

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

Narrative Summary

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

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

CEA-Related observations in Reach PC1 include:

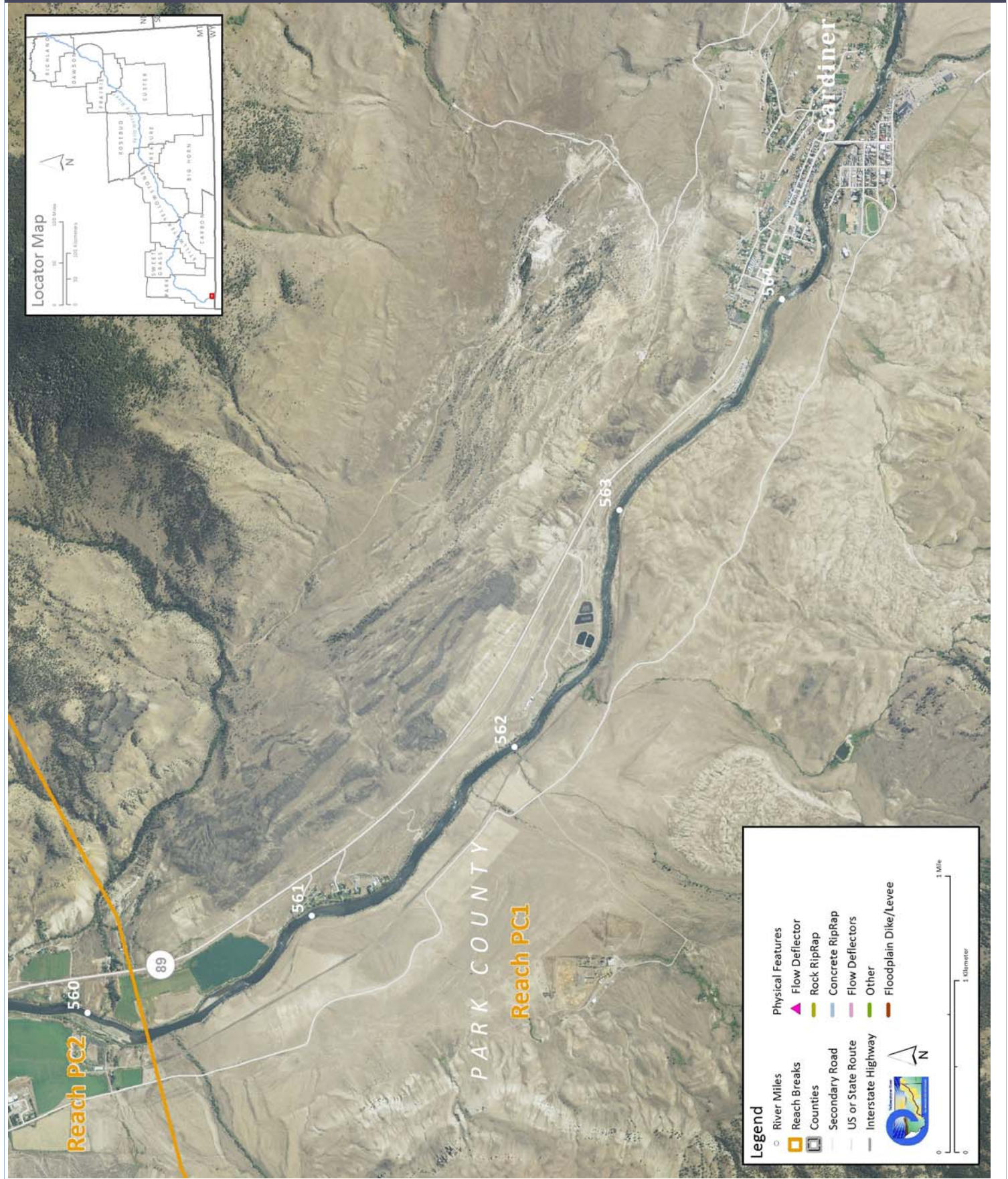
- Urban/Exurban development at Gardiner

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

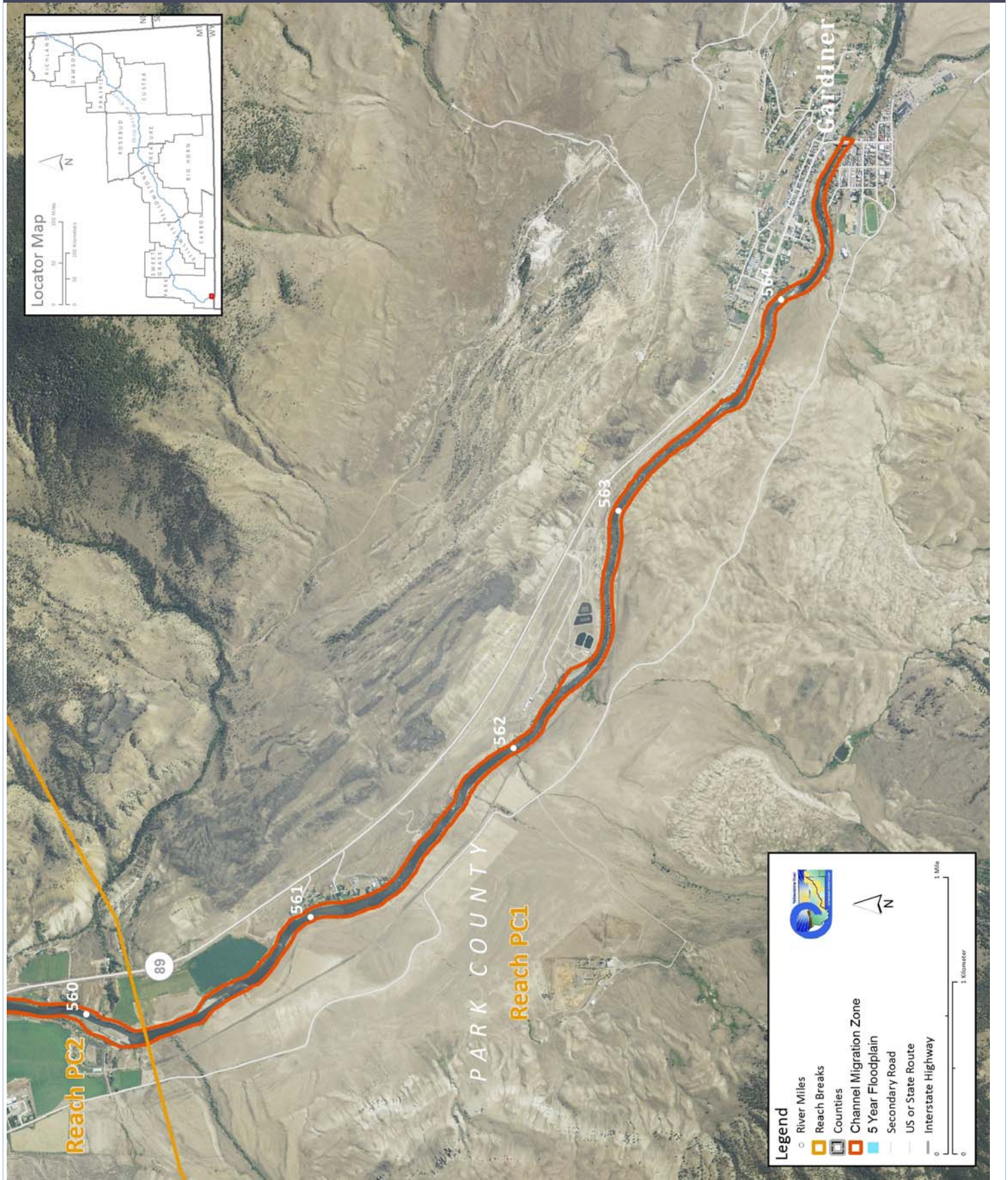
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 16,800 | 16,800 | 0.0% | | | |
| 100 Year (cfs) | 32,100 | 32,100 | 0.0% | | | |
| 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. |
| | 107.2 | | | 110.1 | 2.9 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 0 | 0.0% | 0 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 0 | 0.0% | 0 | | | |
| Total | 0 | 0.0% | 0 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres | | | acres | | | |
| Acres/Year | | | | | | |
| Acres/Year/Valley Mile | | | | | | |
| 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 | | | | | | |
| 100 Year | | | | | | |
| 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. | | | |
| | | | | | | |
| 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) | 1,647.8 | 1,399.5 | Flood (Ac) | 42.4 | 0.0 | |
| Ag. Infrastructure (Ac) | 1.8 | 0.0 | Sprinkler (Ac) | 0.0 | 36.0 | |
| Exurban (Ac) | 31.5 | 157.9 | Pivot (Ac) | 0.0 | 0.0 | |
| Urban (Ac) | 51.6 | 174.6 | | | | |
| Transportation (Ac) | 60.1 | 58.0 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 0.0 | 0.0 | 0.0 | | | |
| Emergent | 0.0 | 0.0 | 0.0 | | | |
| Scrub/Shrub | 0.0 | 0.0 | 0.0 | | | |
| 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. | | | |
| | 0.1 | 0.3% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

CEA-Related observations in Reach PC2 include:

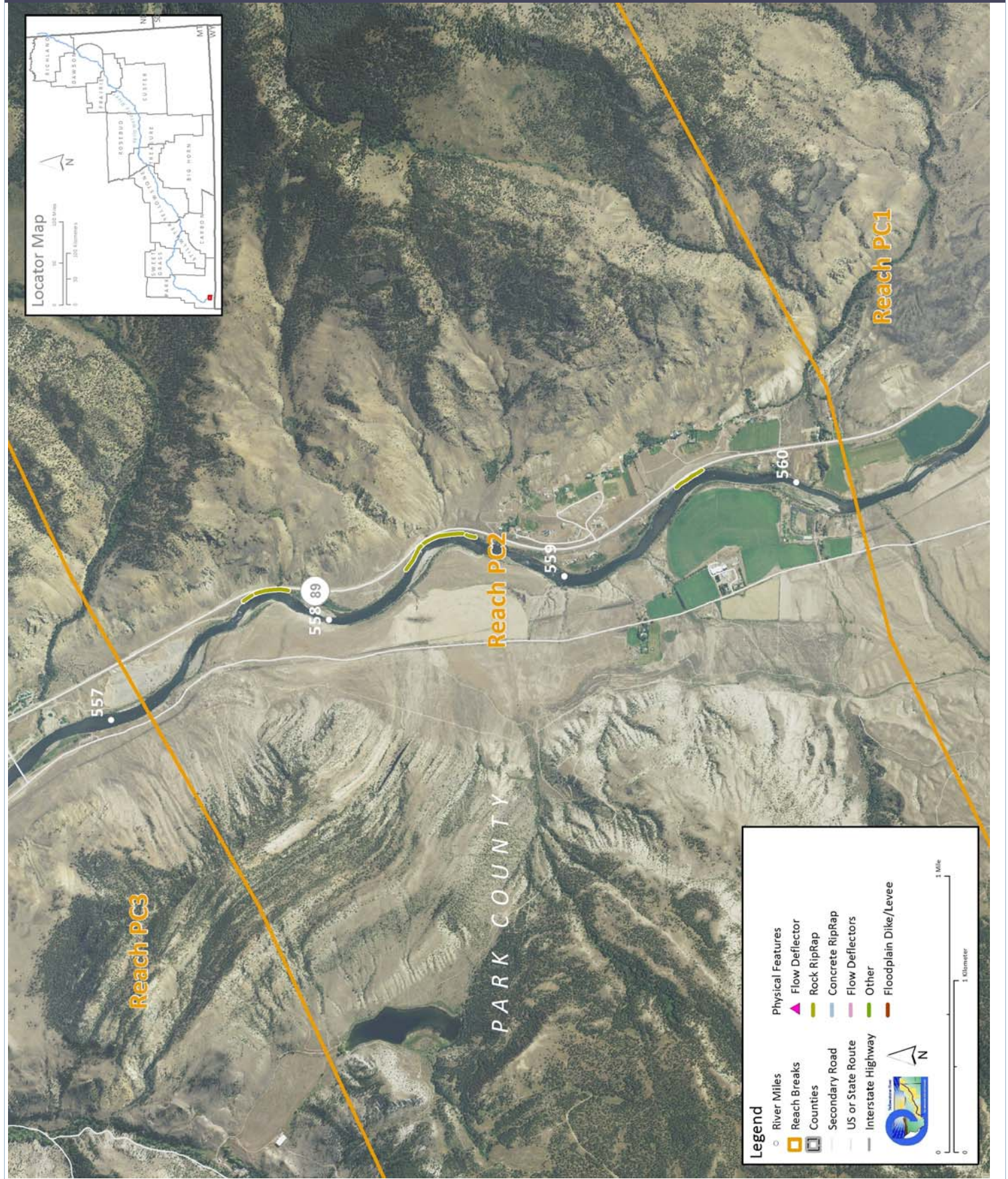
- Urban/Exurban development at Gardiner

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

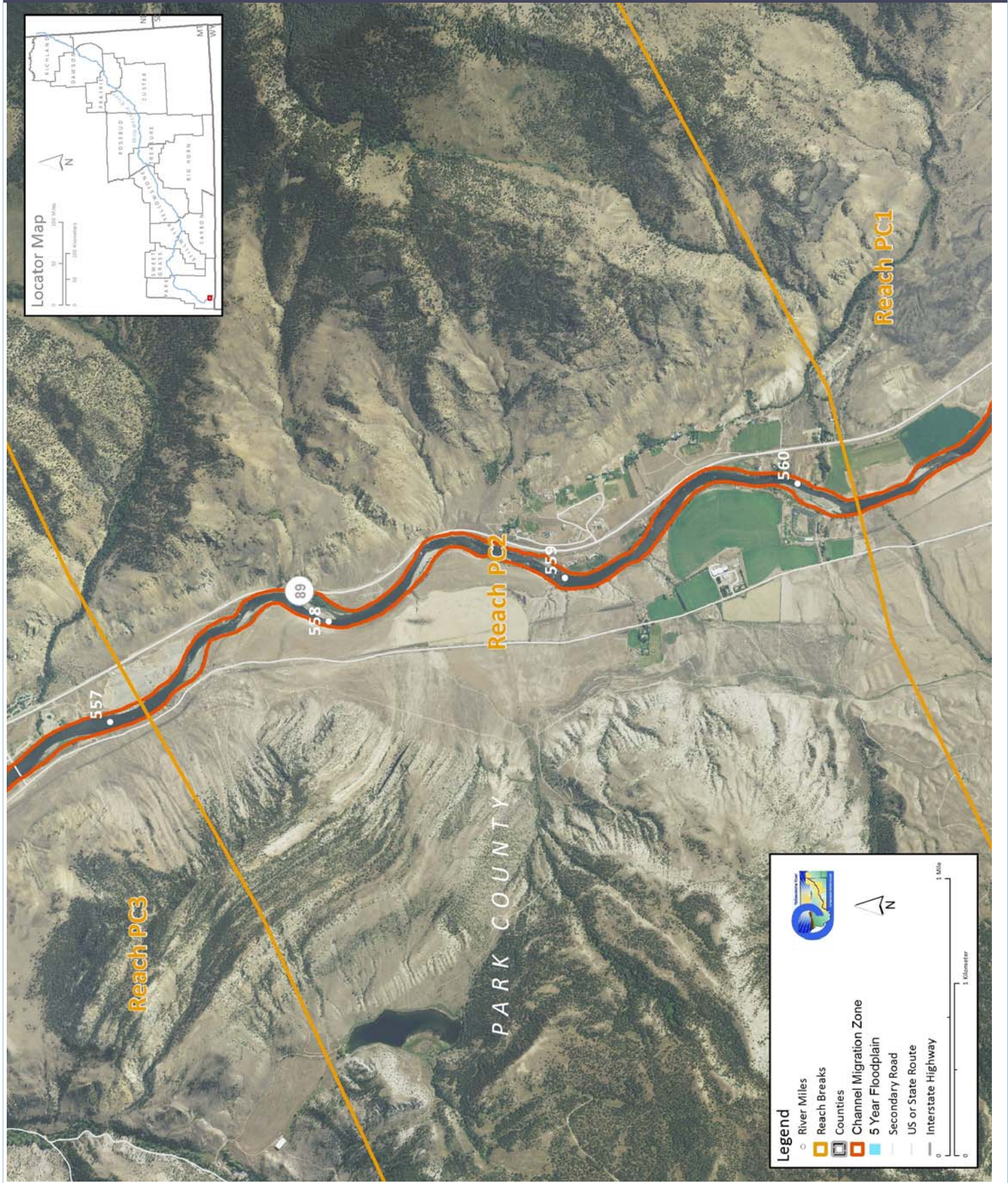
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 17,600 | 17,600 | 0.0% | | | |
| 100 Year (cfs) | 33,500 | 33,500 | 0.0% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 107.2 | | | 98.5 | -8.8 | |
| 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 | 3,043 | 9.3% | 1,255 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 0 | 0.0% | 0 | | | |
| Total | 3,043 | 9.3% | 1,255 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | | | | | | |
| 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) | 1,158.9 | 1,026.8 | Flood (Ac) | 250.9 | 0.0 | |
| Ag. Infrastructure (Ac) | 20.8 | 24.1 | Sprinkler (Ac) | 0.0 | 132.7 | |
| Exurban (Ac) | 9.2 | 145.5 | Pivot (Ac) | 0.0 | 61.6 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 35.8 | 35.8 | | | | |
| 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. | |
| | | | | | | |
| 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 | 0.0 | 0.0 | 4.9 | | | |
| Emergent | 2.5 | 0.9 | | | | |
| Scrub/Shrub | 2.4 | 0.9 | | | | |
| 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. | | | |
| | 0.0 | 0.2% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

CEA-Related observations in Reach PC3 include:

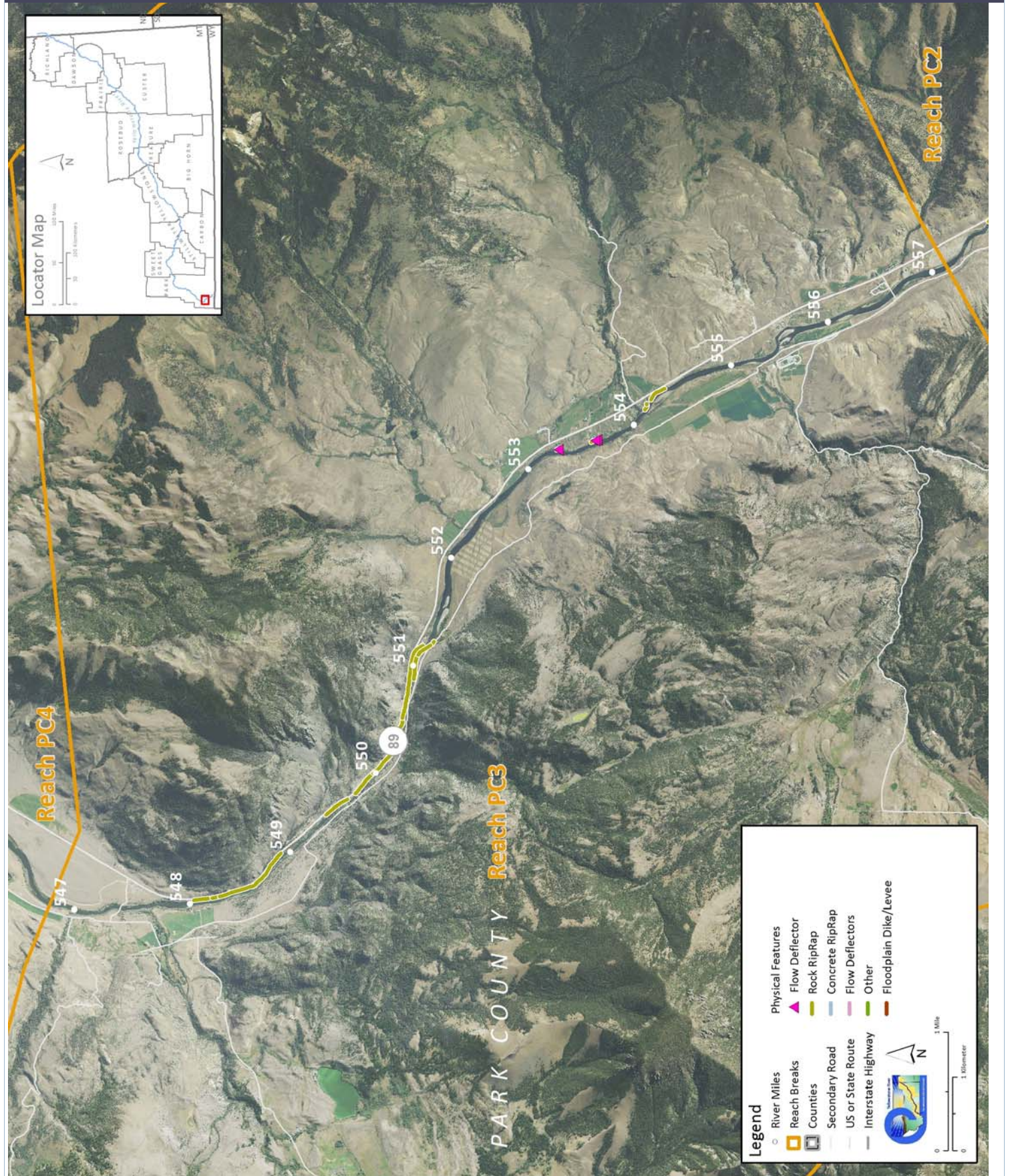
- Conversion of flood irrigation to sprinkler
- Net loss of irrigated land

