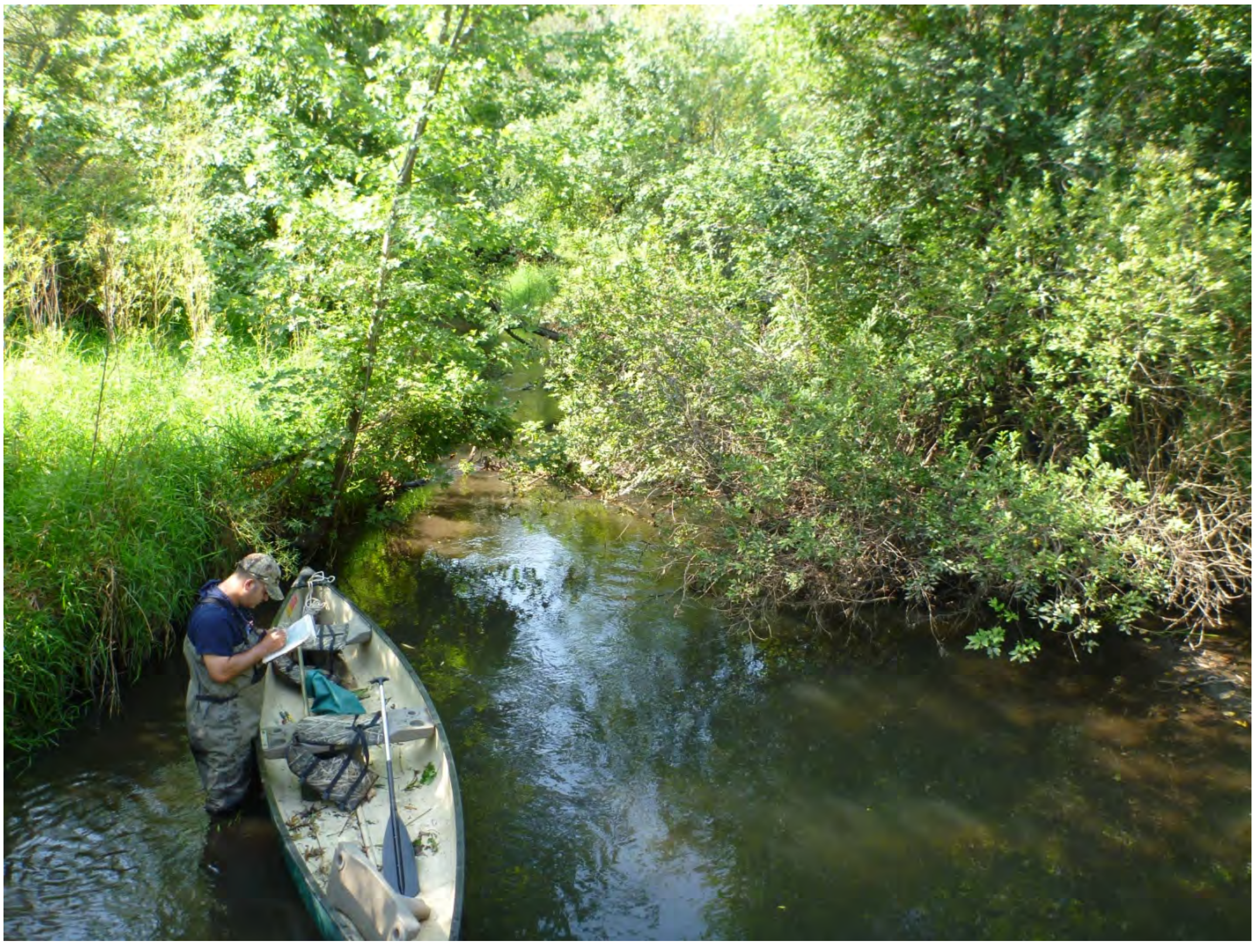
Vermillion River Watershed Joint Powers Organization

# Empire Drainages Geomorphic Assessment, Dakota County, MN: Final Report

April 30, 2013



Prepared for:

Vermillion River Watershed Joint Powers Organization
Physical Development Division
14955 Galaxie Avenue
Apply Valley, MN 55124

inter·fluve inc.
301 S. Livingston St., Suite 200
Madison, WI 53703

# 1. Executive Summary

The Vermillion River Watershed Joint Powers Organization (VRWJPO) contracted with Inter-Fluve Inc. to conduct a fluvial geomorphic assessment of the Vermillion River and its tributaries within the Empire Township from approximately the end of Linden St. in Farmington to State Highway 52 (Coates Blvd.) in western Dakota County. The goals of this rapid geomorphic assessment were to:

1. Understand the streambed and bank stability
2. Identify grade control points, knickpoints, and areas of accelerated erosion
3. Characterize aquatic and riparian habitats
4. Identify opportunities for restoring geomorphic processes and habitat conditions

The study area included 12.3 miles of the Vermillion River and 36.5 miles of its tributaries. The geomorphic assessment noted information such as soils, streamflow, streambed grain size, infrastructure, land use, and vegetation. We also researched the history and geology of the watershed.

Historically, this portion of the Vermillion watershed was marsh and wetland surrounded by prairie with some riparian forest. Past agricultural and urban endeavors have altered the drainage characteristics of the land. Early settlers commonly drained the land, removed riparian vegetation, and straightened the channels for agriculture. While much of the watershed remains in agricultural use, the western edge of the study area has seen increased development pressures with associated stormwater issues, lack of riparian buffers, and flood control. Presently, the river is continuing to adjust to anthropogenic changes in the landscape.

Inter-Fluve identified 28 potential projects along the Vermillion River and 20 potential projects along the tributaries within the study area. We used a ranking system based on 13 metrics to prioritize these projects. The highest scoring projects within the drainage involved:

1. Restoring tributary channels to a more natural, sinuous planform
2. Restoring mature riparian buffers along the tributaries and the main stem
3. Restricting cattle access to the river
4. Repairing or improving bridge infrastructure and crossings

In general, we noted five recurring issues that require restoration attention throughout the Empire drainages:

1. Localized bank erosion
2. A young, sparsely vegetated riparian corridor
3. Encroachment from pasturing and residential development
4. Undersized bridges
5. Lack of in-stream habitat complexity

There are distinct locations within the Empire drainages that have previously been restored. It is our recommendation that future restoration projects connect to existing restoration efforts. We also recommend capitalizing on the educational and recreational opportunities that intact river systems provide. As many of our recommended projects will require landowner permission, we suggest extensive public outreach and landowner interaction to find mutually agreeable solutions.

## Table of Contents

## 2. Introduction

In May 2012, the Vermillion River Watershed Joint Powers Organization (VRWJPO) contracted with Inter-Fluve to conduct a fluvial geomorphic assessment of the Empire Drainages, which included the Vermillion River and associated tributaries within the Empire Township between Linden St. and State Highway 52 (Coates Blvd.) (Figure 1). The goals of this rapid assessment were to improve our understanding of river bank stability by identifying grade control points, knickpoints, areas of accelerated erosion, and habitat quality issues as well as identifying opportunities where restoring geomorphic processes and habitat conditions would be beneficial.

The report that follows is a summary of the data collected and the potential restoration and management projects identified along the Empire Drainages. In 2011 and 2012, Inter-Fluve completed a similar geomorphic assessment along North and Middle Creeks and their tributaries for the VRWJPO. This document is set up in a similar format to allow the VRWJPO to efficiently read the results and analyses. As in the prior report, individual reach descriptions, channel reconnaissance forms, potential project forms, detailed scoring sheets for the potential projects, and potential project maps have been placed in the appendices:

- Appendix A: Review of Geomorphology Principles
- Appendix B: Management Recommendations - Description of Project Types
- Appendix C: Reach Descriptions
- Appendix D: Channel Reconnaissance Forms
- Appendix E: Potential Project Forms
- Appendix F: Detailed scoring sheets for the potential projects
- Appendix G: Detailed maps of the potential projects

Inter-Fluve conducted the field work for the fluvial geomorphic assessment in May and August 2012. During the assessment, we identified 28 potential restoration projects along the Vermillion River and 20 along the tributaries. In order to prioritize these projects for funding allocation, we developed a scoring and ranking system based on 13 metrics. Each project can be ranked by a single metric or multiple metrics, so its priority can be a result of any combination of metrics chosen by the VRWJPO staff. For this assessment, we added a metric called 'Land Use Type.' Because these reaches are in more urban and heavily agricultural areas than those in the North Creek and Middle Creek assessment, knowledge of adjacent land use will give us a better understanding for the level of restoration that can take place.

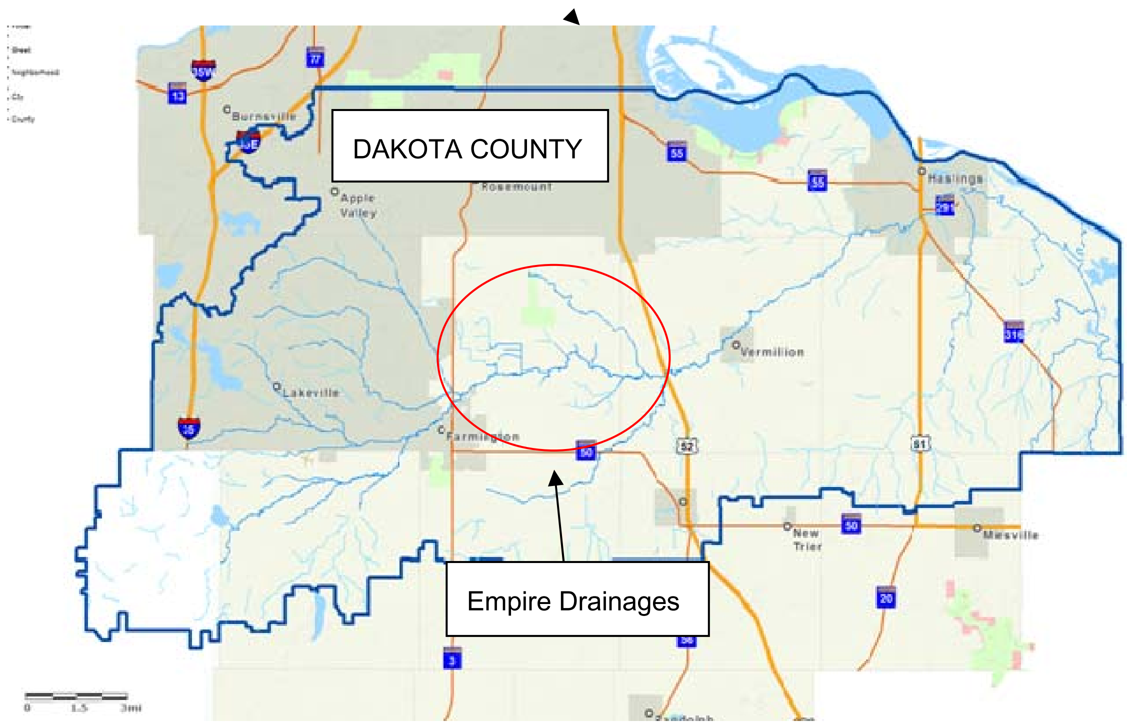



Figure 1: The Empire Drainages within the Vermillion River Watershed are in the central portion of Dakota County (dark blue polygon).

*Summary of Vermillion River Watershed Standards*

The VRWJPO adopted a Watershed Management Plan in 2005 and a set of amended Standards in 2008. The Standards are water quality outcomes that were put in place to guide activities in the Vermillion River watershed and cover six topics:

- Floodplain Alteration
- Wetland Alteration
- Buffers
- Stormwater Management

- Drainage Alteration
- Agriculture

The criteria associated with each of these Standards regulates all new development in the watershed including commercial, residential, and industrial construction, road crossings, drainage systems, and river and habitat restoration. Having these Standards in place is extremely important for maintaining high quality aquatic and riparian habitat and improving habitat elsewhere. During our assessment of the Empire Drainages, we observed recently-constructed residential and commercial developments, and all of these have associated stormwater retention basins to catch and filter runoff before it enters the stream system. It is unknown if these stormwater basins are sufficient to capture the amount of stormwater produced. In addition, older developments do not have stormwater basins.

Sufficient riparian buffers are essential for high quality aquatic and riparian habitat, and the Vermillion River Watershed Joint Powers Organization (VRWJPO) developed a classification scheme for waterways and wetlands with associated standards for buffer widths. The largest buffer requirement is provided for the Conservation Corridor Lower and Upper Reaches with 150 foot average, and 100 foot minimum, buffer width. A 100 foot average and 65 foot minimum buffer width is required for Principal Connector channels in an Aquatic Corridor. A 50 foot average and 35 foot minimum buffer width is required for Tributary Connectors in the Aquatic Corridor. Water Quality Corridors require the smallest buffer with 30 foot average and 20 foot minimum widths (VRWJPO, 2008). The main stem Vermillion is classified as a Conservation Corridor with the 150 foot buffer requirements (Figure 2). Many of the tributaries are Principal Connectors (100 foot buffer requirements) and Secondary Connectors (50 foot buffer requirements), with some of the lower portions of the Principal Connectors classified as trout streams. During our assessment, we found much of the main stem Vermillion River to have the required riparian buffer, but many of the tributaries have minimal buffer widths.

The VRWJPO Standards require the buffer regulations to be met during the process of subdivision of land or lot split. In cases where subdivision of land or lot split has not occurred on a water where a buffer is required, then a reduced, or no, buffer may exist. Dakota County's Shoreland Ordinance was adopted to meet the Department of Natural Resources (DNR) requirements for state shoreland regulations. The ordinance requires a 50-ft buffer on agricultural lands along DNR protected waterways within the unincorporated communities. Cities are solely responsible for implementing DNR shoreland regulations in their own communities and is not under the purview of the VRWJPO or Dakota County. In this case, the County Shoreland ordinance applies to the main stem and larger tributaries, but not to many of the principal or secondary connectors as they are not DNR protected waters. Voluntary buffer implementation would be the only avenue to achieve sufficient riparian buffers for those reaches where the VRWJPO Standards or the Dakota County Shoreland Ordinance are not applicable.

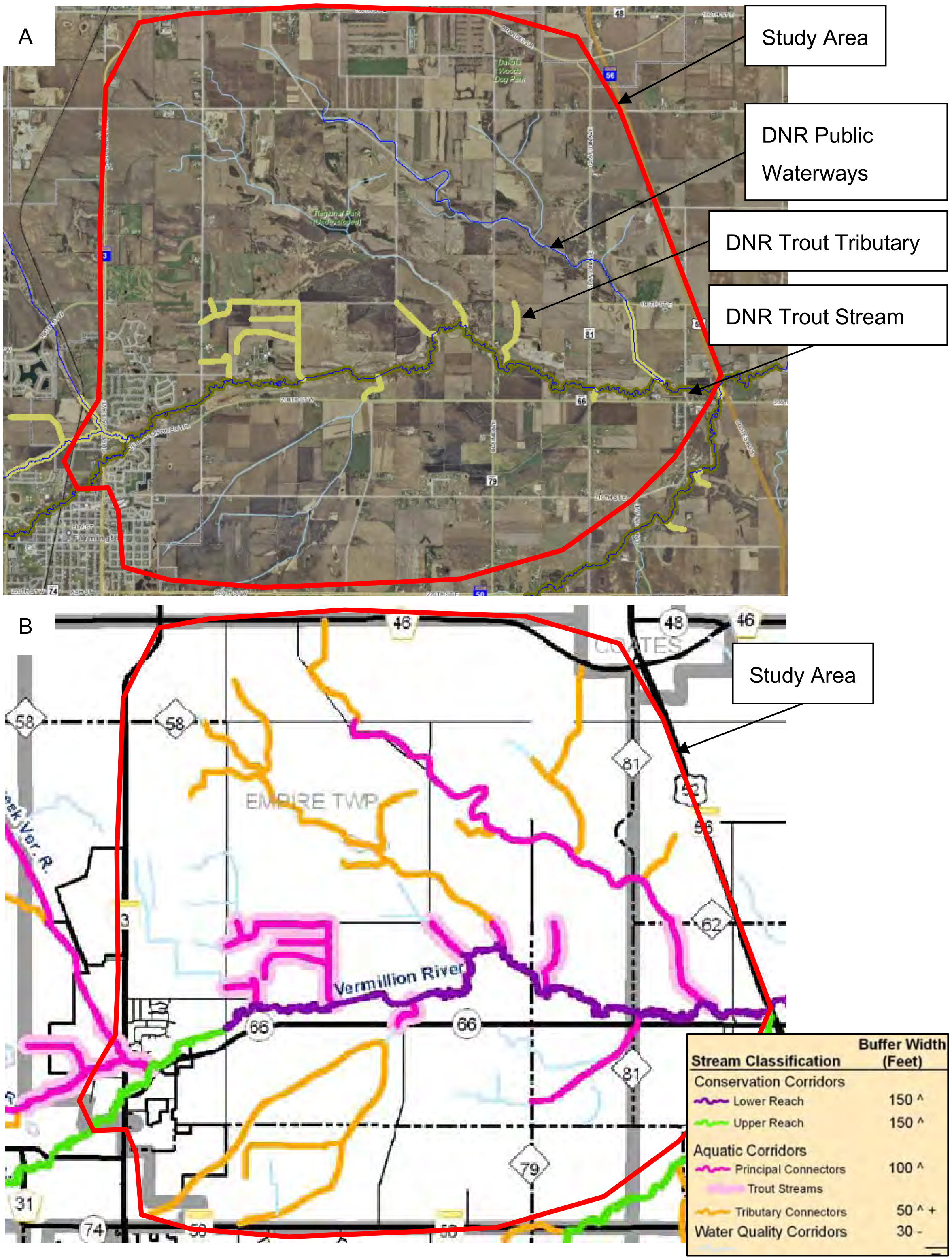



Figure 2: (A) DNR public waterways and trout streams within the study area (Dakota County GIS) and (B) stream classification and buffer width standards for the Vermillion River and its tributaries within the study area (modified from VRWJPO, 2006).

# 3. Data Collection / Methods

## 3.1. *Existing Data*

Inter-Fluve personnel collected and analyzed existing information about the Vermillion River and its tributaries including aerial photographs, plat maps, and geologic maps.

The Empire Drainages are located within the central portion of Dakota County and the Vermillion River watershed. The Vermillion River within the study area is 12 miles in length, and eight primary and secondary tributaries combine for a total of 36.5 miles. The Empire Drainages stream networks primarily flow through agricultural lands with some residential developments in the western portion of the study area (Figure 3).

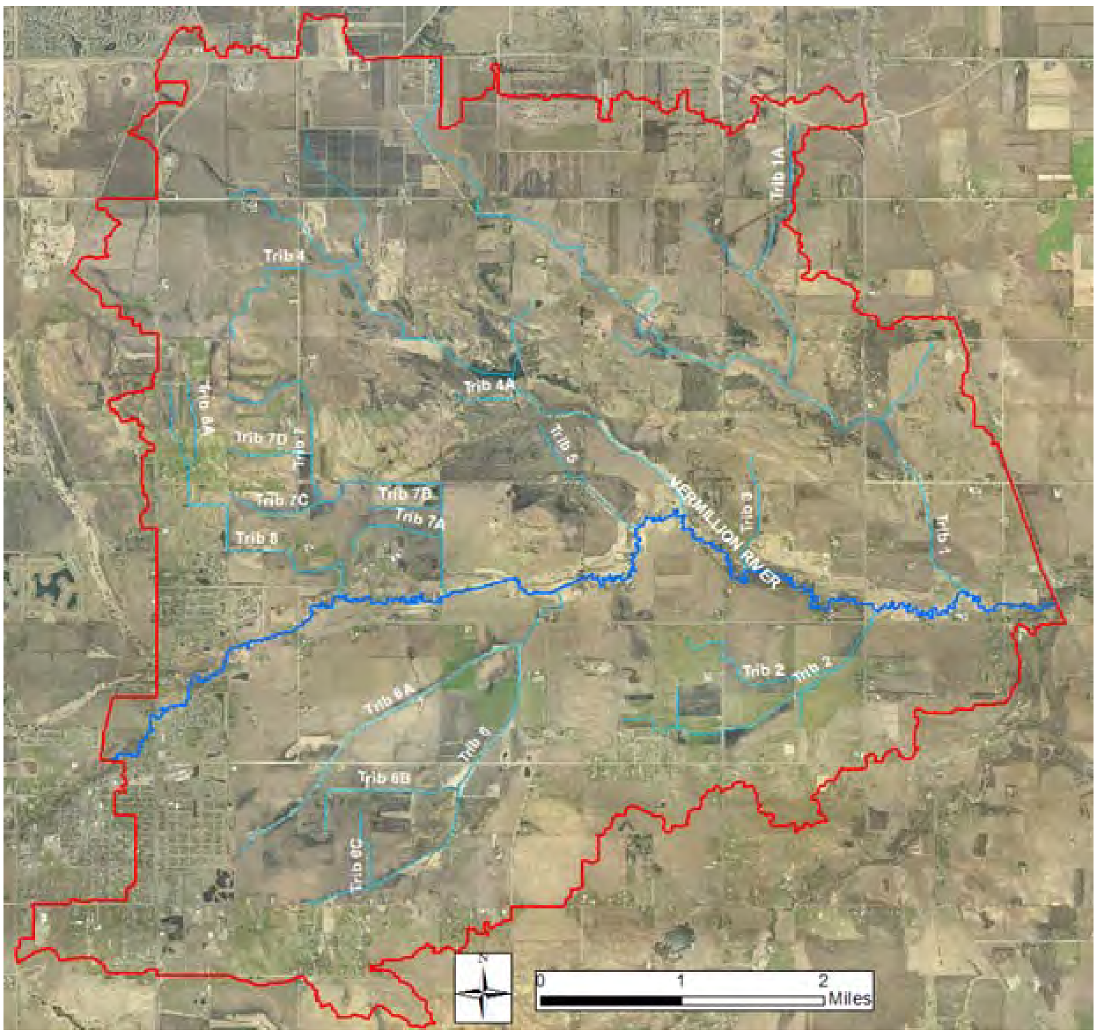



Figure 3: The Vermillion River (dark blue) and its tributaries (light blue) within the study area (red line).

The bedrock within the study area consists primarily of Prairie du Chien dolostone, containing thin beds of sandstone and chert. St. Peter Sandstone is found between Tributaries 1 and 4 north of the Vermillion River. The St. Peter Sandstone is fine to medium-grained and outcrops frequently in Dakota County. The lower reaches of the Vermillion River in the study area contain Jordan Sandstone, a coarser-grained sandstone (Figure 4).

Along the main stem of the Vermillion River, the surficial geology is primarily floodplain alluvium with Des Moines Lobe mixed outwash along the southern tributaries and in the north-central portion of the study area. Superior Lobe outwash is in the northern part of the study area along with till and small areas of exposed bedrock (Figure 4).

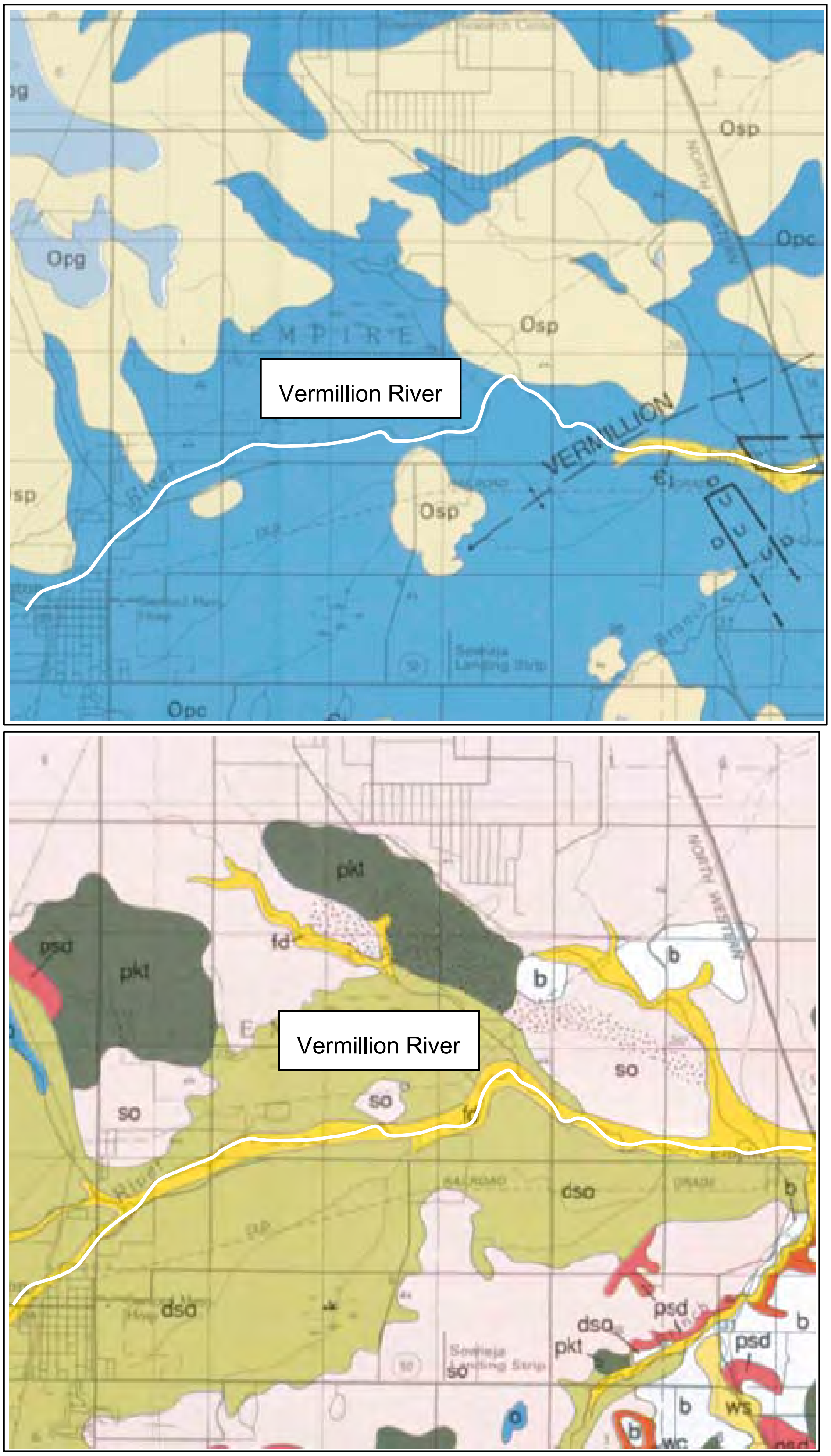



Figure 4. Bedrock (top) and surficial (bottom) geology in the Empire Drainages study area. Bedrock: Opc - Prairie du Chien, Osp - St. Peter Sandstone, ϵj - Jordan Sandstone. Surficial: dso - Des Moines Lobe mixed outwash, so - Superior Lob outwash, pkt - "old gray" till, b - bedrock, fd - floodplain alluvium.

The first land surveys in Dakota County were documented in plat maps from 1855. Later USGS topographic maps (1957, 1974, 1985) and aerial photographs (1937, 1951, 1964, 1974, 1991, 1997, and nearly every year since 2000) show more detail and the channel and land use changes that have occurred. The 1855 maps show the Vermillion River as a sinuous channel ranging from 13 to 16.5 feet in width (20-25 links) (Figure 5). Later topographic maps and air photos show an increase in agriculture and residential development (Figure 6). The urbanization within the Empire drainages reaches is restricted to the river near Farmington and tributaries outside of the main stem Vermillion River (Figure 6).

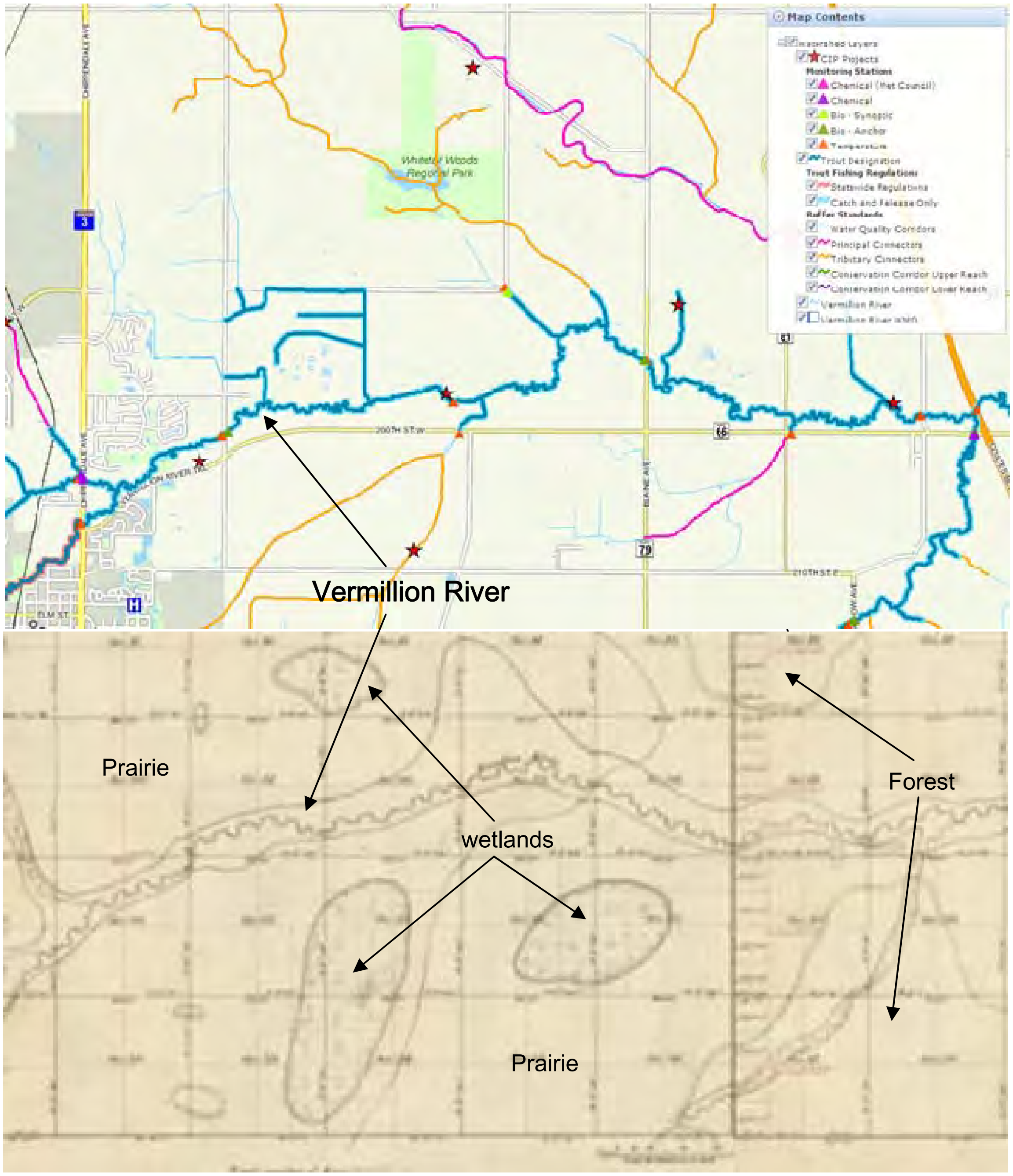



Figure 5: Comparison of current conditions (top) with the plat maps of 1855 (bottom). Much of the area was prairie in 1855, with some wetlands and forested areas.

