Attachment 2

# Reclamation Effectiveness Monitoring (REM) for Placer Mined Streams

## Introduction

This document provides the BLM-Alaska framework for evaluating the physical, chemical, and biological functionality of a stream and provides various functional parameters, measurements, and performance standards to help the Bureau determine whether mine operators conducting operations under 43 CFR Part 3809 have successfully completed reclamation as specified in their approved Plan of Operations or reviewed Notice.  This framework is rooted in the Functional Lift Pyramid concept developed by Harman, et al. (2012). Much of the following information was taken directly from Harman et al. (2012) with permission and is intended for use, as applicable, by BLM staff tasked with evaluating attainment of specific stream function objectives with respect to reclamation conducted under 43 CFR Part 3809.

## Policy

This guidance presents a clearly defined, common suite of metrics for evaluating stream reclamation success.  This guidance also provides a consistent framework that benefits the Bureau as well as mining operators by establishing clear expectations for achieving the performance standard in 43 CFR 3809.420[1]. Determining when the specific performance standard (or reclamation requirement) is met has been largely based on qualitative measures, creating uncertainty and unclear expectations between the BLM and the operator. To address this situation, policy presents a framework for how stream reclamation and rehabilitation of fisheries will be evaluated. Successful rehabilitation of fisheries habitat, in addition to attainment of other reclamation requirements, will determine the release of the operator's financial guarantee.

### <u>New and modified Plans of Operations or Notices</u>

Stream function level reclamation objectives should be included in all new and modified Plans or Notices which include stream disturbance.

For BLM reviewers to most effectively evaluate a reclamation plan that may affect a perennial stream, specific baseline environmental information describing the current conditions of the site must be included (see Attachment 1). This information will be used by BLM staff to develop site specific, measurable reclamation objectives using the framework described below that are tied to the reclamation performance standards (43 CFR 3809.420). In the absence of baseline data, BLM staff should evaluate the site potential of the area based on information from adjacent areas to determine appropriate measureable

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[1] Pre-2001 operations are required to complete reclamation of all areas disturbed to the standard described in 43 CFR § 3809.1-3(d), which included the rehabilitation of fisheries and wildlife habitat. Satisfying these reclamation requirements would be expected of a “prudent operator” and result in prevention of UUD. This reclamation requirement became a performance standard (43 CFR § 3809.420) in the 2001 regulations.

reclamation objectives or from regional datasets such as BLM's Aquatic Assessment, Inventory, and Monitoring data.

Existing Plans of Operations or Notices

In addition to specific measurable objectives outlined in approved Reclamation Plans, offices should utilize the stream function pyramid framework (Level 3 objectives) as well as measureable objectives defined in the approved Reclamation Plan to evaluate attainment of the rehabilitation of fisheries and wildlife habitat requirement or performance standard[2].

## Background

The BLM handbook, H-3809-1 (Surface Management), issued in September 2012, provides the procedures and processes for employees to implement the BLM's mining surface management program. The H-3809-1 handbook states (page 5-14) that the rehabilitation of fisheries habitat should result in "…a stable channel form with adequate vegetation to reduce erosion, dissipate stream energy, and promote the recovery of instream habitats similar to levels which were present prior to mining and consistent with BLM policy." This handbook guidance is similar to BLM-Alaska's historic interpretation of the requirement rehabilitation of fisheries habitat. The 1988 Placer Mining EISs for Birch Creek, Beaver Creek, and the Fortymile River contain virtually the same language regarding stream reclamation requirements under the 1981 regulations (e.g., rebuilding the stream channel to approximately pre-mining characteristics in the original floodplain with pools, riffles, boulders, and original gradient (see Birch Creek EIS pg 4-53, Beaver Creek EIS pg 4-48, Fortymile EIS pg 4-55)). The ROD for the Fortymile EIS also included additional mitigation that required "restoring the streambed to a condition that will provide for the recovery of fish and wildlife habitat and channel stability".

The Reclamation Effectiveness Monitoring (REM) approach provides a common suite of metrics that the BLM will use to determine when stream reclamation is complete and when the reclamation bond may be released. The REM approach is rooted in the Stream Function Pyramid concept developed by Harman et al. (2012)[3]. By using the REM approach, the BLM can ensure clear and measurable stream reclamation objectives are included in the operator's approved Reclamation Plan (required as part of a Plan of Operations or Notice) and employ a consistent approach to evaluating the reclamation requirement or performance standard of rehabilitating fisheries and wildlife habitat to existing Plans or Notices.

