Vermillion River Watershed Joint Powers Organization

Fluvial Geomorphic Assessment of Etter Creek and the Ravenna Coulees, Dakota County, MN: Final Report

February 25, 2011

Prepared for:

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1. Introduction

In the summer of 2010, the Vermillion River Watershed Joint Powers Organization (VRWJPO) contracted with Inter-Fluve to conduct a fluvial geomorphic assessment of Etter Creek and the Ravenna Coulee subwatersheds. The goals of this rapid assessment were to improve our understanding of stream bank stability throughout the subwatersheds; identify grade control points, knickpoints, areas of accelerated erosion, and habitat quality issues; and identify opportunities where restoring geomorphic processes and conditions would be beneficial.

The report that follows is a summary of the data collected and the potential restoration and management projects identified along Etter Creek, four Ravenna Coulees, and associated tributaries. In 2009, Inter-Fluve completed a similar geomorphic assessment along South Creek and its tributaries for the VRWJPO. In an effort to streamline this report and allow the VRWJPO to efficiently read through the results and analyses of this assessment, we have moved some information that is similar to that presented in the South Creek Report to appendices. Also in appendices are the individual reach descriptions, channel reconnaissance forms, potential project forms, detailed scoring sheets for the potential project, potential project maps, and maps of knickpoints:

- 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
- Appendix H: Detailed maps of the knickpoints throughout the subwatersheds

The fluvial geomorphic assessment was conducted in October 2010. During the assessment, 29 potential restoration projects were identified in the Etter Creek and Ravenna Coulee subwatersheds. In order to prioritize these projects for funding allocation, we developed a ranking system for the restoration projects. This ranking system scores potential stream project sites based on 10 metrics. Each metric contributes a value of 1 through 7 for the site, and the total of all of the metrics is the potential project score. Each project can be ranked by a single metric or multiple metrics, so priority can be a result of any combination of metrics chosen by the VRWJPO staff. Landowner cooperation, a new metric added specifically for this assessment, has three values: -7 points for uncooperative and not allowed on property, 0 points for unknown level of cooperation, and 7 points for access approved and cooperative. This metric was added because the streams and ravines of this assessment are within private property. If any restoration project is to be completed, approval and cooperation from landowners will be required. Although letters of notice were sent to all landowners prior to this assessment, few landowners responded with comments or questions. As the VRWJPO begins enacting these projects, the score for this metric may change as contact with landowners is made.

For the South Creek Geomorphic Assessment, we reviewed the Vermillion River Watershed Standards and discussed their impact on the streams throughout the watershed. These Standards would not have a large impact on the water bodies within the Etter Creek and Ravenna Coulee subwatersheds because many of the Standards work to control significant land use changes and would only be triggered upon the occurrence of such changes. All of the streams within the Etter Creek and Ravenna Coulee subwatersheds are intermittent and only flow following rain events or snowmelt conditions. Therefore, standards protecting in-stream and riparian habitat do not apply. In many cases, the stream channels were difficult to identify and no floodplains existed. There is also little development in the subwatersheds and much of the land within the subwatersheds is being used for agriculture. The standards provide recommendations for agriculture, but the responsibility for best agricultural practices lies with the landowner.

2. Data Collection / Methods

2.1 Existing Data

Inter-Fluve personnel collected and analyzed existing information about the Etter Creek and Ravenna Coulee subwatersheds, including aerial photographs, plat maps, and geologic maps. Additionally, staff analyzed aerial photographs in a GIS to determine reach breaks based on land use and changes in valley form, soils, longitudinal profile, planform, and road crossings.

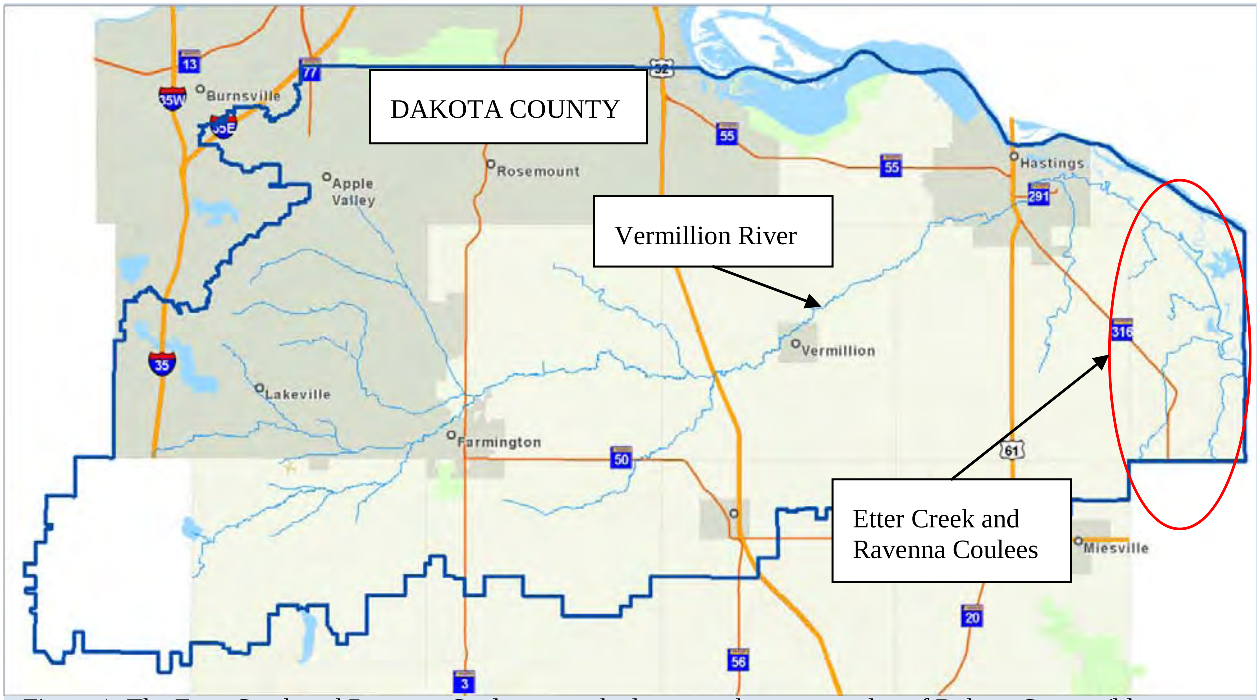

Figure 1: The Etter Creek and Ravenna Coulee watersheds are on the eastern edge of Dakota County (blue polygon). Map modified from the VRWJPO.

Etter Creek and the four Ravenna Coulees are located along the eastern edge of Dakota County and drain directly to the Vermillion River near its mouth at the Mississippi River (Figure 1). The southern portion of the Etter Creek subwatershed as well as the southeast corner of the Ravenna 4 subwatershed are within Goodhue County. These subwatersheds flow through the steep terraces created by the historic down-cutting of glacial rivers that predated the Mississippi River as we recognize it today. We identified four distinct Ravenna Coulees and, for consistency throughout this study, numbered these 1 through 4 from north to south (Figure 2). Although some residential development has occurred, much of the land within these subwatersheds is currently used

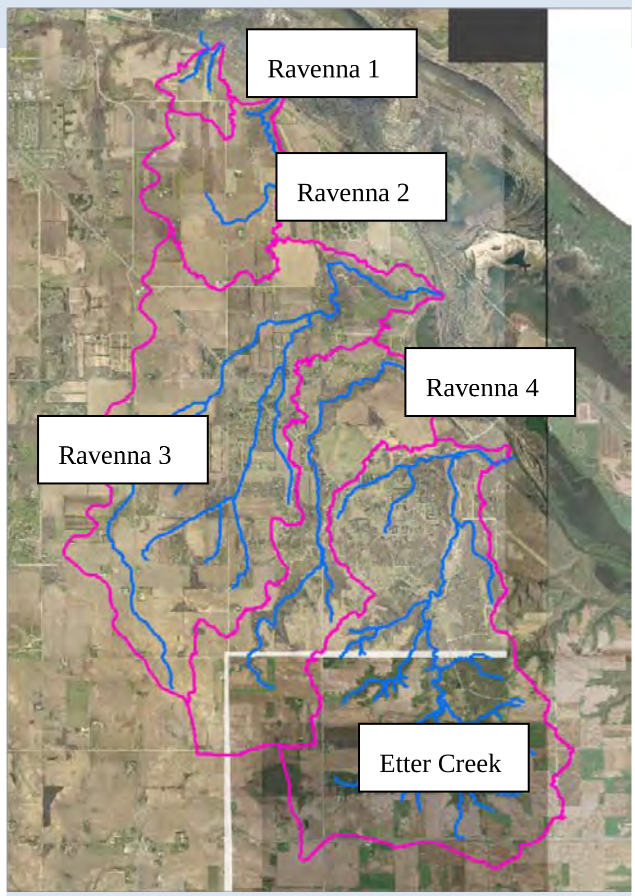

Figure 2: The Etter Creek and Ravenna Coulee watersheds (pink polygons).

for agriculture. Some areas along the channels and hill slopes are wooded because they are too steep to farm.

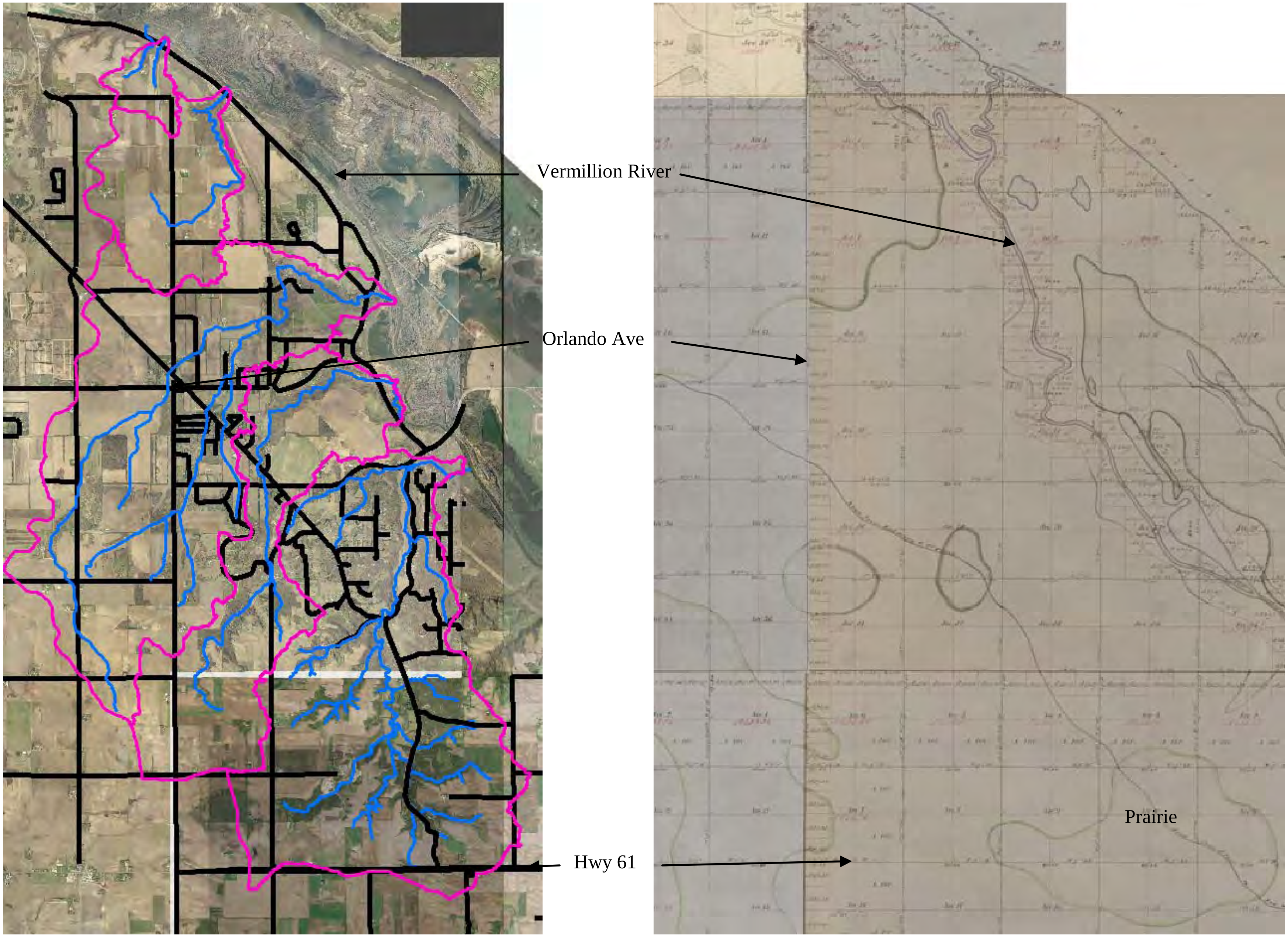

Figure 3: Comparison of current conditions (left) with the plat maps created in 1855 (right). The green polygons on the plat maps were identified as prairie. No channels in the Etter Creek and Ravenna Coulee watersheds are identified in the 1855 maps.

The first land surveys in Dakota County resulted in plat maps from 1855. These maps show no indication of streams in the current location of Etter Creek, the Ravenna Coulees, and their associated tributaries (Figure 3). The mouth of Ravenna Coulee 4 is drawn, but this is because it is within the backwater of the Vermillion River. A few small areas were identified as 'prairie' on the plat maps and these areas were primarily on the tops of hills surrounding the steeper ravines. Much of the rest of the area was presumably forested. Although these maps are not comprehensive and are not exact representations of the conditions in 1855, they do provide some insight into the land-use and ecosystems within the subwatersheds as well as the relative significance of the stream channels. In comparing these maps with current conditions, much of the forested and prairie land has been converted to agriculture. Only the areas too steep to farm have not been cleared, and many of these areas were logged at some point in their history. This change in land-use is likely a primary cause for many of the erosion and degradation problems within the subwatersheds today. Clearing of the land for agriculture reduced the infiltration rates and sped the flow of rainwater and snowmelt off of fields and into the stream channels. As will be described in more detail throughout this report, these channels have been adjusting their geometry by incising and widening to compensate for these higher flow volumes. This degradation results in sedimentation downstream, loss of land, damage to infrastructure, and reduction of riparian habitat.

Much of the bedrock in the upper Etter Creek subwatershed and the Ravenna Coulee subwatersheds is in the Lower Ordovician, Prairie Du Chien Group (Mossler, 1990). The Prairie Du Chien Group consists of dolomite, and in these subwatersheds it is likely Oneota Dolomite because the outcrops are massive to thickly bedded, rather than the thin-bedded dolomite of the Shakopee Formation. The lower part of the Etter Creek subwatershed consists of the St. Lawrence and Franconia Formations. These formations are made up of dolomitic shale, thin-bedded siltstone, and thin-bedded and very fine grained glauconitic sandstone and shale.

The surficial geology is more varied than the bedrock geology. Near the Vermillion River, the steep bluffs, or terraces, are composed of sand and gravel and in the northern coulees, Ravenna 1 and 2, bedrock is generally within 10 ft of the surface (Hobbs et al., 1990). Further from the Vermillion River and west of the steep bluff, sand, loamy sand, and gravel make up the Des Moines Lobe deposits. In the upper portions of the drainages of Etter Creek and its tributaries, silt from reworked loess overlies angular carbonate clasts in a silty-sand matrix.

Portions of these drainages are made up of poorly bedded sand from glacial drift. The surrounding hills consist of bedrock overlain by generally less than 5 ft of loess.

2.2 Fluvial Geomorphology

Inter-Fluve geomorphologists walked most of the lengths of Etter Creek, the four Ravenna Coulees, and their tributaries. Portions of the upper Ravenna subwatersheds were assessed at road crossings as the streams were barely perceptible, channel conditions did not change, and no problems were identified. Etter Creek is approximately 6 miles in length, but its 12 tributaries and associated drainages add 16.5 miles for a total stream length of 22.5 miles in the Etter Creek subwatershed. The Ravenna Coulees 1 through 4 have total stream lengths of 1.2, 2.9, 16.4, and 7 miles. Information on soils, streamflow, stream bed grain size, infrastructure, land use, and vegetation was noted for each reach on reconnaissance forms. Digital photographs were also taken at many locations along each reach, at all road crossings, of all culverts, and of all potential restoration projects.

The reconnaissance form was developed by Inter-Fluve scientists and 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). A sketch of a cross-section at a location typical for the reach is provided as well as a brief summary of conditions and a list of potential restoration projects. Appendix C provides a description of each reach based on these forms.

2.3 Project Identification

Potential projects were identified in the field and evaluated and ranked based on 10 metrics (Table 1). In this system, metrics refer 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, either 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 immanent risk. This assessment included an evaluation of all culverts and road crossings for corrosion or decay as well as for their effect on local hydrology. Other metrics gauge the effect of potential projects on channel stability, ecological benefit, and nutrient loading. Because of the interconnectivity of river systems, Inter-Fluve believes strongly that watershed restoration and management should focus on the headwaters and move in a downstream direction. To incorporate this science into the project ranking, we have ranked headwaters projects higher, and scores for this metric decrease with distance from the headwaters.

Potentially expensive projects are scored lower, and more complicated larger projects score lower as well. 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 which projects to focus on that accomplish their 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, or no infrastructure present	Low to moderate infrastructure risk and minimal risk to public safety with no action, or inf. value <$100,000	Infrastructure at moderate but not immediate risk, moderate public safety risk, or infrastructure value <$200,000	Infrastructure at high or immanent risk of failure with no action. Public safety at risk or infrastructure value >$200,000
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
Location	Mouth to lower ¼ of watershed	Lower 1/4 to 1/2 of watershed	1/2 to upper 3/4 of watershed	Upper 3/4 to headwaters
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
Property Ownership	-7: not allowed; not cooperative	0: unknown	7: 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
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

3. Summary of Restoration Projects

We identified 29 problem areas in the Etter Creek and Ravenna Coulee subwatersheds; 28 of these potential projects are located in the Etter Creek subwatershed and one is located in Ravenna Coulee 1 (Table 2, Figure 4; see Appendix F for full scoring spreadsheets; see Appendix G for detailed maps). We will focus our discussion in this section on the Etter Creek subwatershed, and in particular the upper portion of the subwatershed, because this is where most of the projects are located.

A few geologic features are likely contributing to the disparity between numbers of problem areas in the Etter Creek subwatershed versus the Ravenna Coulees. First, and maybe most significant, the topography between the subwatersheds is different. The drainages in the Etter Creek subwatershed, particularly the upper half (southern half), are extremely steep and the surrounding hill slopes are also extremely steep (Figure 5). Water flows off of these hills with greater velocity, and therefore greater erosive force, than the lower gradient Ravenna Coulees. Second, although the bedrock is similar throughout the subwatersheds, the surficial geology described earlier in this report does vary. In the upper portions of the Etter Creek subwatershed, multiple feet of highly erodible loess overlie gravel and bedrock. Water flowing off of the steep slopes easily erodes through this fine-grained material. In Ravenna 1 and 2, the bedrock is closer to the surface and outcrops in the drainages, limiting the severity of incision that could occur. Lastly, the subwatershed size may contribute to the large number of projects in the Etter Creek subwatershed. The Etter Creek subwatershed is 9 mi^2, and the Ravenna Coulees 1-4 are 0.4, 2.2, 8.8, and 4.7 mi^2 respectively. Larger subwatersheds result in greater volumes of water entering these streams and a greater potential for erosion and flooding problems. All of these geologic features, combined with the land use change from forest and prairie to agriculture, likely contribute to the instability we see in the Etter Creek subwatershed today.

The majority of projects along the Etter Creek mainstem were bank stabilization and road crossing projects; along the tributaries, floodplain and riparian management projects made up nine of the 13 projects (see Appendix B for discussion of project types). The highest scoring projects, and thus highest priority, are floodplain and riparian management projects that involve long portions of channel or entire subwatersheds.

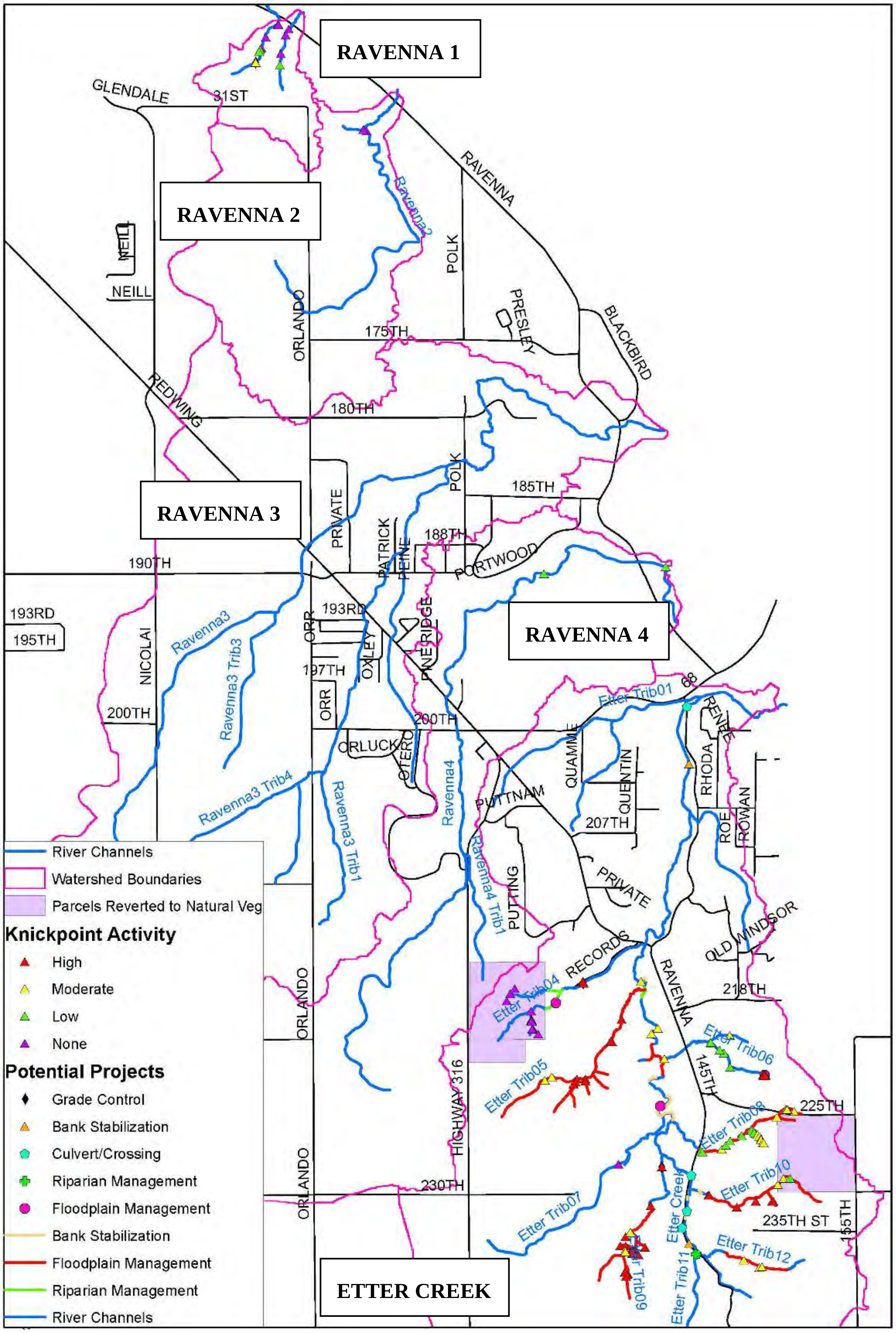

Figure 4: Overview of potential projects and knickpoints in the study area.

Table 2: Summary of potential restoration and management projects with scores. Projects are on Etter Creek unless otherwise indicated. T = Tributary; C = culvert/crossing; B = bank stabilization; R = riparian management; F = floodplain management; G = grade control.

Project Number	Location	Primary Project Type	Total Score	Description
PP01	Stn 4050	C	**28**	Undersized culvert at Ravenna Trail
PP02	Stn 6150	B	**25**	Minor gullying
PP03	Stn 15,600-15,750	B	**27**	Bluff erosion
PP04	Stn 16,000-16,400	R	**29**	ATV traffic in channel and on floodplains causing erosion
PP05	Stn 18,600-20,000	F	**51**	Removal of vegetation, incision along drainage, and gullying from grazing and vehicle traffic in and adjacent to stream
PP06	Stn 20,350-20,600	B	**31**	Bluff erosion
PP07	Stn 21,500-23,200	B	**33**	Bank erosion nearing crops
PP08	Stn 21,950	F	**29**	Incision in drainage could affect nearby crops
PP09	Stn 26,150	C	**38**	Minor scour around upstream end of culvert under 145th Ave
PP10	Stn 26,950-27,050	B	**38**	Bank erosion nearing 145th Ave
PP11	Stn 27,450	C	**31**	Corroded culvert with cracked concrete
PP12	Stn 27,450-27,700	R	**35**	No riparian buffer
PP13	Stn 27,625-27,675	B	**31**	Eroding bank nearing 145th Ave
PP14	Stn 28,050	C	**40**	Perched culvert for drainage under 145th Ave; erosion very close to road
PP15	Stn 28,650	B	**38**	Bank erosion very close to 145th Ave
PP16	T4, Stn 2600	G	**33**	Deep incision with knickpoint nearing road
PP17	T4, Stn 3400-4300	R	**49**	Unrestricted cattle grazing has denuded channel and hillsides; gullying on hills
PP18	T4, Stn 3900	F	**47**	Dam and culvert could be retrofitted to improve retention basin
PP19	T5, Stn 0-7700	F	**45**	Multiple large knickpoints throughout subwatershed; incision and bank erosion
PP20	T6, Stn 4400-4450	F	**35**	Multiple knickpoints; excessive overland flow
PP21	T8, Stn 1500-5800	F	**39**	Multiple knickpoints; excessive overland flow
PP22	T9, Stn 450	G	**31**	5-ft knickpoint between fields
PP23	T9, Stn 2300-5800	F	**49**	Vertically unstable - knickpoints migrating into row crops
PP24	T10, Stn 300-450	B	**25**	Excessive erosion on outside of bends
PP25	T10, Stn 750-4100	F	**39**	Multiple knickpoints throughout; no retention
PP26	T11, Stn 100	C	**31**	Minor scour around culvert, fencepost
PP27	T11, Stn 150	R	**31**	Minor scour hole in field
PP28	T12, Stn 1000-3300	F	**39**	Multiple knickpoints
Ravenna 1-PP01	Ravenna Coulee 1, Stn 3100	G	**31**	Small knickpoint near fields

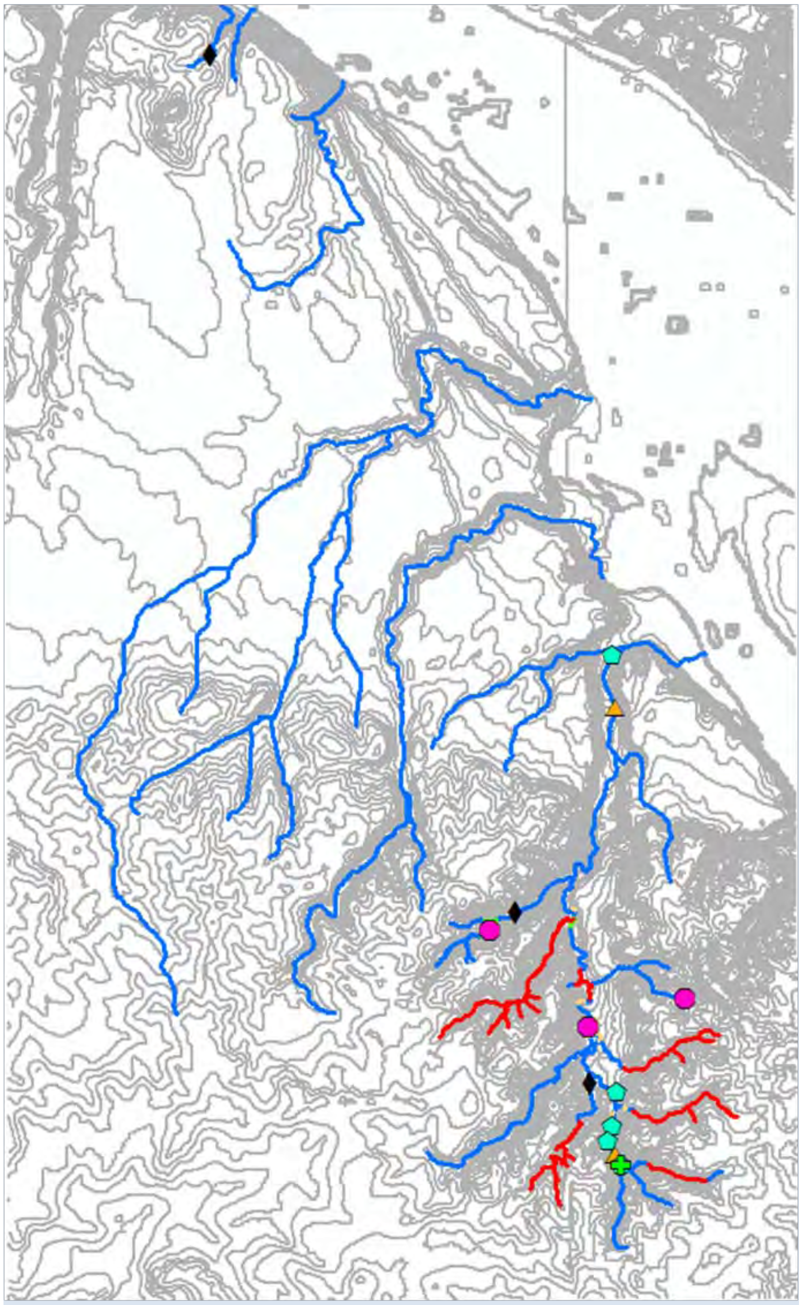

Figure 5: Topography of study area; gray lines are 10-ft contour lines.

We have grouped multiple grade control, floodplain management, and riparian management problems into single priority projects in an effort to address the problems holistically from the subwatershed scale. We identified 117 knickpoints (see Appendix A for discussion of knickpoints) throughout the subwatersheds ranging from 1 to 15 ft in height (see Appendix H for detailed maps of knickpoints); 62% of these knickpoints continue to migrate with high or moderate rates of activity (Appendix H). Many of the highly active knickpoints are located in the upper extremities of the Etter Creek subwatershed along Tributaries 4-12 (Figure 6). These knickpoints are indicative of vertical instability and suggest that the channel geometry is still adjusting to the increased hydrology due to changes in land use. As the knickpoints migrate upstream, sediment is carried downstream causing problems along Etter Creek. The incision results in over-steepened banks that subsequently fail and cause additional sedimentation.

The root cause of this instability is an increase in the amount of water flowing off of the farmland into the channels due to the land use changes that occurred throughout the 19th and 20th centuries. We have grouped unstable channels and drainages into single projects to focus on reducing the amount of water flowing to the channel, rather than simply stabilizing the channel bed and banks. Our highest scoring projects involve multiple large knickpoints and gullying along the mainstem Etter Creek in Reach 4 (project #5, 51 points), 3500 ft of Tributary 9 (project #23, 49 points), a denuded section of Tributary 4 (project #17, 49 points), and the entire subwatershed of Tributary 5 (project #19, 45 points). These problems could likely be stemmed through a combination of management practices that will be discussed in more detail below, but include altered farming methods, increased retention of water, and increased infiltration. Tributaries 8, 10, and 12 also have significant channel instability that could be addressed through these management practices.

Other types of projects include road crossings and bank stabilization. Many road crossings are in good condition, but many others are undersized for the current hydrology and others are old and in poor condition. The highest scoring road crossing project is project #14: a small drainage flows under 145th Ave and into Etter Creek at Stn 28,050 (40 points). The culvert is perched about 5 ft due to incision on Etter Creek and erosion around the culvert is beginning to impact the road. Although the location of the culvert has probably prevented upstream incision of the drainage, there is no space between the edge of the road and the edge of the culvert. Additional erosion around the culvert could cause damage to the road and be hazardous to traffic.

Bank stabilization projects did not score as high because they are more isolated. Some areas of erosion are within 5 to 10 ft of roads (projects #10 and 15), and these should be addressed. We identified a few bluffs that were eroding into the channel because of toe erosion, lack of vegetation, and/or seeps destabilizing the slopes. These, however, do not score high because they will generally stabilize over time and substantial infrastructure was not at risk.

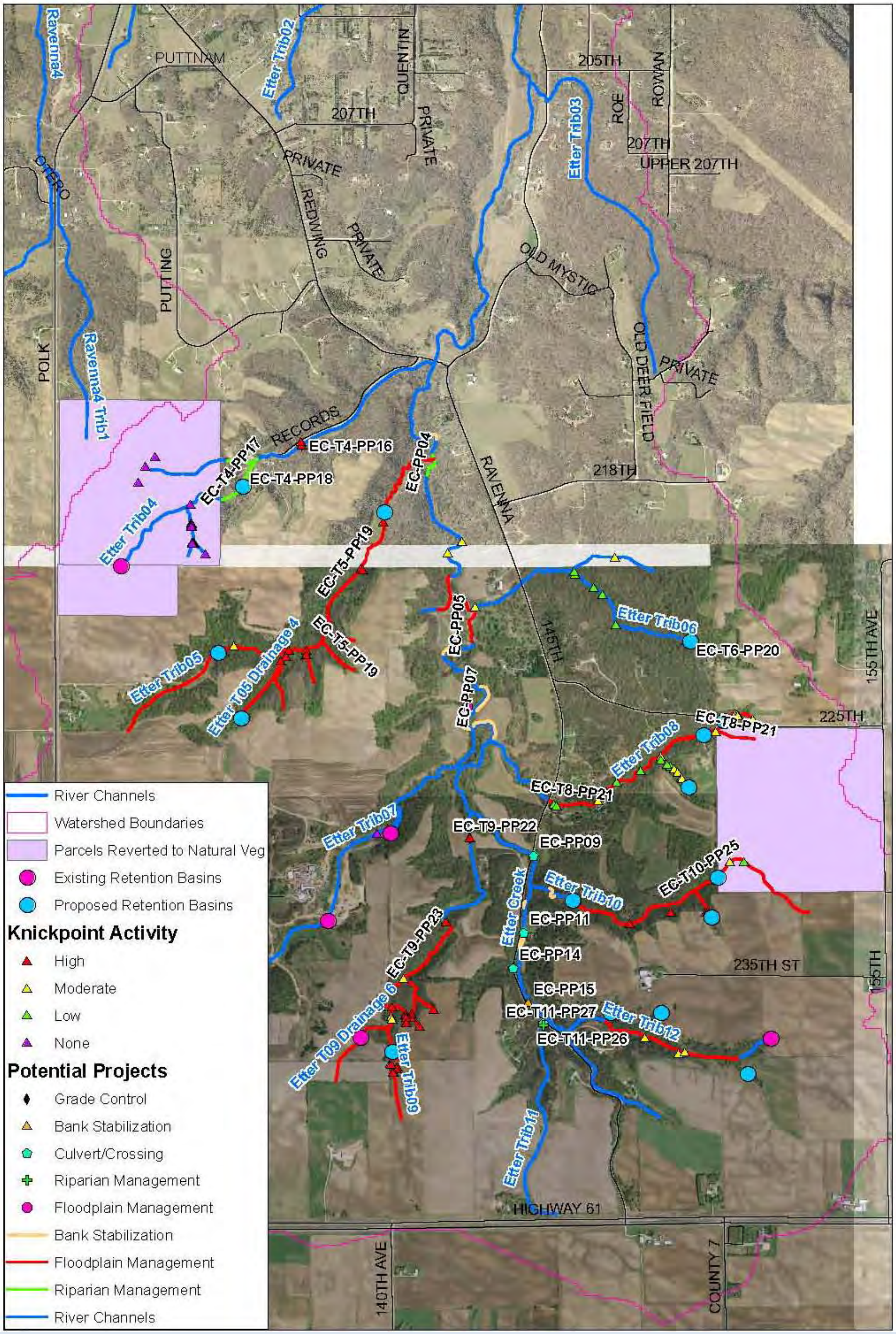

Figure 6: The headwaters of Etter Creek showing the location and activity of knickpoints and the location of potential projects, existing and proposed retention basins, and parcels that have been converted to native vegetation.

4. General Recommendations and Conclusions

We recommend addressing the higher scoring projects in two phases. Although the Phase 1 projects can be completed more quickly, we recommend starting both Phases concurrently as Phase 2 addresses the root cause of most of the problems and will take years to complete. Phase 1 addresses short-term issues that have the potential to impact infrastructure such as roads, culverts, and driveways within a few years. This phase includes the following priority projects (PP):

- PP10 - 40 points - bank erosion on Etter Creek between Stn 26,950 and 27,050 that is within 10 ft of 145th Ave
- PP15 - 40 points - bank erosion on Etter Creek at Stn 28,650 that is within 8 ft of 145th Ave
- PP14 - 40 points - culvert under 145th Ave for a drainage that flows into Etter Creek at Stn 28,050; erosion around the culvert threatens the road
- PP11 - 33 points - culvert under a private driveway at Stn 27,450; the pipe is corroded and the concrete is severely cracked

Although PP11 has a lower score than PP09 (38 points), the risk to infrastructure at PP11 is greater. PP09 received a higher score because it is on public property and will likely be cheaper and less complex.

Phase 2 addresses the longer-term subwatershed-wide problems. These are the channel and bank stability issues that can be fixed through a number of management practices. Rather than fixing each individual knickpoint or area of bank erosion, we suggest working towards reducing the volume of water entering these channels and subwatersheds. Reducing the amount of water flowing into the channels in the headwaters will reduce the rate of incision and erosion and possibly eliminate the sedimentation and flooding issues in downstream reaches. Although this may be more challenging immediately, it will be more cost-effective in the long-term and will likely prevent similar problems in the future.

Addressing the instability in Etter Creek should include a combination of a few management and restoration practices: changing farming practices, building retention basins, converting farmland to native vegetation, building grade control structures and stabilizing channel banks. Because the majority of the land within the Etter Creek subwatershed is privately owned and farmed, all of these options will require cooperation from landowners. These options are likely not desirable to many landowners at first glance, but some may be convinced given the severity of the loss of land to erosion in some portions of the subwatershed. A great deal of public outreach and education will be necessary and monetary incentives would likely be beneficial.

A few different types of farming practices have been known to slow erosion and increase infiltration in the Midwest and throughout the world. The WI NRCS has a very informative website with many different farm conservation solutions: http://www.wi.nrcs.usda.gov/programs/solutions/. A few solutions that could be used in the Etter Creek subwatershed include contour farming, contour buffer strips, stripcropping, and the construction of terraces (Figure 7). Contour farming is likely the simplest and cheapest alternative and involves farming along the contour lines of the hills, rather than across contours. Tilling and planting along the contours creates small ridges that slow the flow of water downslope. Contour buffer strips involve the creation of strips of permanent vegetation (grass, native vegetation) along the contours of the hill between the row crops. Water flowing onto these strips will slow down and infiltrate, reducing overland runoff. In a similar manner, stripcropping is the practice of alternating strips of row crops with strips of hay, other grain, or native vegetation. Strips in this method are often wider than in buffer strips and are rotated rather than being permanent. Lastly, terracing involves the construction of embankments that follow the contours of the slope. These embankments intercept the flow of water, which may collect and infiltrate in a ditch on one side or transport the water to a stable grass waterway or retention basin. Terracing is expensive but can be effective on steeper slopes.

Figure 7: Farm conservation solutions include contour farming and stripcropping (top), contour buffer strips (middle), and terraces (bottom). All pictures from WI NRCS.

Retention basins are created by building a small dam with a high-flow discharge pipe; these are designed to store runoff from rain or snow-melt events and allow the water to infiltrate rather than flow downstream. These have been effective in a few locations in the Etter Creek subwatershed (Figure 8). We identified locations where retention basins could be built to stem overland flow (Figure 6). It will be impossible to build retention basins at the head of each drainage and it is not feasible to build large dams and impoundments in these subwatersheds. We feel that the construction of some of these smaller retention basins in combination with some of the other restoration and conservation practices will be effective.

Converting erodible cropland to other vegetative cover such as native grasses, prairie grasses, and native shrubs and trees can be very effective in slowing the flow of water to stream channels. Sufficient ground cover slows the flow of water and encourages infiltration and the roots from the plants stabilize the soil. The Conservation Reserve Program, administered by the NRCS, is active in Dakota and neighboring Counties and is an effective way of encouraging farmers to make this conversion. A few parcels have been converted to native grasses and shrubs in the Etter Creek subwatershed (Figure 6). Our on-the-ground assessment and discussions with downstream landowners confirmed that this type of management, combined with retention basins, can be very effective at limiting stormwater flow and minimizing downstream degradation (Figure 8).

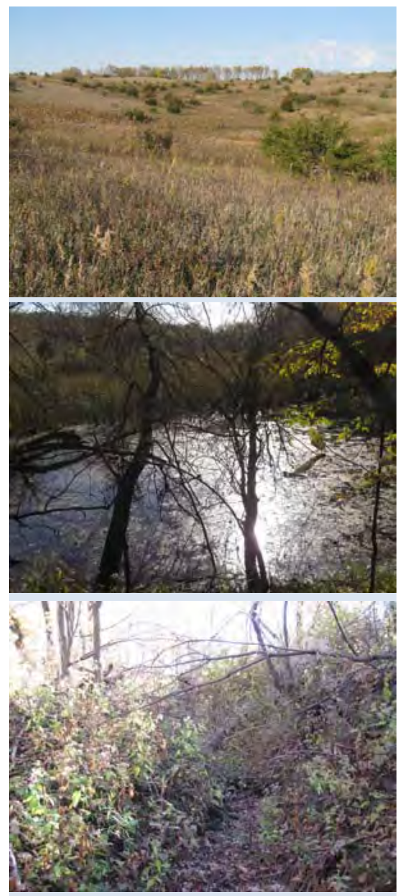

Figure 8: In the headwaters of Etter Creek Tributary 4, row crops were converted to native vegetation (top), a retention basin was built (middle), and previously active knickpoints are now inactive and obscured by vegetation.

In certain instances, it may be necessary to build grade control structures along the channel bed to provide vertical stability or stabilize channel banks to prevent excessive bank erosion. Grade control structures can be made of natural materials such as rocks and logs or man-made materials such as sheet pile and concrete. These structures must be designed and built sufficiently so that the channel does not avulse causing incision to continue adjacent to the control structure. Similarly, bank stabilization must be constructed so as not to push the problem to another location.

