SHEEP CREEK SEDIMENT MONITORING AND ASSESSMENT PROJECT - 2015

Sampling and Analysis Plan

Prepared for:

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1.0 INTRODUCTION AND BACKGROUND INFORMATION

This document details plans for sediment monitoring in Sheep Creek for the 2015 field season.

1.1 DESCRIPTION OF THE SHEEP CREEK DRAINAGE

Sheep Creek (MT41J002_030) is in the Smith River TMDL Planning Area (TPA) and is contained within Meagher County. It is designated as a B-1 state classified waterbody. The drainage is in the 10030103 fourth-code hydrologic unit code (HUC), and is in the area of the Little Belt Mountains. Sheep Creek is 41.3 miles long. Most of the Sheep Creek drainage lies in the Middle Rockies level 3 ecoregion. The lower 3 stream miles of Sheep Creek are in the Northwestern Great Plains level 3 ecoregion, and in the Shields-Smith Valleys level 4 ecoregion.

The headwaters of Sheep Creek are near Kings Hill Pass and the Showdown ski area. The total area of the watershed is approximately 170 square miles. Major tributaries to Sheep Creek include Calf Creek, Moose Creek, Pole Creek, Big Butte Creek, Little Sheep Creek. An underground copper mine is in the planning stages at a location near the center of the Sheep Creek drainage. Several small tributaries to Sheep Creek are located near the proposed mine and mill sites.

Figure 1.1 shows the Sheep Creek drainage and the proposed sediment monitoring sites that are included in the study.

Land ownership in the Sheep Creek drainage is mostly United States Forest Service and large ranches. Land uses include recreation, livestock grazing, and silviculture. Four small abandoned mines and at least one gravel quarry are present in the drainage.

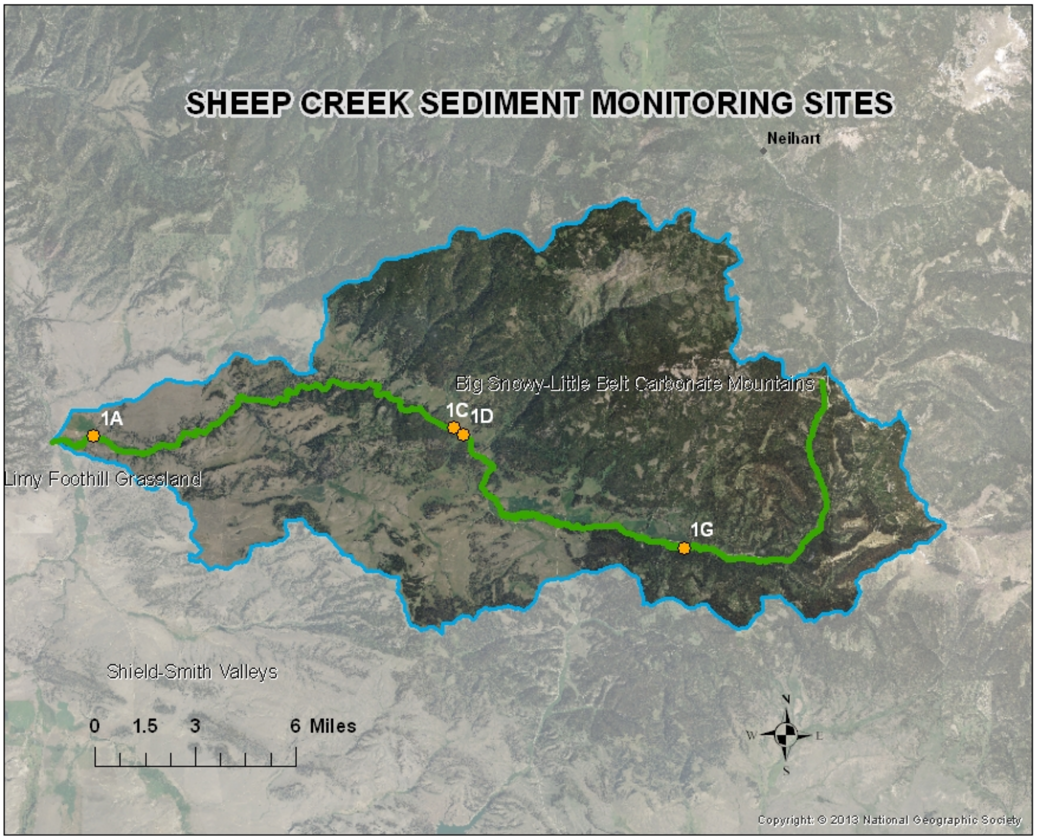


Figure 1.1 – The Sheep Creek Drainage (HUC 10030103) and the Proposed Sediment Monitoring Sites

1.2 Scope of 2015 Sediment Monitoring

Sheep Creek is the only waterbody included in this study. Sheep Creek is not listed as impaired for sediment or habitat degradation on the 2014 303(d) list. The stream is listed for three pollutants: E.coli, iron, and aluminum. Those pollutants are addressed in a separate sampling and analysis plan (Sheep Creek Drainage Sampling Project-2015: Metals, Nutrients, Escherichia-coli).

2.0 Project Objectives, Goals and Sampling Design

This section describes the project objectives and specific monitoring goals for 2015 sediment monitoring in the Sheep Creek drainage, as well as the principles used to develop the sampling design.

2.1 Project Objectives and Goals

The primary objectives of this project are:

1. to collect water quality data to facilitate assessment of current sediment condition and beneficial use support of Sheep Creek, and

2. to support the development of a sediment TMDL for Sheep Creek, if required.

DEQ assessment methods for sediment (Kusnierz *et al.* 2013) will guide the analysis of the resulting dataset. These methods define the data quality requirements for sediment and guide impairment decisions.

