# Memorandum

To: Lindsey Clark, Stillwater Valley Watershed Council Coordinator

From: Chad Raisland, Pioneer Technical Services, Inc. and Karin Boyd, Applied Geomorphology, Inc.

CC: Tanya Lester, Stillwater Conservation District Administrator

Date: 8/2/2016

Re: West Fork Stillwater River Avulsion Assessment

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# 1 Introduction and Major Findings

Pioneer Technical Services, Inc. (Pioneer) and Applied Geomorphology (AGI) were contracted as a project team to evaluate a reach of the West Fork Stillwater River (West Fork) located in the southwest quarter of Section 26, Township 04 South, Range 15 East, Principal Montana Meridian, (project site) that was identified as potentially prone to an avulsion (rapid relocation of the main river channel). The main concern with an avulsion occurring within this reach is the potential for flooding and geomorphic instability downstream through the community of Nye, Montana. The purpose of this document is to summarize existing site conditions and potential treatment alternatives at the project site. The information provided in this document was also presented at a stakeholder meeting in Fishtail, Montana on April 19, 2016.

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Conclusions developed by the project team resulting from the assessment are as follows:

1. The identified avulsion risk is associated with the recent enlargement of a side channel that has the potential to feed a much older floodplain channel that extends from the project site southeast through Nye to its confluence with the Stillwater River. The side channel enlarged and migrated towards the older floodplain channel during the 2011 flood.
2. Although the risk of avulsion at the site has increased with the recent side channel enlargement, the overall risk of a wholesale avulsion at the site remains low.
3. Several natural features are in place to dissuade erosion at the site including channel topography, floodplain topography, and floodplain roughness.
4. If landowners are interested, further measures could be implemented to additionally reduce the long-term risk of erosion at the site.
5. Although the risk of a rapid, catastrophic avulsion into the historic floodplain channel at the project site is low, the channel will convey any water received through Nye and thus should be recognized as a potential flood hazard.
6. There are other locations down the valley that may pose some avulsion risk into the historic channel.

Figure 1 shows the location of the project site, which is about 2.7 miles upstream of the mouth of the West Fork near Nye. As the West Fork flows southeastward towards Nye, it flows across a coarse glacial outwash/alluvial fan that has both active and inactive channel threads. Many of these channels probably reflect historic glacial conditions rather than modern hydrology and sediment loads. That said, there are distinct channels that are continuous and well-vegetated, with the potential to convey flow and/or sediment down the valley. The issue at the project site is whether a historical channel that originates near the mouth of Horseman Creek has the potential to capture the main thread of the West Fork.