For the Phase 2 projects, we recommend a holistic, watershed-scale approach. Parcels where management and restoration practices would be beneficial need to be identified and landowners need to be contacted and brought into the discussion. Sufficient information and education needs to be provided so that these landowners can make educated decisions that could have long-lasting impacts on the health of their land and potentially their lifestyle. By changing their farming practices, adjacent farmers with similar erosion problems can all contribute towards a collective solution. Combining these practices with the construction of retention basins in key areas and the conversion of highly erodible land to native vegetation will minimize the amount of overland flow and likely minimize or eliminate the erosion, sedimentation, and flooding issues throughout the Etter Creek subwatershed. The Phase 2 projects include:

- PP05 - 51 points - gullying along hillsides and incision in a drainage on Etter Creek between Stn 18,600 and 20,000
- PP23 - 49 points - severe incision with 10 to 15-ft knickpoints migrating into row crops in the headwaters of Tributary 9; knickpoints are between Stn 2300 and 5800 and are located along all drainages; this may be of higher priority due to its higher infrastructure risk score
- PP17 and PP18 - 49 and 47 points, respectively - these are both in the same area of Tributary 4, between Stn 3400 and 4300; denuding of vegetation, gullying, opportunity to retrofit and detention basin to store more water as a retention basin; improving retention will also help stem the migration of the 12-ft knickpoint downstream (PP16)
- PP19 - 45 points - multiple knickpoints between Stn 0 and 7700 of Tributary 5; deep incision and lateral bank erosion near the mouth and knickpoints nearing crops in headwaters

In conclusion, many active knickpoints throughout the Etter Creek subwatershed suggest that the drainages are still adjusting to land use changes and increased volumes of water from overland runoff. These drainages will continue to adjust and the knickpoints will continue to migrate upstream causing a loss of row crops and increased sedimentation downstream. A combination of pro-active, forward-thinking restoration and management measures could be used to fix the source of all these problems by reducing the amount of water flowing into the channels. This will likely be a long process of outreach, education, and implementation. These efforts, identified as Phase 2 above, should begin as soon as possible so as to stem continued erosion. Phase 1 projects are more simple and involve infrastructure and roads that are at risk due to erosion. These projects should be implemented within the next few years and could be done in conjunction with annual, or semi-annual road maintenance. Other projects in the priority list should be monitored. Scores will change over time as landowner cooperation changes, risk to infrastructure changes, or other metrics change.

5. Evaluation of Previously Restored Section of Etter Creek

A section of Etter Creek downstream from Redwing Boulevard was restored in the fall of 2003 (Dakota County SWCD, 2003). A tall bank on river left had been eroding excessively and Ravenna Trail was in danger of being undercut on river right. The culverts under Redwing Boulevard were replaced to be able to pass existing flows and the channel downstream was realigned away from the eroding bank and road. Rock veins were placed to prevent channel migration and the area was fenced off to prevent cattle from grazing in or near the stream. Today, the stream remains stable and the eroding bank is no longer being undercut by the stream (Figure 9). Dense stands of young willows now occupy the stream bed and banks. These willows have trapped some sediment moving downstream. Some of these willows and sediment will likely be removed and washed downstream once a large flood flows through this section again, but large floods have not occurred since 2003 according to landowners nearby. Over time, the willows on the banks will provide sufficient root stabilization.

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APPENDIX A: Review of Geomorphology Principles

In order to fully visualize and understand the problems occurring in the Etter Creek subwatershed, 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.

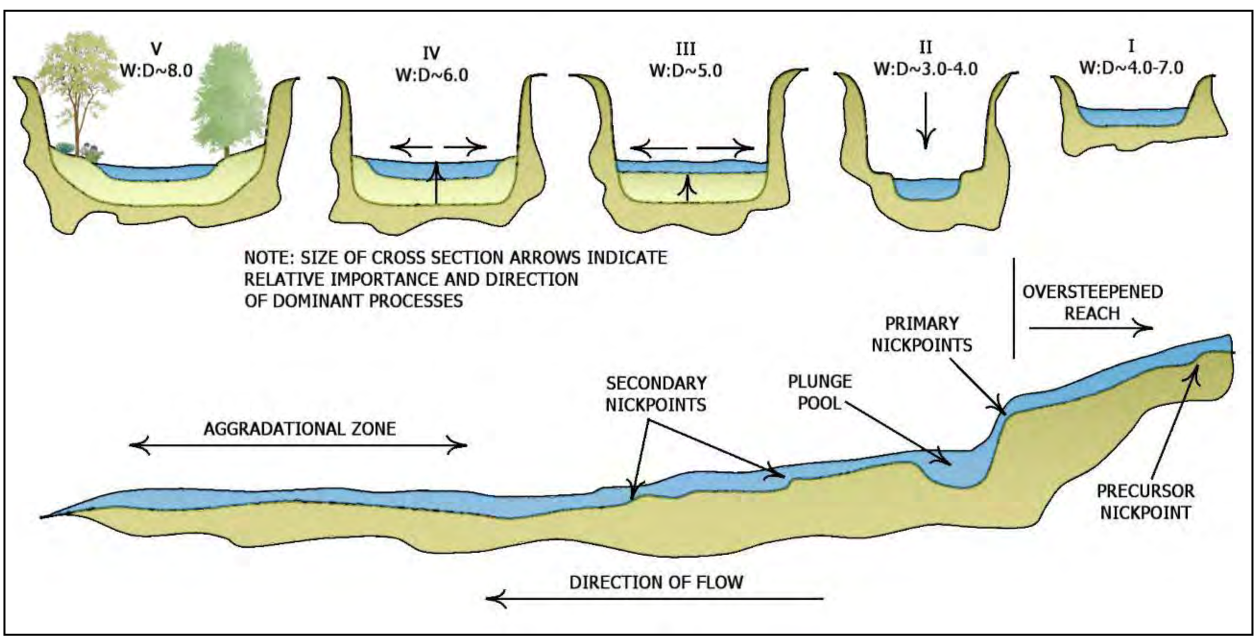


Figure A-3: The Schumm channel evolution model (modified from Schumm, 1984).

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 landuse, 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

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

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, 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.

The **Etter Creek** channels do not have continuous flow and therefore do not provide fish habitat or fish passage opportunities. However, many crossings in this subwatershed are undersized for the existing hydrologic conditions and many are in poor condition. Projects identified in this assessment focused on culverts that needed replacing to prevent failure and to provide full passage of flows.

<u>Bank Stabilization</u>

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.

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.

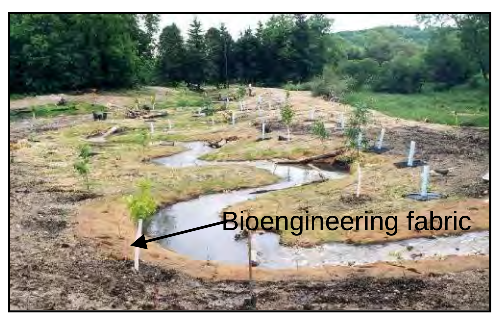


Figure B-3: Grasses are beginning to grow through biodegradable bioengineering fabric along this restored stream (photograph: Inter-Fluve).

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.

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 landuse 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

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

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 times, 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.

Appendix C: Reach description of existing conditions for the Etter Creek and Ravenna Coulee subwatersheds

1. Existing Conditions

Inter-Fluve geomorphologists conducted a rapid geomorphic assessment of the Etter Creek and Ravenna Coulee subwatersheds in Dakota County. Channels were divided into reaches based on channel planform and adjacent land use. The mainstem of Etter Creek was divided into five reaches, the 12 tributaries to Etter Creek were divided into 15 reaches, and the Ravenna Coulees and tributaries were divided into 16 reaches (Table 1). We do not discuss in-stream habitat or fish passage issues in these reach descriptions because the streams are intermittent and do not support aquatic species.

Table 1: Reach lengths for the Etter Creek and Ravenna Coulee subwatersheds.

Reach	Length (miles)	Etter Creek Stn at Confluence (ft/miles)	Notes
1	0.4		
2	1.7		
3	1.3		
4	1.6		
5	0.9		
Total	**5.9**		
Trib 1	1.7	3475	
Trib 2	0.9	3350	Joins Trib 1
Trib 3	1.2	8000	
Trib 4	1.2	13850	
Trib 5	1.5	16100	
Trib 6, Reach 1	0.2	19350	
Trib 6, Reach 2	0.7		
Trib 7, Reach 1	0.4	24050	
Trib 7, Reach 2	1.2		
Trib 8	1.1	23250	
Trib 9, Reach 1	0.3	24850	
Trib 9, Reach 2	0.9		
Trib 10	1.0	26700	
Trib 11	0.7	29050	
Trib 12	0.8	29350	
All Etter Channels	**19.7**		

Reach	Length (miles)	Ravenna Coulee Stn at Confluence (ft/miles)	Notes
Ravenna 1-East	0.6		
Ravenna 1-West	0.8		
Total	**1.4**		
Ravenna 2, Reach 1	0.9		
Ravenna 2, Reach 2	1.9		
Total	**2.8**		
Ravenna 3, Reach 1	2.5		
Ravenna 3, Reach 2	5.6		
Ravenna 3, Trib 1	3.5	13400	
Ravenna 3, Trib 2	1.6	4000	Joins Trib 1
Ravenna 3, Trib 3	1.1	22300	
Ravenna 3, Trib 4	1.3	12450	Joins Trib 1
Ravenna 3, Trib 5	0.7	1150	Joins Trib 4
Total	**16.3**		
Ravenna 4, Reach 1	2.1		
Ravenna 4, Reach 2	1.3		
Ravenna 4, Reach 3	0.7		
Ravenna 4, Reach 4	2.0		
Ravenna 4, Trib 1	0.9	20150	
Total	**7**		

3.1 Etter Creek

The 6 miles of Etter Creek were divided into five reaches. The five reaches averaged 1.2 miles in length, but ranged from 0.4 to 1.7 miles. Etter Creek is steep and wooded in its headwaters but then flattens out as it flows out of the steep hills. Downstream from Redwing Boulevard the stream is low-gradient, relatively straight, and flows through agriculture fields and a wide delta at its mouth at the Vermillion River. The landuse in the subwatershed is mostly agriculture with some residential houses. Four to six feet of incision was observed throughout the mainstem of Etter Creek. The knickpoints currently moving through the tributaries have generally already moved through the mainstem. Some banks are over-steepened and eroding because of the incision and some culverts are degrading and undersized.

Figure C-1: Etter Creek, Reach 1 (Top) Stn 650 looking downstream at Vermillion River backwater; (middle) Stn 1,400 looking downstream at newly created channel; (bottom) Stn 1,950 looking downstream at aggradational reach.

3.1.1 Etter Creek, Reach 1

Reach 1 of Etter creek is a wide delta that extends 2,200 feet from its confluence with the Vermillion River. Highway 68 currently splits the delta, and human intervention has forced all Etter Creek flows to the east/southeast of the highway. This reach is very low-gradient, and, in places, it is hard to find a well defined channel. Much of the reach is influenced by the water levels in the Vermillion River. For example, at the time of our survey, the Vermillion was flooding, and its floodwaters were backed up into Etter Creek to station 650 (Figure C-1). A few dirt roads are the only apparent development in the delta, probably due to the frequent flooding and difficult access.

The channel substrate is predominantly sand, and the reach is aggradational as sand from higher gradient areas upstream is deposited. As the channel fills with deposited sand, water is forced onto the floodplain where it forms a new channel. This process probably causes frequent channel changes in this reach, and we did observe multiple channels during our survey, including new channels with fresh deposition and debris that was caught on trees whose roots had been buried in the sand (Figure C-1).

The bankfull width of the channel in this reach is 20 ft, and the depth is less than 1 ft. As this reach is the delta of Etter Creek, no defined floodplain was observed; the riparian corridor is within that of the Vermillion River, so the canopy and ground cover are nearly complete with woody vegetation and graminoids. Silver maple was the dominant tree species, and elm, box elder, and cottonwood also occurred frequently. There is no aquatic habitat in this reach, as flows only occur with rain events or snowmelt. The reach is aggradational, but no infrastructure is at risk. The channel does flow at the base of a steep, 100 ft, bluff between stations 1300 and 2200.

3.1.2 Etter Creek, Reach 2

Reach 2 of Etter Creek is 9,000ft long and flows from station 2,200 to station 11,200. It is a narrow stream with low sinuosity that flows between agricultural fields. The channel does not hold water continuously, so there is no aquatic habitat. The bank substrate is sand while the bed is composed of sand and gravel. The bankfull width ranges from 12-15ft and the bank height is 4-8ft.

Figure C-2: Etter Creek, Reach 2 (Top) Stn 4,050 looking downstream undersized culverts under Ravenna Trail; (bottom) Stn 5,500 looking upstream at straightened channel.

We observed evidence of past incision as the surface of the surrounding fields is up to 8ft higher than the channel bed (Figure C-2). The incision may be as much as 4ft, but we did not observe active incision (migrating knickpoints, headcuts, etc.) in this reach. There is gravel and cobbles on the stream bed in a number of locations, and incision may have slowed when this gravel layer was reached. Some active bank erosion is occurring on the outside of bends, but tree roots are attempting to stabilize in many of these locations.

The riparian corridor for much of this reach is 80-90ft, and the floodplain is 20-50ft wide. The channel banks are heavily vegetated with grasses and shrubs, and there is a 30-50ft vegetation buffer between the channel banks and farm fields. About 75% of the vegetation is woody and includes large cottonwoods, box elders, pine, and sumac. At the upstream end of the reach, in-set floodplains up to 30ft wide have developed 1-2ft above the channel bed suggesting the channel is nearing a new equilibrium state.

The Ravenna Trail crossing at Stn 4050 consists of 2, 5-ft corrugated metal pipes. The culverts are undersized and partially filled with sand (Figure C-2). A road sign indicated that flooding over the road has been a problem. Minor erosion around the upstream end of the culverts might continue into the road. These culverts should be replaced with larger culverts, similar to the new culverts at Redwing Boulevard. Minor gullying at Stn 6150 suggests excessive overland runoff near fields.

3.1.3 Etter Creek, Reach 3

Reach 3 of Etter Creek is 7,125ft long and extends from station 11,200 to station 18,325. It is a meandering reach that flows within steep, forested hills (Figure C-3). The channel bed and bank material is primarily sand and fine sand/silt that is easily mobilized once it is eroded by floods. The banks are 4-8ft tall, and the bankfull width ranges between 12-15ft. The channel does not hold water continuously, so there is no aquatic habitat.

Figure C-3: Etter Creek, Reach 3 (Top) Stn 14,500 looking upstream; (middle) Stn 13,800 looking downstream at restored channel; (bottom) Stn 15,700 looking upstream at eroding bluff.

There is evidence of past incision of the channel. The current stream channel is 4-8ft below the floodplain surface and valley floor, but in the past, the channel was likely a shallow swale. We identified multiple small (0.5-1ft) knickpoints throughout the reach, which suggests that minor incision continues to occur. Etter Creek has incised to limestone in a few locations, and this will likely slow or halt the incision.

No development or farming has occurred within the riparian corridor, which is 50-100ft wide. The valley bottom is wide and maintains good riparian habitat with thick vegetation cover. Canopy cover is about 70%, and about 85% of the vegetation is woody. Willows are the most prevalent woody vegetation with elm, ash, box elder, and some conifers also present. Though water is not present year round, we did observe a few pools that may sustain macroinvertebrates.

New box culverts under Redwing Boulevard at station 13,800 are in good condition. Just downstream of Redwing Boulevard is the location of a previous channel realignment/restoration project to move the channel away from a tall eroding bluff. The channel is no longer eroding the bluff and willows have colonized the channel and channel banks following the exclusion of cattle. Upstream, ATVs drive on the channel bed through some portions of this reach, making vegetation growth on the bed and some banks impossible. Elsewhere, vegetation has taken root in the narrow channel, on sand bars, and on the channel banks, which helps to stabilize the channel.

We have identified two areas for potential projects in reach 3. At station 15,600-15,750 a 50-ft bluff on the right side of the channel is eroding into the channel. The toe of the bluff is being eroded by Etter Creek, and seeps halfway up the bluff are destabilizing the slope (Figure C-3). Mowed paths have been maintained at the top of the bluff, and a bench is about 6 ft from the edge of the bluff. If left alone, the bluff may continue to erode, threatening the bench, but eventually the eroded material will push the channel away from the bluff and the lower angle of the bluff will minimize future erosion. At station 16,000-16,400, ATVs drive along the channel bed and over the banks in many locations limiting vegetation growth and destabilizing the channel banks. Minimizing ATV traffic to distinct stream crossings will help stabilize the channel and reduce the movement of sediment downstream.

3.1.4 Etter Creek, Reach 4

Reach 4 of Etter Creek is 8,375ft from station 18,325 to station 26,700. An active, meandering stream that flows through a riparian corridor surrounded by agriculture, reach 4 has no continuous aquatic habitat, because the channel, with a bankfull width of 10-20ft, does not hold water year-round (Figure C-4). The channel bed and bank material is primarily sand and find sand/silt, which is easily erodible and mobilized after erosion occurs. The channel does migrate, and this migration can result in eroding banks and point bar deposits.

Multiple periods of incision on Etter Creek has resulted in multiple floodplain and terrace surfaces. Low, inset floodplains are vegetated with grasses and *Equisetum sp*, a higher floodplain surface above this has saplings and trees, and a terrace above that has larger cottonwoods and maples. The width of the floodplain ranges from 50-100ft, and the width of the vegetated riparian corridor is 200-300ft. The two higher terraces are vegetated with woody species and have a canopy cover of 50%.

Active grazing and vehicle traffic is occurring in some portions of this reach, minimizing vegetation growth and destabilizing the channel and banks (Figure C-4). Agriculture and grazing close to the channel banks with little or no buffer has resulted in excessive overland runoff and bank erosion. This excessive erosion causes increased sedimentation in Etter Creek and results in the loss of farmland and degradation of riparian and forest habitat.

Figure C-4: Etter Creek, Reach 4 (Top) Stn 23,750 looking downstream; (middle) Stn 18,750 looking upstream at grazing and eroding hillslopes; (bottom) Stn 20,550 looking downstream at eroding bluff.

We recommend projects at five areas along reach 4. Between stations 18,600-20,000, there is active grazing within the channel and on channel banks, active vehicle traffic in the channel and on channel banks, and little to no buffer between crops and the channel or drainages. Excessive incision and headcutting is occurring on adjacent drainages, especially on the left side of the channel, and this is resulting in excessive sedimentation of Etter Creek.

At stations 20,350-20,600, the 25-50ft bluff on the left side of the channel is eroding (Figure C-4). There is some vegetation stabilizing the hillside but no trees to stabilize, and crops are growing only 30ft from the edge of the slope.

The 8-10ft banks at stations 21,500-23,200 are eroding, and there is very little buffer between crops and the channel. At station 21,950, a small drainage enters on the left side of channel and has incised about 150ft up its drainage. A 4-ft knickpoint is actively moving upstream. Finally, at station 26,150, a 7-ft corrugated metal pipe has some erosion and piping occurring on the upstream end.

3.1.5 Etter Creek, Reach 5

Reach 5 of Etter Creek runs 50,00ft from station 26,700 to station 31,700. This reach is primarily an incised roadside ditch with a bankfull width of 4-12ft and depth of 2-8ft (Figure C-5). Very little buffer exists between the channel and the abutting road or residential yards. The channel bed is composed of sand with some limestone cobbles and gravel. The channel has incised up to 8ft historically, but we did not observe active incision. The gravel and cobbles on the channel bed may be helping to slow incision. The steep banks are up to 8ft tall and composed of sand and fine sand. Bank erosion is active due to past incision creating over-steepened banks, excessive water flow, increased channel slope due to ditching, and lack of vegetation (Figure C-5).

Figure C-5: Etter Creek, Reach 5 (Top) Stn 27,600 looking downstream at straightened channel with no riparian buffer; (bottom) Stn 28,850 looking upstream at eroding banks nearing the road.

This reach contains very little riparian habitat, and the vegetated riparian zone is only 30 feet. In some areas, lawns are maintained up to the edge of the banks. Other areas have some woody species, primarily elm and oak, which create a canopy with 30-60% cover.

This reach goes through residential and agricultural areas. Most of the culverts under driveways appear to be in good condition with little sediment accumulation or blockage by woody debris, but some of the culverts are corroding or cracking. The primary problems in reach 5 involve bank erosion, and we have identified 6 areas for restoration projects.

1) At station 26,950-27,050, the left bank is eroding and is now only 10ft from the edge of the road. No trees can grow on the banks to help stabilize it, and the concrete rip rap that was placed on the bank is falling into the channel. 2) At station 27,450, a 5ft corrugated metal pipe culvert is corroded and needs replacing. Downstream of the culvert, concrete, bricks, and other debris have been put on the left and right banks to help minimize erosion, but these may be exacerbating the problem because vegetation and their stabilizing roots cannot grow. 3) The

channel banks at station 27,450-27,700 are over-steepened and eroding. Grass is mowed to the edge of the banks, and there are only a small number of trees. No riparian corridor exists and insufficient shrubs and trees grow along the banks to help stabilize. 4) Piping and erosion is only 4ft from the road edge at station 27,625-27,675. Rip rap on the left bank is failing and accumulating in the channel, further destabilizing the banks. 5) The corrugated metal pipe for a small drainage under 145th Ave. at station 28,050 has a 5ft drop to the channel bed at the downstream end. Additionally, the base of the wingwalls are cracking, and there is erosion on the top and side of the right wingwall about 3ft from the road edge. 6) Finally, at station 28,650, the eroding left bank is 8ft from the road edge.

3.1.6 Etter Creek, Tributary 1

Tributary 1 of Etter Creek is 8900ft long, but the channel is hard to identify in many places, and we could not find the tributary's connection with the mainstem of Etter Creek near Ravenna Trail. In some places, the channel is a shallow swale in the wooded area next to the road. This wooded area is comprised of ash and oak, with some buckthorn and other saplings. Where it flows through residential areas, the 'channel' is mowed as part of the lawns. The few indicators of water flow include a 5ft culvert at station 4500 and a 4ft culvert at station 7450. These culverts are partially filled with 2ft and 3ft of sand respectively (Figure C-6). This tributary is stable and no restoration projects were identified.

Figure C-6: Etter Creek, Tributary 1 (Top) Stn 4,450 looking upstream at partially filled culvert.

Figure C-7: Etter Creek, Tributary 2 Stn 2,800 looking upstream at mowed 'channel'.

3.1.7 Etter Creek, Tributary 2

Tributary 2 of Etter Creek is 4600ft long and flows into Tributary 1. It has very similar attributes as Tributary 1: Tributary 2 is a shallow swale or is undetectable in yards as part of the mowed lawn (Figure C-7). When the swale goes through wooded areas, the predominant species are ash and oak, with some buckthorn and other saplings. One culvert at station 2800 indicates occasional water flow, and this 4ft corrugated metal pipe is partially filled with 2ft of sand. This tributary is stable and no restoration projects were identified.

3.1.8 Etter Creek, Tributary 3

Figure C-8: Etter Creek, Tributary 3 Stn 5,300 looking downstream at trail/channel.

Tributary 3 of Etter Creek is 6400ft long, but we could not find its outlet into Etter Creek. The channel is difficult to identify even where culverts indicate it should flow under Ravenna Trail. There is a U-shaped valley at the upper end of the subwatershed, but it has no noticeable channel. When water does flow through this valley, it likely flows along the footpaths (Figure C-8). The subwatershed is mostly forested with large oaks (~24 inch dbh), smaller maples and elms, and little understory. This tributary is stable and no restoration projects were identified.

3.1.9 Etter Creek, Tributary 4

Figure C-9: Etter Creek, Tributary 4 (Top) Stn 1,900 looking downstream; (middle) Stn 3,550 looking upstream at eroding slopes; (bottom) Stn 0 of Drainage 2 looking upstream at inactive knickpoint.

This subwatershed is made up of the mainstem of Tributary 4, the North Drainage that flows into the mainstem of Tributary 4 at station 3500, and two minor drainages that flow into the mainstem at station 4900. The 6500-ft Tributary 4 joins Etter Creek at station 13,850. Although we have placed all of Tributary 4 into one reach, three subreaches can be described. Below station 2600, the channel is mostly a roadside ditch that is actively incising and widening; new inset floodplains in some areas suggest portions may be approaching a new equilibrium channel geometry (Figure C-9). An active 12ft knickpoint at station 2600 continues to migrate upstream. From station 2600 to 4300 cattle graze throughout the channel and riparian area (Figure C-9). Much of the vegetation has been removed in this section and the hillslopes have eroded into deep ravines. Farming no longer occurs upstream of station 4300, so the hillsides are wooded, and the abandoned fields are becoming grass and shrublands. Throughout, the channel bed is made of silt and the banks are silty loam and clay.

Incision is working through Tributary 4 and its associated drainages, though land use changes and active management in the headwaters have decreased problems in the upper portion of the subwatershed. We observed knickpoints sporadically along Tributary 4, Drainages 1 and 2, and the upper portions of the North Drainage. The knickpoint at station 2600 is actively migrating upstream, and a portion of this knickpoint is within a few feet of Records Trail. Active cattle grazing has reduced the vegetation throughout the valley bottom and hillslopes in the middle portion of Tributary 4, and the hillslopes are badly eroding. Old detention basins at station 3850 of Tributary 4 and 400 of the North Drainage may have previously helped stem some of the erosion and incision. As the land surrounding the headwaters stopped being farmed and a new retention basin and 20-ft earthen dam was created at station 6550, incision and erosion between the headwaters and station 4300 has been stemmed. The knickpoints in the headwaters, though noticeable, are vegetated and do not appear active (Figure C-9). The channels are obscured by vegetation in this area, and we saw no evidence of recent erosion.

The channel does not hold continuous water, so there is no aquatic habitat. There is some good wooded habitat upstream of the cattle grazing. In this area the riparian corridor is 50-75ft wide and made up of 60% woody species with a dense understory. The most common trees are elm, oak, box elder, and maple.

We identified three priority areas for projects in this Tributary: 1) At station 2600, the 12ft knickpoint is migrating upstream, and a smaller, 3ft knickpoint is within 10ft of Records Trail. 2) Unrestricted cattle grazing between stations 3400-4300 of the mainstem and stations 0-400 of the North Drainage is causing excessive erosion. 3) The detention basin at station 3900 could be retro-fitted into a retention basin to hold more water for longer in a wetland basin similar to the one at station 6550.

3.1.10 Etter Creek, Tributary 5

Tributary 5 flows between steep valley walls and more than five drainages flow into the tributary. This tributary is 7700ft long and enters Etter Creek at station 16,100. The subwatershed is heavily forested in the steeper areas, but agriculture is active where vehicles can navigate the terrain. Tributary 5 and its drainages are characterized by successive knickpoints that are migrating upstream. Large cottonwood trees do help slow the rate of migration, but knickpoints are continuing upstream and into the drainages and are nearing the row crops. We identified 10 knickpoints throughout the subwatershed, eight of which are highly active and the other two are moderately active. These knickpoints ranged in height from 3-10ft. The 10ft knickpoint is located at station 1650, and downstream of this knickpoint a new channel geometry is forming (Figure C-10). The bankfull width and depth in this section are 15-25ft and 15ft respectively. Further upstream, the bankfull width and depth are 6ft and 2ft respectively (Figure C-10). The channel bed is fine sand and silt. The steep banks are composed of compacted fine silt. Incision throughout the subwatershed, ranging from 10ft near the mouth to 2-6ft upstream, results in bank and slope failure and excessive sedimentation of Etter Creek.

Figure C-10: Etter Creek, Tributary 5 (Top) Stn 1,650 looking downstream at channel after 10 ft of incision; (middle) Stn 4,750 looking upstream; (bottom) Stn 4800 looking upstream at knickpoint.

There is no continuous aquatic habitat due to lack of year-round water, but where the channel goes through wooded areas, the forest habitat is good. The canopy cover is 70%, and there is a healthy understory. There are many elm trees and some large cottonwoods.

We recommend that this entire subwatershed be managed to control the actively migrating knickpoints and excessive erosion. The knickpoints may impact agriculture, and the incision and bank failure is the source of much of the sediment found in Etter Creek. Fixing individual knickpoints may temporarily halt incision, but long-term solutions should likely involve a combination of management practices: changes in farming practices, conversion of fields to native vegetation, construction of retention basins, stabilizing the channel and banks in select places.

3.1.11 Etter Creek, Tributary 6

3.1.11a Etter Creek, Tributary 6, Reach 1

Reach 1 of Tributary 6 is 1000ft long and enters Etter Creek at station 19,350. It is a shallow swale through grazing fields with a bankfull width of 5ft and depth of 2ft. The channel bed is comprised of sand and silt while the banks are silt and fine silt. The banks rise gradually and are covered with graminoids. The channel is stable, though a small, 2ft knickpoint near the mouth should be monitored for continued migration. Most of the vegetation abutting the stream is grasses and forbs that cattle graze, so there is little canopy cover (Figure C-11). The few trees that are present are mostly cottonwoods. There is no aquatic or riparian habitat in this reach. We are not recommending any projects for Reach 1 of Tributary 6.

Figure C-11: Etter Creek, Tributary 6, Reach 1; Stn 950 looking downstream.

3.1.11b Etter Creek, Tributary 6, Reach 2

Reach 2 of Tributary 6 extends from station 1000 to station 4500 and also contains the North Fork, which is 1400ft long and joins Tributary 6 at station 2100. Both Tributary 6 and the North Fork are heavily forested with no encroachment by development. The section between stations 1000 and 2500 is aggradational as silt from upstream is deposited, and we could not identify a specific channel (Figure C-12). Upstream of station 2500 and on the North Fork, the channel flows through steeper hillsides and is better defined. In this section, the bankfull width is 15ft and depth is 8ft, and the banks are steeper and composed of fine sand, silt, and fine silt. The channel bed throughout is composed of fine sand with some gravel and cobble.

Figure C-12: Etter Creek, Tributary 6, Reach 2; (Top) Stn 1,750 looking upstream; (bottom) Stn 4,500 looking upstream at

Upstream of station 2500, we observed low to moderately active knickpoints. At station 4500, 8-11 ft knickpoints are nearing open fields. Landowners have dumped woody debris into the channel here and have attempted to slow the incision by diverting the water, but these actions appear to have created knickpoints on the sides of the channel as well. This incision is resulting in excessive bank erosion and sedimentation (Figure C-12).

The stream is intermittent, so there is not continuous aquatic habitat. There is good forest habitat with 70% canopy cover, and an understory layer. The vegetated riparian area is 50-150ft wide, and woody species make up 90% of the vegetation. Elm, oak, box elder, and ash are the most prevalent tree species, and cottonwoods are also present.

We recommend management of the 8-11ft knickpoints at station 4400-4500. These knickpoints are active, nearing open fields, and resulting in bank erosion and sedimentation. An increased riparian buffer upstream of these knickpoints, or a retention basin to capture runoff would help stem the incision and bank erosion.

3.1.12 Etter Creek, Tributary 7

3.1.12a Etter Creek, Tributary 7, Reach 1

Reach 1 of Tributary 7 is 1850ft long and enters Etter Creek at station 24,050. Due to incision on Etter Creek, Tributary 7 avulsed and carved a new channel that is about 1400ft upstream of the original mouth (Figure C-13). The knickpoint created by this avulsion migrated up through reach 1, resulting in channel widening and 6-10ft of incision. This process caused additional sediment to be deposited into Etter Creek. The channel may currently be depositional as up to 1ft of sand occurs on top of the compacted silt bed. The bankfull width and depth are 6ft and 1ft respectively. Since the knickpoint moved through, 1-ft high inset floodplains have developed within the steep channel walls. These floodplains have trees up to 18 inches growing on them. This suggests that the channel has been relatively stable for a number of years and that the channel geometry has adjusted to the new hydrology (Figure C-13).

Figure C-13: Etter Creek, Tributary 7, Reach 1; (Top) Stn 500 of abandoned channel looking downstream; (middle) Stn 900 looking upstream; (bottom) Stn 1,450 looking downstream.

Reach 1 mostly goes through wooded areas with some agriculture in the lower section. There is not continuous aquatic habitat, but there is good riparian habitat with 60% canopy cover and understory grasses and forbs. The vegetated corridor is 50-75ft wide. Cottonwoods are the dominant tree species, with elm, ash, and buckthorn also present.

Due to the channel stability and lack of aquatic habitat, we are not recommending any projects in this reach.

3.1.12b Etter Creek, Tributary 7, Reach 2

Reach 2 of Tributary 7 is 6,550ft long and extends from station 1850 to station 8400. The reach has been heavily manipulated, and between stations 2300 and 5500, the channel runs through a sand mine (or other mining operation). The rest of the channel goes through agricultural areas. The knickpoint that migrated through Reach 1 was stopped by the combination of a pile of 4-ft diameter boulders and an earthen berm and retention basin (Figure C-14). These structures have stabilized the channel and halted excessive incision and migration of knickpoints.

Figure C-14: Etter Creek, Tributary 7, Reach 2; (Top) Stn 2,150 looking downstream at retention basin; (middle) Stn 2,500 looking upstream at incision in corn field; (bottom) Stn 2,750 looking upstream at mining operation.

Where mining occurs, the valley floor is essentially a dirt road for large excavators and trucks to use (Figure C-14). Water comes off of agriculture fields upstream, flows through a couple of small retention basins, then across the roads, through a small corn field, and then into the retention basin at station 2000. The roads and small corn field are likely re-graded every year as the incision through the sand between the corn rows was obviously different this year than on air photos from past years (Figure C-14).

There is no aquatic or riparian habitat in reach 2. Where there is a vegetated corridor, it is up to 100ft wide and comprised completely of grasses and forbs. We did not investigate the channel upstream beyond the mining operation, and we are not recommending any projects for this reach.

3.1.13 Etter Creek, Tributary 8

Tributary 8 of Etter Creek is 5800ft long and enters Etter Creek at station 23,250. The tributary contains two drainages in the upper portions of the subwatershed. Drainage 1 drains agriculture fields, contains multiple knickpoints, and flows into Tributary 8 at station 3650. Drainage 2 also drains fields, but it is not as steep at Drainage 1, so knickpoints are not as problematic. Drainage 2 reaches the mainstem at station 4800. The section of Tributary 8 that is upstream of 145th Ave. flows through steep hillslopes and contains small knickpoints that range in height from 1-6ft (Figure C-15). Knickpoints often stop at tree roots, but continue to be found further upstream. In this section, the bankfull width is 8ft and the depth is 4-6ft. The steep banks are made up of silty loam, and the channel bed is sand and silt. Downstream of 145th Ave., the channel is difficult to detect, and the alluvial valley appears to have been an area where eroded sediment from the headwaters is deposited (Figure C-15).

Figure C-15: Etter Creek, Tributary 8 (Top) Stn 1,100 looking upstream; (middle) Stn 3,700 looking upstream; (bottom) Stn 3,900 looking upstream .

The riparian corridor is mostly forested (Figure C-15), though the channel does run along a field near 145th Ave. The width of the vegetated riparian corridor is 100ft, and the canopy coverage is 70%. Oaks make up 50% of the woody species, and elm and cottonwood are also present. There is no aquatic habitat, because water does not flow year-round.

Tributary 8 flows through three culverts. At station 1500, the channel flows under 145th Ave through an irregularly-shaped culvert whose upstream end is concrete and downstream end is metal. At station 4600, a corrugated metal pipe culvert allows water to flow under a private driveway; this culvert is perched on the downstream end and has a flow deflector on the upstream end. The driveway acts as a dam creating a detention basin. At station 5000, two corrugated metal pipes lie under 225th St. One of the two pipes is 90% filled with sand. The culverts under the driveway at station 4600 and under the road at station 5000 could be retrofitted to increase their ability to retain water behind the road prisms.

Our recommended projects focus on the knickpoints between stations 1500-5800. These knickpoints are nearing farm fields and will continue to migrate unless retention is improved and stormwater can infiltrate before it reaches the stream.

3.1.14 Etter Creek, Tributary 9

3.1.14a Etter Creek, Tributary 9, Reach 1

Reach 1 of Tributary 9 is 1600ft long and enters Etter Creek at station 24,850. It is a straightened reach that primarily flows through agriculture fields (Figure C-16). It is mostly a flat reach that is located at the base of surrounding steep hills. The upper portion of the reach does flow through a wooded area that characterizes reach 2. An active knickpoint, resulting from the lowering of Etter Creek, has begun migrating into the agriculture fields and landowners have subsequently dumped woody debris, sawdust, and other materials into the hole created (Figure C-16). Where incised, the banks are nearly vertical and made of fine silt and clay, and the bankfull width and depth are 8ft and 6ft respectively. Upstream where there is less incision, the channel is a shallow swale with a bankfull width of 9ft and depth of 3ft. This incision will likely continue upstream, however, unless management actions are taken.

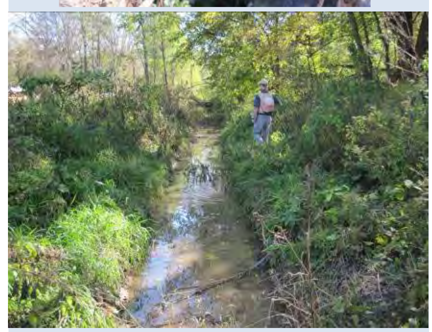


Figure C-16: Etter Creek, Tributary 9, Reach 1 (Top) Stn 450 looking upstream at knickpoint; (bottom) Stn 850 looking upstream .

There is no continuous aquatic habitat in this reach and very little riparian habitat as most of the reach goes through fields. Where the channel does have a vegetated riparian corridor, it is 50ft wide, and in a few areas, the canopy coverage reaches 60%. The most prevalent woody species are ash, elm, and cottonwood.

We recommend stabilizing the knickpoint at station 450. Floodplain and riparian management upstream in reach 2 to reduce the volume of water flowing downstream will help stem upstream migration of this knickpoint, but immediate stabilization may help reduce loss of fields.

3.1.14b Etter Creek, Tributary 9, Reach 2

Reach 2 of Tributary 9 of Etter Creek is 4800ft long, from station 1600 to station 6400. Most of the reach flows through forested habitat that is surrounded by agriculture, and the upper portion of the subwatershed contains more than 7 small drainages. Downstream of station 3500, the channel bed is mostly sand with consolidated silt below, and the bankfull width and depth at 15ft and 5ft respectively (Figure C-17). Upstream of station 3500, the bed has cobbles and boulders, and the bankfull width and depth are both 12ft.

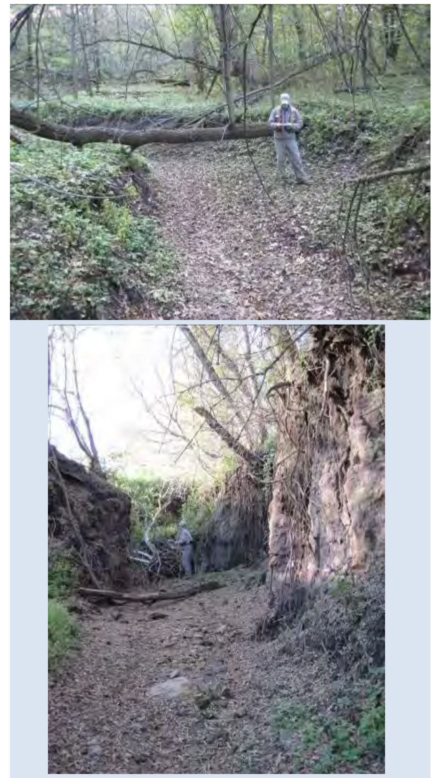


Figure C-17: Etter Creek, Tributary 9, Reach 2; (Top) Stn 4,700 looking downstream; (bottom) Stn 5,700 looking upstream at

This reach is degrading with 22 knickpoints, 19 of which are highly active. All of the smaller drainages also have active, migrating knickpoints. Most of the knickpoints in this reach are currently at the interface between forest and agriculture fields. These knickpoints are 6-15 ft in height and will continue migrating into the fields and impacting farm production (Figure C-17). Incision from knickpoints is causing excessive erosion and sedimentation.

There is no continuous aquatic habitat, but the forest and riparian habitat through this reach is good. The width of the vegetated riparian corridor is 50-100ft, and the canopy coverage is 80%. Maples make up 80% of the woody species with willow, oak, and box elder comprising the remainder.

At station 2100, power lines cross the channel. There is a dirt road crossing and a 3ft knick point at station 2300. The knickpoint may continue to migrate upstream, which would further lower the base level elevations and increase incision and depth of knickpoints in the drainages. A small retention basin combined with a grassy swale between row crops along Drainage 6 has likely halted current and future incision through this drainage. In the mainstem and drainages surrounding this, however, incision continues, and we recommend subwatershed-scale management to decrease the amount of overland runoff and halt the incision and erosion. Row crops are actively falling into the knickpoints. A combination of using different farming practices, building retention basins, and converting farm fields to native vegetation will help stem the degradation.

3.1.15 Etter Creek, Tributary 10

Tributary 10 of Etter Creek is 5400ft long and joins Etter Creek at station 26,700. It has one associated drainage and runs through a valley with steep, wooded slopes and surrounding agriculture. Tributary 10 has 9 knickpoints, 6 of which are highly active. Incision has exposed gravel and cobbles in the banks and, in the lower portions of the tributary, boulders and cobbles make up the channel bed (Figure C-18). As the knickpoints migrate upstream, the channel banks become very steep and sometimes fail, resulting in channel widening. The boulder and cobble bed near the mouth will help slow future incision, but incision continues through a bed of compacted fine silt and clay mixed with gravel and cobbles upstream. In the mainstem, the channel has a bankfull width of 15ft and depth of 7ft (Figure C-18). In the Drainage, the bankfull width and depth are 8ft and 4ft respectively. Between knickpoints, the channel is less well defined.

Figure C-18: Etter Creek, Tributary 10; (Top) Stn 100 looking upstream; (middle) Stn 1,900 looking upstream at knickpoint; (bottom) Stn 2,900 looking

There is no continuous aquatic vegetation, but canopy cover is high (70%) all along the channel with mixed understory vegetation as well. The width of the vegetated riparian corridor is 50-100ft. Woody species make up 80% of the vegetation, and oak, elm, cottonwood, and box elder are all present.

A few parcels have been put out of production in the headwaters of Tributary 10, and the increased infiltration has likely slowed the rate of knickpoint migration. The southern portion of the headwaters, however, is still actively farmed, and the lack of infiltration through fields may be causing the continued migration of knickpoints through the tributary 10 and Drainage 1. The knickpoints in Drainage 1 are nearing row crops and may impact farming in the coming years.

The primary restoration project that we recommend is to address the knickpoints between stations 750 and 4100 (Figure xx). These knickpoints are 2-4ft in height and are migrating upstream, and the incision is causing bank erosion and increased sedimentation. The eroding bank from station 300 to station 450 should also be monitored. The erosion may be slowed if farming practices are changed or management practices are put into place upstream.

3.1.16 Etter Creek, Tributary 11

Tributary 11 is 3600ft long and enters the mainstem of Etter Creek at station 29,050. The tributary has been dramatically altered by the construction of an earthen dam and retention basin at station 500 (Figure C-19). The dam and retention basin were likely built to stem incision and erosion and prevent additional water and sediment from flowing into Etter Creek. This has been very successful, and the retention basin has been able to capture all stormwater upstream. Upstream of the retention basin, the channel goes through a wooded section, but upstream of that, the channel is essentially a grassy swale between farmed hills.

Figure C-19: Etter Creek, Tributary 11; (Top) Stn 100 looking upstream at minor erosion around post and in field; (middle) Stn 200 looking upstream to dam; (bottom) Stn 500 looking upstream at retention basin.

The earthen dam is maintained and mowed frequently with no larger vegetation allowed to grow, but the retention basin does provide year-round wetland habitat. In the wooded section, there is a 20-50ft vegetated corridor with 60% canopy coverage. As the channel runs through farm fields, there is no canopy and little non-cultivated vegetation.