The goals for this monitoring project are as follows and will be applied to all sites on Sheep Creek, unless otherwise specified:

- Collect macroinvertebrate and periphyton samples at each monitoring site.
- Collect pool-tail grid tosses, and residual pool depth in all pools within the site.
- Collect 100 pebble counts in first 4 riffles encountered (total of 400 pebbles/ site).
- Longitudinal surveys will include riparian greenline surveys, and eroding bank information (BEHI), to be performed at each of the selected sample sites.
- Collect RSI (Residual Stability Index) at the depositional feature downstream of each riffle sampled for the pebble count.
- Perform width to depth (W/D) measurements at each sampled riffle.
- Measure cross section at 10 evenly-spaced transects throughout the site for ISI (Instability Index) on waterbodies that appear to be aggrading.
- Collect sitewide pebble counts at the 10 cross section transects (total of 100 pebbles/site) on waterbodies that appear to be aggrading.
- Measure slope from the top of the site to the bottom using a clinometer.
- Perform Rosgen Channel Type measurements at the sampled riffles:

..1. Bankfull width
..2. Mean Depth
..3. Width/Depth Ratio
..4. Maximum Depth
..5. Width of Flood Prone Area
..6. Entrenchment Ratio
..7. Water Surface Slope from riffle to riffle for the length of the site
..8. Channel Sinuosity for the length of the site

2.2 Sampling Planning and Site Selection

2.2.1 Selecting Monitoring Sites

Before site locations could be selected in the Sheep Creek drainage, the waterbody was "stratified" to divide it into comparable reaches. The stream stratification process (DEQ 2008) is a GIS-based approach that uses hard breaks to divide waterbodies into reaches based on ecoregion, Strahler stream order, valley confinement, and valley gradient. Once these divisions are made, each of these individual reaches is further broken into subreaches. Subreach divisions are called soft breaks and are determined by characteristics such as land use and landcover. The reaches are then classified into reach types, which display the specific ecoregion, valley gradient, stream order, and confinement for that individual reach. For example MR-0-3-U is the reach type that represents the Middle Rockies ecoregion (MR-0-3-U), 0-<2% gradient (MR-0-3-U), stream order 3, (MR-0-3-U), and unconfined channel (MR-0-3-U).

The stratification process was completed for Sheep Creek, yielding in multiple reach types. Part of the site selection process included choosing a representative number of reach types for the watershed to allow for future TMDL (Total Maximum Daily Load) source assessment considerations. A goal of sampling three to four sites was set for the drainage. In addition to getting a representative site type selection, reach types with high gradient or 1st order classification were included sparingly as they are not usually sediment depositional zones. Sites were also spaced out within the Sheep Creek drainage to capture changes in land use.

One site (Site 1C) is included in the monitoring plan because it is a potential internal reference site, based on channel morphology and riparian condition.

A list of sites with latitudes and longitudes can be found in **Appendix A**.

2.2.2 Sampling Timeframe

Sheep Creek will be sampled for sediment parameters during low stream flow conditions. This should occur between July 1st and September 30th. All sampling will be completed during the 2015 field season.

3.0 Field Procedures

All field procedures described throughout this Sampling and Analysis Plan are documented in DEQ's Western Montana Sediment Assessment Method (Kusnierz *et al.* 2013) unless otherwise noted.

3.0.1 General Sampling Sequence

To minimize site disturbance which may bias samples, at each site parameters most sensitive to disturbance will be collected before parameters less sensitive. The following order of activities will be followed at each sediment monitoring site, listed in **Appendix A**:

1. Set up the EMAP site and collect macroinvertebrate and periphyton samples at each transect while moving upstream. Samples should not be collected in pool tails.
2. While moving upstream, georeference the site; measure the sediment site; place flagging at the beginning and end of the sediment site, and at each riffle and pool within the site; map the sampling site.
3. While moving downstream, check to make sure the map, flagging, and location of pools and riffles are correct. Collect grid toss data and residual pool depths.
    - Once at the downstream end of the sediment site, continue back upstream and collect riffle pebble counts, measure riffle cross sections for width/depth ratios and flood-prone width, and ISI if necessary.
    - Moving downstream, collect slope measurements.
4. After steps 1-3 have been completed, greenline data collection can occur. The timeline for completing this step may overlap the previous steps as long as no in-stream sediment disturbance is occurring in the reach.
    - String the appropriate length measuring tape along the streambank from the downstream end of the reach to the upstream end of the reach to lay out the reach.
    - Mark the end of each cell with flagging.
    - Follow the greenline data collection procedures as outlined in the "Field Methodology for the assessment of TMDL Sediment and Habitat Impairments"(Montana Department of Environmental Quality, 2012).
5. Once the measuring tape identifying the greenline/BEHI reach is laid out, BEHI data collection can occur following the procedures outlined in the "Field Methodology for the Assessment of TMDL Sediment and Habitat Impairments", provided there is no disturbance of in-stream

sediment before the completion of tasks 1-3. (Montana Department of Environmental Quality, 2012).

3.1 Biology Samples

3.1.1 Macroinvertebrates

Macroinvertebrate samples will be collected at sites as indicated in Appendix A. Samples will be collected at 11 transects following the EMAP sitewide procedure (Peck et al. 2006, DEQ 2012). A kick net with 500 µm mesh will be used to collect the sample at each transect and kick samples from each transect will be composited in 1 L HDPE bottles and preserved (topped off) with 95% ethanol (EtOH).

3.1.2 Periphyton

Periphyton samples will be collected at sites as indicated in Appendix A. Periphyton will be collected with the EMAP sitewide approach using the PERI-1mod method (DEQ 2012). It is a single composite sample representing a miniature replica of the stand of algae which are present at the study site. Micro- and macroalgae will be collected using this protocol.

3.2 Sediment Monitoring Parameters

Complete all sediment monitoring parameters at each monitoring site.

<u>Determine site length by identifying bankfull width:</u>

Bankfull width will be identified using the following six indicators (all six may not be present):

- **Examine streambanks for an active floodplain.** This is a relatively flat, depositional area that is commonly vegetated and above the current water level unless there is a large amount of spring runoff or there has been a substantial rain event (i.e., stream running at bankfull stage).

