Geomorphic Monitoring Plan for the Fargo-Moorhead Metropolitan Area Flood Risk Management Project

Attachment B of the Draft Adaptive Management and Mitigation Plan

November 2022

1. GEOMORPHIC MONITORING PLAN OVERVIEW

The Fargo-Moorhead Metropolitan Area Flood Risk Management Project (FMM Project) will directly alter the hydrology of the Red River and tributaries in the FMM Project vicinity by partially diverting high flows. This change in hydrology has the potential to affect the geomorphic characteristics of the streams in the vicinity of the FMM Project. Therefore, this Geomorphic Monitoring Plan (GMP) was developed to monitor the geomorphic characteristics over time to allow for a data-driven evaluation of any changes in the FMM Project vicinity and, if detrimental geomorphic impacts relative to the pre-project dynamics of the system and the reference reaches occur and are attributable to the FMM Project, to implement beneficial corrective actions.

This GMP was developed collaboratively by experts representing local, state, and federal organizations referred to herein as the Geomorphic Monitoring Team (GMT). The GMP will follow the adaptive management framework as outlined in the FMM Project's Adaptive Management and Monitoring Plan (AMMP), which was developed and will be managed by the Adaptive Management Team (AMT). The scope of this GMP is reflective of the complexity and uncertainty associated with sediment and hydrologic channel interactions in a large system with many driving variables that are not completely understood. The nature of FMM Project operation (which may not occur for years or may occur multiple years in a row), and the fact that impacts in river systems (e.g., to channels, riparia, and biota) can occur abruptly are examples of the stochasticity inherent in the system which make monitoring essential in the absence of validated predictability.

For the purposes of this GMP, pre-FMM Project is defined as the time period prior to and during construction activities. Post-FMM Project is defined as the time period following construction completion of all the FMM Project features (currently anticipated to begin in 2027).

The US Army Corps of Engineers (USACE) is responsible for ensuring adherence to and execution of the GMP until 24 October 2024 with the non-Federal sponsors (Metro Flood Diversion Authority, City of Fargo, North Dakota, and City of Moorhead, Minnesota) responsible for this after this date.

The GMP shall govern if the AMMP and GMP language is in conflict, unless otherwise agreed to by the AMT.

2. GEOMORPHIC MONITORING PLAN GOALS

Monitoring how the geomorphic characteristics of each river reach in the FMM Project vicinity change through time provides necessary empirical data for assessment of the FMM Project's impacts. The first goal of the GMP is to understand what the natural and adaptive range of geomorphic changes is for each river reach and to recognize and measure changes over time. Pre-FMM Project surveys and other supporting data allow for the establishment of these baseline ranges.

The second goal of the GMP is identifying measured geomorphic change triggers that, if exceeded, would be considered to be outside the natural and adaptive ranges. The trigger exceedance cause may or may not be attributable to the FMM Project. Identifying contributing factors other than those due to the FMM Project may require obtaining additional data beyond the data specified in this GMP, such as land use records, drainage change information, and precipitation and runoff data. Evaluating the contributing factors against FMM Project influences may also require modifications to the GMP and its triggers over time based on interpretation of additional gathered data. In the event that trigger exceedance is attributable to the FMM Project and if the changes are deemed to be detrimental, this GMP guides the process for development of corrective actions.

The third goal of this GMP is to outline a framework to maintain clear and effective communication between the non-Federal sponsors, other AMMP work groups, regulatory agencies, and stakeholders/ affected parties for sharing information specific to the geomorphic aspects of adaptive management, monitoring, and corrective action taking.

3. PRE- AND POST-FMM PROJECT CONDITIONS

3.1. Pre-FMM Project Conditions

USACE has contracted with WEST Consultants, Inc. (WEST) to conduct three separate pre-FMM Project geomorphic assessments in the vicinity of the FMM Project. The first assessment was completed in 2012 using survey and field data collected in 2010 and 2011. The second assessment was completed in 2019 using survey and field data collected in 2018. Survey and field data for the third assessment was collected in 2020, with bankfull flow hydraulic models (containing bankfull top widths and bankfull flow depths) and bank line locations delineated using aerial imagery provided to USACE on 15 June 2021 for use in establishing natural ranges of variability. The full set of results and report from this third assessment are anticipated to be available in fall 2021.

WEST presented a global overview of the current river system condition in Section 10.6 of the 2012 report as follows:

> "Results of the geomorphic assessment indicate that the involved study reaches are not prone to significant change in morphology over short or even moderate periods of time. Channel migration rates are on the order of a few inches per year. The erosion resistant nature of the cohesive glacial lake bed soils and the very flat gradient of the channels prevent significant changes in channel cross section geometry and results in very low rates of lateral migration. Further, the sediment supply from upstream and the surrounding landscape is generally composed of silt-and clay sized material with only minor amounts of sand-sized material. The study streams appear to have sufficient capacity to transport nearly all of the sediment supplied to them in suspension as wash load…"

Additional GMT observations of pre-FMM Project conditions in the for specific areas in the vicinity of the FMM Project features are noted in the following sections.

3.1.1. Staging Area

The Red River in the proposed FMM Project staging area is generally the starting point of taller stream banks compared to the stream banks within the proposed benefitted area. These taller stream banks are more susceptible to rotational failures due to their height and when fail contribute more sediment to the channel and result in larger changes to the riparian area. Structures crossing the Red River, such as the Cass County Highway 18 bridge, tend to induce bank failure near the structures due to concentrated flows and higher velocities during flood events. Additionally, a Red River meander cutoff appears imminent near Oxbow, ND, which will drive a geomorphic response due to the riverine slope increase.

The Wild Rice River exhibits a number of major rotational failures throughout the proposed FMM Project staging area. These failures contribute large amounts of sediment and cause changes to the riparian areas, including the collapse of large trees into the Wild Rice River channel. Some reaches of the Wild Rice River become unnavigable by boat during normal flow conditions due to the abundance and concentration of woody debris.

3.1.2. Benefitted Area

The area proposed to benefit from the FMM Project (i.e., north of the dam and east of the diversion channel) generally consists of shorter bank heights and more abundant vegetation than within the proposed staging area. These two factors have resulted in less overall bank slumping and rotational failures within the proposed benefitted area.

3.1.3. Tributaries

Long stretches of both the Rush River and Lower Rush River have been channelized to increase flow capacity over the past few decades. These anthropogenic changes have resulted in geomorphic characteristics that deviate significantly from streams considered to be fully functioning.

In 2018, the Buffalo-Red River Watershed District began a large stream restoration effort on Wolverton Creek. As of 2021, Wolverton Creek from the upstream extent of the geomorphic monitoring area downstream to 28th Street South has been restored. Restoration has not occurred between 28th Street South and Wolverton Creek's confluence with the Red River.

The Maple River and Buffalo River are both generally considered to be stable streams with little lateral movement over the pre-Project period. Some bank collapses were observed within the Maple River reaches but these did not appear to influence the stream stability or to be the result of widespread stream instability.

The Sheyenne River is similar to the Wild Rice River, in that its tall banks are susceptible to rotational failure and collapse, impacting the riparian area. Landowner concerns with bank collapse and channel movement have been noteworthy enough to be reported on by local news organizations (https://www.inforum.com/news/science-and-nature/1356423-Flooding-effects-Homeowners-along- Sheyenne-River-in-West-Fargo-watching-yards-trees-wash-away). Normal to low flows in the Sheyenne River have also been artificially increased by pumping of Devil's Lake flows. According to a 2020 USACE white paper on the subject, the 50 percent annual exceedance flow has increased from 330 cfs to 560 cfs for the portion of the Sheyenne River above the Sheyenne River Diversion near Horace, ND for the period of time that the Devil's Lake pumping has occurred. The increase of low to normal flows may have an impact on the Sheyenne River geomorphic characteristics due to channel banks being saturated at higher levels and for longer periods of time.

3.2. Possible Post-FMM Project Conditions

The 2012 WEST report presented a global overview of post-FMM Project conditions predictions as follows:

> "Bank stability and riparian vegetation density are expected to slightly increase in the reaches that are protected from high flows by the proposed diversion alignment.

Conversely, bank stability and riparian vegetation density are expected to slightly decrease in the staging areas upstream of the diversion alignment as a result of more frequent overbank inundation and sedimentation."

The 2019 WEST report echoed a similar tone, with the following language:

> "Because [project operations] are expected to occur on an infrequent basis, they are not expected to result in significant changes in the channel morphology over the long-term."

While the WEST reports do not predict notable changes globally in the FMM Project vicinity, the reports do state it is possible that localized impacts may occur. Potential types and locations of impacts, including some not listed in the WEST reports, are outlined below.

3.2.1. Local Bed Aggradation

Increased bed aggradation may occur downstream of the Maple River and Sheyenne River aqueduct structures, with it more likely to occur downstream of the Sheyenne River aqueduct due to the prevalence of sand-sized material transported by the Sheyenne River (compared to clay- and silt-sized material transported by the Maple River). Bed aggradation may occur as water from the top of the water column (which typically has a lower sediment concentration) is diverted into the Diversion Channel at the aqueduct structures while water from the bottom of the water column (containing proportionally more sediment) continues across each aqueduct and into the natural river channel downstream of each aqueduct. The ability of the rivers to transport sediment will be reduced, but the proportion of sediment will not be proportionally reduced, indicating a potential for sediment deposition.

Increased bed aggradation may also occur in the vicinity of the Red River Structure and Wild Rice River Structure for the periods of time the structures are not operating, due to the increased cross-sectional area of the engineered channels and structure width, which potentially will result in lower velocities and thus, sediment deposition. It is also possible that during operation of these structure that the high flow velocities through the Red River Structure and Wild Rice River Structure will move this deposited material and some native material from the downstream portion of the engineered channel and deposit it further downstream where velocities are closer to those occurring under pre-FMM Project conditions.

3.2.2. Local Overbank Deposition and Bank Slumping

Additional overbank sedimentation on the floodplain near the Wild Rice River and Red River channels upstream of the dam is possible due to the increased flood durations and depths in this area. Any deposited material is likely to deposit on or near the stream banks, which has the potential to decrease bank stability. Less sedimentation is anticipated further away from the rivers and is not anticipated to result in geomorphic concerns.

3.2.3. Local Bed Degradation

Localized bed degradation is possible upstream of the Sheyenne River and Maple River aqueducts due to the possibility that both the aqueducts and the spillways diverting flow into the Diversion Channel are more hydraulically efficient than the existing river channels, thus reducing backwater levels and increasing velocities in the portions of the rivers upstream of the aqueducts. These increased velocities have the potential to erode the streambed, resulting in the local bed degradation.

3.2.4. Local Bank and Bed Erosion

Increased flow velocities immediately downstream of the Red River Structure and Wild Rice River Structure during operation of these structures has the potential to result in small amounts of erosion of the engineered channel and its banks and, for events less frequent than the 1/1,000 annual exceedance probability event (commonly referred to as the 1,000-year event), erosion of the natural channel bed and banks downstream of the structures.

4. GEOMORPHIC MONITORING STATION SELECTION

The GMT has adaptively managed the selection of each Geomorphic Monitoring Station (GMS) over the course of the pre-FMM Project timeframe to ensure both reference reaches that are not anticipated to be impacted by the FMM Project as well as areas that may show post-FMM Project impacts are included. Of the geomorphic monitoring stations shown in Figure 4-1, the following stations are currently defined as reference sites: RU01, LR01, MA03, SH08, WR07, WR08, RE10, and WC04.

Depending on the flood size, sites closer to the Southern Embankment (such as WR06 and RE09) may also function as reference sites to assist in evaluating geomorphic changes post-FMM Project. The sampling locations support Rosgen Classification (Rosgen, 2006) and other geomorphic assessment methods with sampling locations in stratified valley types, stream types, and in-stream habitat types represented by crossings/riffles and pools. Post-FMM Project, it may be needed to add additional GMS locations beyond those currently specified in this GMP if geomorphic changes become evident or if continued local concerns are raised to the GMT and AMT.

> **Terminology Note:** The Red River exhibits a Crossing and Pool pattern of in-channel features where the crossings represent the zone where the direction of current crosses the channel center point as it flows in a meandering pattern from one bank to the other. Because the term “riffle” is used in classification systems of rivers with coarser bed material that cause “riffles” in the water surface at crossings, the term “crossing” and “riffle” might be used somewhat interchangeably. On the Red River and fine grained tributaries, “crossing” is used as being more descriptive of the actual river feature.

Additional detail on each GMS and its permanent, monumented cross sections is provided in the following sections.

4.1. Geomorphic Monitoring Stations Recommended for Pre- and Post-FMM Project

This section describes each of the 39 GMSs with a total of 245 monitoring cross sections that has been used for pre-FMM Project monitoring and is recommended for use in post-FMM Project monitoring. The location of each pre-FMM Project GMS is shown in Figure 4-1 and a summary of the number of cross sections in each GMS is provided in Table 4-1. Table 4-2 lists information on whether data was collected at each GMS for each WEST assessment; if the GMS is referred to in the WEST report using a different GMS identifier, this is noted as well.

4.1.1. Red River:

- **RE01** - Farthest downstream GMS. Contains seven cross sections. Important monitoring GMS just downstream of all FMM Project features.
- **RE02** - Covers the area immediately upstream and downstream of the FMM Project’s Diversion Channel outlet. Contains ten cross sections. This GMS is separated into two separate GMSs with six cross sections in each GMS for geomorphic assessments after 2022.
- **RE03** - This GMS is located adjacent to Trollwood Park, just downstream of Edgewood Golf Course, and upstream of Broadway. Contains six cross sections.
- **RE04** - Located just downstream of Interstate 94, bounded on the west by Lindenwood Park in Fargo and Gooseberry Mound Park in Moorhead. Contains six cross sections.
- **RE05** - Located near Briarwood, ND. Contains six cross sections.

- **RE06** - This GMS is located just downstream of the Wild Rice River confluence. Contains six cross sections. It is noted that RE06 was defined in the WEST (2019) assessment to contain both the cross sections for this updated RE06 and the updated RE06A defined below.
- **RE06A** - This GMS is located just upstream of the Wild Rice River confluence. Contains six cross sections. It is noted that the cross sections for this GMS were contained within RE06 in the WEST (2019) assessment.
- **RE07** – Located downstream of the dam and just upstream of 110th Ave S in Fargo. Contains six cross sections.
- **RE08A** –Located one mile upstream of the FMM Project dam. Contains nine cross sections, including three most downstream cross sections that were part of RE08A.
- **RE09** - GMS is located in upper staging area. Contains six cross sections.
- **RE10** - This is the furthest upstream GMS and is located just downstream of Abercrombie, ND. Contains six cross sections. Not anticipated to be impacted by FMM Project operations and therefore serves as a reference reach.

4.1.2. Wild Rice River

- **WR01** – Most downstream Wild Rice River GMS upstream of its confluence with the Red River. Contains six cross sections.
- **WR02** - This GMS is located downstream of 100th Ave S. Contains six cross sections.
- **WR03** - Located downstream of the Wild Rice River dam. Contains six cross sections.
- **WR04** - Located within the staging area. Contains six cross sections.
- **WR05** - This GMS is located in the upper retention footprint. Contains six cross sections.
- **WR06** - Upstream of staging area footprint. Contains six cross sections.
- **WR07** - Located upstream of County Road 28. Contains six cross sections. Not anticipated to be impacted by FMM Project operations and therefore serves as a reference reach. The GMT should consider removing this GMS or WR08 from future assessments, as both serve as a reference reach.
- **WR08** - Located upstream of County Road 4. Contains seven cross sections. Not anticipated to be impacted by FMM Project operations and therefore serves as a reference reach. The GMT should consider removing this GMS or WR07 from future assessments, as both serve as a reference reach.