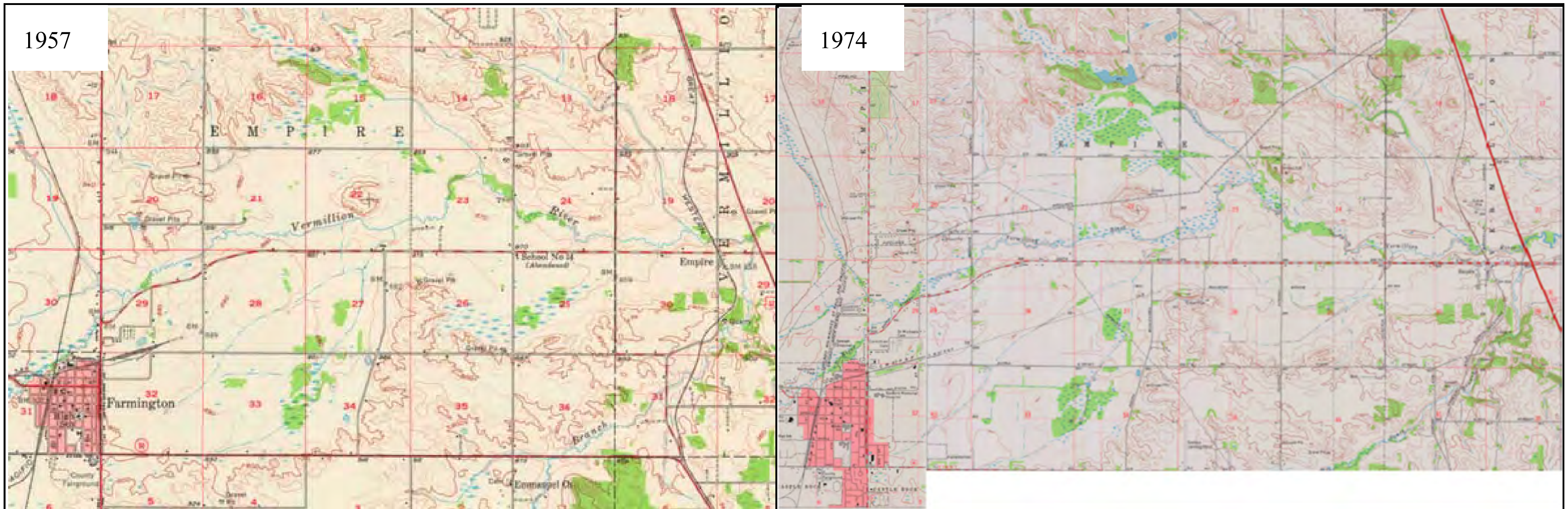



Figure 6: USGS maps from (clockwise from upper left) 1957, 1974, and 2010 show the changes in land use over time. The urbanization of the western edge of the watershed is especially evident in the 2010 map.

The main stem Vermillion River in the Empire Drainages study area is generally a sinuous channel flowing through a wide riparian corridor with agriculture fields nearby. The channel is generally in good geomorphic condition with decent aquatic habitat compared to some of the more straightened tributaries in the watershed. Analysis of historic air photos suggests, though, that changes have been made in and along the Vermillion River main stem. Portions of the channel were straightened prior to 1937, likely due to road construction, and straightening continued through the following decades (Figure 7). Most of the trees appeared to have been cleared along the riparian corridor in the 1937 or 1974 air photos, but in later photos these areas were filling in again with riparian vegetation. Fields continue to be tilled close to the channel in some places, but, in most of the study area, the Vermillion River has a substantial riparian buffer.

Most of the tributaries to the Vermillion River in the study area had been straightened and ditched by 1937 or 1951. Some of those ditched between 1937 and 1951 were unrecognizable as a channel in 1937 but are now clearly visible channels, suggesting increased drainage from fields.

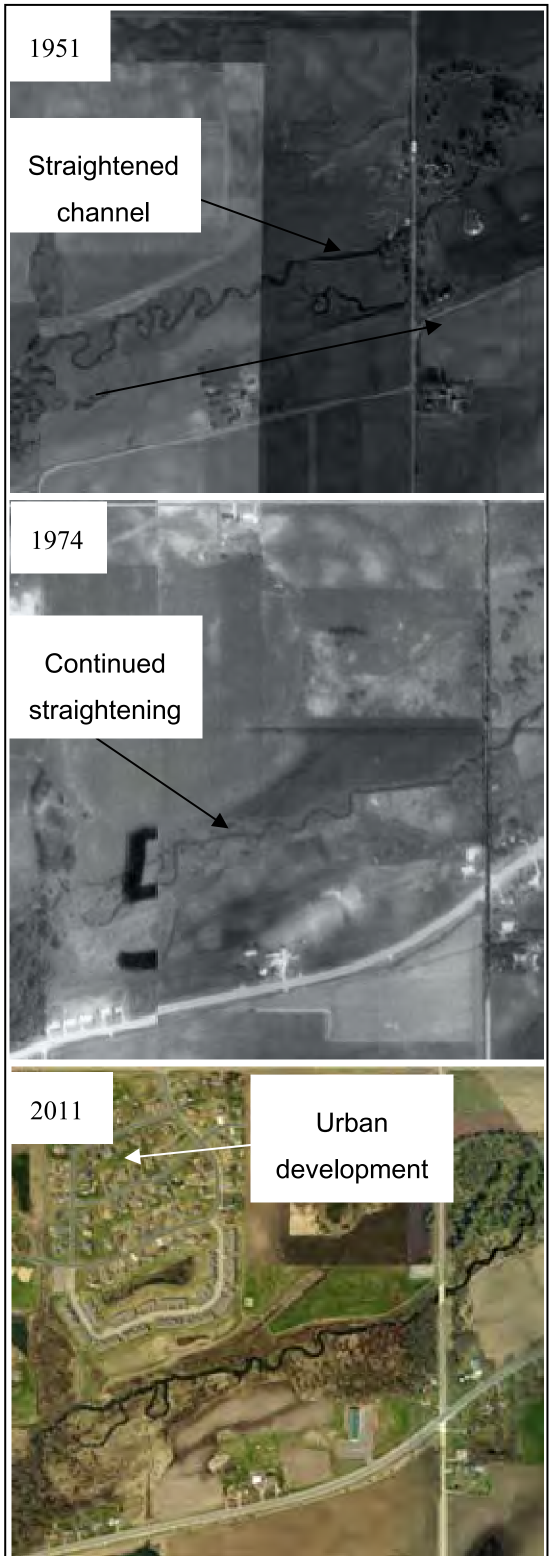



Figure 7: Air photos from (top to bottom) 1951, 1974, and 2011 showing a section of the Vermillion River where land use practices have straightened the river and altered the riparian corridor.

### 3.2. Fluvial Geomorphology

Inter-Fluve geomorphologists assessed the main stem Vermillion River and its tributaries within the Empire Drainages subwatershed. We completed a rapid geomorphic assessment by boat along the 12.3 miles of the Vermillion River. We noted information on soils, stream bed grain size, infrastructure, land use, and vegetation on reconnaissance forms. Because all of the tributaries were either straightened ditches or barely perceptible swales in the landscape, we completed a rapid reconnaissance survey by car of the 35 miles of tributary channel, stopping at the road crossings to assess the channel on each side and the crossing itself. We took digital photographs at representative locations, identifying geomorphic traits, land use influences on the river, and sites that should be restored. We identified these sites as potential projects.

Inter-Fluve scientists developed the reconnaissance form, and it includes information on general channel and fluvial geomorphic conditions, sediment composition, depositional features, riparian vegetation and floodplain morphology, channel stability, channel geometry, and human impacts on the channel and floodplain (Appendix D). Appendix C provides a description of each reach based on these forms.

### 3.3. Project Identification

Inter-Fluve staff identified potential projects in the field and evaluated and ranked the projects based on 13 metrics (Table 1). In this system, the scoring refers mainly to the degree that a completed project will affect each metric. For example, an infrastructure risk score of 1 reflects that, if nothing is done, there will still be no risk to infrastructure from channel instability. The lack of risk could be because no infrastructure exists at the site or the risk is extremely low. Conversely, a score of 7 indicates that if nothing is done, public safety and property are under imminent risk. Other metrics gauge the effect of potential projects on channel stability, ecological benefit, and nutrient loading.

Potentially expensive projects are scored lower, as are more complicated, larger projects. Sediment and nutrient loading, erosion control, and public education metrics are reflective of project size, and thus the ranking system allows for some cost versus benefit analysis. A relatively inexpensive project that can restore a large area or length of stream with manageable design and permitting will score among the highest under this system. The VRWJPO should use this ranking as a guide to determine the projects that accomplish its goals and objectives and stay within the available budget. Appendix E includes all of the potential project forms that describe each project, recommend management and restoration solutions, provide the metric scores, and include pictures of the problem area.

Table 1: Metrics for scoring potential projects

| *Metric Score:* | *1* | *3* | *5* | *7* |
|---|---|---|---|---|
| **Infrastructure risk** | No risk to infrastructure with no action, no infrastructure present, or no risk to public safety | Low to moderate infrastructure risk and minimal risk to public safety with no action, or inf. value <$50,000 | Infrastructure at moderate but not immediate risk, moderate public safety risk, no potential injury, or infrastructure value <$500,000 | Infrastructure at high, immanent risk of failure with no action, or potential loss of life. Public safety at risk or infrastructure value >$500,000 |
| **Erosion/channel stability** | Minimal improvement to overall stream stability and function, <250 ft of channel bank | Low to moderate improvement of 250-1000 ft of channel bank | Moderate improvement 1000-2500 ft of channel bank | Significant improvement to overall stream stability and function or >2500 ft |
| **Project complexity** | Groundwater and surface water issues, professional specialty design services required, heavy oversight, major earthwork, EAW/EIS permitting | Surface water restoration, engineering plans required, earthwork involved, significant permitting | Moderately complex, no specialty engineering required, minor earthwork, some basic permitting | Elementary solution, shelf design, volunteer and hand labor implementation, no permits |
| **Sediment/nutrient loading** | No load reduction resulting | Some minor reduction in sediment pollution, increased filtration of nutrients | Moderate reduction in bank erosion and surface runoff entering stream through buffer or other BMPs > 30 ft | Major erosion control through significant BMP installation, stormwater detention, infiltration or buffer filter. |
| **Project cost** | > $300K | $201 - $300K | $51 - 200K | $0 - $50K |
| **Aesthetic impact** | No impact | Low impact | Moderate positive impact | High positive impact |
| **Location** | Mouth to lower 1/4 of watershed | Lower 1/4 to 1/2 of watershed | 1/2 to upper 3/4 of watershed | Upper 3/4 to headwaters |
| **Fish Passage** | No impact on fish passage | Low impact (eg. improve depth through culvert, minimal velocity reduction) | Moderate impact (removes perch or other small barrier, natural bottom culvert replacement) | High impact (dam removal) |
| **Property Ownership** | 1: not allowed; not cooperative | 3: unknown | 5: access approved; cooperative | |
| **Public Education** | No public education value | Low value - Poor site access, difficult to see, small project | Moderate value - Good access, moderate demonstration value | High value - Easy access, cooperating landowner, good demonstration and high visual impact |
| **In-stream Ecological Benefit** | No in-stream ecological benefit | Low benefit - Spot location, small size | Moderate benefit - subreach based, moderate sized project | High benefit - Reach based, >1000 ft of stream |
| **Riparian Ecological Benefit** | No riparian ecological benefit | Low benefit - Spot location, small size | Moderate benefit - subreach based, moderate sized project | High benefit - Reach based, large riparian areas, floodplain scale |
| **Landuse Type** | Highly urbanized, dense commercial, or industrial development | Residential, moderate density within 100' of channel | Agriculture, may have buffer | Within a natural buffer, no adjacent infrastructure |

# 4. Summary of Restoration Projects

## *4.1. Main stem Vermillion River*

We identified 28 areas along the main stem Vermillion River with some degree of geomorphic or ecological problem. See Appendix F for full scoring spreadsheets and Appendix G for detailed maps.

The Vermillion River is a low gradient, meandering river that enters the Mississippi River near Hastings and Red Wing, MN. Our study area included a 12.3 mile section from State Highway 52 (Coates Blvd.) in western Dakota County upstream to the end of Linden St. in Farmington, MN. The land uses in this reach are primarily agriculture, with some cattle pasturing, and urbanization. Due to tributary ditching and straightening and tiling of agricultural fields, the amount of water entering the Vermillion River has increased. These practices have resulted in flashy runoff events and compromised in-stream habitat diversity. The majority of potential restoration projects that we identified along the Vermillion River main stem are bank stabilization and riparian management (see Appendix B for discussion of project types). The highest scoring projects involved restoring long sections of straightened channels to more natural sinuous channels, restoring riparian buffers, and replacing bridges.

Historical land use involved clearing the land for agricultural use and encroachment upon the riparian corridor and associated channelizing to maximize the cropland. Agricultural land has decreased infiltration capacity and reduced the vegetated riparian corridor, resulting in larger quantities of rainwater reaching the creeks more quickly. With residential development increasing in the later decades of the 20th century, more land became less pervious, forcing even more water into the river following storms. Increased water flow has caused incision and bank erosion as the river adjusts to the changing conditions. The main stem Vermillion River channel has more than doubled in width from 13 to 16.5 feet in 1855 to 30 to 40 feet in 2012.

While challenging and costly, natural channel restoration has the potential to improve the natural functions of the river and floodplains and dramatically improve habitat. One of the biggest challenges with this type of restoration is obtaining landowner permission and cooperation.

The upstream reaches of this assessment took place in Farmington where the Vermillion River flows through residential neighborhoods with landowners that maintain mowed lawns to the edge, or within a few feet of the edge, of the channel. The lack of riparian buffer reduces the infiltration time and increases the potential for fertilizers, pesticides, herbicides, and other household contaminants to flow unchecked into the river, thus reducing water quality. Additionally, storm events wash off chemicals applied to residential landscaping as well as dirt from city streets. These chemicals go untreated into the Vermillion River resulting in decreased water quality during many periods of the year. Increasing riparian buffers and planting native riparian trees, shrubs, and forbs could increase water quality by dramatically decreasing the amount of contaminants (including fine-grained sediment) that reach the river.

Stormwater retention or detention basins could significantly slow the release of water downstream following storms in many areas of the more urban reaches of the Empire Drainages and also throughout the watershed. Expansive wetlands historically served this purpose (see plat maps from 1855 in Figure 5).

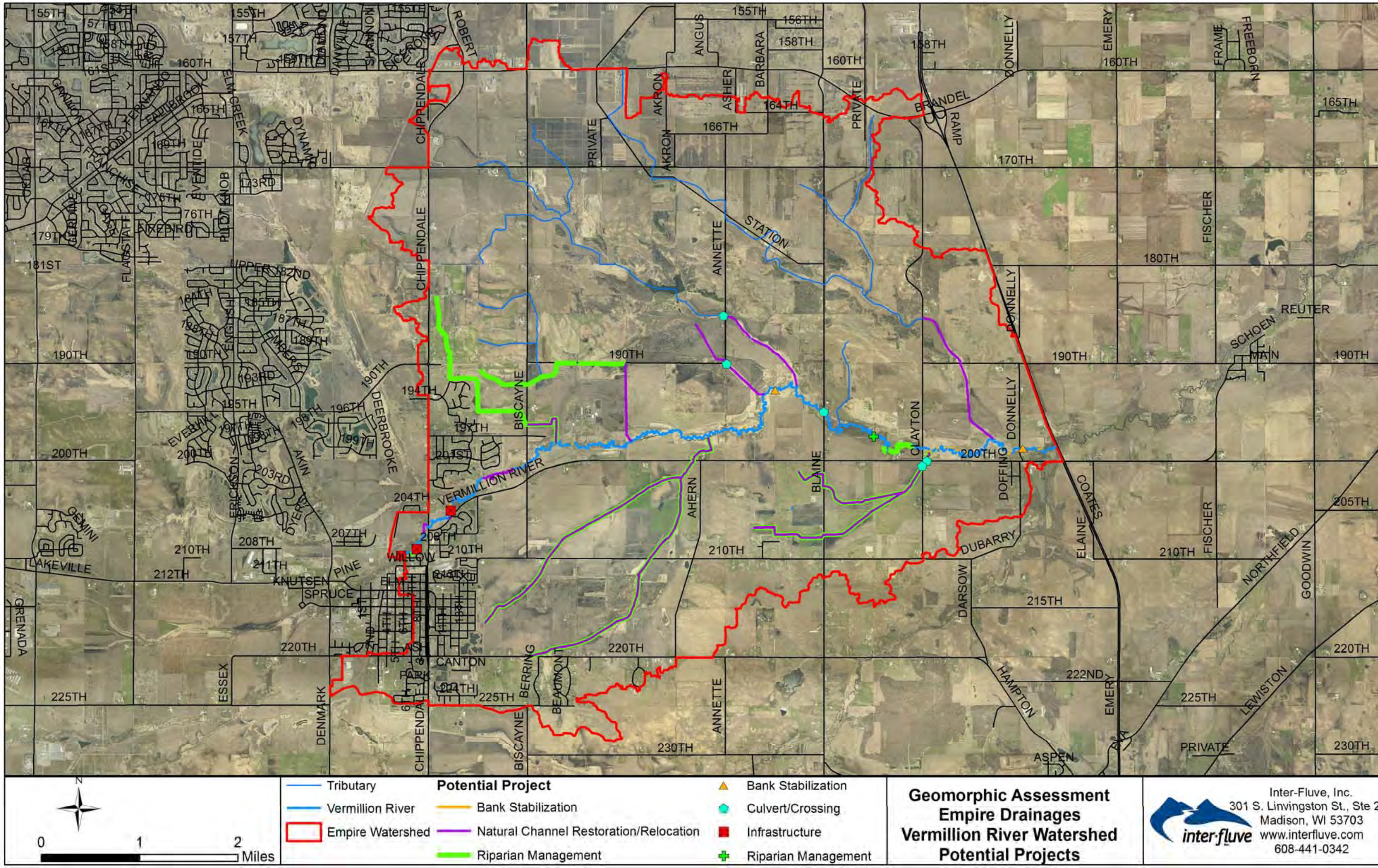



Figure 8: Overview of potential projects in the study area.

Table 2: Summary of potential restoration and management projects with scores. Projects are on the Vermillion River in the Empire Drainages study area. B = bank stabilization; R = riparian management; C = crossings; N = natural channel restoration/relocation; I = infrastructure.

| Project Number | Location | Primary Project Type | Total Score | Description |
|---|---|---|---|---|
| **PP01** | 1050-1150, left bank | B | **41** | Bank erosion, lack of woody debris |
| **PP02** | 2250, left bank | B | **43** | Concrete debris on bank |
| **PP03** | 3150-3250, right bank | B | **45** | Minor bank erosion |
| **PP04** | 7800-7875, right bank | B | **43** | Minor bank erosion |
| **PP05** | 8150-8300, left bank | B | **43** | Minor bank erosion |
| **PP06** | 9150-9250, left bank | B | **43** | Minor bank erosion |
| **PP07** | 9825-9900, left bank | B | **41** | Minor bank erosion |
| **PP08** | 10,250-10,350, left bank | B | **43** | Minor bank erosion |
| **PP09** | 11,200-11,250, left bank | B | **41** | Minor bank erosion |
| **PP10** | 11,450-11,500, left bank | B | **43** | Minor bank erosion |
| **PP11** | 11,825-11,900, left bank | B | **43** | Minor bank erosion |
| **PP12** | 12,100-12,200, left bank | B | **41** | Minor bank erosion |
| **PP13** | 13,200-15,000, right bank | R | **43** | Land use encroachment onto riparian corridor, minor rip rap use on banks; grazing impacts |
| **PP14** | 15,500-15,200, right bank | R | **41** | Right bank is devoid of riparian buffer |
| **PP15** | 17,400, left bank | R | **45** | Encroachment; minimal riparian cover |

| | | | | |
|---|---|---|---|---|
| **PP16** | 22,850 | C | **41** | Bridge replacement |
| **PP17** | 27,500 | B | **42** | Minor outside bend erosion |
| **PP18** | 32,800-32,950 | B | **45** | Minor bank erosion |
| **PP19** | 44,350-44,400, left bank | B | **47** | Minor bank erosion |
| **PP20** | 47,450-47,550, right bank | B | **49** | Right bank erosion around lunkers |
| **PP21** | 52,600-55,000 | N | **57** | Channel straightening, lack of vagetation |
| **PP22** | 58,100-58,200, left bank | B | **45** | Minor bank erosion |
| **PP23** | 58,500 | I | **45** | Footbridge should be removed, no longer functioning |
| **PP24** | 58,950-59,050, right bank | N | **45** | Eroding bank near road |
| **PP25** | 61,000-61,625 | N | **59** | Bank erosion due to cattle trampling; straightened channel |
| **PP26** | 63,000 | I | **47** | Footbridge should be removed, no longer functioning |
| **PP27** | 63,500-63,600, right bank | R | **43** | Grass clippings on channel bank |
| **PP28** | 64,400, right bank | I | **41** | Storm pipe causing erosion |

### 4.2. Tributaries

We identified 20 areas along the tributaries of the Vermillion River with some degree of geomorphic or habitat problem (Table 3). All of the tributaries are straightened ditches conveying water between and through farm fields. Many of these ditches may not have been historically perennial streams and most do not appear on the 1855 plat maps. Because of the draining of wetlands, tiling of fields, increased development, and increased rainfall in recent decades, many of these streams contain water year-round. The cool water emanating from the field tiles and large tracts of land owned by state and municipal entities provides opportunities for river and wetland restoration.

Of the 20 potential projects identified, nine are natural channel restoration projects and six are riparian management (buffer width and riparian vegetation) projects. Many of these are unlikely to be feasible in the near term as they involve many landowners and are adjacent to active agriculture. In areas where channel restoration is not feasible, maintaining sufficient riparian buffers and planting trees and shrubs may be more feasible. The remaining projects in the tributaries include road crossings and bank erosion. One culvert is in disrepair, and this is starting to impact a paved road. This should be assessed by a bridge/road engineer and repaired or replaced in the near future. Another dirt road crossing was partially washed away during a rain event. If the road is no longer necessary, the remainder of the road and culvert should be removed to restore full channel and floodplain connection.

In the upper portions of the tributary watersheds, developing natural wetlands or stormwater basins instead of natural channel restoration would be helpful in slowing down the release of stormwater downstream. Construction of basins in the tributary areas would require the full cooperation of the farmers who own and operate much of the land. Basins could be a beneficial solution for all stakeholders, because large portions of the farms are currently flooded during storm events. By converting portions of cropland to stormwater basins, some cropland will be lost but cropland downstream could be flooded less frequently. Stormwater basins would also reduce the excessive sediment flux downstream, reduce bank erosion and incision, and slow the release of warm stormwater into the channels.

Table 3: Summary of potential restoration and management projects with scores. Projects are on the tributaries to the Vermillion River. B = bank stabilization; R = riparian management; C = crossings; N = natural channel restoration/relocation; I = infrastructure.

| Project Number | Location | Primary Project Type | Total Score | Description |
|---|---|---|---|---|
| **Trib 1 PP29** | 0-8100 | N | **41** | Straightened ditch with little riparian buffer |
| **Trib 2 PP30** | 700 | C | **37** | Perched culvert and steep - fish passage barrier |
| **Trib 2 PP31** | 1,100 | C | **38** | Culvert in disrepair - hazard to road and safety risk; perched 2ft - fish passage barrier |
| **Trib 2 PP32** | 1050-1100 | B | **41** | Left bank erosion near road |
| **Trib 2 PP33** | 0-12,000 | N | **43** | Straightened ditch with little riparian buffer |
| **Trib 2 PP34** | 0-12,000 | R | **43** | Narrow riparian buffer with no canopy cover |
| **Trib 2A PP35** | 0-7100 | R | **43** | Narrow riparian buffer with no canopy cover |
| **Trib 2A PP36** | 0-7100 | N | **43** | Straightened ditch with little riparian buffer |
| **Trib 4 PP37** | 0-5500 | N | **54** | Straightened ditch with little riparian buffer |
| **Trib 4 PP38** | 5,500 | C | **37** | Undersized culvert - road prism blocks floodplain connection |
| **Trib 5 PP39** | 2,700 | C | **51** | Dirt road and culvert partly washed away |
| **Trib 5 PP40** | 0-5600 | N | **55** | Straightened ditch with little riparian buffer |
| **Trib 6 PP41** | 0-17,100 | N | **55** | Straightened ditch with little riparian buffer |
| **Trib 6 PP42** | 0-17,100 | R | **59** | Narrow riparian buffer with little canopy cover |
| **Trib 6A PP43** | 0-13,600 | N | **55** | Straightened ditch with little riparian buffer |

| | | | | |
|---|---|---|---|---|
| **Trib 6A PP44** | 0-13,600 | R | **59** | Narrow riparian buffer with little canopy cover |
| **Trib 7 PP45** | 0-4300 | N | **57** | Straightened ditch |
| **Trib 7 PP46** | 4300-12,900 | R | **61** | Narrow riparian buffer with little canopy cover |
| **Trib 8 PP47** | 0-3100 | N | **54** | Straightened ditch with little riparian buffer |
| **Trib 8 PP48** | 0-14,200 | R | **61** | Narrow riparian buffer with little canopy cover |

# 5. General Recommendations and Conclusions

The Vermillion River and surrounding landscape within the study area has been dramatically altered since agriculture and settlement began in the mid-1800s. Prairies and forestland were cleared and wetlands were filled in or drained for agriculture, river channels were straightened and the dimensions altered, and portions of farmland were later converted to residential development. All of this has significantly impacted the aquatic habitat in a number of ways. Warm stormwater, originating primarily from tributary watersheds, more rapidly enters the stream networks carrying many chemicals applied to lawns and crops as well as sediment from farms and streets. Wetlands have either been eliminated or are no longer fully functional, resulting in the loss of stormwater retention capacity and wetland habitat. Riparian vegetation is generally not well established and consists of young trees or the invasive reed canary grass. While most of the upper watersheds draining to the Empire Drainages were likely prairie in the past, portions of the riparian corridors may have been forested or contained occasional trees. The lack of mature trees today results in poor canopy cover, reduced shading, and reduced woody recruitment in the channel and the loss of resultant aquatic habitat.

A few factors within this study area are positive and will help the chances of successful geomorphic and habitat restoration. There are multiple sections of the Vermillion River that have been recently restored. These include both in-channel work such as placement of rock veins, large woody debris and associated root-balls, and even re-configuring hundreds of feet of channelized river into a more sinuous planform. The restoration is not restricted to the in-channel work, and many sections of the riparian corridor have been restored as well. There is evidence of extensive tree planting and possibly river setbacks in place. The Empire Drainages is therefore still adapting to a newly restored environment.  In areas where the channel would benefit from increased sinuosity, the generally wide riparian buffer along the Vermillion River and predominately agricultural land use provide the opportunity to implement restoration practices to increase channel sinuosity and improve in-stream habitat. The 1855 plat maps and historic air photos provide a template for a more natural channel planform.

The tributaries to the Vermillion River may provide more opportunity for channel and habitat restoration than the Vermillion River, and their restoration may improve water quality conditions on the main stem as well. All of the tributaries to the Vermillion River in the study area have been straightened into ditches. Natural channel and wetland restoration for lower portions of some of these tributaries could provide excellent habitat for aquatic organisms, riparian habitat for terrestrial organisms, recreational opportunities for residents, stormwater retention, decreased downstream sediment flux, and improved water quality to the Vermillion River. We have identified the most opportune places for this restoration in the recommendations below.

The following restoration recommendations would increase in-stream channel complexity and habitat. Landowner permission and cooperation may be a challenge at certain locations in the Empire Drainages. Sufficient funding, careful planning, and significant public outreach will be necessary to implement many of the projects. The following priority list provides a possible way to proceed. However, these priorities can be altered depending on the goals and objectives of the project partners.

Phase 1

- Threats to infrastructure and safety
    - Tributary 2, PP36 (score: 38) - The concrete box culvert under Clayton Ave needs to be replaced as it is in disrepair and resulting in erosion between the culvert and the road and cracks in the road pavement. It is also a fish passage barrier so replacement with a larger bridge or culvert would improve passage.
    - Tributary 5, PP43 (score: 51) - Dirt road crossing is partially washed out. The road is no longer safely passable, and it is causing a fish passage barrier. The road should be removed or replaced. Not urgent as this is not a heavily used road.
- Restoration on public lands
    - Tributary 5, PP44 (score: 55) - Entire tributary is on state property and includes some fields no longer used for agriculture. This perennial stream would be a great opportunity to restore 1 mile of stream and wetland habitat.
    - Tributary 7, PP49 (score: 57) - About 0.8 miles of this tributary is on state property downstream of 190th St W. The fields are no longer used for agriculture, and the water temperatures are cool.

Phase 2

- Public outreach - reach out to landowners, discuss the issues, understand their concerns
    - Identify farmers and landowners within the Vermillion River watershed that have previously cooperated on restoration projects and have had a positive experience.
    - Ask these farmers to assist in the public outreach.
    - Describe to the landowners the options for compensation, alternative methods of farming, and the restoration alternatives.

- Tributary 6 and 6A (projects 45-48) - Identify reasons for poor water quality; attempt to obtain easement to restore channels and wetlands along these two tributaries, and improve the riparian corridor.
- Implement and enforce riparian corridor setbacks, particularly along perennial streams. These would need to include differences in setback criteria for areas that are urbanized, agricultural, and wild.
- Stabilize main stem channel banks experiencing localized bank erosion.

# 6. References

Dakota County SWCD in cooperation with Ravenna Township, 2003. Etter Creek Watershed Assessment and Bank Restoration Project Final Report.

Hobbs, H.C., Aronow, S., and Patterson, C.J., 1990. Geologic Atlas of Dakota County, Minnesota: Surficial Geology. County Atlas Series, Atlas C-6, Plate 3 of 9. University of Minnesota and Minnesota Geological Survey.

Leopold, L.B., Wolman, M.G., and Miller, J.P., 1964. Fluvial Processes in Geomorphology. Dover Publications, Inc. New York, NY. 522pp.