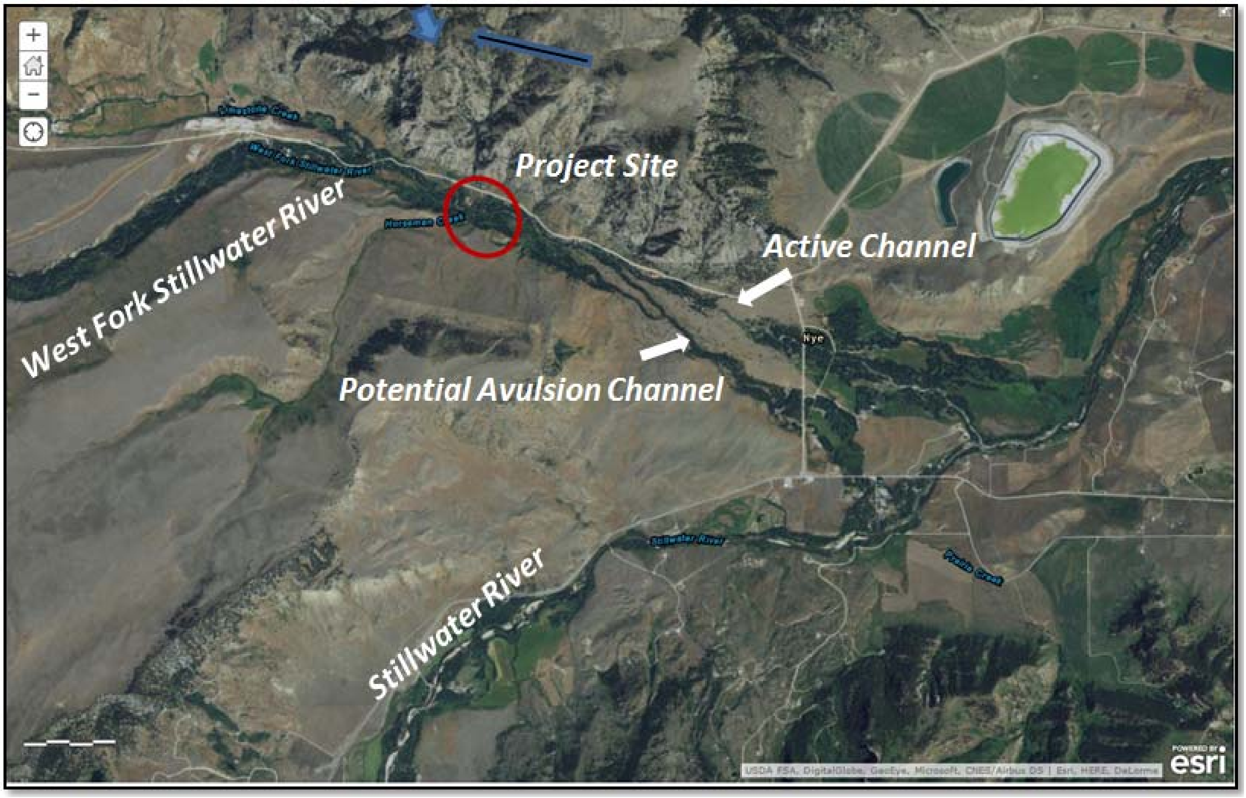


**Figure 1. West Fork avulsion project location map showing major features.**

## 2 Site Conditions and Risk of Avulsion

The project site was identified as having a risk of avulsion in the Upper Stillwater Watershed Assessment (Kellogg, 2014). The assessment noted that the bendway migration that occurred on a side channel of the West Fork during high water in 2011 increased the risk of the West Fork being captured by a historic channel that could cause erosion and flood damages in Nye. Figure 2 shows several features at the project site that relate to the potential avulsion issue. The "North Channel" is the main thread of the West Fork. It is a steep, boulder bed channel that carries coarse glacially derived bedload material. The "South Channel" refers to the side channel that has enlarged with recent flooding (notably 2011). The South Channel is blocked at its entrance by a woody debris jam, which currently limits flow into the South Channel (see Figure 3). Just downstream of the debris jam, however, the South Channel shows evidence of flood-induced enlargement, downcutting, and migration (see Figure 4), including high eroding banks, a distinct headcut, and variable bank heights due to headcut migration. One concern is that the failure of the debris jam at the entrance of the South Channel may cause it to enlarge further and potentially become a more prominent secondary channel or even the main thread of the West Fork. This would in turn increase the frequency and duration of overbank flows into the area where the historic channel flows towards Nye. Increased flow into the South Channel could also drive its migration down valley into the historic channel area.