4.1.3. Sheyenne River

- **SH01** - Located upstream of the confluence with the Red River, this is the farthest downstream GMS on this river. Contains seven cross sections.
- **SH02** - Located between the Rush River’s and Lower Rush River’s confluences with the Sheyenne River. Contains six cross sections.
- **SH03** - Located just downstream of the Maple River confluence. Contains six cross sections.
- **SH04** - Located downstream of existing West Fargo Diversion. Contains six cross sections.
- **SH05** - Located in West Fargo upstream of the Main Avenue crossing and downstream of the existing West Fargo Diversion. Contains six cross sections.
- **SH06A** – Located near the 64th Avenue South crossing and downstream of the existing Horace to West Fargo Diversion. Contains six cross sections. Note that this GMS was not included in the WEST (2019) geomorphic assessment but it was included in the WEST (2012) assessment. Survey data was collected in this GMS by WEST in 2012 and by USACE in 2019.
- **SH06** - Located close to the USGS sediment monitoring site just downstream of Wall Street in Horace and downstream of the existing Horace to West Fargo Diversion. Contains six cross sections.
- **SH07** - Located just upstream of the FMM Project Diversion Channel and Sheyenne River Aqueduct. Contains eight cross sections.

- **SH08** - Furthest upstream Sheyenne River GMS. Contains six cross sections. Not anticipated to be impacted by FMM Project operations and therefore serves as a reference reach.
- No additional GMSs would be added. However, additional data collection efforts will be considered in the future to collect longitudinal profiles and video/photographic data.

4.1.4. Maple River

- **MA01** - Most downstream Maple River GMS located between the Maple River's confluence with the Sheyenne River and the Maple River Aqueduct. Contains a total of seven cross sections.
- **MA02** - Located just upstream of FMM Project Diversion Channel and Maple River Aqueduct. Contains six cross sections.
- **MA03** - Near Mapleton, this is the furthest upstream GMS on the Maple River. Contains six cross sections. Not anticipated to be impacted by FMM Project operations and therefore serves as a reference reach.
- No additional GMSs would be added. However, additional data collection efforts will be considered in the future to collect longitudinal profiles and video/photographic data.

4.1.5. Lower Rush River

- **LR01** - Located upstream of FMM Project Diversion Channel. Contains six cross sections. LR01 is the only GMS on the Lower Rush River. Not anticipated to be impacted by FMM Project operations and therefore serves as a reference reach.

4.1.6. Rush River

- **RU01** - Located upstream of FMM Project Diversion Channel. Contains seven cross sections. RU01 is the only GMS on the Rush River. Not anticipated to be impacted by FMM Project operations and therefore serves as a reference reach.

4.1.7. Wolverton Creek

- **WC01** – Downstream-most GMS located between 130th Ave S and 3rd St S. GMS was not surveyed as part of the WEST effort in 2019 but was surveyed as part of the WEST efforts in 2012 and 2021. Contains six cross sections.
- **WC02** - Located downstream of Highway 75 and upstream of 130th Ave S. GMS was not surveyed as part of the WEST effort in 2019 but was surveyed as part of the WEST efforts in 2012 and 2021. Contains six cross sections.
- **WC03** – Located just downstream of the FMM Project dam. Contains six cross sections.
- **WC04** –Located upstream of the FMM Project dam. Contains six cross sections. Not anticipated to be impacted by FMM Project operations and therefore serves as a reference reach.

4.1.8. Buffalo River

- **BU01** - Only GMS located on the Buffalo River located on the western edge of Georgetown, Minnesota, downstream of Mason Street. GMS was not surveyed as part of the WEST effort in 2019 but was surveyed as part of the WEST efforts in 2012 and 2021. Contains six cross sections.

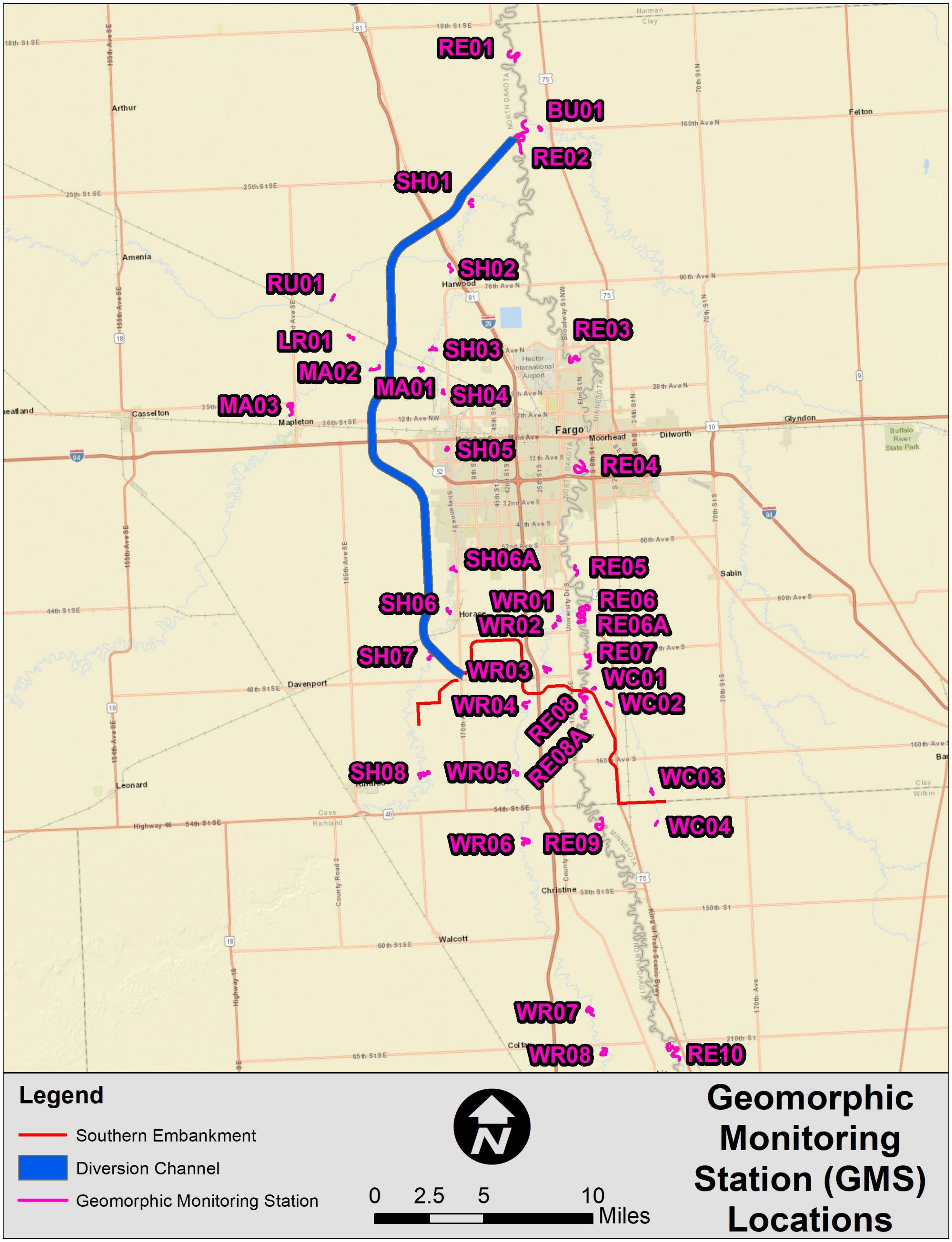


Figure 1. Geomorphic Monitoring Station Locations.

NOTE: 1) RE02 is divided into two GMS, one on each side of Diversion Channel Outlet.
2) Move the three most upstream cross-sections in RE-08 into RE-08A, delete RE-08.

Table 4-1: FMM Project Geomorphic Monitoring Station Cross Section Count

#	GMS	Cross Sections
1	RE01	7
2	RE02 & RE02A	12
3	RE03	6
4	RE04	6
5	RE05	6
6	RE06	6
7	RE06A	6
8	RE07	6
10	RE08A	9
11	RE09	6
12	RE10	6
13	WR01	6
14	WR02	6
15	WR03	6
16	WR04	6
17	WR05	6
18	WR06	6
19	WR07	6
20	WR08	7
21	SH01	7
22	SH02	6
23	SH03	6
24	SH04	6
25	SH05	6
26	SH06	6
27	SH06A	6
28	SH07	8
29	SH08	6
30	MA01	7
31	MA02	6
32	MA03	6
33	LR01	6
34	RU01	7
35	WC01	6
36	WC02	6
37	WC03	6
38	WC04	6
39	BU01	6
TOTAL		*245*

Table 4-2: Geomorphic Monitoring Station Changes throughout Pre-FMM Project Geomorphic Assessments by WEST

GMS	2012 WEST Assessment	2019 WEST Assessment	2021 WEST Assessment
RE01	Referred to as Red River – 1 – 410.65	Part of assessment	Part of assessment
RE02	Referred to as Red River – 2 – 419.14	Part of assessment	Part of assessment
RE03	Referred to as Red River – 3 – 440.57	Part of assessment	Part of assessment
RE04	Referred to as Red River – 4 – 452.52	Part of assessment	Part of assessment
RE05	Referred to as Red River – 5 – 463.56	Part of assessment	Part of assessment
RE06	Not part of assessment	Included both RE06 and RE06A under the heading of RE06 in this assessment	Part of assessment
RE06A	Referred to as Red River – 6 – 470.23		Part of assessment
RE07	Not part of assessment	Part of assessment	Part of assessment
RE08	Not part of assessment	Part of assessment	Part of assessment
RE08A	Not part of assessment	Not part of assessment	Part of assessment
RE09	Referred to as Red River – 7 – 492.47	Part of assessment	Part of assessment
RE10	Referred to as Red River – 8 – 521.18	Part of assessment	Part of assessment
WR01	Referred to as Wild Rice River – 1 – 3.01	Part of assessment	Part of assessment
WR02	Referred to as Wild Rice River – 2 – 4.23	Part of assessment	Part of assessment
WR03	Not part of assessment	Part of assessment	Part of assessment
WR04	Not part of assessment	Part of assessment	Part of assessment
WR05	Referred to as Wild Rice River – 3 – 17.52	Part of assessment	Part of assessment
WR06	Referred to as Wild Rice River – 4 – 22.94	Part of assessment	Part of assessment
WR07	Referred to as Wild Rice River – 5 – 38.49	Part of assessment	Part of assessment
WR08	Referred to as Wild Rice River – 6 – 42.36	Part of assessment	Part of assessment
SH01	Referred to as Sheyenne River – 1 – 4.20	Part of assessment	Part of assessment
SH02	Referred to as Sheyenne River – 2 – 11.56	Part of assessment	Part of assessment
SH03	Referred to as Sheyenne River – 3 – 18.15	Part of assessment	Part of assessment
SH04	Referred to as Sheyenne River – 4 – 22.27	Part of assessment	Part of assessment
SH05	Referred to as Sheyenne River – 5 – 26.47	Part of assessment	Part of assessment
SH06	Not part of assessment	Part of assessment	Part of assessment
SH06A	Referred to as Sheyenne River – 6 – 35.82	Not part of assessment; survey data collected by USACE in summer 2019 for use in future assessments	Part of assessment

GMS	2012 WEST Assessment	2019 WEST Assessment	2021 WEST Assessment
SH07	Referred to as Sheyenne River – 7 – 43.27	Part of assessment	Part of assessment
SH08	Referred to as Sheyenne River – 8 – 55.75	Part of assessment	Part of assessment
MA01	Referred to as Maple River – 1 – 0.78	Part of assessment	Part of assessment
MA02	Not part of assessment	Part of assessment	Part of assessment
MA03	Referred to as Maple River – 2 – 11.39	Part of assessment	Part of assessment
LR01	Referred to as Lower Rush River – 2 – 6.03	Part of assessment	Part of assessment
RU01	Referred to as Rush River – 2 – 6.15	Part of assessment	Part of assessment
WC01	Referred to as Wolverton Creek – 1 – 0.64	Not part of assessment	Part of assessment
WC02	Referred to as Wolverton Creek – 2 – 2.02	Not part of assessment	Part of assessment
WC03	Not part of assessment	Not part of assessment	Part of assessment
WC04	Not part of assessment	Not part of assessment	Part of assessment
BU01	Referred to as Buffalo River – 1 – 1.19	Not part of assessment	Part of assessment

4.2. Geomorphic Monitoring Stations Recommended for Post-FMM Project

This section describes an additional 3 GMSs with a total of 18 monitoring cross sections along the Diversion Channel that are recommended for post-FMM Project monitoring. Monitoring of these GMSs will inform sediment delivery from watercourses intersected by the Diversion Channel and will also inform whether native material from the Diversion Channel is being eroded and potentially delivered to the Red River. All 3 GMSs should include three pool and three riffle cross sections, and a longitudinal profile that follows the thalweg of the meandered low flow channel within the Diversion Channel.

4.2.1. Diversion Channel

- **DC01** – Downstream-most Diversion Channel GMS. Recommended to be located above confluence with Red River and downstream of Rush River and Highway 29.
- **DC02** - Middle Diversion Channel GMS. Recommended to be located just below Drain 14, downstream of Interstate 94, and upstream of the Maple River aqueduct.
- **DC03** - Upstream-most Diversion Channel GMS. Recommended to span both upstream and downstream of the Sheyenne River aqueduct.

The GMT should also consider adding GMSs immediately downstream of the Sheyenne River aqueduct, immediately downstream of the Maple River aqueduct, upstream of the Rush River inlet to the Diversion Channel, and upstream of the Lower Rush River inlet to the Diversion Channel. These are all areas not currently being monitored but were identified as locations that may experience changes in Section 3.2.

5. GEOMORPHIC MONITORING METHODS

Monitoring for geomorphic changes in the FMM Project vicinity generally follows the Before-After Control-Impact (BACI) (Smith, 2002) accounting method. The BACI sampling framework compares the *before* (pre-FMM Project condition using baseline data) condition to the *after* (post-FMM Project) condition of the area. To account for changes that may occur within the system that are natural changes, the area of impact is compared to another area, which is referred to as a reference site. This is a site that is not expected to be impacted by FMM Project operations but is within close proximity of the FMM Project components and is representative of the reach/site in which changes may be observed due to the FMM Project. To establish baseline conditions, sampling is carried out on a number of occasions before FMM Project operation and a number of occasions following. The sampling design has incorporated BACI methods by recommending sampling areas both inside and outside the potential impact areas. Sampling has occurred three times before FMM Project construction and will occur for a minimum of three times after FMM Project construction as well. This approach allows for comparisons for assessing if an impact occurs.

The following sections describe the monitoring efforts that are recommended for all FMM Project geomorphic assessments. The Scope of Work that outlined the WEST (2021) work effort, developed and approved by the GMT, is included as Appendix A and is the general recommended approach for any future geomorphic monitoring effort.

5.1. Field Data Collection

Field-collected data is a core component of this GMP. Pre-FMM Project data has been collected in 2010/2011, 2018, and 2020 (it is noted that longitudinal profiles are only available for the Red River for 2010/2011). The following sections list specific types of field data that has been and is recommended to continue to be collected as part of each geomorphic assessment.

5.1.1. Cross Sections

Collection of data at cross sections is an important GMP component. Each GMS is comprised of permanent cross sections that allow for replicate data collection to evaluate whether the stream is aggrading, degrading, depositing, or eroding laterally at a specific location. The end of each cross section has a permanent monument that has been installed at or below the existing ground grade to assist in the collection of replicate cross sections. Pre-FMM Project cross section data were collected and are documented in the WEST reports (2012, 2019, and 2021). The WEST reports contain ArcGIS shapefiles and maps noting the location of each cross section. Post-FMM Project cross-sectional surveys shall try to survey the exact locations of the WEST cross sections to allow for appropriate comparisons. The GMT should also leverage any other bathymetric data collected in the FMM Project vicinity, as available. The non-Federal project sponsors have already acquired property easements to allow for geomorphic assessments for a number of the properties covering the GMS locations and are in the process of obtaining the easements for the remaining locations. All easements are anticipated to be obtained by 2022 or 2023.