There is one road crossing on this tributary at station 100. A 6ft concrete pipe goes underneath 145th Ave. Near the crossing, we observed small pockets of erosion around a fencepost, in the middle of the grassy swale, and on the left side of the culvert (Figure C-19). This erosion should be monitored and addressed if it continues.

3.1.17 Etter Creek, Tributary 12

Tributary 12 is 4000ft long and enters the mainstem of Etter Creek at station 29,350. A few small drainages enter Tributary 12, and the mainstem and the drainages are slowly degrading. A 20ft earthen dam and retention basin were built decades ago at station 3900 (Figure xx). This reduces the amount of water flowing into this tributary, but lack of infiltration and storage elsewhere in the subwatershed results in excessive overland flow and too much water volume for Tributary 12. There are 3 moderately active, 4ft knickpoints between stations 1500 and 2425 (Figure C-20). Around station 2300, the bankfull width is 10ft and depth is 6ft (Figure C-20). Downstream at station 400, the bankfull width is 8ft and the depth is 1ft. The channel bed is comprised of silt and cobble, and the banks are fine silt and clay.

Figure C-20: Etter Creek, Reach 3 (Top) Stn 1,500 looking upstream at knickpoint; (middle) Stn 2,150 looking upstream; (bottom) Stn 3,900 looking upstream at retention basin.

The retention basin provides year-round wetland habitat, and box elders are now growing on the slopes of the dam along with smaller elms. The rest of the channel runs through a wooded area that is surrounded by agriculture. Canopy cover in the wooded area is high (80%), and the 50-75ft riparian corridor maintains good habitat, though no aquatic habitat is available other than the wetland created by the earthen dam. Oak is the predominant woody species along with elm and box elder.

Our recommended projects focus on the three knickpoints that are between stations 1750 and 2425. They are slowly migrating upstream. The migration is not currently impacting fields but could in the future. Subwatershed-scale management of stormwater would reduce incision and erosion.

3.2 Ravenna Coulees

There are four coulees that make up the Ravenna Coulees, and these four coulees are broken up into a total of 16 reaches or tributaries. Overall, the Ravenna Coulees comprise 27.5 miles of stream. We arbitrarily numbered these Coulees 1 through 4 from north to south for consistency. The drainages in the Coulees are intermittent and appeared to only rarely hold water. The channels are stable as they flow through mowed lawns, private property, and wooded valleys. Bedrock was observed in a number of locations along the stream bed in Coulees 1 and 2, halting any incision that may have been occurring. No major problems were identified in these Coulees, though one small knickpoint could be stabilized in Coulee 1.

3.2.1 Ravenna Coulee 1

3.2.1a Ravenna Coulee 1, East Drainage

The east drainage of Ravenna Coulee 1 runs 3200ft from its confluence with the Vermillion River and is an ephemeral drainage that carries rainwater and snowmelt. The channel is steep with dolomite bedrock ledges every 50-100ft along the face of a steep bluff that descends to the Vermillion River (Figure C-21). These ledges, which are up to 6ft, provide grade control, and there are no significant areas of erosion. Where the stream bed is not bedrock, it is gravel and cobble. The banks are silty loam and up to 3ft in height, and there is just one 3ft knickpoint in the silty loam at station 2200, but it is not visibly active.

The stream valley is fairly narrow (~250ft) and steep (~50ft). The bankfull width and depth are 10ft and 2ft respectively, and the riparian corridor is 80ft wide. Due to the lack of perennial water, vegetation grows on the floodplain, banks, and in the channel. Woody species make up about 80% of the vegetation and proved 80% canopy cover, and the dominant species include ash, elm, oak, and maple. With only sporadic flows, this drainage has no aquatic habitat.

This reach does have two culverts for the railroad bridge at station 200-250 and Ravenna Trail at station 650, and both are in moderate condition (Figure C-21). No restoration projects were identified.

3.2.1b Ravenna Coulee 1, West Drainage

The west drainage of Ravenna Coulee 1 is similar to the east drainage. It runs 4000ft from the Vermillion River and is an ephemeral stream that only holds water during rainstorms or snowmelt. The west drainage runs through agricultural fields and the stream bed is only composed of dolomite bedrock ledges or cobbles and gravel downstream of station 2500. Upstream of station 2500, the stream bed is silty loam underlain by gravel. The stream banks are also composed of silty loam and are up to 5ft in height. The channel in this drainage has a bankfull width of 15ft and a bankfull depth of 4-5ft (Figure C-21).

Figure C-21: Ravenna Coulee 1, (Top) East Drainage, Stn 600 looking upstreamat Ravenna Trail crossing; (middle) East Drainage, Stn 1,300 looking upstream; (bottom) West Drainage, Stn 2,400 looking upstream.

The west drainage has little lateral erosion, and downstream of station 2500, 2-3 ft bedrock ledges control grade. Between stations 2100 and 3150, the channel has experienced 3-5ft of incision. Upstream of station 2500, 3 small (1-3ft) knickpoints are eroding through loam to gravel layer or bedrock.

The 20ft wide riparian corridor is forested with 80% canopy cover for most of the drainage, though just upstream of station 3100, the channel is a mowed swale through farm fields. The floodplain vegetation is predominantly woody and made up of ash, elm, oak, and maple. No aquatic habitat exists in this drainage due to the lack of sustained flow, but the channel does have the structure and large woody debris needed for aquatic habitat.

Our recommendations for management in the west drainage of Ravenna Coulee 1 focus on a 2-ft knickpoint at station 3100. Cobbles have been put on the knickpoint to slow its upstream migration. The knickpoint is about 40-50ft from the vegetation line, and, though it does not present a big threat, it will soon migrate across a farm path. Upstream of this knickpoint is the area of channel that is just a mowed swale. No storage is currently built into this swale. The other small knickpoints may also continue to migrate and incise.

3.2.2 Ravenna Coulee 2

3.2.2a Ravenna Coulee 2, Reach 1

Reach 1 of Ravenna Coulee 2 runs 4600 feet from its mouth at the Vermillion River. The channel is stable but barely noticeable for most of its length. Between stations 1900 and 2600, the stream bed is dolomite bedrock or cobbles, and the channel banks are steep rock. The rest of the reach, however, is a swale with barely perceptible banks and a channel bed of sand and gravel (Figure C-22). The reach is ephemeral and only holds water after rainfall or snowmelt. There is no consistent aquatic habitat, but the floodplain is heavily forested.

Figure C-22: Ravenna Coulee 2, Reach1 (top to bottom): Stn 300 looking upstream at Ravenna Trail crossing; Stn 2,100 looking upstream at bedrock ledge; Stn 2,850 looking upstream; Reach 2, Stn 4,600 looking upstream.

Between stations 1900 and 2600, the channel does have multiple large drops, including a 10ft 'waterfall' (Figure C-22). The bedrock helps control the grade, and there are no incision problems in the drainage. The bankfull width in the bedrock section is 20ft while the rest of the reach has a bankfull width of about 7ft. The bankfull depth is 2ft. There is a small knickpoint at station 50, but there are no incision problems upstream.

The floodplain and riparian corridor range from 20ft to 100ft, and the valley floor and steep valley walls are heavily vegetated. Woody vegetation creates 80% canopy cover, with oak being the dominant genus, but some elm and ash are also present. The invasive shrub, buckthorn, was also identified.

There are box culverts at a railroad bridge (station 300-350) and Ravenna Trail (station 400), and these are generally in good condition (Figure C-22). We do not have management recommendations for this reach.

3.2.2b Ravenna Coulee 2, Reach 2

Reach 2 of Ravenna Coulee 2 extends 10,000ft from station 4600 to station 14,600. The channel is a shallow swale in the ground that flows through farm fields (Figure C-22). It is barely noticeable in places and crops are grown in the swale itself. There are no defined banks or bars, and the stream bed is sand or silt loam. The channel is stable.

Reach 2 has no vegetated riparian corridor, and 98% of the surrounding vegetation is grasses or forbs. There is no perennial water and no aquatic habitat. We do not recommend any restoration projects for this reach.

3.2.3 Ravenna Coulee 3

3.2.3a Ravenna Coulee 3, Reach 1

Reach 1 of Ravenna Coulee 3 flows 13,400ft from its mouth at the Vermillion River. The channel goes through a wide, flat valley bottom and is not well defined in areas. Although the valley is forested, it is surrounded by agriculture and heavily used by ATV riders and hunters. In some areas, the wide valley has channel-like features, but in other areas, the channel is vegetated or within ATV trails. Where the channel can be distinguished, the bankfull width is 20ft and the depth is 6ft, and the channel is stable (Figure C-23). Very little water flows through this channel at any time as evidenced by the number of trees growing in the channel.

Figure C-23: Ravenna Coulee 3 (top to bottom): Reach 1, Stn 3,700 looking upstream; Reach 1, Stn 8,950 looking upstream; Reach 2, Stn 20,450 looking at culverts under 190th St; Reach 2, Stn 20,450 looking downstream.

There is no aquatic habitat in this reach, but there is forest habitat. Water did flow from a small pool at station

2250, but there was no water upstream of this station. Though there is no defined floodplain, the vegetated riparian corridor is 400-800ft. Woody species only make up 10% of the vegetation, but the canopy cover is 75%. Oak and aspen are the most common trees along with buckthorn, which can comprise 90% of the vegetation in spots.

We did not identify any potential restoration projects in this reach.

3.2.3b Ravenna Coulee 3, Reach 2

Reach two of Ravenna Coulee 3 runs 29,600ft from station 13,400 to station 43,000. It is primarily a shallow swale through residential yards and agriculture fields (Figure C-23). It is imperceptible in many locations and can only be identified by the road culverts and sometimes a slight depression in the ground. There are no instability problems in this reach. There is no perceptible floodplain and only 0-10ft of riparian vegetation along the channel. There is only riparian vegetation or canopy cover occasionally along the channel, and most of the reach has no canopy cover. Row crops or bare soil make up 80% of the area along the reach.

We did not identify any potential restoration projects in this reach.

3.2.4. Ravenna Coulee 3, Tributary 1

Tributary 1 of Ravenna Coulee 3 flows 18,300ft and joins the mainstem at station 13,400. It is primarily a shallow swale through residential yards and agriculture fields (Figure C-24). The channel is imperceptible in many locations and can only be identified by the road culverts and sometimes a slight depression in the ground. There is no aquatic or floodplain habitat, and there are no instability problems. The only canopy cover is in a few short portions of the swale that is within a wooded area with maple and pine trees. In this area, the canopy coverage is 90%, but most of the rest of the channel is abutted by lawns or row crops.

We do not recommend any restoration projects for this tributary.

3.2.5 Ravenna Coulee 3, Tributary 2

Tributary 2 of Ravenna Coulee 2 is 8300ft long and joins tributary 1 at station 4000. It is primarily a shallow swale through residential yards and agriculture fields (Figure C-24). The channel is imperceptible in many locations and can only be identified by the road culverts and sometimes a slight depression in the ground. There is no aquatic or floodplain habitat, and there are no instability problems. The only canopy cover is in a few short portions of the swale that is within wooded areas that abut residential developments. In this area, maple and pine trees create a canopy coverage of 90%. The rest of the channel runs through lawns and row crops.

We do not recommend any restoration projects for this tributary.

3.2.6. Ravenna Coulee 3, Tributary 3

We did not conduct a field investigation of Tributary 3 of Ravenna Coulee 3. Based on air photo analysis, this tributary is similar to the other 'channels' in the subwatershed. It is a barely perceptible swale through agriculture fields that is 6000ft long and joins the mainstem at station 22,300. It has no perennial water, no aquatic habitat, and no instability problems. About 600ft of channel is in a wooded area at the upper end, and the remainder of the channel goes through agricultural fields.

3.2.6 Ravenna Coulee 3, Tributary 4

Tributary 4 of Ravenna Coulee 3 runs 7100ft and joins Tributary 1 at station 12,450. It is similar to the other tributaries in this subwatershed. The channel only contains water when it runs off of farm fields. It is a shallow swale through fields and has no canopy cover through most of its length. Though most of the channel has no banks, there are 1-2ft banks at the Orlando Ave. crossing (Figure C-24). These banks are composed of sand and silt loam as is the bed of the channel. There is no aquatic habitat and no instability problems.

Figure C-24: Ravenna Coulee 3 (Top to bottom): Tributary 1, Stn 6,500 looking downstream; Tributary 2, Stn 6,550 looking upstream; Tributary 4, Stn 450 looking downstream; Tributary 5, Stn 3,800 looking upstream.

Where there is woody vegetation along the channel, it is weedy and includes box elders and willows. The rest of the channel is abutted by row crops. We are not recommending any restoration projects for this tributary.

3.2.7 Ravenna Coulee 3, Tributary 5

Tributary 5 of Ravenna Coulee 3 is 3700ft long and joins Tributary 4 at station 1150. It is similar to the other tributaries in this subwatershed. The channel only contains water that runs off of farm fields. It is a shallow swale through fields with no banks and no instability problems. There is no perennial water and no aquatic habitat. Most of the channel runs through row crops (Figure C-24), and the parts of the channel that goes through wooded areas has an 80% canopy cover. The main woody species are box elder and willow. We do not recommend any restoration projects for this tributary.

3.2.8 Ravenna Coulee 4

3.2.8a Ravenna Coulee 4, Reach 1

Reach 1 of Ravenna Coulee 4 runs 11,100ft from its confluence with the Vermillion River. The reach consists of a sandy, intermittent channel that flows through a wide, low-gradient valley. The valley is undeveloped, but there are residential neighborhoods to the north and agricultural areas to the south. Through most of the reach, the sandy banks are ill-defined, making it difficult to determine channel dimensions. The bankfull width appears to range between 12-30ft, and the bankfull depth is 1-2ft. We observed many hunting stands and ATV trails throughout the valley, and these trails often followed the same path as the stream channel.

Figure C-25: Ravenna Coulee 4, Reach 1 (Top) Stn 2,750 looking downstream; (middle) Stn 3,700 looking upstream at channel/ATV path; (bottom) Stn 4,400 looking towards left valley wall.

During rain events, the water likely spreads out across the valley floor and follows different paths downstream. Although it appears that ATV traffic along the steep valley walls results in erosion and traffic along the valley bottom prevents establishment of vegetation, downstream movement of sand does not appear to be problematic (Figure C-25). The channel passes underneath Ravenna Trail through three concrete arch culverts, which are in good condition. The bases of the culverts are layered with sand, but the openings are large and clear of obstructions.

Downstream of this crossing, water likely spreads out over a large surface area, decreasing its depth and velocity and the amount of sediment it can carry. The sand appears to deposit primarily downstream of the culvert, and we did not see much deposition where this Coulee reaches the Vermillion River.

The floodplain in Reach 1 is 100-200ft wide, and the width of the vegetated riparian corridor is 250-300ft. Woody species cover 70% of the riparian zone, and oaks are the dominant tree species. Elm, birch, and buckthorn are also present, along with some other species. In the wooded areas, the canopy cover is 90%. About 30% of the riparian zone is just bare sand.

If this valley contained a perennial stream with viable aquatic habitat, or if it appeared that large amounts of sediment were being washed into the Vermillion River, we would recommend limiting ATV use through the valley to encourage the establishment of vegetation and stability of the sandy soils. Since no aquatic habitat is present due to the lack of water, and the sand appears to settle out in the flat valley prior to reaching the Vermillion River, we do not have any potential priority projects in this reach.

3.2.8b Ravenna Coulee 4, Reach 2

Reach 2 of Ravenna Coulee 4 is 6,600ft long between stations 11,100 to 17,700. It consists of an undefined channel or a shallow swale that rarely has flowing water (Figure C-26). The channel bed is made of sand, and there are no defined channel banks. The vegetated riparian area ranges from 12-100ft in width. About 50% of the vegetation is woody, including elm samplings, silver maple, and box elder. The wooded areas have a canopy cover up to 95%, but the channel is hard to find. Where the vegetation is comprised of grasses and forbs, vegetation fills in the width of the swale. The land use around the riparian zone is agricultural and residential. There are concrete culverts at stations 14,400 and 15,700, which are in good condition. There is no continuous flow, no aquatic habitat, and no instability problems, so we are not recommending any restoration projects.

3.2.8c Ravenna Coulee 4, Reach 3

Reach 3 of Ravenna Coulee 4 runs 3,700ft from stations 17,700 to 21,400ft. Unlike the reaches upstream and downstream, reach 3 has a well-defined channel. Like the rest of the Coulee, reach 3 only has water intermittently. The channel bed is sand, and the banks are 3-5ft and made of sand and silt. The upper half of this reach is a road-side ditch along Polk Avenue with a bankfull width of 10ft and depth of 3ft. The ditch collects water from the steeper hillsides to the south and southwest. After joining a small tributary at station 20,150, the channel widens and deepens before becoming less defined in Reach 2. In this section, the bankfull width is 15ft and depth is 5ft. Although the channel has some historical incision, there is no current instability.

Figure C-26: Ravenna Coulee 4, (Top) Reach 2, Stn 14,450 looking upstream; (middle) Reach 3, Stn 20,750 looking downstream; (bottom) Tributary 1, Stn 200 looking upstream at roadside ditch.

The riparian corridor near the road is narrow, 20ft, but it widens to 50ft downstream of the tributary. Likewise, the floodplain is only 10ft near the road and 30ft further downstream. Canopy cover in the riparian zone is 80% with woody species making up 85% of the vegetation. Woody species present include elm, silver maple, cottonwood, oak, and box elder. Saplings and grasses grow in the channel as well as on the banks. Land use around the channel is residential.

There is a large concrete box culvert at station 20,700, which looks new and in good condition (Figure C-26). The size of this culvert indicates that large quantities of water can move through the channel. We do not recommend any restoration projects for this reach.

3.2.8d Ravenna Coulee 4, Reach 4

Reach 4 of Ravenna Coulee 4 is 10,700ft long from stations 21,400 to 32,100. It consists of a shallow swale or small channel flowing through agriculture fields and steep forest. The channel bed is sand, and there are no defined banks. We did not investigate the entire reach since, from the downstream end, it appeared similar to other swales and drainages in the other

Coulee subwatersheds. Looking at the drainage from the downstream end and conducting an air photo analysis, there does not appear to be instability problems, though the channel steepens through the forested section of this reach.

The only forest habitat is between stations 24,000 and 27,700. In this section, the canopy cover reaches 90%, but in the other sections there is no canopy cover. The width of the vegetated riparian corridor is only 10-20ft, and about 50% of the vegetation is woody while the other 50% is grasses or forbs. We do not recommend any projects for this reach.

3.2.8 Ravenna Coulee 4, Tributary 1

Tributary 1 of Ravenna Coulee 4 flows for 4700ft and enters Reach 3 of the mainstem at station 20,150. Tributary 1 begins in open fields that we believe are part of the Conservation Reserve Program (CRP). It then flows through thick forest with no defined channel down a steep hillside. At station 1700, the Tributary emerges from the steep forest into the back yards of residences and then becomes a road side ditch before passing under Polk Avenue and into the mainstem of Coulee 4 (Figure C-26). The culvert under Polk Avenue is in good condition. On the downstream end of the Polk Avenue crossing, an energy dissipating pool (riprap) slows flows as they enter the mainstem. Flow is rare, however, as evidenced by the lack of defined channel in portions of the forest and vegetation growing in the channel next to the road. The channel bed is sand and, where defined, the banks are sand and silt. The channel has no instability problems.

The 10-20ft riparian corridor is either prairie or wooded. Woody species make up 75% of the riparian vegetation and create a canopy cover of 90%. Cottonwood is the dominant tree species with oak, elm, and buckthorn also present. We do not recommend any restoration projects for this reach.

Appendix D: Channel reconnaissance forms

Channel Reconnaissance Form

Date	Oct 4, 2010
Stream/Drainage	Etter Creek
Stream Reach ID	Reach 1
Field Team	NN, BW

Station 0 **To** 2200

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	Sand
Bars	NA
Bed	Sand

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	This is an aggradational reach; it is very low gradient and is basically a large delta for Etter Creek as it enters the Vermillion River; this deposition is not new, but has probably been occurring for thousands of years to build the delta. Highway 68 currently splits the delta and human intervention has forced all Etter Creek flows to the east/southeast of the highway. As one channel fills with sand, water spills onto the floodplain and creates a new channel. This delta is flat and it is difficult to find the channel in many places.				
Lateral stability *deposition, erosion*	Channel likely changes course frequently.				
Erosion (excessive/site specific)	No excessive 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)*: Short banks are composed of sand.				
Terrace/Valley	*Valley form* – This reach is within the wide valley of the Vermillion River; the channel flows at the base of a steep 100-ft bluff from Stn 1300 to 2200	*Land Use* –forest			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	None				

Sediment Impacts

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

Bars / depositional features

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

Riparian Vegetation and Floodplain

Root coverage of banks (%)	90%
Width of veg. riparian corridor*	>500 ft (within riparian corridor of Vermillion R.
Canopy coverage (%)	90%

** 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	50
woody species	50
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Silver maple	70
Elm, elder	20
cottonwood	10

Tree Stand Age (if applicable)

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

Habitat

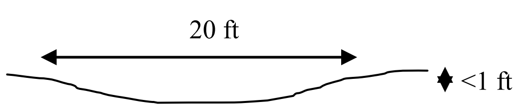
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; channel does not hold continuous water
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	4
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		Low banks, overflows, surficial erosion	5
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools		Extensive bar pressure	4
Relative Width:Depth ratio	Low		Average		High	5
Channel pattern	Single thread		Single thread		Multiple thread/braided	4
Average bank slope	<3:1		>3:1	3		
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9	**= 32/8 = 4**					

Representative cross-section sketch		
Bankfull width = 20 ft Bankfull depth = <1 ft	Floodplain width = >500 ft	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 1400



Station:

GENERAL REACH NOTES

Reach 1 of Etter Creek is a wide delta at the confluence with the Vermillion River. The entire reach is likely influenced by the Vermillion River water levels; at the time of the survey, the Vermillion was backed up to Stn 650. This is an aggradational reach that likely experiences frequent channel change: sand from upstream is deposited in this low-gradient reach and as the channel fills with this deposition, water is forced onto the floodplain and forced to form a new channel. Multiple channels were observed during the survey and new channels were apparent as the deposition was fresh and debris was caught on trees with roots buried in sand. Although a few dirt roads were observed through this reach, no development was apparent likely due to the frequent flooding. Logging may be a historic and current activity. Canopy and ground cover is nearly complete in this reach. There is no aquatic habitat in this reach as flow only occurs with rain events or snowmelt. No stability problems were observed.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Oct 4, 2010
Stream/Drainage	Etter Creek
Stream Reach ID	Reach 2
Field Team	NN, BW

Station 2200 **To** 11,200

General Channel Conditions

Channel Shape (check)
- ☒Rectangular
- ☐Shallow Rectangular
- ☐Irregular
- ☒Trapezoidal
- ☐Parabolic
- ☐Other ______

Sediment Particle Size Estimate	
Banks	Sand
Bars	Few: sand
Bed	Sand, gravel

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Historically incised ~4 ft but currently relatively stable; depositional areas mixed with scour holes downstream of ~Stn 4000				
Lateral stability *deposition, erosion*	Stable; minor bank erosion and bar formation upstream of Stn 10,000				
Erosion (excessive/site specific)	No excessive 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)*: Nearly vertical banks composed of sand with gravel layers visible in some areas; heavily vegetated				
Terrace/Valley	*Valley form* – wide (up to 1000 ft on the valley floor), flat valley with channel in a narrow ditch through most of the reach; valley walls are steep and up to 100 ft higher than the valley	*Land Use* –agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 4050: 2, 5-ft corrugated metal pipes; partially flattened but in good condition; partially filled with sand; traps debris on the upstream end Stn 9600: dirt crossing for farm equipment;				

Sediment Impacts

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

Bars / depositional features

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

Riparian Vegetation and Floodplain

Root coverage of banks (%)	70%
Width of veg. riparian corridor*	80-90 ft
Canopy coverage (%)	0-40%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	25
woody species	75
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Cottonwood	40
Box elder	40
Pine	20

Tree Stand Age (if applicable)

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

Habitat

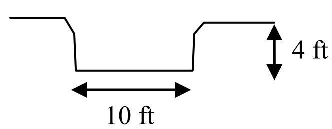
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; channel does not hold continuous water; channel is relatively straight with steep banks and little complexity
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

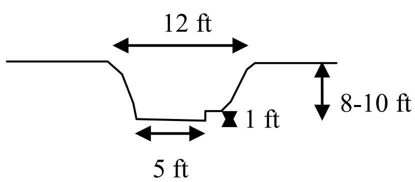
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		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	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 22/9 = 2.44**				

Representative cross-section sketch		
Bankfull width = 15/12 ft Bankfull depth = 4/8 ft	Floodplain width = 20-50 ft	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 4500



Station: 9000



GENERAL REACH NOTES

Reach 2 of Etter Creek is a narrow, historically incised stream that flows between agriculture fields. It has low sinuosity and is straight through some sections. The crop surface is up to 8 ft higher than the channel bed, indicating that incision has occurred. This incision may be as much as 4 ft. Active incision (migrating knickpoints, headcuts, etc.) was not observed and gravel and cobbles were found on the bed in a number of locations. Incision may have slowed since this gravel layer was reached. There is a 30-50 ft vegetation buffer between the channel banks and the row crops through most of this reach with large cottonwoods, box elders, pines, sumac, and other trees and shrubs making up the vegetation. The channel banks are steep and heavily vegetated with grasses and shrubs. Local incision at channel bends was observed and tree roots were observed stabilizing the banks at most of these locations. At the upstream extent of this reach, a few low in-set floodplains were identified. These surfaces are 2-3 ft above the channel bed, but up to 8 ft below the top of the terrace, and are up to 30 ft wide. These floodplains are vegetated with grass and sand deposits were observed in the grass.

POTENTIAL PROJECTS

Stn 4050: 2, 5-ft corrugated metal pipes under Ravenna Trail are undersized and result in large woody debris blockages, flooding of the road, and erosion around the culverts

Stn 6150: gullies in the channel banks and adjacent slopes have formed as a result of concentrated overland flows from water flowing off of fields

Channel Reconnaissance Form

Date	Oct 4, 2010
Stream/Drainage	Etter Creek
Stream Reach ID	Reach 3
Field Team	NN, BW

Station			
Station	11,200	**To**	18,325

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☒Irregular
☒Trapezoidal
☐Parabolic
☐Other _ ______

Sediment Particle Size Estimate	
Banks	Sand/fine sand; occasional limestone
Bars	Sand/fine sand
Bed	Sand/fine sand; occasional limestone cobbles

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Incised 6-8 ft historically; multiple small (0.5-1 ft) active knickpoints were identified				
Lateral stability *deposition, erosion*	Channel does migrate, resulting in eroding cut banks and point bar deposits; sometimes, this channel migration will undermine steep slopes resulting in slope erosion and sedimentation				
Erosion (excessive/site specific)	Eroding bluffs and banks at Stn 15,650, 17,700, and 18,000				
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)*: Banks are 4-8 ft tall and composed of sand and silt; the sand and silt is hard and compacted during periods of little rain, but it is easily erodible.				
Terrace/Valley	*Valley form* – About 300-400 ft wide from the tops of the bluffs; valley floor is about 50-100 ft wide and about 60-100ft lower than the adjacent hills		*Land Use* –agriculture		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 12,800-13,750: restored channel with rock veins and many young willows Stn 13,800: 3, 12x8-ft box culverts with concrete check dams on the upstream side to stem the movement of sediment; new and in good condition Stn 17,050: small 'bridge' made out of a truck bed				

Sediment Impacts

Riffle sediment type	Limestone cobble; sand	Pool sediment type	Sand/silt
Sorting / Imbrication	Not well sorted		

Bars / depositional features

Sediment type/size	Sand
Mid, alternate, braided	Alternate and point
Bar Vegetation (type, age)	*Equisetum sp.*, grasses
Floodplain soils	Sand
Overbank deposition	Sand deposition, but nothing recently

Riparian Vegetation and Floodplain

Root coverage of banks (%)	60-80%
Width of veg. riparian corridor*	50-100ft
Canopy coverage (%)	70%

** 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	85
bare/other	
Exotic/invasive species	Buckthorn

Woody Species present	% of total tree community
Willow	40
Elm/ash/box elder	40
Conifers	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
			Many willows less than 20 years old throughout reach

Habitat

LWD density (pieces / 100 ft)	10
Residual pool depth	Up to 2 ft
Undercut bank frequency	Low
Riffle / Other frequency	Mod

General Habitat Notes: No continuous aquatic habitat because the channel does not hold water year-round. A few small pools were observed that may sustain macroinvertebrate populations. No viable fish habitat because of the lack of water.

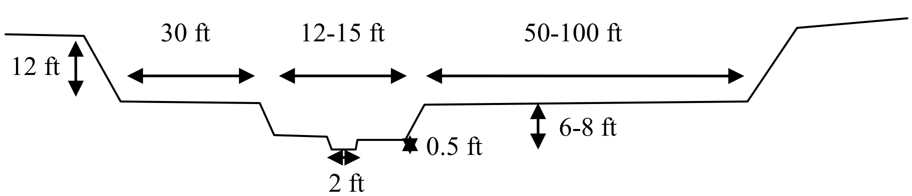
Channel Stability Form

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	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		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	1	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9	**= 21/9 = 2.33**					

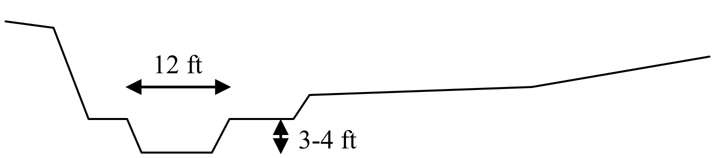
Representative cross-section sketch

Bankfull width = 15/12 ft Bankfull depth = 7/4 ft	Floodplain width = 20-100 ft	Water depth (at survey) = 0-0.2 ft Water width (at survey) = 0-3 ft

Station: 14,500



Station: 16,600



GENERAL REACH NOTES

In Reach 3, Etter Creek is an active, meandering stream flowing within steep, forested hills. No development or farming has occurred within the riparian corridor. The valley bottom is wide and maintains good riparian habitat with thick vegetation cover. The channel bed and bank material is primarily sand and fine sand/silt that is easily mobilized once eroded by floods. The stream channel is 4 to 8 ft below a floodplain surface and valley floor. Small, vegetated, inset sand bars and floodplains have formed within that active channel width. The historic channel was likely a shallow, ill-defined swale on the valley floor that only contained water during rain and snow melt events. This suggests that up to 7 ft of incision has occurred historically through this reach. Multiple small (0.5-1 ft) knickpoints were identified throughout the reach, suggesting that the channel continues to incise slowly. The incision of the mainstem has resulted in incision in the tributaries and drainages linked to Etter Creek. Etter Creek has incised to limestone in a few locations, and this will likely slow or halt the incision. ATVs drive on the channel bed through some portions of this reach, making vegetation growth on the bed and some banks impossible. Elsewhere, vegetation has taken root in the narrow channel, on sand bars, and on the channel banks and this helps to stabilize the channel. The restored section downstream of Redwing Boulevard appears to have accomplished its goal: no excessive erosion is occurring in that reach and thick willow vegetation has taken root in the channel and on the banks. This vegetation will help stabilize the channel and trap sediment, limiting downstream sedimentation.

POTENTIAL PROJECTS

Stn 15,600-15,750: a 50-ft bluff on the right side of the channel is eroding into the channel because the toe of the bluff is being eroded by Etter Creek and seeps halfway up the bluff are destabilizing the slope. Mowed paths have been maintained at the top of the bluff and a bench is about 6 ft from the edge of the bluff.

Stn 16,000-16,400: ATVs drive along the channel bed and over the banks in many locations limiting vegetation growth and destabilizing the channel banks.

Channel Reconnaissance Form

Date	Oct 4-6, 8, 2010
Stream/Drainage	Etter Creek
Stream Reach ID	Reach 4
Field Team	NN, BW

Station 18,325 **To** 26,700

General Channel Conditions

Channel Shape (check)
☐Rectangular
☐Shallow Rectangular
☒Irregular
☒Trapezoidal
☐Parabolic
☐Other _ _____

Sediment Particle Size Estimate	
Banks	Sand/fine sand
Bars	Sand/fine sand
Bed	Sand/fine sand; occasional limestone gr. & cobbles

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Incised up to 8 ft historically; aggradation occurring locally where drainages discharge slugs of sediment; scour holes are created around woody debris or obstructions in the channel; currently relatively stable vertically with no large active knickpoints.				
Lateral stability *deposition, erosion*	Channel does migrate, resulting in eroding cut banks and point bar deposits; sometimes, this channel migration will undermine steep slopes resulting in slope erosion and sedimentation; this erosion is more pronounced and excessive where there is little vegetation to stabilize the banks.				
Erosion (excessive/site specific)	Eroding banks at Stn 18,600-20,000; 20,350-20,600; 21,500-23,200; 26,000				
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)*: Banks are composed of sand and silt; the sand and silt is hard and compacted on the vertical banks, but it is easily erodible. Different periods of incision has resulted in an active channel and multiple terrace levels. The lowest banks are 1-2 ft above the bed, a high floodplain is about 5 ft above the bed, and the crops are on a terrace surface about 8 ft above the channel bed.				
Terrace/Valley	*Valley form* – Valley floor, including crops, is up to 800 ft wide and up to 160 ft below the tops of the surrounding hillsides	*Land Use* –agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 18,325-20,100: cattle grazing in channel and on banks and hillslopes Stn 26,150: 7-ft corrugated metal pipe under 145th Ave; good condition, though some piping occurring				

Sediment Impacts

Riffle sediment type	Limestone cobble; sand	Pool sediment type	Sand/silt
Sorting / Imbrication	Not well sorted		

Bars / depositional features

Sediment type/size	Sand
Mid, alternate, braided	Alternate and point
Bar Vegetation (type, age)	*Equisetum sp.*, grasses
Floodplain soils	Sand
Overbank deposition	Sand deposition, but no recent deposition

Riparian Vegetation and Floodplain

Root coverage of banks (%)	20%
Width of veg. riparian corridor*	200-300 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	15
woody species	85
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Cottonwood	40
Elm	40
Ash, box elder, maple	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
			Some cottonwoods are 12-24 inches DBH

Habitat

LWD density (pieces / 100 ft)	10	General Habitat Notes: No continuous aquatic habitat because the channel does not hold water year-round. A few small pools were observed that may sustain macroinvertebrate populations. No viable fish habitat because of the lack of water. Moderate riparian habitat.
Residual pool depth	1-2 ft	
Undercut bank frequency	NA	
Riffle / Other frequency	Mod	

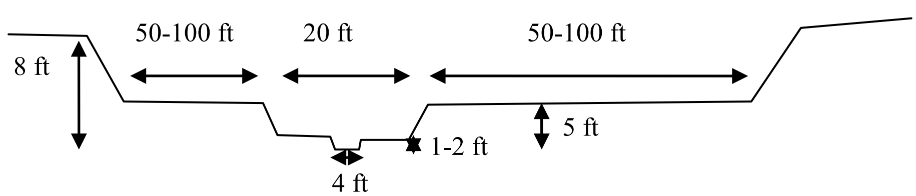
Channel Stability Form

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	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	2	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 19/9 = 2.11**				

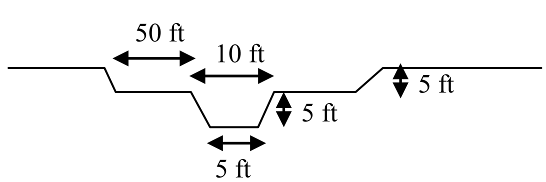
Representative cross-section sketch

Bankfull width = 20/10 ft Bankfull depth = 7/5 ft	Floodplain width = 50-100 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 23,800



Station: 25,000



GENERAL REACH NOTES

In Reach 4, Etter Creek is an active, meandering stream flowing a riparian corridor surrounded by agriculture. The channel bed and bank material is primarily sand and fine sand/silt that is easily mobilized once eroded by floods. Multiple periods of incision on Etter Creek has resulted in multiple floodplain and terrace surfaces. Low, inset sand bars are vegetated with grasses and *Equisetum sp*, a higher floodplain surface above this has saplings and trees, and a terrace above that has larger cottonwoods and maples. The incision of the mainstem has resulted in incision in the tributaries and drainages linked to Etter Creek. Active grazing and vehicle traffic is occurring is some portions of this reach, minimizing vegetation growth and destabilizing the channel and banks. Agriculture and grazing close to the channel banks with little or no buffer has resulted in excessive overland runoff and bank erosion; extreme cases are 4 to 7-ft knickpoints actively migrating up drainages and hillslopes. This excessive erosion causes increased sedimentation in Etter Creek and results in the loss of farmland and degradation of riparian and forest habitat.

POTENTIAL PROJECTS

Stn 18,600-20,000: active grazing within the channel and on channel banks; active vehicle traffic in channel and on channel banks; little to no buffer between crops and channel or drainages; excessive incision and headcutting occuring on adjacent drainages, especially on the left side of the channel, and this is resulting in excessive sedimentation of Etter Creek.

Stn 20,350-20,600: 25 to 50-ft eroding bluff on left side of channel; seeps were not observed and there was some vegetation stabilizing the hillside; no trees to stabilize, however, and crops were growing about 30 ft from the edge of the slope

Stn 21,500-23,200: eroding 8 to 10-ft banks; very little buffer between crops and channel

Stn 21,950: small drainage entering on left side of channel has incised about 150 ft up its drainage and a 4-ft knickpoint is actively moving upstream

Stn 26,150: 7-ft corrugated metal pipe has some erosion and piping occurring on upstream end

Channel Reconnaissance Form

Date	Oct 4-6, 8, 2010
Stream/Drainage	Etter Creek
Stream Reach ID	Reach 5
Field Team	NN, BW

Station | 26,700 | **To** | 31,700 |

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☒Parabolic
☐Other ______

Sediment Particle Size Estimate	
Banks	Sand/fine sand
Bars	NA
Bed	Sand; limestone cobbles and gravel

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Much of this reach is a roadside ditch that has been incised historically up to 8 ft; active incision was not observed				
Lateral stability *deposition, erosion*	Steep banks are eroding throughout this reach				
Erosion (excessive/site specific)	Eroding banks at Stn 26,950-27,050; 27,650; 27,900-28,050; 28,750				
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)*: Banks are nearly vertical and composed sand and fine sand. Concrete, riprap, and other techniques have been used to stabilize. Banks are up to 8 ft tall.				
Terrace/Valley	*Valley form* – Valley floor, including crops and residential areas, is up 100-200 ft wide and up to 100 ft below the tops of the surrounding hillsides, which are about 1000 ft apart	*Land Use* –residential and agriculture on valley floor; forest on hillslopes; agriculture on hill tops			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 27,450: 5-ft corrugated metal pipe under concrete driveway; pipe has corroded through the bottom to sand and gravel Stn 28,050: 3.5-ft corrugated metal pipe in concrete casing under 145th Ave; this is for a small drainage flowing into the left side of Etter Creek; downstream end is 5 ft above the channel bed; some erosion around the wingwalls Stn 29,200: 4x6-ft concrete bridge for driveway; concrete on upstream banks Stn 29,550: 2, 3.5-ft concrete culverts under driveway Stn 31,100: 2, 2.5x4-ft elliptical corrugated metal pipes				

Sediment Impacts

Riffle sediment type	Limestone cobble; sand	Pool sediment type	Sand/silt
Sorting / Imbrication	Not well sorted		

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 (%)	20%
Width of veg. riparian corridor*	30 ft
Canopy coverage (%)	30-60%

** 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	30
woody species	70
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Elm	50
Oak	50

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA
Residual pool depth	NA
Undercut bank frequency	NA
Riffle / Other frequency	NA

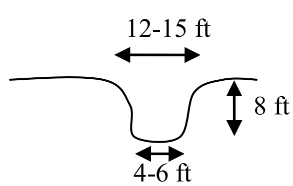
General Habitat Notes: No continuous aquatic habitat because the channel does not hold water year-round. Poor riparian habitat.

Channel Stability Form

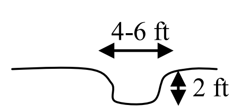
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed	1	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	2	Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low	1	Average		High	
Channel pattern	Single thread	1	Single thread		Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 17/9 = 1.89**				

Representative cross-section sketch		
Bankfull width = 12/4 ft Bankfull depth = 8/2 ft	Floodplain width = 15 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 28,700



Station: 29,700



GENERAL REACH NOTES

In Reach 5, Etter Creek is primarily an incised roadside ditch. There is very little buffer between the channel the road or yards and in some cases the yards or road edges are maintained up to the channel banks. Incision does not appear to be active and limestone gravel and cobbles were observed on the bed throughout this reach, suggesting that this may be helping to slow incision. Bank erosion is active, however, due to excessive water flow, increased slope due to ditching, and lack of vegetation growth. Most culverts under the driveways appeared in good condition with little sediment accumulation or blockage by woody debris. There is no aquatic habitat and little riparian habitat in this reach. The primary problems involve bank erosion.

POTENTIAL PROJECTS

Stn 26,950-27,050: concrete riprap placed on the left bank is falling into the channel; the eroding left bank is about 10 ft from the edge of the road and no trees can grow on the banks to stabilize

Stn 27,450: 5-ft corrugated metal pipe is corroded and needs to be replaced; concrete, bricks and other debris have been dumped on the left and right banks on the downstream end of the culvert in attempts to minimize erosion

Stn 27,450-27,700: grass is mowed to the edge of the channel banks; some trees are growing on the banks, but most of the banks are bare except for grass. This reduces bank stability, riparian habitat, and infiltration.

Stn 27,6255-27,675: riprap on left bank; piping and erosion was observed about 4-ft from the road edge

Stn 28,050: 3.5-ft corrugated metal pipe for small drainage under 145th Ave; on the downstream end, there is a 5-ft concrete drop to the channel bed; base of the wingwalls are cracking and erosion was observed on the top and side of the right wingwall about 3 ft from the road edge; piping on left side also

Stn 28,650: eroding left bank is about 8 ft from the road edge

Channel Reconnaissance Form

Date	Oct 9, 2010
Stream/Drainage	Etter Creek, Tributary 1
Stream Reach ID	Reach 1; joins Etter at Stn 3475
Field Team	NN

Station 0 **To** 8900

General Channel Conditions

Channel Shape (check)

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

Sediment Particle Size Estimate	
Banks	Sand/grass
Bars	NA
Bed	Sand/grass

Bar Types:

☐ Alternate lateral	☐ Point / transverse	☒ None
☐ Mid-channel	☐ Point / mid	☐ Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	No incision observed; channel barely noticeable				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	NA				
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)*: No banks - channel is a shallow swale when visible				
Terrace/Valley	*Valley form* – generally flat, though within narrow valley ~60 tall between stations 1200 and 4000.			*Land Use* –forest and residential	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 550: channel should cross Ravenna Trail, though no channel was noticeable and no culverts were found Stn 4500: 5-ft corrugated metal pipe under Quamme Ave filled with about 2 ft of fine sand Stn 7450: 4-ft corrugated metal pipe under Redwing Blvd with about 3 ft of sand				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	No riparian zone
Canopy coverage (%)	0-70%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	25
woody species	75
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Ash/oak	90
Saplings and buckthorn	10

Tree Stand Age (if applicable)

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

Habitat

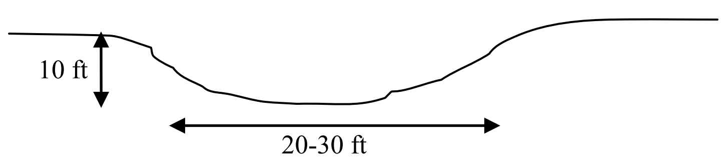
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Channel barely noticeable; mown lawns in places; forest habitat elsewhere
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

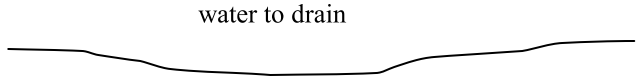
Representative cross-section sketch		
Bankfull width = Bankfull depth =	Floodplain width =	Water depth (at survey) = Water width (at survey) =

Station: 4400



Station: 7400

No noticeable channel; mown lawns; barely a low spot for water to drain



GENERAL REACH NOTES

Channel is hard to identify throughout. We could not find the connection with the mainstem of Etter Creek. In some places it is a shallow swale in the forest next to the road; elsewhere the 'channel' is a mowed lawn. The only indicators of water flow are the culverts.