- **Examine depositional features such as point bars.** The highest elevation of a point bar usually indicates the lowest possible elevation for bankfull stage. However, depositional features can form both above and below the bankfull elevation when unusual flows occur during years preceding the survey. Large floods can form bars that extend above bankfull whereas several years of low flows can result in bars forming below bankfull elevation.

- **A break in slope of the banks and / or change in the particle size distribution** from coarser bed load particles to finer particles deposited during bank overflow conditions.

- **Define an elevation where mature key riparian woody vegetation exists**. The lowest elevation of birch, alder, and dogwood can be useful, whereas willows are often found below the bankfull elevation.

- **Examine the ceiling of undercut banks.** This elevation is normally below the bankfull elevation.

- **Stream channels actively attempt to reform bankfull features such as floodplains after shifts or down cutting in the channel.** Be careful not to confuse old floodplains and terraces with the present indicators.

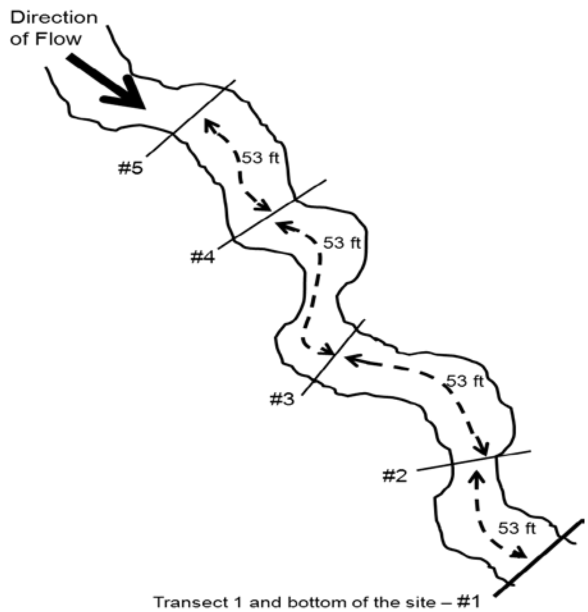


Figure 3.1 – Bankfull measurements

Bankfull width will be measured five times; once at the bottom of the site, and four subsequent times moving upstream, at 53 foot intervals. These measurements will be recorded on the "Assessment Site Location and Map Form," and averaged. The average value will be used to determine the site length using Table 3.1.

Table 3.1 – Width categories for determining site length.

Average bankfull width (ft)	Width Category	Minimum site length (ft)
0 to 26	26	520
26.1 to 33	33	660
33.1 to 39	39	780
39.1 to 46	46	920
46.1 to 53	53	1060
53.1 to 59	59	1180
59.1 to 66	66	1320
66.1 to 72	72	1440
>72	79*	1580

* If a stream's average bankfull width is greater than 79 ft, the minimum site length will be 20 times the measured value.

Identify pools/riffles for sampling and map the site:

1) Pools that have a maximum depth ≥ 1.5 times the pool-tail depth along the pool's thalweg will be identified. All pools that meet the depth requirement will have a grid toss performed. The size of the pool will be recorded based on the size description (> 50% = large pool, < 50% = small pool).
2) Riffles will be identified.

3) Pools and riffles will be marked and labeled with a number and a distance from the downstream extent of the site, beginning downstream and working upstream. Those that will be sampled with a pebble count, grid toss, width/depth ratio, and/or residual pool depth will be marked accordingly.
4) All features and measurements will be recorded on the "Assessment Site Location and Map" field form.

Pool-Tail Grid Toss:

Grid tosses will be performed on every pool that meets the depth criteria as previously described and is formed by the scouring action of water (not by logs or other debris completely damming the downstream end of the pool; partial damming of the pool is acceptable as long as a scour-formed pool tail is present. Grid tosses occur at points 25%, 50%, and 75% across the pool's wetted width at a distance that is 10% of the pool's length or 1 m from the pool tail crest, whichever is less. The number of the internal intersections (49 total) completely covering particles will be counted and recorded. The median (i.e., D50) substrate size class of the substrate under the grid will be estimated for each grid toss and recorded as: s = sand (< 2 mm), g = gravel (2 mm - 64 mm), c = cobble (64 mm – 256 mm), b = boulder (256 mm - 2048 mm), and bd = bedrock (> 2048 mm). If the grid falls on a small boulder or larger particle, these intersections will not be assessed. The number of particles < 6mm out of the total number assessed will be recorded on the "Residual Pool Depth and Pool Tail Fines" field form.

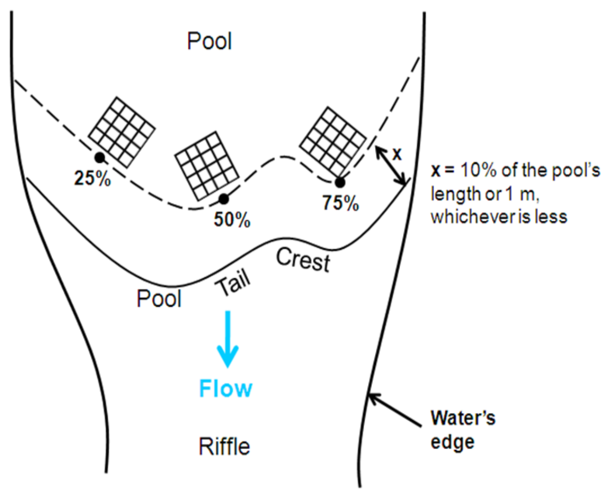


Figure 3.2 – Pool-Tail Grid Tosses

Residual Pool Depth:

Residual pool depth will be measured in every pool where a pebble count is performed. A stadia rod will be inserted to measure from the substrate surface to the water surface at two locations:
1) the deepest point in the pool along the thalweg (dp), and
2) the depth of the riffle crest at the thalweg (drc).