In addition to collecting cross-sectional overbank and bathymetric survey data at each cross section, the following tasks shall also be conducted:

- Field-stake points corresponding to top-of-bank elevation (channel bank), bankfull elevation (only if there are obvious changes from previously observed bank conditions), and water surface elevation at time of field observation, both along a straight line of sight trajectory from monument end to monument end for each cross section as well as along a “hydraulic modeling” trajectory. Extend geomorphic investigation beyond the top of bank to capture the riparian area and possible overbank deposition, slumping, vegetation surveys, etc. using field stakes indicating needed survey extent.
- Make a qualitative description of riparian vegetation types and how that would impact bank stability.
- Estimate percentage of banks slumping within each GMS based on field observations.
- Document any erosion or deposition features and significant sources of sediment.
- Look for, identify, and document contributing factors (e.g., land use changes, obvious drainage changes, etc.) other than those due to the FMM Project that may be affecting the channel morphology and stability since the most recent geomorphic assessment.
- Obtain field data needed for Rosgen (2006) Level II (all worksheets) and Level III (only worksheets 3-1, 3-5, 3-6, and 3-10).
- Continue collecting photos at long-term photo stations for monitoring change at each cross section to add to the electronic photographic record of field investigations. Take photos upstream, downstream, and of both banks; include the entire channel cross-section with a vertical survey rod in the frame. If possible, show a survey team member pointing to the bankfull elevation. Photographs of a survey team member collecting the sample shall also be taken. Use a wide-angle lens to show the relative extent of floodplain or confinement on both sides of the channel. These are complimentary to the cross section measurements and provide additional

5.1.2. Longitudinal Profiles

Longitudinal profiles collect bed topography data in the down-channel direction and provide additional points to capture changes in the thalweg and channel slope that might otherwise be missed between the monumented cross sections and is a cost effective way of capturing that data. Longitudinal profiles could be sampled with acoustic Doppler current profilers coupled with GPS-grade survey gear covering multiple paths (following the thalweg or in the case of deeper water using a zig-zag pattern or point cloud sampling approach from which the thalweg could be picked out of). It is critical that horizontal and vertical control be established and be the same as for the cross sections and other monitoring efforts.

For the purposes of this GMP, longitudinal profiles are collected from the upstream most cross section to the downstream most cross section for each of the GMSs listed. If additional bathymetric data is collected in the FMM Project vicinity, this data should be leveraged as possible.

5.1.3. Sediment Sampling

Sediment sampling related to the geomorphology of rivers is conducted in the stream bed, bars, banks, and overbanks. Pre-FMM Project stream bed, bar, bank, and overbank samples were collected for each GMS by WEST and are documented in the 2012, 2019, and 2021 reports. For post-FMM Project sampling, it is recommended that stream bed, bar, bank, and overbank samples be collected for any new GMS. Post-FMM Project sediment sampling shall only occur in any GMS in which significant sediment type or size changes are observed.

5.1.4. Rosgen (2006) Assessments

Rosgen Level II assessments have been conducted for each of the WEST (2012, 2019, and 2021) assessments and shall continue to be conducted. Data shall also be collected for Rosgen Level III worksheets 3-1, 3-5, 3-6, and 3-10 to help track the changes in the system over time.

5.2. Hydrology Assessment

USGS gages provide a long-term record of stage-discharge rating curves. Changes in stage for the same discharge can be used as an indicator of channel aggradation or degradation. As part of post-FMM Project hydrology assessments, it is recommended that the geomorphic assessment team obtain stage- discharge rating curve data from the USGS and update the specific gage analysis for each gage within the FMM study area to analyze gage changes over time working from the WEST (2021) (or subsequent) analysis forward.

5.3. Stability Analysis using Survey Data

Field-collected survey data allows for direct, repeatable comparisons of channel geometry at a specific location as well as along longitudinal profiles over time. As part of any future survey data-based stability analysis, the following tasks are recommended:

- Evaluate changes in surveyed cross section geometry for all historic data reported in WEST (2021) and all subsequent survey data. The data shall be summarized electronically in a spreadsheet listing the station and elevation information (in the Project datum) for each cross section. The data shall also be plotted in a cross-sectional format to show any changes compared to all available historic data.
- Evaluate surveyed longitudinal profile. The data shall be summarized electronically in a spreadsheet listing the station and elevation information (in the Project datum) for each GMS. The data shall also be plotted in a profile format so changes in bed elevation along the profile can be viewed and compared to all available historic data.

5.4. Stability Analysis using Aerial Imagery

Aerial imagery is useful for observing changes and to provide early information highlighting possible changes. It is especially useful for capturing surface changes during and after major flood events that might not be recognizable at the ground level. The primary goal of the aerial imagery analysis in this GMP is to locate areas where obvious lateral shifts in the bank location or vegetation type/density have occurred compared to previous data sets and to flag these areas for further investigation. Pre-FMM Project high-resolution aerial imagery has been collected by the FMM Project's non-Federal sponsors every three years beginning in 2008 and spanning through 2020. Post-FMM Project imagery shall also be collected by the FMM Project's non-Federal sponsors. This imagery collection ideally will occur when water levels in the FMM Project vicinity are within their banks to allow for accurate bank delineation to occur.

Aerial imagery has been historically collected every three years and used to capture trends in the land surface, including use and observations of impacts from the Project and other causes. During construction and post-construction, the intervals should be conducted to occur in the autumn months before scheduled geomorphological field assessments (scheduled every 5 years) to inform the assessment scope of work. The aerial surveys could continue to be conducted every three years as determined by the local agencies which use the aerial information for other purposes.

As part of post-FMM Project stability analyses using aerial imagery, the following tasks are recommended:

- Delineate bank lines throughout the project area using the protocols established in Section 7.1.4.
- Locate, measure, and document where lateral shifts in the bank line locations have occurred compared to those locations identified in the WEST (2021) report or other subsequent assessments. The WEST (2021) report contains the delineated bank line locations in ArcGIS shapefiles and/or geodatabases.
- Determine sinuosity, channel (meander) migration and erosion rates, and meander amplitude and frequency.
- Evaluate trends in sedimentary features (in-stream sediment bars), changes in large woody debris (LWD), and changes in riparian vegetation type using the aerial imagery.
- Evaluate the degree of incision. If channel is incised, then the influence of contained flow may increase channel erosion.

5.4.1. Use of Video Footage to Document Changes in Geomorphology

The Corps is working with WEST to evaluate video footage methods to document unstable banks, erosion, deposition, and other changes that could occur due to the Project or other items. The study will consider technical and economic factors related to the use of drone-mounted LiDAR, multiple cameras mounted on boats, and other methods. Following the study, the results shall be presented to the AMT for further consideration to improve data collection.

6. TRIGGERS AND RESPONSES

The Red River and tributaries are dynamic river systems and are expected to show movement of their mobile boundaries. Sites that already show changes in response to existing processes need to be monitored as well as sites that are expected to show change in response to the FMM Project construction and operation. Reference sites outside of the FMM Project impact area will also be monitored to help establish rates of change and natural variability in response to drivers other than the FMM Project. Getting reference and pre-FMM Project data will help establish reference ranges of change rather than singular thresholds for delineating accelerated change outside of the range of norms. A first step for evaluating the system and rates of change is to use pre-FMM Project data collected as part of the WEST (2012, 2019, and 2021) assessments to determine observed types of change and what types and scales of change would trigger a need for action.

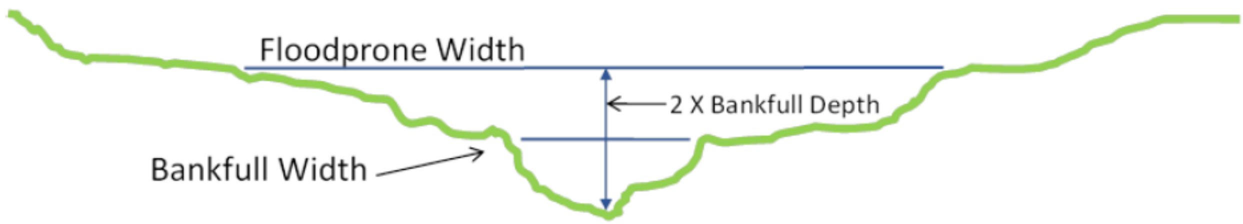
6.1. Triggers

Parameters for defining triggers warranting additional action were discussed with the AMT and GMT during a series of meetings spanning April through June 2021. Three variables were identified for use as triggers during the discussions: Entrenchment Ratio, Bank Height Ratio, and Aerial Image-Derived Bank Line Location. The use of the Rosgen Bank Erosion Hazard Index (BEHI) / Near-Bank Stress (NBS) ratings was considered by the GMT for use as a threshold but was ultimately dismissed because its use may not be entirely applicable to the Red River system and because the aerial image-derived bank line location approach would serve as a similar trigger. Additionally, measured change in bankfull cross-sectional area was also considered for use as a threshold but was ultimately dismissed because this data is a main component in the Entrenchment Ratio and Bank Height Ratio calculations and because this type of approach does not appear to have been used in practice or discussed in literature.

It is noted that as part of the adaptive management and monitoring component of this GMP, the GMT should consider and provide recommendations to the AMT whether triggers should be added, adjusted, or removed based on additional data, information, and/or observed detrimental impacts that are not covered by the triggers established herein.

6.1.1. Entrenchment Ratio

According to Rosgen (1994), a stream's Entrenchment Ratio is a quantitative expression of the "interrelationship of the stream to its valley and/or landform features" and "distinguishes whether the flat adjacent to the channel is a frequent floodplain, a terrace (abandoned floodplain) or is outside of a flood-prone area." Rosgen (1994) defined the Entrenchment Ratio as the flood-prone width divided by the bankfull width, with the flood-prone width "defined as the width measured at an elevation which is determined at twice the maximum bankfull depth." Additionally, Rosgen (1994) stated that "field observation shows this (flood-prone) elevation to be a frequent flood (50 year return period) or less, rather than a rare flood elevation." Figure 6-1 shows an example of these variables.



$$ER = \frac{Flood\ Prone\ Width}{Bankfull\ Width}$$

Figure 6-1: Entrenchment Ratio Example Graphic

The development of the Entrenchment Ratio action triggers for this AMMP relied on triggers established in literature as well as data collected during the pre-FMM Project geomorphic assessments.

The Minnesota Stream Quantification Tool (MN SQT) Steering Committee developed a scientific support document for the MN SQT, in which Entrenchment Ratio performance standards are provided.

According to the scientific support document, an Entrenchment Ratio of greater than 2.2 is considered to indicate a fully functioning stream for the Rosgen C and E stream types, which according to the WEST (2019) report are the Rosgen stream classifications for all of the geomorphic monitoring stations within the FMM Project study area. Therefore, the first step in the Entrenchment Ratio trigger establishment considered whether a stream that previously had an Entrenchment Ratio of greater than 2.2 transitioned to a stream with an Entrenchment Ratio of 2.2 or less.

The second part of the trigger establishment evaluated the Entrenchment Ratios determined using the datasets collected by WEST in 2012 and 2019, with the methodology that was followed in calculating these Entrenchment Ratios defined in Section 7.1. The observed range of Entrenchment Ratios within both datasets for each stream is summarized in Table 6-1. As shown in the table, most Entrenchment Ratios far exceed the value of 2.2, which indicates that most of the streams are considered fully functioning, primarily due to the well-developed floodplains prevalent in the FMM Project vicinity.

Table 6-1: Observed Entrenchment Ratios by Stream

Stream	Entrenchment Ratio
Buffalo River	2.8 – 3.0
Lower Rush River	6.4 – 8.1
Maple River	5.3 – 11.1
Red River	3.8 – 10.3
Rush River	17.0 – 26.9
Sheyenne River	7.5 – 14.0
Wolverton Creek	2.0 – 5.0
Wild Rice River	2.6 – 8.0

In defining an appropriate trigger based on the observed Entrenchment Ratios, it was deemed appropriate and consistent with the Rosgen (1994) paper to allow the trigger to be 0.2 Entrenchment Ratio units less than the minimum observed Entrenchment Ratio value. Therefore, this second step in the Entrenchment Ratio trigger establishment considered the lowest observed Entrenchment Ratio for each stream, then subtracted 0.2 off that value for each stream.

The final trigger establishment was to set the trigger for each stream at the lesser of either 2.2 (based on the MN SQT) or the lowest observed Entrenchment Ratio minus 0.2, with the trigger values displayed in Table 6-2.

Table 6-2: Entrenchment Ratio Action Triggers by Stream

Stream	Action Trigger
Buffalo River	<2.3
Lower Rush River	<2.3
Maple River	<2.3
Red River	<2.3
Rush River	<2.3
Sheyenne River	<2.3
Wolverton Creek	<1.8
Wild Rice River	<2.3

It is noted that these Entrenchment Ratio action triggers will be re-evaluated by the AMT and GMT if any additional pre-FMM Project geomorphic assessments are completed (which would only happen if a flood occurs in the pre-FMM Project timeframe). The methodology that shall be used to calculate Entrenchment Ratios using any additional pre-FMM Project datasets for the purposes of supplementing and/or adjusting the action triggers is outlined in Section 7.1.

In the event an Entrenchment Ratio trigger is exceeded, the GMT and AMT shall consider whether the reference reaches have also shown changes in the Entrenchment Ratio when working to establish whether the Entrenchment Ratio trigger exceedance is attributable to the FMM Project construction.

It is also noted that Wolverton Creek sites WC03 and WC04 were part of a large stream restoration project completed by the Buffalo-Red River Watershed District between 2018 and 2020. The data collected as part of the 2021 effort was collected after the restoration project was completed in these portions of Wolverton Creek. The GMT and AMT should take this into consideration when evaluating any Entrenchment Ratio triggers on Wolverton Creek.

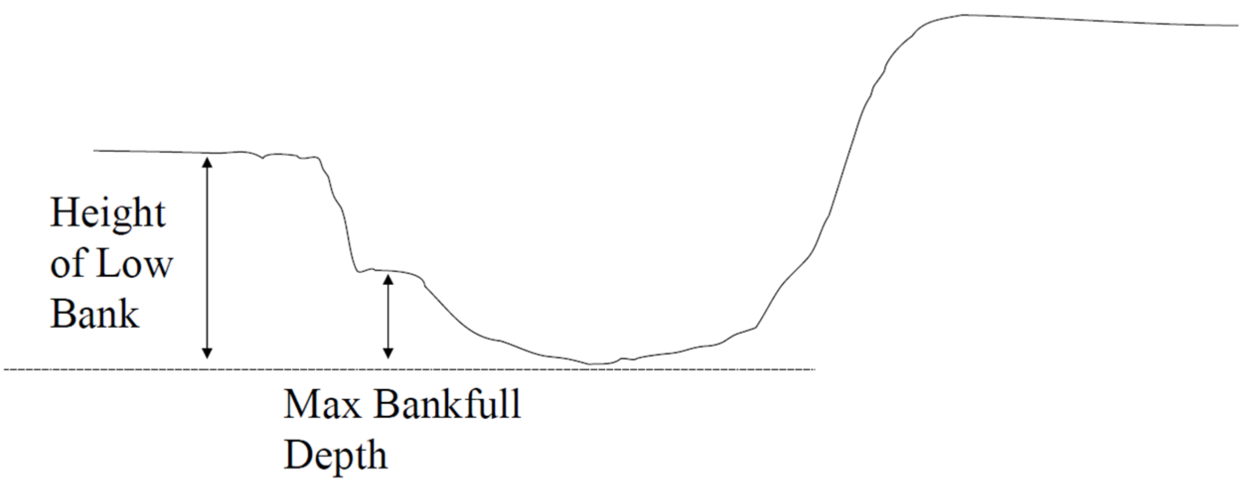
The Corps is working with WEST to develop recommendations to evaluate changes to the action triggers that would consider either values above those recorded in the three intervals of the baseline data at each location or a set percentage above the last measured change for each GMS. The evaluation will consider causes and impacts of changes.

The Corps is working with WEST to develop recommendations for Entrenchment Ratio action triggers by GMS instead of by stream.

The Corps is working with WEST to develop recommendations for Entrenchment Ratio investigation triggers by GMS instead of by stream. The Entrenchment Ratio investigation triggers would be based upon a percent difference to the historically observed values. The investigation triggers would be set to 5 percent, 10 percent, or 15 percent increments based upon the maximum differences that have been observed for each GMS.

6.1.2. Bank Height Ratio

According to the MN SQT, a stream's Bank Height Ratio "is a measure of channel incision and indicates whether a stream is or is not connected to an active floodplain or bankfull bench." Rosgen (1996) defined the Bank Height Ratio as "the depth from the top of the low bank to the thalweg divided by the depth from the bankfull elevation to the thalweg." Figure 6-2 shows an example of these variables.



$$BHR = \frac{Low\ Bank\ Height}{Dmax}$$

Figure 6-2: Bank Height Ratio Example Graphic

Similar to the Entrenchment Ratio action triggers, the development of the Bank Height Ratio action triggers for this AMMP relied on triggers established in literature as well as data collected during the pre-FMM Project geomorphic assessments.

