Clark Fork River Plains Reach Assessment & Restoration Prioritization

Prepared for Middle Clark Fork River Plains Reach Recovery Committee
Prepared by RESPEC

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CLARK FORK RIVER

PLAINS REACH ASSESSMENT

AND

RESTORATION PRIORITIZATION

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1.0 Introduction

Sanders County received grant funding from the Montana Department of Natural Resources and Conservation (DNRC) Renewable Resource Planning Grant program to conduct a Watershed Assessment of the Middle Clark Fork River – Plains Reach. The Middle Clark Fork River Plains Reach Recovery Committee, which is comprised of local stakeholders including local government officials, landowners, and business owners, is leading the effort to address lateral channel migration and streambank erosion within the Plains Reach. In February 2014, the Committee commissioned RESPEC to conduct an assessment of the Plains Reach of the Clark Fork River and develop a restoration plan for the entire reach.

The Plains Reach extends 8.0 miles from Henry Creek to Lynch Creek along the town of Plains in western Montana (**Figure 1-1**). This reach of the Clark Fork River is located downstream of the confluence with the Flathead River and upstream of Thompson Falls Dam, Noxon Rapids Dam and Cabinet Gorge Dam. Within the Plains Reach, the Clark Fork River is a large meandering gravel bed river. Since the 1997 flood event, local stakeholders have observed increased lateral channel migration and streambank erosion, along with a reduction in side channel connectivity. Specific concerns identified by the stakeholders include streambank erosion above and below a short section of riprap at the Town of Plains Waste Water Treatment Plant (WWTP) outfall, the influence of the historic 5th Avenue South Bridge pylons, which remain in the channel, a reduction in flows in the west channel during low flow periods, and streambank erosion affecting both private lands and businesses along the river. To address the identified concerns, this study focuses on the 1995-2013 timeframe since stakeholders have observed significant rates of lateral channel migration and streambank erosion since the 1997 flood event and because aerial imagery extending back to 1995 was readily available.

The Clark Fork River Plains Reach Assessment and Restoration Prioritization study consists of a review of existing hydrologic data, a geomorphic assessment, a Channel Migration Zone analysis, a streambank erosion analysis, an evaluation of restoration alternatives, project prioritization, and a review of permitting requirements and potential funding sources. The hydrologic assessment was performed to characterize the flow regime within the Plains Reach. The geomorphic assessment was conducted within the Plains Reach to characterize the existing channel conditions and examine changes in channel pattern over time. The Channel Migration Zone analysis was conducted along the Plains Reach to evaluate future channel migration scenarios. The streambank erosion assessment examined areas of actively eroding bank at the outsides of meander bends and along mid-channel bars. Based on this assessment, a suite of restoration alternatives have been identified to improve conditions along the Plains Reach of the Clark Fork River and restore natural channel processes while protecting critical infrastructure and economically important lands. Projects identified during this assessment will require funding from various sources, with the immediate goal of obtaining funding from the DNRC Renewable Resource Grant and Loan (RRGL) program to proceed with the design and implementation of restoration projects.

Figure 1-1. Plains Reach Overview

2.0 Hydrology

Within the Plains Reach of the Clark Fork River, the principal hydrology affecting channel form and function is the mainstem river flow. Henry Creek and Lynch Creek, which are the upstream and downstream boundaries for the study reach, respectively, along with Boyer Creek and Combest Creek, which flow into the reach, represent very small inputs to the overall system. The United States Geological Survey (USGS) stream gage 12389000 (Clark Fork near Plains, MT) is located within the study reach approximately 800 feet downstream of Henry Creek and includes a drainage area of 19,958 square miles. This gage has a 102 year period of record (1912-present), which allows for a good statistical analysis of the annual peak flow events. Within the period of record, however, two dams were constructed on the Flathead River system upstream of Plains, both of which function to regulate flows downstream. Kerr Dam was completed at the outlet of Flathead Lake in 1938, while Hungry Horse Dam was completed on the South Fork Flathead River in 1953. Thus, a 60 year period of flow data (1954-2013) post-dam construction is available for statistical analysis and is representative of the existing conditions within the watershed.

A flood frequency analysis of the post-dam annual peak flow dataset was completed in accordance with the USGS guidelines in Bulletin 17B (USGS 1982) and flow values for various flood return intervals are presented in **Table 2-1**. A flood frequency analysis of the entire annual peak flow dataset (1912-2013) was also completed to facilitate a comparison of pre- and post-dam discharge-frequency relationships (**Table 2-2**). A comparison of the peak discharge-frequency relationships for the post-dam (1954-2013) and complete (1912-2013) periods of record reveal only a small reduction in discharge values for the different recurrence intervals after the dams (Kerr and Hungry Horse) were completed. The percent reduction in flows varies between 3.5% – 4.5% for the recurrence intervals presented in the tables. These results indicate that the impact of upstream storage on flood discharge values for the Clark Fork River at Plains is minimal. It should be noted, however, that an investigation of the specific management strategies for each reservoir was beyond the scope of this study and the potential for increasing the effect of upstream storage on flood discharge magnitudes at Plains is not known.

Table 2-1. Peak Discharge in Cubic Feet per Second (cfs) at USGS Gaging Station 12389000 for Indicated Recurrence Intervals Post-Dam Completion (1954-2013)

Recurrence Interval					
2-Year	**5-Year**	**10-Year**	**50-Year**	**100-Year**	**500-Year**
72,900	95,400	106,900	125,600	131,600	142,200

NOTE: Although a 60-year, post-dam period of record was statistically evaluated, the historic maximum flood recorded in 1948 (134,000 cfs) was included in the flood frequency computations.

Table 2-2. Peak Discharge in Cubic Feet per Second (cfs) at USGS Gaging Station 12389000 for Indicated Recurrence Intervals (1912-2013)

Recurrence Interval					
2-Year	**5-Year**	**10-Year**	**50-Year**	**100-Year**	**500-Year**
76,200	99,200	111,000	130,300	136,400	147,500

From both a sediment transport and channel restoration standpoint, approximating a bankfull discharge is useful. A commonly accepted and universally applicable definition of bankfull was provided by Dunne and Leopold (1978): "The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work results in the average morphologic characteristics of channel." Bankfull events typically have a recurrence interval of 1.5 years. Based on the computed flood frequency curve at the USGS gage, the 1.5-year recurrence interval discharge is approximately 65,000 cfs. A qualitative analysis of the peak discharges throughout the period of record demonstrate that flow magnitudes exceeding roughly 65,000 - 75,000 cfs, and the duration that flows remain elevated above this range, have the most significant impact on bank erosion and channel alteration.

As discussed in Section 1.0, this study focuses on the 1995-2013 timeframe in which stakeholder's have observed significant rates of lateral channel migration and streambank erosion. The 1995-2013 timeframe includes two flood events exceeding 100,000 cfs, with a peak of 110,000 cfs in 1997 and 104,000 cfs in 2011 (**Table 2-3**). Over the 102 period of record, streamflow has equaled or exceeded 100,000 cfs twenty times, with a maximum peak discharge of 134,000 cfs in 1948, followed by 128,000 cfs in 1964.

Table 2-3. USGS Gage 12389000 Peak Discharge 1995-2013

Date	Streamflow (cfs)	Gage Height (Feet)
6/9/1995	73,700	13.37
6/11/1996	90,300	14.98
5/19/1997	110,000	17.10
5/28/1998	58,900	11.97
6/20/1999	63,000	12.49
6/18/2000	42,600	10.08
5/16/2001	29,300	8.27
6/4/2002	86,200	14.62
6/2/2003	66,400	12.74
5/30/2004	40,800	9.85
6/7/2005	69,800	13.08
5/22/2006	74,700	13.60
6/8/2007	50,100	10.95
6/3/2008	75,900	13.71
6/2/2009	58,100	11.86
6/18/2010	58,500	11.91
6/10/2011	104,000	16.53
6/20/2012	75,300	13.71
5/15/2013	63,700	12.47

3.0 Geomorphology

3.1 Methods

A geomorphic assessment was conducted within the Plains Reach of the Clark Fork River to characterize the existing channel conditions, examine changes in channel pattern over time, and provide a foundation for the Channel Migration Zone Analysis presented in Section 4 and the Streambank Erosion Analysis presented in Section 5. The existing channel conditions assessment examined channel width, slope, sinuosity, confinement, and the pool riffle sequence. Existing channel conditions were evaluated in GIS using 2013 National Agricultural Imagery Program (NAIP) color aerial imagery, along with field observations conducted in February-April 2014 and survey data collected in April and May 2014. The channel pattern assessment examined the evolution of the active channel between 1995, 2005 and 2013 to document ongoing channel changes over the past 18 years. For the channel pattern assessment, the active channel was mapped based on baseflow conditions observed in the aerial imagery. The active channel includes both the mainstem and side channels, along with exposed gravel bars. Vegetated islands were also mapped and excluded from the active channel. Changes in channel pattern over time were assessed using USGS Digital Orthophoto Quarter Quadrangles (DOQQs) black and white aerial imagery from 1995 and NAIP color aerial imagery from 2005 and 2013, with baseflow conditions mapped at streamflows ranging from 7,510 cfs to 9,750 cfs, which is a difference of approximately 0.6 feet at the USGS gaging station (**Table 3-1**). The existing channel conditions and channel patterns were assessed within the 8.0 mile Plains Reach extending from Henry Creek downstream to Lynch Creek, while an additional 1.1 miles was included when evaluating the pool riffle sequence to capture a complete sequence at the upstream and downstream ends of the study reach.

Table 3-1. Aerial Photo Date and Streamflow: 1995, 2005, and 2013

Year	Date	Mean Daily Streamflow (cfs)
1995	8/25/95 and 9/1/95	8,350 and 9,400
2005	8/27/2005	9,750
2013	8/21/2013	7,510

3.2 Results

The Plains Reach of the Clark Fork River is a meandering gravel bed river with a pool riffle morphology that is confined in places by both man-made structures (i.e. riprap) and natural bedrock outcrops. This condition is described as a “forced” pool riffle morphology (Montgomery and Buffington 1997) and a C4 stream type (Rosgen 1996). Pool riffle channels consist of a laterally oscillating sequence of pools and riffles that causes scour on alternating banks. Pool riffle channels are generally sediment transport limited, with sediment accumulating on point bars on the insides of meander bends and on mid-channel bars in areas with high width-to-depth ratios. In pool riffle channels, the channel pattern results from lateral channel migration, channel avulsion and flooding (Montgomery and Buffington 1997). These channels are susceptible to accelerated bank erosion, with the rate of lateral channel migration strongly influenced by the presence and condition of riparian vegetation (Rosgen 1996). Within the Plains Reach, changes to channel pattern observed between 1995 and 2013 include an increased amount of exposed gravel bars, increased active channel width, increased sinuosity, and decreased access to side channels.

3.2.1 Existing Channel Conditions

The results of the existing channel conditions assessment examining channel width, slope, sinuosity, confinement, and the pool riffle sequence are presented in the following sections.

3.2.1.1 Baseflow and Active Channel Widths

Based on 85 cross-section measurements performed in GIS using the 2013 NAIP aerial imagery, the mean baseflow (wetted) channel width is 660 feet at 7,510 cfs, with a median width of 590 feet (**Figure 3-1** , **Figure 3-2** and **Table 3-2**). The mean active (bankfull) channel width is 1,049 feet, with a median width of 1,011 feet. The maximum baseflow channel width is 1,829 feet, while the maximum active channel width is 2,451 feet. Between 1995 and 2013, the area occupied by the active channel (excluding vegetated islands) increased 10% from approximately 875 acres to 970 acres, indicating the channel is becoming wider within the Plains Reach.

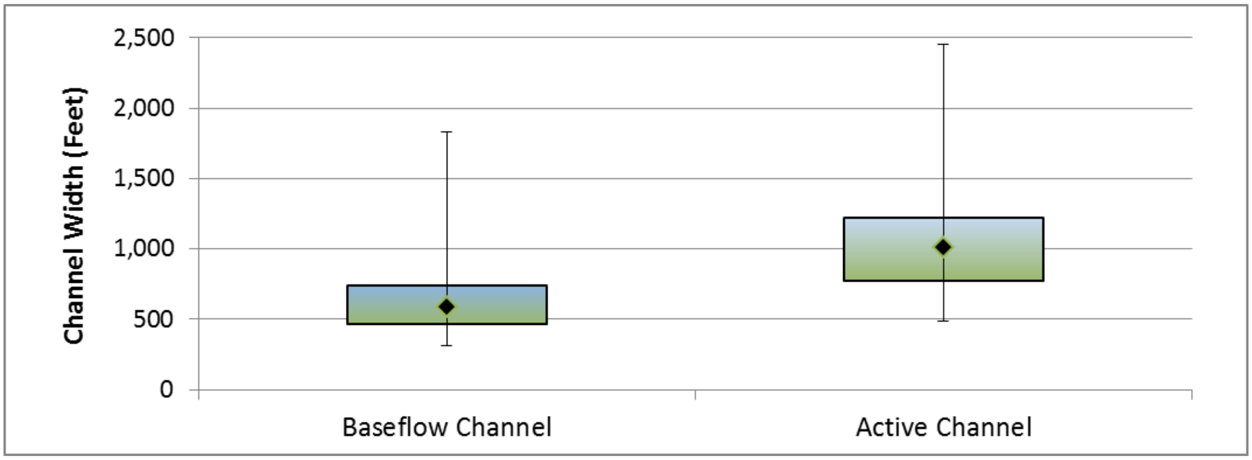


Figure 3-1. Baseflow and Active Channel Widths, 2013

Table 3-2. Baseflow and Active Channel Widths, 2013

Statistical Parameter	Baseflow Channel Width (Feet)	Active Channel Width (Feet)
Minimum	316	484
25th Percentile	469	775
Median	590	1,011
75th Percentile	736	1,224
Maximum	1,829	2,451

3.2.1.2 Slope and Sinuosity

For the 8.0 mile reach of the Clark Fork River between Henry Creek and Lynch Creek, the sinuosity is 1.40 and a surface water slope of 0.053% was measured at 53,700 cfs (11.37 feet) on May 7, 2014 between the USGS gaging station and the confluence of Lynch Creek. Field observations in February-April of 2014, along with the 2013 NAIP aerial imagery, indicate the channel slope is very low between the town of Plains and the bedrock outcrop at the downstream end of Big Eddy where the channel is comprised of a series of long pools and glides. Channel slope increases downstream of the head of the west channel, with a series of riffles and runs extending downstream past the head of the east channel.

Figure 3-2. Baseflow and Active Channel Cross-Section Locations, 2013

3.2.1.3 Channel Confinement

Both man-made obstructions and naturally occurring bedrock confine the channel in the Plains Reach of the Clark Fork River. This assessment identified approximately 4,000 feet of rock riprap between Henry Creek and Lynch Creek, while an additional 4,600 feet of the river right bank along the town of Plains has been stabilized using a variety of materials including old cars, concrete blocks, wooden poles, sheet metal, and native rock material. Within the Plains Reach, rock riprap and other bank stabilization measures have been implemented along the railroad, River Road East, the town of Plains, the abutments of the 5th Avenue South Bridge, the Sanders County Fairgrounds, the Garrison/Herschbach Property, and along the Town of Plains WWTP (**Figure 3-3**). Natural channel confinement occurs at the bedrock outcrop at the downstream end of Big Eddy, along with periodic valley confinement along river left downstream of the island that separates the west channel from the main channel (**Figure 3-4**). In addition, the 5th Avenue South Bridge constricts the river to approximately 896 feet, which is a 17% constriction at bankfull flows when compared to a mean active channel width of 1,049 feet. The bridge is at an angle to the current channel configuration, which further constricts the flow, while the historic bridge pylons remain in the channel, creating additional turbulence as water passes under the bridge (**Figure 3-5** and **Figure 3-6**).

Figure 3-3. Rock Riprap Upstream of Bank 5 (Left) and at the Town of Plains WWTP (Right)

Figure 3-4. Bedrock Outcrop at Downstream End of Big Eddy

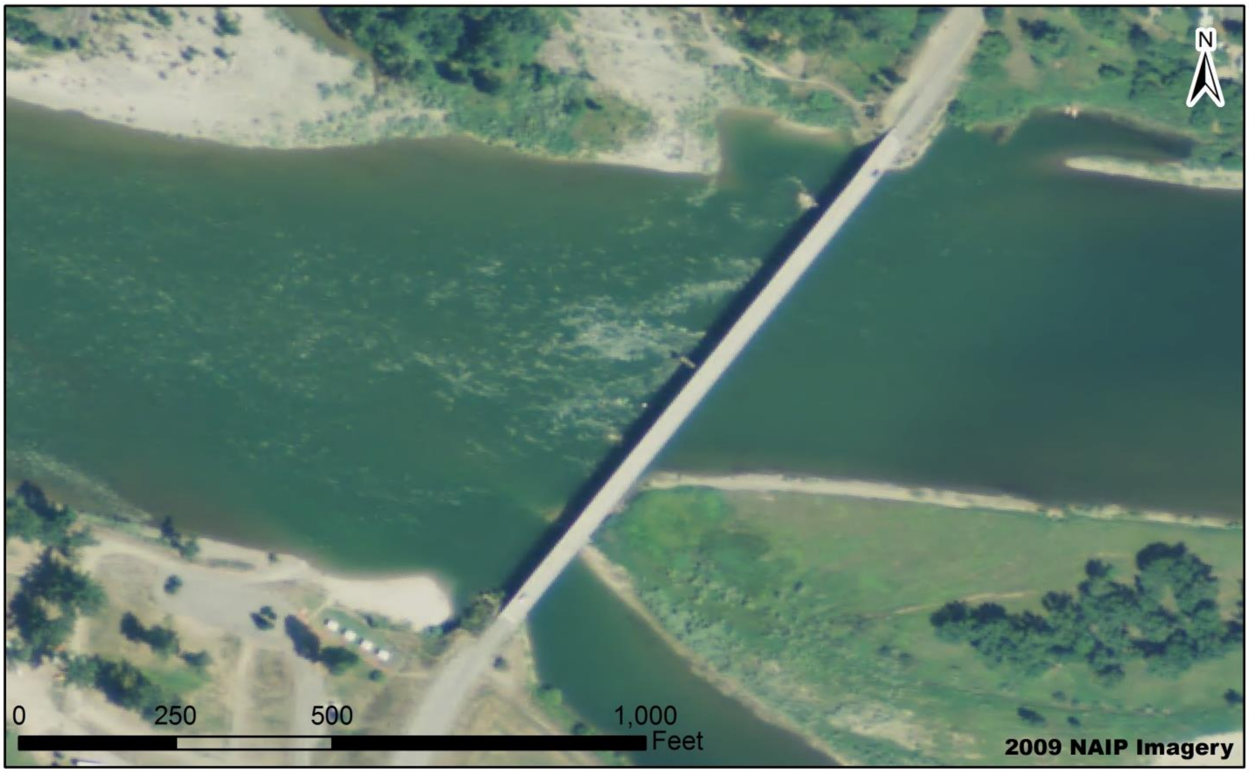
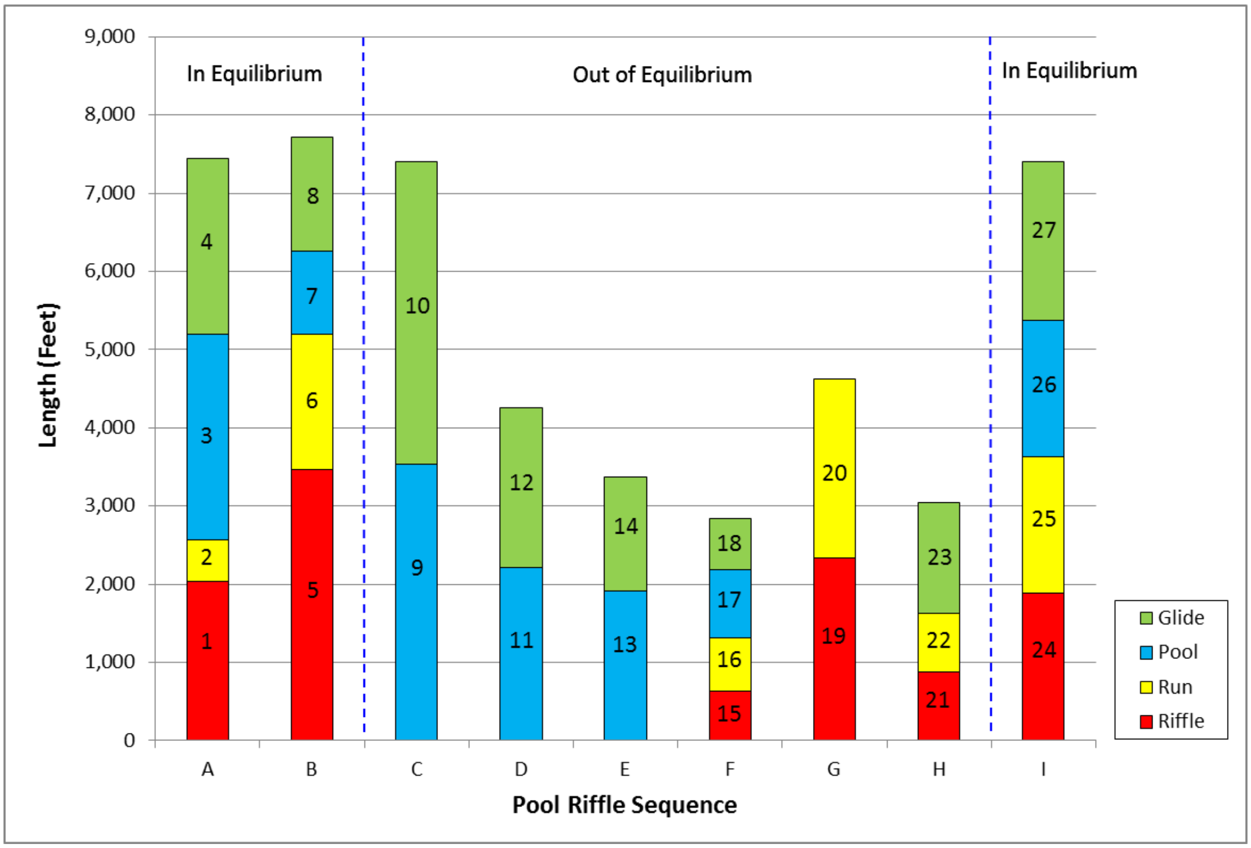


Figure 3-5. 5th Avenue South Bridge (2009 NAIP Imagery)

Figure 3-6. 5th Avenue South Bridge (~30,000 cfs)

3.2.1.4 Pool Riffle Sequence

The pool riffle sequence describes the expected sequence of channel features observed progressing downstream along the longitudinal profile. Each feature occurs at a different channel slope and is expressed as varying water velocities and depths. A riffle occurs in the steepest part of the channel and is defined as “fast, shallow”, while the run downstream of a riffle is defined as “fast, deep”. A pool occurs in the deepest part of the channel and is defined as “slow, deep”, while the glide downstream of the pool is defined as “slow, shallow” and precedes the river going over the next riffle (**Figure 3-8**). This natural sequence of channel features allows the river to effectively dissipate stream energy. When man-made obstructions and bedrock outcrops are encountered, this sequence is adjusted to effectively dissipate stream energy. When obstructions to the lateral migration of the channel are placed at consecutive meander bends, stream energy is translated downstream and becomes focused on un-protected areas, leading to accelerated bank erosion, particularly in areas lacking dense riparian vegetation. Accelerated rates of bank erosion result in increased sediment supply, which can cause the channel to become out of equilibrium with the sediment supply and flow regime under which the channel pattern became established. This condition is observed in the Plains Reach of the Clark Fork River extending from the town of Plains downstream past where the west channel and main channel rejoin (**Figure 3-7** and **Figure 3-9**). The channel is out of equilibrium due to upstream channel confinement, accelerated rates of bank erosion, and sediment deposition within the reach.



Note that in areas with mid-channel bars, an “inset” sequence with a pool/run and glide was typically observed between the riffle crest observed at the top of the bar and the riffle crest observed at the downstream end of the bar. Where this occurred, the entire length of channel influenced by the mid-channel bar was considered a riffle for the purposes of evaluating the larger scale pool riffle sequence.

Figure 3-7. Length of Channel Classified as Riffle, Run, Pool and Glide

Figure 3-8. Channel Features within the Plains Reach: Riffle , Run , Pool , and Glide (Top to Bottom)

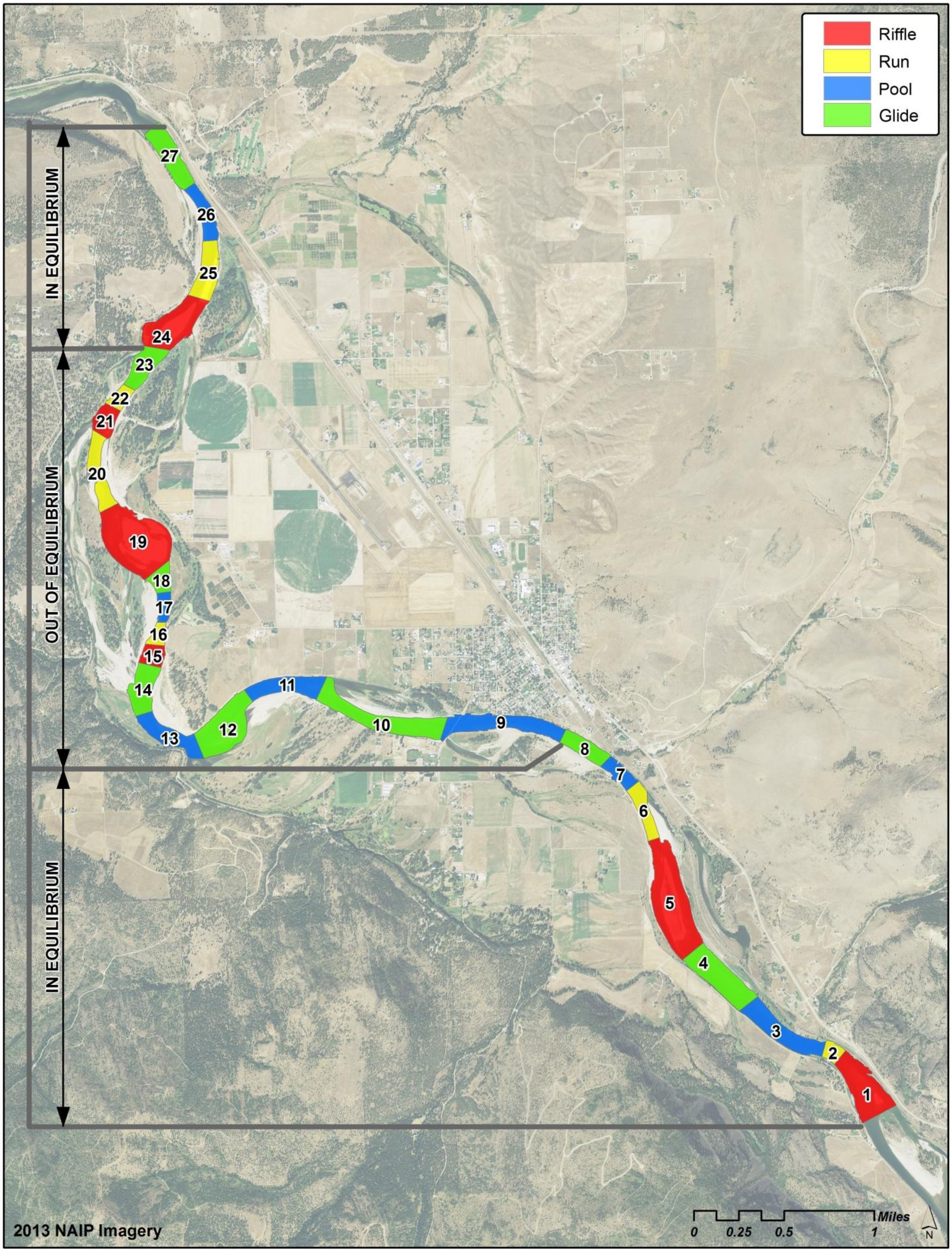


Figure 3-9. Pool Riffle Sequence

3.2.2 Channel Pattern

The channel pattern assessment examined the evolution of the active meandering channel between 1995, 2005 and 2013 to document ongoing channel changes over the past 18 years, which includes streamflow events exceeding 100,000 cfs in 1997 and 2011. For the channel pattern assessment, the active channel was mapped based on baseflow conditions observed in the aerial imagery. The active channel includes both the mainstem and side channels, along with exposed gravel bars. Vegetated islands were also mapped and excluded from the active channel. Between 1995 and 2013, lateral channel migration and the rate of streambank erosion has accelerated downstream of the rock outcrop below Big Eddy (**Figure 3-11**). Changes to channel pattern observed between 1995 and 2013 include an increased amount of exposed gravel bars, increased sinuosity, increased active channel width, and decreased access to side channels. As side channels aggrade and are abandoned, lateral channel migration has increased in the mainstem, resulting in additional sediment contributions from streambank erosion. Accelerated bank erosion has led to sediment deposition on point bars, mid-channel bars, and at that heads of side channels. Between 1995 and 2013, the area occupied by exposed gravel bars increased 36% from approximately 228 acres to 355 acres, indicating excess sediment deposition is occurring within the Plains Reach (**Figure 3-10**). This corresponded with a decrease in the area occupied by vegetated islands and an increase in the area occupied by the active channel. During this same timeframe, approximately 104 acres of floodplain lands were lost to bank erosion. The majority of the eroded bank material is currently retained within this sediment transport limited reach, with the coarse grained material typically accumulating on the next gravel bar downstream (**Figure 3-12**).