The timeframes associated with meeting the reclamation objectives will vary depending on the reclamation effort performed by the miner. For example, an appropriately designed channel with the installation of vegetative matting on the reclaimed stream bank would be expected to result in faster vegetative recovery and channel stabilization as compared to stream reclamation that was limited to diverting water down a recently recontoured valley, relying upon natural processes to dictate the rate of

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[2] Pre-2001 operations are required to complete reclamation of all areas disturbed to the standard described in 43 CFR § 3809.1-3(d), which included the rehabilitation of fisheries and wildlife habitat. Satisfying these reclamation requirements would be expected of a "prudent operator" and result in prevention of UUD. This reclamation requirement became a performance standard (43 CFR § 3809.420) in the 2001 regulations.

[3] Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. *A Function-Based Framework for Stream Assessment and Restoration Projects.* US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.

revegetation and channel stabilization. In most situations, meeting reclamation objectives may likely take more than 3 years and possibly greater than 10 years following initial commencement of reclamation.

For new Notice-level operations, mining compliance staff must insure that the operator provides adequate environmental information for BLM to assess prevention of UUD through meeting the performance standards in 43 CFR 3809.420 (see page 3-6 of H-3809-1) before they accept the Notice's Reclamation Plan. In cases where the Notice does not adequately address the performance standards, the BLM must notify the operator of the specific modifications needed to prevent UUD, and should ensure the operator includes reclamation objectives describing the stream function level to be attained in the Reclamation Plan. As specified in the following paragraphs, a stream function reclamation objective of Level 3 stream function quantifiably demonstrates rehabilitation of fisheries habitat and is required to prevent UUD (see 43 CFR 3809.420). BLM's review of Notices must adhere to timeline requirements at 43 CFR 3809.11 in reviewing if the Notice is complete and if UUD would be prevented.

For all (existing and new/modified) Notice and Plan level mining activity that includes stream disturbance, a Level 3 stream functional objective with an upward trend is the minimum threshold for acceptable reclamation. At this level of stream function a stable channel form, riparian functionality, and progress toward higher stream functional objectives, such as Level 4 (Water Quality) is presumed to be achievable. For new or modified Plans of Operation or Notices, higher level stream function (e.g. Level 4 or 5) should be considered for previously unmined areas or areas that support (or supported in the past) high value fish resources, such as anadromous fish. There are two circumstances when the Authorized Officer may approve stream reclamation objectives at a level less than Level 3:

1. Streams that occur in valley types or landforms consisting of steep depositional fans, steep glacial troughs and outwash valleys, or broad alluvial mountain valleys, and exhibiting naturally braided or multi-threaded channels. Where mining is proposed in these kinds of naturally-occurring streams, reclamation objectives should focus on achieving site appropriate valley profiles and establishing vegetation on the outer edges of the channel. This situation is expected to be very rare.
2. Streams that have been historically disturbed and altered, where the current sediment supply is excessive (e.g., braided channel conditions) and cannot be mitigated in the reclamation design and/or by improved land management in the watershed. These sites may be reclaimed to a stream functional objective less than Level 3. Reduced stream functional levels can only be applied when it is determined through field monitoring that stream potential is less than Level 3, and it is consistent with the desired outcomes in the appropriate land use plan.

To ensure consistent and appropriate application of these exceptions, Authorized Officers must coordinate with the AKSO 930 Branch Chiefs and affected program leads when considering stream reclamation objectives at a level less than Level 3 for existing or new Plans of Operations or Notices.