The Minnesota Stream Quantification Tool (MN SQT) Steering Committee developed a scientific support document for the MN SQT, in which Bank Height Ratio performance standards are provided. According to the scientific support document, a Bank Height Ratio of less than 1.3 is considered to indicate a fully functioning stream. Therefore, the first step in the Bank Height Ratio trigger establishment considered whether a stream that previously had an Bank Height Ratio of less than 1.3 transitioned to a stream with a Bank Height Ratio of 1.3 or greater.

The second part of the trigger establishment evaluated the Bank Height Ratios determined using the datasets collected by WEST in 2012 and 2019, with the methodology that was followed in calculating these Bank Height Ratios defined in Section 7.1. The observed range of Bank Height Ratios within both datasets for each stream is summarized in Table 6-3. The Bank Height Ratios generally are in the fully functioning or partially functioning category, which indicates moderate levels of incision on a number of streams in the FMM Project vicinity.

Table 6-3: Observed Bank Height Ratios by Stream

Stream	Bank Height Ratio
Buffalo River	1.3 – 1.3
Lower Rush River	1.1 – 1.4
Maple River	1.0 – 1.2
Red River	1.0 – 1.3
Rush River	1.2 – 1.5
Sheyenne River	1.0 – 1.4
Wolverton Creek	0.8 – 2.1
Wild Rice River	0.9 – 1.3

In defining an appropriate trigger based on the observed Bank Height Ratios, it was deemed appropriate to allow the trigger to be 0.1 Bank Height Ratio units less than the minimum observed Bank Height Ratio value due to the fact that the Bank Height Ratio relies on rounding to the nearest 0.1 units. Therefore, this second step in the Bank Height Ratio trigger establishment considered the highest observed Bank Height Ratio for each stream, then added 0.1 to that value for each stream.

The final action trigger establishment was to set the trigger for each stream at the greater of either 1.2 (based on the MN SQT) or the highest observed Bank Height Ratio plus 0.1, with the trigger values displayed in Table 6-4.

Table 6-4: Bank Height Ratio Action Triggers by Stream

Stream	Action Trigger
Buffalo River	>1.4
Lower Rush River	>1.5
Maple River	>1.3
Red River	>1.4
Rush River	>1.6
Sheyenne River	>1.5
Wolverton Creek	>2.2
Wild Rice River	>1.4

It is noted that these Bank Height Ratio action triggers will be re-evaluated by the AMT and GMT if any additional pre-FMM Project geomorphic assessments are completed (which would only happen if a flood occurs in the pre-FMM Project timeframe). The methodology that shall be used to calculate Bank Height Ratios using any additional pre-FMM Project datasets for the purposes of supplementing and/or adjusting the action triggers is outlined in Section 7.1.

In the event a Bank Height Ratio trigger is exceeded, the GMT and AMT shall consider whether the reference reaches have also shown changes in the Bank Height Ratio when working to establish whether the Bank Height Ratio trigger exceedance is attributable to the FMM Project construction.

It is also noted that Wolverton Creek sites WC03 and WC04 were part of a large stream restoration project completed by the Buffalo-Red River Watershed District between 2018 and 2020. The data collected as part of the 2021 effort was collected after the restoration project was completed in these portions of Wolverton Creek. The GMT and AMT should take this into consideration when evaluating any Bank Height Ratio action triggers on Wolverton Creek.

The Corps is working with WEST to develop recommendations to evaluate changes to the action triggers that would consider either values above those recorded in the three intervals of the baseline data at each location or a set percentage above the last measured change for each GMS. The evaluation will consider causes and impacts of changes.

The Corps is working with WEST to develop recommendations to revise the methodology in this section of the GMP to use a fixed bankfull elevation for determining BHR and to develop a list of assumptions to check after each sampling event and after the third cycle of sampling.

The Corps is working with WEST to develop recommendations for BHR action triggers by GMS instead of by stream.

The BHR investigation triggers shall be BHR+0.1 for all sites. The Corps is working with WEST to develop investigation triggers for each GMS to monitor system changes.

6.1.3. Bank Line Location

Defining quantitative action triggers for aerial imagery-derived bank line movement is inherently difficult, as every stream naturally moves and adjusts its location in response to a variety of causes and because of the uncertainty in the bank line delineation process due a variety of factors such as differing water levels and delineator judgments. Pre-FMM Project geomorphic assessments have included the delineation of bank line locations using aerial imagery, with these delineations creating information that can be used to assess channel movement outside of the surveyed cross section locations. The WEST (2012) report delineated bank line locations spanning from 2010 to as early as 1939 for some streams in the study area. The WEST (2019) report delineated bank line locations spanning from 2018 to 2010. The WEST (2021) report includes re-delineated bank line locations using only high-resolution aerial imagery collected between 2008 and 2020 and using a larger scale (1:1,000 vs. 1:3,000 previously) during bank line delineation to determine bank line location changes more clearly.

Triggers that would require the GMT and AMT to take further action are listed below:

- In the event any member of the GMT or AMT receives complaints from the public stating that the FMM Project is causing increased bank line movements in areas not within the immediate vicinity of a monitored cross section, the GMT shall meet to evaluate the complaint and compare the observed bank line movement that resulted in the complaint against historically-observed movement within the same area. The GMT shall then provide a consensus-based response to the AMT stating the following:
    - Whether the GMT judges the observed bank line movement that resulted in the complaint to be inside or outside the range of natural variability for that reach of the stream
    - If outside the range of natural variability, whether the GMT judges the observed bank line movement to be the result of the FMM Project
    - If the result of the FMM Project, the recommended corrective action

- Post-FMM Project construction geomorphic assessments will evaluate bank line locations and any associated movement and apply judgment to highlight areas that may fall outside of normal ranges (referring to the WEST 2012, 2019, and 2021 reports as background). These areas shall be further investigated by the GMT. The GMT shall then provide a consensus-based response to the AMT stating the following:
    - Whether the GMT judges the observed bank line movement that resulted in the complaint to be inside or outside the range of natural variability for that reach of the stream
    - If outside the range of natural variability, whether the GMT judges the observed bank line movement to be the result of the FMM Project
    - If the result of the FMM Project, the recommended corrective action

The GMT and AMT shall consider whether the reference reaches have also shown changes in bank line locations when working to establish whether this trigger has been exceeded and whether the trigger exceedance is attributable to the FMM Project construction.

6.2. Trigger Exceedance Response

In the event any of the triggers identified in Section 6.1 are exceeded or if it is the GMT's judgment that other significant change is occurring throughout the system and is not being captured by the currently established triggers, the following process shall be followed by the GMT and the findings provided to the AMT within the timelines established in Section 8.

6.2.1. GMT Investigations

First, the GMT shall provide a recommendation to the AMT as to whether the trigger exceedance is attributable to the FMM Project and, if possible, to what degree. Probable and possible causes for the exceedances should be detailed with documented data by the GMT for the AMT. The GMT should evaluate aerial imagery, LiDAR data, hydrology records, and any other available data sources as part of the attribution effort. One important component of this effort is to evaluate the reference reaches that were unimpacted by FMM Project operations to see if those reaches are showing similar geomorphic patterns. If those reaches are not showing similar geomorphic trends, it is possible (though not certain) that the FMM Project is the primary driver of the trigger exceedance. It is possible that some trigger exceedances will be easily verifiable as being principally caused by the FMM project or some other driver, such as changes in land use, drainage patterns, or precipitation. There are a number of reasons for trigger exceedances that may not be in any way influenced by the FMM Project, including but not limited to hydrology change, sediment load change, stream slope change, land use change, and standard geomorphic responses to large flood events that may have occurred both with and without the FMM Project. It is also possible that trigger exceedances may have a mix of drivers contributing to the exceedance or that they may initially appear to be indeterminant. In the cases where identifying the relative impact of multiple drivers is challenging, the AMT and GMT should consider engaging third- party facilitation to help articulate important criteria for making recommendations and for identifying follow-up actions to ultimately reach a recommendation.

Second, if the GMT concludes that the trigger exceedances were fully or in part attributable to the FMM Project, the GMT shall provide a recommendation to the AMT as to whether the impact is detrimental from the stakeholder perspective. In this instance, stakeholders include (but are not limited to) local, state, and federal agencies as well as local landowners. An example of a clearly detrimental impact is FMM Project-induced erosion that is threatening the stability of a bridge crossing.

Third, if the GMT concludes that the trigger exceedances were fully or in part attributable to the FMM Project and that the impacts are detrimental, the GMT shall provide one or more recommended corrective actions, commensurate with the detrimental level of impact and with the level of attribution to the FMM Project, for consideration to the AMT. A list of geomorphic issues grouped into themes that may be experienced in the FMM Project vicinity and a list of associated potential corrective actions is provided in Section 6.2.2.

The Corps is working with WEST to evaluate video footage methods to document unstable banks, erosion, deposition, and other changes that could occur due to the Project or other items. The study will consider technical and economic factors related to the use of drone-mounted LiDAR, multiple cameras mounted on boats, multi-beam sonar (especially along the Red River), and other methods. Following the study, the results shall be presented to the AMT for further consideration to improve data collection.

6.2.2. List of Themes and Potential Corrective Actions for GMT Consideration

Issues potentially requiring corrective actions can be grouped into themes related to the physical processes that cause them. This can be helpful in treating the root cause of a trigger exceedance rather than just the appearances or symptoms. Treating the symptom instead of the cause may simply result in the same impacts reoccurring over time if the causes remain untreated. Cause determination will require the GMT to thoughtfully analyze the data and use their combined experience and expertise to attribute the issue(s)/symptom(s) to the actual cause(s). It is important to note that streams adapt to some changes over time. Therefore, the GMT shall consider the current stream condition state in relation to its ongoing and evolving geometry before determining the recommended corrective action(s).

A list of themes of geomorphic-related issues and associated potential corrective actions is included in this Section to support early discussions and facilitate a more rapid response when the GMT is recommending that corrective actions are needed. This list is not considered to be all-inclusive or contain any of the specificity required for actual design or implement of the ideas and will be modified over time as new techniques and structural corrective measures are developed. Within the list are references to texts with more information and examples of actions already implemented in the region that can inform discussion. Extensive, expert work will be required to bring contextual ideas to meaningful application based on the specific and unique characteristics of each area being evaluated and what the AMT and GMT determine is beneficial.

Five documents are supplied as appendices B through F to this GMP that give a thorough description of stream bed and bank issues and corrective actions. The appendices are:

B. Resource Sheet 1: Streambank Erosion and Restoration (Minnesota DNR)
C. Resource Sheet 2: The Value and Use of Vegetation (Minnesota DNR)
D. Stream Restoration: Toe Wood-Sod Mat (Minnesota DNR)
E. Chapter 11 of National Engineering Handbook 654 (Natural Resources Conservation Service)
F. Chapter 14 of National Engineering Handbook 654 (Natural Resources Conservation Service)

6.2.2.1. Theme: Increased Bank Erosion and/or Channel Migration Rate

All natural streams have meander patterns that gradually migrate in a downstream direction with time, which requires some degree of erosion and deposition. Locations with increased rates of bank erosion, meander migration, and meander pattern change have often been destabilized due to hydrologic and hydraulic changes and/or changes in vegetation. Bank erosion/collapse in one location can produce sediment that is transported and deposit in downstream reaches, thereby producing a shallower channel in those areas. This, in turn, can destabilize those banks as the river tries to widen to handle the flows, resulting in a feedback cycle of destabilization throughout a system.

One potential corrective action is to reduce the flow velocity near the eroding bank. This can be done through the staking of live cuttings of deep-rooted woody vegetation that naturally occurs within the Red River valley ecosystem or the planting of willows, shrubs, grasses, and rooted forbes, among other vegetation, as this vegetation can significantly lower near-bank velocities. An example of willow plantings is shown in Figure 6-3.

Figure 6-3: Willow Plantings on the Mississippi River

Another potential corrective action is to install toe wood with a sod mat along the bank toe. This stabilizes the bank toe with both the toe wood and with the dense sod mat vegetation. It also has the added benefit of providing aquatic and terrestrial habitat. Toe wood-sod mats are sometimes an additional practice to the restoration of bank vegetation while other times just bank restoration is needed. Figure 6-4 shows the toe wood-sod mat concept while Figure 6-5 shows project examples where this technique has been used.

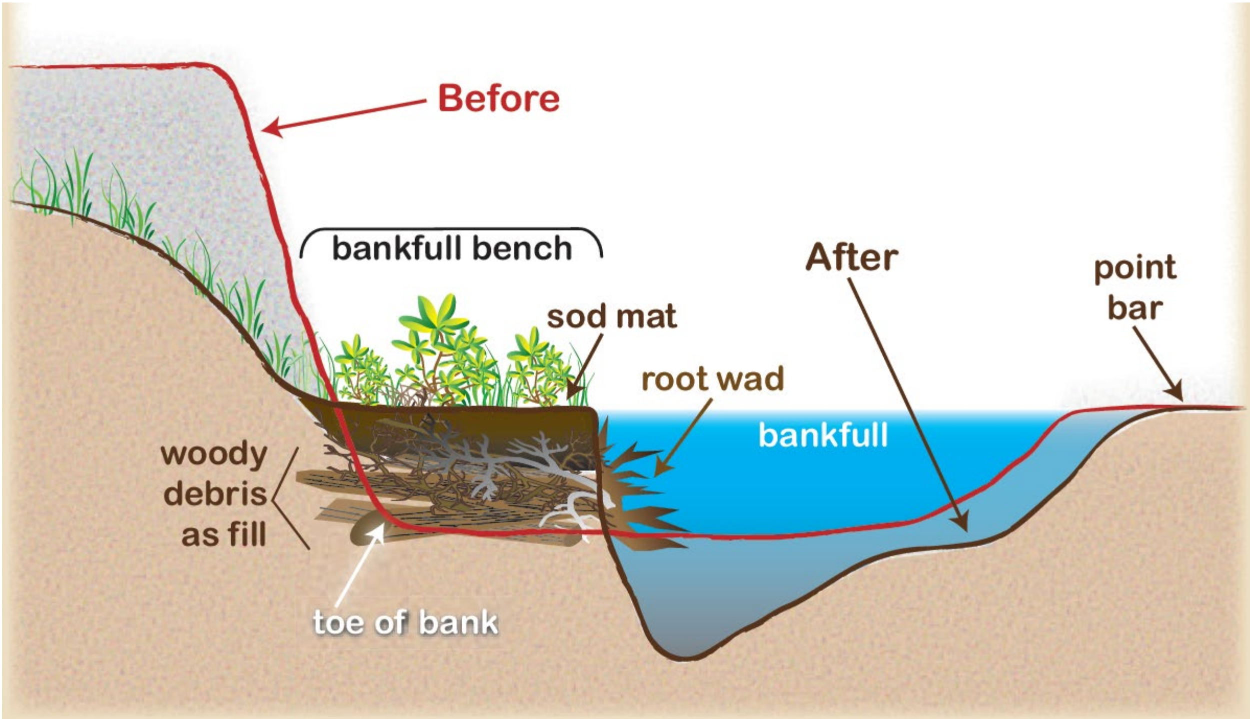


Figure 6-4: Toe Wood-Sod Mat Conceptual Example (source: Minnesota DNR)

Figure 6-5: Toe Wood-Sod Mat Construction Examples (source: Minnesota DNR)

A third potential corrective action is to construct J-hook vanes "designed to reduce bank erosion by reducing near-bank slope, velocity, velocity gradient, stream power and shear stress" (Rosgen, 2001). As flow passes over the length of the J-hook vane, the turbulence dissipates the flow energy and directs it toward the channel thalweg. Multiple J-hook vanes can be implemented, or toe-wood can be put between J-hook vanes on long outside bends. Figure 6-6 shows a generic plan, profile, and cross- sectional view of the J-hook vane.

