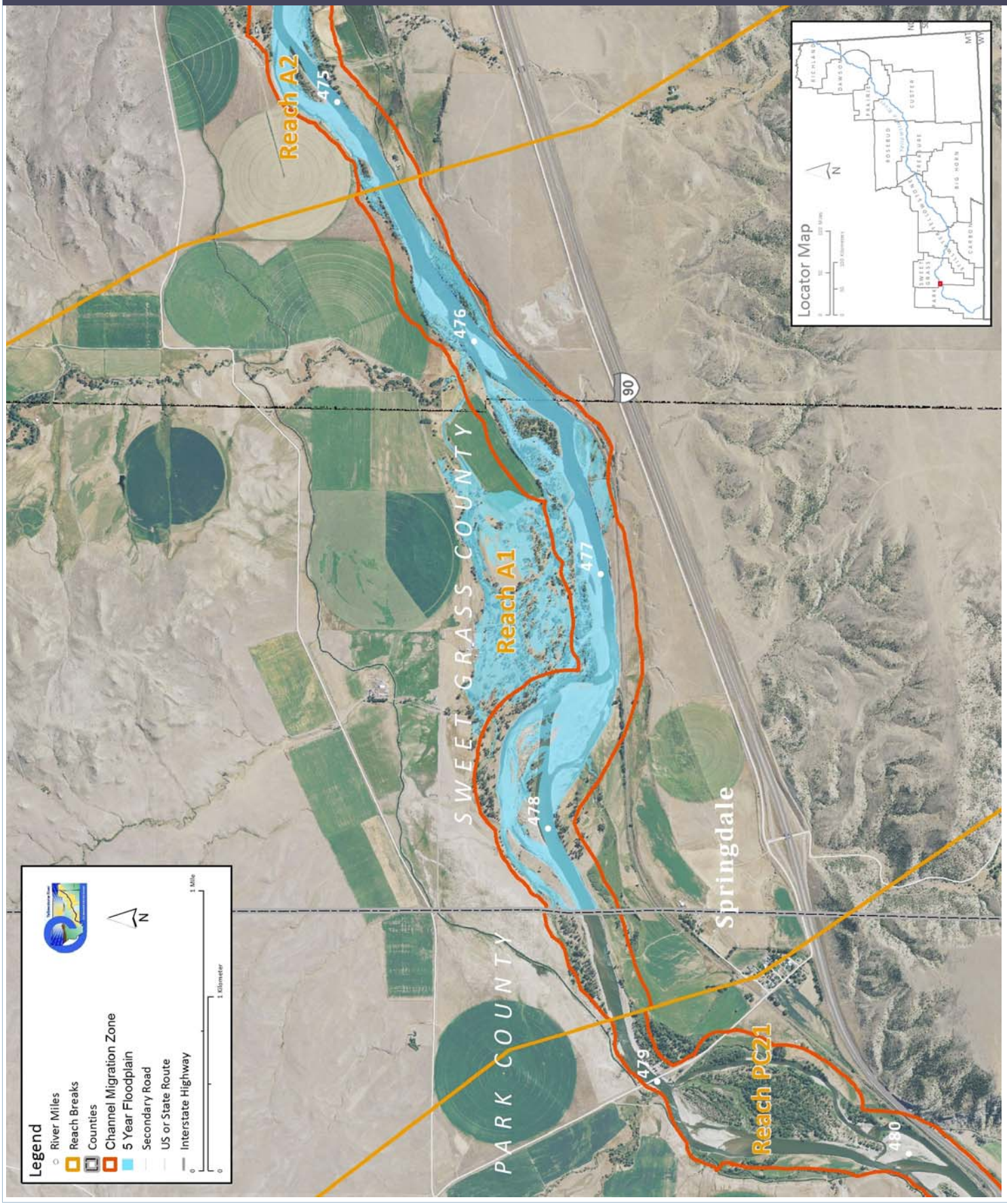
| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 475.4 |
| **Classification** | UB: Unconfined braided | **Downstream River Mile** | 468.5 |
| **General Location** | Grey Bear fishing access | **Length** | 6.90 mi (11.10 km) |

## Narrative Summary

Reach A2 is 6.9 miles long and extends from about one mile below the Prather Mayborn Westfall Ditch Diversion to about a mile below the Grey Bear fishing access. Reach A2 is classified as Unconfined Braided (UB), indicating a relatively small influence of the valley wall on reach geomorphology as well as a preponderance of open gravel bars in the channel. Reach A2 has changed markedly since the 1950s due to loss of riparian forest and side channel length.

As a consequence of its unconfined and dynamic nature, there are over two miles of rock riprap in the reach that cover almost 18 percent of the total bankline. Of those 10,633 feet of rock riprap, 1,673 feet was constructed since 2001. The physical features mapping also indicated 945 feet of tree revetments in the reach in 2001, however these were not identified in the 2011 mapping. This is the most upstream-reach with mapped concrete rubble riprap; there are over 1,000 feet of concrete riprap on the left bank at RM 474.6.

Sometime prior to 1950, one 3,125 foot long channel was blocked at RM 473. In 1950, there were still over 6 miles of active anabranching channels, but by 2011 that side channel length had dropped to 4 miles, resulting in a 15 percent reduction of braiding parameter in the reach.

There is also intermittent transportation encroachment by the railroad on the south side of the river. The transportation encroachment, which is due to the rail line, extends over two miles along the south bank and isolates 23 acres of historic floodplain. Similarly, 140 acres of the natural Channel Migration Zone (CMZ) area has been restricted by bank armor and the railroad prism.

Floodplain turnover values show that turnover rates have dropped from 4.5 acres per year to 3.7 acres per year since 1976. The channel has also enlarged by over 30 acres as anabranching channels have consolidated into a larger single thread. About 23 acres of 100-year floodplain area has been isolated by dikes.

Land uses in Reach A2 are primarily agriculture, with about ½ of the total agricultural land in some form of irrigation. About 26 acres of the existing 5-year floodplain are currently under irrigation, most of which is in flood.

Over 300 acres of wetland have mapped in the reach, most of which is emergent marsh-type areas. About 40 acres of emergent wetland are in an area of historic floodplain isolated by the railroad at RM 471.2. Approximately ½ of an acre of Russian olive was mapped in Reach A2.

Reach A2 has had extensive riparian clearing over the last century. In 1950, there were 431 acres of closed timber in the reach, and that footprint had contracted to 275 acres by 2001. Almost 12 acres of riparian forest in the reach per valley mile have been identified as being at low risk of cowbird parasitism due to the distance of those areas from agricultural infrastructure.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The biggest influence has been on low flows: severe low flows described as 7Q10 (the lowest average 7-day flow anticipated every ten years) for summer months has dropped from an estimated 1,760 cfs to 1,580 cfs with human development, a reduction of 10.2 percent. More typical summer low flows, described as the summer 95% flow duration, have dropped from 1,760 cfs under unregulated conditions to 1,680 cfs under regulated conditions at the Livingston gage, a reduction of 4.6 percent.

CEA-Related observations in Reach A2 include:
- Blockage of over 3,000 feet of side channel prior to 1950
- Passive abandonment of over two additional miles of side channel since 1950.
- Loss of over 150 acres of closed timber since 1950, most of which is in the 5-year floodplain.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A2 include:
- Side Channel Restoration (RM 473)
- CMZ management due to extent of encroachment (140acres restricted)

# Yellowstone River Reach Narratives — Reach A2

**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 |
|---|---|---|---|
| 2 Year (cfs) | 23,300 | 22,900 | -1.7% |
| 100 Year (cfs) | 43,400 | 43,200 | -0.5% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

### Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 442.3 | 474.7 | 464.9 | 480.2 | 37.9 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

### Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 12,305 | 16.9% | 1,673 |
| Concrete Riprap | 1,015 | 1.4% | 1,015 |
| Flow Deflectors | 154 | 0.2% | 154 |
| Total | **13,475** | **18.5%** | **2,842** |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

### Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 3,125 | 0 |

Numerous side channels have been blocked by small dikes.

### Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 |
|---|---|---|
| Total Acres | 117.5 | 93.0 |
| Acres/Year | 4.5 | 3.7 |
| Acres/Year/Valley Mile | 0.7 | 0.6 |

1950-2001 In-channel riparian encroachment (negative number indicates retreat)

-30.58 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

### Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

### Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | 16.1 | 4% |
| 100 Year | 23.4 | 3% |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

### Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 140.5 | 11% |

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.

### Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 3,713.3 | 3,548.8 |
| Ag. Infrastructure (Ac) | 141.0 | 217.9 |
| Exurban (Ac) | 0.0 | 13.4 |
| Urban (Ac) | 0.0 | 0.0 |
| Transportation (Ac) | 91.6 | 150.5 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 2,014.7 | 1,213.3 |
| Sprinkler (Ac) | 0.0 | 93.9 |
| Pivot (Ac) | 0.0 | 737.0 |

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.

### 1950s Riparian Vegetation Converted to a Developed Land Use (ac)

| To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. |
|---|---|---|---|
| 4.3 | 0.8 | 5.1 | 1.0% |

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

### National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 17.0 | 2.6 |
| Emergent | 257.8 | 39.9 |
| Scrub/Shrub | 80.9 | 12.5 |

Total Wetland Acres: **355.7**

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).

### Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 0.4 | 0.1% |

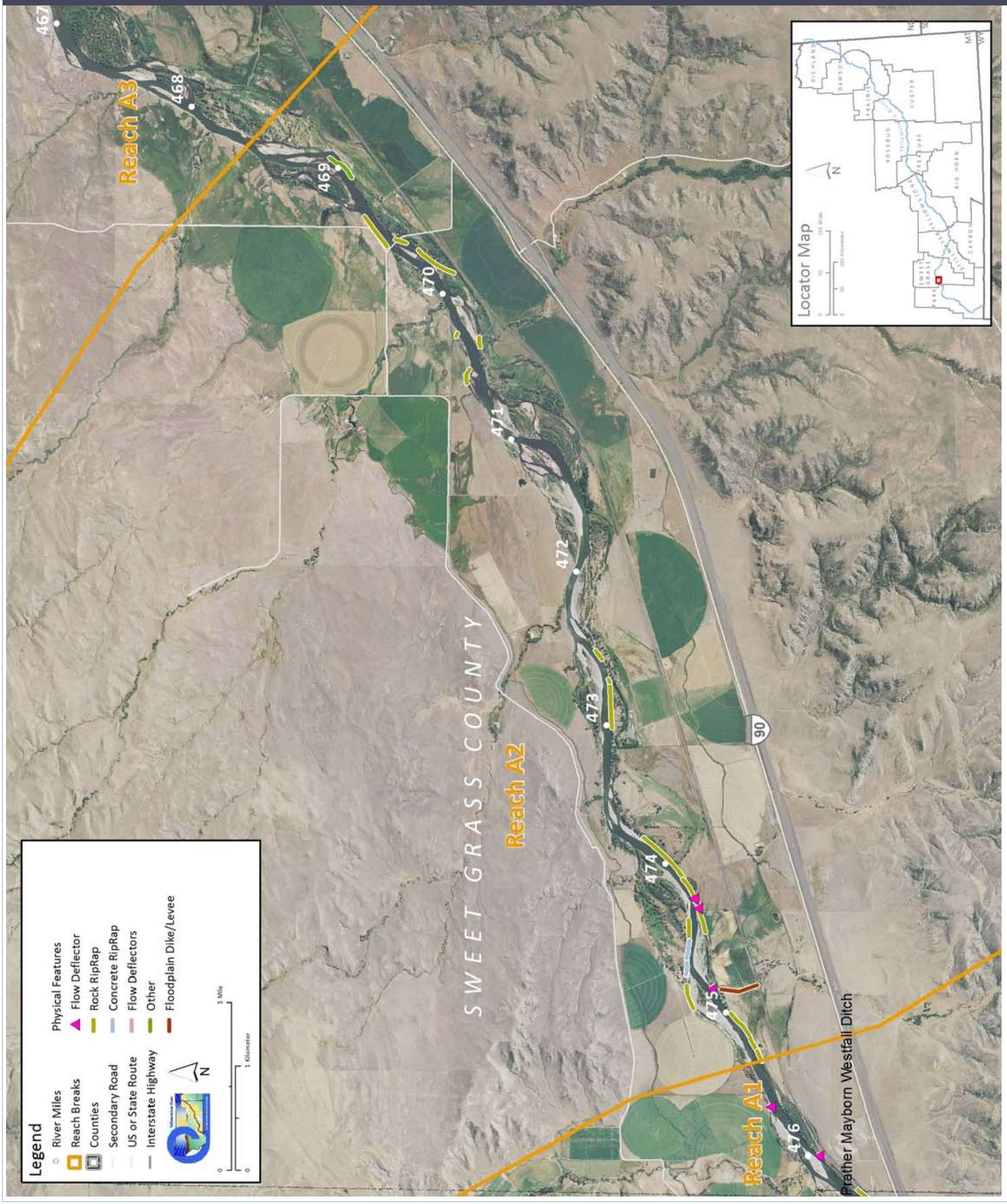
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

### Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

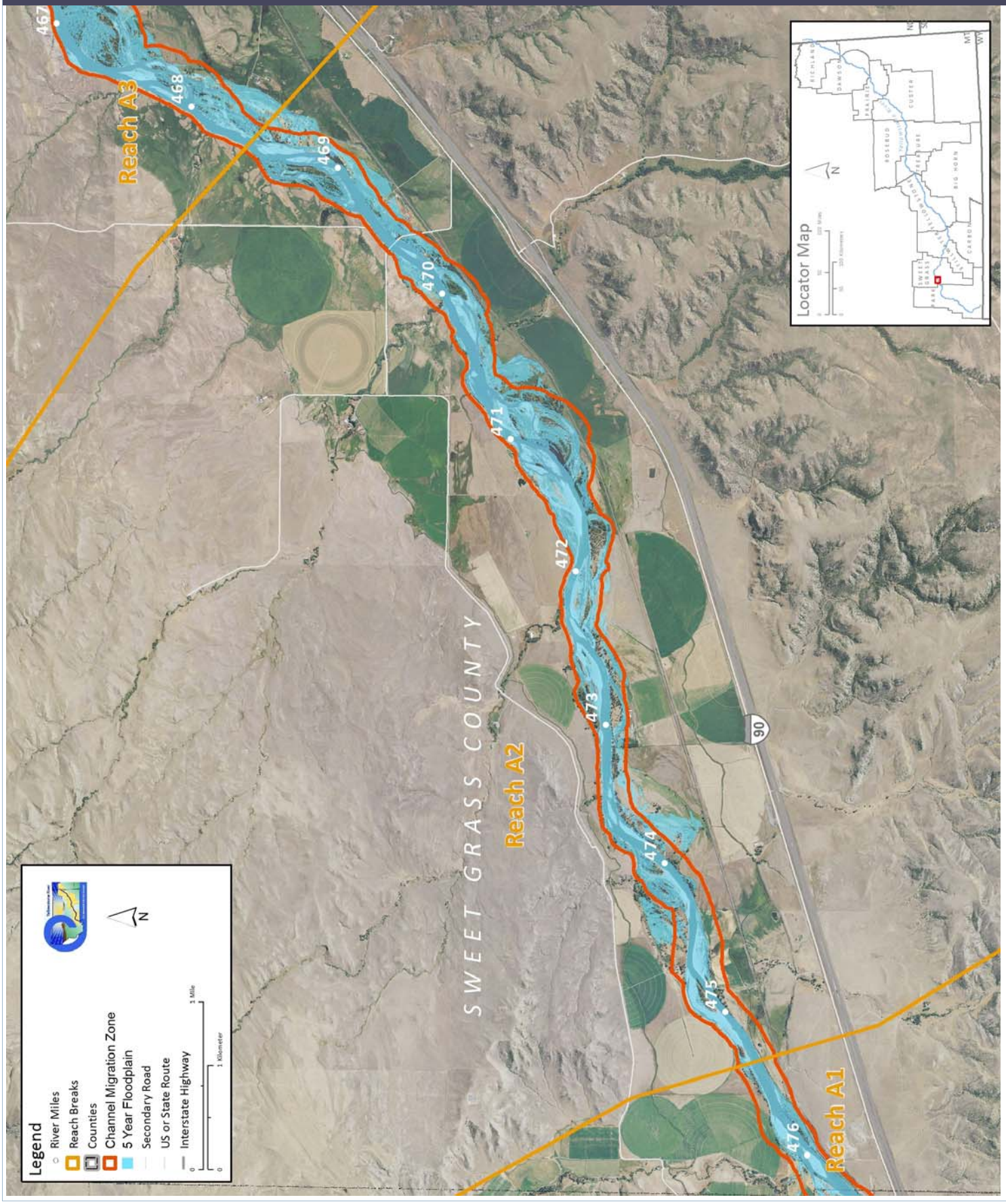
| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| 11.6 | 11.4 | 6.9 | -4.8 |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 468.5 |
| **Classification** | PCB: Partially confined braided | **Downstream River Mile** | 463 |
| **General Location** | Upstream of Big Timber | **Length** | 5.50 mi (8.85 km) |

## Narrative Summary

Reach A3 is 5.5 miles long and is just located upstream of the town of Big Timber. It is classified as a Partially Confined Braided (PCB) reach type indicating some valley wall influence and relative extensive open gravel bars and low flow secondary channels. This reach shows the passive loss of miles of anabranching channel length since 1950, similar to Reach A2 just upstream. The river has converted from having more than one primary channel to having a dominant main thread with intermittent side channels.

About 12.5 percent of the banks in Reach A3 are armored, with the majority of that armor being rock riprap. Between 2001 and 2011, about 1,700 feet of new bank armor, of which 277 feet are flow deflectors, were installed. There are about 2,000 feet of floodplain dikes in the reach.

Similar to Reach A2 just upstream, this reach has experienced extensive loss of anabranching channel length since 1950. In 1950, the total length of anabranching channels was 6.7 miles, and by 2001 that length had dropped to 4.7 miles, resulting in a reduction in braiding parameter of 17 percent.

Reach A3 shows a reduction in floodplain turnover rates since 1976; prior to that time, average rates of turnover were 103 acres per year, and since that time the average rate of floodplain erosion by the river has been reduced to 65.4 acres per year.

Land use in Reach A3 is predominantly agricultural, with about ½ of all agricultural acreage in flood irrigation. Approximately 13 percent of the 5-year floodplain has been isolated in the reach. This isolation reflects the slight reduction in the magnitude flows in this reach due primarily to irrigation-related withdrawals upstream.

Over 600 acres of wetland have been mapped in Reach A3, most of which is emergent marshes and wet meadows on the south side of the river. The 4.6 acres of Russian olive mapped is dispersed throughout the riparian corridor.

Almost 50 acres of riparian forest per valley mile is considered at low risk of cowbird infestation due to its relative distance from agricultural infrastructure that provides cowbird foraging habitat.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 11,900 cfs to 11,500 cfs, a drop of about 3.4 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 1,770 cfs to 1,580 cfs with human development, a reduction of 11 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 A3 include:
- Passive abandonment of over two miles of side channel since 1950.
- Conversion from a river channel with multiple large primary channels to a single main thread with small anabranches.
- Reduced floodplain turnover rates.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A3 include:
- Russian olive removal
- Wetland management/restoration due to high density of mapped emergent wetland

# Yellowstone River Reach Narratives — Reach A3

**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 |
|---|---|---|---|
| 2 Year (cfs) | 23,300 | 22,900 | -1.7% |
| 100 Year (cfs) | 43,400 | 43,200 | -0.5% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

### Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 343.5 | 379.6 | 366.8 | 376.5 | 33.0 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

### Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 6,765 | 12.0% | 1,291 |
| Concrete Riprap | 0 | 0.0% | 0 |
| Flow Deflectors | 277 | 0.5% | 277 |
| Total | **7,042** | **12.5%** | **1,568** |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

### Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 0 | 0 |

Numerous side channels have been blocked by small dikes.

### Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 |
|---|---|---|
| Total Acres | 103.0 | 65.4 |
| Acres/Year | 4.0 | 2.6 |
| Acres/Year/Valley Mile | 0.9 | 0.6 |

1950-2001 In-channel riparian encroachment (negative number indicates retreat)

-7.98 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

### Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

### Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | 13.2 | 3% |
| 100 Year | 0.0 | 0% |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

### Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 99.5 | 9% |

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.

### Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 3,050.1 | 2,981.2 |
| Ag. Infrastructure (Ac) | 7.3 | 22.0 |
| Exurban (Ac) | 0.0 | 0.0 |
| Urban (Ac) | 0.0 | 0.0 |
| Transportation (Ac) | 3.3 | 6.3 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 1,492.4 | 1,670.4 |
| Sprinkler (Ac) | 0.0 | 0.0 |
| Pivot (Ac) | 0.0 | 0.0 |

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.

### 1950s Riparian Vegetation Converted to a Developed Land Use (ac)

| To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. |
|---|---|---|---|
| 3.6 | 0.0 | 3.6 | 1.0% |

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

### National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 5.1 | 1.1 |
| Emergent | 558.7 | 120.5 |
| Scrub/Shrub | 86.5 | 18.7 |

Total Wetland Acres: **650.3**

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).

### Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 4.6 | 0.3% |

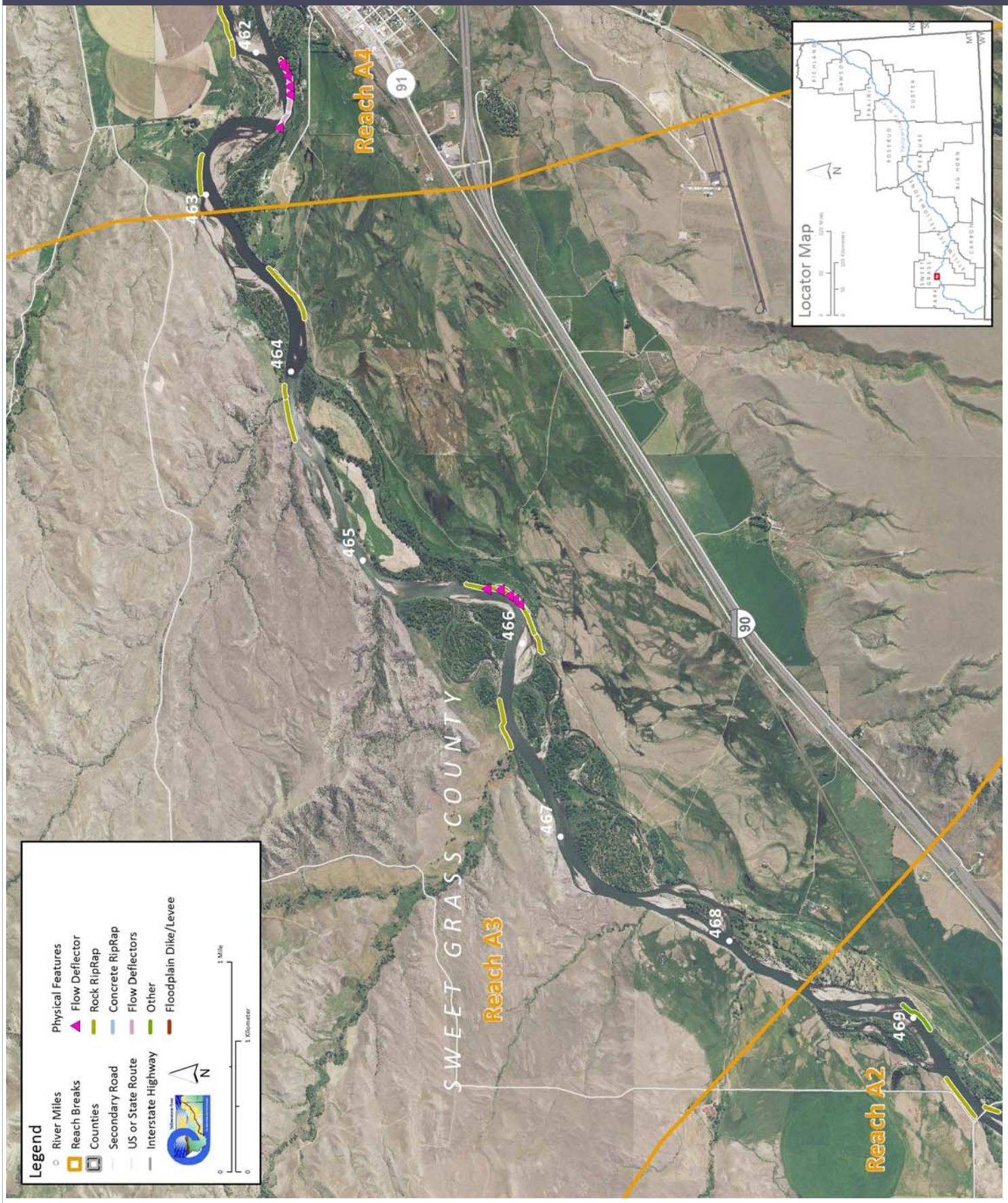
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

### Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

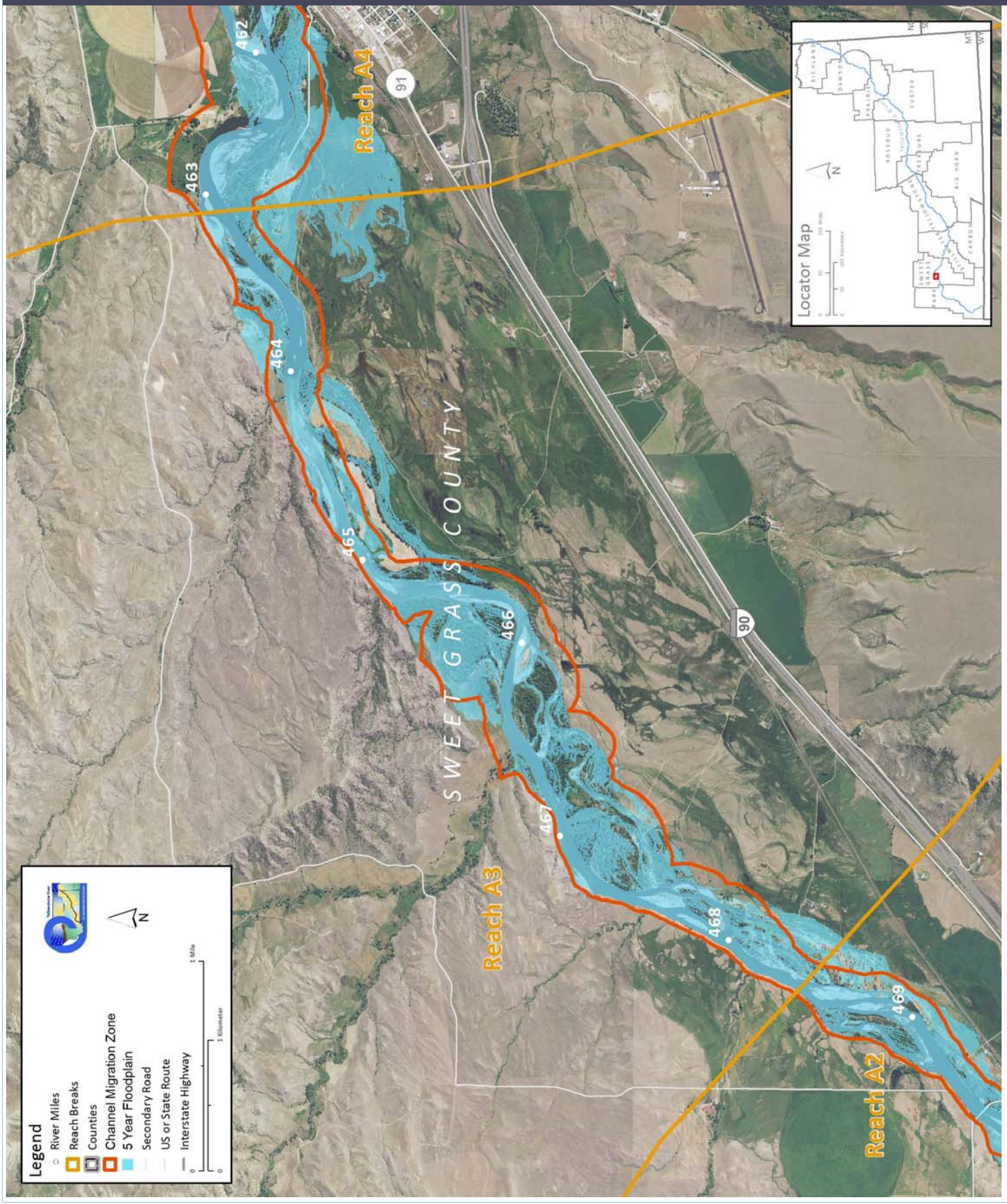
| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| 46.4 | 60.5 | 49.5 | 3.0 |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 463 |
| **Classification** | UB: Unconfined braided | **Downstream River Mile** | 459.7 |
| **General Location** | Big Timber | **Length** | 3.30 mi (5.31 km) |

## Narrative Summary

Reach A4 is approximately 3.3 miles long, extending from near the Sweet Grass County Fairgrounds downstream to the Boulder River confluence. Reach A4 is very dynamic with active channel migration, threats to infrastructure, bank armor, flanked barbs, and active riparian recruitment on raw gravel bars. The most dynamic portion of the reach is upstream of the Highway 191 Bridge; in spring of 2013 a large meander formed a 1,500 foot long chute cutoff near the fairgrounds which abandoned about 3,500 feet of channel to the south.

About 19 percent of the banks in Reach A4 are armored, with the majority of that armor being rock riprap. Between 2001 and 2011, there was a loss of about 1,000 feet of armor in the reach. Over 800 feet of that lost bank protection was flow deflectors; flanked barbs are visible in the middle of the channel downstream of the fairgrounds. With the avulsion of 2013, those flanked barbs are now sitting in the abandoned channel. Similar to reaches upstream, the river channel in Reach A4 has increased in size since 1950 by about 19 acres, and the channel expansion has been at the expense of riparian cover. Almost a quarter of the Channel Migration Zone (CMZ) has been restricted by physical features, and the restrictions are primarily due to bank armor that is protecting agricultural land.

Since 1950, over 7,500 feet of side channels in Reach A4 have been blocked by berms, which have caused a 25 percent drop in braiding parameter for the reach. Russian olive has colonized these historic channels. Like many other reaches the loss of active side channels in this reach has been accompanied by a lengthening of the main thread. Between 1950 and 2001, the main channel lengthened by about 1,000 feet through the 3.3 mile reach.

Land use in Reach A4 is predominantly agricultural, although there are several hundred acres of urban/exurban development associated with the town of Big Timber. Most of the agricultural land is non-irrigated; however there are hundreds of acres of flood, sprinkler, and pivot irrigation in the reach. Almost 150 acres of irrigated ground are within the 5-year floodplain in Reach A4, and most of that commonly flooded ground is south of the fairgrounds. This area also has most of the 160 acres of mapped wetlands in the reach.

There is one mapped dump site in Reach A4, which is on the high terrace edge at Big Timber. There is also one major petroleum product pipeline in the reach that runs parallel to the river on its north side. The pipeline is owned by ConocoPhillips, and passes under both Big Timber Creek and Otter Creek within 1,500 feet of the Yellowstone River.

Almost 200 acres of land in Reach A4 are within the mapped Channel Migration Zone. This includes 83 acres of flood, 42 acres of sprinkler, and 37 acres of pivot. A total of 21 acres of land in the CMZ has been developed to urban/exurban use.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 11,900 cfs to 11,500 cfs, a drop of about 3.4 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 1,880 cfs to 1,620 cfs with human development, a reduction of 14 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 A4 include:
- Restriction of the Historic Migration Zone (HMZ) isolating side channels and reducing riparian turnover.
- Primary channel lengthening in association with loss of side channels.
- Rapid migration and channel realignment resulting in barb flanking and abandonment of rock in channel.
- Isolation of historic channels (over 7,500 feet) by berms.
- Russian olive colonization within isolated side channels.
- Riparian recruitment (cottonwood establishment) on islands created by channel migration.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A4 include:
- Removal of flanked armor at RM 462.3
- Side channel restoration/management (RM 461.2, RM 462)
- CMZ management due to encroachment (200 acres restricted)
- Russian olive removal (2.7 acres)
- Solid waste removal from dump on right bank at RM 461
- Pipeline management at Big Timber Creek and Otter Creek tributary crossings just north of Yellowstone River.

# Yellowstone River Reach Narratives — Reach A4

**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 |
|---|---|---|---|
| 2 Year (cfs) | 23,300 | 22,900 | -1.7% |
| 100 Year (cfs) | 43,400 | 43,200 | -0.5% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

### Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 203.9 | 238.6 | 235.7 | 257.2 | 53.3 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

### Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 6,143 | 16.8% | -168 |
| Concrete Riprap | 0 | 0.0% | 0 |
| Flow Deflectors | 932 | 2.5% | -854 |
| Total | **7,075** | **19.3%** | **-1,022** |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

### Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 0 | 7,575 |

Numerous side channels have been blocked by small dikes.

### Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 |
|---|---|---|
| Total Acres | 64.1 | 58.2 |
| Acres/Year | 2.5 | 2.3 |
| Acres/Year/Valley Mile | 0.8 | 0.8 |

1950-2001 In-channel riparian encroachment (negative number indicates retreat)

-35.78 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

### Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

### Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | 8.5 | 3% |
| 100 Year | 0.0 | 0% |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

### Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 183.0 | 23% |

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.

### Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 2,380.8 | 2,154.9 |
| Ag. Infrastructure (Ac) | 112.7 | 138.6 |
| Exurban (Ac) | 22.3 | 105.2 |
| Urban (Ac) | 176.6 | 268.6 |
| Transportation (Ac) | 60.8 | 64.4 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 1,161.8 | 385.3 |
| Sprinkler (Ac) | 0.0 | 194.7 |
| Pivot (Ac) | 0.0 | 301.5 |

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.

### 1950s Riparian Vegetation Converted to a Developed Land Use (ac)

| To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. |
|---|---|---|---|
| 2.4 | 8.2 | 10.6 | 3.0% |

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

### National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 3.7 | 1.3 |
| Emergent | 140.0 | 47.6 |
| Scrub/Shrub | 20.5 | 7.0 |

Total Wetland Acres: **164.1**

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).

### Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 2.7 | 0.3% |

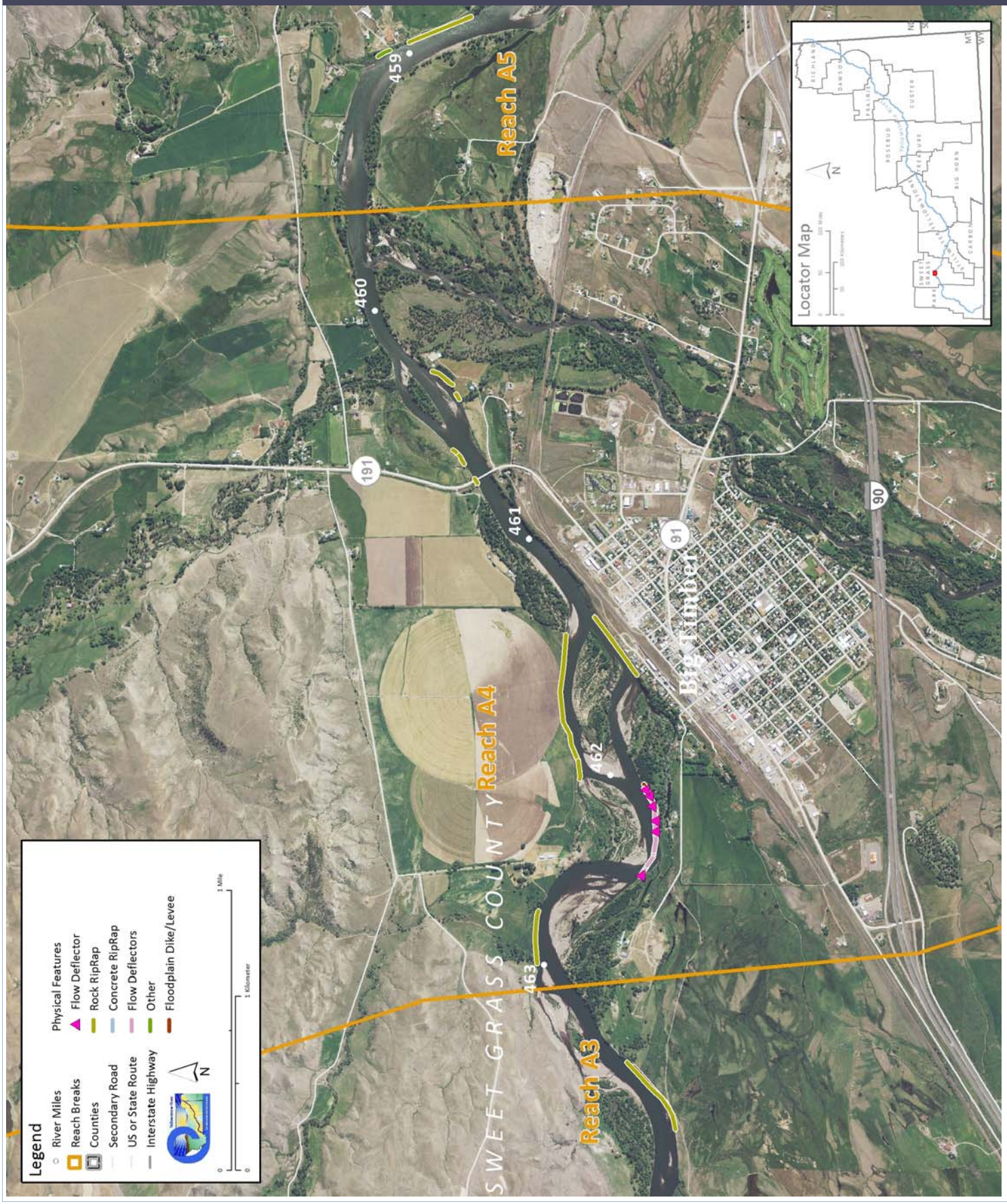
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

### Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

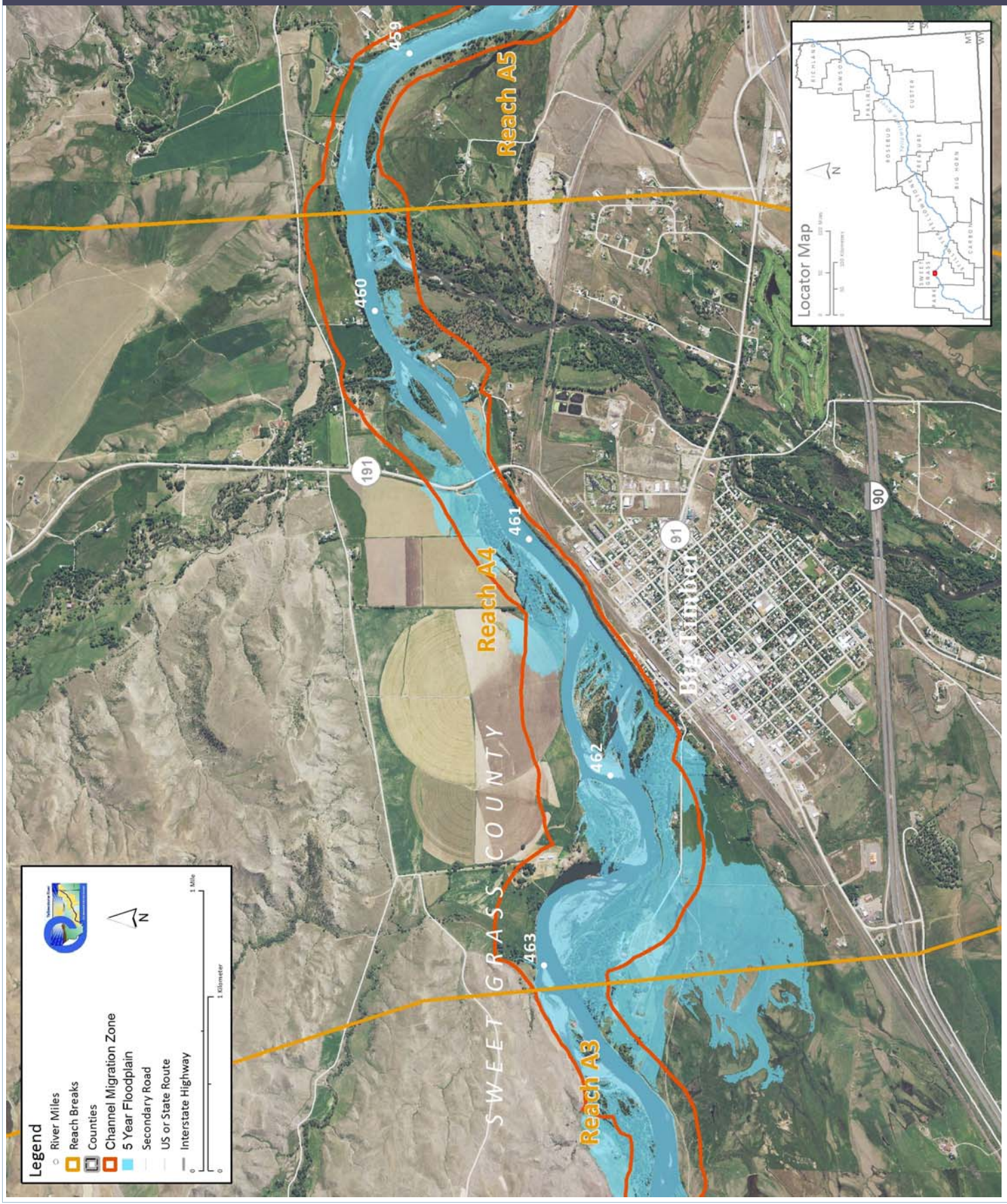
| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 459.7 |
| **Classification** | UB: Unconfined braided | **Downstream River Mile** | 456.4 |
| **General Location** | Big Timber Creek | **Length** | 3.30 mi (5.31 km) |

## Narrative Summary

Reach A5 is approximately 3.3 miles long, and is located just below Big Timber near the Otter Creek Fishing Access Site starting just below the mouth of the Boulder River. Reach A5 is shows low migration rates and has a relatively narrow CMZ as a result. Similar to other reaches in Region A, the channel footprint has enlarged since 1950; in this reach the channel shows continual expansion from 1950 to 2001 of about 24 acres. This has been accompanied by a loss of 16 acres of riparian area in the main river corridor.

About 7 percent of the banks in Reach A5 are armored by rock riprap. Another 250 feet of bank is protected by tree revetments which are unusual on the Yellowstone River.

Land use in Reach A5 is predominantly agricultural, although there over 60 acres of urban/exurban development on the outskirts of Big Timber. Most of the agricultural land is non-irrigated, although there are almost 400 acres of ground under flood irrigation and another 150 acres under pivot. There are corrals associated with an Animal Holding Facility on the left bank of the river at RM 459.

Reach A5 has substantial irrigated land in the Channel Migration Zone. Land use mapping for 2011 conditions show 62 acres of flood, 2 acres of sprinkler, and 9 acres of pivot irrigated land within the CMZ boundary.

Reach A5 has seen almost a quarter (18 acres) of its riparian corridor converted to developed land uses since 1950. Most of that (17 acres) was conversion to irrigation.

Over 170 acres of wetland have been mapped in Reach A5. Most of the wetland area is on the eastern portion of the large alluvial fan formed at the mouth of the Boulder River, where there are open water wetlands and wet marsh areas.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 12,600 to 12,100 cfs, a drop of about 4 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 1,910 cfs to 1,630 cfs with human development, a reduction of 15 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 A5 include:
- Riparian clearing in support of irrigation.
- Presence of corrals on the edge of the corridor at RM 459.
- Extensive wetland complex on low alluvial ground at the toe of a terrace.
- Encroachment of irrigated land into Channel Migration Zone.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A5 include:
- Nutrient management at corrals at RM 459
- Wetland management/restoration due to extent of emergent marsh (>170 acres)

# Yellowstone River Reach Narratives — Reach A5

**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 |
|---|---|---|---|
| 2 Year (cfs) | 24,500 | 24,000 | -2.0% |
| 100 Year (cfs) | 45,500 | 45,200 | -0.7% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

### Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 188.3 | 195.7 | 203.1 | 219.2 | 30.9 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

### Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 2,117 | 6.2% | 851 |
| Concrete Riprap | 0 | 0.0% | 0 |
| Flow Deflectors | 0 | 0.0% | |
| Total | **2,117** | **6.2%** | |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

### Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 0 | 0 |

Numerous side channels have been blocked by small dikes.

### Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 |
|---|---|---|
| Total Acres | 24.7 | 29.3 |
| Acres/Year | 0.9 | 1.2 |
| Acres/Year/Valley Mile | 0.3 | 0.4 |

1950-2001 In-channel riparian encroachment (negative number indicates retreat)

-15.9 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

### Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

### Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | 1.2 | 0% |
| 100 Year | 0.0 | 0% |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

### Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 16.1 | 4% |

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.

### Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 1,580.8 | 1,447.0 |
| Ag. Infrastructure (Ac) | 18.0 | 62.8 |
| Exurban (Ac) | 0.8 | 64.2 |
| Urban (Ac) | 0.0 | 0.0 |
| Transportation (Ac) | 7.1 | 7.1 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 733.8 | 391.5 |
| Sprinkler (Ac) | 0.0 | 8.3 |
| Pivot (Ac) | 0.0 | 154.4 |

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.

### 1950s Riparian Vegetation Converted to a Developed Land Use (ac)

| To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. |
|---|---|---|---|
| 16.6 | 1.4 | 18.0 | 24.0% |

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

### National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 6.3 | 2.1 |
| Emergent | 157.3 | 52.8 |
| Scrub/Shrub | 9.5 | 3.2 |

Total Wetland Acres: **173.2**

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).

### Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 0.2 | 0.1% |

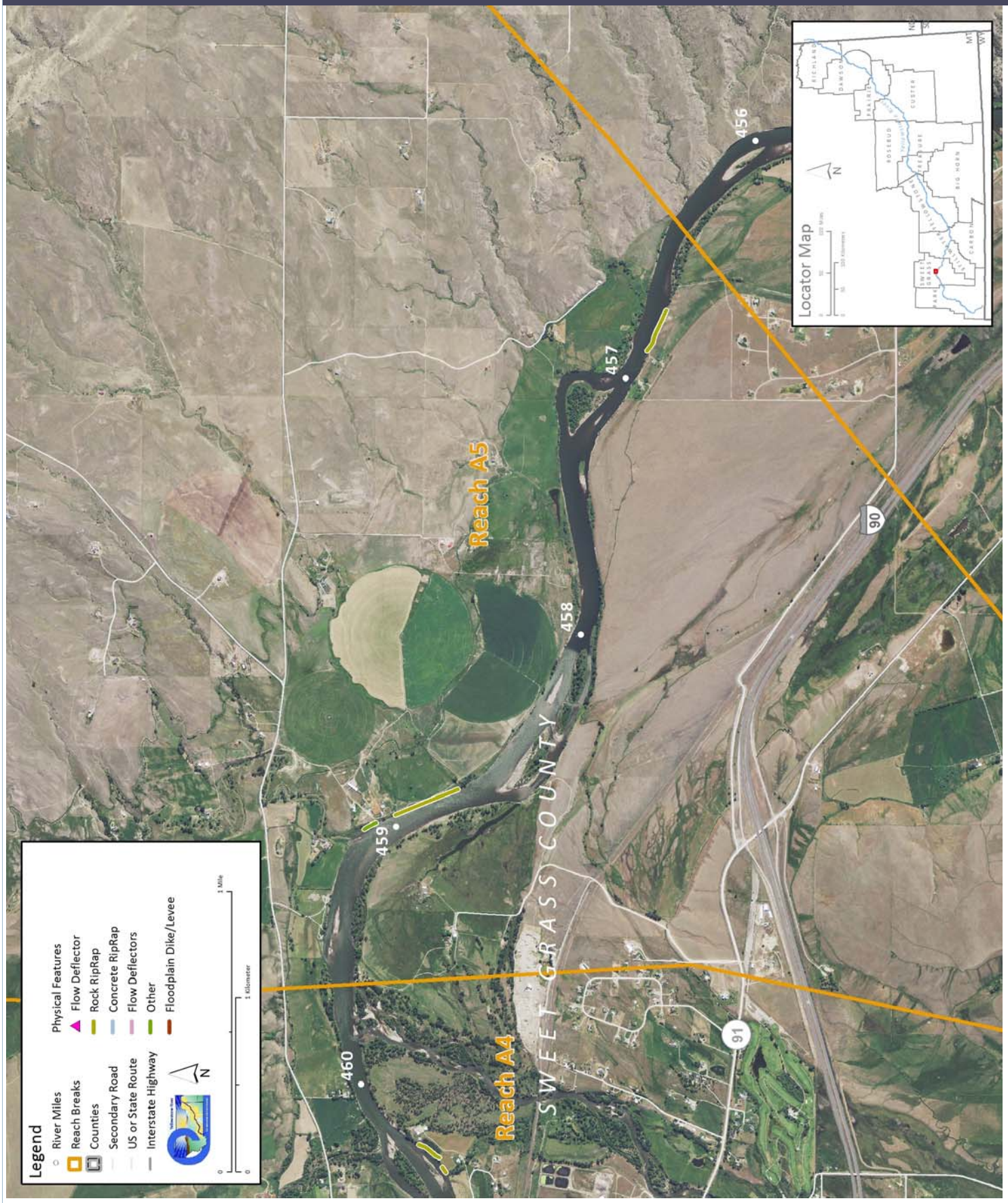
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

### Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

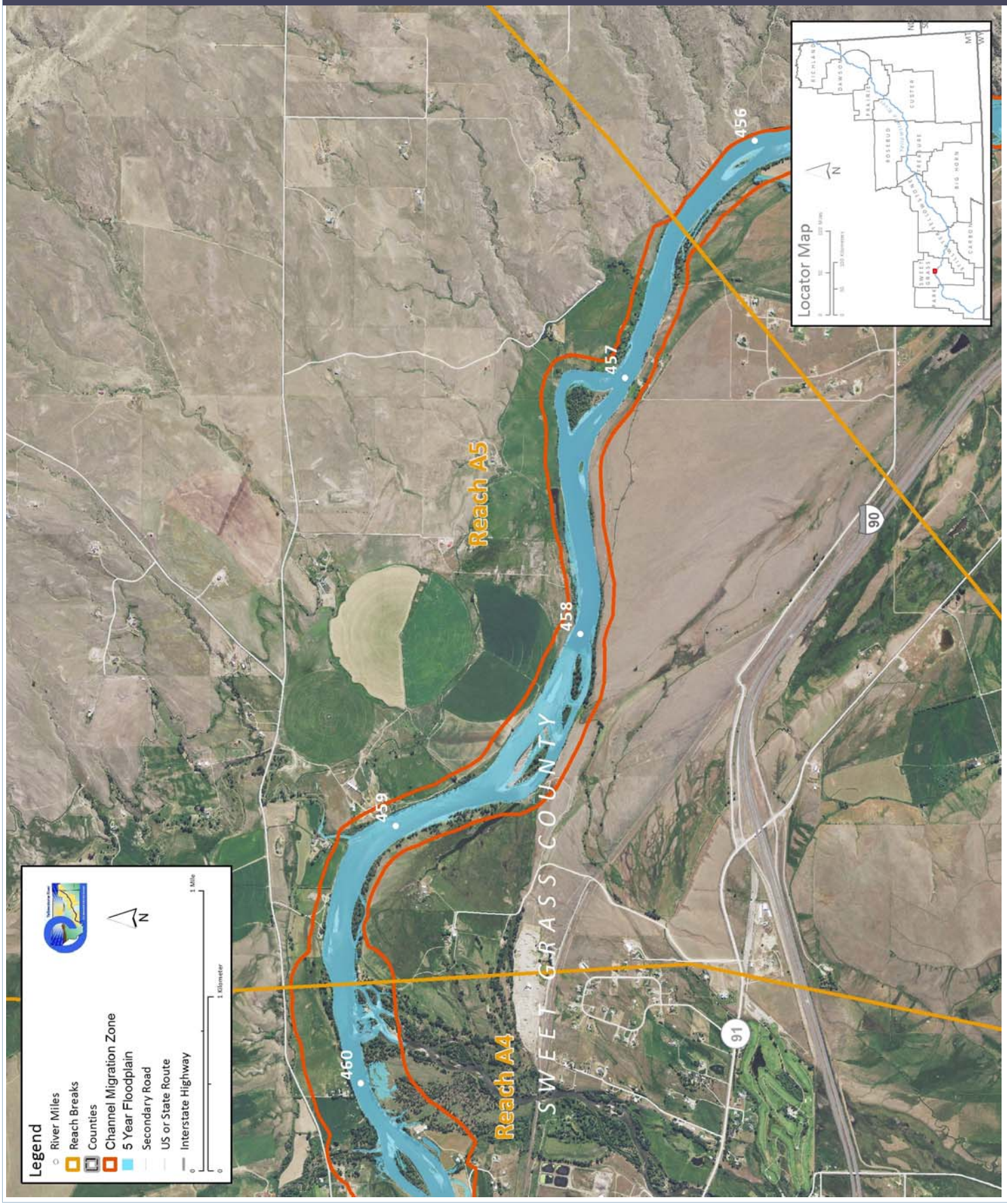
| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| 3.6 | 3.3 | 2.3 | -1.3 |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 456.4 |
| **Classification** | PCS: Partially confined straight | **Downstream River Mile** | 453.3 |
| **General Location** | Below Big Timber | **Length** | 3.10 mi (4.99 km) |