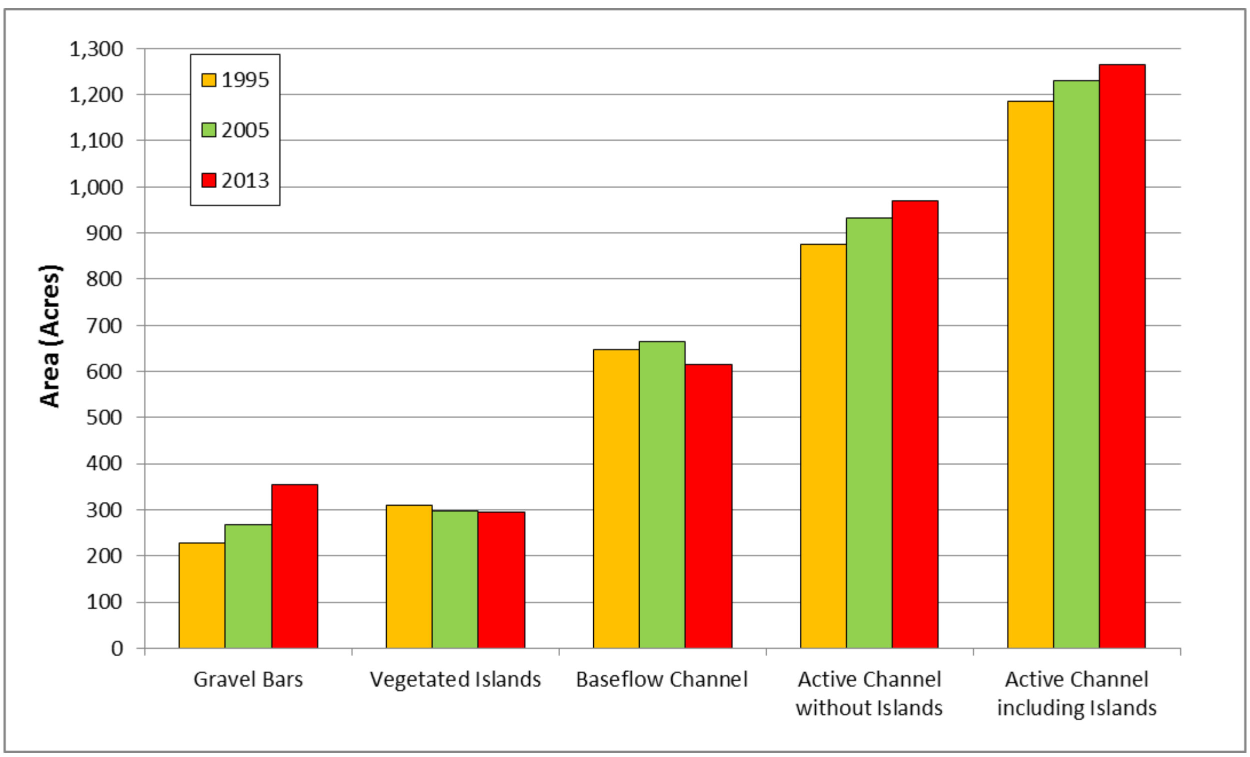


Figure 3-10. Area Occupied by Gravel Bars, Vegetated Islands, and the Active Channel, 1995-2013

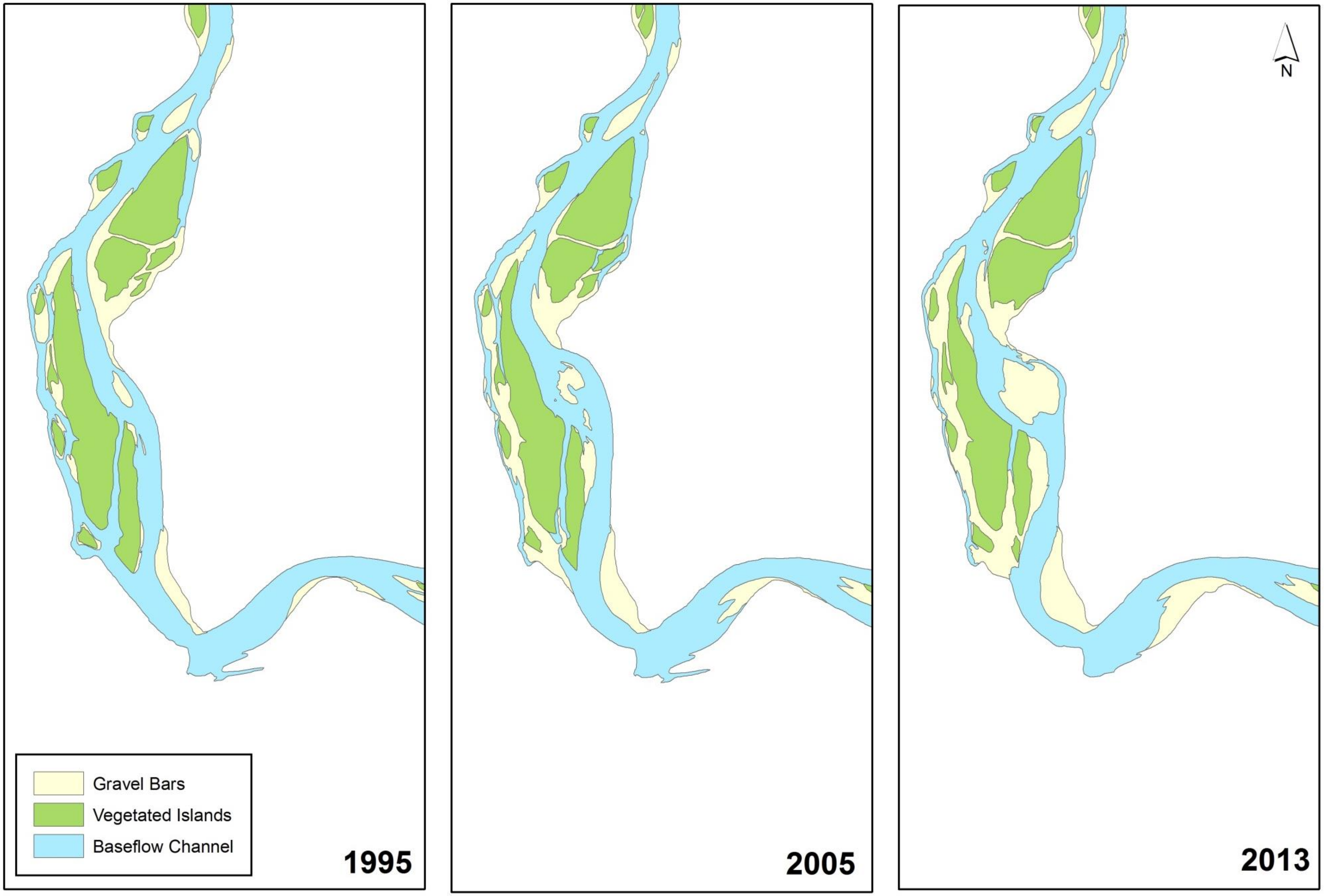


Figure 3-11. Channel Pattern: 1995, 2005 and 2013

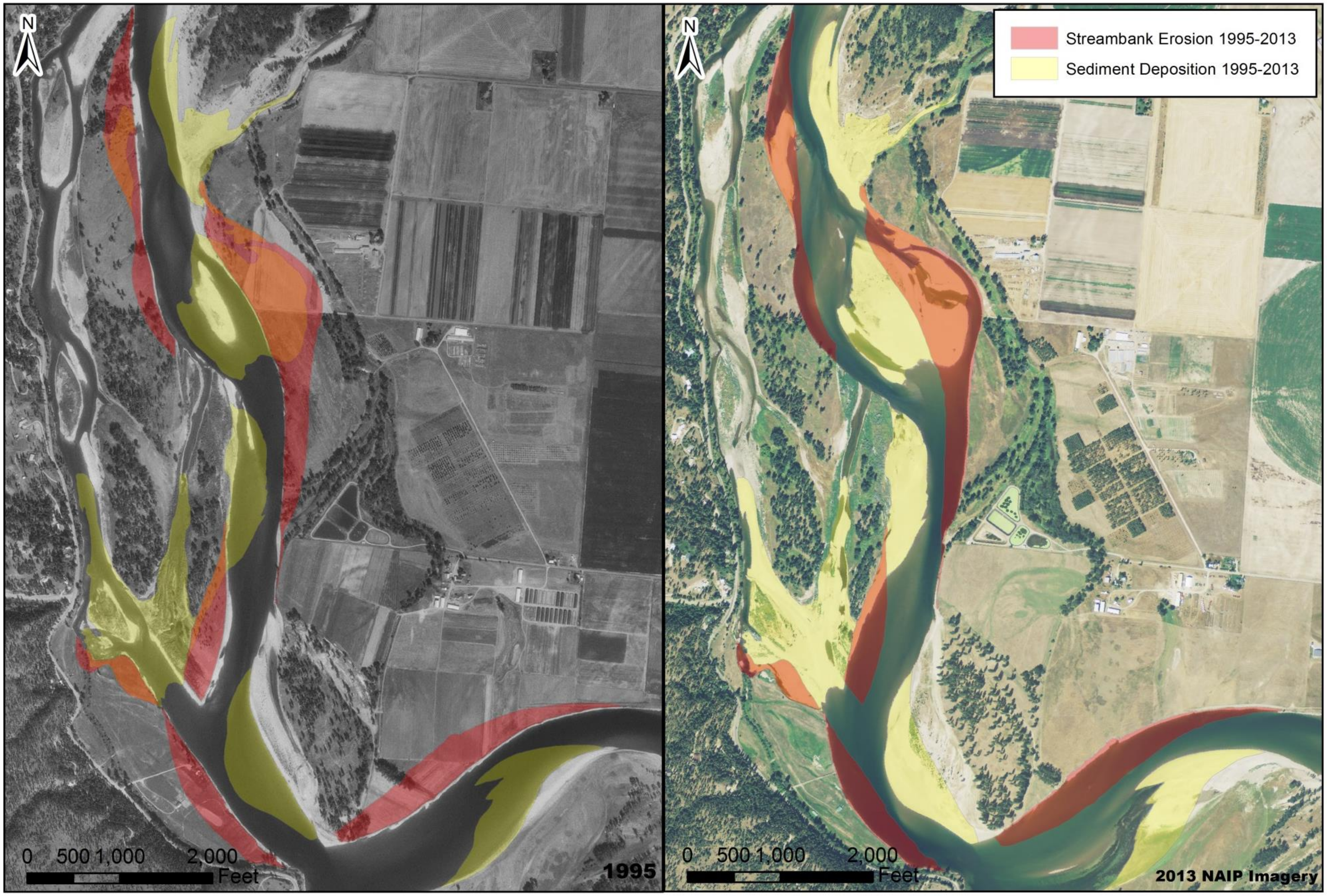


Figure 3-12. Streambank Erosion and Sediment Deposition, 1995-2013

3.3 Discussion

The Clark Fork River in the Plains Reach is a large meandering gravel bed river that has experienced increased lateral channel migration and streambank erosion since 1995. Accelerated streambank erosion has increased the sediment load within the reach, resulting in an expansion of gravel bars. Sediment deposition at the heads of side channels has resulted in more flow in the main channel, leading to increased stream power and additional bank erosion. As the channel becomes wider, its ability to transport sediment is reduced. In response to the increased sediment load, the channel has become steeper between the head of the west channel downstream past the head of the east channel in order to transport out the excess sediment. The conditions observed within the Plains Reach indicate that the channel is out of equilibrium due to upstream channel confinement, accelerated rates of bank erosion, and sediment deposition with the reach. The observed pool riffle sequence is currently adjusting to the increased sediment load, with sediment contributed from eroding banks being deposited on point bars, mid-channel bars, and at that heads of side channels, which are being abandoned as the Plains Reach transitions from a multichannel system to a single channel system.

4.0 Channel Migration Zone Analysis

4.1 Methods

A Channel Migration Zone (CMZ) analysis was conducted along the Plains Reach to examine historic channel migration and evaluate future channel migration scenarios. This assessment was conducted by adapting methods described in *A Framework for Delineating Channel Migration Zones* (Rapp and Abbe 2003) and methods used in *Yellowstone River Channel Migration Zone Mapping* (Thatcher et al. 2009). The CMZ is an estimate of the area in which future channel migration might occur and can be used for planning development and land management activities within the identified area. The CMZ is not intended to be used for regulatory purposes. The CMZ includes an assessment of the Historical Migration Zone (HMZ), the development of an Erosion Buffer, identification of Avulsion Potential Areas, and incorporation of Restricted Migration Areas.

4.1.1 Historical Migration Zone

The Historical Migration Zone is the area occupied by the active channel over time. For the Plains Reach, the HMZ was delineated by digitizing the active channel margin in 1995, 2005, and 2013 in GIS using aerial imagery. The active channel includes both the mainstem and side channels, along with exposed gravel bars as discussed in Section 3.1. In addition to the 1995-2013 imagery, historic aerial imagery from 1955, 1964, 1972, 1979, 1982, and 1990 was obtained from the Aerial Photography Field Office. This imagery was obtained relatively late in the project and was used to estimate the outer extent of the active channel during the 1955 to 1995 timeframe. Thus, the HMZ is based on the active channel in 1995, 2005, and 2013, along with an estimate of the outer extent of the channel margin between 1955 and 1995.

4.1.2 Erosion Buffer

The Erosion Buffer is the area outside of the Historical Migration Zone that is prone to erosion. The Erosion Buffer was developed for a 100 year planning period using retreat rates measured within the Plains Reach between 1995 and 2013. During the bank erosion assessment, 261 cross-section measurements were performed in GIS on 14 eroding banks, with a mean annual retreat rate of 7.56 feet (see Section 5.0). Based on this retreat rate, an Erosion Buffer of 756 feet was applied to HMZ to evaluate the potential for future bank erosion over a 100 year planning period.

4.1.3 Avulsion Potential Area

The Avulsion Potential Area is the area outside of the Historical Migration Zone that the channel may occupy at some point in the future. Avulsion Potential Areas were delineated based on overflow channels and floodplain swales identified using a 3-Meter DEM from 1999 and aerial imagery, along with on-the-ground observations conducted in February-April, 2014.

4.1.4 Restricted Migration Area

The Restricted Migration Area is the area in which man-made structures prevent future channel migration. The Restricted Migration Area was delineated along riprap, levees, roads and railroads, which were identified through an analysis of aerial imagery and on-the-ground observations conducted in February-April, 2014.

4.2 Results

The Channel Migration Zone (CMZ) analysis incorporates the Historic Migration Zone (HMZ), Erosion Buffer, Avulsion Potential Areas, and Restricted Migration Areas to provide an estimate of future channel migration. The HMZ analysis indicates extensive lateral channel migration between 1995 and 2005 and between 2005 and 2013 within approximately 2.5 miles extending from the large meander bend across from Big Eddy downstream past the head of the east channel. A review of historic aerial imagery prior to 1995 indicates that the channel downstream of the rock outcrop below Big Eddy was relatively stable between 1964 and 1995, while the meander bend upstream of the rock outcrop below Big Eddy was actively eroding (**Figure 4-1**). Between 1955 and 1964, bank erosion was observed along the river right bank upstream of the rock outcrop at Big Eddy and along the river left bank downstream of the bedrock outcrop below Big Eddy, likely as a result of the 1964 flood event when the river peaked at 128,000 cfs, which is the second highest recorded flow after the 1948 flood event, which peaked at 134,000 cfs (**Figure 4-2**).

Using the HMZ for the 1995-2013 timeframe and the estimated outer extent of the channel margin between 1955 and 1995, an Erosion Buffer was developed to estimate lateral channel migration over a 100 year time period. The Erosion Buffer identifies several areas where critical infrastructure and economically important lands are located within the CMZ, including:

- River Road West
- Town of Plains WWTP
- Lawyer Nursery

Within the Erosion Buffer, lateral channel migration has been restricted due to streambank stabilization at the following locations:

- Railroad
- River Road East
- Town of Plains
- 5th Avenue South Bridge
- Sanders County Fairgrounds
- Garrison/Herschbach Property
- Town of Plains WWTP

The results of the CMZ analysis for the Plains Reach are presented in **Figure 4-3**, with a detailed examination of the area surrounding the Town of Plains WWTP in **Figure 4-4**.

4.3 Discussion

Channel Migration Zone mapping along the Plains Reach of the Clark Fork River indicates that ongoing lateral channel migration will likely impact both critical infrastructure and economically important lands. A site-by-site analysis is provided in the next section, followed by an evaluation of restoration alternatives and project prioritization.

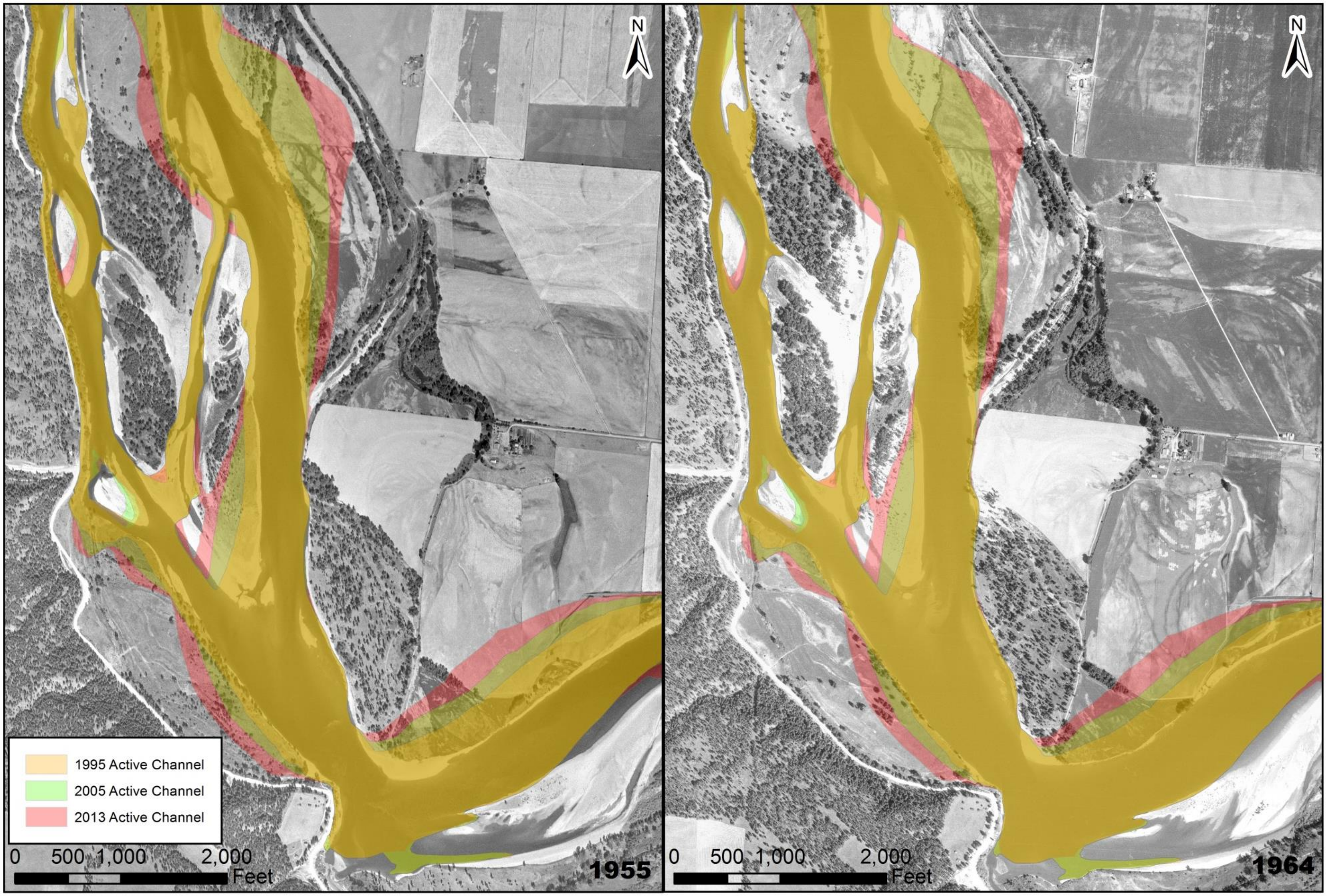


Figure 4-1. Active Channel 1995, 2005, and 2013 Compared to 1955 (Left) and 1964 (Right) Aerial Imagery

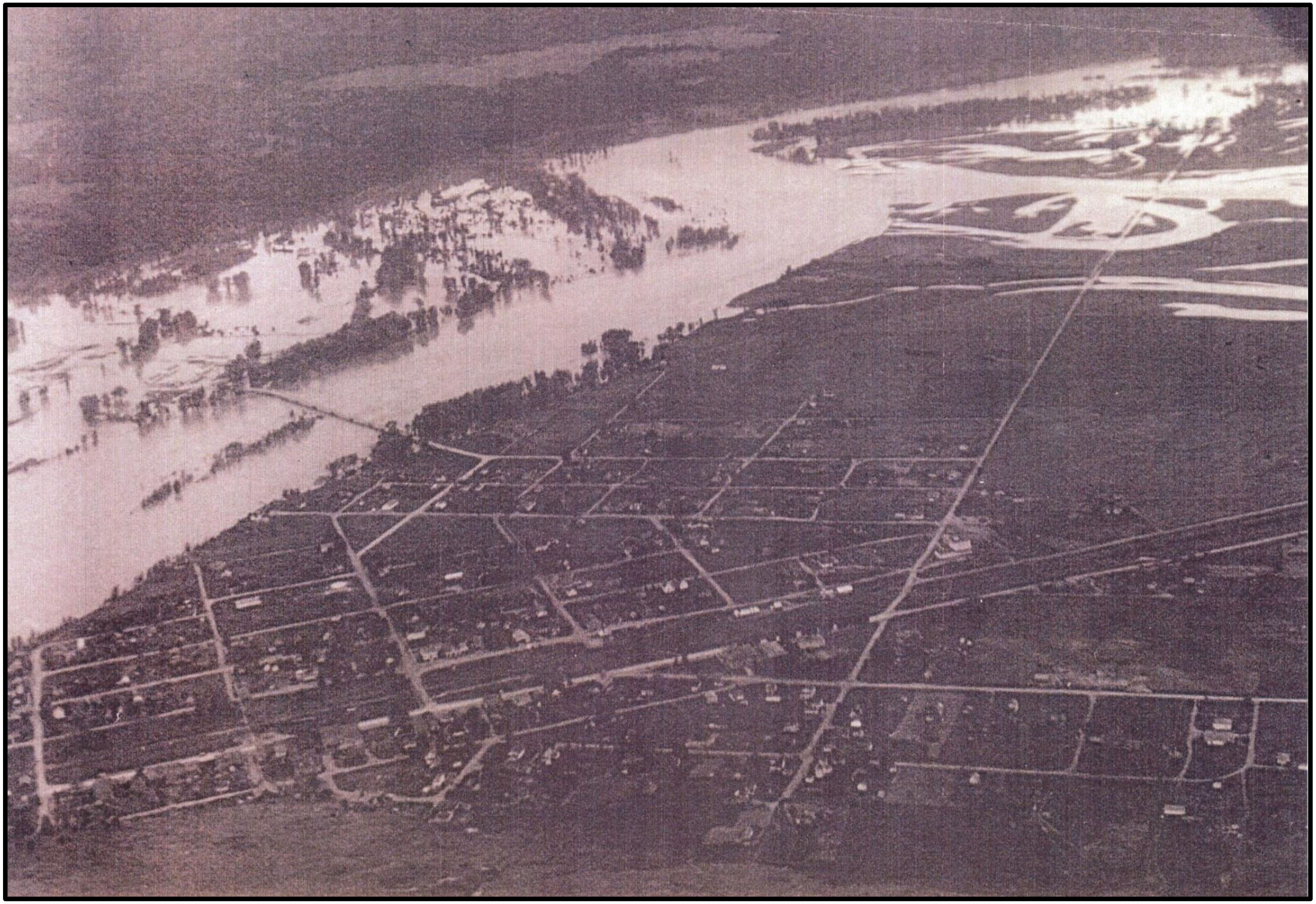


Figure 4-2. 1948 Flood Event (photo courtesy of Randy Garrison)

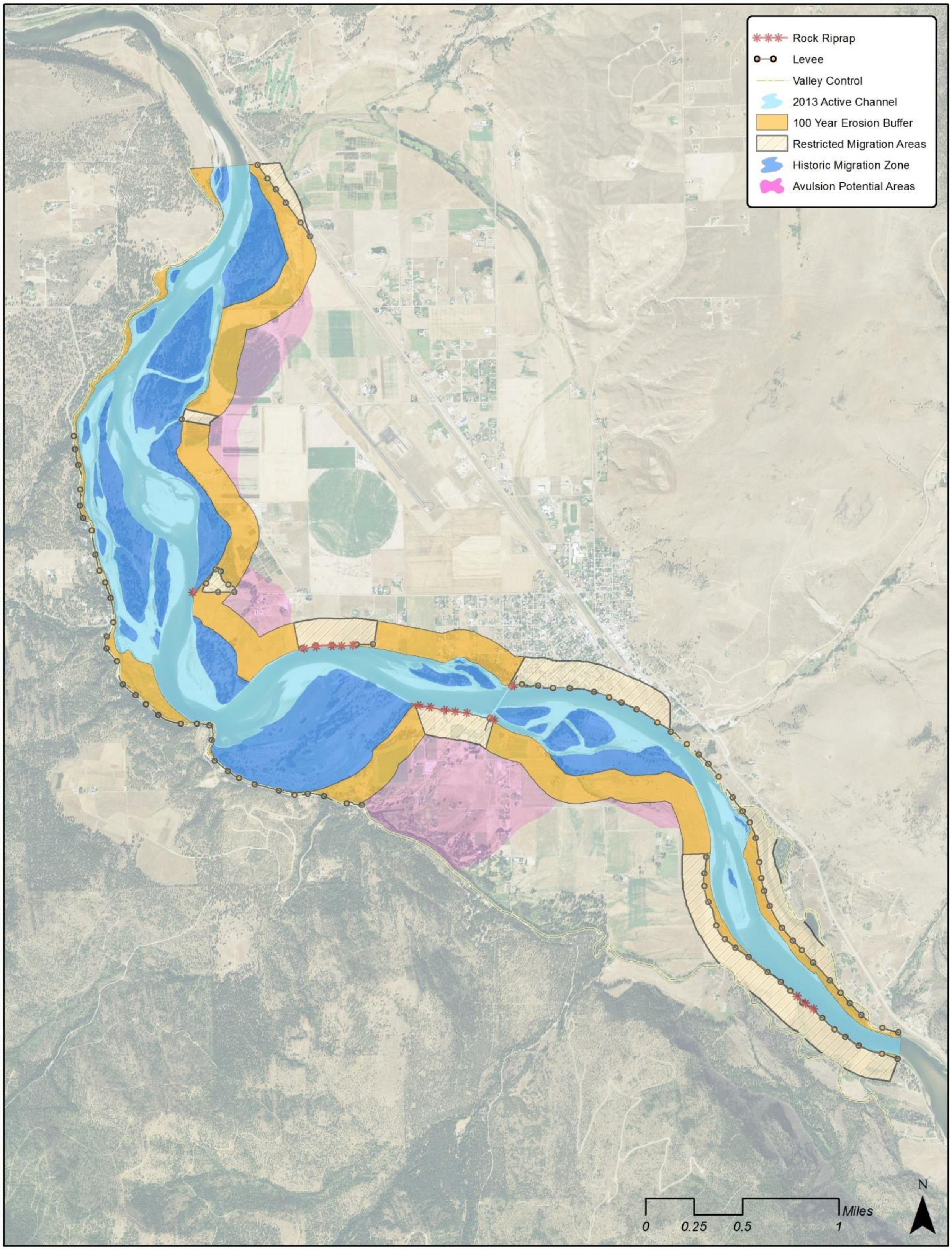


Figure 4-3. Plains Reach Channel Migration Zone

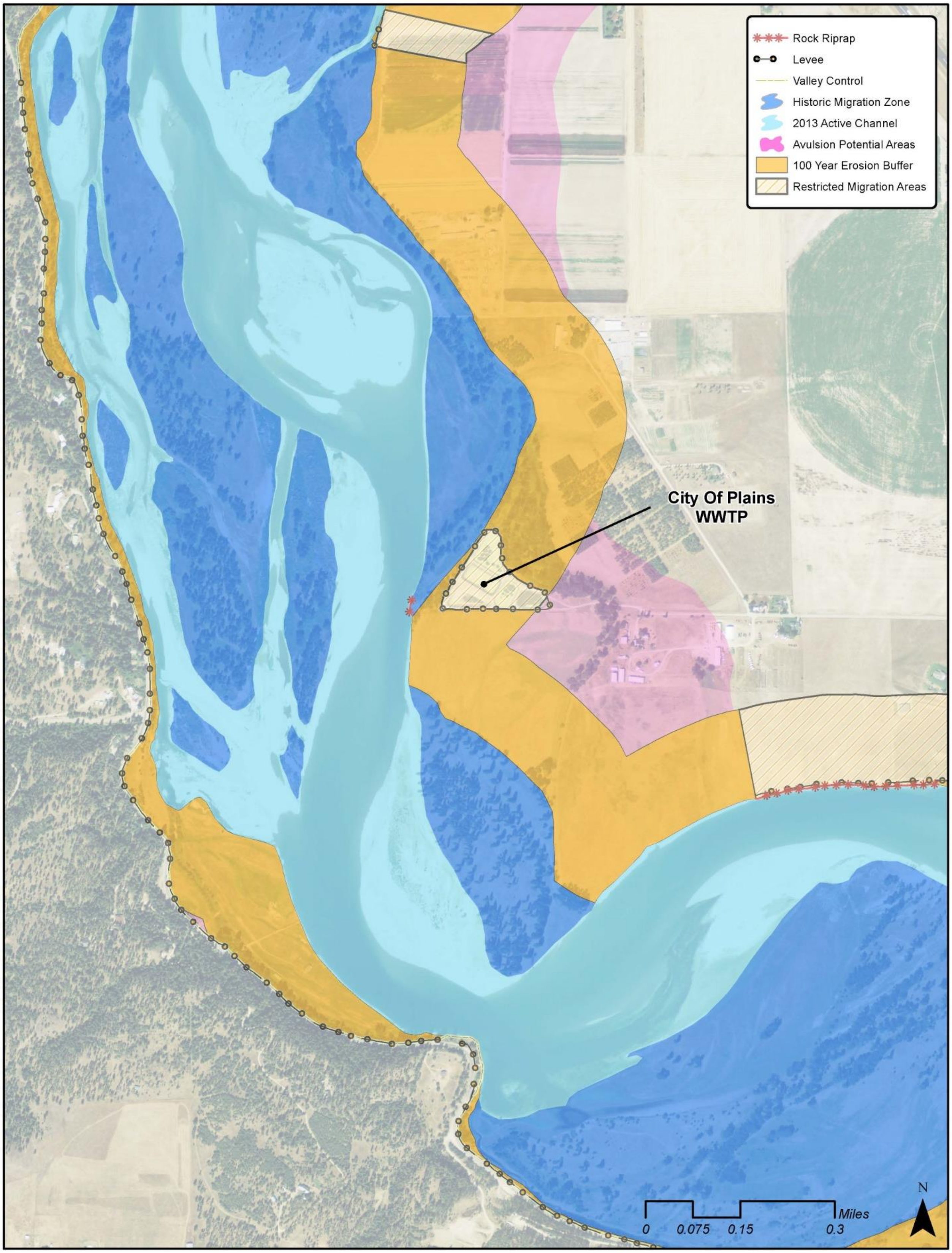


Figure 4-4. Channel Migration Zone in Vicinity of the Town of Plains WWTP

5.0 Streambank Erosion Analysis

5.1 Methods

Streambank erosion was assessed along an 8.0 mile reach of the Clark Fork River between Henry Creek and Lynch Creek for an 18 year time frame extending from 1995 through 2013. Areas of actively eroding bank at the outsides of meander bends along mid-channel bars were identified through a review of aerial imagery and bank locations were digitally mapped in GIS. This assessment examined bank retreat using black and white USGS Digital Orthophoto Quarter Quadrangles (DOQQs) from 1995 and USDA National Agriculture Imagery Program (NAIP) color imagery from 2005, 2009, 2011 and 2013, along with field observations performed in February and March of 2014. In addition, aerial imagery for 1955, 1964, 1972, 1979, 1982, and 1990 was obtained from the Aerial Photography Field Office, though this imagery was obtained near the end of the project and only used for comparative purposes. A 1981 aerial image from Montana Aerial Photography was also used for comparative purposes since the resolution was too course for detailed analysis. For each eroding bank, erosion was measured in GIS at 20 cross-sections and the average rate of retreat was calculated for the 18 year period of record from 1995 to 2013 (**Figure 5-1**). The maximum rate of bank retreat was also measured for each bank and the mean annual retreat rate was calculated for the 18 year period of record. Based on the mean annual retreat rate, erosion over the next 20 years was estimated for each eroding bank under the assumption that conditions over the next 20 years will resemble those observed over the past 18 years, which included flood events exceeding 100,000 cfs in 1997 and 2011 (see Section 2.0).