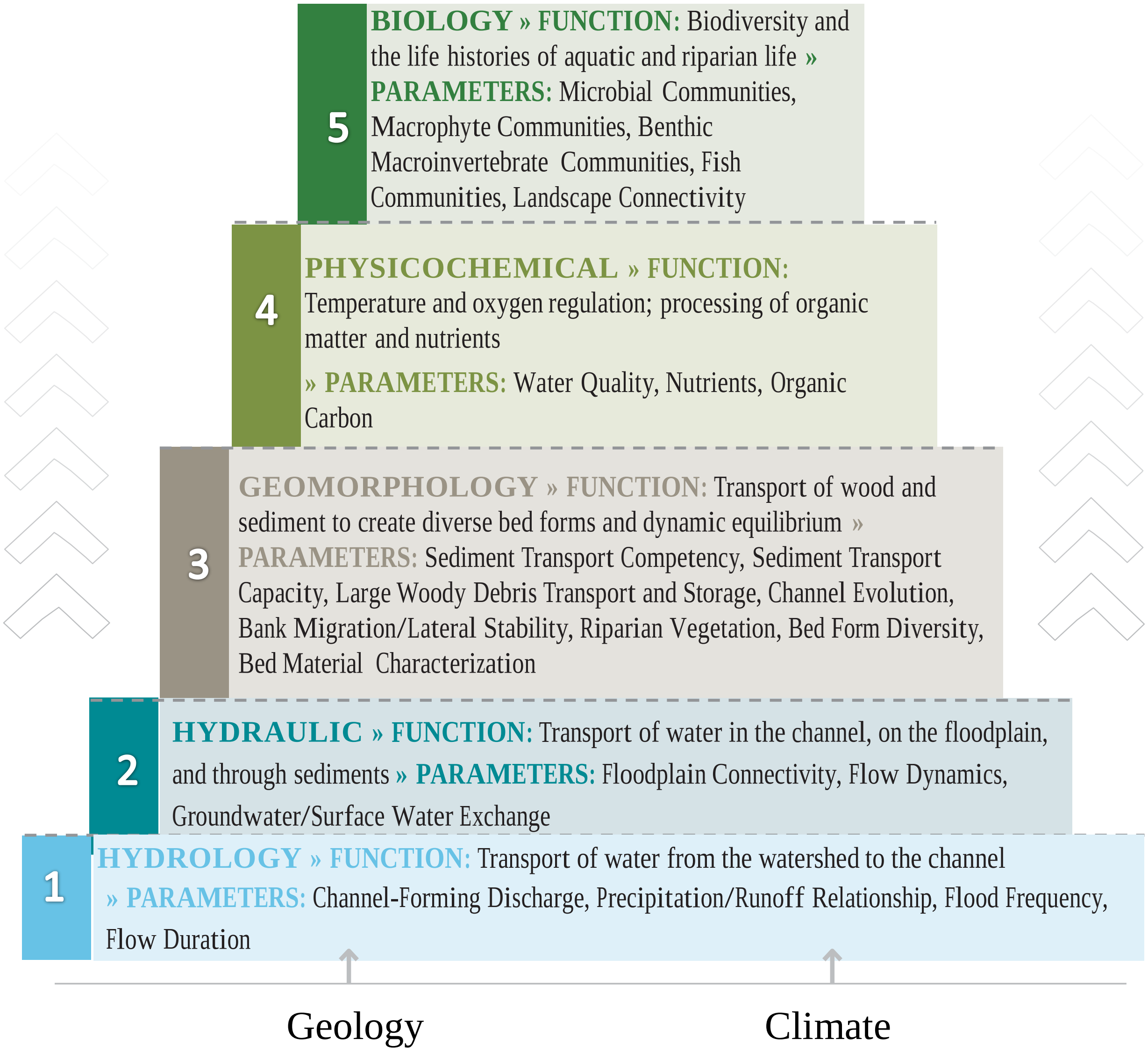
All monitoring should be conducted by an interdisciplinary team if possible, but at a minimum fisheries staff and a hydrologist should be present.

# Table of Contents

## Background of the Stream Functional Level Pyramid Concept

In 2006, the US Army Corp of Engineers (Fischenich 2006) and a group of scientists, engineers, and stream restoration practitioners identified 15 critical stream and riparian functions that define the physical, biological, and chemical nature of streams and that could be used for ecosystem evaluation. These functions were summarized in five categories. The functional categories identified in Fischenich (2006) were later modified to more closely match functions with parameters commonly used in the fields of hydrology, hydraulics, geomorphology, physiochemistry, and biology (Harman et al. 2012). The intent was to help practitioners match project goals with corresponding stream functions thereby avoiding the implementation of ineffective restoration designs because they ignored the underlying hydrology, hydraulic, and geomorphic functions. These parameters were organized into a pyramid form designed to illustrate that goal setting, stream restoration, and stream assessment methods must address functions in a specific hierarchical order. This pyramid summarizes the Stream Functional Level Objectives and Parameters that can be used to derive stream function at each level.

Figure 1. STREAM FUNCTIONS PYRAMID — FUNCTIONS & PARAMETERS



5 **BIOLOGY » FUNCTION:** Biodiversity and the life histories of aquatic and riparian life » **PARAMETERS:** Microbial Communities, Macrophyte Communities, Benthic Macroinvertebrate Communities, Fish Communities, Landscape Connectivity

4 **PHYSICOCHEMICAL » FUNCTION:** Temperature and oxygen regulation; processing of organic matter and nutrients

» **PARAMETERS:** Water Quality, Nutrients, Organic Carbon

3 **GEOMORPHOLOGY » FUNCTION:** Transport of wood and sediment to create diverse bed forms and dynamic equilibrium » **PARAMETERS:** Sediment Transport Competency, Sediment Transport Capacity, Large Woody Debris Transport and Storage, Channel Evolution, Bank Migration/Lateral Stability, Riparian Vegetation, Bed Form Diversity, Bed Material Characterization

2 **HYDRAULIC » FUNCTION:** Transport of water in the channel, on the floodplain, and through sediments » **PARAMETERS:** Floodplain Connectivity, Flow Dynamics, Groundwater/Surface Water Exchange

1 **HYDROLOGY » FUNCTION:** Transport of water from the watershed to the channel » **PARAMETERS:** Channel-Forming Discharge, Precipitation/Runoff Relationship, Flood Frequency, Flow Duration

For each functional level in the pyramid, parameters are identified which can be measured to indicate functional status. Along with the list of parameters, various methods of measuring the parameters are defined (see Harman et al. 2012).