## Narrative Summary

Reach A6 is approximately 3.1 miles long, and is located below Big Timber. The reach is classified as Partially Confined Straight (PCS), which indicates some valley wall influences on river form and minimal meandering. Within this reach, the river consistently follows the northern bluff line of the river valley which is comprised of Cretaceous-age Hell Creek Formation sandstones and mudstones. The other side of the river consists of low floodplain and terrace deposits. Because of the valley wall confinement, migration rates are low in the reach and the Channel Migration Zone (CMZ) is narrow.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 161 acres but by 2001 it had expanded to 202 acres.

About 7 percent of the banks in Reach A6 are armored, and most of that bank protection is flow deflectors (2,165 feet). There is another 650 feet of rock riprap, all of which was constructed between 2001 and 2011.

One side channel in Reach A6 was blocked prior to 1950. It is about 2,700 feet long and is blocked by a dike as well as flow deflectors along the bank. The side channel currently hosts riverine and emergent wetland areas.

Land use in Reach A6 is predominantly agricultural, although there almost 200 acres of exurban development on the low terraces between the river and I-90. Most of the agricultural land is non-irrigated, although there are 760 acres of ground under flood irrigation and another 64 acres under pivot. A total of 35 acres of flood irrigated land are in the Channel Migration Zone.

Reach A6 has seen 28 percent (18 acres) of its riparian corridor converted to developed land uses since 1950. Most of that (17 acres) was conversion to irrigation.

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

A hydrologic evaluation of flow depletions indicates that flow alterations over the last century have been moderate in this reach. The mean annual flood is estimated to have dropped from 12,600 to 12,100 cfs, a drop of about 4 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 1,910 cfs to 1,630 cfs with human development, a reduction of 15 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.

The reduction in flows is evident by the contraction of the 5-year floodplain area in Reach A6 by 4.8 acres, or 30 percent.

CEA-Related observations in Reach A6 include:
- Riparian clearing in support of irrigation.
- Side Channel Blockage
- Contraction of 5-year floodplain due to flow alterations.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A6 include:
- Side channel restoration at RM 454.5

# Yellowstone River Reach Narratives — Reach A6

**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 |
|---|---|---|---|
| 2 Year (cfs) | 24,500 | 24,000 | -2.0% |
| 100 Year (cfs) | 45,500 | 45,200 | -0.7% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

### Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 160.9 | 160.3 | 176.7 | 201.9 | 41.0 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

### Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 648 | 2.1% | 648 |
| Concrete Riprap | 0 | 0.0% | 0 |
| Flow Deflectors | 2,165 | 6.9% | 42 |
| Total | **2,814** | **9.0%** | **690** |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

### Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 2,691 | 0 |

Numerous side channels have been blocked by small dikes.

### Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 |
|---|---|---|
| Total Acres | 11.5 | 22.6 |
| Acres/Year | 0.4 | 0.9 |
| Acres/Year/Valley Mile | 0.2 | 0.3 |

1950-2001 In-channel riparian encroachment (negative number indicates retreat)

-6.51 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

### Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

### Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | 4.8 | 30% |
| 100 Year | 0.0 | 0% |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

### Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 20.1 | 6% |

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.

### Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 1,821.9 | 1,538.8 |
| Ag. Infrastructure (Ac) | 16.8 | 6.4 |
| Exurban (Ac) | 0.0 | 198.5 |
| Urban (Ac) | 0.0 | 0.0 |
| Transportation (Ac) | 19.1 | 77.4 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 936.4 | 761.1 |
| Sprinkler (Ac) | 0.0 | 0.0 |
| Pivot (Ac) | 0.0 | 64.1 |

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.

### 1950s Riparian Vegetation Converted to a Developed Land Use (ac)

| To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. |
|---|---|---|---|
| 16.9 | 0.8 | 17.7 | 28.0% |

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

### National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 14.3 | 5.1 |
| Emergent | 23.3 | 8.3 |
| Scrub/Shrub | 1.1 | 0.4 |

Total Wetland Acres: **38.6**

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).

### Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 0.1 | 0.0% |

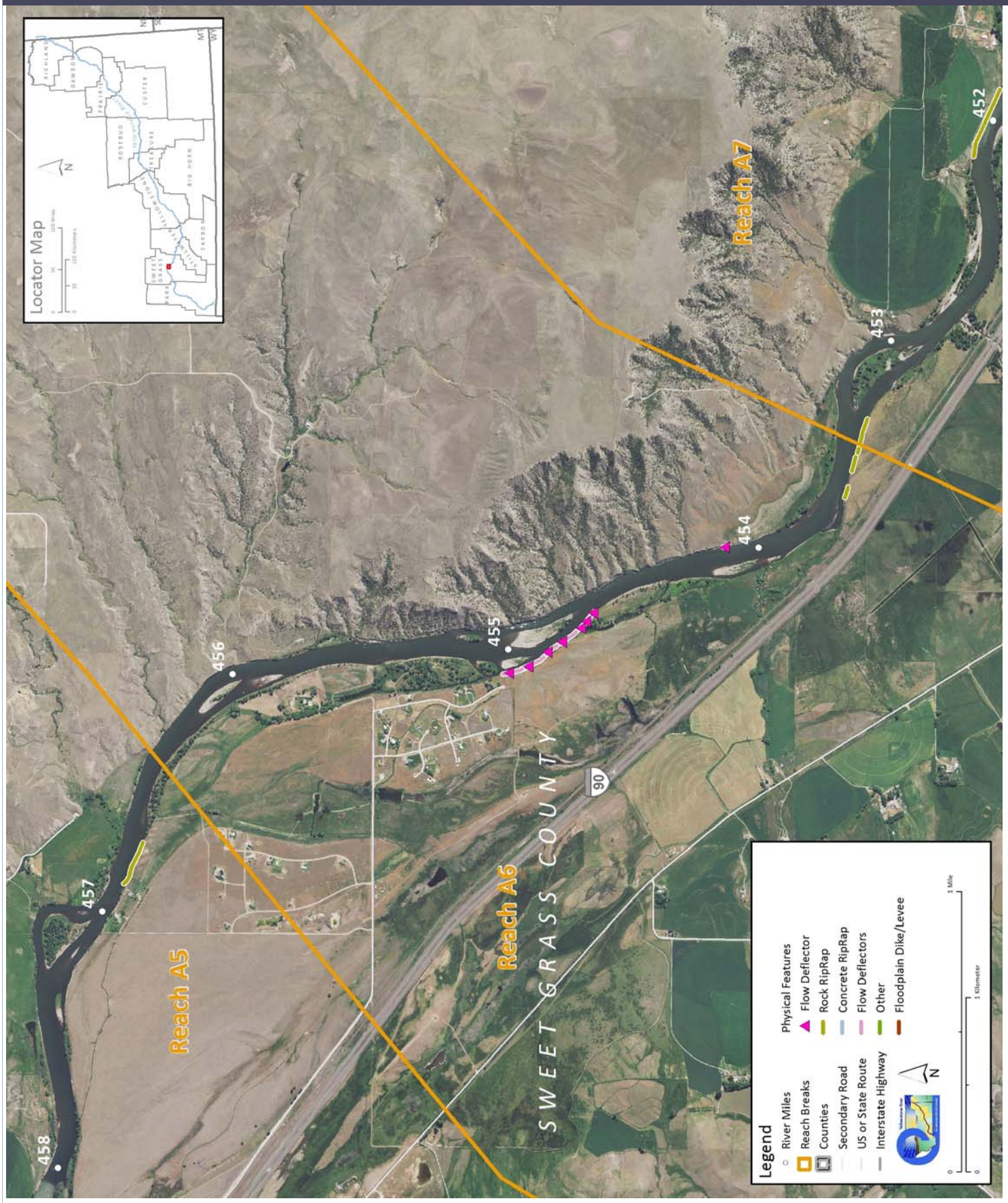
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

### Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

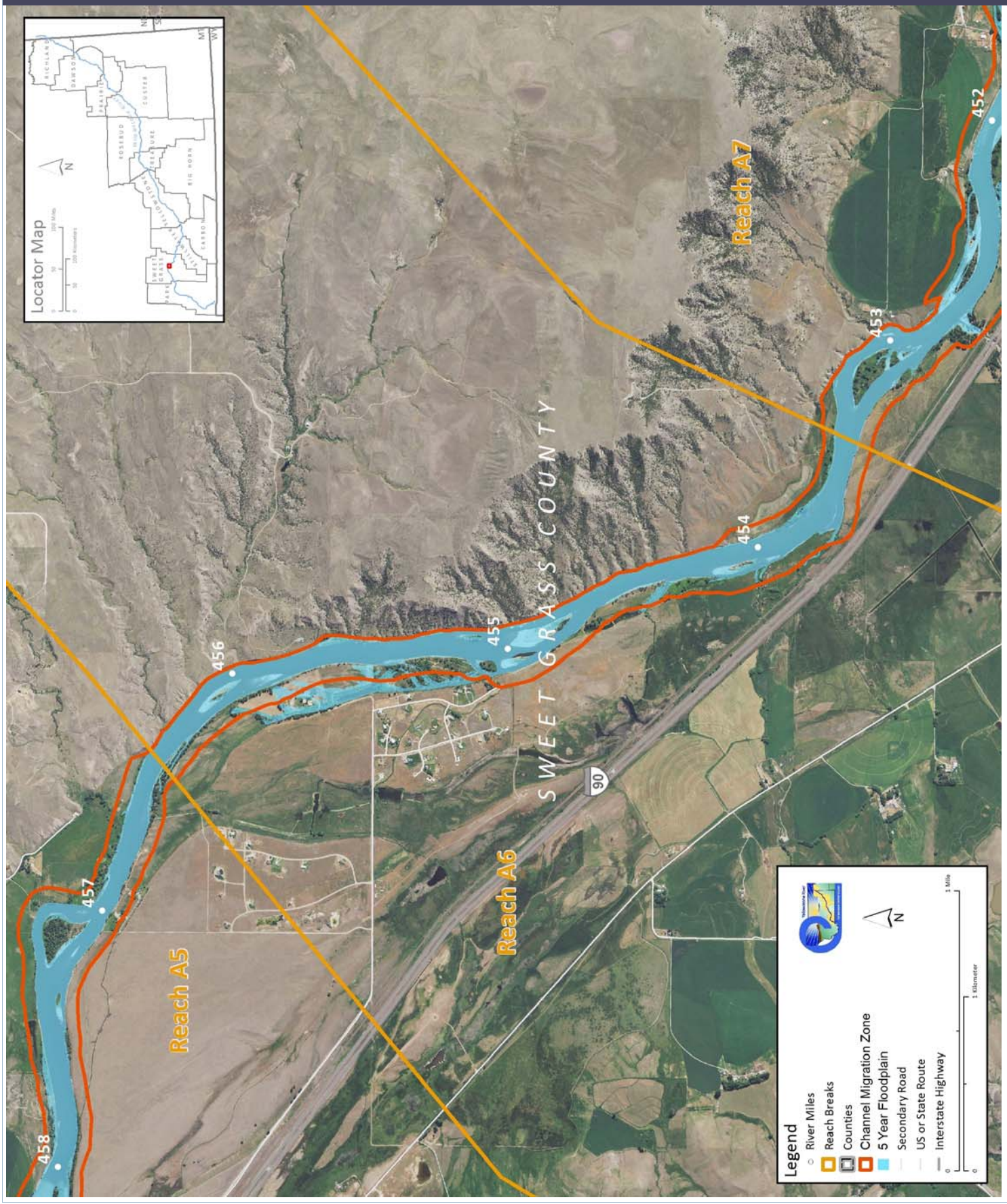
| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| 0.8 | 0.0 | 0.7 | -0.1 |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 453.3 |
| **Classification** | PCB: Partially confined braided | **Downstream River Mile** | 443.6 |
| **General Location** | Greycliff | **Length** | 9.70 mi (15.61 km) |

## Narrative Summary

Reach A7 is approximately 9.7 miles long, and is at Greycliff. The reach is classified as Partially Confined Braided (PCB), which indicates some valley wall influences on river form and relatively extensive gravel bars and low flow channel complexity. Within this reach, the river intermittently follows the northern bluff line of the river valley which is comprised of Cretaceous-age Hell Creek Formation sandstones and mudstones. The other side of the river valley consists of low floodplain and terrace deposits. In several places, such as at Greycliff Bridge, the terrace toe is sandstone. Several tributaries enter the river in this reach, including Sweet Grass Creek and Deer Creek.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 613 acres but by 2001 it had expanded to 723 acres.