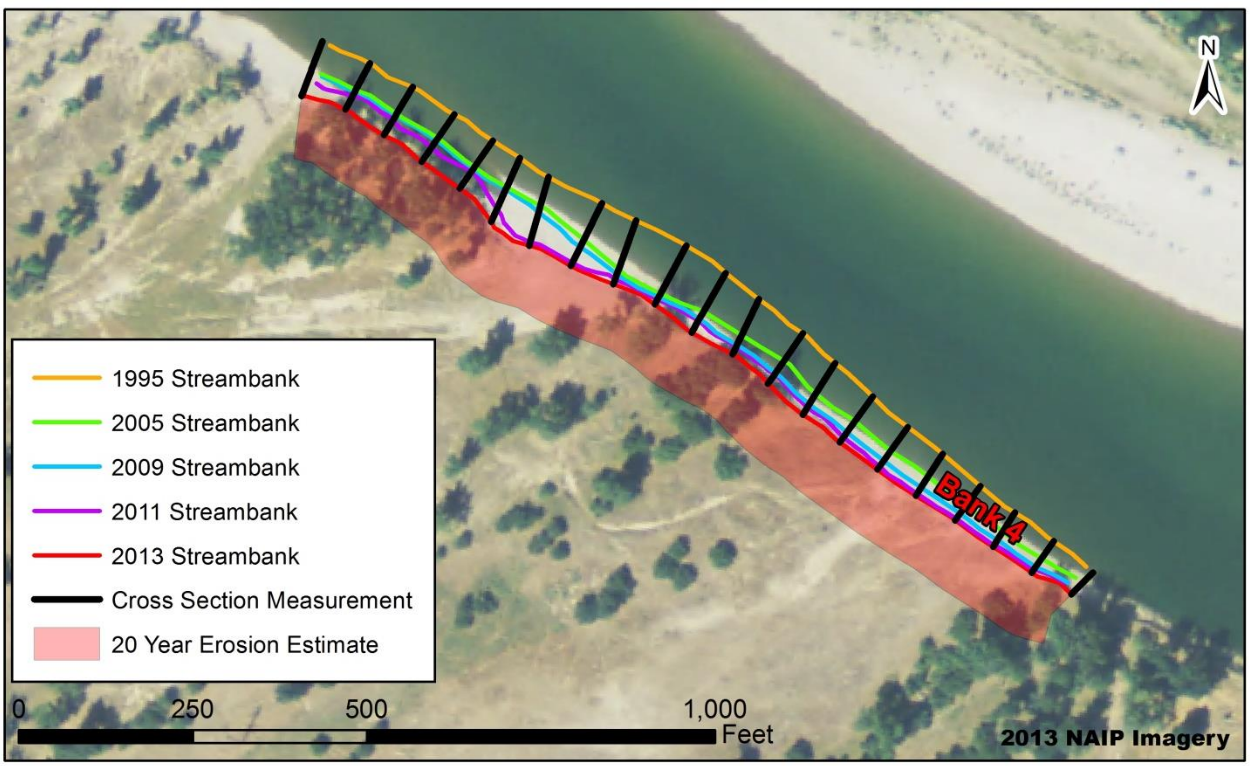


Figure 5-1. Bank Erosion Cross Section Measurement Example

5.2 Results

A total of 14 eroding streambanks were identified for the 1995 to 2013 timeframe, totaling 24,786 feet (4.69 miles) of erosion along the 8.0 mile study reach (**Table 5-1**, **Figure 5-2, 5-3** and **5-4**). A maximum retreat rate of 742 feet was measured at bank 10 along the Lawyer Nursery, followed by 413 feet at bank 5 on the Garrison/Herschbach property. Bank 10 eroded an average of 437 feet over 18 years, followed by bank 5 which eroded an average of 322 feet. This analysis indicates accelerated bank erosion is occurring at banks 5, 6, 7, 8, 10 and 11 with mean annual retreat rates at these six banks ranging from 7.8 feet to 24.3 feet. A review of aerial imagery from 1995 through 2013 indicates that the majority of the bank retreat occurs during years with flows exceeding 100,000 cfs, such as occurred in 1997 and 2011. These two flood events are observed between the 1995 and 2005 aerial imagery and the 2005 and 2011 aerial imagery, respectively. Banks 12, 13, and 14 are lined by undisturbed riparian vegetation and represent natural rates of streambank erosion expected in situations where mid-channel bars direct the water towards the channel margin. Based on measurements from these three banks, a mean annual retreat rate ranging from 2.1 to 5.3 feet is estimated for banks in a natural condition along the Plains Reach of the Clark Fork River. A detailed discussion of conditions along each of the 14 banks is presented in the following sections, including an estimate of ongoing retreat over the next 20 years based on the mean annual retreat rate for the past 18 years (**Table 5-1**).

Table 5-1. Streambank Erosion, 1995-2013

Parameter	Eroding Streambank												
	1	2	4	5	6	7	8	9	10	11	12	13	14
Length (Feet)	1129	3215	1334	2515	2389	1373	1096	715	4175	3925	1161	411	1261
Area (Acres)	0.3	1.6	2.5	20.0	10.4	4.3	9.1	0.4	34.7	16.6	1.0	0.9	2.0
Mean Annual Retreat Rate (Feet)	0.6	1.3	4.5	17.9	11.5	8.6	7.8	1.2	24.3	10.9	2.1	5.3	3.8
Mean Retreat Rate (Feet)	11	23	81	322	207	154	140	22	437	196	37	95	69
Maximum Retreat Rate (Feet)	22	50	102	413	313	260	299	40	742	336	52	118	119
20 Year Erosion Estimate (Feet)	12	25	90	358	230	172	156	24	486	218	41	105	77

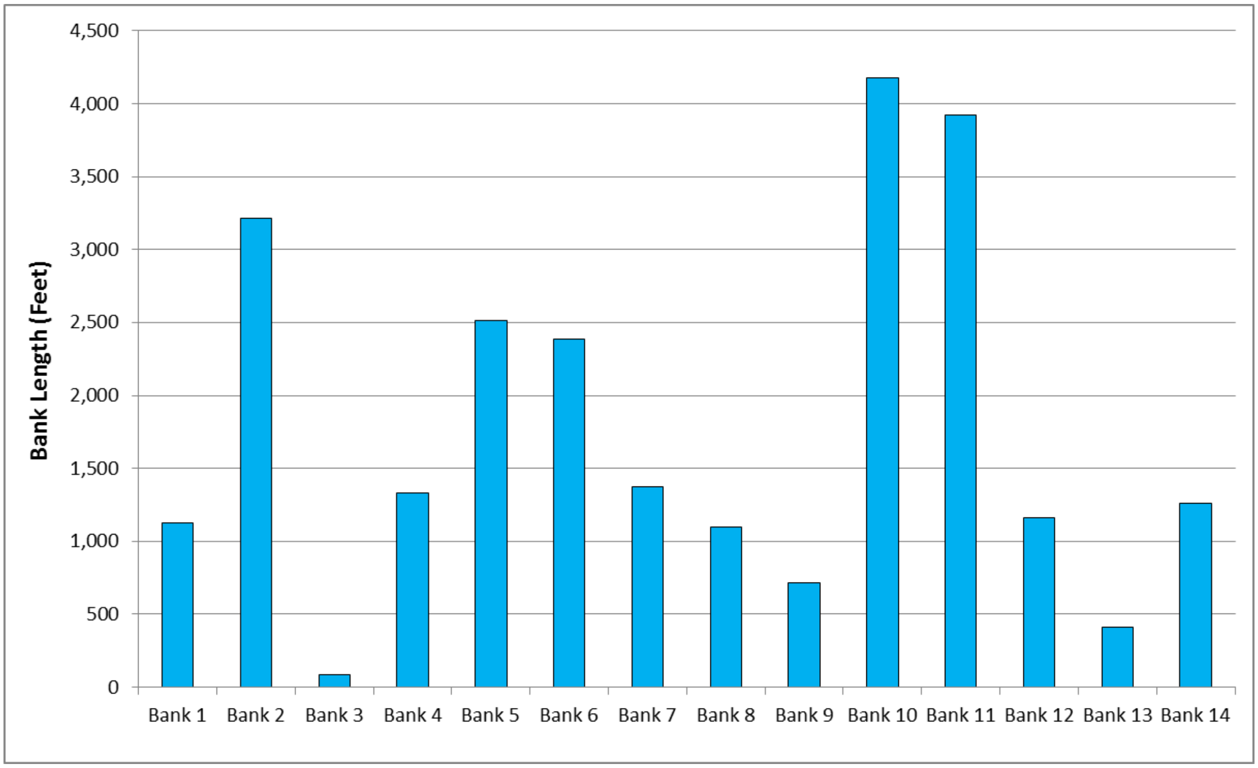


Figure 5-2. Length of Eroding Streambank, 2013

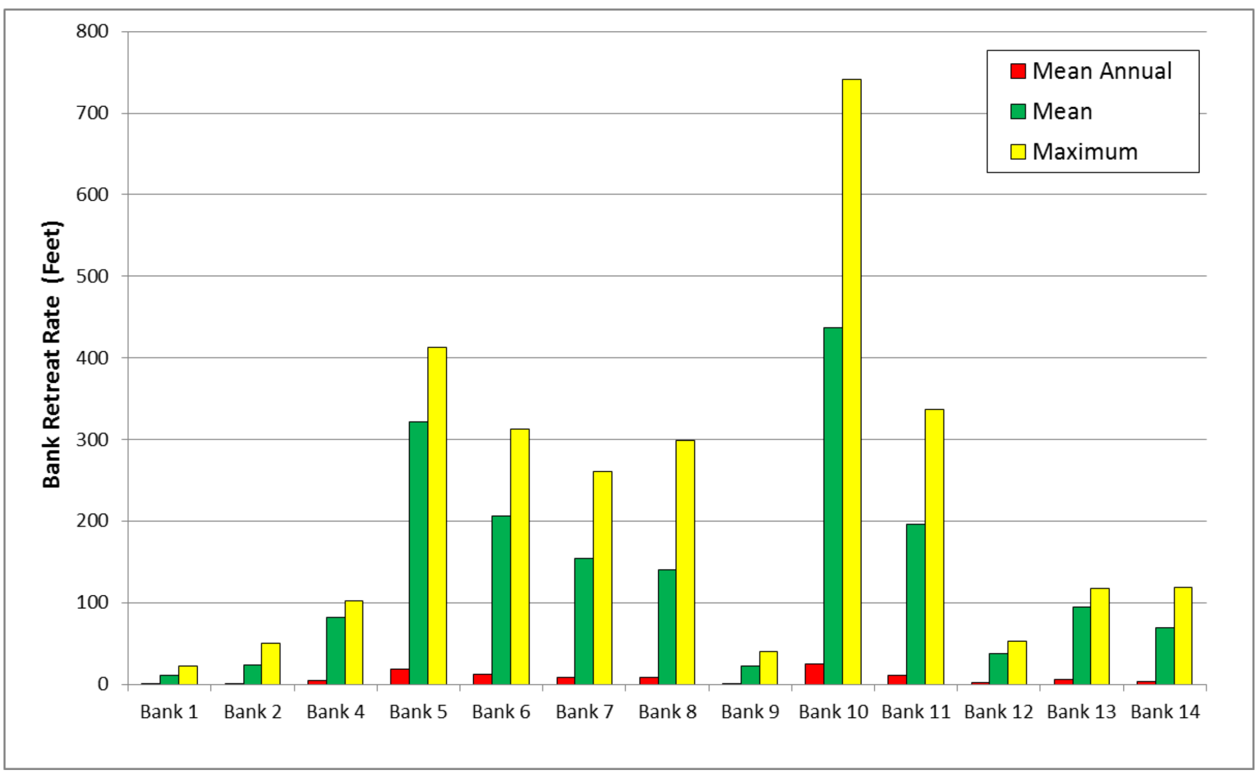


Figure 5-3. Streambank Erosion Retreat Rates, 1995-2013

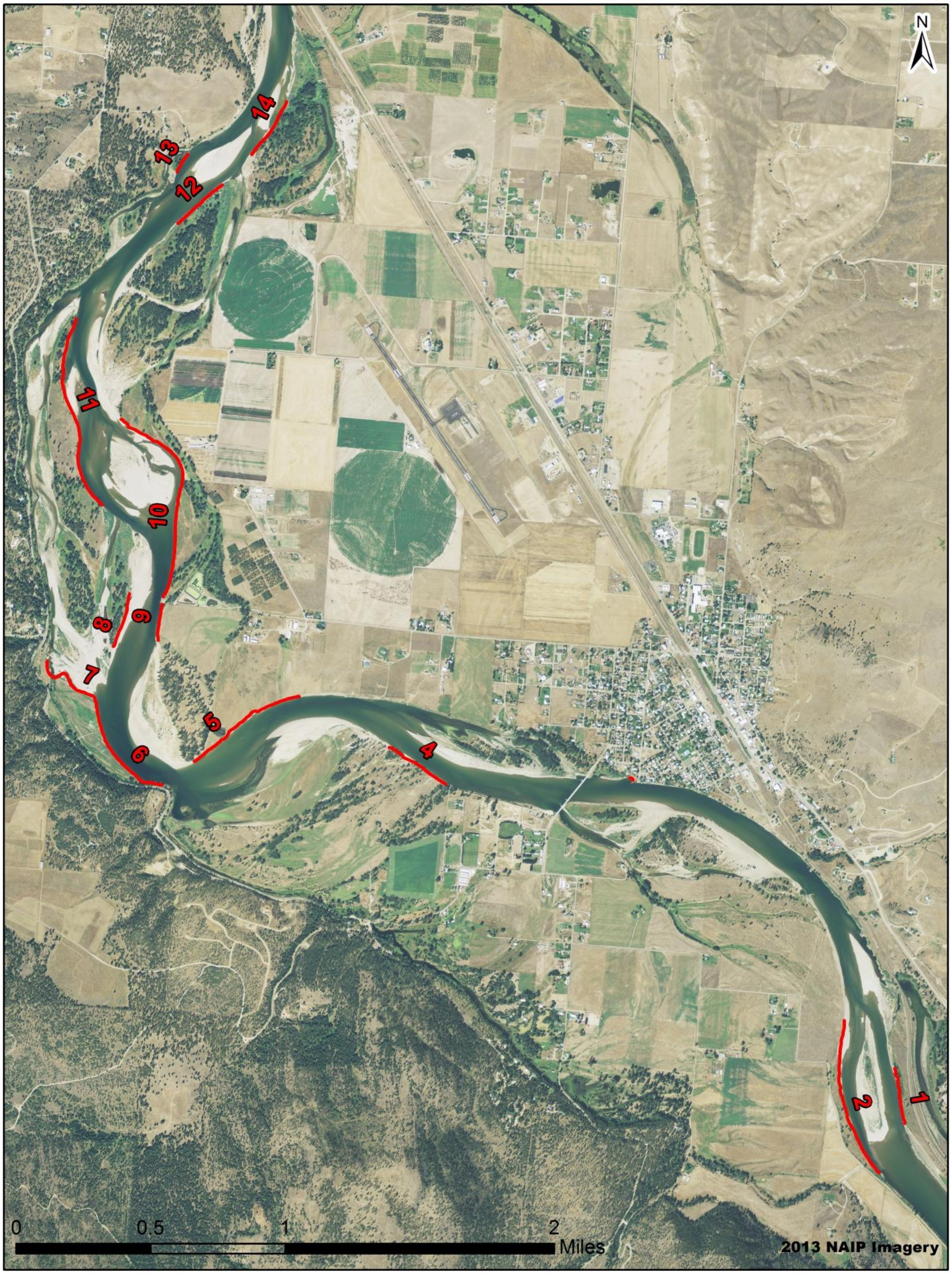


Figure 5-4. Eroding Streambanks within the Plains Reach

5.2.1 Bank 1

Bank 1 is 1,129 feet long and located on river right adjacent to Smiley's Slough. Between 1995 and 2013, bank 1 has eroded an average of 11 feet, with a mean annual retreat rate of 0.6 feet. Bank 1 is comprised of fine grained material, with gravel and cobble in the toe (**Figure 5-4**). The primary factor influencing erosion of bank 1 is a mid-channel bar that directs water towards the channel margin. Compounding factors include upstream channelization on river left by the levee along River Road East and on river right by the railroad, which has cut off the river's access to Smiley's slough (**Figure 5-7**).

Figure 5-5. Bank 1 Viewed Downstream from River Road East, March 2014

5.2.2 Bank 2

Bank 2 is 3,215 feet long and is located on river left along River Road East and across from Smiley's Slough. Between 1995 and 2013, bank 2 has eroded an average of 23 feet, with a mean annual retreat rate of 1.3 feet. Bank 2 is comprised of course grained material, including gravel and cobble (**Figure 5-6**). The primary factors influencing erosion of bank 2 are a mid-channel bar that directs water towards the channel margin, the banks location along the outside of meander bend, and a lack of deep rooted riparian vegetation. Compounding factors include upstream channelization on river left by the levee along River Road East and on river right by the railroad, which has cut off the river's access to Smiley's slough (**Figure 5-7**).

Figure 5-6. Bank 2 Viewed Upstream from the Bend on River Road East, March 2014

Figure 5-7. Bank 1 and Bank 2 Erosion 1995-2013

5.2.3 Bank 3

Bank 3 is 87 feet long and is located on river right in the town of Plains just upstream of the 5th Avenue South Bridge crossing (**Figure 5-8**). An assessment of bank retreat since 1995 was not conducted along this short bank, though aerial imagery from 1995 indicates it used to be lined by woody vegetation. The majority of the river right bank along the town of Plains upstream of the 5th Avenue South Bridge has been stabilized and this short section appears to be eroding due to a lack of bank armoring, along with flow deflection from upstream stabilization measures. Bank 3 is primarily comprised of course grained material, with fine grained material in the upper portion of the bank (**Figure 5-9**).

Figure 5-8. Bank 3 Upstream of the 5th Avenue South Bridge

Figure 5-9. Bank 3, March 2014

5.2.4 Bank 4

Bank 4 is 1,334 feet long and is located on river left downstream of the Sanders County Fairgrounds. Bank 4 extends downstream from the end of the rock riprap placed along the fairgrounds by the Army Corps of Engineers, which covered the fairgrounds under approximately four feet of water (Randy Garrison, personal communication, 2/4/14). Riprap extends nearly 1,600 feet above the start of bank 4. Bank 4 is partially vegetated with ponderosa pine and cottonwoods and bisected by two overflow channels that lead into Big Eddy (**Figures 5-10** and **5-11**). Between 1995 and 2013, bank 4 has eroded an average of 81 feet, with a mean annual retreat rate of 4.5 feet. Portions of the bank occupied by the overflow channels are comprised of gravel and cobble, while vegetated areas have fine grained material throughout the bank with gravel and cobble in the toe. The primary factors influencing erosion of bank 4 are upstream channel constriction by the 5th Avenue South Bridge and the growth of the gravel bar on the opposite side of the channel. The gravel bar has developed downstream of the 5th Avenue South Bridge and likely formed in response to the placement and alignment of the bridge, which was originally constructed in 1911. A review of aerial imagery dating back to 1955 indicates this gravel bar has become larger and more vegetated over the past 58 years, which has directed the river towards bank 4. Compounding factors influencing erosion along bank 4 include upstream channelization on river right along the town of Plains which has effectively restricted lateral migration of the river upstream of the bridge over the past 100 years.

Figure 5-10. Bank 4, March 2014

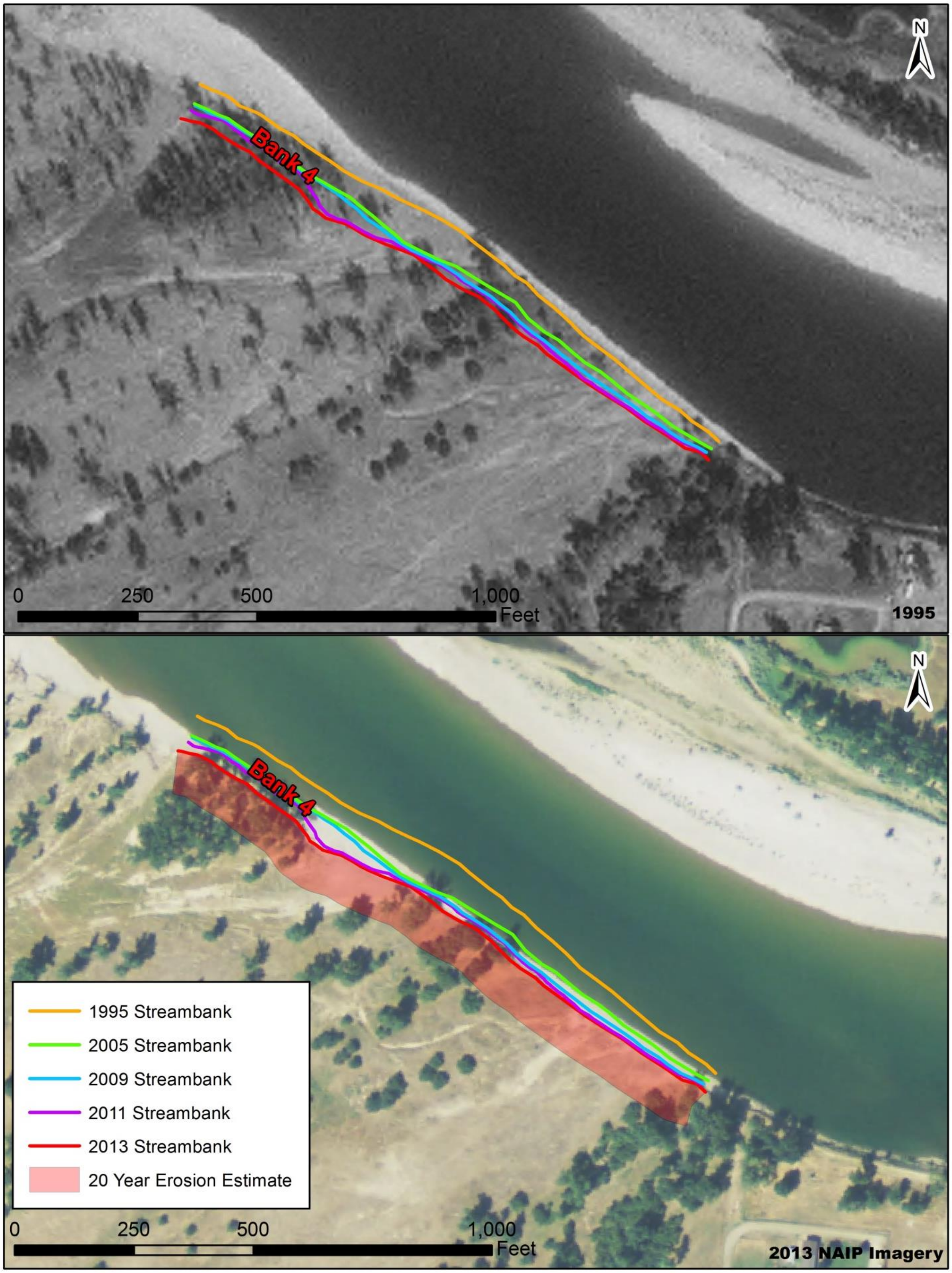


Figure 5-11. Bank 4 Erosion 1995-2013

5.2.5 Bank 5

Bank 5 is 2,515 feet long and located on river right at the outside of a meander bend that is naturally experiencing lateral retreat and has been partially stabilized with rock riprap. Erosion along bank 5 extends downstream from a section of riprap placed by the Army Corps of Engineers that was reinforced in 2011 as water was overtopping the bank. The newly placed riprap extends approximately 900 feet upstream from the upper end of bank 5, while the historic riprap extends approximately 600 additional feet, leading to approximately 1,500 feet of bank stabilization upstream of bank 5. Prior to 2011, active retreat was observed along the 900 feet of bank that was reinforced with riprap in 2011. The majority of bank 5 is actively eroding into an agricultural field currently used for livestock grazing, though a stand of cottonwoods and a stand of ponderosa pines reduce the retreat rate at the downstream end (**Figures 5-12** and **5-13**). The majority of bank 5 is comprised of gravel in the toe that often extends up into the lower third of the bank, with fine grained material in the upper two thirds. A 150 foot section of bank 5 is comprised entirely of fine grain material and is eroding at an accelerated rate. Between 1995 and 2013, bank 5 has eroded an average of 322 feet, with a mean annual retreat rate of 17.8 feet. The primary factors influencing erosion of bank 5 are its location at the outside of meander bend and the lack of deep rooted riparian vegetation along the top of the bank. Compounding factors include upstream bank stabilization along the fairgrounds, channel constriction under the 5th Avenue South Bridge, and upstream channel confinement by the levee along River Road East that restricts higher flows from accessing the floodplain in the South Plains area. Material eroded from bank 5 has been deposited on the next point bar downstream where a young stand of cottonwoods is becoming established (**Figures 5-14** and **5-15**).