The residual pool depth will be calculated as RPD (dr) = dp - drc, and recorded on the "Residual Pool Depth and Pool Tail Fines" field form.

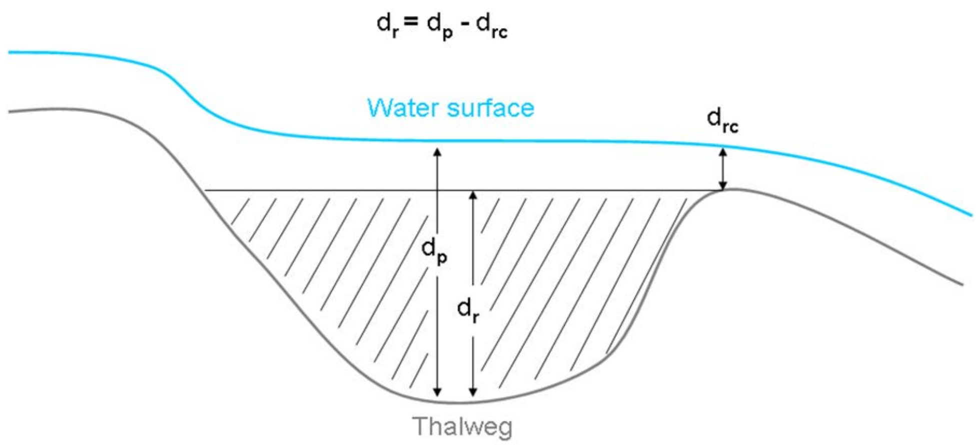


Figure 3.3 – Residual Pool Depth

Riffle Pebble Count:

A 100 pebble count will be conducted at each of four riffles totaling 400 particles. If more than four riffles are present, the first four riffles encountered moving from downstream to upstream will be sampled (or an alternative random sampling). If fewer than four riffles are present, a total of 400 particles will be counted with the number of particles evenly distributed among the number of riffles sampled. Within each riffle, the length will be measured, and four transects will be evenly distributed (from downstream to upstream) at 20, 40, 60, and 80% of the riffle length. Along each transect, 25 sampling locations will be evenly spaced within the bankfull width, so the maximum distance between each is 1/25 of the bankfull width.

Sampling will begin at the downstream transect from river left to river right, then proceed to the next upstream transect and sample from river right to river left; this pattern will be repeated moving upstream to the final two transects. Beginning at bankfull width and at 0 on the measuring tape, and standing downstream of the tape, each particle will be selected by pointing directly down off the tip of the sampler's boot at each sampling location on the measuring tape. The particle directly below will be selected. Each particle will be measured using a gravelometer and recorded on the "DEQ Sediment Assessment Pebble Count" field form. If a particle is too large to move, estimate its size.

<u>Riffle Stability Index:</u>

At each riffle sampled for the pebble count, the lateral bar or depositional feature directly downstream will be identified. Approximately 10 dominant large particles present that have been recently moved will be identified in this depositional region. Recently moved particles are those that are brighter in color, not embedded, and lack staining algae, or attached moss. The B-axis of each of these particles will be measured and recorded on the "DEQ Sediment Assessment Pebble Count" field form.

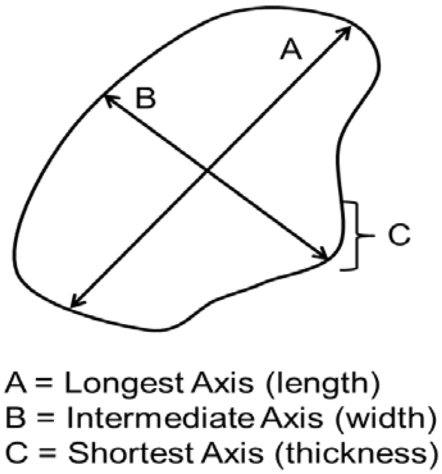


Figure 3.4 – Measuring B-axis for RSI

Width/Depth Ratio:

The width/depth (W/D) ratio will be measured at each of the four riffles where pebble counts were sampled. At the crest of each riffle, a cross-section will be set up by tightly stretching a tape between pins placed at bankfull width. Undercut banks, islands, boulders, bars, brushy banks, logs, and uneven water surface will all be avoided if possible during measurement. The width of the stream at the cross section and 10 depth measurements (from channel bottom to tape measure) will be measured at equidistant intervals using a measuring rod, and moving from river left to river right. Whether the measurement was collected within the wetted channel or between the water's edge and bankfull, will also be recorded on the "Riffle W/D Ratio" field form.

During each width/depth ratio measurement, flood-prone width will also be calculated. The cross-section thalweg will be measured and multiplied by two to find the flood-prone elevation. The flood-prone width will be measured by placing the measuring rod on the left bank at the start of the measuring tape (at 0), and placing a clinometer at the flood-prone elevation on the measuring rod. The clinometer will be balanced at zero while the distance to that point is measured with a measuring tape up to 200 feet. This will be repeated on the right side of the channel and again on each riffle measured for width/depth ratio.

Instability Index (ISI):

Instability index measurements will be collected on one site per waterbody that appears to be aggrading. It will be collected at a site where macroinvertebrates and periphyton are also being collected. This data will be collected by taking cross section measurements as described in the width/depth ratio. The cross section measurements will be taken at ten evenly spaced transects. These transects will begin at twice the distance of the bankfull width and continue at that interval until the end of the site, for a total of 10 transects. Cross section and width and depth information will be recorded on the "ISI Cross Section and Slope" form.

