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Enbridge Line 6B MP 608
Marshall, MI Pipeline Release

Court Case No.: 15-1411-CE

Work Plan for the Evaluation of Habitat Functions in Portions of Talmadge Creek Affected by the Line 6B Release

Prepared for Michigan Department of Environmental Quality

Enbridge Energy, Limited Partnership

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FIGURES

ATTACHMENTS

Attachment A **Instream Shelter and Canopy Density Measurement Methods**

Attachment B **Pfankuch Channel Stability Field Form**

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LIST OF ACRONYMS

CMP	corrugated-metal pipes
Enbridge	Enbridge Energy, Limited Partnership
GPS	Global Positioning System
Line 6B	The pipeline owned by Enbridge Energy, Limited Partnership that runs just south of Marshall, Michigan
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources

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1.0 INTRODUCTION

This Work Plan was prepared to describe the means by which data will be gathered and evaluated to assess the stream habitat functionality of the portion of Talmadge Creek that was affected by the Enbridge Energy, Limited Partnership (Enbridge) Line 6B crude oil release. To complete this evaluation, field surveys will be conducted at appropriate reference reaches and along the portion of the Talmadge Creek that was affected by response activities. The implementation of this Work Plan, and the findings obtained from the field surveys will be used in the preparation and submittal of the *Talmadge Creek Channel Habitat Report* that will be submitted to Michigan Department of Environmental Quality (MDEQ) for review and approval.

The field surveys addressed in this Work Plan will provide data relating to current channel stability and the appropriateness of in-stream habitat.

1.1 Background

The affected reach of Talmadge Creek was mass-excavated on two separate occasions and reconstructed with backfill, bank restoration materials, and new culverts using 2010 pre-excavation civil survey data to verify the location of the reconstructed reach. Additionally, the MDEQ and Michigan Department of Natural Resources (MDNR) have been performing annual P51 fish and macroinvertebrate sampling before and after the Line 6B crude oil release within the affected reach of Talmadge Creek. A more detailed discussion of the survey and the P51 studies and a discussion regarding the outcome of a joint Enbridge and MDEQ meeting on June 11, 2014 are provided below.

1.1.1 Civil Survey

Talmadge Creek and its associated topography were documented by civil survey data in August 2010, prior to any channel excavation or restoration. Other than this survey, Enbridge has little topographic data for Talmadge Creek prior to the Line 6B crude oil release. Topography was re-surveyed in 2013 to compare pre- and post-construction elevations. This analysis is presented in the approved *Report for Monitoring, Restoration, and Invasive Species Control in Wetlands along Talmadge Creek and the Source Area - 2013*, submitted to the MDEQ on March 12, 2015 (Enbridge, 2015) which concluded that:

> "Overall, the morphology of Talmadge Creek as indicated by width, depth, and location measurements taken in 2013 is consistent with the condition of the creek in 2010 prior to the Line 6B crude oil release."

1.1.2 Habitat Quality

As part of its annual P51 fish and macroinvertebrate monitoring, the MDNR and MDEQ have been sampling Talmadge Creek at one location within the area of the Talmadge Creek affected by the Line 6B crude oil release and two upstream control locations not affected by the Line 6B crude oil release. Annual P51 monitoring results will be addressed within the subsequent Report detailed in *Section 5.0*. Additional habitat quality data related to aquatic vegetation, sediment toxicity, and the remedial investigation (sediment, surface water, and groundwater testing results) will be considered, and references provided, if applicable and relevant to the assessment of habitat quality.

1.1.3 Field Visit

Enbridge representatives met with MDEQ and MDNR personnel on June 11, 2014 to discuss issues regarding the post-cleanup recovery of Talmadge Creek. The group also conducted site visits at representative sections of Talmadge Creek within the affected portion of the creek. Concerns voiced by MDEQ and MDNR staff regarding Talmadge Creek and the status of restoration and recovery fell within one of three general categories:

- Structural habitat complexity,
- Geomorphic stability, and
- Longitudinal habitat connectivity.