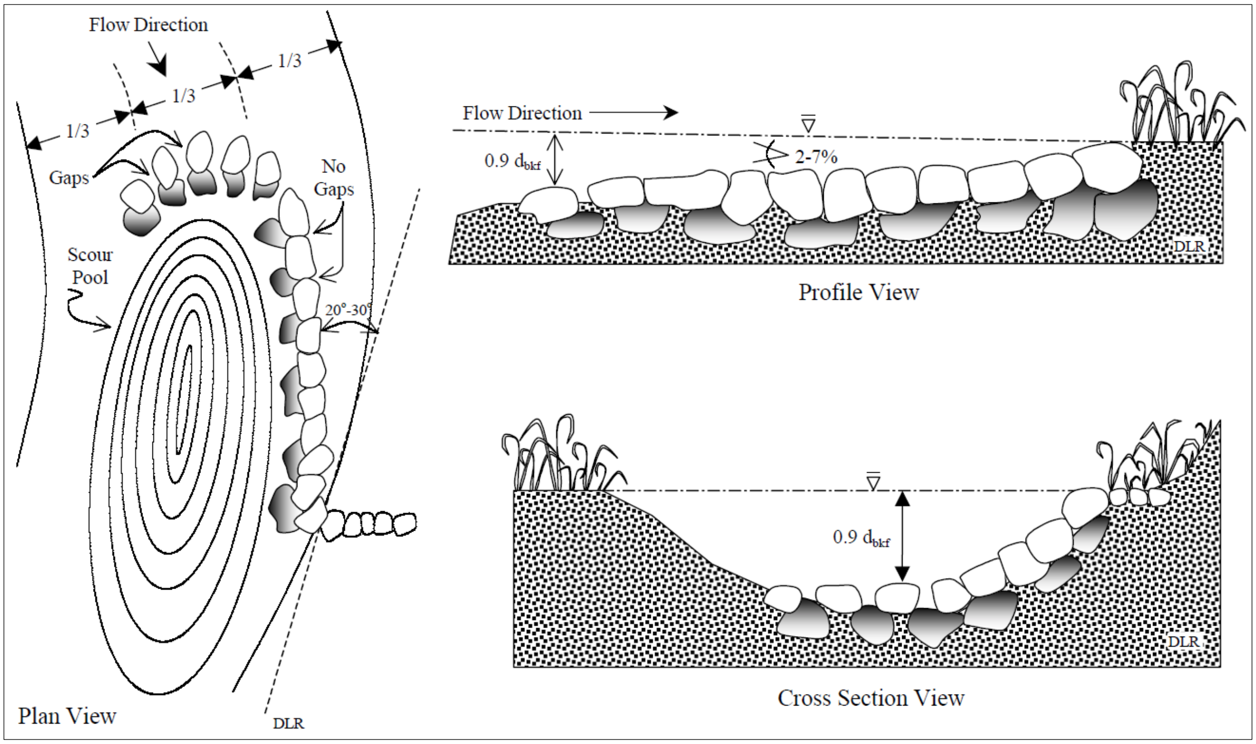


Figure 6-6: Generic J-Hook Vane Plan, Profile, and Cross-Sectional View Detail

A fourth potential corrective action for areas exhibiting bank erosion and channel migration is to add a longitudinal stone toe. This is similar to the toe wood-sod mat technique but has rock at the base of the toe. The use of rock over natural toe wood limits habitat for transitional aquatic species and transfers energy downstream, potentially resulting in erosion downstream of the corrective action area; therefore, this corrective action should primarily be considered only where the feature is protecting something of high value (roads, homes, etc.) where the tolerance to risk of failure is low. Figure 6-7 and Figure 6-8 show an example of a 'longitudinal stone toe' without bank re-shaping or creation of a berm behind the rock. The feature traps sediment from the eroding bank and produces a more stable slope that can be naturally vegetated. This corrective action is considered to be a last-resort remedy when infrastructure or residences are being threatened by erosion.

Figure 6-7: Longitudinal Stone Toe - Immediately After Construction (No Bank re-shaping)

Figure 6-8: Longitudinal Stone Toe – One Year After Construction (No Bank Re-shaping)

6.2.2.2. Theme: Channel Bed Degradation

Degrading channels are typically the result of either increases in reach discharge/velocity typically due to local drainage infrastructure or river crossings, reductions in sediment from upstream reaches or other sources (potentially due to perched crossings or, in the case of the FMM Project, the Sheyenne River and Maple River aqueducts), and/or increases in the river water surface slope due to the removal of downstream constrictions that increase the velocity and sediment transport capability of a reach.

Channel degradation results in deeper water along the banks, which can cause bank sloughing into the stream. Deeper and faster water along the banks makes them more likely to fail due to the undercutting of material along the bank toe.

One potential corrective action for river reaches that have experienced or are experiencing channel degradation is adding riffles to increase roughness and dissipate energy to prevent further degradation. An elliptically-shaped riffle can also be used to focus velocities away from the banks and direct them toward the pool portion of the stream. Generic plan, profile, and cross-sectional view details with generic dimensions are shown in Figure 6-9, Figure 6-10, and Figure 6-11, respectively.

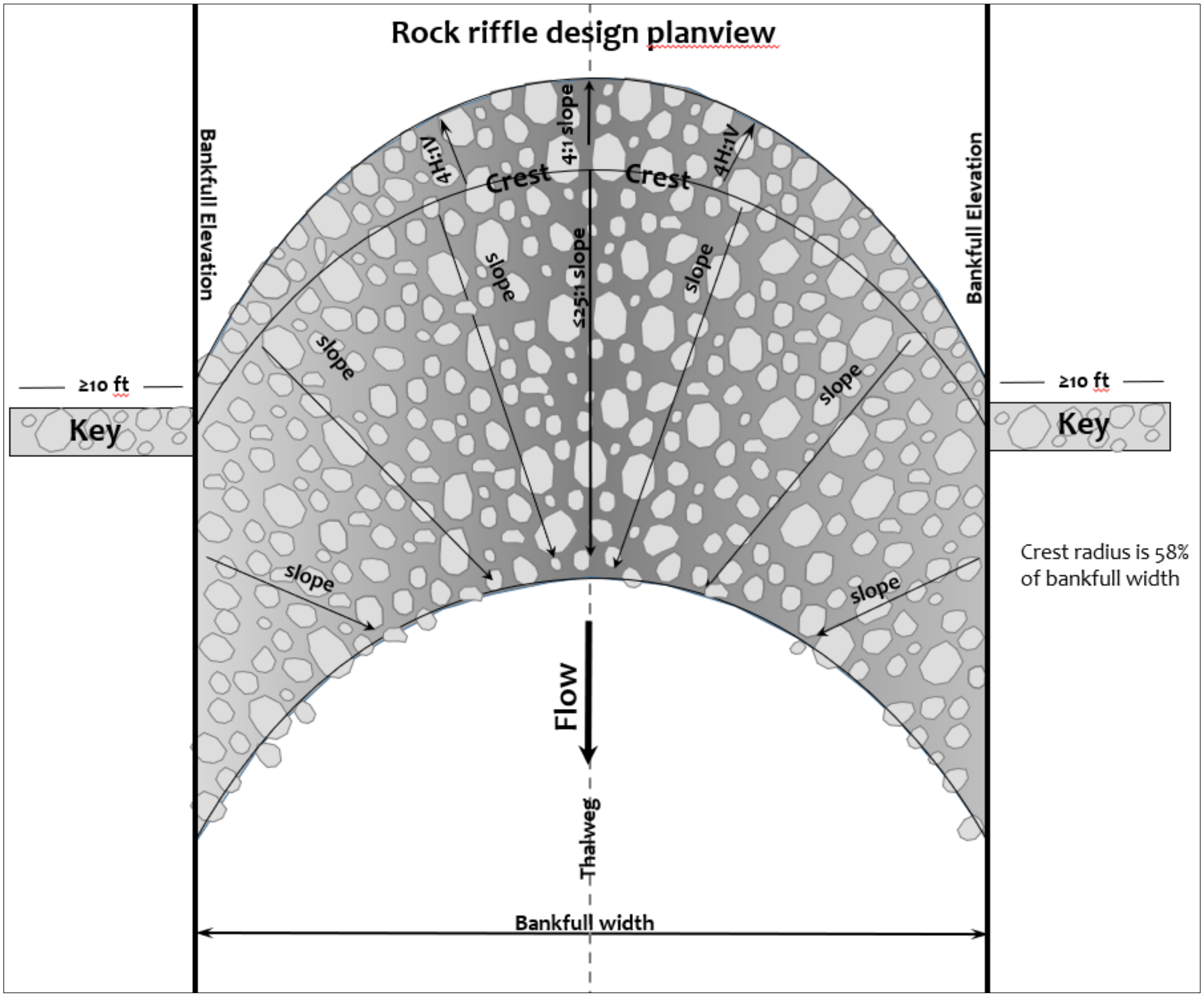


Figure 6-9: Generic Riffle Plan View Detail (Minnesota DNR)

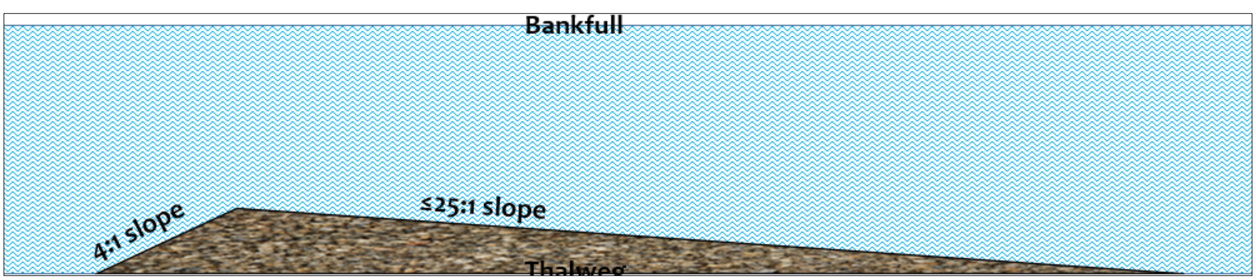


Figure 6-10: Generic Riffle Longitudinal Profile View Detail (Minnesota DNR)

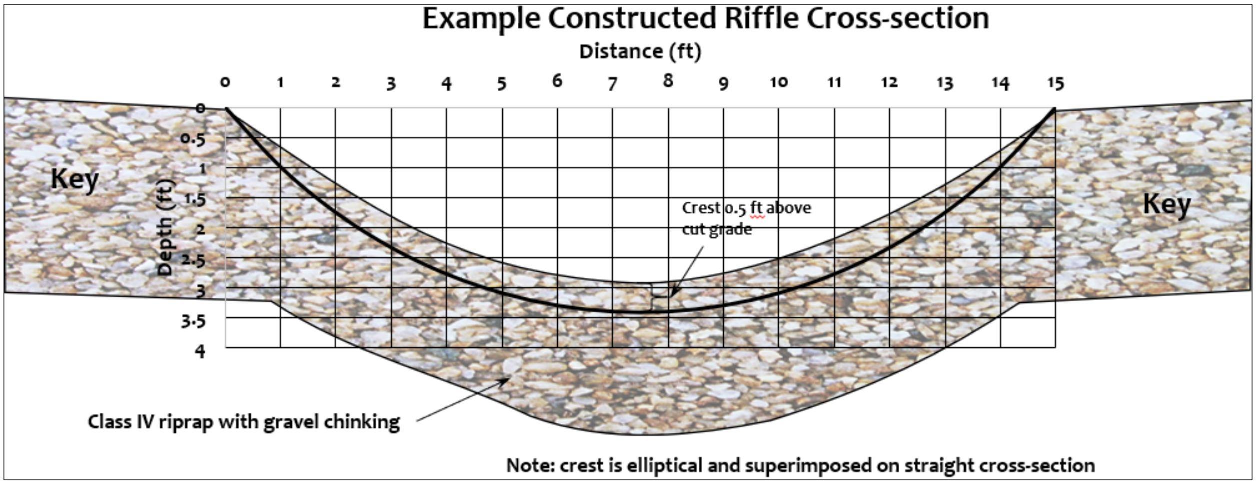


Figure 6-11: Generic Riffle Cross-Sectional View Detail (Minnesota DNR)

Another potential corrective action for a degrading stream bed is to add channel length through greater channel sinuosity and the addition of meanders, in concert with appropriate bed features with riffles at the cross-over and pools in the outside bends. Figure 6-12 shows a re-meandered section of Wolverton Creek near the town of Wolverton, Minnesota.

Figure 6-12: Re-meandered Segment of Wolverton Creek (source: Houston Engineering, Inc.)

A third method of reducing channel degradation is to lengthen the flood flow path of streams through the use of cut-off blockages. Toe wood-sod mat plugs (previously discussed in Section

6.2.2.1) and other similar woody debris/root wad configurations have been used to block cut-off areas along channels. It is noted that this method is most appropriate when there is enough land between the cut-off meanders. If the cut-off distance is too small, it has a high potential of cutting off again. Detailed and careful analysis by the GMT is necessary when considering this corrective action. Figure 6-13 shows a constructed toe wood-sod mat plug aimed at preventing channel cut-off.

Figure 6-13: Plug of Cut-Off Channel using Toe Wood-Sod Mat on the Pomme de Terre River in Minnesota

A fourth method to reduce bed degradation is the installation of J-hook vanes. The J-hook vane concept was previously discussed in Section 6.2.2.1.

6.2.2.3. Theme: Channel Bed Aggradation

Channel aggradation is oftentimes the result of a channel widened through bank erosion (thus reducing flow velocities and encouraging sediment deposition through the aggrading section), changes to upstream sediment supply (such as channel bank collapses and any resulting change in material sizes/characteristics), and/or flattening of the river surface slope due to a permanent downstream constriction (such as a new bridge or a road raise).

Bank collapse resulting in either a widened channel at the aggrading site or an increased sediment supply to the aggrading site can be addressed through the corrective actions discussed in Section 6.2.2.1.

A flattened water surface slope can be addressed by increasing the capacity of the river crossing resulting in the issue. It is noted that the Diversion Channel and associated infrastructure features are proactively being designed to minimize backwater increases and the associated flattened river water surface slopes, which minimizes the potential for these features to result in channel aggradation of the Rush River, Lower Rush River, Maple River, Sheyenne River, and the various drains and ditches intersected by the Diversion Channel.

6.2.2.4. Theme: Unstable Bank Slopes due to Sediment Deposition

In some situations, increases in overbank sediment deposition could increase the potential for slope stability problems. Unstable bank slopes can also result in slumping or collapse of riverbanks into the rivers. This is exacerbated in areas with a large amount of clay in floodplain sediments (such as the Red River and most of its tributaries) but can happen anywhere where the bank slope exceeds stable thresholds.

A potential corrective action is to increase slope stability by re-grading the channel banks in the affected area to slopes that are more stable and able to withstand any additional sediment deposition. Regrading the channel banks to create a more trapezoidal cross section is considered to be a last-resort remedy when infrastructure or residences are being threatened by the unstable bank slopes.

Another potential corrective action is to determine whether changes in the FMM Project's operating plan would decrease the sediment supply to the channel banks. Any changes to the operating plan would need to be balanced with the FMM Project's operational goals and if those goals result in additional environmental, economic, social, or cultural impacts beyond those disclosed in the FMM Project's NEPA documentation, additional corrective action would also be required to remedy those impacts. Any operational change shall be formally approval by the appropriate regulating agencies, including the US Army Corps of Engineers.

6.2.2.5. Theme: Localized Erosion

Erosion problems can also be locally based due to the presence of gated structures (such as the Red River Structure and Wild Rice River Structure), flow eddies, debris jams, bridges, elevated roadways, and other generally localized phenomena. A potential corrective action to localized erosion due to local hydraulics is to provide natural or non-natural erosion protection measures, such as large woody debris (natural) or riprap (non-natural). Other potential corrective actions for this theme could include modifications to or removal of the local cause of the erosion-inducing issue, such as reshaping of the channel banks or removal of debris jams.

7. PROTOCOLS AND STANDARDS

Rigor and consistency of data collection techniques and standards is critical for quality assurance and verifiable quantification of change. Discussing protocols and keeping them up to date with changing contractors and agency personnel is critical for ensuring accuracy and comparability of data sets over time. Therefore, reviewing and discussing sampling protocols shall occur in advance of scheduled field work, in the event of a flood event sampling situation, when there is a change in organizations/contractors conducting the sampling, and when there is a change in protocol or technologies. These discussions may include joint field visits of GMT members and the sampling organization/contractors to go over field methodologies and other protocols.

