ATKINS

Yellowstone River Conservation District Council

Yellowstone River Pipeline Risk Assessment and Floodplain Reclamation Planning Project

FINAL Report

September 21, 2012

Plan Design Enable

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Acronyms

AGI – Applied Geomorphology Inc.

BMP – best management practice

CEA – cumulative effects assessment

CMZ – channel migration zone

COE – U.S. Army Corps of Engineers

DNRC – Department of Natural Resources and Conservation

GIS – geographic information system

HDD – horizontal directional drilling

HEC18 – Hydraulic Engineering Circular No. 18

MIC – microbiologically-influenced corrosion

NPMS – National Pipeline Mapping System

PCA – partially confined anabranching

PCB – partially confined branching

PCM – partially confined meandering

PFT – Physical Features Timeline

PHMSA – Pipeline and Hazardous Materials Safety Administration

RDGP – Reclamation and Development Planning Grant

RM – river mile

T&E – Threatened and Endangered

UB – unconfined braided

USGS – U.S. Geological Survey

WAI – Womack and Associates, Inc.

YRCDC – Yellowstone River Conservation District Council

Executive Summary

The project team of Atkins North America, Inc (Atkins), Applied Geomorphology Inc. (AGI), and Womack and Associates, Inc. (WAI) were contracted by Custer County Conservation District on behalf of the Yellowstone River Conservation District Council (YRCDC) to assess factors that affect the risk of a pipeline failure on the Yellowstone River. The goals of this project include:

1. Development of a pipeline crossing data base;
2. Determine risk to gas and/or hazardous material pipelines passing within the Yellowstone River channel migration zone (CMZ); and
3. Potential for floodplain mitigation to reduce risk in these locations.

Comparison of pipeline location and CMZ data sets for the Yellowstone River identified 21 sites where pipelines cross or intersect the CMZ. Based on Atkins' review of the available information, each of the 21 sites was assigned a pipeline risk value of "low", "moderate", or "high" as indicated on Figure 40. The pipelines with the highest risk of failure due to river process are located at:

- Site 16, Laurel bridge;
- Site 12, South Billings Boulevard bridge;
- Site 5, Black Bridge near Glendive; and
- Site 2, a crossing southeast of Sidney.

Lateral migration analysis indicates only Sites 5 (River Mile 94) near Glendive and 14 (River Mile 281.5) downstream of Laurel are projected to have a risk of being exposed by lateral migration in the near future. Depth of cover and current channel armoring should be reviewed at these two sites.

The original intent of this project was to locate a potential project site where historical modifications/restrictions to the Yellowstone River floodplain had increased the risk of gas and/or hazardous material pipeline failure through increase in stream energy and scour potential. A grant was then to be sought to complete site evaluation and project construction.

After carefully studying all the crossings, the project team assigned each of the 21 sites a floodplain restoration potential value of "low", "moderate", or "high" as shown in Figure 40. The project team came to the conclusion that improvement of channel conditions is rarely an option. Many pipeline crossings are in developed areas where changes to channel geometry are impractical. In rural settings, crossings are simply not located in places where portions of the floodplain can be reclaimed. Most of the crossings are in relatively narrow reaches where alternative channels are not available.

The ideal site would have a reduced floodplain width/function that could be restored, thus spreading flood energy over a greater area and reducing scour depths and lateral migration rates. <u>No such ideal project site was found.</u> Section 3.0 and Appendix A provide a narrative and maps of where the pipelines either cross or are in the CMZ.

Since restoration is generally not an option, available options include channel armoring or pipe relocation with horizontal directional drilling (HDD). HDD can remove the pipeline from dynamic river

effects such as lateral migration, scour, or long term channel degradation (down cutting). HDD does not have the negative geomorphic impacts that accompany locking portions of the channel in place with riprap, bendway weirs, levees, etc. Conversations with Conservation District Administrators indicate that HDD has become a common practice for new pipeline crossings on the Yellowstone. HDD should be considered as a standard Best Management Practice (BMP) for future pipelines as well as a replacement option for threatened pipelines.

Recommendations include:

- Request depth of cover data for all 37 pipelines within the CMZ from NPMS (National Pipeline Mapping System);
- Complete risk of exposure assessment of each pipeline based on depth of cover and site specific scour analysis;
- Each Conservation District is encouraged to adopt a Best Management Practice (BMP) policy of using Horizontal Directional Drilling (HDD) for future pipeline crossings and for existing at-risk pipelines.

1 Introduction

The project team of Atkins North America, Inc (Atkins), Applied Geomorphology Inc. (AGI), and Womack and Associates, Inc. (WAI) were contracted by Custer County Conservation District on behalf of the Yellowstone River Conservation District Council (YRCDC) to assess factors that affect the risk of a pipeline failure on the Yellowstone River. The project is funded through a Reclamation and Development Planning Grant (RDGP) awarded to YRCDC by the Montana Department of Natural Resources and Conservation (DNRC). The project builds on existing information and results developed by the YRCDC and the U.S. Army Corps of Engineers (COE) for cumulative effects assessment (CEA) along the Yellowstone River corridor and is intended to inform operators, local government, and the general public about the risks associated with ruptures and leaks in sections of petroleum pipelines that cross the Yellowstone Rivers and immediate tributaries.

1.1 Project Background

The flooding and erosion associated with the seasonal high water of 2011 resulted in significant damage along the Yellowstone River mainstem and tributaries. Floodwaters on the Yellowstone near Billings peaked July 2, 2011 at 70,600 cfs, which is an estimated 25-50-year event. Damages sustained to critical infrastructure include ExxonMobil's Silvertip Pipeline, a 12-inch diameter crude oil pipeline that, until its rupture, crossed under the Yellowstone River near Laurel. Originally installed approximately 5-7 feet beneath the riverbed, hydraulic forces had since scoured away the overlying gravel such that on July 1, 2011, the pipeline ruptured, spilling an estimated 50,000 gallons of oil into the Yellowstone River. As the river receded, oil was detected miles downstream of the rupture and millions of dollars were spent in the clean-up effort. This environmental accident has heightened public awareness both locally and nationally. The Yellowstone River is the longest free-flowing river in the lower 48 states and is home to threatened and endangered (T&E) species including the Pallid Sturgeon. In addition, numerous communities along the river tap the Yellowstone for their public water supply systems.

Figure 1. 2011 Oil spill, Yellowstone River (Billings Gazette).

Consequently, the YRCDC applied for and received a RDG planning grant from DNRC. In general, the overall goal of this contract is to estimate the level of effort necessary to demonstrate and remediate the cumulative effects of flood and erosion control structures on the Yellowstone River. In particular, this RDG planning grant project was intended to scope a Reclamation and Development Grant Program (RDGP) project that analyzed the risk of failure associated with a prioritized set of petroleum and hazardous material pipelines identified by the planning grant project. Key outcomes of the planning grant work include estimation of the level of effort necessary to determine what, if any, role adjacent land use may play in elevating the risk of failure associated with a given pipeline, and identification of channel and floodplain reclamation opportunities that may mitigate this risk.

1.2 Project Location

For purposes of this project, the geographic scope includes the entire Yellowstone River floodplain from the Yellowstone National Park boundary to the Missouri River confluence. The project focuses on those reaches of the river that contain identified pipeline crossings, or have a segment of pipeline that intersects the CMZ.

1.3 Tasks

The following tasks and associated deliverables were specified in the original contract between the Atkins Team and Custer County CD:

1. Prepare detailed inventory of gas and hazardous material pipelines that exist within the Yellowstone River CMZ and floodplain. <u>Deliverables - draft report and ESRI geodatabase.</u>

2. Preliminarily identify at-risk pipelines. Scope and estimate costs associated with the technical analyses (geomorphic, hydraulic and other technical analyses necessary to quantify pipeline failure risk including determining the lateral and vertical channel stability) needed to assess the risk of pipeline failure for the highest risk pipelines. <u>Deliverables - draft work plan and cost estimate.</u>

3. Preliminarily identify potential floodplain reclamation sites. Scope and estimate costs associated with the technical analyses necessary to identify feasible candidate sites for floodplain reclamation that mitigate the risk of failure for pipeline segments identified in Task 2 above. Prioritize these sites based on criteria such as cost and efficacy. <u>Deliverable – Alternative Floodplain Reclamation Sites Development Report.</u>

4. Based on the results of Tasks 1, 2, and 3, prepare a Reclamation and Development Grant Program application aimed at conducting a pipeline risk assessment and constructing a selected floodplain reclamation project. <u>Deliverables - work plans and cost estimates from Tasks 2 and 3 included in the final RDGP application; prepare the presentation and gain YRCDC approval.</u>

1.4 Mapping Scale and Distribution

Two types of maps are included in this report. The first are county-wide maps indicating general gas and hazardous liquid pipeline locations relative to towns, major roads and rivers. These maps are of a scale consistent with the NPMS Public Map Viewer and are appropriate for general public distribution as per the confidentiality agreement between YRCDC and PHMSA. The map quality is intentionally coarse for security purposes. These maps are presented at the beginning of each of the following sections.

The second type of map is specific for each pipeline location of interest. These maps present the data available from past CEA studies along with the more detailed pipeline locations. It should be noted that the pipeline locations presented in these maps is restricted information and is not intended for public distribution. These maps are presented in Appendix A. **Appendix A should be removed prior to wider distribution of this report.**

1.5 Data Limitations and Disclaimers

The most significant limitation with respect to data used in this report is the lack of channel geometry data, depth of cover, and pipeline configurations at river crossings. For example, pipelines at bridges may be suspended from the bridge deck, or conversely, buried tens of feet below the riverbed. This assessment describes the potential for lateral and vertical movement of the river which could expose shallowly-buried lines. True risk assessment requires an integration of the results reported here with proprietary pipeline geometry data unavailable to this investigation.

It is also important to note that all pipelines could be replaced/relocated, which may be more cost-effective than any channel/floodplain modifications.

2 Methods

2.1 Task 1: Data Compilation and Analysis

The initial step for the project was to gather available data. Numerous data sources and past studies were utilized for this investigation including:

2.1.1 Cumulative Effects Assessment

Data developed by the Yellowstone River Conservation District Council and US Army Corps of Engineers (COE) in support of the Yellowstone River Cumulative Effects Assessment include a geomorphic reach delineation and classification of the river, a summary of erosion control extents by reach, a physical features inventory, historic air photos, and Channel Migration Zone (CMZ) mapping (*www.NRIS.MT.gov/Yellowstone*).

2.1.2 National Pipeline Mapping System (NPMS)

The US Department of Transportation through the Pipeline and Hazardous Materials Safety Administration (PHMSA) maintains the National Pipeline Mapping System (NPMS). Part of this system is a geographic information system (GIS) that includes pipeline locations, owner's data, pipeline data, etc. Detailed pipeline location maps and data are available from the NPMS for government agencies such as the YRCDC, and pipeline owners. NPMS pipeline data was obtained by the YRCDC in its capacity as a unit of local government. Atkins obtained the NPMS data from YRCDC with the understanding that the data could not be shared.

PHMSA Data Base. For security reasons, limited data was received from PHMSA concerning details of pipeline installation. Data received in a GIS database included:

- Pipeline location maps,
- Operator name,
- System name,
- Subsystem name,
- Pipe diameter,
- Commodity.

For a limited number of crossing sites, additional data was obtained via a spreadsheet that includes:

- 2011 depth of cover,
- Worst case discharge,
- Short-term remedial action schedule,
- Long-term remedial action schedule.

These additional data did not include a verifiable source for citing or a means of correlating them to the GIS database. Therefore, these data are discussed here in general terms rather than site-specific terms. The main item of note with these data is that 2011 cover inventory reports indicate a range of five to eight feet with no crossing reported to have been directionally drilled. Today, companies building across major rivers typically use horizontal directional drilling (HDD) methods to install pipelines in alluvial material well below the channel bottom or in stable rock deep below the bed of the river (25 – 100 feet). The data provided by PHMSA did not include information regarding the age of a given pipeline crossing or whether it had been placed or replaced by HDD methods

2.1.3 Hydrologic Analysis and Hydraulic Models

Hydrology and hydraulics reports/models were obtained through DNRC's floodplain program personnel and the USGS. Hydrologic analysis assesses the peak flow rate along the river corridor and then computes flow rates for given annual risk values. The most typical assessment is for the 1-percent annual chance flow event (sometimes referred to as the 100-year return interval) which is the flow rate that has a 1-percent chance of being equaled or exceeded in any given year. Hydraulic models combine topographic data of the channel and floodplain with flow data (hydrologic data) to determine water surface elevations/profiles for given flood return intervals. The following hydraulic models were obtained for the Yellowstone River:

- The COE has completed a hydraulic model and floodplain mapping for Yellowstone County that is in the final adoption process by the County, DNRC and FEMA.
- COE has also completed draft hydraulic models and floodplain mapping for Sweet Grass and Stillwater Counties. These two models are under review by both DNRC and FEMA.
- The Upper Yellowstone River in Park County has a series of hydraulic models and floodplain mapping completed by both the COE and US Geologic Survey (USGS) that have been adopted as the effective floodplain maps by FEMA, DNRC and the County.

These models provide a suitable foundation on which to conduct the channel stability analyses necessary for assessing pipeline failure risk and identifying floodplain reclamation opportunities once high-risk pipelines are identified.

<u>Channel Substrate.</u> USGS completed Scientific Investigations Report 2011-5107 titled "Investigation of Pier Scour in Coarse-Bed Streams in Montana, 2001 through 2007" in 2011. The report includes substrate gradation data for the Yellowstone River.

<u>Water Temperature.</u> Sediment transport and scour analysis is dependent on water temperature which impacts water density and other factors. USGS gaging and water quality data were assessed for the monitoring station 06214500 – Yellowstone River at Billings, MT.

<u>Topographic Data.</u> Hydraulic modeling and floodplain mapping for the Yellowstone River has been based on topographic data collected specifically for this purpose. Data has been collected for each of the 12 counties involved in this study. Data was collected in 1999, 2004 and 2007 as indicated on Figure 2.

2.1.4 Landownership

Landownership of each river bank was determined for each crossing using State of Montana's Cadastral database (http://svc.mt.gov/msl/mtcadastral/). Data are presented in Table 2. The State of Montana owns the Yellowstone River bed and Right of Way must be obtained from the Montana DNRC, Trust

Land Division, for construction of permanent structures under or over the river. Right of Way permit data is presented in **Appendix B**.

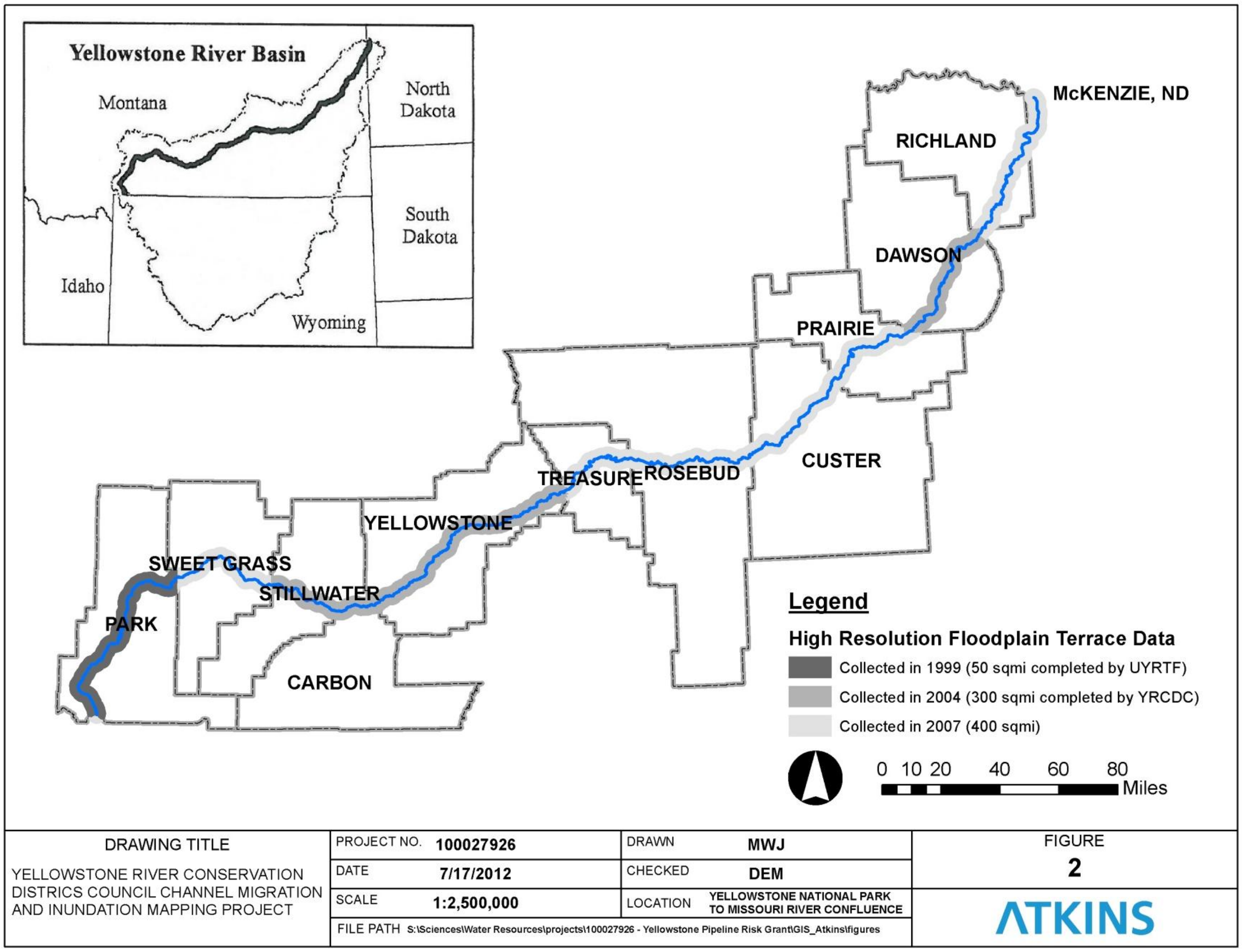

Figure 2. Yellowstone River floodplain terrain data collection schematic

2.1.5 310 Permit Application Review

Conservation District Administrators were contacted in an effort to attain more complete depth of cover data and pipeline profiles relative to channel bottom. Telephone conversations with Administrators found the following:

- 310 applications are not available for the majority of the identified pipeline crossings. This is due to a variety of reasons including: pipeline predates 310 law, 310 applications are only retained for a set number of years and are no longer available, horizontal directional drilling does not require a 310 permit.
- Administrators have personal knowledge of some pipeline installations that indicate trenching methods were used and therefore the pipelines would be relatively shallow with respect to the channel bottom (e.g. the five pipelines grouped at site 9).

2.2 Task 2: Identification of At-Risk Pipelines.

The goal of Task 2 is to identify potentially at-risk pipelines. Numerous internal and external factors affect a pipeline's failure potential, including factors such as:

- Microbiologically-influenced corrosion (MIC)
- Internal corrosion due to free moisture
- External corrosion due to inadequate cathodic protection
- Material failure, pipe
- Material failure, weld
- Material failure, valve
- Material failure, fitting
- Material failure due to improper installation
- Excavation damage
- Incorrect operation
- Exposure of pipe

For this effort, the risk associated with pipeline failure is specifically related to exposure of the pipeline due to shifts in the bed and/or banks of the Yellowstone River. Although the surficial exposure of a pipeline will not necessarily result in failure, it is critical that such conditions be rapidly identified and rehabilitated as necessary.

In order to assess the overall potential for a given pipeline to become exposed due to river processes, the data sets described Task 1 were combined to identify the locations of pipelines, and to assess current conditions and rates of change in the river in these areas. For the pipeline sections located within the CMZ four potential risks were considered:

1. Lateral migration of the river with eventual intersection of a pipeline route that is parallel to the river (Figure 3),
2. Lateral migration of the river at a pipeline crossing, where shallow margins of the crossing are exposed,
3. Reach-scale, systemic channel degradation (lowering of the channel bottom) due to natural or man-caused channel changes (Figure 4 and Figure 5),
4. Short term scour during flood events; this can be difficult to identify as it is typically not visible during low flows.

Figure 3. Exposed section of ConocoPhillips gasoline pipeline on Beaver Creek near York, Montana showing exposure from both lateral movement and vertical downcutting. (http://ravallirepublic.com)

Figure 4. Pipeline exposed from vertical bed degradation, Travyanaya River, Russia. (http://www.sakhalin.evinronment.ru)

Figure 5. Exposure of two pipelines on small creek in Vermont. (http://world.350.org)

In order to assess exposure risks associated with lateral channel migration, pipeline locations were overlain with channel migration zones. Digitized banklines from 1950, 1976, and 2001 were compared with 2011 air photos to then assess historic and recent rates of bank movement in the vicinity of pipelines.

The second risk type, long term channel degradation (lowering of the channel bottom), was previously assessed by WAI for specific river reaches/locations within Yellowstone County. This assessment was updated for locations that coincided with pipeline crossings based on new topographic data collected for the COE floodplain assessment.

Five cross-section locations in Yellowstone County were examined for evidence of changes over time that might affect pipelines; specifically, long-term degradation or short-term scour during large floods as part of the YRCDC CEA (See Figure 2). Portions of the project reach were surveyed by FEMA (1968), Aquoneering (1999), and COE (2004). Cross-sections near pipeline crossings in Yellowstone County are presented in Section 3 of this report. Elevation (y-axis) was surveyed and is, therefore, deemed accurate. Matching relative horizontal coordinates (x-axis), however, is uncertain because plan form survey data were not available for all data sets. The cross-sections are superimposed at each crossing and channel bottom elevation and width/depth ratio (at approximately bankfull flow) were compared.

The third risk type, short term scour during flood events, was analyzed using the available hydraulic models, USGS gradation data, USGS water temperature data and pipeline locations (see Section 2.1.4). Data from NPMS was limited to aerial location and did not include pipeline elevation. The Atkins team believes the elevation data exists but we were only able to attain limited data at this stage of the investigation. A complete assessment of pipeline risk is not possible without these elevation data. Therefore, this potential risk was investigated on a broader scale. Instead of looking at specific pipeline crossings, worst case scour scenarios were evaluated for maximum scour.

Scour computations were completed based on the US Department of Transportation Federal Highway Administration's Hydraulic Engineering Circular No. 18 (HEC 18) – Evaluating Scour at Bridges. HEC 18 is incorporated within COE's HEC-RAS hydraulic model software. The scenarios were evaluated at bridges near some of the pipeline crossings. Three types of scour were evaluated: contraction scour, pier scour, and abutment scour. The scour values were then combined for a worst case scenario.

Based on potential failure methods discussed above, each site was then assigned a pipeline failure potential of low, medium or high.

2.3 Task 3: Preliminary Identification of Potential Floodplain Reclamation Sites

The goal of Task 3 is to preliminarily identify potential floodplain reclamation sites. Pipelines within the CMZ were compared to the CEA data base looking for at-risk pipeline sites potentially impacted by floodplain/river manipulation. The ideal site for reclamation will increase river access to the floodplain due to removal of high flow channel plugs or flood control dikes. It is anticipated that such reduction in floodplain access concentrates flow/energy, increases potential for lateral migration and vertical scour and thus increases risk of pipeline failure. Based on the availability of and potential for floodplain mitigation in the vicinity of each pipeline site, a "Floodplain Mitigation Potential" of low, medium or high was assigned.

2.4 Task 4: Preparation of RDGP Application

The goal of Task 4 is the preparation of a Reclamation and Development Grant Program application aimed at conducting a pipeline risk assessment and constructing a selected floodplain reclamation project. This task has yet to be completed as discussed in the Executive Summary of this report.