To address these concerns, the following field methods will be implemented in the identified locations to evaluate the current channel stability and the appropriateness of existing in- stream habitat to facilitate enhancement/modifications as appropriate within the affected reach of Talmadge Creek.

This Work Plan does not include methods to evaluate longitudinal habitat connectivity, because the concept of improving and/or removing the subject culverts is proposed. A more detailed discussion regarding this concept is provided in *Section 3.2*.

2.0 REFERENCE REACHES AND TALMADGE CREEK SECTIONS

For comparison purposes to the affected reach of Talmadge Creek, reference reaches have been mutually selected by MDEQ and Enbridge to approximate pre-release conditions in relation to stability and habitat. Additionally, the affected Talmadge Creek reach was segmented into nine separate sections (*Figure 1*) to better define habitat and stability conditions along the entire affected reach. The individual Talmadge Creek sections, and reference reaches are described below.

Two areas have been identified as reference reaches (*Figure 2*):

1) The forested section of Talmadge Creek immediately upstream of the Source Area will be referenced to the section of Talmadge Creek extending from the Source Area to Division Drive (Section 7 through Section 9).
2) The lower section of Dibble Drain will reference the section of Talmadge Creek extending from Division Drive to the confluence of the Kalamazoo River (Section 1 through Section 6).

Reference reaches were chosen for their ability to represent (as close as possible) stable conditions that existed in Talmadge Creek prior to the spill and/or for desirable ecological attributes (e.g., riparian forest development, etc.) in comparison to affected reaches. The dimensions and configuration of the reference reaches will be compared to the restored Talmadge Creek to determine the degree to which it has been restored or is moving toward recovery.

3.0 FIELD METHODS

To assess the condition of the affected reach of Talmadge Creek, field data collection is required. The intent of the field surveys is to gain a better understanding of the channel's state of stability, and the ability to predict dynamic conditions over time. This Work Plan details the performance of longitudinal profiles and strategic cross-section measurements to assess the affected reach in terms of stability and the appropriateness of in-stream habitat.

3.1 Structural Habitat Complexity and Geomorphic Stability

The longitudinal profile and cross section measurements will assess both structural habitat complexity and geomorphic stability. In addition to those field measurements, other stream dynamic variables will include: bed material, woody debris, and bank erosion to further define habitat and stability. The specific field methods for each of those variables are presented below.

3.1.1 Longitudinal Profiles

To analyze the existing functionality of Talmadge Creek and the reference reaches, the performance of a longitudinal profile will be completed. A longitudinal profile will be performed in each of the Talmadge Creek stream sections and reference reaches, to characterize the overall stream slopes/patterns, definition of habitat features (e.g., riffle and pool) and overall stream depths.

The longitudinal profile will be performed per established guidelines (Rosgen, 2008) where a conventional stationing system will be applied to the approximate centerline of the stream to reference the measurement locations. The longitudinal profile will include obtaining elevation measurements either every 50 feet of stream centerline, and/or at the beginning, mid-point, and end of geomorphic breaks/habitat features. If geomorphic breaks/habitat features are found to occur less than 50 feet of stream centerline, the 50-foot interval may be reduced to represent that distance. Four types of features will be measured at each station location:

- Thalweg,
- water surface,
- bankfull,
- top of lowest bank, and
- Invert elevations of installed structures, (i.e., culverts – inlet and outlet) will also be obtained.

The longitudinal profile survey will be performed using survey-grade global positioning system (GPS) to ensure reproducibility.

3.1.2 Cross-Section Survey

To further define in-stream habitat features, cross-section surveys will be completed during the longitudinal profile activities. Cross-section data will be collected following established guidelines (Rosgen, 2008). The following features will be measured at each cross-section location, which will span the distance of the flood-prone elevation:

- left bankfull;
- left edge water;
- thalweg;
- right edge water; and,
- right bankfull.