Figure 5-12. Bank 5, March 2014

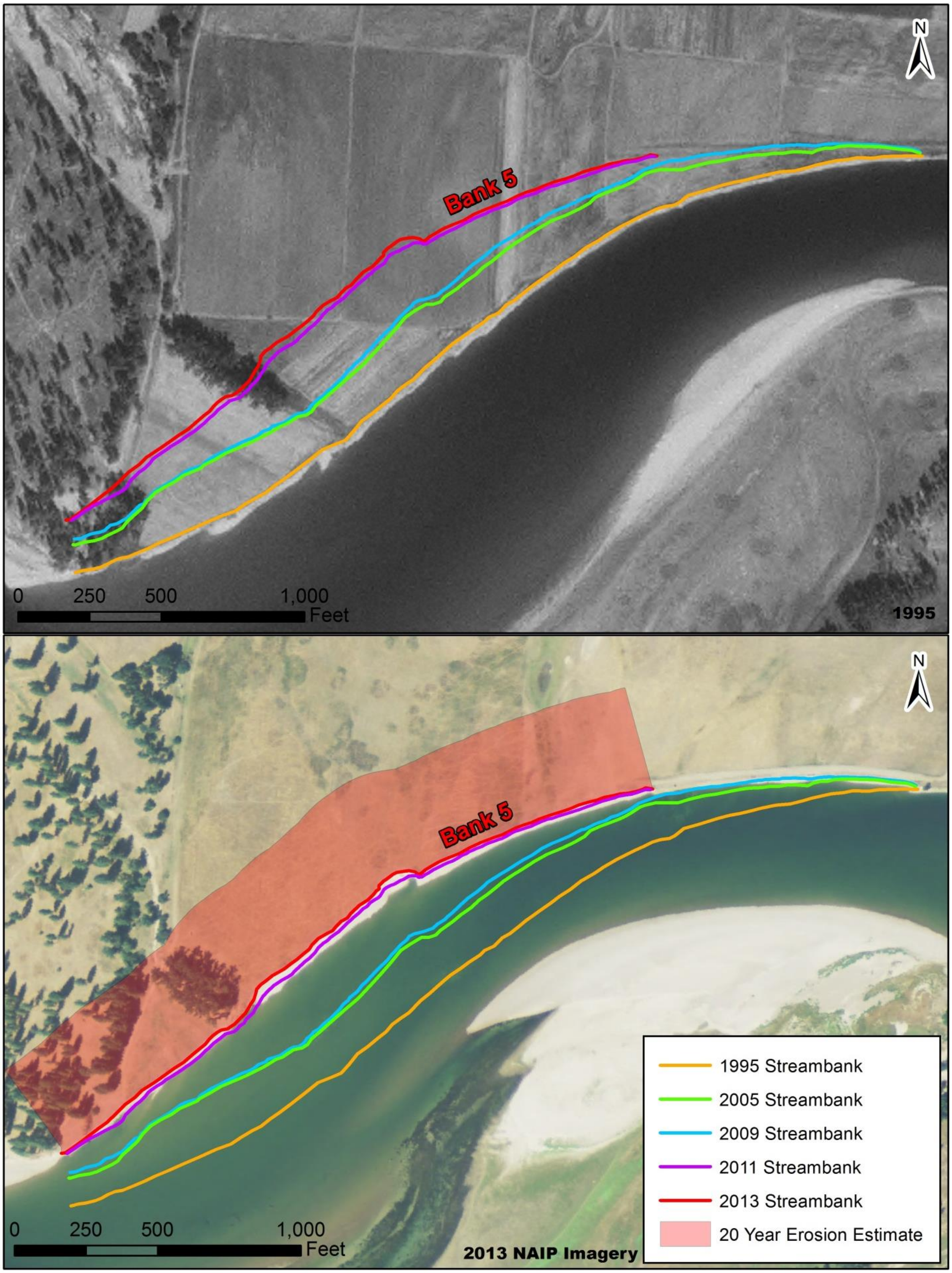


Figure 5-13. Bank 5 Erosion 1995-2013

Figure 5-14. Cottonwood Regeneration on Point Bar Development Downstream of Bank 5

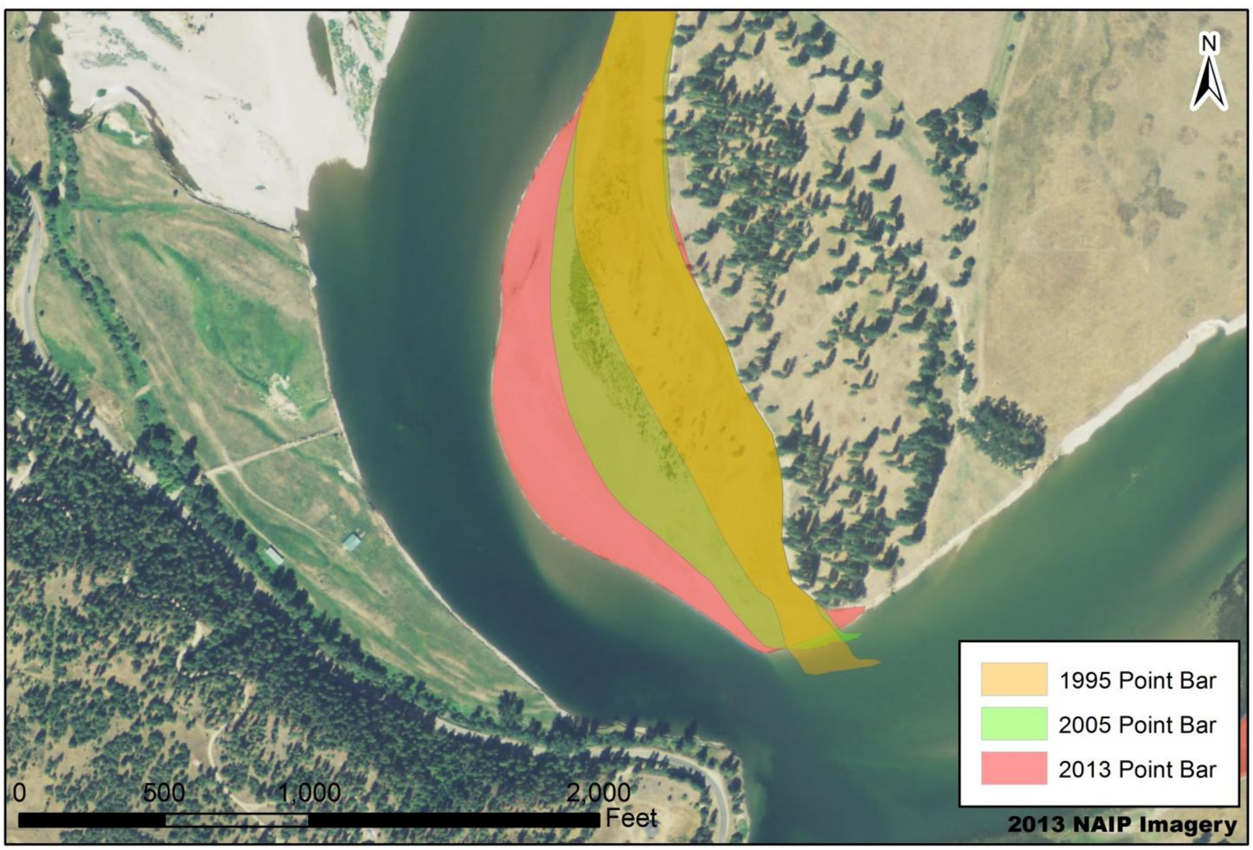


Figure 5-15. Sediment Deposition on Point Bar Downstream of Bank 5

5.2.6 Bank 6

Bank 6 is 2,389 feet long and located on river left downstream of the bedrock outcrop below Big Eddy. Bank 6 is comprised of fine grained material with gravel and cobble in the toe and periodically extending approximately a third of the way up the bank (**Figures 5-16** and **5-17**). This bank is actively eroding into an area currently used for livestock grazing. Between 1995 and 2013, bank 6 has eroded an average of 207 feet, with a mean annual retreat rate of 11.5 feet. The primary factor influencing the erosion of bank 6 since 1995 is downstream channel migration which now directs the majority of the stream power directly at bank 6, along with the lack of deep rooted riparian vegetation along the top of the bank. An analysis of aerial imagery extending back to 1955 indicates that this area was relatively stable for the 40 year period between 1955 and 1995 (**Figure 5-18**). During the past 18 years, active bank erosion has occurred at this site and appears to have been initiated by the 1997 flood event (**Figure 5-19**). In 1997, a house built near the edge of this bank was burned down as the river undercut the foundation of the house, which remains visible within the channel. Prior to the 1997 flood event, the bedrock outcrop on river left downstream of Big Eddy dissipated much of the stream power, allowing the water to flow past bank 6 in a naturally straight section of the channel (**Figure 5-20**). The bedrock outcrop essentially "reset" the channel to a natural meander pattern relatively uninfluenced by upstream channel alterations. As bank 5 upstream has eroded and the channel has meandered downstream and to the north, the majority of the flow has begun to bypass the bedrock outcrop and be directed at bank 6, which has developed into a meander bend that continues to actively erode, while the point bar on the opposite side of the channel expands. Material eroded from bank 6 has been deposited at the head of the west channel, which has become aggraded and cut off from lower flows (**Figure 5-21**).

Figure 5-16. Bank 6 Looking Downstream from River Road West, March 2014

Figure 5-17. Bank 6, March 2014

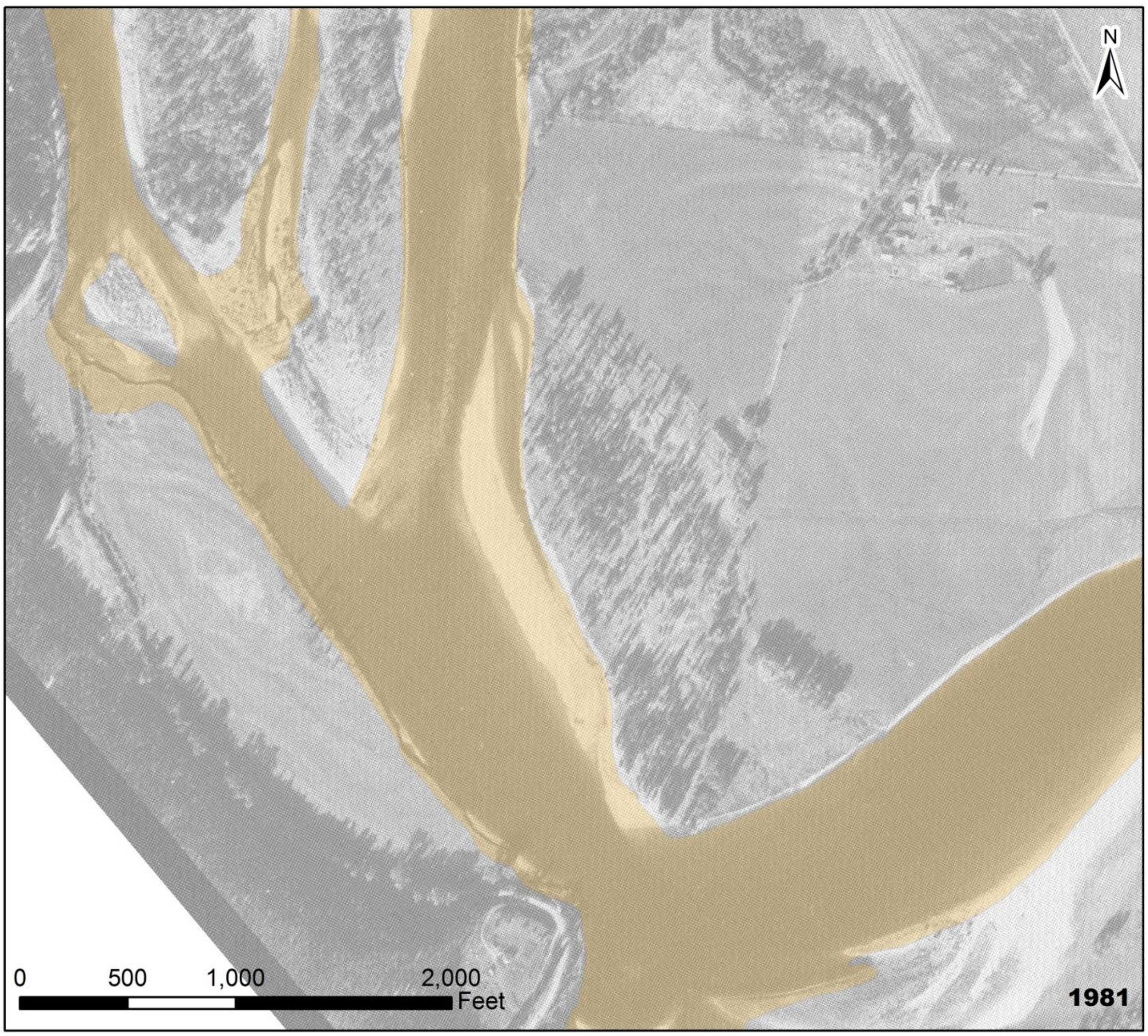


Figure 5-18. 1981 Aerial Imagery Compared to 1995 Active Channel (in orange) along Bank 6

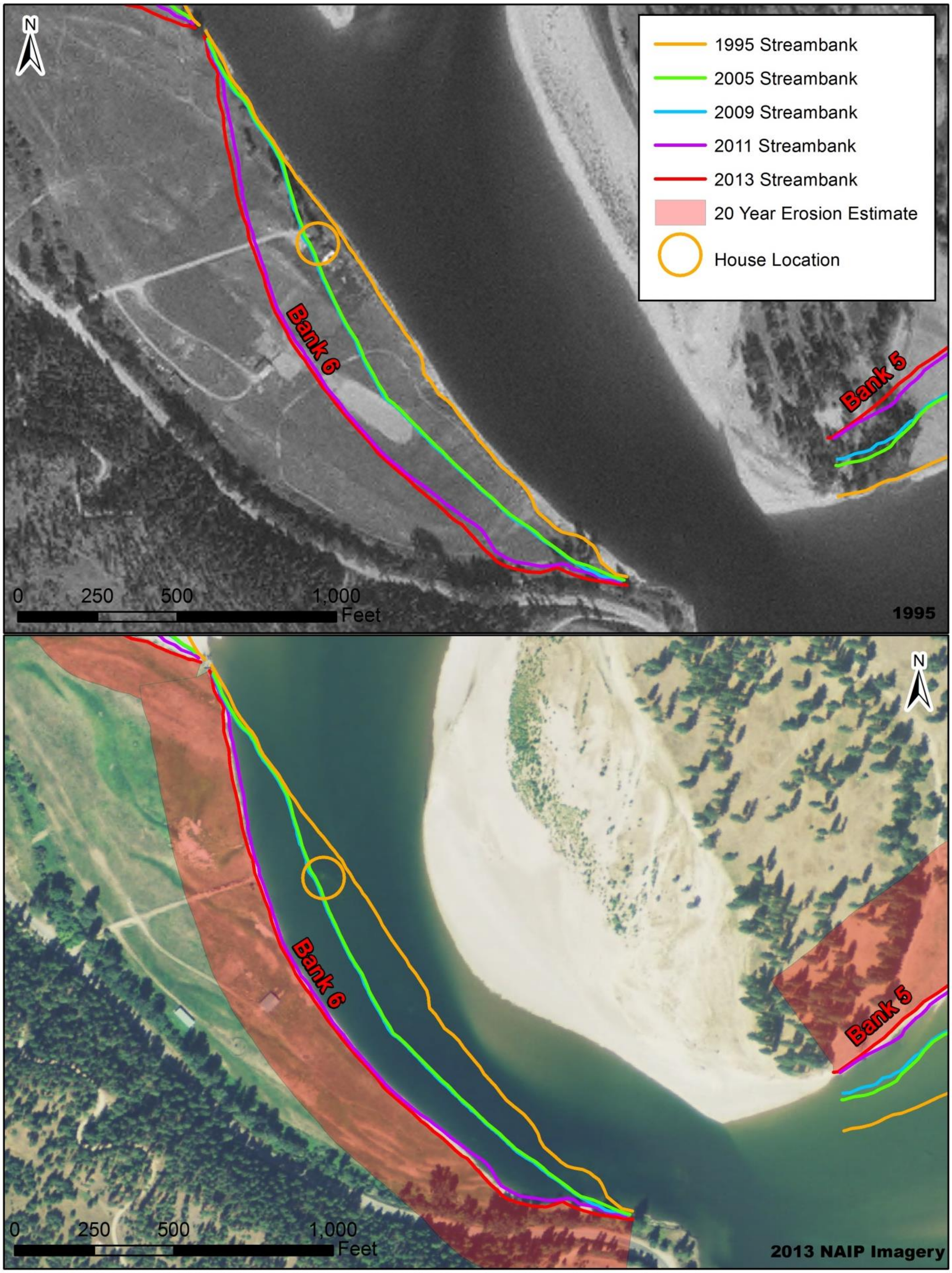


Figure 5-19. Bank 6 Erosion 1995-2013

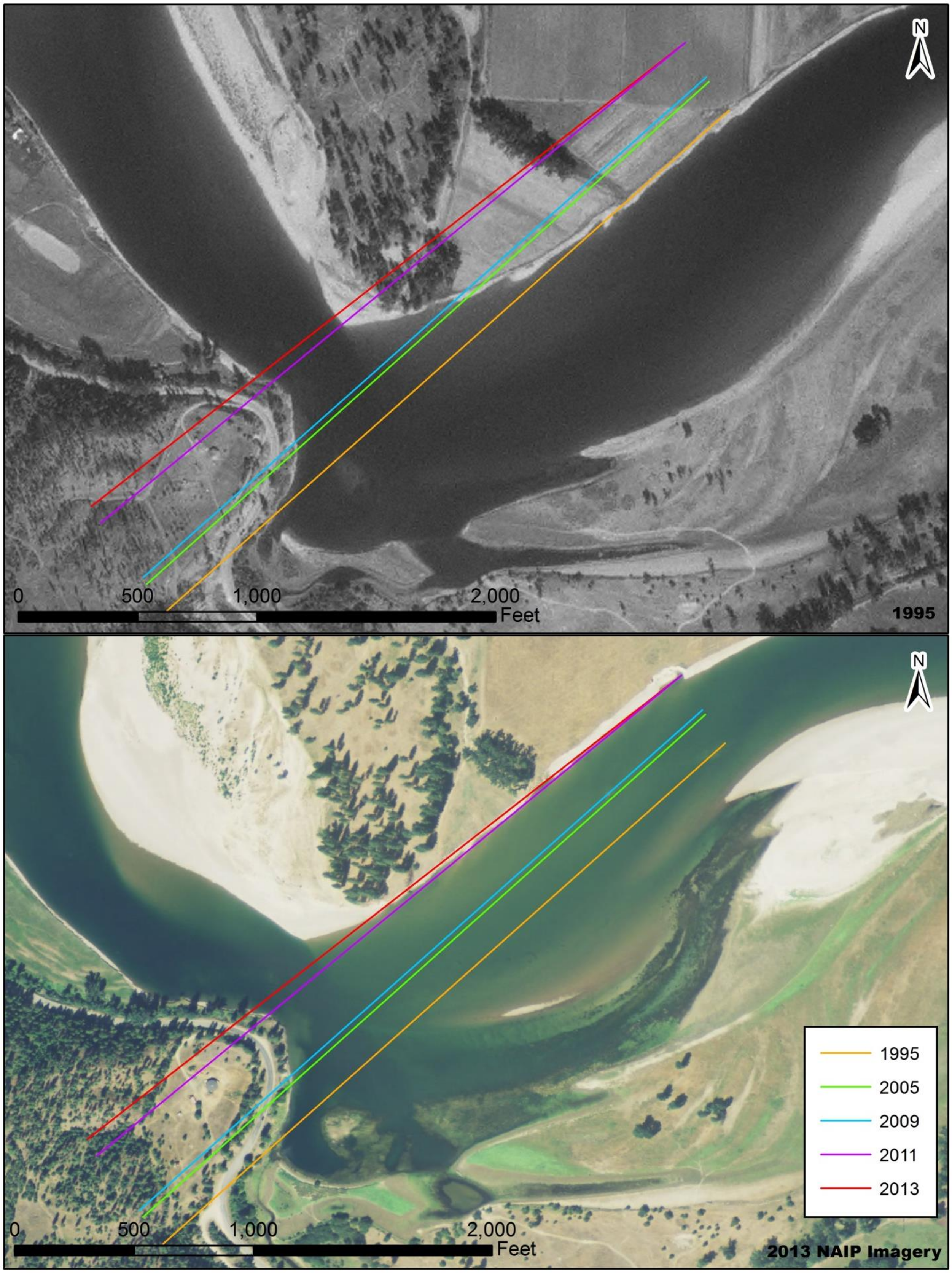


Figure 5-20. Channel Migration downstream of the Bedrock Outcrop below Big Eddy, 1995-2013

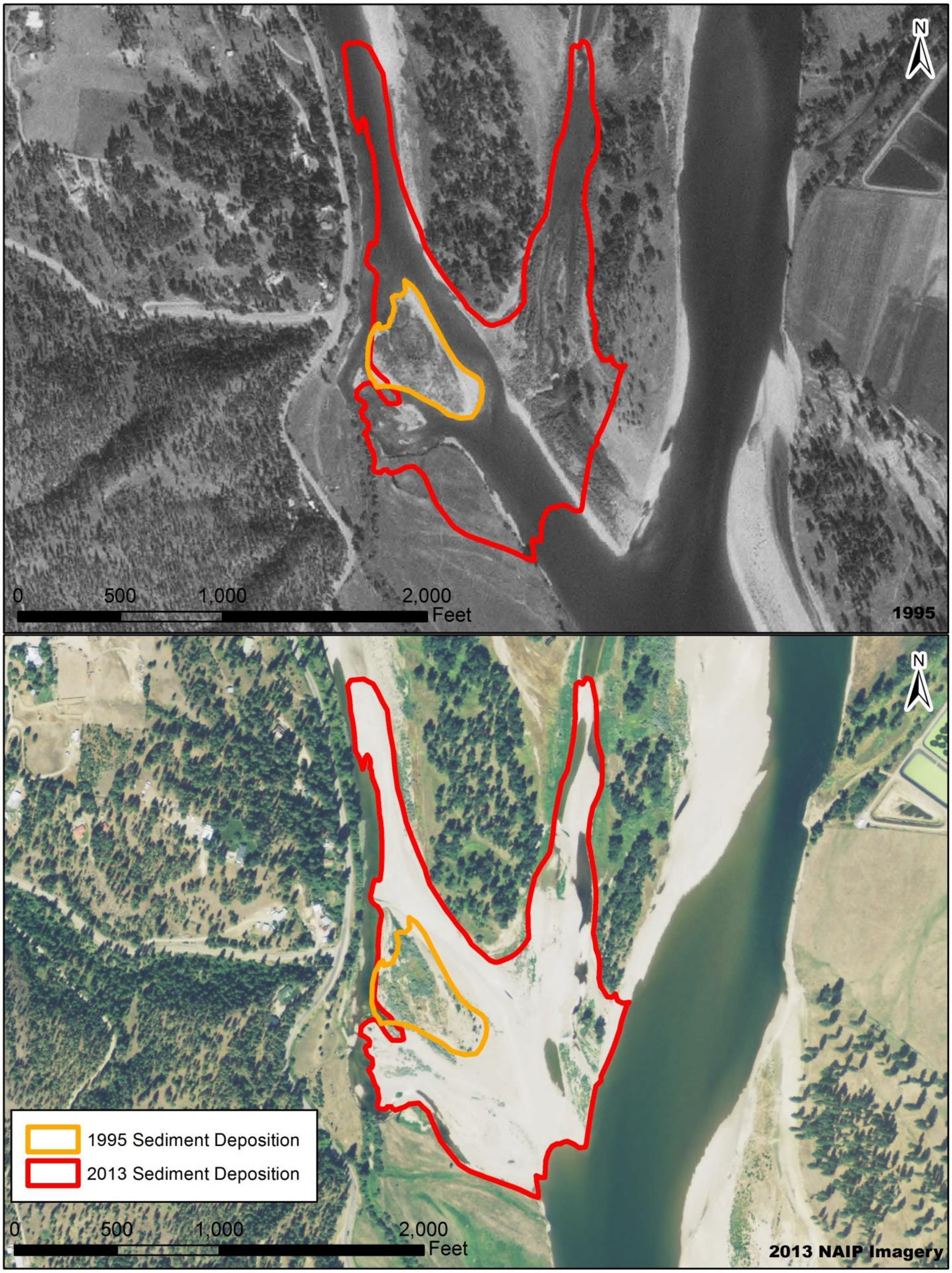


Figure 5-21. Sediment Deposition at the Head of the West Channel, 1995-2013

5.2.7 Bank 7

Bank 7 is 1,373 feet long and located on river left along the head of the west channel. Bank 7 is a vertical bank comprised of highly erosive fine grained material (**Figure 5-22**). A small pile of rocks placed on the floodplain that have fallen into the channel partially stabilize the downstream end of bank 6 and one cottonwood remains at a small point that separates the main channel along bank 6 from the west channel along bank 7. When combined, banks 6 and 7 total 3,762 feet. Between 1995 and 2013, bank 7 has eroded an average of 154 feet, with a mean annual retreat rate of 8.6 feet. In the 1995 aerial imagery, the west channel branches off the main channel further upstream and the majority of bank 7 is situated along a straight section of the west channel (**Figure 5-23**). The primary factors influencing erosion of bank 7 since 1995 are an extension of the processes influencing bank 6, including downstream channel migration and a lack of deep rooted riparian vegetation along the top of the bank. In addition, the accumulation of coarse grained material eroded from bank 6 at the head of the west channel has led to channel aggradation and over-widening, which has directed more of the flow toward bank 7 along the river left channel margin (**Figure 5-24**). Coarse grained material from the toe of bank 7 likely remains at the head of the west channel, while fine grained material eroded from bank 7 has been deposited throughout the west channel, with an increase in fine grained material observed at the downstream end of the west channel (Karen Thorson, personal communication, 3/26/14).

Figure 5-22. Bank 7

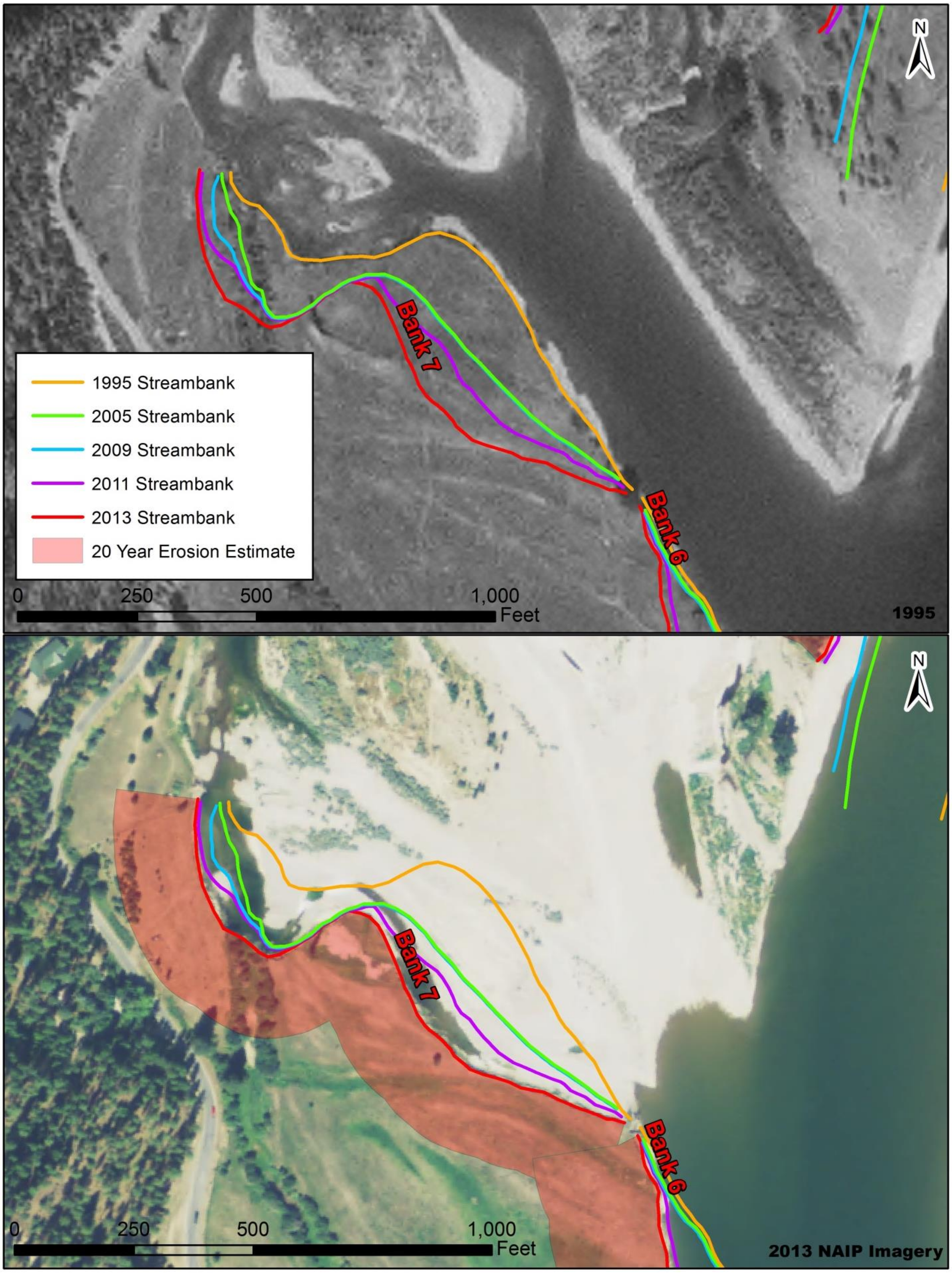


Figure 5-23. Bank 7 Erosion 1995-2013

5.2.8 Bank 8

Bank 8 is 1,096 feet long and is located along the point of the island that separates the west channel from the main channel. Since 1995, this point has migrated downstream, with the majority of the erosion occurring along the outside of the island along the main channel. The point of the island is a partially vegetated gravel bar bisected by two overflow channels (**Figures 5-24** and **5-25**). Progressing downstream, the island gains elevation and contains mature riparian vegetation. Between 1995 and 2013, bank 8 has eroded an average of 140 feet, with a mean annual retreat rate of 7.8 feet. The majority of bank retreat since 1995 has occurred at the upstream end of bank 8 along the lower elevation portion of the point of the island that separates the west channel from the main channel (**Figure 5-26**). The primary factors influencing erosion of bank 8 are downstream channel migration and aggradation at the head of the west channel. Downstream channel migration observed since 1995 is being driven by erosion of bank 5 and subsequent deposition of eroded material on the downstream point bar, along with erosion of bank 6 and bank 7 and deposition of material at the head of the west channel. Reduced access to the west channel leads to increased stream power in the main channel, which is now actively meandering into bank 8. Material eroded from bank 8 at the point of the island is being deposited along the channel margin downstream, leading to the development of a point bar that is directing more of the flow towards bank 9, the Town of Plains WWTP, and bank 10.