3 Results and Discussion

Between Gardiner and the Missouri River, a total of 21 sites were identified where one or multiple pipelines encroach into the CMZ of the Yellowstone River (Table 1 and Table 2). Each site is identified in terms of "River Mile", which is the distance along the channel centerline above the Missouri River confluence. The majority of sites are located in Yellowstone County, where 16 pipelines cross the river and at 10 locations pipelines run subparallel to the river within the CMZ (Figure 6). These sites are concentrated in reaches B1 and B2, which is the channel segment from confluence with Clarks Fork River to just downstream of Interstate 90 bridge crossing (Figure 7). These crossings are described as eight overall site locations. Four or fewer pipeline crossings/CMZ encroachments were identified in McKenzie (1), Richland (4), Dawson (2), Prairie (2), Stillwater (2), Sweet Grass (2), and Park (1) Counties. Each of these sites was then evaluated based on overall potential for significant change in the bank location or bed elevation of the river. As information regarding the exact configuration of the pipeline (depth and distance from bank) was notably lacking, the assessment is focused on potential for lateral movement or downcutting on the river, with no direct reference to the current vulnerability of a given pipeline to those changes.

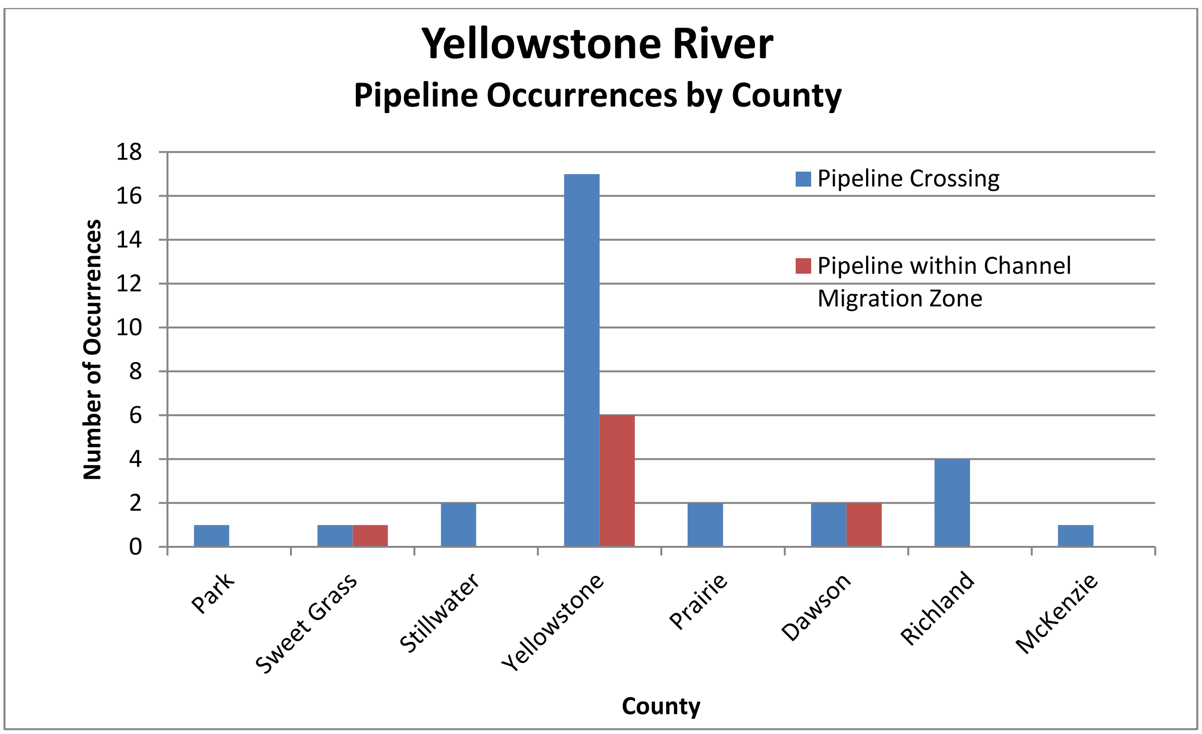

Figure 6. Number of Yellowstone River pipeline sites by county.

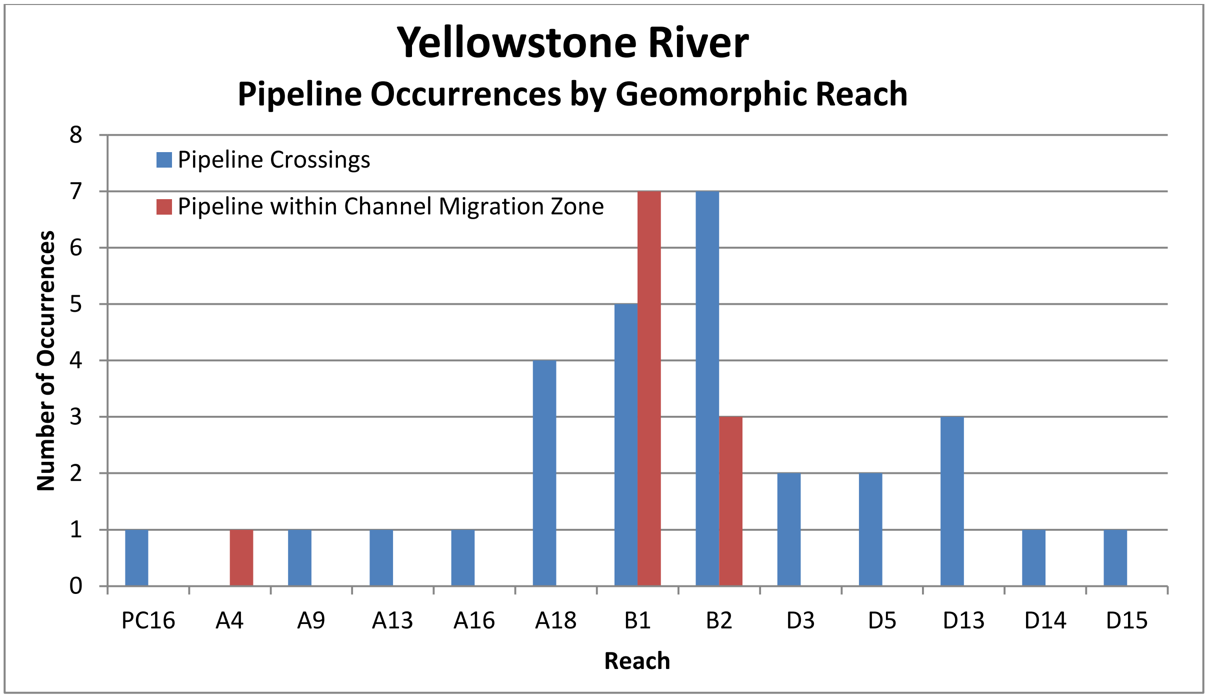

Figure 7. Number of Yellowstone River assessment sites by geomorphic reach.

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Table 1. Summary of pipeline locations evaluated in this report.

Yellowstone Pipeline Crossing Risk Assessment							
Site Summary							
River Mile	*Site Number*	*Location*	*Type of Crossing*	*Pipe Diameter (inches)*	*Commodity*	*System/Sub System Name*	*Owner*
PARK COUNTY							
498	21	Downstream of Livingston (Rustad Lane)	Parallel, Crossing	12	Natural Gas	Dry Creek-Bozeman Line	Northwestern Energy LLC
SWEET GRASS COUNTY							
460	20	Big Timber	Tributary Crossing (Big Timber Cr)	10	Product	Billings Pump STA/Missoula	Conoco Phillips
438	19	Upstream of Reed Pt	Crossing	12	Natural Gas	Big Coulee-Reed Point Line	Northwestern Energy
STILLWATER COUNTY							
417	18	Near Columbus just downstream of Stillwater Confluence	Crossing	4	Natural Gas	Lake Basin-Absarokee Line	Northwestern Energy Lake Basin-Absarokee Line
397	17	Downstream of Columbus	Parallel, Crossing	24	Crude Oil	Express Pipeline	Kinder Morgan Pipelines
YELLOWSTONE COUNTY							
385	16D	Laurel	Crossing	8	Crude Oil	Glacier Crude-Byron 8 in, Frannie Sta/Billings Pump Sta	Conoco Phillips
385	16C	Laurel	Crossing	16	Natural Gas	Lovel Elk Basin Billings System, Worland Sub-System	Willistion Basin Interstate Pipeline Co.
385	16B	Laurel	Crossing	16	Natural Gas	Lovel Elk Basin Billings System, Worland Sub-System	Willistion Basin Interstate Pipeline Co.
385	16A	Laurel	Crossing	12.75	Crude Oil	Montana Crude, Edgar-Laurel Terminal 12" MT-14	ExxonMobil Pipeline Co.
382	15B	Downstream of Laurel	Crossing	8	Natural Gas	Northwestern Energy GT&S, CENEX Tap Line	Northwest Energy LLC
382	15A	Downstream of Laurel	Crossing	8	Crude Oil	Glacier Crude-Byron 8 in, Frannie Sta/Billings Pump Sta	Conoco Phillips
381.5	14B	Downstream of Laurel	Parallel	8	Natural Gas	Northwestern Energy GT&S, CENEX Tap Line	Northwest Energy LLC
381.5	14A	Downstream of Laurel	Parallel	8	Crude Oil	Glacier Crude-Byron 8 in, Frannie Sta/Billings Pump Sta	Conoco Phillips
380	13	Downstream of Laurel	Parallel	8	Crude Oil	Glacier Crude-Byron 8 in, Frannie Sta/Billings Pump Sta	Conoco Phillips
371	12D	South Billings Blvd.	Parallel	12	Natural Gas	Lovel Elk Basin Billings System, Worland Sub-System	Williston Basin Interstate Pipeline Co
371	12C	South Billings Blvd.	Crossing	8	Crude	Glacier Crude-Byron 8in, Frannie Sta/Billings Pump Sta	Conoco Phillips
371	12B	South Billings Blvd.	Crossing	8	Natural Gas	Warren-Billings Steam Plant Line	Northwestern Energy LLC
371	12A	South Billings Blvd.	Crossing	6	Natural Gas	Blue Creek-Billings Steam Plant Line	Northwestern Energy LLC
368	11	Billings	Parallel	12	Natural Gas	Worland Sub-System	Williston Basin Interstate Pipeline

Yellowstone Pipeline Crossing Risk Assessment							
Site Summary							
River Mile	***Site Number***	***Location***	***Type of Crossing***	***Pipe Diameter (inches)***	***Commodity***	***System/Sub System Name***	***Owner***
YELLOWSTONE COUNTY Cont.							
367	10B	Billings	Crossing	12	Crude	Rocky Mountain, Beartooth	Beartooth Pipeline
367	10A	Billings	Crossing	8	Product	Siminor 8 in Products, Billings Pump Sta/Sinclair Pump Sta	Conoco Phillips
365	9G	Billings	Crossing	10	Crude Oil	Glacier 10 In Crude Conoco Refinery/ExxonMobil Refinery	Conoc Philips
365	9F	Billings	Parallel	8	Product	CENEX Pipeline System, Laurel to Billings 8 in Product	CENEX Pipeline LLC
365	9E	Billings	Crossing	10	Crude	Glacier 10 In Crude Conoco Refinery/ExxonMobil Refinery	Conoco-Phillips (upstream I-90
365	9D	Billings	Crossing	8	Natural Gas	Montan - Dakota Utilities Billings Exxon Line	Montana - Dakota Utilities Co.
365	9C	Billings	Crossing	8	Product	Exxon Refinery Seminoe 8 in suction	Conoco Phillips
365	9B	Billings	Crossing	12.75	Crude	Montana Crude Billings Meter Station - Billings Refinery	ExxonMobil Pipeline Co.
365	9A	Billings	Crossing	8	Product	Cennex Pipeline System Laurel to Billings 8in Products	CENEX Pipeline LLC
PRAIRIE COUNTY							
126	8B	Fallon	Crossing	8	Product	8" Products - Fallon to Glendive	Abandoned
126	8A	Fallon	Crossing	10	Product	CENEX Pipeline System MP 191 to Glendive 101N	CENEX Pipeline LLC
DAWSON COUNTY							
104	7	Glendive	Parallel	10	Crude Oil	No Data	Bridger Pipeline
100	6	Glendive	Crossing	10	Crude Oil	No Data	Bridger Pipeline
94	5	Glendive (Black Bridge)	Crossing	16	Natural Gas	West Mon-Dak Subsystem	Williston Basin Interstate Pipeline
77	4	Downstream of Glendive	Parallel	12	Natural Gas	West Mon-Dak Subsystem	Williston Basin Interstate Pipeline
RICHLAND COUNTY							
32	3C	Sidney	Crossing	4.5	LPG	Williston Basin/River View	Bear Paw Energy LLC
31	3B	Sidney	Crossing	8	Natural Gas	Cabin Creek Willistion System West Mon-Dak Subsystem	Williston Basin Interstate Pipeline
31	3A	Sidney	Crossing	8	LPG, Natural Gas, Product	River View, West Mon-Dak Subsystem, Glendive to Minot 8in	CENEX Pipeline LLC
27	2	Downstream of Sidney	Crossing	8.62	Crude Oil	8" Putnam to Sidney	Tesoro - High Plains Pipeline Co
McKENZIE COUNTY, ND							
9	1	Fairview	Crossing	12	Natural Gas	West Mon-Dak Subsystem	Williston Basin Interstate Pipeline

Table 2. Geomorphic reach types, and selected parameters at each pipeline site.

County	*Reach*	*Site Numbers*	*Classification*	*Comments*	*Percent Change in Bankfull Braiding Parameter (1950-2001)*	*Percent Diked/ Leveed*	*Percent Erosion Control*
McKenzie	D15	1	PCM/I: Partially confined meandering/islands		34.70%	0.00%	0%
Richland	D14	2	PCM/I: Partially confined meandering/islands	Into McKenzie County, North Dakota: High sinuosity	36.20%	0.00%	2%
	D13	3	PCM/I: Partially confined meandering/islands		-12.20%	0.00%	13%
Dawson	D8	4	PCA: Partially confined	To Intake	14.20%	0.94%	4%
	D5	5-7	PCA: Partially confined anabranching	Long secondary channels; to *Glendive*	1.90%	5.90%	4%
Prairie	D3	8	PCS: Partially confined straight	Hugs right bank wall; into Dawson County	11.40%	0.00%	1%
Yellowstone	B2	9-10	PCB: Partially confined braided	*Billings*; WAI Reach E	-8.80%	22.28%	34%
	B1	11-15	UB: Unconfined braided	Extensive armoring *u/s Billings*; WAI Reaches B,C,D	-18.90%	30.18%	34%
	A18	16	UA: Unconfined anabranching	To Clark Fork; land use change to row crops; WAI Reach A	12.80%	0.00%	38%
Stillwater	A16	17	PCA: Partially confined anabranching	*Park City*: Major shift in land use, and increase in valley bottom width	-6.70%	0.00%	6%
	A13	18	PCA: Partially confined anabranching	*Columbus*; extensive armoring, broad islands	4.70%	0.00%	25%
Sweet Grass	A9	19	UA: Unconfined anabranching	To *Reed Pt*; extensive secondary channels in corridor	0.10%	0.00%	8%
	A4	20	UB: Unconfined braided	To *Boulder River* confluence; encroachment at Big Timber; extensive armor	-25.60%	5.83%	24%
Park	PC16	21	PCA: Partially confined anabranching	To just upstream of *Hwy 89 bridge*	-14.90%	----	----

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3.1 McKenzie County, North Dakota (Site 1)

One pipeline crossing was identified just east of Fairview in McKenzie County, North Dakota. The crossing follows the "Fairview Bridge and Cartwright Tunnel Trail", which is an old railroad trestle just south of Highway 200 that has been converted to a pedestrian/bike bridge (Figure 8). The pipeline is owned by Williston Basin Interstate Pipeline, and is a 12-inch natural gas line.

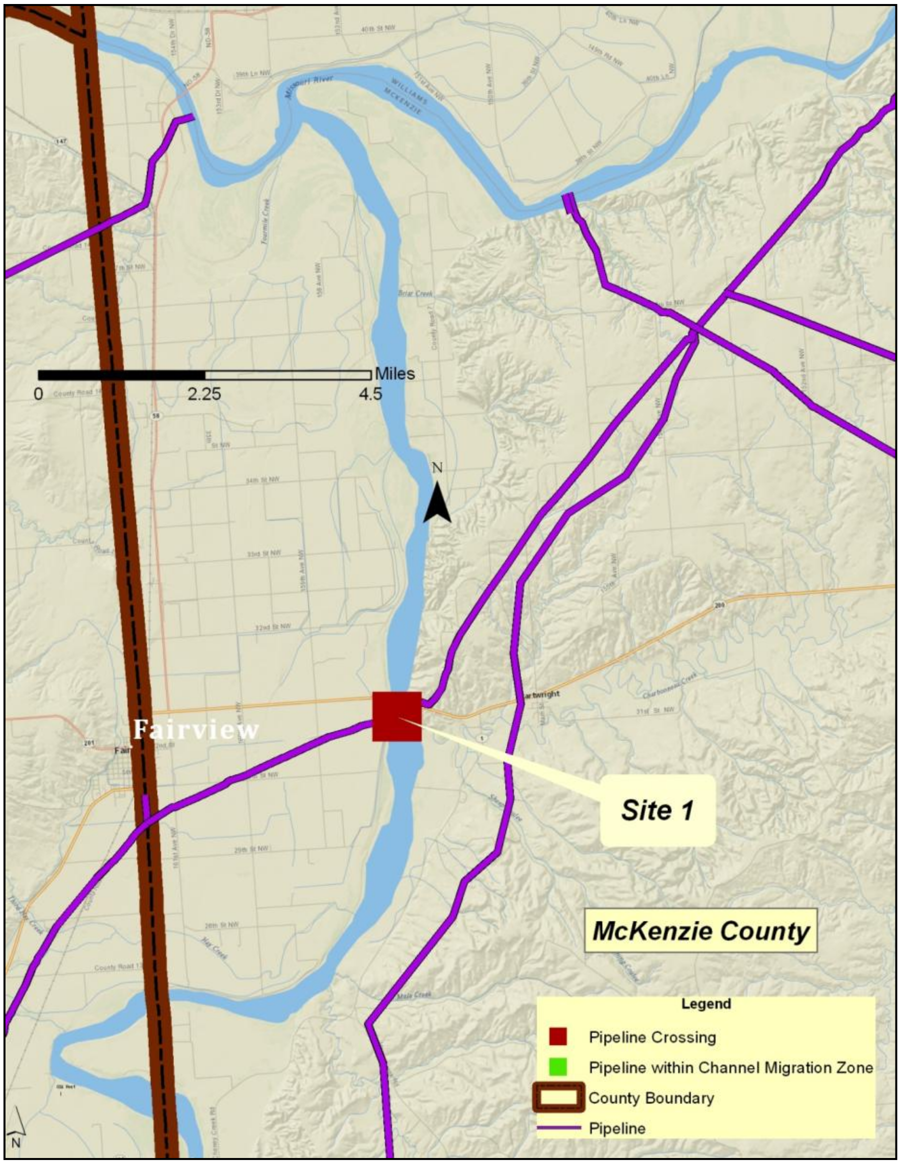

Figure 8. McKenzie County Pipeline Site.

This crossing is in Reach D15, which is a Partially Confined Meandering (PCM) reach type, indicating that the reach consists primarily of a single-thread meandering channel with some valley wall influences that locally confine the channel. There is less than 1 percent erosion control in this reach. The mean migration distance calculated in this reach since 1950 is 226 feet, which is quite low for the lower Yellowstone River, indicating low rates of channel migration. No discernible (on aerial photography) bank movement has occurred at the crossing since 1950, although just upstream, the bank has migrated over 500 feet to the east since 1950 (Figure 9). The right bank is an erosion-resistant bedrock bluff.

There is no evidence to suggest that there is a high risk of pipeline exposure at this site, although the river corridor is narrowed though the bridge, and the bedrock valley wall could drive some relatively deep local scour. There are three piers supporting the bridge that could also cause some local scour. If the potential for deep scour is identified at the site, floodplain reclamation on the left (west) bank could potentially reduce in-stream energy during high flow events. Currently, the left bank is a public park (Sundheim Park).

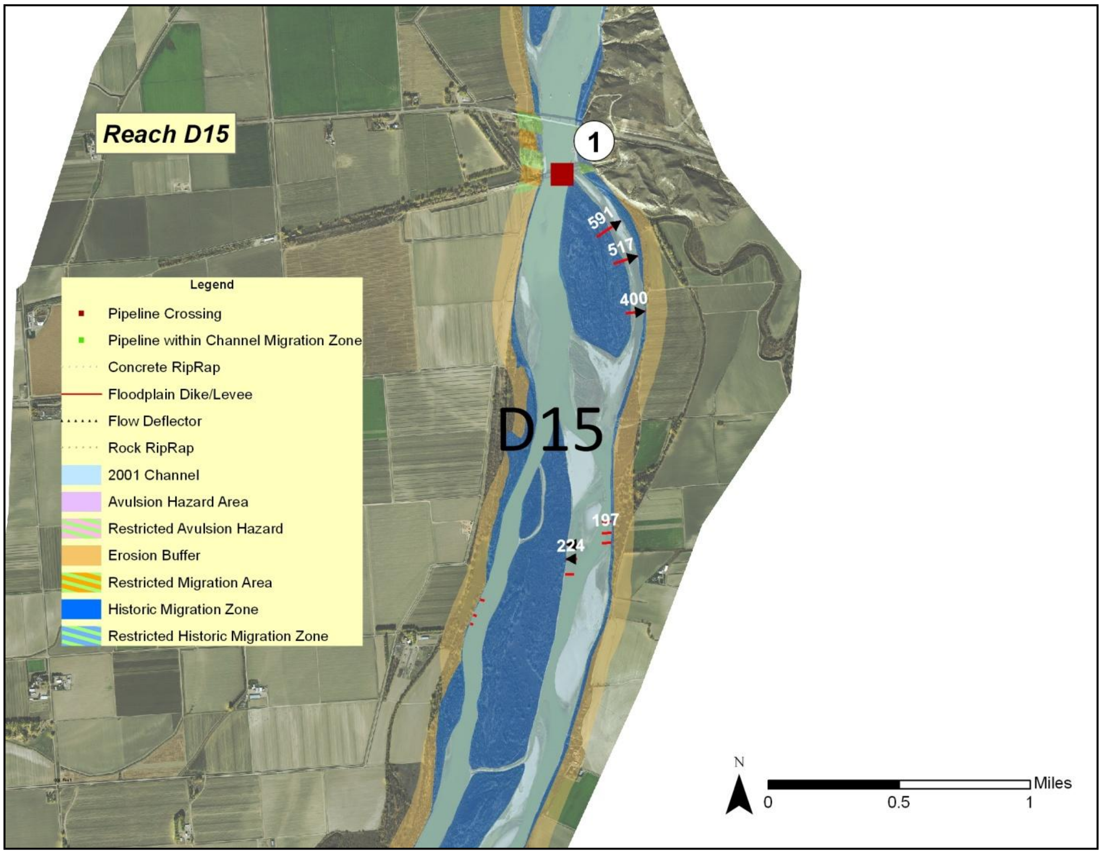

Figure 9. Reach D15 showing mapped physical features and Channel Migration Zone; red arrows show 1950-2001 bank migration labeled in feet.

Site 1 Risk Potential: ***__Low__***, due to corridor narrowing at bridge and local scour potential against the bedrock bluff on east side of channel.

Site 1 Floodplain Restoration Potential: ***__Low,__*** with a very small isolated floodplain area in Sondheim Park area.