In addition to the features mentioned above, measurements will be collected in sufficient intervals to identify elevation changes from top of bank to top of bank, with a maximum distance of 1 foot. Cross-sections will be placed in at least two riffles and two pools for each section in the affected portion of Talmadge Creek, as well as approximately one-third of the original transects utilized for the survey referenced in *Section 1.1.1* for a total of 42 cross-sections performed in Talmadge Creek. Enbridge and MDEQ will jointly select the original transect locations to re-measure with the intent that cross-sections will target in-stream habitat, major features, or lack thereof. A total of eight cross sections will be placed in each reference reach four in riffles and four in pools. The locations of the cross-sections will be captured using survey-grade GPS units capturing latitude and longitude coordinates to ensure reproducibility.

3.1.3 Physical Habitat

The longitudinal profile will identify in-stream habitat features (i.e. riffle, pool) however field personnel will further define the habitat units by performing pebble counts (see *Section 3.1.5*), and visually estimating in-stream shelter complexity and canopy cover density. Both in-stream shelter and canopy cover density will be measured using habitat inventory methods established in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al., 2010). Specifically, in-stream shelter will be measured using the method described in Section III-43 of the *California Salmonid Stream Habitat Restoration Manual* at 25% (every fourth) observed habitat features (e.g., pool, riffle, and run) within each survey reach. Minimally, two in-stream shelter measurements will be taken for each available habitat feature (e.g., pool, riffle, and run) within each survey reach. Canopy cover density will be measured using the method provided in *Appendix M-5* of the *California Salmonid Stream Habitat Restoration Manual*, and will be measured at every fourth pool within the survey reach, or at least at an average of every 300 feet over the affected reach. Copies of each method are included in *Attachment A*.

3.1.4 Woody Debris

Field personnel will record the type, length, diameter, and orientation of any wood pieces greater than 3-inches in diameter observed within the bankfull channel. The type of woody debris will be defined as trees, logs, limbs, stumps or root masses. The location of these pieces will be mapped using a GPS device and the number of wood pieces inventoried per 100 channel-feet will be reported.

3.1.5 Bed material

Bed material characterization and monitoring will be carried out using a technique known as a "pebble count". The methods for this procedure are described more fully in the *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson et al., 1994) and involve randomly collecting and measuring 100 substrate particles from the bed. A riffle pebble count will be conducted for each of the nine affected Talmadge Creek sections and in two riffle locations in each reference section. The pebble counts will be performed in select riffle locations where cross-section measurements are performed. A reach average pebble count will be conducted for each of the nine sections and reference reaches.

3.1.6 Bank stability

Any significant bank erosion will be documented following the Pfankuch Channel Stability Assessment (Rosgen, 2001). The Pfankuch Channel Stability Assessment (Rosgen, 2001) is a qualitative visual assessment method intended to quickly assess various morphologic variables that contribute to channel stability. Elements of the analysis include riparian vegetation, flow regime, stream size, meander pattern, depositional pattern, debris/channel blockages, width/depth ratio state, Pfankuch stability rating, and bank height ratio. These individual metrics are rated to produce an overall numeric rating for the area under consideration.

Field personnel will walk the length of each section while recording observations relating to metrics described above. Assessments will be completed for all nine study sections as well as the upstream reference section and the Dibble Drain reference reach, and will be recorded on data sheets and photographed. In addition to performing the Pfankuch analysis, any significant erosion such as bank sloughing or exposed soil from recent erosion will be noted and GPS referenced. A summary of variables that will be evaluated in the field and their relative qualitative rankings is presented in *Attachment B*.

3.2 Aquatic Habitat Connectivity

Based on discussions with MDEQ personnel on May 7, 2015, the concept of improving or removing the two installed culverts south of Division Drive and the culvert immediately north of Division Drive was proposed. This concept was proposed as an alternative to assessing and evaluating aquatic connectivity throughout these sections. The existing culverts consist of corrugated-metal pipes (CMP). Completely removing the subject CMPs, or replacing with properly sized box culverts or clear span bridges, can improve the existing habitat connectivity by providing fish passage and allowing unrestricted bankfull flow through the reach while maintaining channel stability and appropriate sediment transport. The proposed culvert removal and/or improvement design(s) will be detailed in the subsequent report.