Figure 5-24. Point of Island Separating the West Channel from the Main Channel, March 2014

Figure 5-25. Bank 8, March 2014

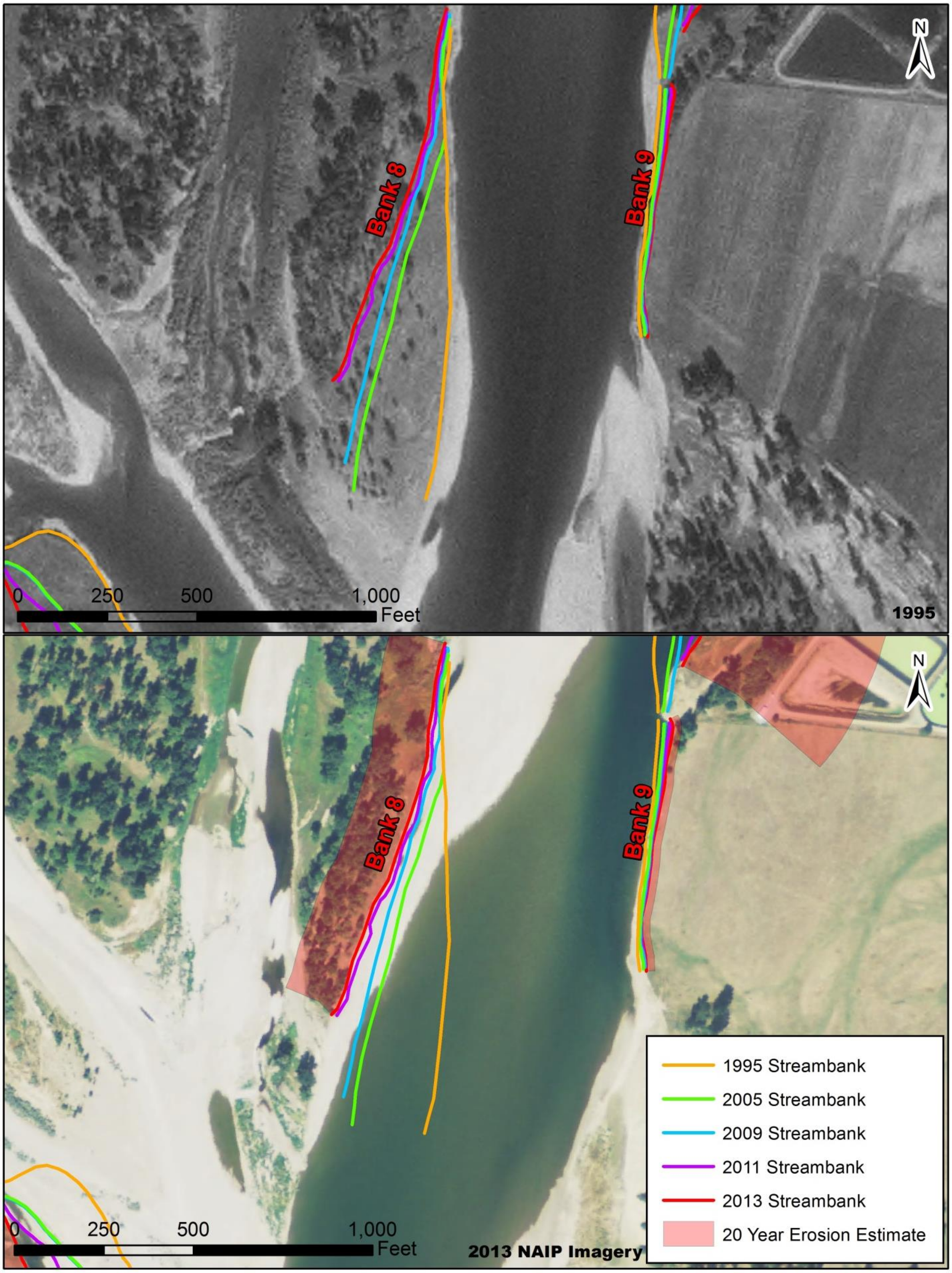


Figure 5-26. Bank 8 and Bank 9 Erosion 1995-2013

5.2.9 Bank 9

Bank 9 is 715 feet long and is located along river right upstream of the Town of Plains WWTP outfall. Bank 9 is separated from bank 10 by approximately 137 feet of rock riprap placed at the outfall of the WWTP prior to runoff in 2010. Bank 9 is comprised of fine grained material with gravel and cobble in the toe at the lower end (**Figure 5-27**). Wind transport of the fine grained material in bank 9 was observed during a site visit in March 2014. Gravel and cobble comprise a greater portion of the bank at the upper end where the bank merges with the downstream end of a point bar. This bank is slowly eroding into an area currently used for livestock grazing. Between 1995 and 2013, bank 9 has eroded an average of 22 feet, with a mean annual retreat rate of 1.2 feet. During a site visit in March 2014, fence posts formerly lining the top of the bank were observed along the toe of the bank. Since 2010, erosion has primarily occurred immediately upstream of the riprap, creating a scallop approximately 100 feet long that is prone to future erosion (**Figure 5-26**). The top of the bank in the 100 feet upstream of the riprap is also approximately three feet lower than the top of the bank immediately upstream. The primary factors influencing erosion of bank 9 are downstream channel migration, increased stream power due to reduced access to the west channel, the lack of deep rooted riparian vegetation along the top of the bank, and the hydrologic impacts induced by the placement of the rock riprap at the Town of Plains WWTP outfall. Material eroded from bank 9 is likely deposited on the next mid-channel bar downstream, which is rapidly expanding and directing additional stream power towards the lower portion of bank 10.

Figure 5-27. Bank 9 Looking Downstream toward Riprap at WWTP Outfall, March 2014

5.2.10 Bank 10

Bank 10 is 4,175 feet long and located on river right downstream of the WWTP outfall. Prior to stabilization of the Town of Plains WWTP outfall in 2010, bank 9 and bank 10 formed one continuous bank extending approximately 5,000 feet. Bank 10 is comprised almost entirely of fine grained material with a layer of gravel at the toe that is essentially the bed of the channel (**Figure 5-28**). At the downstream end of bank 10, a layer of woody material from historic mill waste dumped on the floodplain partially hardens the bank and reduces the rate of erosion (**Figure 5-29**). This layer of hard woody material has restricted lateral channel migration at the downstream end of bank 10 and forced the channel to erode into the fine grained material in the upstream portion of the bank, resulting in an area of extreme erosion and channel over-widening, with a maximum bank retreat of 742 feet observed over the 18 year period between 1995 and 2013 along Lawyer Nursery property. Prior to 1995, a review of aerial imagery indicates this bank was relatively stable during the 40 year period between 1955 and 1995 along an area used for agricultural production, with the current accelerated rate of erosion likely initiated by the 1997 flood event (**Figure 5-30**). Between 1995 and 2013, bank 10 has eroded an average of 437 feet, with a mean annual retreat rate of 24.3 feet. The primary factors influencing erosion of bank 10 are increased stream power due to reduced access to the west channel, a mid-channel bar that directs water towards the channel margin, the banks location along the outside of a developing meander bend, and a lack of deep rooted riparian vegetation along the top of the bank. While the mid-channel bar is visible in the historic aerial imagery, it has expanded significantly since 1995 (**Figure 5-31**). The source of material in the mid-channel bar is thought to be material transported from upstream bank erosion, along with material from the toe of bank 10 that has remained in place as the finer grained material higher in the bank washed away. Material eroded from bank 10 is also being deposited at the head of the east channel, with finer grained material extending further downstream (**Figures 5-32** and **5-33**). On the opposite side of the channel, bank 11 has also been eroding and the channel has become over-widened in this area from a maximum width of approximately 900 feet in 1995 to a maximum width of approximately 1,700 feet in 2013.

Figure 5-28. Erosion along Bank 10 and Sediment Deposition on Mid-channel Bar, March 2014

Figure 5-29. Mill Waste in Downstream End of Bank 10 and Deposited on Gravel Bar, March 2014

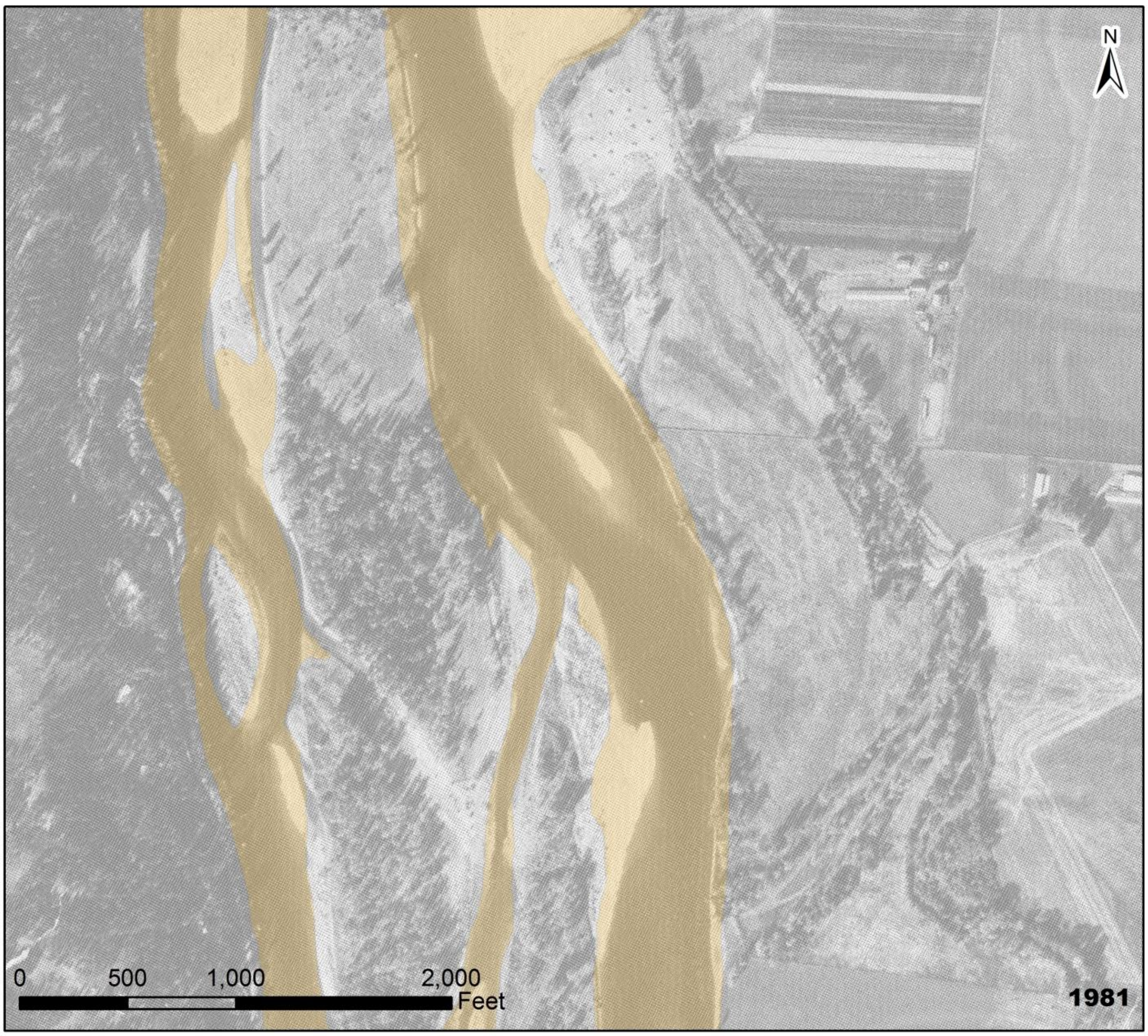


Figure 5-30. 1981 Aerial Imagery Compared to 1995 Active Channel (in orange) along Bank 10

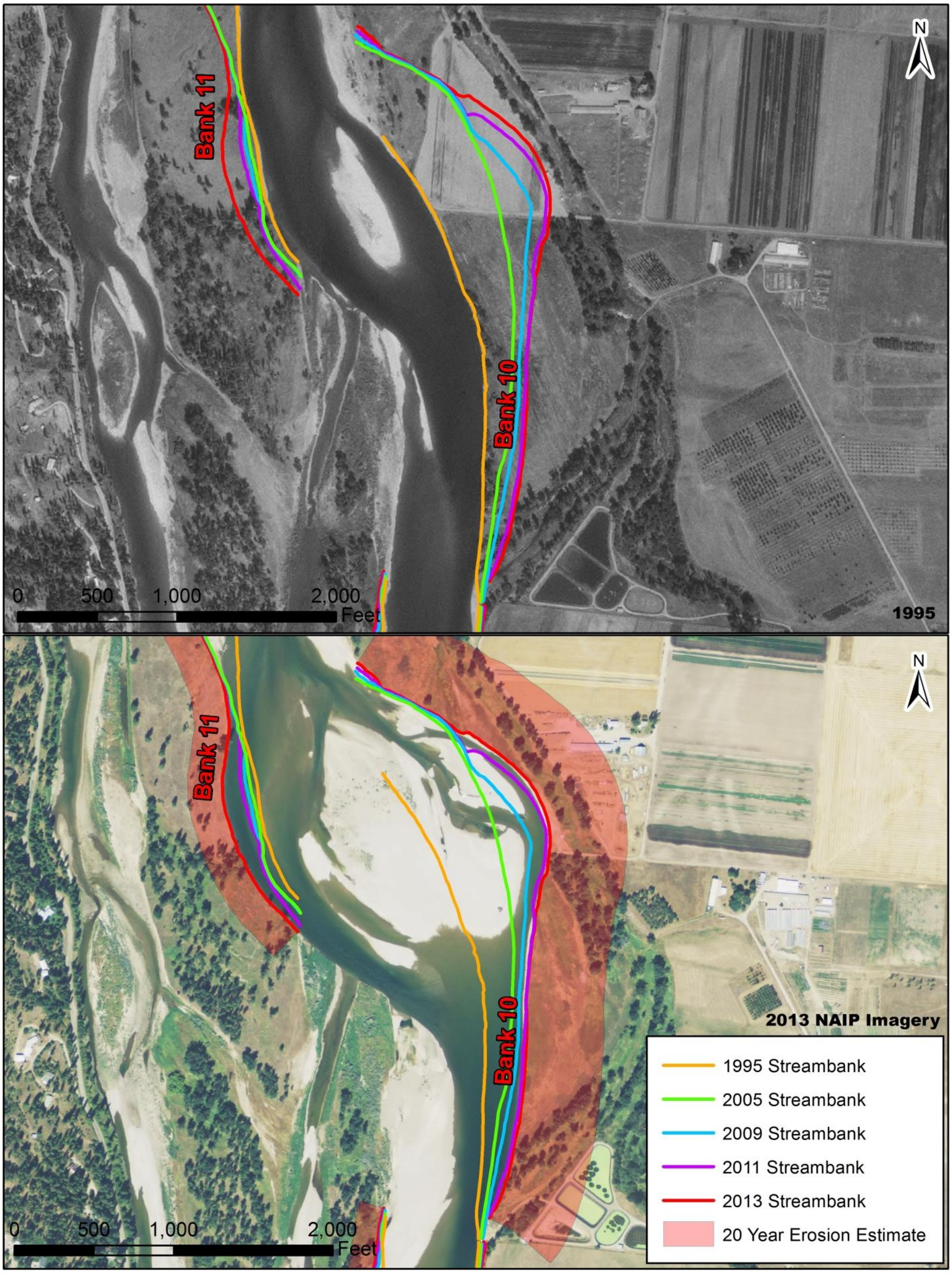


Figure 5-31. Bank 10 Erosion 1995-2013

Figure 5-32. Bank 10 with Mid-channel Bar and Sediment Deposition at the Head of the East Channel

Figure 5-33. Sediment Deposition Downstream of Bank 10

5.2.11 Bank 11

Bank 11 is 3,925 feet long and located at the downstream end of the island that separates the west channel from the main channel and is along the river left margin of the main channel across from Lawyer Nursery. Bank 11 is comprised primarily of fine grained material with periodic bands of gravel (**Figure 5-34**). Between 1995 and 2013, bank 11 has eroded an average of 196 feet, with a mean annual retreat rate of 10.9 feet (**Figure 5-35**). The primary factor influencing erosion of bank 11 is the large mid-channel bar that directs water towards the channel margin, along with reduced flows in the east channel due to the deposition of material eroded from bank 10, which influences the erosion along the lower end of bank 11. Decreased flows in the east channel are also indicated by more exposed gravel observed in the 1995 aerial imagery than in the 2013 aerial imagery (**Figure 5-35**). If the head of the east channel continues to aggrade and the current rate of erosion along bank 11 continues, the lower 1,500 feet of the island that separates the west channel from the main channel could become completely eroded away.

Figure 5-34. Bank 11, March 2014

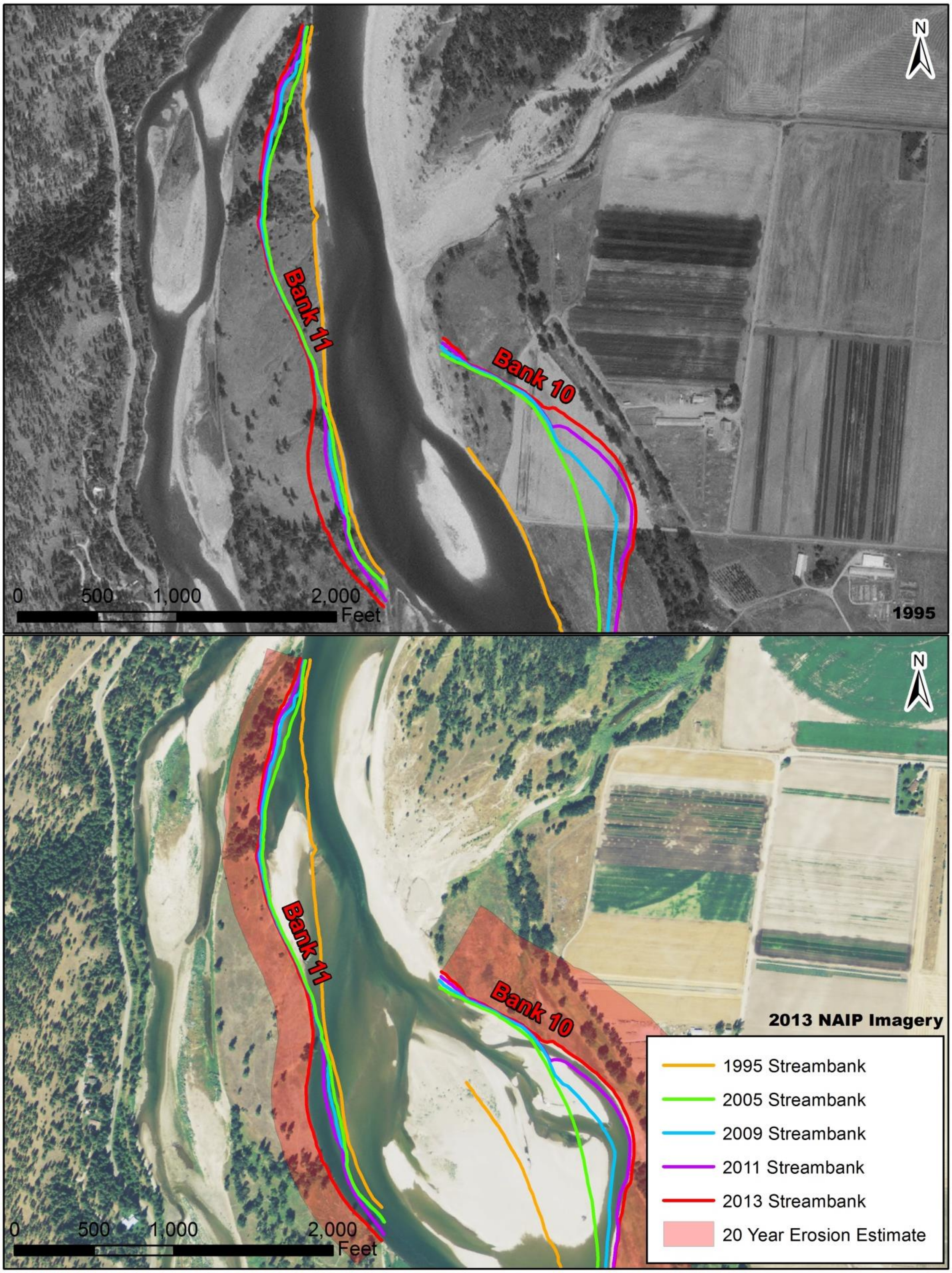


Figure 5-35. Bank 11 Erosion 1995-2013

5.2.12 Bank 12

Bank 12 is 1,161 feet long and located along the river right bank on a portion of the Lawyer Nursery property referred to as the Clark Fork Reserve. Bank 12 is comprised of fine grained material with gravel in the toe (**Figure 5-36**). Between 1995 and 2013, bank 12 has eroded an average of 37 feet, with a mean annual retreat rate of 2.1 feet. This area contains undisturbed riparian vegetation and represents natural rates of streambank erosion expected in situations where there are mid-channel bars directing the flow towards the channel margins (**Figure 5-39**). However, decreased flows in the east channel, along with increased sediment deposition on the mid-channel bar from upstream bank erosion, may also influence erosion rates along this bank.

Figure 5-36. Bank 12, March 2014

5.2.13 Bank 13

Bank 13 is 411 feet long and located along a small island on the river left margin of the main channel. Bank 13 is comprised of fine grained material with gravel in the toe (**Figure 5-37**). Between 1995 and 2013, bank 13 has eroded an average of 95 feet, with a mean annual retreat rate of 5.3 feet. This island contains undisturbed riparian vegetation and represents natural rates of streambank erosion expected in situations where there are mid-channel bars directing the flow towards the channel margins (**Figure 5-39**). However, decreased flows in the east channel, along with increased sediment deposition on the mid-channel bar from upstream bank erosion, may also influence erosion rates along this bank.

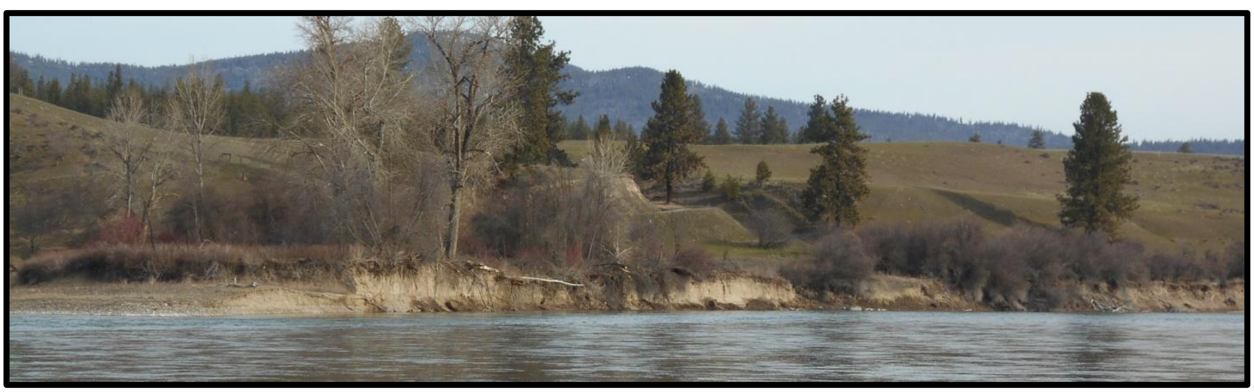


Figure 5-37. Bank 13, March 2014

5.2.14 Bank 14

Bank 14 is 1,261 feet long and is located along the river right bank upstream of the confluence with Lynch Creek. Bank 14 is comprised of fine grained material with gravel in the toe that periodically extends higher into the bank (**Figure 5-38**). Between 1995 and 2013, bank 14 has eroded an average of 69 feet, with a mean annual retreat rate of 3.8 feet. This area contains undisturbed riparian vegetation and represents natural rates of streambank erosion expected in situations where there are mid-channel bars directing the flow towards the channel margins (**Figure 5-39**). However, decreased flows in the east channel, along with increased sediment deposition on the mid-channel bar from upstream bank erosion, may also influence erosion rates along this bank.

Figure 5-38. Bank 14, March 2014

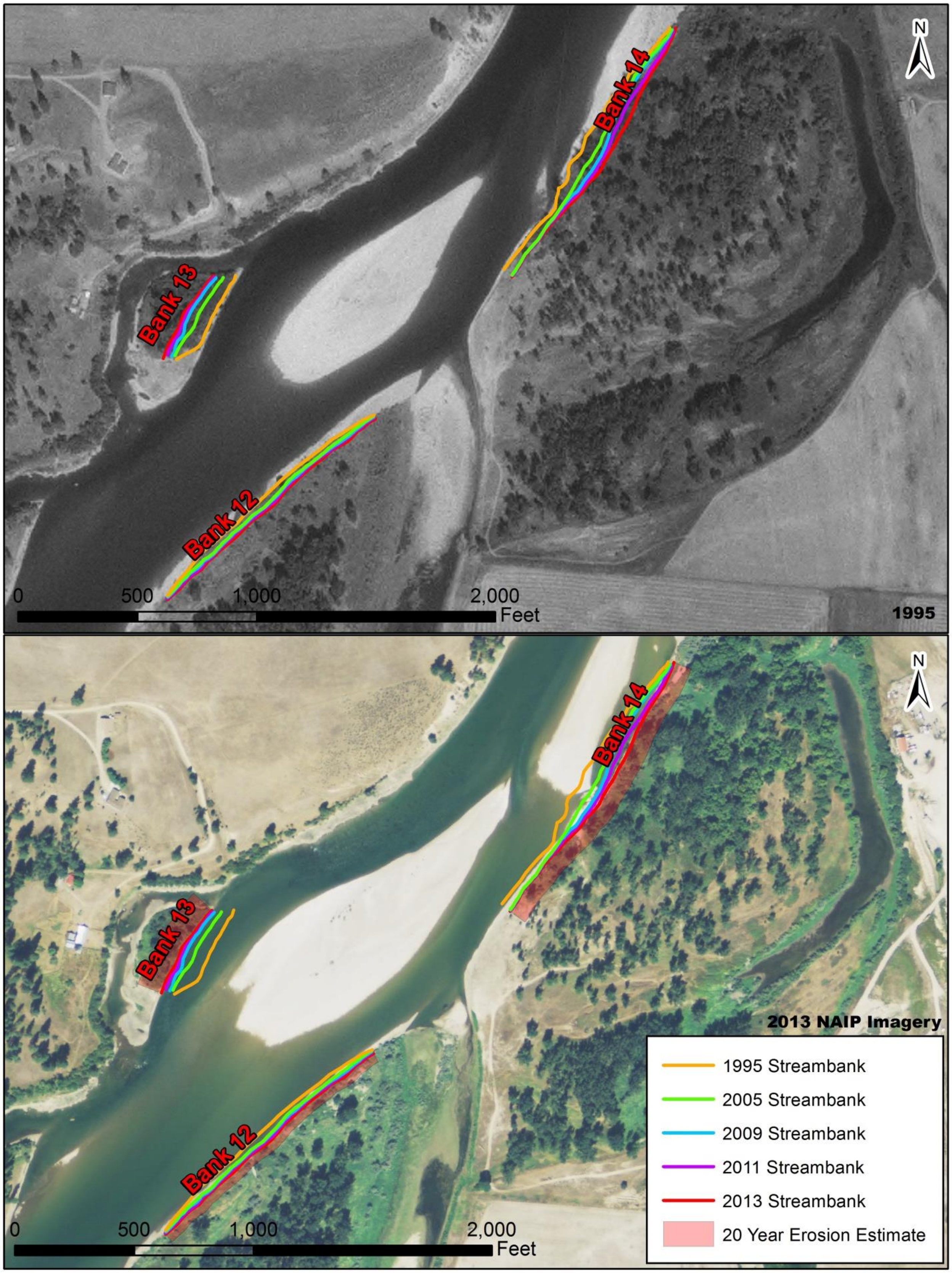


Figure 5-39. Banks 12, 13, and 14 Erosion 1995-2013

5.3 Discussion

Over the past 100 years, the addition of channel stabilization structures along River Road East, the town of Plains, the 5th Avenue South Bridge, the Sanders County Fairgrounds, and along the Herschbach property have affected lateral channel migration and streambank erosion in the Plains Reach of the Clark Fork River between Henry Creek and the bedrock outcrop at the downstream end of Big Eddy. As expected, bank stabilization activities along one meander bend have led to bank erosion along the opposite meander bend downstream. Stabilization of the bank along town and at the 5th Avenue South Bridge crossing has led to erosion along the Sanders County Fairgrounds, which was stabilized following the 1948 flood. A slight change in channel direction due to bridge construction and the subsequent formation of the gravel bar downstream, along with bank stabilization at the fairgrounds, has led to erosion along the bank at Herschbach property (bank 5), which was partially stabilized following the 1948 flood and again during the 2011 flood. In addition, clearing of riparian and floodplain vegetation for the development of agriculture has reduced bank stability overall and led to accelerated rates of bank erosion. Prior to the 1997 flood, the bedrock outcrop at the downstream end of Big Eddy effectively dissipated the energy coming off of the riprap along the Herschbach property (bank 5). Downstream of the bedrock outcrop, the channel was essentially "reset" historically and took on the characteristics of an unconfined meandering multichannel system.

The results of the streambank erosion analysis indicate that erosion along bank 5 between 1995 and 2013 has led the channel to meander downstream and bypass the protection of the bedrock outcrop at the downstream end of Big Eddy. This downstream channel migration has directed the majority of the stream power directly at the bank along the Keith's property (bank 6), which has subsequently exposed a portion of River Road West to increased erosion. Eroded material from the bank along the Keith's has been deposited at the head of the west channel, which has aggraded and become partially disconnected from the main channel, with water starting to flow into the west channel at approximately 12,000 cfs (John Thorson, personal communication, 3/24/14). In addition, the point that separates the west channel from the main channel has eroded and retreated downstream as the channel meanders downstream, decreasing its capacity to capture a portion of the flow. Reduced flows in the west channel have increased the stream power in the main channel, leading to bank erosion upstream and downstream of the Town of Plains WWTP outfall (bank 9 and bank 10). In addition, material from upstream bank erosion has been deposited on a large mid-channel bar downstream of the Town of Plains WWTP outfall, which has directed a greater portion of the stream flow towards the banks along Lawyer Nursery and along the island that separates the west channel from the main channel (bank 10 and bank 11). Material eroded from the bank along Lawyer Nursery is found in the large mid-channel gravel bar and at the head of the east channel, which is also aggrading, with a secondary channel further downstream now providing the majority of the overflow capacity. Downstream of the convergence of the west channel and main channel, the streambanks contain well developed riparian vegetation and bank erosion rates are greatly reduced, with mid-channel bars deflecting flow towards the channel margins being the primary mechanism leading to bank erosion.