Leopold, L.B., 1994. A View of the River. Harvard University Press, Cambridge, MA. 298pp.

Mossler, J.H., 1990. Geologic Atlas of Dakota County, Minnesota: Bedrock Geology. County Atlas Series, Atlas C-6, Plate 2 of 9. University of Minnesota and Minnesota Geological Survey.

Schumm, S.A., 1984. River Morphology and Behavior: Problems of Extrapolation. See Elliott 1984, pp 16-29.

## APPENDIX A: Review of Geomorphology Principles

In order to fully visualize and understand the problems occurring in the Empire Drainages, it is important to have a basic understanding of fluvial geomorphology. This section discusses the principles behind fluvial processes. Stable stream systems are in a delicate balance between the processes of erosion and deposition. Streams are continually moving sediment eroded from the bed and banks in high velocity areas such as the outside of meander bends and around logs and other stream features. In the slow water at the inside of meander bends or in slack water pools, some of this material is deposited. This process of erosion and deposition results in the migration of rivers within their floodplains. The process by which streams meander slowly within the confines of a floodplain is called *dynamic equilibrium* and refers mainly to this balance of sediment erosion and deposition. Streams typically have reaches that fall along the continuum of degradation (eroding) to aggradation (depositing) at any one time in the scale of channel evolution. The location and character of these individual reaches changes over time. When a stream channel is in equilibrium, it may move across the floodplain, erode and deposit sediment, but general planform geometry, cross-sectional shape, and slope remain relatively constant over human lifetimes.

Many factors can influence this equilibrium by altering the input of sediment and the quantity and timing of runoff. These factors include soil types, rooted vegetation that holds soil in place, flashy flows that erode banks, large rainfall events or increased sediment pollution that deposits sand or other fine sediment in the channel. When a channel loses its equilibrium due to changes in flood power and sediment load, it can in turn lose essential habitat features. The fundamental channel shaping variables in balance are slope, discharge (amount of water flow per time), sediment load and sediment size. The balance between the amount/size of sediment and slope/discharge is manifested in complex drainage networks of streams with a specific channel area and slope. Any change in one of the variables can upset this balance, resulting in either aggradation or degradation of the channel.

For example, given that the primary function of streams and rivers is to transport water and sediment downstream, changes in land use that affect the timing of runoff can affect sediment transport. Clearing of watershed forests, row crop agriculture and urban development cause storm water to reach the stream channel faster, and increase the peak discharge in the stream. Geomorphically, an increase in stream discharge might result in an increase in channel incision or lateral bank erosion, and hence, the amount of sediment being transported downstream. These changes may also result in changes to channel slope. The stream's evolution will persist until it reaches a new dynamic equilibrium between the channel shape, slope, and pattern (Schumm 1984, Leopold et al. 1964).

In a comprehensive geomorphic assessment, the physical attributes of the stream channel are measured to determine its geomorphic stability and the processes and factors responsible for that instability. Parameters typically measured include channel planform and profile, cross-section geometry, slope, watershed landuse, riparian vegetation, soils, and channel erosion.

*Channel dimension*

The cross-sectional size and shape of a stream are products of evolutionary processes that have, over time, determined what channel size is necessary to accommodate the most frequent floods. Several parameters can be used to determine the effect of channel shape on stream flow, including channel width, depth, width to depth ratio, wetted perimeter (the length of cross-section perimeter contacting water), hydraulic radius (cross-sectional area divided by wetted perimeter), and channel roughness. The bankfull surface is a common measure used to scale cross-section features to allow for comparisons with different sections within the same watershed or in different watersheds. In a natural river in equilibrium, the bankfull surface is at the top of the banks, the point where water begins to spill out onto the floodplain. In rivers not in equilibrium, the bankfull surface can occur elsewhere on the cross-section.

Figure A-1: 2003 aerial photograph showing the sinuous nature of the Minnesota River. Flow is from south to north.

*Channel planform*

Flowing water is constantly encountering friction from streambed and banks, and the energy of the stream is dissipated through work. This work is manifested mainly as the entrainment or movement of soil and sediment particles. Energy in linear systems such as rivers is dissipated in the manner that minimizes work (the rate of energy loss), the sine wave form. The energy of a straight line is thus dissipated over a lower slope by the formation of sinuosity, or the typical "S" shape of stream channels (Figure A-1). The erosion and deposition of sediment balanced by the resistance of particles to erosion causes and maintains this condition. Sinuosity can be measured as either the stream slope/valley slope, or the thalweg length/valley length, where the thalweg is the highest energy point (usually approximated by the deepest point) in the stream channel (Leopold 1994).

*Channel profile*

The gradient or slope of a stream channel is directly related to its cross-sectional geometry, soils, and planform geometry. Higher gradient streams in hilly or mountainous areas tend to have a lower sinuosity and dissipate energy over turbulent step-pools of harder substrates whereas low gradient streams such as those common to the Midwest have a higher sinuosity and dissipate energy through lower slopes and regular riffle pool sequences. Degradation of streambeds caused by disturbance is problematic, for unlike lateral bank erosion that tends to be localized, changes in bed elevation can be felt over several miles. Channel incision, or downcutting, generally migrates upstream until a stable gradient is achieved.

*Channel stability*

As discussed in the above paragraphs, a channel in equilibrium may erode and deposit without being considered unstable. Some erosion in stream channels is normal, and a channel in dynamic equilibrium, balancing erosion with sediment transport, is considered stable. The stability of channel planform and profile are dependent on many factors, including soils, roughness, slope, and disturbance. The *vertical stability* of a channel refers to the state of incision or aggradation of the streambed.

Figure A-2: A headcut and incised channel on a small stream in Scott County.

Vertical instability often follows a certain pattern whereby changes in the bed elevation of a stream are translated upstream through a series of small vertical drops called *knickpoints* or *headcuts*. This situation can arise from the straightening of streams and an associated decrease in channel length or by direct changes in the bed elevation of a stream (eg. improper road crossing installation or decreased bed elevation in a main channel). This process of downcutting is called *incision*. A waterfall would be an extreme example of a knickpoint in bedrock. As a headcut moves upstream, the stream becomes more incised and the flood energy increases as more and more volume is confined to an incised or *entrenched* channel (Figure A-2). Whereas prior to incision, the stream was able to dissipate its energy over a wide floodplain, after incision this energy is concentrated. Following incision, the stream typically begins to erode laterally with the end result being new floodplain formation at a lower grade. The Schumm channel evolution model demonstrates how a headcut creates an incised channel that becomes laterally unstable and eventually forms a new stable channel at a lower elevation (Figure A-3).

Channels in equilibrium provide structure and complexity to support habitat for aquatic species. When a channel becomes unstable, aquatic species have a difficult time adjusting to rapidly changing conditions. Erosion and incision can remove habitat features, and deposition can fill pools and cover spawning gravels.

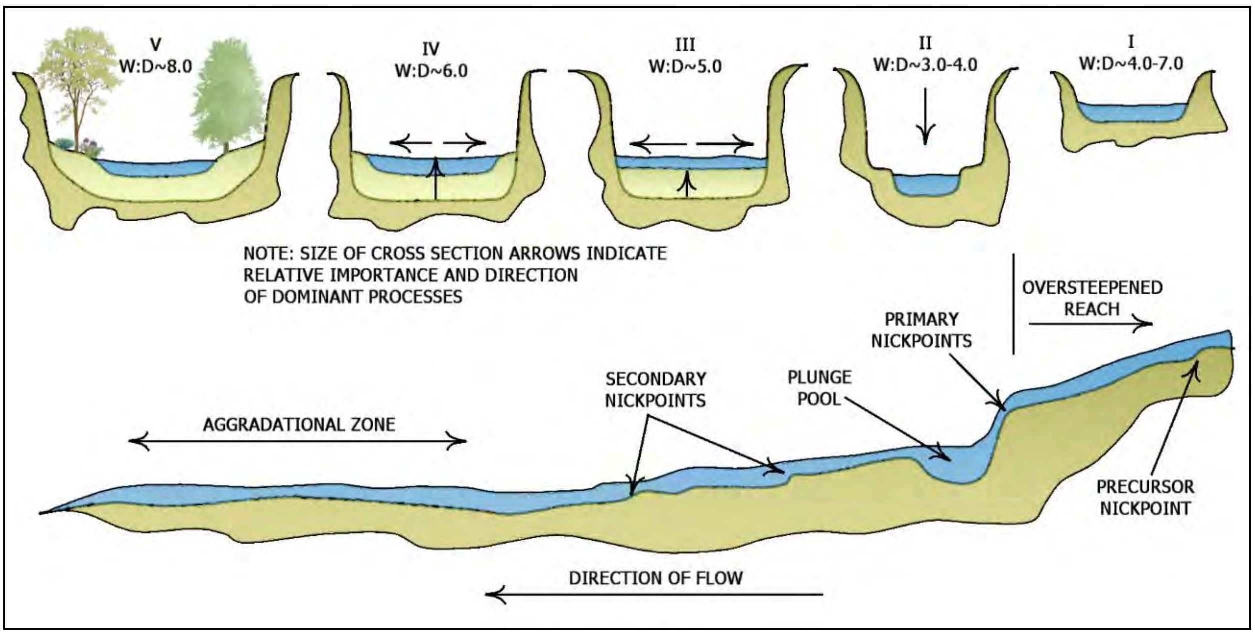



Figure A-3: The Schumm channel evolution model (modified from Schumm, 1984).

In a reconnaissance-level fluvial geomorphic assessment, a stream is examined for signs of channel instability such as active headcuts, bank erosion and channel scour, bed sediment type and stability, type, age and stability of bank and bar vegetation, algae, macrophyte and macroinvertebrate populations, type and sorting of various depositional features, floodplain deposition, type and consolidation of floodplain soils, and bank erodibility.

*Sediment transport*

One of the most common misconceptions about streams is that erosion is inherently bad. As discussed above, the dynamic equilibrium of streams involves the opposing forces of erosion and deposition, and this process is normal when equilibrium is maintained. As streams flow, particularly during rainfall or snowmelt events, they entrain particles from the channel bottom and banks. Particles small enough to become suspended in the water column are called *washload*, while particles that move along the channel bottom are called *bedload*. Together, these components make up the sediment transported in the channel. When this balance of erosion and deposition is upset by changing land use, streams respond in various ways depending on the change. For instance, after clear cut logging, runoff from rainfall reaches the stream faster and the erosive power of a stream can increase, causing excessive incision and/or bank erosion in some areas. As that sediment moves downstream, it will eventually come to areas of low gradient and will be dropped out of the water column. Thus streams can erode excessively in some areas and deposit excess sediment in other areas of the same system. Both consequences of a disturbed sediment equilibrium can have detrimental effects on fish and wildlife habitat.

## APPENDIX B: Management Recommendations

The following descriptions outline the project types shown in the Priority Project ranking system. Many projects involve some aspect of more than one of the types listed.

Grade Control

In reaches with extreme incision or active downcutting, grade control is often prudent. Grade control involves the installation of an armored riffle or drop structure placed to prevent any further incision from traveling upstream. Grade controls can be discrete weirs, concrete structures or armored riffles (Figure B-1). Inter-Fluve recommends the latter in natural stream systems to avoid blocking fish passage and to maintain natural geomorphic function.

Figure B-1. The above photos show a riffle-pool channel (A) just after and (B) 2 years after construction. Grade controlling riffles can be built either in conjunction with armored banks to prevent channel migration, or with sediment input in mind, so that as the stream moves laterally, new riffle lobes will form (photos Inter-Fluve).

Floodplain Management

Floodplain management projects vary considerably, but include expansion of riparian buffers, removal of infrastructure, and stormwater management. New development must capture stormwater and encourage as much infiltration as possible or the stream will experience a sharp decline in water quality. Building retention or detention basins or retrofitting existing stormwater systems will help improve water quality and prevent incision and erosion problems. Conservation farming practices, as described in the main body of the report above, would also fall into this project type. Changing the farming practices would help slow the movement of water into the stream channels and increase infiltration.

Riparian Management

One way of improving filtration of nutrients, reducing stream temperature and restoring the connectivity of green corridors is to revegetate streambanks and riparian areas where row cropping and urban development have encroached on the channel. Revegetation projects are relatively simple to institute and can be inexpensive. Plants can be purchased through local NRCS or nurseries and can be planted using volunteer labor.

When the forest canopy is removed the channel is exposed to more direct sunlight, and removal of soil binding tree roots can result in major bank erosion. Organisms dependent on forest leaf litter for energy can be impacted, and fertilizer from expanding lawns likely drain directly and quickly into the channel, resulting in increased algal growth and decreased oxygen levels. The streamside natural area is critical to the connectivity of watersheds. Migratory birds and other animals use these green corridors through their range or to migrate seasonally. Removal of these buffers fragments habitat for already stressed organisms. This pattern can be reversed, however, by increasing natural buffers of both native grasses and forested riparian areas.

It is extremely important to buffer even small ditches and channels. Water pollution in rivers is cumulative. Once you have poor water quality, it does not generally improve with distance downstream. Any attempts at reforestation should consider the impact of exotic species such as reed canary grass and buckthorn. Special measures such as removal and herbicide treatment must be taken before establishing native species.

Crossing

Where continuous water flow is available for fish passage, culverts must be well-placed and partially buried to provide in-stream habitat and limit perching. Perching is caused by either incorrect placement of the culvert above the downstream channel bed or by incision traveling upstream and causing the channel bed below the culvert to downcut. Most warmwater fish have poor leaping ability, so even a six inch perch can present problems. Perched culverts can be made passable by raising the channel bed downstream,

Figure B-2: Bottomless arch that is partially buried for better habitat and fish passage conditions.

backwatering through the culvert or by replacing the culvert. Culvert replacement should consider bottomless arch options or culverts that are partially buried to mimic a natural channel bottom (Figure B-2).

Low flows can present a passage barrier at any culvert, and this is not only a function of the culvert design, but also the hydrology of the system. During midsummer, when flows are very low, all culverts may be impassible. Low flow can be concentrated or backwatered through a culvert to minimize passage problems. For instance, flow up to a certain elevation can be easily diverted (eg. low concrete weir) into one box of a double box culvert, essentially doubling the amount of water in the culvert at low flow.

Bank Stabilization

Bank stabilization projects in urban and agricultural areas seek to minimize soil loss and prevent stream channel migration and property loss. Urban and agricultural streams are often in a state of flux; the streams are trying to adjust their cross-section (get bigger) to accommodate the increase in flows.

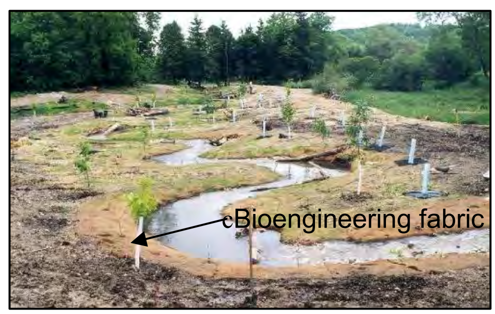



Figure B-3: Grasses are beginning to grow through biodegradable bioengineering fabric along this restored stream (photograph: Inter-Fluve).

In general, bank stabilization should consider infrastructure constraints, future channel migration patterns, and riparian buffer protection. A simple bank restoration project is to plant trees away from the eroding bank and allow those trees to grow to maturity before the channel has a chance to erode to their base. By the time the channel has moved, the trees will be large enough to provide deep rooted bank stabilization. The most successful trees for this purpose would be cottonwood, black willow and silver maple, all common riparian or “wet feet” trees capable of withstanding frequent inundation. Another approach is to provide some toe protection in the form of rock or encapsulated gravel combined with planting. Rock is sized or protected such that it remains stable long enough for vegetation to grow. Bioengineering fabrics can be used to provide structural stabilization and to prevent the piping of soils during high flow. These materials biodegrade once the vegetation is established (Figure B-3). A combination of rock toe protection, geocells, and fabric are often useful for large, steep banks (Figure B-4).

Figure B-4: Rock toe, stacked geocells, and fabric at hart Park, Milwaukee.

Figure B-5: The root structure of trees hold the bank material together to stabilize the banks against rapid erosion.

The least expensive bank stabilization is simply for landowners to leave the stream alone. New and existing landowners in forested reaches should be encouraged to remove exotics such as buckthorn and garlic mustard but to otherwise leave the streamside vegetation to manage itself (Figure B-5). This encourages natural stabilization and habitat formation. In most cases, our best intentions are actually detrimental to the stream environment. Erosion and deposition of streambank sediment are the essential physical forces behind stream and floodplain formation. Some degree of bank erosion is natural. When watershed changes or riparian land use practices cause the stream to be out of equilibrium, however, abnormal erosion rates can result. What constitutes abnormal erosion is somewhat subjective and depends on sediment pollution concerns, habitat degradation, and concerns over nearby infrastructure such as roads, houses and underground conduits. Prior to undertaking a project, it is therefore important to obtain professional opinions from land managers, geomorphologists, and engineers. If the erosion appears dramatic, but the erosion rate is extremely low, there may be no real basis for a stabilization project. Conversely, erosion may not appear dramatic, but the rate may be high, requiring some immediate stabilization. Determining the risk of no action is extremely important.

Often, people see a downed tree, or a scour area around a rootwad or tree base, and associate bank erosion with trees. In fact, had the tree not been there until it fell, the bank would have probably eroded at a much greater rate. Box elder trees are primary colonizers and are very quick to establish in areas where trees have fallen and clearings result. This association of box elder with unstable banks also leads to the misconception that box elders, and thus all trees, cause erosion. Common riparian trees have evolved over time to do just the opposite. Eastern cottonwood, black willow and silver maple, our three most common streamside trees, have evolved deep, water searching root systems to provide for added stability in the dynamic streamside environment. Black willow roots can travel dozens of feet up and downstream, creating an extremely well-armored bank.

Native grasses provide adequate streambank root protection down to approximately 3 to 4 feet and are useful in smaller streams or areas where prairie restoration makes sense. Larger streams or incised channels with banks taller than 3 feet need deeper and stronger root protection. No vegetation can provide long term stability beyond five feet of streambank height, and the root protection is then limited to trees and grasses in the upper banks. The Minnesota River is a good example of this dynamic.

Project type – Natural channel restoration/ Relocation

Channel relocation is also called natural channel restoration, natural channel design, or re-meandering and all involve actually building a portion of stream channel different from the existing plan and profile. Inter-Fluve typically refers to channel relocation projects when discussing the movement of a channel to avoid some planned infrastructure. For instance, when new roads are constructed, it is sometimes cost effective to move a stream channel out of the path of the road or to construct a more stable crossing alignment. These situations are often good opportunities to restore channelized reaches into a more geomorphically and ecologically stable configuration (Figure B-6).

Figure B-6. This segment of Spring Creek in the Black Hills was relocated and restored as part of new highway construction (photo Inter-Fluve).

Natural channel restoration projects involve the construction of a meandering channel with habitat and geomorphic features mimicking natural forms. Gravitational forces, the rotation of the earth, and the friction of water on soil all combine to cause flowing water to assume a sinuous planform. Steeper streams in rockier terrain tend to be straighter and dissipate energy readily through

Figure B-7. This segment of Trout Creek on the Oneida Reservation was channelized in the early 1900s (top). The restored segment (bottom) involved floodplain excavation, woody debris habitat installation and native plantings (photo Inter-Fluve).

cascading riffles or waterfalls. Lower down in the watershed, or in flatter areas like the Midwest, streams erode slowly through sand, silt and loam to form lazy, winding rivers and streams. Minnesota has several million acres of drained land, with over 80 percent of that drainage achieved through ditches and channelized stream segments. It is very likely that all ditches with perennial flow were at one time meandering streams, and many of our dry summer ditches were at one time intermittent stream channels or wetlands. Restoring the geomorphic function of these ditches through natural channel restoration can lead to dramatic improvements in habitat and water quality (Figure B-7). Ditches are generally deeper and more incised than their sinuous predecessors. Incised streams move flood water quickly, and they do so by concentrating more of the flood flow in a large channel rather than across the floodplain. By adding sinuosity, we can decrease the slope of the channel and in some cases raise the bed of the stream, thereby reconnecting the stream with its former floodplain. Restoring floodplain connectivity slows the exit of water off of the land and allows for greater infiltration, higher baseflows, lower stream temperatures and lower peak flood flows. Restoring incised ditches can be accomplished in three main ways. The first and most inexpensive way is to introduce roughness elements that encourage the formation of a sinuous channel inside the ditch cross-section, essentially using natural forces to carve out a floodplain over a long period of time. The other methods involve either lowering the floodplain through excavation, or raising the channel bed. Clearly, restoring meanders to a stream requires that the stream occupy a wider swath of land than did the straightened ditch. In areas where little or no buffer currently exists, restoration would need to include expansion of the buffer. The meander limit, or belt width of a stream, is generally a function of the watershed area and the discharge of the stream. For small headwater channels, a reasonable belt width might be in the range of 50 to 100 feet (assuming a channel top width of 15 to 30 feet).

Hydraulic modeling and hydrologic analysis are important components of stream restoration in regulatory drainages. Flood peaks spreading out on downstream farmland can actually be reduced by attenuating the flashy floods upstream through floodplain reconnection and stream restoration. Ditch construction in the Midwest typically occurs without any hydraulic modeling of flood flows to see if ditching actually accomplishes the intended goal. Computer modeling of flood elevations can now be used to determine the practical value of ditches and determine the impact of channel restoration.

Natural channel restoration involves several steps, the first of which is dewatering. Given enough floodplain width, this can be accomplished with little or no effort by simply building the new channel completely off line from the existing ditch. The new channel is constructed "in the dry" adjacent to the existing ditch. Rough channel excavation is completed, with the spoils either removed off site or stockpiled near the existing stream for later filling. Fine grading involves bank stabilization, riffle and pool construction where appropriate, and incorporation of habitat elements. Once the channel has been stabilized, either using fabric methods or by allowing vegetation to grow for a period of time, then water is diverted permanently into the new sinuous channel and the old one is filled in to the floodplain level (Figure B-8).

Figure B-8: Stream restoration in agricultural areas can sometimes involve reconstructing a new valley form or incipient floodplain (photograph: Inter-Fluve).

Natural channel restoration in farmed headwater systems can be complicated by the elevation of road crossing inverts. Many modern culvert crossings were installed flush with the bottom of the ditch at the time of construction. The elevation of the channel bottom at the time of culvert installation was more than likely much lower than the elevation of the channel bed prior to ditching, when the stream was a smaller, sinuous channel with good floodplain access. Restoration projects in agricultural areas don't typically involve raising the channel bed at road crossings, which would require replacement of the culvert to minimize or eliminate any upstream rise in flood elevation. The cost of creating an incipient floodplain on a restored stream, or raising the channel and possibly replacing crossings can limit the amount of restoration that a local group can reasonably accomplish.

New stream channel construction can vary greatly in cost between $50 and $200 per foot, depending on constraints and floodplain restoration strategies. A large project might restore a mile of stream channel, placing the cost between $200,000 and $1 million. Granting programs in the Midwest are fairly limited in their ability to fund many large projects of this type, and many coastal and Great Lakes programs are currently focused on fish passage. Hopefully, future granting programs, farm bills and state restoration programs will recognize the importance of headwater stream restoration in our agricultural watersheds.

*Restoration and Ditch Law*

A major obstacle in restoring headwater streams is current drainage law, governed in Minnesota by Minnesota Statutes, Chapter 103. The ideal option for restoring a farm ditch would be abandonment of the public drainage easement, which is a very difficult process in Minnesota. The State Water Resources Board (later BWSR) originally authorized the creation of watershed districts, who in turn could govern drainage systems within their geographic boundaries. County boards were required by law to assess the potential environmental and natural resources impacts of drainage projects, but much of this was done before watershed issues were deemed important to the general public. Since the 1960s, more watershed residents have raised questions about drainage and water quality, and whether the current drainage law protects the public good in the best possible way. The Clean Water Act and subsequent farm bills have placed more of an emphasis on wetland protection, but because the existing laws are designed to increase drainage, not reduce it, abandonment is still challenging. A ditch is owned by the landowners, and therefore the costs for maintenance of ditches is typically borne by the landowners. Restoration in regulatory ditches typically involves either full abandonment, partial abandonment, and impoundment. Full abandonment requires initiation by landowners, a signed petition by 51 percent of the landowners assessed for the system, and final approval by the authority. This is usually done in urban areas where the ditch is no longer in existence or in areas with few landowners. Abandonment through the RIM program is possible but often requires an engineering study and some drainage modifications to prevent downstream flooding from worsening. Partial abandonment is not usually done because the drainage authority can be lost if some portion of the system is abandoned. Installation of water control structures to restore wetland conditions is also a possibility, but those structures must be maintained by the landowner.

Two alternative ways of restoring floodplains and streams within existing ditch law have been demonstrated by the Minnesota DNR and others. The first involves *ditch improvement*, whereby a channelized ditch can be confined within parallel berms running along both sides of the channel dozens or hundreds of feet from the channel center (Figure B-9). Within these berms, a lower floodplain can be excavated or the channel raised and a meandering stream restored. The second involves *diversion for public benefit*, whereby both ends of a segment are blocked and the ditch is then no longer maintained. A meandering channel can then be built off line from the existing ditch.

Wetland restoration as floodplain management ties directly into the discussion of ditch management and natural channel restoration. Although there are a few small wetlands in the watershed, a central ditch and its associated tile lines still drain the landscape. Wetland restoration is a good method of improving water storage in reaches with only ephemeral flows. Wetland restoration and/or wetland stream restoration would need to include managing tile drainage and minimizing or eliminating ditch drainage so that water stays on the wetland longer. In recent projects completed with the Oneida Tribe in Green Bay, Wisconsin, Inter-Fluve has combined wetland and stream restoration with buffer management in headwater tributaries to a small agricultural stream. In just four years, the water quality of the system has improved to the point where trout will be re-introduced (Snitgen and Melchior 2007). Many such examples of a headwater restoration approach can be found around the Midwest. The flow of water during wet times of the year, natural ground water flow, hyporheic flow and abundant wetland vegetation combine to eliminate any increase in water temperature before the water flows downstream. The ability to reintroduce trout into a system with newly restored wetlands and stream is evidence that water temperatures remained low.

A major obstacle to native plant wetland restoration is the ubiquitous presence of reed canary grass (*Phalaris arudinacea*), giant reed grass (*Phragmites australis*) and cattail (*Typha angustifolia*). These invasive species have taken over most of the wetlands in the Midwest, with reed canary grass often colonizing disturbed sites to become monoculture. The fecundity of these plants, their ease of seed spreading, and their proximity to moving water make wetland restoration with native plants extremely difficult. However, the hydrologic benefits of invaded wetlands still remain. Eventually, better methods will be discovered that will help improve the diversity of restored wetlands and minimize invasion by exotic species.

Figure B-9: Restoration of a ditch within levees to create a meandering stream with a vegetated riparian buffer (courtesy of L. Aadland, MN DNR).

# APPENDIX C: Reach descriptions of existing conditions for the Vermillion River within the Empire Drainages subwatershed

### Existing Conditions

The main stem Vermillion River within the Empire Drainages is 12.3 miles long, while the tributaries are a combined 36.5 miles in length. The Vermillion River was divided into nine distinct reaches based on channel planform, slope, bedforms, riparian characteristics, and adjacent land use (Table C-1). Each tributary was characterized, but no reaches within the tributaries were identified and characterized separately as most of the tributaries were straightened ditches.

*Table C-1: Reach lengths for the Vermillion River within the Empire Drainages.*

| *Reach* | *Length (ft)* | *Length (miles)* |
|---|---|---|
| **1** | 2,450 | 0.46 |
| **2** | 10,100 | 1.91 |
| **3** | 10,300 | 1.95 |
| **4** | 11,850 | 2.24 |
| **5** | 7,400 | 1.40 |
| **6** | 9,650 | 1.83 |
| **7** | 6,500 | 1.23 |
| **8** | 3,375 | 0.64 |
| **9** | 3,175 | 0.60 |
| **Total** | **64,800** | **12.27** |

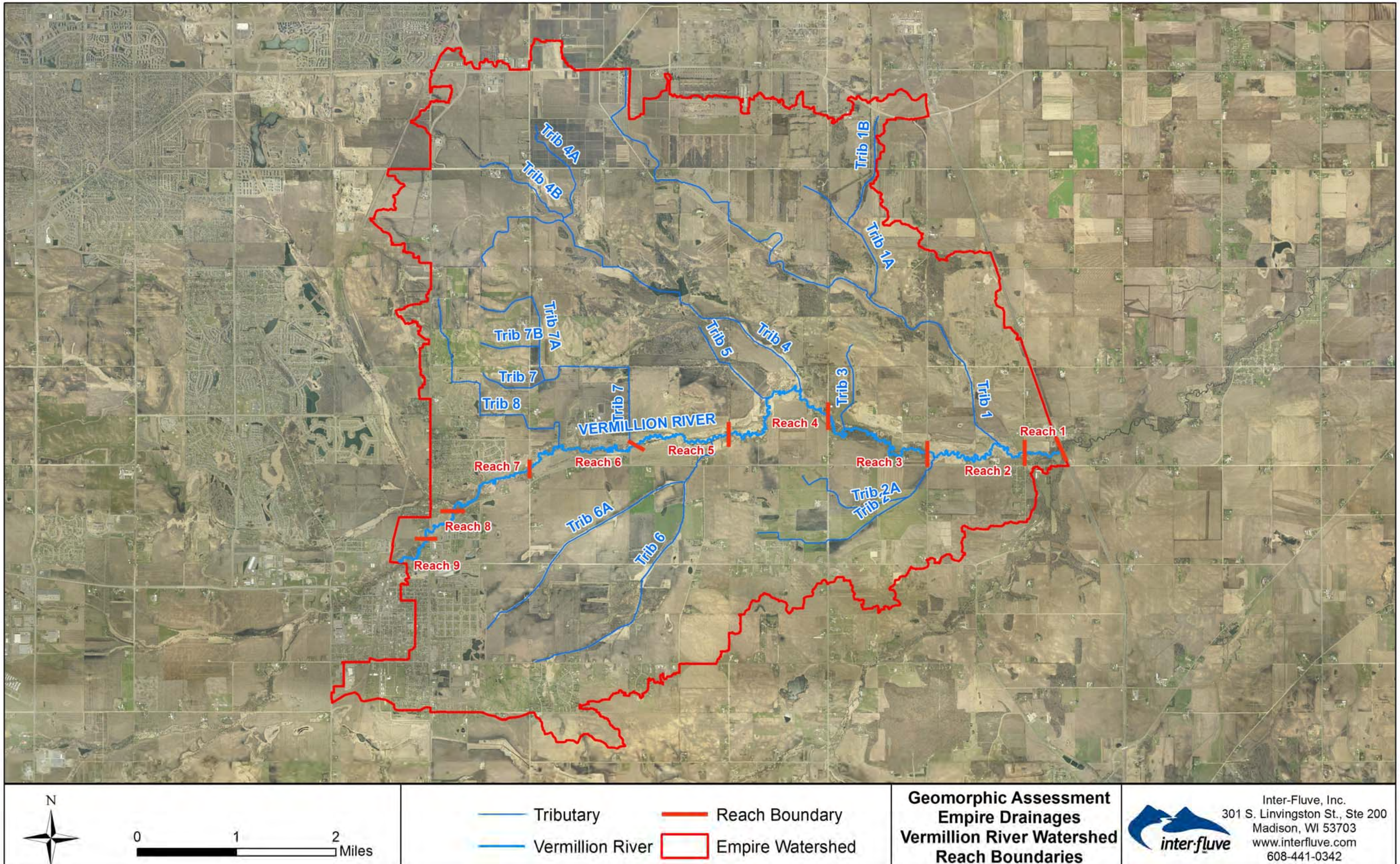



Figure C-1: Streams and stream reaches of the Vermillion River and its tributaries in the Empire Drainages study area.