4.0 DATA EVALUATION

The data obtained from the field surveys discussed in this Work Plan from both the affected reach sections and reference reaches will be compiled and evaluated by personnel preparing the *Talmadge Creek Habitat Report*. Figures showing the overall longitudinal profiles, as well as individual cross-sections will be prepared and utilized during the data evaluation. Historic data, such as the civil survey cross-section/elevation data will be compared to the data obtained during the surveys. Other field data collected, such as aquatic habitat, woody debris, bed material, and bank stability will be included in the report and utilized as part of the overall evaluation.

4.1 Structural Habitat Complexity

Data from the longitudinal profile, cross-section measurements, and habitat mapping surveys will be compiled and evaluated and will include a comparison of habitat conditions in the impacted sections with the reference reaches and the criteria provided in the document recommended by *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman et al., 2012). More specifically, the criteria established in Function 1 through Function 3 of the Stream Functions Pyramid as reported in the referenced document will be the main focus of the analysis, where Function 4 and Function 5 are being assessed as described in *Section 1.1*. For a limited number of variables it may be possible to use inferential statistics to compare sections (e.g., cover type frequencies and macrohabitat lengths). Specifically, the following items will be evaluated:

- Macrohabitat length proportionality reported as a percentage of the total stream section(s) length,
- Percent cover by macrohabitat type and study section,
- Frequency of dominant substrate types by study section and macrohabitat type,
- Canopy cover by study section,
- Pool to pool spacing and pool and riffle depths, and
- Wood piece frequency and volume by macrohabitat type and study section.

Factors that may influence the decision to make additional functional enhancements are:

- Comparison of sampled variables in the affected sections of the Talmadge Creek will be compared to the reference reaches first, and then to referenced literature, if needed,
- The potential risk of inaction to overall objectives of the restoration work (e.g., failure to repair bank erosion leads to excessive lateral channel migration), and
- The potential risk of action to overall objectives of the restoration work (e.g., wood placement causes excessive bank erosion).

4.2 Geomorphic Stability

Geomorphic data will be combined and assembled for each section using basic metrics obtained from the field methods described in *Section 3.1* such as width to depth ratios, bank height ratios, entrenchment ratio, channel slope, sinuosity, cross-sectional area, and sediment grain size. This information will also be used to determine Rosgen channel type for each section surveyed, including the reference reaches. These variables, as well as the data obtained from the bank stability analysis, will be assembled by section and overall for the impacted reach. These variables will be compared to those of the reference reaches first, and then if needed, compared to the performance standards provided in the referenced literature.

5.0 REPORTING

A report will be prepared detailing the results of structural habitat complexity and geomorphic stability analyses. The report will include a schedule for implementation of any proposed restoration activities, and will identify monitoring of sufficient duration to determine if the restoration actions have restored the habitat and withstood the range of expected environmental conditions.

5.1 Structural Habitat Complexity and Geomorphic Stability

Project personnel will summarize the structural habitat complexity and geomorphic stability Work Plan objectives, present field data collection methods, data evaluation methods, and report the results of the analyses performed which includes comparing the data between the affected portion of Talmadge Creek, the references reaches, and the referenced literature, if needed, proposed by the MDEQ.

Recommendations for habitat or bank stability enhancements will be provided in the report, if the analysis indicates as such. The report will identify a monitoring program to verify the improvements (if implemented) have restored the habitat to an appropriate condition.

5.2 Longitudinal Habitat Connectivity

As previously mentioned, the concept of improving or removing the two installed culverts upstream of Division Drive and the culvert immediately downstream of Division Drive are proposed to eliminate perceived habitat connectivity concerns. The report will provide details for improving or for the removal of the three culverts and will include corresponding bank and bed restoration details.

6.0 SCHEDULE

Field surveys and data collection for habitat and geomorphic stability will be initiated in late 2015 or during the spring of 2016, and is estimated to be complete in approximately two to three weeks. A report including a summary of all of the data collected and conclusions and recommendations for any appropriate additional enhancements will be submitted to MDEQ for review and approval no later than 6 months following completion of the last field survey activities.