6.0 Restoration Alternatives and Prioritization

A suite of restoration alternatives have been identified to improve conditions along the Plains Reach of the Clark Fork River and restore natural channel processes while protecting critical infrastructure, including the Town of Plains WWTP and River Road West. The long-term solution to managing the Plains Reach of the Clark Fork River will likely include a mix of project types, which are evaluated in the following sections.

6.1 Types of Projects

A total of six types of projects have been identified with descriptions of each type of project provided in the following sections. Project types include:

- Streambank Stabilization and Revegetation
- Floodplain Revegetation
- Flow Enhancement in Side Channels and Overflow Channels
- Debris Removal from Streambanks and Channel
- Culvert Upgrades on Roads Crossing Overflow Channels
- Irrigation Infrastructure Improvements

6.1.1 Streambank Stabilization and Revegetation

6.1.1.1 Streambank Stabilization using Rock Riprap

Streambank stabilization using rock riprap can provide long-term protection for properties on the adjacent floodplain when applied correctly. However, many of the streambank erosion and channel migration concerns identified during this assessment arise from the historic use of rock riprap and other stabilization measures applied along the railroad, River Road East, the town of Plains, the abutments of the 5th Avenue South Bridge, the Sanders County Fairgrounds, the Garrison/Herschbach Property, and along the Town of Plains WWTP. This assessment has identified approximately 4,000 feet of rock riprap in the Plains Reach of the Clark Fork River between Henry Creek and Lynch Creek, while an additional 4,600 feet of the river right bank along the town of Plains has been stabilized using a variety of materials. Placement of additional rock riprap is advised in situations where critical infrastructure is threatened and other techniques, such as streambank bioengineering and floodplain revegetation, are deemed unable to provide sufficient infrastructure protection.

6.1.1.2 Streambank Bioengineering and Revegetation

Streambank bioengineering techniques restore natural channel migration rates through streambank revegetation. Bioengineered streambanks are designed to eliminate bank erosion in the short term. Over the long term, bioengineered streambanks are designed to erode naturally, allowing for natural rates of lateral channel migration and restoration of the sediment transport processes that maintain an evolving network of side channels and depositional areas where new riparian vegetation can become established. Streambank bioengineering techniques include the use of woody material, biodegradable coir fabric, gravel, soil, and willows, which are layered to produce a stable bank that will quickly develop riparian vegetation. Streambank bioengineering is typically accompanied by the creation of a vegetated riparian buffer on the floodplain, which is intended to provide long term stability as the channel continues to migrate. Recommended areas for streambank bioengineering and revegetation have been identified where the channel is shallower along the toe of the bank, such as along glides, and where mid-channel bars reduce the depth of the channel (**Figure 6-1**). Portions of an eroding bank where the channel is deep and the thalweg is situated along the toe of the bank will likely require the use of rock riprap in the toe or some other stabilization measure, such as large woody debris, with the goal of creating a smooth surface along the bank that does not include any scour features.

Figure 6-1. Potential Streambank Bioengineering and Revegetation Sites

6.1.2 Floodplain Revegetation

Two alternative floodplain revegetation strategies are presented for the Plains Reach of the Clark Fork River and a complete approach to floodplain restoration could include both of the strategies:

1. Development of a 150-foot wide riparian buffer along restored streambanks
2. Development of floodplain vegetation outside of the estimated 20 year erosion zone

In areas where streambank restoration activities are undertaken, a 150 foot wide vegetated riparian buffer is recommended. This recommendation is based on a mean annual retreat rate of 7.6 feet for the Plains Reach, which is estimated based on 261 cross-section measurements at the 14 identified eroding banks. The estimated mean annual retreat rate includes bank erosion measurements from both naturally vegetated slowly eroding banks and un-vegetated banks that are rapidly eroding. Based on the estimated mean annual retreat rate along the Plains Reach, 152 feet of erosion is estimated over a 20 year period and a 150 foot wide vegetated riparian buffer is recommended for all banks treated with revegetation and bioengineering techniques. The 150 foot wide vegetated riparian buffer could also be a beneficial habitat improvement for any banks treated with rock riprap and could provide mitigation credits required under the Montana Stream Mitigation Procedure.

For streambanks left to erode, floodplain planting areas have been identified to help restore natural rates of lateral channel migration, while also stabilizing the floodplain to reduce the potential for channel avulsions. Floodplain planting areas identified as part of this strategy generally exclude the area identified within the estimated 20 year erosion zone to allow time for the vegetation to become established before it is adjacent to the channel. The identified floodplain planting areas are typically used for grazing and generally lack any woody vegetation (**Figure 6-2**). For each floodplain planting area, the estimated 20 year erosion zone is based on the specific retreat rate of the bank along which floodplain revegetation will occur. However, floodplain plantings are recommended within the area identified as vulnerable for erosion over the next 20 years in situations where infrastructure is more immediately threatened. Priority planting areas are identified for floodplain revegetation in the near term, with secondary planting areas identified for long-term floodplain restoration efforts.

Riparian buffers and floodplain plantings should include a mix of trees, such as cottonwoods and ponderosa pines, and woody shrubs, such as willows and red osier dogwood, along with various grass and sedge species depending on soil characteristics and depth to the water table. Enhancement of existing floodplain swales (**Figure 6-3**) and the creation of additional floodplain swales with areas connected to the water table are recommended within the 150-foot vegetated riparian buffer and floodplain planting areas to reduce the need for irrigation. In addition, floodplain plantings will require protection from browse by wildlife to ensure the plantings become established, along with appropriate grazing management strategies for areas used by livestock. Management of beaver will also likely be required since beaver activity was observed on several large cottonwoods in March 2014.

6.1.3 Flow Enhancement in Side Channels and Overflow Channels

Accelerated rates of streambank erosion documented within the Plains Reach of the Clark Fork River over the past 18 years have led to sediment deposition within the reach and aggradation at the heads of side channels, including the west channel downstream of the of the bedrock outcrop below Big Eddy and the east channel downstream of the WWTP. Enhancing flows in the west channel and east channel by removing gravel from the heads of the channels is one option that may alleviate stream power within the main channel and reduce the accelerated rates of bank erosion, particularly along bank 10 and bank 11. Excavation of gravel from side channels should be performed in concert with restoration of the upstream eroding banks to reduce the potential for additional sediment deposition at the head of the side channels. In addition to the west and east side channels, overflow channels across the floodplain could also be enhanced to become activated at lower flows, including overflow channels on river left along River Road East, river left above 5th Avenue South Bridge, and river left upstream of Big Eddy. Overflow channel enhancements could include the addition of meanders and increased access at lower flows. Streambank and floodplain plantings should be included in overflow channel enhancement projects undertaken in areas currently used for agriculture.

6.1.4 Debris Removal from Streambanks and Channel

Over the past 100 years, various items have been used to stabilize the river, including rock riprap, concrete blocks, old cars, wooden poles, and sheet metal. In addition, the historic 5th Avenue South Bridge pylons remain in the channel, along with the foundation of a house that used to be along the edge of bank 6 and is now in the middle of the channel. While some of the historic bank stabilization measures continue to provide important protection from bank erosion, places where unnecessary material exists could be identified and the items removed. In particular, excess material in the streambank along the town of Plains, the historic 5th Avenue South Bridge pylons, excess riprap that was washed downstream during the emergency stabilization above bank 5 in 2011, and the foundation of the house that used to reside along the edge of bank 6 could be removed from the streambanks and channel.

Figure 6-2. Typical Conditions in Areas Recommended for Floodplain Revegetation

Figure 6-3. Naturally Occurring Floodplain Swale

6.1.5 Culvert Upgrades on Roads Crossing Overflow Channels

Roads crossing overflow channels with undersized culverts were identified on the Town of Plains WWTP access road, which crosses an overflow channel activated when water overtops bank 5, and along the overflow channel that starts downstream of the riprap at the Town of Plains WWTP and outlets in the east channel. Culverts on active access roads could be replaced with larger culverts, while culverts on abandoned access roads could be removed. In addition, River Road East has been developed into a levee that restricts flood flows from accessing the South Plains area. While residential development in South Plains has increased, there may be opportunities to add culverts to East River Road and re-establish flows in overflow channels that could alleviate some of the stream power in the main channel as it passes through the town of Plains and under the 5th Avenue South Bridge.

6.1.6 Irrigation Infrastructure Improvements

This assessment has identified one irrigation source that is currently threatened by streambank erosion: irrigation water for the Lawyer Nursery is obtained from a shallow groundwater well that is currently within approximately 65 feet of bank 10. This well could be re-located to higher ground away from the channel margin.

6.2 Restoration Project Areas

Out of 14 eroding streambanks identified during this assessment, eight were identified for restoration activities, including banks 2, 3, 4, 5, 6, 7, 9, and 10, while "no action" is currently advised for six streambanks considered to be in a relatively natural condition and/or not affecting existing infrastructure, including banks 1, 8, 11, 12, 13, and 14 (**Figure 6-4**). The goal of streambank restoration is to reduce the accelerated rate of bank erosion and lateral channel migration and restore the sediment transport capacity of the system, while providing protection to critical infrastructure already in place. In addition to streambank restoration, other restoration activities are discussed, including floodplain revegetation, re-establishing flow in side channels, removal of debris along streambanks and the channel, upgrades to existing culverts on roads crossing overflow channels, and irrigation infrastructure improvements. Specific restoration project sites are discussed in the following sections.

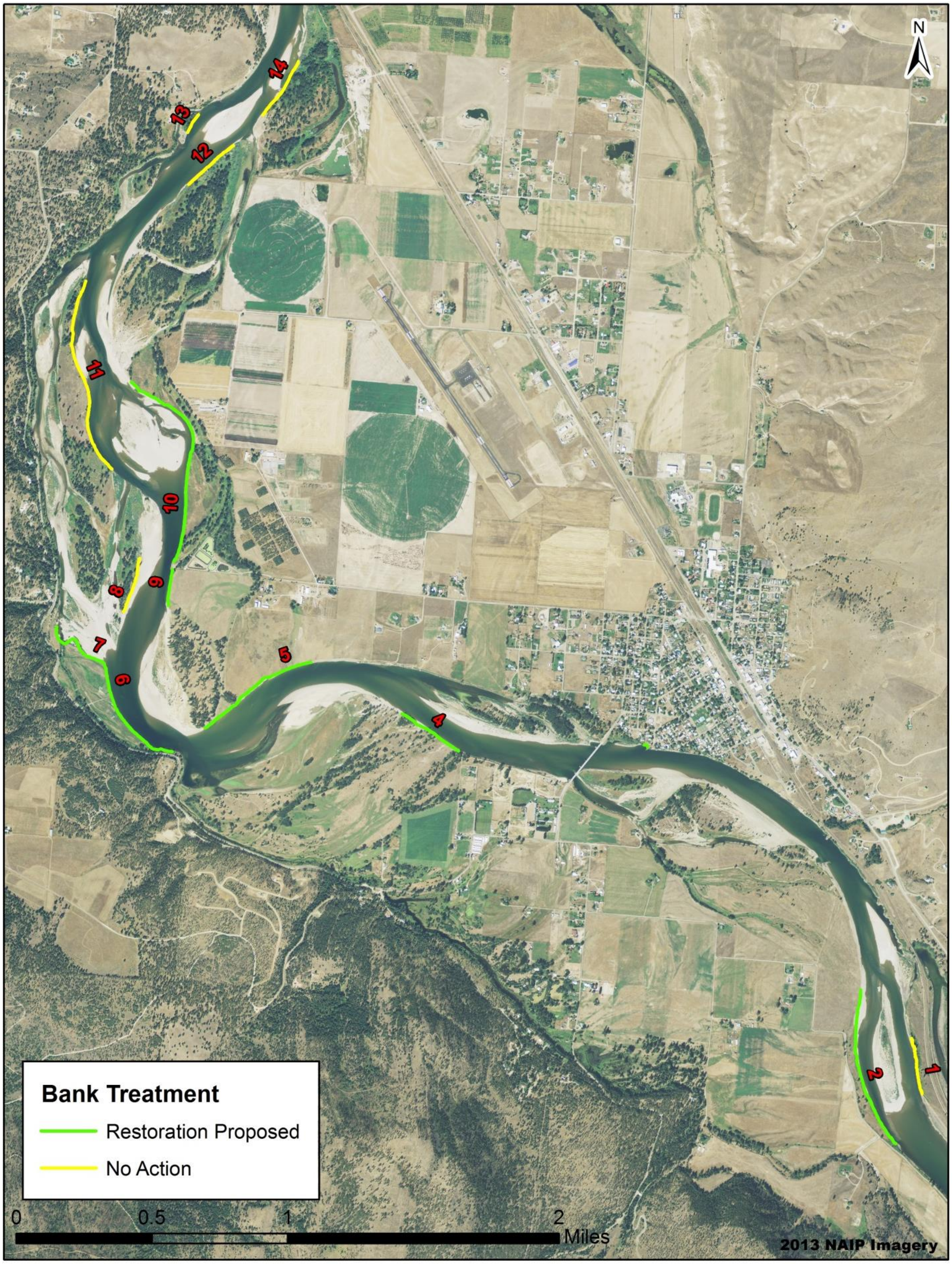


Figure 6-4. Streambanks with Proposed Restoration Treatments

6.2.1 Project 1 - Eroding Bank 2

Bank 2 is 3,215 feet long and is located on river left along River Road East and across from Smiley's Slough. Restoration activities for bank 2 include:

- Floodplain Revegetation
- Flow Enhancement in Side Channels and Overflow Channels

Floodplain plantings along bank 2 between the channel margin and River Road East, along with floodplain plantings in the adjacent field, are recommended to promote long term channel and floodplain stability within this section. Floodplain plantings could be applied to 55 acres, including along the eroding portion of bank 2 and in an adjacent field. Establishing a 100-150 foot wide vegetated buffer extending approximately 5,000 feet along the channel margin is the primary priority and would cover approximately 17 acres, with the remaining 38 acres on the floodplain a secondary priority (**Figures 6-5** and **6-6**). A 25 foot setback from the top of the existing bank is recommended to accommodate bank retreat over the next 20 years. In addition to floodplain revegetation, enhancement of overflow channels on the floodplain along river left may alleviate stream power along the town of Plains, create flow convergence at the 5th Avenue South Bridge, and potentially direct more flow toward the gravel bar along river right downstream of the bridge, which may alleviate erosion on bank 4 (**Figure 6-7**). Enhancement of overflow channels currently inaccessible due to the levee along River Road East would increase floodplain connectivity and alleviate stream power through the town of Plains and along bank 5, while creating convergent flows where Combest Creek enters Big Eddy, which may alleviate stream power along bank 6 (**Figure 6-7**).

Figure 6-5. Riparian Buffer and Floodplain Revegetation Sites along Bank 2 and River Road East

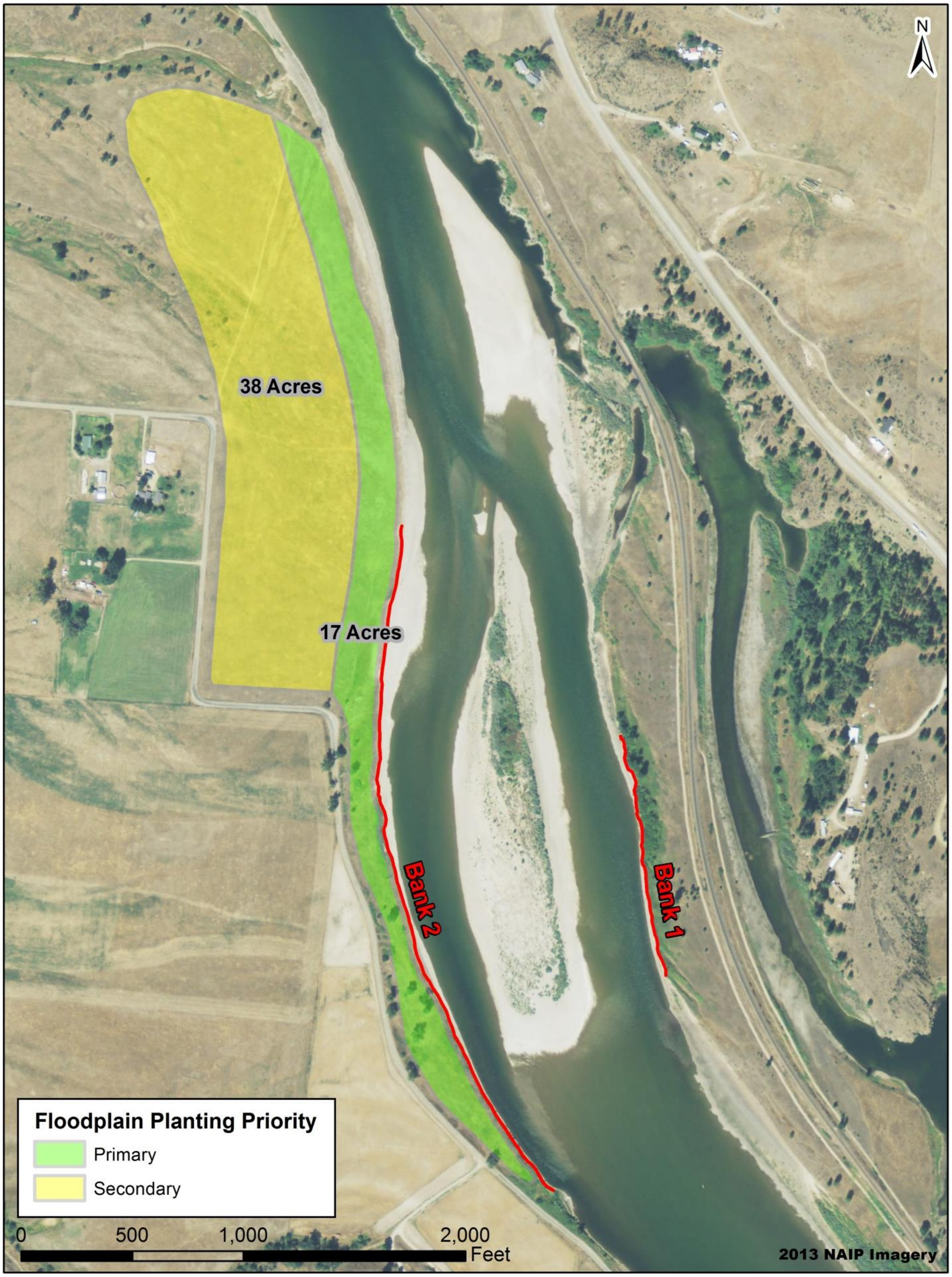


Figure 6-6. Floodplain Revegetation Sites along Bank 2 and River Road East

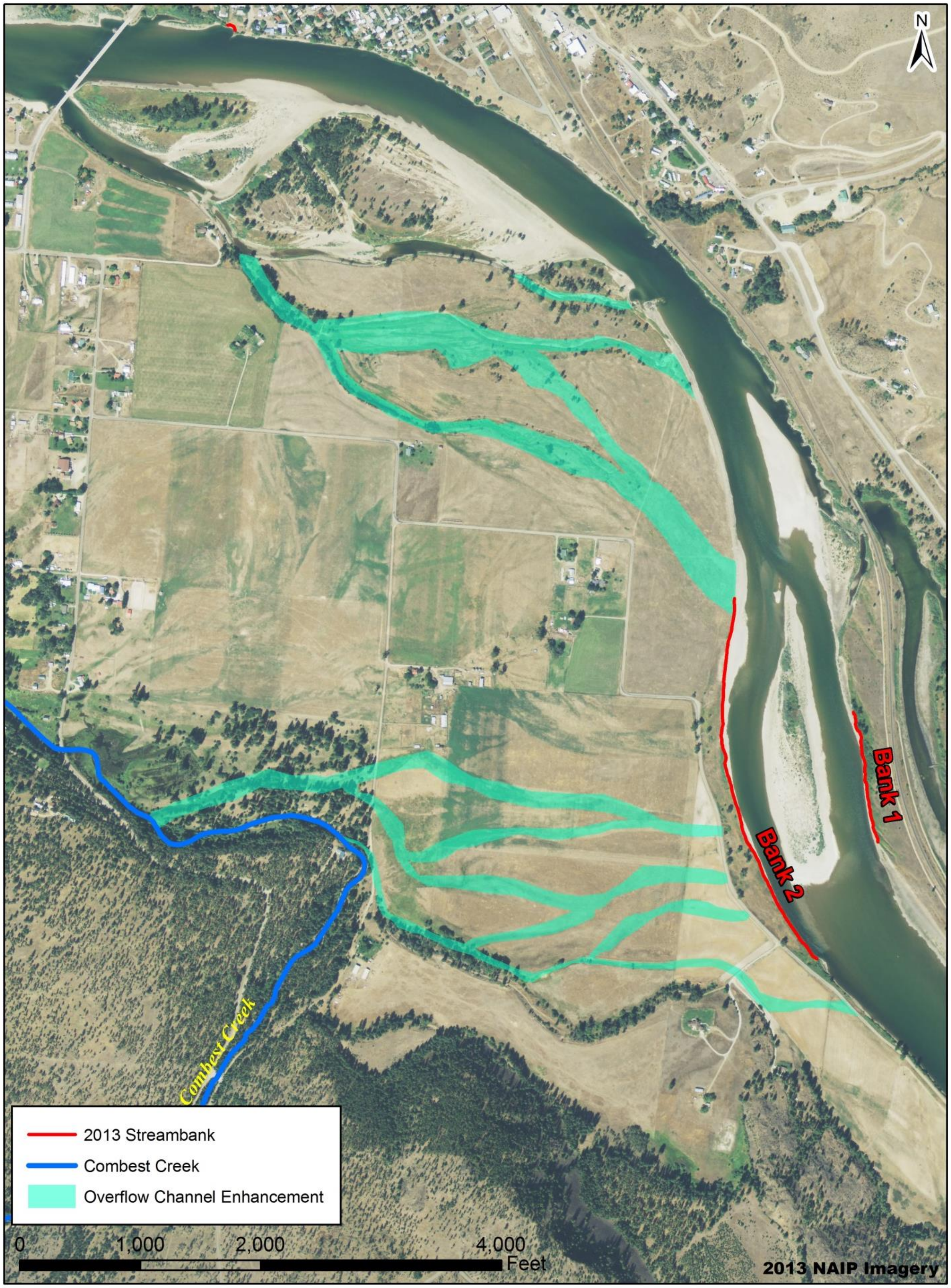


Figure 6-7. Overflow Channel Enhancement along Bank 2 and River Road East

6.2.2 Project 2 - Town Bank

The "town bank" is located on river right along the town of Plains and extends approximately 4,600 feet between Boyer Creek and the 5th Avenue South Bridge. Restoration activities for the "town bank" include:

- Debris Removal from Streambanks and Channel

Over the past 100 years, various items have been used to stabilize the river right bank along the town of Plains upstream of the 5th Avenue South Bridge, including old cars, concrete blocks, wooden poles, sheet metal, and native rock material, many of which date back to the time when the lumber mill was in operation (**Figure 6-8**). While some of this material provides important stabilization to the streambank, places where unnecessary material exists could be identified and the items removed. Without some level of streambank protection, much of the bank along town would likely resemble bank 3 (**Figure 6-9**).

Figure 6-8. Various Bank Stabilization Treatments Found along the Town of Plains

6.2.3 Project 3 - Eroding Bank 3

Bank 3 is 87 feet long and is located on river right in the town of Plains between 1st Street and 2nd Street just upstream of the 5th Avenue South Bridge crossing (**Figure 6-9**). Restoration activities for bank 3 include:

- Streambank Stabilization and Revegetation

Stabilization of bank 3 may be warranted due to it close proximity to residential development in Plains. Due to the height of this bank, stabilization will likely require some form of bank hardening, such as rock riprap, though vegetation could be included along the top of the bank.

Figure 6-9. Bank 3 upstream of 5th Avenue South Bridge

6.2.4 Project 4 - Historic Bridge Pylons

The pylons from the original 5th Avenue South Bridge constructed in 1911 were left in place following construction of the second bridge in 1976. Restoration activities for the historic bridge pylons include:

- Debris Removal from Streambanks and Channel

A total of five pylons remain in the channel from the original bridge, with three foundations, one toppled pylon/foundation, and one fully intact and upright pylon (**Figure 6-10**). The bridge constricts the river by at least 17% at bankfull flows, which leads to an increase in stream power as water passes under the bridge. Removal of the historic bridge pylons is recommended to reduce the amount of constriction at the bridge and decrease the turbulence created as the river flows under the bridge.

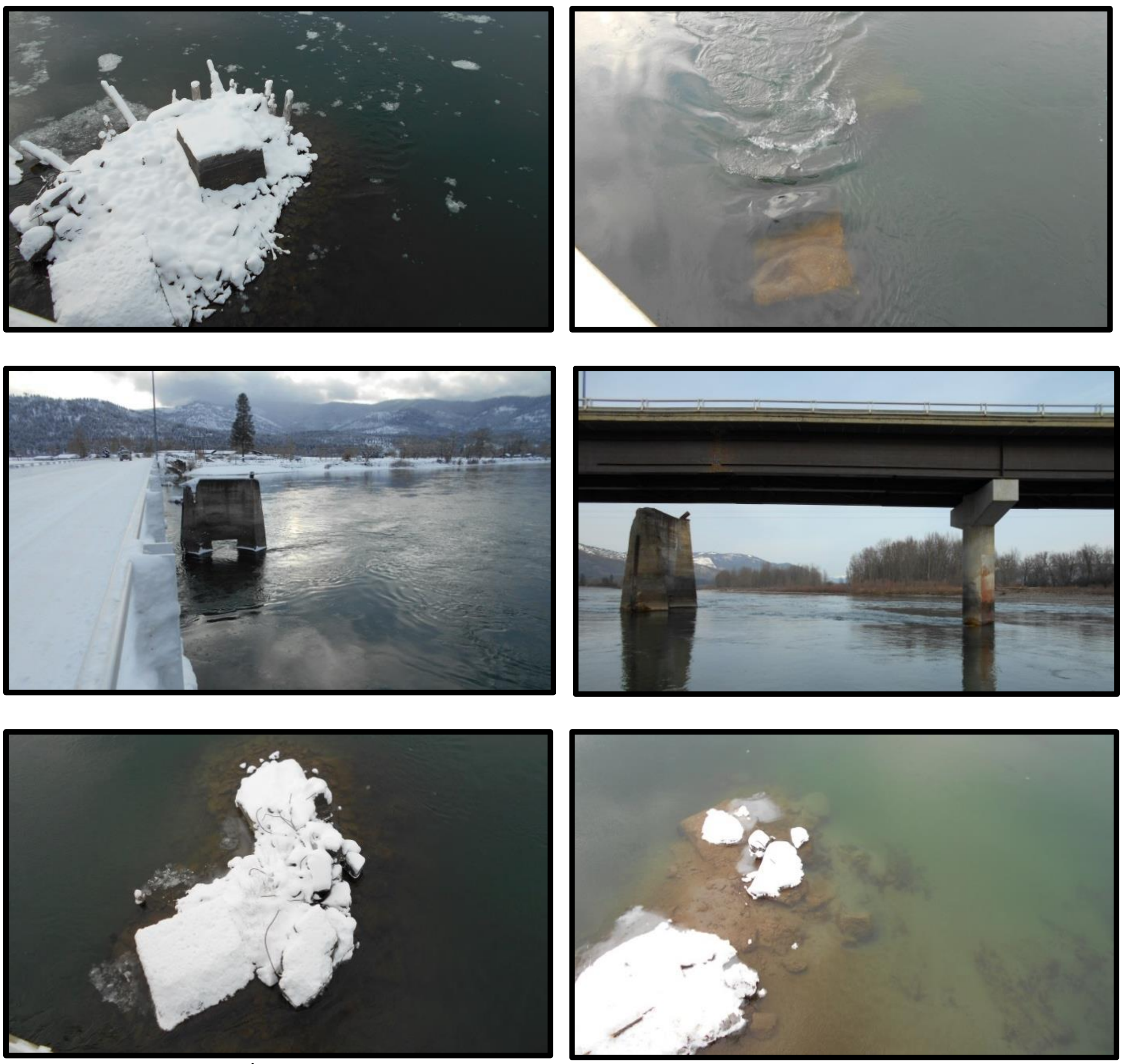


Figure 6-10. Historic 5th Avenue South Bridge Pylons

6.2.5 Project 5 - Eroding Bank 4

Bank 4 is 1,334 feet long and is located on river left downstream of the Sanders County Fairgrounds. Restoration activities for bank 4 include:

- Streambank Stabilization and Revegetation
- Flow Enhancement in Side Channels and Overflow Channels

Bank 4 has retreated an average of 81 feet over the past 18 years, though this retreat rate is not excessive for a river of this size and no stabilization is recommended at this time. However, the gravel bar across the channel has expanded over the past 18 years and additional growth of this gravel bar, along with the accompanying development of riparian vegetation, may lead to increased stream power along bank 4. If bank erosion becomes accelerated in the future, bioengineering techniques could be applied to work with the existing vegetation. Since this bank is bisected by two primary overflow channels, stabilization will likely increase the amount of stream power directed towards the next meander bend downstream (bank 5), which is partially stabilized by rock riprap. As an alternative to bank stabilization, the overflow channels that bisect bank 4 could be enhanced and additional water directed across the low floodplain that leads into Big Eddy (**Figure 6-11**). This may help alleviate stream power along bank 5 while also creating convergent flows as it rejoins the main channel above the bedrock outcrop, which could potentially deflect stream energy currently directed at bank 6 and River Road West. However, increased stream flows in Combest Creek along River Road West upstream of the bedrock outcrop should be further evaluated prior to overflow channel enhancement. Additional overflow channels could also potentially be developed in the gravel bar across the channel from bank 4.