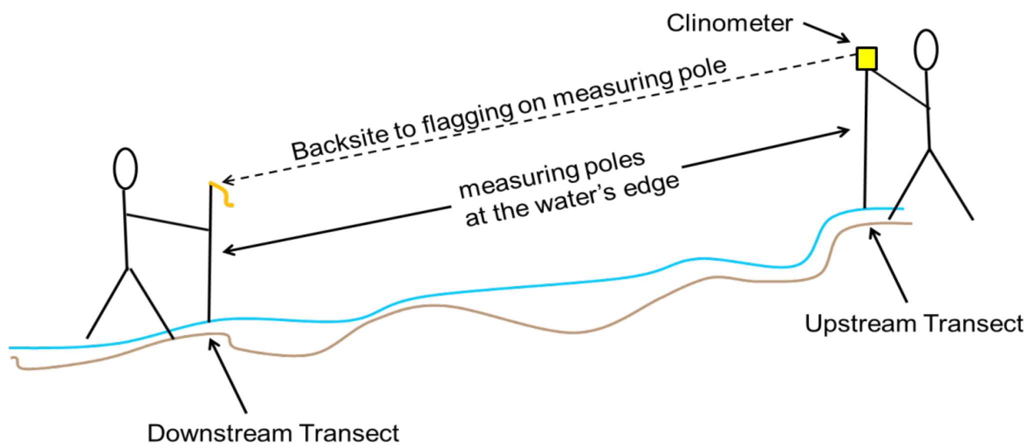
Sitewide Pebble Count:

A sitewide pebble count will be collected by measuring the B-axis of one particle from each of the following locations: 5, 15, 25, 35, 45, 55, 65, 75, 85, and 95% of bankfull width. This will be done at the 10 ISI transects within the site for a total of 100 pebbles. This will only be measured at sites where ISI is being collected.

Slope Measurement:

Slope will be measured from the top of the site to the bottom. If there is not a clear path between these points, the angle will be measured between transects where there is visibility. One person will stand at the downstream end holding a vertical measuring pole with flagging attached to a specific height.

A second person will stand at the upstream transect with a measuring pole held vertically on the same side of the stream. The person at the upstream end will use a clinometer and hold it at the same point on the pole where the downstream person has their pole flagged. By pointing the clinometer at this flagging, the slope between the two points will be measured. The slope information will be collected on the "Cross Section, Slope, and Sinuosity" form.



Rosgen Channel Type Measurement:

Rosgen channel type will be determined in the office after field sampling using a cross section measurement with the following data:

- Entrenchment – ratio of the flood-prone width divided by the bankfull channel width
- Width/Depth Ratio – bankfull width divided by bankfull mean depth
- Channel Slope – for a site approximately 20-30 bankfull channel widths
- Sinuosity – stream length divided by valley length (using GIS in the office); or estimated from the ratio of valley slope divided by channel slope

Riparian Greenline Data Collection:

The greenline tasks categorize general riparian vegetation types along the ground cover, understory and overstory over the length of the assessment site. The greenline field crew is also responsible for stringing the stationing tape along the assessment site once the beginning of the site has been established by the field team. Before greenline and BEHI data collection can start, the length of the survey site must be determined. Site length for greenline and BEHI data collection is determined by bankfull channel width and may vary from the collection from the other sediment data**(Table 3-2)**.

Table 3-2. Survey Site and Survey Cell Lengths.

Bankfull Channel Width (Feet)	Survey Site Length (Feet)	Length of Survey Cell (Feet)				
		Cell 1	**Cell 2**	**Cell 3**	**Cell 4**	**Cell 5**
< 10	500	0-100	100-200	200-300	300-400	400-500
> 10 to < 50	1000	0-200	200-400	400-600	600-800	800-1000
> 50 to < 75	1500*	0-300	300-600	600-900	900-1200	1200-1500
>75	2000*	0-400	400-800	800-1200	1200-1600	1600-2000

* The selection of either a 1500 or 2000 foot survey site length at bankfull channel widths of > 50 will be determined on an individual basis.

Data collected during the riparian greenline assessment should be recorded on the **Riparian Greenline Field Form**. The steps to performing the riparian greenline assessment go as follows:

1. Starting at the downstream end of the cell, perform measurements at 10-foot intervals progressing upstream along the greenline, which is located at approximately the bankfull channel margin (Windward 2000).
2. Every 10-feet, the ground cover (<1.5 feet tall), understory (1.5 to 15 feet tall) and overstory (>15 feet tall) riparian vegetation will be assessed (USEPA 2004).
3. The ground cover (<1.5 foot tall) vegetation will be described in the following categories:

   W = Wetland vegetation, such as sedges and rushes
   G = Grasses or forbs, rose, snowberry (vegetation lacking binding root structure)
   B = Disturbed/bare ground
   R = Rock, when a large cobble or boulder is encountered
   RR = Riprap

4. When the 10-foot interval falls at the base of a shrub or tree, place a dash (-) on the field form.
5. When pugging and hummocking due to the mechanical hoof action of grazing ungulates is observed, add "/H" to the field form (i.e. "G/H" indicates grass or forb ground cover with evidence of pugging and hummocking).
6. When Bare/Disturbed ground is observed, if the location appears to have the potential to support an herbaceous or woody vegetative community under "natural" circumstances, add "/D" to the field form.
7. If moss is encountered, simply choose the category that best describes the feature that the moss is associated with.
8. The understory vegetation (1.5 to 15 feet tall) and overstory vegetation (>15 feet tall) will be described in the following categories:

   C = Coniferous
   D = Deciduous, riparian shrubs and trees with sufficient rooting mass and depth to provide protection to the streambanks
   M = mixed coniferous and deciduous