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

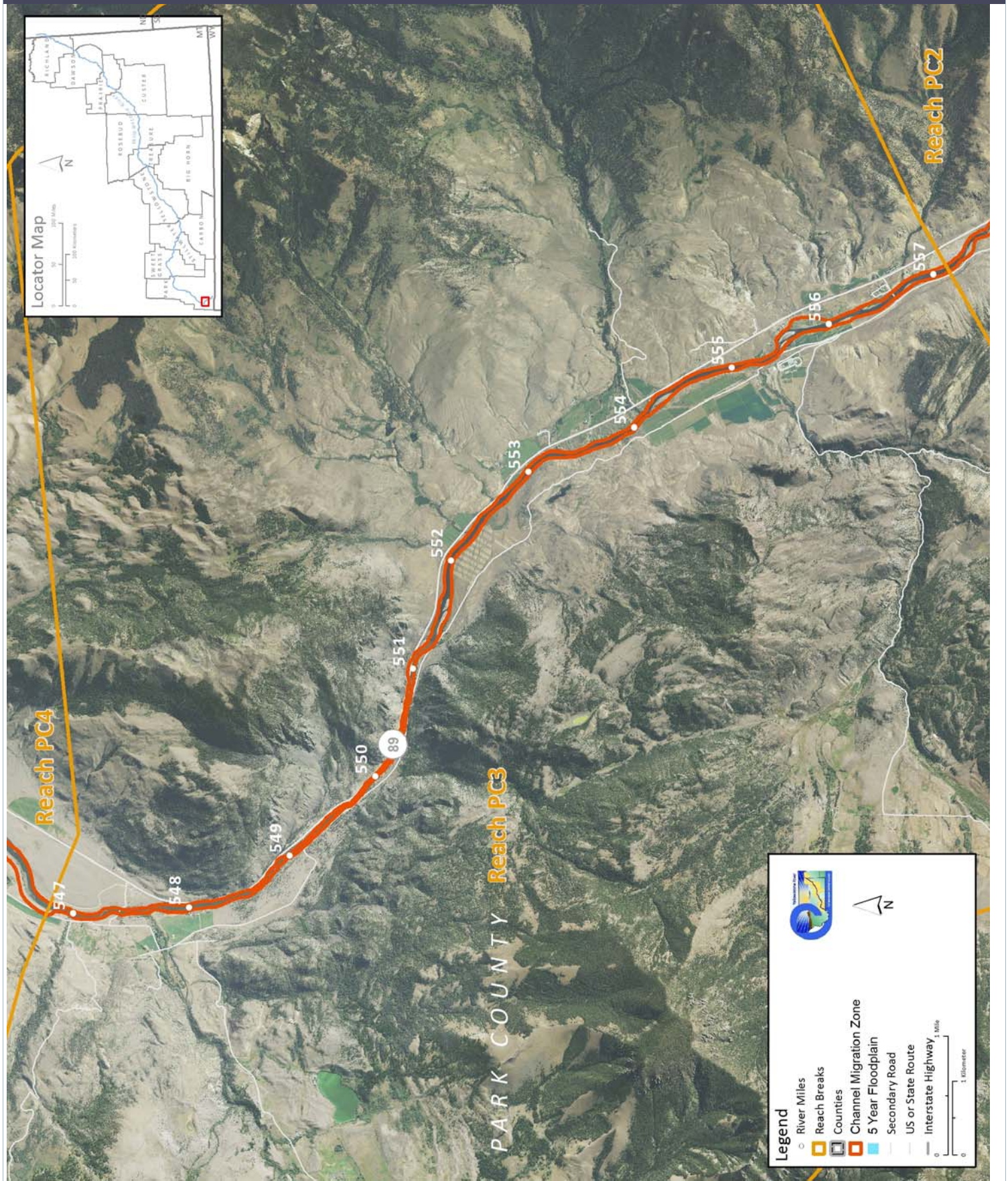
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 17,600 | 17,600 | 0.0% | | | |
| 100 Year (cfs) | 33,500 | 33,500 | 0.0% | | | |
| 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. |
| | 317.3 | | | 295.5 | -21.8 | |
| 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 | 16,334 | 15.0% | 711 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 294 | 0.3% | 0 | | | |
| Total | 16,627 | 15.2% | 711 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres | | | acres | | | |
| Acres/Year | | | | | | |
| Acres/Year/Valley Mile | | | | | | |
| 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 | | | | | | |
| 100 Year | | | | | | |
| 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. | | | |
| | | | | | | |
| 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) | 1,158.9 | 1,026.8 | Flood (Ac) | 635.1 | 183.7 | |
| Ag. Infrastructure (Ac) | 20.8 | 24.1 | Sprinkler (Ac) | 0.0 | 188.1 | |
| Exurban (Ac) | 9.2 | 145.5 | Pivot (Ac) | 0.0 | 32.3 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 35.8 | 35.8 | | | | |
| 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. | |
| | | | | | | |
| 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 | 0.3 | 0.0 | 14.0 | | | |
| Emergent | 7.3 | 0.7 | | | | |
| Scrub/Shrub | 6.4 | 0.6 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.0 | 0.2% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

Reach PC4 marks the entrance of the Yellowstone River into the Paradise Valley. This is geomorphically indicated by the onset of point bar formation and sediment storage in the channel. One large bar deposit located about ¼ mile of the Highway 89 bridge has driven almost 300 feet of bank movement since 1950. As result, the Channel Migration Zone area in this reach has expanded relative to upstream, with an erosion buffer of 258 feet assigned to the alluvial edge of the river. Reach PC4 also has over 2,000 feet of active side channels.

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

CEA-Related observations in Reach PC4 include:

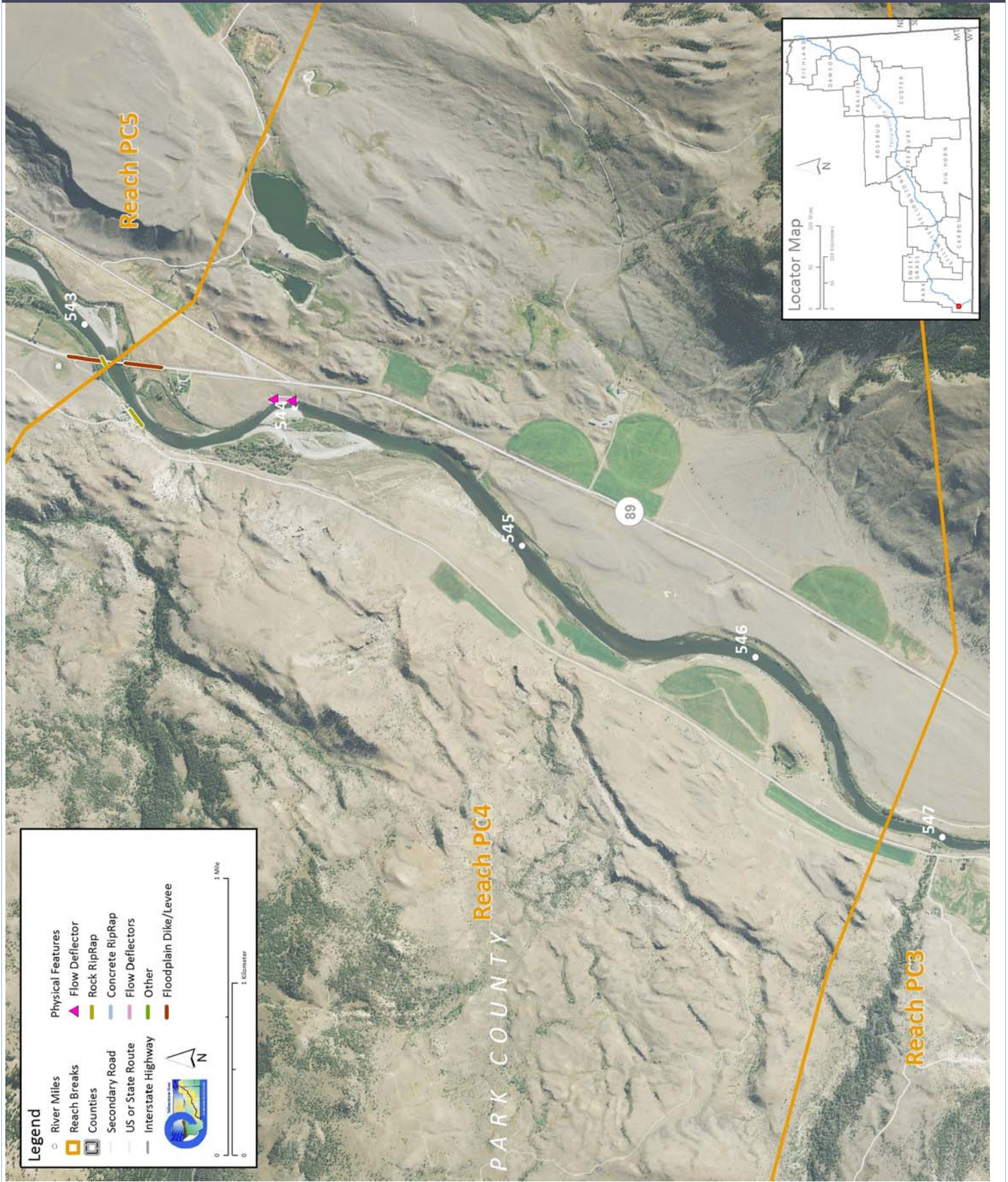
- Increased bank migration and Channel Migration Zone area entering Paradise Valley
- Net expansion of irrigated lands

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

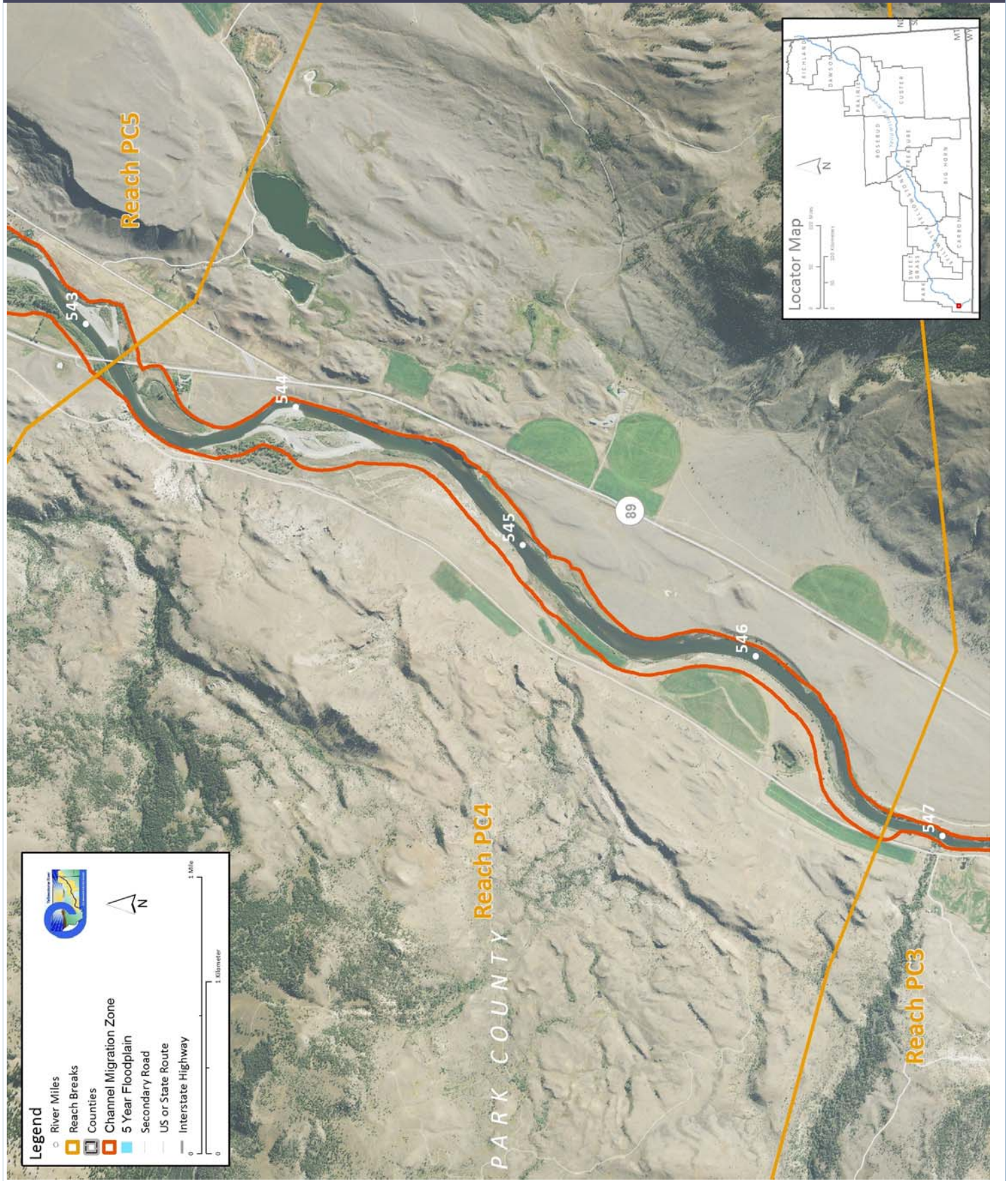
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 19,100 | 19,000 | -0.5% | | | |
| 100 Year (cfs) | 36,000 | 36,000 | 0.0% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 180.7 | | | 163.9 | -16.8 | |
| 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 | 367 | 1.0% | 0 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 434 | 1.1% | 0 | | | |
| Total | 801 | 2.1% | 0 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 2.7 | 1% | | | | |
| 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) | 1,471.0 | 1,442.7 | Flood (Ac) | 62.7 | 8.6 | |
| Ag. Infrastructure (Ac) | 8.0 | 3.8 | Sprinkler (Ac) | 0.0 | 84.6 | |
| Exurban (Ac) | 0.0 | 23.2 | Pivot (Ac) | 0.0 | 96.7 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 29.4 | 43.6 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 0.0 | 0.0 | 30.5 | | | |
| Emergent | 5.5 | 1.7 | | | | |
| Scrub/Shrub | 25.0 | 7.6 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.0 | 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. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

CEA-Related observations in Reach PC5 include:

- Blockage of a 3,500feet-long side channel by a dike which may have a culvert
- Flanking of rock riprap and accelerated erosion behind
- Net expansion of irrigated lands

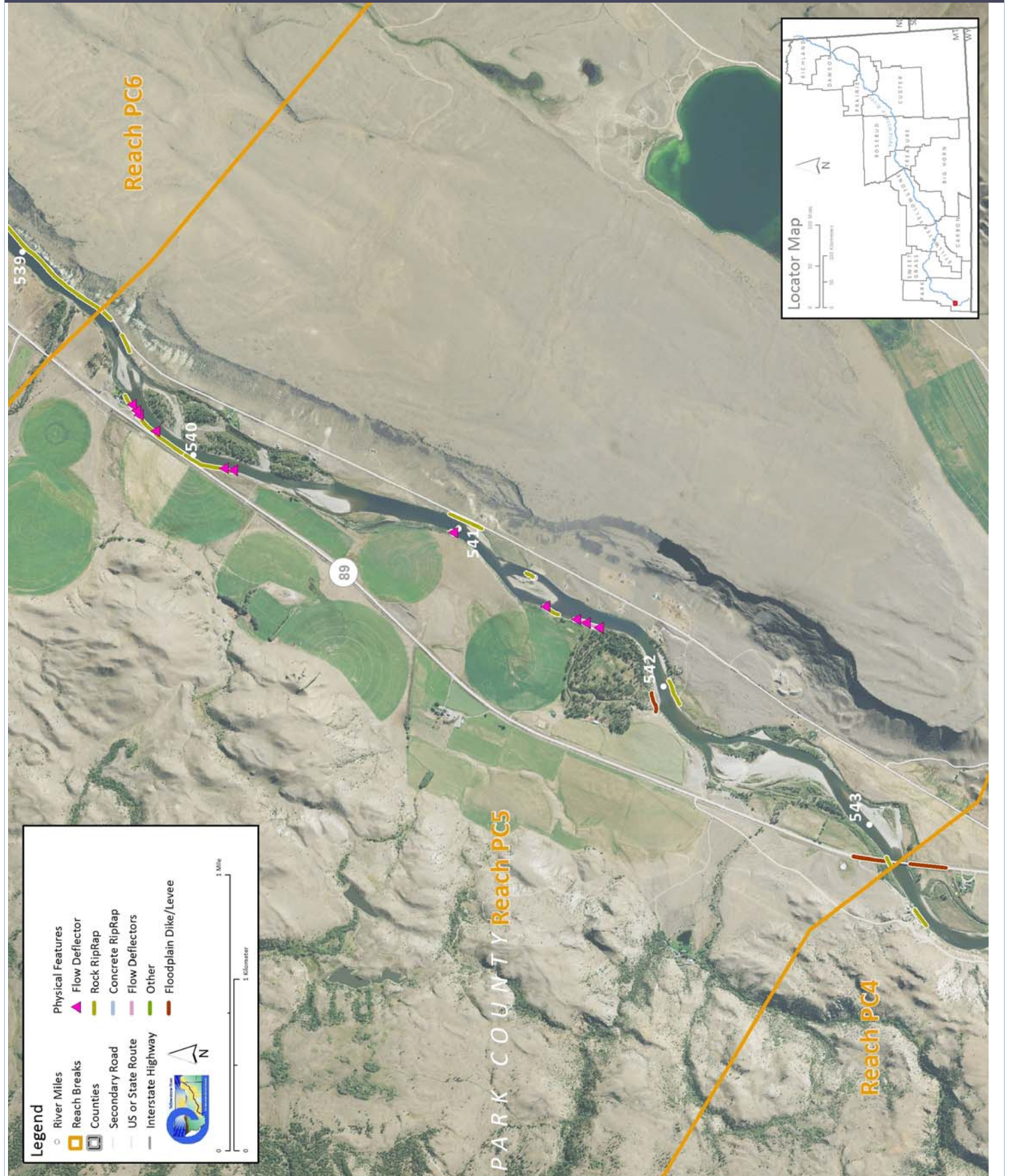
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC5 include:

- Side Channel Restoration at RM 542
- Removal of flanked bank armor at RM 541.4

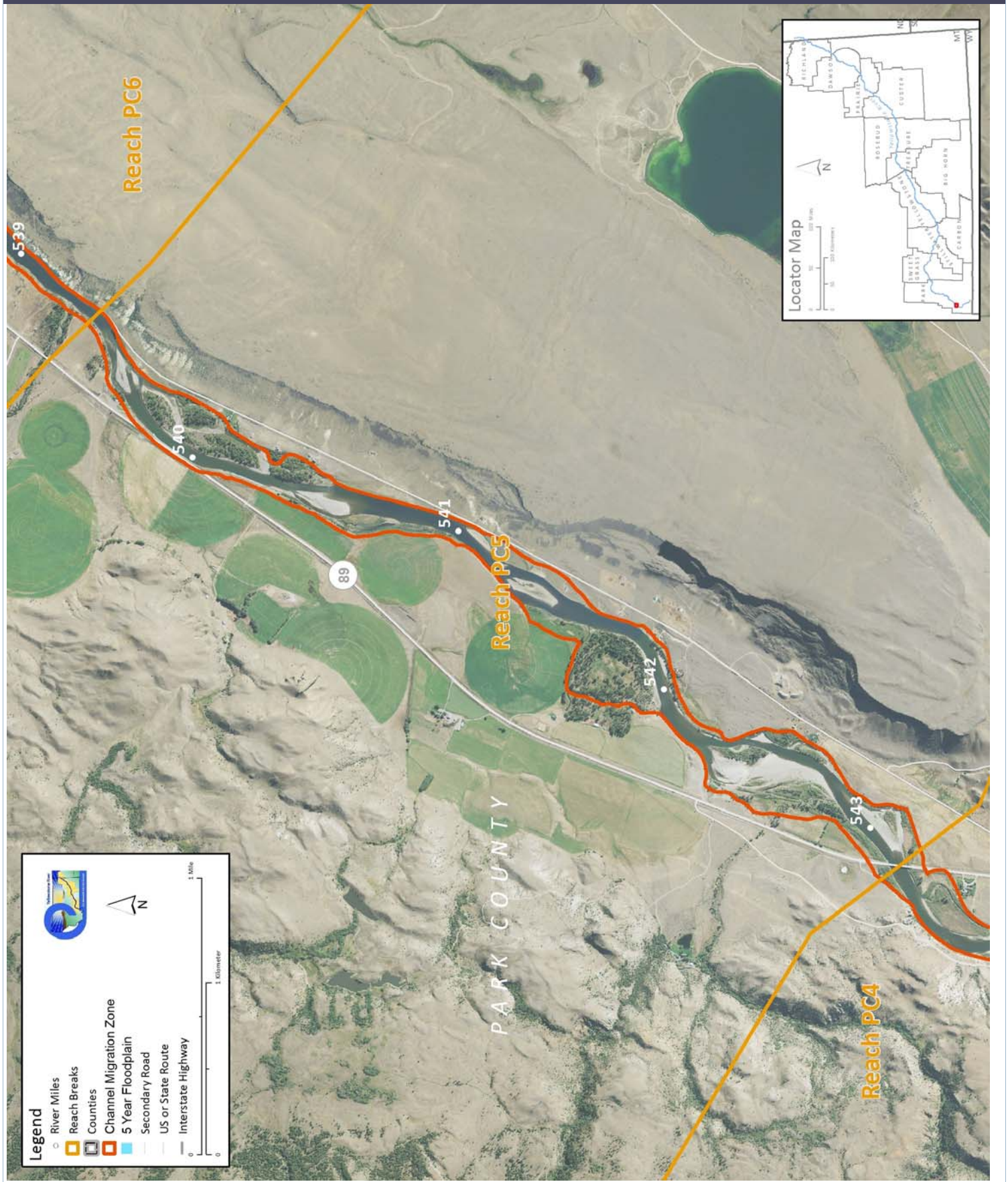
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 19,100 | 19,000 | -0.5% | | | |
| 100 Year (cfs) | 36,000 | 36,000 | 0.0% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 219.7 | | | 199.2 | -20.5 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 4,371 | 10.8% | -201 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 993 | 2.5% | -81 | | | |
| Total | 5,365 | 13.3% | -282 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 3,503 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 22.3 | 6% | | | | |
| Land Use | 1950 | 2011 | 1950 | 2011 | Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land. | |
| Agricultural Land (Ac) | 994.5 | 892.7 | Flood (Ac) | 188.3 | 38.7 | |
| Ag. Infrastructure (Ac) | 0.0 | 13.8 | Sprinkler (Ac) | 0.0 | 74.2 | |
| Exurban (Ac) | 0.0 | 102.2 | Pivot (Ac) | 0.0 | 222.4 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 34.7 | 49.2 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 0.0 | 0.0 | 60.4 | | | |
| Emergent | 26.4 | 7.4 | | | | |
| Scrub/Shrub | 34.0 | 9.6 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.1 | 0.1% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

CEA-Related observations in Reach PC6 include:

- Conversion of agricultural land to exurban development
- Agricultural and exurban development close to the active channel within the CMZ