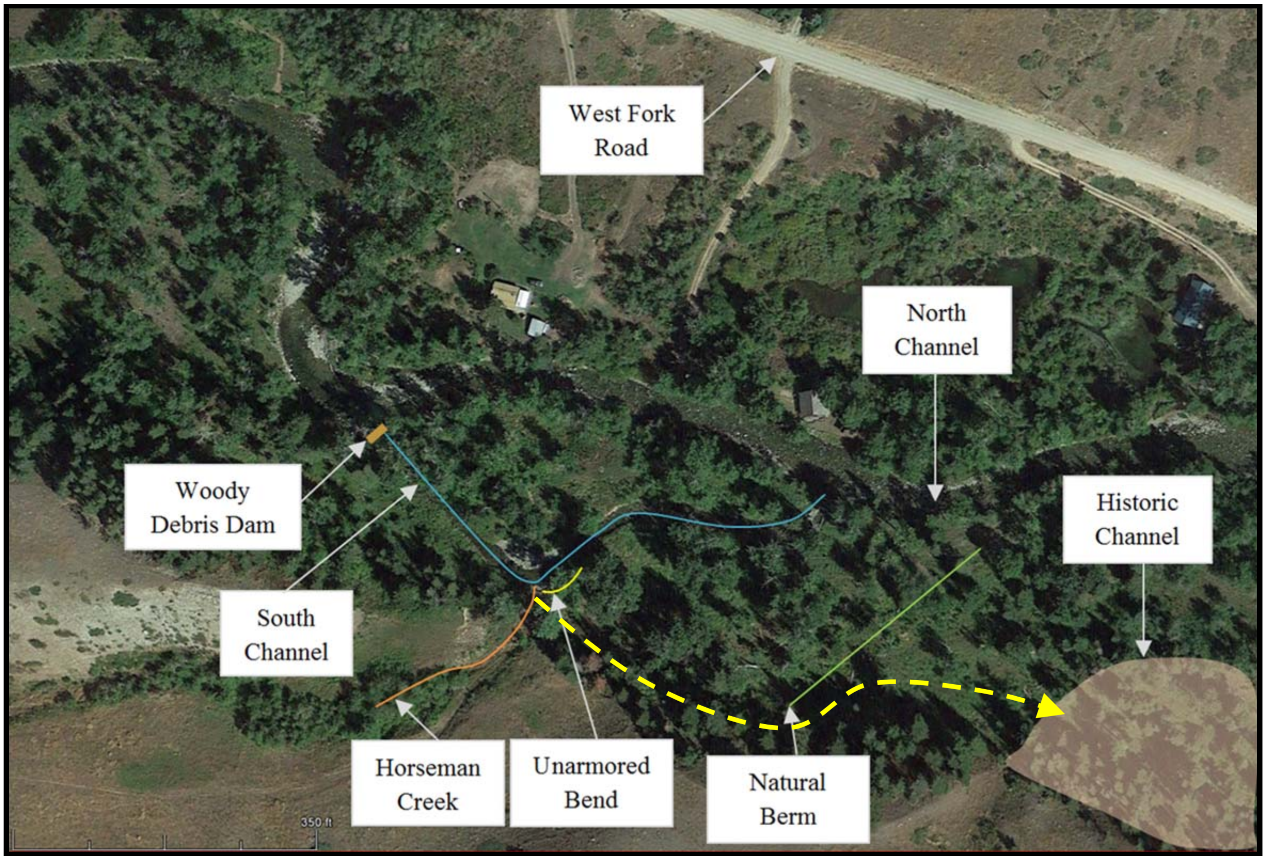


**Figure 2. Project site overview (avulsion path of concern in yellow).**

**Figure 3. Debris jam at the entrance of the South Channel (main thread of the West Fork flows to the left).**

**Figure 4. View down the South Channel showing unarmored bendway (avulsion point of concern is at the pickup).**

## 2.1 Potential Avulsion Mechanisms at Site

Alluvial fan systems should always be evaluated in terms of avulsion potential when there are investments made along historic distributary channels. These alluvial fan features are notoriously dynamic and susceptible to dramatic change during floods. At the project site, there are several potential scenarios that could drive an avulsion at the site, although site conditions do not indicate that an avulsion is imminent without some sort of large scale flood event. Regardless, it is important to understand the dominant mechanisms presented on site when considering risk and potential alternatives to mitigate that risk.

The overall mechanism for an avulsion at the site is the whole or partial capture of the West Fork by the historic outwash fan channel. There are potential conditions/events that would contribute factors to that mechanism, and they are described below.

### 2.1.1 Continued Enlargement and Migration of South Channel

The relocation of the majority of the West Fork flow into the South Channel would increase the risk of subsequent avulsion into the historic channel. Typical drivers for this could include debris or ice blockages on the main channel, or perching of the main channel above the South Channel, making the current flow split unstable. A major blockage of the main West Fork channel ("North Channel" shown on Figure 2) may be the most likely scenario for wholesale flow relocation into the South Channel. This would require a blockage to form in the North Channel somewhere near the entrance of the South Channel, which is currently blocked by a debris jam of its own. Thus, a major relocation of flow would require blockage of the main North Channel and simultaneous breaching of the existing debris jam at the entrance of the South Channel (see Figure 3).

With regard to topographic perching, a survey of the project site indicates that the secondary South Channel is currently perched above the main North Channel (see Figure 5), which greatly reduces the potential for the South Channel to capture the main thread flow of the West Fork.


**Figure 5. Surveyed profile of the main North Channel (green) and secondary South Channel (red) showing perching of the South Channel.**

The bed of the South Channel is covered in coarse boulders that probably accumulated as an armor layer during the flood-induced erosion of 2011. In the event that the channel receives more flow, this coarse boulder material will help resist continued channel enlargement under most flow conditions. In the event of an extreme event, however, the boulders should be considered mobile (see Figure 6).

**Figure 6. View upstream of South Channel showing boulder bed material.**

## 2.1.2 Erosion and Enlargement of Historic Channel by Floodwaters

If flood flows were to extend across the floodplain surface and reach the head of the historic channel, there is a possibility that those overbank flows would concentrate in historic channel and enlarge it, which could create upstream migrating headcuts that would increase the risk of wholesale avulsion. The primary mechanisms for this scenario would include floodwater access to the floodplain channel and erosion of that feature. Figure 7 shows that the "Historic

Channel Area" is out of the 100-floodplain and separated from the South Channel by a "Natural Floodplain Berm" which is probably a glacial moraine remnant from the mouth of Horseman Creek (see Figure 8).