POTENTIAL PROJECTS

NA

Channel Reconnaissance Form

Date	Oct 9, 2010
Stream/Drainage	Etter Creek, Tributary 2
Stream Reach ID	Reach 1; joins Trib 1 at Stn 3350
Field Team	NN

Station | 0 | **To** 4600 |

General Channel Conditions

Channel Shape (check)

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

Sediment Particle Size Estimate	
Banks	Sand/grass
Bars	NA
Bed	Sand/grass

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	No incision observed; channel barely noticeable				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	NA				
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)*: No banks - channel is a shallow swale when visible				
Terrace/Valley	*Valley form* – generally flat, though within narrow valley ~40 tall between stations 0 and 1000.			*Land Use* –forest and residential	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 2800: 4-ft corrugated metal pipe under 203rd St; half filled with sand on downstream end				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	No riparian zone
Canopy coverage (%)	0-50%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	50
woody species	50
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Ash/oak	90
Saplings and buckthorn	10

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA	General Habitat Notes: Channel barely noticeable; mown lawns in places; forest habitat elsewhere
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

Representative cross-section sketch

Bankfull width = Bankfull depth =	Floodplain width =	Water depth (at survey) = Water width (at survey) =

Station: 2800

No noticeable channel; mown lawns; barely a low spot for water to drain

Station:

GENERAL REACH NOTES

Channel is hard to identify throughout. Channel is a shallow swale or part is undetectable in yards as mown lawns. The only indicator of water flow is the culvert.

POTENTIAL PROJECTS

NA

Channel Reconnaissance Form

Date	Oct 8-9, 2010
Stream/Drainage	Etter Creek, Tributary 3
Stream Reach ID	Reach 1; joins Etter at Stn 8000
Field Team	NN, BW

Station 0 **To** 6400

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☒Parabolic
☐Other ______

Sediment Particle Size Estimate	
Banks	silt/vegetation
Bars	NA
Bed	silt/ vegetation

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	No incision observed; channel barely noticeable				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	NA				
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)*: No banks - channel is a shallow swale when visible				
Terrace/Valley	*Valley form* – generally flat, though upstream of Stn 4500, valley walls are about 40 ft high and 300 ft apart.		*Land Use* –mostly forest with some agriculture near mouth		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 450: 1.5-ft corrugated metal pipe under Ravenna Trail; partially crushed on both ends; captures road runoff, but no noticeable channel nearby				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	100%
Width of veg. riparian corridor*	No riparian zone
Canopy coverage (%)	90%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	10
woody species	80
bare/other	Fields: 10
Exotic/invasive species	

Woody Species present	% of total tree community
Large oaks	80
Maple and elm	20

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA	General Habitat Notes: Channel barely noticeable in U-shaped valley; water probably flows down paths in places
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

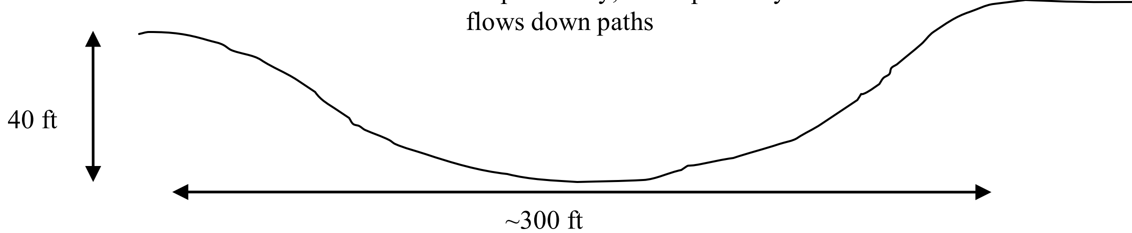
Channel Stability Form

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

Representative cross-section sketch		
Bankfull width = Bankfull depth =	Floodplain width =	Water depth (at survey) = Water width (at survey) =

Station: 4600

No noticeable channel in U-shaped valley; water probably flows down paths



Station:

GENERAL REACH NOTES

Channel is hard to identify throughout. There is no noticeable channel in the U-shaped valley at the upper end of the subwatershed. Any water likely flows down trails throughout the forest. Culvert channel water under Ravenna Trail, but no channel could be found near the culverts. The channel mouth at Etter Creek was also unable to be found. The subwatershed is mostly forested with large 24-inch oaks and smaller maples and elms; there is little understory.

POTENTIAL PROJECTS

NA

Channel Reconnaissance Form

Date	Oct 9, 2010
Stream/Drainage	Etter Creek, Tributary 4
Stream Reach ID	1, joins Etter Creek at Stn 13,850
Field Team	NN, BW

Station 0 **To** 6500

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	Silty loam, clay
Bars	NA
Bed	Silt

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	12-ft active knickpoint at Stn 2600 continues to erode upstream and near Records Trail; downstream of Stn 2600, the channel is adjusting to new flows and widening and creating new inset floodplains; upstream of Stn 3800, detention basins and abandoned fields have stemmed the amount of overland runoff and reduced erosive forces				
Lateral stability *deposition, erosion*	The incised and active portion of the stream continues to widen slightly; upstream, uncontrolled grazing has reduced the vegetation and hillslopes are eroding				
Erosion (excessive/site specific)	Knickpoint at 2600 Eroding hillslopes between Stn 3500 and 4300				
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)*: Banks are nearly vertical and composed of silt and silty loam. In the incised channel, banks are up to 12 ft tall; upstream of Stn 4300, banks are smaller and incision is not active.				
Terrace/Valley	*Valley form* – Steep hillslopes up to 80 ft above the valley floor; valley floor ~100 ft wide; tops of hills ~600 ft apart			*Land Use* –active and inactive agricultural fields; forest within steep valley walls in upper part of subwatershed	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 3850 on mainstem and 500 on North Fork: detention basins in the form of 15-ft earthen dams and 1.5-ft and 1-ft corrugated metal pipes, respectively, draining the reservoirs; upstream of dam, sediment may have filled in basin as ground is substantially higher than downstream Stn 3200-4300: active grazing throughout channel and riparian area Stn 6550: 20-ft earthen dam and retention basin - water still held in healthy wetland; 1-ft corrugated metal pipe releases water once water fills the basin.				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	<5% below knickpoint; 90% upstream of cattle grazing
Width of veg. riparian corridor*	50-75 ft
Canopy coverage (%)	80% upstream of cattle grazing

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	40
woody species	60
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Elm	30
Oak	30
Box elder, maple	40

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA
Residual pool depth	NA
Undercut bank frequency	NA
Riffle / Other frequency	NA

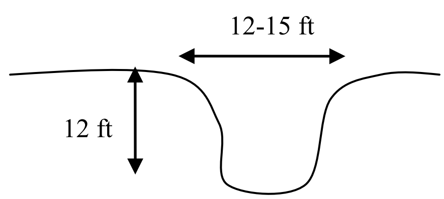
General Habitat Notes: No continuous aquatic habitat because the channel does not hold water year-round. Forest habitat is good upstream of the cattle grazing; here, the canopy coverage is high and the understory is dense.

Channel Stability Form - INCISED SECTION DOWNSTREAM OF STN 2600; UPSTREAM CHANNEL IS STABLE

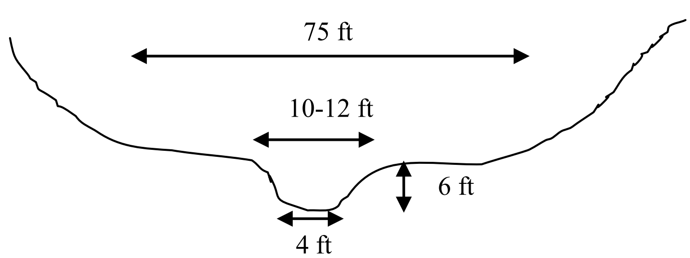
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	1	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	1	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	2	Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low	1	Average		High	
Channel pattern	Single thread	1	Single thread		Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	1	Extensive		Poor	
Field stability rating (add all cells)/9		**= 13/9 = 1.44**				

Representative cross-section sketch		
Bankfull width = 12 ft Bankfull depth = 12/6 ft	Floodplain width = 30/50 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 2500



Station: 5700



GENERAL REACH NOTES

This subwatershed is made up of the mainstem of Tributary 4, the North Drainage that flows into the mainstem at Stn 3500, and two drainages that flow into the mainstem at Stn 4900. Incision is working through Tributary 4 and associated drainages, though land use changes and active management in the headwaters has decreased problems in the upper portion of the subwatershed. A 12-ft knickpoint at Stn 2600 is actively migrating upstream and a portion of this knickpoint is within a few feet of Records Trail. Upstream of this point, active cattle grazing has reduced the vegetation throughout the valley bottom and hillslopes to short grass and a few tall trees. The hillslopes are eroding badly through this middle portion of Trib 4 and the beginning of the North Drainage. Old detention basins on Trib 4 and on the North Drainage may have helped stem some of the erosion and incision in the past. Upstream of these basins, and upstream of the cattle grazing, the valley bottom and hillslopes are heavily forested. Knickpoints were observed sporadically along Trib 4, Drainages 1 and 2, and where the North Drainage began to erode into agriculture fields. However, the land surrounding the headwaters is no longer farmed and is made up of native grasses and shrubs. This land use change, along with a newer retention basin at the upper extent of Trib 4 has stemmed the incision and erosion between the headwaters and the farm with active cattle grazing. The knickpoints in the headwaters, though noticeable, were vegetated and did not appear active. No evidence of recent erosion was observed and the channels were obscured by vegetation.

POTENTIAL PROJECTS

Stn 2600: 12-ft knickpoint is migrating upstream; a smaller 3-ft knickpoint is within 10 ft of the edge of Records Trail.

Stn 3400-4300; 0-400 on North Drainage: unrestricted cattle grazing through bottom of the valley and on hillslopes has caused excessive and devastating erosion

Stn 3900: detention basin could be retro-fitted into a retention basin to hold more water for longer in a wetland basin similar to that in the headwaters

Channel Reconnaissance Form

Date	Oct 6, 2010
Stream/Drainage	Etter Creek, Tributary 5
Stream Reach ID	1; more than five drainages flow into Trib 5; flows into Etter at Stn 16,100
Field Team	NN, BW

Station	0	**To** 7700

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☒Irregular
☐Trapezoidal
☒Parabolic
☐Other ______

Sediment Particle Size Estimate	
Banks	Silt, fine silt
Bars	NA
Bed	Fine sand and silt

Bar Types:

☐Alternate lateral	☐Point / transverse	☒None
☐Mid-channel	☐Point / mid	☐Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Active incision, highlighted by 10 knickpoints, was observed throughout this subwatershed. A 10-ft knickpoint at Stn 1650 is migrating upstream and has resulted in a channel with steeply eroding 10-20 banks. Upstream, additional knickpoints are migrating upstream.				
Lateral stability *deposition, erosion*	Where incision is occurring, lateral erosion and bank instability follows; this tributary is in a valley with steep slopes and the these slopes fail as the channel incises; channel is widening in an effort to achieve equilibrium				
Erosion (excessive/site specific)	Knickpoint at 1650, 2550, 4550, 5500, 5800, and 50 and 150 on Drainage 3, and 150 and 250 on Drainage 4 Excessive bank/slope erosion downstream from Stn 1650				
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)*: Banks are steep and composed of compacted/consolidated fine silt				
Terrace/Valley	*Valley form* – Channel flows through steep valley - tops of surrounding hills are ~130 ft higher than the valley floor and more than 1000 ft apart; valley floor is about 100 ft wide			*Land Use* –forested along valley floor and slopes; agriculture on top of hills	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Agriculture				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	<5% where knickpoints have moved through; 40% elsewhere
Width of veg. riparian corridor*	~100 ft
Canopy coverage (%)	70%

** 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	20
woody species	80
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Elm	90
Cottonwood	10

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
2300	Cottonwood		5x10 ft in diameter; many large cottonwoods halting or slowing incision

Habitat

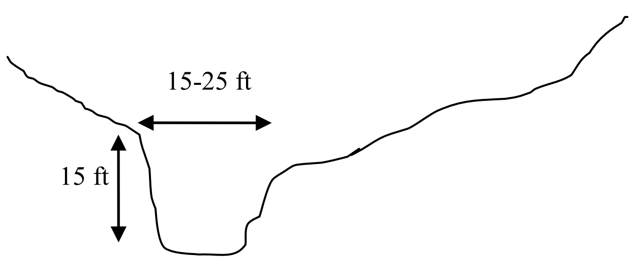
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No continuous aquatic habitat because the channel does not hold water year-round. Forest habitat is good with canopy cover and a healthy understory.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

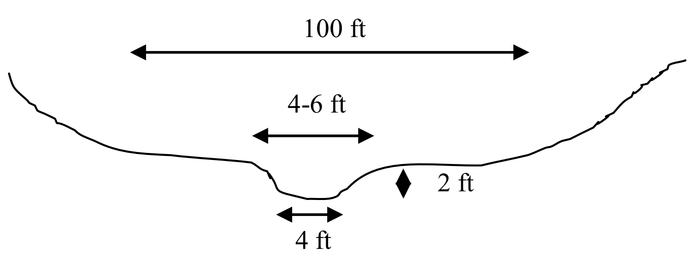
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	1	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed	1	Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	2	Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low	1	Average		High	
Channel pattern	Single thread	1	Single thread		Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	1	Extensive		Poor	
Field stability rating (add all cells)/9		**= 13/9 = 1.44**				

Representative cross-section sketch		
Bankfull width = 20/6 ft Bankfull depth = 12/2 ft	Floodplain width = 20/50 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 1600



Station: 2800



GENERAL REACH NOTES

Tributary 5 flows between steep valley walls and many drainages flow into the tributary. Tributary 5 and its tributaries is characterized by successive knickpoints migrating upstream These knickpoints generally stop at the root clusters of large cottonwood trees or other species. As the erosive forces increase in following storms, the knickpoints break through the roots and stop at the next tree. The incision throughout the subwatershed, ranging from 10 ft near the mouth to 2-6 ft upstream, results in bank and slope failure and excessive sedimentation of Etter Creek. Downstream of the 10-ft knickpoint at Stn 1650, saplings have begun to grown along the channel bed as a new equilibrium channel geometry is forming. The subwatershed is heavily forested in the steeper areas, but agriculture is active where vehicles can navigate the terrain. The knickpoints are continuing upstream and into the drainages. The knickpoints are nearing crops along these drainages.

POTENTIAL PROJECTS

Stn 0-7700: entire subwatershed needs to be managed to control the actively migrating knickpoints and excessive erosion; knickpoints are migrating upstream and may impact agriculture; this incision and bank failure is the source of much of the sediment found in Etter Creek

Channel Reconnaissance Form

Date	Oct 8, 2010
Stream/Drainage	Etter Creek, Tributary 6
Stream Reach ID	1; flows into Etter at Stn 19,350
Field Team	NN, BW

Station 0 **To** 1000

General Channel Conditions

Channel Shape (check)

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

Sediment Particle Size Estimate	
Banks	Silt, fine silt
Bars	NA
Bed	Fine sand and silt

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Shallow swale through cattle farm; a 2-ft knickpoint was identified ~15 ft from Etter Creek; this could continue to migrate upstream				
Lateral stability *deposition, erosion*	Stable - no sign of channel migration				
Erosion (excessive/site specific)	2-ft knickpoint at Stn 15; no excessive channel erosion in the tributary, though there is much hillslope erosion on the opposite side of Etter Creek				
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)*: Banks are gradual as the channel is mostly a shallow swale; banks composed silt and covered with graminoids				
Terrace/Valley	*Valley form* – Flat agriculture fields		*Land Use* –agriculture		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Agriculture Stn 1000: 3x3-ft limestone box culvert extended on the upstream side with a 4-ft corrugated metal pipe under Ravenna Trail/145th Ave.				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	90% - grasses mostly
Width of veg. riparian corridor*	50 ft
Canopy coverage (%)	5%

** Verify with orthoquad data*

Canopy structure : (check one)

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

Primary veg forms present: (%)

grasses/forbs	90
woody species	10
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Cottonwood	90
Miscellaneous saplings	10

Tree Stand Age (if applicable)

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

Habitat

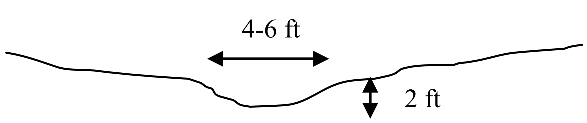
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No continuous aquatic habitat because the channel does not hold water year-round. Grazing land, so little overall habitat.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	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		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		**= 23/8 = 2.88**				

Representative cross-section sketch		
Bankfull width = 5 ft Bankfull depth = 2 ft	Floodplain width = NA	Water depth (at survey) = NA Water width (at survey) = NA

Station: 800



Station:

GENERAL REACH NOTES

Reach 1 of Tributary 6 is a shallow swale through grazing fields with little canopy cover or native vegetation. The channel is stable, though the small knickpoint near the mouth should be monitored for continued migration. There is no substantial habitat in this reach and cattle graze throughout.

POTENTIAL PROJECTS

NA

Channel Reconnaissance Form

Date	Oct 8, 2010
Stream/Drainage	Etter Creek, Tributary 6
Stream Reach ID	2; and North Fork
Field Team	NN, BW

Station 1000 **To** 4500

General Channel Conditions

Channel Shape (check)

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

Sediment Particle Size Estimate	
Banks	Silt, fine silt
Bars	NA
Bed	Fine sand; some gravel and cobble

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stn 1000-2500 is low-gradient and stable; upstream of Stn 2500 - a few small knickpoints with little recent activity were identified; more incised upstream of Stn 4000 with 8-ft banks; at Stn 4500 multiple 8 to 12-ft knickpoints are nearing open fields; active migration				
Lateral stability *deposition, erosion*	Mostly stable, though some widening where incision is increasing upstream of Stn 4000				
Erosion (excessive/site specific)	Knickpoints at Stn 2100, 2500, 3200, 4400-4500; also at Stn 0 and 800 of the North Fork of Trib 6				
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)*: barely perceptible in places; in steeper areas, banks are steep and composed of fine sand, silt, fine silt				
Terrace/Valley	*Valley form* – valley floor about 80-ft below tops of hills; about 150 ft wide below Stn 2500, 50 ft wide above Stn 2500	*Land Use* –forest on slopes and valley floor; agriculture fields on top of hills			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1000: 3x3-ft limestone box culvert extended on the upstream side with a 4-ft corrugated metal pipe under Ravenna Trail/145th Ave.				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	5% in incised area; 80% elsewhere
Width of veg. riparian corridor*	50-150 ft
Canopy coverage (%)	70%

** 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	10
woody species	90
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Elm, oak	40
Box elder, ash	40
Cottonwood	20

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA	General Habitat Notes: No continuous aquatic habitat because the channel does not hold water year-round. Good forest habitat with canopy cover, underbrush.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

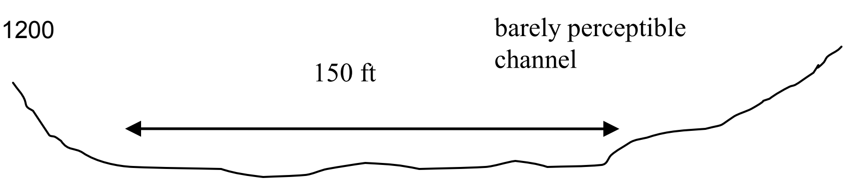
Channel Stability Form - IN INCISED AREAS

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	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	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	2	Local erosion/pools		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	1	>3:1			
Vegetative bank protection	Poor	1	Extensive		Poor	
Field stability rating (add all cells)/9		**= 15/8 = 1.88**				

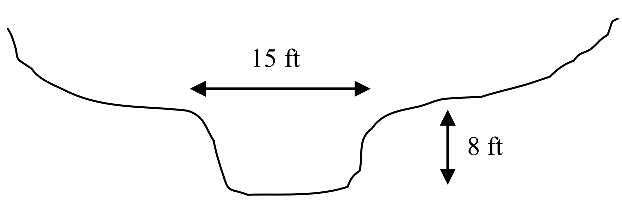
Representative cross-section sketch

Bankfull width = ?/15 ft Bankfull depth = ?/8 ft	Floodplain width = 150/50	Water depth (at survey) = NA Water width (at survey) = NA

Station: 1200



Station: 4200 or 800 of North Fork



GENERAL REACH NOTES

Reach 2 of Tributary 6 also contains the North Fork, which is 1400 ft long and joins Tributary 6 at Stn 2100. Both Tributary 6 and the North Fork are heavily forested with thick canopy cover and mixed underbrush with no encroachment by development. Downstream from Stn 2500 is an aggradational section where the silt from upstream is deposited and no defined channel could be identified. Upstream of Stn 2500 and on the North Fork, the channel is defined as it flows through the steeper hillsides; here, low to moderately active knickpoints were observed. At Stn 4500, 8-11 ft knickpoints are nearing open fields. Landowners have dumped woody debris into the channel here and have attempted to slow the incision by diverting the water; but this appears to have created knickpoints on the sides of the channel as well. This incision results in excessive bank erosion and sedimentation of the lower section of this reach.

POTENTIAL PROJECTS

Stn 4400-4500: 8 to 11-ft knickpoints at head of Tributary 6; active and nearing open fields; resulting in excessive bank erosion and sedimentation

Channel Reconnaissance Form

Date	Oct 5, 2010
Stream/Drainage	Etter Creek, Tributary 7
Stream Reach ID	1; joins Etter at Stn 24,050
Field Team	NN, BW

Station | 0 | **To** | 1850

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☒Parabolic
☐Other ______

Sediment Particle Size Estimate	
Banks	Sandy loam
Bars	NA
Bed	Sand deposits on top of compacted silt

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	6-10 ft of incision has already occurred and the channel geometry has adjusted with inset floodplains and mature vegetation; the reach may be depositional now as layers of sand were observed on top of compacted silt - this may from continued erosion from Reach 2				
Lateral stability *deposition, erosion*	Generally stable now that incision has moved through; during period of incision, the channel did avulse and enter Etter Creek about 1400 ft upstream from its original mouth				
Erosion (excessive/site specific)	Stn 1400 - 8-ft eroding bank				
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)*: banks are steep and composed of dark, compacted sandy loam				
Terrace/Valley	*Valley form* – steep hillslopes rise about 100-ft above the valley; valley floor 50-150 ft wide		*Land Use* –forest with some agriculture in lower section		
Altered state (human) - dams, bridges, canoe landings, parks, etc.					

Sediment Impacts

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

Bars / depositional features

Sediment type/size	sand
Mid, alternate, braided	A few point bars
Bar Vegetation (type, age)	NA
Floodplain soils	Sand on inset floodplains with grasses and mature trees
Overbank deposition	Sand on inset floodplains

Riparian Vegetation and Floodplain

Root coverage of banks (%)	10%
Width of veg. riparian corridor*	50-75 ft
Canopy coverage (%)	60%

** 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	10
woody species	90
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Cottonwood	70
Elm, ash	30
Buckthorn	10

Tree Stand Age (if applicable)

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

Habitat

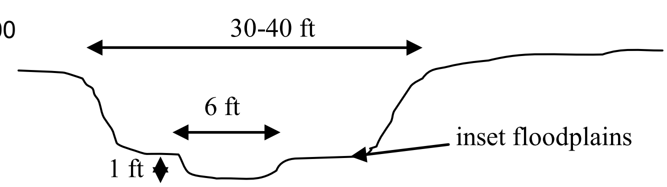
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No continuous aquatic habitat because the channel does not hold water year-round. Good riparian habitat with canopy cover, underbrush.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form - IN INCISED AREAS

Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	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	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		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	1	>3:1			
Vegetative bank protection	Poor	1	Extensive		Poor	
Field stability rating (add all cells)/9		**= 18/9 = 2**				

Representative cross-section sketch		
Bankfull width = 6 ft Bankfull depth = 1 ft	Floodplain width = 10	Water depth (at survey) = NA Water width (at survey) = NA

Station: 1200



Station:

GENERAL REACH NOTES

Reach 1 of Tributary 7 has undergone 6-10 ft of incision. As Etter Creek incised, Tributary 7 avulsed and carved a new channel about 1400 ft upstream of original mouth. The knickpoint migrated upstream through Reach 1, depositing sediment in Etter Creek and resulting in channel widening and Tributary 7. Since the knickpoint moved through, 1-ft high inset floodplains have developed within the steep channel walls. These floodplains have trees up to 18 inches growing on them. Up to 1 ft of sand has deposited on the channel bed, likely from upstream erosion, but this reach appears to be currently stable.

POTENTIAL PROJECTS

NA

Channel Reconnaissance Form

Date	Oct 5, 2010
Stream/Drainage	Etter Creek, Tributary 7
Stream Reach ID	2
Field Team	NN, BW

Station 1850 **To** 8400

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☒Irregular
☐Trapezoidal
☐Parabolic
☐Other ______

Sediment Particle Size Estimate	
Banks	NA
Bars	NA
Bed	Sand where there is a channel

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Appears vertically stable because of management measures: 8-ft knickpoint at Stn 2100 has been halted by the placement of many large boulders up to 4 ft in diameter; at Stn 2000, an earthen berm was built and retention basin now captures stormwater and sediment eroding from mining operation				
Lateral stability *deposition, erosion*	No active channel observed				
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)*: No real channel observed, so no banks observed				
Terrace/Valley	*Valley form* – steep hillslopes rise about 100-ft above the valley; valley floor 100-150 ft wide			*Land Use* –Appears to be a sand mining operation in and around the channel/riparian area; also agriculture	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 2000: Earthen berm dam and retention basin Stn 3900: retention basin Mining operation and agriculture				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	NA
Width of veg. riparian corridor*	100 ft
Canopy coverage (%)	0%

** 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	100
woody species	
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community

Tree Stand Age (if applicable)

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

Habitat

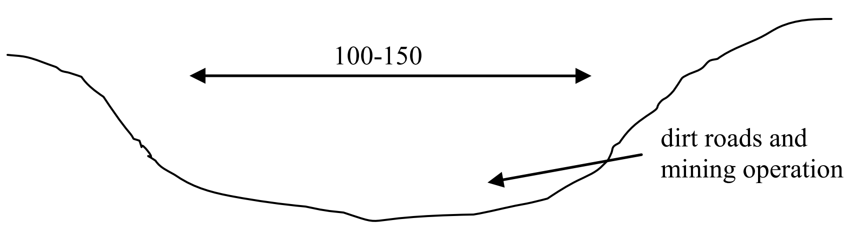
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No habitat.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

Representative cross-section sketch		
Bankfull width = NA Bankfull depth = NA	Floodplain width = NA	Water depth (at survey) = NA Water width (at survey) = NA

Station:



Station:

GENERAL REACH NOTES

Reach 2 of Tributary 7 has been heavily manipulated. The knickpoint that migrated through Reach 1 was stopped by the combination of an pile of 4-ft diameter boulders and an earthen berm and retention basin. Between Stn 2300 and 5500, there appears to be a sand mining operation (or other mining operation). The valley floor is essentially a dirt road for large excavators and trucks to use. Water coming off of agriculture fields upstream, flows through a couple of small retention basins, then across the roads, through a small corn field, and then into the retention basin at Stn 2000. The roads and small corn field are likely re-graded every year as the incision through the sand between the corn rows was obvious. We did not investigate the channel upstream beyond the mining operation. The boulder stabilization method and the earthen berm/retention basin have essentially stabilized the channel and halted excessive incision and migration of knickpoints.

POTENTIAL PROJECTS

NA

Channel Reconnaissance Form

Date	Oct 5, 8, 2010
Stream/Drainage	Etter Creek, Tributary 8
Stream Reach ID	1, two drainages; joins Etter at Stn 23,250
Field Team	NN, BW

Station 0 **To** 5800

General Channel Conditions

Channel Shape (check)

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

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Mostly sand and silt; some area with cobbles

Bar Types:

☐ Alternate lateral	☐ Point / transverse	☒ None
☐ Mid-channel	☐ Point / mid	☐ Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Small knickpoints throughout channel upstream of145th Ave/Ravenna Trail; these knickpoints have low to moderate activity, but will likely continue with future rain events				
Lateral stability *deposition, erosion*	Stable				
Erosion (excessive/site specific)	At knickpoints				
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)*: Steep banks composed of silty loam with vegetation on top				
Terrace/Valley	*Valley form* – upstream of 145th Ave: steep hillslopes rise about 50-ft above the valley; valley floor 100 ft wide		*Land Use* –Mostly forested along channel and slopes; agriculture on tops of hills		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1500: irregularly-shaped concrete box culvert under 145th Ave; upstream end is 8x10-ft box culvert, but inside it drops down 2 ft and the downstream end is made up of an 8-ft corrugated metal pipe Stn 4600: 2-ft corrugated metal pipe under private dirt driveway; perched 4 ft on downstream end; upstream end has a vertical section with a flow deflector and the road prism acts as a dam creating a retention basin Stn 5000: 2, 2.5-ft corrugated metal pipes under 225th St; 1 is 90% filled with silt				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	70%
Width of veg. riparian corridor*	100 ft
Canopy coverage (%)	70%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	30%
woody species	70%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Oak	50
Elm	30
Cottonwood	20

Tree Stand Age (if applicable)

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

Habitat

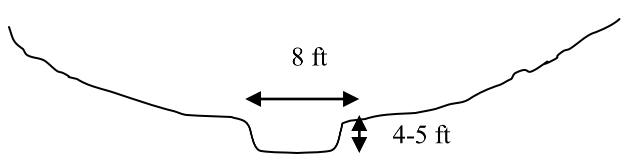
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Good forest habitat through most of this tributary.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

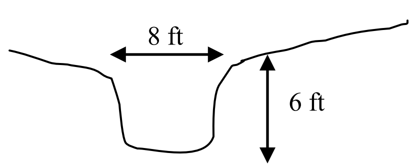
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial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

Representative cross-section sketch		
Bankfull width = 8/8 ft Bankfull depth = 4/6 ft	Floodplain width = 50/0 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 4100



Station: 600 of Drainage 1



GENERAL REACH NOTES

Tributary 8 contains two drainages in the upper portions of the subwatershed: Drainage 1 flows into Tributary 8 at Stn 3650, draining agriculture fields and containing multiple knickpoints with moderate activity; Drainage 2 flows into Tributary 8 at Stn 4800, also draining fields but not as steep so knickpoints are not as problematic. This tributary contains small knickpoints, ranging in height from 1-6 ft from 145th Ave to the top of the subwatershed. Downstream of 145th Ave, the channel is difficult to detect and the alluvial valley appears to have been a depositional section for the sediment being eroded out of the headwaters. Upstream of 145th Ave, the riparian corridor is mostly forested, though the channel does run along a field near 145th Ave. Knickpoints often stop at tree roots, but continue to be found further upstream. The culverts under the driveway at Stn 4600 and under the road at Stn 5000 could be retrofitted to increase their ability to retain water behind the road prisms.

POTENTIAL PROJECTS

Stn 1500-5800: Knickpoints throughout with varying degrees of activity; these knickpoints will continue to migrate unless retention is improved and stormwater can infiltrate before it reaches the stream; knickpoints are nearing fields

Channel Reconnaissance Form

Date	Oct 5, 6, 2010				
Stream/Drainage	Etter Creek, Tributary 9				
Stream Reach ID	1; joins Etter at Stn 24,850				
Field Team	NN, BW	**Station**	0	**To**	1600

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	Silt, clay; silty loam
Bars	NA
Bed	Silt, sand

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Active knickpoints were identified within 500 ft of the channel mouth; these knickpoints will likely continue migrating upstream unless management actions are taken				
Lateral stability *deposition, erosion*	As incision continues, banks are too steep to be maintained and will erode over time. The channel is not migrating, however.				
Erosion (excessive/site specific)	Diffuse knickpoint at Stn 100 and a 5-ft knickpoint at Stn 450				
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)*: Where incised, the banks are nearly vertical and made up of fine silt/clay with vegetation on top; elsewhere, banks are not as tall or steep as the channel is shallow swale through fields and through forest				
Terrace/Valley	*Valley form* – flat through fields, though 100-ft slopes are nearby to the west	*Land Use* –Agriculture, some forest			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1400: cars, barrels dumped on edge of channel Agriculture				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	70% (10% in incised area)
Width of veg. riparian corridor*	50 ft
Canopy coverage (%)	0-60%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	80%
woody species	20%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Ash	30
Elm	30
Cottonwood	40

Tree Stand Age (if applicable)

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

Habitat

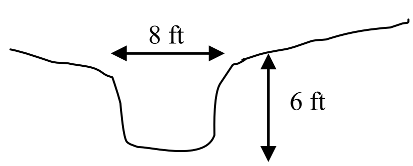
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No riparian habitat through fields; in forest, good canopy cover and riparian habitat
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

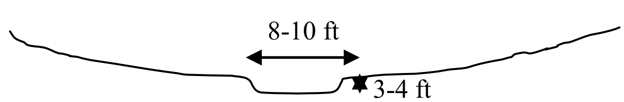
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		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	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 18/8 = 2.25**				

Representative cross-section sketch		
Bankfull width = 8/9 ft Bankfull depth = 6/3 ft	Floodplain width = 10/50 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 350



Station: 1500



GENERAL REACH NOTES

Reach 1 of Tributary 9 is a straightened reach that primarily flows through agriculture fields. The upper portion of the reach begins to flow through forest that characterizes Reach 2. Reach 1 is flat and is located at the base of surrounding steep hills. An active knickpoint, resulting from the lowering of Etter Creek, has begun migrating into the agriculture fields and landowners have subsequently dumped woody debris, sawdust, and other materials into the hole created. This incision will likely continue upstream, however, unless management actions are taken. There is very little habitat through this reach with little canopy cover except in the forested section.

POTENTIAL PROJECTS

Stn 450: a 5-ft knickpoint is migrating through silty loam in agriculture fields; landowners have dumped woody debris, sawdust, and other materials in the hole to try to slow migration

Channel Reconnaissance Form

Date	Oct 5, 6, 2010
Stream/Drainage	Etter Creek, Tributary 9
Stream Reach ID	2; seven drainages characterized
Field Team	NN, BW

Station 1600 **To** 6400

General Channel Conditions

Channel Shape (check)

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

Sediment Particle Size Estimate	
Banks	Silt, clay; silty loam; upstream of 3500 gravel emerges in portions of the banks
Bars	NA
Bed	Sand, consolidated silt below sand; cobbles/boulders upstream of Stn 3500

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Knickpoints up to 15 ft were identified throughout this reach, particularly in the upper extremities of the reach and drainages; active knickpoint at Stn 2300 will likely mean continued incision through the relatively stable middle portion of this reach; knickpoints at the upstream end of the tributary and along the drainages are migrating into agriculture fields and could cause damage to property and farm equipment				
Lateral stability *deposition, erosion*	The incision has created steep banks throughout reach, resulting in bank failure and channel widening; in middle portion of reach, the slightly meandering channel is eroding the slopes on the outside of bends				
Erosion (excessive/site specific)	Knickpoints at Stn 2300, along all of the drainages, and where Tributary 9 meets the agriculture fields				
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)*: Steep, nearly vertical, banks throughout due to incision; composed of consolidated and compacted fine silt and clay, which allows banks to remain steep				
Terrace/Valley	*Valley form* – valley floor is about 80 ft below tops of adjacent hills; steep slopes; valley floor is 50-100 ft wide	*Land Use* –Forest along channel and steep slopes; agriculture surrounding			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 2300: dirt road crossing; 3-ft knickpoint on downstream end of road Stn 2100: power lines cross the channel; vegetation burned on hillslope Agriculture surrounding steep valley				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	10-60%
Width of veg. riparian corridor*	50-100 ft
Canopy coverage (%)	80%

** 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	20%
woody species	80%
bare/other	

Woody Species present	% of total tree community
Maple	80
Willow, oak, box elder	20

Exotic/invasive species

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA
Residual pool depth	NA
Undercut bank frequency	NA
Riffle / Other frequency	NA

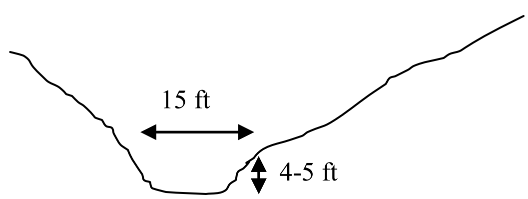
General Habitat Notes: Good riparian and forest habitat throughout; good canopy cover, some underbrush

Channel Stability Form

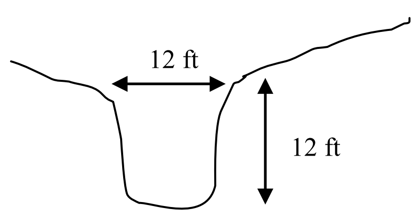
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	1	Local erosion/pools		Extensive bar pressure	
Relative Width:Depth ratio	Low	1	Average		High	
Channel pattern	Single thread	2	Single thread		Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 14/8 = 1.75**				

Representative cross-section sketch		
Bankfull width = 15/12 ft Bankfull depth = 5/12 ft	Floodplain width = 10 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 3500



Station: 5700



GENERAL REACH NOTES

Reach 2 of Tributary 9 is a degrading reach with 22 active knickpoints, 19 of which were identified as highly active. The upper portion of this subwatershed contains more than 7 small drainages, all of which have active knickpoints migrating through. Most of the knickpoints in this reach are currently at the interface between forest and agriculture fields. These knickpoints are 6 to 15 ft in height and will continue migrating into the fields and impacting farm production. However, a 3-ft knickpoint at Stn 2300 could also continue to migrate upstream, which would further lower the base level elevations and increase incision and depth of knickpoints in the drainages. The forest habitat through this reach is good, but the incision is resulting in excessive erosion and sedimentation. A small retention basin combined with a grassy swale between row crops along Drainage 6 has likely halted current and future incision through this drainage. In the mainstem and drainages surrounding this, however, incision continues.

POTENTIAL PROJECTS

Stn 2300-5800: a 3-ft knickpoint at the downstream end of a dirt road crossing at Stn 2300; this is active and could continue upstream, compromising the road crossing and resulting in increased incision upstream; 6-15 ft active knickpoints identified in the headwaters and along all drainages except Drainage 6 - these knickpoints are actively eroding row crops and will continue to do so with no management

Channel Reconnaissance Form

Date	Oct 6, 2010
Stream/Drainage	Etter Creek, Tributary 10
Stream Reach ID	1; one drainage; joins Etter at Stn 26,700
Field Team	NN, BW

Station 0 **To** 5400

General Channel Conditions

Channel Shape (check)

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

Sediment Particle Size Estimate	
Banks	Silt, clay; silty loam; gravel emerges a few feet below surface
Bars	NA
Bed	Boulder, cobbles, gravel in lower 1000 ft; elsewhere gravel mixed with silt

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	9 knickpoints were identified throughout this Tributary and Drainage 1, 6 of which are highly active; knickpoints are only 2-4 ft in height, but they will likely continue to migrate resulting in further incision, bank erosion, sedimentation, and possible loss of farmland; land put out of production in the headwaters may have slowed the migration of the knickpoints				
Lateral stability *deposition, erosion*	The incision has created steep banks throughout reach, resulting in bank failure and channel widening; erosion along a few meander bends migrating into steep slopes was observed				
Erosion (excessive/site specific)	Knickpoints at Stn 740, 760, 1850, 2600, 3825, 4075, and Stn 400 on Drainage 1; some bank erosion on meander bends between Stn 300 and 500				
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)*: Steep, nearly vertical, banks throughout due to incision; composed of consolidated and compacted fine silt and clay, with gravel and cobbles mixed in (particularly a few feet below the surface)				
Terrace/Valley	*Valley form* – valley floor is about 70 ft below tops of adjacent hills; steep slopes; valley floor is 50-100 ft wide		*Land Use* –Forested along channel and steep slopes; agriculture surrounding		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Agriculture surrounding steep valley slopes				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	50%
Width of veg. riparian corridor*	50-100 ft
Canopy coverage (%)	70%

** 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	20%
woody species	80%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Oak, elm, cottonwood, box elder - evenly distributed	100

Tree Stand Age (if applicable)

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

Habitat

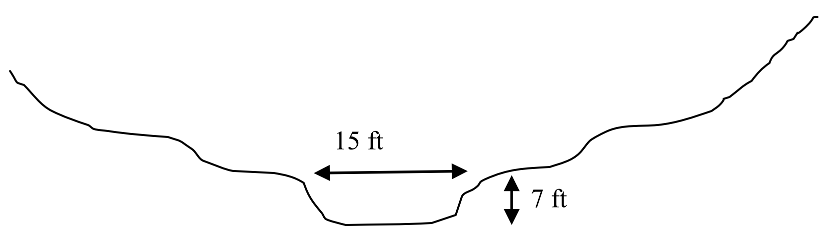
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Good riparian and forest habitat throughout; good canopy cover, some underbrush; no aquatic habitat
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

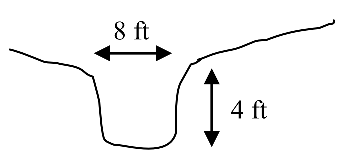
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width	2	Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive	2	Local erosion/pools		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	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 15/8 = 1.88**				

Representative cross-section sketch		
Bankfull width = 15/8 ft Bankfull depth = 7/4 ft	Floodplain width = 40/0 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 3400



Station: 300 on Drainage 1



GENERAL REACH NOTES

Tributary 10, along with Drainage 1, is a degrading Tributary with 9 knickpoints, 6 of which are highly active. Incision has exposed gravel and cobbles in the banks and, in the lower portions of the tributary, boulders and cobbles make up the channel bed. As the knickpoints migrate upstream, the channel banks become very steep and sometimes fail, resulting in channel widening. The boulder and cobble bed near the mouth will help slow future incision resulting from further mainstem downcutting. However, upstream of this, incision continues through compacted fine silt and clay mixed with gravel and cobbles. Upstream of knickpoints, the channels are less defined, until the next knickpoint begins to develop. Canopy cover is high throughout with mixed understory vegetation as well. A few parcels have been put out of production in the headwaters of Tributary 10 and the increased infiltration has likely slowed the rate of knickpoint migration. However, the southern portion of the headwaters is still actively farmed with little infiltration and this may be causing the continued migration of knickpoints through the tributary and through Drainage 1. The knickpoints in Drainage 1 are nearing row crops and may impact farming in the coming years.