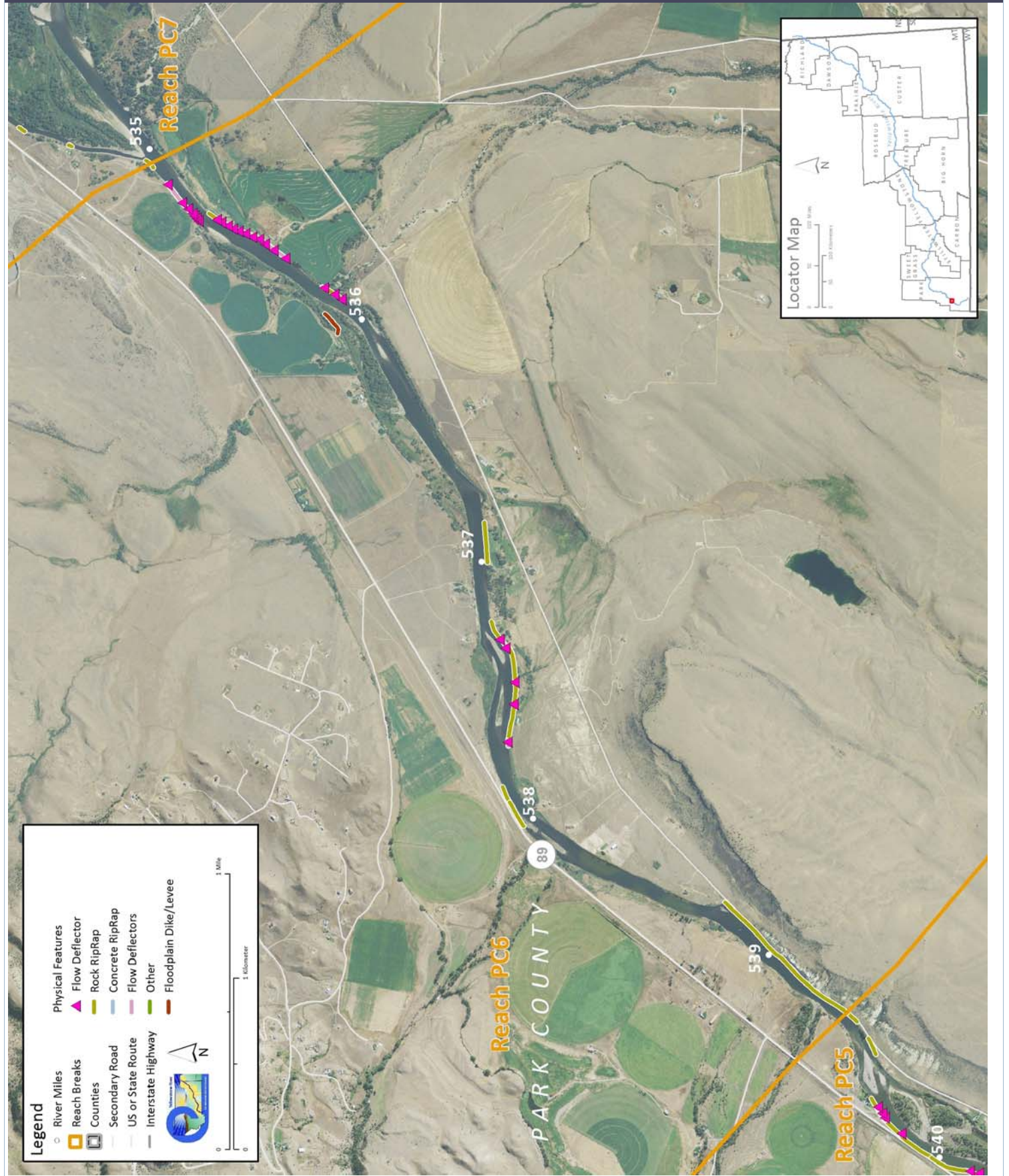
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC6 include:

- CMZ Management due to extensive encroachment of irrigated lands to edge of river.

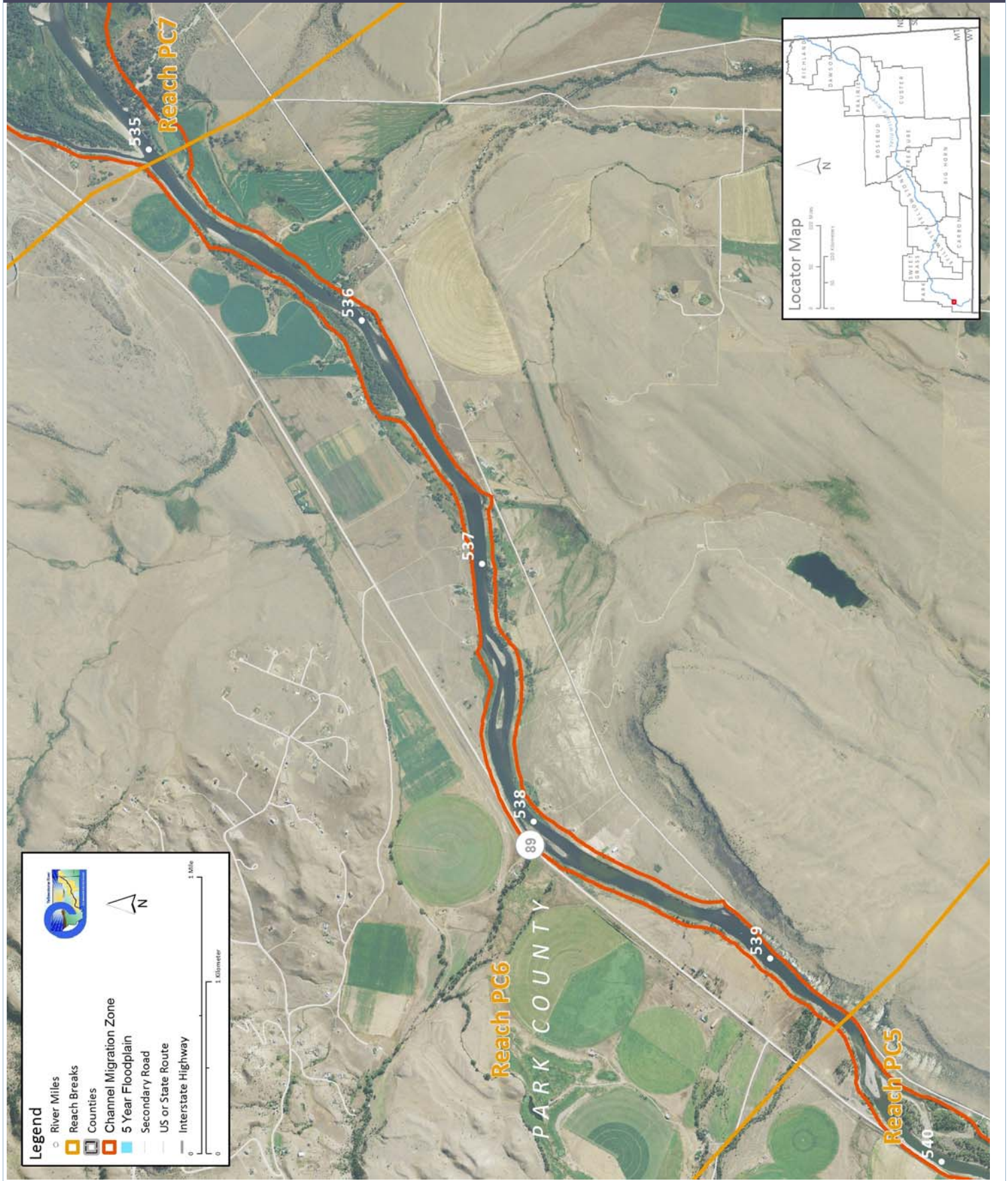
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 19,100 | 19,000 | -0.5% | | | |
| 100 Year (cfs) | 36,000 | 36,000 | 0.0% | | | |
| 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. |
| | 176.9 | | | 169.6 | -7.3 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 7,371 | 16.2% | 0 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 3,278 | 7.2% | 0 | | | |
| Total | 10,649 | 23.4% | 0 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres | | | acres | | | |
| Acres/Year | | | | | | |
| Acres/Year/Valley Mile | | | | | | |
| 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 | | | | | | |
| 100 Year | | | | | | |
| 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. | | | |
| | 24.2 | 8% | | | | |
| 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) | 1,278.4 | 770.1 | Flood (Ac) | 409.1 | 177.9 | |
| Ag. Infrastructure (Ac) | 17.3 | 85.9 | Sprinkler (Ac) | 0.0 | 92.5 | |
| Exurban (Ac) | 4.0 | 446.2 | Pivot (Ac) | 0.0 | 84.5 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 40.7 | 42.1 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 1.0 | 0.2 | 77.2 | | | |
| Emergent | 62.6 | 15.3 | | | | |
| Scrub/Shrub | 13.6 | 3.3 | | | | |
| 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. | | | |
| | 0.0 | 0.1% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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

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

CEA-Related observations in Reach PC7 include:

- Conversion of agricultural land to exurban development
- Post-1950s side channel blockage with identified restoration potential
- Sharp increase in Russian olive extent relative to upstream reaches

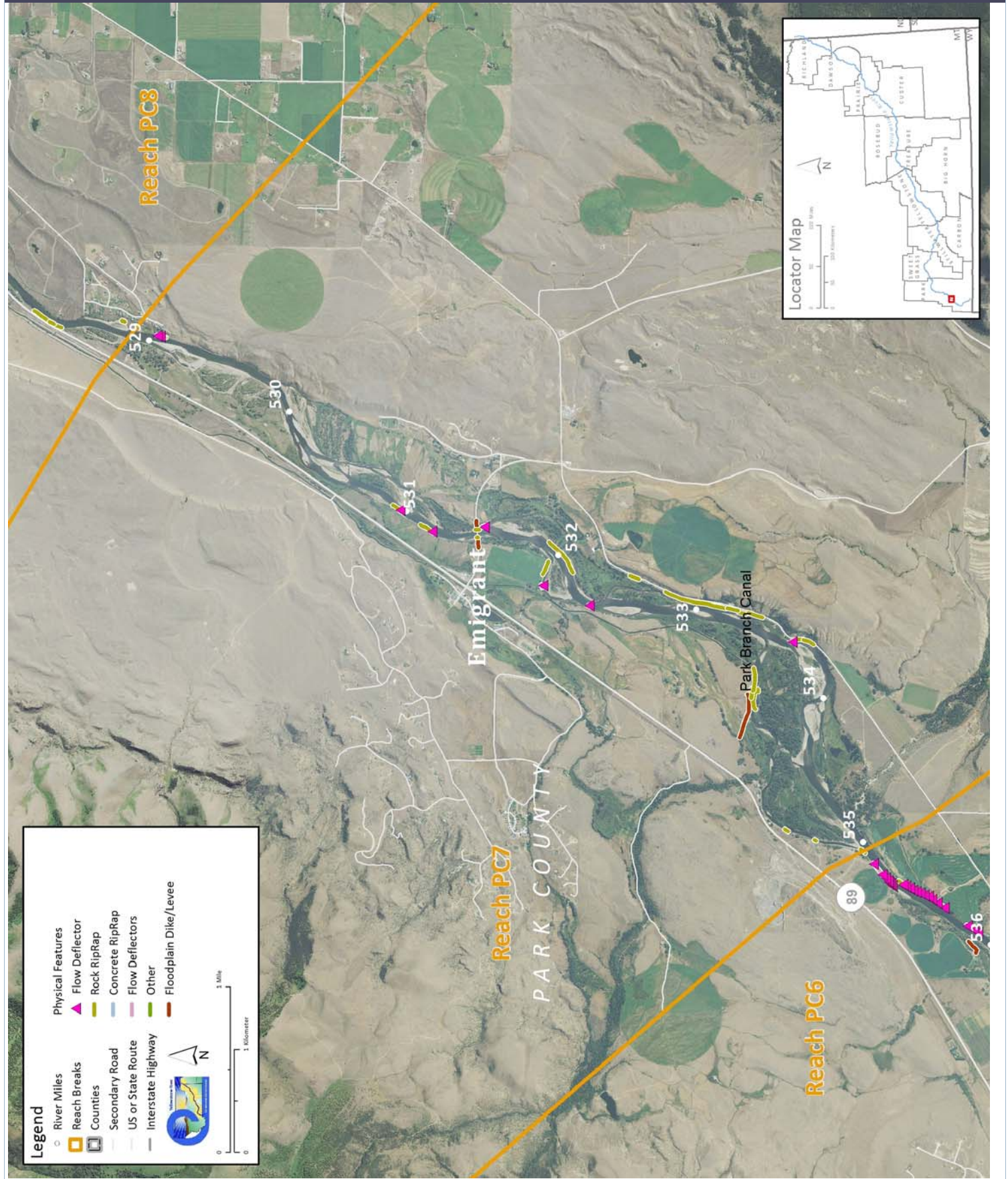
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC7 include:

- Side Channel Restoration at RM 532R.
- Diversion Infrastructure Management at Park Branch Canal, RM 535.5
- Russian olive removal

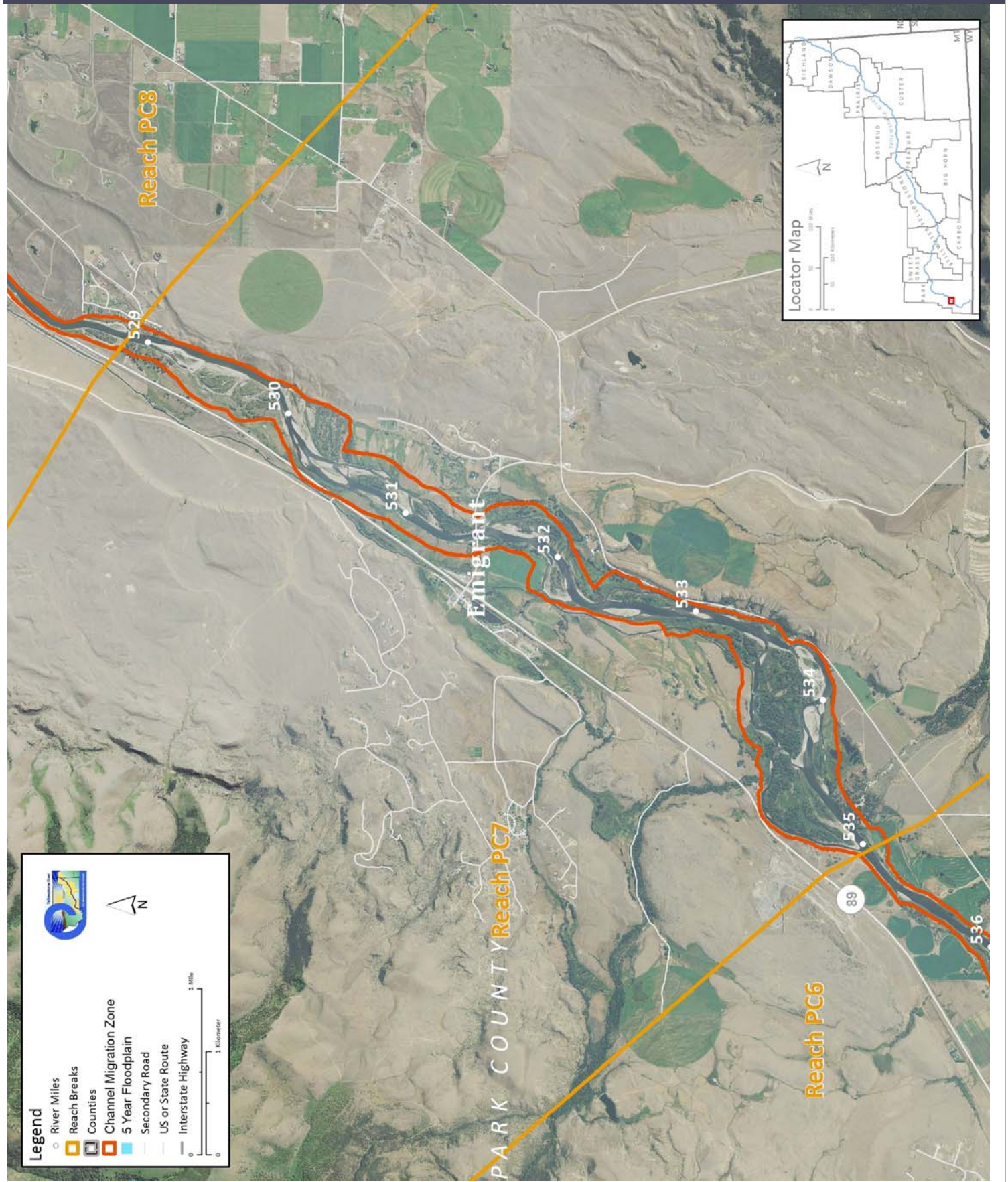
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 19,100 | 19,000 | -0.5% | | | |
| 100 Year (cfs) | 36,000 | 36,000 | 0.0% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 468.5 | | | 449.4 | -19.1 | |
| 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 | 8,840 | 13.6% | 301 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 556 | 0.9% | 54 | | | |
| Total | 9,396 | 14.4% | 354 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 2,950 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 74.3 | 6% | | | | |
| Land Use | 1950 | 2011 | 1950 | 2011 | Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land. | |
| Agricultural Land (Ac) | 1,902.0 | 1,508.7 | Flood (Ac) | 414.7 | 170.0 | |
| Ag. Infrastructure (Ac) | 60.5 | 95.1 | Sprinkler (Ac) | 0.0 | 50.5 | |
| Exurban (Ac) | 24.9 | 297.7 | Pivot (Ac) | 0.0 | 16.9 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 38.7 | 58.5 | | | | |
| 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 | 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 | 12.1 | 2.1 | 328.5 | | | |
| Emergent | 203.9 | 36.0 | | | | |
| Scrub/Shrub | 112.5 | 19.9 | | | | |
| 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. | | | |
| | 1.5 | 0.2% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

CEA-Related observations in Reach PC8 include:

- Major expansion from flood irrigation to pivot
- Conversion of agricultural land to exurban development
- Extensive armoring in naturally stable reach

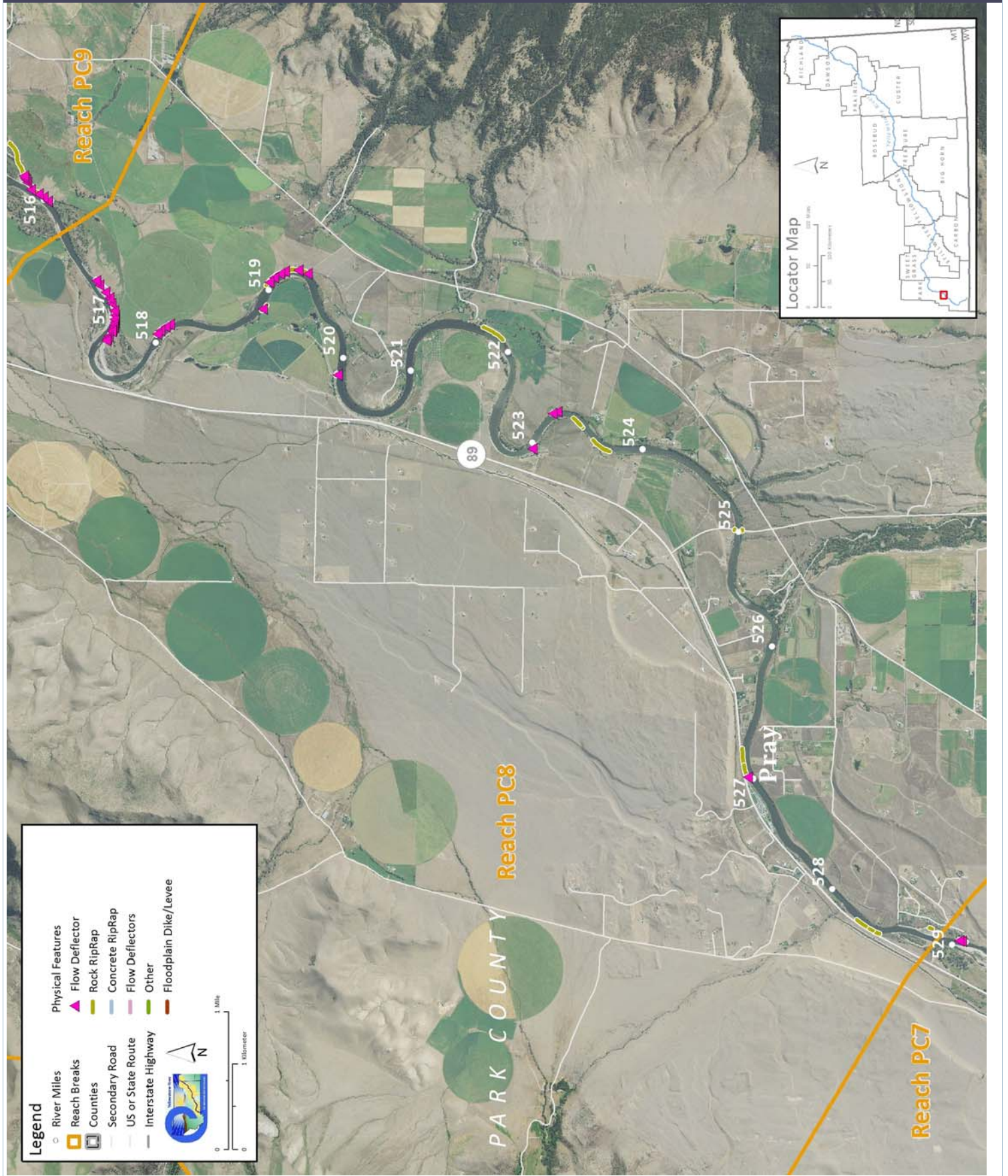
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC8 include:

- Channel Migration Zone (CMZ) management

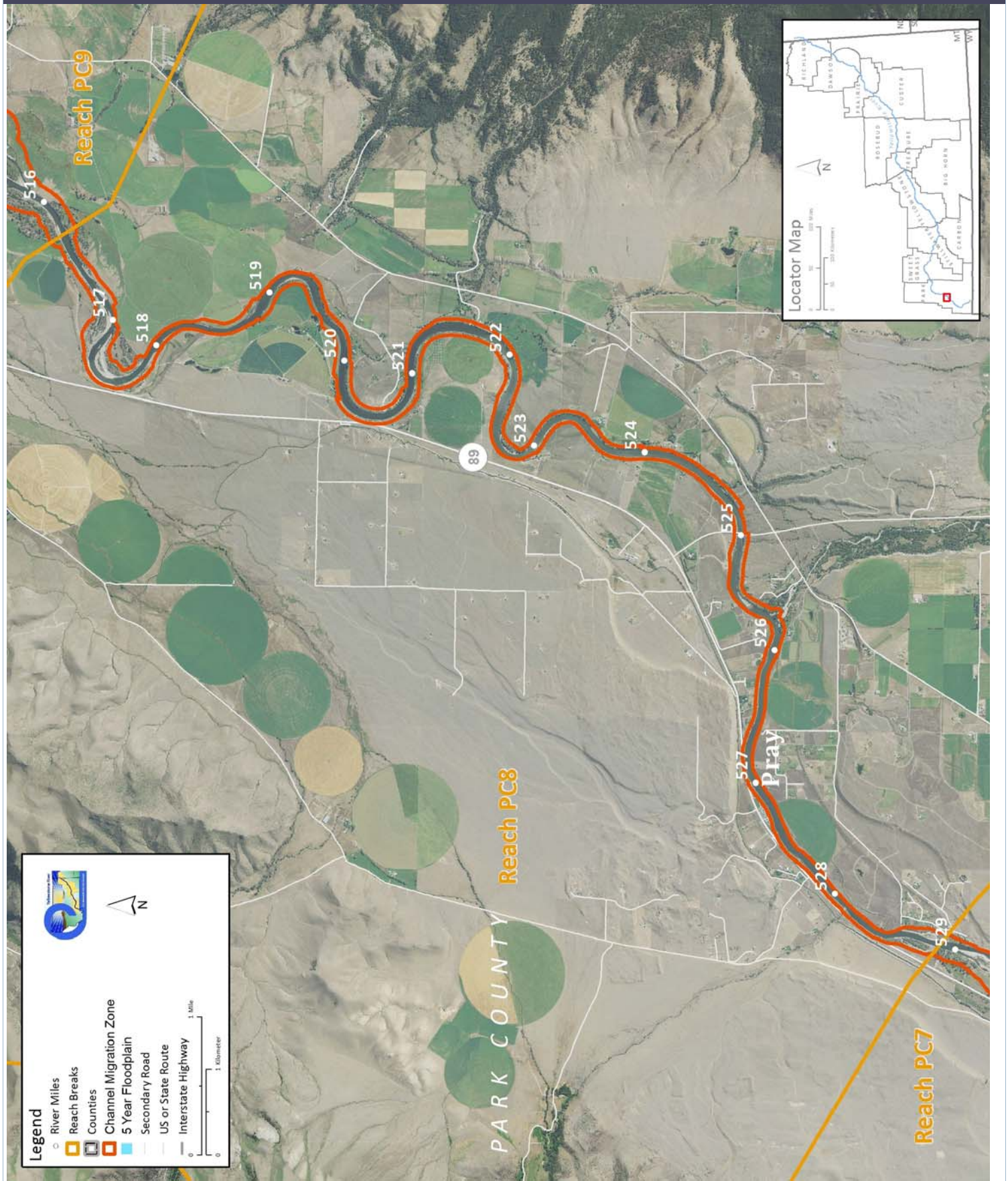
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 19,500 | 19,400 | -0.5% | | | |
| 100 Year (cfs) | 36,800 | 36,800 | 0.0% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 499.3 | | | 497.1 | -2.3 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 7,494 | 5.6% | 3,036 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 2,757 | 2.1% | 163 | | | |
| Total | 10,251 | 7.7% | 3,199 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 14.5 | 2% | | | | |
| Land Use | 1950 | 2011 | 1950 | 2011 | Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land. | |
| Agricultural Land (Ac) | 4,334.7 | 2,838.2 | Flood (Ac) | 1,368.9 | 221.1 | |
| Ag. Infrastructure (Ac) | 72.8 | 100.0 | Sprinkler (Ac) | 0.0 | 171.1 | |
| Exurban (Ac) | 13.6 | 1,433.0 | Pivot (Ac) | 0.0 | 1,014.3 | |
| Urban (Ac) | 0.0 | 3.5 | | | | |
| Transportation (Ac) | 17.1 | 63.7 | | | | |
| 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 | 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 | 3.3 | 0.3 | 48.1 | | | |
| Emergent | 43.2 | 4.5 | | | | |
| Scrub/Shrub | 1.6 | 0.2 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.7 | 0.3% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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

CEA-Related observations in Reach PC9 include:

- Major post-1995 changes in channel geomorphology upstream of natural constriction point.

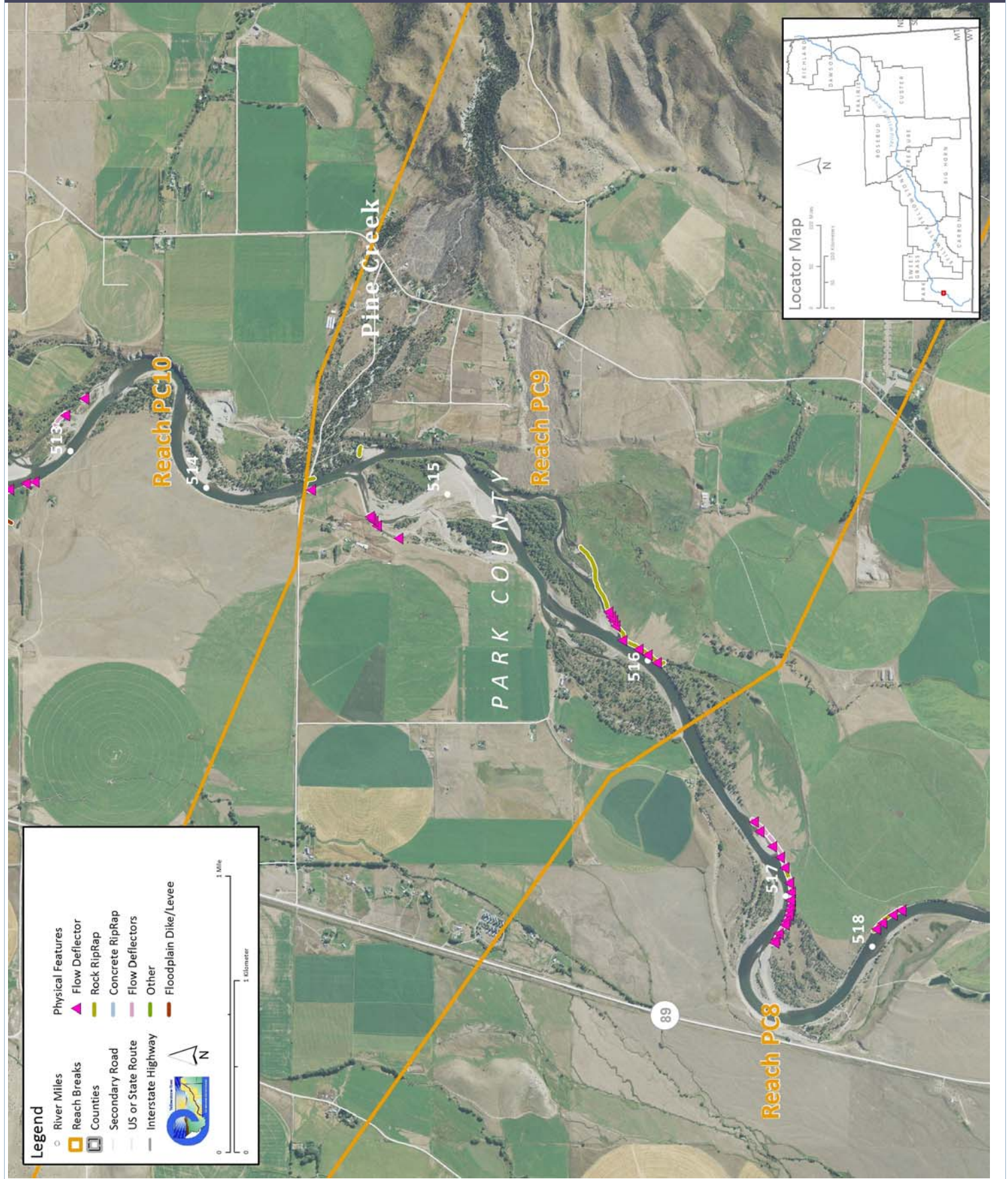
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC9 include:

- Channel Migration Zone (CMZ) management

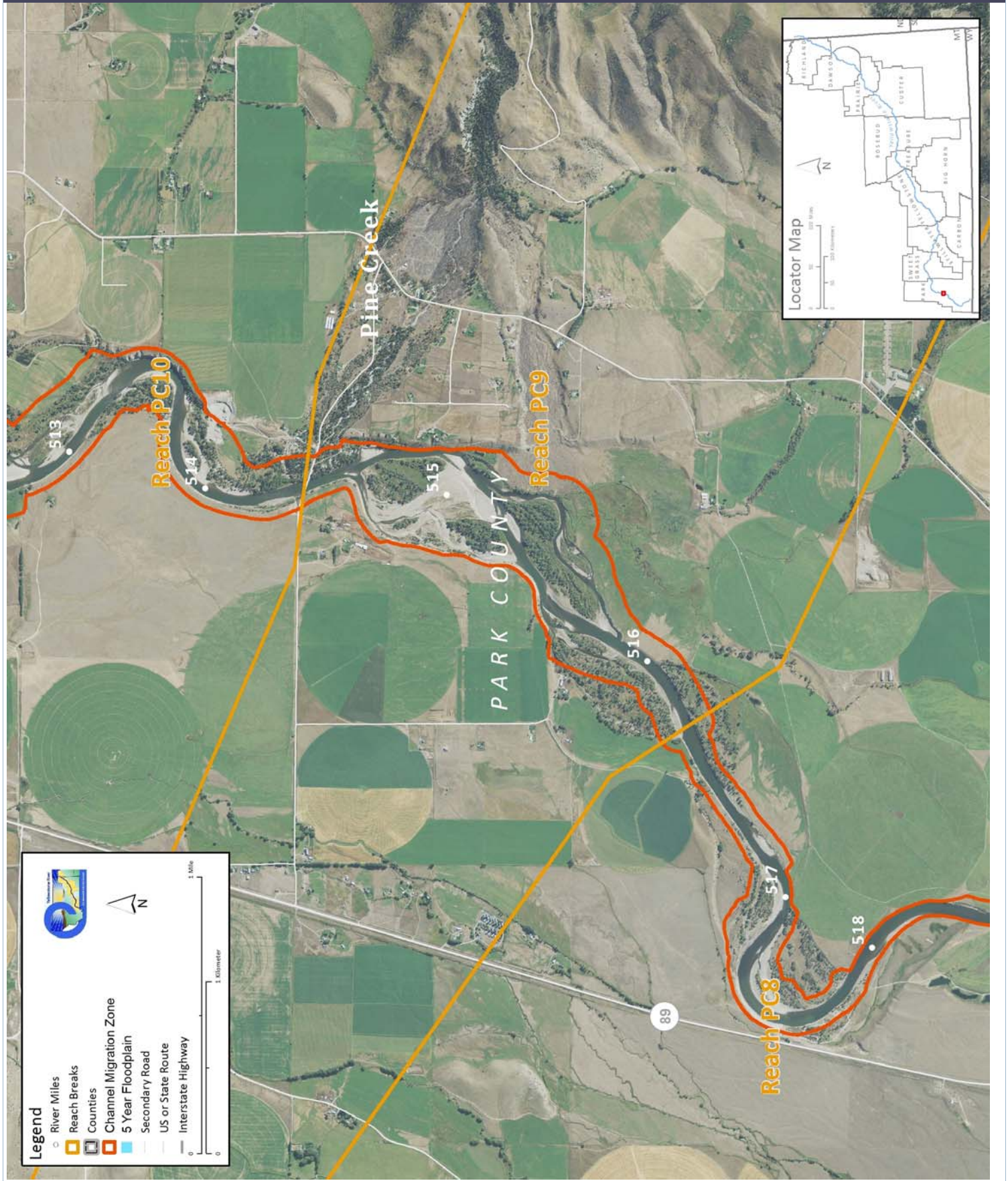
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 19,500 | 19,400 | -0.5% | | | |
| 100 Year (cfs) | 36,800 | 36,800 | 0.0% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 115.1 | | | 147.4 | 32.3 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 2,894 | 14.4% | 154 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 677 | 3.4% | -79 | | | |
| Total | 3,571 | 17.7% | 75 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 40.4 | 11% | | | | |
| Land Use | 1950 | 2011 | 1950 | 2011 | Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land. | |
| Agricultural Land (Ac) | 756.6 | 615.4 | Flood (Ac) | 198.1 | 26.9 | |
| Ag. Infrastructure (Ac) | 4.2 | 39.3 | Sprinkler (Ac) | 0.0 | 142.4 | |
| Exurban (Ac) | 0.0 | 81.6 | Pivot (Ac) | 0.0 | 93.3 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 4.8 | 4.1 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 1.1 | 0.6 | 113.6 | | | |
| Emergent | 94.8 | 55.2 | | | | |
| Scrub/Shrub | 17.7 | 10.3 | | | | |
| 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. | | | |
| | 0.1 | 0.2% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



| | | | |
|-------------------------|--|------------------------------|-------------------|
| County | Park | Upstream River Mile | 514.6 |
| Classification | PCM: Partially confined meandering | Downstream River Mile | 511 |
| General Location | To downstream of Deep Creek; Weeping wall, Jumping Rainbow; onset of spring creeks | Length | 3.60 mi (5.79 km) |

Narrative Summary

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

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

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

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

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

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

CEA-Related observations in Reach PC10 include:

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

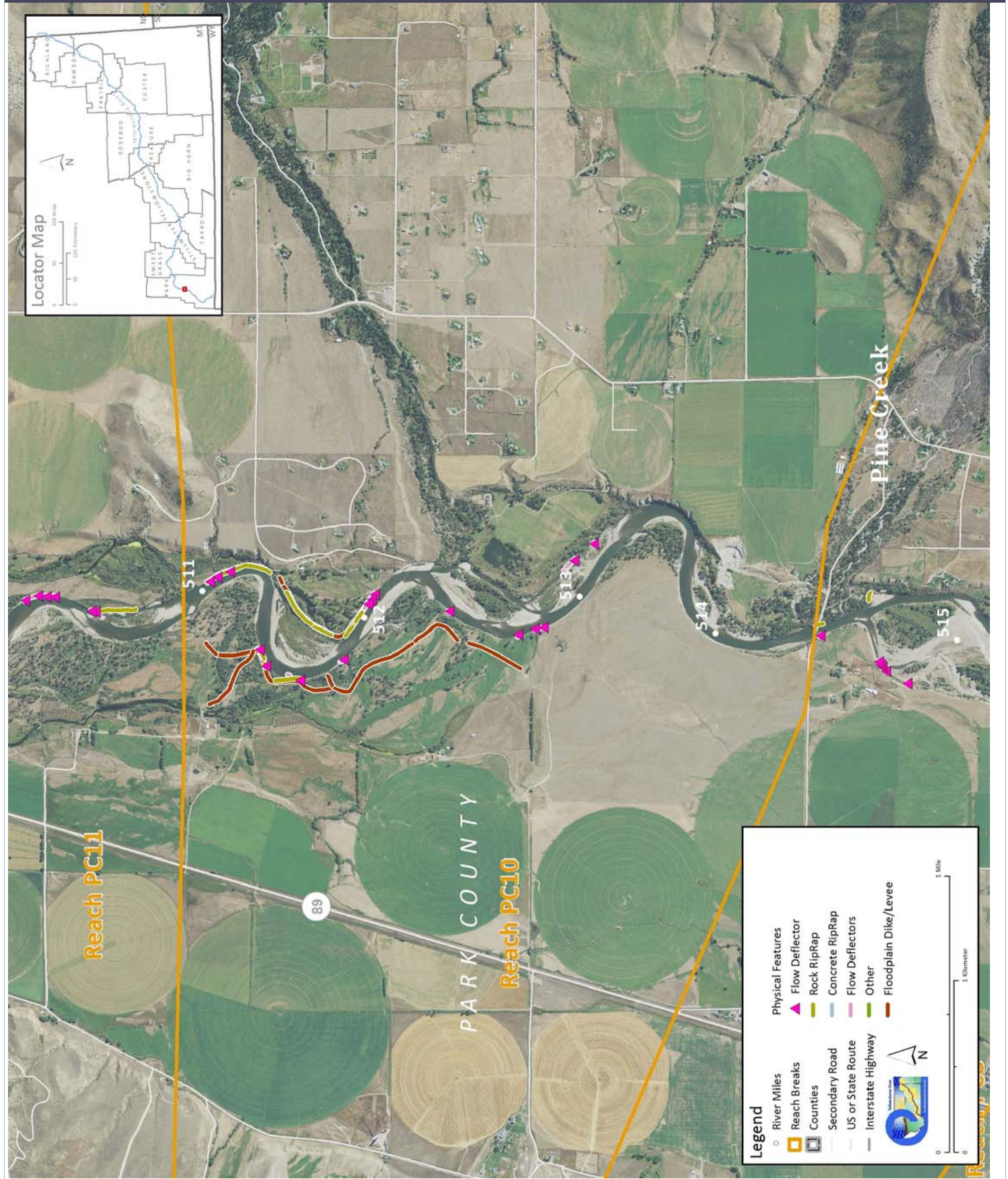
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC10 include:

- Selective side channel restoration at RM 511.5 (may be difficult to reactivate side channels without affecting developed spring creek fishery)
- CMZ Management due to current restriction of 38 percent of the Channel Migration Zone

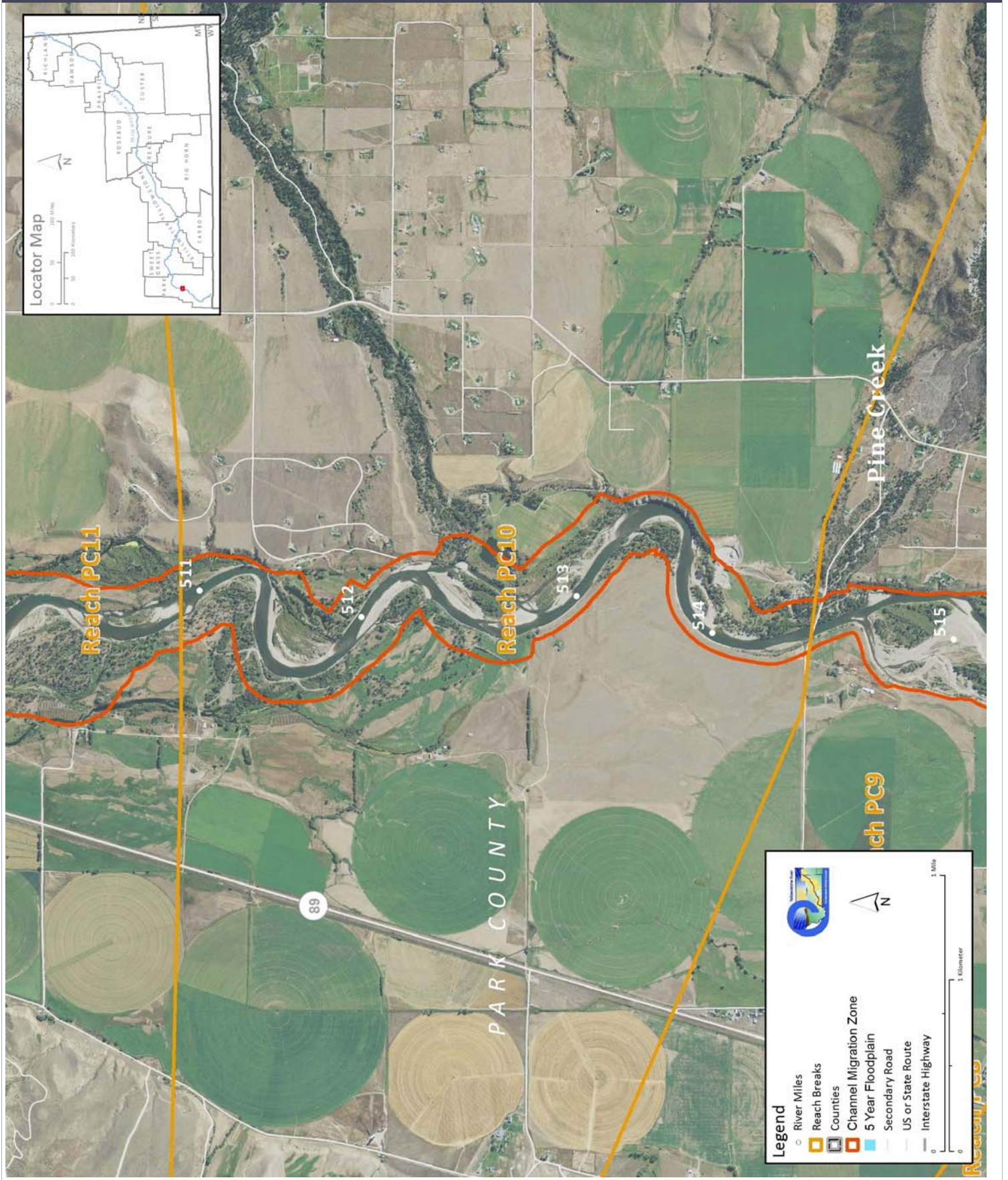
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 19,500 | 19,400 | -0.5% | | | |
| 100 Year (cfs) | 36,800 | 36,800 | 0.0% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 151.0 | | | 190.6 | 39.7 | |
| 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 | 3,753 | 10.3% | 1,086 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 1,197 | 3.3% | -50 | | | |
| Total | 4,950 | 13.5% | 1,037 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 7,000 | 1,454 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 252.8 | 38% | | | | |
| 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) | 1,329.9 | 1,061.1 | Flood (Ac) | 512.4 | 17.1 | |
| Ag. Infrastructure (Ac) | 30.9 | 54.8 | Sprinkler (Ac) | 0.0 | 135.9 | |
| Exurban (Ac) | 0.0 | 178.9 | Pivot (Ac) | 0.0 | 56.1 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 0.8 | 1.0 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 22.5 | 9.7 | 236.7 | | | |
| Emergent | 165.1 | 71.2 | | | | |
| Scrub/Shrub | 49.1 | 21.1 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.1 | 0.2% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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

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

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

CEA-Related observations in Reach PC11 include:

- Channel Migration Zone restrictions by floodplain dikes and bank armor causing simplification.
- Loss of side channel connectivity due to floodplain dikes and bank armor causing simplification.
- Increase in primary channel length with reduction in side channel length.