7.0 REFERENCES

Enbridge, 2015. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Report for Monitoring, Restoration, and Invasive Species Control in Wetlands along Talmadge Creek and the Source Area – 2013*, dated March 12, 2015.

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Rosgen, 2001. Rosgen, D.L. A Stream Channel Stability Assessment Methodology. Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp. II -18-26, March 25-29, 2001, Reno, NV.

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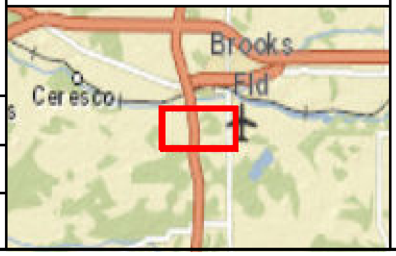
Figures

ENBRIDGE		
Drawn:	EN	6/3/2015
Approved:	BA	6/3/2015
Project #:	60339671	

Map Location



Legend

- P-51 Sampling Location
- Reference Section
- Culvert
- Section 1
- Section 2
- Section 3
- Section 4
- Section 5
- Section 6
- Section 7
- Section 8
- Section 9

Sections 1-9 Affected Portion of Talmadge Creek

N

0 400 800 1,600

Scale in Feet

FIGURE 1
TALMADGE CREEK
HABITAT ASSESSMENT SECTIONS

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\Data_Catalog\Stantec\140710_TC_Habitat_Evaluation_WP_DocID4097\MXD\Enb6b_Talmadge_2014_Habitat_Assessment.mxd

Aerial Photography Date: April 2011 over 2010

ENBRIDGE

Drawn:	EN	6/3/2015
Approved:	BA	6/3/2015
Project #:	60339671	

Map Location

Legend

- Talmadge Creek Reference Section
- Easterly Dibble Drain Reference Section
- Quarter Mile Grid Segments

N

0 1,000 2,000 4,000

Scale in Feet

FIGURE 2
TALMADGE CREEK
REFERENCE SECTION LOCATIONS

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\Data_Catalog\Stantec\141105_TC_Habitat_Evaluation_Reference_Reaches\Talmadge_Reference_Reaches\MXDs\141105_Figure_2_Reference_Sections.mxd

Aerial Photography Date: April 2011 over 2010

Attachment A

Instream Shelter Complexity and Canopy Density Methods

Instream Shelter

Instream shelter within each habitat unit can be rated according to a standard system. This rating system is a field procedure for habitat inventories which utilizes objective field measurements. It is intended to rate, for each habitat unit, complexity of shelter that serves as instream habitat or that creates areas of diverse velocities which are focal points for salmonids. In this rating system, instream shelter is composed of those elements within a stream channel that provide protection from predation for salmonids, areas of reduced water velocities in which fish can rest and conserve energy, and separation between territorial units to reduce density related competition. This rating does not consider factors related to changes in discharge, such as water depth.

Instream Shelter Complexity. A value rating can be assigned to instream shelter complexity. This rating is a relative measure of the quantity and composition of the instream shelter.

Value	Instream Shelter Complexity Value Examples:
0	● No shelter.
1	● One to five boulders. ● Bare undercut bank or bedrock ledge. ● Single piece of large wood (>12" diameter and 6' long) defined as large woody debris (LWD).
2	● One or two pieces of LWD associated with any amount of small wood (<12" diameter) defined as small woody debris (SWD). ● Six or more boulders per 50 feet. ● Stable undercut bank with root mass, and less than 12" undercut. ● A single root wad lacking complexity. ● Branches in or near the water. ● Limited submersed vegetative fish cover. ● Bubble curtain.
3	Combinations of (must have at least two cover types): ● LWD/boulders/root wads. ● Three or more pieces of LWD combined with SWD. ● Three or more boulders combined with LWD/SWD. ● Bubble curtain combined with LWD or boulders. ● Stable undercut bank with greater than 12" undercut, associated with root mass or LWD. ● Extensive submersed vegetative fish cover.