3.2 Richland County, Montana (Sites 2 and 3)

There are four pipeline crossings in Richland County near Sidney, which are described herein as two sites:

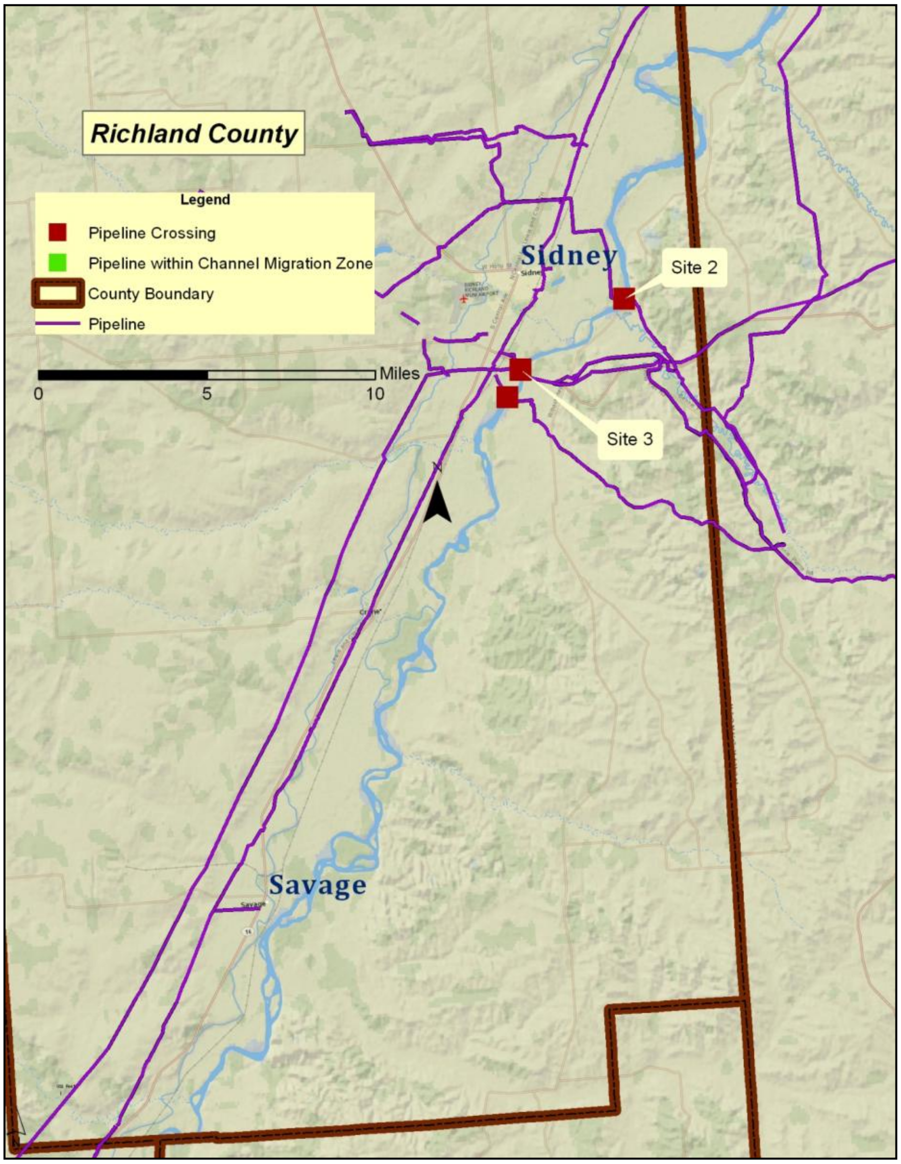

Figure 10. Richland County Pipeline Sites.

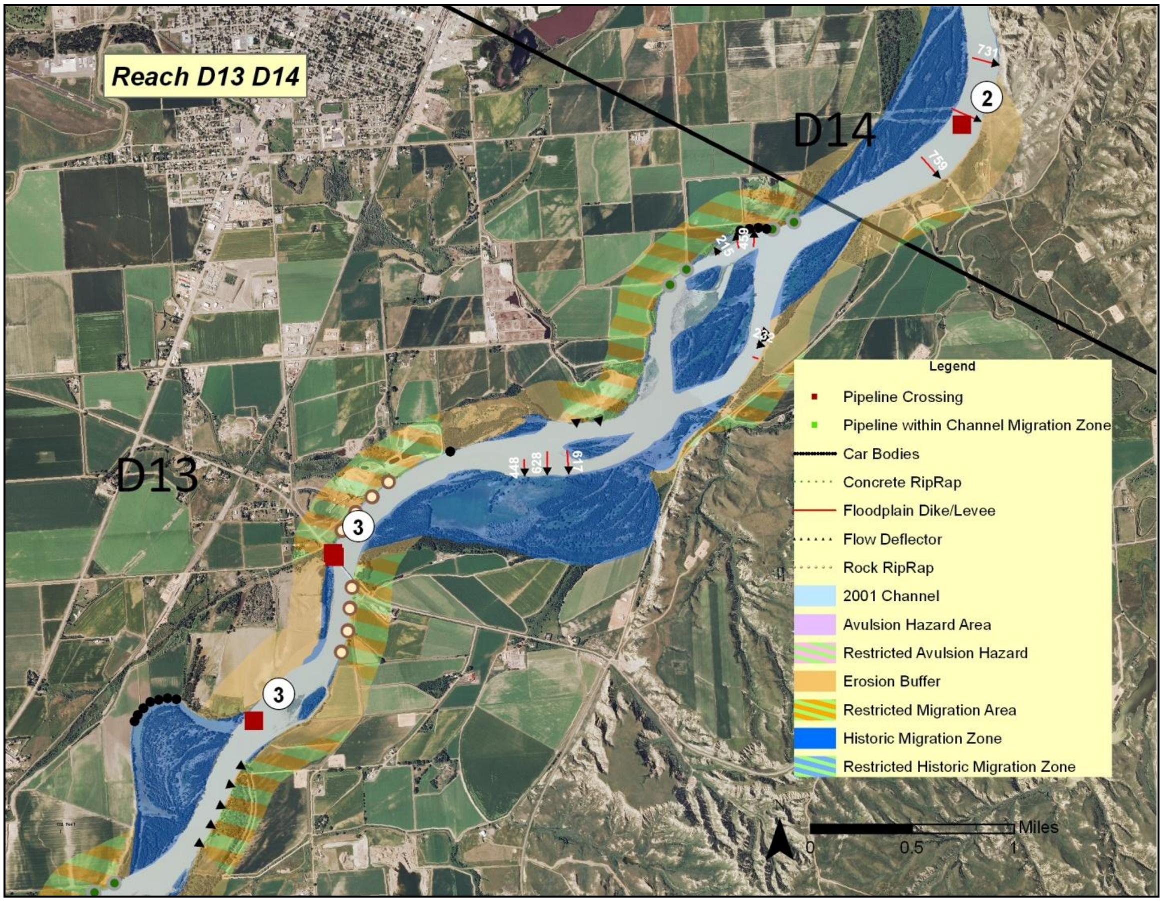

Figure 11. Reach D13 and D14 showing mapped physical features and Channel Migration Zone; red arrows show 1950-2001 bank migration labeled in feet.

3.2.1 Site 2: RM 27

Site 2 is located at RM 27 on a broad easterly-sweeping river bend that has shown over 600 feet of lateral migration since 1950, which is an average rate of 17 feet per year (Figure 11). The pipeline crossing is an 8.62-inch diameter crude oil line owned by Tesoro-High Plains Pipeline Company. The migration appears to have encountered a terrace which is likely more erosion resistant. This site is located in Reach D14, in which approximately 2% of the bankline is armored. A total of 29 ice jams are recorded in the COE ice jam database for this reach.

There is no armoring on the right (east) outer bank at Site 2, and the inside bank has been accreting (growing eastward) since 1950.

Site 2 Risk Potential: ***High*** due to active right bank migration since 1950 and ice jamming potential.

Site 2 Floodplain Restoration Potential: ***Low*** due to the size of river in this area, and lack of floodplain isolation.

3.2.2 Site 3: RM 32

There are three pipeline crossings at Sidney, Montana. The upper crossing (Site 3a) is a 4.5-inch LPG line owned by Bear Paw Energy. Just downstream, two crossings at the bridge (Site 3b) are owned by Cenex

(8-inch product), and Williston Basin Interstate Pipeline (8-inch natural gas). The most striking change at Site 3 is severe left bank erosion that occurred primarily in 2011. Since 2001, the bank has migrated approximately 450 feet, or an average of 45 feet per year. This migrating bankline is between crossings 3A and 3B; no migration is measureable at the crossings themselves.

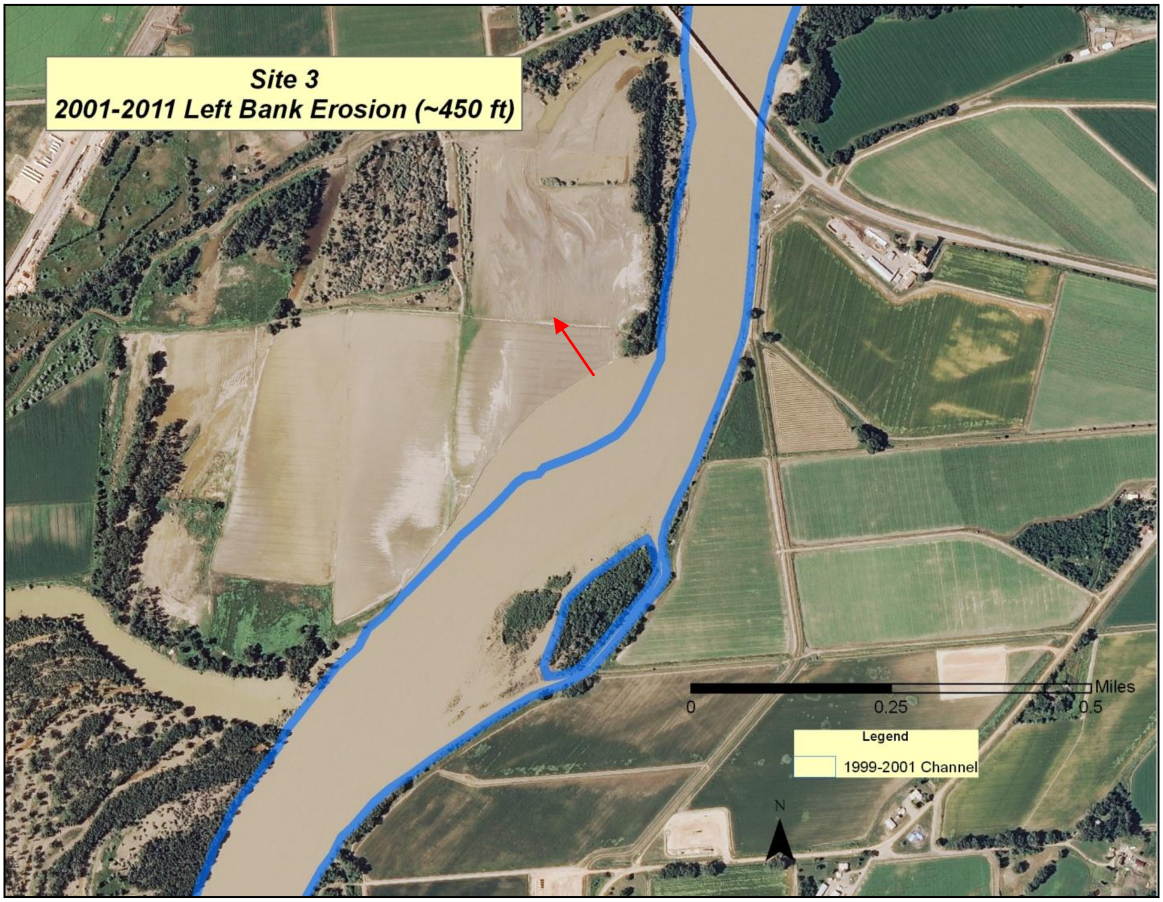

Figure 12. Left bank erosion from 2001-2011 of approximately 450 feet approximately 1000 downstream of Site 3 LPG line crossing.

Site 3 Risk Potential: ***Moderate*** due to rapid left bank migration in between the crossings since 2001.

Site 3 Floodplain Restoration Potential: ***Low*** due to lack of floodplain isolation.

3.3 Dawson County (Sites 4-7)

Four sites have been identified in Dawson County. Two of the sites are pipeline crossings, and two are areas where pipelines encroach into the Yellowstone River Channel Migration Zone.

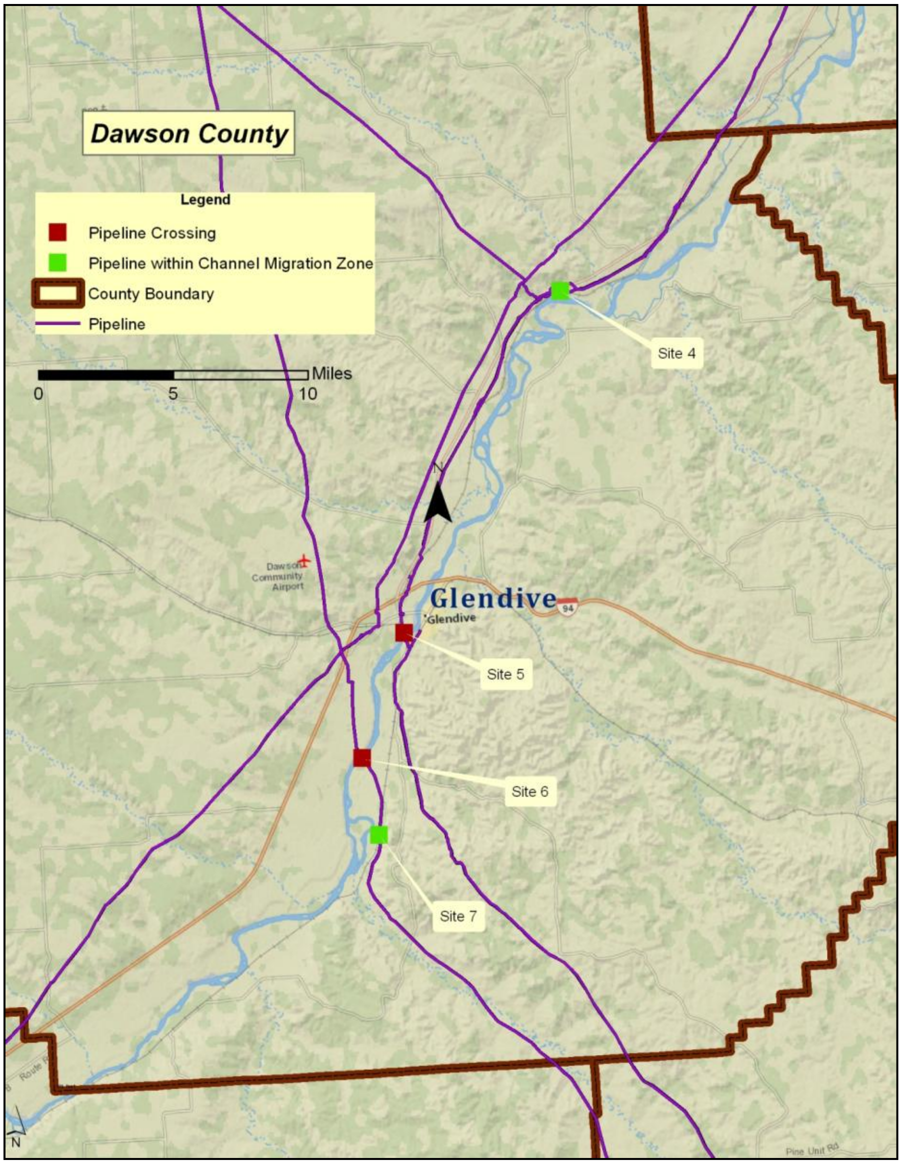

Figure 13. Dawson County Pipeline Sites.

3.3.1 Site Number 4

Site 4 is located at RM 77 downstream of Glendive, where a 12-inch natural gas pipeline owned by Williston Basin Interstate Pipeline closely follows a cut bank that is armored and is located within the valley margin (Figure 14). The pipeline appears to be landward of the railroad. The site is in Reach D8, which is a Partially Confined Anabranching (PCA) reach type, indicating extensive split flow with some valley wall control. Just under 1% of the total bank length is diked, and approximately 4% of the bankline is armored in this reach.

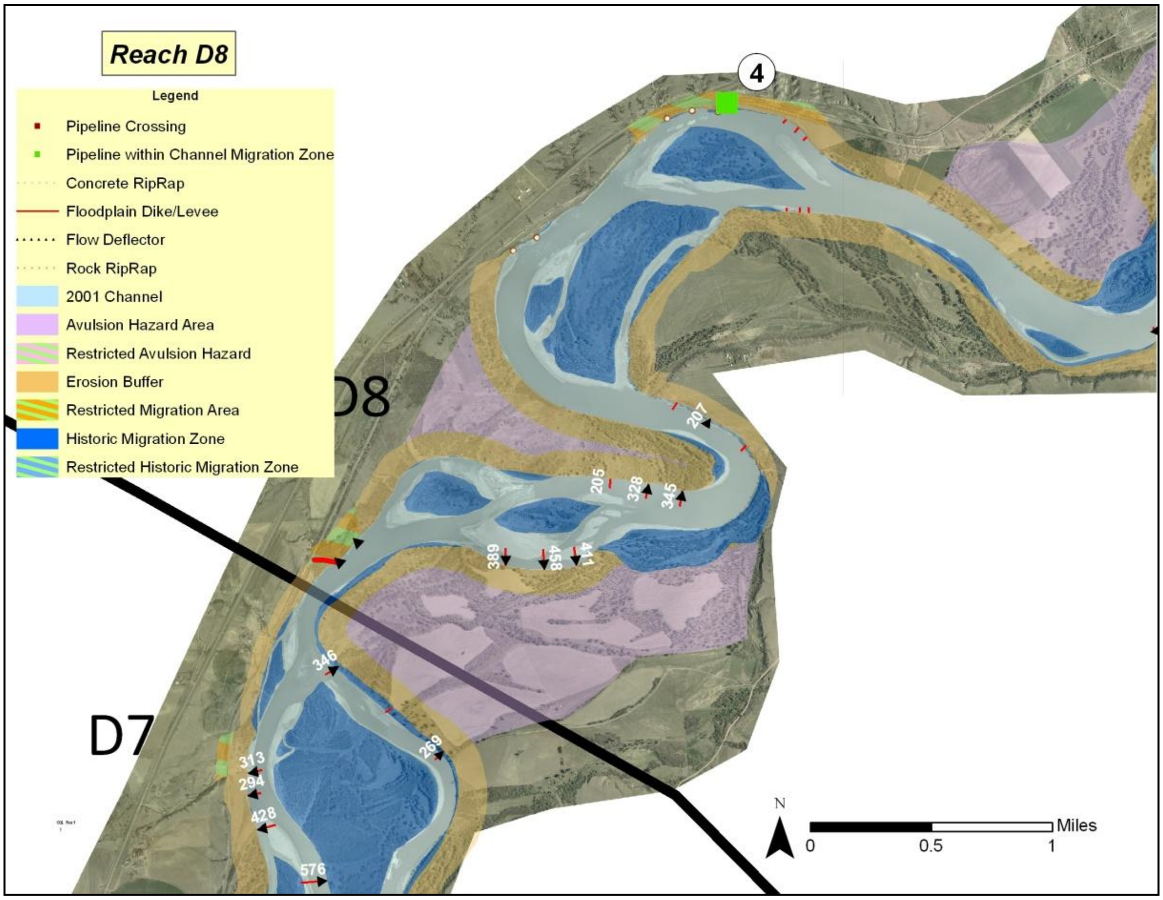

Figure 14. Map of a portion of Reach D8 showing wide CMZ and pipeline encroachment site (Site 4) on armored left bank.

Site 4 Risk Potential: ***Low*** due to armored margin, and location of pipeline landward of railroad.

Site 4 Floodplain Restoration Potential: ***Low*** due to lack of floodplain isolation.

3.3.2 Site Number 5

Site 5 is located at the lowermost end of Reach D6 near Glendive at Black Bridge (RM 94), and consists of a 16-inch natural gas pipeline owned by Williston Basin Interstate Pipeline. The river crossing at Black Bridge has had erosion problems for many years. Just upstream of Black Bridge, the river has migrated over 1000 feet to the east, towards the right bank of the trestle embankment (Figure 14). This location has consistently been a challenging maintenance spot for BNSF railroad and the town of Glendive, Montana. The channel is constricted, and the trestle is skewed to the active channel. In 2011, there was approximately 200 feet of retreat on the right bank, just downstream of the bridge where the pipeline is mapped (Figure 15).

If this pipeline is shallow on the right bank of the river at Black Bridge, it has a high risk of exposure due to the rapid right bank retreat at Black Bridge. As the actual configuration of the pipeline is unknown, however, it is impossible to assess the true likelihood of exposure as a consequence of recent bank movement. Floodplain restoration potential at this site is considered low due to the urbanization of the reach just below in Glendive, and lateral constraints created by the bridge crossing itself.

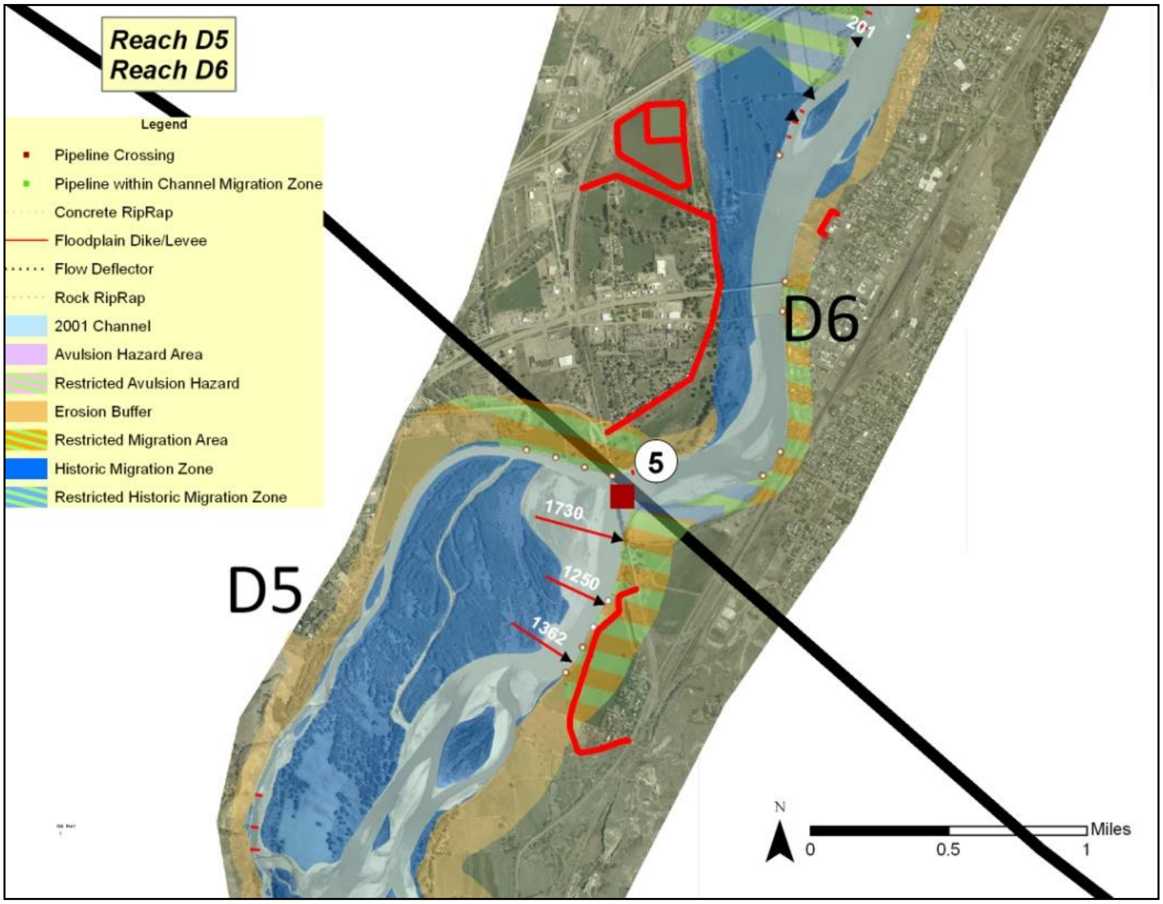

Figure 15. Map of a portion of Reach D5 and D6 showing mapped physical features and Channel Migration Zone; red arrows show 1950-2001 bank migration labeled in feet.