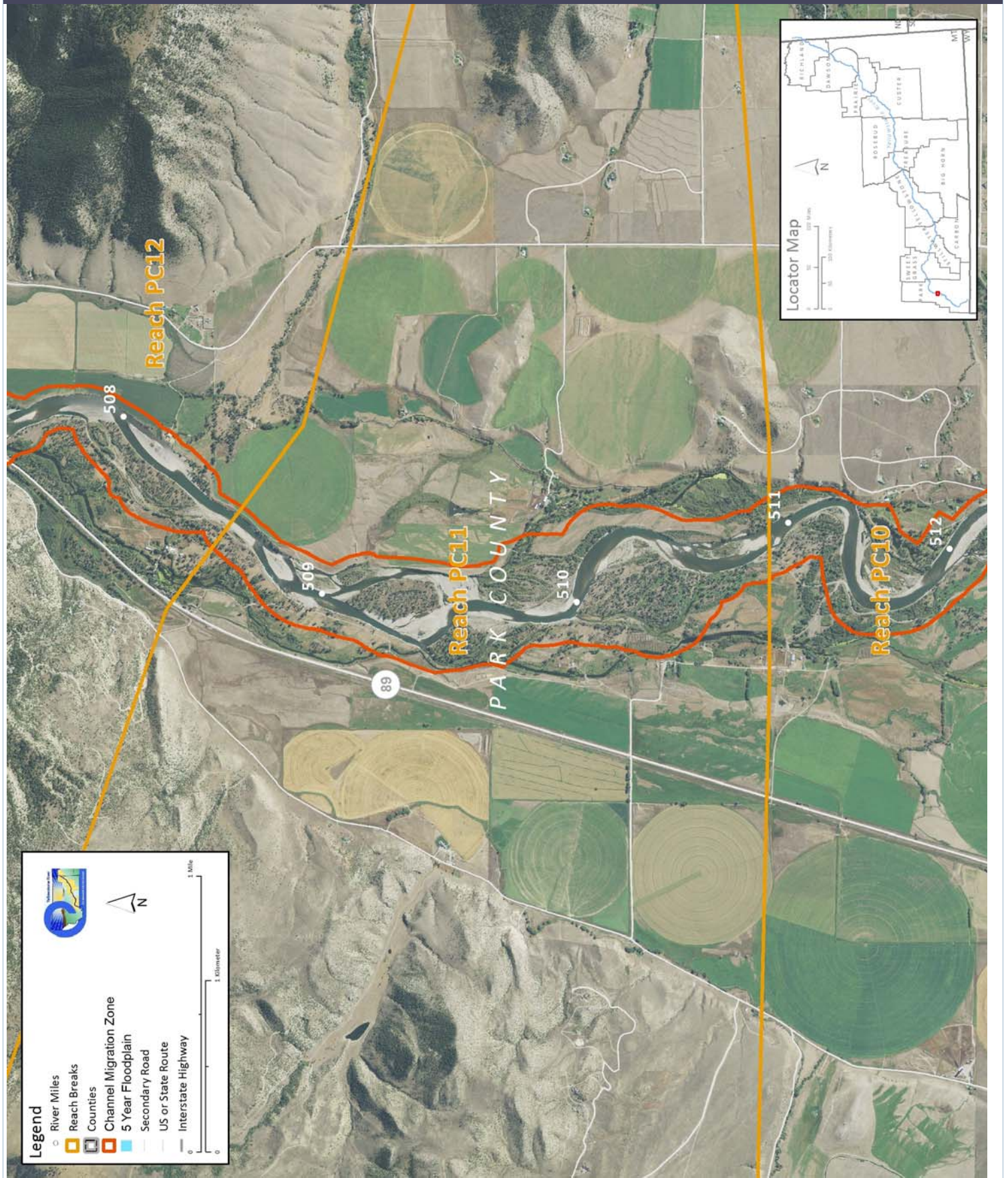
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC11 include:

- Selective side channel restoration at RM 510L (may be difficult to reactivate side channels without affecting developed spring creek fishery)
- CMZ Management due to current restriction of 26 percent of the Channel Migration Zone

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) | 19,500 | 19,400 | -0.5% | | | |
| 100 Year (cfs) | 36,800 | 36,800 | 0.0% | | | |
| 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. |
| | 147.8 | | | 187.6 | 39.9 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 8,645 | 34.8% | 45 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 2,047 | 8.2% | -238 | | | |
| Total | 10,692 | 43.0% | -193 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 1,990 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 154.7 | 26% | | | | |
| 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) | 1,057.0 | 933.5 | Flood (Ac) | 501.0 | 138.5 | |
| Ag. Infrastructure (Ac) | 18.7 | 64.2 | Sprinkler (Ac) | 0.0 | 102.2 | |
| Exurban (Ac) | 0.0 | 2.2 | Pivot (Ac) | 0.0 | 79.5 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 6.1 | 14.0 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 27.5 | 13.5 | 158.0 | | | |
| Emergent | 75.5 | 37.1 | | | | |
| Scrub/Shrub | 55.0 | 27.0 | | | | |
| 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. | | | |
| | 0.3 | 0.1% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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

CEA-Related observations in Reach PC12 include:

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

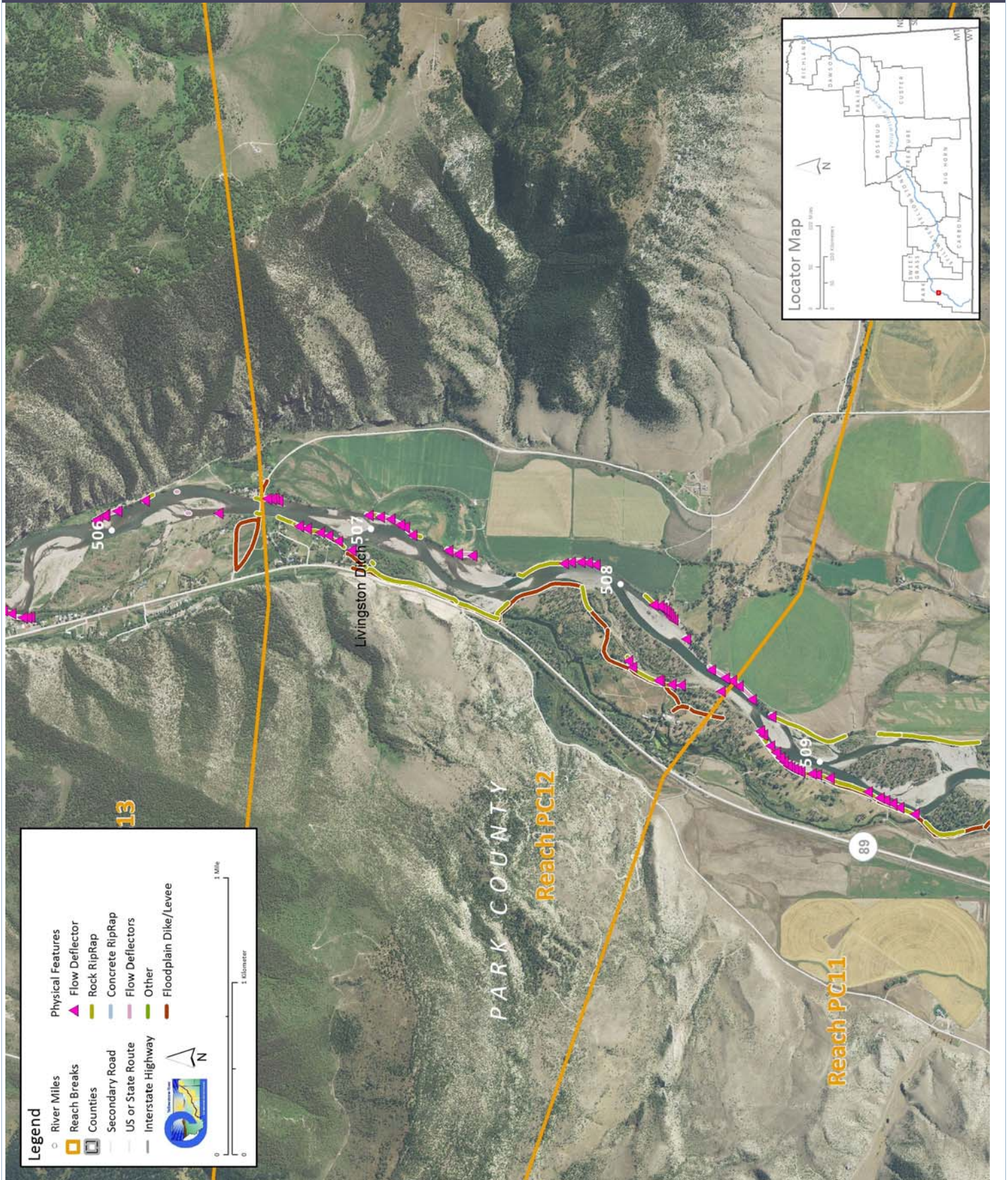
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC12 include:

- Side channel restoration at RM 508L
- CMZ Management due to current restriction of 39 percent of the Channel Migration Zone
- Bank Stabilization Recommended Practices due to 55 percent of banks being armored in reach
- Irrigation diversion management at Livingston Ditch Diversion

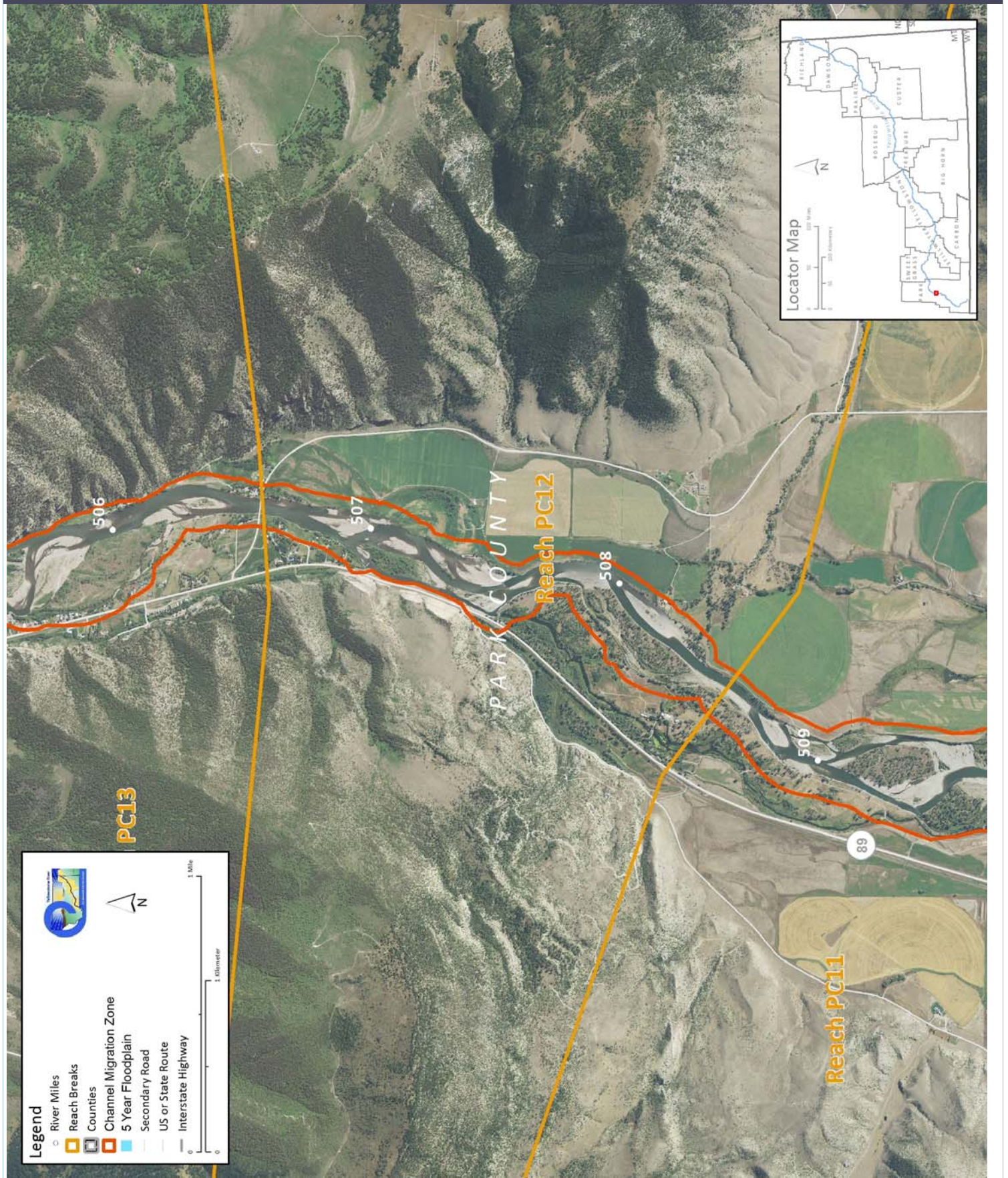
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 20,300 | 20,200 | -0.5% | | | |
| 100 Year (cfs) | 38,200 | 38,100 | -0.3% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 129.5 | | | 125.0 | -4.5 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 7,267 | 35.1% | 109 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 4,106 | 19.9% | -73 | | | |
| Total | 11,373 | 55.0% | 36 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 155.2 | 39% | | | | |
| 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) | 825.0 | 749.2 | Flood (Ac) | 343.0 | 89.4 | |
| Ag. Infrastructure (Ac) | 39.0 | 57.1 | Sprinkler (Ac) | 0.0 | 201.3 | |
| Exurban (Ac) | 0.0 | 50.8 | Pivot (Ac) | 0.0 | 16.1 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 19.3 | 19.0 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| National Wetlands Inventory | Acres | Acres per Valley Mi | Total Wetland Acres | Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation). | | |
| Riverine | 19.8 | 10.8 | 115.8 | | | |
| Emergent | 67.5 | 36.8 | | | | |
| Scrub/Shrub | 28.5 | 15.6 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.2 | 0.1% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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

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

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

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

CEA-Related observations in Reach PC13 include:

- Transformation from a multi-thread, anabranching reach type to a single thread channel with open bars.
- Abandonment of over a mile of side channels since 1950 in a 1.7 mile long reach.

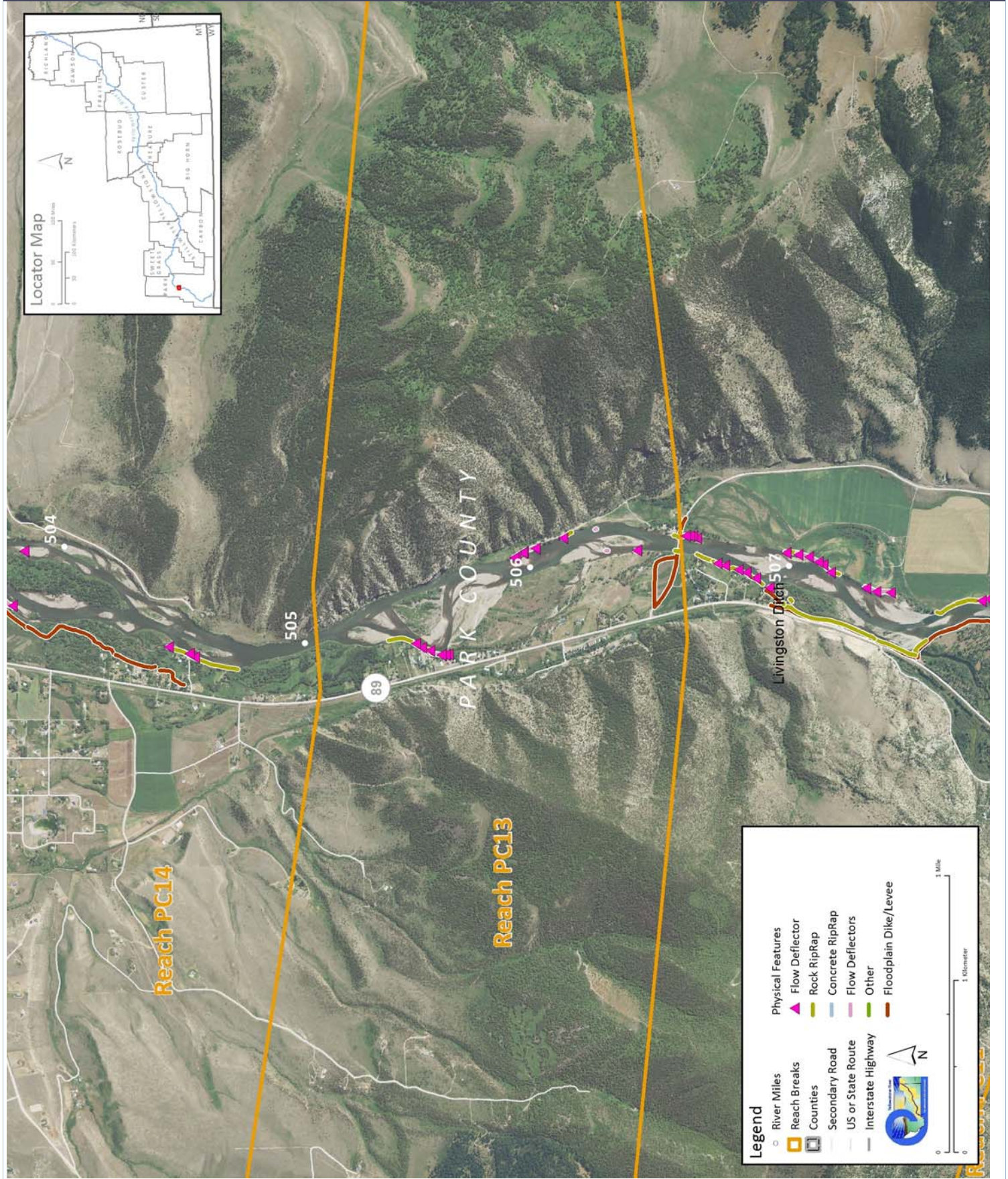
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC13 include:

- CMZ Management due to development pressure in confined reach

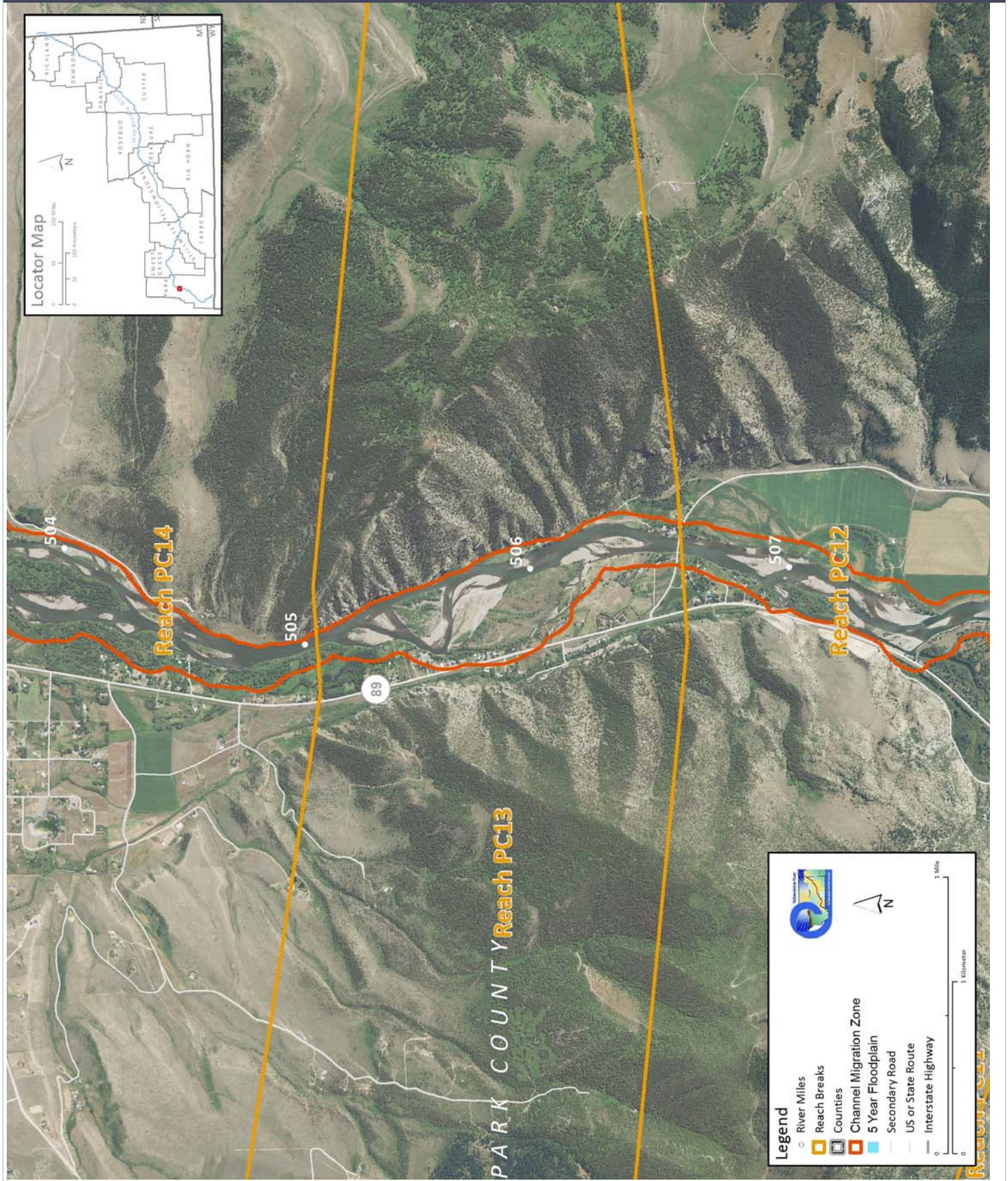
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 20,300 | 20,200 | -0.5% | | | |
| 100 Year (cfs) | 38,200 | 38,100 | -0.3% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 94.6 | | | 109.2 | 14.6 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 1,240 | 7.6% | 153 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 875 | 5.3% | -201 | | | |
| Total | 2,115 | 12.9% | -49 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 19.3 | 8% | | | | |
| Land Use | 1950 | 2011 | Flood (Ac) | 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) | 291.6 | 212.4 | | 35.9 | 4.2 | |
| Ag. Infrastructure (Ac) | 1.6 | 3.9 | Sprinkler (Ac) | 0.0 | 0.0 | |
| Exurban (Ac) | 5.0 | 82.1 | Pivot (Ac) | 0.0 | 0.0 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 12.3 | 11.6 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 0.5 | 0.3 | 12.2 | | | |
| Emergent | 8.4 | 6.1 | | | | |
| Scrub/Shrub | 3.3 | 2.4 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.2 | 0.1% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

CEA-Related observations in Reach PC14 include:

- Physical features blocking over 13,000 feet of side channels.
- Riprap failure at head of Siebeck Island
- Extensive CMZ Restriction with floodplain development.