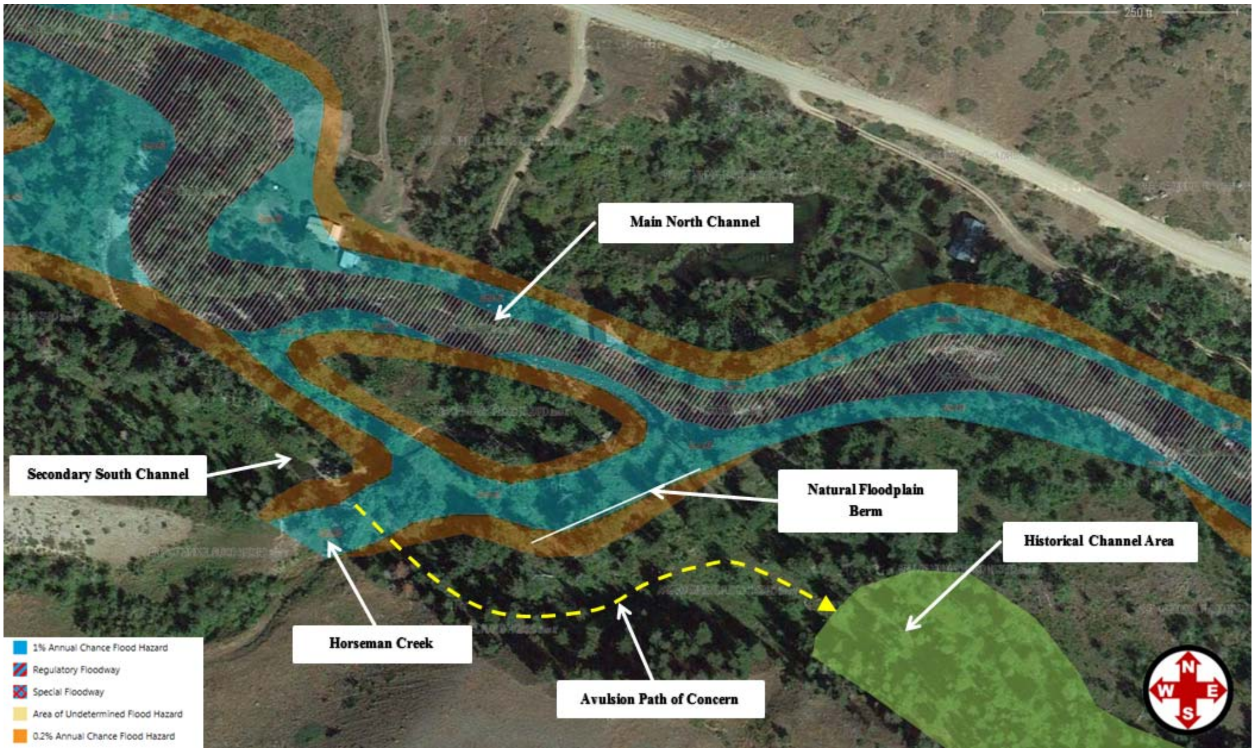


**Figure 7. Stillwater County FIRM map of the project site showing the historical channel area outside the 100-Year floodplain and separated by a natural floodplain berm.**

**Figure 8. View down valley (east) showing coarse floodplain berm separating secondary South Channel (behind photographer) and potential avulsion site in distance.**

### 2.1.3 Backwatering in the Historic Channel by Beaver Dams

Another means of increasing flows over the floodplain and into the historic channel is backwatering in the South Channel by beaver damming. At the time of our field investigation there was a large beaver dam remnant that had clearly backwatered much of the South Channel. Numerous beavers have been trapped out of this area and as a result backwatering is minimal (see Figure 9).

**Figure 9. View upstream on lower end of South Channel showing the historic beaver dam impoundment.**

In the event the historic channel area is accessed by floodwater, it would take high energy flows to erode the existing material due to its coarseness. In general, one major characteristic of this site is coarse floodplain material, which adds natural resilience to avulsion (see Figure 10).

**Figure 10. Floodplain roughness near potential avulsion site.**

# 3 ALTERNATIVES TO REDUCE EROSION RISK

Although all of the characteristics of the project site indicate that the likelihood of the West Fork avulsing into the historic channel is low, it is important to recognize that one component of risk assessment is considering the consequences of an event. Even if the likelihood of occurrence is low, it may be appropriate to implement measures to further avoid the event (in this case channel avulsion) if the consequences are high. Since the community of Nye is located on the historic channel and prone to major damages in the event of an avulsion, consideration of mitigation measures is appropriate.