POTENTIAL PROJECTS

Stn 300-450: 10-ft tall eroding bank; not of major concern, but these should be monitored; if management practices are taken upstream to increase infiltration or storage, bank erosion may be slowed or halted

Stn 750-4100: multiple knickpoints between 2 and 4 ft in height are migrating upstream through the tributary and Drainage 1; this incision is causing bank erosion and increased sedimentation downstream

Channel Reconnaissance Form

Date	Oct 6, 9, 2010
Stream/Drainage	Etter Creek, Tributary 11
Stream Reach ID	1; flows into Etter at Stn 29,050
Field Team	NN, BW

Station | 0 | **To** 3600 |

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☒Irregular
☐Trapezoidal
☐Parabolic
☐Other ______

Sediment Particle Size Estimate	
Banks	NA
Bars	NA
Bed	Silt

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	A dam and retention basin at Stn 500 has eliminated any vertical instability issues				
Lateral stability *deposition, erosion*	Stable; farm swale in headwaters with little water velocity and no channel downstream of dam because of retention basin				
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)*: NA				
Terrace/Valley	*Valley form* – valley floor is about 60 ft below tops of adjacent hills; steep slopes below Stn 1600, rolling hills upstream		*Land Use* –agriculture with wooded areas along streams and steeper slopes		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 100: 6-ft concrete pipe under 145th Ave; slight erosion developing on upstream left side of culvert from road runoff Stn 500: ~30-ft tall earthen dam and retention basin; 20-inch corrugated metal pipe is the high flow outlet; relatively new Agriculture surrounding steep valley slopes and in headwaters				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	80%
Width of veg. riparian corridor*	20-50 ft
Canopy coverage (%)	0-60%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	70%
woody species	30%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Did not investigate upstream of dam	

Tree Stand Age (if applicable)

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

Habitat

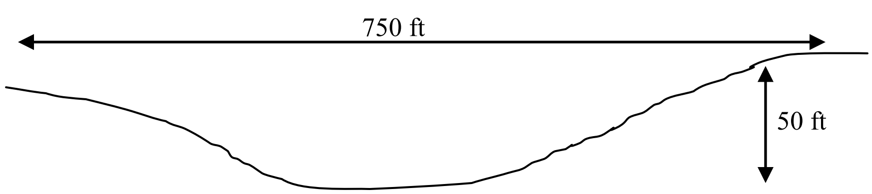
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Retention basin provides year-round wetland habitat; some woodland habitat upstream of the retention basin and downstream of farm fields
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

Representative cross-section sketch		
Bankfull width = NA Bankfull depth = NA	Floodplain width = NA	Water depth (at survey) = NA Water width (at survey) = NA

Station: 3000



Station:

GENERAL REACH NOTES

Tributary 11 has been dramatically altered by the construction of an earthern dam and retention basin. The dam and retention basin were likely built to stem incision and erosion and prevent additional water and sediment flows into Etter Creek. This has been very successful and the retention basin has been able to capture all stormwater upstream. We did not investigate the wooded section upstream of the retention basin, but the portion of the channel upstream of that flows through agriculture fields and is essentially a grassy swale between farmed hills. The earthen dam is maintained and mowed frequently with no larger vegetation allowed to grow. Near the road crossing, small pockets of erosion were observed around a fencepost, in the middle of the grassy swale, and on the left side of the culvert. These should be monitored and treated if they continue to erode.

POTENTIAL PROJECTS

Stn 100: slight erosion on the upstream left side of the 6-ft concrete pipe under 145th Ave; gravel from driveway has fallen in

Stn 150: slight erosion/incision around fencepost; change the location of the fence post and this should not be a problem

Channel Reconnaissance Form

Date	Oct 6, 2010
Stream/Drainage	Etter Creek, Tributary 12
Stream Reach ID	1; joins Etter at Stn 29,350
Field Team	NN, BW

Station 0 **To** 4000

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	Fine silt, clay
Bars	NA
Bed	Silt, cobble

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	A dam and retention basin at Stn 3900 has slowed the degradation through this tributary; however, water draining from adjacent farms through small drainages continues to enter Tributary 12 and cause incision; 3 moderately-active knickpoints were identified in this tributary				
Lateral stability *deposition, erosion*	Fairly stable, with some migration along meander bends; incision results in some bank failures				
Erosion (excessive/site specific)	Knickpoints at Stn 1750, 2350 (30 ft up a small drainage), 2425				
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)*: Steep banks composed of fine silt, clay, and some gravel near the base				
Terrace/Valley	*Valley form* – valley floor is about 70 ft below tops of adjacent hills; steep slopes; valley floor ~50-75 ft wide		*Land Use* –agriculture with wooded areas along streams and steeper slopes		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 3900: ~20-ft earthen dam and retention basin; this is an older dam and basin with trees growing along dam; high water outlet through 18-inch corrugated metal pipe Agriculture surrounding steep valley slopes				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	60%
Width of veg. riparian corridor*	50-75 ft
Canopy coverage (%)	80%

** 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	20%
woody species	80%
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Oak	50
Elm	30
Box elder	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
	oak		Many 18 to 24-inch oaks throughout reach
3900	Box elder		12 to 14-inch box elders along slope of earthen dam

Habitat

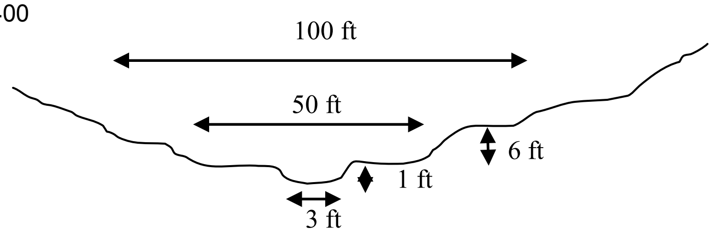
LWD density (pieces / 100 ft)	NA	General Habitat Notes: Retention basin provides year-round wetland habitat; wooded habitat throughout tributary with high percent canopy cover
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

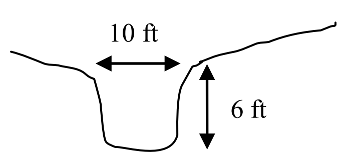
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	2	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	3	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		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	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 18/8 = 2.25**				

Representative cross-section sketch		
Bankfull width = 8/10 ft Bankfull depth = 1/6 ft	Floodplain width = 50/20 ft	Water depth (at survey) = NA Water width (at survey) = NA

Station: 400



Station: 2300



GENERAL REACH NOTES

Tributary 12 is a slowly degrading tributary with 3 moderately active knickpoints 4 ft in height. A 20-ft earthen dam and retention basin were built decades ago at Stn 3900. Box elders 12-14 inches in diameter are now growing on the slopes of the dam along with smaller elms. This reduces the amount of water flowing into this tributary, but lack of infiltration and storage elsewhere in the subwatershed results in excessive overland flow and too much water volume for Tributary 12. Degradation of a few small drainages was also observed. Canopy cover was high and the riparian corridor maintained good habitat, though no aquatic habitat is available other than the wetland created by the earthen dam.

POTENTIAL PROJECTS

Stn 1000-3300: 3 knickpoints 4 ft in height are migrating upstream slowly with moderate levels of activity; although this does not appear to be impacting fields currently, continued upstream migration may result in loss of crops in the future

Channel Reconnaissance Form

Date	October 7, 2010
Stream/Drainage	Ravenna Coulee 1
Stream Reach ID	East Drainage
Field Team	NN, BW

Station 0 **To** 3200

General Channel Conditions

Channel Shape (check)
- ☐ Rectangular
- ☒ Shallow Rectangular
- ☐ Irregular
- ☐ Trapezoidal
- ☐ Parabolic
- ☐ Other ______________

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Many limestone bedrock ledges; gravel/cobble elsewhere

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable; channel is ephemeral and rarely holds water. Bedrock ledges up to 6 ft provide grade control throughout; 1 small 3-ft knickpoint was observed at Stn 2300, but not active enough to be of concern				
Lateral stability *deposition, erosion*	Stable; little streamflow and little erosion				
Erosion (excessive/site specific)	NA				
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)*: Where banks were noticeable, they were up to 3 ft in height and composed of silty loam. Trees and vegetation grew throughout as there is not perennial water flow.				
Terrace/Valley	*Valley form* – Narrow (~250 ft) and steep (50 ft in places)	*Land Use* – Agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 200-250: 7x7.5-ft railroad bridge - walls of limestone blocks; good condition Stn 650: 6x8-ft concrete box culvert; good condition				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	60
Width of veg. riparian corridor*	20 ft
Canopy coverage (%)	80

** 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	20
woody species	80
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Ash	40
Elm	40
Oak, maple	20

Tree Stand Age (if applicable)

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

Habitat

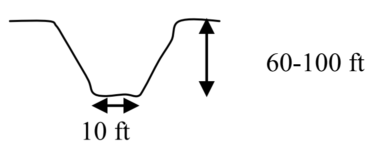
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat, though the structure is there. Water only during rainstorms/snowmelt.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

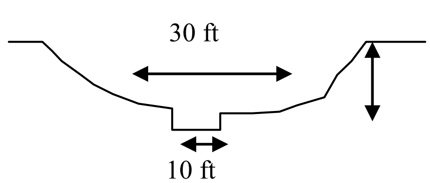
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr	3	>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	NA	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	NA	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	1	>3:1			
Vegetative bank protection	Poor		Extensive	3	Poor	
Field stability rating (add all cells)/9		**= 16/6 = 2.67**				

Representative cross-section sketch		
Bankfull width = 10ft Bankfull depth = 2ft	Floodplain width = 0	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 1200



Station: 2000



GENERAL REACH NOTES

This is a steep channel with limestone bedrock ledges every 50-100 ft along the face of the steep bluff going down to the Vermillion River. There is no aquatic habitat as there is no perennial water. The stream is ephemeral and is really more of a drainage to carry rainwater and snowmelt. There are no significant areas of erosion. There is one small 3-ft knickpoint in silty loam at Stn 2200, but it is not visibly active or serious enough to be considered a potential project.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	October 7, 2010
Stream/Drainage	Ravenna Coulee 1
Stream Reach ID	West Drainage
Field Team	NN, BW

Station | 0 | **To** 4000 |

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	Silty loam
Bars	NA
Bed	Downstream of Stn 2500: Many limestone bedrock ledges; gravel/cobble elsewhere Upstream of Stn 2500: Silty loam with gravel underneath

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Channel is ephemeral and only holds water after rain/snowmelt. Downstream of Stn 2500, limestone ledges control grade; upstream of Stn 2500, multiple small knickpoints are eroding through loam to gravel/bedrock. Between Stn 2100 and 2600: channel has incised 3-5 ft down to the gravel and bedrock and will likely continue through the knickpoints upstream.				
Lateral stability *deposition, erosion*	Stable; little streamflow and little erosion				
Erosion (excessive/site specific)	NA				
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)*: Where banks were noticeable, they were up to 5 ft in height and composed of silty loam. Trees and vegetation grew throughout as there is not perennial water flow.				
Terrace/Valley	*Valley form* – Narrow (~250 ft) and steep (50 ft in places)	*Land Use* – Agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 400-450, railroad bridge: did not investigate - barely noticeable channel on downstream side of Ravenna Trail Stn 1000, Ravenna Trail: 2, 3x5-ft corrugated metal pipes in good condition				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	50
Width of veg. riparian corridor*	20 ft
Canopy coverage (%)	80

** 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	20
woody species	80
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Ash	40
Elm	40
Oak, maple	20

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*
2500	Ash/elm		4-8 inches DBH; probably 15-20 yrs

Habitat

LWD density (pieces / 100 ft)	NA
Residual pool depth	NA
Undercut bank frequency	NA
Riffle / Other frequency	NA

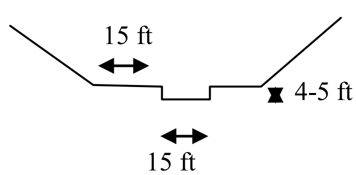
General Habitat Notes: No aquatic habitat, though the structure is there. Water only during rainstorms/snowmelt. LWD throughout, bedrock ledges.

Channel Stability Form

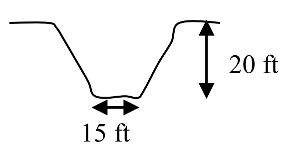
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr	3	>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	NA	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	NA	Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread		Single thread	3	Multiple thread/braided	
Average bank slope	<3:1	1	>3:1			
Vegetative bank protection	Poor	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 14/6 = 2.33**				

Representative cross-section sketch		
Bankfull width = 15ft Bankfull depth = 4-5ft	Floodplain width = 15/0 ft	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 2200



Station: 2900



GENERAL REACH NOTES

Similar to the East Drainage. This is an ephemeral stream only holding water during rainstorms or snowmelt. From Ravenna Trail upstream to about Stn 2100, limestone bedrock underlies the channel and outcrops as 2 to 3-ft ledges in the channel. This limestone helps control the grade through the channel, which has experienced 3 to 5 ft of incision from Stn 2100 upstream to where the channel emerges from the forest at Stn 3150. Upstreawm of Stn 2500, 3 small knickpoints (1 to 3 ft) have emerged, but the incision is stopping at the gravel/cobble layer below. The drainage from the mouth to Stn 3150 is heavily forested with steep valley walls. Good forest habitat, but no aquatic habitat because lack of sustained flow. Water likely does not remain long in pools as the limestone bedrock is very porous.

POTENTIAL PROJECTS

Stn 3100: 2-ft knickpoint through silty loam is about 40-50 ft from the edge of the forest line. Upstream, the 'channel' is a mowed swale about 30 ft wide between crops; there is no storage built into this swale, although the opportunity is there. Cobbles have been dumped onto the knickpoint in an attempt to slow its upstream migration. The threat is not great, though it will soon migrate across a farm path. Small knickpoints from further downstream may continue to migrate and continue to incise. Incision will likely stop when gravel/bedrock is reached, or if the water can be stored upstream.

Channel Reconnaissance Form

Date	October 7, 2010
Stream/Drainage	Ravenna Coulee 2
Stream Reach ID	Reach 1
Field Team	NN, BW

Station 0 **To** 4600

General Channel Conditions

Channel Shape (check)

☐Rectangular
☒Shallow Rectangular
☐Irregular
☒Trapezoidal
☒Parabolic
☐Other ________________

Sediment Particle Size Estimate	
Banks	Silty loam; bedrock in places
Bars	NA
Bed	Gravel, cobble, bedrock in steeper sections; sand, gravel in lower gradient sections

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Channel is ephemeral and only holds water after rain/snowmelt. Very stable with limestone grade control ledges between Stn 1900 and 2600. One 3-ft knickpoint near mouth of small drainage at Stn 1950, but this is slowed by limestone cobbles and it is not rapidly progressing.				
Lateral stability *deposition, erosion*	Stable; little streamflow and little erosion. Ill-defined channel or swale through much of the reach: Stn 700-1900, 2600-4600. Between Stn 1900 and 2600, limestone bedrock makes up one or both banks and much of the channel bed.				
Erosion (excessive/site specific)	NA				
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)*: Not well defined. Limestone ledges through portions of the drainage. The channel is an ill-defined swale in the lower-gradient sections with barely perceptible banks. Where banks are noticeable, they are composed of silty/sandy loam and heavily vegetated.				
Terrace/Valley	*Valley form* – Narrow (250-350 ft) and steep (60-80 ft); valley floor ranges from 100 ft to 20 ft (bedrock section)	*Land Use* – Agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 300-350, railroad bridge: 2 box culverts 8 ft wide; water from Vermillion within 4 ft from top of culvert; good conditions with minor corrosion along wing walls Stn 400, Ravenna Trail: 2 box culverts 10 ft wide; water surface within 1 ft of top of culvert; some corrosion but generally in good condition				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	50
Width of veg. riparian corridor*	20-100 ft
Canopy coverage (%)	80

** 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	20
woody species	80
bare/other	
Exotic/invasive species	Some buckthorn found

Woody Species present	% of total tree community
Oak	80
Elm, ash	20

Tree Stand Age (if applicable)

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

Habitat

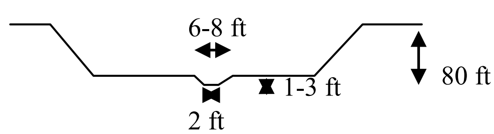
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat due to lack of water, but the structure is there. Water only during rainstorms/snowmelt. LWD throughout, bedrock ledges.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

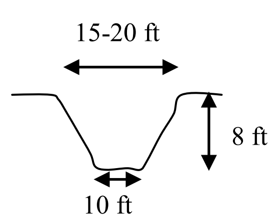
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr	3	>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels	3	Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	NA	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	NA	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	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 17/6 = 2.83**				

Representative cross-section sketch		
Bankfull width = 7/20ft Bankfull depth = 2ft	Floodplain width = 100/20 ft	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 1500



Station: 2550



GENERAL REACH NOTES

Reach 1 of Ravenna Coulee 2 is a very stable drainage is a barely-noticeable channel through most of the reach. Between Stn 1900 and 2600, the channel flows through limestone bedrock - channel banks are steep rock and the bed is either limestone cobbles or limestone bedrock with multiple large drops including a 10-ft 'waterfall'. This limestone helps control the grade, although there are no incision problems in this drainage. This reach is heavily forested with a dense canopy cover. The valley floor is vegetated with oak, ash, and elm of varying sizes. The valley walls are steeply sloped and also heavily vegetated. A smaller drainage enters Reach 1 at Station 1950. There is a small 3-ft knickpoint at Stn 50 of this drainage, but it is stalled in limestone cobbles and there are no problems with incision upstream. This drainage is also heavily vegetated and the channel is at the base of very steep slopes.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	October 7, 2010
Stream/Drainage	Ravenna Coulee 2
Stream Reach ID	Reach 2
Field Team	NN, BW

Station 4600 **To** 14,600

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	No defined banks
Bars	NA
Bed	Sand/silt loam

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: Shallow swale in the ground; in instability.				
Lateral stability *deposition, erosion*	Stable: Shallow swale in the ground; in instability.				
Erosion (excessive/site specific)	NA				
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)*: Not well defined. Shallow swale in the ground. Bed and banks are composed of sand/silt loam similar to the surrounding fields.				
Terrace/Valley	*Valley form* – No defined valley			*Land Use* – Agriculture	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 12,400, culvert under Orlando Avenue: did not investigate				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	0
Width of veg. riparian corridor*	NA
Canopy coverage (%)	75

** Verify with orthoquad data*

Canopy structure : (check one)

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

Primary veg forms present: (%)

grasses/forbs	98
woody species	2
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Oak	80
Elm, ash	20

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA	General Habitat Notes: No perennial water and no aquatic habitat.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

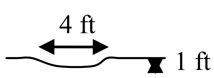
Channel Stability Form

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	NA	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	NA	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	2	Extensive		Poor	
Field stability rating (add all cells)/9		**= 18/6 = 3**				

Representative cross-section sketch

Bankfull width = 4ft Bankfull depth = 1ft	Floodplain width = 0 ft	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 1500



Station:

GENERAL REACH NOTES

Reach 2 of Ravenna Coulee 2 is a shallow swale in the ground that flows through farm fields. It is barely noticeable in places and crops are grown in the swale itself. It is stable, has no instability problems, and has no habitat potential.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	October 8, 2010
Stream/Drainage	Ravenna Coulee 3
Stream Reach ID	Reach 1
Field Team	NN, BW

Station | 0 | **To** 13,400

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☒Parabolic
☒Other __undefined____

Sediment Particle Size Estimate	
Banks	Sand/silt loam where defined
Bars	NA
Bed	Sand/silt loam

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: channel is undefined in many places; valley floor is wide and slope is low gradient.				
Lateral stability *deposition, erosion*	Stable: channel and channel banks are undefined in many places; no water for channel migration to occur.				
Erosion (excessive/site specific)	NA				
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)*: Not well defined in many places. Composed of sand/silt loam where defined. Well vegetated.				
Terrace/Valley	*Valley form* – Wide (500-1000 ft). Valley walls are tall and steep (60 ft), but valley bottom is wide (400-800 ft) and flat	*Land Use* – Agriculture			
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 1650: 6x10-ft concrete arch culvert under Ravenna Trail; good condition Stn 1800: 2, 2-ft metal pipes under ATV path; restricts flow, but fish passage is not an issue because lack of continuous flow and habitat upstream Stn 8950: 2, 4-ft corrugated metal pipes under 180th St; old but ok Stn 12,750: 5.5-ft concrete pipe; old but ok				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	60
Width of veg. riparian corridor*	400-800
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	
high = multiple canopy layers	x

Primary veg forms present: (%)

grasses/forbs	90
woody species	10
bare/other	
Exotic/invasive species	Thick buckthorn patches - in places, makes up 90% of cover

Woody Species present	% of total tree community
Oak/aspen	80
Elm, ash, cedars	20

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA	General Habitat Notes: No perennial water and no aquatic habitat. Small pool of standing water at Stn 2250 - may be a beaver pond, but no active dam or lodge; water flowing from here to mouth, but no water upstream.
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

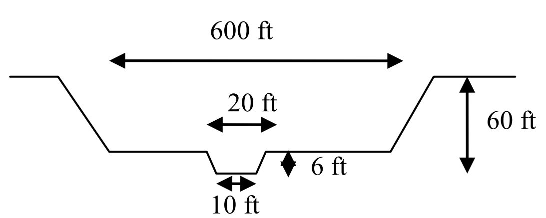
Channel Stability Form

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	NA	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	NA	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	2	Extensive		Poor	
Field stability rating (add all cells)/9	**= 18/6 = 3**					

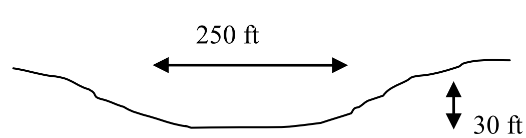
Representative cross-section sketch

Bankfull width = 20ft Bankfull depth = 6ft	Floodplain width = No defined floodplain	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 3700



Station: 12,700



GENERAL REACH NOTES

Reach 1 of Ravenna Coulee 3 consists of wide, flat valley bottom that is heavily vegetated with upland tree species. The channel is not well defined in many places and may be within ATV trails in others. In some areas, the wide valley had many channel-like features, but none appeared to be active. Little water flows through this channel annually as evidenced by the amount of tree growth within the channel where it was defined. Vegetation was thick and included older canopy trees and younger disturbance species such as buckthorn. The area is heavily used by ATVs and hunters and it is unknown if it had been disturbed in the past - logging, sand mining, etc. There is no aquatic habitat in this stream but plenty of thick forest habitat. There are no instability problems or problems at road crossings.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	October 7, 9, 2010
Stream/Drainage	Ravenna Coulee 3
Stream Reach ID	Reach 2
Field Team	NN, BW

Station 13,400 **To** 43,000

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	No defined channel
Bars	NA
Bed	Sand/silt loam

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: channel is a low swale with no defined banks; no instability.				
Lateral stability *deposition, erosion*	Stable: channel is a low swale with no defined banks; no instability.				
Erosion (excessive/site specific)	NA				
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)*: No channel banks				
Terrace/Valley	*Valley form* – No river valley because no real channel; most is rolling farmland		*Land Use* – Agriculture		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 19,350: 4-ft corrugated metal pipe under Orlando Ave; concrete and grass clippings dumped in downstream outlet Stn 19,600: 3x6-ft concrete pipe under Redwing Boulevard; good condition Stn 20,500: 2, 3-ft concrete pipes under 190th St; good condition Stn 29,250: culvert under Nicolai Ave; did not investigate Stn 34,900: culvert under 210th St; did not investigate Stn 37,950: culvert under Nicolai Ave; did not investigate Stn 41,150: 3-ft corrugated metal pipe; in good condition				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	10
Width of veg. riparian corridor*	0-10 ft
Canopy coverage (%)	0-70%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	10
woody species	10
bare/other	Crops/bare soil: 80%
Exotic/invasive species	

Woody Species present	% of total tree community

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; swale in ground with minimal water throughout year
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

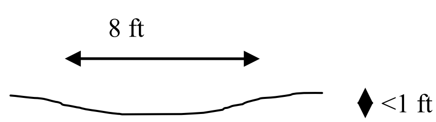
Channel Stability Form

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

Representative cross-section sketch

Bankfull width = 8ft Bankfull depth = <1ft	Floodplain width = No floodplain	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 19,300



Station:

GENERAL REACH NOTES

Reach 2 of Ravenna Coulee 3 is primarily a shallow swale through residential yards and agriculture fields. It is imperceptible in many locations and can only be identified by the road culverts and sometimes a slight depression in the ground. There is no habitat and no instability problems. The only canopy cover is in a few short portions of the swale that is within forest; through most of this reach there is zero canopy cover.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	October 7, 11, 2010
Stream/Drainage	Ravenna Coulee 3
Stream Reach ID	Tributary 1; joins mainstem at Stn 13,400
Field Team	NN, BW

Station 0 **To** 18,300

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	No defined channel
Bars	NA
Bed	Sand/silt loam

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: channel is a low swale with no defined banks; no instability.				
Lateral stability *deposition, erosion*	Stable: channel is a low swale with no defined banks; no instability.				
Erosion (excessive/site specific)	NA				
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)*: No channel banks				
Terrace/Valley	*Valley form* – No river valley because no real channel; most is rolling farmland or residential property		*Land Use* – Residential from Stn 3000-10,900; remainder is agriculture		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 4250: culvert under Patrick Ave; did not investigate Stn 4950: 4-ft corrugated metal pipe and 2.5-ft concrete/metal pipe under 190th St; in good condition Stn 6500: 2, 3-ft concrete pipes under Redwing Boulevard; in good condition Stn 6900: culvert under 193rd St; did not investigate Stn 7350: culvert under Upper 193rd St; did not investigate Stn 7750: culvert under Upper 194th St; did not investigate Stn 10,900: culvert under 200th St; did not investigate				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	0-10
Width of veg. riparian corridor*	0-10 ft
Canopy coverage (%)	0-90%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	40-yards
woody species	10
bare/other	Crops/bare soil: 50%
Exotic/invasive species	

Woody Species present	% of total tree community
Maple	60
Pine	40

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; swale in ground with minimal water throughout year
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

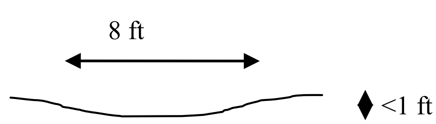
Channel Stability Form

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

Representative cross-section sketch

Bankfull width = 8ft Bankfull depth = <1ft	Floodplain width = No floodplain	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 6400



Station:

GENERAL REACH NOTES

Tributary 1 of Ravenna Coulee 3 is primarily a shallow swale through residential yards and agriculture fields. It is imperceptible in many locations and can only be identified by the road culverts and sometimes a slight depression in the ground. There is no habitat and no instability problems. The only canopy cover is in a few short portions of the swale that is within forest; through most of this reach there is zero canopy cover through row crops or residential yards.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	October 7, 11, 2010
Stream/Drainage	Ravenna Coulee 3
Stream Reach ID	Tributary 2; joins Tributary 1 at Stn 4000
Field Team	NN, BW

Station 0 **To** 8300

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	No defined channel
Bars	NA
Bed	Sand/silt loam

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: channel is a low swale with no defined banks; no instability.				
Lateral stability *deposition, erosion*	Stable: channel is a low swale with no defined banks; no instability.				
Erosion (excessive/site specific)	NA				
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)*: No channel banks				
Terrace/Valley	*Valley form* – No river valley because no real channel; most is rolling farmland or residential property		*Land Use* – Residential from Stn 0-1000 and 2100-4600; remainder is agriculture		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 650: 2-ft corrugated metal pipe under 190th St; in good condition Stn 3100: 2.5-ft concrete pipe under Redwing Boulevard; in good condition Stn 6550: 14-inch concrete pipe with trash grate under 200th St; in good condition				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	0-10
Width of veg. riparian corridor*	0-10 ft
Canopy coverage (%)	0-90%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	10%-yards
woody species	30
bare/other	Crops/bare soil: 60%
Exotic/invasive species	

Woody Species present	% of total tree community
Maple	60
Pine	40

Tree Stand Age (if applicable)

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

Habitat

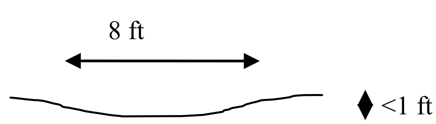
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; swale in ground with minimal water throughout year
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

Representative cross-section sketch		
Bankfull width = 8ft Bankfull depth = <1ft	Floodplain width = No floodplain	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 6400



Station:

GENERAL REACH NOTES

Tributary 2 of Ravenna Coulee 3 is primarily a shallow swale through residential yards, forest, and agriculture fields. It is imperceptible in many locations and can only be identified by the road culverts and sometimes a slight depression in the ground. There is no habitat and no instability problems. The only canopy cover is in forested areas behind houses; through most of this reach there is zero canopy cover through row crops or residential yards.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Did not investigate in the field; air photo analysis
Stream/Drainage	Ravenna Coulee 3
Stream Reach ID	Tributary 3; joins mainstem at Stn 22,300
Field Team	

Station | 0 | **To** 6000 |

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	No defined channel
Bars	NA
Bed	Sand/silt loam

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: channel likely a low swale with no defined banks; no instability.				
Lateral stability *deposition, erosion*	Stable: channel likely a low swale with no defined banks; no instability.				
Erosion (excessive/site specific)	NA				
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)*: Likely no channel banks				
Terrace/Valley	*Valley form* – No river valley because no real channel; all rolling farmland		*Land Use* –agriculture		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	none				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	0
Width of veg. riparian corridor*	0
Canopy coverage (%)	0 for most; 70% in forest

** 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	
woody species	10
bare/other	Crops/bare soil: 90%
Exotic/invasive species	

Woody Species present	% of total tree community

Tree Stand Age (if applicable)

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

Habitat

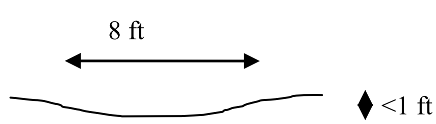
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; swale in ground with minimal water throughout year
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

Representative cross-section sketch		
Bankfull width = 8ft Bankfull depth = <1ft	Floodplain width = No floodplain	Water depth (at survey) = 0 Water width (at survey) = 0

Station:



Station:

GENERAL REACH NOTES

We did not conduct a field investigation of Tributary 3 of Ravenna Coulee 3. Based on air photo analysis, this tributary is similar to the other 'channels' in the subwatershed: a barely perceptible swale through agriculture fields. Only about 600 feet of the channel is in forest at the upper end of the channel; the remainder is through fields.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Oct 11, 2010
Stream/Drainage	Ravenna Coulee 3
Stream Reach ID	Tributary 4; joins Tributary 1 at Stn 12,450
Field Team	NN

Station 0 **To** 7100

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	No defined channel through most; sand/silt near Orlando Ave
Bars	NA
Bed	Sand/silt loam

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: channel a low swale with no defined banks through most; no instability.				
Lateral stability *deposition, erosion*	Stable: channel a low swale with no defined banks through most; no instability.				
Erosion (excessive/site specific)	NA				
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)*: No channel banks through most; near the Orlando Ave crossing banks are steep and 1-2 ft in height and are composed of sand and silt				
Terrace/Valley	*Valley form* – No river valley because no real channel; all rolling farmland		*Land Use* –agriculture		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 450: 4-ft corrugated metal pipe under Orlando Ave; in good condition				

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	2%
Width of veg. riparian corridor*	0
Canopy coverage (%)	0 for most; 80% in forest

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	
woody species	2
bare/other	Crops/bare soil: 98%
Exotic/invasive species	

Woody Species present	% of total tree community
Box elder	40
Willow	40
other	20

Tree Stand Age (if applicable)

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

Habitat

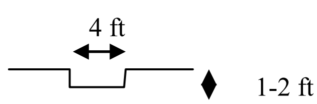
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; swale in ground with minimal water throughout year
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

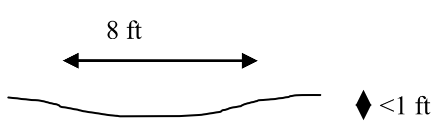
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial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

Representative cross-section sketch		
Bankfull width = 4/8ft Bankfull depth = 1/<1ft	Floodplain width = No floodplain	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 550



Station: 700



GENERAL REACH NOTES

Tributary 4 of Ravenna Coulee 3 is similar to the other tributaries in this subwatershed. The 'stream' only contains rainwater running off of fields. It is a shallow swale through fields and has no canopy cover through most of its length. There is no habitat and no instability problems.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Oct 11, 2010
Stream/Drainage	Ravenna Coulee 3
Stream Reach ID	Tributary 5; joins Tributary 4 at Stn 1150
Field Team	NN

Station 0 **To** 3700

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	No defined channel
Bars	NA
Bed	Sand/silt loam

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable: channel a low swale with no defined banks; no instability.				
Lateral stability *deposition, erosion*	Stable: channel a low swale with no defined banks; no instability.				
Erosion (excessive/site specific)	NA				
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)*: No channel				
Terrace/Valley	*Valley form* – No river valley because no real channel; all rolling farmland		*Land Use* –agriculture		
Altered state (human) - dams, bridges, canoe landings, parks, etc.					

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	NA
Overbank deposition	NA

Riparian Vegetation and Floodplain

Root coverage of banks (%)	40% in forest
Width of veg. riparian corridor*	0
Canopy coverage (%)	0 for most; 80% in forest

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	
woody species	15
bare/other	Crops/bare soil: 85%
Exotic/invasive species	

Woody Species present	% of total tree community
Box elder	40
Willow	40
other	20

Tree Stand Age (if applicable)

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

Habitat

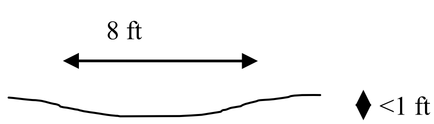
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; swale in ground with minimal water throughout year
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

Representative cross-section sketch		
Bankfull width = 4/8ft Bankfull depth = 1/<1ft	Floodplain width = No floodplain	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 3600



Station:

GENERAL REACH NOTES

Tributary 5 of Ravenna Coulee 3 is similar to the other tributaries in this subwatershed. The 'stream' only contains rainwater running off of fields. It is a shallow swale through fields and has no canopy cover through most of its length. There is no habitat and no instability problems.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Oct 7, 2010
Stream/Drainage	Ravenna Coulee 4
Stream Reach ID	Reach 1
Field Team	NN, BW

Station | 0 | **To** 11,100 |

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☒Irregular
☒Trapezoidal
☒Parabolic
☒Other __undefined____

Sediment Particle Size Estimate	
Banks	Sand
Bars	NA
Bed	Sand

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable, though possible aggradation of sand eroding from hillsides and depositing in channel during rainstorms; infrequent flow - channel is a sandy wash with no distinct channel in most places				
Lateral stability *deposition, erosion*	Stable: no distinct channel in most places - water flow may be in the form of sheet flow over the wide valley with areas of erosion and deposition in different places with each rainstorm				
Erosion (excessive/site specific)	NA				
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)*: When banks are visible, they are 0.5-1 ft in height and composed of sand with little vegetation				
Terrace/Valley	*Valley form* – Top width: 750 ft; bottom width: 280 ft; height: ~70 ft		*Land Use* –river valley is undeveloped; south of valley - agriculture; north of valley - residential		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 3450: 3, 4x9-ft concrete arch culverts under Ravenna Trail; sandy bed with grass growing at mouth; in good condition				

Sediment Impacts			
Riffle sediment type	NA	Pool sediment type	NA
Sorting / Imbrication	NA		

Bars / depositional features	
Sediment type/size	Sand
Mid, alternate, braided	NA
Bar Vegetation (type, age)	NA
Floodplain soils	Sand
Overbank deposition	Sand

Riparian Vegetation and Floodplain

Root coverage of banks (%)	5%
Width of veg. riparian corridor*	250-300 ft
Canopy coverage (%)	0-90%

** 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	
woody species	70
bare/other	Bare sand: 30%
Exotic/invasive species	Some buckthorn

Woody Species present	% of total tree community
oak	60
Elm, birch	20
others	20

Tree Stand Age (if applicable)

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

Habitat

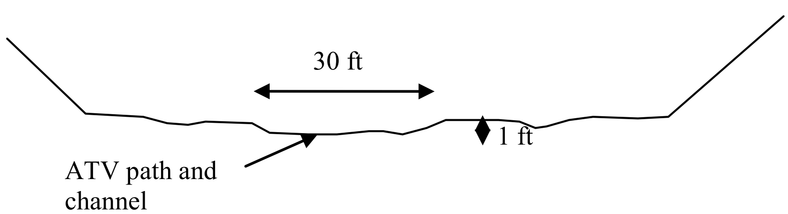
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; channel is a sandy wash with intermittent water flow; valley provides substantial forest habitat and cover, though the use of ATVs throughout is obvious and many hunting stands were also observed
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

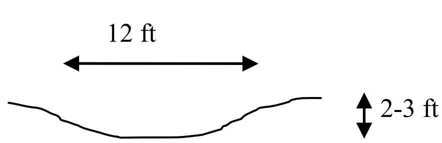
Reach stability		**1-2 Degrading**		**3 Stable**		**4-5 Aggrading**
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	5
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width		Low banks, overflows, surficial erosion	5
Bar development	Poorly formed		Narrow, vegetated		Wide (>1/2 channel length), unveg.	4
Bank erosion extent	Extensive		Local erosion/pools	3	Extensive bar pressure	
Relative Width:Depth ratio	Low		Average		High	5
Channel pattern	Single thread		Single thread		Multiple thread/braided	5
Average bank slope	<3:1	2	>3:1			
Vegetative bank protection	Poor		Extensive		Poor	4
Field stability rating (add all cells)/9		**= 33/9 = 3.67**				

Representative cross-section sketch		
Bankfull width = 30/12ft Bankfull depth = 1/2ft	Floodplain width = 100-200 ft	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 3800



Station: 4900



GENERAL REACH NOTES

Reach 1 of Ravenna Coulee 4 consists of a sandy intermittent channel flowing through a wide, low-gradient valley. Many ATV trails were observed throughout the valley, and the channel often appeared to take the same path as the ATVs, or vice versa. The sand is easily disturbed, so ATV traffic results in slight depressions and in this relatively flat valley, any running water will follow these paths of least resistance. Through most of this reach, channel dimensions were difficult to ascertain due to the lack of definable channel banks. It is likely that during rain events, water flows along different paths and washes rapidly down the valley spreading across the valley floor. Although it appears that ATV traffic along the steep valley walls results in erosion and traffic along the valley bottom prevents vegetation from establishing in some places, downstream movement of this sand does not appear to be problematic. The base of the culverts under Ravenna Trail are layered with sand, but the openings are large and clear of obstructions. Downstream of this crossing, water likely spreads out over a large surface area, decreasing the depth, velocity, and carrying capacity of sediment. The sand appears to deposit here (and upstream of the culvert) and there does not appear to be large amounts of deposition where this Coulee reaches the Vermillion River. At the time of the survey, Vermillion River flows were very high and water reached to about Stn 2500, where the defined channel of the Vermillion stopped at a small knickpoint and the wide sandy wash of Coulee 4 began upstream. If this valley contained a perennial stream with viable aquatic habitat, or if it appeared that large amounts of sediment were being washed into the Vermillion River, we would recommend limiting ATV use through the valley to encourage the establishment of vegetation and stability of the sandy soils. However, because no aquatic habitat is present due to the lack of water and the sand appears to settle out in the flat valley prior to reaching the Vermillion River, we do not have any potential priority projects in this reach.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Oct 7, 2010
Stream/Drainage	Ravenna Coulee 4
Stream Reach ID	Reach 2
Field Team	NN, BW

Station	11,100	To	17,700

General Channel Conditions

Channel Shape (check)

☐Rectangular
☐Shallow Rectangular
☐Irregular
☐Trapezoidal
☒Parabolic
☒Other __undefined____

Sediment Particle Size Estimate	
Banks	Sand
Bars	NA
Bed	Sand

Bar Types:

☐Alternate lateral	☐Point / transverse	☒None
☐Mid-channel	☐Point / mid	☐Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable; shallow swale or undefined channel; no continuous flow or instability				
Lateral stability *deposition, erosion*	Stable; shallow swale or undefined channel; no continuous flow or instability				
Erosion (excessive/site specific)	NA				
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)*: No channel banks				
Terrace/Valley	*Valley form* – Low point in rolling hills; top of slopes are 700-800 ft apart and 20 ft higher than the 'channel'			*Land Use* –agriculture, light residential	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 14,400: 2, 4x10-ft concrete box culverts; in good condition Stn 15,700: 4.5-ft flared concrete pipe with trash grates; in good condition				

Sediment Impacts

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

Bars / depositional features

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

Riparian Vegetation and Floodplain

Root coverage of banks (%)	75%
Width of veg. riparian corridor*	15-100 ft
Canopy coverage (%)	5-95%

** 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	50
woody species	50
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Elm saplings	40
Silver maple	40
Box elder	20

Tree Stand Age (if applicable)

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

Habitat

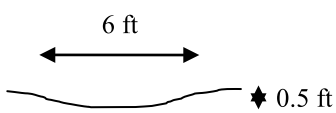
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; channel is undefined or a shallow swale
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

Representative cross-section sketch		
Bankfull width = 30/12ft Bankfull depth = 1/2ft	Floodplain width = 100-200 ft	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 14,200



Station:

GENERAL REACH NOTES

Reach 2 of Ravenna Coulee 4 consists of an undefined channel or a shallow swale with water rarely flowing. Vegetation fills in the swale in the grassy areas with little canopy cover and the channel is difficult to identify in the forested areas. There is no continuous flow, no aquatic habitat, and no instability problems.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Oct 7, 2010
Stream/Drainage	Ravenna Coulee 4
Stream Reach ID	Reach 3
Field Team	NN, BW

Station	17,700	**To** 21,400

General Channel Conditions

Channel Shape (check)

☒Rectangular
☐Shallow Rectangular
☐Irregular
☒Trapezoidal
☐Parabolic
☐Other ______

Sediment Particle Size Estimate	
Banks	Sand
Bars	NA
Bed	Sand

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Likely historically incised - defined channel is in stark contrast to undefined shallow swale upstream and downstream; no current instability				
Lateral stability *deposition, erosion*	Stable; no active or excessive erosion				
Erosion (excessive/site specific)	NA				
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)*: 3 to 5-ft banks are steep but vegetation covers the banks and channel bed; banks consist of sand and silt				
Terrace/Valley	*Valley form* – Low point in rolling hills; top of slopes are 700-800 ft apart and 20 ft higher than the 'channel'			*Land Use* –forest along channel; light residential; agriculture further away	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 20,700: 4x14-ft concrete box culvert in good condition - looks new; riprap around base				

Sediment Impacts

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

Bars / depositional features

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

Riparian Vegetation and Floodplain

Root coverage of banks (%)	75%
Width of veg. riparian corridor*	20-50 ft
Canopy coverage (%)	80%

** 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	85
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Elm saplings	40
Silver maple, cottonwood, oak	40
Box elder	20

Tree Stand Age (if applicable)

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

Habitat

LWD density (pieces / 100 ft)	NA
Residual pool depth	NA
Undercut bank frequency	NA
Riffle / Other frequency	NA

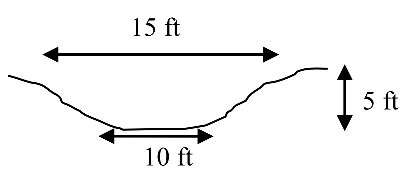
General Habitat Notes: No aquatic habitat; channel does not hold continuous water; forest habitat is substantial with light human impact and copious vegetation cover; near busy road for portions of reach

Channel Stability Form

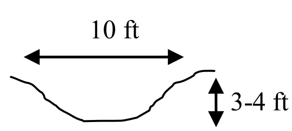
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q	1	2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	4
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial erosion, constant width	NA	Low banks, overflows, surficial erosion	
Bar development	Poorly formed		Narrow, vegetated	NA	Wide (>1/2 channel length), unveg.	
Bank erosion extent	Extensive		Local erosion/pools	NA	Extensive bar pressure	
Relative Width:Depth ratio	Low	2	Average		High	
Channel pattern	Single thread		Single thread	3	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		**= 15/6 = 2.5**				

Representative cross-section sketch		
Bankfull width = 15/10 ft Bankfull depth = 5/3 ft	Floodplain width = 30/10 ft	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 20,100



Station: 20,500



GENERAL REACH NOTES

Reach 3 of Ravenna Coulee 4 consists of a well-defined channel in contrast to reaches upstream and downstream. The upper half of this reach is a road-side ditch along Polk Ave. The ditch collects water from the steeper hillsides to the south and southwest, and after joining a small tributary at Stn 20,150, the channel widens and deepens for a few thousand feet before becoming less defined in Reach 2. The large culvert indicates that large quantities of water can move through this channel, but there are no areas of excessive and active incision or bank erosion. Vegetation (saplings and grasses) grows on the channel banks as well as within the channel itself. Although there is very little riparian corridor near the road, downstream from the confluence with the tributary the riparian corridor is wider and provides habitat for terrestrial species.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Oct 7, 2010
Stream/Drainage	Ravenna Coulee 4
Stream Reach ID	Reach 4
Field Team	NN, BW; primarily air photo analysis

Station | 21,400 | **To** 32,100 |

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	Sand
Bars	NA
Bed	Sand

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable; mostly a shallow swale through fields				
Lateral stability *deposition, erosion*	Stable; mostly a shallow swale through fields				
Erosion (excessive/site specific)	NA				
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)*: No defined banks				
Terrace/Valley	*Valley form* – Narrow and steep through forest: top of steep slopes are about 800 ft apart and about 60 feet above valley floor			*Land Use* –agriculture; middle section flows through forest	
Altered state (human) - dams, bridges, canoe landings, parks, etc.					