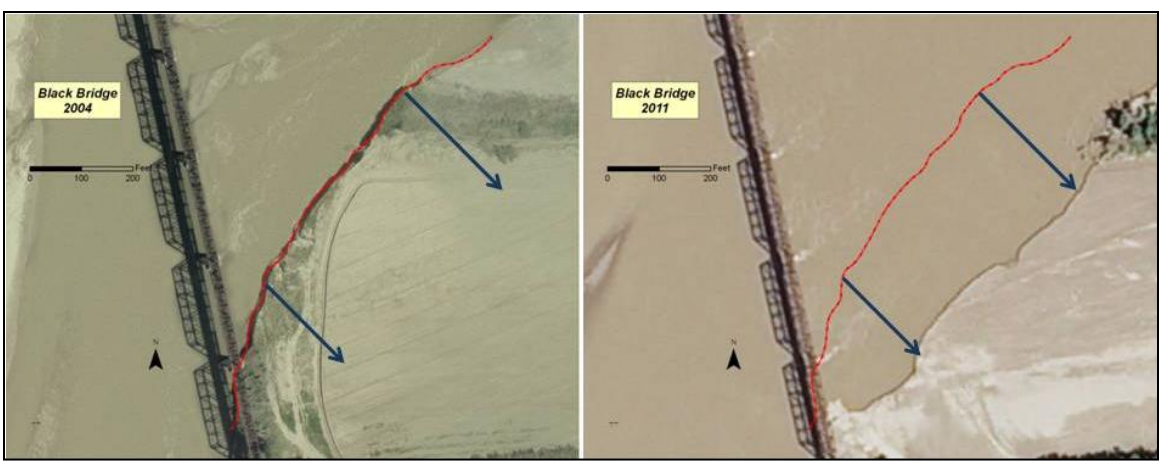

Figure 16. Black Bridge near Glendive, showing 2004 bankline (left) and 2011 bankline (right). Note over 200 feet of bank erosion from 2004-2011 in vicinity of pipeline crossing.

Site 5 Risk Potential: ***High*** due to right bank migration and scour potential at bridge.

Site 5 Floodplain Restoration Potential: ***Low*** due to constraints at bridge crossing and urbanized reach.

3.3.3 Site Number 6

Site 6 consists of a 10-inch pipeline that is owned by Bridge Pipeline and carries crude oil. The pipeline crosses the river on the downstream end of a series of islands in a relatively stable reach. The site is in Reach D5, which is a PCA reach type with ~6% of the bankline diked and 4% of the banks armored. There is some armor on the left bank in the vicinity of the pipeline. The site is immediately downstream of a series of islands that have shown some change in location and size since 1950.

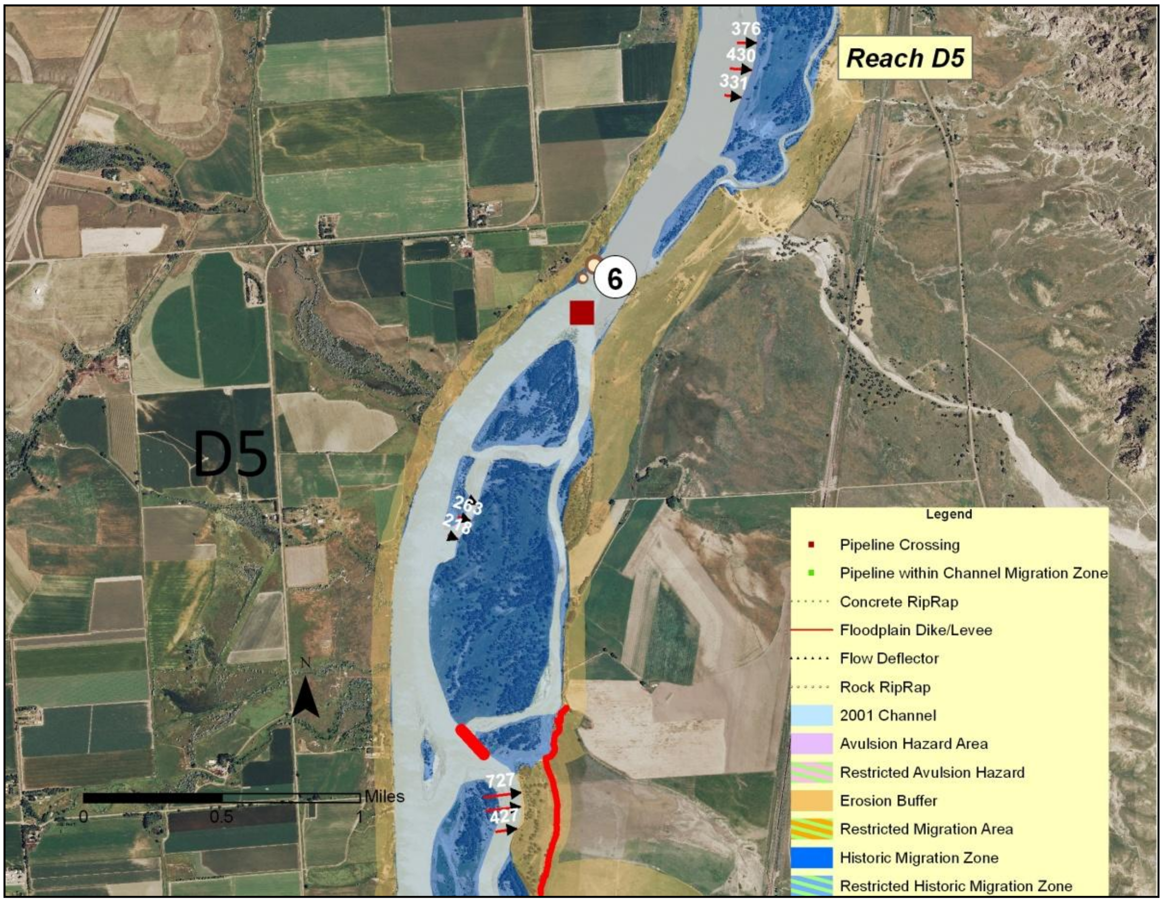

Figure 17. Map of a portion of Reach D5 showing Site 6, mapped physical features and Channel Migration Zone; red arrows show 1950-2001 bank migration labeled in feet.

Site 6 Risk Potential: ***Moderate*** due to erodible banklines in areas of changeable planform due to island formation.

Site 6 Floodplain Restoration Potential: ***Low*** due to lack of floodplain isolation.

3.3.4 Site Number 7

Site number 7 is a 10-inch crude oil pipeline that is owned by Bridger Pipeline and encroaches into the Yellowstone River Channel Migration Zone. The pipeline does not cross the river at this location, but follows the eastern edge of the Historic Migration Zone (dark blue in Figure 18). The side channel at the site is currently blocked by a dike at its upper end; this dike was built sometime prior to 1976. This site is in Reach D5, which is characterized by numerous islands and long secondary channels. Some migration has occurred both upstream and downstream of the site since 1950.

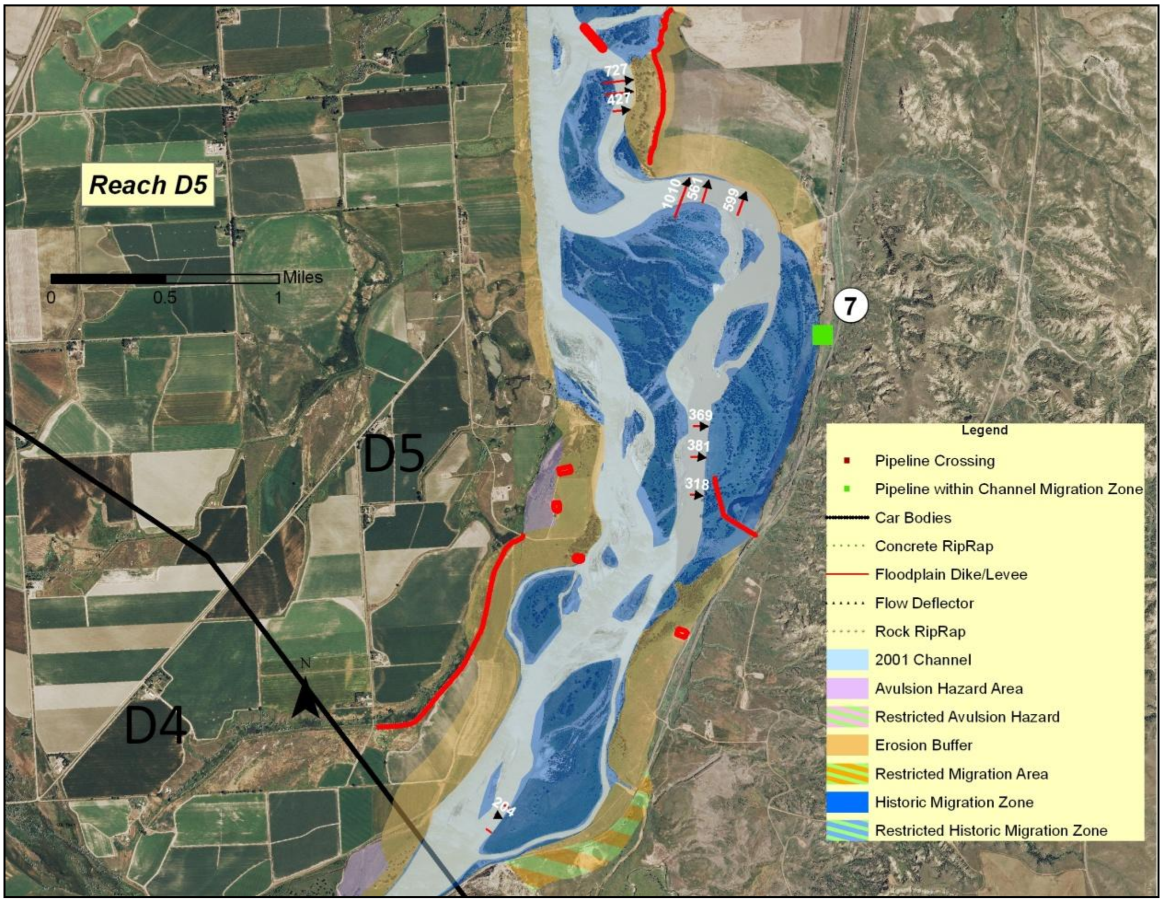

Figure 18. Reach D5 showing Site 7, mapped physical features and Channel Migration Zone; red arrows show 1950-2001 bank migration labeled in feet.

Site 7 Risk Potential: ***<u>Low</u>*** due to location on isolated historic channel.

Site 7 Floodplain Restoration Potential: ***<u>Low</u>*** due to lack of floodplain isolation and the fact that the pipeline is not a crossing but an encroachment into the CMZ.

3.4 Prairie County (Site 8)

There is one pipeline crossing site in Prairie County (two pipelines), and it located several hundred feet downstream of the Interstate 94 bridge crossing (Figure 19).

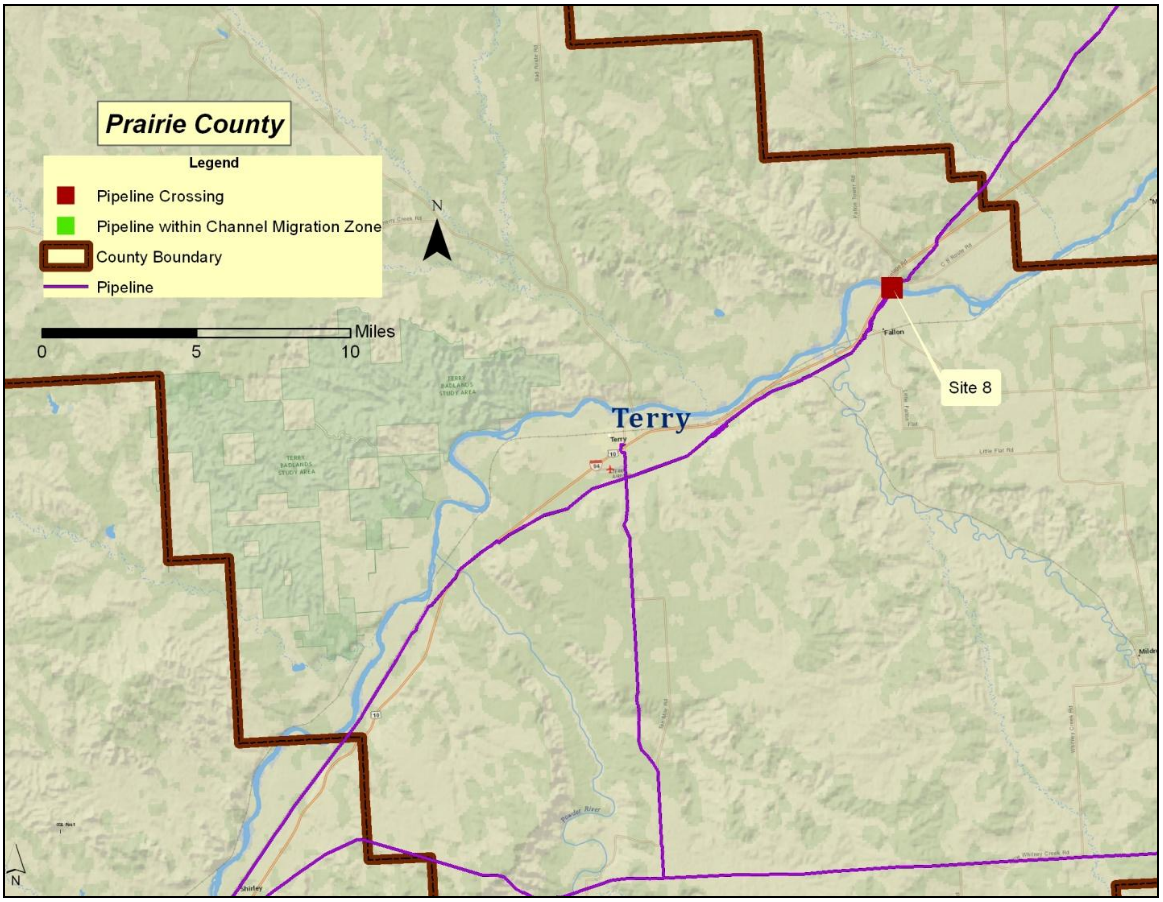

Figure 19. Prairie County Pipeline Sites.

3.4.1 Site Number 8

Two pipelines cross at Site 8: one is an 8-inch abandoned line, and the other is a 10-inch line owned by Cenex that carries product. The crossing is at RM 126 in Reach D3, which is a PCS reach type, indicating little in the way of lateral channel movement and some valley wall bedrock influence. The bridge is armored on both abutments (Figure 20). No migration has been measured at the site. The bridges do have piers that could cause some scour, although the crossings are hundreds of feet downstream of the bridges.

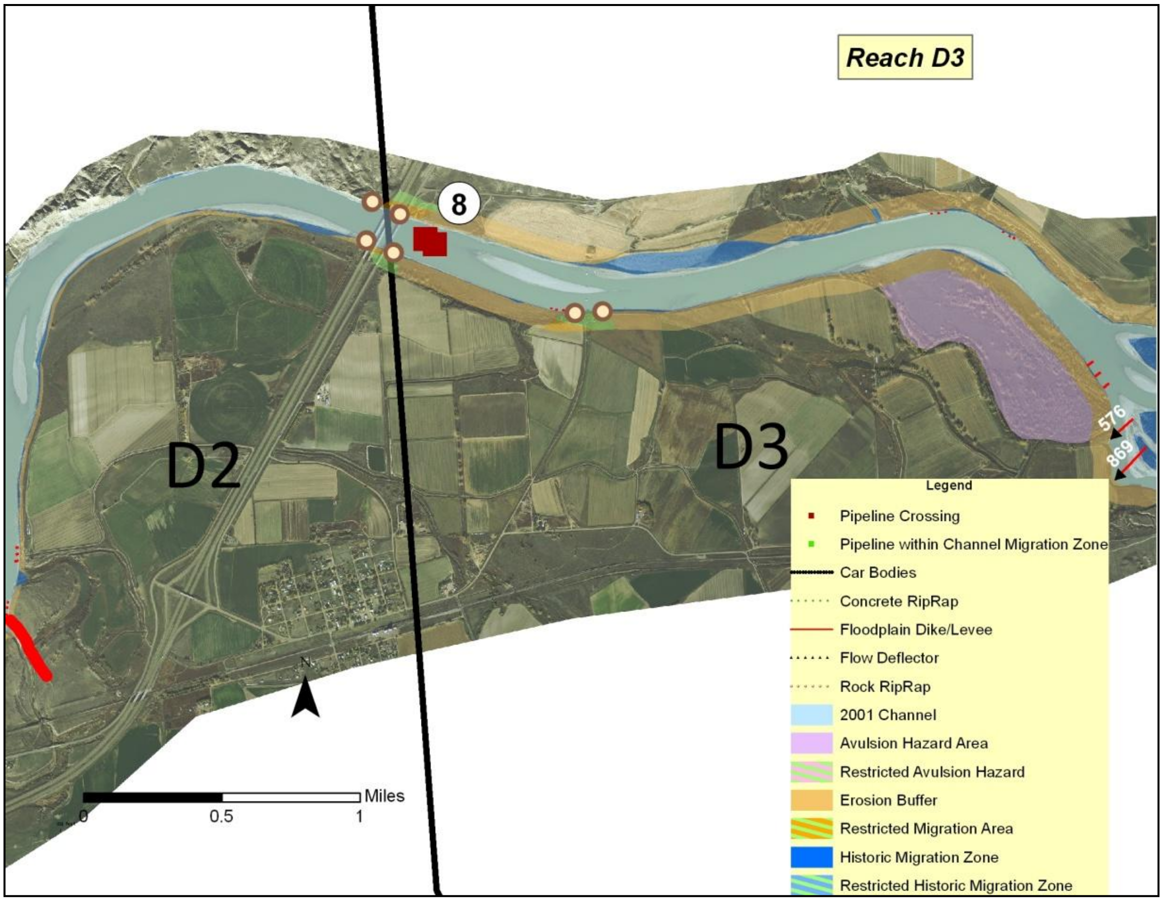

Figure 20. Reach D5 showing Site 8, mapped physical features and Channel Migration Zone; red arrows show 1950-2001 bank migration labeled in feet.

Site 8 Risk Potential: ***<u>Low</u>*** due to overall site stability; however, pier scour at the bridge could potentially affect the crossing site.

Site 8 Floodplain Restoration Potential: ***<u>Low</u>*** due to lack of floodplain isolation.

3.5 Yellowstone County (Sites 9 through 16)

There are a total of eight sites in Yellowstone County (Figure 21). These sites encompass 17 total pipeline crossings and six sites where a pipeline encroaches into the Yellowstone River CMZ (Figure 21).

Sites 9 and 10 are located in Reach B2, which is a PCB (partially confined branching) reach type. Approximately 22% of the total (high flow) bankline is stabilized in this reach, including almost 16,000 feet of concrete riprap, and 3,750 feet of rock riprap. Between 1950 and 2001, the braiding parameter in Reach B2 decreased by 8.8%.

Cross section shape is a function of locations relative to braiding islands. Channel changes over time are primarily in width but not thalweg location indicating overall vertical stability in this reach.

Sites 11 through 16 are in Reach B1, which is an UB reach type that has been heavily impacted by diking and armor. Approximately 25% of the bankline is armored or diked in this reach. The majority of this armor is concrete riprap (31,500 ft or 9% of the bank length), and rock riprap (22,000 ft or 7% of the bank length). There are approximately 19,000 feet of dikes and levees in the reach, which is equivalent to 5% of the total (high flow) bank length. Since 1950, the braiding parameter in the reach has been reduced by approximately 19%.

The WAI report identified three locations of bedrock control between Laurel Bridge and Duck Creek Bridge in Reach B1, which provides a limit to potential downcutting in this reach. A comparison of bed profiles from 1969-1999 shows downcutting is localized at South Billings Blvd Bridge. This downcutting may be due to combined influences of local bridge scour and channel simplification upstream at RM 372.

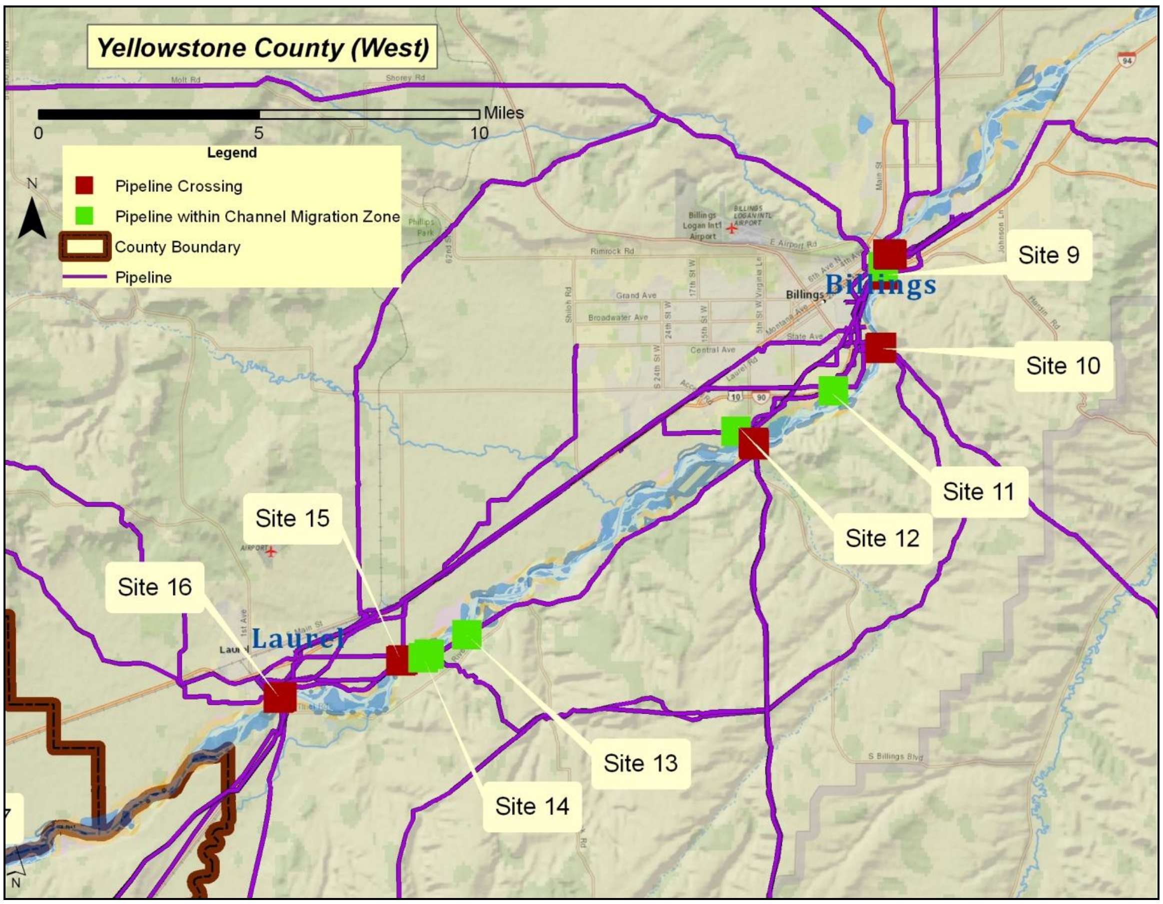

Figure 21. Yellowstone County Pipeline Sites.