9. When assessing understory and overstory vegetation along the greenline, envision an imaginary column about 5 feet or so in diameter extending up from the 10-foot interval at the bankfull margin. If this column intersects the canopy a shrub or tree, then record the data in the appropriate category. Only count vegetation originating from the side of study. Vegetation from the opposite bank that extends into the column is not to be recorded.
10. If no shrub or tree is encountered, place a dash (-) in the column on the field form.
11. When the bankfull channel margin is comprised of exposed sand or gravel due to streambank erosion, the greenline measurement should be made at the top of the bank.
12. When the channel margin is along a gravel bar, the greenline measurement should be made at the estimated bankfull elevation. When this is the case, place an “X” on the field form to denote the measurement was made along the bankfull channel margin at a gravel bar.
13. At 50-foot intervals, the field crew will estimate the vegetated buffer width along both sides of the stream. This can be accomplished with a tape measure in areas where the riparian zone is small or the vegetation is not dense. The buffer width can also be estimated by pacing, visual estimate or with the use of a range finder. This distance should generally correspond with the flood-prone area and, in many instances, will be bound by terraces or other distinct topographic features.
    a. The goal is to estimate the width of vegetation that is buffering the stream from adjacent land use. It is not defined as the actual width of the band of riparian vegetation. This is because both riparian and non-riparian vegetation can act in a buffering capacity.
14. When performing the greenline assessment on larger streams, 2 crew members should progress along opposite sides of the channel simultaneously. In this case, crew members will be responsible for performing the greenline assessment on their respective sides of the channel, though only one crew member will be responsible for recording the data. The crew member assessing the river left side of the channel that lacks the tape should estimate the location of each 10-foot interval based on the guidance of the crew member progressing along the tape measure.
15. Following the completion of greenline measurements, the total number of times each canopy type was observed is tallied in the box at the bottom of the field form.
16. Note that the greenline assessment is specifically designed for areas in which streambank erosion is influenced by riparian shrub coverage. This measurement is optional in situations where riparian shrubs do not play an important role in streambank stability, such as steep mountain streams in coniferous forests.

Bank Erosion Hazard Index (BEHI) Data Collection:

The BEHI tasks include identifying slowly eroding and actively eroding streambanks and conducting measurements related to stream depths, bank dimensions, soil character, vegetation and root depths, and distinguishing potential forces of influence on the bank, including measurement or estimation of near-bank stress.

The steps to performing the streambank erosion assessment are outlined in the following sections.

Eroding Streambank “Type” Delineation

1. The field crew member tasked with performing the eroding stream bank assessment will assess the various “types” of eroding streambanks as he/she moves through the assessment reach.

   a. For this assessment eroding streambanks will be delineated by “type” based on the eroding rate estimation, and BEHI and NBS characteristics, with each unique bank being described as an individual “type”.
   b. When a bank is encountered that is similar to a bank already assessed, it is considered an “add bank” and it is assigned the “type” of the earlier bank.
2. Identify the upstream and downstream end of each unique eroding streambank, and record its type and stationing on the **Streambank Erosion Field Form**.
   a. If the eroding streambank is an “add bank” this data is recorded on the **Additional Streambank Erosion Measurements Form.**
3. Assess streambank erosion in one cell at a time, numbering streambanks in ascending order.
   a. Each individual eroding streambank regardless of “type” will be given a number per #3 above. If the eroding bank is an “add bank” in addition to the bank number, this eroding bank will be assigned the number of the similar bank “type”, and this will be recorded on the **Additional Streambank Erosion Measurements Form.**
4. If a cell lacks an eroding streambank, no streambanks will be assessed in that cell.
5. If an eroding streambank extends between two cells, include it in the downstream cell, which will be the first cell assessed in the upstream progression.
6. If an eroding streambank extends beyond the boundaries of the delineated stream survey site, do not include the portion of the streambank outside of the site.

Bank Erosion Hazard Index and Near Bank Stress

This assessment will be performed on one bank for each bank “type”. The data is recorded on the **Streambank Erosion Field Form**.

1. Visually determine whether the eroding streambank is “Non-vegetated”, or “Vegetated” and record on the field form. Non-vegetated stream banks appear to be obvious sources of sediment, and are typified by minimal to no vegetation and evidence of recent disturbance/erosional processes. Vegetated stream banks are likely contributing some minimal sediment over time, but at a very slow and gradual rate. They are typified by well vegetated and generally stable banks, often composed of erosion resistant streambank materials, and relatively small vertical scale.
2. Estimate the mean height of the eroding streambank from the toe of the bank to the top of the bank by making several measurements along the eroding streambank. The ***toe*** of the streambank is defined as the point where the streambank meets the channel bed. Note that the toe of the streambank will not necessarily be in the water during baseflow conditions.
3. Identify the most representative portion of the streambank and perform the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) estimates and/or measurements at this spot based on methods developed by Rosgen (1996, 2001, 2006) and adopted by the USEPA (2006). The measurements should be conducted in a location correspondent to the mean height of the eroding streambank.
4. The BEHI score is a metric derived from the following measurements which will be performed in the field: bank height, bankfull height, root depth, bank angle, and surface protection (**Figure 3-4**). For each bank, the BEHI score is then adjusted for bank materials and stratification.

   Bank height is measured from the toe of the bank to the top of the bank (note that this is labeled “study bank height” in **Figure 3-4**).

Bankfull height is measured from the toe of the bank to the bankfull elevation. Unless the toe of the bank is at or above the surface water elevation, this height will be greater than the bankfull elevation identified along the survey site.

Root depth is measured as the depth that the predominant roots extend into the soil from the top of the bank.

Root density is estimated as a percent of the area assessed for root depth that is comprised of plant roots. Record estimates to the nearest 10%.

Bank angle is measured from a horizontal plane in degrees from the toe of the bank to the top of the bank, with 90º being a vertical bank and >90º being an undercut bank. The angle of an undercut bank is determined by inserting the measuring rod into the deepest portion of the undercut and gently "prying" it back as close as it will go to vertical. Record measurements to the nearest 5º.