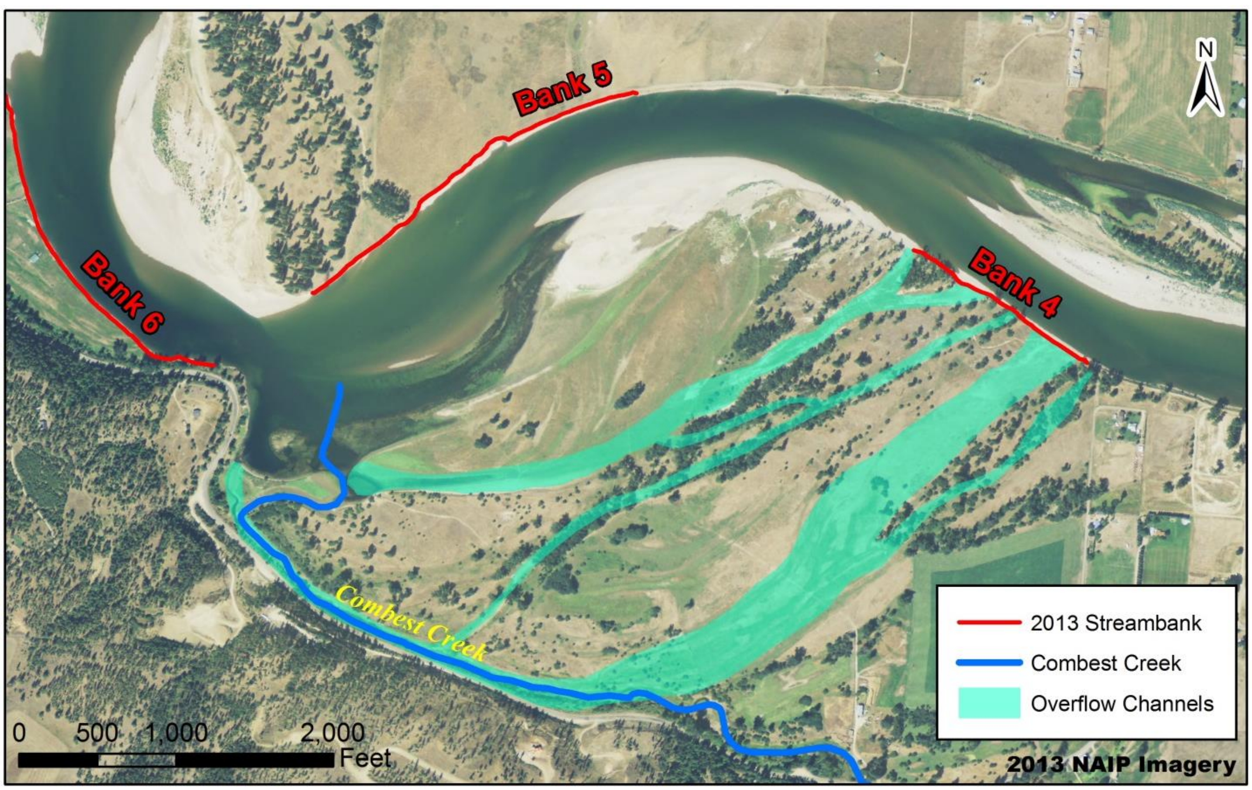


Figure 6-11. Overflow Channel Enhancement along Bank 4 Floodplain Upstream of Big Eddy

6.2.6 Project 6 - Eroding Bank 5

Bank 5 is 2,515 feet long and located on river right at the outside of a meander bend that is naturally experiencing lateral retreat and has been partially stabilized with rock riprap that extends approximately 1,500 feet upstream from the top of bank 5. Restoration activities for bank 5 include:

- Streambank Stabilization and Revegetation
- Floodplain Revegetation
- Debris Removal from Streambanks and Channel

Between 1995 and 2013, bank 5 has eroded an average of 322 feet, with a mean annual retreat rate of 17.8 feet. Aerial imagery indicates that the deepest scour occurs upstream of bank 5 along the riprap placed during high flow in 2011. Thus, bioengineering techniques are likely applicable where the channel is shallower downstream of the existing riprap in combination with the creation of a 150 foot wide vegetated riparian buffer. Streambank revegetation and bioengineering could tie in with the existing stand of cottonwoods and ponderosa pine at the downstream end of this bank. Signs of beaver activity were observed on the cottonwood trees along the channel margin at this site and protection from beaver would help maintain the existing vegetation. While stabilization of bank 5 in its current location will effectively reduce the rate at which this bank erodes, it will also continue to direct a high amount of the stream energy towards bank 6, which will likely necessitate stabilization along the portion of River Road West downstream of the bedrock outcrop.

Floodplain revegetation is highly recommended at this site since water was actively overtopping bank 5 during the 2011 flood event and flowing into a series of overflow channels, including one that flows behind the Town of Plains WWTP. This area was identified as a potential avulsion hazard during the Channel Migration Zone analysis and presents a hazard to the long term maintenance of the WWTP. To help stabilize the floodplain surrounding the WWTP, the existing floodplain topography could be enhanced and floodplain vegetation could be re-established on 61 acres along bank 5 and an additional 32 acres along bank 9. A total of 33 acres were identified as primary floodplain planting areas along bank 5, with an additional 28 acres identified as a secondary priority along bank 5 (**Figures 6-12** and **6-13**). Floodplain planting strategies along bank 5 account for erosion over the next 20 years, which is estimated at 358 feet, while floodplain plantings extend up to the base of the levee behind the existing riprap at the upstream end. In addition to the primary and secondary floodplain planting priorities identified in **Figure 6-12**, understory riparian shrubs could be planted in the area currently occupied by mature cottonwoods along the western edge of the primary floodplain planting area (**Figure 6-14**). If bank 5 is stabilized, then floodplain plantings could be extended to the edge of the stabilized channel or a 150 foot vegetated riparian buffer could be established.

Additional activities along bank 5 include the removal of an underwater obstruction formed by a concrete slab in the channel and removal of excess riprap residing at the downstream end of the riprap that can be seen in the 2013 NAIP aerial imagery extending over 100 feet into the channel (**Figures 6-15** and **6-16**). Riparian vegetation could also be added to the recently placed riprap as a mitigation measure.

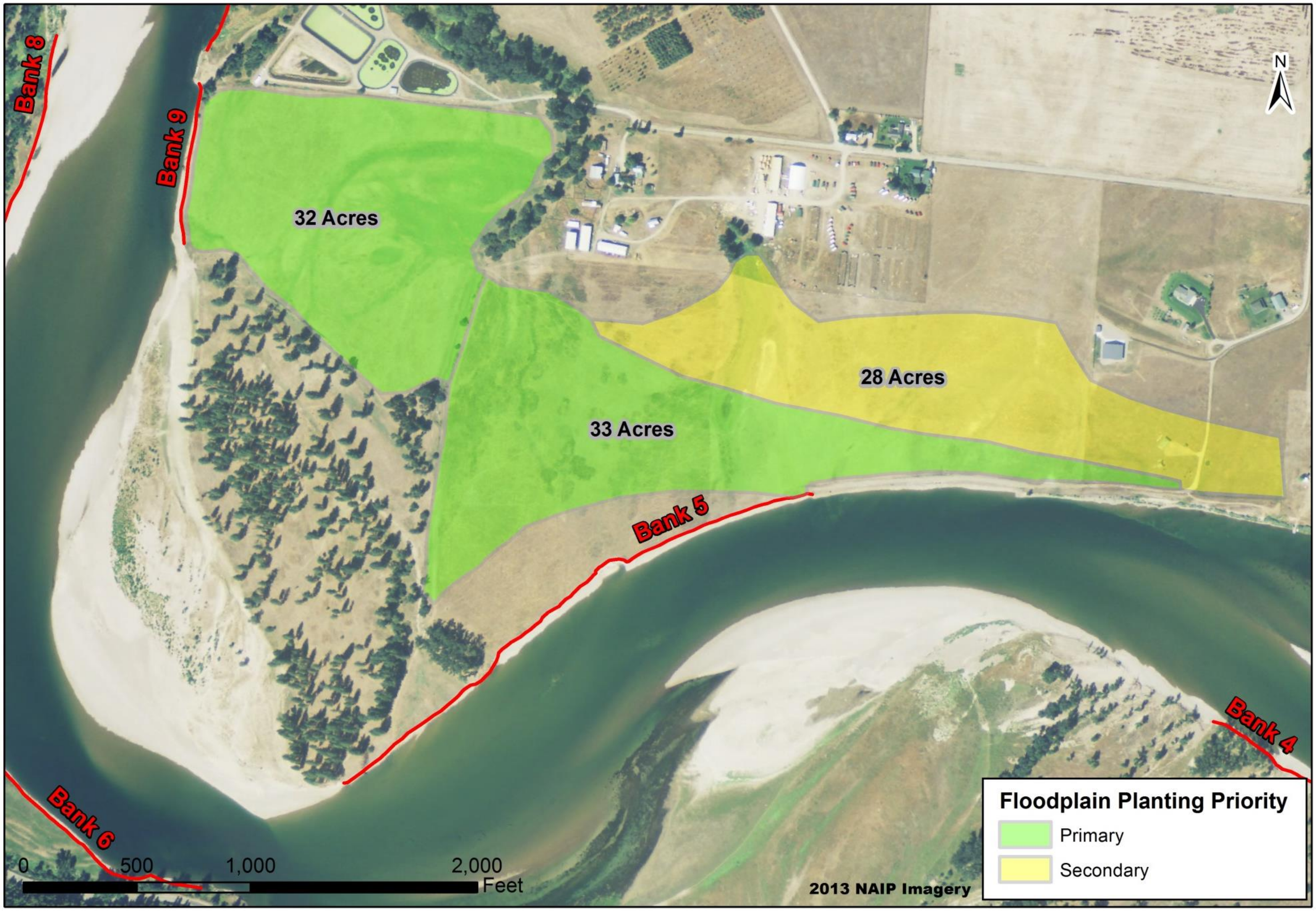


Figure 6-12. Floodplain Revegetation Sites along Bank 5 and Bank 9

Figure 6-13. Riparian Buffer and Floodplain Revegetation Site along Bank 5

Figure 6-14. Primary Floodplain Revegetation Site (Left of Fenceline) and Area Identified for Planting Riparian Shrubs Interspersed with Mature Cottonwoods

Figure 6-15. Underwater Obstruction along Bank 5 formed by Concrete Slab

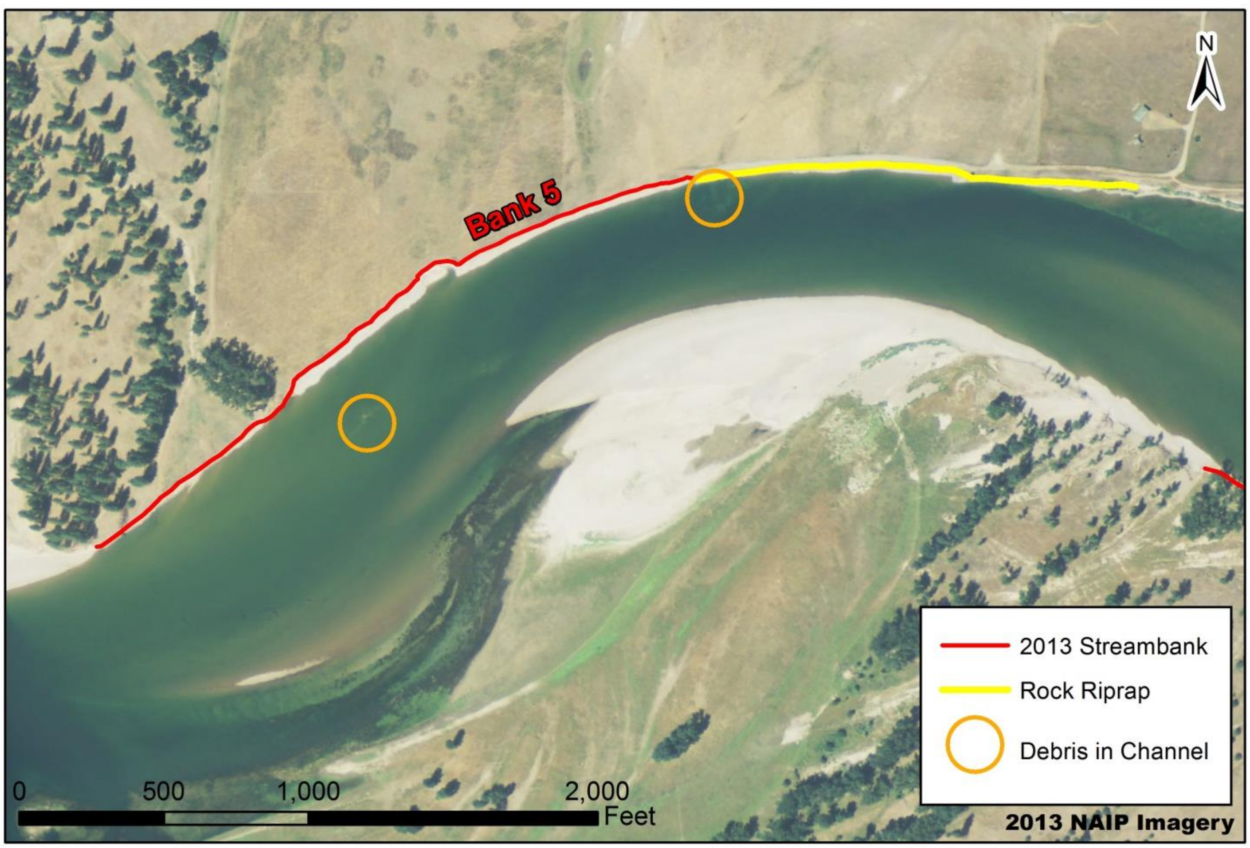


Figure 6-16. Concrete and Rock Riprap Debris in Channel along Bank 5

6.2.7 Project 7 - Eroding Bank 6

Bank 6 is 2,389 feet long and located on river left downstream of the bedrock outcrop below Big Eddy. Potential restoration activities for bank 6 include:

- Streambank Stabilization and Revegetation
- Floodplain Revegetation
- Debris Removal from Streambanks and Channel

Bank 6 has been rapidly eroding since 1995, with an average retreat rate of 11.5 feet per year. There is a high amount of stream power directed at this bank and the channel is very deep. As this bank retreats, River Road West becomes more exposed to the river and will likely require stabilization at some point in the future. Stabilization of bank 6 will likely require rock riprap due to the high stream power and deep channel along the toe of the bank at the upstream end, while bioengineering techniques could be applied at the downstream end. Benefits of stabilizing bank 6 include protecting River Road West and the Keith property, along with decreasing the sediment load currently being deposited at the head of the west channel. However, stabilization of bank 6 will likely increase stream power on the next bank downstream, which is where the WWTP is located, along with potentially limiting access to the west channel. If bank 6 is stabilized, it may be beneficial to remove a portion of the small point currently stabilized by the pile of rocks and one remaining cottonwood to help direct additional flow into the west channel (**Figure 6-17**).

Floodplain plantings covering 18 acres along bank 6 and bank 7 are recommended to provide long term stabilization for the floodplain and River Road West (**Figures 6-17** and **6-18**). However, bank 6 is actively retreating and plantings may eventually be washed away if a streambank stabilization component is not included. Based on the results of the bank erosion assessment, no planting is recommended within the estimated 20 year erosion zone, except at the downstream end behind bank 7 where stream power is lower. If bank 6 is stabilized, then floodplain plantings could be extended to the edge of the stabilized channel or a 150 foot vegetated riparian buffer could be established.

During the 1997 flood event, a house that was built along bank 6 was burned down to prevent it from falling into the river. The foundation of the house remains in the channel and is visible in aerial imagery approximately 200 feet from the 2013 bank line (**Figure 5-18**). It is unknown what impact the house foundation has on channel dynamics, though it essentially acts like a bedrock outcrop below the surface of the water and is currently located at the tail end of the pool formed by the bedrock outcrop below Big Eddy. If possible, it would be beneficial to remove the foundation of the house from the channel. If bank 6 is not stabilized, the existing barn and fence should be removed from the floodplain before additional debris is added to the channel. Woody debris added to the top of the bank and a rock pile on the edge of the bank could also be removed before they are washed away. Woody debris in the form of root wads along the top of the bank and on the floodplain is likely to moderate bank erosion for only a brief period of time (**Figure 6-19**). The rock pile provides some stabilization for the lower end of bank 6, but may also be preventing the channel from migrating towards the west and accessing the west channel.

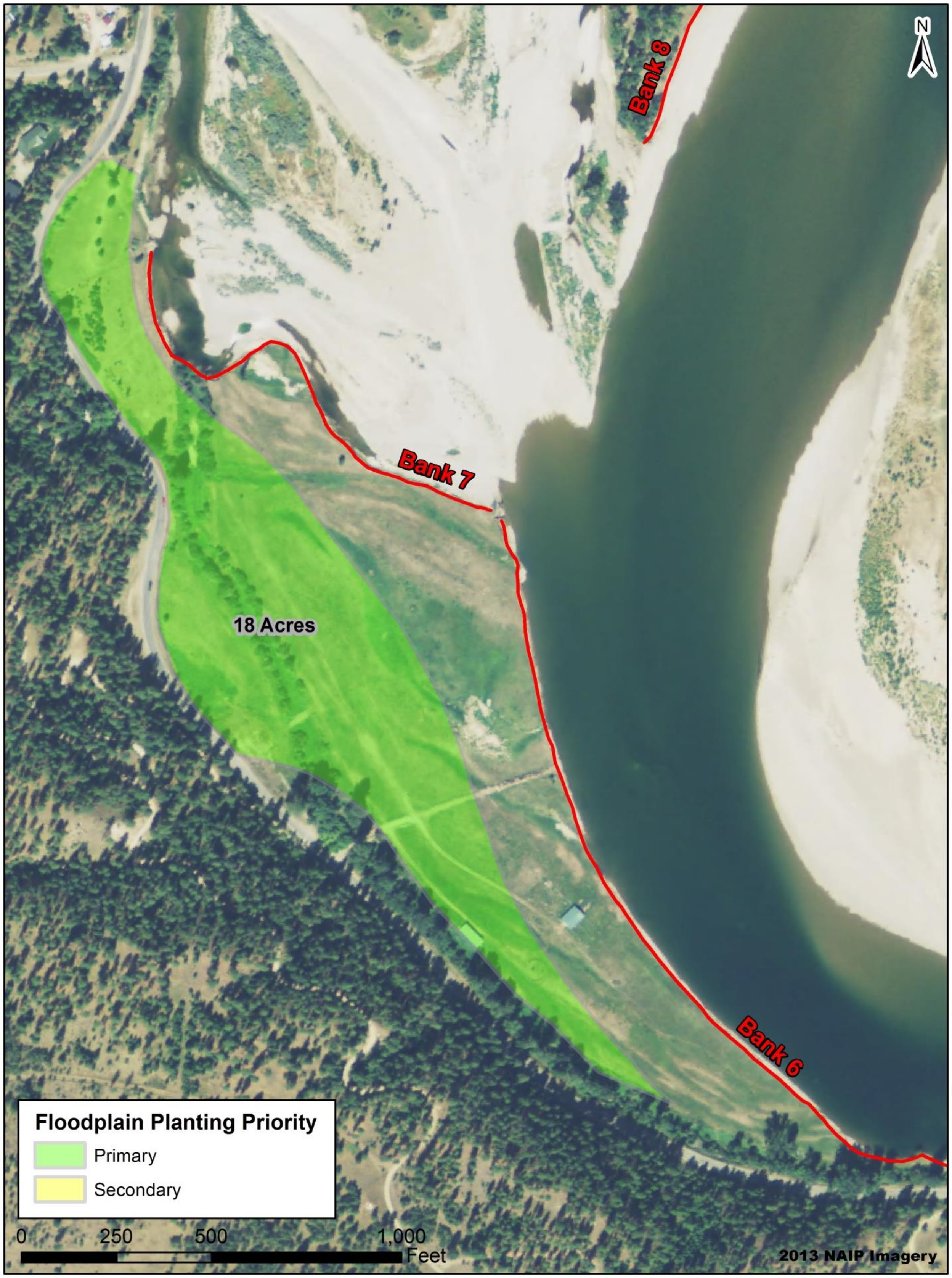


Figure 6-17. Floodplain Revegetation Site along Bank 6 and Bank 7

Figure 6-18. Riparian Buffer and Floodplain Revegetation Site along Bank 6


Figure 6-19. Temporary Bank Stabilization Measures along Bank 6

6.2.8 Project 7 - River Road West

Since 1995, Bank 6 has retreated an average of 207 feet, which has exposed approximately 300 feet of River Road West to potential erosion downstream of where the road is protected by the bedrock outcrop at Big Eddy (**Figure 6-20**). Restoration activities for River Road West downstream of Big Eddy include:

- Streambank Stabilization and Revegetation

While a small floodplain bench currently remains at the toe of the fillslope, additional erosion in upcoming years may necessitate stabilization along River Road West. Since the channel is relatively deep here along the outside of a developing meander bend and has a high amount of stream power, stabilization of River Road West will likely require the use of rock riprap. Additional erosion along Bank 6 will likely expose an even greater length of the road to erosion potential in the future. Assuming the bank retreat rates observed over the past 18 years continue, it is estimated that 400 additional feet of River Road West will become adjacent to the main channel within the next 20 years. In addition, an overflow channel runs along the base of the road. If flows increase in this channel, a longer portion of the road's fillslope may quickly become exposed to scour during high flow events. The small floodplain bench at the toe of the road's fillslope currently provides an opportunity to perform stabilization before the channel erodes additional material and exposes the toe of the fillslope to erosion.

Figure 6-20. River Road West downstream of the Bedrock Outcrop at Big Eddy

6.2.9 Project 9 – Eroding Bank 7

Bank 7 is 1,373 feet long and located on river left along the head of the west channel. Restoration activities for bank 7 include:

- Streambank Stabilization and Revegetation
- Floodplain Revegetation

Between 1995 and 2013, bank 7 has eroded an average of 154 feet, with a mean annual retreat rate of 8.6 feet. Bank 7 is an extension of bank 6, but is along the west channel instead of the main channel. Bank 7 is a vertical bank comprised almost entirely of fine grained material. Due to the lower stream power along the west channel, and a lack of flow during certain times of the year, there is the potential to stabilize this bank using bioengineering techniques. Stabilization of bank 7 should be conducted in concert with stabilization of bank 6 or account for additional retreat of bank 6. If stabilization measures are implemented, it may be beneficial to remove a portion of the point of land where bank 6 and bank 7 meet to allow greater access to the west channel. Benefits of stabilizing bank 7 include protecting River Road West and adjacent properties, along with decreasing the sediment load currently being deposited at the head of the west channel. In addition, a power pole located along bank 7 is precipitously close to the bank.

Floodplain plantings covering 18 acres along bank 6 and bank 7 are recommended to provide long term stabilization for River Road West (**Figures 6-17** and **6-21**). However, bank 6 is actively retreating and plantings may eventually be washed away if a streambank stabilization component is not included. Floodplain planting is recommended within the 20 year erosion buffer along the downstream end of bank 7 where stream power is lower. If bank 7 is stabilized, then floodplain plantings could be extended to the edge of the stabilized channel or a 150 foot vegetated riparian buffer could be established.

Figure 6-21. Riparian Buffer and Floodplain Revegetation Site along Bank 7

6.2.10 Project 10 - West Channel

Sediment deposition at the upstream end of the west channel is due to sediment contributions from erosion along bank 6 and bank 7 (**Figures 6-22** and **6-24**). Restoration activities for the west channel include:

- Flow Enhancement in Side Channels and Overflow Channels

Removal of sediment from the head of the west channel could enhance flows within the west channel during lower flows, while also alleviating stream power along bank 9 and bank 10 during high flow events. However, while bank 6 and bank 7 remain sources of sediment, any sediment removed from the head of the west channel will likely be replaced by sediment eroded from these banks. Alternatively, continued erosion along bank 6 and downstream channel migration may allow the river to naturally flush sediment out of the head of the west channel, potentially sending more water down the west channel. In addition, the point of the island that separates the west channel from the main channel has eroded and retreated downstream, reducing its ability to deflect flows into the west channel. The river has also become much wider at the head of the west channel, leading to decreased stream power and sediment transport capacity. The addition of woody debris to the point of the island through the construction of an engineered log jam could help stabilize the point of the island and direct additional flow towards the west channel. Engineered log jams mimic natural large woody debris accumulations often found at the heads of islands and are observed within the Plains Reach (**Figure 6-23**).

Figure 6-22. Sediment Deposition at the Head of the West Channel

Figure 6-23. Naturally Occurring Log Jam Separating the Main Channel from a Side Channel

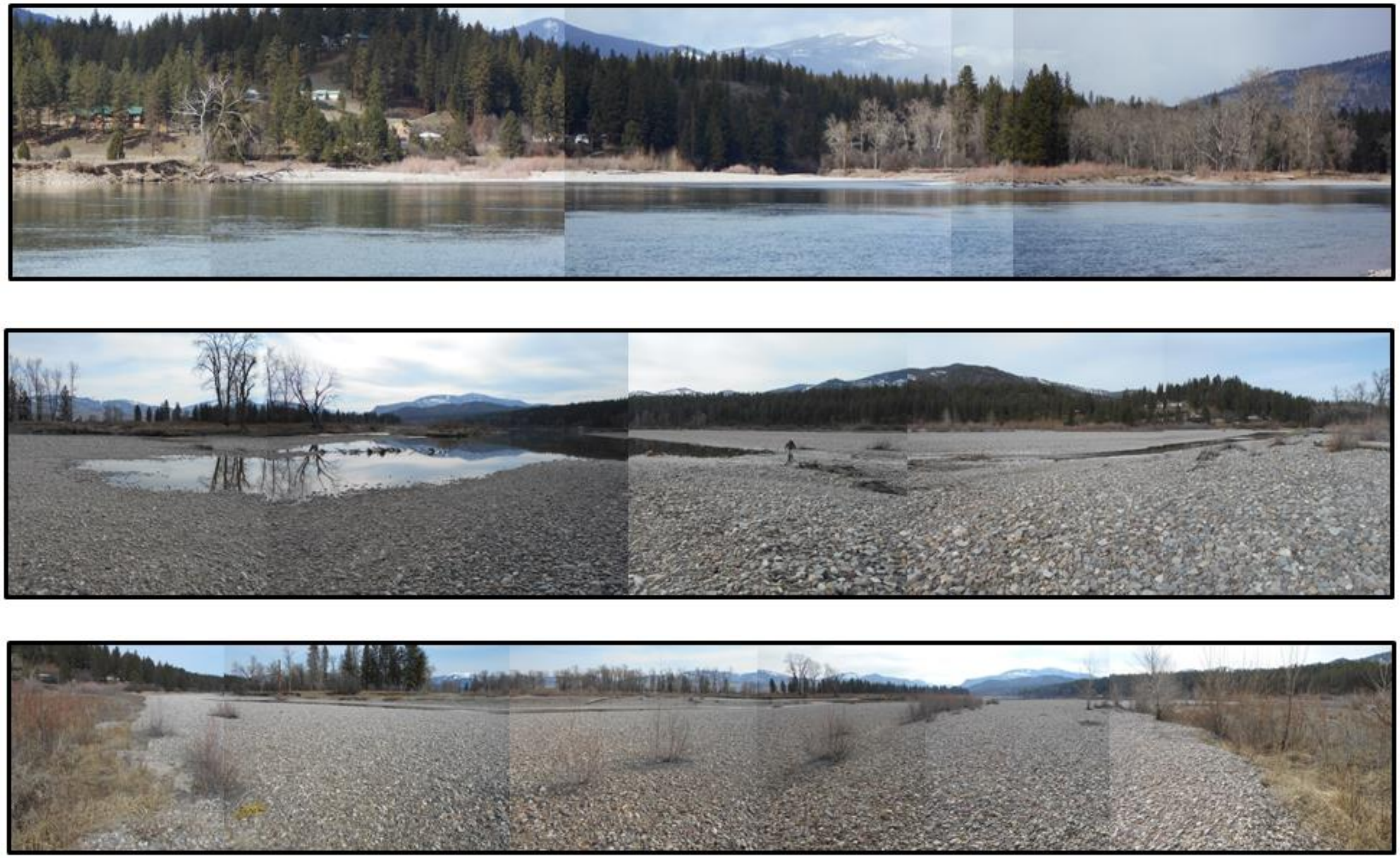


Figure 6-24. Overview of Sediment Deposition at the Head of the West Channel (13,500 cfs)

6.2.11 Project 11 - Eroding Bank 9

Bank 9 is 715 feet long and is located along river right upstream of the Town of Plains WWTP outfall. Restoration activities for bank 9 include:

- Streambank Stabilization and Revegetation
- Floodplain Revegetation
- Culvert Upgrades on Roads Crossing Overflow Channels

Between 1995 and 2013, bank 9 has eroded an average of 22 feet, with a mean annual retreat rate of 1.2 feet. Approximately 137 feet of rock riprap placed at the outfall of the WWTP prior to runoff in 2010 has created an area of increased turbulence along the channel margin and the thalweg is now located along the toe of the riprap (**Figures 6-25** and **5-25**). Active erosion is occurring immediately upstream of the riprap as water recirculates creating a scallop approximately 100 feet long (**Figure 6-26**). Additional rock riprap will likely be required immediately upstream of the existing riprap where the bank is vertical, the water is deep, and the thalweg is along the channel margin. The upstream end of bank 9 starts at the downstream end of a point bar where the bank angle is lower and there is shallower water along the channel margin (**Figure 6-27**). The tallest part of the bank is approximately mid-way between the gravel bar and the riprap at the WWTP (**Figure 6-28**). For bank 9, bioengineering techniques are likely applicable at the upstream end in combination with the creation of a 150 foot wide vegetated riparian buffer, while rock riprap will likely be required at the downstream end.