3.5.1 Site Number 9

Site 9 is located in the vicinity of the I-90 Bridge in Billings (RM 365) and consists of 5 crossings at the bridge, a CMZ encroachment site approximately 1500 feet upstream of the bridge, and another crossing approximately 2400 feet upstream of the bridge. The crossings are individually referred to as follows:

- Site 9A: an 8-inch product pipeline owned by Cenex (I-90 Bridge)
- Site 9B: a 12.75-inch crude oil pipeline owned by Exxon Mobil (I-90 Bridge)
- Site 9C: an 8-inch product pipeline owned by ConocoPhillips (I-90 Bridge)

- Site 9D: an 8-inch product pipeline owned by ConocoPhillips (I-90 Bridge)
- Site 9E: an 8-inch natural gas pipeline owned by Montana-Dakota Utilities (I-90 Bridge)
- Site 9F: an 8-inch product pipeline owned by Cenex (parallel to river ~1500ft upstream of I-90 Bridge)
- Site 9G: a 10-inch crude oil pipeline owned by ConocoPhillips (crossing ~2400 ft upstream of I-90 Bridge)

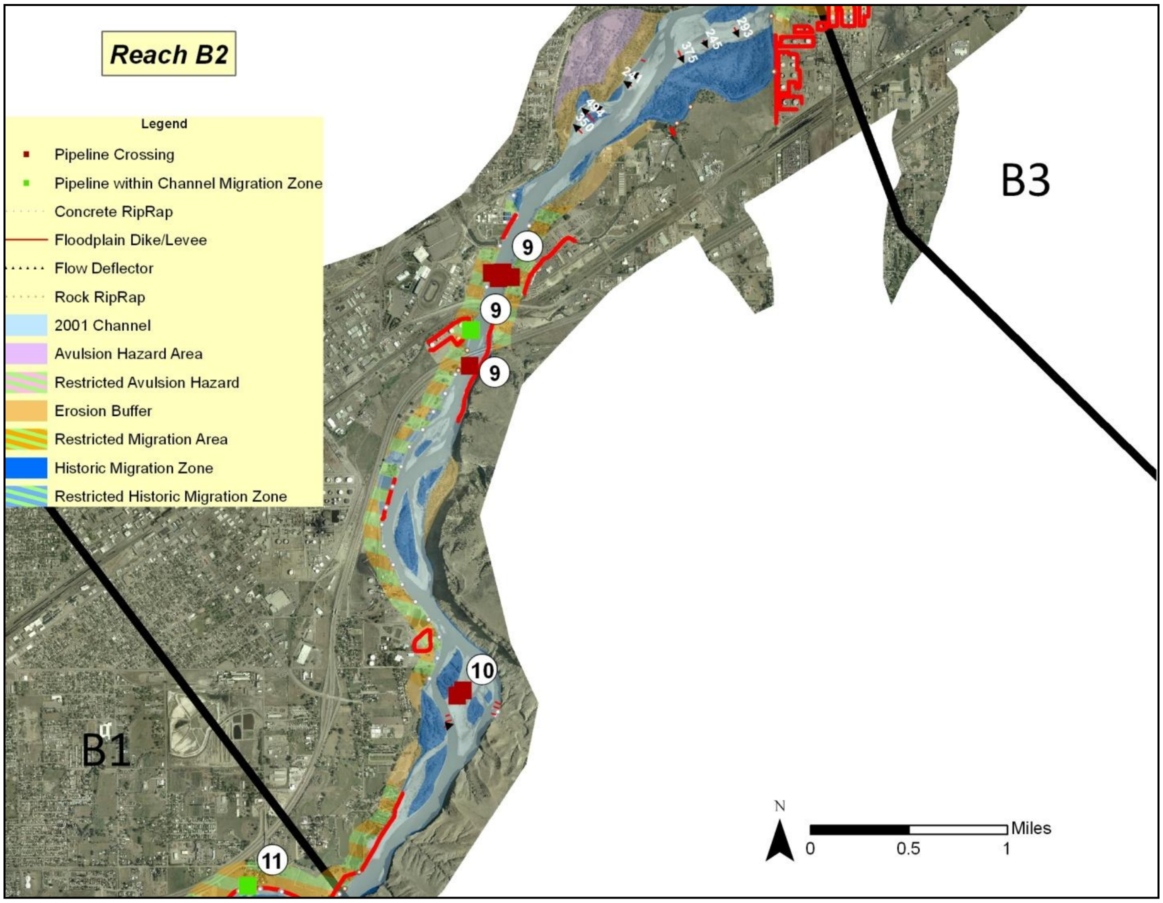

Figure 22. Map of Reach B2 showing Sites 9 and 10 with CMZ and physical features.

At Site 9, the river is confined to a straight section with several bridges, including I-90, a BNSF railroad bridge, and 1st Avenue North. Bank armor is extensive, consisting mostly of concrete riprap. Dikes include containment berms around tank farms associated with the Conoco Phillips refinery. Cross section data provide no evidence of downcutting. Dipping Eagle Sandstone crosses under the river near the bridge and likely provides bedrock control.

Site 9 Risk Potential: ***<u>Low</u>*** due to extensive armoring and bedrock grade controls.

Site 9 Floodplain Restoration Potential: ***<u>Low</u>*** due to urbanization and industrial development.

Scour analysis was conducted for the Interstate 90 highway bridges and the railroad bridge in the vicinity of Site 9 to assess potential scour depths as described in Section 2. Results are presented in Figures 25 and 26. Symbology in the two figures includes:

- Black blocked out area on the left side of the river is an "obstruction." This model feature defines an area as permanently blocked out and decreases flow area. This area is also blocked out in the cross sections upstream and downstream of the bridge.
- Grey blocked out area defines the roadway embankment and bridge. This area is considered "ineffective area" in the cross sections upstream and downstream of the bridge. Ineffective area can fill with water but it does not conduct water through the cross section. This is a good indicator of how well the bridge spans the floodplain.
- The white area below the grey area is the bridge opening.
- Solid vertical lines below the bridge represent piers.
- Horizontal blue line represents the 100-year water surface.
- The dashed lines below the channel bed represent computed scour depths. Scour depths shown graphically are the sum of contraction scour, pier scour and abutment scour.

<u>Railroad Bridge</u>

Examination of Figure 25 indicates that the railroad bridge at Site 9 reduces the 100-year floodplain by approximately 1800 feet on the left bank forcing this water to accelerate under the bridge and around the left abutment. This abutment has the greatest scour potential. It should be noted that scour is greatest adjacent to and immediately downstream of piers and abutments. The computed scour depths reduce with distance downstream of the bridge as the floodplain opens and flow velocities are reduced.

Railroad Bridge Scour Analysis (RM 365): Contraction = 0 feet, Pier = 25 feet, Abutment = 41 feet

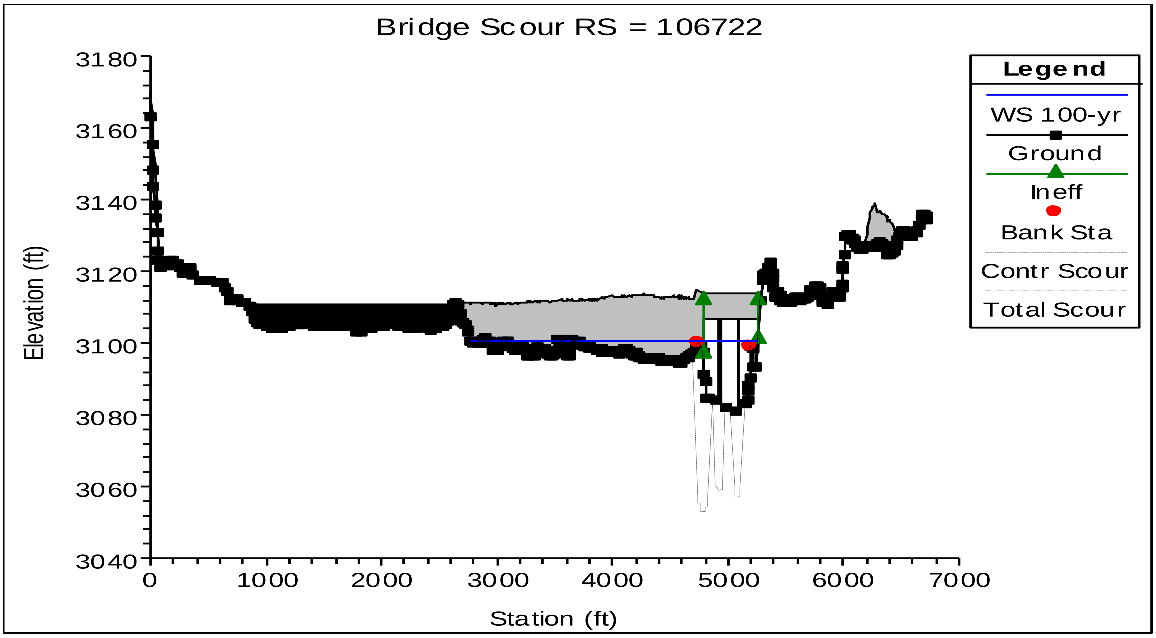

Figure 23. Site 9, RM 365 Bridge Scour Schematic Railroad Bridge (downstream bridge).

Interstate 90 Bridges

Figure 26 presents a schematic of computed scour for the Interstate 90 bridges. Levees upstream of the bridges reduce the rapid contraction of flows. Therefore, computed abutment scour is significantly less than that found for the downstream railroad bridge shown in **Figure 25**.

Interstate 90 Bridge Scour Analysis (RM 365): Contraction = 0 feet, Pier = 19 feet, Abutment = 8.9 feet

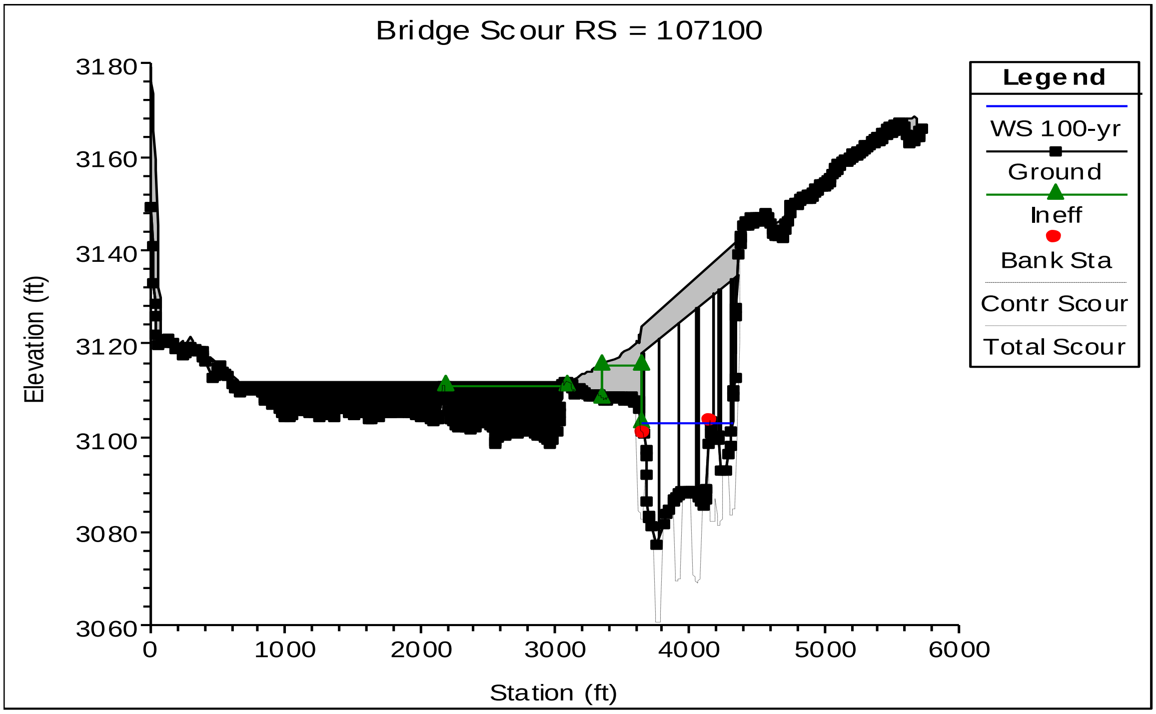

Figure 24. Site 9, RM 365 Bridge Scour Schematic, Interstate 90 bridges (upstream bridge).

3.5.2 Site Number 10

Site 10 consists of two pipeline crossings at RM 367 (Figure 22) including a 12-inch crude oil pipeline owned by Beartooth Pipeline (10a) and an 8-inch Product pipeline owned by ConocoPhillips (10b).

Cross sections collected in the vicinity of RM 368 show no significant change in bed elevation since 1968. The left bank is armored with concrete, and the Physical Features Timeline (PFT) developed by the CEA indicates that it has been armored since 1950. This armor protects a PPL Montana coal fire plant and Billings Public Utilities Department infrastructure.

Since 1950, the right bank has migrated ~180 feet into the mouth of Birch Creek, where the pipelines cross the right bank of the river. The erosion was into deposits at the mouth of Birch Creek. This bank has been armored with concrete since 1950. The upstream end of this armor appears to be flanking and should be carefully monitored (Figure 27).

Figure 25. Mouth of Birch Creek at Site 10 (RM 367) showing flanking on upstream end of riprap.

Site 10 Risk Potential: ***Moderate*** due to actively flanking armor on right bank at the mouth of Birch Creek.

Site 10 Floodplain Restoration Potential: ***Low*** due to urbanization and industrial development.

3.5.3 Site Number 11

Site 11 is located at RM 368 near Billings and consists of a 12-inch natural gas pipeline owned by Williston Basin Interstate Pipeline (Figure 26). The pipeline does not cross the river, but encroaches into the mapped edge of the Channel Migration Zone. In 1950, a primary thread of the Yellowstone River was flowing against this bank; since then, the bank has been armored with flow deflectors, concrete, and a floodplain dike. Just downstream of the site, the river corridor narrows significantly and that narrowing is controlled by bank armor on both banks.

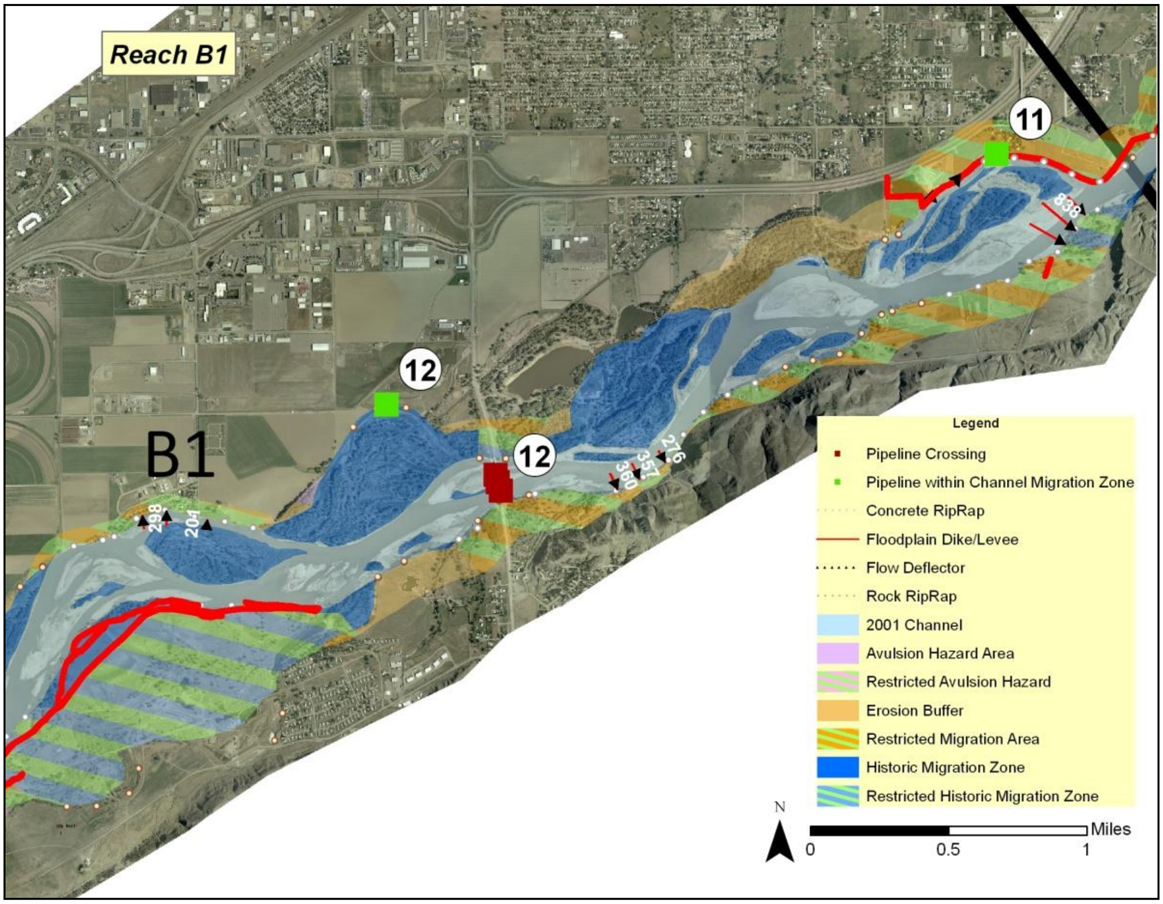

Figure 26. Downstream portion of Reach B1 showing Sites 11 - 12, CMZ, and physical features.

Site 11 Risk Potential: ***__Low__*** due to pipeline location behind an armored bankline

Site 11 Floodplain Restoration Potential: ***__Low__*** because the pipeline is in the floodplain such that reducing energy in the channel and increasing it in the floodplain will increase rather than reduce exposure risk.

3.5.4 Site Number 12

Site 12 consists of three pipeline crossings at South Billings Blvd (RM 371), and a CMZ encroachment site just upstream. The sites are referred to individually as follows:

- Site 12A: An 6-inch natural gas pipeline owned by Northwestern Energy (S. Billings Blvd Bridge)
- Site 12B: An 8-inch natural gas pipeline owned by Northwestern Energy (S. Billings Blvd Bridge)
- Site 12C: A 8-inch natural crude oil pipeline owned by ConocoPhillips (S. Billings Blvd Bridge)
- Site 12D: A 12-inch natural gas pipeline owned by Williston Basin Interstate Pipeline (CMZ encroachment on left edge of corridor upstream of bridge)

The layout of the pipelines at the bridge suggests that the lines may run along the bridge deck rather than beneath the river. The discussion here describes risk associated only with buried lines.

Both the left and right abutments are armored at the bridge, which constricts the river corridor, creating some degradation potential. WAI data show local downcutting at this site, which may be due to a combination of local scour and a systemic response to extensive diking upstream. Upstream of South Billings Blvd Bridge, an approximately 11,000 foot long dike was built on the right bank sometime between 1968 (COE flood survey) and 1976 (air photos). This dike is shown as the red line in the left-hand portion of Figure 26. COE cross sections from 1968 show two main channel threads; by 1976 the south channel had been blocked off.

However, construction of the dikes upstream occurred prior to 1976 and as such, the river's response to this impact is probably largely complete. It is unclear as to whether the diking has caused channel bed degradation downstream at South Billings Blvd. It is clear, however, that a high potential for bed scour at the site is created by corridor and channel narrowing at the bridge itself.

A mid-channel bar has developed under the bridge since 1950. This bar expansion may result in increased left bank erosion above the bridge in the future. However, the pipelines do not cross in this area.

Site 12D is located approximately 2200 feet upstream of the bridge on a high flow channel that is north of the main river. This channel was a primary thread in the 1950s, but that channel has since been largely abandoned. The bank is armored at this location by riprap that has been in place since at least 1950.

Scour analysis was conducted for the South Boulevard bridge with results presented as a schematic in Figure 27. Symbology explanation for the figure is the same as presented for Site 9. Figure 27 reinforces the discussion above concerning confinement of the floodplain at and immediately upstream of the bridge in that the area left of the channel is displayed as "blocked obstruction."

<u>Bridge Scour Analysis (RM 371):</u> Contraction = 0 feet, Pier = 9.0 feet, Abutment = could not be computed due to no flow obstruction in the approach cross section by the abutment.

Site 12 Risk Potential: ***<u>High</u>*** due to scour potential at the bridge and bed profile comparisons that show downcutting at the site (WAI).

Site 12 Floodplain Restoration Potential: ***<u>Moderate</u>*** at the bridge crossing itself. On both of the bridge approaches, floodplain is isolated by the embankments. Because of the river corridor narrowing caused by the structure, widening the bridge span or placing one or more culverts through the embankment would reduce scour potential in the main channel during high water.

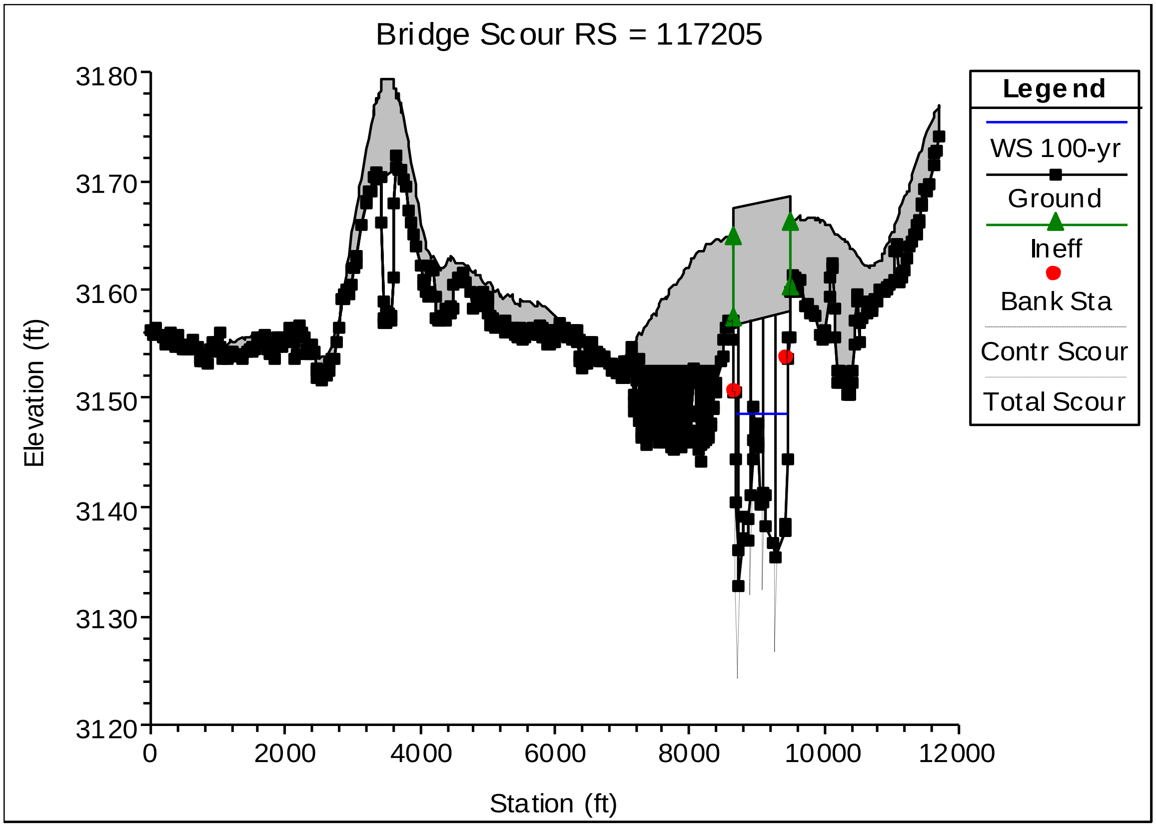

Figure 27. Site 12, RM 371 Bridge Scour Schematic, South Billings Boulevard Bridge.

3.5.5 Site Number 13

Site number 13 is located downstream of Laurel at RM 380, and consists of an 8-inch crude oil pipeline owned by ConocoPhillips that encroaches into the Yellowstone River CMZ.

Since 1950, the right bank has migrated approximately 450 feet towards the pipeline, and most of that migration occurred prior to 1976. In 2004, the bank was within 120 feet of the pipeline alignment shown in the NPMS geodatabase. The bank has been armored with flow deflectors, riprap, and a dike. However, the downstream portion of the riprap has failed since 2004. Erosion is also active upstream of the bank armor at this site.