The following sections describe the protocols and data management/storage/exchange standards that shall be used. Any deviations to specific protocols developed for this GMP requires GMT and AMT approval, with text added to the GMP to describe this protocol change/deviation.

7.1. Protocols for Evaluating Geomorphic Triggers

This section prescribes the methods that shall be used for calculating/determining the Entrenchment Ratio, Bank Height Ratio, and bank line locations for the purpose of determining whether a trigger has been exceeded.

7.1.1. Bankfull Flow Rate Prescription

An accurate establishment of bankfull flows is integral to the calculations of Bank Height Ratio. WEST (2019) determined the bankfull flows for each geomorphic monitoring station by establishing bankfull elevations based on field observations then using a calibrated hydraulic model (HEC-RAS) to determine the flow needed to generate a water surface profile that equaled the field-observed bankfull elevations. The bankfull flows established as part of the WEST (2019) assessment for the Lower Rush River, Maple River, Red River, Rush River, Sheyenne River, and Wild Rice River were used to calculate Entrenchment Ratios and Bank Height Ratios using the survey data from the WEST 2012, 2019, and 2021 assessments. The bankfull flows established as part of the WEST (2021) assessment for the Buffalo River and Wolverton Creek were used to calculate Entrenchment Ratios and Bank Height Ratios using the survey data from the WEST 2012 and 2021 assessments (the 2019 assessment did not cover these streams). Table 7-1 summarizes the bankfull flows that shall be used for each geomorphic monitoring station. It is noted that the flow for SH05 was set to the same values for SH06 and SH04; however, this GMS is not actually connected to the rest of the Sheyenne River as it is protected by the Sheyenne River Flood Control Project. The Sheyenne River mitigation project that will be completed once the FMM Project becomes operational will allow flow to flow through SH05 again naturally. The calculations for the Entrenchment Ratio and Bank Height Ratio variables were completed using hydraulic model settings for the pre-FMM Project conditions with the Sheyenne River Flood Control Project that produced bankfull water surface elevations of approximately 896.7 feet in SH05 in the WEST (2019) hydraulic model. It is recommended that the GMT re-evaluate this flow and determine an appropriate bankfull flow for post-FMM Project calculations in SH05.

Table 7-1: Bankfull Flows for Use in Entrenchment Ratio and Bank Height Ratio Calculations

GMS	Bankfull Flow (cfs)	GMS	Bankfull Flow (cfs)	GMS	Bankfull Flow (cfs)
BU01	800	RE08	2,500	SH08	1,600
LR01	135	RE08A	2,500	WC01	150
MA01	1,050	RE09	2,500	WC02	145
MA02	1,050	RE10	2,300	WC03	30
MA03	1,050	RU01	200	WC04	25
RE01	5,000	SH01	2,800	WR01	1,000
RE02	5,000	SH02	2,700	WR02	1,000
RE03	3,800	SH03	2,600	WR03	850
RE04	3,800	SH04	1,500	WR04	825
RE05	3,800	SH05	750^	WR05	800
RE06	3,800	SH06A	1,500	WR06	775
RE06A	2,800	SH06	1,500	WR07	750
RE07	2,800	SH07	1,600	WR08	750

^See text above regarding Sheyenne River Flood Control Project influence in SH05

To validate the selection of the bankfull flows shown in Table 7-1, the average bankfull cross-sectional area for each geomorphic monitoring station using survey data from the WEST 2021 report was compared with the Minnesota DNR western region curve for this characteristic. Figure 7-1 shows that the bankfull cross-sectional areas generally align within the range of expected values; therefore, the use of these bankfull flows (which generated the associated bankfull cross-sectional areas using the 2021 WEST report survey data) are considered appropriate.

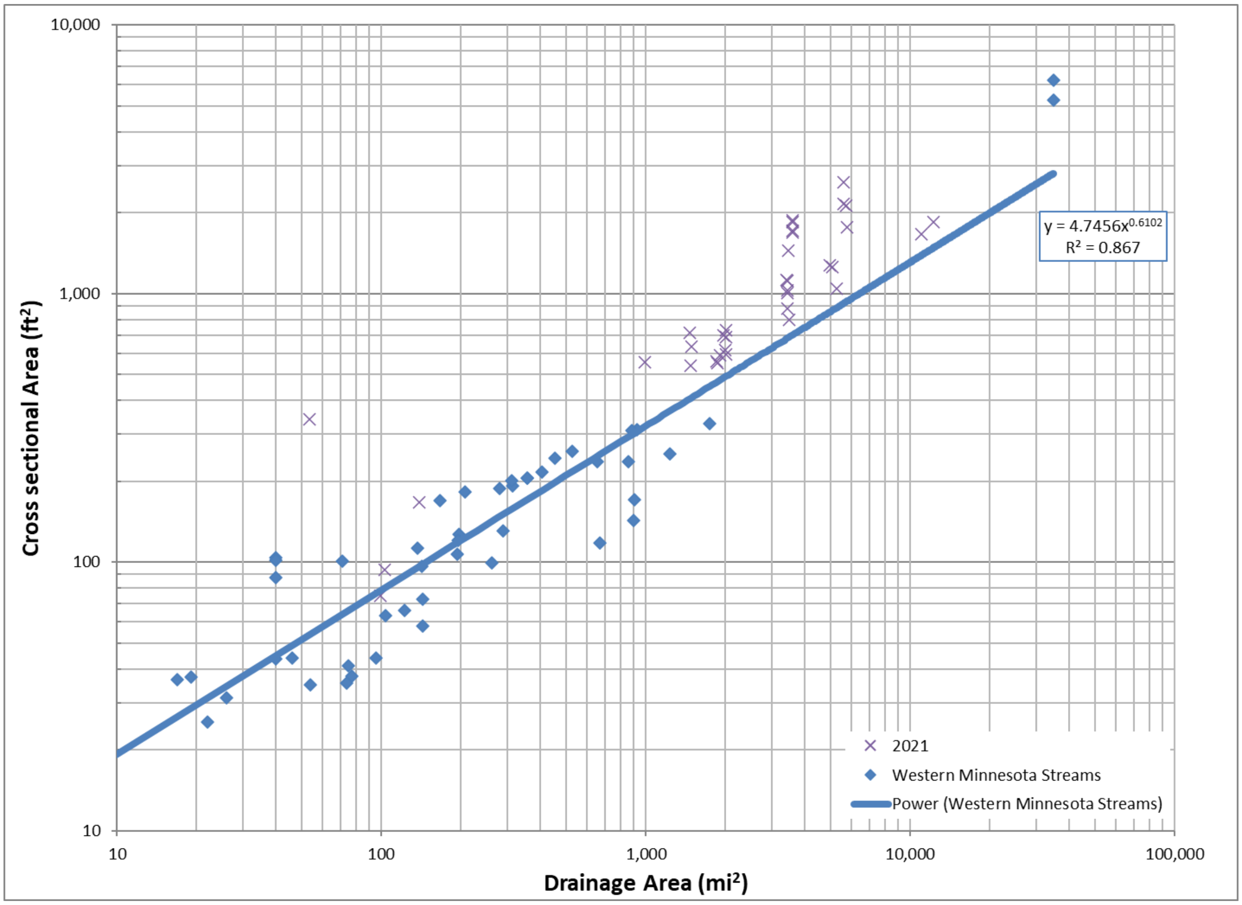


Figure 7-1: Comparison of Bankfull Cross-Sectional Area Calculations for the FMM Project and the MN DNR Western Area Dataset

7.1.2. Entrenchment Ratio Calculation Prescription

The Entrenchment Ratio is calculated for riffle (crossing) sections and is defined as the ratio between the floodprone width and the bankfull width. A close evaluation of the data from the three years of pre- FMM Project monitoring (WEST 2012, 2019, and 2021) indicates that the Entrenchment Ratio can vary substantially because small changes in the floodprone elevation can result in dramatic changes in the floodprone width due to the extremely wide floodplain for streams in the FMM Project vicinity. An example of this is shown in Figure 7-2.

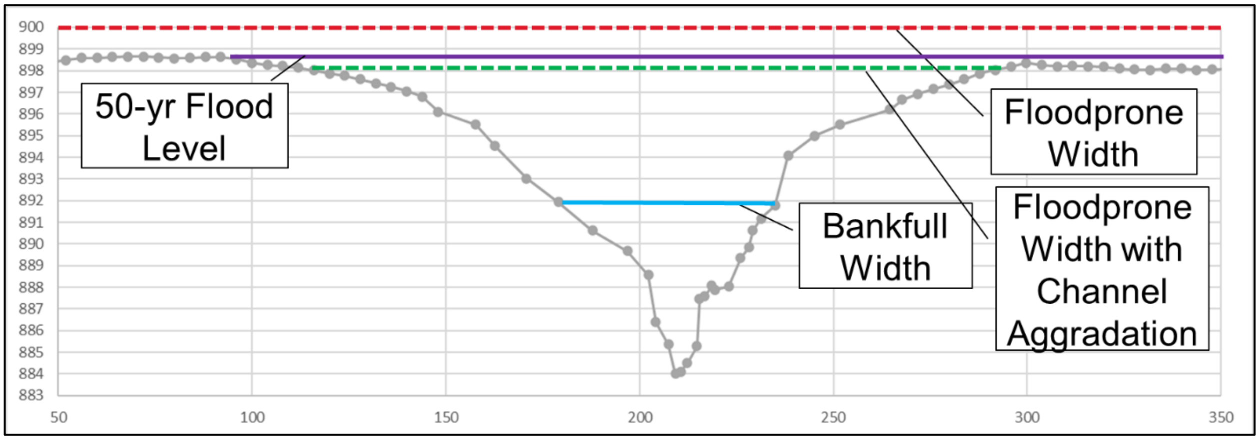


Figure 7-2: Comparison of Floodprone Widths with Small Changes in Floodprone Elevations

Because of the influence on floodprone width in the Entrenchment Ratio calculation, the floodprone width that shall be used for all past and future Entrenchment Ratio calculations completed for the purposes of evaluating trigger exceedance was set to a specified value typically equal to that determined by WEST (2019), with small adjustments at select locations, for each riffle monitoring cross section in the FMM Project vicinity. The specified floodprone widths are shown in Table 7-2. It is noted that in the event the floodprone width exceeded 1,000 feet for all streams besides the Red River, the floodprone width was set to a width of 1,000 feet. For the Red River, the maximum floodprone width threshold was set to 1,500 feet. This ensured that Entrenchment Ratios remained in a reasonable range while also resulting in generally high Entrenchment Ratios that did not approach the low end of the “fully functioning” (per the MN SQT) Entrenchment Ratio threshold.

As of 2022, the GMT and the AMT determined that the Entrenchment Ratio should be calculated using a fixed bankfull elevation. The previous WEST 2012, 2019, and 2021 reports used bankfull flows (see Table 7-1) from which an elevation was determined using a hydraulic model (such as HEC-RAS).

A hydraulic model was used due to the presence of features downstream of each geomorphic monitoring station that influence water surface elevations at bankfull flows. Special attention in the hydraulic model shall be given to boundary conditions to ensure water level changes are associated with changes in cross-sectional geometry and not with hydraulic modeling techniques. The electronic appendix of each WEST (2012, 2019, and 2021) assessment includes the HEC-RAS models used in the bankfull flow and elevation calculations.

Table 7-2: Floodprone Widths for Riffle Monitoring Cross Sections

Cross Section	Floodprone Width (ft)	Cross Section	Floodprone Width (ft)
BU01X01	253	SH01X07	439
BU01X04	233	SH02X01	1,000
BU01X06	196	SH02X03	1,000
LR01X01	1,000	SH02X04	1,000
LR01X03	1,000	SH02X06	1,000
LR01X06	222	SH03X01	412
MA01X01	1,000	SH03X02	1,000
MA01X03	473	SH03X05	1,000
MA01X05	645	SH04X01	1,000
MA01X06	417	SH04X03	1,000
MA02X01	1,000	SH04X05	1,000
MA02X03	1,000	SH05X01	1,000
MA02X06	1,000	SH05X03	1,000
MA03X01	1,000	SH05X06	1,000
MA03X04	1,000	SH06AX02	1,000
MA03X06	1,000	SH06AX04	1,000
RE01X01	768	SH06AX05	1,000
RE01X03	559	SH06X02	1,000
RE01X05	850	SH06X03	1,000
RE01X07	530	SH06X05	1,000
RE02X01	540	SH07X01	1,000
RE02X03	547	SH07X02	1,000
RE02X05	596	SH07X03	1,000
RE02X06	726	SH07X04	1,000
RE02X08	720	SH07X05	1,000
RE02X10	485	SH07X08	1,000
RE03X01	1,037	SH08X01	1,000
RE03X03	980	SH08X06	1,000
RE03X05	1,395	WC01X03	61
RE03X06	1,325	WC01X05	91
RE04X01	765	WC01X06	51
RE04X03	1,500	WC02X02	84
RE04X05	1,500	WC02X04	120
RE05X02	1,500	WC02X06	122
RE05X04	1,406	WC03X01	142
RE05X06	942	WC03X04	142
RE06AX01	1,500	WC03X06	157
RE06AX04	1,500	WC04X02	180
RE06AX06	1,500	WC04X04	144
RE06X01	1,500	WC04X06	157
RE06X02	1,500	WR01X01	444

Cross Section	Floodprone Width (ft)	Cross Section	Floodprone Width (ft)
RE06X03	1,500	WR01X03	383
RE06X05	1,500	WR01X06	328
RE07X01	1,087	WR02X02	1,000
RE07X03	1,500	WR02X04	338
RE07X06	1,171	WR02X06	287
RE08AX02	645	WR03X01	295
RE08AX04	478	WR03X04	289
RE08AX06	1,500	WR03X06	611
RE08X01	893	WR04X02	331
RE08X03	800	WR04X03	359
RE08X04	1,109	WR04X04	270
RE08X06	1,104	WR04X06	288
RE09X02	1,500	WR05X01	240
RE09X03	495	WR05X03	215
RE09X05	1,075	WR05X06	218
RE09X06	1,500	WR06X01	239
RE10X01	1,167	WR06X02	282
RE10X03	1,282	WR06X04	215
RE10X05	1,500	WR06X06	353
RE10X06	1,210	WR07X01	696
RU01X01	1,000	WR07X03	842
RU01X02	1,000	WR07X05	468
RU01X04	1,000	WR07X06	510
RU01X07	249	WR08X01	447
SH01X01	859	WR08X05	503
SH01X03	920	WR08X07	361
SH01X05	798		

Once the Entrenchment Ratios for each monitoring cross section are calculated using the methodology listed above based upon bankfull elevations, the average Entrenchment Ratio of the riffle monitoring cross sections within each geomorphic monitoring station shall then be averaged to determine the geomorphic monitoring station Entrenchment Ratio, which is the basis for comparison to the trigger values.

The new methodology to calculate the Entrenchment Ratios based upon bankfull elevations will not be used until the next set of investigations. Therefore, the following results of the previous calculations based upon bankfull flows are presented for each geomorphic monitoring station as calculated based on the 2012, 2019, and 2021 assessment survey data. The results of these calculations are shown in Table 7-3, Table 7-4, and Table 7-5, respectively. The Entrenchment Ratio values in these tables were then used to establish the maximum and minimum pre- FMM Project Entrenchment Ratio for each stream for trigger setting purposes. In the event additional pre-FMM Project data is collected, the triggers shall be adjusted (as necessary) in the event the range of pre-FMM Project data increases compared to the data set provided in the tables below. It is noted that the calculated Entrenchment Ratio values for trigger identification purposes may differ from those presented in the WEST (2012, 2019, and 2021) reports because it was not possible for WEST to use a constant floodprone width or bankfull flow for each geomorphic monitoring cross section over the course of the three assessment years.