## 1.0 Vermillion River

The Vermillion River within the study area extends for 12.3 miles from State Highway 52 (Coates Blvd.) at its downstream end to approximately the north end of 5th Street in Farmington. We divided this section of the river into 9 separate reaches to be able to compare and contrast different reaches. The reaches vary in length from 0.46 to 2.24 miles. This section of the Vermillion River primarily flows through large agricultural tracts of land. In general, the river has a functional riparian corridor.

### *1.1 Reach 1*

Reach 1 extends from State Highway 52 (Coates Blvd.) upstream to Donnelly Ave. for 0.46 miles. The reach is sinuous and flows through agricultural lands with minimal hardened encroachment. The upstream section lacks the older riparian trees, which exist in the lower section. The lower section has many old silver maples contributing to its approximately 80 percent canopy cover. The understory consists primarily of reed canary grass. In the river there is an abundance of woody debris, which creates excellent fish habitat. In general this reach is in a stable condition, there are two potential bank stabilization projects within this reach.

Figure C-1: Typical site within reach 1, including large silver maples and channel meanders. Photo taken at Station 2000 looking upstream at inside meander bend sand bar, large canopy of silver maples, and reed canary grass as predominant understory.

### *1.2 Reach 2*

Reach 2 extends from Donnelly Ave upstream to Clayton Ave for 1.91 miles. This reach is sinuous but lacks a vegetated riparian corridor and is heavily influenced by agricultural practices. Many of the meander bends suffer from bank erosion as the channel is widening to reach a new geometric equilibrium. The channel is wide relative to adjacent reaches. The banks consist of cohesive soils that prevent them from even further degradation. There is a complete lack of in-stream woody debris. There are ten potential bank stabilization projects in this reach.

### *1.3 Reach 3*

Reach 3 extends from Clayton Ave upstream to Blaine Ave for 1.95 miles. This reach has a relatively intact and extensive riparian zone with 60 to 90 percent canopy cover. The reach meanders primarily through woodlands. There is an abundance of woody debris in the channel, which creates complex in-stream habitat for both fish and invertebrates. There are two potential riparian management projects and one bank stabilization project identified in this reach.


Figure C-3, Reach 3:.A) Station 20,200, showing a typical site within this reach. B) photo (Station 14500) shows the sole exception to this heavily canopied reach and intact riparian corridor.

### *1.4 Reach 4*

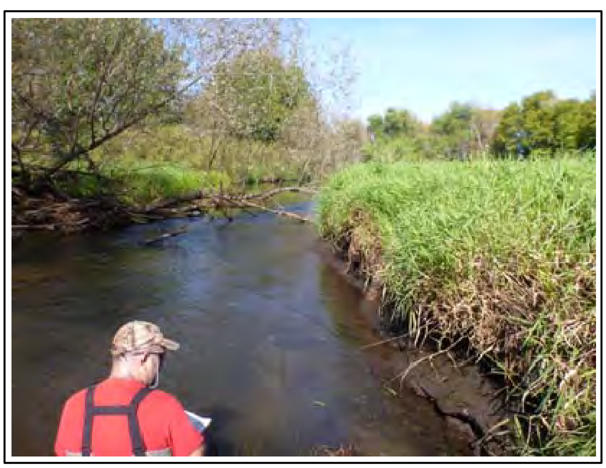


Figure C-4, Reach 4: Station 31,800 looking downstream. Note lack of mature riparian woody vegetation and reed canary grass as predominant understory.

Reach 4 extends from Blaine Ave. upstream for 2.24 miles. The reach meanders through agricultural fields and is joined by two major drainage channels (downstream to upstream designations: Tributary 4 and Tributary 5, respectively) approximately halfway through its length. The reach is characterized by an immature riparian corridor throughout its length. However, the riparian corridor is encroached upon by agricultural practices. During our site reconnaissance, water temperatures coming from the downstream tributary (Tributary 4) were 10° F higher than those observed in the main stem Vermillion (78° F compared to 68° F, respectively). The lack of mature riparian vegetation in this reach likely indicates previous land use practices for which riparian vegetation was completely removed. Fallen wood is available on both the banks and mid-channel, creating good wildlife habitat. Additionally, there are backwater areas, which serve as good habitat for animals seeking shelter from the swifter main current. There is one potential bridge replacement, one riparian management, and three bank stabilization projects identified in this reach.

### *1.5 Reach 5*

Reach 5 extends 1.40 miles from its terminus with reach 4 to its confluence with Tributary 7. Reach 5 is characterized by a major channel restoration endeavor. In the majority of this reach, channel planform, meander length, geometry, and habitat have all been restored within the last two years. The primary restoration techniques included root wad placement on the outside meander bends, woody debris toe protection, woody debris mattressing, rock cross-channel constrictions, and tree plantings throughout the riparian corridor. It is anticipated that this reach will need a few growing seasons and to experience at least one channel forming flow (bankfull flow) before a revised restoration assessment can be made.

Figure C-5, Reach 5: Satellite imagery from 2010 with current restored planform superimposed (blue line). Virtually the entire reach has been recently restored.

### *1.6 Reach 6*

Reach 6 extends 1.83 miles from its terminus with reach 5 at Tributary 7 to Biscayne Ave. The reach is sinuous, flowing though sparse woodlands bordered by agricultural fields. There is minimal encroachment from agriculture onto the riparian corridor within the channel's meander belt, and existing encroachments due to agriculture are limited to the south side of the channel. In-stream habitat is complex, consisting of ample woody debris, associated log jams, and deep water habitat. In addition to these natural features, the habitat is enhanced by root wad and lunker installations. However, many of the lunkers are damaged in place or have floated downstream. The substrate is more coarse than in the downstream reaches, consisting of more gravels and some cobles.  There are three potential bank stabilization projects in this reach.


Figure C-6, Reach 6: A) Looking upstream at Station 47,800 towards a typical section within this reach showing good overstory, deep water, shade and channel meandering. B) Taken at Station 50,450 looking at a misaligned and damaged lunker.

### *1.7 Reach 7*

Reach 7 extends upstream 1.23 miles from Biscayne Ave to just upstream of the confluence with North Creek. The reach is highly influenced by both agricultural practices and urban infrastructure (including Route 66 encroachment). The lower section of this reach is channelized and lacks a dense riparian canopy, whereas the upper half is sinuous and contains mature trees with approximately 50 percent canopy cover. Reach 7 is more incised with greater erosive bank heights. There is a unique feature in this reach that was not observed in any other reach: from Station 55,200 to 55,100, there is a low gradient gravel and cobble dominated riffle. The riffle is located where the channel avulsed and is forming an oxbow. The upper portion of the reach contains many downed logs and associated log jams. The substrate consisted of sands and gravels, which is coarser than downstream reaches. Within the reach, one potential project would increase in-stream woody debris and one potential project would address fix bank erosion.


Figure C-7, Reach 7: A)Shows the lack of sinuousity within this reach. B) Looking downstream at a natural gravel and cobble riffle (Station 55,100).

### 1.8 Reach 8

Reach 8 extends 0.64 miles upstream from its terminus with Reach 7 (just upstream of North Creek). This reach can be divided into two sections: upstream and downstream of Chippendale Avenue. The upstream section is straightened and highly impacted by agricultural practices and pasturing whereas the downstream section is sinuous and flows through a relatively unaltered open space. The upstream section is devoid of riparian vegetation, whereas the downstream reach flows through a multi-story riparian corridor. In-stream habitat downstream of Chippendale Avenue contains woody debris and channel features associated with a sinuous planform such as

Figure C-8, Reach 8: Looking upstream at a log jam at Station 58,900.

deep pools, sand bars, and riffles. In contrast, the upstream reach is straightened and lacks biodiversity. Potential projects include removal of a bridge and fixing some excessive bank erosion.


Figure C-9, Reach 8: Photos taken from the upstream section of Reach 8 at approximately Stn 61,300.

### *1.9 Reach 9*

Reach 9 extends 0.60 miles upstream from its terminus with reach 8. This reach can be divided into two sections: upstream and downstream of Station 63,000. Upstream of Station 63,000, the river is characterized by urban development on the right bank and various restoration initiatives on both banks. The reach has good canopy cover and the in-stream habitat is moderately complex. The restored areas incorporate large woody debris, rootwads, and boulders in the designs and increase channel complexity. Downstream of Station 63,000, the river has a mature riparian corridor on its left bank but is highly impacted on the right bank by current agricultural practices. Two potential bank restoration projects were identified in this reach, and one bridge needs to be removed.


Figure C-10, Reach 9: A) Taken at Station 63,450. B) Looking at right bank at Station 63.350 to show bioengineering restoration techniques, including root wad placement, bioengineering fabric, and rock toe protection.

## 2.0 Vermillion River Tributaries

Approximately 36.5 miles of stream flow into the main stem Vermillion River within the study area. Most of these channels have been straightened and ditched since settlement.

### *2.1 Tributary 1*

Tributary 1 is 7 miles long and has been almost entirely straightened and ditched. The upper approximately 5 miles, upstream of Clayton Ave, are mostly roadside ditches or barely perceptible swales in the farm fields. Downstream of Clayton Ave, the channel is approximately 20 feet wide with 2 to 3-foot banks (Figure C-11). The channel bed consists primarily of fine-grained sediments, and the water surface is covered in green algae. The riparian corridor along portions of this tributary is wide with adjacent agriculture fields, while, in other areas, the fields are tilled within a few feet of the channel banks. The water temperature in the sun and in late morning was approximately 53° F, suggesting that this tributary could provide good cold-water habitat. The primary project for this tributary would be full channel reconstruction to increase geomorphic and habitat complexity.


Figure C-11, Tributary 1: A) Looking upstream from 190th St E at straightened ditch with adjacent wetland vegetation. B) Looking downstream from Clayton Ave at straightened channel with more mature riparian canopy.

### *2.2 Tributary 2 & 2A*

Tributary 2 is 2.3 miles long and is a straightened ditch throughout except the lower ~400 feet as the tributary enters the Vermillion River. The channel has about a 15 foot top width with 4-6 foot banks, and the channel bed consists primarily of sand and silt. With the exception of a small forested riparian corridor in the lower portion of the channel, this tributary has virtually no riparian vegetation to provide canopy cover nor the ability to recruit large woody debris to improve water quality and aquatic habitat. Farming occurs within 5 to 10 feet of the channel banks. The water temperature was about 68° during the assessment. The entirety of this tributary could be a potential project to fully restore the channel to a sinuous planform or swale and to increase the riparian buffer throughout. Two road crossings near the mouth of this tributary should be modified or replaced to remove depth or velocity barriers or to replace aging culverts causing erosion. The culvert under Clayton Ave is cracked in multiple places, holes have developed in the dirt within 1 foot of the road edge, cracks are developing in the road surface, and the downstream end of the culvert is perched about 2 feet (Figure C-12).

Replacing or modifying the two culverts at 200th St E as well as replacing the culvert at Clayton Ave could coincide with natural channel restoration in the approximately 1300 feet upstream of Clayton Ave. This portion of Tributary 2 has a mature riparian buffer with widths ranging from 30-150 feet. This would be a good opportunity to provide improved aquatic habitat while eliminating fish passage barriers and replacing an aging structure that is a risk to human health and property.

Tributary 2A is about 1.4 miles in length and is a straightened and ditched channel with minimal buffers and no channel geomorphic or habitat complexity. The channel is approximately 10 feet wide with 3 foot banks. The entire channel could be improved through natural channel restoration and/or the construction and maintenance of a sufficient riparian buffer.


Figure C-12, Tributary 2, 2A: A) Tributary 2 looking downstream from Blaine Ave. B) looking upstream at perched culvert under Clayton Ave. C) hole developed between culvert and road at Clayton Ave. D) Tributary 2A looking downstream along Blaine Ave.

### *2.3 Tributary 3*

Tributary 3 is a shallow swale through fields with no discernible channel bed or banks. We did not conduct field reconnaissance on this channel because channel features were not noticeable from the air photos.

### *2.4 Tributary 4 & 4A*

Tributary 4 is a straightened channel that begins west of Biscayne Ave as a barely-perceptible channel (Figure C-14). An identifiable channel begins about 2000 feet downstream of Biscayne Ave, and the channel is a rectangular ditch that flows through agriculture fields before entering an impoundment created by a dam about 3200 feet upstream (west) of Annett Ave. This dam creates a large impoundment and wetland, which act as a stormwater basin by slowing the downstream flow of water. The dam also creates a fish passage barrier for fish that can get through the small culvert at Annett Ave. Downstream of the dam, Tributary 4 remains a straightened channel but flows through wetlands 200-400 feet in width. The water within the wetlands did not have noticeable flow but was 55-60° F and supported a good diversity of wetland herbaceous and woody vegetation species.


Figure C-13, Tributary 3: Air photo of the Tributary 3 alignment with no visible channel bed or banks. A shallow swale through the fields carries overland runoff to the Vermillion River, but no channel features are apparent.

Tributary 4A is a short straightened wetland channel joining Tributary 4 just downstream of the dam and impoundment. One drainage swale with no identifiable channel enters Tributary 4 on the north side of the impoundment while two more swales enter Tributary 4 about 1800 feet downstream of Biscayne Ave to the north.

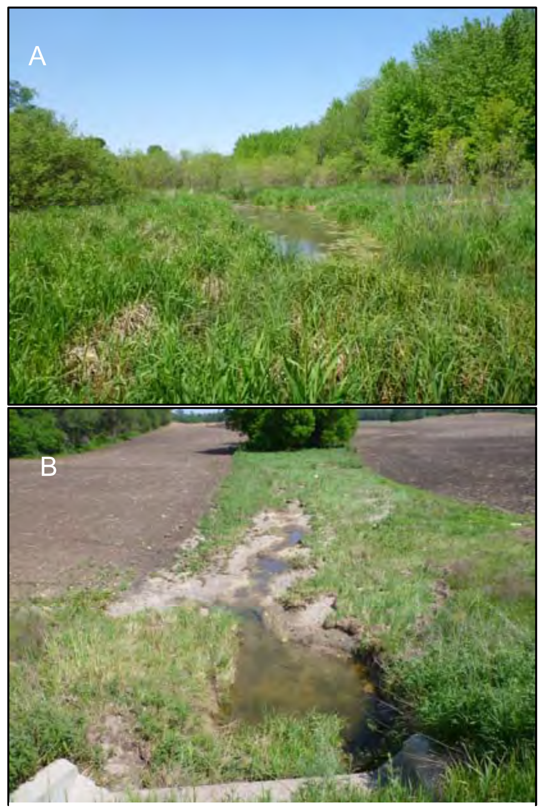



Figure C-14, Tributary 4: A) Wetland channel upstream of Annette Ave and B) barely perceptible channel downstream of Biscayne Ave.

### *2.5 Tributary 5*

Tributary 5 is a straightened ditch about 1 mile in length that flows through agriculture fields before joining the Vermillion River from the northwest about 5500 feet upstream of Blaine Ave. Tributary 5 is wide and shallow, with an approximately 40-foot bankfull width and 3-foot bankfull depth upstream of Annett Ave (Figure C-15). Downstream of Annette Ave, the bankfull depth is 6 to 8 feet with the same bankfull width. Upstream of Annette Ave, riparian vegetation provides about 30 percent canopy cover and consists primarily of cottonwoods along with willow, box elder, and buckthorn. Downstream of Annette Ave, the canopy cover is less than 10 percent and dominated by cottonwood. In-channel cover, however, is about 75 percent, and this is due to aquatic vegetation, bank vegetation, and large woody debris. The riparian buffer of trees and grasses throughout this tributary is between 50 and 100 feet. The channel bed is primarily fine sand and silt, particularly in the upper half of the channel due to small beaver dams and impoundments. Water temperatures in this tributary range from 58° to 63° F.

A dirt road crossing about 250 feet downstream of Annette Ave has partially washed out (Figure C-15), distributing sand and gravel in the channel downstream. Two culverts continue to allow water to flow through, but the road is not safe to travel on and the entire structure could be completely washed out in storm event. If this road is no longer necessary, it should be removed; if it is necessary, it should be rebuilt with a bridge or much larger culverts.

Figure C-15, Tributary 5: A) Looking downstream in upper half of channel. B) Looking downstream at washed out dirt road. C) Looking downstream from the washed out road.

### *2.6 Tributary 6 & 6A*

Tributary 6 is a straightened ditch 3.3 miles in length flowing through agriculture fields from 220th St W to the Vermillion River just north of the 200th St E and Ahern Blvd junction. The channel has a 12 to 15-foot bankfull width near the confluence with the Vermillion River, but becomes over-widened further upstream where the bankfull width is 20-30 feet near 210th St W

(Figure C-16). Grasses make up the majority of the vegetated buffer, which is approximately 5 to 10 feet wide throughout the channel length. Few trees grow along the banks of the ditch providing little to no shade or cover for aquatic organisms. The culvert and trash grate at the 210th St W crossing were 50 percent clogged with branches and other debris at the time of the survey providing a passage barrier for aquatic organisms.

Upstream and downstream of the 210th St W crossing, the water is gray-green and murky with surface scum and a visibility of about 0.5 inches into the water. The source of this poor water quality should be investigated further, but it may be due to runoff containing pesticides, herbicides, fertilizers and other substances used on the fields adjacent to Tributary 6.



Figure C-16, Tributary 6: A) Looking downstream from 210th St W at straightened ditch. B) Looking upstream at the straightened ditch with minimal vegetated buffer. Note the poor water clarity.

Tributary 6A is a straightened ditch 2.6 miles in length with almost no canopy cover or habitat features. The bankfull width is 15 to 20 feet and the bankfull depth is 2 to 3 feet. Downstream of 210th St W, a grass buffer extends about 50 feet from the channel bank to the beginning of agriculture fields. Upstream of 210th St W, the buffer has been removed on river left adjacent to the farm buildings. The water in the vicinity of 210th St W is gray-green with surface algae and a foul odor (Figure C-17). Runoff from adjacent farm fields upstream of the road crossing appears to be the cause of the poor water quality. Specific sources of the pollutants should be identified and adjusted to prevent direct runoff into the channel. and the riparian buffer should be restored to increase infiltration prior to surface water reaching the channel.


Figure C-17, Tributary 6A: A) Looking upstream from 210th St W at straightened ditch with no vegetated buffer. B) Looking upstream at the pool below 210th St W. Note the poor water clarity and quality.

Two smaller tributaries join Tributary 6 upstream of 210 St W. These are straightened ditches through agriculture fields and were not field-assessed.

### *2.7 Tributary 7, 7A, & 7B*

Tributary 7 is a straightened ditch flowing 3.2 miles through agriculture fields to the north and east of the wastewater treatment facility east of Biscayne Ave and north of 200th St W. Downstream portions of the channel have a bankfull width of 20 feet and depth of 3 to 4 feet. Downstream of 190th St W, the channel has a 10 to 20-foot riparian buffer providing up to 90 percent canopy cover of cottonwood and willow (Figure C-18). The channel bed is primarily silt and channel banks are silty loam. The water in the downstream portion of this channel is 52° F, and the channel contains substantial amounts of large woody debris for habitat. The upstream 60 percent of this tributary has substantially less habitat potential with no canopy cover, narrow buffer width, and no in-stream habitat features.

Some of the surrounding fields are no longer farmed, providing increased infiltration, fewer pollutants entering the channel, and additional potential for riparian buffers and in-stream woody habitat. Fields no longer used for farming also provide an opportunity to actively restore natural riparian and wetland stream channels and floodplains along portions of this tributary.

Tributaries 7A and 7B are short, straightened ditches south of 190th St W with mature riparian buffers of up to 50 feet. Two other drainages are grassy swales through fields with no defined channel boundaries and no buffer vegetation. Both cross Biscayne Ave and join Tributary 7 near 190th St W.


Figure C-18, Tributary 7: A) Looking downstream from Biscayne Ave. B) Looking upstream at large woody debris downstream of 190th St W.

### *2.8 Tributary 8 & 8A*

Tributary 8 flows 2.7 miles from the Southern Hills Golf Course to the Vermillion River downstream of Biscayne Ave. The upstream half of Tributary 8 flows through the golf course and through stormwater basins, while the downstream half is a straightened ditch through fields with little riparian buffer (Figure C-19). Empire Township recently constructed a sinuous channel north of Cattail Lane where new residential developments have been built. This sinuous channel winds around detention/retention basins that capture stormwater from this new development. At Biscayne Ave, Tributary 8 is a narrow channel (3-foot bankfull width) within a larger ditch that has a top width of about 20 feet. Within this ditch, Tributary 8 has a bankfull depth of 1.5 feet and narrow, grassy floodplains on each side. The riparian buffer throughout Tributary 8 is primarily grass and about 5 ft in width.

Tributary 8A is a shallow swale through fields before flowing through the golf course and joining Tributary 8 in a pool within the golf course.


Figure C-19, Tributary 8: A) Looking downstream at recently constructed sinuous channel and stormwater basins near Cattail Lane. B) Looking upstream at straightened ditch with minimal buffer at Biscayne Ave.

## APPENDIX D: Channel reconnaissance forms

## Channel Reconnaissance Form

| | |
|---|---|
| Date | August 20, 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 1 |
| Field Team | NN, ED |

**Station** | 0 | **To** 2450 |

### General Channel Conditions

*Channel Shape (check)*
☐Rectangular
☒Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | Sandy/silty loam |
| Bars | NA |
| Bed | Sand, fine sand |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☒None
☐Mid-channel ☐Point / mid ☐Point / alternate

### Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | Vertically stable, riparian wetland on existing floodplain | | | | |
| Lateral stability *deposition, erosion* | Laterally stable | | | | |
| Erosion (excessive/site specific) | Solitary site from approximately 1150 to 1050 | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☒Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: silty loam cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide | | | *Land Use* – agriculture, one elk farm from Stn 800 to 700 | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | The reach is characterized on its upstream and downstream ends with bridges:<br>Stn 2450: low-cord ~8', 2 sets of 5 pilings, width of bridge is pass typical storm events (active channel flows.<br>Stn 0: low-cord ~12 ', two bridges (north and south-bound traffic), each bridge has two sets of 3 pilings, width of bridges are able to pass active channel flows. | | | | |
| Bankfull/Channel forming flow indication | Inside bend bench formation, scour lines on bridge pilings | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | NA | Pool sediment type | Sand, fine sand |
| Sorting / Imbrication | NA | | |

**Bars / depositional features**

| | |
|---|---|
| Sediment type/size | NA |
| Mid, alternate, braided | NA |
| Bar Vegetation (type, age) | NA |
| Floodplain soils | NA |
| Overbank deposition | NA |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 100 |
| **Width of veg. riparian corridor*** | 200 ft |
| **Canopy coverage (%)** | 75 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | |
| low = single canopy layer | |
| medium = at least two canopy layers | x |
| high = multiple canopy layers | |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | 25 |
| woody species | 75 |
| bare/other | |
| Exotic/invasive species | Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Silver Maples | 75 |
| Box Elder | 25 |
| | |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

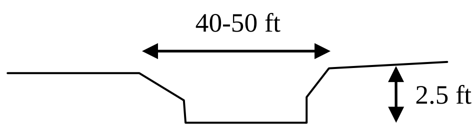
**Habitat**

General Habitat Notes: Reach in good condition, there were some indications of historic riparian areas removed, some concrete bank revetment, and landowner encroachment. However, the channel was not overly degrading or aggrading, also noted formation of mid-channel bars in lower reach Stn 800 to 100. This is most likely due to the dense riparian corridor at this parcel. From 2450 to 800 could use a denser riparian over-story and wider corridor.

**Channel Stability Form**

| Reach stability | | 1-2 Degrading | | 3 Stable | | 4-5 Aggrading |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | 2 | 2-10 yr | | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | | Strong, gravels | | Weak, sand/silt | 4 |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | | Localized surficial erosion, constant width | 3 | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | 2 | Narrow, vegetated | | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | | Local erosion/pools | 3 | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | | Average | 3 | High | |
| Channel pattern | Single thread | | Single thread | 3 | Multiple thread/braided | |
| Average bank slope | <3:1 | | >3:1 | 3 | | |
| Vegetative bank protection | Poor | | Extensive | 3 | Poor | |
| **Field stability rating (add all cells)/9** | | **= 2.9** | | | | |

| **Representative cross-section sketch** | | |
|---|---|---|
| Bankfull width = 40-50 ft<br>Bankfull depth = 3-5 ft | Floodplain width = 100 ft | Water depth (at survey) = 1-2 ft<br>Water width (at survey) = 35 ft |
| Station: | | |
| Station: | | |



GENERAL REACH NOTES

This reach can be divided into two distinct sub reaches: an "altered" reach and a "natural" reach. The "altered" reach extended from Stn 2450 to 800 and consisted of a sinuous channel that has evidence of past riparian corridor clearing.  The reach lacked in-stream woody debris, did not have as dense of a riparian canopy cover as the "natural" reach, contained the two potential projects, and lacked in-stream habitat complexity. The "natural" reach, had >80% canopy cover, lots of wood in the channel, large old trees (primarily silver maples) existed on the banks, water temperatures were low, and there was a tributary coming in on the right bank.

POTENTIAL PROJECTS

Stn 1150 to 1050, approximately 100 ft of left outside bank is eroding. There is a lack of woody vegetation on the bank, which is colonized almost exclusively by reed canary grass.  To remediate this erosion, bio-engineering bank stabilization methods should be incorporated along with tree planting along the bank.

Stn 2250: concrete debris on left bank, very isolated occurrence, most likely placed by landowner to stabilize localized scour.  Due to extensive riparian belt width, this site could be improved by removal of concrete and implementing bio-engineering restoration features such as wood mattress and native live-staking.

.

## Channel Reconnaissance Form

| | |
|---|---|
| Date | August 20, 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 2 |
| Field Team | NN, ED |

| | | |
|---|---|---|
| **Station** | 2450 | **To** 12550 |

### General Channel Conditions

*Channel Shape (check)*

- ☐Rectangular
- ☒Shallow Rectangular
- ☐Irregular
- ☐Trapezoidal
- ☐Parabolic
- ☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | Sandy loam |
| Bars | Sand, small gravel |
| Bed | Sand, fine sand |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☐None ☒Mid-channel ☒Point / mid ☐Point / alternate

### Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | Vertically stable, some minor bank erosion, cohesive banks and vegetation, albeit limited in this reach, seem sufficient to prevent degradation | | | | |
| Lateral stability *deposition, erosion* | Laterally stable, channel width throughout this reach was consistent, no overt lateral movement noticed | | | | |
| Erosion (excessive/site specific) | Minor bank erosion at the following locations: Stns 12200-12100 ;11900-11825; 11500-11450; 11250-11200; 10350-10250; 9900-9825; 9250-9150; 8300-8150; 7875-7800; 3250-3150; | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☒Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: sandy loam cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide | | | *Land Use* – very active agriculture, one area where cattle noted | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | The reach is characterized on its upsteam and downstream ends with bridges:<br>Stn 12550: 2 sets of pilings in low flow channel, width of bridge passes active channel flows.<br>Stn 2450: low-cord ~8', 2 sets of 5 pilings, width of bridge is pass typical storm events (active channel flows). | | | | |
| Bankfull/Channel forming flow indication | Inside bend bench formation, mid-channel bars and point bars with bench characteristics, scour lines on bridge pilings. | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | NA | Pool sediment type | Sand, fine sand |
| Sorting / Imbrication | NA | | |

| **Bars / depositional features** | |
|---|---|
| Sediment type/size | Sand, gravel |
| Mid, alternate, braided | Fine gravel |
| Bar Vegetation (type, age) | grasses |
| Floodplain soils | Sandy loam |
| Overbank deposition | Extensive floodplain |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 100 |
| **Width of veg. riparian corridor*** | 200+ ft |
| **Canopy coverage (%)** | 10 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | |
| low = single canopy layer | x |
| medium = at least two canopy layers | |
| high = multiple canopy layers | |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | 10 |
| woody species | 10 |
| bare/other | |
| Exotic/invasive species | 80% Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Silver Maples | 65 |
| Box Elder | 20 |
| Oak/willow | 15 |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

**Habitat**

General Habitat Notes:

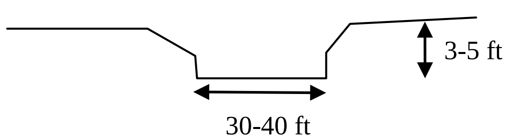
This reach was in poor condition. Characterized by intense farming and lack of riparian trees. The channel was excessively wide relative to adjacent reaches. Only due to cohesive bank soils were banks intact. The reach lacked woody debris and log jams. Additionally, other forms of bank cover were lacking as well. There was almost a complete lack of canopy from trees.

**Channel Stability Form**

| Reach stability | | 1-2 Degrading | | 3 Stable | | 4-5 Aggrading |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | 2 | 2-10 yr | | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | | Strong, gravels | | Weak, sand/silt | 4 |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | | Localized surficial erosion, constant width | 3 | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | 2 | Narrow, vegetated | | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | | Local erosion/pools | 3 | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | | Average | | High | 4 |
| Channel pattern | Single thread | 2 | Single thread | | Multiple thread/braided | |
| Average bank slope | <3:1 | | >3:1 | 3 | | |
| Vegetative bank protection | Poor | | Extensive | | Poor | 4 |
| **Field stability rating (add all cells)/9** | | **= 3** | | | | |

| **Representative cross-section sketch** | | |
|---|---|---|
| Bankfull width = 40-50 ft<br>Bankfull depth = 3-5 ft | Floodplain width = 100+ ft | Water depth (at survey) = 1-2 ft<br>Water width (at survey) = 30-40 ft |

Station:




Station:

GENERAL REACH NOTES

There was a general lack of riparian vegetation and canopy cover. Many of the outside bends had minor bank erosion.  Water temperatures were low, 58 deg F, but most likely benefited from better habitat conditions upstream.