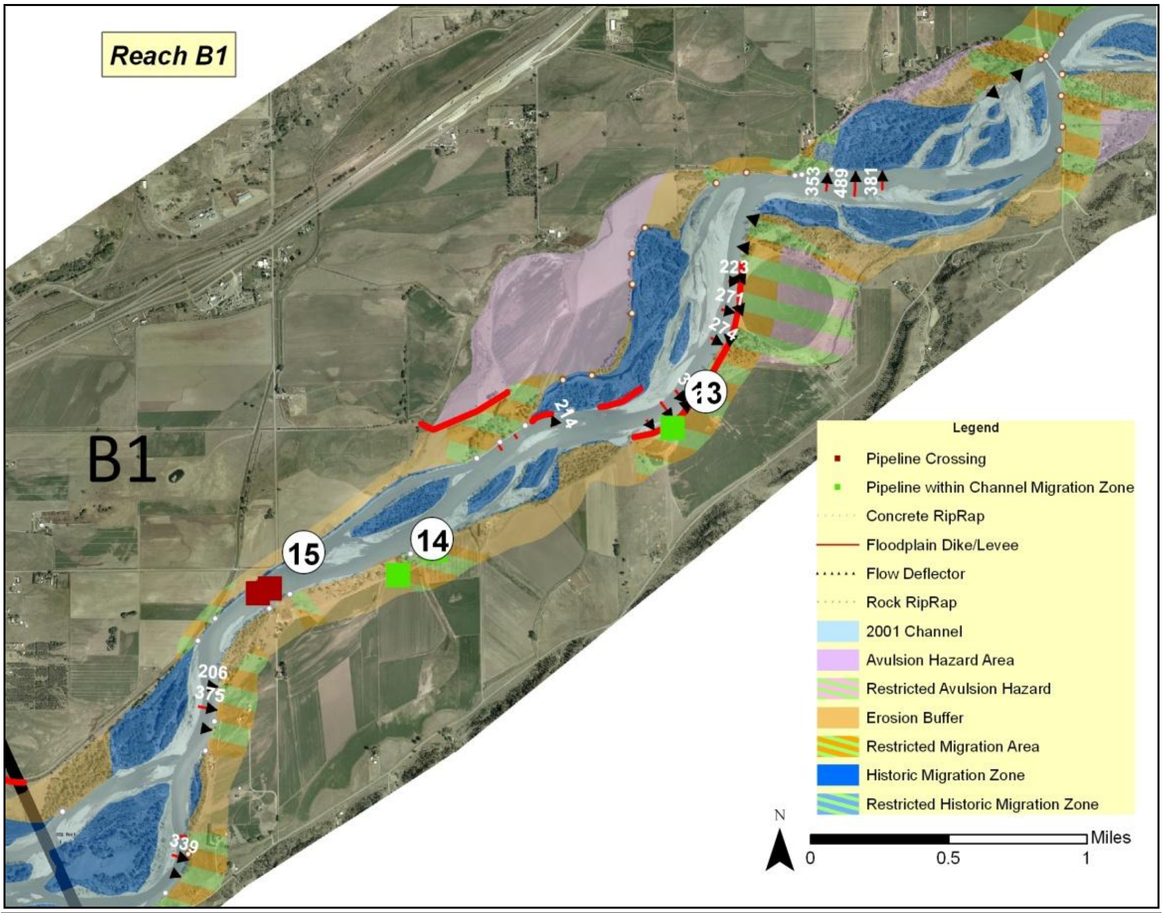

Figure 28. Upstream portion of Reach B1 showing Sites 13-15, CMZ, and physical features.

Site 13 Risk Potential: ***Moderate*** due to damaged bank protection on the right bank.

Site 13 Floodplain Restoration Potential: ***Low*** due to fact that the pipeline does not cross the channel but is running parallel to the channel at the site.

3.5.6 Site Number 14

Site 14 is located downstream of Laurel at RM 381.5, and consists of 2 pipelines that run parallel to the river within its Channel Migration Zone. The pipelines include an 8-inch crude oil pipeline owned by Northwest Energy LLC, and an 8-inch natural gas pipeline owned by ConocoPhillips (Figure 28).

In 1950, the riverbank was 260 feet from the pipeline alignment shown in the NPMS geodatabase. A portion of this bank was armored sometime prior to 1976. By 2011, the river had migrated to within approximately 130 feet of the pipeline, flanking the upper end of this armor.

Figure 29. Site 14 bankline showing 2004 (left) and 2011 (right) conditions; red line is 2004 bankline and yellow is upstream end of armor in 2004. Pipeline runs parallel to field road on lower portion of image.

Site 14 Risk Potential: ***__High__*** due to armor failure and rapid right bank migration on an outside bend.

Site 14 Floodplain Restoration Potential: ***__Low__*** due to fact that the pipeline does not cross the channel but is running parallel to the channel at the site. Risk would be reduced by either relocating the pipeline to the south or repairing the armor.

3.5.7 Site Number 15

Site 15 is located downstream of Laurel at RM 382, and consists of two crossings, including an 8-inch natural gas pipeline owned by Northwestern Energy LLC, and an 8-inch crude oil pipeline owned by ConocoPhillips (Figure 28).

There has been little measureable migration at the crossings since 1950. It is located on a locally straight section of river, and WAI data indicate some bedrock controls in the reach that will contribute to vertical and potentially lateral stability of the channel. Approximately 700 feet downstream of the crossings, the right bank has been actively retreating between this site and Site 14. The risk associated with this migration is described for Site 14.

Site 15 Risk Potential: ***__Moderate__*** at the crossing the site appears stable; however risk increases to high as the pipelines follow the right bank towards Site 14.

Site 15 Floodplain Restoration Potential: ***__Low__*** due to the lack of floodplain isolation at the site.

3.5.8 Site Number 16

Site 16 is at the Laurel Bridge at RM 385, and consists of four pipeline crossings. These individual crossings include the following:

- Site 16A: a 12.75-inch crude oil pipeline owned by Exxon Mobil
- Site 16B: a 16-inch natural gas pipeline owned by Williston Basin Interstate Pipeline
- Site 16C: a 16-inch natural gas pipeline owned by Williston Basin Interstate Pipeline

- Site 16D: an 8-inch crude oil pipeline owned by ConocoPhillips

These sites are located below the Laurel Bridge in Reach A17. WAI shows three locations of bedrock control between the Laurel Bridge and the Duck Creek Bridge. One is between the Laurel Bridge and the mouth of the Clarks Fork. These controls will help limit systemic downcutting in Reaches A17 and B1. However, the bridge at Laurel constricts the channel to approximately 500 feet of topwidth, whereas immediately above the bridge the channel is almost 800 feet wide. This constriction has the potential to cause substantial local scour at the bridge.

Riverside Park is located on the right bank just downstream of the Laurel Bridge. Air photos show over 50 feet of migration into the park from 2009 to 2011.

Site 16 is the location of the 2011 Exxon Mobil pipeline rupture.

The channel cross section in the crossing location is shown in Figure 35. Scour analysis was conducted for the Laurel Bridge with results presented as a schematic in Figure 36. Symbology explanation for the figure is the same as presented for Site 9. Comparison of Figures 35 and 36 reinforces the discussion above concerning restriction of the floodplain at the bridge, forcing water to accelerate around the right abutment resulting in large scour values computed for extreme flow events.

Bridge Scour Analysis (RM 385): Contraction = 0 feet, Pier = 15 feet, Abutment = 74 feet.

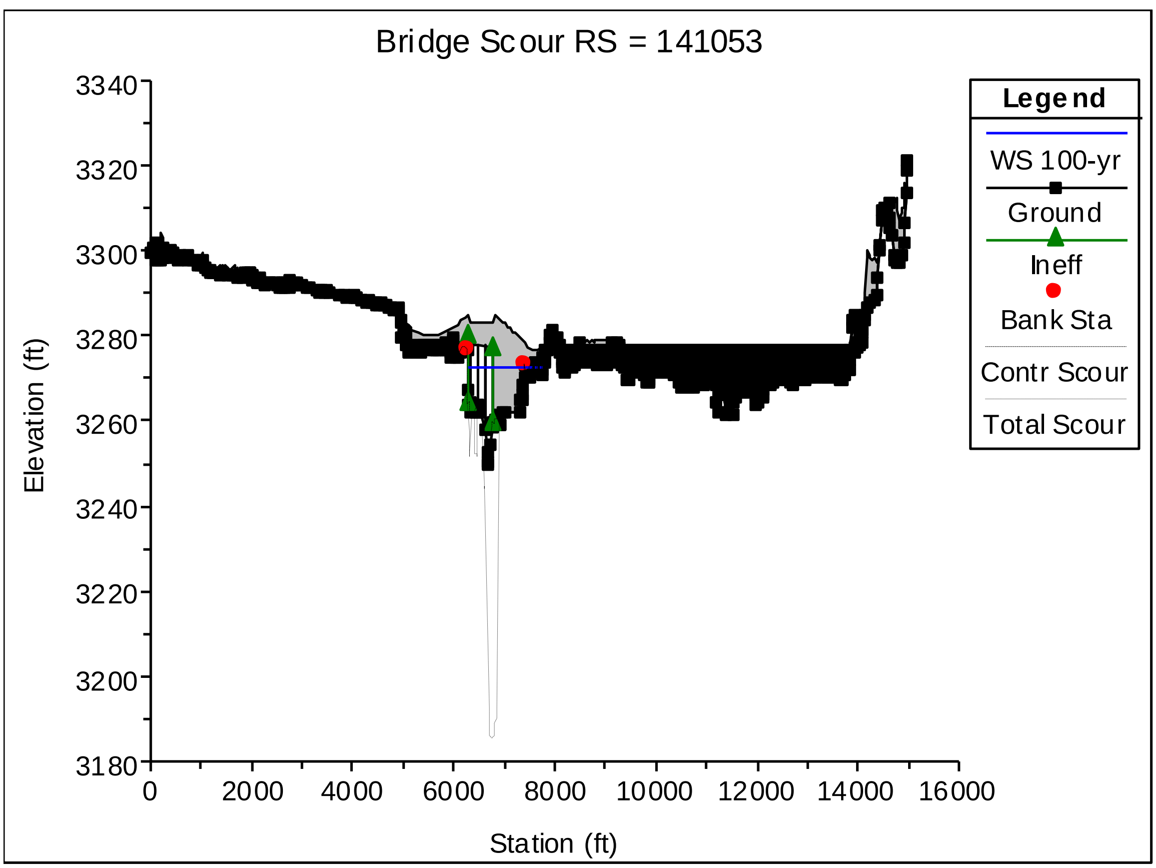

Figure 30. Site 16 Scour Analysis Schematic (RM385), Laurel Bridge.

Site 16 Risk Potential: ***__High__*** scour potential due to constriction by bridge and empirical evidence of recent failure at the Exxon Mobil line.

Site 16 Floodplain Restoration Potential: ***__Low__*** due to urbanization and development on the floodplain. Widening the bridge span or placing one or more culverts through the southern bridge approach could reduce flow concentrations under the bridge. A high flow channel would also cross the pipelines in the park and thus stability at those crossings must be evaluated.

3.6 Stillwater County (Sites 17 and 18)

There are two sites in Stillwater County. Site 17 is located a few miles upstream of Park City, and Site 18 is at the town of Columbus (Figure 31).

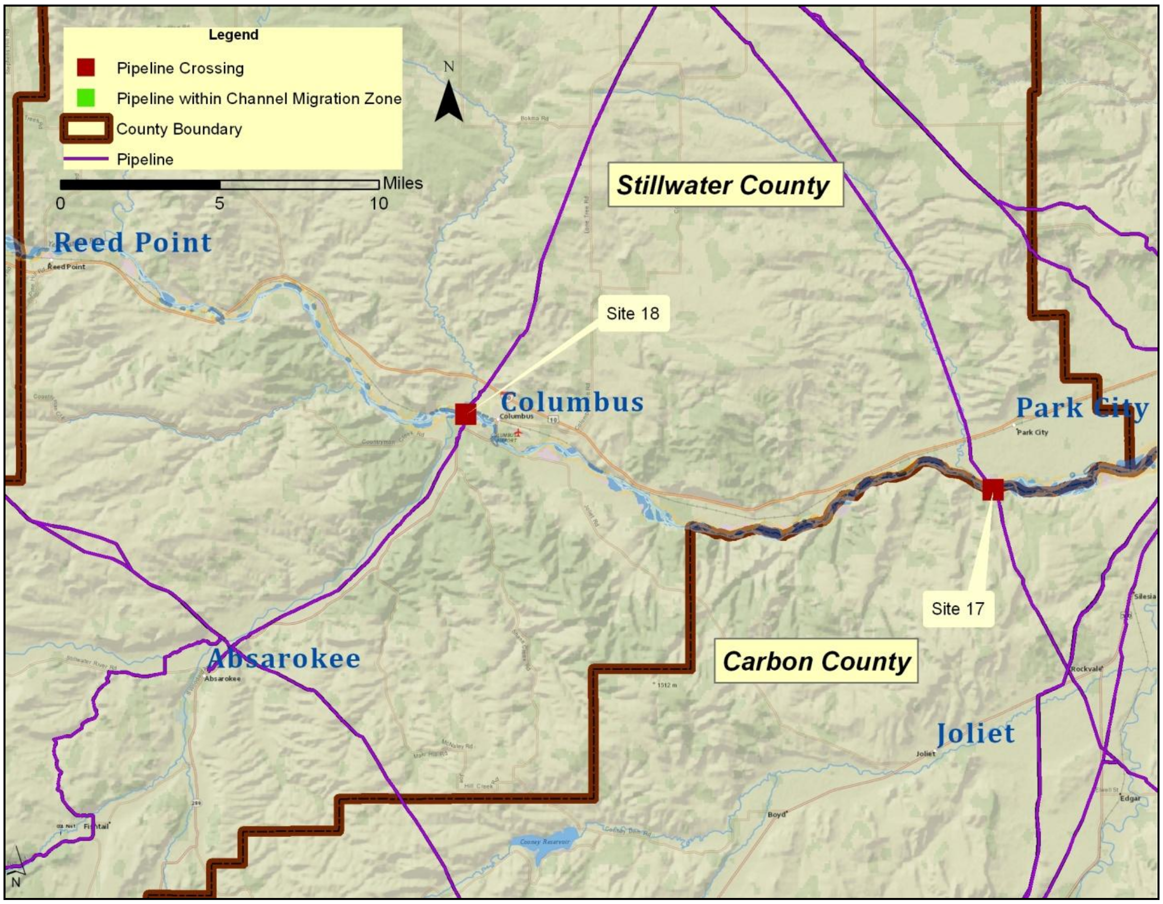

Figure 31. Stillwater County pipeline sites.

3.6.1 Site Number 17

Site number 17 is at River Mile 397, and consists of a 24-inch crude oil pipeline that is owned by Kinder Morgan Pipelines. The pipeline crosses the river at this location, and extends under an area mapped as an avulsion hazard in the CMZ mapping (Figure 32). The site is within river reach A16 which is classified PCA. The Yellowstone River channel is notably narrow at the pipeline crossing suggesting a high potential for scour against the bedrock bluff. Because of the broad, low floodplain north of the channel, there may be some opportunity for side channel creation in this area that would reduce erosive pressure against the bedrock bluff. If additional channels were created, however, the pipeline would have to be buried sufficiently below any side channel. A large dike north of the crossing does not appear to form a restriction at the 100-year flood, limiting its potential as a restoration site.

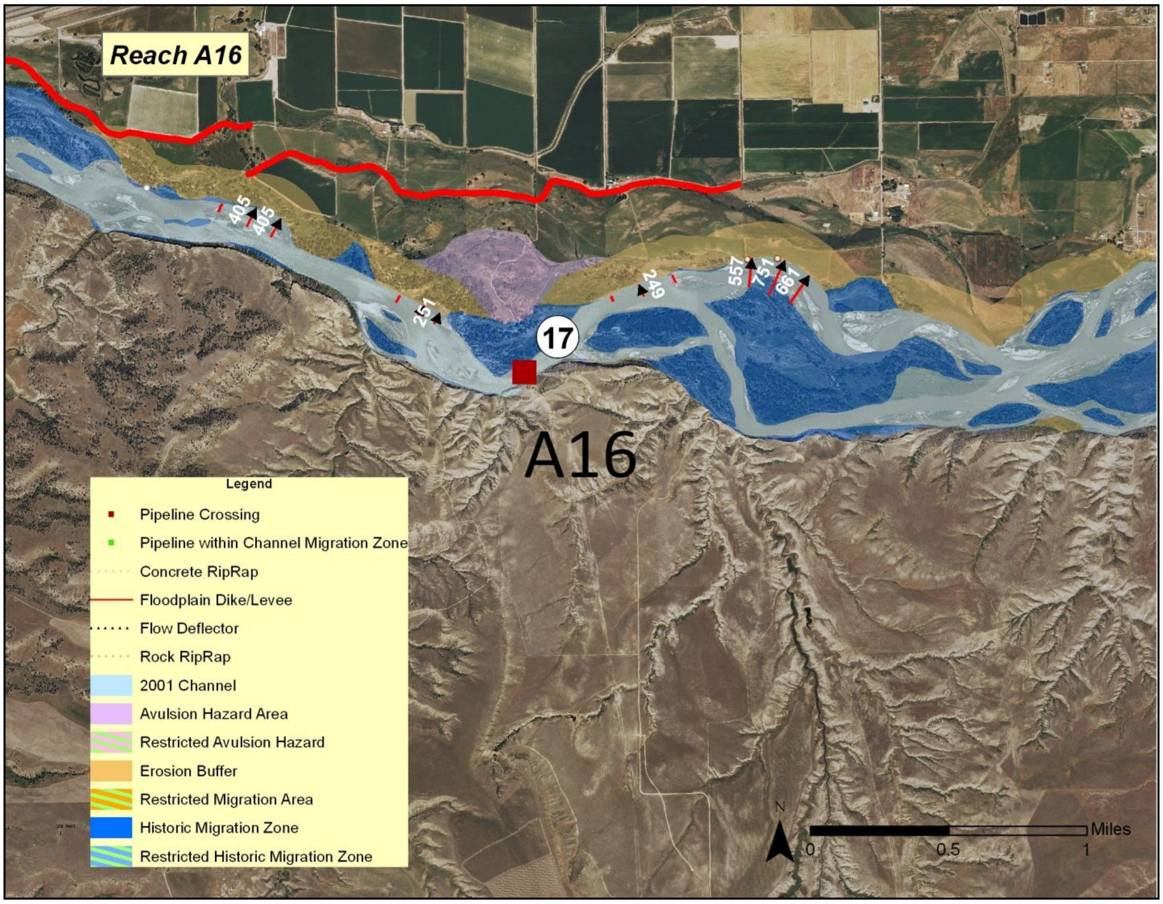

Figure 32. Reach A16 showing mapped physical features and CMZ; red arrows show 1950-2001 bank migration labeled in feet.

Site 17 Risk Potential: ***__Moderate__*** due to narrow, deep channel against south bluff. As this is a 24-inch crude oil pipeline, the site should be carefully monitored for local scour.

Site 17 Floodplain Restoration Potential: ***__Low__*** due to lack of floodplain isolation. Construction of a secondary channel on the northern floodplain could potentially relieve stress on the right bank at the crossing.

3.6.2 Site Number 18

Site 18 is located in Reach A13 below the Stillwater River confluence at Columbus, Montana (RM 417). The site consists of a 4-inch natural gas pipeline crossing that is owned by Northwestern Energy Basin-Absarokee Line. This site is located within river reach A13 which is classified PCA. At this location, the Yellowstone River channel flows within a single thread, although old channels create an avulsion hazard (pink) as shown on the right overbank to the south. These appear to be old Stillwater River channels, and a cross section through the areas shows these channels perched above that of the main Yellowstone

River and inundated at a 100-year flood event (Figure 34). At the crossing, the right bank of the main Yellowstone River channel was mapped in 2001 as having accelerated erosion.

Changes in flow paths at the mouth of the Stillwater River could activate the side channel in the pink area south of the Yellowstone River. This is a complex area at the confluence of a major tributary channel to the Yellowstone. As such, the configuration of the pipeline should be carefully evaluated with respect to the Stillwater River bed elevation, and with respect to right bank erosion on the main Yellowstone River channel.

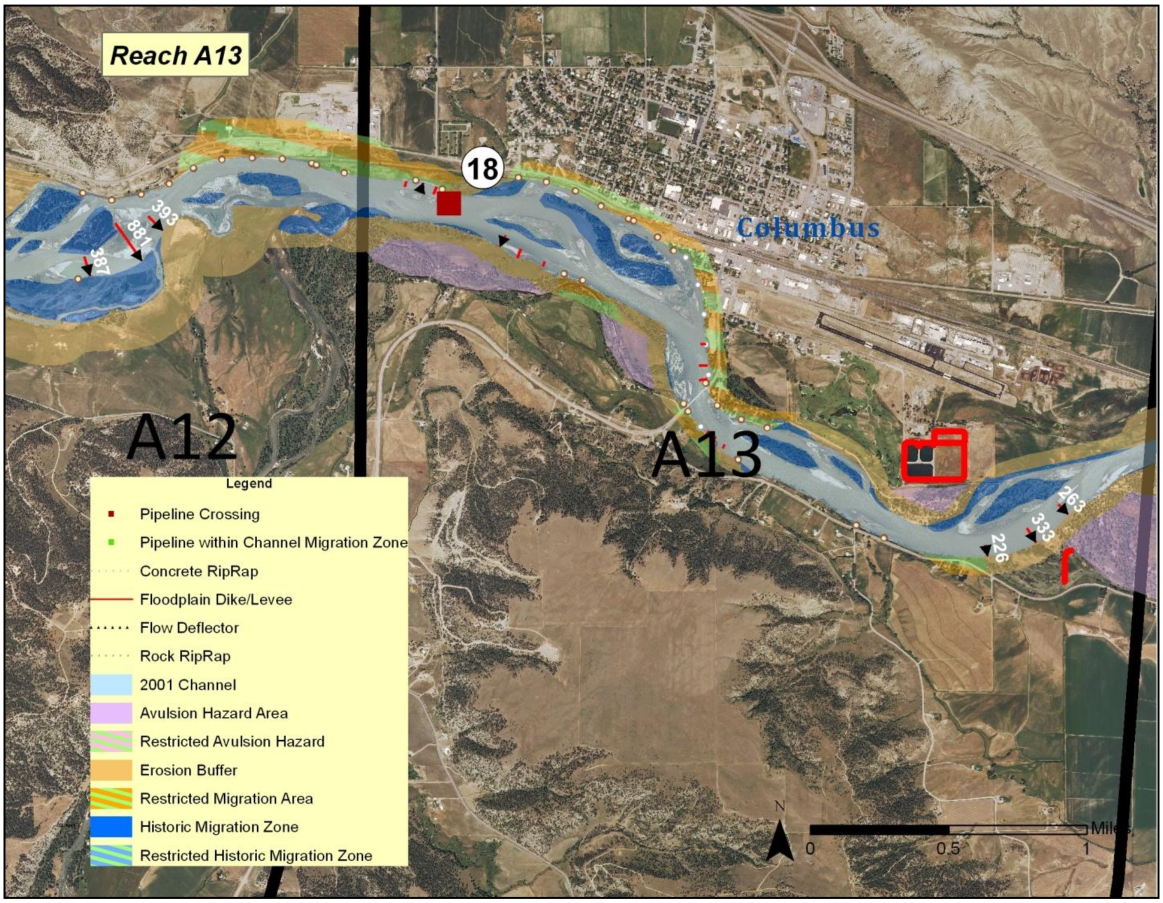

Figure 33. Portion of Reach A13 showing Site 18, mapped physical features and CMZ; red arrows show 1950-2001 bank migration labeled in feet.

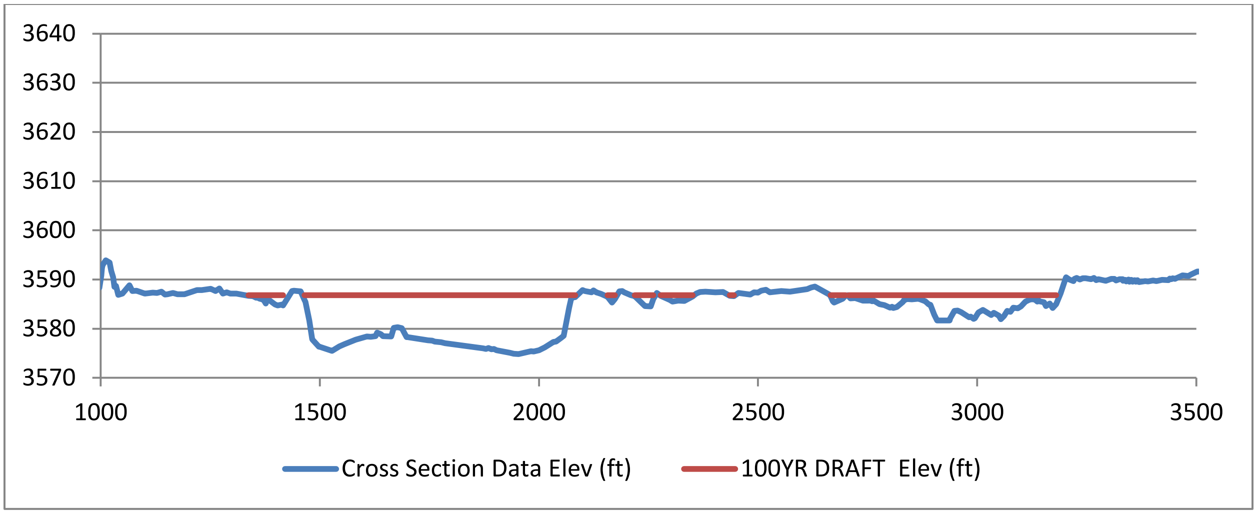

Figure 34. Cross Section at RM 417, 120 feet upstream of Site 18, showing 100-year water surface elevation. Note Yellowstone channel to left and perched (Stillwater River) channel on right.