As of 2011, about 12 percent of the banks in Reach A7 were armored, and most of that bank protection is rock riprap (11,254 feet). There are also 1,500 feet of flow deflectors in the reach. Between 2001 and 2011, about 2,400 feet of riprap and 230 feet of flow deflectors were constructed. There are also minor amounts of gabions and steel retaining wall in the reach.

Reach A7 has experienced the loss of thousands of feet of side channels both pre- and post- 1950. Prior the collection of the 1950s imagery, a channel that was almost a mile long was blocked in multiple places. The land that this blocked side channel is about ½ mile downstream of the Greycliff Bridge on the right bank and is part of the Pelican Fishing Access Site. Currently, only the downstream portion of this channel has good definition; the upper end has largely decayed. Since 1950, side channels have been blocked at RM 445 and RM 452. Both of these side channels were relatively small features that flowed on the south side of the river corridor. In total, 4,600 feet of channel were blocked post-1950. Since 1950 there has been a net loss of about 9,000 feet of side channel in the reach, indicating some passive loss as well as loss due to blockages.

In contrast to the general trend on the river, floodplain turnover rates in Reach A7 have increased since 1976. From 1950-1976 the average floodplain turnover rate in this reach was 3.4 acres per year, and from 1976-2001, that rate had increased to 5.5 acres per year.

Land use in Reach A7 is predominantly agricultural, although there almost 140 acres of exurban development on the low terraces between the river and I-90. Transportation infrastructure also comprises almost 300 acres of the mapping footprint. Most of the agricultural land is non-irrigated, although there are 1,500 acres of ground under flood irrigation, 225 acres under sprinkler and another 914 acres under pivot. A total of 267 acres of developed land are in the Channel Migration Zone. Most of that is in flood irrigation (196 acres), but 51 acres are in pivot. At RM 450, pivots extend to the active streambank on both sides of the river. About 10 percent of the CMZ is restricted by physical features.

Reach A7 has seen 5 percent (33 acres) of its riparian corridor converted to developed land uses since 1950. Most of that (23 acres) was conversion to irrigation. Currently, there are about 26 acres of land under pivot irrigation within the mapped 5-year floodplain.

Reach A7was sampled as part of the avian study. The average species richness in Reach A7 was 9.9, 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 Bobolink, 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 Chimney Swift, Dickscissel, and Ovenbird.

On area in Reach A7 that has become persistently problematic is the Greycliff Bridge at RM 448.5. Bank migration upstream of the bridge has approached 1,000 feet of lateral movement since 1950. Bank armor has been flanked and now sits In the middle of the river. The county road that lies in the CMZ has been threatened; it was treated with buried revetment that has become exposed in recent years. Efforts are ongoing to develop an optimal strategy to funnel the river meanderbelt through the bridge without disrupting sediment transport patterns and causing accelerated erosion.

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 13,200 cfs to 12,700 cfs, a drop of about 4 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 2,000 cfs to 1,670 cfs with human development, a reduction of 17 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.

The reduction in flows is evident by the contraction of the 5-year floodplain area in Reach A7 by 62 acres, or 25 percent.

CEA-Related observations in Reach A7 include:
- Flanking of armor and accelerated erosion behind.
- Side Channel Blockage
- Contraction of 5-year floodplain due to flow alterations.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A7 include:
- Side channel restoration RM 452, RM 447.9, RM 445
- Bank armor removal upstream of Greycliff Bridge

# Yellowstone River Reach Narratives — Reach A7

**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 |
|---|---|---|---|
| 2 Year (cfs) | 25,600 | 25,100 | -2.0% |
| 100 Year (cfs) | 47,400 | 47,100 | -0.6% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

### Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 613.3 | 627.0 | 632.6 | 722.7 | 109.3 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

### Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 11,254 | 10.8% | 2,338 |
| Concrete Riprap | 0 | 0.0% | 0 |
| Flow Deflectors | 1,507 | 1.4% | 226 |
| Total | **12,761** | **12.2%** | **2,564** |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

### Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 4,756 | 4,610 |

Numerous side channels have been blocked by small dikes.

### Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 |
|---|---|---|
| Total Acres | 89.2 | 138.5 |
| Acres/Year | 3.4 | 5.5 |
| Acres/Year/Valley Mile | 0.4 | 0.6 |

1950-2001 In-channel riparian encroachment (negative number indicates retreat)

-3.83 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

### Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

### Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | 62.2 | 25% |
| 100 Year | 12.6 | 2% |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

### Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 164.2 | 10% |

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.

### Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 5,652.9 | 5,154.6 |
| Ag. Infrastructure (Ac) | 77.6 | 167.7 |
| Exurban (Ac) | 17.2 | 138.4 |
| Urban (Ac) | 0.0 | 0.0 |
| Transportation (Ac) | 110.1 | 295.9 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 2,027.4 | 1,465.8 |
| Sprinkler (Ac) | 0.0 | 224.5 |
| Pivot (Ac) | 0.0 | 913.8 |

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.

### 1950s Riparian Vegetation Converted to a Developed Land Use (ac)

| To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. |
|---|---|---|---|
| 22.8 | 9.7 | 32.5 | 5.0% |

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

### National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 14.1 | 1.6 |
| Emergent | 56.6 | 6.2 |
| Scrub/Shrub | 42.5 | 4.7 |

Total Wetland Acres: **113.2**

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).

### Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 0.5 | 0.0% |

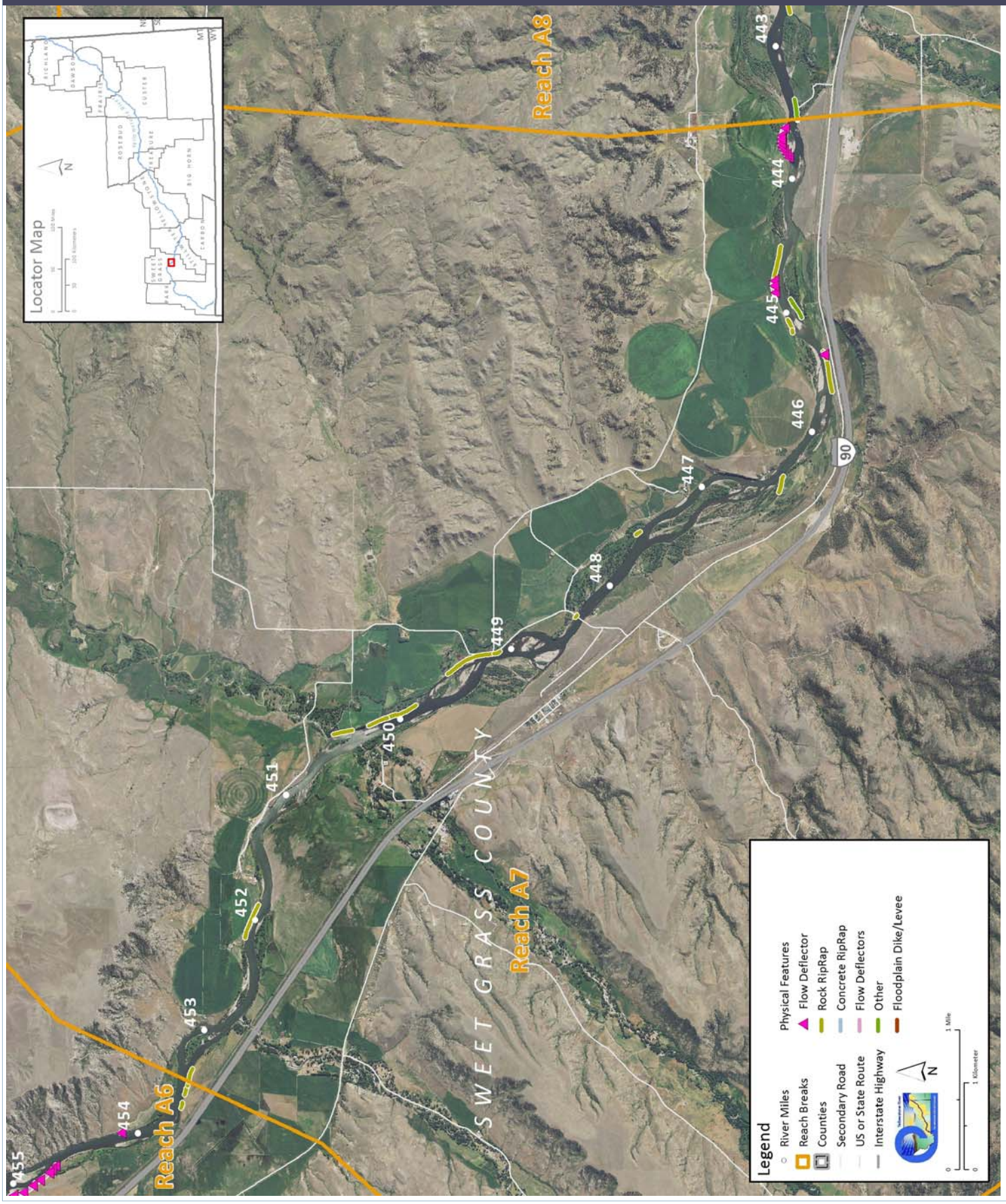
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

### Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

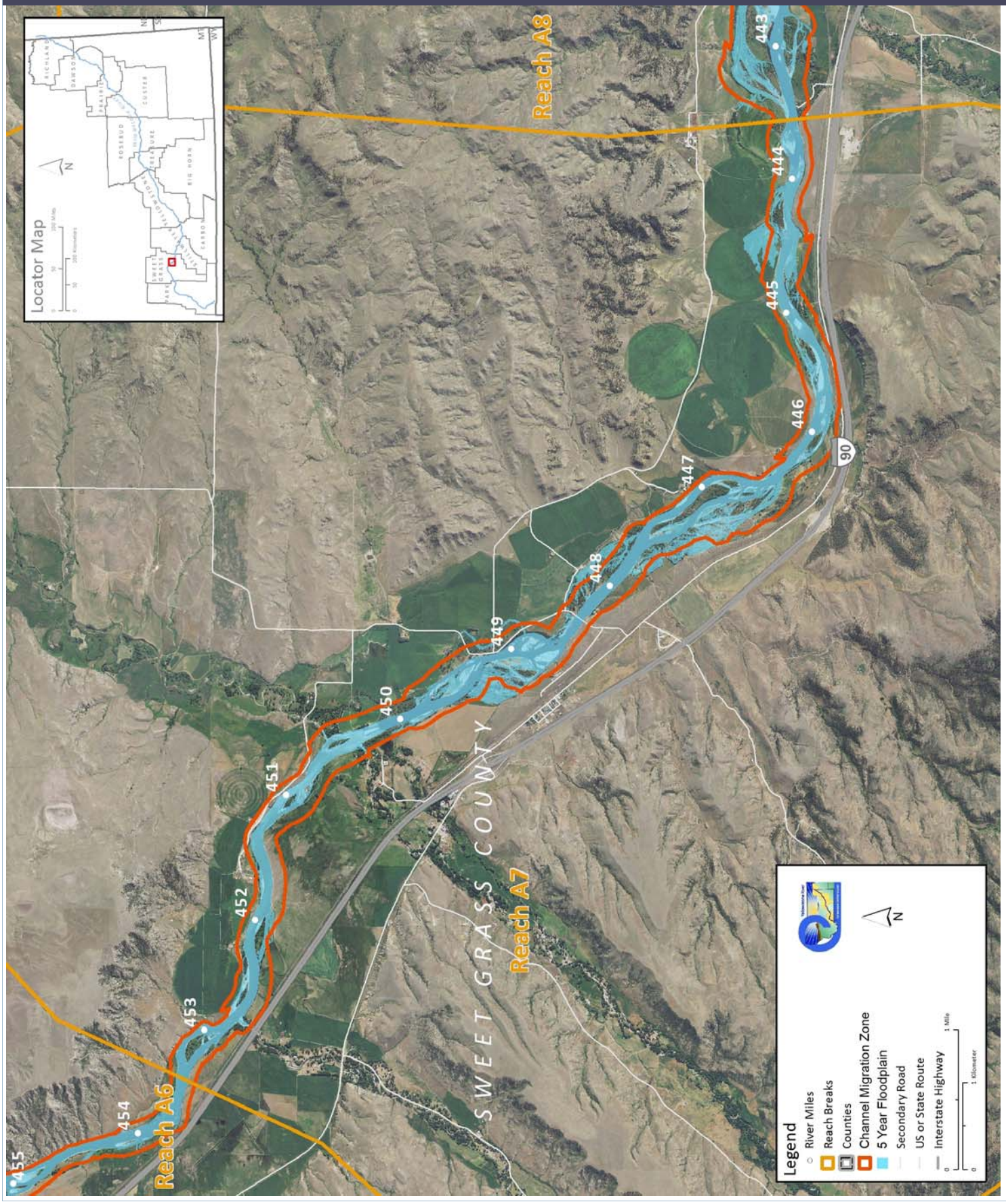
| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| 9.0 | 1.3 | 0.0 | -9.0 |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 443.6 |
| **Classification** | PCB: Partially confined braided | **Downstream River Mile** | 438.5 |
| **General Location** | Bridger Creek | **Length** | 5.10 mi (8.21 km) |

## Narrative Summary

Reach A8 is 5.1 miles long, and is at Bridger Creek. The reach is classified as Partially Confined Braided (PCB), which indicates some valley wall influences on river form and relatively extensive gravel bars and low flow channel complexity. Within this reach, the river intermittently follows the northern bluff line of the river valley which is comprised of Cretaceous-age Hell Creek Formation sandstones and mudstones. The other side of the river valley consists of low floodplain and terrace deposits. The Bratten fishing access site is located in the lower end of the reach.