POTENTIAL PROJECTS

The majority of projects in this reach consisted of bank erosion repairs.  These isolated repairs at Stns 12200-12100 ;11900-11825; 11500-11450; 11250-11200; 10350-10250; 9900-9825; 9250-9150; 8300-8150; 7875-7800; 3250-3150, can be repaired using standard bio-engineering techniques.

# Channel Reconnaissance Form

| | |
|---|---|
| Date | August 21, 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 3 |
| Field Team | NN, ED |

| | | | |
|---|---|---|---|
| **Station** | 12550 | **To** | 22850 |

## General Channel Conditions

*Channel Shape (check)*
☐Rectangular
☒Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | Sandy loam |
| Bars | sandy |
| Bed | Sand, fine sand |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☐None ☒Mid-channel ☐Point / mid ☐Point / alternate

## Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | Vertically stable, no signs of active degradation or aggradation | | | | |
| Lateral stability *deposition, erosion* | Laterally stable, no overt lateral movement noticed | | | | |
| Erosion (excessive/site specific) | Minor bank erosion identified: Stns 16100-15925; 15400; 15150-15250; 15000; 14300-14000 | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☒Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: sandy loam cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide | | | *Land Use* – primarily forested riparian buffer, cattle ranch on two parcels | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | The reach is characterized on its upstream and downstream ends with bridges:<br>Stn 22850: low-cord ~2.5' from water surface, width of bridge does not pass typical storm events (active channel flows), strong evidence of flows backing up due to backwatering.<br>Stn 15550: 2 sets of pilings in low flow channel, width of bridge passes active channel flows. | | | | |
| Bankfull/Channel forming flow indication | Inside bend bench formation, point bars with bench characteristics, scour lines on bridge pilings | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | Sand and sm gravel | Pool sediment type | Sand, fine sand |
| Sorting / Imbrication | NA | | |

| **Bars / depositional features** | |
|---|---|
| Sediment type/size | Sand, gravel |
| Mid, alternate, braided | sandy |
| Bar Vegetation (type, age) | grasses |
| Floodplain soils | Sandy loam |
| Overbank deposition | Extensive floodplain existent |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 100 |
| **Width of veg. riparian corridor*** | 300-500 ft |
| **Canopy coverage (%)** | 75-85 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | |
| low = single canopy layer | |
| medium = at least two canopy layers | |
| high = multiple canopy layers | x |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | 5 |
| woody species | 80 |
| bare/other | 5 |
| Exotic/invasive species | 10% Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Silver Maples | 70 |
| Box Elder | 20 |
| willow | 10 |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

**Habitat**

General Habitat Notes:

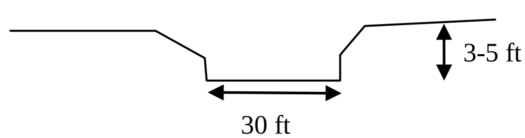
This reach was dominated by a dense canopy cover and riparian zone. Many areas with lots of woody debris (including LWD) and associated log jams. Multiple types of cover for fish.

**Channel Stability Form**

| Reach stability | | 1-2 Degrading | | 3 Stable | | 4-5 Aggrading |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | 2 | 2-10 yr | | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | | Strong, gravels | | Weak, sand/silt | 4 |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | | Localized surficial erosion, constant width | 3 | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | | Narrow, vegetated | 3 | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | | Local erosion/pools | 3 | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | | Average | 3 | High | |
| Channel pattern | Single thread | | Single thread | 3 | Multiple thread/braided | |
| Average bank slope | <3:1 | | >3:1 | 3 | | |
| Vegetative bank protection | Poor | | Extensive | 3 | Poor | |
| **Field stability rating (add all cells)/9** | | **= 3** | | | | |

| **Representative cross-section sketch** | | |
|---|---|---|
| Bankfull width = 35-45 ft<br><br>Bankfull depth = 3-5 ft | Floodplain width = 100+ ft | Water depth (at survey) = 1-2 ft<br><br>Water width (at survey) = 30 ft |

Station:




Station:

GENERAL REACH NOTES

This reach has a relatively intact and extensive riparian corridor. The canopy cover ranges from 60 to 90%. There is an abundance of woody debris in the channel which creates complex in-stream habitat. There is a single section from approximately Stn 15000 to 13200 which is negatively influenced by cattle pasturing operations. Implementing cattle pasture BMPs to include a setback buffer from the river, and offsite watering troughs would be most beneficial to this section's habitat recovery. Water temperatures in this reach were 66 deg F when measured.

POTENTIAL PROJECTS

Stn 15000-13200: cattle pasturing activities have encroached upon riparian corridor; implementing exclusionary fencing and bio-engineered stream bank protection is advised. May be beneficial to have water stations away from the river for cattle. Some rip rap was observed on banks. Again, a better solution would be to implement bio-engineering techniques and native tree plantings.

Stn 15550-15200: entire right bank is devoid of a dense riparian buffer. There is evidence that farmer no longer farms to edge of river and has implemented a setback. Also noted a linear series of tree plantings approximately 15' from edge of water (species unknown). This section would benefit by implementing a native riparian planting plan in cooperation with existing farming practices.

Stn 17400: some bank erosion associated with farm field encroachment up to bank of river, should implement a riparian setback from river and implement riparian vegetation planting.

## Channel Reconnaissance Form

| | |
|---|---|
| Date | August 21, 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 4 |
| Field Team | NN, ED |

**Station** 22850 **To** 34700

### General Channel Conditions

*Channel Shape (check)*
☐Rectangular
☒Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | silts and clay |
| Bars | sandy |
| Bed | Sand, gravel |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☐None ☐Mid-channel ☐Point / mid ☐Point / alternate

### Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | Vertically stable, no signs of active degradation or aggradation | | | | |
| Lateral stability *deposition, erosion* | Laterally stable, no overt lateral movement noticed | | | | |
| Erosion (excessive/site specific) | Minor bank erosion identified: Stns 28150-28200; 24400 | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☒Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: silty clay very cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide | | | *Land Use* – primarily secondary forested riparian buffer, cattle pasturing on a few parcels | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | The reach is characterized by two bridges:<br>Stn 22850: low-cord ~2.5' from water surface, width of bridge does not pass typical storm events (active channel flows), strong evidence of flows backing up due to backwatering.<br>Stn 31800: yellow metal footbridge with constructed riffle underneath, consisting of boulders directing flows into the mid-channel. | | | | |
| Bankfull/Channel forming flow indication | Inside bend bench formation, point bars with bench characteristics, scour lines on bridge pilings | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | Artificial riffle under bridge, gravels | Pool sediment type | Sand, fine sand |
| Sorting / Imbrication | NA | | |

**Bars / depositional features**

| | |
|---|---|
| Sediment type/size | NA |
| Mid, alternate, braided | NA |
| Bar Vegetation (type, age) | NA |
| Floodplain soils | NA |
| Overbank deposition | Sand/silt loam |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 100 |
| **Width of veg. riparian corridor*** | 300+ ft |
| **Canopy coverage (%)** | 75-85 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | |
| low = single canopy layer | |
| medium = at least two canopy layers | x |
| high = multiple canopy layers | |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | 15 |
| woody species | 70 |
| bare/other | 5 |
| Exotic/invasive species | 10% Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Silver Maples | 65 |
| Box Elder | 20 |
| willow | 10 |
| Ash | 5 |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

**Habitat**

General Habitat Notes:

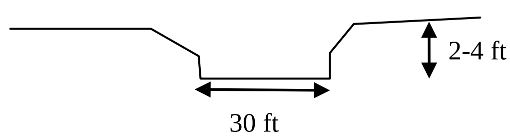
This reach was characterized by a secondary growth riparian corridor which was relatively intact. There are areas where farm encroachment is impacting the corridor. This reach has some larger cobbles and gravels within the bed and bank. There were a few locations where LWD was noted along the banks and mid-channel. There were a few backwater areas as well that served as good habitat for animals seeking shelter from the swifter main current.

**Channel Stability Form**

| Reach stability | | 1-2 Degrading | | 3 Stable | | 4-5 Aggrading |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | | 2-10 yr | 3 | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | | Strong, gravels | | Weak, sand/silt | 4 |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | | Localized surficial erosion, constant width | 3 | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | | Narrow, vegetated | 3 | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | | Local erosion/pools | 3 | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | | Average | | High | 4 |
| Channel pattern | Single thread | | Single thread | 3 | Multiple thread/braided | |
| Average bank slope | <3:1 | | >3:1 | 3 | | |
| Vegetative bank protection | Poor | | Extensive | 3 | Poor | |
| **Field stability rating (add all cells)/9** | | **= 3.2** | | | | |

| Representative cross-section sketch | | |
|---|---|---|
| Bankfull width = 30-40 ft<br><br>Bankfull depth = 2-4 ft | Floodplain width = 100+ ft | Water depth (at survey) = 1-2 ft<br><br>Water width (at survey) = 30 ft |

Station:




Station:

GENERAL REACH NOTES

This reach has a relatively intact riparian zone. There are isolated locations where minor bank erosion is occurring. The riparian zone and greater meander belt has been encroached upon by farming practices. The water temperatures coming from tributary 4 were 10° F higher than those observed in the main stem Vermillion (78° F compared to 68° F, respectively). Within the State Wildlife Management Area, two whitetail deer crossing river and a pair of sandhill cranes were observed. Reach looked as though riparian cover was not too old and likely indicates previous land use practices where riparian vegetation had been completely removed. Current farming practices encroach upon the river, thus hindering the development of a complex riparian habitat.

POTENTIAL PROJECTS

Stn 22850 Blaine Avenue Bridge is undersized. The bridge needs to be replaced by a structure that can pass the 100 year flows. Presently the bridge backs up water upstream of Blaine avenue.

Stn 25600: The mouth of Tributary 4 is contributing elevated water temperatures to the Vermillion. Should consider tributary 4 as an independent project to reduce water temperature within that drainage. See recommendations for this tributary, but most likely will include increasing canopy cover.

Stn 27500: outside bend erosion occurring at a location where an oxbow is forming, similar to Stn 32800. Riparian buffer needs to be extended with bio-engineered instream habitat restoration techniques.

Stn 31000: outside bend erosion, riparian zone is limited in this reach as farming practices have encroached upon river, there is a linear tree planting next to plowed fields, this may be responsible for "hardening" of the banks and causing localized scour within the wetted channel, a wider buffer needs to be established followed with bio-engineered restoration and native live-stake plantings.

Stn 32800-32950: localized bank erosion, this is a location where an oxbow is forming in the river, in short time the river will evulse and create an oxbow, farmer has additionally encroached upon river meander belt, farming practices should be limited to outside the established meander belt and areas of excessive erosion potential.

## Channel Reconnaissance Form

| | |
|---|---|
| Date | August 21, 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 5 |
| Field Team | NN, ED |

| **Station** | 34700 | **To** 42100 |
|---|---|---|

### General Channel Conditions

*Channel Shape (check)*
☐Rectangular
☒Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | silts and clay |
| Bars | gravels |
| Bed | Sand, gravel |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☐None
☐Mid-channel ☐Point / mid ☐Point / alternate

### Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | Vertically stable, this reach is characterized by being recently restored (within a year or two) no signs of active degradation or aggradation | | | | |
| Lateral stability *deposition, erosion* | Laterally stable, the reach has been recently restored, no overt lateral movement noticed | | | | |
| Erosion (excessive/site specific) | | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☒Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: silty clay very cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide | | | *Land Use* – primarily restored reach with new riparian buffer plantings and installation of rootwads on outside bank. Within the flood terrace there is much farming. | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | This reach is characterized by being almost entirely restored using bio-engineering techniques. | | | | |
| Bankfull/Channel forming flow indication | Difficult to discern due to new channel construction and lack of any definitive bankfull indicators. Most likely due to lack of bankfull flows since restoration. | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | NA | Pool sediment type | Sand, fine sand |
| Sorting / Imbrication | NA | | |

**Bars / depositional features**

| | |
|---|---|
| Sediment type/size | N |
| Mid, alternate, braided | NA |
| Bar Vegetation (type, age) | NA |
| Floodplain soils | Sand/silty loam |
| Overbank deposition | NA |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 100 |
| **Width of veg. riparian corridor*** | 200+ ft |
| **Canopy coverage (%)** | 35 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | |
| low = single canopy layer | |
| medium = at least two canopy layers | x |
| high = multiple canopy layers | |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | 15 |
| woody species | 40 |
| bare/other | 5 |
| Exotic/invasive species | 40% Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Willow | 40 |
| Box Elder | 40 |
| Other | 20 |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

**Habitat**

General Habitat Notes:

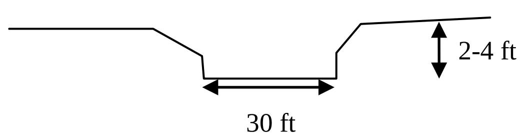
This reach was almost entirely restored within the last year or two. The primary restoration techniques included the use of root wads on the outside bends pointing upstream, woody debris mattressing, and riparian corridor restoration (tree plantings).

**Channel Stability Form**

| Reach stability | | 1-2 Degrading | | 3 Stable | | 4-5 Aggrading |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | | 2-10 yr | 3 | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | 2 | Strong, gravels | | Weak, sand/silt | |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | | Localized surficial erosion, constant width | 3 | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | | Narrow, vegetated | 3 | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | | Local erosion/pools | 3 | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | | Average | 3 | High | |
| Channel pattern | Single thread | | Single thread | 3 | Multiple thread/braided | |
| Average bank slope | <3:1 | | >3:1 | 3 | | |
| Vegetative bank protection | Poor | | Extensive | | Poor | 4 |
| **Field stability rating (add all cells)/9** | | **= 3** | | | | |

| **Representative cross-section sketch** | | |
|---|---|---|
| Bankfull width = 30-40<br><br>Bankfull depth = 2-4 | Floodplain width = 100+ ft | Water depth (at survey) = 1-2 ft<br><br>Water width (at survey) = 30 ft |

Station:




Station:

GENERAL REACH NOTES

This reach is characterized by the extensive amount of restoration that has recently been implemented. This reach has been recently restored and a completely new river meander created. The primary restoration techniques included root wad placement on the outside of bends, woody debris toe protection, and rock cross-channel constrictions creating deeper water habitat.

POTENTIAL PROJECTS

At Stn 38650 there is minor erosion occurring on the right bank. This site could benefit from some additional riparian plantings.

## Channel Reconnaissance Form

| | |
|---|---|
| Date | August 21, 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 6 |
| Field Team | NN, ED |

| **Station** | 42100 | **To** | 51750 |
|---|---|---|---|

### General Channel Conditions

*Channel Shape (check)*
☐Rectangular
☒Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | silts and clay |
| Bars | silt |
| Bed | Sand, gravel |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☐None ☐Mid-channel ☐Point / mid ☐Point / alternate

### Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | Vertically stable, habitat in equilibrium | | | | |
| Lateral stability *deposition, erosion* | Laterally stable | | | | |
| Erosion (excessive/site specific) | There were no signs of erosion in this reach | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☐Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: silty clay very cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide | | | *Land Use* – the river is within a meandering corridor, the adjacent land uses include a sanitary treatment plant to the north and agricultural use to the south | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | Stn 46250, there is a treatment plant overflow structure along the left bank | | | | |
| Bankfull/Channel forming flow indication | Outside bend benches and debris lines. | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | NA | Pool sediment type | Sand, fine sand |
| Sorting / Imbrication | NA | | |

**Bars / depositional features**

| | |
|---|---|
| Sediment type/size | NA |
| Mid, alternate, braided | NA |
| Bar Vegetation (type, age) | NA |
| Floodplain soils | NA |
| Overbank deposition | NA |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 100 |
| **Width of veg. riparian corridor*** | 300-500 ft |
| **Canopy coverage (%)** | 40 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | |
| low = single canopy layer | |
| medium = at least two canopy layers | x |
| high = multiple canopy layers | |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | 5 |
| woody species | 75 |
| bare/other | |
| Exotic/invasive species | 20% Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Willow | 40 |
| Box Elder | 40 |
| Other | 20 |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

**Habitat**

General Habitat Notes:

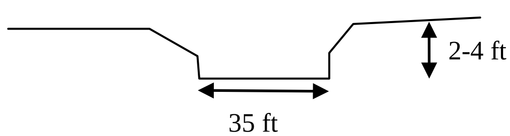
This reach is sinuous with lots of woody debris in the channel. Additionally, there are lots of log jams in the middle of the river adding significantly to channel habitat complexity. This reach also has experienced some habitat enhancement via installation of root wads and lunkers. The lunkers are in various states of damage, with some failing and others washed downstream.

**Channel Stability Form**

| Reach stability | | 1-2 Degrading | | 3 Stable | | 4-5 Aggrading |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | | 2-10 yr | 3 | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | | Strong, gravels | | Weak, sand/silt | 4 |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | | Localized surficial erosion, constant width | 3 | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | 2 | Narrow, vegetated | | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | | Local erosion/pools | 3 | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | | Average | 3 | High | |
| Channel pattern | Single thread | | Single thread | 3 | Multiple thread/braided | |
| Average bank slope | <3:1 | | >3:1 | 3 | | |
| Vegetative bank protection | Poor | | Extensive | 3 | Poor | |
| **Field stability rating (add all cells)/9** | **= 3** | | | | | |

| Representative cross-section sketch | | |
|---|---|---|
| Bankfull width = 30-40 ft<br>Bankfull depth = 2-4 ft | Floodplain width = 100+ ft | Water depth (at survey) = 1-2 ft<br>Water width (at survey) = 30 ft |

Station:




Station:

GENERAL REACH NOTES

The reach is sinuous with a relatively intact meander belt.  There are a few locations on the south side of the river where farming practices have encroached upon the riparian corridor.  Woody debris was observed throughout this reach with many log jams.  Many of the logs within the log jams originated from beaver activity. Sites with logjams had complex habitats, with associated deep water.  This reach also had many lunkers placed along the banks. Many of these lunkers were falling out of the banks resulting in bank erosion or had failed completely and washed downstream. Within the reach, the substrate was more coarse than in the downstream reaches, consisting of more gravels and some cobles.

POTENTIAL PROJECTS

Stn 47550-47450, failed lunkers and erosion occurring behind. The river has eroded the bank behind the lunkers in this reach.

Stn 44400-443500 and 43950-438500, approximately 4' eroding bank, banks are bare and lack trees. The solution for this section would be to stabilize the banks using bio-engineering methods such as brush mattresses and live stake plantings.

# Channel Reconnaissance Form

| | |
|---|---|
| Date | August 21, 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 7 |
| Field Team | NN, ED |

**Station** 51750 **To** 58250

## General Channel Conditions

*Channel Shape (check)*
☒Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | silts and clay |
| Bars | gravels |
| Bed | Sand, gravel |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☐None ☐Mid-channel ☐Point / mid ☐Point / alternate

## Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | Vertically stable | | | | |
| Lateral stability *deposition, erosion* | Laterally stable | | | | |
| Erosion (excessive/site specific) | Minor bank erosion identified:<br>Stn 58200-58100 left bank eroding on outside bend, approximately 3' high<br>Stn 54600-54500 left bank erosion not associated with local geomorphic feature | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☒Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: silty clay very cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide | | | *Land Use* – there is a mix of landuses in this reach, including recent urbanization and associated home development and infrastructure, agriculture, and a major road encroaching on river meander belt | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | Stn 51750, Biscayne Avenue Bridge has 2 sets of 7 pilings in the wetted channel | | | | |
| Bankfull/Channel forming flow indication | Outside bend benches, and debris lines, scour at bridge pilings. | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | Gravels, course sand | Pool sediment type | NA |
| Sorting / Imbrication | NA | | |

### Bars / depositional features

| | |
|---|---|
| Sediment type/size | NA |
| Mid, alternate, braided | NA |
| Bar Vegetation (type, age) | NA |
| Floodplain soils | Silty loam |
| Overbank deposition | NA |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 100 |
| **Width of veg. riparian corridor*** | 300-400 ft |
| **Canopy coverage (%)** | 50 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | |
| low = single canopy layer | |
| medium = at least two canopy layers | |
| high = multiple canopy layers | x |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | 5 |
| woody species | 75 |
| bare/other | |
| Exotic/invasive species | 20% Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Willow | 40 |
| Box Elder | 40 |
| Silver Maples | 20 |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

**Habitat**

General Habitat Notes:

This reach is characterized by being influenced from three major landuses: route 66 (Vermillion River Trail) encroachment, farming practices, and urbanization. Overall canopy cover was good at 50% cover. Substrate consisted of sands and gravels, which was more coarse than downstream reaches. This reach has evidence of being straightened in some areas in the past and not as sinuous as both upstream and downstream reaches.

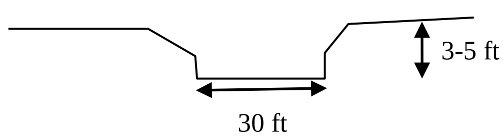
**Channel Stability Form**

| Reach stability | | 1-2 Degrading | | 3 Stable | | 4-5 Aggrading |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | | 2-10 yr | 3 | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | | Strong, gravels | 3 | Weak, sand/silt | |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | | Localized surficial erosion, constant width | 3 | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | 2 | Narrow, vegetated | | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | | Local erosion/pools | 3 | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | 2 | Average | | High | |
| Channel pattern | Single thread | 2 | Single thread | | Multiple thread/braided | |
| Average bank slope | <3:1 | 2 | >3:1 | | | |
| Vegetative bank protection | Poor | | Extensive | 3 | Poor | |
| **Field stability rating (add all cells)/9** | | **= 2.56** | | | | |

**Representative cross-section sketch**

| | | |
|---|---|---|
| Bankfull width = 25-35 ft<br>Bankfull depth = 3-5 ft | Floodplain width = 100+ ft | Water depth (at survey) = 1-2 ft<br>Water width (at survey) = 30 ft |

Station:




Station:

GENERAL REACH NOTES

The reach is characterized by being influenced by three major anthropogenic factors: farming, a road and urbanization. The upstream end of this reach is bordered by a major tributary, North Creek, whereas the downstream end of this reach is bordered by the Biscayne Avenue Bridge. The lower section of this reach has been channelized and generally lacks a dense riparian canopy, whereas the upper half is sinuous and contains mature trees. The reach has more coarse substrate than the lower reaches and is more incised with greater erosive bank heights. There is a unique feature in this reach that was not observed in any other reach within the Vermillion: from Stn 55200-55100 there is a low gradient gravel and cobble dominated riffle. The riffle is located where the channel cut across a meander and is forming an oxbow. In the upper reach, there are many downed logs and associated log jams which creates complex habitat.

POTENTIAL PROJECTS

Stn 58200-58100 left bank eroding on outside bend, approximately 3' high, this area is located at the confluence with North Creek, most likely an area where overtopping of the bank often occurs. Implementing a wider riparian buffer, in addition to a localized bank revegetation program should decrease the erosion at this site.

Stn 55000-52600 general lack of woody debris in the channel, and banks are sparsely population with mature trees. This section has been straightened and would benefit from re-contouring the river within the original meander belt. There is room to re-meander this river section to increase its length and sinuousity.

## Channel Reconnaissance Form

| | |
|---|---|
| Date | August 21, 22 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 8 |
| Field Team | NN, ED |

**Station** 58250 **To** 61625

## General Channel Conditions

*Channel Shape (check)*
☒Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | silts and clay |
| Bars | NA |
| Bed | Sand, gravel |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☒None
☐Mid-channel ☐Point / mid ☐Point / alternate

## Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | From Stn 51625-60950 the banks were eroding and not stable. Downstream of this section and for the remainder of the reach the banks were vertically stable. | | | | |
| Lateral stability *deposition, erosion* | From Stn 51625-60950 the channel was widening and laterally unstable. The downstream reaches were stable. | | | | |
| Erosion (excessive/site specific) | Minor bank erosion identified:<br>Stn 51625-61000 both banks eroding due to complete lack of bank vegetation and cattle trampling.<br>Stn 59050-58950 right bank has 4' bank erosion | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☒Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: silty clay very cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide | *Land Use* – There is one cattle pasture in the upstream section of this reach, downstream of Chippendale Avenue to the North Creek confluence, the river is located in open space, there is a single family home located on the right bank near the upstream end of the reach | | | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | Stn 60900-Chippendale Avenue Bridge<br>Stn 58500-double 'I-Beam' foot bridge, approximately 30' long, minor erosion around edges, no longer functional, low-cord =1.5' | | | | |
| Bankfull/Channel forming flow indication | Outside bend benches, and debris lines, scour at bridge pilings. | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | NA | Pool sediment type | NA |
| Sorting / Imbrication | NA | | |

**Bars / depositional features**

| | |
|---|---|
| Sediment type/size | NA |
| Mid, alternate, braided | NA |
| Bar Vegetation (type, age) | NA |
| Floodplain soils | Sand/silty loam |
| Overbank deposition | NA |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 80 |
| **Width of veg. riparian corridor*** | 0-200 ft |
| **Canopy coverage (%)** | 10 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | x |
| low = single canopy layer | |
| medium = at least two canopy layers | |
| high = multiple canopy layers | |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | 70 |
| woody species | 5 |
| bare/other | 25 |
| Exotic/invasive species | 75% Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Willow | 40 |
| Box Elder | 40 |
| Silver Maples | 20 |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

**Habitat**

General Habitat Notes:

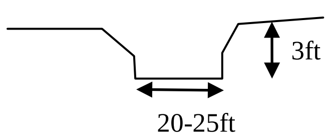
This reach can be broken up into two distinct sub-reaches: upstream and downstream of Chippendale Avenue. The habitat upstream of Chippendale Avenue is severely compromised by excessive cattle grazing. Downstream habitat is within open space, but lacks tree maturity and riparian cover. In-stream cover is low at approximately 5%. Vermillion River Trail encroaches upon river.

**Channel Stability Form**

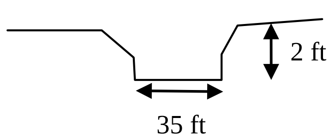
| Reach stability | | 1-2 Degrading | | 3 Stable | | 4-5 Aggrading |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | | 2-10 yr | 3 | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | | Strong, gravels | | Weak, sand/silt | 4 |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | 2 | Localized surficial erosion, constant width | | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | 2 | Narrow, vegetated | | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | 2 | Local erosion/pools | | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | | Average | | High | 4 |
| Channel pattern | Single thread | 2 | Single thread | | Multiple thread/braided | |
| Average bank slope | <3:1 | 2 | >3:1 | | | |
| Vegetative bank protection | Poor | 2 | Extensive | | Poor | |
| **Field stability rating (add all cells)/9** | | **= 2.6** | | | | |

| Representative cross-section sketch | | |
|---|---|---|
| Bankfull width = 20-30 ft<br>Bankfull depth = 2-4 ft | Floodplain width = 100+ ft | Water depth (at survey) = 1-2 ft<br>Water width (at survey) = 20 ft |

Station: d/s of Chippendale Ave




Station: u/s of Chippendale Ave



GENERAL REACH NOTES

This reach can be separated into two distinct sections: upstream and downstream of Chippendale Avenue.  The section upstream is highly impacted by cattle over-grazing and trampling.  This upper section is devoid of riparian vegetation.  The lower reach is in open space but lacks a mature riparian canopy.  Additionally, the existent riparian canopy is sparsely populated.  In-stream habitat in the upper reach contains woody debris, signs of wildlife, and is a sinuous channel.  In contrast, the upstream reach has been straightened and channelized.

POTENTIAL PROJECTS

Stn 51625-61000 both banks eroding due to complete lack of bank vegetation and cattle trampling.  The river here should be re-contoured to increase its meander length.  A riparian buffer needs to be established and cattle access to the river completely or near completely removed.  Develop an offsite water system to exclude cattle from riparian corridor.

Stn 59050-58950 right bank has 4 ft of bank erosion.  This section has the potential to undermine Vermillion River Trail.  For this reason, the river should be re-routed, from approximately Stn 59200-58800, to the northwest.

Stn 58500-double 'I-Beam' foot bridge, approximately 30' long, minor erosion around edges, no longer functional, low-cord =1.5'.  This footbridge should be removed as it may cause flooding from accumulating debris during flood events.

## Channel Reconnaissance Form

| | |
|---|---|
| Date | August 22, 2012 |
| Stream/Drainage | Vermillion River/Empire |
| Stream Reach ID | Reach 9 |
| Field Team | NN, ED |

**Station** 61625 **To** 64800

### General Channel Conditions

*Channel Shape (check)*
☒Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☐Parabolic
☐Other _______________

| Sediment Particle Size Estimate | |
|---|---|
| Banks | Silts and sands |
| Bars | silts |
| Bed | Corse sand, small gravel |

**Bar Types:** ☐Alternate lateral ☐Point / transverse ☐None ☐Mid-channel ☐Point / mid ☐Point / alternate

### Fluvial Geomorphic Conditions

| | | | | | |
|---|---|---|---|---|---|
| Vertical Stability *degradation/aggradation* | From Stn 63000-61800 the right bank was eroding and not stable. Outside of this section the banks were vertically stable. | | | | |
| Lateral stability *deposition, erosion* | From beginning of Stn 64000 downstream, the channel widened, but did not show instability outside of the Stn 63000-61800 right bank reach. | | | | |
| Erosion (excessive/site specific) | Minor bank erosion:<br>Stn 63000-61800 the right bank was eroding and not stable. | | | | |
| Dominant bank erosion types (circle any that apply) | *Fluvial* | ☒Undercut / cantilever | ☐Selective erosion of noncohesive laters | ☐Dry flow | ☐Seepage |
| | *Gravitational* | ☐Rotational | ☐Planar | ☐Wedge | |
| Bank composition | *Notes (shape/character)*: sandy silty cohesive banks | | | | |
| Terrace/Valley | *Valley form* – flat and wide on left bank, right bank is elevated and urbanized | *Land Use* – This reach is bordered on the left bank by open space woodlands. The right bank is dominated by single family homes with mixed setbacks from the river. | | | |
| Altered state (human) - dams, bridges, canoe landings, parks, etc. | Stn 64400 right bank, 3'RCP with flared wingwalls<br>Stn 63000 dilapidated wooden bridge<br>Stn 62525 private landowner bridge<br>Stn 61800 24" CMP | | | | |
| Bankfull/Channel forming flow indication | Outside bend benches, and debris lines | | | | |

## Sediment Impacts

| | | | |
|---|---|---|---|
| Riffle sediment type | NA | Pool sediment type | NA |
| Sorting / Imbrication | NA | | |

**Bars / depositional features**

| | |
|---|---|
| Sediment type/size | NA |
| Mid, alternate, braided | NA |
| Bar Vegetation (type, age) | NA |
| Floodplain soils | Sand/silt loam |
| Overbank deposition | NA |

## Riparian Vegetation and Floodplain

| | |
|---|---|
| **Root coverage of banks (%)** | 75 |
| **Width of veg. riparian corridor*** | 200-300 ft |
| **Canopy coverage (%)** | 40 |

** Verify with orthoquad data*

**Canopy structure : (check one)**

| | |
|---|---|
| none = anthro / maintained (lawn, field, pasture) | |
| low = single canopy layer | |
| medium = at least two canopy layers | x |
| high = multiple canopy layers | |

**Primary veg forms present: (%)**

| | |
|---|---|
| grasses/forbs | |
| woody species | 70 |
| bare/other | 15 |
| Exotic/invasive species | 15% Canary Reed Grass |

| Woody Species present | % of total tree community |
|---|---|
| Willow | 33 |
| Box Elder | 33 |
| Silver Maples | 33 |

**Tree Stand Age (if applicable)**

| *Station* | *Species* | *Age* | *Notes / Location within XS* |
|---|---|---|---|
| | | | |
| | | | |

**Habitat**

General Habitat Notes:

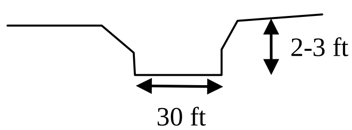
This reach can be divided into two sections: upstream and downstream of Stn 63000. The upstream section was characterized by urban development on the right bank and historic Trout Unlimited-supported bank restoration. The reach has good canopy cover, in-stream habitat was moderately complex with deep pools and various types of cover. The restored areas incorporated large woody debris, rootwads, and boulders in their designs and increased channel complexity. The downstream reach was characterized by having a mature riparian corridor on its left bank and a right bank that was impacted by current landuse practices.