Site 18 Risk Potential: ***Moderate*** due to the complex geomorphic nature of this area, with abandoned channels to the south potentially capable of capturing Stillwater River and/or Yellowstone River flows. Also right bank erosion on Yellowstone may increase risk.

Site 18 Floodplain Restoration Potential: ***Low*** due to lack of floodplain isolation and complex geomorphic environment. Any remedy should consider ensuring a deep, long pipeline crossing.

3.7 Sweet Grass County (Sites 19 and 20)

There are two sites in Sweet Grass County. Site 19 is a pipeline crossing upstream of Reed Point, and Site 20 is a pipeline that crosses lower Big Timber Creek within the Channel Migration Zone of the Yellowstone River.

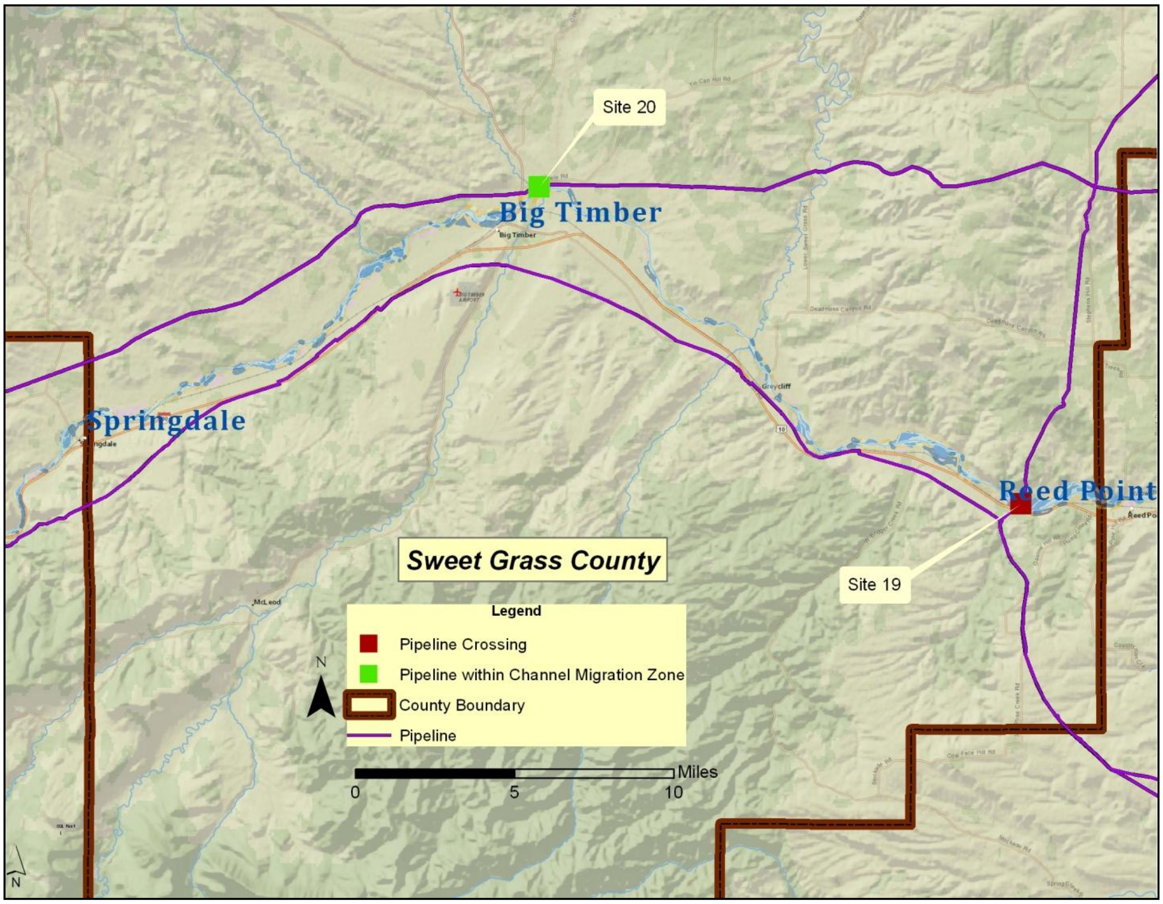

Figure 35. Sweet Grass County pipeline sites.

3.7.1 Site Number 19

Site 19 is located upstream of Reed Point in Reach A9 (RM 438). The crossing is a 12-inch natural gas pipeline owned by Northwestern Energy. Reach A9 is an Unconfined Anabranching reach type, indicating multiple channels and a typically dynamic planform. Approximately 8% of the bankline is armored in the reach. This reach had a ~26% reduction in braiding parameter between 1950 and 2001, indicating some isolation of side channels during that time frame.

At the crossing site, the left bank appears fairly erosion resistant, and the right bank is armored upstream. The 2011 NAIP imagery shows no measureable change at this site.

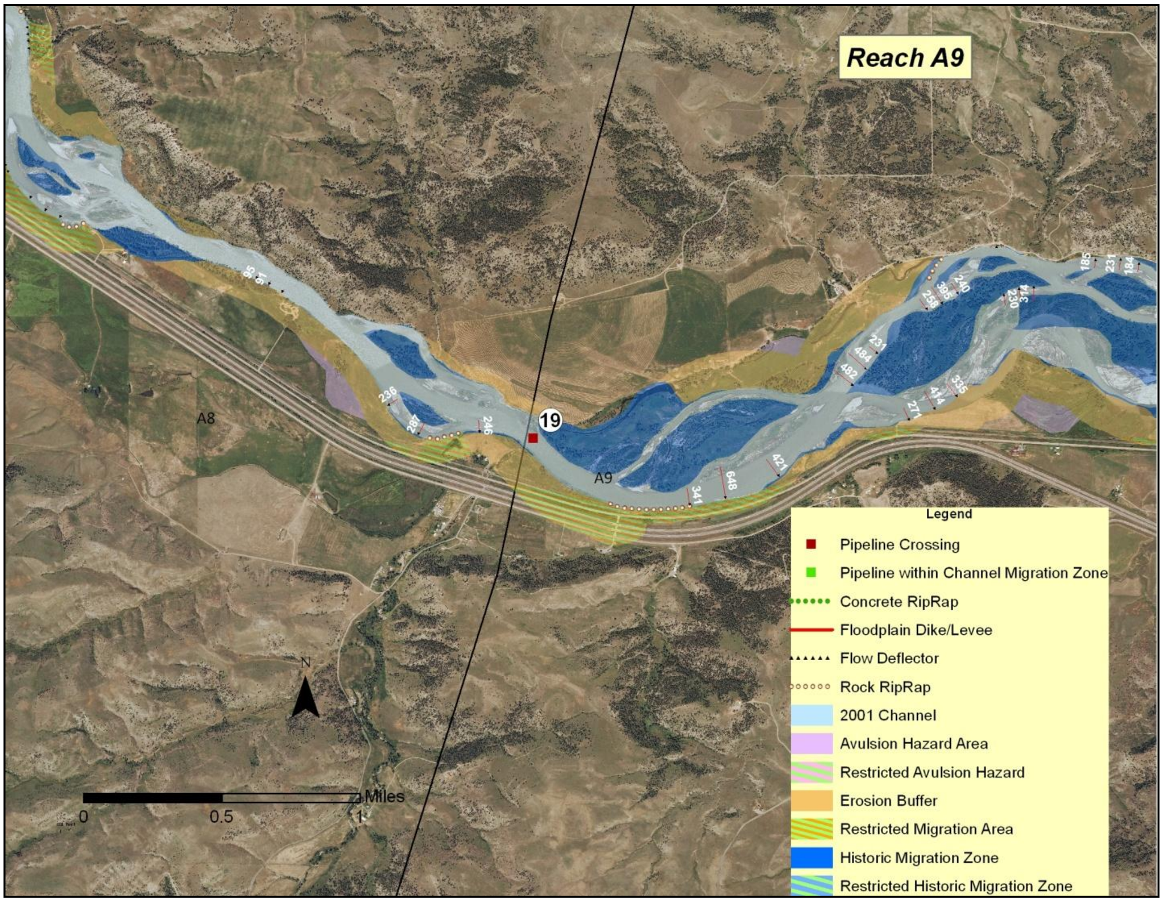

Figure 36. Portion of Reach A9 showing Site 19, mapped physical features and CMZ; red arrows show 1950-2001 bank migration labeled in feet.

Site 19 Risk Potential: ***Low*** due to overall channel stability.

Site 19 Floodplain Restoration Potential: ***Low*** due to lack of floodplain isolation.

3.7.2 Site Number 20

Site 20 is located just northeast of Big Timber at RM 460, where a 10-inch product pipeline owned by ConocoPhillips passes under Big Timber Creek within the Yellowstone River Channel Migration Zone. The pipeline crosses Big Timber Creek approximately 700 feet upstream of the confluence of the creek with the Yellowstone River. One concern with this site is that the base level of Big Timber Creek is controlled by that of the Yellowstone. Any down cutting on the Yellowstone River could trigger tributary downcutting and exposure of this pipeline. The crossing is in Reach A4, which is an unconfined, braided channel type. Approximately 24% of the bankline is armored, and the braiding parameter in the reach dropped 25.6% between 1950 and 2001. The left bank of the Yellowstone River has shown no measureable left bank migration in this area since 1950.

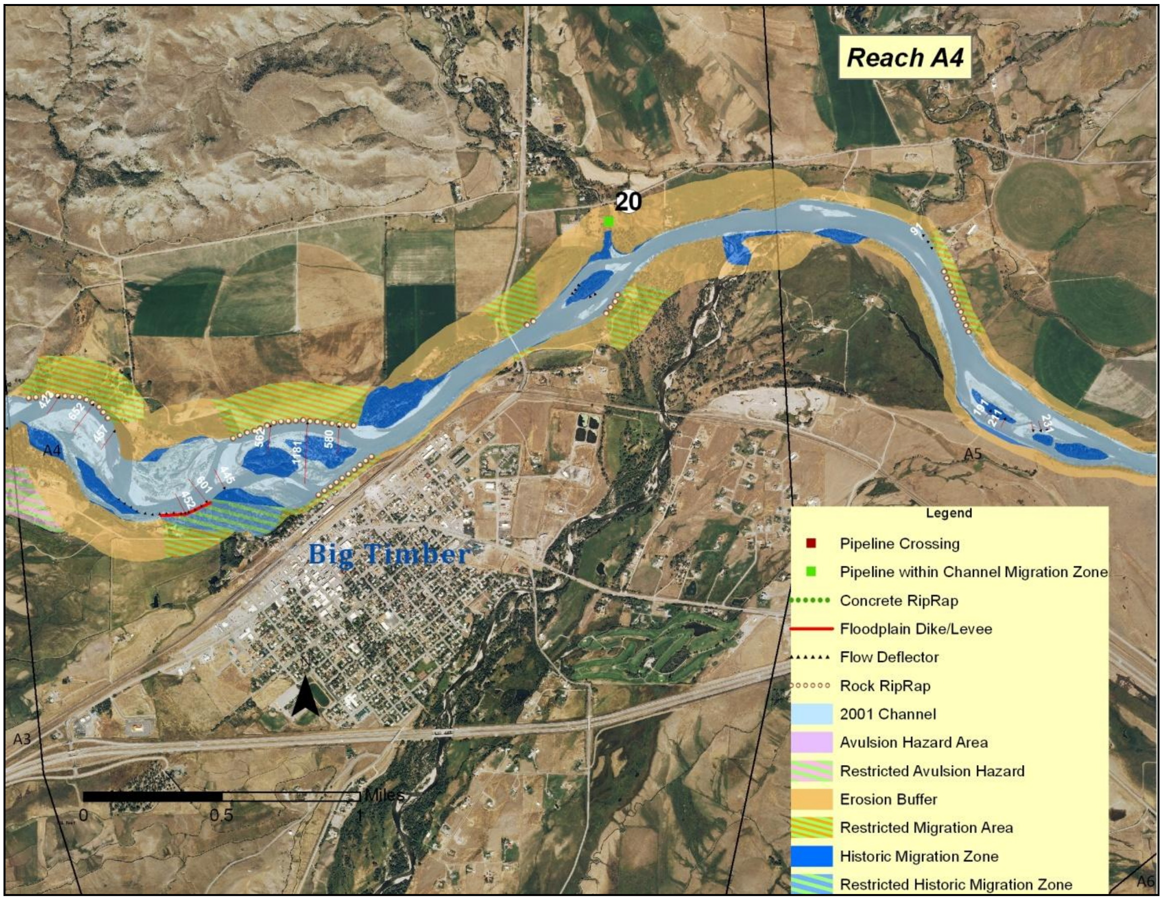

Figure 37. Portion of Reach A4 showing Site 20, mapped physical features and CMZ; red arrows show 1950-2001 bank migration labeled in feet.

Site 20 Risk Potential: ***Moderate*** due to extent of bank armor (24%) and the 1950-2001 reduction in braiding parameter (-26%), both of which may cause downcutting in the main Yellowstone River channel.

Site 20 Floodplain Restoration Potential: ***Low*** due to lack of floodplain isolation.

3.8 Park County (Site 21)

Park County has one pipeline site which is a crossing at RM 498 (Figure 38).

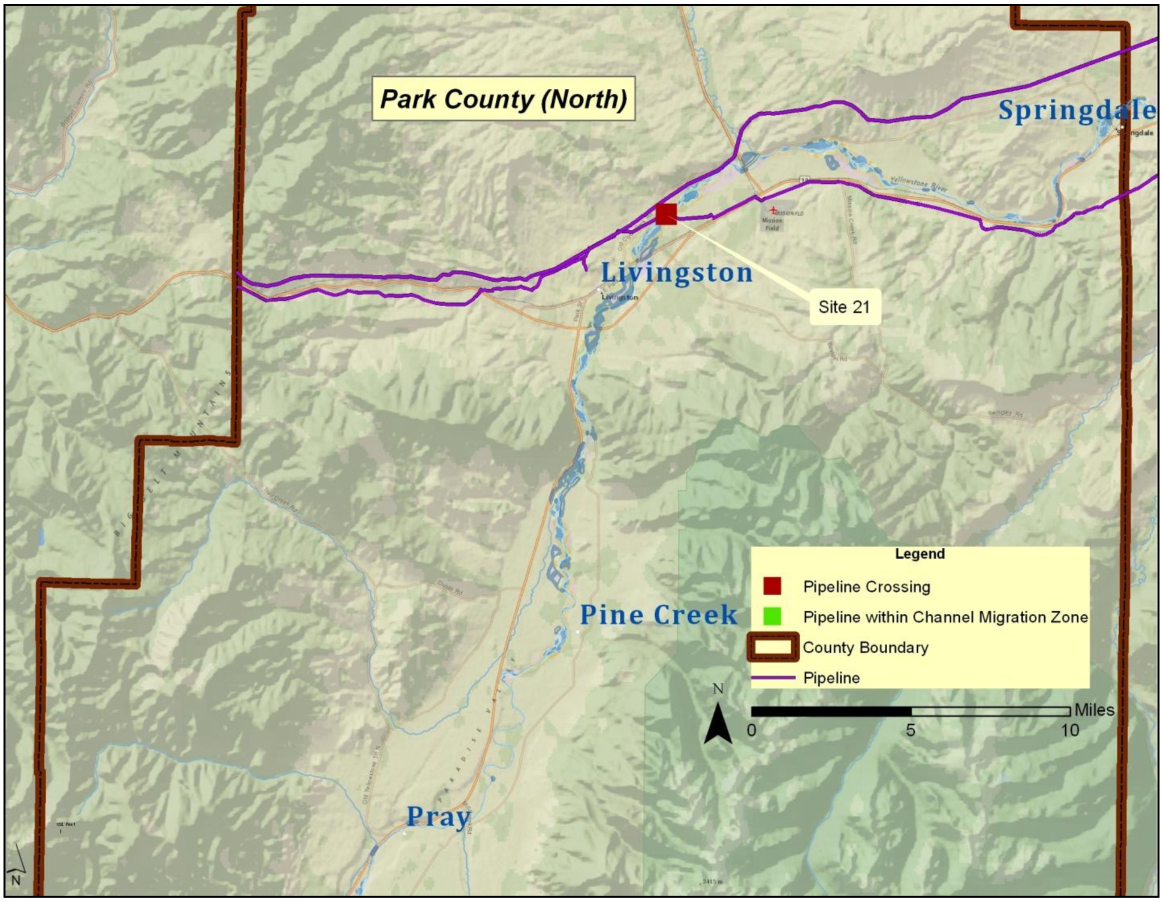

Figure 38. Park County pipeline sites.

3.8.1 Site Number 21

Site 21 is a 12-inch natural gas pipeline that is owned by Northwestern Energy, and crosses the river downstream of Livingston in Reach PC16 (RM 498). The pipeline crossing is at a relatively narrow point in the river meander corridor. The left bank is erosion resistant, and the right bank is armored with riprap, flow deflectors, and a dike (Figure 39). Prior to being armored, this bank migrated 246 feet toward the southeast since 1950. Floodplain access at this site is likely constrained by the dike located on the right bank immediately upstream of the crossing.

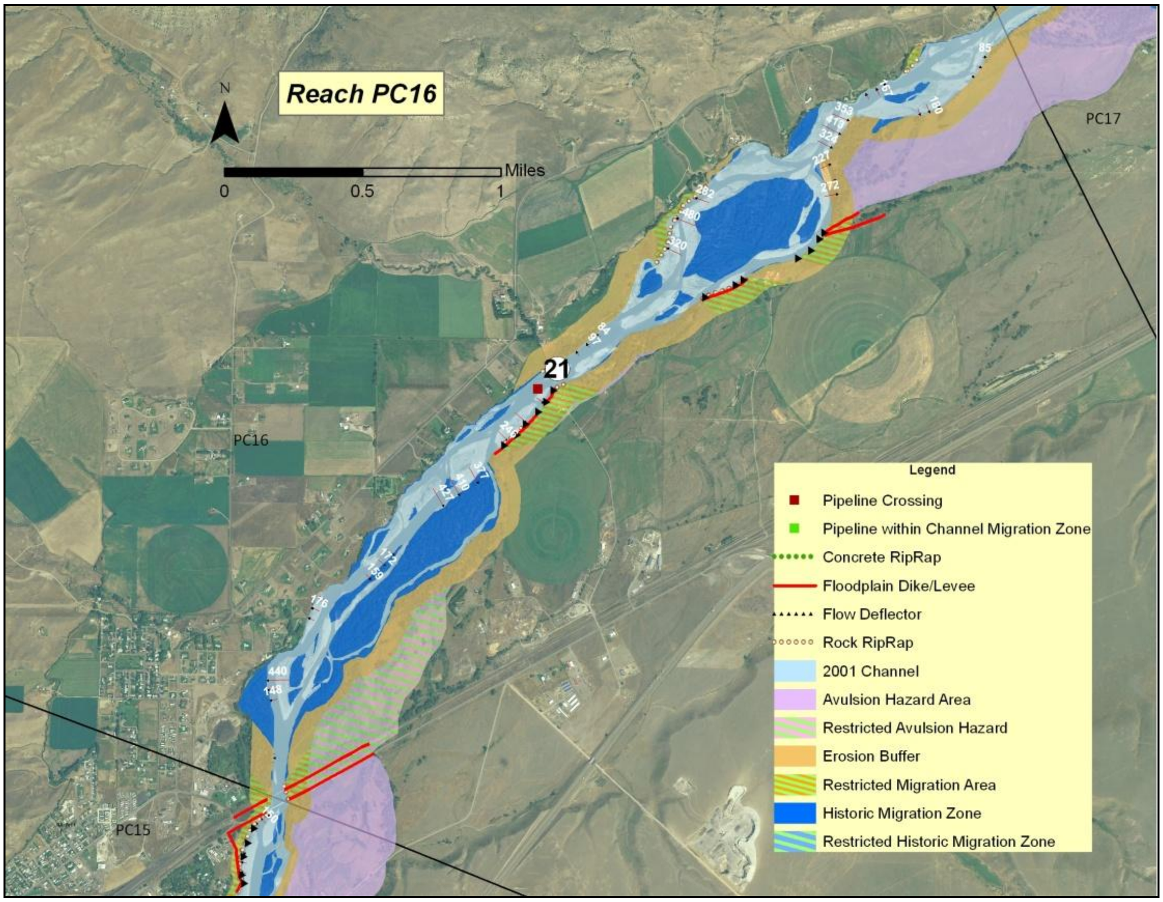

Figure 39. Portion of Reach PC16 showing Site 21, mapped physical features and CMZ; red arrows show 1950-2001 bank migration labeled in feet.

Site 21 Risk Potential: ***<u>Moderate</u>*** due to flow concentration and river corridor constriction by right bank dike and armor.

Site 21 Floodplain Restoration Potential: ***<u>Moderate:</u>*** Removal/breaching of the right bank dike could potentially reduce pipeline exposure potential. However, the dike currently protects structures on the end of Rustad Lane; hence the feasibility for floodplain reactivation is likely limited.

Table 3. Yellowstone Pipeline Crossing Risk Assessment Site Summary.