In the event that the measures presented below are further considered for implementation, it is strongly recommend that the channels below the project site that connect the West Fork to the historic channel be similarly evaluated for avulsion risk. This evaluation would identify and prioritize sites posing the greatest demonstrable risk downstream.

## *3.1 Alternative 1: No Action*

Under the No Action alternative, there would be no attempts to modify current conditions and the channel configurations would be left in place. This alternative would also require the acknowledgement that even without an avulsion, flooding could occur downstream along the historic channel during high water events.

There are no costs associated with Alternative 1.

## *3.2 Alternative 2: Adaptive Management*

The concept of Adaptive Management allows stakeholders to respond to changing conditions in a measured, strategic, and cost-effective manner. This is appropriate in systems where catastrophic change or a continued degradation of site conditions is not anticipated. At this site, adaptive management may be appropriate due to the current system resilience to the mechanisms of avulsions. This would include monitoring and managing debris jams, beaver dams, bank erosion, and floodplain erosion, and continually maintaining system resilience.

Costs have not been developed for Alternative 2; however this approach would require expenditures for monitoring, design, and implementation as necessary.

## 3.3 Alternative 3: Flow Deflectors and Bank Reconstruction on Main Thread

As described previously, there is currently a large debris jam blocking the entrance of the South Channel (see Figure 11). Just upstream of this debris jam, the right bank of the main North Channel has experienced some accelerated erosion due to the flanking of bank armor, which has made the entrance of the secondary South Channel more accessible to typical river flows. Alternative 3 would consist of reconstructing the right bank and installing flow deflectors to reduce access to the South Channel feature. The complete blockage of the secondary South Channel is not recommended due to its contribution to fish habitat and geomorphic complexity on the West Fork.

The estimated cost for Alternative 3 is approximately $118,000.

**Figure 11. View downstream towards debris jam located at the secondary South Channel entrance (center of photo) showing right bank erosion and flanked large boulder riprap remnants in the Main Channel.**

## 3.4 Alternative 4: Install Grade Control and Riprap in South Channel

As enlargement of the secondary South Channel is a major concern with regard to increased avulsion potential, preventing additional enlargement and channel migration in the South Channel may be appropriate. Alternative 4 consists of installing a grade control structure in the bed of the South Channel and placing riprap along the eroding bend at the potential point of avulsion (see Figure 12). Schematic cross-sections for the grade control structure and riprap are shown on Figure 13 and Figure 14, respectively.

The estimated cost for Alternative 4 is approximately $70,000.