**Channel Stability Form**

| **Reach stability** | | **1-2 Degrading** | | **3 Stable** | | **4-5 Aggrading** |
|---|---|---|---|---|---|---|
| Estimated sediment mobility (D50 moves at:) | <2yr Q | | 2-10 yr | 3 | >10 yr | |
| Substrate consolidation | Strong, gravels/cobble | | Strong, gravels | | Weak, sand/silt | 4 |
| Bank failure mechanism | High banks, grav. collapse, variable channel width | | Localized surficial erosion, constant width | 3 | Low banks, overflows, surficial erosion | |
| Bar development | Poorly formed | 2 | Narrow, vegetated | | Wide (>1/2 channel length), unveg. | |
| Bank erosion extent | Extensive | 2 | Local erosion/pools | | Extensive bar pressure | |
| Relative Width:Depth ratio | Low | | Average | 3 | High | |
| Channel pattern | Single thread | | Single thread | 3 | Multiple thread/braided | |
| Average bank slope | <3:1 | 2 | >3:1 | | | |
| Vegetative bank protection | Poor | 2 | Extensive | | Poor | |
| **Field stability rating (add all cells)/9** | | **= 2.7** | | | | |

| **Representative cross-section sketch** | | |
|---|---|---|
| Bankfull width = 20-30 ft<br>Bankfull depth = 2-3 ft | Floodplain width = 100+ ft | Water depth (at survey) = 1-2 ft<br>Water width (at survey) = 20 ft |

Station:




Station:

GENERAL REACH NOTES

This reach can be divided into two sections: upstream and downstream of Stn 63000. The upstream reach was characterized by urban development on the right bank and historic Trout Unlimited-supported bank restoration. The reach has good canopy cover, instream habitat was moderately complex with deep pools and various types of cover. The restored areas incorporated large woody debris, rootwads, and boulders in the designs and increased channel complexity. The downstream reach was characterized by having a mature riparian corridor on its left bank and a right bank that was highly impacted by current agricultural practices.

POTENTIAL PROJECTS

Stn 64400 right bank, 3-foot reinforced concrete pipe with flared wingwalls, storm drain located on right bank on middle third of outside meander pool, immediately downstream is excessive bank erosion, top of bank should receive plantings to strengthen bank and minimize erosion, culvert is both positioned and discharging perpendicular to river flow, this site would benefit from directing flows downstream, parallel with main channel flow. Additionally, if possible and not too expensive, re-align outlet so that discharge is to a riffle or run habitat and not outside meander pool.

Stn 63600-63500, grass clipping observed on bank of river, outreach efforts in general would inform homeowners of negative impacts of yard waste on waterways, implementing backyard setbacks where urban gardening is discouraged would also have benefits to the river.

Stn 63000 dilapidated wooden bridge, needs to be removed as it no longer serves its purpose and has potential to serve as an in-stream snag and increase flooding.

Stn 61800-61750 stretch just downstream of 24-inch corrugated metal pipe where right bank has been rip-rapped, this site is where the river begins to become straightened by urban and agricultural landuses, restoration effort should be combined with contiguous sections both upstream and downstream.

## APPENDIX E: Potential project forms

**Potential Project** **PP 01**

| Stream: Vermillion, Reach 1 | Problem description: Approximately 100 ft of left outside bank is eroding. There is a lack of woody vegetation on the bank, which is colonized almost exclusively by canary reed grass. |
|---|---|
| Station: 1050-1150, left bank | |
| Solution: To remediate this erosion, bio-engineering bank stabilization methods should be incorporated along with tree planting along the bank. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 1 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 02**

| Stream: Vermillion, Reach 1 | Problem description: Concrete debris has been placed along left bank and channel. Likely placed by landowner to stabilize localized scour. |
|---|---|
| Station: 2250, left bank | |
| Solution: Remove concrete and plant native vegetation. If widespread erosion continues, consider bank stabilization with bioengineering techniques. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 03**

| Stream: Vermillion, Reach 2 | Problem description:<br>Minor bank erosion. |
|---|---|
| Station: 3150-3250, right bank | |
| Solution:<br>Plant native trees and shrubs. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 5 | MN DNR |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

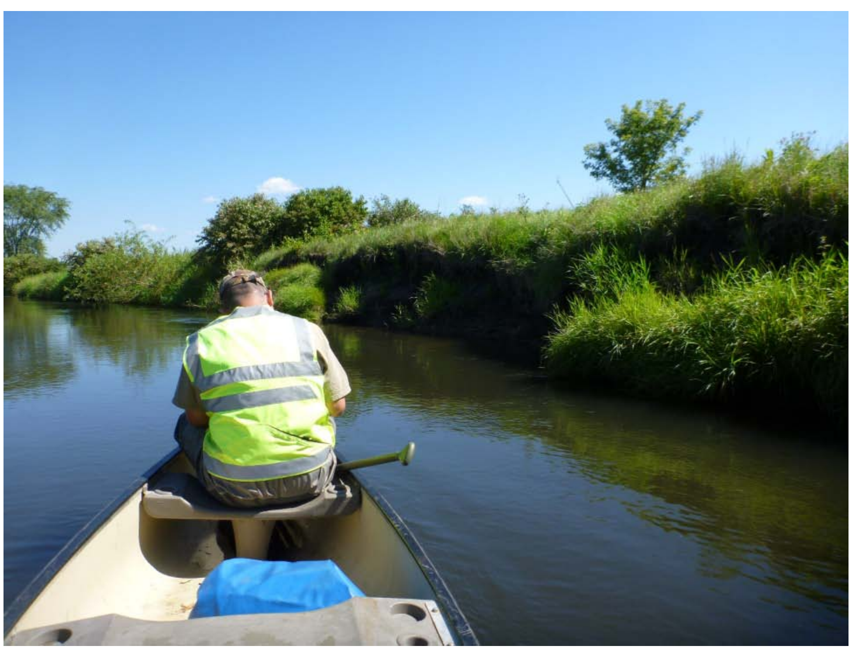
 

**Potential Project** **PP 04**

| Stream: Vermillion, Reach 2 | Problem description: Minor bank erosion. |
|---|---|
| Station: 7800-7875, right bank | |
| Solution: The site can be repaired using standard bio-engineering techniques and native plantings. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**



## Potential Project PP 05

| Stream: Vermillion, Reach 2 | Problem description:<br>Minor bank erosion. |
|---|---|
| Station: 8150-8300, left bank | |
| Solution:<br>The site can be repaired using standard bio-engineering techniques and native plantings. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 06**

| Stream: Vermillion, Reach 2 | Problem description: Minor bank erosion along 4 to 5-ft banks. |
|---|---|
| Station: 9150-9250, left bank | |

Solution:
The site can be repaired using standard bio-engineering techniques and native plantings. The fencing that has fallen, would also need to be removed.

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

## Potential Project **PP 07**

| Stream: Vermillion, Reach 2 | Problem description:<br>Minor bank erosion. |
|---|---|
| Station: 9825-9900, left bank | |
| Solution:<br>The site can be repaired using standard bio-engineering techniques and native riparian planting. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

## Potential Project PP 08

| Stream: Vermillion, Reach 2 | Problem description: Minor bank erosion and lack of root stabilization from trees. |
|---|---|
| Station: 10250-10350; left bank | |
| Solution: The site can be repaired using standard bio-engineering techniques and native riparian planting. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 09**

| Stream: Vermillion, Reach 2 | Problem description:<br>Minor bank erosion and no trees to provide root stabilization. |
|---|---|
| Station: 11200-11250, left bank | |
| Solution:<br>The site can be repaired using standard bio-engineering techniques and native riparian planting. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 10**

| Stream: Vermillion, Reach 2 | Problem description:<br>Minor bank erosion and little bank stabilization from tree roots. |
|---|---|
| Station: 11450-11500, left bank | |
| Solution:<br>The site can be repaired using standard bio-engineering techniques and native riparian planting. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

## Potential Project                                                    PP 11

| Stream: Vermillion, Reach 2 | Problem description: Minor bank erosion. |
|---|---|
| Station: 11825-11900; left bank | |
| Solution: The site can be repaired using standard bio-engineering techniques and native riparian planting. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

## Potential Project PP 12

| Stream: Vermillion, Reach 2 | Problem description:<br>Minor bank erosion and little bank stabilization from tree roots. |
|---|---|
| Station: 12100-12200; left bank | |
| Solution:<br>The site can be repaired using standard bio-engineering techniques and native riparian planting. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 13**

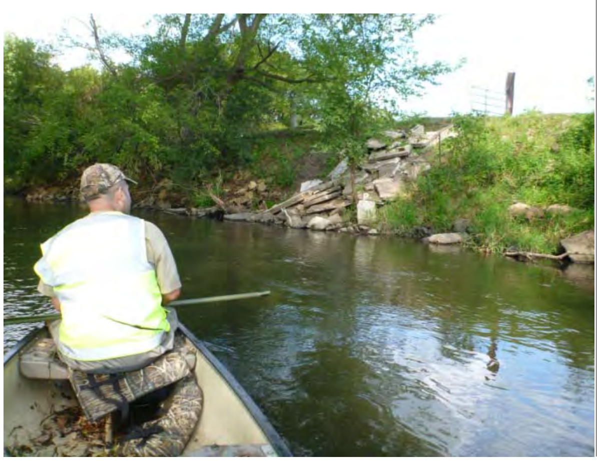
| Stream: Vermillion, Reach 3 | Problem description:<br>Cattle ranch activities have encroached upon riparian corridor resulting bank erosion and likely decreasing water quality. Approximately 50' of rip-rap has been placed along the right bank to stabilize the bank, but this prevents native trees and shrubs from growing and providing bank stabilization. |
|---|---|
| Station: 13200-15000, right bank | |

Solution:

Implement exclusionary fencing to prevent cattle from accessing the river and trampling the channel banks. Provide watering stations away from the river for cattle. Remove rip-rap, re-grade the channel bank, and stabilize the bank using bio-engineering restoration techniques and native tree plantings.

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 3 | Fence at the top of the hill |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 5 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 3 | |

**Project Area Photo/Map Location**



**Potential Project** **PP 14**

| Stream: Vermillion, Reach 3 | Problem description:<br>Entire right bank is devoid of a dense riparian buffer. |
|---|---|
| Station: 15500-15200, right bank | |

Solution:
There is evidence that the farmer no longer farms to the edge of the river and has implemented a setback. This section would benefit by implementing a native riparian planting plan in cooperation with existing farming practices.

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

## Potential Project **PP 15**

| Stream: Vermillion, Reach 3 | Problem description: Minor bank erosion associated with farm field encroachment up to the bank of the river. |
|---|---|
| Station: 17400, left bank | |
| Solution: Implement a riparian setback from river and riparian vegetation planting. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 3 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

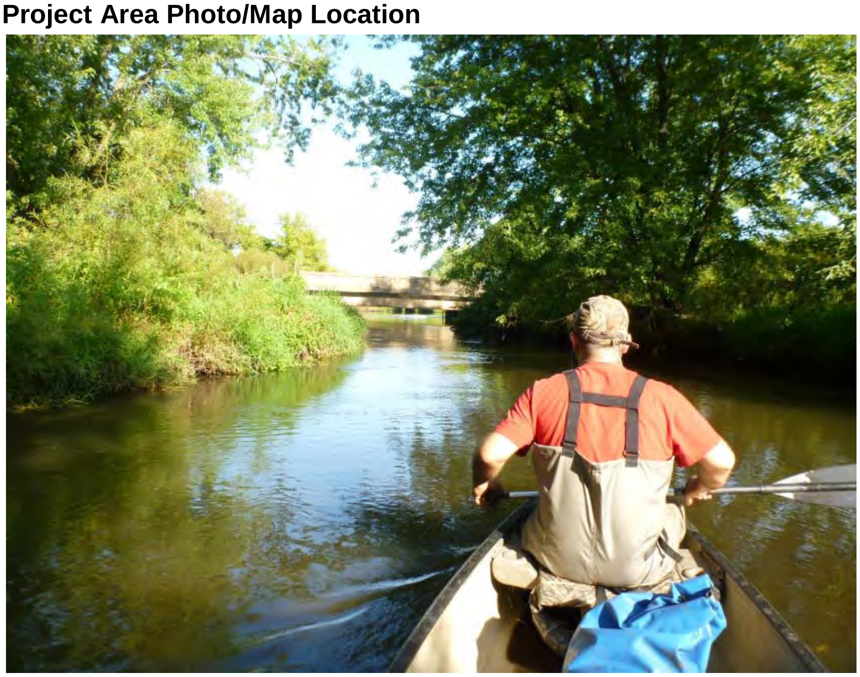
**Project Area Photo/Map Location**

## Potential Project PP 16

| | |
|---|---|
| Stream: Vermillion, Reach 4 | Problem description:<br>Blaine Avenue Bridge is undersized. Presently the bridge backs up water upstream of Blaine avenue and does not provide full floodplain connectivity. While major damage to the bridge was not observed, this pressure on the bridge could result in damage to the bridge over time. |
| Station: 22850 | |
| Solution:<br>Replace the bridge with a structure that can pass the 100 year flows. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 5 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 1 | |
| **Location** | 3 | |
| **Sediment/nutrient loading** | 1 | |
| **Project cost** | 1 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 5 | Public road |
| **Public Education** | 7 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 5 | |
| **Landuse Type** | 3 | |

**Project Area Photo/Map Location**

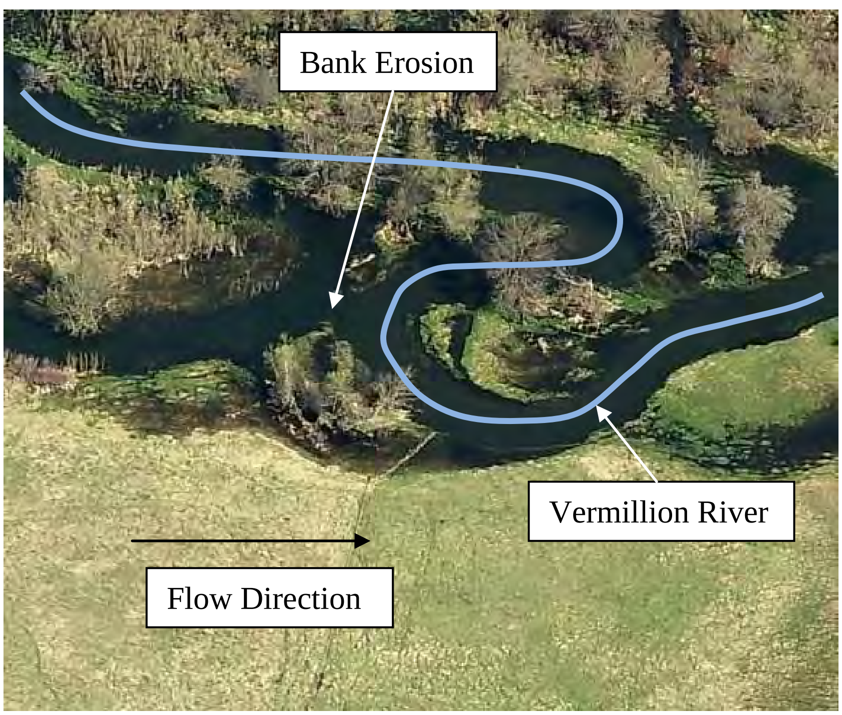


**Potential Project** **PP 17**

| Stream: Vermillion, Reach 4 | Problem description: Minor bank erosion along outside bend where an oxbow has formed. |
|---|---|
| Station: 27500 | |
| Solution: Extend riparian buffer with native tree and shrub plantings. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 3 | |
| **Sediment/nutrient loading** | 1 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 1 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 4 | Border with MN DNR |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**



## Potential Project PP 18

| Stream: Vermillion, Reach 4 | Problem description: Minor bank erosion. |
|---|---|
| Station: 32800-32950 | |
| Solution: Plant native trees and shrubs to provide bank stabilization. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 1 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 19**

| Stream: Vermillion, Reach 6<br>Station: 44350-44400, left bank | Problem description:<br>Minor bank erosion along 4-ft eroding bank. Banks are bare and lack trees. |
|---|---|
| Solution:<br>Grade banks back and plant native trees and shrubs. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 5 | Metro Council of Environmental Services |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 20**

| Stream: Vermillion, Reach 6 | Problem description: Lunkers placed along the banks have failed and fallen into the channel or washed downstream. The river has eroded the bank behind the lunkers in this reach. |
|---|---|
| Station: 47450-47550, right bank | |

Solution:

Remove the failed lunkers and stabilize the banks using bio-engineering methods. Large woody habitat structures could be placed to improve habitat and stabilize the banks. Plant native vegetation.

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 5 | Metropolitan Council of Environmental Services |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 7 | |

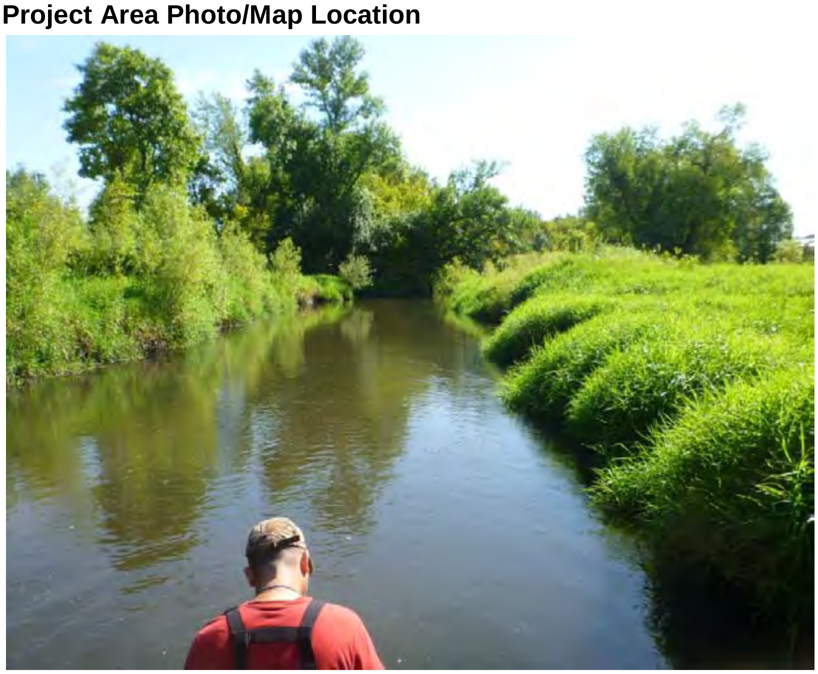
**Project Area Photo/Map Location**

**Potential Project** **PP 21**

| Stream: Vermillion, Reach 7<br>Station: 52600-55000 | Problem description:<br>This section has been straightened, has a general lack of woody habitat in the channel, and the banks are sparsely populated with mature trees. This lack of geomorphic complexity has led to a lack of habitat complexity. |
|---|---|
| Solution:<br>Increase the channel sinuosity, and incorporate large woody habitat structures. Implement riparian tree planting plan. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 3 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 7 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 5 | Empire Township Maintenance Facility and City of Farmington |
| **Public Education** | 7 | |
| **In-stream Ecological Benefit** | 7 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 7 | |

**Project Area Photo/Map Location**



**Potential Project** **PP 22**

| Stream: Vermillion, Reach 7 | Problem description:<br>Minor bank erosion along banks 3 ft high. |
|---|---|
| Station: 58100-58200, left bank | |

| Solution: |
|---|
| Plant native trees and shrubs. |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 23**

| | |
|---|---|
| Stream: Vermillion, Reach 8 | Problem description:<br>A double 'I-beam' foot bridge, approximately 30 feet long, spans the river at this site. The bridge is in disrepair and does not appear to be in use. Minor erosion was observed on the banks and the bridge likely backs water up and traps debris. |
| Station: 58500 | |
| Solution:<br>This footbridge should be removed as it may cause flooding from accumulating debris during flood events. It may also be a hazard to boaters. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 1 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 24**

| Stream: Vermillion, Reach 8 | Problem description: The Vermillion River approaches to within 15 of Vermillion River Trail at this location. The 4-foot banks are eroding and while the road is not currently at risk, continued erosion could result in undermining of the road. |
|---|---|
| Station: 58950-59050, right bank | |

Solution:

The river should be entirely re-routed, from approximately Station 58800-59200, to the northwest. The outer banks, near the road, should be stabilized using bioengineering techniques and using native vegetation.

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 5 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 7 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 3 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 25**

| | |
|---|---|
| Stream: Vermillion, Reach 8 | Problem description:<br>Bank erosion due to lack of bank vegetation and cattle trampling has caused an increase in sediment delivery to the channel and decrease in water quality. This reach of river has also been straightened, reducing the geomorphic and habitat complexity. |
| Station: 61000-61625, both banks | |

| |
|---|
| Solution:<br>Increase channel sinuosity to improve geomorphic and habitat complexity. A riparian buffer should be established and cattle access to the river limited. A water system for cattle away from the channel would provide water supply while limiting the bank erosion due to cattle trampling the banks. |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 5 | |
| **Project complexity** | 3 | |
| **Location** | 7 | |
| **Sediment/nutrient loading** | 7 | |
| **Project cost** | 5 | |
| **Aesthetic impact** | 7 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 5 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 26**

| | |
|---|---|
| Stream: Vermillion, Reach 9 | Problem description:<br>Dilapidated wooden footbridge needs to be removed as it no longer serves its purpose and is a barrier to water flow. |
| Station: 63000, spans river | |
| Solution:<br>Remove bridge and re-vegetate areas where abutments existed. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 7 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 3 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 1 | |
| **Landuse Type** | 3 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 27**

| Stream: Vermillion, Reach 9 | Problem description: Grass clipping observed on bank of river. Yard waste on channel banks prevents native vegetation from growing and providing bank stabilization. |
|---|---|
| Station: 63500-63600, right bank | |

| Solution: |
|---|
| Outreach efforts would inform homeowners of negative impacts of yard waste placed next to the river. Implement a backyard setback where non-native landscapes are prohibited. The solution here is primarily based on outreach efforts. |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 7 | |
| **Location** | 7 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 1 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 3 | |

**Project Area Photo/Map Location**

**Potential Project** **PP 28**

| | |
|---|---|
| Stream: Vermillion, Reach 9 | Problem description:<br>A 3-foot reinforced concrete pipe with flared wingwalls is located on the right bank on middle third of outside meander pool. Direction of pipe and outflow is perpendicular to channel flow resulting in bank erosion downstream. |
| Station: 64400, right bank | |
| Solution:<br>Redirect pipe and outflow to be more parallel with channel flow. If possible, change location of outlet to a more stable riffle or run. Plant native vegetation on the channel banks to provide bank stabilization. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 7 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 5 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 3 | |
| **Landuse Type** | 3 | |

**Potential Project** **PP 29**

| Stream: Empire Drainages, Tributary 1 | Problem description: Channel has been straightened into a ditch. While the channel has a substantial grassy buffer width, there is little canopy cover through most of this reach and habitat is minimal. |
|---|---|
| Station: 0-8100: Clayton Ave to mouth | |
| Solution: Within existing buffer width, create sinuous wetland channel with native wetland plantings. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 1 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 1 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 7 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Looking downstream from 190th St E.

**Potential Project** **PP 30**

| Stream: Empire Drainages, Tributary 2<br>Station: 700: 200th St E | Problem description: 2, 4.5-ft concrete pipes perched 0.5 ft on downstream end and very steep at upstream end. Fish passage barrier - depth, velocity, perched. |
|---|---|
| Solution: Raise pool elevation at downstream end to backwater the culvert to provide improved fish passage. Replacing the culverts would be better, but more expensive. Could create small blockage at upstream end of one culvert so that low flows were directed into a single culvert providing additional depth for passage. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 1 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 1 | |
| **Fish Passage** | 5 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 1 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Looking upstream at perched culverts under 200th St E.

**Potential Project** **PP 31**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 2<br>Station: 1100: Clayton Ave | Problem description: 8' x 4' concrete box culvert with flared wingwalls is cracked in many places; a 1-ft sinkhole has developed between the edge of the culvert and the road surface; the pavement in the road is cracked indicating undermining; the culvert is perched about 2 ft on the downstream end resulting in a fish passage barrier. |
| Solution: Replace culvert with a bridge, bottomless arch culvert, or larger box culvert. Ensure natural substrate on the bottom of the structure to enhance aquatic habitat and passage. This site should be assessed by a road/bridge engineer. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 6 | Holes and cracks developing near and in road. |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 1 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 1 | |
| **Fish Passage** | 5 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 1 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

See next page

Top left: looking upstream at perched culvert at Clayton Ave.
Top right: looking north along Clayton Ave.
Bottom left: cracks in road adjacent to culvert
Bottom right: hole developing between culvert and road

**Potential Project** **PP 32**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 2 | Problem description: The left bank immediately upstream of Clayton Ave is eroding. The bank is about 4 ft tall and composed of silty loam. Erosion this close to road crossings can put the crossing at risk. |
| Station: 1050-1100: just upstream from Clayton Ave | |
| Solution: Stabilize with rock toe and bioengineering above. Plant native vegetation on banks to provide root stabilization. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 3 | Continued erosion could impact the crossing downstream |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 5 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 1 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Looking upstream at bank erosion on left bank.

**Potential Project** **PP 33**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 2 | Problem description: The channel is a straightened ditch with no geomorphic or habitat complexity. |
| Station: 0-12,000: entire tributary | |
| Solution: The entire tributary could be restored, but we recommend starting with the section of channel within the forested riparian corridor between Clayton Ave and 1200 ft upstream. Because the channel is incised, the channel could be raised to reactivate the floodplain and the sinuosity could be increased. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 5 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Air photo of Tributary 2 with the forested section upstream of Clayton Ave.

**Potential Project** **PP 34**

| Stream: Empire Drainages, Tributary 2 | Problem description: Lack of riparian buffer and no canopy cover. |
|---|---|
| Station: 0-12,000: entire tributary | |
| Solution: Enforce a riparian buffer and plant native shrubs and trees along entire length of channel. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 5 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Channel with little buffer downstream of Blaine Ave.

**Potential Project** **PP 35**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 2A | Problem description: Lack of riparian buffer and no canopy cover. |
| Station: 0-7100: entire tributary | |
| Solution: Enforce a riparian buffer and plant native shrubs and trees along entire length of channel. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 5 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Channel with little buffer upstream of Blaine Ave.

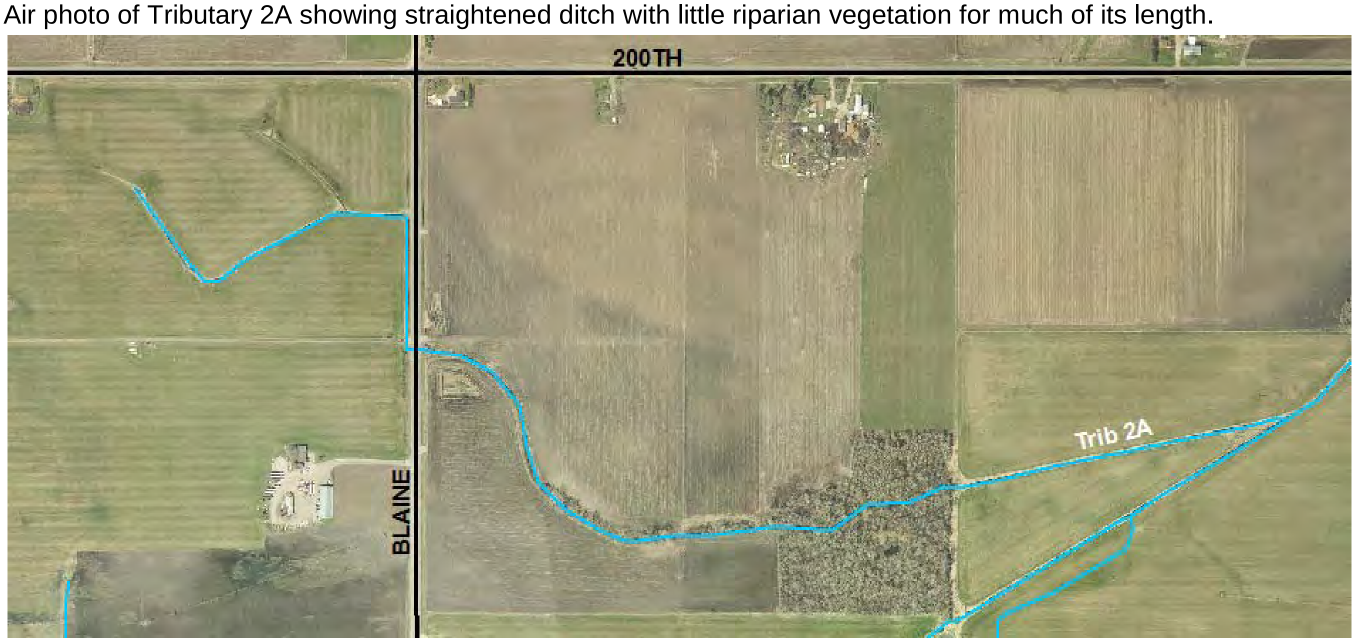
## Potential Project PP 36

| | |
|---|---|
| Stream: Empire Drainages, Tributary 2A | Problem description: The channel is a straightened ditch with no geomorphic or habitat complexity. |
| Station: 0-7100: entire channel | |
| Solution: The entire tributary could be restored. Increase channel sinuosity within narrow belt-width. Combine with PP35 to provide riparian buffer vegetation. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 1 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 5 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Air photo of Tributary 2A showing straightened ditch with little riparian vegetation for much of its length.