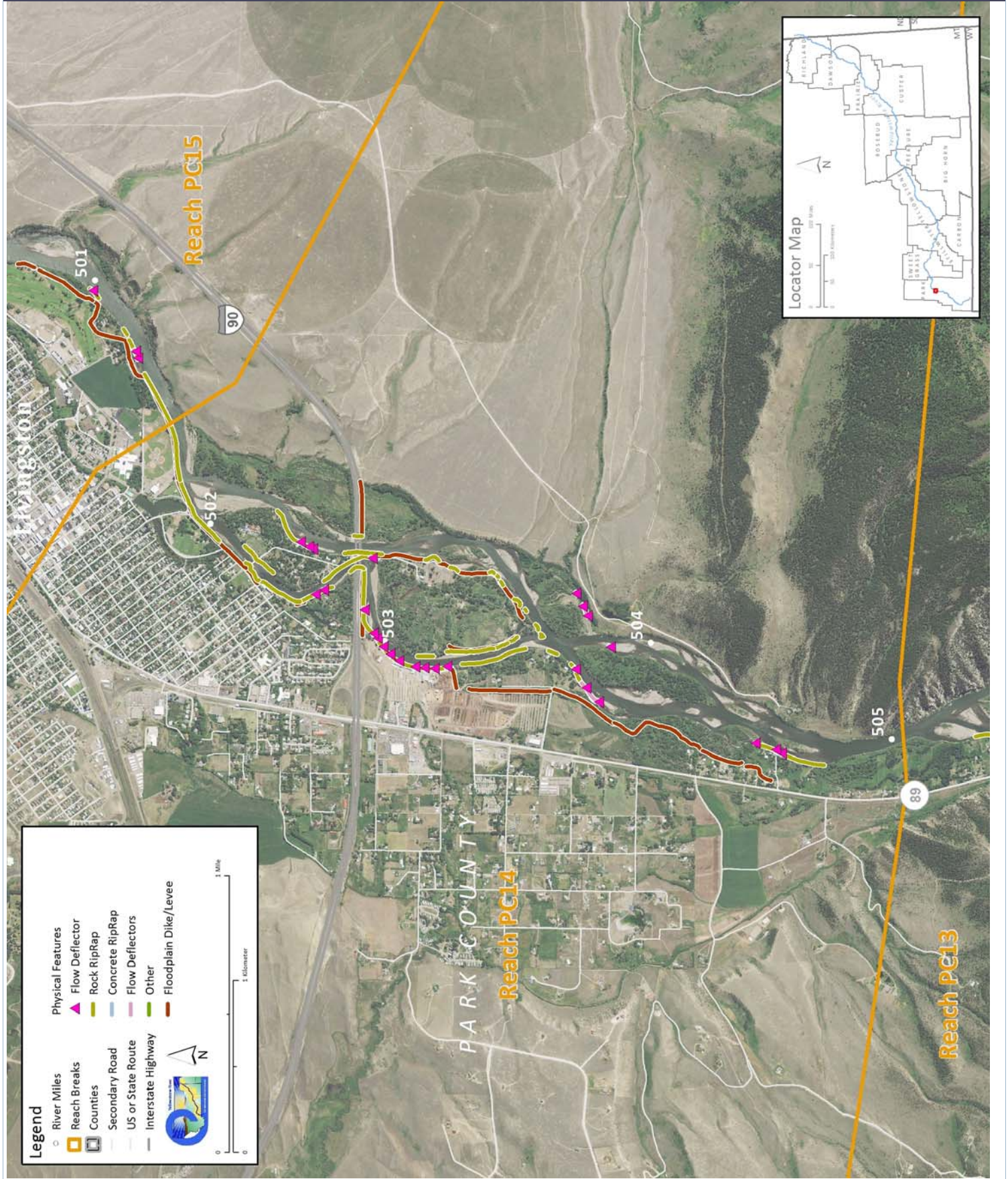
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC14 include:

- Side channel restoration at RM 504.6L
- Bank armor removal at head of Siebeck Island at RM 503.8
- CMZ management due to 38 percent restriction of Channel Migration Zone
- Russian olive removal
- Bank Stabilization Recommended Practices due to extensive armoring in reach (51 percent of bankline)

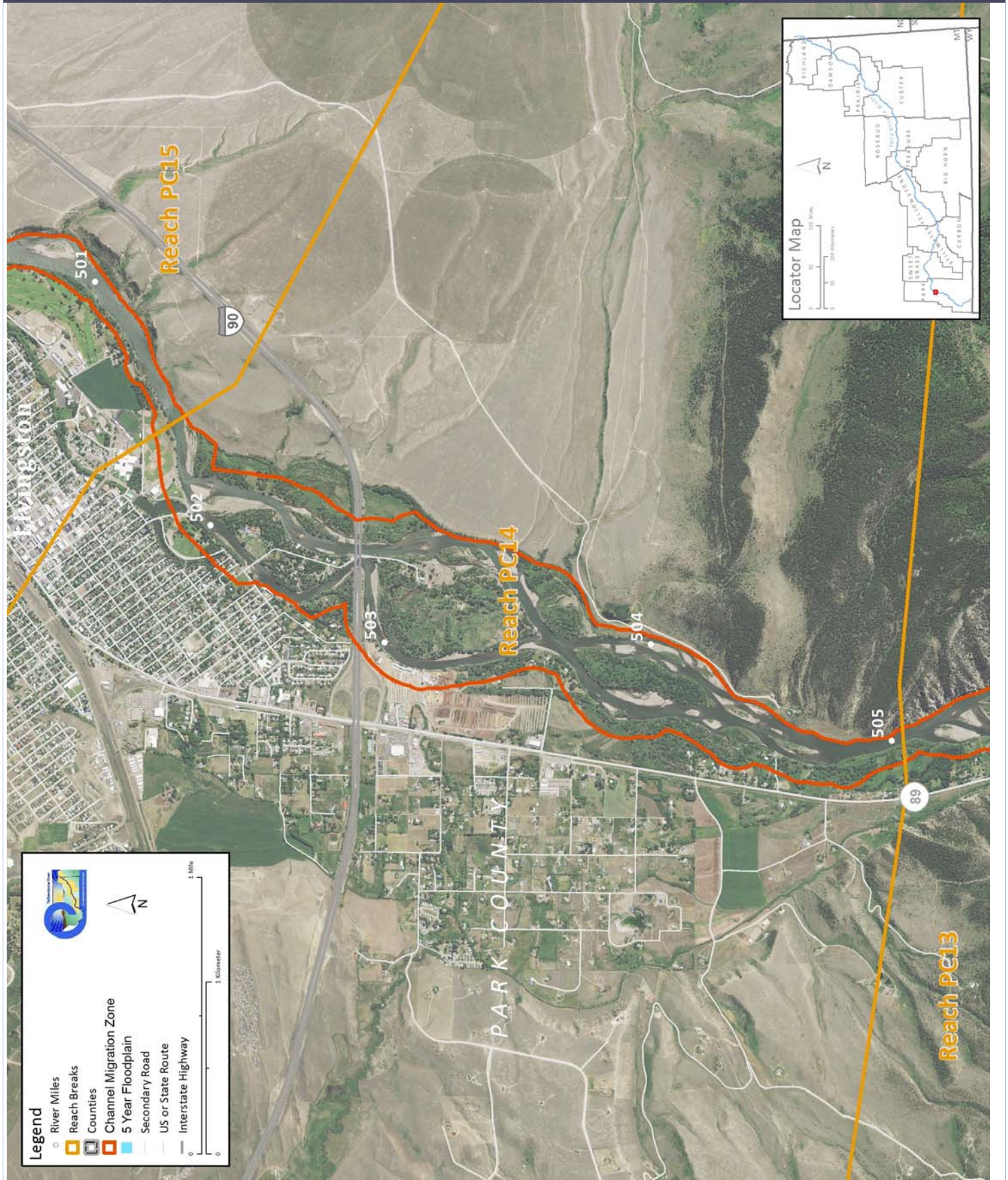
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 20,300 | 20,200 | -0.5% | | | |
| 100 Year (cfs) | 38,200 | 38,100 | -0.3% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 216.2 | | | 240.0 | 23.8 | |
| 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 | 16,931 | 46.4% | -389 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 1,581 | 4.3% | -8 | | | |
| Total | 18,512 | 50.7% | -398 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 8,601 | 5,546 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 268.2 | 38% | | | | |
| 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) | 811.2 | 444.1 | Flood (Ac) | 149.7 | 0.8 | |
| Ag. Infrastructure (Ac) | 2.1 | 1.4 | Sprinkler (Ac) | 0.0 | 32.9 | |
| Exurban (Ac) | 37.5 | 266.5 | Pivot (Ac) | 0.0 | 0.0 | |
| Urban (Ac) | 277.1 | 328.2 | | | | |
| Transportation (Ac) | 18.4 | 74.7 | | | | |
| 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 | Total Wetland Acres | Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation). | | |
| Riverine | 15.3 | 5.1 | 93.0 | | | |
| Emergent | 26.4 | 8.8 | | | | |
| Scrub/Shrub | 51.2 | 17.1 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 4.7 | 0.9% | | | | |
| 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



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

Narrative Summary

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

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

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

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

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

CEA-Related observations in Reach PC15 include:

- Physical features blocking over 13,000 feet of side channels.
- Extensive CMZ Restriction with floodplain development.

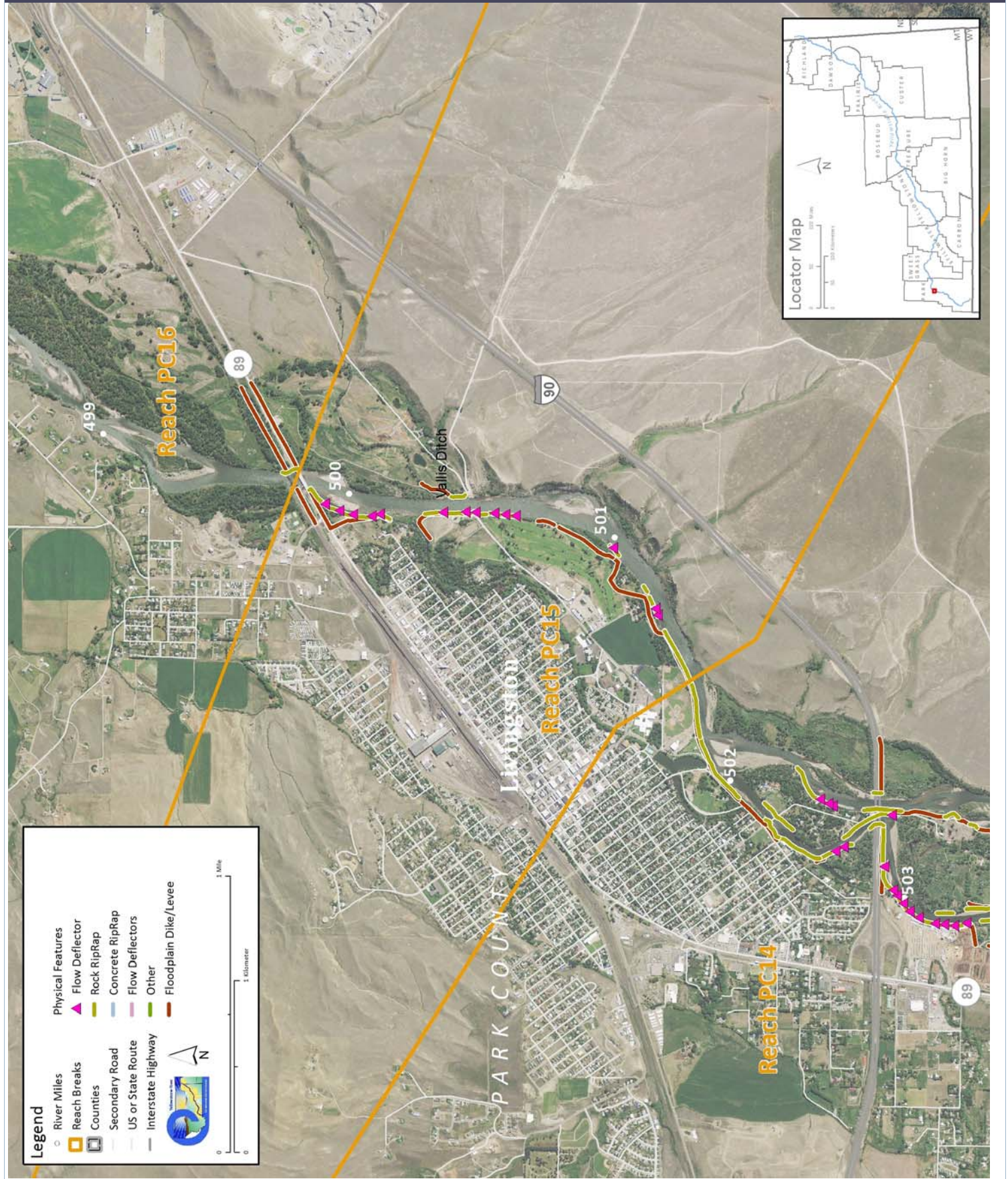
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC15 include:

- CMZ Management due to current restriction of 53 percent of the Channel Migration Zone
- Channel Bank Stabilization Recommended Practices due to 29 percent of banks being armored in reach
- Irrigation diversion management at Vallis Ditch Diversion

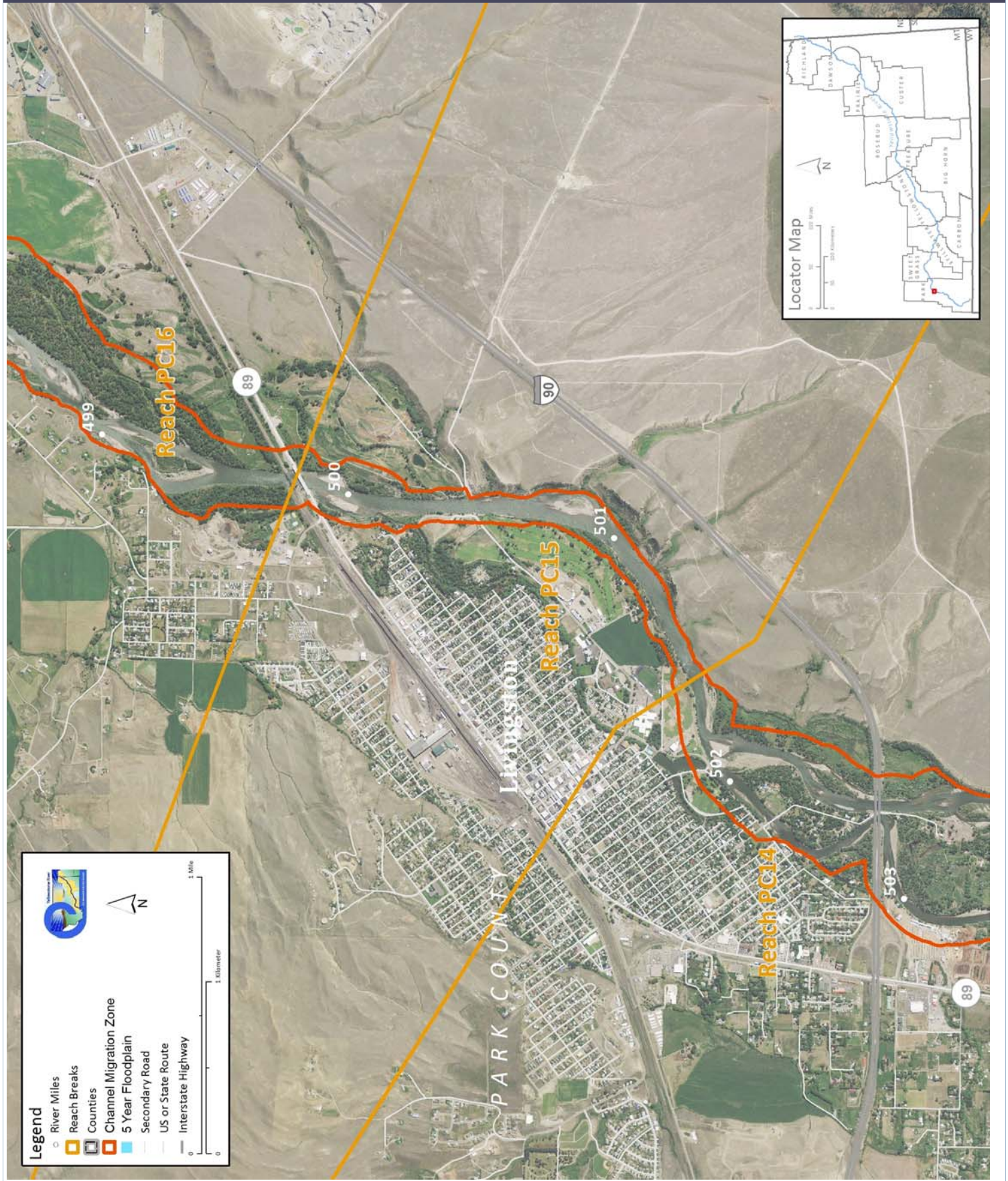
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 20,300 | 20,200 | -0.5% | | | |
| 100 Year (cfs) | 38,200 | 38,100 | -0.3% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 86.6 | | | 99.9 | 13.3 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 4,880 | 25.8% | 243 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 613 | 3.2% | -139 | | | |
| Total | 5,493 | 29.1% | 104 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 232.1 | 53% | | | | |
| Land Use | 1950 | 2011 | Flood (Ac) | 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) | 517.5 | 368.5 | Sprinkler (Ac) | 13.5 | 0.0 | |
| Ag. Infrastructure (Ac) | 6.7 | 25.6 | Pivot (Ac) | 0.0 | 18.1 | |
| Exurban (Ac) | 7.7 | 50.7 | | | | |
| Urban (Ac) | 393.6 | 463.3 | | | | |
| Transportation (Ac) | 31.5 | 33.6 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| National Wetlands Inventory | Acres | Acres per Valley Mi | Total Wetland Acres | | Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation). | |
| Riverine | 2.8 | 1.6 | 50.5 | | | |
| Emergent | 36.7 | 20.9 | | | | |
| Scrub/Shrub | 10.9 | 6.2 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.7 | 0.2% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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

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

CEA-Related observations in Reach PC16 include:

- Flanking of flow deflectors and sever erosion behind.

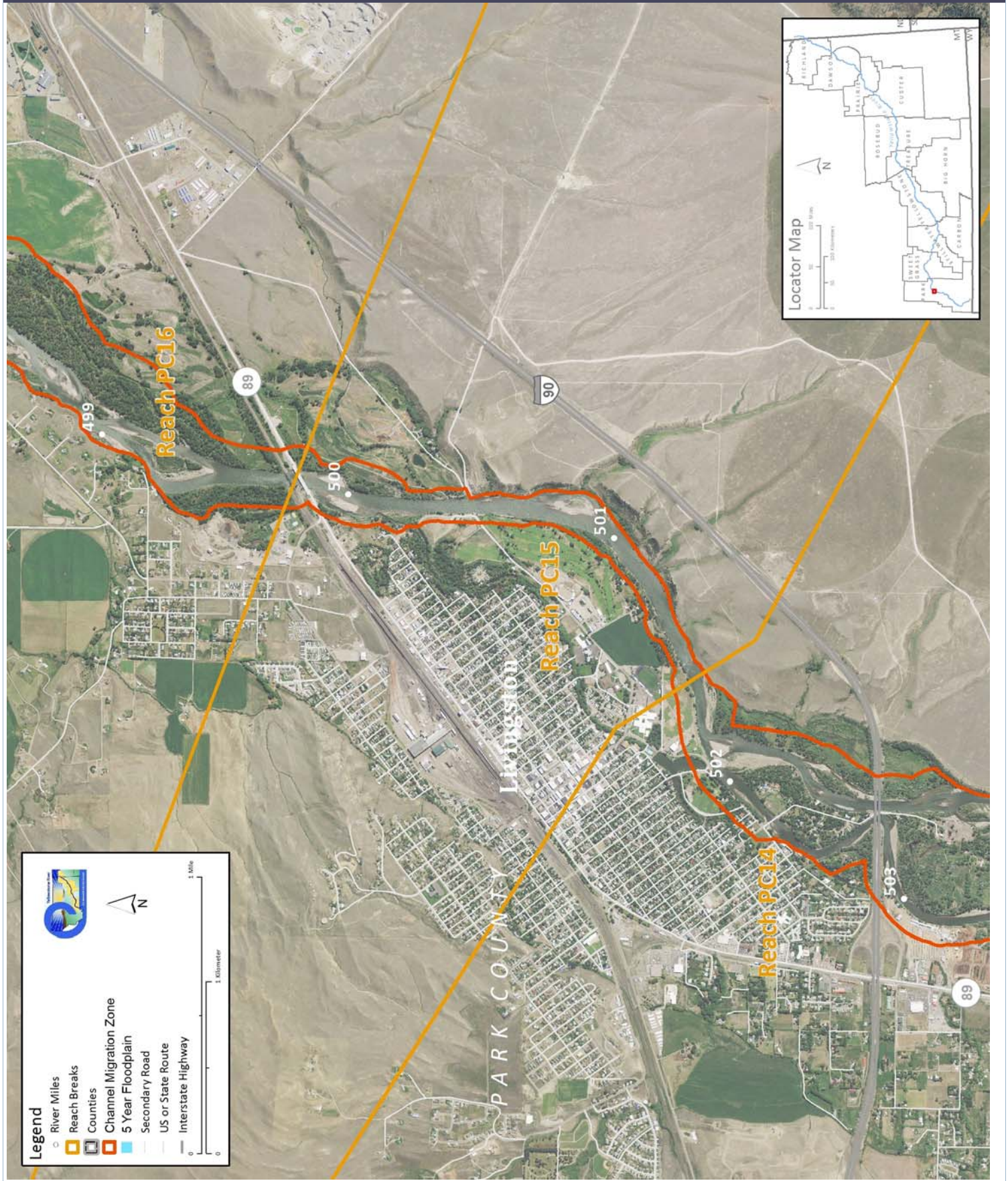
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC16 include:

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

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) | 20,600 | 20,500 | -0.5% | | | |
| 100 Year (cfs) | 38,700 | 38,600 | -0.3% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 253.3 | | | 308.0 | 54.7 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 6,474 | 14.2% | 2,276 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 1,703 | 3.7% | -206 | | | |
| Total | 8,178 | 18.0% | 2,069 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 1,901 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 139.8 | 14% | | | | |
| Land Use | 1950 | 2011 | 1950 | 2011 | Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land. | |
| Agricultural Land (Ac) | 1,961.2 | 1,530.1 | Flood (Ac) | 662.0 | 69.8 | |
| Ag. Infrastructure (Ac) | 46.6 | 155.8 | Sprinkler (Ac) | 0.0 | 172.9 | |
| Exurban (Ac) | 1.0 | 208.4 | Pivot (Ac) | 0.0 | 245.7 | |
| Urban (Ac) | 7.7 | 69.4 | | | | |
| Transportation (Ac) | 32.4 | 32.8 | | | | |
| 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. | |
| | | | | | | |
| National Wetlands Inventory | Acres | Acres per Valley Mi | Total Wetland Acres | Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation). | | |
| Riverine | 10.6 | 2.7 | 216.5 | | | |
| Emergent | 154.4 | 39.4 | | | | |
| Scrub/Shrub | 51.5 | 13.1 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.8 | 0.1% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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

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

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

CEA-Related observations in Reach PC17 include:

- Constriction of CMZ at bridge and poor river alignment to structure.
- Side channel blockage by transportation embankment.