Sediment Impacts

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

Bars / depositional features

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

Riparian Vegetation and Floodplain

Root coverage of banks (%)	75%
Width of veg. riparian corridor*	10-20 ft
Canopy coverage (%)	0-90%

** 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	x
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	50
woody species	50
bare/other	
Exotic/invasive species	

Woody Species present	% of total tree community
Did not investigate	

Tree Stand Age (if applicable)

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

Habitat

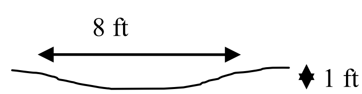
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; channel does not hold continuous water
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

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

Representative cross-section sketch		
Bankfull width = 8 ft Bankfull depth = 1 ft	Floodplain width = NA	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 21,500



Station:

GENERAL REACH NOTES

Reach 4 of Ravenna Coulee 4 consists of a shallow swale or small channel flowing through agriculture fields and steep forest. We did not investigate the entire reach as it appeared similar to other swales and drainages in the other Coulee subwatersheds from the downstream end. Looking at the drainage from the downstream end and conducting an air photo analysis, there does not appear to be instability problems, through the channel steepens through the forested section of this reach. No aquatic habitat is available and only forest habitat is available between Stns 24,000 and 27,700.

POTENTIAL PROJECTS

Channel Reconnaissance Form

Date	Oct 7 & 9, 2010
Stream/Drainage	Ravenna Coulee 4
Stream Reach ID	Tributary 1; joins Reach 3 at Stn 20,150
Field Team	NN, BW

Station 0 **To** 4700

General Channel Conditions

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

Sediment Particle Size Estimate	
Banks	Sand
Bars	NA
Bed	Sand

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

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	Stable; mostly a roadside ditch or undefined swale through forest and agriculture fields; may be some historic incision between Stn 1100 and 1700 as the flow comes out of the steep hillsides upstream; no apparent current and active instability				
Lateral stability *deposition, erosion*	Stable; no continuous flow and no channel migration				
Erosion (excessive/site specific)	NA				
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)*: Sand and silt where defined				
Terrace/Valley	*Valley form* – Forest section is narrower and steeper: top of hillsides are about 600 ft apart and 40 ft above valley floor			*Land Use* –agriculture, residential, forest	
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Stn 150: 2, 3.5x6-ft concrete pipes under Polk Ave; upstream end: 2, 1-ft concrete dams and one has a v-notch in it - possibly for sediment control?; no sediment trapped; good condition Stn 1000: 2-ft corrugated metal pipe; overgrown				

Sediment Impacts

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

Bars / depositional features

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

Riparian Vegetation and Floodplain

Root coverage of banks (%)	80%
Width of veg. riparian corridor*	10-20 ft
Canopy coverage (%)	0-90%

** 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	x

Primary veg forms present: (%)

grasses/forbs	25
woody species	75
bare/other	
Exotic/invasive species	Buckthorn in forested section

Woody Species present	% of total tree community
cottonwood	60
Elm, oak	20
buckthorn	20

Tree Stand Age (if applicable)

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

Habitat

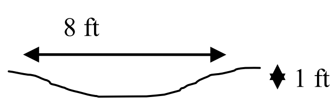
LWD density (pieces / 100 ft)	NA	General Habitat Notes: No aquatic habitat; channel does not hold continuous water
Residual pool depth	NA	
Undercut bank frequency	NA	
Riffle / Other frequency	NA	

Channel Stability Form

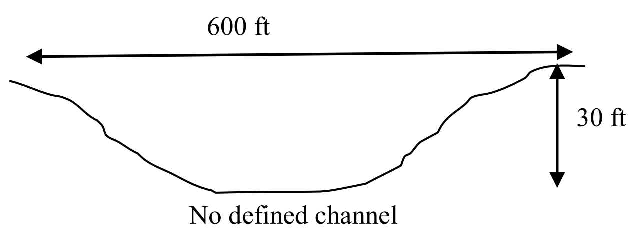
Reach stability		1-2 Degrading		3 Stable		4-5 Aggrading
Estimated sediment mobility (D50 moves at:)	<2yr Q		2-10 yr		>10 yr	
Substrate consolidation	Strong, gravels/cobble		Strong, gravels		Weak, sand/silt	
Bank failure mechanism	High banks, grav. collapse, variable channel width		Localized surficial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

Representative cross-section sketch		
Bankfull width = 8 ft Bankfull depth = 1 ft	Floodplain width = NA	Water depth (at survey) = 0 Water width (at survey) = 0

Station: 700



Station: 3000



GENERAL REACH NOTES

Tributary 1 of Ravenna Coulee 4 flows into Reach 3 of the mainstem at station 20,150. Tributary 1 begins in open fields that we believe are part of the Conservation Reserve Program (CRP). It then flows through thick forest with no defined channel down a steep hillside. At Stn 1700, the Tributary emerges from the steep forest into the back yards of residences, then becomes a road side ditch before passing under Polk Ave and into the mainstem of Coulee 4. No aquatic habitat is present, but forest habitat and prairie habitat is plentiful. On the downstream end of the Polk Ave crossing, an energy dissipating pool (riprap) slows flows as they enter the mainstem. Flow is rare, however, as evidenced by the lack of defined channel in portions of the forest and vegetation growing in the channel next to the road. No instability problems were identified.

POTENTIAL PROJECTS

Appendix E: Potential project forms

Potential Project **PP 01**

Stream: Etter Creek, Reach 2 Station: 4050	Problem description: 2, 5-ft corrugated metal pipes under Ravenna Trail are undersized. The pipes are partially blocked with sand and coarse woody debris is trapped on the upstream faces of the culverts. Signs on the road indicate that flooding of the road has occurred, though conversations with landowners suggest this has not occurred in recent years. Minor erosion is occurring around the culverts. Flooding of the road and erosion of the road is a risk to infrastructure and human safety. The culverts also restrict the flow of water and sediment from naturally moving downstream.
Solution: Replace the culverts with larger structures - the new box culverts under Redwing Boulevard appear adequate and this consist of 3, 12x8-ft box culverts. The road prism may need to be raised to account for pipes or culverts with a larger capacity. A bottomless arch culvert would also provide adequate capacity and would provide a natural channel bed.	

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	1	
Project complexity	3	
Location	1	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	3	
Property Ownership	7	Town of Ravenna
Public Education	3	
Riparian Ecological Benefit	1	

Project Area Photo/Map Location

(Left to right): Stn 4000 looking upstream; Stn 4075 looking downstream.

Potential Project **PP 02**

Stream: Etter Creek, Reach 2	Problem description: Erosion gullies have formed on the right bank and terrace slope of Etter Creek. These gullies are likely the result of excessive concentrated flows from water flowing off of fields and into a channel that has incised to a lower base level.
Station: 6150, right bank	
Solution: Increase the riparian buffer so that overland flows have more opportunity to seep into the ground.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	1	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	1	
Property Ownership	0	unknown
Public Education	1	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Stn 6150 looking at erosion and gullies on the right bank.

Potential Project **PP 03**

Stream: Etter Creek, Reach 3	Problem description: A bluff ~50 ft tall is actively eroding and slumping. This is natural and was seen elsewhere, but at this location paths are maintained to the edge of the bluff and a bench that has been cemented into the ground is about 6 ft from the edge of the bluff. Through channel migration, the channel has destabilized the toe of the bluff and seeps 30 ft above the channel destabilize the slope. Recent slumps were observed and the sediment lobes had pushed over small willow saplings on the banks of the channel.
Station: 15,600-15,750; right bank	

Solution: The cost effective approach would be to allow the bluff and channel come to an equilibrium: the slumping material will push the channel far enough away from the bluff that further erosion will be minimized. The lower slope will stabilize, revegetate, and the seeps will likely not cause further erosion of the upper slopes. This option would require that the bench be moved away from the eroding slope and that the top of the bluff be planted with shrubs and trees so the roots can help stabilize the slope. A second option is to actively stabilize the toe of the slope with rock or logs and plant vegetation along the slope. The scoring below is for the first option; costs and complexity would greatly increase for the second option.

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	1	
Project complexity	7	
Location	3	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	1	
Property Ownership	0	unknown
Public Education	1	
Riparian Ecological Benefit	1	

Project Area Photo/Map Location

Stn 15,650 looking at the eroding bluff on the right bank.

Potential Project PP 04

Stream: Etter Creek, Reach 3	Problem description: ATVs drive along the channel bed, over the channel banks, and along the floodplains. This activity prevents vegetation growth, destabilizes the channel, and increases sedimentation. This activity is not of huge concern as it is fairly localized, there is no aquatic habitat that it impairs, and the main problems in the subwatershed are the large knickpoints and excessive water flow. However, ATV use does decrease stability and increase sedimentation.
Station: 16,000-16,400	
Solution: Limit ATV use to a few stable crossings and paths that have a substantial vegetative buffer between them and the channel.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	
Location	3	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	1	
Property Ownership	0	unknown
Public Education	1	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Stn 16,075 looking downstream at an ATV crossing.

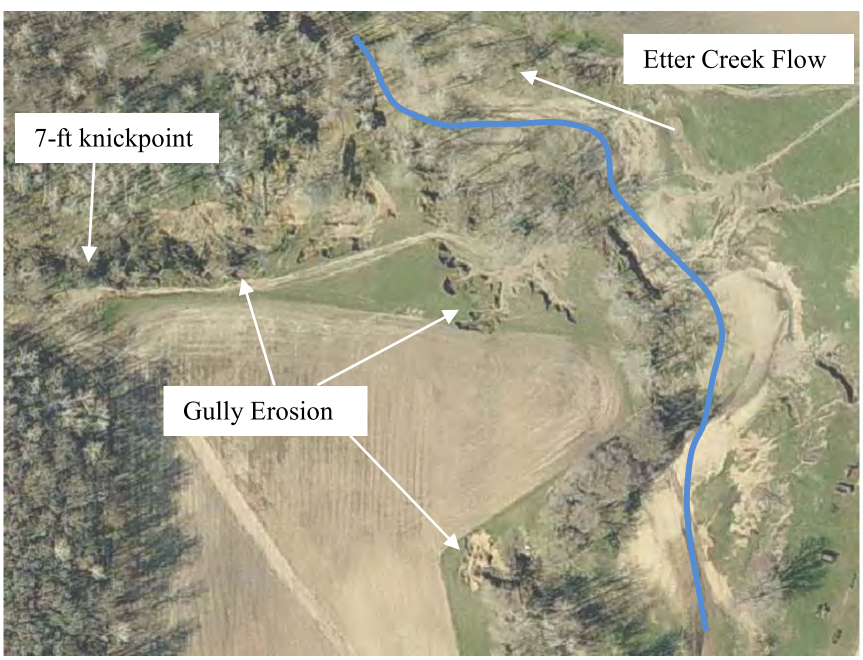
Potential Project PP 05

Stream: Etter Creek, Reach 4	Problem description: Excessive bank and hillslope erosion and incision of drainages is resulting in increased sedimentation in Etter Creek and loss of hillslope crop land and forest habitat. The channel, channel banks, and hillslopes are actively grazed and much of the understory has been reduced to short grass. Farm vehicle traffic throughout the channel has also altered the channel form and reduced the vegetative growth. One drainage has a 7-ft knickpoint and gorge resulting from the incision here and elsewhere is visible on aerial photography.
Station: 18,600-20,000	
Solution: Limit vehicle and animal access to the channel to one or two crossings. Create a vegetation buffer adjacent to the stream and the eroding drainages. Vegetation should include native forbs, shrubs, and trees to provide root stabilization as well as vegetative roughness to slow and reduce the overland flow of rainwater. Revegetate hillslopes and limit grazing on left side to minimize overland flow that's resulting in large gullies and incision.	

	Score	*Notes*
Infrastructure risk	5	Risk to farm equipment and livestock
Erosion/channel stability	3	
Project complexity	7	Could use volunteer labor to plant vegetation and build fences
Location	5	
Sediment/nutrient loading	7	
Project cost	7	Could use volunteer labor to plant vegetation and build fences; may be costs to land owner in the form of loss of revenue or farming potential
Aesthetic impact	7	
Property Ownership	0	unknown
Public Education	5	
Riparian Ecological Benefit	5	

Project Area Photo/Map Location

Air photo with the knickpoint and gullies identified.



Clockwise from top left: Stn 18,750 looking upstream; Stn 100 of drainage entering Etter Creek at Stn 18,950 - looking downstream towards Etter Creek; Stn 350 of drainage - looking upstream at 7-ft knickpoint.

Potential Project PP 06

Stream: Etter Creek, Reach 4	Problem description: The channel is eroding the toe of a 25 to 50-ft bluff. No seeps were observed and grasses and forbs are growing on the slope, but no trees are on the slope to stabilize. The top of the bluff has no root stabilization and crops are growing about 30 ft from the bluff edge. No infrastructure is at risk, and the bluff and channel will eventually come to an equilibrium, but stabilization may be necessary if the landowner is concerned about losing land.
Station: 20,350-20,600; left bank	
Solution: Monitor to determine the likelihood of loss of cropland. Revegetate the bluff slope and the top of the bluff to minimize soil loss. If necessary, stabilize the toe of the slope. The scores and costs below do not include toe stabilization.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	Could use volunteer labor to plant vegetation
Location	5	
Sediment/nutrient loading	3	
Project cost	7	Could use volunteer labor to plant vegetation
Aesthetic impact	1	
Property Ownership	0	unknown
Public Education	1	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Stn 20,600 looking downstream at bluff along left bank.

Potential Project PP 07

Stream: Etter Creek, Reach 4	Problem description: The channel is eroding the terrace surface along the outside bends in this section. The steep banks are 8-10 ft tall with little vegetation and the erosion is approaching crops in some locations. Very little vegetative buffer is between the channel banks and crops. The channel migration is natural, but because of the historic incision that has occurred throughout the reach, the erosion becomes problematic when it begins to impact the upper terrace surface on which the crops are planted. Further bank erosion could result in loss of crops. Excessive erosion results in increased sand deposits in the stream, potentially leading to further instability.
Station: 21,500-23,200; outside bends of both banks	
Solution: Stabilize the toe of the banks, regrade the banks, and plant native riparian shrubs and trees. Build a riparian buffer zone between the banks and the crops to improve infiltration and soil/bank stability.	

	Score	***Notes***
Infrastructure risk	3	Crop land
Erosion/channel stability	5	
Project complexity	3	Could use volunteer labor to plant vegetation
Location	5	
Sediment/nutrient loading	5	
Project cost	3	Could use volunteer labor to plant vegetation
Aesthetic impact	1	
Property Ownership	0	unknown
Public Education	3	
Riparian Ecological Benefit	5	

Project Area Photo/Map Location

Left to right: Stn 21,550 looking downstream at eroding right bank; Stn 22,650 looking upstream at eroding right bank.

Potential Project **PP 08**

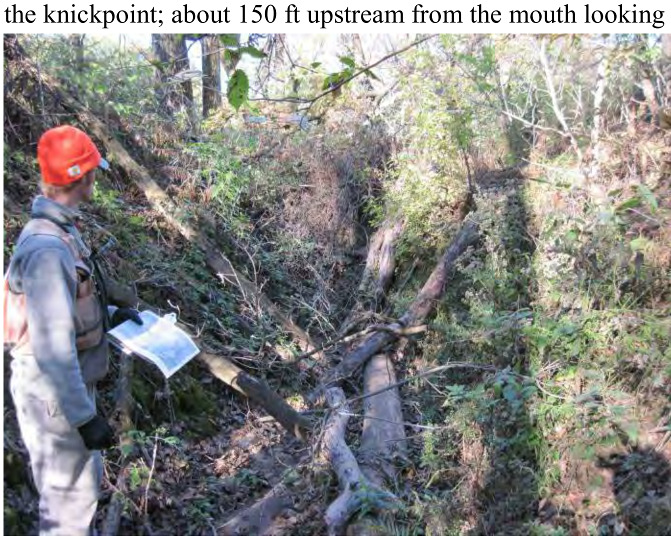
Stream: Etter Creek, Reach 4	Problem description: A small drainage entering Etter Creek on the left bank has incised about 150 ft upstream and a 4-ft knickpoint is actively moving upstream. Continuation of this knickpoint will increase sedimentation of Etter Creek and will result in further instability of the this small drainage. Increased incision could result in problems for farming with the movement of farm equipment. If the knickpoint reaches the hillside, gullying along the slope could occur and could result in loss of land and increased sedimentation.
Station: 21,950	

Solution: Increase the riparian buffer width to maximize infiltration and reduce overland flow to the stream. Monitor: if incision continues and threatens crops or hillslope, build grade control or convert the drainage into a stormwater detention basin. Scores below do not include active channel work, only the development of a riparian buffer.

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	3	
Project complexity	7	Could use volunteer labor to plant vegetation
Location	5	
Sediment/nutrient loading	3	
Project cost	7	Could use volunteer labor to plant vegetation
Aesthetic impact	1	
Property Ownership	0	unknown
Public Education	1	
Riparian Ecological Benefit	1	

Project Area Photo/Map Location

Left to right, drainage that enters the mainstem at Stn 21,950: About 100 ft upstream from the mouth and looking upstream at the knickpoint; about 150 ft upstream from the mouth looking upstream at the drainage.



Potential Project PP 09

Stream: Etter Creek, Reach 4	Problem description: Minor erosion and piping is occurring around the upstream end of the 7-ft corrugated metal pipe under 145th Ave. If erosion continues, it could affect the dirt road and compromise the integrity and effectiveness of the culvert.
Station: 26,150	
Solution: Monitor the erosion. If erosion and piping worsens, re-grade banks and stabilize with stone and/or native vegetation.	

	Score	***Notes***
Infrastructure risk	3	
Erosion/channel stability	1	
Project complexity	7	Monitoring
Location	7	
Sediment/nutrient loading	1	
Project cost	7	
Aesthetic impact	1	
Property Ownership	7	Probably owned by county or township, though property data does not identify the owner
Public Education	3	
Riparian Ecological Benefit	1	

Project Area Photo/Map Location

Left to right: Stn 26,175 looking downstream at the culvert with erosion visible on the right side of the culvert; Stn 26, 150 looking at the gap underneath the upstream end of the culvert.

Potential Project PP 10

Stream: Etter Creek, Reach 5	Problem description: The left bank is eroding and the top of the eroding bank is about 10 ft from the edge of 145th Ave. Concrete rubble and riprap had previously been placed on the bank, but this is in disrepair and much of the concrete has fallen into the channel. The debris in the channel increases instability and the concrete on the banks prevents vegetation from growing and stabilizing the banks naturally. Increased erosion could threaten to undermine the road, putting human life in danger.
Station: 26,950-27,050; left bank	
Solution: Remove the concrete rubble. Stabilize the toe of the slope and then build lifts that will support vegetation growth to the top of the bank. Plant native vegetation with deep roots and roots that spread out laterally to help stabilize the soil.	

	Score	***Notes***
Infrastructure risk	5	
Erosion/channel stability	1	
Project complexity	5	
Location	7	
Sediment/nutrient loading	3	
Project cost	5	
Aesthetic impact	1	
Property Ownership	7	May be within road corridor; if not, the cooperation of the adjacent landowner is unknown
Public Education	3	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Left to right: Stn 27,000 looking upstream at concrete rubble; Stn 27,000 looking downstream at concrete on the banks and in the stream.

Potential Project PP 11

Stream: Etter Creek, Reach 5	Problem description: A 5-ft corrugated metal pipe encased in a concrete driveway is corroded through its base so that water flows through the holes in the metal and along the gravel bed under the culvert. Cracks in the concrete have already developed and continued erosion could further compromise the structural integrity of the culvert and driveway. In addition, concrete, bricks, and other debris have been placed on both banks immediately downstream of the culvert in an effort to minimize erosion. Some of this debris has fallen into the channel increasing instability and the debris on the banks prevents vegetation from stabilizing the banks.
Station: 27,450	
Solution: Replace the culvert with a larger culvert that will not result in a hydraulic jump on the downstream end. This would likely minimize the bank erosion on the downstream end; the debris could then be removed from the bed and the banks could be stabilized with native vegetation.	

	Score	*Notes*
Infrastructure risk	5	
Erosion/channel stability	1	
Project complexity	5	
Location	7	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	3	
Property Ownership	0	Unknown
Public Education	3	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Left to right: Stn 27,475 looking downstream at culvert; Stn 27,450 looking downstream at rubble on channel bed and banks.

Potential Project PP 12

Stream: Etter Creek, Reach 5	Problem description: Most of the native vegetation has been removed and the grass is mowed to the edge of the channel banks. Other than a few trees, there is no native riparian buffer and this decreases bank stability, riparian habitat, and infiltration.
Station: 27,450-27,700	
Solution: Plant native trees, shrubs, and forbs throughout a 10 to 20-ft riparian buffer.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	7	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	3	
Property Ownership	0	Unknown on the right bank; may be within road corridor on left bank
Public Education	3	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Left to right: Stn 27,450 looking upstream; Stn 27,550 looking towards the right bank.

Potential Project **PP 13**

Stream: Etter Creek, Reach 5	Problem description: Piping and erosion was observed on the left bank approximately 4 ft from the edge of 145th Ave. Riprap has been placed along the left bank, but water seeping behind the riprap and erosion is continuing. The riprap prevents any native riparian vegetation from growing and stabilizing the channel banks. The area between the riprap and the road is mowed grass and managed to prevent larger vegetation from growing. Further erosion could cause damage to the road and increase risk to public safety.
Station: 27,625-27,675; left bank	
Solution: Remove riprap, stabilize the toe of the bank, build lifts that support vegetation to the top of the bank, and plant native shrubs and trees along the top of the bank to stabilize the soil.	

	Score	*Notes*
Infrastructure risk	3	
Erosion/channel stability	1	
Project complexity	5	Could use volunteer labor to plant vegetation
Location	7	
Sediment/nutrient loading	1	
Project cost	5	Could use volunteer labor to plant vegetation
Aesthetic impact	3	
Property Ownership	0	Unknown on the right bank; may be within road corridor on left bank
Public Education	3	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Stn 27,650 looking downstream at piping and erosion along the left bank.

Potential Project PP 14

Stream: Etter Creek, Reach 5	Problem description: A small drainage flows into Etter Creek at this location. About 50 ft from the mouth of the drainage, it flows underneath 145th Ave through a 3.5-ft corrugated pipe encased in concrete. Because of mainstem incision, the downstream end of the pipe is 5 ft above the channel bed. The base of the wingwalls are cracking and erosion is occurring on the top and side of the right wingwall about 3 ft from the edge of 145th Ave. Piping was observed on the left side as well. This erosion and piping could damage the road and risk human safety.
Station: 28,050	

Solution: Replace culvert with a longer and wider culvert that will provide adequate width for vehicular traffic and a buffer between the road and the channel. The culvert will need to be placed, and grade control built, so that incision does not continue upstream of the road and erosion does not increase between the drainage outlet and the mainstem. Native riparian vegetation should then be planted between the channel banks and the road to stabilize the banks.

	Score	*Notes*
Infrastructure risk	7	Road edge is very close to the culvert edge and erosion
Erosion/channel stability	1	
Project complexity	3	
Location	7	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	3	
Property Ownership	7	Probably within road corridor
Public Education	5	
Riparian Ecological Benefit	1	

Project Area Photo/Map Location

Left to right: Stn 28,050 looking up the drainage at the downstream end of the culvert; looking at the erosion along the right side of the culvert and wingwalls on the downstream end.

Potential Project **PP 15**

Stream: Etter Creek, Reach 5	Problem description: The ~8-ft left bank is eroding at this location and approximately 8 ft from the edge of 145th Ave. Increased erosion could damage the road and increase risk to human safety. There is no native riparian buffer between the road and the channel at this location.
Station: 28,650; left bank	
Solution: Stabilize the bank toe, build lifts that can support vegetation to the top of the bank, and plant native riparian vegetation to stabilize the banks. Alternatively, the channel could be moved further from the road edge with landowner permission. This would provide enough space to regrade the left bank and provide additional buffer.	

	Score	*Notes*
Infrastructure risk	5	
Erosion/channel stability	1	
Project complexity	5	Could use volunteer labor to plant vegetation
Location	7	
Sediment/nutrient loading	1	
Project cost	5	
Aesthetic impact	3	
Property Ownership	7	May be within road corridor
Public Education	3	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Left to right: Stn 28,650 looking upstream at erosion; Stn 28,650 looking at eroding left bank.

Potential Project **PP 16**

Stream: Etter Creek, Tributary 4	Problem description: A 12-ft knickpoint is actively migrating upstream. A smaller, 3-ft knickpoint is about 10 ft from the edge of Records Trail. Migrating knickpoints can result in significant erosion and sedimentation of streams, damage to infrastructure, and damage to roads. Logs, concrete, and grass clippings have been dumped onto the knickpoints, but this only exacerbates the problem because this debris prevents native vegetative growth that could stabilize the banks. The knickpoints are likely the result of incision on Etter Creek migrating up the tributaries combined with increased water volumes due to land clearing.
Station: 2600	

Solution: A temporary solution (and the one that the scores below are based on) is to re-grade the channel into a series of grade controlling steps and energy-diffusing pools. The banks should also be re-graded to a gentler slope and planted with native riparian vegetation. The buffer between the road and the channel should be increased during this process and vegetation planted to increase infiltration and limit the amount of water draining directly off the road and into the channel. A more long-term solution is to increase the riparian buffer further upstream and incorporate stormwater retention practices to slow the flow of water downstream.

	Score	***Notes***
Infrastructure risk	3	Continued incision could damage the road
Erosion/channel stability	5	
Project complexity	3	Could use volunteer labor to plant vegetation
Location	3	
Sediment/nutrient loading	5	
Project cost	5	
Aesthetic impact	3	
Landowner Cooperation	0	Unknown
Public Education	5	Close to a road and good demonstrative value
Riparian Ecological Benefit	1	

Project Area Photo/Map Location

Left to right: Stn 2600 looking upstream at knickpoint; Stn 2600 looking upstream at smaller knickpoint (filled with grass clippings) that is nearing the road edge.

Potential Project PP 17

Stream: Etter Creek, Tributary 4	Problem description: This area is heavily impacted by grazing (primarily cattle, but sheep are also held in a small pen). There is no defined channel and the valley floor and slopes are devoid of vegetation except for grass grazed very low and a few trees. Overland flow off of the hillsides is resulting in gullying and excessive erosion because there is little vegetation to hold the soil in place. This overgrazing and lack of vegetation decreases infiltration and increases water flow to downstream sections, likely resulting in the upstream migration of the 12-ft knickpoint described in PP16.
Station: 3400-4300; 0-400 on North Drainage	
Solution: Eliminate, or greatly reduce, grazing on the valley floor and steep hill slopes. If grazing is continued, reduce the number of cattle and limit the grazing to portions of the property that can withstand the impacts. Limit the movement of livestock along the valley floor to one or two crossings. Revegetate valley floor and slopes with native grasses, forbs, shrubs, and trees.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	5	
Project complexity	7	Could use volunteer labor to plant vegetation and build fences
Location	5	
Sediment/nutrient loading	7	
Project cost	7	Could use volunteer labor to plant vegetation and build fences
Aesthetic impact	7	
Landowner Cooperation	0	Unknown; landowners were kind enough to allow access to property and answer a few questions
Public Education	5	Close to a road and good demonstrative value
Riparian Ecological Benefit	5	

Project Area Photo/Map Location

See next page

Clockwise from lower left: Stn 3800 looking upstream overgrazing and erosion on dam; Stn 3500 looking towards the hillslope to the right of the channel; Stn 3500 looking upstream; Stn 100 of North Drainage looking upstream.

Potential Project PP 18

Stream: Etter Creek, Tributary 4 Station: 3900	Problem description: An earthen dam built across the valley floor at this location has likely been successful at reducing water and sediment flow downstream. The 1.5-ft pipe that allows water through the dam does not provide a great deal of storage and instead allows any water flowing through the grazed channel upstream to flow directly downstream. By eliminating grazing and retro-fitting the culvert, the area upstream of the dam could be converted into a stormwater retention basin in the form of a wetland similar to that at the headwaters of this tributary. This, combined with the reduction/elimination of grazing, would likely halt the migration of the knickpoint further downstream.
Solution: Retro-fit the pipe by attaching a vertical pipe with a trash grate and debris deflector to the upstream end. The top of this pipe could be 1-2 ft below the top of the dam. Once water begins to collect, plant wetland vegetation.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	5	Improves stability downstream by slowing incision
Project complexity	7	Could use volunteer labor to plant vegetation and build fences
Location	5	
Sediment/nutrient loading	7	
Project cost	7	Could use volunteer labor to plant vegetation and build fences
Aesthetic impact	5	
Landowner Cooperation	0	Unknown; landowners were kind enough to allow access to property and answer a few questions
Public Education	5	Close to a road and good demonstrative value; easy to incorporate volunteer labor
Riparian Ecological Benefit	5	

Project Area Photo/Map Location

Left to right: Stn 3900 looking downstream at pipe and dam; Stn 3900 looking upstream.

Potential Project **PP 19**

Stream: Etter Creek, Tributary 5	Problem description: Mainstem Etter Creek incision has drastically impacted Tributary 5 and its numerous small drainages. At least 11 knickpoints, ranging in height from 3 to 10 ft, are actively migrating upstream. Upstream of these knickpoints, the channel generally returns to a shallow swale. This incision results in decreased lateral stability - as the channel incises, the banks become steeper and erode into the channel. From the mouth of this tributary to the 10-ft knickpoint at Stn 1675, numerous 12 to 15-ft banks are eroding on the outsides of channel bends. This vertical and horizontal instability results in increased sediment loads to Etter Creek and may begin to impact row crops if the incision continues to the top of the Tributary and the drainages.
Station: 0-7700: entire reach	

Solution: Instability problems along this subwatershed will likely be best solved using a subwatershed-scale approach. Halting farming over large portions of this subwatershed is not feasible. Nor, however, is building a stormwater retention basin at the mouth of each incised drainage and on the mainstem Tributary 5. A combination of the two methods, however, may be the best approach. Retention basins at Stn 1500, around Stn 1400 on the drainage that flows into Trib 5 at Stn 4500, and at Stn 5800 on Trib 5 will help capture stormwater and will create wetland habitats that could be conducive to many wetland plant and animal species. Converting row crops to native grass and tree cover, particularly along the south and southeast portions of this tributary and its drainages would improve infiltration and reduce the amount of water entering Tributary 5.

	Score	*Notes*
Infrastructure risk	3	Farmland at risk
Erosion/channel stability	7	Will improve stability throughout subwatershed
Project complexity	1	Building retention basins will be complex and costly; could use volunteer labor to plant vegetation
Location	5	
Sediment/nutrient loading	7	
Project cost	1	Building retention basins will be complex and costly; could use volunteer labor to plant vegetation
Aesthetic impact	7	
Landowner Cooperation	0	Unknown; many landowners would need to be involved
Public Education	7	Large scale project with multiple components; accessible through farm fields; good demonstrative value
Riparian Ecological Benefit	7	

Project Area Photo/Map Location

See photos on next page.

A) Stn 250 looking at the eroding 12 to 15-ft left bank of Tributary 5; B) Stn 1650 looking upstream at eroding bank with 10-ft knickpoint behind N. Nelson; C) Stn 2650 looking upstream at 4-ft knickpoint halted by the roots of a large cottonwood tree; D) Stn 4800 looking upstream at 6-ft knickpoint halted by tree roots; E) Stn 5675 looking upstream at upper portion of 8-ft knickpoint halted by tree roots; Stn 5700 looking upstream at channel upstream of the knickpoint in photo E.

Potential Project **PP 20**

Stream: Etter Creek, Tributary 6	Problem description: Tributary 6 and its North Drainage have multiple knickpoints throughout their length, but the widespread vegetative cover and the lack of nearby infrastructure has minimized the impact of this incision. However, seven 8 to 10-ft knickpoints were identified between Stn 4400 and 4450. These knickpoints are not in succession along the channel, but form 'fingers' of incision where the knickpoints meet the fields. The additional knickpoints may have been caused by diversions meant to halt the primary knickpoint. These knickpoints are active and will continue to migrate upstream with stormwater runoff causing damage farmland and increasing sedimentation downstream.
Station: 4400-4450	
Solution: Build a stormwater retention basin at Stn 4500 or allow native grasses, shrubs, and trees to grow in the upper part of the subwatershed. The retention basin will capture stormwater and create a small wetland and the revegetation will increase infiltration and reduce water flow downstream.	

	Score	*Notes*
Infrastructure risk	3	Farmland at risk
Erosion/channel stability	5	Will improve stability throughout subwatershed
Project complexity	3	Permitting, modeling, and earthwork could be complex
Location	5	
Sediment/nutrient loading	5	
Project cost	5	
Aesthetic impact	3	
Landowner Cooperation	0	Unknown
Public Education	3	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

See photos on next page.

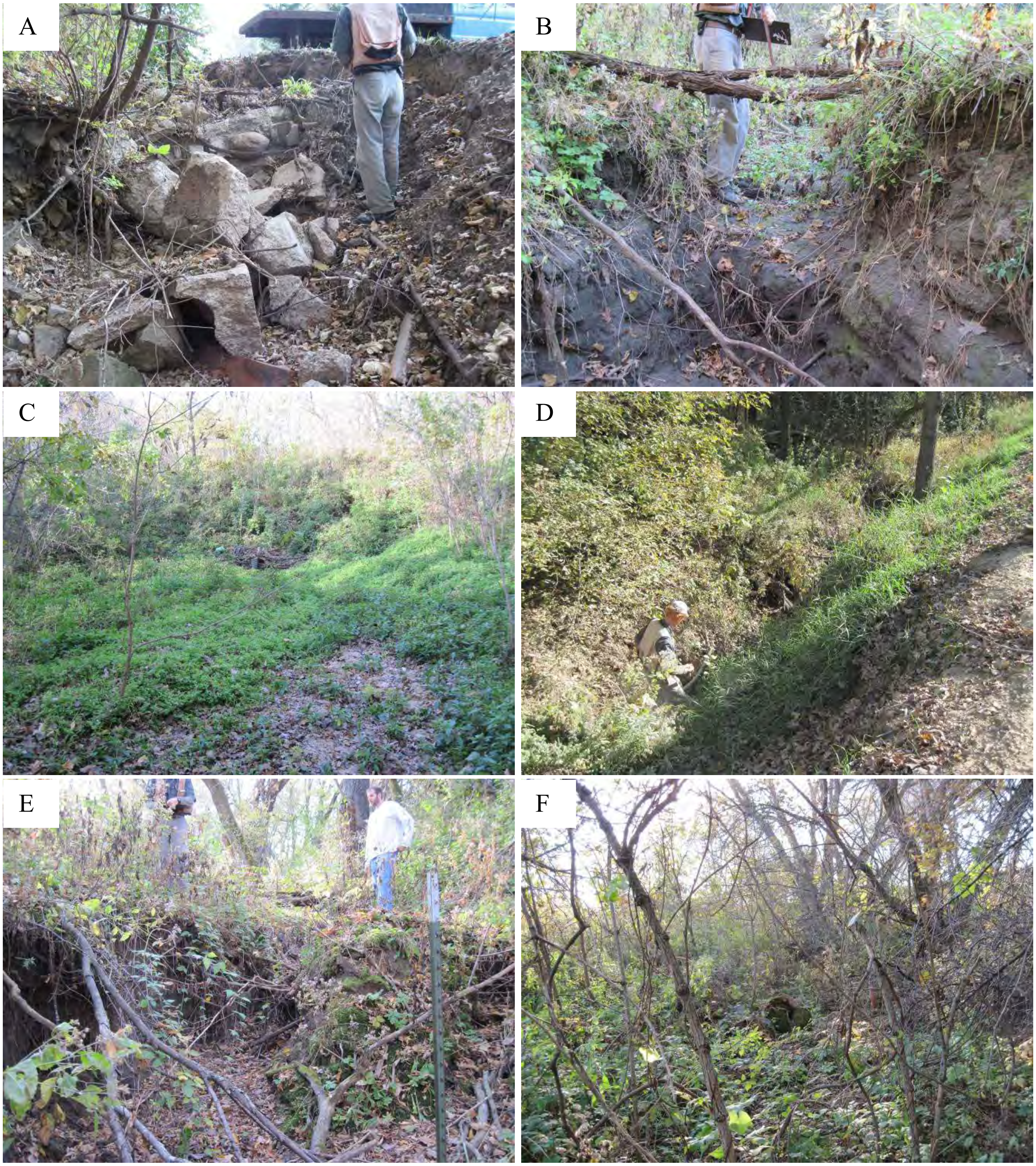
A) Stn 4425 looking upstream at 11-ft primary knickpoint; B) Stn 4425 looking upstream at one of the secondary knickpoints; C) Stn 4450 looking upstream at primary knickpoint; D) Stn 4450 looking upstream of all knickpoints at survey marker in field.

Stream: Etter Creek, Tributary 8, Reach 2	Problem description: More than 20 knickpoints were identified throughout this reach and the associated drainages. Most of the knickpoints were between 1 and 3 ft in height, but an 8-ft knickpoint was identified at Stn 2375. These knickpoints are likely the result of increased hydrology due to agriculture in the upper portions of the subwatershed. The knickpoints increase sedimentation downstream (sand and silt partially fill the culvert under 145th Ave and much deposition has occurred below the culvert) and can result in damage to infrastructure or property. The 8-ft knickpoint and knickpoints at the upstream extent of this tributary and the drainages are encroaching on managed yards, fields, and crops.
Station: 1500-5800; entire reach including small drainages	
Solution: Similar to Tributary 5, a combination of stormwater retention basins and conversion of managed fields to native vegetation is likely the most effective way of diminishing the water volume and minimizing sediment transport. The driveway crossing at Stn 4575 and the road crossing at Stn 5000 are both 8 to 10 ft higher than the channel bottom on the upstream end. The topography in these two areas provides an opportunity to retrofit the two culverts with risers that would cause additional retention of water and create small wetlands. An additional retention basin could be built on the small drainage that enters Tributary 8 at Stn 3625. About 9 knickpoints were identified between the mouth of this drainage and about 700 ft upstream from the mouth. Upstream of Stn 700 there is no defined channel; this may provide a good location for a retention basin that would further slow the downstream flow of water. Finally, converting cropland and managed fields to native grasses, shrubs, and trees in the headwaters of the small drainage and on either side of 225th St at the headwaters of the mainstem would increase infiltration and reduce the downstream flow of water.	

	Score	***Notes***
Infrastructure risk	3	Farmland at risk
Erosion/channel stability	5	Will improve stability throughout subwatershed
Project complexity	3	Permitting, modeling, and earthwork could be complex
Location	7	
Sediment/nutrient loading	5	
Project cost	5	
Aesthetic impact	3	
Landowner Cooperation	0	Unknown; multiple landowners
Public Education	5	Easily accessible; good demonstrative value
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

See photos on next page.



A) Stn 2375 looking upstream at 8-ft knickpoint and concrete rubble; B) Stn 3700 looking upstream at 3-ft knickpoint; C) Stn 4675 looking downstream at driveway crossing and culvert underneath; D) Stn 5000 looking upstream from the 225th St crossing; E) Stn 700 of drainage that enters Tributary 8 at Stn 3625 looking upstream at 5-ft knickpoint; F) Stn 900 of drainage that enters Tributary 8 at Stn 3625 looking upstream.

Potential Project **PP 22**

Stream: Etter Creek, Tributary 9, Reach 1	Problem description: A 5-ft knickpoint has developed at this location where the channel flows between two fields. Burned stumps, sawdust, and logs have been dumped into the incised channel at the knickpoint. Vehicular and pedestrian travel between the fields could be hazardous with this knickpoint and incised channel, but the two fields are owned by different families, so this may not be a problem. The knickpoint could continue to migrate upstream resulting in decreased channel stability and increased sedimentation into Etter Creek.
Station: 450	
Solution: Build a grade control structure to prevent continued incision and headcutting. Plant native trees along a buffer where the channel flows between the two fields to stabilize the soils.	

	Score	*Notes*
Infrastructure risk	3	Farmland at risk; safety hazard
Erosion/channel stability	3	
Project complexity	5	
Location	7	
Sediment/nutrient loading	3	
Project cost	5	
Aesthetic impact	1	
Landowner Cooperation	0	Unknown; multiple landowners
Public Education	1	
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Left to right: Stn 425 looking upstream at pile of sawdust in incised channel; Stn 450 looking upstream at knickpoint.