Floodplain revegetation is highly recommended at this site to help provide long term stabilization along bank 9 and the associated floodplain directly upstream of the Town of Plains WWTP. To help stabilize the floodplain surrounding the WWTP, the existing floodplain topography could be enhanced and floodplain vegetation could be re-established on 32 acres along bank 9 (**Figure 6-29** and **6-12**). In addition, understory shrubs could be planted in the area currently occupied by mature cottonwoods along the southern edge of the primary floodplain planting area (**Figure 6-14**).

Additional activities along bank 9 include upgrades to the culvert on the WWTP access road crossing an overflow channel that flows behind the WWTP when water overtops bank 5 (**Figure 6-30**).

Figure 6-25. Turbulence along the WWTP Riprap (13,500 cfs)

Figure 6-26. Bank 9 and Riprap at the Town of Plains WWTP Outfall

Figure 6-27. Upstream End of Bank 9

Figure 6-28. Bank 9 View from the River, from Downstream to Upstream (Left to Right)

Figure 6-29. Riparian Buffer and Floodplain Revegetation Site along Bank 9 upstream of the Town of Plains WWTP, Looking Downstream (Top) and Upstream (Bottom)

Figure 6-30. Town of Plains WWTP Access Road across Overflow Channel

6.2.12 Project 12 - Eroding Bank 10

Bank 10 is 4,175 feet long and located on river right downstream of the Town of Plains WWTP outfall. Prior to the installation of riprap at the WWTP outfall, bank 9 and bank 10 was one continuous bank extending approximately 5,000 feet. The Town of Plains owns the property along the upper half of bank 10, while Lawyer Nursery owns the property along the lower half of bank 10. Potential restoration activities for bank 10 include:

- Streambank Stabilization and Revegetation
- Floodplain Revegetation
- Debris Removal from Streambanks and Channel
- Culvert Upgrades on Roads Crossing Overflow Channels
- Irrigation Infrastructure Improvements

Between 1995 and 2013, bank 10 has eroded an average of 437 feet, with a mean annual retreat rate of 24.3 feet. A maximum retreat of 742 feet was observed over the 18 year period between 1995 and 2013 along Lawyer Nursery property. While the estimated 20 year erosion zone indicates continued accelerated rates of erosion along bank 10, future rates of erosion will likely be reduced when the channel migrates into the band of cottonwoods along the margin of the overflow channel, which may also relieve stream power as water is routed down the overflow channel that leads into the east channel. The second band of cottonwoods along the overflow channel is located at the base of a terrace, which will likely slow the erosion rate even further. Thus, ongoing erosion is predicted while stream power is focused along the existing channel margin, which is comprised on fine grained material. As the channel migrates into established vegetation and the potentially coarser grained material of the terrace, erosion rates will likely be reduced. In addition, mill waste deposited on the floodplain influences lateral channel migration, reducing the rate of bank erosion at the downstream end of bank 10.

Bank 10 exhibits two distinct characteristics progressing from upstream to downstream, with a vertical bank at the upstream end transitioning to a lower angled bank at the downstream end. The upper portion of bank 10 is located downstream of the riprap at the Town of Plains WWTP outfall where the thalweg is along the channel margin (**Figure 6-31**). Stabilization at the upstream end may require extending the rock riprap downstream of the existing riprap at the WWTP outfall downstream. In April of 2014, a large eddy was observed off the downstream of the rock riprap and was recirculating from approximately 300 feet downstream at a flow of approximately 31,000 cfs. Recirculating water in this large eddy is leading to accelerated bank erosion at the head of an overflow channel. At the tail end of this eddy, plumes of sediment were observed washing from the streambank, which contained a high amount of sandy material (**Figure 6-32**). As the channel becomes shallower along bank 10 in the vicinity of the mid-channel bar and the bank height decreases, bioengineering techniques may be appropriate. However, flow deflection from the mid-channel bar may increase the relative stream power along this portion of the bank and partial dredging to remove sediment from this mid-channel bar may help reduce stream power along bank 10. Also, the influence of mill waste material within the bank at the downstream end should be considered when developing a restoration strategy for bank 10. A potential option would be to remove a portion of the area with the mill waste, thereby opening up additional flow toward the east channel and potentially alleviating stream power on the highly erodible bank material upstream.

Establishment of riparian vegetation on the floodplain downstream of the Town of Plains WWTP and within the historic side channel along Lawyer Nursery is recommended to slow the rate of lateral channel migration and to help protect this area which was identified as a potential avulsion risk during the Channel Migration Zone analysis due to the presence of overflow channels across the floodplain (**Figures 6-33** and **6-34**). The floodplain area downstream of the Town of Plains WWTP resembles floodplain areas used for grazing along banks 5, 6, and 9, while the overflow channel along Lawyer Nursery is vegetated with native and introduced grass species (**Figures 6-35** and **6-36**). Signs of beaver activity were observed on the cottonwood trees along the channel margin at this site and protection from beaver would help maintain the existing vegetation.

Additional activities along bank 10 include upgrades to four identified culverts on roads crossing the overflow channel that starts downstream of the WWTP and outlets into the east channel, along with re-location of an irrigation pump and ground water well that is approximately 65 feet from the edge of bank 10 (**Figure 6-37**). Culverts on abandoned access roads could be removed, while culverts on roads that continue to be used could be replaced (**Figure 6-38** and **6-39**). In addition, a power pole located along bank 10 is precipitously close to the bank near the existing pump house.


Figure 6-31. Bank Erosion at the Upstream End of Bank 10 Downstream of Riprap at WWTP Outfall


Figure 6-32. Plumes of Sediment Eroding from the Upper End of Bank 10 (~31,000 cfs)

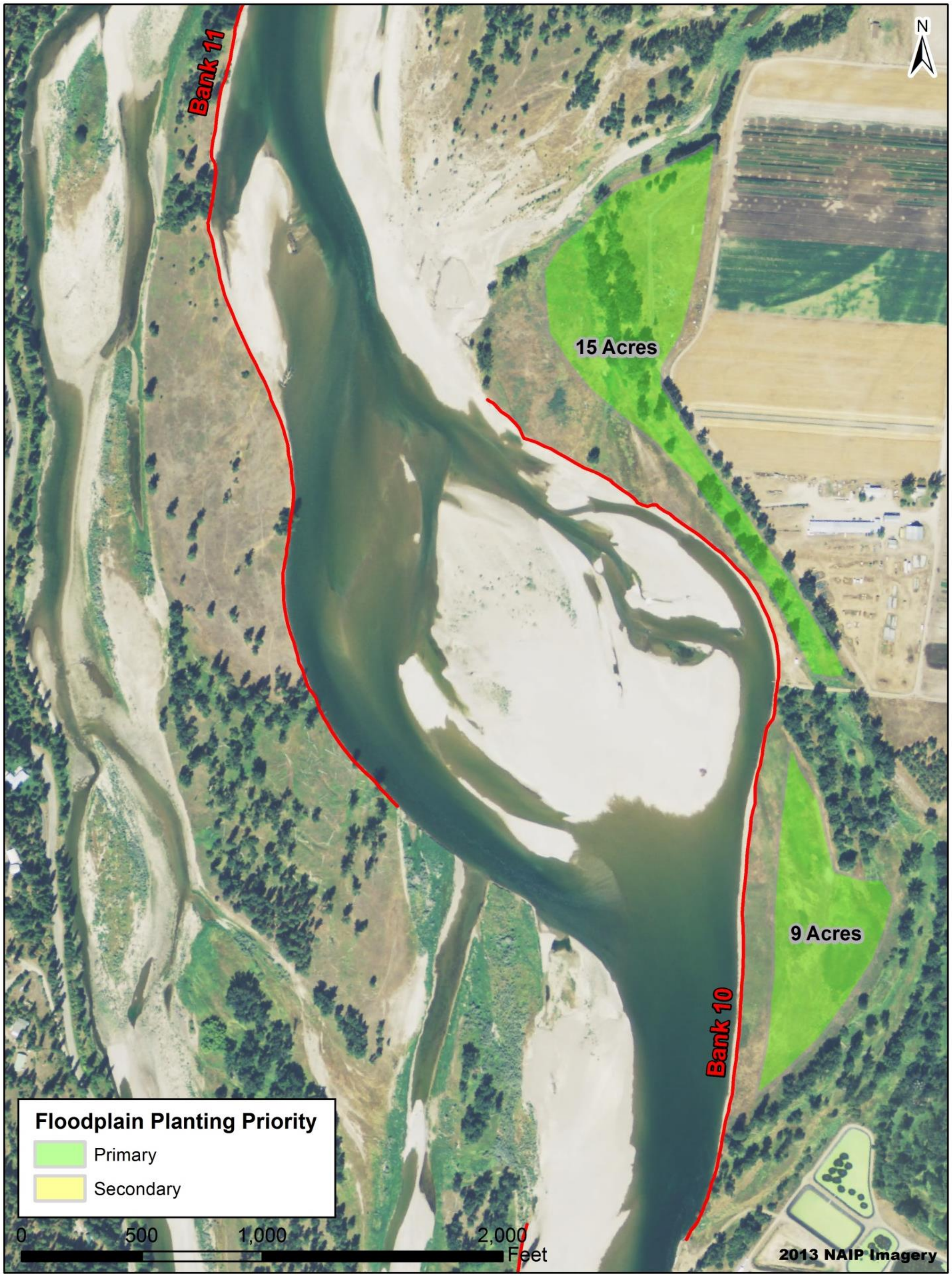


Figure 6-33. Floodplain Revegetation Sites along Bank 10

Figure 6-34. Avulsion Potential into Overflow Channel lined by Cottonwoods along Bank 10

Figure 6-35. Floodplain Revegetation Site along Bank 10, Town of Plains Property

Figure 6-36. Floodplain Revegetation Site along Bank 10, Lawyer Nursery Property

Figure 6-37. Pump House Located Approximately 65 Feet from Bank 10

Figure 6-38. Pump House Access Road across Overflow Channel

Figure 6-39. Abandoned Access Road across Overflow Channel

6.2.13 Project 13 - East Channel

Sediment deposition at the upstream end of the east channel is due to sediment contributions from erosion along bank 10 (**Figure 6-40**). Potential restoration activities for the east channel include:

- Flow enhancement in Side Channels and Overflow Channels

Removal of sediment from the head of the east channel could enhance flows within the east channel during lower flows, while also alleviating stream power along bank 11 during high flow events. However, while bank 10 remains a source of sediment, any sediment removed from the head of the east channel will likely be replaced by sediment eroded bank 10. While not as extensive as the sediment deposition in the west channel, sediment deposition at the head of the east channel and decreased stream flows during high water directs additional flow towards bank 11, which is on the island that separates the west channel from the main channel. The estimated 20 year erosion zone for bank 11 indicates that the lower 1,500 feet of the island may become completely washed away if bank erosion continues at the rate of erosion observed over the past 18 years (**Figures 6-41** and **5-35**).

Figure 6-40. Sediment Deposition at the Head of the East Channel

Figure 6-41. Lower End of Island Separating the Main Channel (Top) from the West Channel (Bottom)

6.2.14 Project 14 - Develop Floodplain Planting Nursery Stock

Streambank and floodplain revegetation will require healthy plants to be successful. Since it may take three to four years for some of this vegetation to become the appropriate size for planting, it is recommended that nursery stock should be developed for willows, red osier dogwood, alder, cottonwoods, ponderosa pine, and other desirable species as soon as possible. Once established, floodplain plantings will require ongoing management to ensure success.

6.3 Restoration Project Prioritization

Restoration projects along the Plains Reach of the Clark Fork River identified during this assessment were awarded points in three categories presented in **Table 6-1** based on the results of this assessment and input from the Middle Clark Fork River Plains Reach Recovery Committee, including:

1) Streambank Erosion Reduction
2) Socio-Economic Importance
3) Timeframe

Project Areas progressing from upstream to downstream are evaluated in **Table 6-2**, with stationing for identified projects presented in **Figure 6-42**. A summary of the restoration project prioritization is presented in **Table 6-3**, with projects ranked based on a maximum score of 15 points. Project scoring is intended to help prioritize long-term restoration planning efforts, with the availability of funding and landowner interest also being key considerations. Channel adjustments due to continued channel migration and patterns of sediment deposition may either increase or decrease the stream power along a given bank and the length of bank exposed to erosion. Thus, this restoration project prioritization is intended to be adaptable as conditions within the Plains Reach change over time.

Table 6-1. Scoring Criteria

Category	Description	Points
Streambank Erosion Reduction	Streambank Stabilization and Revegetation	5
	Floodplain Revegetation	3
	Flow Enhancement in Side Channels and Overflow Channels	3
	Debris Removal from Streambanks and Channel	1
	Culvert Upgrades on Roads Crossing Overflow Channels	1
	Irrigation Infrastructure Improvements	1
Socio-Economic Importance	Safeguard the Town of Plains WWTP	5
	Safeguard River Road West	4
	Afford greater protection to east bank property owners	3
	Increase west channel flows	2
	Other	1
Timeframe	Near-term	5
	Mid-term	3
	Long-term	1

Table 6-2. Restoration Project Prioritization, Extending from Upstream to Downstream

Project Area	Project Site	Project Type	Length of Bank Treatment (Feet)	Stationing at Upstream End (Feet)	Revegetated Riparian Buffer Width (Feet)	Revegetated Riparian Buffer (Acres)	Floodplain Revegetation (Acres)	Project Score				Project Cost Estimate (X1,000)	Notes
								Streambank Erosion Reduction	Socio-Economic Importance	Timeframe	Overall Project Score		
1	Eroding Bank 2	Floodplain Revegetation - Primary Priority					17.1	3	1	3	7	$250-500	Along River Road East
		Floodplain Revegetation - Secondary Priority					37.9	3	1	1	5	$500-750	In adjacent field
		Flow Enhancement in Side Channels and Overflow Channels						3	3	5	11	$500-750	Levee on River Road East and side channels upstream of bridge
2	Town Bank	Debris Removal from Streambanks and Channel						1	1	1	3	$25-100	Debris includes old cars, concrete blocks, wooden poles, and sheet metal
3	Eroding Bank 3	Streambank Stabilization and Revegetation	87	147+68				5	3	5	13	$25-100	Historic stabilization exists above and below bank 3
4	Historic Bridge Pylons	Debris Removal from Streambanks and Channel						1	1	1	3	$100-250	Reduce channel constriction under 5th Avenue South Bridge
5	Eroding Bank 4	Streambank Stabilization and Revegetation	1,334	183+48	150	4.6		5	1	1	7	$250-500	Mature ponderosa pine and cottonwoods between overflow channels
		Flow Enhancement in Side Channels and Overflow Channels						3	3	5	11	$500-750	Reduce stream power on bank 5 and bank 6
6	Eroding Bank 5	Streambank Stabilization and Revegetation	2,515	216+93	150	8.6		5	3	5	13	$750-1,000	Downstream of existing riprap
		Floodplain Revegetation - Primary Priority					33.2	3	3	3	9	$250-500	Intended to stabilize floodplain surrounding WWTP
		Floodplain Revegetation - Secondary Priority					28.4	3	3	1	7	$250-500	Intended to stabilize floodplain surrounding WWTP
		Debris Removal from Streambanks and Channel						1	1	1	3	$0-25	Concrete slab and pieces of rock riprap in the channel
7	Eroding Bank 6	Streambank Stabilization and Revegetation	2,389	248+53	150	8.2		5	4	5	14	$500-750	Rock riprap will likely be required when the thalweg is along the toe of the bank, particularly along the upstream end of bank 6 along River Road West
		Floodplain Revegetation					18.1	3	4	3	10	$250-500	Same floodplain planting area as bank 7
		Debris Removal from Streambanks and Channel						1	1	1	3	$0-25	Barn on floodplain, house foundation in channel
8	River Road West	Streambank Stabilization and Revegetation	~300*	248+53*				5	4	5	14	$100-250	*Upstream end of bank 6, potentially longer as bank 6 continues to erode
9	Eroding Bank 7	Streambank Stabilization and Revegetation	1,373	269+16	150	4.7		5	4	5	14	$250-500	At head of west channel
		Floodplain Revegetation					18.1**	3	4	3	10	$250-500**	**Same floodplain planting area as bank 6
10	West Channel	Flow Enhancement in Side Channels and Overflow Channels						3	2	5	10	$100-250	Aggradation due to bank 6 and bank 7 erosion, currently accessed at ~12,500 cfs
11	Eroding Bank 9	Streambank Stabilization and Revegetation	715	282+90	150	2.5		5	5	5	15	$100-250	Scallop forming upstream of riprap along WWTP outfall likely requires additional rock riprap, transitioning to streambank revegetation progressing upstream
		Floodplain Revegetation					32.4	3	5	3	11	$250-500	Intended to stabilize floodplain surrounding WWTP
		Culvert Upgrades on Roads Crossing Overflow Channels						1	5	1	7	$0-25	WWTP access road
12	Eroding Bank 10	Streambank Stabilization and Revegetation	4,175	290+43	150	14.3		5	3	5	13	>$1,000	Rock riprap likely required downstream of WWTP outfall, transitioning to streambank revegetation progressing downstream
		Floodplain Revegetation - Town of Plains					8.6	3	3	3	9	$100-250	On floodplain downstream of WWTP
		Floodplain Revegetation - Lawyer Nursery					15.1	3	3	3	9	$100-250	In historic overflow channel
		Debris Removal from Streambanks and Channel						1	1	1	3	$25-100	Historic lumber mill waste in banks and on floodplain
		Culvert Upgrades on Roads Crossing Overflow Channels						1	1	1	3	$0-25	4 road crossings in overflow channel downstream of WWTP
		Irrigation Infrastructure Improvements						1	3	5	9	$25-100	Pump house within 65 feet of channel margin
13	East Channel	Flow Enhancement in Side Channels and Overflow Channels						3	1	3	7	$100-250	Aggradation due to bank 10 erosion
14	Floodplain Planting Nursery Stock	N/A						N/A	N/A	N/A	N/A	N/A	~12,600 feet of bank treatments, 43 acres riparian buffer, 191 acres floodplain restoration
		TOTALS	12,588			43.0	190.8					~$6-10 Million	

Table 6-3. Summary of Restoration Project Prioritization

Project Area	Project Site	Project Type	Project Score			
			Streambank Erosion Reduction	Socio-Economic Importance	Timeframe	Overall Project Score
11	Eroding Bank 9	Streambank Stabilization and Revegetation	5	5	5	15
8	River Road West	Streambank Stabilization and Revegetation	5	4	5	14
7	Eroding Bank 6	Streambank Stabilization and Revegetation	5	4	5	14
9	Eroding Bank 7	Streambank Stabilization and Revegetation	5	4	5	14
3	Eroding Bank 3	Streambank Stabilization and Revegetation	5	3	5	13
6	Eroding Bank 5	Streambank Stabilization and Revegetation	5	3	5	13
12	Eroding Bank 10	Streambank Stabilization and Revegetation	5	3	5	13
1	Eroding Bank 2	Flow Enhancement in Side Channels and Overflow Channels	3	3	5	11
5	Eroding Bank 4	Flow Enhancement in Side Channels and Overflow Channels	3	3	5	11
11	Eroding Bank 9	Floodplain Revegetation	3	5	3	11
10	West Channel	Flow Enhancement in Side Channels and Overflow Channels	3	2	5	10
7	Eroding Bank 6	Floodplain Revegetation	3	4	3	10
9	Eroding Bank 7	Floodplain Revegetation	3	4	3	10
6	Eroding Bank 5	Floodplain Revegetation - Primary Priority	3	3	3	9
12	Eroding Bank 10	Floodplain Revegetation - Lawyer Nursery	3	3	3	9
12	Eroding Bank 10	Floodplain Revegetation - Town of Plains	3	3	3	9
12	Eroding Bank 10	Irrigation Infrastructure Improvements	1	3	5	9
1	Eroding Bank 2	Floodplain Revegetation - Primary Priority	3	1	3	7
5	Eroding Bank 4	Streambank Stabilization and Revegetation	5	1	1	7
6	Eroding Bank 5	Floodplain Revegetation - Secondary Priority	3	3	1	7
11	Eroding Bank 9	Culvert Upgrades on Roads Crossing Overflow Channels	1	5	1	7
13	East Channel	Flow Enhancement in Side Channels and Overflow Channels	3	1	3	7
1	Eroding Bank 2	Floodplain Revegetation - Secondary Priority	3	1	1	5
2	Town Bank	Debris Removal from Streambanks and Channel	1	1	1	3
4	Historic Bridge Pylons	Debris Removal from Streambanks and Channel	1	1	1	3
6	Eroding Bank 5	Debris Removal from Streambanks and Channel	1	1	1	3
7	Eroding Bank 6	Debris Removal from Streambanks and Channel	1	1	1	3
12	Eroding Bank 10	Debris Removal from Streambanks and Channel	1	1	1	3
12	Eroding Bank 10	Culvert Upgrades on Roads Crossing Overflow Channels	1	1	1	3

Figure 6-42. Plains Reach Centerline Stationing

6.4 Permitting Requirements

Montana Natural Streambed and Land Preservation Act ("The 310 Law")

- Administered by local Conservation District with input from Montana Fish, Wildlife & Parks (FWP); SPA 124 Permit is required in lieu of a 310 permit for projects proposed by a public entity

County Floodplain Development Permit

- Required for projects within FEMA-designated floodplains/floodways

Short-term Water Quality Standard for Turbidity (318 Authorization)

- Administered by Montana Department of Environmental Quality; permit may be waived by FWP during their review of a project

Federal Clean Water Act (Section 404 Authorization)

- Administered by the U.S. Army Corps of Engineers; authorizes placement of fill material below the ordinary high water mark

Montana Stream Mitigation Procedure (U.S. Army Corps of Engineers)

- Compensatory mitigation to ensure minimal individual and cumulative adverse impacts to aquatic resources
- Part of an overall sequence in project evaluation that dictates avoidance of impacts first, followed by minimization of impacts, and then compensation for remaining impacts
- Mitigation for impacts typically consists of natural revegetation, bioengineered bank stabilization, natural buffers, aquatic habitat improvements, floodplain re-connection, weed removal/management, fencing, and allowing for natural channel migration
- Based on a system of debits and credits that are applied to each project to determine if, and to what extent, mitigation will be required
- *Magnitude*: Individual projects > 300 feet in length typically require mitigation; cumulative projects > 1,000 feet in length increases debit responsibility
- *Location*: Mitigation activities can occur on-site, off-site, or outside of watershed
- *Timing*: Mitigation activities can occur prior to the impacts, concurrent with the impacts, or after the impacts

Montana Department of Natural Resources and Conservation

- Water rights

6.5 Potential Funding Sources

Table 6-4. Potential Funding Sources

Agency	Program Name	Assistance	Project Types	Maximum Financial Award							
				None	Under $10,000	Under $25,000	Under $50,000	Under $100,000	Over $100,000	Varies widely	Match Required
LOCAL											
Sanders County Conservation District	**NA**	Technical	Liaisons between landowners and government agencies, in-kind administrative and technical assistance, program coordination/partnering	X							
STATE											
Montana Department of Environmental Quality	**Nonpoint Source Implementation Grants - 319 Program**	Financial, technical	Water quality BMP's							X	
Montana Fish, Wildlife & Parks	**Future Fisheries Improvement Program**	Financial, technical	Restore rivers, streams, and lakes. Improve and restore wild fish habitats							X	X

Table 6-4. Potential Funding Sources

Agency	Program Name	Assistance	Project Types	Maximum Financial Award							
				None	Under $10,000	Under $25,000	Under $50,000	Under $100,000	Over $100,000	Varies widely	Match Required
Montana Department of Natural Resources and Conservation	**Reclamation and Development Grants Program (RDG)**	Financial	Serve the public interest and the State of Montana. Develop natural resources and promote and protect Montana's total environment and the general health, safety, welfare, and public resources of Montana's citizens and communities						X		
	Renewable Resource Grant and Loan Program (RRGL)	Financial	Fund conservation, management, development and preservation of Montana's renewable resources						X		
FEDERAL											
U.S. Department of Agriculture	**Conservation Reserve Program (CRP)**	Financial, technical	Remove environmentally sensitive land from agricultural production and plant species to improve environmental health and quality							X	
	Conservation Reserve Easement Program (CREP)	Financial, technical	Combined with CRP program to improve water quality and enhance wildlife habitat in nine Montana counties							x	
U.S. Department of Agriculture/ Farm Service Agency	**Conservation Improvement Grant (CIG)**	Financial, technical	Stimulate development and adoption of innovative approaches and technologies for conservation on agricultural lands							X	

Table 6-4. Potential Funding Sources

Agency	Program Name	Assistance	Project Types	Maximum Financial Award							
				None	Under $10,000	Under $25,000	Under $50,000	Under $100,000	Over $100,000	Varies widely	Match Required
	Emergency Conservation Program (ECP)	Financial, technical	Farmland damaged by natural disasters, emergency livestock watering conservation in severe drought							X	X
	Environmental Quality Incentive Program (EQIP)	Financial, technical	Implement conservation practices or activities like conservation planning							X	
	Watershed Protection and Flood Prevention Program (WFPO)	Financial, technical	Watershed protection, water quality control, erosion and sediment control, wetland creation and enhancement, fish and wildlife enhancement, flood control, public recreation							X	
	Wetland Reserve Easement Program	Financial, technical	Restore, protect and enhanced enrolled wetlands							X	
Natural Resources Conservation Service	**Emergency Watershed Protection (EWP)**	Financial, technical	Remove debris from streams, protect stream banks, establish cover on eroding lands, conservation practices, and flood plain easements							X	X

Table 6-4. Potential Funding Sources

Agency	Program Name	Assistance	Project Types	Maximum Financial Award							
				None	Under $10,000	Under $25,000	Under $50,000	Under $100,000	Over $100,000	Varies widely	Match Required
	Resource Conservation and Development Program (RC&D)	Financial, technical	Accelerates/improves State, local agencies and nonprofit groups in rural areas to plan, develop and carry out programs for resource conservation and development							X	
	National Grazing Lands Coalition (GLC)	Technical	Improve health, management, and productivity, of privately owned grazing land	X							
	Conservation Stewardship Program (CSP)	Financial, technical	Help agricultural producers maintain and improve existing conservation systems and adopt additional conservation activities				X				
U.S. Department in Interior and Bureau of Reclamation	**Cooperative Range Improvement Agreement**	Financial, technical	Spring developments, wells, reservoirs and associated pipelines							X	
	WaterSMART Grants (formerly Water Challenge Grants)	Financial, technical	Conserve and use water more efficiently, increase the use of renewable energy, or facilitate water markets.							X	X
U.S. Environmental Protection Agency	**Targeted Watershed Grants Program**	Financial	Aquatic, wetland, riparian and upland habitat improvement and protection							X	X

Table 6-4. Potential Funding Sources

Agency	Program Name	Assistance	Project Types	Maximum Financial Award							
				None	Under $10,000	Under $25,000	Under $50,000	Under $100,000	Over $100,000	Varies widely	Match Required
	Wetland Program Development Grants	Financial, technical	Promote research/studies to prevent/eliminate water pollution						X	X	X
U.S. Fish and Wildlife Service	**Partners for Fish and Wildlife**	Financial, technical	Habitat restoration to benefit federal trust species, conservation programs, and various fish and wildlife restoration projects							X	X
	North American Wetlands Conservation Act Program	Financial	Variety of wetland conservation projects					X		X	X
	Landowner Incentive Program (Non-tribal)	Financial, technical	Funding to WG&F to support fish, wildlife restoration and wetland conservation projects							X	X
	Wildlife and Sport Fish Restoration Programs	Financial, technical	Conserve, protect, and enhance fish, wildlife, their habitats, and the hunting, sport fishing and recreational boating opportunities they provide								
	State Wildlife Grant Program (SWG)	Financial, technical	Developing wildlife conservation plans and on-the-ground conservation projects							X	X
PRIVATE OR NON-PROFIT ORGANIZATIONS											
National Fish and Wildlife Foundation (NFWF)	**Pulling Together Initiative (PTI)**	Financial, technical	Long-term invasive species weed control							X	X
	Five-Star Restoration Program	Financial, technical	Wetland and wildlife habitat restoration							X	

Table 6-4. Potential Funding Sources

Agency	Program Name	Assistance	Project Types	Maximum Financial Award							
				None	Under $10,000	Under $25,000	Under $50,000	Under $100,000	Over $100,000	Varies widely	Match Required
	Bring Back the Natives Grant Program	Financial	Riverine habitat and aquatic species restoration projects				X				X
	National Plant Conservation Initiative (NPCI)	Financial	Restoration of native plant communities							X	
Trout Unlimited	**Watershed Restoration**	Financial	Erosion control, fish habitat, structures, willow and other riparian plantings							x	
	Habitat Protection and Enhancement Fund	Financial	Improve water quality, riparian protection, enhance stream flows and watershed health, protect important trout habitat							x	

7.0 References

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, New York.

Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach Morphology in Mountain Drainage Basins. Bulletin of the Geological Society of America, 109:596-611.

Rapp, C.f. and T.B. Abbe. 2003. A Framework for Delineating Channel Migration Zones. Washington State Department of Ecology and Washington State Department of Transportation. Ecology Final Draft Publication #03-06-027.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Thatcher, T., K. Boyd, and B. Swindell. 2009. Yellowstone River Channel Migration Zone Mapping. Prepared for Custer County Conservation District and Yellowstone River Conservation District Council. Prepared by DTM Consulting and Applied Geomorphology.

USGS. 1982. Guidelines for Determining Flood Flow Frequency. Bulletin #17B of the Hydrology Subcommittee.