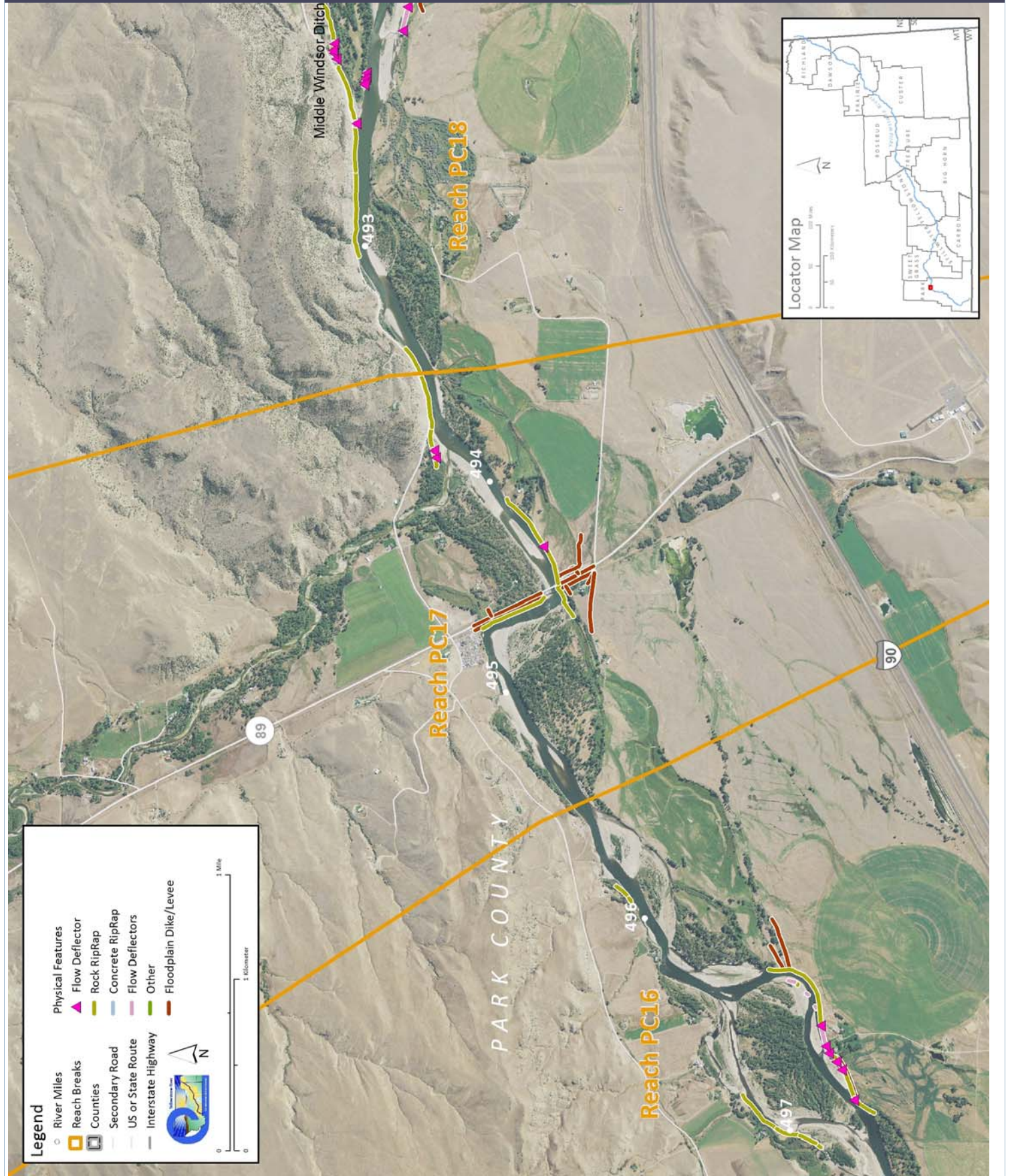
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC17 include:

- Floodplain restoration/connectivity below transportation embankment at RM 494.5
- Side channel restoration below transportation embankment at RM 494.5
- CMZ Management due to current restriction of 25 percent of the Channel Migration Zone
- Bank Stabilization Recommended Practices due to the extent of armoring in the reach (28 percent armored banks)

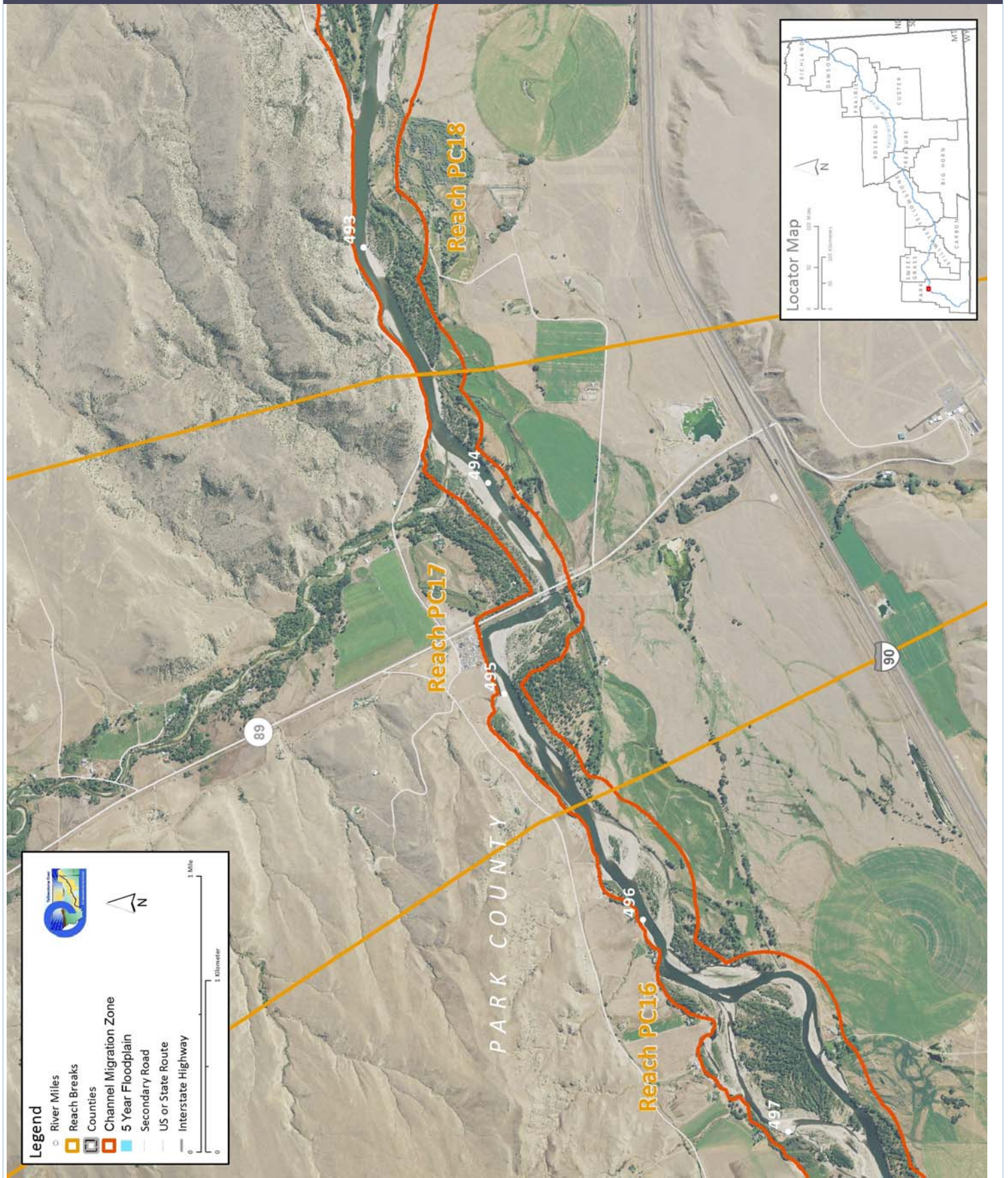
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 20,600 | 20,500 | -0.5% | | | |
| 100 Year (cfs) | 38,700 | 38,600 | -0.3% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 92.4 | | | 118.1 | 25.7 | |
| 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 | 5,704 | 27.3% | -56 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 134 | 0.6% | 56 | | | |
| Total | 5,838 | 28.0% | 0 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 3,948 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 106.0 | 25% | | | | |
| Land Use | 1950 | 2011 | 1950 | 2011 | Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land. | |
| Agricultural Land (Ac) | 845.9 | 736.1 | Flood (Ac) | 383.7 | 18.3 | |
| Ag. Infrastructure (Ac) | 10.9 | 43.6 | Sprinkler (Ac) | 0.0 | 60.4 | |
| Exurban (Ac) | 0.0 | 39.7 | Pivot (Ac) | 0.0 | 46.7 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 18.4 | 20.0 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| National Wetlands Inventory | Acres | Acres per Valley Mi | Total Wetland Acres | Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation). | | |
| Riverine | 2.0 | 1.2 | 86.1 | | | |
| Emergent | 65.1 | 37.9 | | | | |
| Scrub/Shrub | 19.0 | 11.0 | | | | |
| 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. | | | |
| | 0.3 | 0.1% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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

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

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

CEA-Related observations in Reach PC18 include:

- Blocked side channels that are thousands of feet long.
- Concentrated Russian olive infestation within mapped emergent wetland.

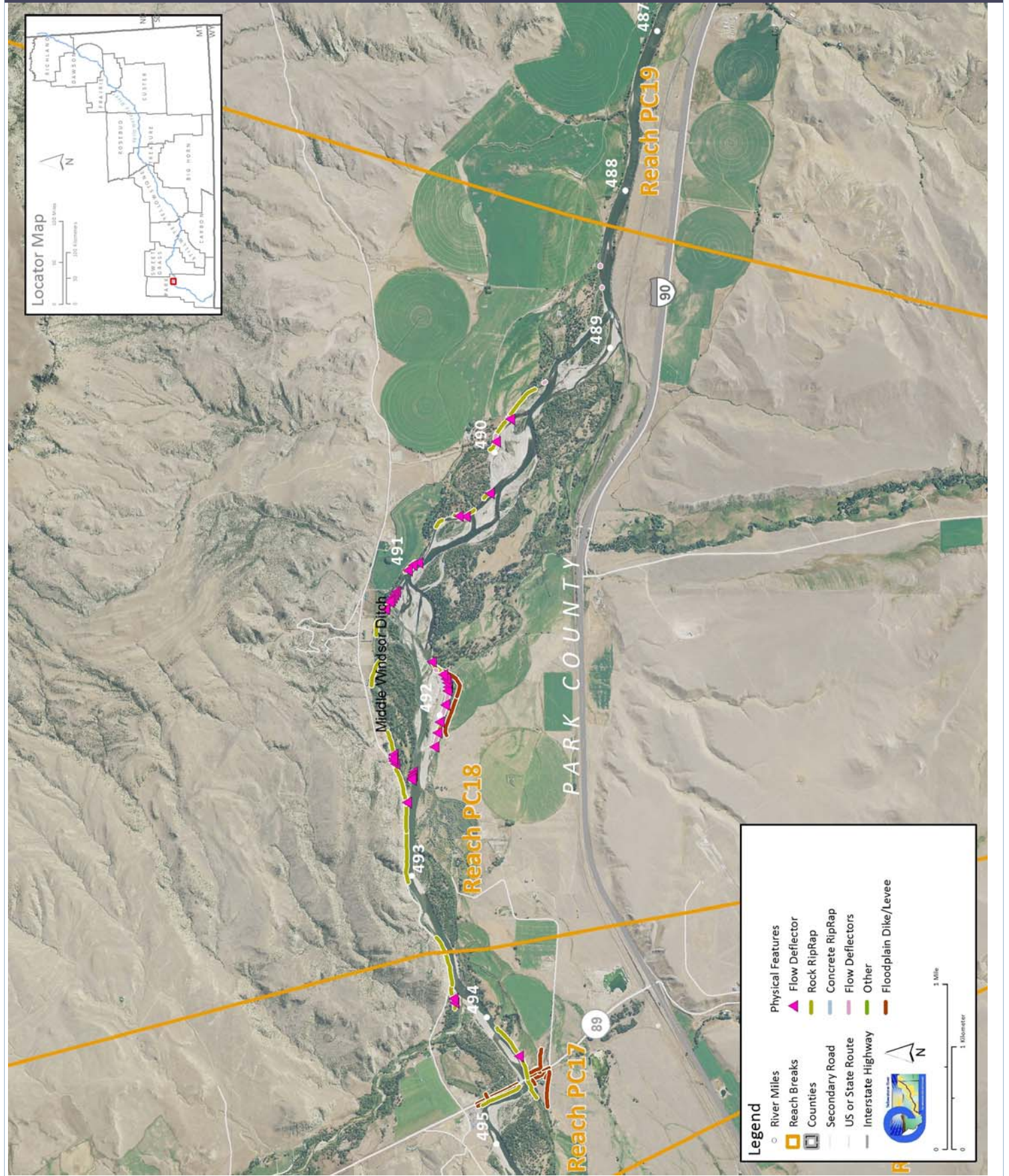
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC18 include:

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

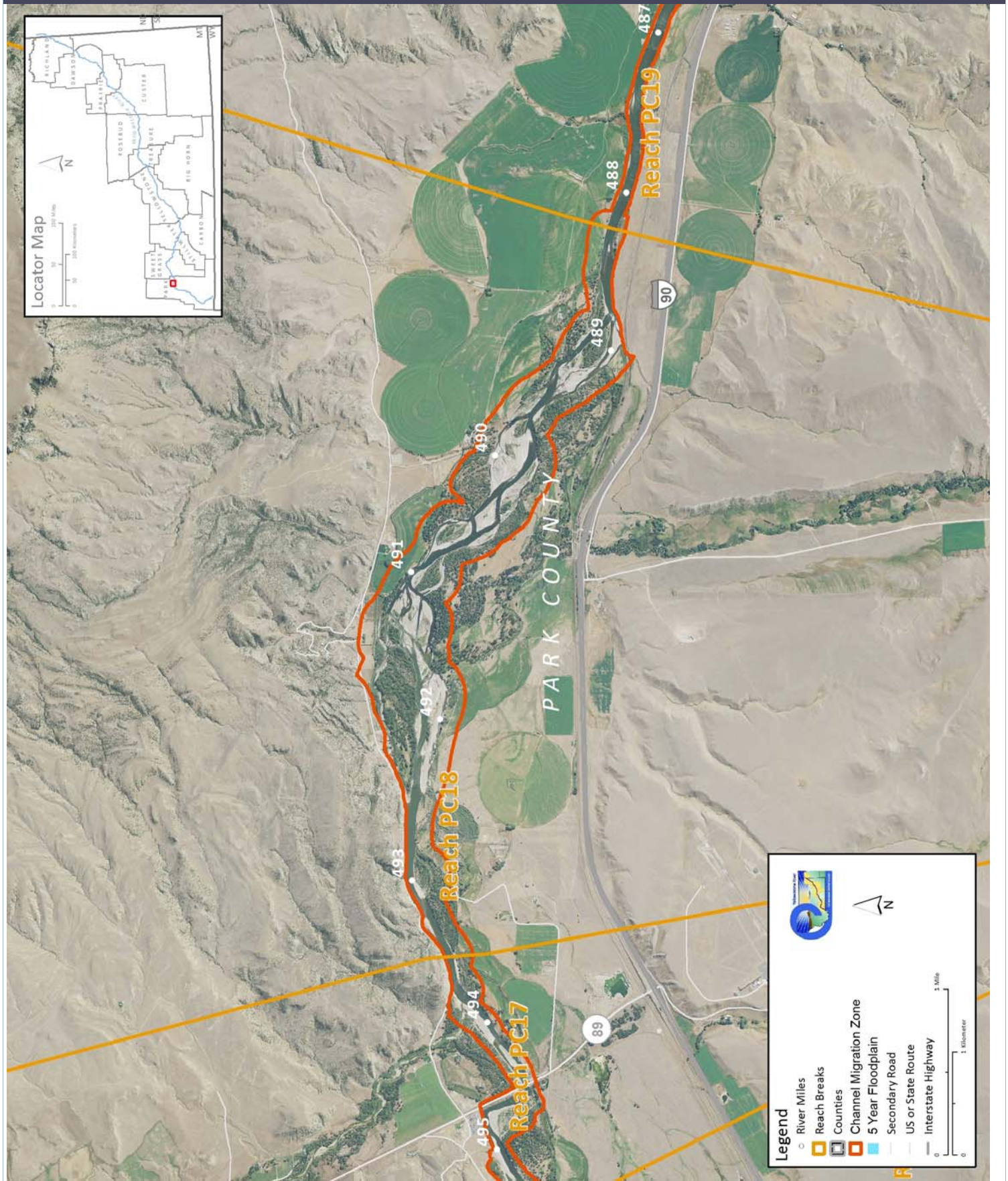
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 22,400 | 22,000 | -1.8% | | | |
| 100 Year (cfs) | 41,800 | 41,600 | -0.5% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 327.7 | | | 399.4 | 71.7 | |
| 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 | 11,486 | 20.6% | 1,836 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 3,462 | 6.2% | 1,748 | | | |
| Total | 14,948 | 26.8% | 3,584 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 3,369 | 7,999 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 184.6 | 14% | | | | |
| Land Use | 1950 | 2011 | 1950 | 2011 | Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land. | |
| Agricultural Land (Ac) | 3,092.7 | 2,728.1 | Flood (Ac) | 1,364.7 | 302.5 | |
| Ag. Infrastructure (Ac) | 86.3 | 170.6 | Sprinkler (Ac) | 0.0 | 128.4 | |
| Exurban (Ac) | 0.0 | 155.3 | Pivot (Ac) | 0.0 | 412.2 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 83.6 | 155.2 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 6.5 | 1.4 | 579.4 | | | |
| Emergent | 504.8 | 105.6 | | | | |
| Scrub/Shrub | 68.1 | 14.3 | | | | |
| 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. | | | |
| | 16.7 | 0.8% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

CEA-Related observations in Reach PC19 include:

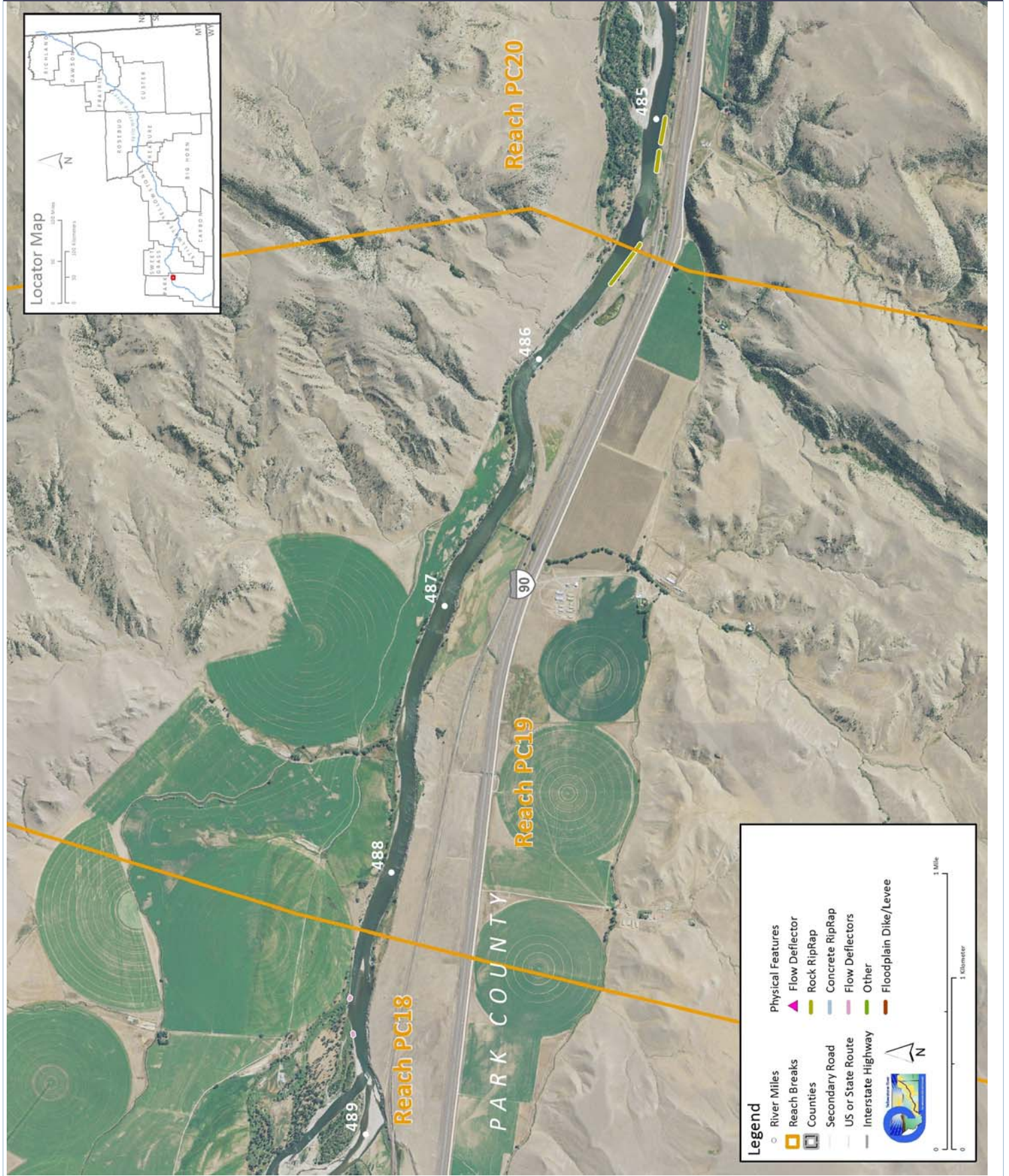
- Corridor confinement by transportation infrastructure.
- Agricultural development and irrigation of historic floodplain area that has become isolated from the river by transportation infrastructure.