Stream: Etter Creek, Tributary 9, Reach 2	Problem description: About 20 knickpoints were identified throughout this reach and the associated drainages. Some of the knickpoints were between 1 and 3 ft in height, but many were between 6 and 15 ft in height. These knickpoints are likely the result of increased hydrology due to agriculture in the upper portions of the subwatershed. These knickpoints increase sedimentation downstream and can result in damage to infrastructure or property. It is unlikely that much sediment is transported to Etter Creek given the low gradient between the channel mouth and Stn 3000. However, increased sedimentation can lead to decreased lateral stability downstream and increased bank erosion. Active knickpoints at the head of each drainage are on the edge of tilled fields and some knickpoints have entered the fields. Crops were observed falling into the channels. Besides the loss of crops, farm vehicles or laborers could fall into these incised channels resulting in severe damage to property and potential hazard to human life.
Station: 2300-5800 including 7 drainages	
Solution: Similar to Tributary 5, a combination of stormwater retention basins and conversion of managed fields to native vegetation is likely the most effective way of diminishing the water volume and minimizing sediment transport. A small retention basin on the drainage that flows into Etter Creek at Stn 5025 may have decreased incision in this drainage as no knickpoints were found. An additional retention basin built around Stn 5400 would further reduce the water volume flowing downstream. Building retention basins for the remaining five drainages does not appear feasible due to the surrounding topography. To minimize further incision in these drainages, we recommend converting some crop land to native grasses, shrubs, and trees. By creating a native vegetation buffer around these drainages, infiltration will increase and water volumes flowing downstream will decrease.	

	Score	***Notes***
Infrastructure risk	7	Immanent hazard to human health and to farm equipment; farmland is actively eroding
Erosion/channel stability	7	Will improve stability for multiple drainages in the headwaters
Project complexity	3	Permitting, modeling, and earthwork could be complex
Location	7	
Sediment/nutrient loading	7	
Project cost	5	Volunteer labor could be used to plant vegetation
Aesthetic impact	3	
Landowner Cooperation	0	Unknown; multiple landowners
Public Education	3	Not easily accessible; good demonstrative value
Riparian Ecological Benefit	7	

Project Area Photo/Map Location

See photos on next page.

A) Stn 200 on drainage flowing into Trib 9 at Stn 4650: looking upstream at 15-ft knickpoint incising into crops; B) Stn 5650 looking upstream at 13-ft incised channel walls; C) Stn 5675 looking upstream at 13-ft knickpoint; D) Stn 5700 looking upstream at headwaters with no riparian buffer; E) Stn 300 of drainage flowing into Trib 9 at Stn 4250: looking downstream at 6-ft knickpoint at head of drainage about 10 ft from crops.

Potential Project PP 24

Stream: Etter Creek, Tributary 10	Problem description: Excessive bank erosion on the outside of two meander bends. Banks are 10-ft vertical banks composed of compacted silt. Increased bank erosion will increase sedimentation to Etter Creek downstream.
Station: 300-450	
Solution: Re-grade channel banks, stabilize the toe of the banks, and revegetate channel banks with native riparian vegetation.	

	Score	***Notes***
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	5	
Location	7	
Sediment/nutrient loading	1	
Project cost	5	Volunteer labor could be used to plant vegetation
Aesthetic impact	1	
Landowner Cooperation	0	Unknown; multiple landowners
Public Education	1	Not easily accessible
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Left to right: Stn 300 looking upstream at eroding right bank; Stn 400 looking upstream at eroding left bank.

Potential Project **PP 25**

Stream: Etter Creek, Tributary 10	Problem description: At least 9 knickpoints were identified throughout this reach and the associated drainages. These knickpoints are between 1 and 6 ft in height and are likely the result of increased hydrology due to agriculture in the upper portions of the subwatershed. These knickpoints are not threatening to erode crops immediately, but a few of the smaller drainages may eventually incise to cropland. Upstream of Stn 3500, the land has been converted to native grasses and shrubs. This has likely helped slow the knickpoints in this area. Elsewhere, however, there is little buffer between the crops and the edges of the steep hillsides of the drainages leading to increased water flow and headcutting.
Station: 750-4100, including drainages	

Solution: Similar to Tributary 5, a combination of stormwater retention basins and conversion of managed fields to native vegetation is likely the most effective way of diminishing the water volume and minimizing sediment transport. Retention basins could be built near Stn 800 and Stn 3500 of Trib 10 and Stn 500 of the drainage that flows into Trib 10 at Stn 3100. These basins will slow the flow of water and sediment to Etter Creek. To minimize further incision in this subwatershed, we recommend converting some crop land to native grasses, shrubs, and trees. While some land has already been converted, little buffer exists between crops to the south of the channel and the steep hillslopes of the drainages in that area. By creating a native vegetation buffer around these drainages, infiltration will increase and water volumes flowing downstream will decrease.

	Score	***Notes***
Infrastructure risk	3	Cropland may be threatened if incision continues
Erosion/channel stability	5	Will improve stability throughout subwatershed
Project complexity	3	Permitting, modeling, and earthwork could be complex
Location	7	
Sediment/nutrient loading	5	
Project cost	5	Volunteer labor could be used to plant vegetation
Aesthetic impact	1	
Landowner Cooperation	0	Unknown; multiple landowners
Public Education	3	Not easily accessible; good demonstrative value
Riparian Ecological Benefit	7	

Project Area Photo/Map Location

Left to right: Stn 750 looking upstream at 4-ft knickpoint; Stn 1650 looking upstream at 4-ft knickpoint; Stn 4075 looking upstream at 3-ft knickpoint and fallow fields beyond.



Potential Project PP 26

Stream: Etter Creek, Tributary 11	Problem description: Minor erosion is occurring on left side of the upstream end of the concrete culvert that is under 145th Ave. The erosion is nearing the driveway and some effort has been made to reduce the erosion by placing riprap and pouring gravel on the bank. Erosion and piping continue.
Station: 100	
Solution: Regrade the bank, stabilize the toe, and plant shrubs and trees so the longer roots can stabilize the bank. Also, remove the fence post in the middle of the 'channel' as scour is beginning to occur around the base of the post.	

	Score	*Notes*
Infrastructure risk	3	Erosion is about 4 ft from edge of road
Erosion/channel stability	1	
Project complexity	7	
Location	7	
Sediment/nutrient loading	1	
Project cost	7	Volunteer labor could be used to plant vegetation
Aesthetic impact	1	
Landowner Cooperation	0	May be within roadway, though fence likely is not
Public Education	3	Easily accessible
Riparian Ecological Benefit	1	

Project Area Photo/Map Location

Stn 125 looking downstream at culvert and erosion.

Potential Project PP 27

Stream: Etter Creek, Tributary 11	Problem description: A small scour hole has formed in the middle of the grassy field. This could lead to further scour or incision.
Station: 150	
Solution: Convert grassy field to native vegetation including grasses, shrubs, and trees. The increased diversity in vegetation and root length will improve stability throughout the field and will also improve riparian habitat.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	Volunteer labor could be used to plant vegetation
Location	7	
Sediment/nutrient loading	1	
Project cost	7	Volunteer labor could be used to plant vegetation
Aesthetic impact	1	
Landowner Cooperation	0	
Public Education	3	Easily accessible
Riparian Ecological Benefit	3	

Project Area Photo/Map Location

Stn 100 looking upstream at small scour hole in grassy field

Potential Project **PP 28**

Stream: Etter Creek, Tributary 12	Problem description: Three 4-ft knickpoints were identified throughout this reach and the associated drainages. These knickpoints are likely the result of increased hydrology due to agriculture in the upper portions of the subwatershed. These knickpoints are not threatening to erode crops immediately, but a few of the smaller drainages may eventually incise to cropland. The retention basin built at Stn 4000 has likely reduced incision and there are currently no active knickpoints between this basin and the junction with a small drainage at Stn 3200. The three knickpoints, however, appear to be slowly migrating upstream, which could impact side drainages and eventually cropland.
Station: 1000-3300, including drainages	
Solution: Similar to Tributary 5, a combination of stormwater retention basins and conversion of managed fields to native vegetation is likely the most effective way of diminishing the water volume and minimizing sediment transport. Additional retention basins could be build on the drainages that flow into Tributary 12 at Stns 1000, 1600, and 3200. To minimize further incision in this subwatershed, we recommend converting some crop land to native grasses, shrubs, and trees in the vicinity of these three drainages as well as along the southern border of Tributary 12 between Stns 2200 and 3200. By creating a native vegetation buffer around these drainages, infiltration will increase and water volumes flowing downstream will decrease.	

	Score	***Notes***
Infrastructure risk	3	Cropland may be threatened if incision continues
Erosion/channel stability	5	Will improve stability throughout subwatershed
Project complexity	3	Permitting, modeling, and earthwork could be complex
Location	7	
Sediment/nutrient loading	5	
Project cost	5	Volunteer labor could be used to plant vegetation
Aesthetic impact	1	
Landowner Cooperation	0	Unknown; multiple landowners
Public Education	3	Not easily accessible; good demonstrative value
Riparian Ecological Benefit	7	

Project Area Photo/Map Location

Left to right: Stn 2400 looking upstream at 4-ft knickpoint at grass road crossing; Stn 1750 looking upstream at 4-ft knickpoint.

Potential Project **PP 01**

Stream: Ravenna Coulee 1, West Drainage	Problem description: 2-ft knickpoint through silty loam is about 40-50 ft from the edge of the forest line. Upstream, the 'channel' is a mowed swale about 30 ft wide between crops; there is no storage built into this swale, although the opportunity is there. Cobbles have been dumped onto the knickpoint in an attempt to slow its upstream migration. The threat is not great, though it will soon migrate across a farm path. Small knickpoints from further downstream may continue to migrate and continue to incise.
Station: 3100	
Solution: Build storage upstream in the swale not being farmed. Storage can be in the form of a raingarden, meadow, or forested meadow. Alternatively, a grade control structure could be built at the knickpoint, but this would need to be large enough to prevent downstream knickpoints from migrating through.	

	Score	*Notes*
Infrastructure risk	1	
Erosion/channel stability	1	
Project complexity	7	
Location	7	
Sediment/nutrient loading	3	
Project cost	7	
Aesthetic impact	1	
Landowner Cooperation	0	Unknown
Public Education	3	
Riparian Ecological Benefit	1	

Project Area Photo/Map Location

Stn 3050 looking upstream at cobbles dumped onto knickpoint.

Appendix F: Detailed scoring sheet for all potential projects

Stream: Etter Creek and Ravenna Coulee Potential Projects
Location: Dakota County, MN
Client: Vermillion River Watershed Joint Powers Organization

Potential Project - Priority Ranking List

ETTER CREEK

Project Number	Station Number	Primary Project	Secondary Project	*Inf. Risk*	*Channel stability*	*Project Complexity*	*Location*	*Sed/Nutrient Loading*	*Cost*	*Aesthetic impact*	*Landowner Cooperatio*	*Public Education*	*Riparian Ecological*	*Total Score*
Bank Stabilization														
PP10	26,950-27,050	B		5	1	5	7	3	5	1	7	3	3	**40**
PP15	28,650	B		5	1	5	7	1	5	3	7	3	3	**40**
PP07	21,500-23,200	B	R	3	5	3	5	5	3	1	0	3	5	**33**
PP06	20,350-20,600	B		1	3	7	5	3	7	1	0	1	3	**31**
PP13	27,625-27,675	B		3	1	5	7	1	5	3	0	3	3	**31**
PP03	15,600-15,750	B		3	1	7	3	3	7	1	0	1	1	**27**
PP02	6150	B		1	1	7	1	3	7	1	0	1	3	**25**
Culvert or Other Crossing														
PP14	28,050	C		7	1	3	7	1	5	3	7	5	1	**40**
PP09	26,150	C		3	1	7	7	1	7	1	7	3	1	**38**
PP11	27,450	C	B	5	1	5	7	1	5	3	0	3	3	**33**
PP01	4050	C		3	1	3	1	1	5	3	7	3	1	**28**
Floodplain Management														
PP05	18,600-20,000	F	R	5	3	7	5	7	7	7	0	5	5	**51**
PP08	21,950	F	R	1	3	7	5	3	7	1	0	1	1	**29**
Riparian Management														
PP12	27,450-27,700	R		1	1	7	7	3	7	3	0	3	3	**35**
PP04	16,000-16,400	R		1	3	7	3	3	7	1	0	1	3	**29**

ETTER CREEK TRIBUTARIES

Project Number	Station Number	Primary Project	Secondary Project	*Inf. Risk*	*Channel stability*	*Project Complexity*	*Location*	*Sed/Nutrient Loading*	*Cost*	*Aesthetic impact*	*Landowner Cooperatio*	*Public Education*	*Riparian Ecological*	*Total Score*
Bank Stabilization														
PP24-Trib 10	300-450	B		1	1	5	7	1	5	1	0	1	3	**25**
Culvert or Other Crossing														
PP26-Trib 11	100	C		3	1	7	7	1	7	1	0	3	1	**31**
Floodplain Management														
PP23-Trib 9	2300-5800	F	R	7	7	3	7	7	5	3	0	3	7	**49**
PP18-Trib 4	3900	F	R	1	5	7	5	7	7	5	0	5	5	**47**
PP19-Trib 5	0-7700	F	R	3	7	1	5	7	1	7	0	7	7	**45**
PP21-Trib 8	1500-5800	F	R	3	5	3	7	5	5	3	0	5	3	**39**
PP25-Trib 10	750-4100	F	R	3	5	3	7	5	5	1	0	3	7	**39**
PP28-Trib 12	1000-3300	F	R	3	5	3	7	5	5	1	0	3	7	**39**
PP20-Trib 6	4400-4450	F	R	3	5	3	5	5	5	3	0	3	3	**35**
Grade Control														
PP16-Trib 4	2600	G		3	5	3	3	5	5	3	0	5	1	**33**
PP22-Trib 9	450	G		3	3	5	7	3	5	1	0	1	3	**31**
Riparian Management														
PP17-Trib 4	[illegible] on North Drainage	R	F	1	5	7	5	7	7	7	0	5	5	**49**
PP27-Trib 11	150	R		1	1	7	7	1	7	1	0	3	3	**31**

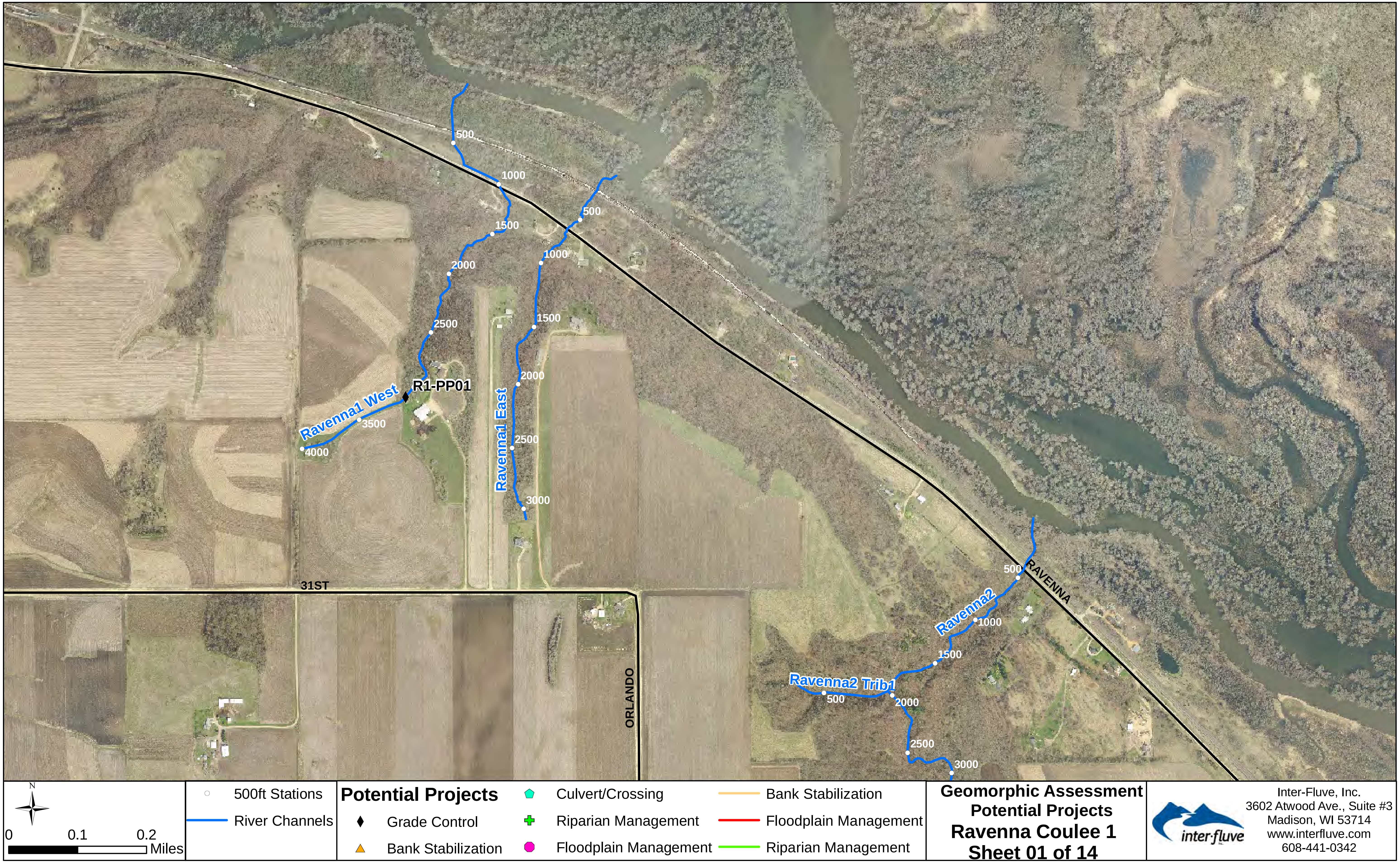
RAVENNA COULEES

Ravenna Coulee 1, West Drainage, PP01	3100	G		1	1	7	7	3	7	1	0	3	1	**31**

Project type

B Bank stabilization
C Culvert or other crossing
F Floodplain management
G Grade control
R Riparian management

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



Ravenna1 West
R1-PP01
Ravenna1 East
Ravenna2
Ravenna2 Trib1
31ST
ORLANDO
RAVENNA
500
1000
1500
2000
2500
3000
3500
4000
N
0
0.1
0.2
Miles
500ft Stations
River Channels
Potential Projects
Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management
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Potential Projects
Ravenna Coulee 1
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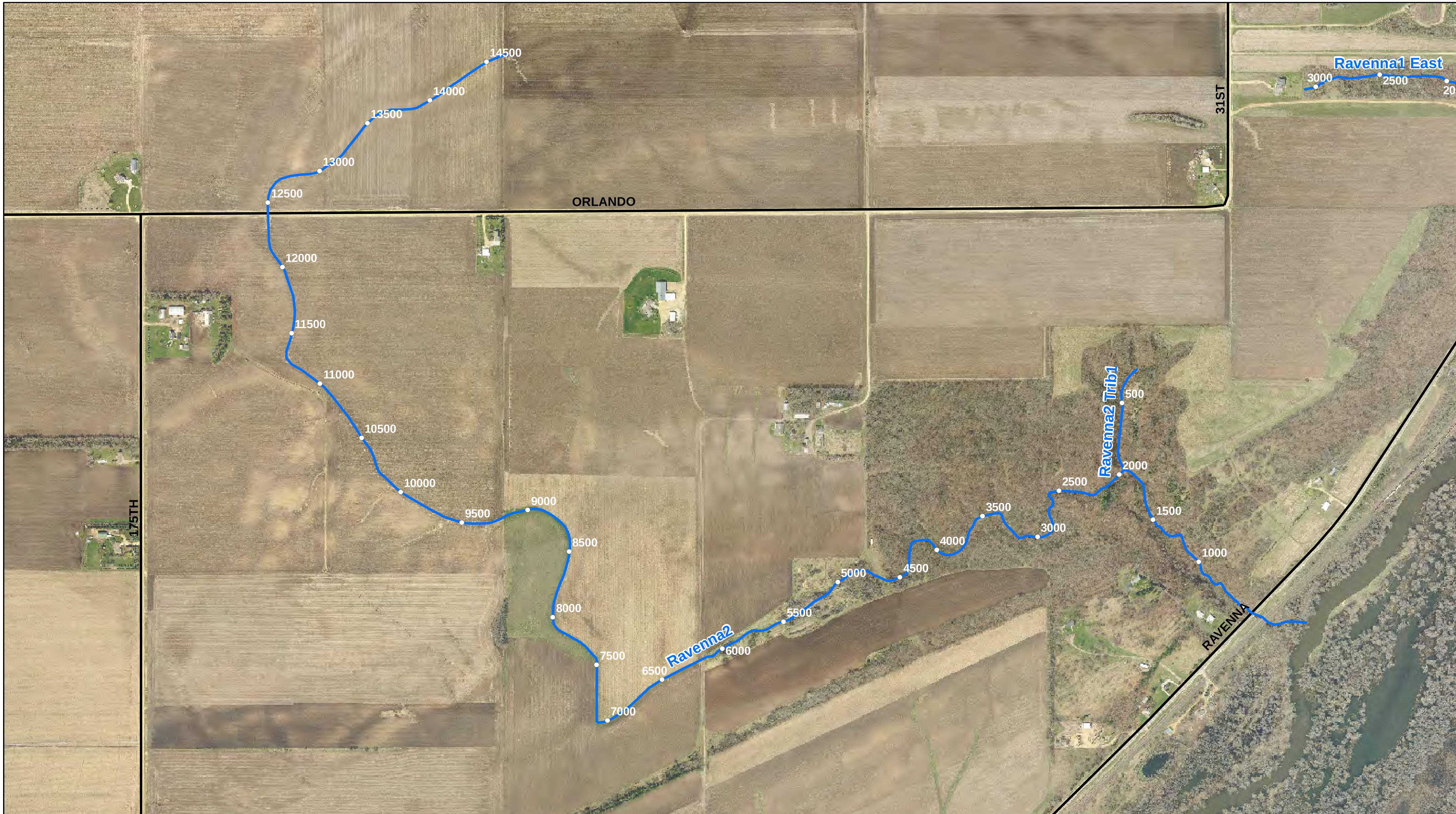

0 0.1 0.2 Miles

○ 500ft Stations
River Channels

Potential Projects

Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

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Ravenna Coulee 3
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0 0.1 0.2 Miles

○ 500ft Stations
River Channels

Potential Projects

Grade Control	Culvert/Crossing	Bank Stabilization
Bank Stabilization	Riparian Management	Floodplain Management
	Floodplain Management	Riparian Management

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Potential Projects
Ravenna Coulee 3
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N	500ft Stations	**Potential Projects**	
0 0.1 0.2 Miles	River Channels	Grade Control	Riparian Management
		Bank Stabilization	Floodplain Management
		Culvert/Crossing	Bank Stabilization
			Floodplain Management
			Riparian Management

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500ft Stations
River Channels

Potential Projects

Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

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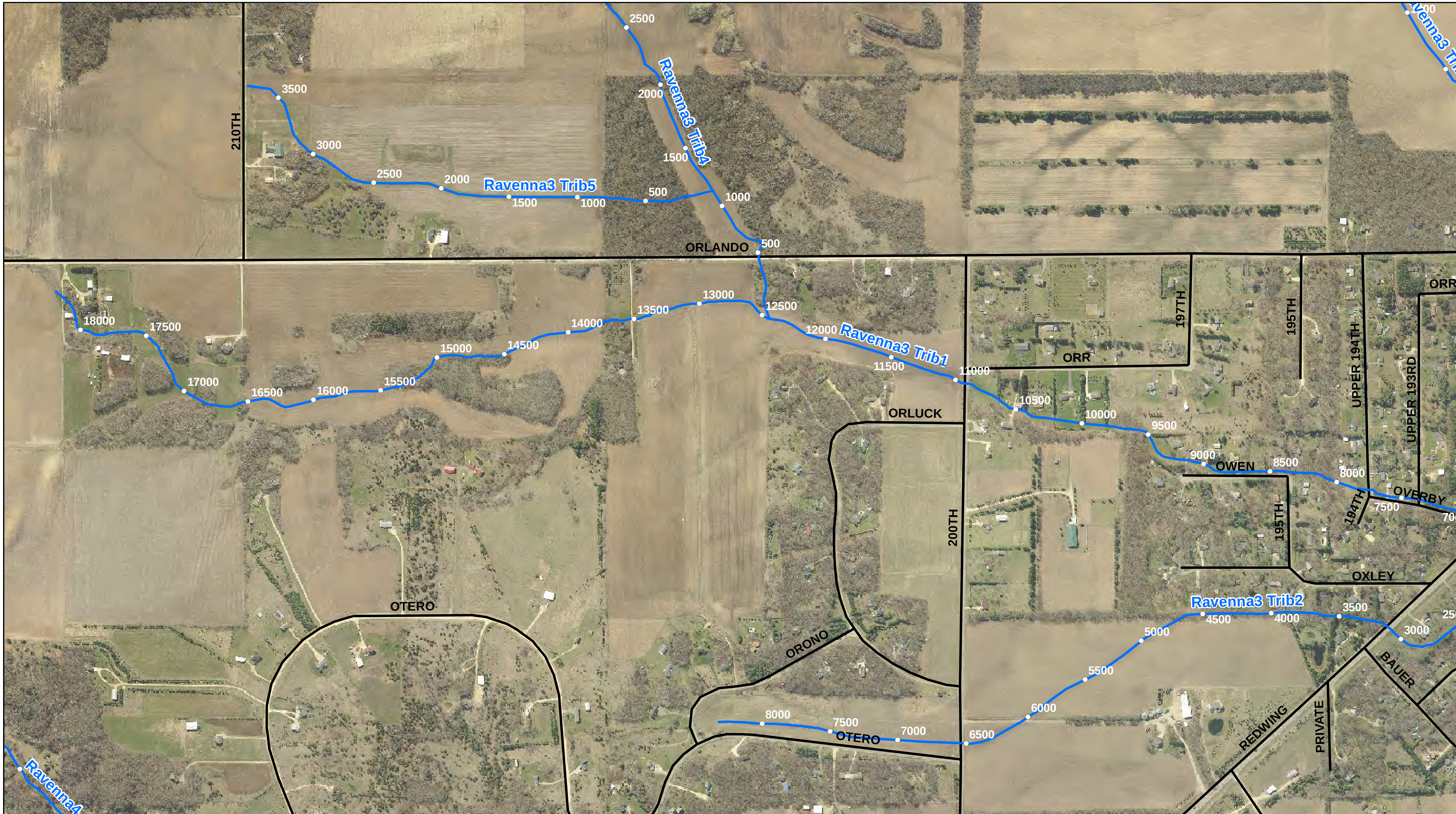

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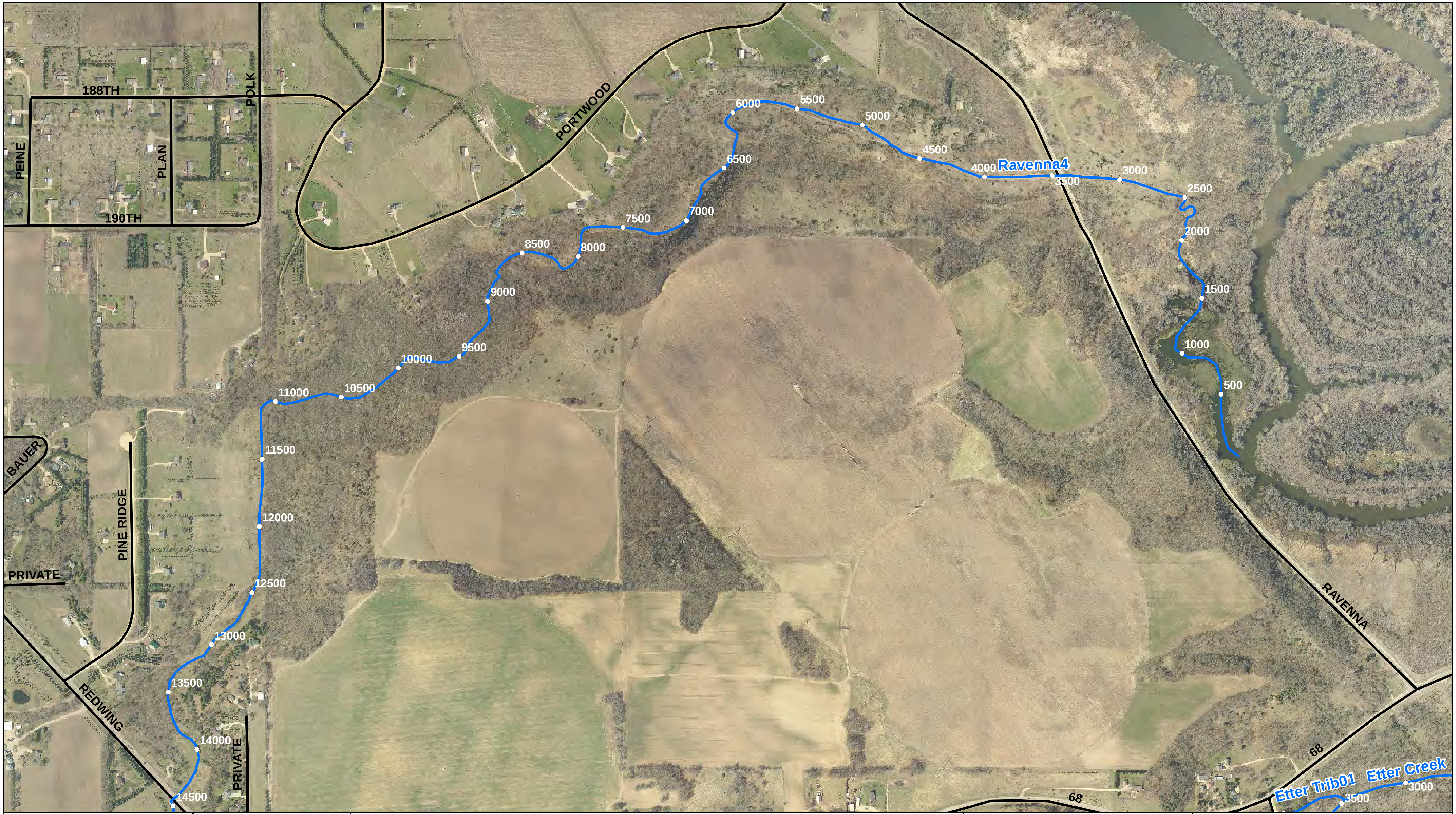

N

0 0.1 0.2 Miles

500ft Stations
River Channels

Potential Projects

Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

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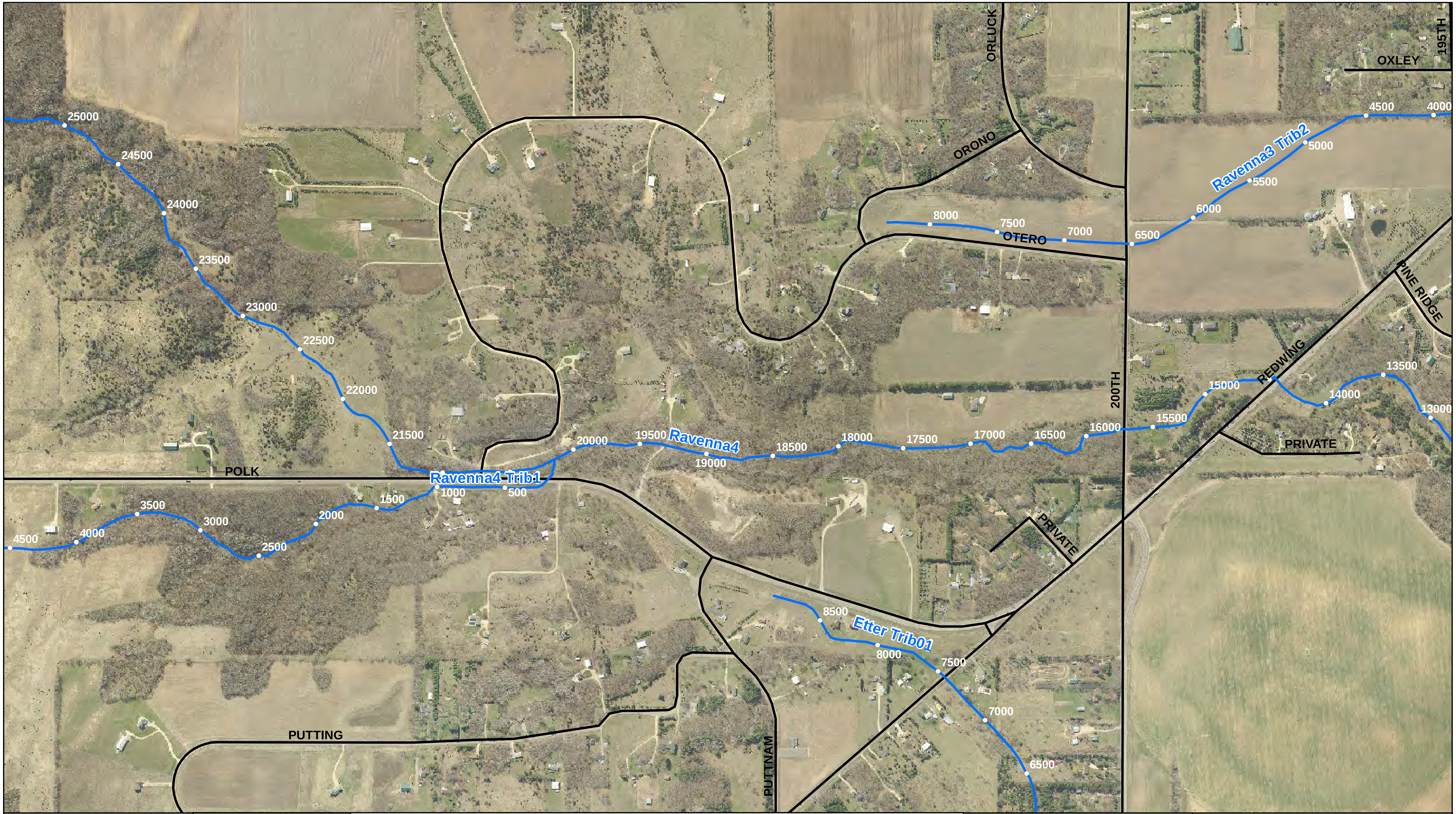

0 0.1 0.2 Miles

500ft Stations
River Channels

Potential Projects

Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

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Potential Projects
Ravenna Coulee 4
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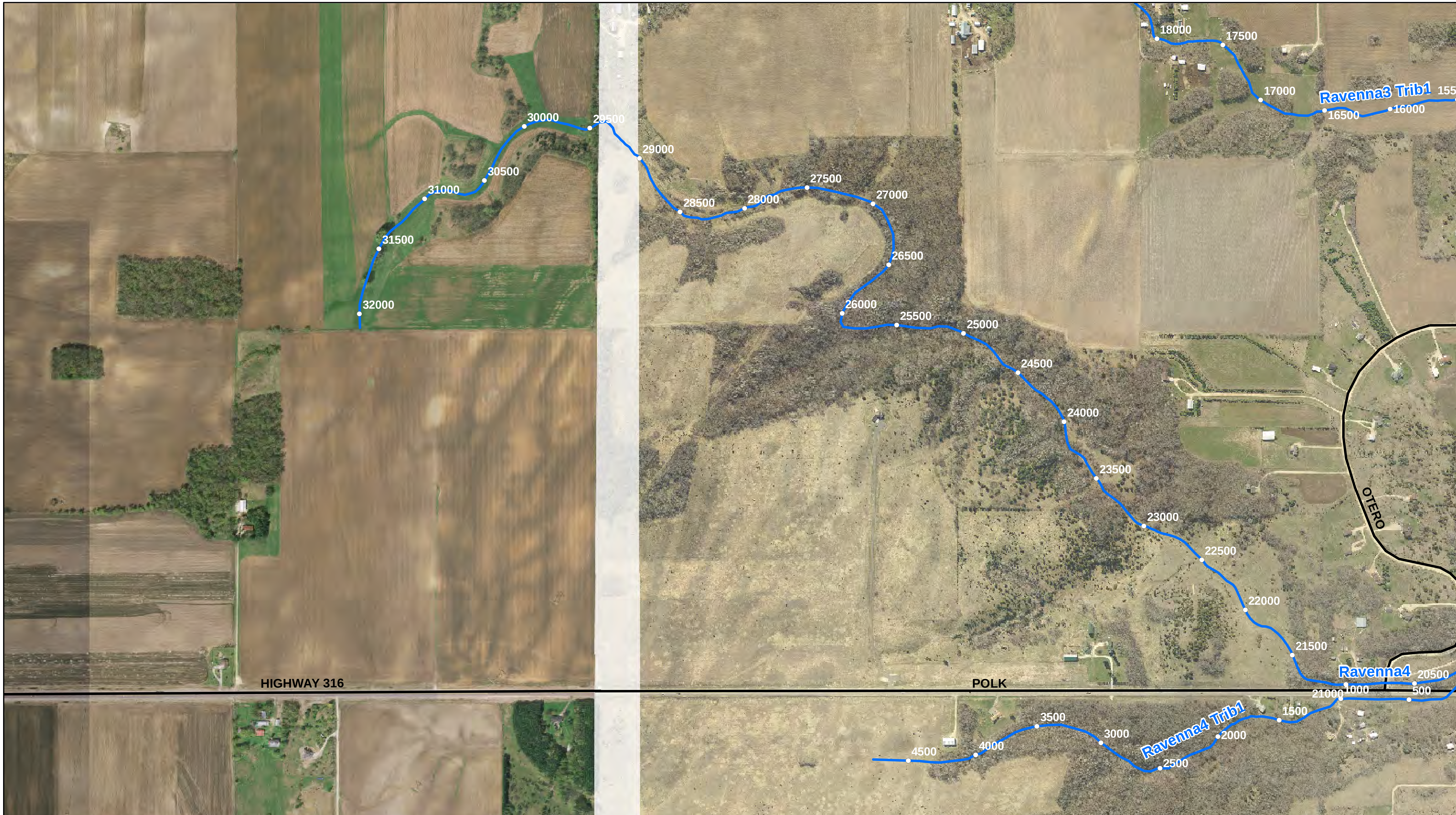

500ft Stations	**Potential Projects**	Culvert/Crossing	Bank Stabilization
River Channels	Grade Control	Riparian Management	Floodplain Management
	Bank Stabilization	Floodplain Management	Riparian Management

0 0.1 0.2 Miles

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Ravenna Coulee 4
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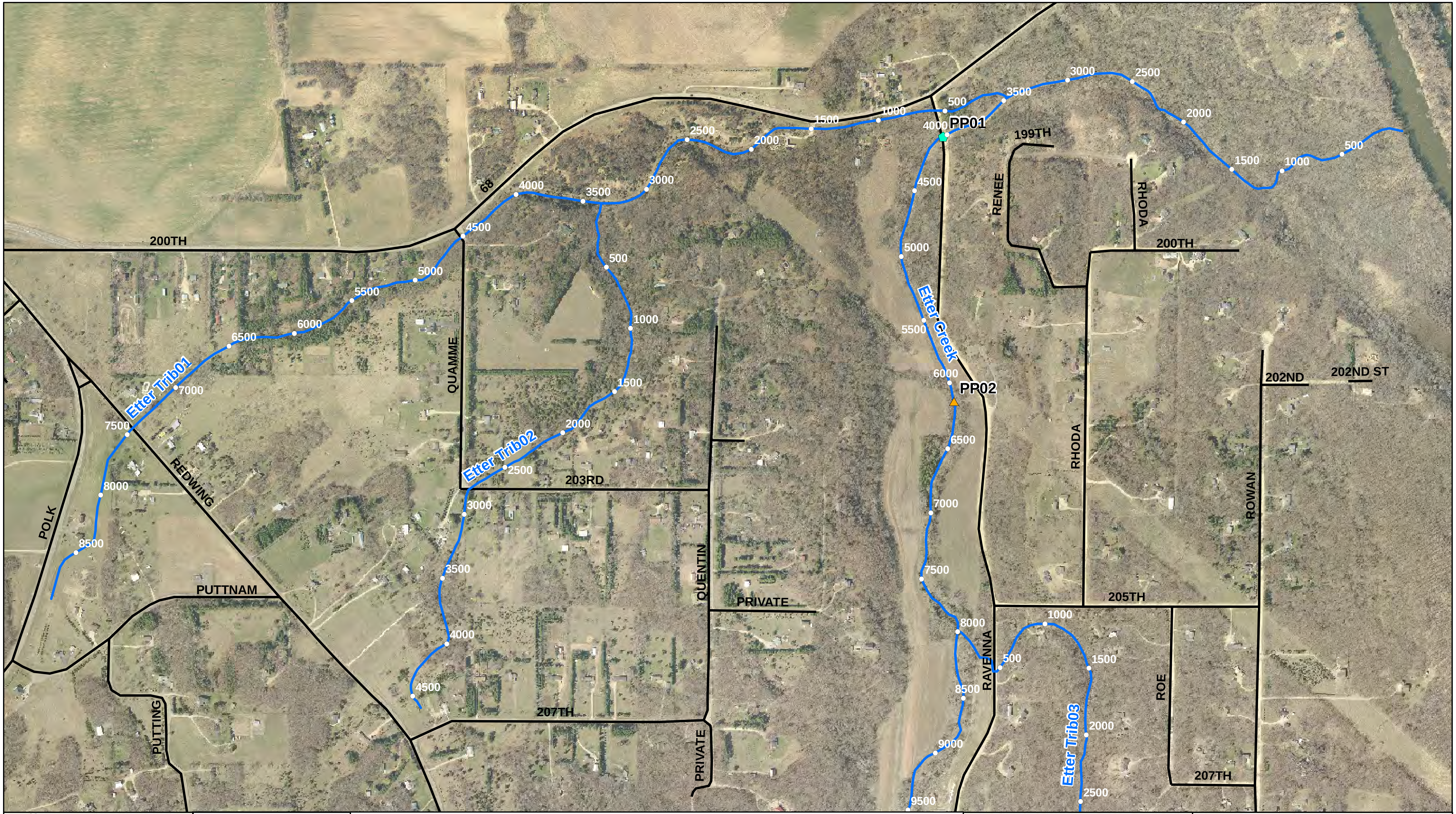

N

0 0.1 0.2 Miles

500ft Stations

River Channels

Potential Projects

Grade Control

Bank Stabilization

Culvert/Crossing

Riparian Management

Floodplain Management

Bank Stabilization

Floodplain Management

Riparian Management

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Potential Projects
Etter Creek
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500ft Stations	Potential Projects		
River Channels	Grade Control	Culvert/Crossing	Bank Stabilization
	Bank Stabilization	Riparian Management	Floodplain Management
		Floodplain Management	Riparian Management