Instream Shelter Percent Covered. Instream shelter percent covered is a measure of the area of a habitat unit occupied by instream shelter. The area is estimated from an overhead view.

The primary drawback to using GPS in streams is the difficulty in receiving and maintaining satellite signals under vegetation or stream canopy. GPS radio signals travel "line-of-sight" and do not penetrate solid objects well. Basically, if you cannot see the sky, the GPS unit will not receive the satellite signal. This problem is overcome by using "offsets" when determining a fix. Offsets require the GPS unit to be located in an adjacent open area where a fix can be obtained, at a measured distance and direction from the stream. Remote antennas have also proven useful to acquire signals under stream canopy cover. The antenna, attached to a pole, is moved and tilted around until satellites are "locked on".

Spherical Densiometer

The spherical densiometer can be used as a hand held instrument to estimate relative vegetative canopy closure or canopy density caused by vegetation. Vegetation canopy closure is the area of the sky over the selected stream channel that is bracketed by vegetation (regardless of density). Canopy density is the amount of the sky blocked within the closure by vegetation. Canopy closure can be constant throughout the season if fast growing vegetation is not dominant, but density can change drastically if canopy vegetation is deciduous.

Spherical densiometers are produced with either convex or concave reflecting surfaces. These instructions are for a convex (Model A) spherical densiometer. The mirror surface of the densiometer has 37 grid intersections forming 24 squares. At a probability level of 95 percent, tests show the average measurements of the same overstory area can be excepted to be within ±2.4 percent of the mean. Because the instrument has a curved (convex or concave) reflecting surface resulting in a field the includes lateral as well as overhead positions, an overlap of side readings occurs when readings are taken from the same point. To account for this bias, the modifications developed by Strichler (1959) are used and modified to more accurately measure canopy closure and density. Strichler uses only 17 of the line intersects as observation points by taping a right angle on the mirror surface (Figure M- 1).

For Stream Orders 1 Through 4 - Stand in the middle of the habitat type area and in the center of the stream facing downstream. The densiometer is held in the hand, in front of the body at about waist level, with the arm from the hand to the elbow parallel to the water surface. The convex densiometer is held away from the observer's body with the apex of the V pointed toward the observer. The observer's eye reflection should seen along the margin of the original grid (Figure M-1). Level the densiometer using the bubble indicator and maintain the level and standard eye positions while recording. The grid between the V formed by the tape encloses 17 observation points. Each point has a value of 1.5 percent when four different recordings are made. The number of points (line grid intersects) that are covered by vegetation are counted when measuring canopy density. The number of points surrounded by vegetation are counted when measuring canopy closure. Measurements are taken in the four quadrants while standing on the same point (facing downstream, right bank, upstream, left bank).

The points counted for each reading are totaled and multiplied by 1.5 to obtain the percentage of canopy density or closure.

If all possible observation points are counted the total value will be 102 percent (68 × 1.5 = 102). Although this error is small and not considered important for comparisons of relative values, the following correction factor can be applied to determine the correct percentile:

Calculated value	Subtract from Calculated value
less than 30	0
30 to 60	-1
over 60	-2