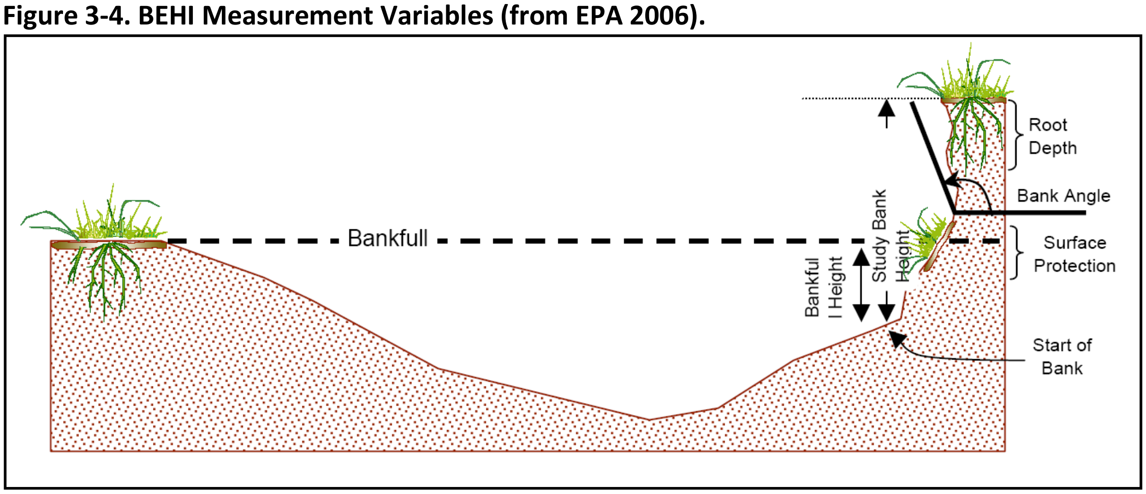
Surface protection is measured as the percent of the streambank that is exposed to erosion. Surface protection can be provided by sod mats (i.e. vegetated slumps), large woody debris or boulders. Record measurements to the nearest 10%.

The **bank material adjustment** is applied as follows:

- Subtract 10 points if the bank is comprised of cobbles.
- Add 5-10 points if the bank is comprised of gravel and sand, depending on the amount of sand.
- Add 10 points if the bank is comprised of sand.
- No adjustment is necessary for clay banks.

The **stratification adjustment** is applied depending on the position of the layers in relation to the bankfull stage. A streambank should be considered stratified when a more erosive layer is situated or "sandwiched" between two less erosive layers within the bankfull zone.

Figure 3-4. BEHI Measurement Variables (from EPA 2006).



5. Perform the NBS assessment and/or record estimate.

a. To perform the NBS assessment, chose and apply the most appropriate method for NBS determination from the following choices:

   i. Channel Pattern Estimate: This method does not require any measurements but is appropriate for cases when obvious conditions affecting NBS are present and channel pattern features create a disproportionate energy distribution in the near-bank region. Chute cutoffs and split channels that converge against study banks will have NBS ratings from High to Extreme. In addition, depositional features including transverse bars and central bars also have NBS ratings of High to Extreme; in these areas, changes in slope and velocity are evident. The NBS will be estimated based on the channel pattern features.
      1. If transverse and/or central bars exist, and are short and/or discontinuous in nature, NBS will be recorded as High or Very High, dependent upon the judgment of the assessor.
      2. If *extensive* deposition is evident and is continuous and cross-channel, NBS will be recorded as Extreme.
      3. If chute cutoffs, down-valley meander migration, or converging flow are evident, NBS will be recorded as Extreme.

   ii. Ratio of Near-Bank Maximum Depth top Bankfull Mean Depth (d_{nb}/d_{bkf}): This method calculates the ratio of the near-bank maximum bankfull depth (d_{nb}) at study site to mean depth (d_{bkf}) from the study site or a nearby riffle cross-section. This method is generally most appropriate in relatively straight sections or gently turning bends.
      1. Perform approximately 5 bankfull depth measurements at roughly equal spacing across the bankfull width of the stream channel. Record these measurements in the *Bankfull mean depth calculations* box on the field form and calculate the mean bankfull depth. Use the d_{bkf} from one of the cell cross-sections if the cell cross-section occurs nearby and resembles the conditions of your study site.
      2. Measure the *near bank maximum depth*, which is the deepest bankfull channel depth (measured from the channel bed to the bankfull elevation) within the 1/3 of the channel closest to the eroding bank along the cross-section. Record this depth on the field form.
      3. Calculate the ratio of near-bank maximum depth to bankfull mean depth (d_{nb}/d_{bkf}) and record this value and the subsequent NBS ratings (**Table 3-3**).

Table 3-3. Conversion Table of d_{nb}/d_{bkf} Values to NBS Ratings.

NBS ratings based on d_{nb}/d_{bkf}	
d_{nb}/d_{bkf} ratio	**NBS rating**
< 1.00	**Very Low**
1.00 – 1.50	**Low**
1.51 – 1.80	**Moderate**
1.81 – 2.50	**High**
2.51 – 3.00	**Very High**
> 3.00	**Extreme**

   iii. Ratio of Radius of Curvature to Bankfull Width (R_c/W_{bkf}): This method can be rapidly completed in the field or on an aerial photograph. This method is most appropriate for eroding banks at meander bend locations.
      1. Measure the radius of curvature of the meander bend where your study site is located. Radius of curvature is the radius or distance from the center of the

approximating circle that best fits a given meander bend. For a given meander bend, identify the beginning and end points of the arc of the meander bend and measure the distance from these points to the center of a circle that would best fit along that arc. (In theory, the distance from the center of the circle to the beginning and end points of the arc is the same, however, due to field variability and vegetation, measurements may slightly differ from one another. In that case, the average of the two measurements can be used for the radius of curvature determination.)

2. Measure the bankfull channel width at a close by riffle. Typically this riffle will occur in the reach leading to or away from the meander at the study site.
3. Calculate the ratio of radius of curvature to bankfull width (R_c/W_{bkf}) and record this value and the subsequent NBS rating (**Table 3-4**).

Table 3-4. Conversion Table of R_c/W_{bkf} Values to NBS Ratings.