No reach-specific Practices were identified for Reach PC19.

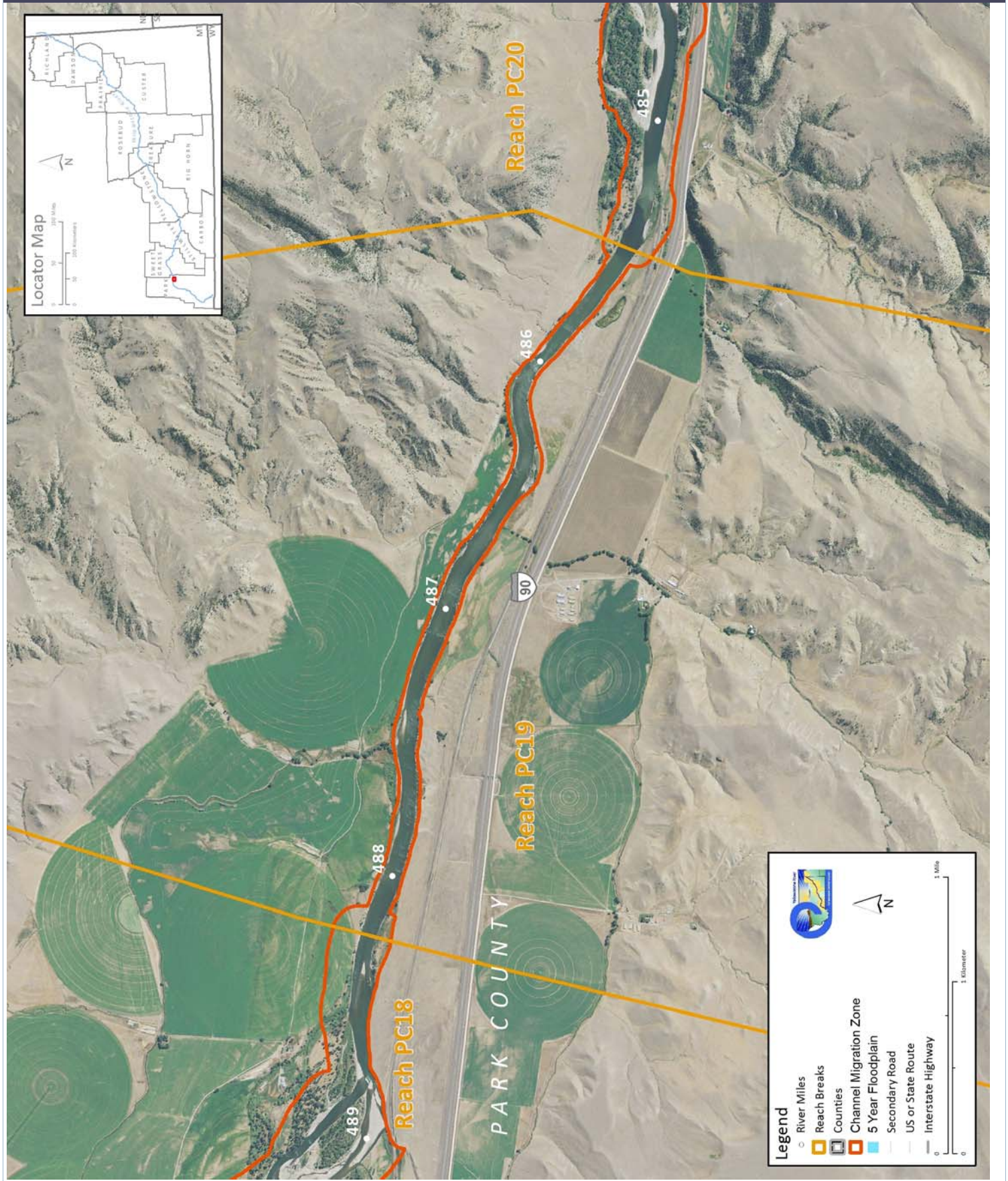
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 22,400 | 22,000 | -1.8% | | | |
| 100 Year (cfs) | 41,800 | 41,600 | -0.5% | | | |
| 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. |
| | 115.7 | | | 119.3 | 3.6 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 805 | 2.8% | 805 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 0 | 0.0% | | | | |
| Total | 805 | 2.8% | | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 2.2 | 1% | | | | |
| 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) | 1,522.4 | 1,450.2 | Flood (Ac) | 685.8 | 211.3 | |
| Ag. Infrastructure (Ac) | 9.0 | 22.2 | Sprinkler (Ac) | 0.0 | 201.4 | |
| Exurban (Ac) | 0.0 | 0.0 | Pivot (Ac) | 0.0 | 240.9 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 47.0 | 102.8 | | | | |
| 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. | |
| | | | | | | |
| National Wetlands Inventory | Acres | Acres per Valley Mi | Total Wetland Acres | Wetlands units summarized from National Wetlands Inventory Mapping include Riverine (typically open water sloughs), Emergent (marshes and wet meadows) and Shrub-Scrub (open bar areas with colonizing woody vegetation). | | |
| Riverine | 2.2 | 0.8 | 51.9 | | | |
| Emergent | 40.7 | 15.2 | | | | |
| Scrub/Shrub | 8.9 | 3.3 | | | | |
| 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. | | | |
| | 0.0 | 0.1% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



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

Narrative Summary

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

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

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

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

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

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 PC20 include:

- Corridor confinement by transportation infrastructure.
- Agricultural development and irrigation of historic floodplain area that has become isolated from the river by transportation infrastructure.

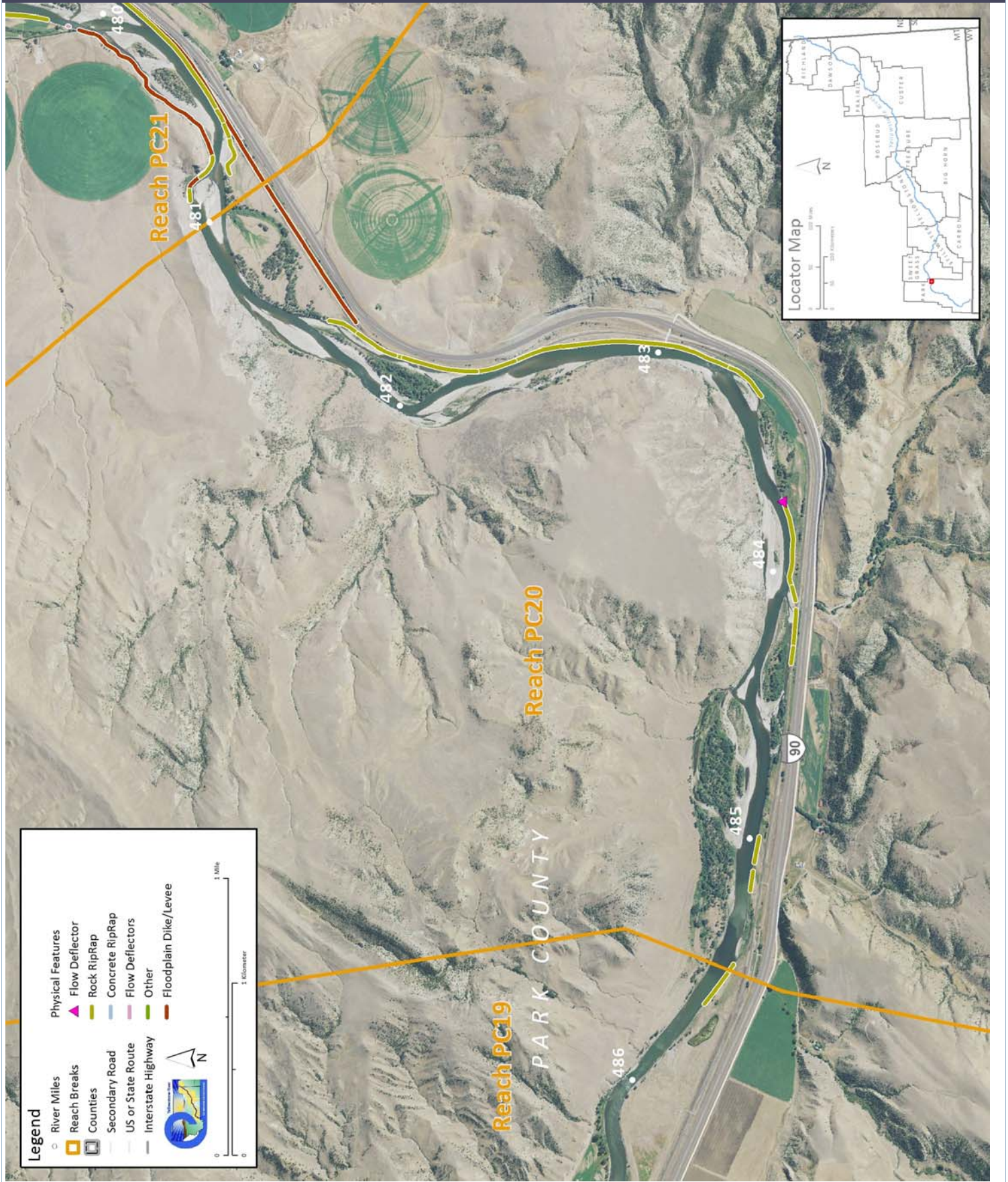
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC20 include:

- CMZ Management due to current restriction of 11 percent of the Channel Migration Zone
- Bank Stabilization Recommended due to 27 percent of banks being armored in reach

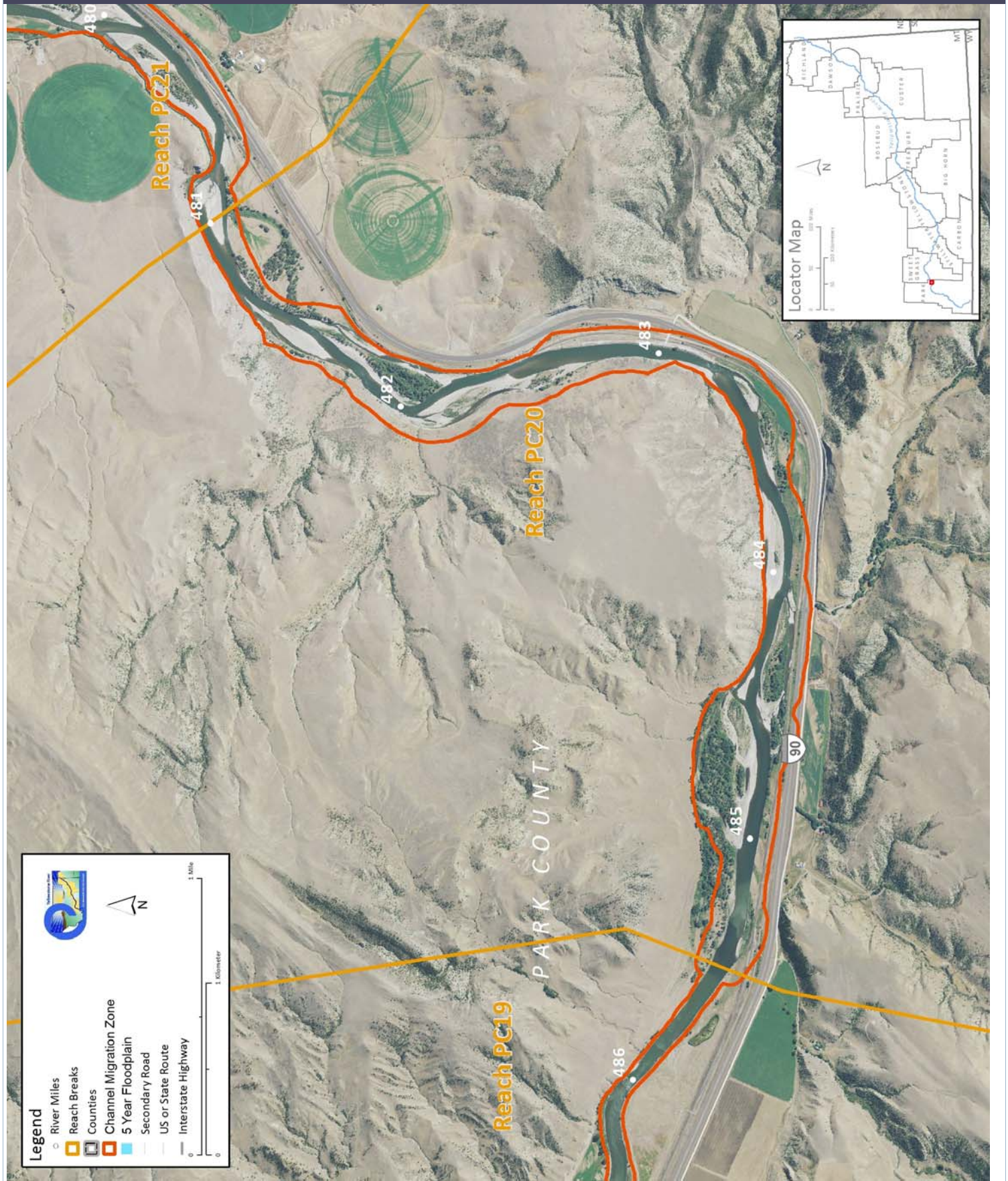
The following table summarizes some key CEA results that have been used to describe overall condition and types of human influences affecting the river. The values are specific to this single reach. Blanks indicate that a particular value was not available for this area. This information is consolidated 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) | 22,400 | 22,000 | -1.8% | | | |
| 100 Year (cfs) | 41,800 | 41,600 | -0.5% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 230.9 | | | 259.5 | 28.7 | |
| 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 | 12,763 | 27.0% | 1,099 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 56 | 0.1% | 56 | | | |
| Total | 12,819 | 27.1% | 1,155 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 66.7 | 11% | | | | |
| Land Use | 1950 | 2011 | 1950 | 2011 | Changes in land use reflect the development of the river corridor through time. The irrigated agricultural are is a sub-set of the mapped agricultural land. | |
| Agricultural Land (Ac) | 2,165.7 | 1,987.4 | Flood (Ac) | 133.5 | 9.2 | |
| Ag. Infrastructure (Ac) | 27.4 | 71.6 | Sprinkler (Ac) | 0.0 | 79.1 | |
| Exurban (Ac) | 0.0 | 0.0 | Pivot (Ac) | 0.0 | 114.9 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 81.6 | 150.5 | | | | |
| 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 | 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 | 1.0 | 0.3 | 111.1 | | | |
| Emergent | 64.3 | 15.8 | | | | |
| Scrub/Shrub | 45.8 | 11.2 | | | | |
| Russian Olive (2001) (Appx. 100-yr Floodplain) | Acres | % | Russian olive is considered an invasive species and its presence in the corridor is fairly recent. Its spread can be used as a general indicator of invasive plants within the corridor. | | | |
| | 0.2 | 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. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP



| | | | |
|-------------------------|--------------------------------------|------------------------------|-------------------|
| 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.

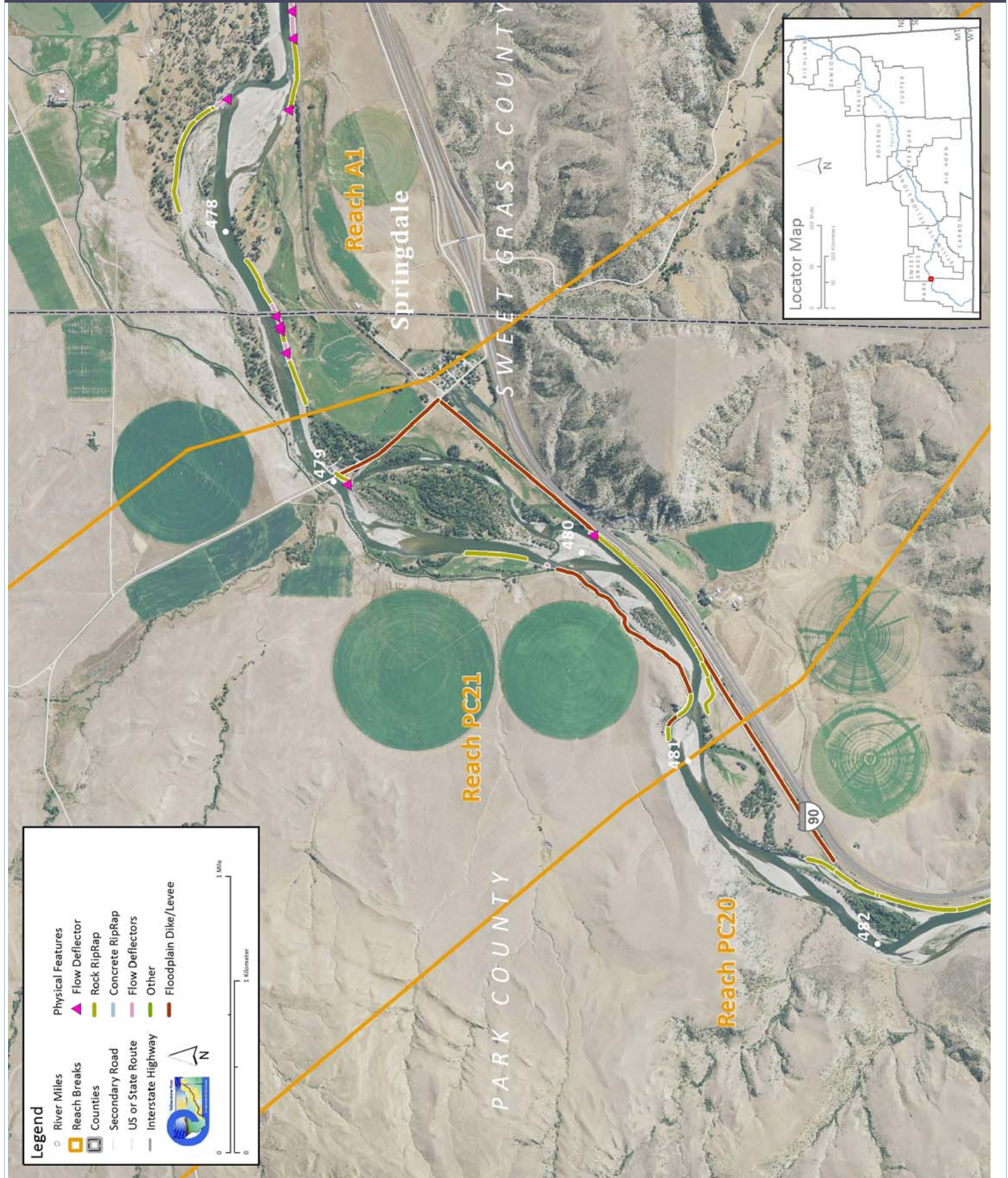
Recommended Practices (may include Yellowstone River Recommended Practices--YRRPs) for Reach PC21 include:

- 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.

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) | 22,400 | 22,000 | -1.8% | | | |
| 100 Year (cfs) | 41,800 | 41,600 | -0.5% | | | |
| Bankfull Channel Area (Ac) | 1950 | 1976 | 1995 | 2001 | 1950-2001 | Bankfull channel area is the total footprint of the river inundated at approx. the 2-year flood. |
| | 136.7 | 13.1 | | 148.9 | 12.2 | |
| Physical Features | 2011 Length (ft) | % of Bankline | 2001-2011 Change | There are additional types of bank armor such as car bodies and steel retaining walls, but they are relatively minor. | | |
| Rock RipRap | 6,270 | 26.2% | 169 | | | |
| Concrete Riprap | 0 | 0.0% | 0 | | | |
| Flow Deflectors | 123 | 0.5% | 62 | | | |
| Total | 6,393 | 26.7% | 232 | | | |
| Length of Side Channels Blocked (ft) | Pre-1950s | Post-1950s | Numerous side channels have been blocked by small dikes. | | | |
| | 0 | 0 | | | | |
| Floodplain Turnover | 1950 - 1976 | 1976 - 2001 | 1950-2001 In-channel riparian encroachment (negative number indicates retreat) | The rate of floodplain turnover reflects how many acres of land are eroded by the river. Turnover is associated with the creation of riparian habitat. | | |
| Total Acres Acres/Year Acres/Year/Valley Mile | | | acres | | | |
| Open Bar Area | Point Bars | Bank Attached | Mid-Channel | Total | The type and extent of open sand and gravel bars reflect in-stream habitat conditions that can be important to fish, amphibians, and ground-nesting birds such as least terns. | |
| Change in Area '50 - '01 (Ac) | | | | | | |
| Floodplain Isolation | Acres | % of FP | Floodplain isolation refers to area that historically was flooded, but has become isolated do to flow alterations or physical features such as levees. | | | |
| 5 Year 100 Year | | | | | | |
| 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. | | | |
| | 64.9 | 19% | | | | |
| 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) | 918.3 | 832.0 | Flood (Ac) | 148.2 | 69.8 | |
| Ag. Infrastructure (Ac) | 18.2 | 73.8 | Sprinkler (Ac) | 0.0 | 9.3 | |
| Exurban (Ac) | 12.5 | 21.3 | Pivot (Ac) | 0.0 | 256.5 | |
| Urban (Ac) | 0.0 | 0.0 | | | | |
| Transportation (Ac) | 38.1 | 58.3 | | | | |
| 1950s Riparian Vegetation Converted to a Developed Land Use (ac) | To Irrigated | To Other Use | Total Rip. Converted | % of 1950s Rip. | Changes in the extents of riparian vegetation are influenced by land use changes within the corridor. | |
| | | | | | | |
| 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 | 1.9 | 1.0 | 89.3 | | | |
| Emergent | 61.8 | 31.4 | | | | |
| Scrub/Shrub | 25.6 | 13.0 | | | | |
| 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. | | | |
| | 0.2 | 0.2% | | | | |
| Riparian Forest at low risk of Cowbird Parasitism (Ac/Valley Mile) | 1950 | 1976 | 2001 | Change 1950-2011 | Cowbirds are associated with agricultural and residential development, displacing native bird species by parasitizing their nests. | |
| | | | | | | |

PHYSICAL FEATURES MAP (2011)



CHANNEL MIGRATION ZONE MAP