**Potential Project** **PP 37**

| Stream: Vermillion Tributary 4 | Problem description: Tributary 4 is contributing elevated water temperatures to the Vermillion River downstream of its confluence. Water temperatures were 10° F higher in the tributary than the mainstem. Increased water temperatures can be detrimental to aquatic habitat and water quality. The channel is straightened with no canopy cover. |
|---|---|
| Station: 0-5500 | |

Solution:
Restore Tributary 4 to a more natural riparian corridor. Increase channel sinuousity, implement riparian stream plantings, increase wetted channel canopy, increase stream channel complexity, decrease nutrient loads to tributary.

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 5 | |
| **Project complexity** | 1 | |
| **Location** | 3 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 1 | |
| **Aesthetic impact** | 7 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 4 | Upstream of Stn 2700, property owned by U of MN |
| **Public Education** | 7 | |
| **In-stream Ecological Benefit** | 7 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Potential Project** **PP 38**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 4<br>Station: 5500 | Problem description: Culvert under Annette Ave is undersized. Road prism blocks wetland flows. |
| Solution: Build bridge across wetland to provide full channel and floodplain access. A cheaper option to place larger culverts under the road. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 1 | |
| **Project complexity** | 3 | |
| **Location** | 3 | |
| **Sediment/nutrient loading** | 1 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 1 | |
| **Fish Passage** | 3 | |
| **Property Ownership** | 5 | County and state property on both sides of road |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 5 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Culvert under Annette Ave.

**Potential Project** **PP 39**

| Stream: Empire Drainages, Tributary 5 | Problem description: A dirt road crossing downstream from Annette Ave has partially washed out and is creating a blockage to flows and danger to those crossing over the stream. |
|---|---|
| Station: 2700 | |
| Solution: Remove dirt road and culvert. If road is necessary, build crossing with larger culverts embedded in natural substrate. Scores below assume removal of road and culvert. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 5 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 3 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 3 | |
| **Fish Passage** | 3 | |
| **Property Ownership** | 5 | State property |
| **Public Education** | 3 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 1 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Washed out dirt road and culvert.

## Potential Project PP 40

| Stream: Empire Drainages, Tributary 5 | Problem description: Entire channel is a straightened ditch and much of it has only a narrow riparian buffer. |
|---|---|
| Station: 0-5600: Entire tributary | |

Solution: Entire tributary is within state lands, so this could be good opportunity to restore an entire tributary to natural planform and provide recreational opportunities for residents (trails, birdwatching, etc.). Complete channel restoration with increased sinuosity, reduction of channel width, creation of active floodplain, and planting of native trees and shrubs along expanded riparian buffer

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 3 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 7 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 5 | State property |
| **Public Education** | 7 | |
| **In-stream Ecological Benefit** | 7 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

(Left) Looking upstream at channel upstream of Annette Ave; (right) looking downstream at channel downstream of washed out dirt road.

## Potential Project

**PP 41**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 6 | Problem description: Entire channel is a straightened ditch and much of it has only a narrow riparian buffer. Water quality in upper half of channel is poor - lack of infiltration and riparian buffer may be cause. |
| Station: 0-17,100: Entire tributary | |
| Solution: Completely reconstruct natural channel and wetland within reasonable easement width between farm fields. Increase sinuosity, provide floodplain/wetland flooding, and plant native trees and shrubs to provide sufficient riparian buffer width (PP42). | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 7 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | Multiple landowners |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 7 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

(Left) Looking upstream and (right) looking downstream at channel at 210th St W.

**Potential Project** **PP 42**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 6 | Problem description: Only a narrow riparian buffer through majority of tributary length. Water quality in upper half of channel is poor - lack of infiltration and riparian buffer may be cause. |
| Station: 0-17,100: Entire tributary | |
| Solution: Enforce wider riparian buffer and plant native trees and shrubs. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | Multiple landowners |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

(Left) Looking upstream and (right) looking downstream at channel at 210th St W.

**Potential Project** **PP 43**

| Stream: Empire Drainages, Tributary 6A<br>Station: 0-13,600: Entire tributary | Problem description: Entire channel is a straightened ditch and much of it has only a narrow riparian buffer. Water quality in upper half of channel is poor - farm chemicals/nutrients and lack of infiltration and riparian buffer may be cause. |
|---|---|
| Solution: Completely reconstruct natural channel and wetland within reasonable easement width between farm fields. Increase sinuosity, provide floodplain/wetland flooding, and plant native trees and shrubs to provide sufficient riparian buffer width (PP44). | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 7 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | Multiple landowners |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 7 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

(Left) Looking downstream and (right) looking upstream at channel at 210th St W.


**Potential Project** **PP 44**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 6A<br>Station: 0-13,600: Entire tributary | Problem description: Only a narrow riparian buffer through entirety of tributary length. Water quality in upper half of channel is poor - farm chemicals/nutrients and lack of infiltration and riparian buffer may be cause. |
| Solution: Enforce wider riparian buffer and plant native trees and shrubs. Identify source of poor water quality and fix. | |

| | *Score* | *Notes* |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 5 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | Multiple landowners |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

(Left) Looking downstream and (right) looking upstream at channel at 210th St W.

**Potential Project** **PP 45**

| Stream: Empire Drainages, Tributary 7 | Problem description: The channel is a straightened ditch with little geomorphic complexity and little interaction with floodplain. |
|---|---|
| Station: 0-4300: Downstream of 190th St W | |
| Solution: Complete channel restoration with a sinuous planform, active and wide floodplain and wetland complex, and copious riparian plantings. The land to the east is state property and to the west is the Metropolitan Council of Environmental Services (waste treatment facility). Could be a good location to provide recreational opportunities for residents. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 7 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 5 | State property |
| **Public Education** | 7 | |
| **In-stream Ecological Benefit** | 7 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Looking upstream at straightened channel filled with woody debris and large cottonwoods growing on floodplain.

**Potential Project** **PP 46**

| | |
|---|---|
| Stream: Empire Drainages, Tributary 7 | Problem description: Narrow riparian buffer with few trees provides limited infiltration of overland flow. Buffer ranges from 5 to 20 ft in width and is primarily composed of grasses with some cottonwoods and willows. |
| Station: 4300-12,900: upper half of watershed | |
| Solution: Enforce wider riparian buffer with increased tree and shrub planting to provide shade and improved riparian habitat. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 7 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | Multiple landowners |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 3 | |
| **Riparian Ecological Benefit** | 5 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

(Left) Looking downstream from 190th St W; (right) looking downstream from Biscayne Ave.

**Potential Project** **PP 47**

| Stream: Empire Drainages, Tributary 8 | Problem description: Channel is a channelized ditch with reduced geomorphic and habitat complexity. |
|---|---|
| Station: 0-3100: Biscayne Ave to mouth | |
| Solution: Complete channel restoration with increased sinuosity, increase channel-floodplain connections, and improved in-channel and riparian habitat. Upstream of Biscayne Ave, much of the water emanates from field tiles, so the opportunity for restoration upstream is low and downstream high due to cool water from tiling. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 3 | |
| **Location** | 7 | |
| **Sediment/nutrient loading** | 3 | |
| **Project cost** | 3 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 4 | Part owned by Metropolitan Council of Environmental Services |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 7 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

Looking downstream from Biscayne Ave.

## Potential Project PP 48

| Stream: Empire Drainages, Tributary 8 | Problem description: Very narrow riparian buffer does not provide sufficient channel or riparian shading, habitat, or infiltration. |
|---|---|
| Station: 0-14,200: Entire tributary | |
| Solution: Enforce a wider riparian buffer and plant native trees and shrubs throughout. | |

| | ***Score*** | ***Notes*** |
|---|---|---|
| **Infrastructure risk** | 1 | |
| **Erosion/channel stability** | 3 | |
| **Project complexity** | 7 | |
| **Location** | 7 | |
| **Sediment/nutrient loading** | 5 | |
| **Project cost** | 7 | |
| **Aesthetic impact** | 5 | |
| **Fish Passage** | 1 | |
| **Property Ownership** | 3 | |
| **Public Education** | 5 | |
| **In-stream Ecological Benefit** | 5 | |
| **Riparian Ecological Benefit** | 7 | |
| **Landuse Type** | 5 | |

**Project Area Photo/Map Location**

(Left) Looking downstream and (right) upstream from Biscayne Ave.s

# APPENDIX F: Detailed scoring sheet for all potential projects

Stream: Empire Drainages - Vermillion River Mainstem
Location: Dakota County, MN
Client: Vermillion River Watershed Joint Powers Organization

**Potential Project - Priority Ranking List**

| Project Number | Station Number | Primary Project | Secondary Project | *Inf. Risk* | *Channel stability* | *Project Complexity* | *Location* | *Sed/Nutrient Loading* | *Cost* | *Aesthetic impact* | *Fish Passage* | *Property Ownership* | *Public Education* | *In-stream Ecological* | *Riparian Ecological* | *Landuse Type* | ***Total Score*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PP01** | 1050-1150, left bank | B | R | 1 | 1 | 7 | 1 | 3 | 7 | 1 | 1 | 3 | 3 | 3 | 3 | 7 | **41** |
| **PP02** | 2250, left bank | B | R | 1 | 1 | 7 | 1 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **43** |
| **PP03** | 3150-3250, right bank | B | R | 1 | 1 | 7 | 1 | 3 | 7 | 3 | 1 | 5 | 3 | 3 | 3 | 7 | **45** |
| **PP04** | 7800-7875, right bank | B | R | 1 | 1 | 5 | 1 | 5 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **43** |
| **PP05** | 8150-8300, left bank | B | R | 1 | 1 | 5 | 1 | 5 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **43** |
| **PP06** | 9150-9250, left bank | B | R | 1 | 1 | 5 | 1 | 5 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **43** |
| **PP07** | 9825-9900, left bank | B | R | 1 | 1 | 5 | 1 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **41** |
| **PP08** | 10250-10350, left bank | B | R | 1 | 1 | 5 | 1 | 5 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **43** |
| **PP09** | 11200-11250, left bank | B | R | 1 | 1 | 5 | 1 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **41** |
| **PP10** | 11450-11500, left bank | B | R | 1 | 1 | 7 | 1 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **43** |
| **PP11** | 11825-11900, left bank | B | R | 1 | 1 | 7 | 1 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **43** |
| **PP12** | 12100-12200, left bank | B | R | 1 | 1 | 5 | 1 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **41** |
| **PP13** | 13200-15000, right bank | R | B | 3 | 3 | 3 | 1 | 5 | 5 | 5 | 1 | 3 | 3 | 5 | 3 | 3 | **43** |
| **PP14** | 15500-15200, right bank | R | | 1 | 1 | 7 | 1 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 5 | **41** |
| **PP15** | 17400, left bank | R | B | 1 | 1 | 7 | 3 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 7 | **45** |
| **PP16** | 22,850 | C | | 5 | 1 | 1 | 3 | 1 | 1 | 3 | 1 | 5 | 7 | 5 | 5 | 3 | **41** |
| **PP17** | 27,500 | B | R | 1 | 1 | 7 | 3 | 1 | 7 | 1 | 1 | 4 | 3 | 3 | 3 | 7 | **42** |
| **PP18** | 32800-32950 | B | R | 1 | 1 | 7 | 5 | 3 | 7 | 1 | 1 | 3 | 3 | 3 | 3 | 7 | **45** |
| **PP19** | 44350-44400, left bank | B | R | 1 | 1 | 7 | 5 | 3 | 7 | 1 | 1 | 5 | 3 | 3 | 3 | 7 | **47** |
| **PP20** | 47450-47550, right bank | B | R | 1 | 1 | 7 | 5 | 3 | 7 | 3 | 1 | 5 | 3 | 3 | 3 | 7 | **49** |
| **PP21** | 52600-55000 | N | | 1 | 1 | 3 | 5 | 3 | 3 | 7 | 1 | 5 | 7 | 7 | 7 | 7 | **57** |
| **PP22** | 58100-58200, left bank | B | R | 1 | 1 | 7 | 5 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 3 | 5 | **45** |
| **PP23** | 58,500 | I | | 1 | 3 | 7 | 5 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 1 | 5 | **45** |
| **PP24** | 58950-59050, right bank | N | | 5 | 3 | 3 | 5 | 3 | 3 | 3 | 1 | 3 | 7 | 3 | 3 | 3 | **45** |
| **PP25** | 61000-61625 | N | | 1 | 5 | 3 | 7 | 7 | 5 | 7 | 1 | 3 | 5 | 5 | 5 | 5 | **59** |
| **PP26** | 63,000 | I | | 1 | 3 | 7 | 7 | 3 | 7 | 3 | 3 | 3 | 3 | 3 | 1 | 3 | **47** |
| **PP27** | 63500-63600, right bank | R | | 1 | 1 | 7 | 7 | 3 | 7 | 3 | 1 | 3 | 3 | 1 | 3 | 3 | **43** |
| **PP28** | 64400, right bank | I | | 1 | 1 | 5 | 7 | 3 | 5 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | **41** |

**Project type**

| | |
|---|---|
| B | Bank stabilization |
| C | Culvert or other crossing |
| F | Floodplain management |
| G | Grade control |
| I | Infrastructure (outfalls, buildings etc.) |
| N | Natural channel restoration/relocation |
| R | Riparian management |

Stream: Empire Drainages Tributaries
Location: Dakota County, MN
Client: Vermillion River Watershed Joint Powers Organization

**Potential Project - Priority Ranking List**

| Project Number | Station Number | Primary Project | Secondary Project | *Inf. Risk* | *Channel stability* | *Project Complexity* | *Location* | *Sed/Nutrient Loading* | *Cost* | *Aesthetic impact* | *Fish Passage* | *Property Ownership* | *Public Education* | *In-stream Ecological* | *Riparian Ecological* | *Landuse Type* | *Total Score* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trib 1 PP29** | 0-8100 | N | R | 1 | 1 | 1 | 1 | 3 | 1 | 5 | 1 | 3 | 5 | 7 | 7 | 5 | **41** |
| **Trib 2 PP30** | 700 | C | | 1 | 1 | 5 | 1 | 1 | 7 | 1 | 5 | 3 | 3 | 3 | 1 | 5 | **37** |
| **Trib 2 PP31** | 1,100 | C | | 6 | 3 | 3 | 1 | 1 | 3 | 1 | 5 | 3 | 3 | 3 | 1 | 5 | **38** |
| **Trib 2 PP32** | 1050-1100 | B | | 3 | 3 | 5 | 1 | 3 | 7 | 3 | 1 | 3 | 3 | 3 | 1 | 5 | **41** |
| **Trib 2 PP33** | 0-12,000 | N | R | 1 | 3 | 3 | 1 | 3 | 3 | 5 | 1 | 3 | 5 | 5 | 5 | 5 | **43** |
| **Trib 2 PP34** | 0-12,000 | R | | 1 | 3 | 7 | 1 | 3 | 3 | 3 | 1 | 3 | 3 | 5 | 5 | 5 | **43** |
| **Trib 2A PP35** | 0-7100 | R | | 1 | 3 | 7 | 1 | 3 | 3 | 3 | 1 | 3 | 3 | 5 | 5 | 5 | **43** |
| **Trib 2A PP36** | 0-7100 | N | | 1 | 3 | 3 | 1 | 3 | 3 | 5 | 1 | 3 | 5 | 5 | 5 | 5 | **43** |
| **Trib 4 PP37** | 0-5500 | N | R | 1 | 5 | 1 | 3 | 5 | 1 | 7 | 1 | 4 | 7 | 7 | 7 | 5 | **54** |
| **Trib 4 PP38** | 5,500 | C | | 1 | 1 | 3 | 3 | 1 | 3 | 1 | 3 | 5 | 3 | 3 | 5 | 5 | **37** |
| **Trib 5 PP39** | 2,700 | C | | 5 | 3 | 7 | 3 | 3 | 7 | 3 | 3 | 5 | 3 | 3 | 1 | 5 | **51** |
| **Trib 5 PP40** | 0-5600 | N | R | 1 | 3 | 3 | 3 | 3 | 3 | 7 | 1 | 5 | 7 | 7 | 7 | 5 | **55** |
| **Trib 6 PP41** | 0-17,100 | N | R | 1 | 3 | 3 | 5 | 5 | 3 | 7 | 1 | 3 | 5 | 7 | 7 | 5 | **55** |
| **Trib 6 PP42** | 0-17,100 | R | | 1 | 3 | 7 | 5 | 5 | 7 | 5 | 1 | 3 | 5 | 5 | 7 | 5 | **59** |
| **Trib 6A PP43** | 0-13,600 | N | R | 1 | 3 | 3 | 5 | 5 | 3 | 7 | 1 | 3 | 5 | 7 | 7 | 5 | **55** |
| **Trib 6A PP44** | 0-13,600 | R | | 1 | 3 | 7 | 5 | 5 | 7 | 5 | 1 | 3 | 5 | 5 | 7 | 5 | **59** |
| **Trib 7 PP45** | 0-4300 | N | R | 1 | 3 | 3 | 7 | 3 | 3 | 5 | 1 | 5 | 7 | 7 | 7 | 5 | **57** |
| **Trib 7 PP46** | 4300-12,900 | R | | 1 | 3 | 7 | 7 | 5 | 7 | 5 | 1 | 3 | 5 | 5 | 7 | 5 | **61** |
| **Trib 8 PP47** | 0-3100 | N | R | 1 | 3 | 3 | 7 | 3 | 3 | 5 | 1 | 4 | 5 | 7 | 7 | 5 | **54** |
| **Trib 8 PP48** | 0-14,200 | R | | 1 | 3 | 7 | 7 | 5 | 7 | 5 | 1 | 3 | 5 | 5 | 7 | 5 | **61** |

**Project type**

| | |
|---|---|
| B | Bank stabilization |
| C | Culvert or other crossing |
| F | Floodplain management |
| G | Grade control |
| I | Infrastructure (outfalls, buildings etc.) |
| N | Natural channel restoration/relocation |
| R | Riparian management |

**APPENDIX G: Detailed maps of all streams and subwatersheds with potential projects identified. Green numbers are 500 foot stationing along the channel centerline; black numbers within the white halo are the number of the potential project.**


500 ft Stations
Reach Boundary
Empire Watershed

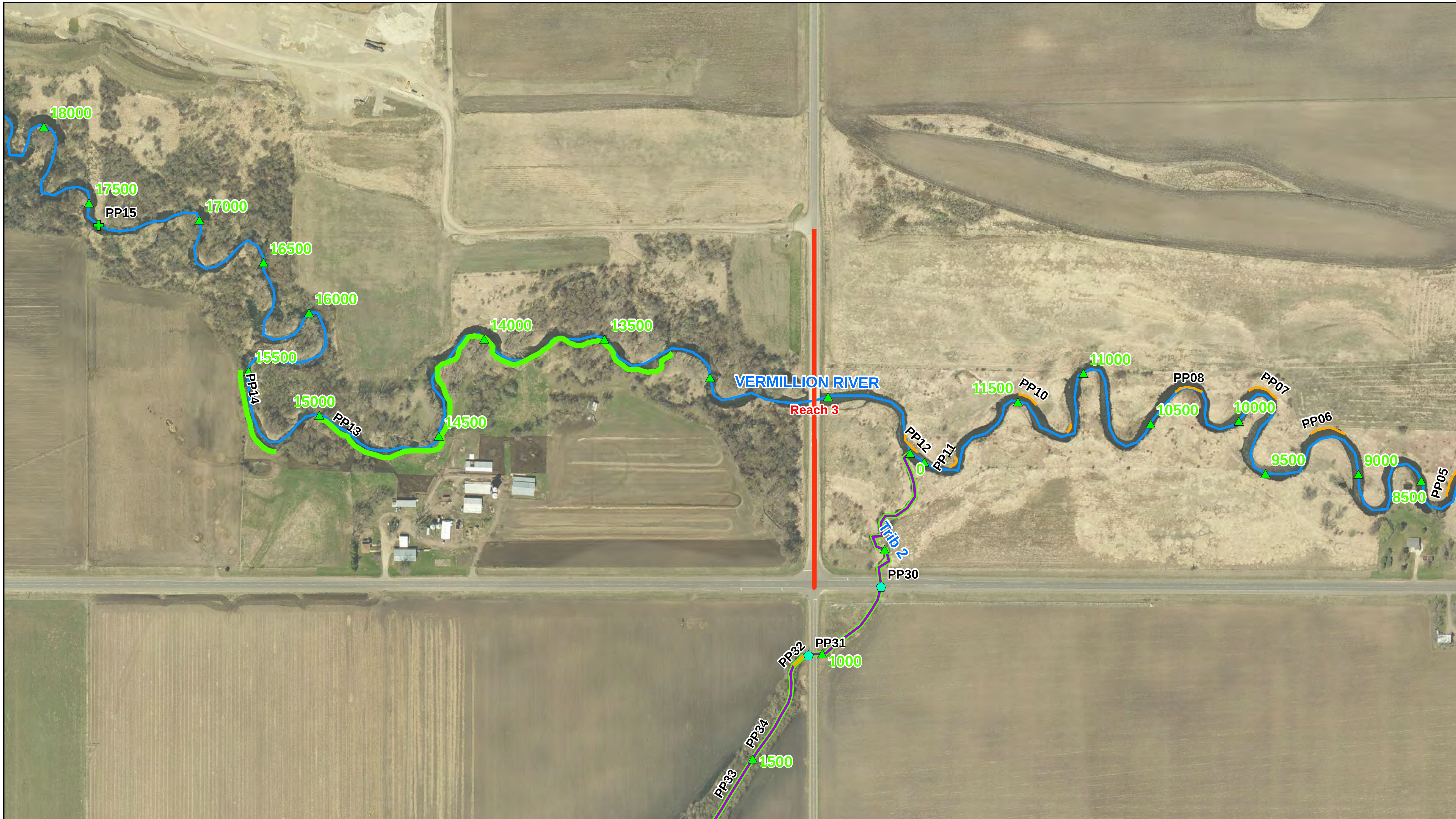
**Potential Project**

Bank Stabilization
Natural Channel Restoration/Relocation
Riparian Management

Bank Stabilization
Culvert/Crossing
Infrastructure
Riparian Management

**Geomorphic Assessment**
**Empire Drainages, Vermillion River**
**Potential Projects**
**Sheet 1 of 8**


inter·fluve
Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342



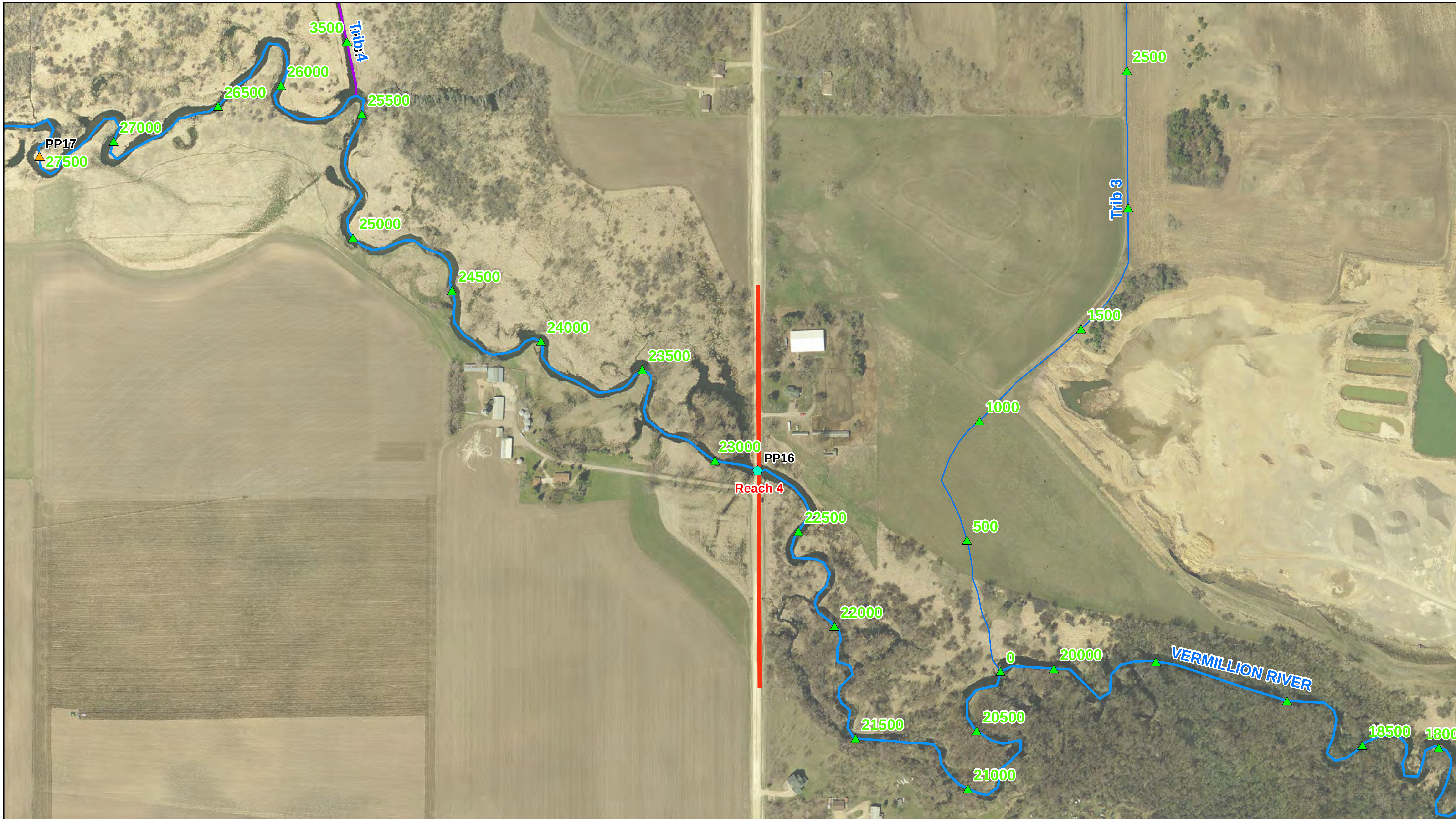

N

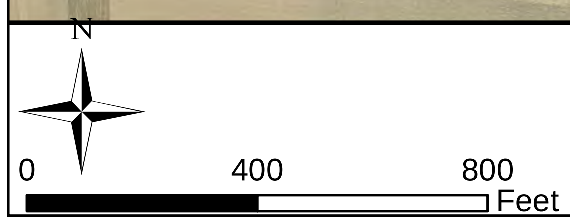
0 400 800 Feet

| | | | |
|---|---|---|---|
| ▲ 500 ft Stations | **Potential Project** | | Bank Stabilization |
| Reach Boundary | Bank Stabilization | | Culvert/Crossing |
| Empire Watershed | Natural Channel Restoration/Relocation | | Infrastructure |
| | Riparian Management | | Riparian Management |