NBS ratings based on R_c/W_{bkf}	
R_c/W_{bkf} ratio	**NBS rating**
> 3.00	**Very Low**
2.21 – 3.00	**Low**
2.01 – 2.20	**Moderate**
1.81 – 2.00	**High**
1.50 – 1.80	**Very High**
< 1.50	**Extreme**

6. Once the BEHI and NBS estimates and/or measurements have been made take one photo looking downstream at the eroding streambank and second photo facing the streambank at the site where the BEHI and NBS assessment was performed (**Figure 3-5**). Include the measuring rod and the line level in the photo for reference, with the base of the rod placed at the toe of the streambank. Provide a brief description in the **Photo Log** (i.e. “d/s view at BEHI 1”, “view toward bank at BEHI 1”).
7. If the eroding streambank is “complex” and appears to have more than one BEHI value and/or more than one NBS value, then the streambank may need to be broken into two or more eroding streambank “types”. If only the NBS changes along the streambank, then two separate NBS measurements can be performed for one eroding bank so long as the length of eroding bank associated with each NBS measurement is recorded.

Figure 3-5. Example of Appropriate Photos of Eroding Streambanks.

Streambank Composition and Erosion Source Assessment

1. For each bank that undergoes the BEHI assessment, visually estimate the streambank material composition and identify the sources of streambank erosion.
2. When assessing the streambank composition, first estimate the percent comprised of coarse gravel, cobbles and boulders (>6mm). Next, evaluate and the percent comprised of sands and clays (<2mm). Finally, assessed the amount of streambank comprised of fine gravels (2mm-6mm). Assess each category to the nearest 10%.
3. Indicate if hoof shear is observed by circling either "present" or "absent" on the field form. If hoof shear is observed, document it with a photograph and provide a brief description in the **Photo Log**.
4. For all eroding stream banks regardless of "type", identify sources of streambank instability and estimate a percent in the following categories:
   - Transportation
   - Riparian Grazing
   - Cropland
   - Mining
   - Silviculture
   - Irrigation-shifts in stream energy
   - Historic (provide a description of the source)
   - Natural Sources
   - Other (provide a description of the source)

5. If a source of streambank erosion is not observed, do not record a value. The exception is for natural sources, which must always be estimated, even if that value is 0%. Eroding streambanks at the outside of meander bends, for example, are likely due at least partially to natural sources, though human sources may be leading to increased instability and erosion.
6. Sources of streambank instability should be attributed to the factors most influential on the study bank. This does not necessarily equate to those factors most visible or directly adjacent to the study bank. For instance, historic practices may have denuded the riparian area and resulted in prolonged instability. Current riparian condition however may be that of early growth vegetation in a stage of recovery, although the full recovery of stream stability may still take

years. In this case, some of the sources of instability should be accounted for as 'Historic', with a description of the practices that likely created the instability. As another example, the existence of placer mining and stream channelization may have occurred upstream of the study bank. The resultant changes in hydrology and stream power extend below the mining location and affects the erosional processes at the study bank. In this case, 'Mining' would receive a percentage of streambank instability sources even though no mining is actively present at the study bank.

7. The attribution of sources of streambank instability relates to the context of a given site within its watershed and should be conducted by a member or members of the team who are best qualified to make that determination. Knowledge should include history of the stream or reach, familiarity with hydrology and geomorphology principles, and understanding of the effects of many land use practices.

4.0 Sample Handling Procedures

Field samples will be collected and preserved in accordance to Section 3. DEQ monitoring crews will be responsible for proper labeling, sample custody, documentation, and storage in accordance to the specifications in the Field Procedures Manual and QAPP (WQPB 2012). Macroinvertebrate and periphyton samples will be delivered to Rhithron, Inc. for analysis.

5.0 Quality Assurance and Quality Control Requirements

This project will follow the WQPB "internal process". All QA/QC requirements followed by MT DEQ will be instituted for this project. The QA/QC requirements are described in MT DEQ (Montana Department of Environmental Quality, 2005).

6.0 Handling Sampling Records

Site Visit Forms, field forms, and digital photos will be processed by WQPB staff using QA/QC procedures described in the QAPP (WQPB 2012). Analytical laboratories will provide results to DEQ in the required EDD format. DEQ will perform the necessary data evaluations and will manage the data in accordance with the QAPP.

7.0 Schedule

The Water Quality Monitoring and Assessment staff will sample all sites listed in **Appendix A** during low flow conditions during the period of July – September 2015.

8.0 Project Team and Responsibilities

The Water Quality Monitoring and Assessment staff will lead the monitoring component. Darrin Kron will oversee the Monitoring and Assessment section activities. Alan Nixon will lead the sediment monitoring. Monitoring and Assessment Section and Watershed Management Section staff will provide monitoring support in the field. Jordan Tollefson will lead the greenline and bank erosion data collection efforts. Dean Yashan will oversee the TMDL activities for this project.

9.0 REFERENCES

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10.0 APPENDICES

APPENDIX A. LIST OF SITES ON SHEEP CREEK TO BE MONITORED FOR SEDIMENT AND THE RATIONALE FOR THE SITE SELECTION

Station Site Description	Site ID	Latitude	Longitude	Rationale
Sheep Creek, near the mouth at Smith Creek Road bridge	1A	46.80750	-111.15860	Lower most site near the mouth. This reach is Strahler Order 4
Sheep Creek, downstream of the Sheep Creek CG	1C	46.81424	-110.93133	Potential internal reference reach
Sheep Creek, at Sheep Creek Campground	1D	46.81141	-110.92538	Site is downstream of the proposed mine site and downstream of Moose Creek. This site is near the center of the drainage, and is Strahler Order 3
Sheep Creek, at the USFS CG, about 6 mi upstream of the Tintina mine	1G	46.76380	-110.78510	Upper most site. Site is upstream of the proposed mine. The reach is Strahler Order 2. Site is 9 miles from the headwaters.