Table 7-3: Entrenchment Ratios using 2012 Survey Data and the Calculation Methodology Outlined in this Section

GMS	Entrenchment Ratio	GMS	Entrenchment Ratio	GMS	Entrenchment Ratio
BU-01	3.0	RE-08	-	SH-08	11.9
LR-01	8.1	RE-08A	-	WC-01	2.4
MA-01	8.2	RE-09	8.4	WC-02	3.9
MA-02	-	RE-10	7.7	WC-03	-
MA-03	11.1	RU-01	26.9	WC-04	-
RE-01	4.1	SH-01	7.5	WR-01	4.5
RE-02	4.2	SH-02	8.3	WR-02	6.1
RE-03	7.0	SH-03	7.9	WR-03	-
RE-04	7.6	SH-04	11.7	WR-04	-
RE-05	7.4	SH-05	13.8	WR-05	2.8
RE-06	-	SH-06A	14.0	WR-06	3.6
RE-06A	10.3	SH-06	-	WR-07	7.3
RE-07	-	SH-07	11.4	WR-08	5.3

Table 7-4: Entrenchment Ratios using 2019 Survey Data and the Calculation Methodology Outlined in this Section

GMS	Entrenchment Ratio	GMS	Entrenchment Ratio	GMS	Entrenchment Ratio
BU-01	-	RE-08	5.8	SH-08	11.5
LR-01	6.7	RE-08A	-	WC-01	-
MA-01	5.3	RE-09	8.5	WC-02	-
MA-02	9.9	RE-10	7.6	WC-03	-
MA-03	9.2	RU-01	17.0	WC-04	-
RE-01	3.9	SH-01	7.9	WR-01	3.8
RE-02	3.8	SH-02	8.7	WR-02	5.8
RE-03	6.7	SH-03	8.2	WR-03	4.6
RE-04	6.8	SH-04	11.5	WR-04	3.1
RE-05	6.9	SH-05	12.7	WR-05	2.7
RE-06	7.9	SH-06A	12.3	WR-06	3.2
RE-06A	9.6	SH-06	12.0	WR-07	6.1
RE-07	8.0	SH-07	10.4	WR-08	4.9

Table 7-5: Entrenchment Ratios using 2021 Survey Data and the Calculation Methodology Outlined in this Section

GMS	Entrenchment Ratio	GMS	Entrenchment Ratio	GMS	Entrenchment Ratio
BU-01	2.8	RE-08	6.6	SH-08	11.8
LR-01	6.4	RE-08A	6.4	WC-01	2.0
MA-01	8.3	RE-09	8.6	WC-02	5.0
MA-02	10.4	RE-10	8.1	WC-03	3.9
MA-03	10.0	RU-01	18.1	WC-04	4.9
RE-01	3.9	SH-01	7.9	WR-01	4.0
RE-02	3.9	SH-02	8.5	WR-02	6.0
RE-03	7.4	SH-03	7.5	WR-03	5.4
RE-04	6.3	SH-04	10.7	WR-04	3.3
RE-05	6.3	SH-05	12.2	WR-05	2.6
RE-06	9.2	SH-06A	10.2	WR-06	3.0
RE-06A	10.3	SH-06	10.8	WR-07	8.0
RE-07	8.9	SH-07	9.9	WR-08	5.2

7.1.3. Bank Height Ratio Calculation Prescription

The Bank Height Ratio is calculated for riffle (crossing) sections and is defined as the ratio between the low bank height and maximum bankfull depth. A close evaluation of the data from the three years of pre-FMM Project monitoring (WEST 2012, 2019, and 2021) indicates that the Bank Height Ratio can vary substantially due to different interpretations of low bank height by the geomorphic investigator. An example of this is shown in Figure 7-3.

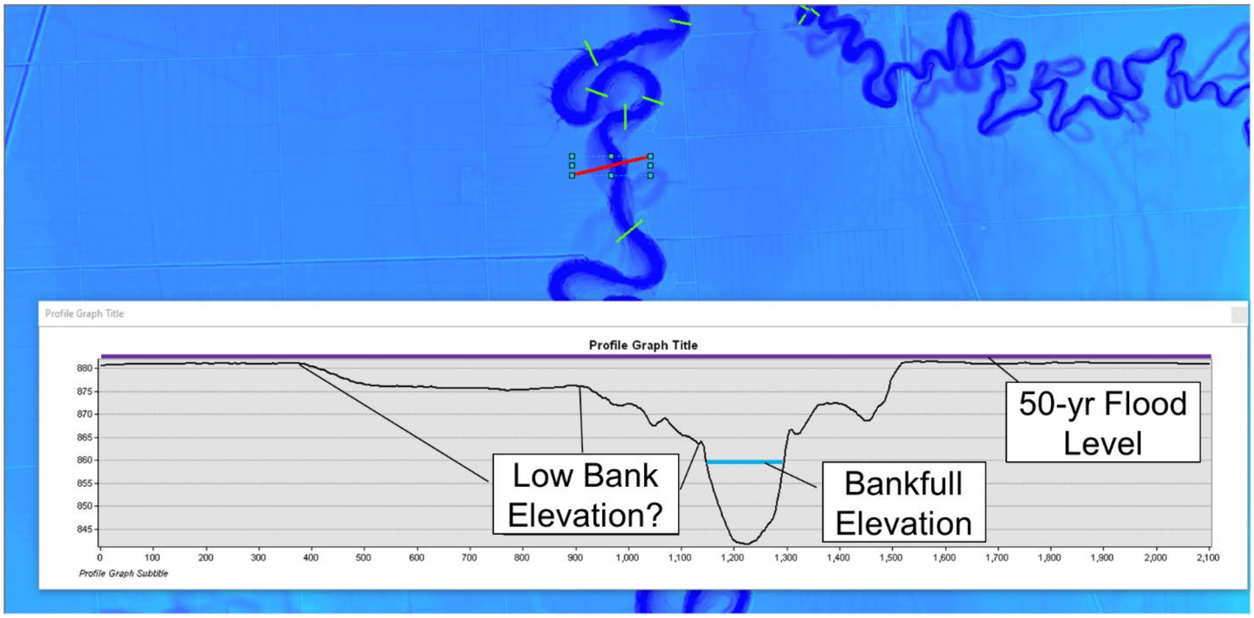


Figure 7-3: Comparison of Low Bank Height Possibilities

Because of the influence of the low bank elevation in the Bank Height Ratio calculation, the low bank elevation that shall be used for all past and future Bank Height Ratio calculations completed for the purposes of evaluating trigger exceedance was set to a specified value typically equal to that determined by WEST (2019), with small adjustments at select locations, for each riffle monitoring cross section in the FMM Project vicinity. The specified low bank elevations are shown in Table 7-6.

Finally, as discussed in Section 2, an accurate establishment of bankfull flows is integral to the Bank Height Ratio calculation. Therefore, all Bank Height Ratio calculations completed for the purposes of evaluating trigger exceedance shall use the bankfull flow rates shown in Table 7-1 and a hydraulic model (such as HEC-RAS) to determine the bankfull elevation from which the maximum bankfull depth is to be calculated. A hydraulic model shall be used due to the presence of features downstream of each geomorphic monitoring station that influence water surface elevations at bankfull flows. Special attention in the hydraulic model shall be given to boundary conditions to ensure water level changes are associated with changes in cross-sectional geometry and not with hydraulic modeling techniques. The electronic appendix of each WEST (2012, 2019, and 2021) assessment includes the HEC-RAS models used in the bankfull flow and elevation calculations.

Table 7-6: Low Bank Elevations for Riffle Monitoring Cross Sections

Cross Section	Low Bank Elevation (ft NAVD88)	Cross Section	Low Bank Elevation (ft NAVD88)
BU01X01	859.8	SH01X07	875.3
BU01X04	862.9	SH02X01	884.2
BU01X06	862.1	SH02X03	883.9
LR01X01	896.1	SH02X04	884.7
LR01X03	896.6	SH02X06	884.5
LR01X06	895.7	SH03X01	886.8
MA01X01	888.7	SH03X02	886.8

Cross Section	Low Bank Elevation (ft NAVD88)	Cross Section	Low Bank Elevation (ft NAVD88)
MA01X03	887.4	SH03X05	886.4
MA01X05	887.4	SH04X01	894.0
MA01X06	889.7	SH04X03	893.9
MA02X01	890.8	SH04X05	893.3
MA02X03	890.7	SH05X01	897.5
MA02X06	892.2	SH05X03	902.3
MA03X01	899.8	SH05X06	902.6
MA03X04	897.8	SH06AX02	908.3
MA03X06	898.7	SH06AX04	911.6
RE01X01	857.6	SH06AX05	908.0
RE01X03	857.7	SH06X02	911.3
RE01X05	856.4	SH06X03	911.6
RE01X07	856.6	SH06X05	910.6
RE02X01	862.9	SH07X01	918.3
RE02X03	861.8	SH07X02	915.1
RE02X05	862.2	SH07X03	917.2
RE02X06	863.8	SH07X04	918.8
RE02X08	864.0	SH07X05	918.5
RE02X10	862.0	SH07X08	919.3
RE03X01	875.7	SH08X01	932.9
RE03X03	872.9	SH08X06	932.6
RE03X05	873.7	WC01X03	892.0
RE03X06	873.8	WC01X05	894.2
RE04X01	881.5	WC01X06	896.0
RE04X03	881.5	WC02X02	899.4
RE04X05	881.8	WC02X04	900.3
RE05X02	887.7	WC02X06	901.1
RE05X04	888.2	WC03X01	912.3
RE05X06	887.5	WC03X04	912.7
RE06AX01	888.1	WC03X06	912.7
RE06AX04	891.0	WC04X02	915.0
RE06AX06	890.4	WC04X04	915.2
RE06X01	888.8	WC04X06	914.9
RE06X02	889.7	WR01X01	890.5
RE06X03	888.9	WR01X03	889.9
RE06X05	888.2	WR01X06	891.8
RE07X01	891.4	WR02X02	891.7
RE07X03	890.9	WR02X04	891.0
RE07X06	890.4	WR02X06	891.6
RE08AX02	894.6	WR03X01	895.7
RE08AX04	890.7	WR03X04	896.6

Cross Section	Low Bank Elevation (ft NAVD88)	Cross Section	Low Bank Elevation (ft NAVD88)
RE08AX06	893.4	WR03X06	895.2
RE08X01	891.5	WR04X02	896.9
RE08X03	890.5	WR04X03	899.1
RE08X04	891.8	WR04X04	898.5
RE08X06	894.1	WR04X06	900.0
RE09X02	900.9	WR05X01	901.8
RE09X03	900.9	WR05X03	902.0
RE09X05	901.9	WR05X06	902.2
RE09X06	901.0	WR06X01	906.1
RE10X01	917.1	WR06X02	904.2
RE10X03	917.1	WR06X04	905.2
RE10X05	917.0	WR06X06	905.2
RE10X06	918.3	WR07X01	912.3
RU01X01	893.4	WR07X03	914.0
RU01X02	892.2	WR07X05	914.5
RU01X04	894.0	WR07X06	915.7
RU01X07	893.6	WR08X01	918.7
SH01X01	872.1	WR08X05	914.3
SH01X03	871.0	WR08X07	917.1
SH01X05	873.3		

Once the Bank Height Ratios for each monitoring cross section are calculated using the methodology listed above, the average Bank Height Ratio of the riffle monitoring cross sections within each geomorphic monitoring station shall then be averaged to determine the geomorphic monitoring station Bank Height Ratio, which is the basis for comparison to the trigger values.

Using the Bank Height Ratio calculation process listed above, the Bank Height Ratios for each geomorphic monitoring station were calculated based on the 2012, 2019, and 2021 assessment survey data. The results of these calculations are shown in Table 7-7, Table 7-8, and Table 7-9, respectively. The Bank Height Ratio values in these tables were then used to establish the maximum and minimum pre- FMM Project Bank Height Ratio for each stream for trigger setting purposes. In the event additional pre- FMM Project data is collected, the triggers shall be adjusted (as necessary) in the event the range of pre- FMM Project data increases compared to the data set provided in the tables below. It is noted that the calculated Bank Height Ratio values for trigger identification purposes may differ from those presented in the WEST (2012, 2019, and 2021) reports because it was not possible for WEST to use a constant low bank elevation or bankfull flow for each geomorphic monitoring cross section over the course of the three assessment years.

Table 7-7: Bank Height Ratios using 2012 Survey Data and the Calculation Methodology Outlined in this Section

GMS	Bank Height Ratio	GMS	Bank Height Ratio	GMS	Bank Height Ratio
BU-01	1.3	RE-08	-	SH-08	1.4
LR-01	1.4	RE-08A	-	WC-01	2.1
MA-01	1.2	RE-09	1.2	WC-02	1.1
MA-02	-	RE-10	1.2	WC-03	-
MA-03	1.2	RU-01	1.5	WC-04	-
RE-01	1.2	SH-01	1.2	WR-01	1.3
RE-02	1.2	SH-02	1.4	WR-02	1.1
RE-03	1.0	SH-03	1.1	WR-03	-
RE-04	1.0	SH-04	1.3	WR-04	-
RE-05	1.1	SH-05	1.3	WR-05	1.1
RE-06	-	SH-06A	1.4	WR-06	1.2
RE-06A	1.0	SH-06	1.2	WR-07	1.0
RE-07	-	SH-07	1.3	WR-08	1.1

Table 7-8: Bank Height Ratios using 2019 Survey Data and the Calculation Methodology Outlined in this Section

GMS	Bank Height Ratio	GMS	Bank Height Ratio	GMS	Bank Height Ratio
BU-01	-	RE-08	1.0	SH-08	1.4
LR-01	1.2	RE-08A	-	WC-01	-
MA-01	1.1	RE-09	1.2	WC-02	-
MA-02	1.0	RE-10	1.1	WC-03	-
MA-03	1.1	RU-01	1.2	WC-04	-
RE-01	1.2	SH-01	1.3	WR-01	1.1
RE-02	1.2	SH-02	1.4	WR-02	1.1
RE-03	1.0	SH-03	1.3	WR-03	1.0
RE-04	1.0	SH-04	1.4	WR-04	1.0
RE-05	1.0	SH-05	1.3	WR-05	1.1
RE-06	1.0	SH-06A	-	WR-06	1.1
RE-06A	1.0	SH-06	1.2	WR-07	0.9
RE-07	1.0	SH-07	1.3	WR-08	1.0

Table 7-9: Bank Height Ratios using 2021 Survey Data and the Calculation Methodology Outlined in this Section

GMS	Bank Height Ratio	GMS	Bank Height Ratio	GMS	Bank Height Ratio
BU-01	1.3	RE-08	1.0	SH-08	1.4
LR-01	1.1	RE-08A	1.1	WC-01	1.7
MA-01	1.1	RE-09	1.3	WC-02	1.2
MA-02	1.0	RE-10	1.3	WC-03	0.8
MA-03	1.1	RU-01	1.2	WC-04	0.9
RE-01	1.2	SH-01	1.3	WR-01	1.1
RE-02	1.3	SH-02	1.4	WR-02	1.1
RE-03	1.1	SH-03	1.2	WR-03	1.2
RE-04	1.0	SH-04	1.3	WR-04	1.1
RE-05	1.0	SH-05	1.3	WR-05	1.1
RE-06	1.0	SH-06A	1.1	WR-06	1.2
RE-06A	1.0	SH-06	1.0	WR-07	1.2
RE-07	1.0	SH-07	1.2	WR-08	1.2

7.1.4. Aerial-Image Derived Bank Line Locations

Identification of bank line locations using aerial imagery is dependent on many factors, including scale, process, and judgment. The following protocol has been used by WEST in their geomorphic assessments and is recommended for use in future assessments for trigger comparison purposes. For demonstration purposes, the protocol described below uses the year 2020, which is the most recent year for which bank line locations were delineated by WEST in their 2021 report. The actual year in the protocol will change and should be based on the most recent year for which bank line locations have been delineated.

- Load the 2020 aerial imagery and 2020 delineated bank line shapefile into GIS.
- Set the scale in GIS to 1:1,000, which is the scale at which the WEST (2021) assessment delineated bank line locations.
- Compare the delineated 2020 bank line locations with the 2020 aerial imagery to understand and the general judgment process used for delineating the 2020 bank line locations so it can be replicated for determining the current year bank line locations.
- Make a copy of the 2020 bank line locations shapefile, rename it to the current year being evaluated, and load it into GIS.
- Load the current year aerial imagery into GIS.
- Compare the copied/renamed 2020 bank line locations shapefile with the current year aerial imagery. If bank line locations have notably moved at the 1:1,000 scale, edit the copied/renamed 2020 bank line locations shapefile to reflect the change.