0 0.1 0.2 Miles

Geomorphic Assessment Potential Projects
Etter Creek
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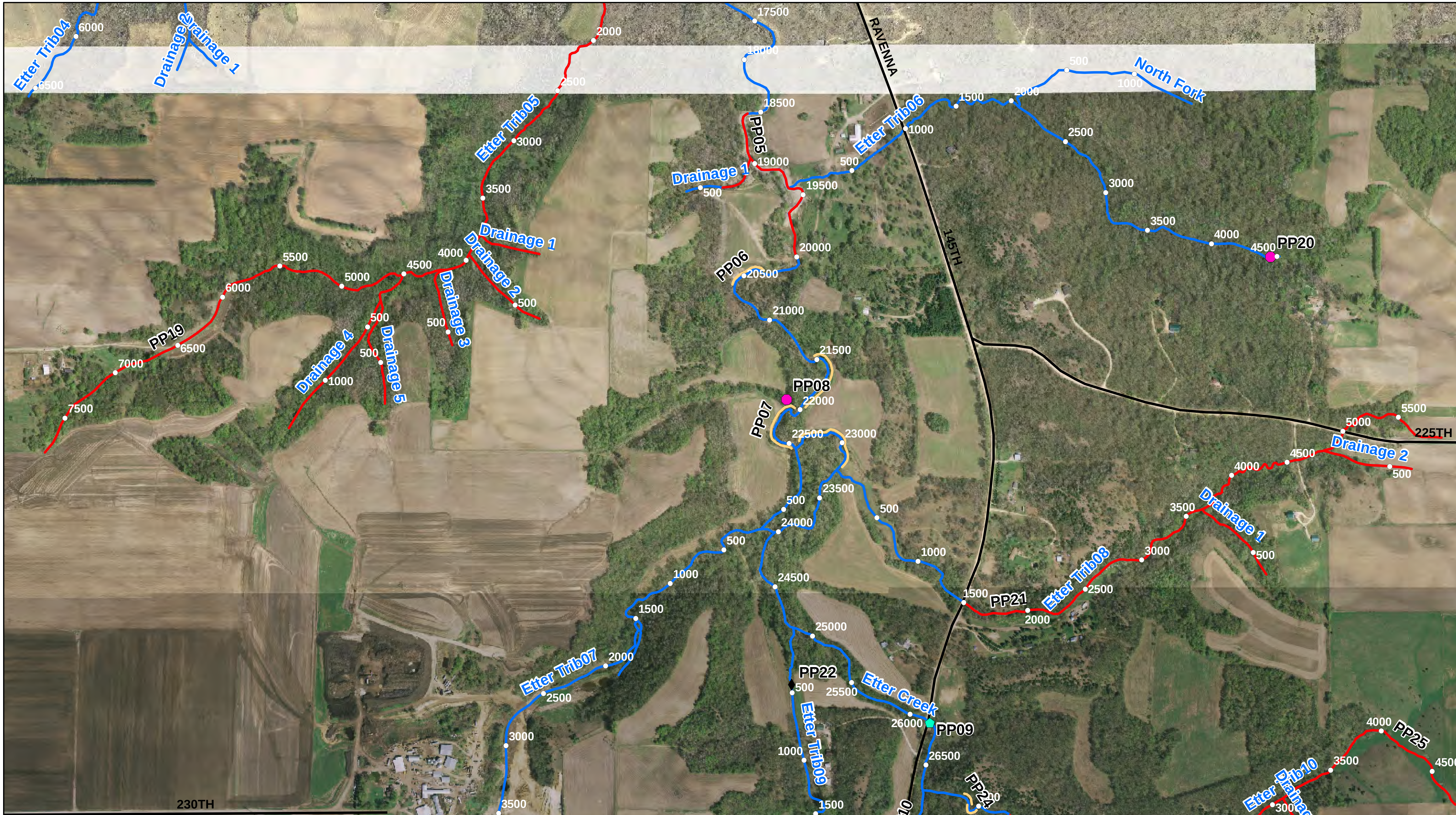
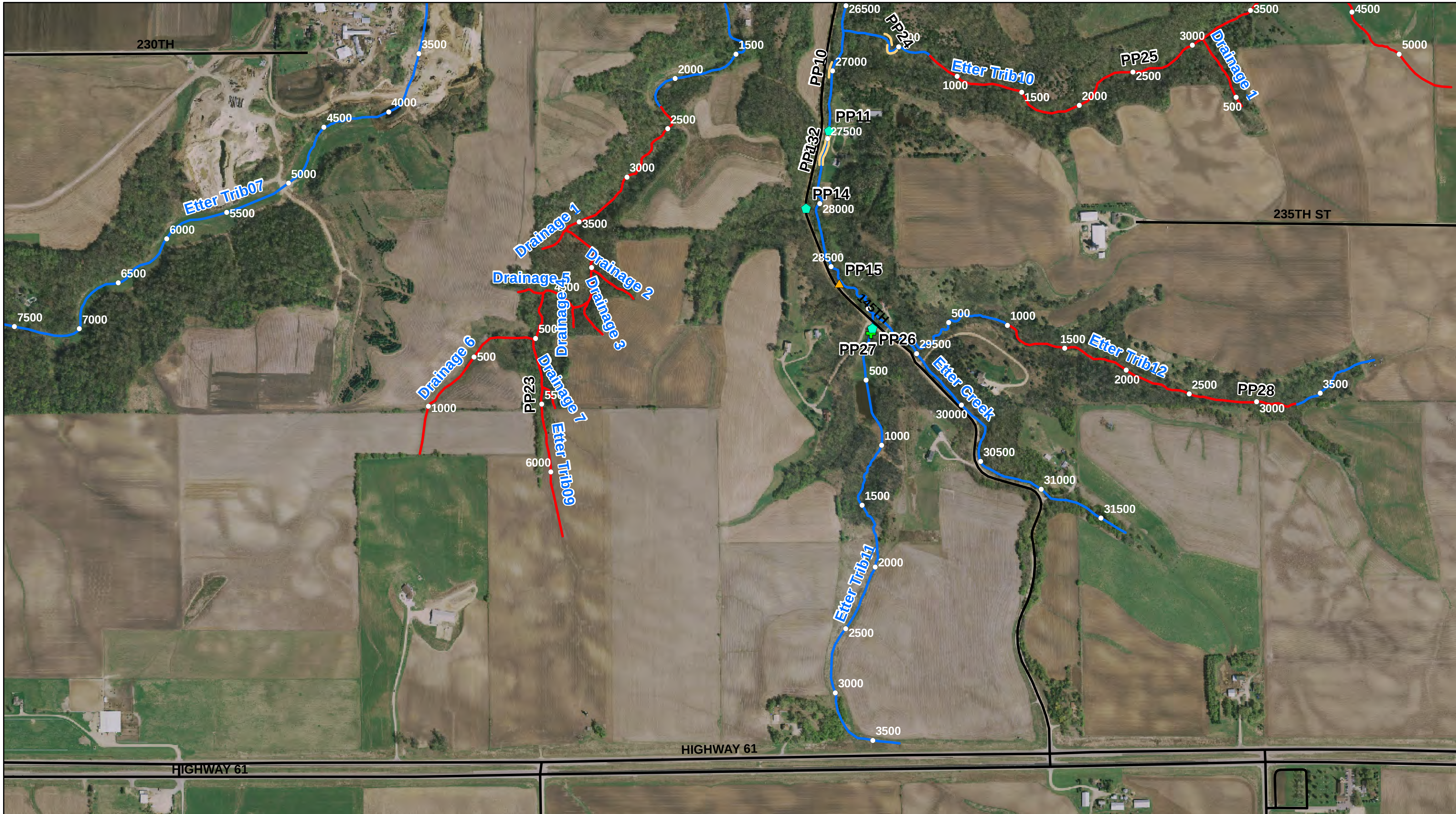


N	○ 500ft Stations	**Potential Projects**	Culvert/Crossing	Bank Stabilization	**Geomorphic Assessment Potential Projects Etter Creek Sheet 13 of 14**	Inter-Fluve, Inc. 3602 Atwood Ave., Suite #3 Madison, WI 53714 www.interfluve.com 608-441-0342
0 0.1 0.2 Miles	River Channels	Grade Control	Riparian Management	Floodplain Management		
		Bank Stabilization	Floodplain Management	Riparian Management		



○ 500ft Stations	**Potential Projects**	Culvert/Crossing	Bank Stabilization
River Channels	Grade Control	Riparian Management	Floodplain Management
	Bank Stabilization	Floodplain Management	Riparian Management

N

0 0.1 0.2 Miles

Geomorphic Assessment
Potential Projects
Etter Creek
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Appendix H: Detailed maps of knickpoints, potential projects, and proposed and existing retention basins. White numbers are 500ft stationing along the channel centerline; black numbers in a white halo are the height of each knickpoint.

500ft Stations	**Knickpoint Activity**	**Potential Projects**	Culvert/Crossing	Bank Stabilization
River Channels	High	Grade Control	Riparian Management	Floodplain Management
Existing Retention Basins	Moderate	Bank Stabilization	Floodplain Management	Riparian Management
Proposed Retention Basins	Low			
	None			

N

0 0.1 0.2 Miles

Geomorphic Assessment
Knickpoint Activity
Ravenna Coulee 1
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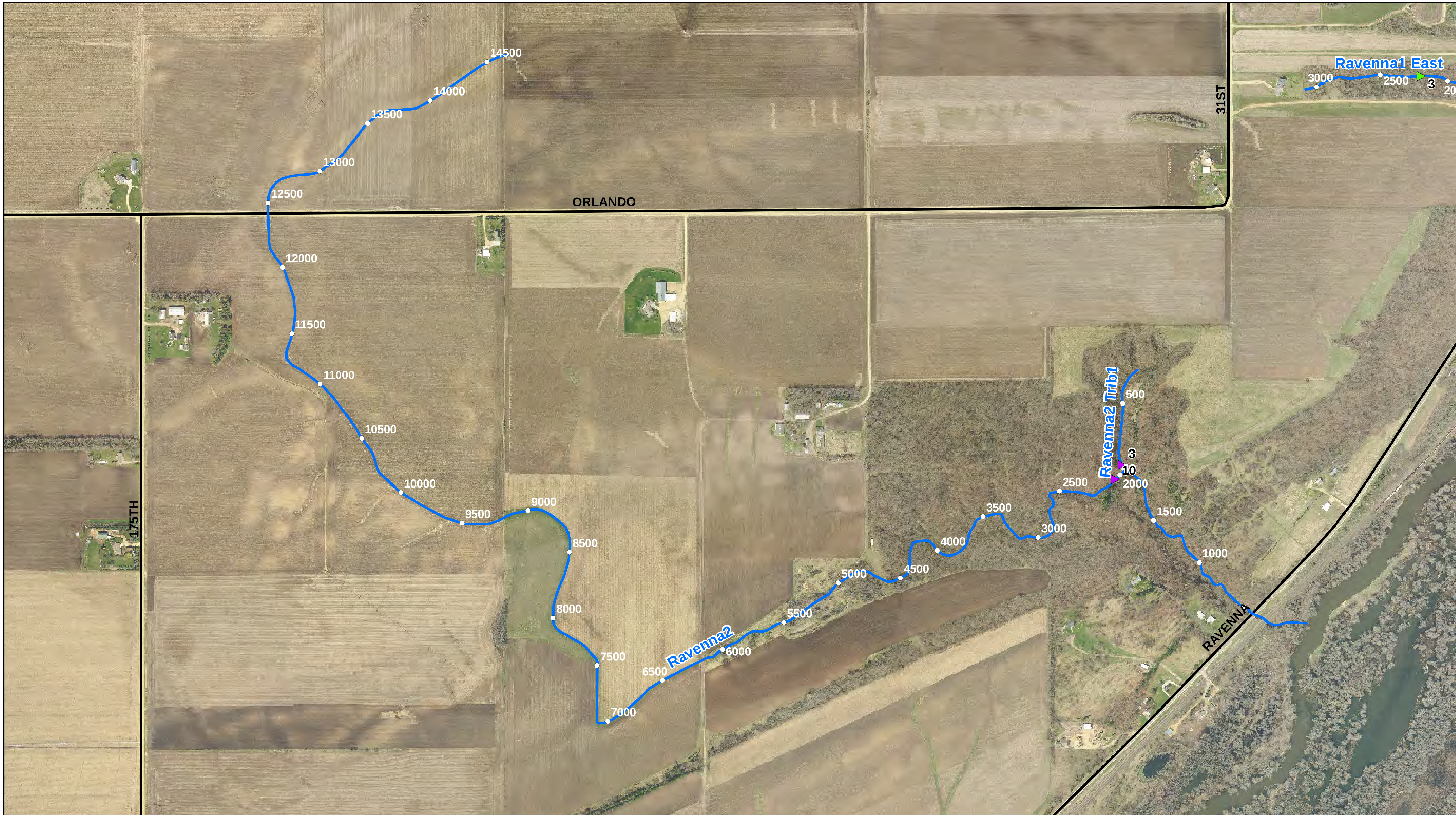

N

0 0.1 0.2 Miles

○	500ft Stations
—	River Channels
●	Existing Retention Basins
●	Proposed Retention Basins

Knickpoint Activity

- ▲ High
- ▲ Moderate
- ▲ Low
- ▲ None

Potential Projects

- ♦ Grade Control
- ▲ Bank Stabilization
- ⬟ Culvert/Crossing
- ✚ Riparian Management
- ● Floodplain Management
- — Bank Stabilization
- — Floodplain Management
- — Riparian Management

Geomorphic Assessment
Knickpoint Activity
Ravenna Coulee 2
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N

0 0.1 0.2 Miles

500ft Stations
River Channels
Existing Retention Basins
Proposed Retention Basins

Knickpoint Activity
High
Moderate
Low
None

Potential Projects
Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

Geomorphic Assessment Knickpoint Activity Ravenna Coulee 3 Sheet 03 of 14

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0 0.1 0.2 Miles

500ft Stations
River Channels
Existing Retention Basins
Proposed Retention Basins

Knickpoint Activity
High
Moderate
Low
None

Potential Projects
Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

Geomorphic Assessment
Knickpoint Activity
Ravenna Coulee 3
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500ft Stations
River Channels
Existing Retention Basins
Proposed Retention Basins

Knickpoint Activity
High
Moderate
Low
None

Potential Projects
Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

Geomorphic Assessment
Knickpoint Activity
Ravenna Coulee 3
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N

0 0.1 0.2 Miles

500ft Stations
River Channels
Existing Retention Basins
Proposed Retention Basins

Knickpoint Activity
High
Moderate
Low
None

Potential Projects
Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

Geomorphic Assessment
Knickpoint Activity
Ravenna Coulee 3
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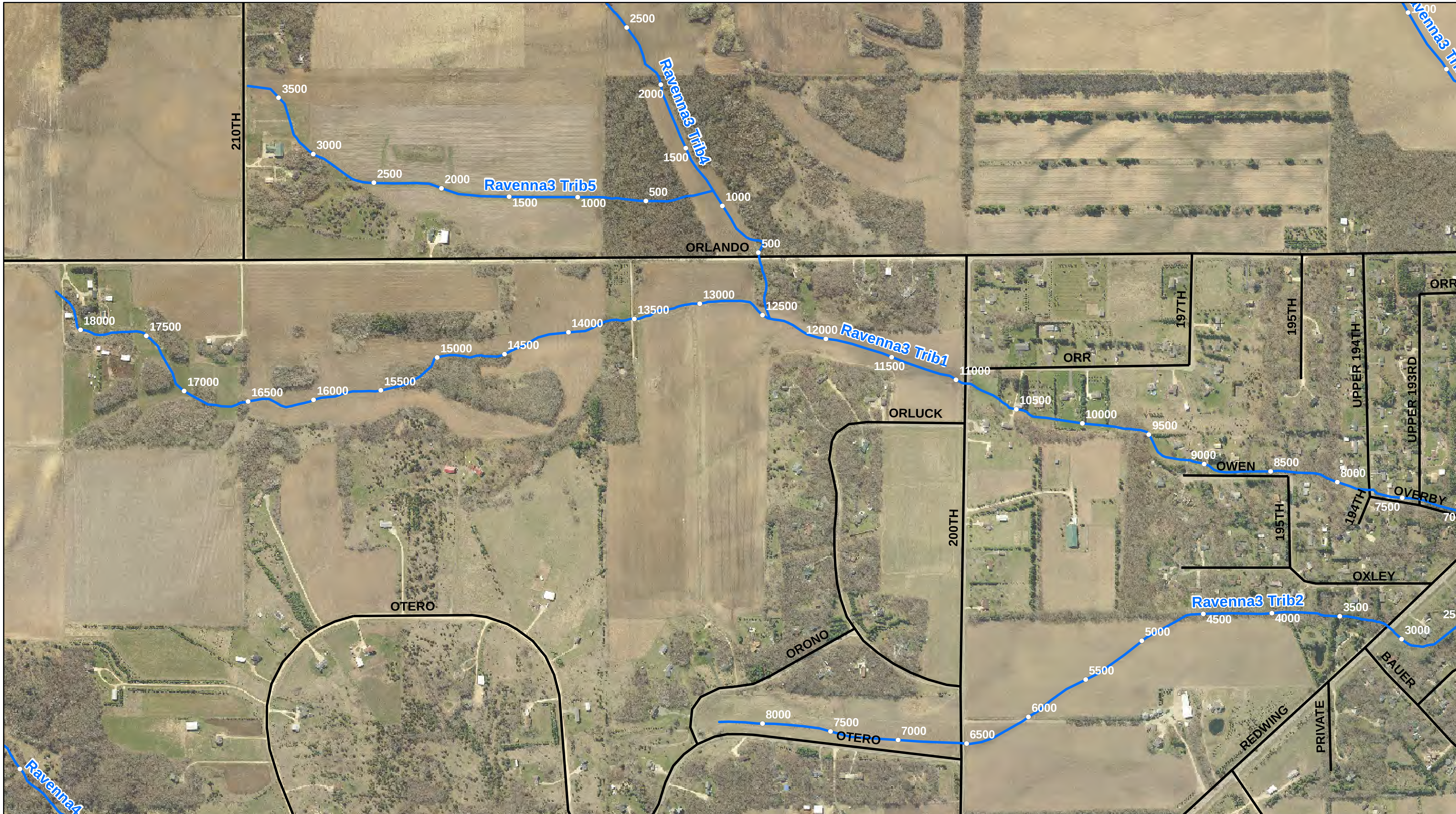

N

0 0.1 0.2 Miles

○ 500ft Stations
River Channels
Existing Retention Basins
Proposed Retention Basins

Knickpoint Activity
- High
- Moderate
- Low
- None

Potential Projects
- Grade Control
- Bank Stabilization
- Culvert/Crossing
- Riparian Management
- Floodplain Management
- Bank Stabilization
- Floodplain Management
- Riparian Management

Geomorphic Assessment
Knickpoint Activity
Ravenna Coulee 3
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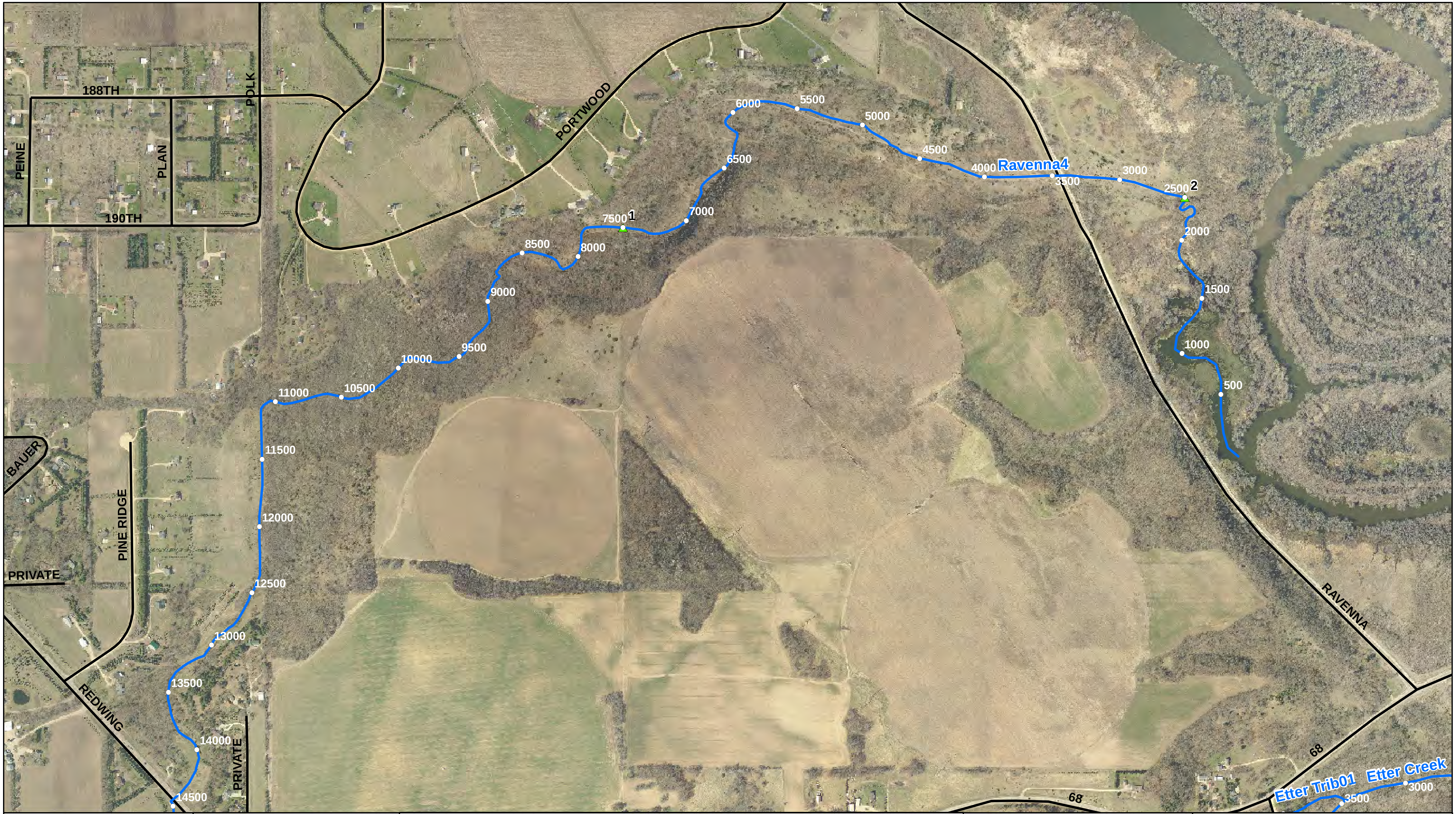

N

0 0.1 0.2 Miles

- 500ft Stations
- River Channels
- Existing Retention Basins
- Proposed Retention Basins

Knickpoint Activity
- High
- Moderate
- Low
- None

Potential Projects
- Grade Control
- Bank Stabilization
- Culvert/Crossing
- Riparian Management
- Floodplain Management
- Bank Stabilization
- Floodplain Management
- Riparian Management

Geomorphic Assessment
Knickpoint Activity
Ravenna Coulee 4
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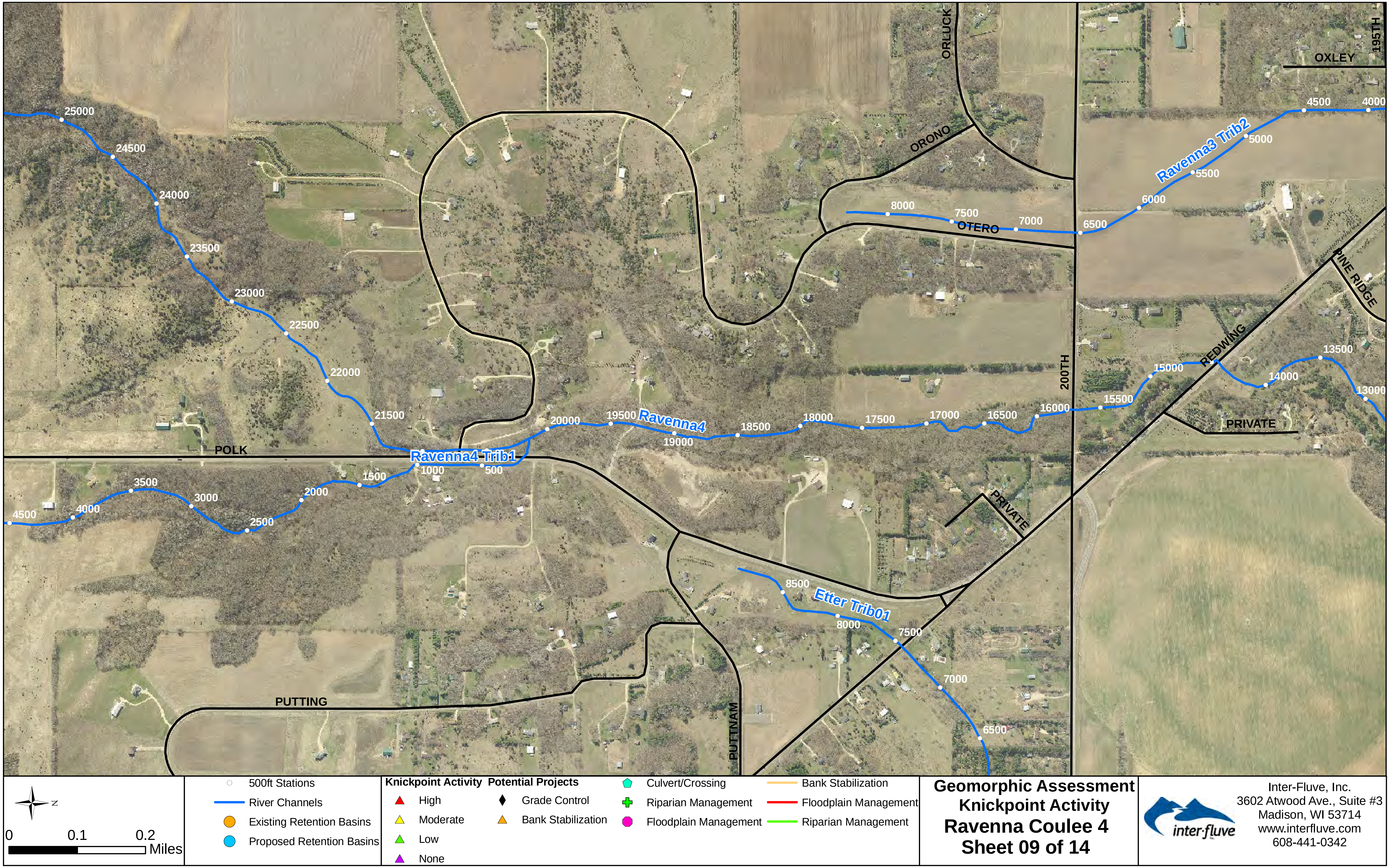

500ft Stations	**Knickpoint Activity**	**Potential Projects**	Culvert/Crossing
River Channels	High	Grade Control	Riparian Management
Existing Retention Basins	Moderate	Bank Stabilization	Floodplain Management
Proposed Retention Basins	Low		
	None		

Bank Stabilization
Floodplain Management
Riparian Management

Geomorphic Assessment
Knickpoint Activity
Ravenna Coulee 4
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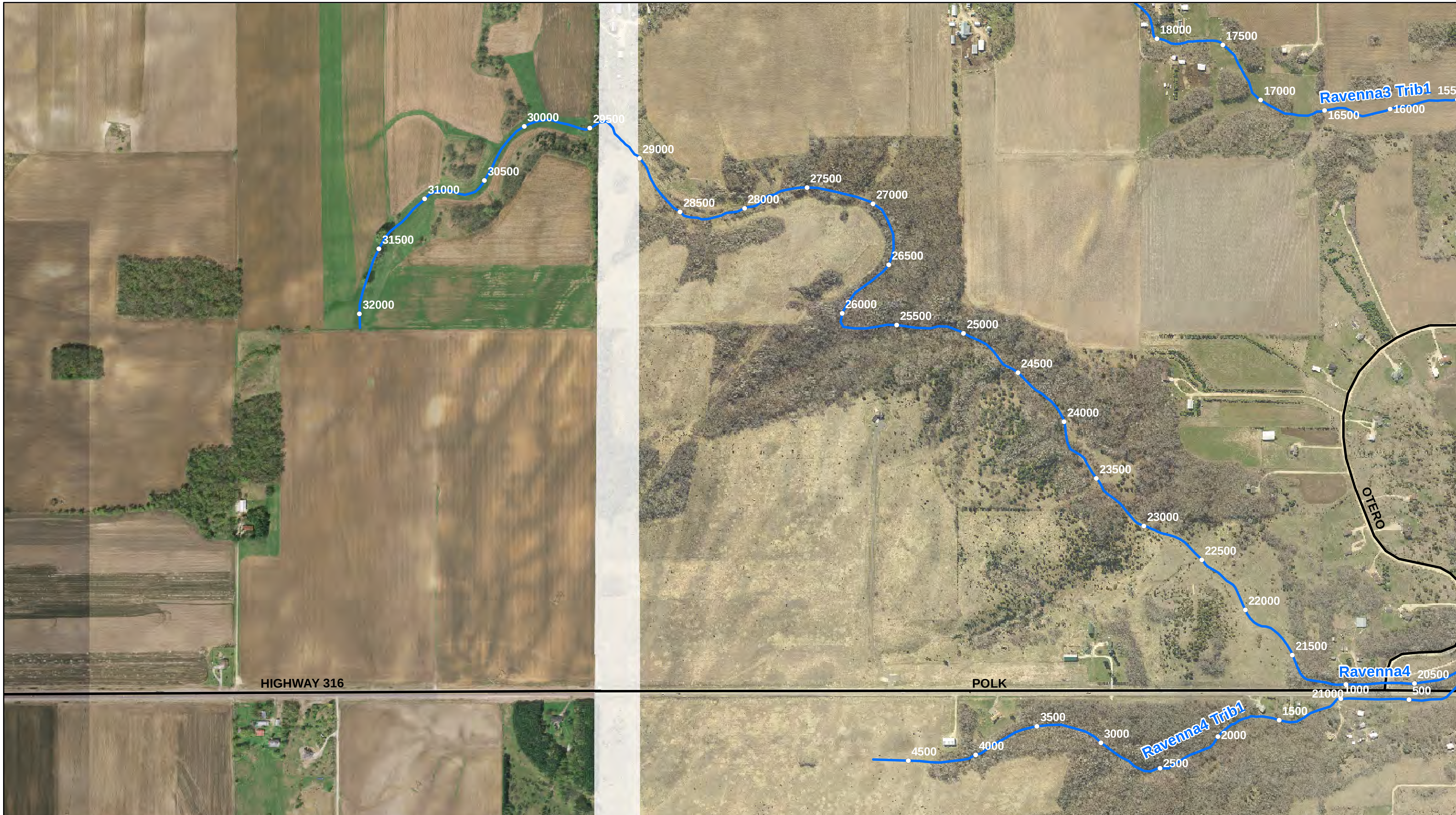

0 0.1 0.2 Miles

500ft Stations
River Channels
Existing Retention Basins
Proposed Retention Basins

Knickpoint Activity
High
Moderate
Low
None

Potential Projects
Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

Geomorphic Assessment Knickpoint Activity Ravenna Coulee 4 Sheet 10 of 14

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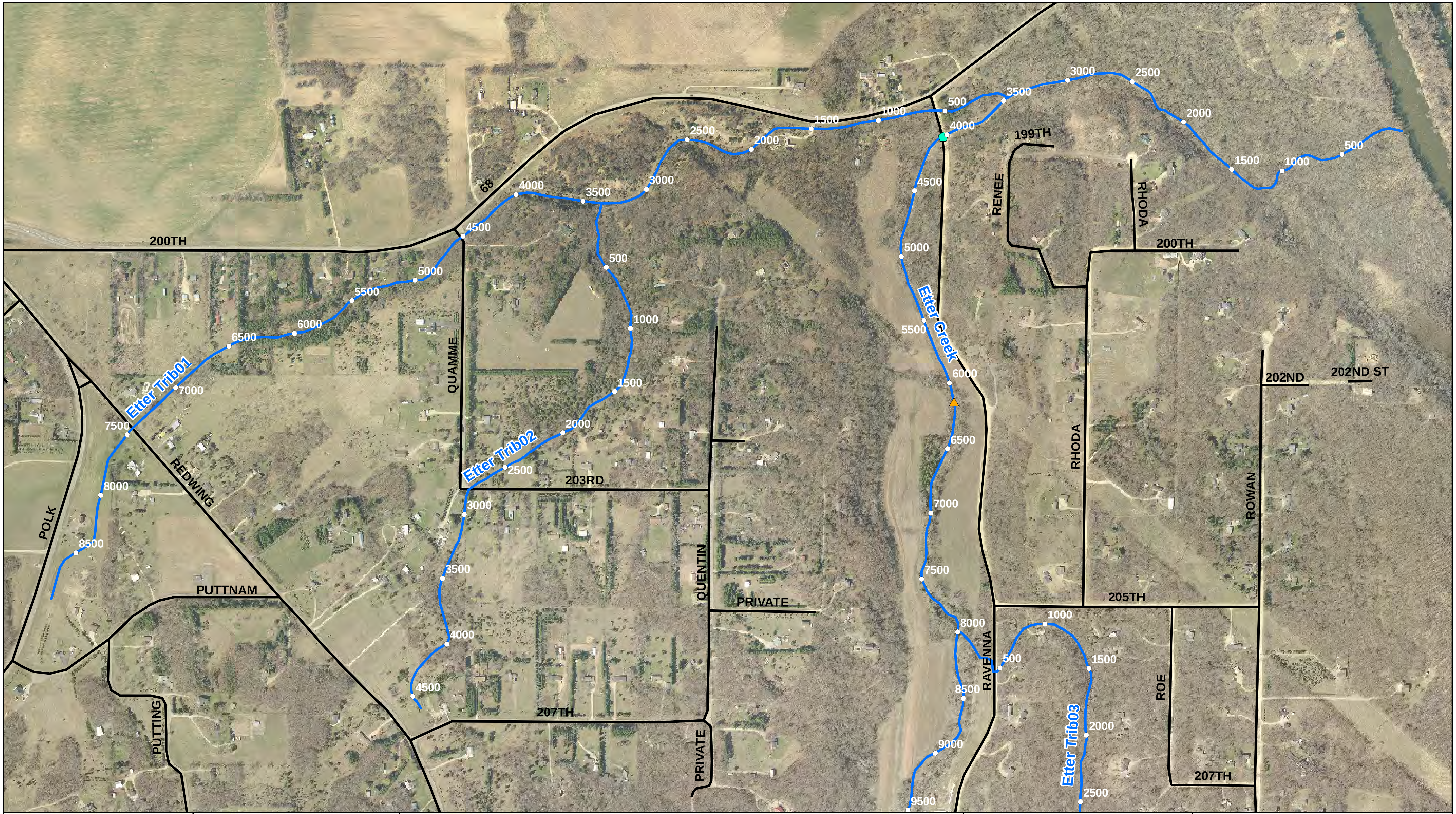

N

0 0.1 0.2 Miles

500ft Stations	**Knickpoint Activity**	**Potential Projects**	Culvert/Crossing	Bank Stabilization
River Channels	High	Grade Control	Riparian Management	Floodplain Management
Existing Retention Basins	Moderate	Bank Stabilization	Floodplain Management	Riparian Management
Proposed Retention Basins	Low			
	None			

Geomorphic Assessment
Knickpoint Activity
Etter Creek
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500ft Stations	**Knickpoint Activity**	**Potential Projects**	Culvert/Crossing
River Channels	High	Grade Control	Riparian Management
Existing Retention Basins	Moderate	Bank Stabilization	Floodplain Management
Proposed Retention Basins	Low		Bank Stabilization
	None		Floodplain Management
			Riparian Management

Geomorphic Assessment
Knickpoint Activity
Etter Creek
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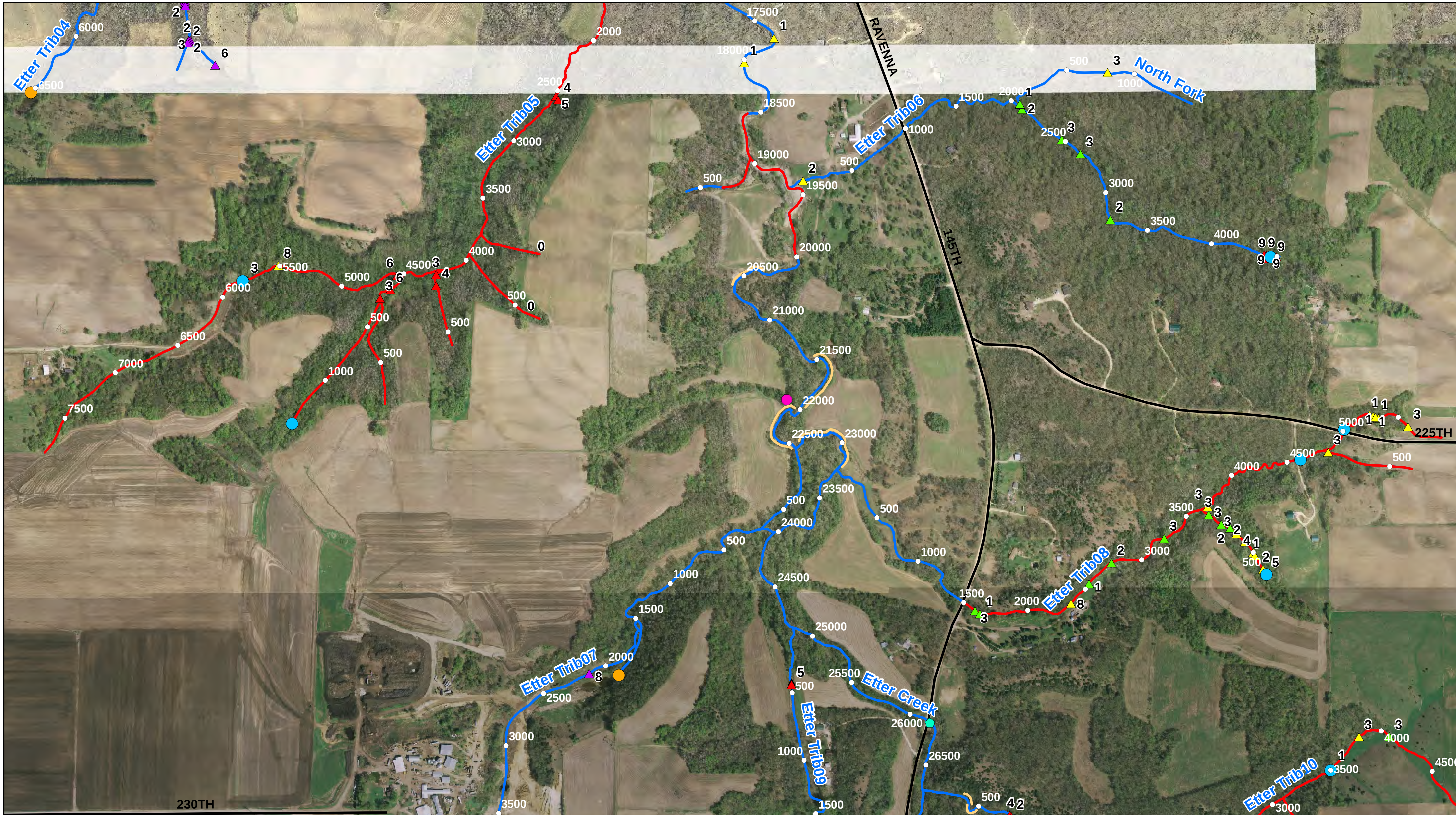

N

0 0.1 0.2 Miles

500ft Stations
River Channels
Existing Retention Basins
Proposed Retention Basins

Knickpoint Activity
High
Moderate
Low
None

Potential Projects
Grade Control
Bank Stabilization
Culvert/Crossing
Riparian Management
Floodplain Management
Bank Stabilization
Floodplain Management
Riparian Management

Geomorphic Assessment Knickpoint Activity Etter Creek Sheet 13 of 14

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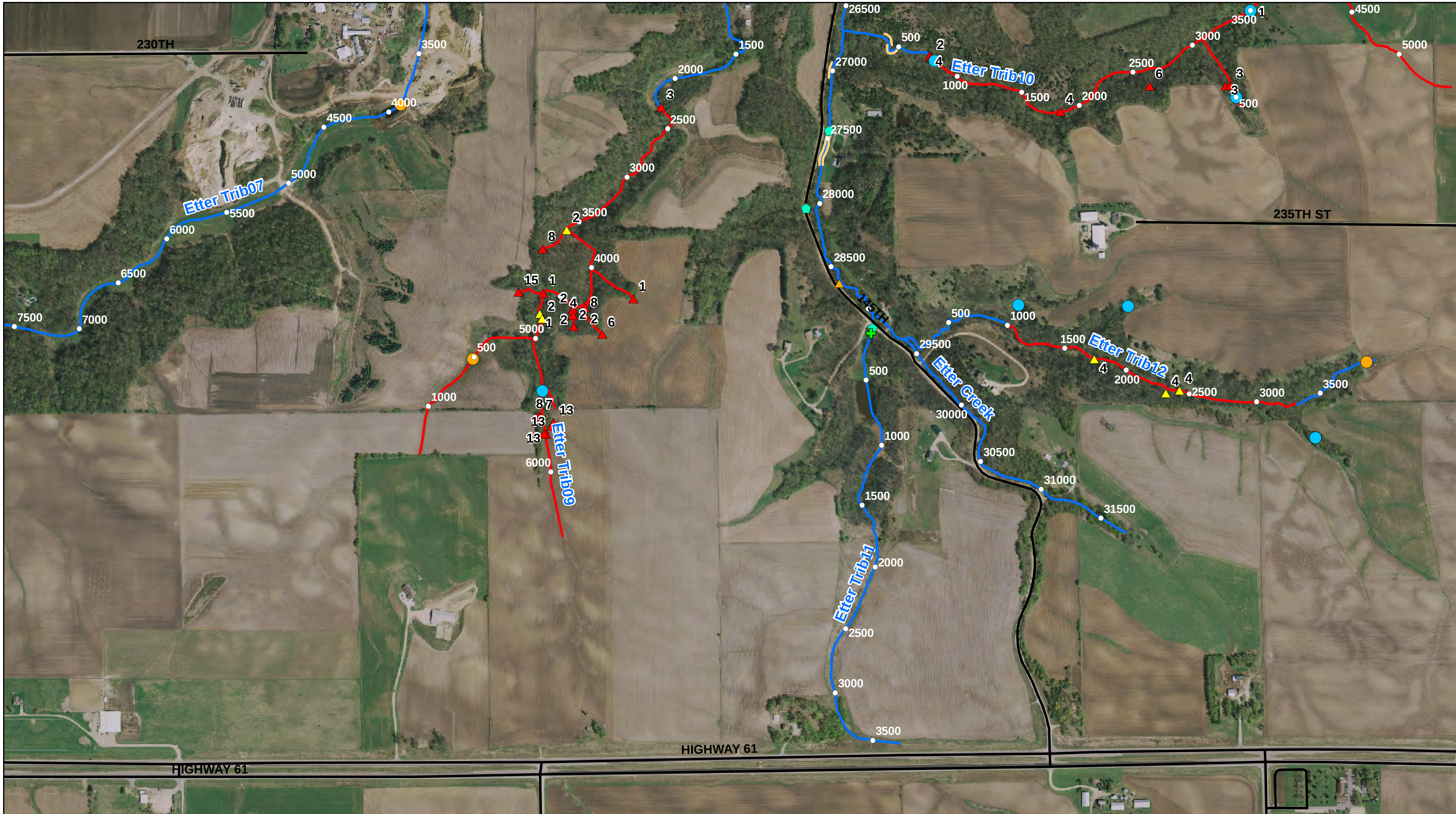

N

0 0.1 0.2 Miles

500ft Stations	**Knickpoint Activity**	**Potential Projects**	Culvert/Crossing
River Channels	High	Grade Control	Riparian Management
Existing Retention Basins	Moderate	Bank Stabilization	Floodplain Management
Proposed Retention Basins	Low		Bank Stabilization
	None		Floodplain Management
			Riparian Management

Geomorphic Assessment
Knickpoint Activity
Etter Creek
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