Similar to other reaches in Region A, the overall footprint of the river channel has increased in size since 1950. In 1950, the channel footprint was 436 acres but by 2001 it had expanded to 482 acres.

As of 2011, about 10 percent of the banks in Reach A8 were armored by almost 4,000 feet of rock riprap and 1,400 feet of flow deflectors. There is also a ~760 foot long retaining wall on the right bank at the very upstream most end of the reach that protects several structures. At Rm 441.1, rock riprap on both sides of the river has constricted the channel corridor to essentially the width of the active channel, which is about 550 feet. Physical features also occupy the floodplain; over three miles of transportation encroachment and 1,800 feet of floodplain dikes have been mapped in the reach. Transportation infrastructure and agriculture-related dikes have isolated 25 percent of the historic 100-year floodplain in the reach.

Reach A8 has experienced the loss of almost a mile of side channel since the 1950s due to dike construction. All of the side channel loss is from one project at the mouth of Bridger Creek, where the lower portion of the creek was channelized downstream of the I-90 Bridge. This channelization included re-routing the creek through a channelized section to an active side channel of the Yellowstone River. The channelization included construction of a dike that guides Bridger Creek into the side channel, and blocks the side channel at the intersection, essentially turning the lower portion of the side channel into lowermost Bridger Creek. The channelization of lower Bridger Creek occurred between 1950 and 1976.

Even though Reach A8 has experienced some side channel loss, it still supports extensive side channel length. As of 2001 there were 6.6 miles of active side channel in the 5.1 mile long reach.

Land use in Reach A8 is predominantly agricultural, although there almost 230 acres of transportation-related development in the mapping footprint. Most of the agricultural land is non-irrigated, although there are 900 acres of ground under flood irrigation and 56 acres under pivot. A total of 236 acres of developed land are in the Channel Migration Zone. Most of that is in flood irrigation (211 acres), but 8 acres are in pivot and 4 are in exurban development. About 16 percent of the CMZ is restricted by physical features.

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 13,700 cfs to 13,000 cfs, a drop of about 5 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 2,020 cfs to 1,670 cfs with human development, a reduction of 17 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.

The reduction in flows is evident by the contraction of the 5-year floodplain area in Reach A8 by 24 acres, or 11 percent.

CEA-Related observations in Reach A8 include:
- Side channel loss as part of tributary channelization
- Isolation of 25 percent of historic 100-year floodplain primary due to transportation infrastructure
- Contraction of 5-year floodplain due to flow alterations.

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A8 include:
- Side channel restoration at RM 442
- Floodplain restoration/reconnection on south side of interstate at RM 439.5
- CMZ management due to extent of CMZ restriction (16 percent)

# Yellowstone River Reach Narratives — Reach A8

**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) | 26,600 | 25,800 | -3.0% | |
| 100 Year (cfs) | 49,000 | 48,500 | -1.0% | |

| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood. |
|---|---|---|---|---|---|---|
| | 436.3 | 445.2 | 460.7 | 482.4 | 46.1 | |

| 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 | 3,970 | 7.4% | 274 | |
| Concrete Riprap | 0 | 0.0% | 0 | |
| Flow Deflectors | 1,415 | 2.6% | -134 | |
| Total | **5,386** | **10.1%** | **140** | |

| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. |
|---|---|---|---|
| | 0 | 4,657 | |

| 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. Tunover is associated with the creation of riparian habitat. |
|---|---|---|---|---|
| Total Acres | 107.8 | 106.2 | 33.22 acres | |
| Acres/Year | 4.1 | 4.2 | | |
| Acres/Year/Valley Mile | 0.9 | 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 | 23.6 | 11% | |
| 100 Year | 197.0 | 25% | |

| 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. |
|---|---|---|---|
| | 195.8 | 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) | 3,285.3 | 3,019.8 | Flood (Ac) | 1,161.0 | 903.6 | |
| Ag. Infrastructure (Ac) | 63.0 | 128.0 | Sprinkler (Ac) | 0.0 | 0.0 | |
| Exurban (Ac) | 0.0 | 10.2 | Pivot (Ac) | 0.0 | 55.9 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 54.6 | 228.8 | | | | |

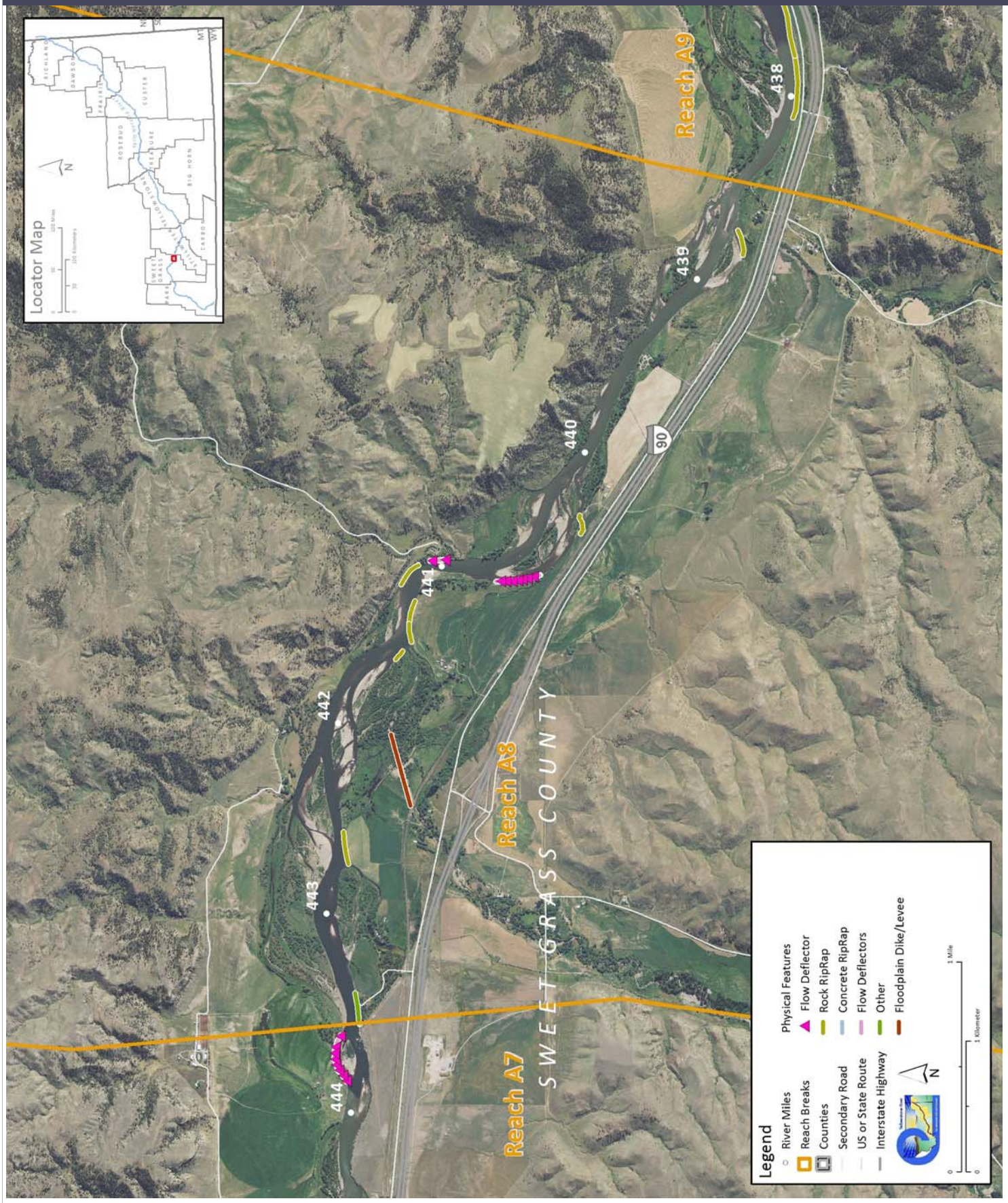
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. |
|---|---|---|---|---|---|
| | 1.1 | 3.6 | 4.7 | 1.0% | |

| 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 | 14.8 | 3.2 | **112.5** | |
| Emergent | 73.1 | 15.7 | | |
| Scrub/Shrub | 24.6 | 5.3 | | |

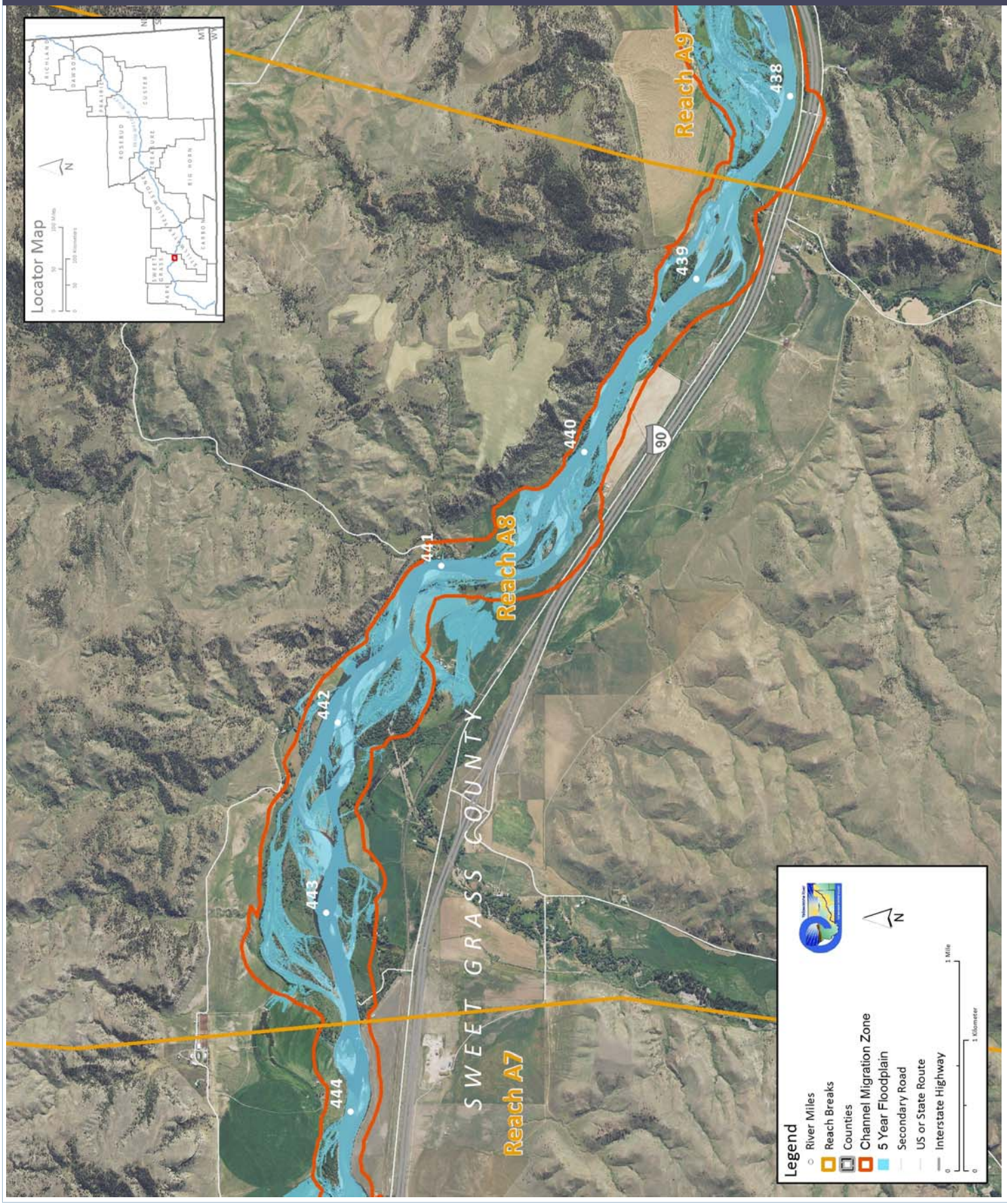
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. |
|---|---|---|---|
| | 0.4 | 0.0% | |

| 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. |
|---|---|---|---|---|---|
| | 0.0 | 2.2 | 0.0 | 0.0 | |

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP



| | | | |
|---|---|---|---|
| **County** | Sweet Grass | **Upstream River Mile** | 438.5 |
| **Classification** | UA: Unconfined anabranching | **Downstream River Mile** | 434.7 |
| **General Location** | Reed Point | **Length** | 3.80 mi (6.12 km) |

## Narrative Summary

Reach A9 is located in lowermost Sweet Grass County, just upstream of the Sweet Grass/Stillwater county line near Reed Point. The reach is an Unconfined Anabranching reach type. The reach is 3.8 miles long, extending from RM 434.7 to RM 438.5. The lower reach break is the bridge crossing just north of Reed Point. This bridge was originally constructed in 1911 and rebuilt in 2000.