Example: (8+11+7+12)(1.5) = 57%   subtract 1% = 56% density

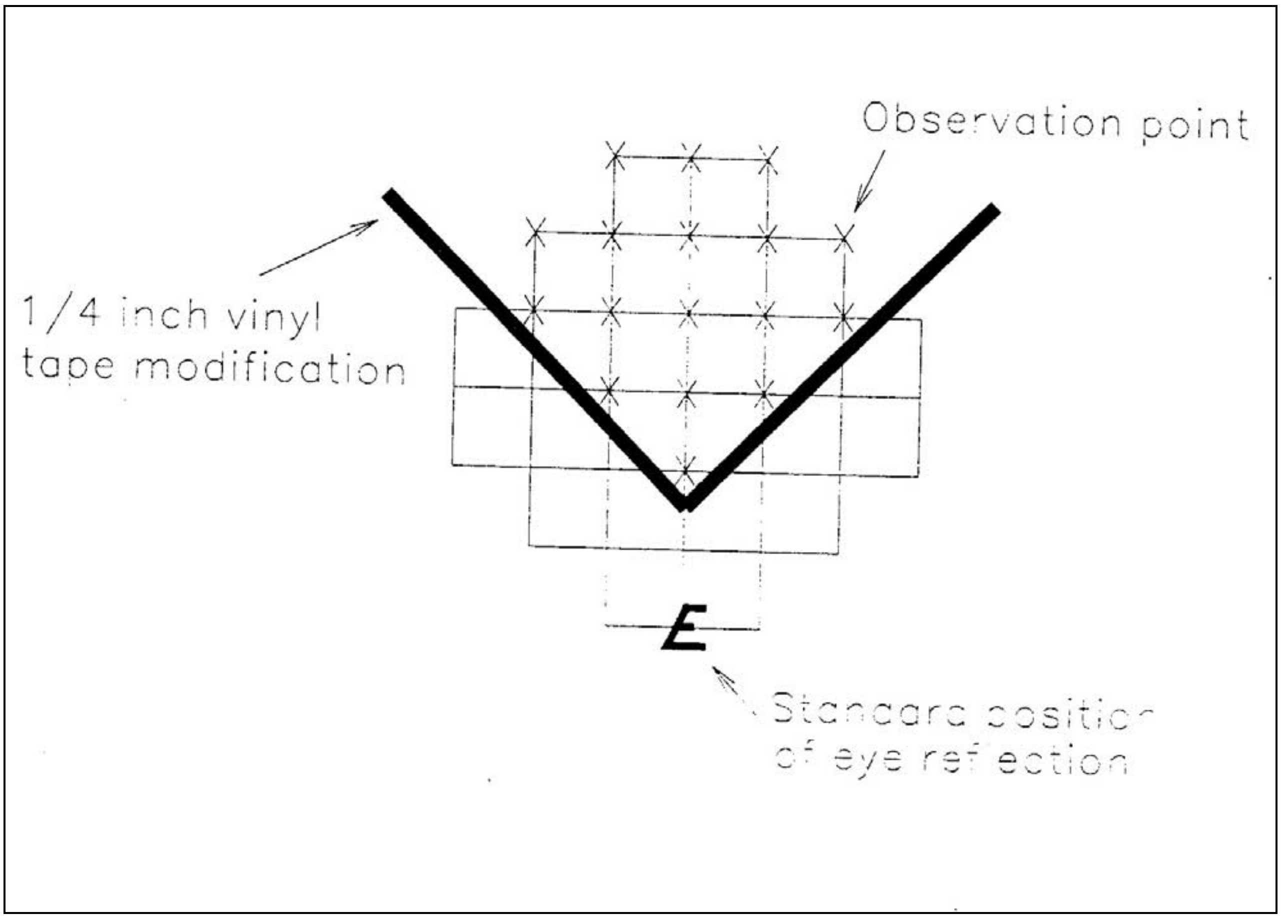


Figure M-1. Modified grid of convex spherical densiometer showing the 17 observations points (X's) and the position of the observer's eye reflection.

Attachment B

Pfankuch Channel Stability Field Form

Stream: Location: Valley Type: Observers: Date:

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper Banks	1	Landform slope	Bank slope gradient <30%	2	Bank slope gradient 30-40%	4	Bank slope gradient 40-60%	6	Bank slope gradient >60%	8
	2	Mass erosion	No evidence of past or future erosion	3	Infrequent, mostly healed over, low future potential	6	Frequent or large, causing sediment nearly yearlong	9	Frequent or large, causing sediment nearly yearlong or immenent danger of same	12
	3	Debris jam potential	Essentially absent from immediate channel area	2	Present, but mainly small twigs and limbs	4	Moderate to heavy amounts, mostly larger sizes	6	Moderate to heavy amounts, predominantly larger sizes	8
	4	Vegetative bank protection	>90% plant density, vigor and variety suggest deep, dense soil-binding roots	3	70-90% density, fewer species or less vigor suggest less dense or deep root mass	6	50-70% density, lower vigor & fewer species from a shallow discontinuous root mass	9	<50% density, plus fewer species & less vigor indicating poor shallow& discontinuous root mass	12
Lower Banks	5	Channel capacity	Bank heights sufficient to contain bankfull stage, width/depth ratio departure from reference width/depth ratio=1.0. Bank-Height ratio (BHR)=1.0	1	Bankfull stage is contained within banks, width/depth ratio departure from reference width/depth ratio=1.0-1.2. Bank-Height ratio (BHR)=1.0-1.1	2	Bankfull stage is not contained, width/depth ratio departure from reference width/depth ratio=1.2-1.4. Bank-Height ratio (BHR)=1.1-1.3	3	Bankfull stage is not contained,overbank flow are common with flows less than bankfull, width/depth ratio departure from reference width/depth ratio= >1.4. Bank-Height ratio (BHR)= >1.3	4
	6	Bank rock content	>65% with large angular boulders 12"+ common	2	40-65%, mostly boulders and small cobble 6-12"	4	20-40% most in the 3-6" range	6	<20% rock fragments of gravel sizes, 1-3" or less	8
	7	Obstructions to flow	Rocks and logs firmly imbedded flow pattern w/o cutting or deposition	2	Some present causing erosive cross currents and minor pool filling, obstructions fewer and less firm	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting	6	Frequent obstructions and deflectors causing bank erosion yearlong, sediment traps full, channel migration	8
	8	Cutting	Little or none, infrequent raw banks <6"	4	Some, intermittently at out-curves and constrictions, raw banks may be up to 12"	6	Significant, cuts 12-24" high, root mat overhangs and sloughing evident	12	Almost continous cuts, some over 24", failure of overhangs frequent	16
	9	Deposition	Little or no enlargement of channel or point bars	4	Some new bar increase, mostly from coarse gravel	8	Moderate deposition of new gravel and coarse sand on old and some new bars	12	Extensive deposit of predominantly fine particles, accelerated bar development	16
Bottom	10	Rock Angularity	Sharp edges and corners, plane surfaces rough	1	Rounded corners and edges, surfaces smooth and flat	2	Corners and edges well rounded in 2 dimensions	3	well rounded in all dimensions, surfaces smooth	4
	11	Brightness	Surfaces dull, dark or stained, generally not bright	1	Mostly dull, but may have <35% bright surfaces	2	Mixture dull and bright i.e. 35-65% mixture range	3	Predominantly bright, >65% exposed or scoured surfaces	4
	12	Consolidation of particles	Assorted sized tightly packed or overlapping	2	Moderately packed with some overlapping	4	Mostly loose assortment with no apparent overlap	6	No packing evident, loose assortment easily moved	8
	13	Bottom size distribution	No size change evident, stable material 80-100%	4	Distribution shift light, stable material 50-80%	8	Moderate change in sizes, stable materials 20-50%	12	Marked distribution change, stable materials 0-20%	16
	14	Scouring & deposition	<5% of bottom affected by scour or deposition	6	5-30% affected, scour at constrictions and where grades steepen, some deposition in pools	12	30-50% affected, deposits and scour at obstructions, constrictions, and bends, some filling of pools	18	More than 50% of the bottom in a state of flux or change nearly yearlong	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial in swift water	1	Common, algae forms in low velocity and pool areas, moss here too	2	Present but spotty, mostly in backwater, seasonal algae growth makes rocks slick	3	Perennial types scarce or absent. Yellow-green short-term bloom may be present	4
			Excellent Total=		Good Total =		Fair Total =		Poor Total =	

Stream Type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. Unstable)	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+
Stream Type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**		
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107		
Fair (Mod. Unstable)	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120		
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+		

*Rating is adjusted to potential stream type not existing

Grand Total =	
Existing Stream Type=	
*Potential Stream Type=	
Modified Channel Stability Rating=	