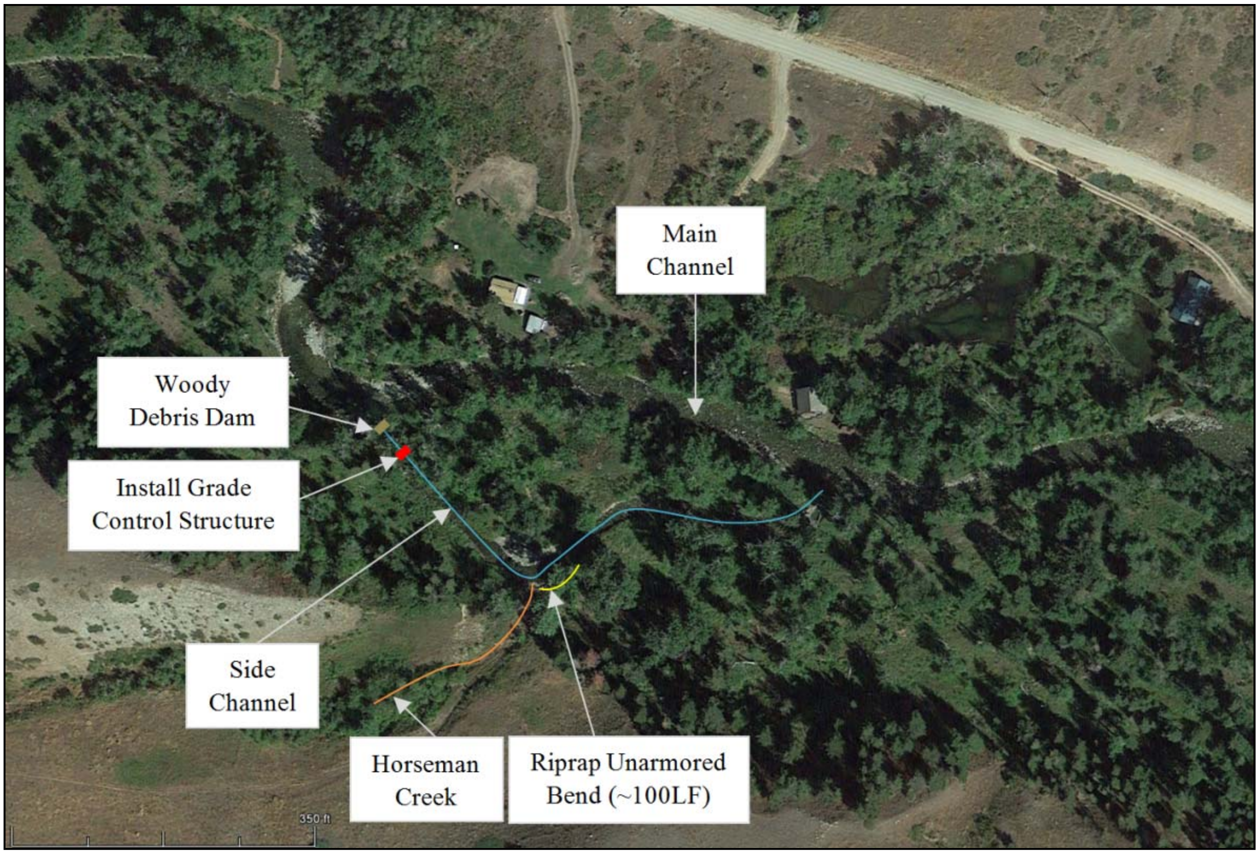


**Figure 12. Proposed locations for a grade control structure and riprap, Alternative 4.**

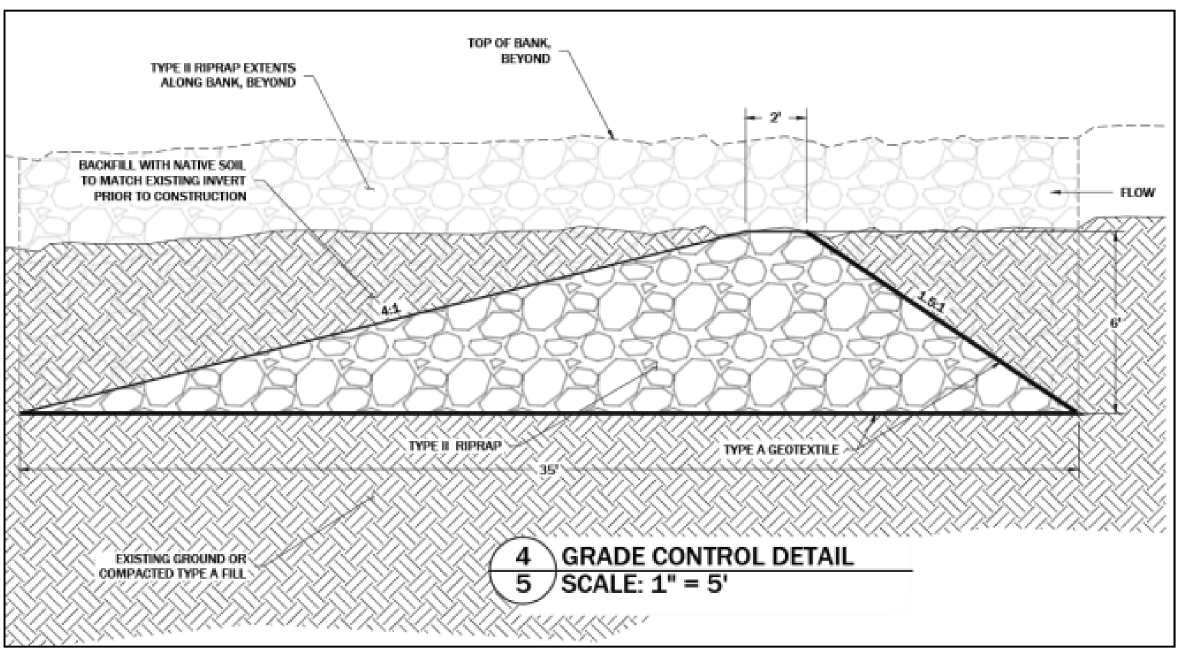


**Figure 13. Schematic cross- section of the proposed South Channel grade control structure.**

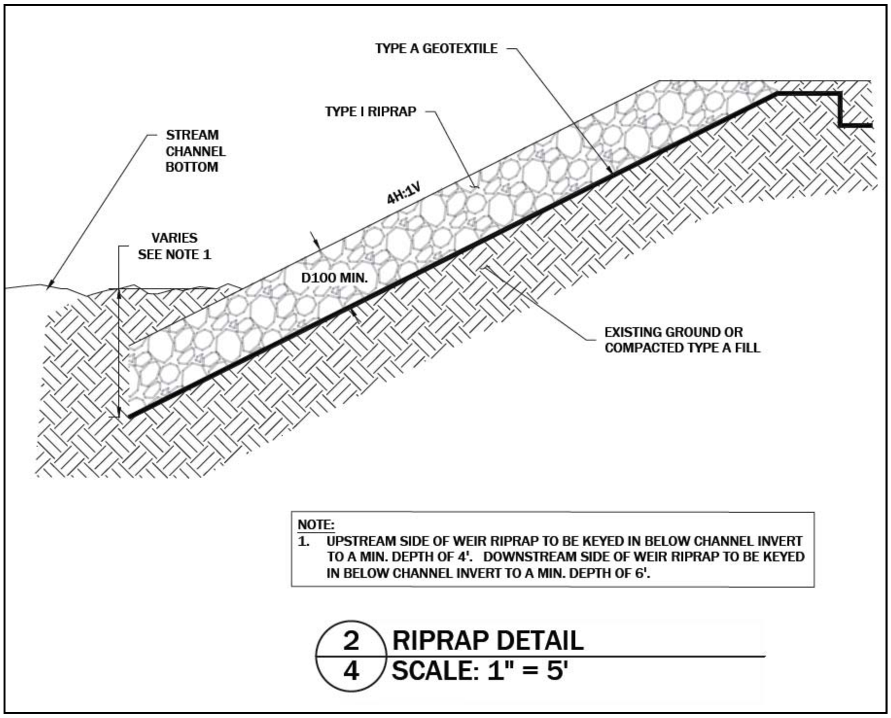


**Figure 14. Schematic cross- section of the proposed South Channel riprap.**

## 3.5 Alternative 5: Install Floodplain Berm and Introduce Additional Floodplain Roughness

To reduce overbank flows into the historic channel and prevent floodplain erosion, Alternative 5 consists of installing a floodplain berm and incorporating floodplain roughness elements (see Figure 15). The proposed floodplain berm would be approximately 200 feet long and would be integrated with large woody debris to further dissuade floodplain erosion.