Yellowstone Pipeline Crossing Risk Assessment

Site Summary

								Right Bank				Left Bank								Adjacent to Bridge	
River Mile	Site Number	Location	Type of Crossing	Pipe Diameter (inches)	Commodity	System/Sub System Name	Owner	1950-2011 Migration Distance (ft)	1950-2011 Average Rate (ft/yr)	Armoring	Landowner	1950-2011 Distance	1950-2011 Average Rate (ft/yr)	Armoring	Landowner	Distance to Pipeline (ft)	Potential Failure Method*	Risk Potential	Floodplain Restoration Potential		Comment
PARK COUNTY																					
498	21	Downstream of Livingston (Rustad Lane)	Parallel, Crossing	12	Natural Gas	Dry Creek-Bozeman Line	Northwestern Energy LLC	87	1.7	1600 ft barbs, riprap, dike	Yellowstone Community Partners	0	0	None	Virginia Gorton	0 (crossing)	LMP, LMC, DLS, DS	Moderate	Moderate	No	Choke pt on river; new bar formation putting pressure on right bank; hard armor present---large barbs were recently constructed. I believe I have photos from this site. Scour potential at this site appears high due to channel confinement.
SWEET GRASS COUNTY																					
460	20	Big Timber	Tributary Crossing (Big Timber Cr)	10	Product	Billings Pump STA/Missoula	Conoco Phillips	NA	NA	NA	Mark Norem (right bank Big Timber Creek)	NA	NA	NA	Wilson Revocable Living Trust (left bank Big Timber Creek)	NA (Crossing)	LMP	Moderate	Low	No	Pipeline crosses under Big Timber Creek ~700 feet up from confluence with Yellowstone. Yellowstone instability could cause tributary downcutting/pipeline exposure
438	19	Upstream of Reed Pt	Crossing	12	Natural Gas	Big Coulee-Reed Point Line	Northwestern Energy	157	3.1	Rock riprap 1400 ft upstream; appears to be unmapped barbs ~800 ft upstream.	Bland Family Limited Partnership	0	0.0	Appears to have bedrock toe	Springtime Land LLC	200	LMC, DLS, DS	Low	Low	No	Narrow river section; scour potential likely high.
STILLWATER COUNTY																					
417	18	Near Columbus just downstream of Stillwater Confluence	Crossing	4	Natural Gas	Lake Basin-Absarokee Line	Northwestern Energy Lake Basin-Absarokee Line	89	1.7	Rock Riprap	Linda Bay	64	1.3	None	Burlington Northern Railroad	NA (Crossing)	LMC, DLS, DS	Moderate	Low	No	Right bank retreat could expose line in bank. Side channel to south could develop/downcut.
397	17	Downstream of Columbus	Parallel, Crossing	24	Crude Oil	Express Pipeline	Kinder Morgan Pipelines	0	0	Bedrock	Porchfire Enterprises LLC	400	7.8	None	Martin Mohr	471	LMC, DLS, DS	Moderate	Low	No	Left bank bend migration towards pipeline; narrow channel at crossing; scour potential likely high.
YELLOWSTONE COUNTY																					
385	16D	Laurel	Crossing	8	Crude Oil	Glacier Crude-Byron 8 in, Frannie Sta/Billings Pump Sta	Conoco Phillips	50	1.0	At bridge immediately upstream	City of Laurel: Riverside Park	0	0	Rock Riprap	CHS Inc	NA (Crossing)	LMC, DLS, DS	High	Low	Yes	Multiple crossings just downstream of Laurel bridge. Risk is vertical scour (may be associated with bridge confinement) or right bank retreat; 50 feet of right bank migration since 2001 (may all be during 2011 flooding)
385	16C	Laurel	Crossing	16	Natural Gas	Lovel Elk Basin Billings System, Worland Sub-System	Willistion Basin Interstate Pipeline Co.	50	1.0	At bridge immediately upstream	City of Laurel: Riverside Park	0	0	Rock Riprap	CHS Inc	NA (Crossing)	LMC, DLS, DS	High	Low	Yes	Multiple crossings just downstream of Laurel bridge. Risk is vertical scour (may be associated with bridge confinement) or right bank retreat; 50 feet of right bank migration since 2001 (may all be during 2011 flooding)
385	16B	Laurel	Crossing	16	Natural Gas	Lovel Elk Basin Billings System, Worland Sub-System	Willistion Basin Interstate Pipeline Co.	50	1.0	At bridge immediately upstream	City of Laurel: Riverside Park	0	0	Rock Riprap	CHS Inc	NA (Crossing)	LMC, DLS, DS	High	Low	Yes	Multiple crossings just downstream of Laurel bridge. Risk is vertical scour (may be associated with bridge confinement) or right bank retreat; 50 feet of right bank migration since 2001 (may all be during 2011 flooding)
385	16A	Laurel	Crossing	12.75	Crude Oil	Montana Crude, Edgar-Laurel Terminal 12" MT-14	ExxonMobil Pipeline Co.	50	1.0	At bridge immediately upstream	City of Laurel: Riverside Park	0	0	Rock Riprap	CHS Inc	NA (Crossing)	LMC, DLS, DS	High	Low	Yes	Multiple crossings just downstream of Laurel bridge. Risk is vertical scour (may be associated with bridge confinement) or right bank retreat; 50 feet of right bank migration since 2001 (may all be during 2011 flooding)
382	15B	Downstream of Laurel	Crossing	8	Natural Gas	Northwestern Energy GT&S, CENEX Tap Line	Northwest Energy LLC	100	2.0	Discontinuous concrete riprap	Robert A and Patric Castleberry; C J Land and Livestock	0	0.0	Resistant bank	Flying Box Ranch Co	NA (Crossing)	LMC, DLS, DS	Moderate	Low	No	Straight reach with minimal width change through time, slight bend to north with resistant bankline (terrace)
382	15A	Downstream of Laurel	Crossing	8	Crude Oil	Glacier Crude-Byron 8 in, Frannie Sta/Billings Pump Sta	Conoco Phillips	100	2.0	Discontinuous concrete riprap	Robert A and Patric Castleberry; C J Land and Livestock	0	0.0	Resistant bank	Flying Box Ranch Co	NA (Crossing)	LMC, DLS, DS	Moderate	Low	No	Straight reach with minimal width change through time, slight bend to north with resistant bankline (terrace)
381.5	14B	Downstream of Laurel	Parallel	8	Natural Gas	Northwestern Energy GT&S, CENEX Tap Line	Northwest Energy LLC	400	7.8	None	C J Land and Livestock	0	0.0	Resistant bank	NA (parallel on right bank)	133	LMP	High	Low	No	**110 feet of right bank movement 2009-2011. High risk area for two pipelines. Pipelines could be moved to south.**
381.5	14A	Downstream of Laurel	Parallel	8	Crude Oil	Glacier Crude-Byron 8 in, Frannie Sta/Billings Pump Sta	Conoco Phillips	400	7.8	None	C J Land and Livestock	0	0.0	Resistant bank	NA (parallel on right bank)	133	LMP	High	Low	No	**110 feet of right bank movement 2009-2011. High risk area for two pipelines. Pipelines could be moved to south.**
380	13	Downstream of Laurel	Parallel	8	Crude Oil	Glacier Crude-Byron 8 in, Frannie Sta/Billings Pump Sta	Conoco Phillips	440	9	Dike, Flow deflectors	C J Land and Livestock	0	0.0	Accreting	NA (parallel on right bank)	100	LMP	Moderate	Low	No	Very close to bank, but armored
371	12D	South Billings Blvd.	Parallel	12	Natural Gas	Lovel Elk Basin Billings System, Worland Sub-System	Williston Basin Interstate Pipeline Co	0	0	Armored Bridge Abutment	Bridge	0	0.0	Armored Bridge Abutment	Bridge	<40' upstream of bridge on left	LMP	High	Moderate	Yes	Side channel on left bank is within 40 ft of pipeline
371	12C	South Billings Blvd.	Crossing	8	Crude	Glacier Crude-Byron 8in, Frannie Sta/Billings Pump Sta	Conoco Phillips	0	0	Armored Bridge Abutment	Bridge	0	0.0	Armored Bridge Abutment	Bridge		LMC, DLS, DS	High	Moderate	Yes	Bridge scour concern
371	12B	South Billings Blvd.	Crossing	8	Natural Gas	Warren-Billings Steam Plant Line	Northwestern Energy LLC	0	0	Armored Bridge Abutment	Bridge	0	0.0	Armored Bridge Abutment	Bridge		LMC, DLS, DS	High	Moderate	Yes	Bridge scour concern
371	12A	South Billings Blvd.	Crossing	6	Natural Gas	Blue Creek-Billings Steam Plant Line	Northwestern Energy LLC	0	0	Armored Bridge Abutment	Bridge	0	0.0	Armored Bridge Abutment	Bridge		LMC, DLS, DS	High	Moderate	Yes	Bridge scour concern
368	11	Billings	Parallel	12	Natural Gas	Worland Sub-System	Williston Basin Interstate Pipeline	NA (parallel on left bank)	NA (parallel on left bank)	Riprap	NA	0	0.0	Riprap, Dike, Flow deflectors	Western Sugar Company	85	LMP	Low	Low	No	Heavily armored

Yellowstone Pipeline Crossing Risk Assessment

Site Summary

River Mile	Site Number	Location	Type of Crossing	Pipe Diameter (inches)	Commodity	System/Sub System Name	Owner	Right Bank: 1950-2011 Migration Distance (ft)	Right Bank: 1950-2011 Average Rate (ft/yr)	Right Bank: Armoring	Right Bank: Landowner	Left Bank: 1950-2011 Distance	Left Bank: 1950-2011 Average Rate (ft/yr)	Left Bank: Armoring	Left Bank: Landowner	Distance to Pipeline (ft)	Potential Failure Method*	Risk Potential	Floodplain Restoration Potential	Adjacent to Bridge	Comment
YELLOWSTONE COUNTY Cont.																					
367	10B	Billings	Crossing	12	Crude	Rocky Mountain, Beartooth	Beartooth Pipeline	120	2	Bedrock	Barry O'Leary Inc.	0	0.0	Riprap	City of Billings	NA (Crossing)	LMC, DLS, DS	Moderate	Low	No	Very wide, multi-thread section; could be good hydraulic comparison; reference for side channel reactivation. On right bank, pipelines go up Bitter Creek and appear to cross the tributary channel; Yellowstone River downcutting could expose pipelines in bed of tributary
367	10A	Billings	Crossing	8	Product	Siminor 8 in Products, Billings Pump Sta/Sinclair Pump Sta	Conoco Phillips	120	2	Bedrock	Barry O'Leary Inc.	0	0.0	Riprap	City of Billings	NA (Crossing)	LMC, DLS, DS	Moderate	Low	No	Very wide, multi-thread section; could be good hydraulic comparison; reference for side channel reactivation. On right bank, pipelines go up Bitter Creek and appear to cross the tributary channel; Yellowstone River downcutting could expose pipelines in bed of tributary
365	9G	Billings	Crossing	10	Crude Oil	Glacier 10 In Crude Conoco Refinery/ExxonMobil Refinery	Conoc Philips	Minimal	Minimal	Riprap	City of Billings	0	0.0	Riprap	Lockwood Area Yellowstone Water	NA (Crossing)		Low	Low	Yes	
365	9F	Billings	Parallel	8	Product	CENEX Pipeline System, Laurel to Billings 8 in Product	CENEX Pipeline LLC	Minimal	Minimal		City of Billings	0	0.0	None	USA	0 (runs under edge of river)		Low			
365	9E	Billings	Crossing	10	Crude	Glacier 10 In Crude Conoco Refinery/ExxonMobil Refinery	Conoco-Phillips (upstream I-90	Minimal	Minimal	Riprap	City of Billings	0	0.0	Riprap	USA	NA (Crossing)		Low	Low	Yes	Trenched installation according to CD Administrator
365	9D	Billings	Crossing	8	Natural Gas	Montan - Dakota Utilities Billings Exxon Line	Montana - Dakota Utilities Co.	Minimal	Minimal	Riprap	City of Billings	0	0.0	Riprap	USA	NA (Crossing)		Low	Low	Yes	Trenched installation according to CD Administrator
365	9C	Billings	Crossing	8	Product	Exxon Refinery Seminoe 8 in suction	Conoco Phillips	Minimal	Minimal	Riprap	City of Billings	0	0.0	Riprap	USA	NA (Crossing)		Low	Low	Yes	Trenched installation according to CD Administrator
365	9B	Billings	Crossing	12.75	Crude	Montana Crude Billings Meter Station - Billings Refinery	ExxonMobil Pipeline Co.	Minimal	Minimal	Riprap	City of Billings	0	0.0	Riprap	USA	NA (Crossing)		Low	Low	Yes	Trenched installation according to CD Administrator
365	9A	Billings	Crossing	8	Product	Cennex Pipeline System Laurel to Billings 8in Products	CENEX Pipeline LLC	Minimal	Minimal	Riprap	City of Billings	0	0.0	Riprap	USA	NA (Crossing)		Low	Low	Yes	Trenched installation according to CD Administrator
PRAIRIE COUNTY																					
126	8B	Fallon	Crossing	8	Product	8" Products - Fallon to Glendive	Abandoned	0	0	Armored Bridge Abutment Upstream	Bernard Rakes	0	0.0	Armored Bridge Abutment Upstream	Bruce Denby	NA (Crossing)	LMC, DLS, DS	Low	Low	Yes	~575 feet downstream of Interstate 94 Bridge
126	8A	Fallon	Crossing	10	Product	CENEX Pipeline System MP 191 to Glendive 101N	CENEX Pipeline LLC	0	0	Armored Bridge Abutment Upstream	Bernard Rakes	0	0.0	Armored Bridge Abutment Upstream	Bruce Denby	NA (Crossing)	LMC, DLS, DS	Low	Low	Yes	~575 feet downstream of Interstate 94 Bridge
DAWSON COUNTY																					
104	7	Glendive	Parallel	10	Crude Oil	No Data	Bridger Pipeline	0	0	None-Side channel	Cedar Cr Grazing Assn, BLM	NA	NA	NA	NA	60 ft from right bank of blocked side channel	LMP	Low	Low	No	Reactivation of side channel could threaten pipeline
100	6	Glendive	Crossing	10	Crude Oil	No Data	Bridger Pipeline	253	5	None		0	0.0	Riprap		285	LMC, DLS, DS	Moderate	Low	No	Right Bank erosion; recent shift in upstream flow split could accelerate retreat at this location
94	5	Glendive (Black Bridge)	Crossing	16	Natural Gas	West Mon-Dak Subsystem	Williston Basin Interstate Pipeline	600	12	Railroad Bridge Abutment	Kellee Crisfulli	85	1.7	Railroad Bridge Abutment	MTFWP	NA (Crossing)	LMC, DLS, DS	High	Low	Yes	Severe 2011 bank retreat on pipeline trend (right bank) ~200 feet retreat
77	4	Downstream of Glendive	Parallel	12	Natural Gas	West Mon-Dak Subsystem	Williston Basin Interstate Pipeline	NA	NA	NA	NA	Minimal		Riprap		100	LMP	Low	Low	No	Armored
RICHLAND COUNTY																					
32	3C	Sidney	Crossing	4.5	LPG	Williston Basin/River View	Bear Paw Energy LLC	120	2	Riprap just upstream of bridge		112	2.2	Bridge abutment	Stip Trust (Upper crossing)	NA (Crossing)	LMC, DS	Moderate	Low	Yes	Conservation District notes that Bear Paw Energy was purchased by ONEOK. 310 permit submitted in 2011 for new pipeline adjacent to this site indicates there is an additional existing pipeline within same easement. New pipeline proposes directional drilling with a minimum 20' below channel low point. Minor left bank migration; sever erosion downstream of upper crossing (340 ft left bank retreat)
31	3B	Sidney	Crossing	8	Natural Gas	Cabin Creek Willistion System West Mon-Dak Subsystem	Williston Basin Interstate Pipeline	120	2	Riprap just upstream of bridge		112	2.2	Bridge abutment		NA (Crossing)	DLS, DS	Moderate	Low	Yes	Scour potential at bridge
31	3A	Sidney	Crossing	8	LPG, Natural Gas, Product	River View, West Mon-Dak Subsystem, Glendive to Minot 8in	CENEX Pipeline LLC	120	2	Riprap just upstream of bridge		112	2.2	Bridge abutment		NA (Crossing)	DLS, DS	Moderate	Low	Yes	Scour potential at bridge
27	2	Downstream of Sidney	Crossing	8.62	Crude Oil	8" Putnam to Sidney	Tesoro - High Plains Pipeline Co	36	0.7	None	Robert L and Joan L Bell Trust	0	0.0	Accreting		NA (Crossing)	LMC, DLS, DS	High	Low	No	Notable 2011 flood retreat on right bank into resistant terrace unit. 1996 310 permit indicates directional drilling from island to right bank. Permit does not indicate depth of pipeline.
McKENZIE COUNTY, ND																					

4 Discussion and Recommendations

Factors that affect pipeline failure risk can be broadly divided into two categories: internal and external. Internal factors are those factors intrinsic to the pipeline itself, such as corrosion or weld failure. External factors are those that are a function of the environment through which the pipeline must pass, such as erosion in a fluvial environment. This study focused on the latter, preliminarily evaluating the risk posed by gas and/or hazardous material (petroleum) pipelines in the high energy, environmentally sensitive environment of the Yellowstone River channel migration zone (CMZ). The Yellowstone River's steep gradient combined with a relatively natural hydrology (at least above the Big Horn River confluence), provides the erosive force necessary to affect large vertical and horizontal changes of its active channel and thus potential exposure of pipelines buried in the erodible material that forms the bed and banks of the river. In addition, and particularly in channel types prone to lateral and vertical channel movement, installation of transportation infrastructure (bridges), and flood and erosion control structures (riprap, flow deflectors, dikes, etc.) can exacerbate the potential for exposure of shallowly buried pipelines by concentrating erosive forces.

The primary objectives of this project were to:

1. Develop a pipeline crossing data base that identifies pipelines within the Yellowstone River CMZ;
2. Determine risk to gas and/or hazardous material pipelines passing within the Yellowstone River CMZ; and
3. Determine the potential for floodplain mitigation to reduce risk in these locations.

The term "floodplain mitigation" used in this sense means altering the hydraulic environment in the immediate vicinity of a pipeline so as to reduce the erosive force acting upon it and thus reduce the potential for exposure and failure. Approximate plan form (aerial view) locations for pipelines were made available through an agreement between YRCDC and NPMS. These data were compared to the channel migration zone (CMZ) for the Yellowstone River. Analysis of available data identified 21 sites where pipelines cross or intersect the CMZ. Some of the sites include multiple pipelines with the following products listed:

Crude oil	14
Refined product	7
Natural gas	16
LPG (propane)	2
Total	39

Crude oil presents the greatest environmental risk due to lack of dispersion and difficulties collecting the released oil.

Risk Potential

Pipeline failure and spill into the Yellowstone River requires two elements: the river must be unstable and the pipeline must be vulnerable. As a case in point, consider the pipeline failure downstream of the Highway 212 Bridge at Laurel in 2011. First, the bridge is short and creates a pinch point in the river, such that the crossing is unusually susceptible to scour during floods (Scour analysis, section 3.5.8). Second, the pipeline had inadequate cover and was vulnerable to exposure.

This report addresses the first aspect of risk assessment: i.e. how stable is the river at locations where pipelines cross or are buried in close proximity to the bank? The project team has studied the river for decades and has been able to evaluate river stability with reasonable confidence at each location.

The report does not address the second point in detail because detailed information on location, geometry, depth, method of installation, and condition of pipelines was limited or unavailable. For example, pipeline cover data was provided for a few sites but could not be cross referenced to specific sites. The limited pipeline cover depth data indicates that many of the pipelines are buried less than eight feet below the channel bottom. These pipelines are at risk of exposure during flood events.

Of the 39 pipelines within the CMZ, 20 crossed the river near bridges. As would be expected, design engineers (highway, rail, pipelines) have consistently chosen the most narrow available bridge locations. Bridge abutments are often placed as near the banks as possible to reduce the footprints of the bridges. The crossings are hardened, mostly using riprap.

Scour analysis was performed at bridge crossings in Yellowstone County (Sites 9, 12, and 16) adjacent to pipeline river crossings to get a sense of scour potential. These analyses predict extreme, temporary down cutting (10's of feet) during floods, due to the "jetting" effect created by backwatering. Because most of the pipeline crossings occur near bridges, their location makes pipelines vulnerable to exposure, unless they are deeply buried, directionally drilled, or attached to the bridge superstructure.

Armoring installed to protect bridges, highways, railroads, refineries, and other vital infrastructure sometimes serves to protect the pipeline crossings. For example, five pipelines cross the Yellowstone at the east end of Billings near I-90, 1st Avenue North, and BNSF bridges. These important bridges and other urban and industrial infrastructure are protected and the pipeline crossings are considered low risk.

The highest concentration of pipelines is in the Billings to Laurel reach (Figure 5), where land use changes and resulting channel and floodplain modifications have been the most profound. Comparison of historic channel cross-sections in the Billings to Laurel reach showed that local degradation occurred as a result of artificial narrowing and confining of the channel. The river profile surveyed for the WAI 2000 report shows three areas of bedrock control downstream of Laurel, along with bedrock control near the east end of Billings. Therefore, downcutting is local rather than systemic.

Lateral migration analysis indicates only Sites 5 (River Mile 94) near Glendive and 14 (River Mile 281.5) downstream of Laurel are projected to have a risk of being exposed by lateral migration in the near future. Depth of cover and current channel armoring should be reviewed at Sites 5 and 14.

Changes in flow paths at the mouth of the Stillwater River could activate the side channel south of the Yellowstone River. This is a complex area at the confluence of a major tributary channel to the Yellowstone. As such, the configuration of the pipeline should be carefully evaluated with respect to the Stillwater River bed elevation, and with respect to right bank erosion on the main Yellowstone River channel.

Based on Atkins' review of the available information, each of the 21 sites was assigned a pipeline risk value of "low", "moderate", or "high" as indicated on Figure 40. The pipelines with the highest risk of failure due to river process are located at:

- Site 16, Laurel bridge;
- Site 12, South Billings Boulevard bridge;
- Site 5, Black Bridge near Glendive; and
- Site 2, a crossing southeast of Sidney is ranked "high" due to active right bank lateral migration since 1950 and ice jam potential.

<u>Mitigation Potential</u>
The original intent of this project was to locate a potential project site where historical modifications/restrictions to the Yellowstone River floodplain had increased the risk of gas and/or hazardous material pipeline failure through increase in stream energy and scour potential. A grant was then to be sought to complete site evaluation and project construction.

After carefully studying all the crossings, the project team assigned each of the 21 sites a floodplain restoration potential value of "low", "moderate", or "high" as shown in Figure 40. The project team came to the conclusion that improvement of channel conditions is rarely an option. Many pipeline crossings are in developed areas where changes to channel geometry are impractical. In rural settings, crossings are simply not located in places where portions of the floodplain can be reclaimed. Most of the crossings are in relatively narrow reaches where alternative channels are not available.

The ideal site would have a reduced floodplain width/function that could be restored, thus spreading flood energy over a greater area and reducing scour depths and lateral migration rates. <u>No such ideal project site was found.</u> Since no such site was found a RDG application was not completed. Section 3.0 and Appendix A provide a narrative and maps of where the pipelines either cross or are in the CMZ.

Since restoration is generally not an option, available options include channel armoring or pipe relocation with horizontal directional drilling (HDD). HDD can remove the pipeline from dynamic river effects such as lateral migration, scour, or long term channel degradation (down cutting). HDD does not have the negative geomorphic impacts that accompany locking portions of the channel in place with riprap, bendway weirs, levees, etc. Conversations with Conservation District Administrators indicate that HDD has become a common practice for new pipeline crossings on the Yellowstone. HDD should be considered as a standard Best Management Practice (BMP) for future pipelines as well as a replacement option for threatened pipelines.

Recommendations include:

- Request depth of cover data for all 39 pipelines within the CMZ from NPMS;
- Complete risk of exposure assessment of each pipeline based on depth of cover and site specific scour analysis;
- Each Conservation District is encouraged to adopt a Best Management Practice (BMP) policy of using Horizontal Directional Drilling (HDD) for future pipeline crossings and for existing at-risk pipelines.

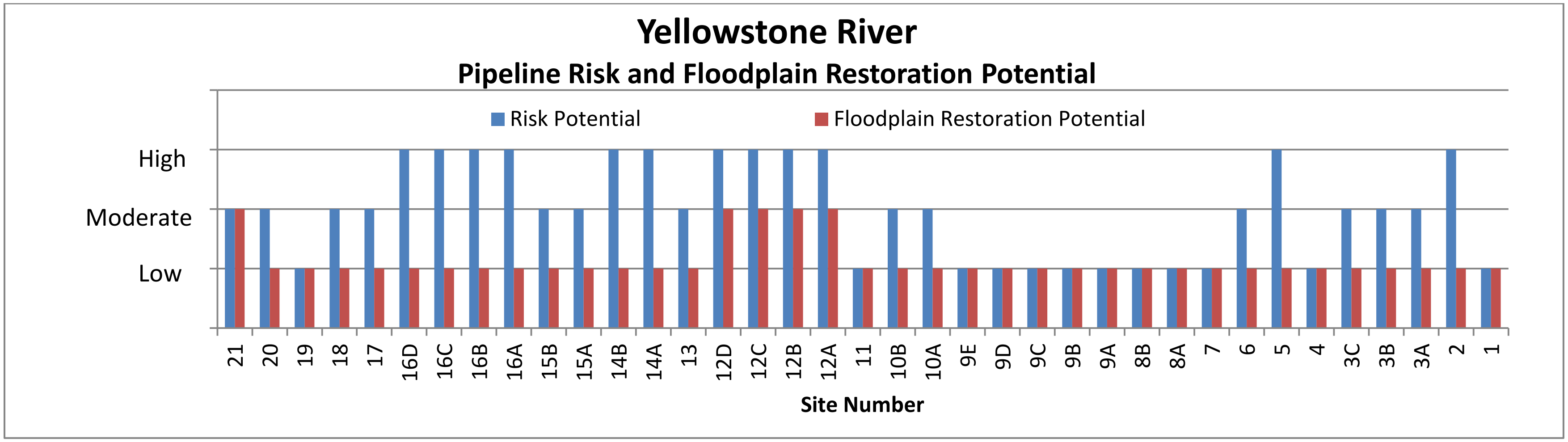

Figure 40. Summary of Site Risk Potential and Floodplain Restoration Potential

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3810 Valley Commons Drive
Suite 4
Bozeman, Montana 59718
Tel: 406.587.7275
Fax: 406.587.7278

www.atkinsglobal.com/northamerica

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