In the event multiple years of aerial imagery are to be evaluated during one assessment, the use of the most recent year of delineated bank lines should still be used. For example, if conducting an assessment using 2023 and 2026 aerial imagery, the 2020 bank line shapefile should be the one edited to define the 2023 bank line locations, while the newly created 2023 bank line shapefile should be the one edited to define the 2026 bank line locations, always working in sequential order from oldest to newest imagery.

If channel sinuosity, meander amplitude, or meander frequency metrics are desired, the following process shall be used:

- Create stream centerline shapefiles using the delineated left and right bank line shapefiles and the "Collapse Dual Lines to Centerline" tool in ArcGIS's ArcToolbox (or similar tool for a different GIS program). Centerlines obtained from the "Collapse Dual Lines to Centerline" tool are very similar and for the most part identical to what would be obtained if the stream centerline were digitized separately.
- Use the methodology described in Heo et al. (2009) to find the centroid and radius of an imaginary circle best fit to the data points along the digitized bank line that represents the bend line.

7.1.5. Use of Video Footage to Document Changes in Geomorphology

The Corps is working with WEST to evaluate video footage methods to document unstable banks, erosion, deposition, and other changes that could occur due to the Project or other items. The study will consider technical and economic factors related to the use of drone-mounted LiDAR, multiple cameras mounted on boats, and other methods. Following the study, the results shall be presented to the AMT for further consideration to improve data collection.

7.2. Protocols for Other Work

7.2.1. Survey Data

Cross-sectional survey data below the top of bank shall be collected with no more than 10 feet between each point, with at least 5 points along the channel bottom and 3 points along each channel bank, as well as points at every notable slope change location. Between the cross-section monuments and top of bank, data shall be collected with no more than 20 feet between each point and at every notable slope change location. Longitudinal profile data shall be collected with no more than a 10 foot spacing between each point along the profile.

7.2.2. Sediment Sample Analysis

All sediment samples shall be assessed by identifying the classification (following ASTM D2488), particle size distribution (following ASTM D7928), particle density (following ASTM D854, Method B), and organic content analysis (following ASTM D2974, Method C). A photograph and the northing and easting location for each sample collected shall also be collected.

7.2.3. Rosgen Assessments

All Rosgen assessments and worksheets shall be conducted and completed in accordance with those processes outlined in Watershed Assessment of River Stability and Sediment Supply (Rosgen, 2006). All field assessment crew leads shall have at least 10 years of experience in riverine geomorphic assessments, measurements, and analysis. If more than one field crew is deployed at the same time, the field crew lead for each team shall meet this requirement. It is also recommended, though not required, that all geomorphic assessment field crew leads have Rosgen training through the Level III channel stability assessment.

7.2.4. Data Management

The RIVERMorph data management software package (www.rivermorph.com) associated with the Rosgen stream assessments should be part of the data management and analysis package. Surveyed cross-sectional data, field-observed bankfull elevations, longitudinal profile data, sediment size data, roughness parameters, and riparian vegetation characteristics shall be entered into the software for each cross section. If field-observed values (such as bankfull elevation calls) are manually changed or altered due to additional/outside analysis (such as HEC-RAS or other modeling), the Contractor shall include a list of the changes as well as the explanation for each change. This list shall include both the field-estimated values as well as the adjusted values.

Other data, such as survey data, hydraulic models, spreadsheets analyses, and GIS data, shall be provided in an electronic format as an attachment to the geomorphic assessment report.

Data Storage and Exchange

The data will need to be accessible and shared for redundancy and analysis purposes as well as stored as part of the monitoring record and for future data needs. The FMM Project's non-Federal sponsors shall manage and host the official repository of all of the data sets and completed analysis related to the FMM Project into perpetuity and make this data accessible via a web interface. Data from the watershed districts and others may be included in this data base. At present, the Aconex site (https://us1.aconex.com/Logon) serves as the repository for all reports and associated electronic data. The FMM Project's non-Federal sponsors shall provide access to this site for all members of the GMT and AMT upon request.

Raw data shall be shared within 2 months of the end of the data collection or as soon as possible. Post- processed data shall be shared with all GMT and AMT members within 2 weeks of finalization. Results shall be shared to AMT members at least 6 months prior to the next anticipated field geomorphic monitoring effort.

8. GEOMORPHIC MONITORING SCHEDULE AND GMP UPDATES

8.1. Pre-FMM Project

A total of three pre-FMM Project geomorphic assessments have been completed and are documented in WEST (2012, 2019, and 2021). All three sets of monitoring results were analyzed by the GMT during working meetings initiated within 90 calendar days of the final 2021 WEST report, noting any changes deemed significant by the GMT. The working meetings for interpreting the analyzed data with regards to geomorphic stability should be open and scheduled for participation by all of the interested agencies. It is noted that external facilitation might be a beneficial approach, especially if it is anticipated that reaching consensus decisions may be difficult. As a result of the meetings, the GMT provided a summary of the interpretation and a list of recommended GMP updates (if any) to the AMT within 180 calendar days of the final 2021 WEST report.

The GMT considered the following in their recommendations:

- the magnitude and rate of the noted changes and the significance of the potential consequences resulting for those changes, including whether triggers should be added, removed, or adjusted
- whether each geomorphic assessment component is providing relevant and valuable information and, if it is not, recommend additions/subtractions/alterations to the AMT to ensure the appropriate data is being gathered
- whether the monitoring schedule for different reaches is appropriate, and if not, identify what frequency of sampling is needed (for example, if the Red River is deemed to be more stable than the tributaries, the tributaries may need more frequent monitoring than the Red River)

The AMT will ultimately be responsible for determining appropriate responses and actions based on the GMT recommendations.

During Project Construction Prior to Operations: Pre-operation sampling events may occur during construction if a large flood event occurs that would have resulted in operation of the Red River and Wild Rice River structures if the Project construction was complete which is defined as an event when the combined flows at the USGS gages on the Red River at Enloe and the Wild Rice River at Abercrombie exceed 21,000 cfs, equivalent to slightly less frequent than a 5% annual exceedance probability event. In the event of multiple successive years of project operation floods, the GMT will meet to recommend whether the second or later events are monitored and at what level of detail based on the data collected from the previous event(s). After successive events close in time, the GMT will meet to see if it can identify criteria for supporting the decision-making process related to future assessments. Information collected during Project Construction will be compared to information presented in the 2012, 2019, and 2021 reports to provide a baseline for comparisons to post-FMM Project conditions.

8.2. Post-FMM Project

Post-FMM Project, data for field data-based investigations (see Section 5.1) shall be collected within one year of FMM Project completion and a report summarizing the geomorphic monitoring efforts (see Sections 5.2 through 5.4) finalized within 2 years to establish baseline post-FMM Project conditions. Two additional Post-FMM Project geomorphic assessments shall also be completed: one 5 years after this initial post-FMM Project assessment and one 10 years after the initial assessment.

It is noted that the total cost of each pre-FMM Project geomorphic assessment was approximately

$1,000,000 for the combined survey and geomorphic assessment effort. Therefore, to ensure taxpayer funds are used in an efficient, effective, and appropriate manner, the GMT shall convene and provide a recommendation to the AMT about reducing the geomorphic assessment frequency to every 10 years (or some other frequency), especially if no significant changes in the channel morphology are noted. As part of its recommendation to the AMT, the GMT shall also consider whether future assessment efforts should only be focused on any areas exhibiting significant changes.

For each of the areas flagged for further investigation by the aerial imagery-based stability analysis, a site-specific field reconnaissance and survey may need to be conducted to understand the local conditions of the site and to help understand the causation for the noted changes.

The first three sets of post-FMM Project monitoring results shall be analyzed by the GMT during working meetings following receipt of the third round of post-FMM Project monitoring (e.g., 10 years after the initial post-FMM Project geomorphic monitoring), noting any changes deemed significant by the GMT. These meetings shall be initiated within 90 calendar days of the finalization of the third post- FMM Project report. The working meetings for interpreting the analyzed data with regards to geomorphic change should be open and scheduled for participation by all of the interested agencies. It is noted that external facilitation might be a beneficial approach, especially if it is anticipated that reaching consensus decisions may be difficult. As a result of the meetings, the GMT shall then provide a summary of the interpretation and a list of recommended GMP updates (if any) to the AMT within 180 calendar days of the finalization of the third post-FMM Project report. At a minimum, the GMT should consider the following in their recommendations:

- the magnitude and rate of the noted changes and the significance of the potential consequences resulting for those changes, including whether triggers should be added, removed, or adjusted
- whether each geomorphic assessment component is providing relevant and valuable information and, if it is not, recommend additions/subtractions/alterations to the AMT to ensure the appropriate data is being gathered
- what future post-FMM Project monitoring schedule is needed (for example, once every 10 years, only after the FMM Project operates, etc.), taking into consideration that the monitoring schedule may differ for different reaches
- what future aerial imagery collection schedule is needed, with data collected the year prior to the next scheduled geomorphic assessment so that the data is available for the assessment

8.3. Flood Event

If a flood occurs that would have resulted or did result in operation of the Red River and Wild Rice River structures, another geomorphic assessment shall occur. The field investigation portion of the geomorphic assessments shall be completed either by the end of the calendar year in which the operation occurred or within 6 months after flows recede to below bankfull flow levels, whichever is later. The final flood event report shall be provided within 1 year of the completion of the field investigation effort.

The GMT shall be provided an opportunity to provide input to and review the flood event scope of work prior to the field assessment being conducted. All comments shall be provided by the GMT to USACE or the non-Federal sponsors, as appropriate, within 21 calendar days of scope of work receipt.

The GMT shall provide a recommendation to the AMT whether a flood event assessment can be used as a substitute for any regularly-scheduled geomorphic assessment.

8.4. Trigger Timelines

When triggers are known to be exceeded, likely either a result of public/agency notification and subsequent review or as a result of a post-FMM Project geomorphic assessment, GMT meeting(s) will be held within 30 calendar days of notification for the purpose of making recommendations to the AMT in accordance with the process outlined in Section 6.2. The GMT shall then provide recommendations to the AMT for action / no action supported by data, analysis, and discussion by the experts within the next 30 calendar days for a total of 60 calendar days from notification to recommendation. The GMT shall remain responsive to the AMT, providing additional information and clarifications when requested and may need to call additional meeting(s) if further recommendations are required to achieve a rated consensus.

As part of the AMT's consideration of the GMT's recommendations, for effective adaptive management, the AMT, GMT, and other monitoring teams shall meet together to discuss the inter-related impacts of the changes in the system and potential corrective actions. Near bank vegetation and habitat both in and out of the stream are tied to the geometric and geomorphic characteristics of a stream.

9. GEOMORPHIC MONITORING TEAM COMMUNICATON PLAN AND DECISION PROCESS

To successfully implement a GMP will require coordinated communication and clear decision rules for the collaborative work of the agencies and stakeholders in planning, funding, and executing the GMP. The AMMP contains much of the structure needed to support GMT; therefore, the communication plan described herein is in addition to the structure outlined in the AMMP. Requests from GMT members to schedule meetings to discuss specific concerns (i.e., meetings that not regularly scheduled) shall be addressed within 30 calendar days of the request being made.

9.1. Communication Plan and Meetings

Regularly-scheduled annual or more frequent communication shall be established with GMT members, any interested AMT member(s), representatives from agencies, and other interested stakeholders (including but not limited to the USDA-NRCS, college extension services, farming co-ops and local landowners, irrigation and drainage districts, etc.). Such communication efforts will allow for real or perceived changes in channel morphology to be documented and flagged for further evaluation.

Regular communications will help focus the monitoring efforts and allow for concerns to be documented and appropriately addressed.

Prior to each of the post-FMM Project geomorphic assessments, coordination between the identified technical experts/organizations shall be done at least 6 months in advance of the actual field work to allow for schedule adjustments or GMP modifications. It is acknowledged that the AMT will be sent the recommended schedule and any deviations based on the geomorphic needs. In turn, the AMT shall be informed at least 6 months in advance of the field season and provided the opportunity to suggest changes or necessary deviations based on other criteria like funding or changes in FMM Project operation and other unanticipated changes. The advance notice is needed to allow time for changes in scope to be negotiated with the geomorphic assessment team (or contractors) after review and input from the GMT.

After each individual geomorphic assessment, a summary of findings shall be presented to the GMT. The GMT members shall also be provided with an opportunity to review each geomorphic assessment report. All GMT member review comments will be due to either USACE or the non-Federal sponsors, as appropriate, within 21 calendar days of report receipt.

As discussed in greater detail in Section 8, working meetings shall also be held to evaluate the three pre-FMM Project geomorphic assessments and the first three post-FMM Project geomorphic assessments with the purpose of determining GMP modification recommendations, as appropriate.

All AMT members shall be informed of and invited to GMT meetings to provide for the opportunity for AMT members to observe and participate in these meetings. GMT members are responsible for informing the AMT of upcoming personnel changes and providing an agency-authorized alternate or replacement upon retirement or reassignment.

The GMT shall be notified by the AMT and/or non-Federal sponsors of geomorphic issues or concerns identified outside of the regular monitoring process and hold a meeting to identify next steps within 45 calendar days of initial notification to the AMT and/or non-Federal sponsors.

9.2. Decision Process

The GMT is charged with providing expert technical advice and recommendations to the AMT for their consideration. The GMT will use a consensus-based approach for providing recommendations to the AMT. One approach for reaching and documenting consensus that the GMT has used successfully is a 5- point rating that helps distinguish the level of buy in by the participants on a specific recommendation. The 5-point scores are ratings that are not to be added to form an overall score for a specific proposal and does not constitute a vote. Rather, the 5-point scores serve as expert elicitation that can be attributed to specific GMT members if helpful for the AMT consideration.

9.2.1. 5-Point Consensus Rating Scale

The following bullets represent descriptions of each of the 5 ratings:

- 5 – Fully support idea, would endorse and/or help to implement
- 4 – Good idea, maybe not exactly as would have chosen, but good enough
- 3 – Meets expectations, can "live with it" but have some questions and/or reservations
- 2 – Needs improvement and/or have some serious questions or suggestions for revision
- 1 – Poor and/or cannot support in current form at all

9.2.2. 5-Point Consensus Rating Process

The 5-Point consensus process is a rapid way of checking in with a team on their level of buy-in on an idea and to daylight both enthusiasm and issues or concerns with its potential implementation in a documentable format. There are a few steps to the process:

- Formulate recommendation statement
- Participants ask clarifying questions about the recommendation
    - It is important that individuals are clear on what they are rating.
    - At this point, wait to have in-depth discussion of support or concerns until after the rating.
- Each individual rates the recommendation using the 5-point rating scale
    - In a face to face meeting this can start with everyone just raising a hand with the number of fingers raised to indicate their rating and the meeting facilitator can do a quick hand count of the groups rating.
    - On a virtual meeting the scores may be entered into a chat feature, spoken by the attendees, or using a polling tool or white board for people to indicate on the 5-point scale their rating.
- For any scores 3 and below: the individual shall share what it would take to raise the score to a 4
    - The very process of choosing a score helps an individual identify why they believe their rating is correct. The individual will have a sense of what prevents it from having a higher score and why it does not deserve a lower score, which will allow benefits and concerns to be captured and discussed.
    - Sharing that insight with the team helps identify a path forward through discussion or needed actions for issue resolution.

- If all scores rise to a score of 3 or higher the GMT recommendation shall be carried forward to the AMT.
    - Ask for and document any remaining questions or issues or endorsements for the recommendation that the GMT experts would like the AMT to consider in their decisions.
- If scores remain below 3 then the recommendation can be dropped, or specific tasks defined to resolve remaining issues for future consideration by the GMT.
- Finally, document the recommendations with a tally of the ratings and statements of support, issue consideration and resolution, and outstanding questions for future consideration to forward to the AMT. This provides the AMT with a complete understanding of the level of consensus and details that may help the AMT's decision process.

10. REFERENCES

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