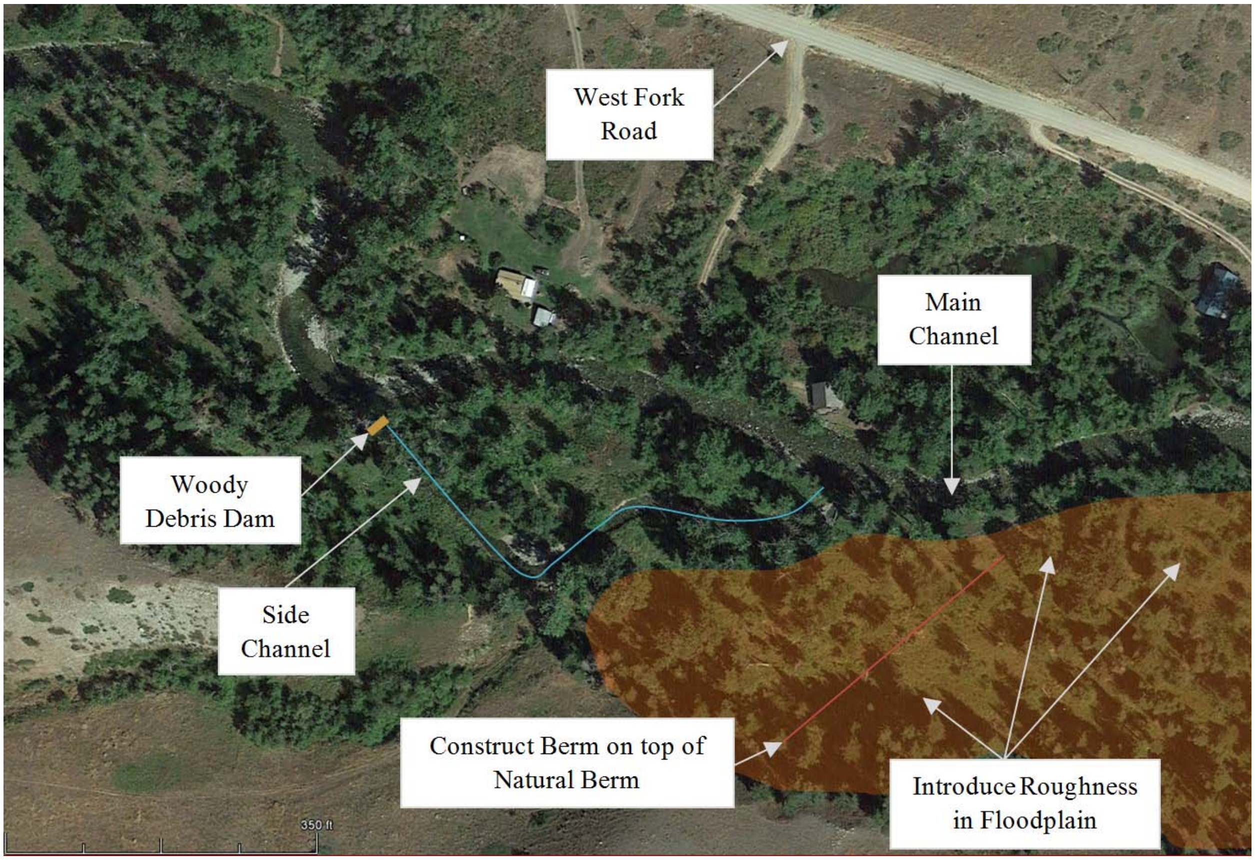


**Figure 15. Proposed locations for a floodplain berm and roughness elements.**

The estimated cost for Alternative 5 is approximately $83,000.

# 4 COST BREAKDOWN FOR PROJECT ALTERNATIVES

The table below shows a cost breakdown for the alternatives described above.

| SUMMARY OF ALTERNATIVE COSTS ESTIMATES | | | | | |
|---|---|---|---|---|---|
| **Alternative** | **1** | **2** | **3** | **4** | **5** |
| | No Action | Adaptive Management | Install Flow Deflectors/ Rebuild Bank | Install Side Channel Grade Control and Riprap | Install Floodplain Berm / Introduce Roughness |
| Project Management/ Project Planning | $ - | $ - | $1,100.00 | $1,100.00 | $1,100.00 |
| Site Reconnaissance and Survey | $ - | $ - | $2,600.00 | $2,600.00 | $2,600.00 |
| Engineering Analysis and Design | $ - | $ - | $7,000.00 | $5,600.00 | $4,000.00 |
| Construction Contractor Procurement | $ - | $ - | $3,300.00 | $3,300.00 | $3,300.00 |
| Permitting | $ - | $ - | $26,000.00 | $4,100.00 | $4,100.00 |
| Construction Oversight and As-Builts | $ - | $ - | $6,500.00 | $5,800.00 | $5,800.00 |
| Professional and Technical Subtotal | $ - | $ - | $46,500.00 | $22,500.00 | $20,900.00 |
| 25% Contingency | $ - | $ - | $11,625.00 | $5,625.00 | $5,225.00 |
| **Professional and Technical Total** | $ - | $ - | **$58,125.00** | **$28,125.00** | **$26,125.00** |
| Construct Side Channel Grade Control | $ - | $ - | $0.00 | $11,200.00 | $0.00 |
| Riprap Side Channel Bend | $ - | $ - | $0.00 | $17,100.00 | $0.00 |
| Rebuild Bank | $ - | $ - | $4,000.00 | $0.00 | $0.00 |
| Riprap Rebuilt Bank | $ - | $ - | $11,200.00 | $0.00 | $0.00 |
| Construct Flow Deflectors | $ - | $ - | $24,000.00 | $0.00 | $0.00 |
| Construct Berm | $ - | $ - | $0.00 | $0.00 | $36,600.00 |
| Introduce Woody Debris to Floodplain | $ - | $ - | $0.00 | $0.00 | $3,000.00 |
| Construction Subtotal | $ - | $ - | $39,200.00 | $28,300.00 | $39,600.00 |
| 25% Contingency | $ - | $ - | $9,800.00 | $7,075.00 | $9,900.00 |
| **Construction Total** | **$ -** | **$ -** | **$49,000.00** | **$35,375.00** | **$49,500.00** |
| **Alternative Subtotal** | **$ -** | **$ -** | **$107,125.00** | **$63,500.00** | **$75,625.00** |
| **Contract Administration (10%)** | **$ -** | **$ -** | **$10,712.50** | **$6,350.00** | **$7,562.50** |
| **ESTIMATED TOTAL ALTERNATIVE COST** | **$ -** | **$ -** | **$117,837.50** | **$69,850.00** | **$83,187.50** |

# 5 REFERENCES

Kellogg, W., 2014. Upper Stillwater River Assessment. Stream & Watershed Counsulting, Helena, Montana. March 2014. Page 65.