Reach A9 provides an excellent example of a dynamic, largely unmodified Unconfined Anabranching reach type. The stream corridor is typically one half mile wide through the reach, with significant narrowing of that corridor in the downstream direction as the river approaches the bridge at Reed Point. In the uppermost portion of the Reach (RM 437-438.5), the northern valley margin consists of an alluvial fan deposit that is currently irrigated with center pivots. Downstream, the river abuts Cretaceous-age Hell Creek Formation on the northern valley wall, which contains sandstones that tend to form steep cliffs. The reach is characterized by high displacement ratios, extensive split flow and islands, and riparian turnover. Although riparian turnover is evident, the rates of that turnover have gone down in the reach since 1976. Prior to that time (1950-1976), average turnover rates were 5.9 acres per year; from 1976 to 2001 that average rate dropped to 3.6 acres of riparian turnover per year.

Bank armor in Reach A9 consists primarily of 10,000 linear feet of riprap which drapes about 24 percent of the stream bank. About 2,000 feet of that armor was constructed since 2001. This new armor is on the right bank at RM 437.8 where the river was rapidly migrating southward toward the rail line. By the time the bank was armored, the river was within 60 feet of the tracks.

Much of the riprap in Reach A9 is located along the south bank of the river on lower end of the reach where the Yellowstone River approaches the bridge near Reed Point. This bridge marks a major narrowing of the river corridor from about 2,000 feet wide ½ mile upstream of the bridge to 360 feet at the bridge itself. The narrowing is achieved by a ~mile long section of bank armor on the right bank that on its lower end runs due north/south, which is perpendicular to the overall east/west trend of the river. This has caused the river to consolidate into a main thread and abandon an historic side channel just upstream of the bridge at the Indian Fort Fishing Access Site.

Reach A9 has experienced the loss of almost about 3,700 feet of side channel since the 1950s due to dike construction. All of the side channel loss is from one project at the upstream end of the reach, where a side channel was blocked on the north side of the river at RM 438.5.

Even though Reach A9 has experienced some side channel loss, it still supports extensive side channel length. As of 2001 there were 5.1 miles of active side channel in the 3.8 mile long reach. Large islands have persisted in the reach since 1950.

Land use in Reach A9 is predominantly agricultural, although there several hundred acres of non-agricultural uses due to the proximity of the transportation corridor as well as the town of Reed Point. Since 1950, 160 acres of agricultural land have been converted to pivot. A total of 300 acres of developed land are in the Channel Migration Zone. Most of that is in flood irrigation (250 acres), but 40 acres are in transportation. About 13 percent of the CMZ is restricted by physical features.

There is natural gas one pipeline that crosses under the Yellowstone River in Reach A9. It crosses at the upper most end of the reach at RM 438.5 and is consists of a 6 inch pipeline that is owned by Northwestern Energy.

Since 1950, Reach A9 has lost most of its forest that would be considered at low risk of cowbird infestation due to its separation from agricultural infrastructure. In 1950, about 17 acres of forest per valley mile were identified as low risk and by 2001 that forest area had been reduced to 2.5 acres due to development within the reach.

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 14,000 cfs to 13,300 cfs, a drop of about 5 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 2,030 cfs to 1,680 cfs with human development, a reduction of 17 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.

The reduction in flows is evident by the contraction of the 5-year floodplain area in Reach A9 by 15 acres, or 6 percent.

CEA-Related observations in Reach A9 include:
- Reduced floodplain turnover rates since 1976
- Approximately 3,700 feet of side channel has been lost due to channel plugging between 1950 and 2011
- Meander belt encroachment at bridge crossing
- Side channel loss as part of armoring at bridge approach

Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach A9 include:
- Side channel restoration at RM 438.5
- CMZ management due to extent of CMZ restriction (13 percent)
- Pipeline management for 6-inch natural gas pipeline that crosses under the river at RM 438.5

# Yellowstone River Reach Narratives — Reach A9

**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 |
|---|---|---|---|
| 2 Year (cfs) | 27,100 | 26,300 | -3.0% |
| 100 Year (cfs) | 49,900 | 49,400 | -1.0% |

"Undeveloped" flows represent conditions prior to significant human development, whereas "developed" flows reflect the current condition of both consumptive and non-consumptive water use.

### Bankfull Channel Area (Ac)

| 1950 | 1976 | 1995 | 2001 | 1950-2001 |
|---|---|---|---|---|
| 351.0 | 420.9 | 364.2 | 403.1 | 52.1 |

Bankful channel area is the total footprint of the river inundated at approx. the 2-year flood.

### Physical Features

| | 2011 Length (ft) | % of Bankline | 2001-2011 Change |
|---|---|---|---|
| Rock RipRap | 9,898 | 24.2% | 2,012 |
| Concrete Riprap | 0 | 0.0% | 0 |
| Flow Deflectors | 107 | 0.3% | 107 |
| Total | **10,005** | **24.4%** | **2,119** |

There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor.

### Length of Side Channels Blocked (ft)

| Pre-1950s | Post-1950s |
|---|---|
| 0 | 3,717 |

Numerous side channels have been blocked by small dikes.

### Floodplain Turnover

| | 1950 - 1976 | 1976 - 2001 |
|---|---|---|
| Total Acres | 154.6 | 90.0 |
| Acres/Year | 5.9 | 3.6 |
| Acres/Year/Valley Mile | 1.8 | 1.1 |

1950-2001 In-channel riparian encroachment (negative number indicates retreat): 45.11 acres

The rate of floodplain turnover reflects how many acres of land are eroded by the river. Tunover is associated with the creation of riparian habitat.

### Open Bar Area

| | Point Bars | Bank Attached | Mid-Channel | Total |
|---|---|---|---|---|
| Change in Area '50 - '01 (Ac) | | | | |

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.

### Floodplain Isolation

| | Acres | % of FP |
|---|---|---|
| 5 Year | 14.9 | 6% |
| 100 Year | 19.0 | 4% |

Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees.

### Restricted Migration Area

| Acres | % of CMZ |
|---|---|
| 150.9 | 13% |

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.

### Land Use

| | 1950 | 2011 |
|---|---|---|
| Agricultural Land (Ac) | 2,009.3 | 1,760.1 |
| Ag. Infrastructure (Ac) | 27.7 | 26.9 |
| Exurban (Ac) | 0.0 | 67.4 |
| Urban (Ac) | 15.6 | 48.0 |
| Transportation (Ac) | 54.4 | 169.1 |

| | 1950 | 2011 |
|---|---|---|
| Flood (Ac) | 462.8 | 450.6 |
| Sprinkler (Ac) | 0.0 | 0.0 |
| Pivot (Ac) | 0.0 | 163.4 |

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.

### 1950s Riparian Vegetation Converted to a Developed Land Use (ac)

| To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. |
|---|---|---|---|
| 16.2 | 0.0 | 16.2 | 5.0% |

Changes in the extents of riparian vegetation are influenced by land use changes within the corridor.

### National Wetlands Inventory

| | Acres | Acres per Valley Mi |
|---|---|---|
| Riverine | 9.8 | 2.9 |
| Emergent | 32.5 | 9.7 |
| Scrub/Shrub | 30.9 | 9.2 |

Total Wetland Acres: **73.2**

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).

### Russian Olive (2001) (Appx. 100-yr Floodplain)

| Acres | % |
|---|---|
| 0.1 | 0.0% |

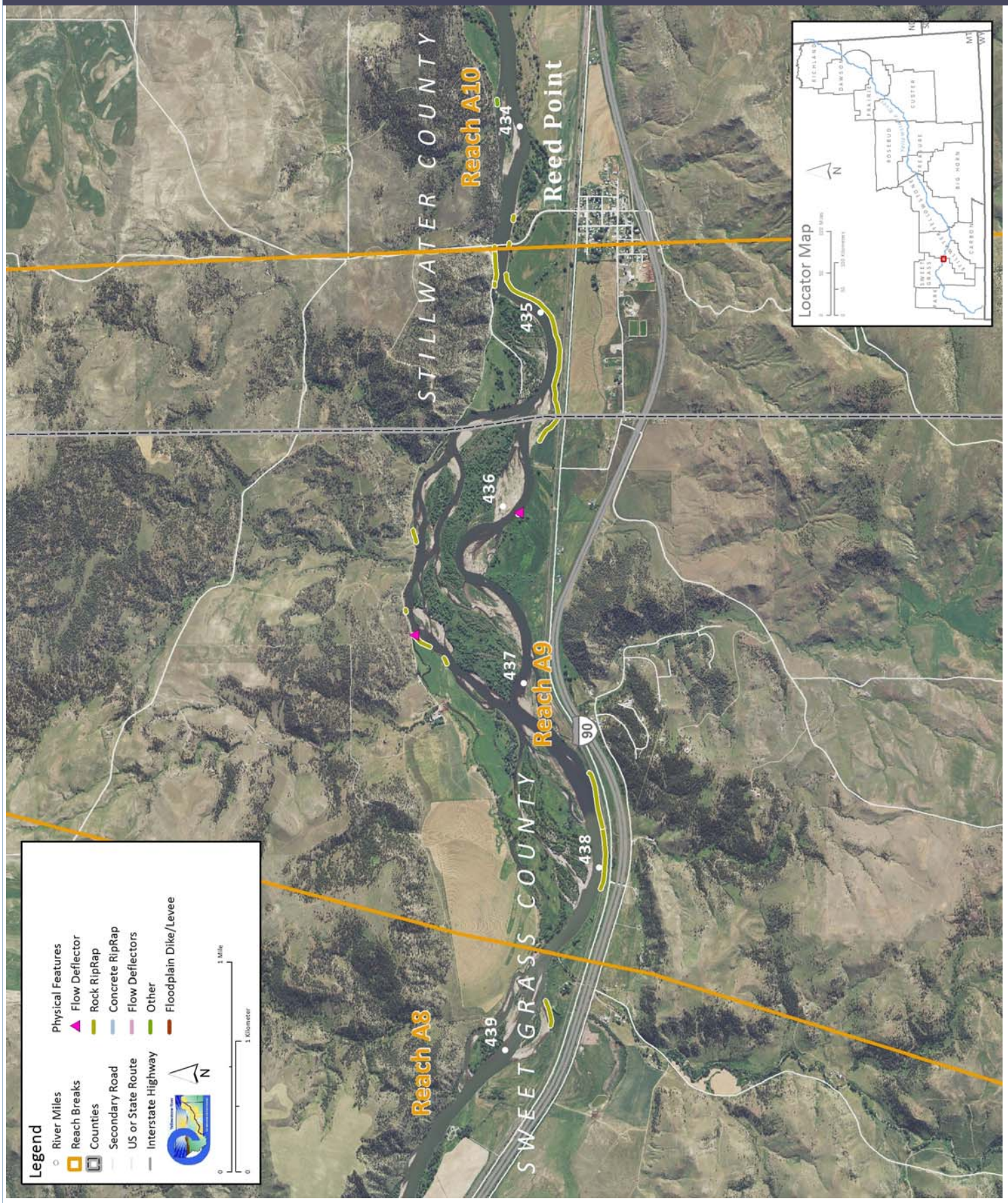
Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor.

### Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile)

| 1950 | 1976 | 2001 | Change 1950-2011 |
|---|---|---|---|
| 16.6 | 2.1 | 2.5 | -14.2 |

Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests.

## PHYSICAL FEATURES MAP (2011)



## CHANNEL MIGRATION ZONE MAP