**Geomorphic Assessment**
**Empire Drainages, Vermillion River**
**Potential Projects**
**Sheet 2 of 8**


Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342

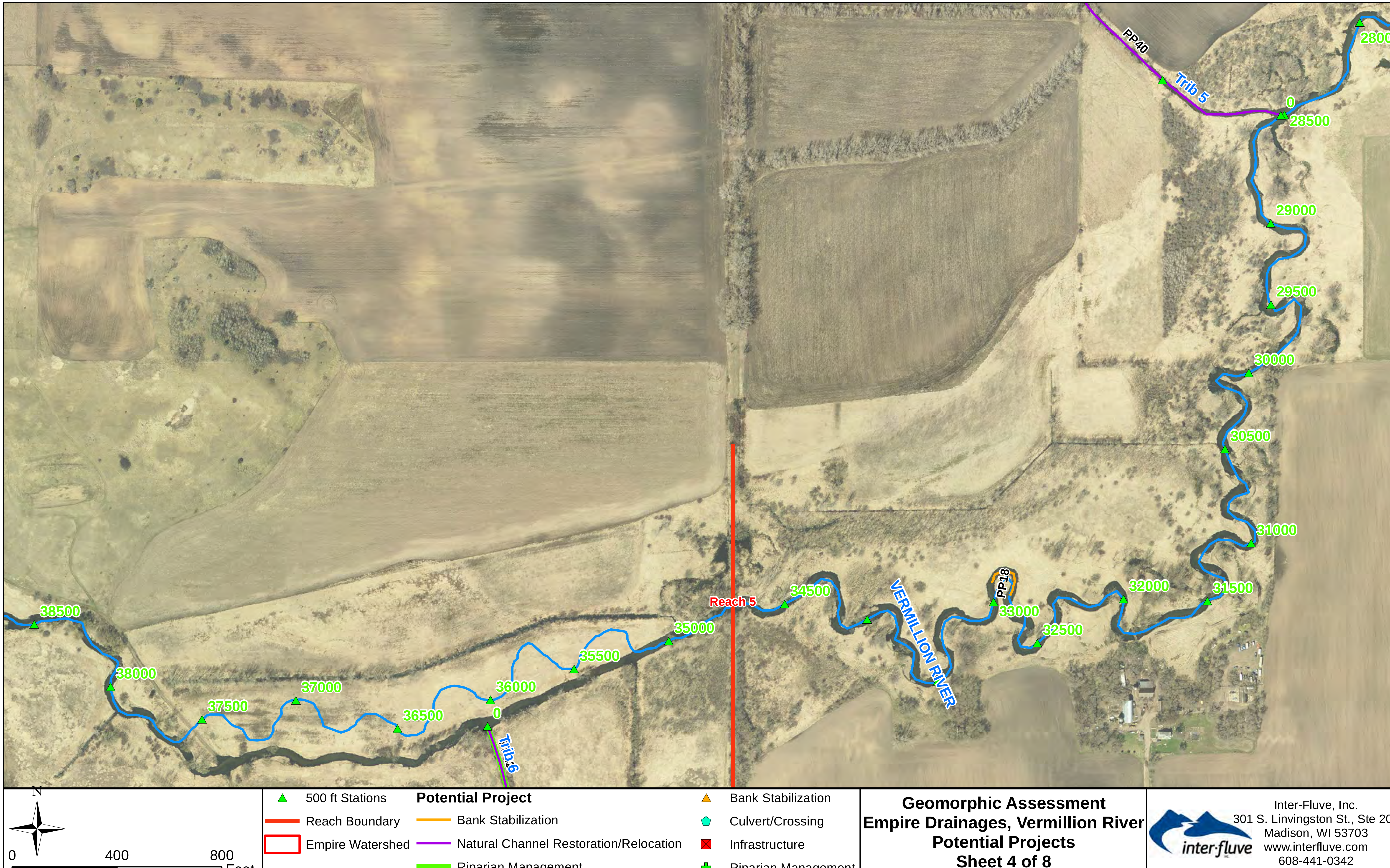


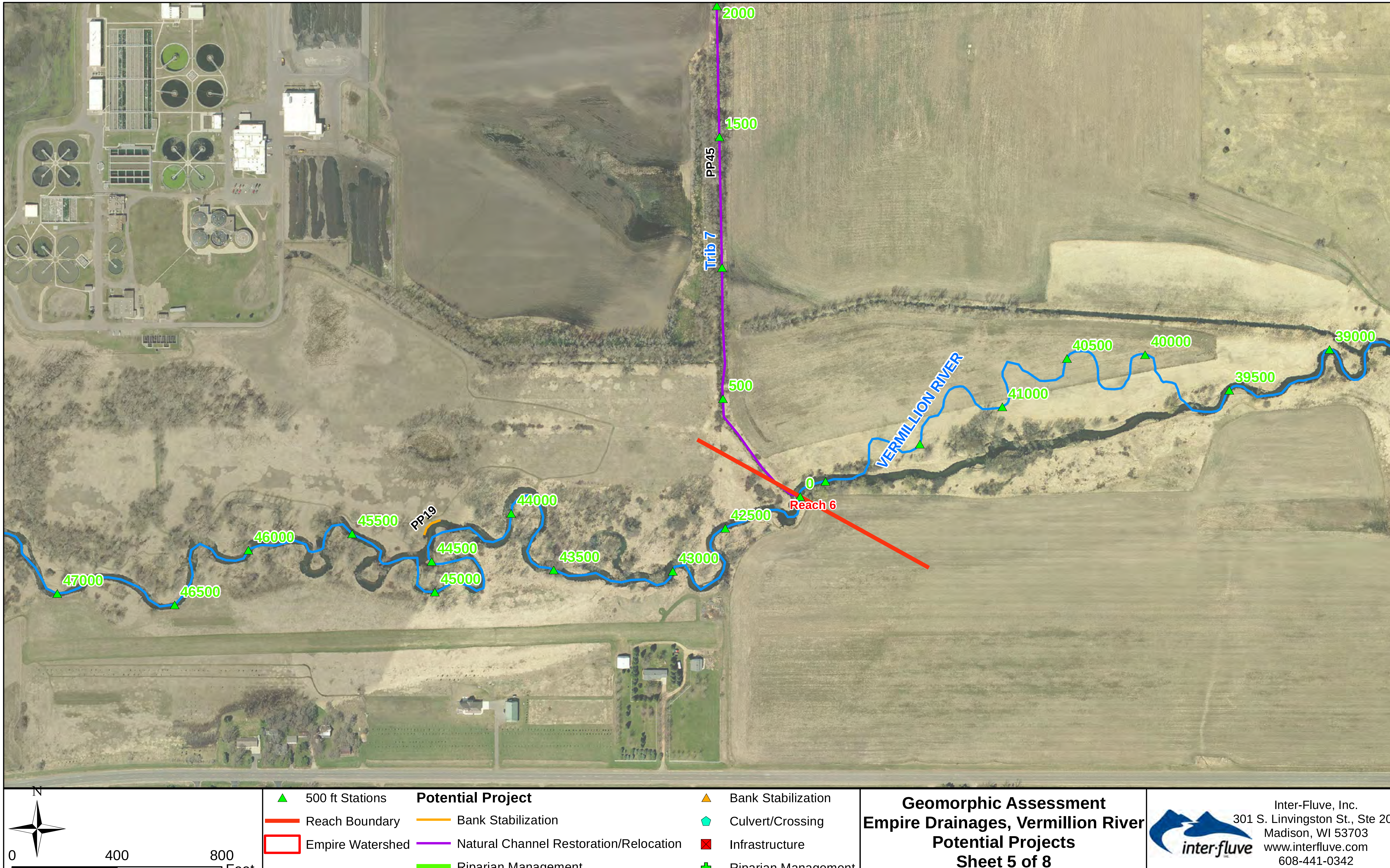

| | | | |
|---|---|---|---|
| 500 ft Stations | **Potential Project** | Bank Stabilization | |
| Reach Boundary | Bank Stabilization | Culvert/Crossing | |
| Empire Watershed | Natural Channel Restoration/Relocation | Infrastructure | |
| | Riparian Management | Riparian Management | |

**Geomorphic Assessment**
**Empire Drainages, Vermillion River**
**Potential Projects**
**Sheet 3 of 8**


Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342



PP40
Trib 5
28000
0
28500
29000
29500
30000
30500
31000
31500
32000
32500
33000
PP18
VERMILLION RIVER
34500
Reach 5
35000
35500
36000
0
Trib 6
36500
37000
37500
38000
38500
N
0
400
800
Feet
500 ft Stations
Reach Boundary
Empire Watershed
Potential Project
Bank Stabilization
Natural Channel Restoration/Relocation
Riparian Management
Bank Stabilization
Culvert/Crossing
Infrastructure
Riparian Management
Geomorphic Assessment
Empire Drainages, Vermillion River
Potential Projects
Sheet 4 of 8
inter·fluve
Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342




| | | | |
|---|---|---|---|
| 500 ft Stations | **Potential Project** | | Bank Stabilization |
| Reach Boundary | Bank Stabilization | | Culvert/Crossing |
| Empire Watershed | Natural Channel Restoration/Relocation | | Infrastructure |
| | Riparian Management | | Riparian Management |

**Geomorphic Assessment**
**Empire Drainages, Vermillion River**
**Potential Projects**
**Sheet 5 of 8**

Inter-Fluve, Inc.
301 S. Linvingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342

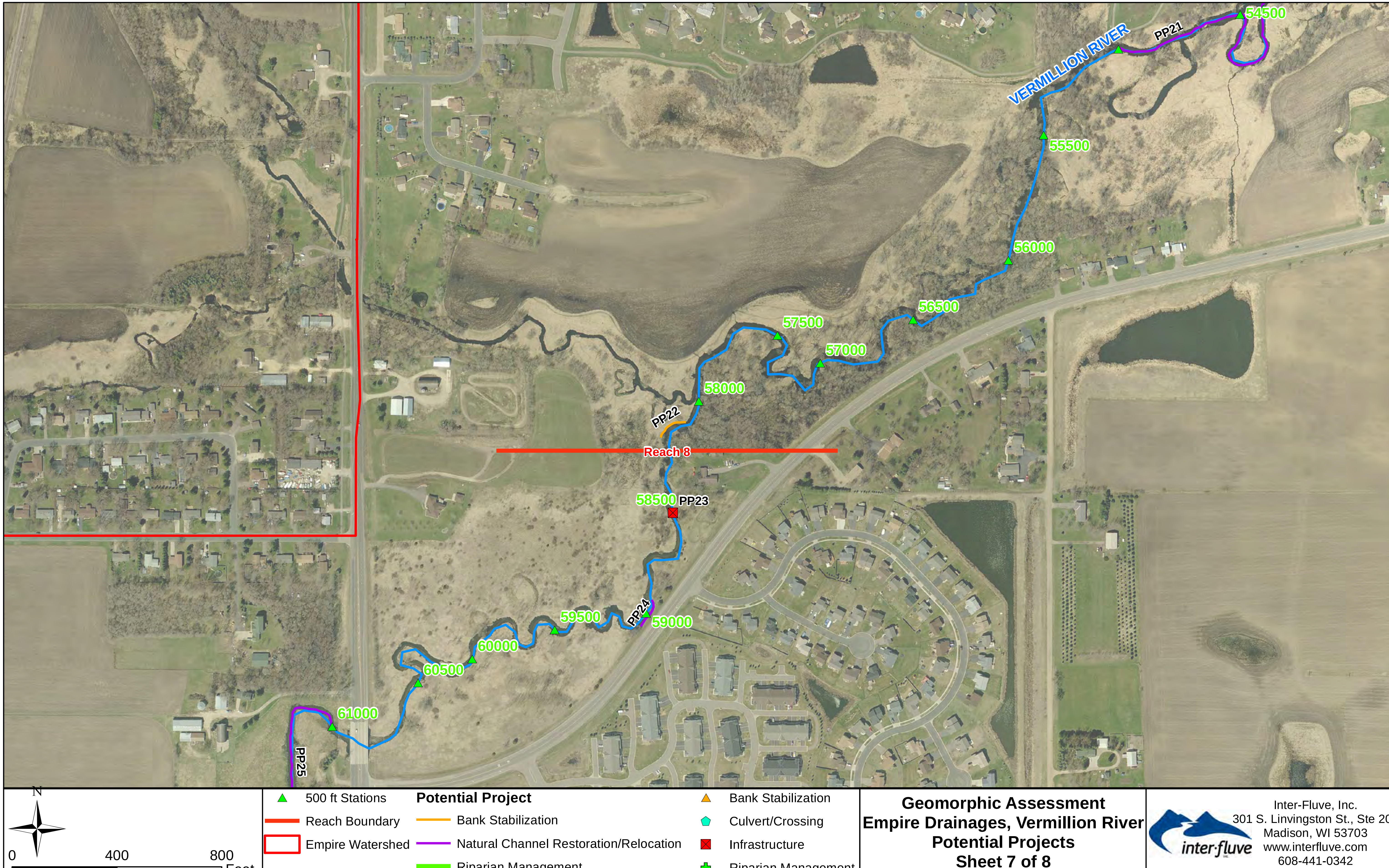

N

0 400 800 Feet

| | | | |
|---|---|---|---|
| 500 ft Stations | **Potential Project** | Bank Stabilization | |
| Reach Boundary | Bank Stabilization | Culvert/Crossing | |
| Empire Watershed | Natural Channel Restoration/Relocation | Infrastructure | |
| | Riparian Management | Riparian Management | |

**Geomorphic Assessment**
**Empire Drainages, Vermillion River**
**Potential Projects**
**Sheet 6 of 8**

Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342



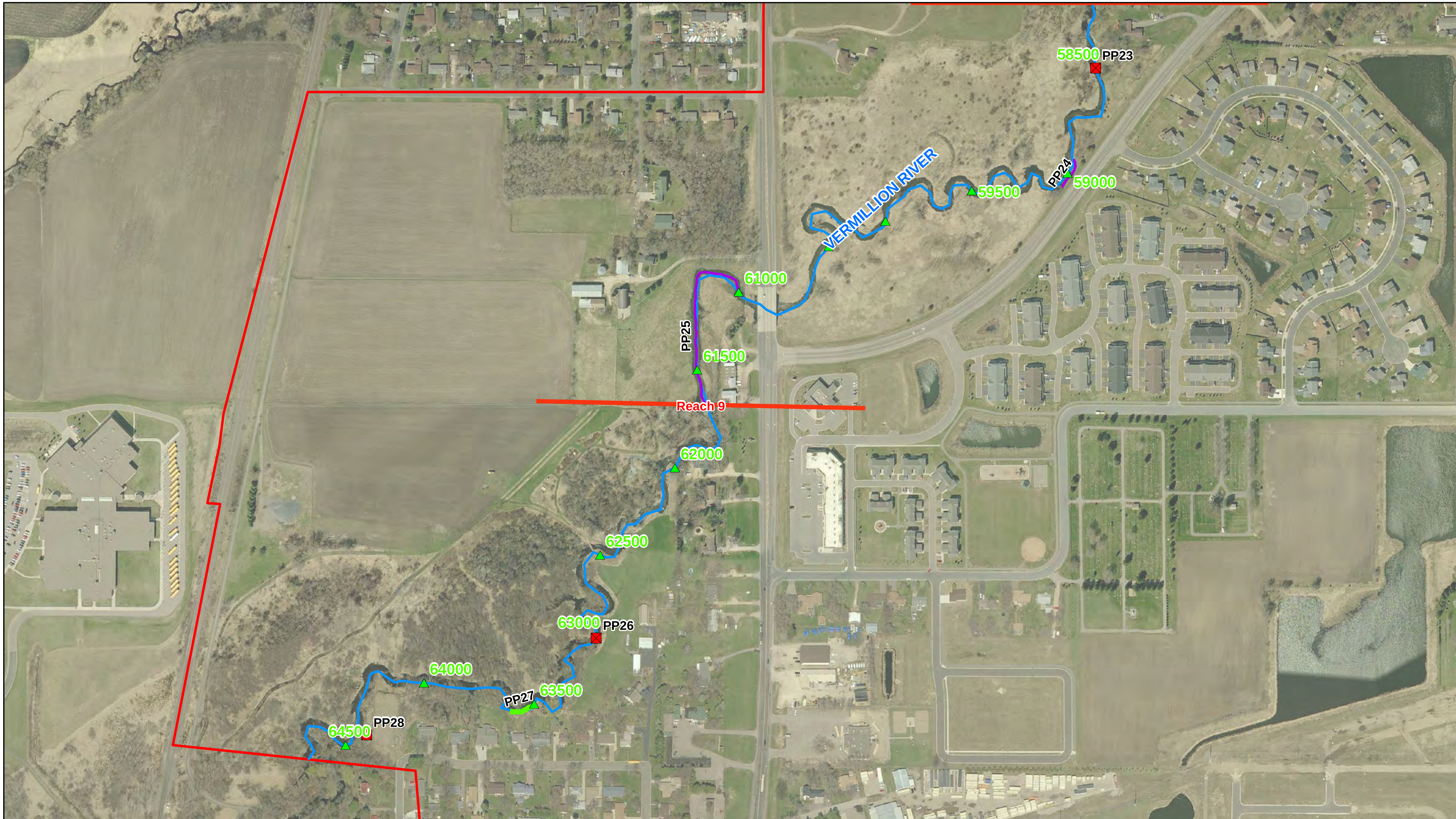

500 ft Stations
Reach Boundary
Empire Watershed

**Potential Project**
Bank Stabilization
Natural Channel Restoration/Relocation
Riparian Management

Bank Stabilization
Culvert/Crossing
Infrastructure
Riparian Management

**Geomorphic Assessment**
**Empire Drainages, Vermillion River**
**Potential Projects**
**Sheet 7 of 8**


Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342




N
0 400 800 Feet

**Legend**

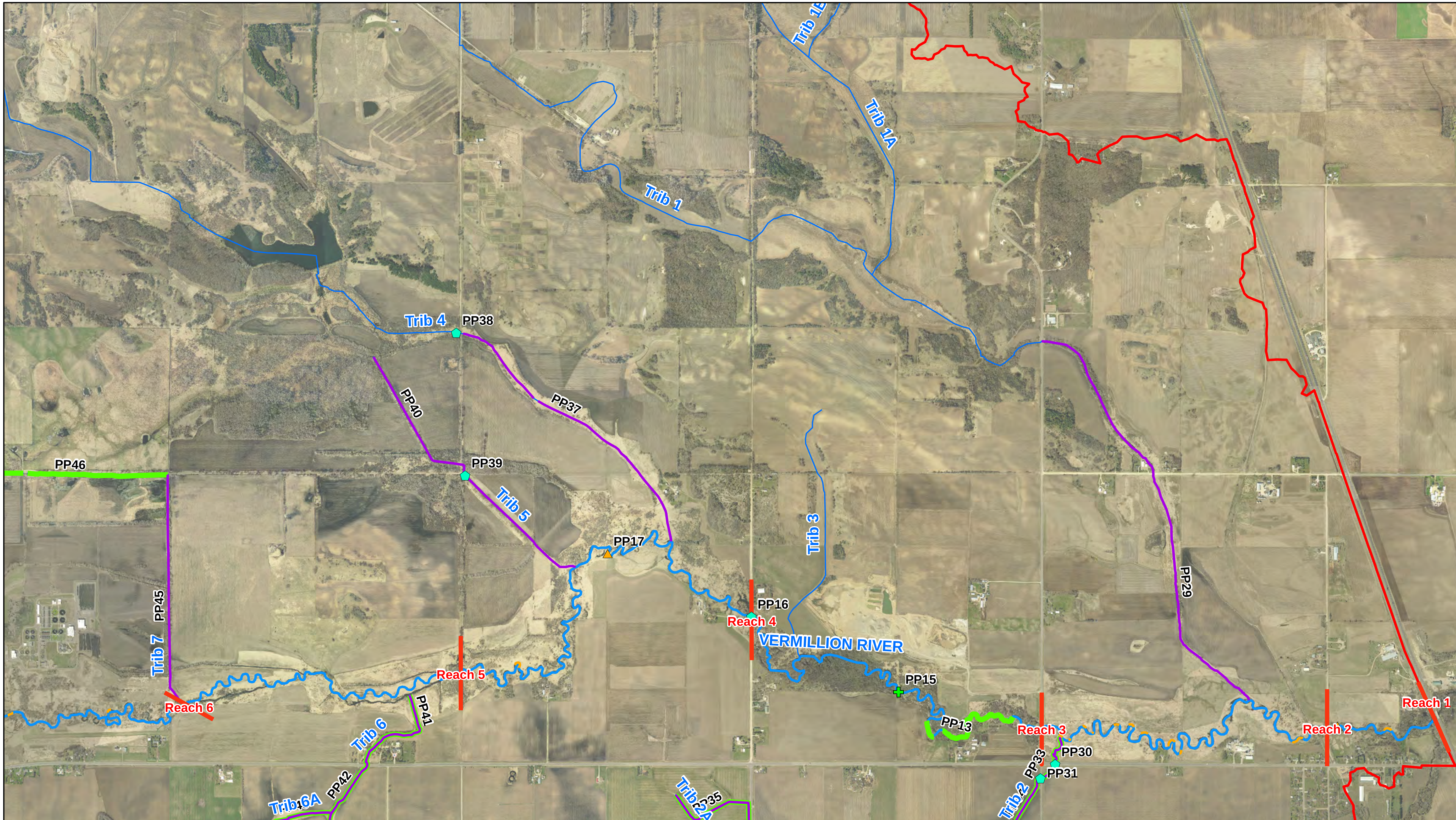
- 500 ft Stations
- Reach Boundary
- Empire Watershed

**Potential Project**

- Bank Stabilization
- Natural Channel Restoration/Relocation
- Riparian Management
- Bank Stabilization
- Culvert/Crossing
- Infrastructure
- Riparian Management

**Geomorphic Assessment**
**Empire Drainages, Vermillion River**
**Potential Projects**
**Sheet 8 of 8**

Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342




Reach Boundary
Empire Watershed

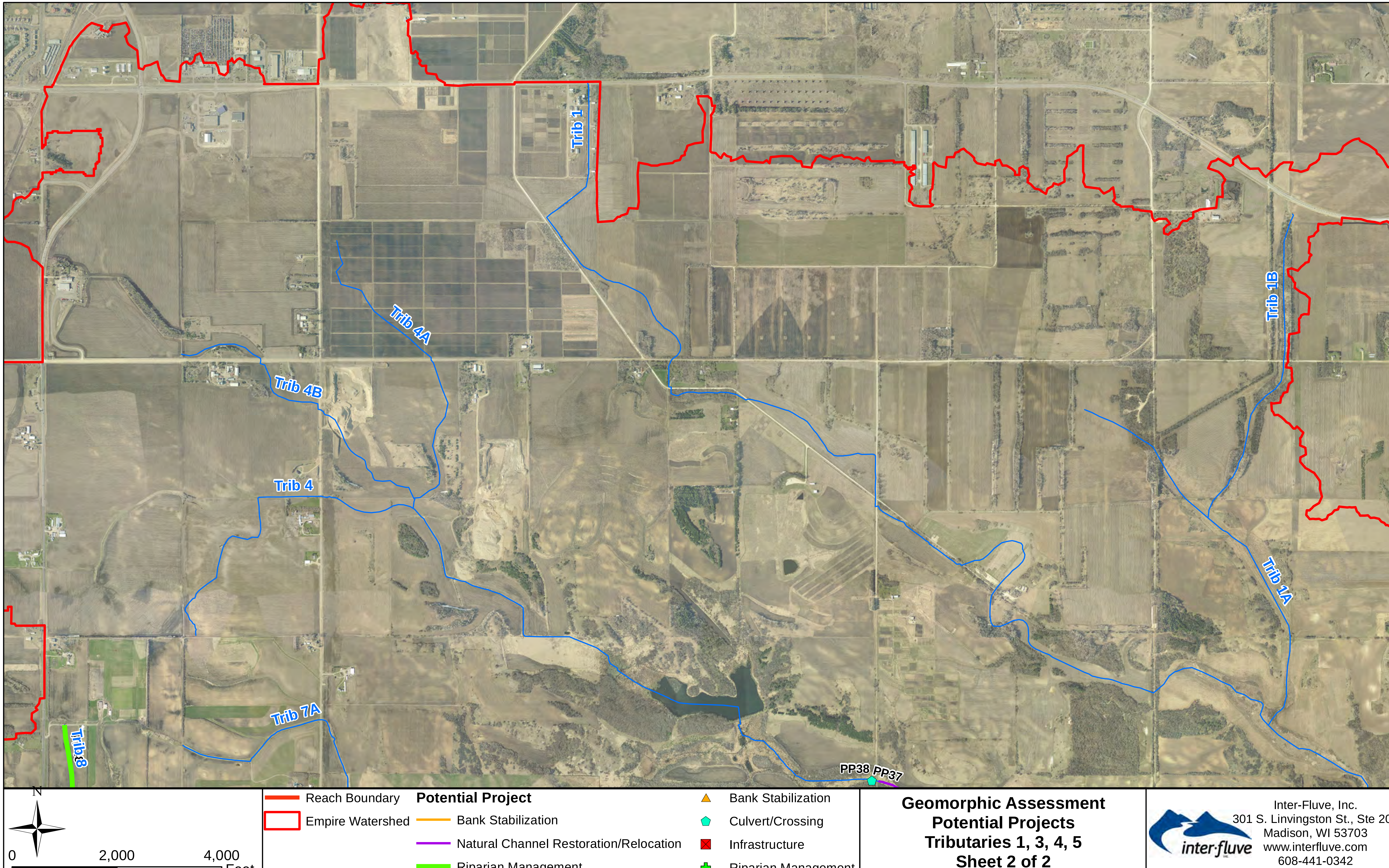
**Potential Project**

Bank Stabilization
Natural Channel Restoration/Relocation
Riparian Management
Bank Stabilization
Culvert/Crossing
Infrastructure
Riparian Management

**Geomorphic Assessment**
**Potential Projects**
**Tributaries 1, 3, 4, 5**
**Sheet 1 of 2**

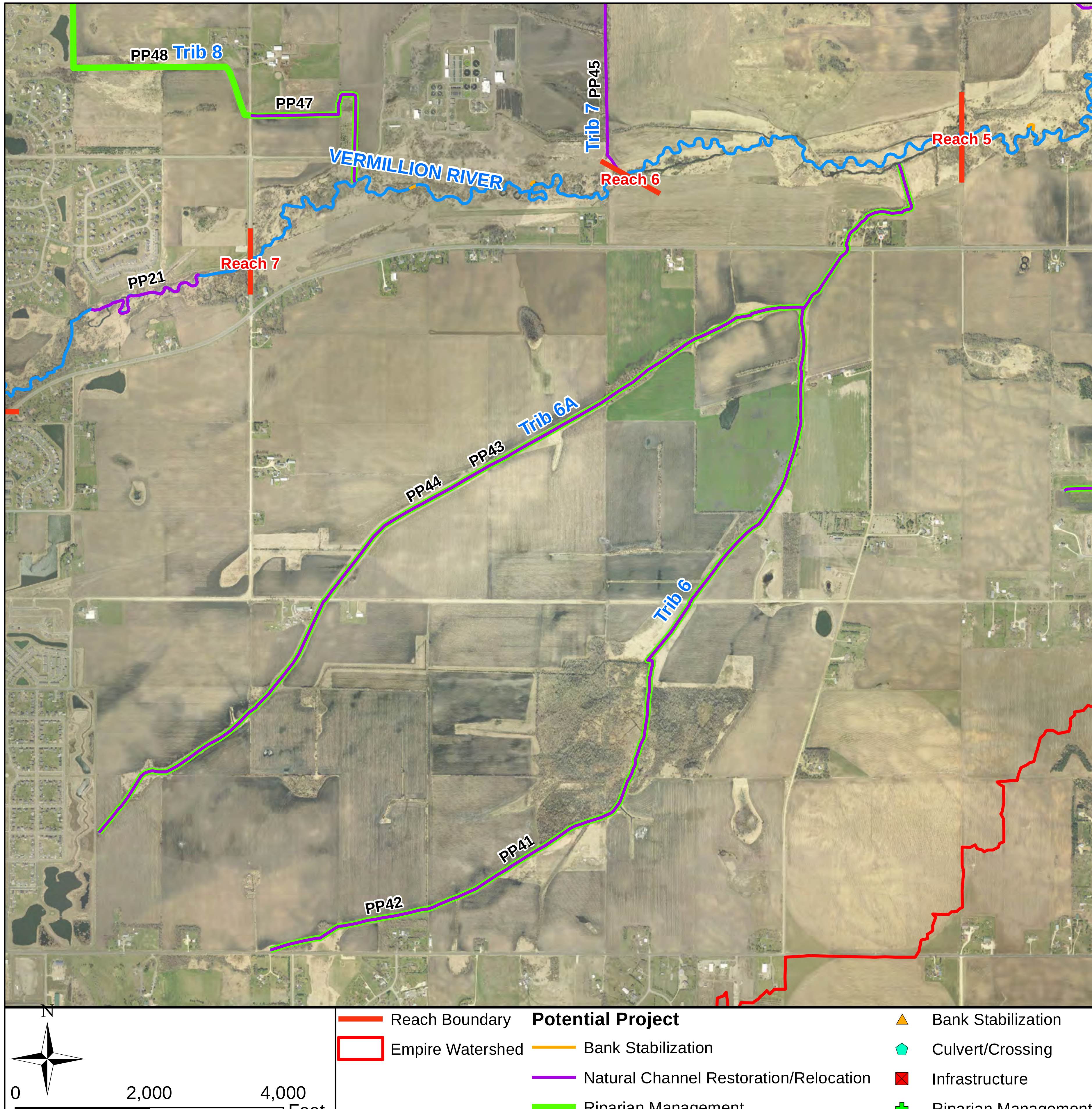

inter·fluve

Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342



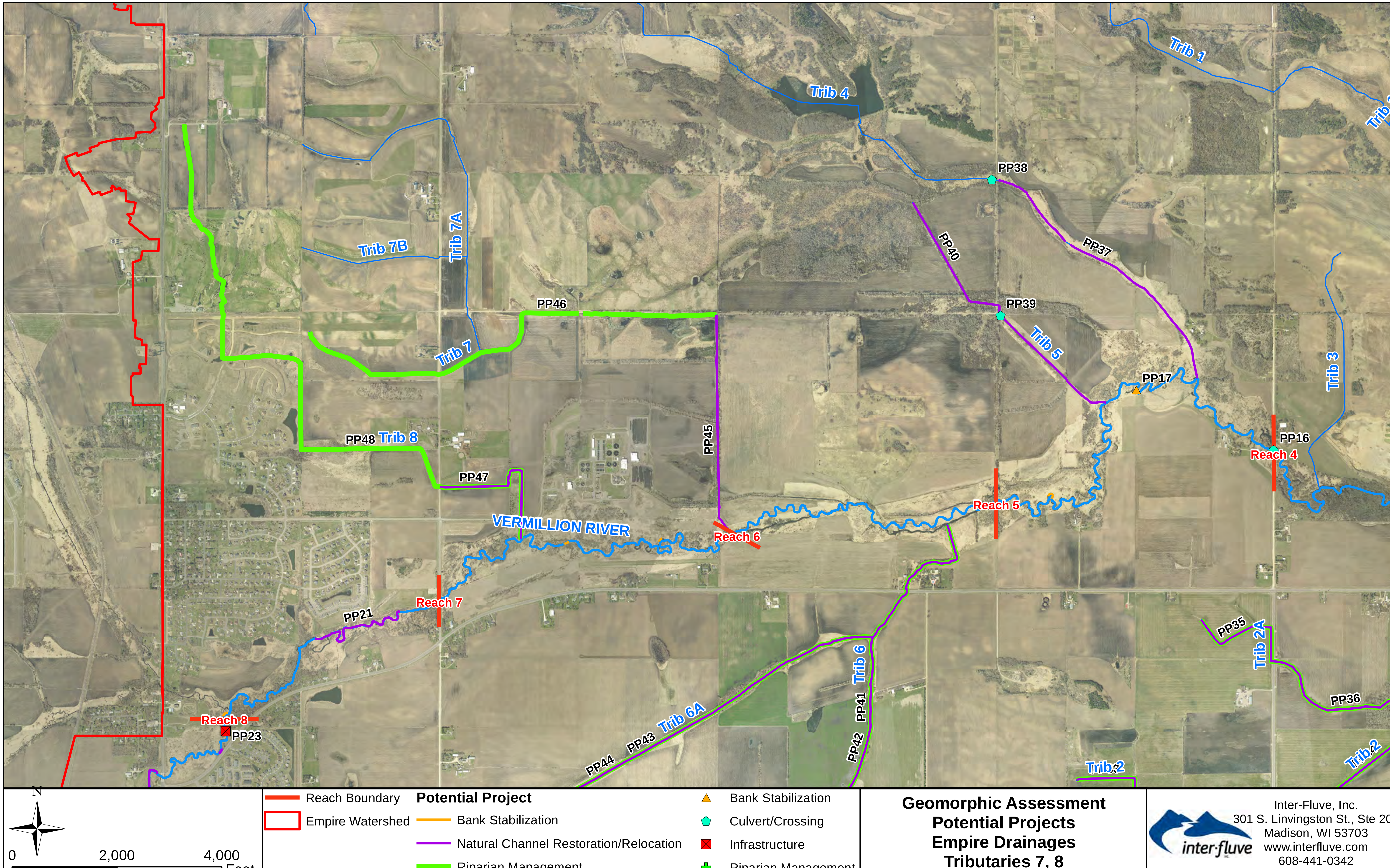

**Geomorphic Assessment**
**Potential Projects**
**Tributaries 1, 3, 4, 5**
**Sheet 2 of 2**


Inter-Fluve, Inc.
301 S. Linvingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342




**Geomorphic Assessment**
**Potential Projects**
**Empire Drainages**
**Tributaries 2, 6**

inter-fluve
Inter-Fluve, Inc.
301 S. Linvingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342




Reach Boundary
Empire Watershed

**Potential Project**
Bank Stabilization
Natural Channel Restoration/Relocation
Riparian Management

Bank Stabilization
Culvert/Crossing
Infrastructure
Riparian Management

**Geomorphic Assessment**
**Potential Projects**
**Empire Drainages**
**Tributaries 7, 8**

inter·fluve

Inter-Fluve, Inc.
301 S. Livingston St., Ste 200
Madison, WI 53703
www.interfluve.com
608-441-0342