Within the functional lift pyramid, higher-level functions are supported by lower-level functions. For example, re-establishing floodplain connectivity, a level 2 parameter,  is the most important task a reclamation project can do since it affects so many of the upper level functions. Fish communities, on the other hand, represent a level 5 parameter, and influence relatively few lower level functions.  The intent of the pyramid is to use a variety of parameters to describe the overall stream function at a particular level.

## Applicability to the 43 CFR 3809.420 Performance Standards[4]

The BLM regulations require that all operations prevent unnecessary or undue degradation (UUD), which is defined in 43 CFR § 3809.5 as, among other things, compliance with the general and specific performance standards set forth in § 3809.420. In respect to reclamation these standards include, but are not limited to:

- Saving of topsoil for final application after reshaping of disturbed areas have been completed;
- Measures to control erosion, landslides, and water runoff;
- Measures to isolate, remove, or control toxic materials;
- Reshaping the area disturbed, application of the topsoil, and revegetation of disturbed areas, where reasonably practicable; and
- Rehabilitation of fisheries and wildlife habitat.

The REM approach is focused on evaluating the rehabilitation of fisheries habitat requirement, which according to the Functional Lift Pyramid would equate to Level 3 function. The remaining performance standards would be evaluated against the specific reclamation objectives outlined in the decision that approved the Plan of Operations or the submitted Notice to ensure prevention of UUD.

### Rehabilitation of Fish Habitat

The BLM's Surface Management Handbook (H-3809-1) states on page 5-14 that:

*"The operator is required to rehabilitate or repair damage caused to fisheries or wildlife habitat. This may require reconstruction of certain landforms or planting of specific vegetation types during reclamation.*

*The requirement to rehabilitate fisheries and wildlife habitat does not always mean the exact same habitat that was present pre-disturbance must be reestablished upon completion of mining activities. The general intent is for this standard to be applied on a broad basis when large-scale landscape alteration is*

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[4] Plans of Operation or Notices that were in place prior to the 43 CFR 3809 regulations promulgated in 2001 are required to satisfy the reclamation requirements outlined in the 43 CFR 3809 regulations promulgated in 1981. The 1981 regulations required attainment of the standards listed in 3809.1-3(d) which are the same as the specific performance standards listed in 2001 regulations at 3809.420.

*involved; however certain types of mining such as placer mining should always include measures to rehabilitate fisheries and wildlife habitat given its potential effect on instream and riparian habitats.*

*This standard allows for a change in fisheries or wildlife habitat type without requiring a restoration of the original habitat provided that the overall effect on fisheries or wildlife is in accordance with BLM policy (e.g. Aquatic Resource Management Policy 6720) and 43 CFR 3809.420. For example, construction of a tailings impoundment that resulted in the development of riparian habitats could be replaced with non-riparian habitats reclamation, but should be consistent with surrounding upland vegetative communities. Conversely, fisheries habitats altered by placer mining operations should be rehabilitated to provide a stable channel form with adequate vegetation to reduce erosion, dissipate stream energy, and promote the recovery of instream habitats similar to levels which were present prior to mining and consistent with BLM policy."*

## Field Parameters and Measurement Methods

The following parameters and measurement methods are based on Harman et al. (2012) and peer reviewed publications. Most of the parameters used to measure each Stream Functional Level have at least two measurement methods. Some measurement methods to quantify the parameters are relatively simple and fast to apply, and others require more intensive monitoring and analysis. Additional parameters and methods can be used to assess Stream Functional Level beyond what is identified below are listed in Appendix A and are described in detail within Harman et al. (2012).

**Stream Functional Level 1 (Hydrology)**

Hydrology functions transport water from the watershed to the channel. Hydrology is placed at the bottom of the Pyramid because water contributed from the watershed strongly affects the higher-level functions. In summary, without surface water flow, there would not be channel formation and the subsequent aquatic ecosystem.

### Parameter: Channel Forming Discharge

Channel-forming discharge theory suggests that a unique flow over an extended period of time would yield the same channel morphology that is shaped by the natural sequence of flows. Inglis (1947) stated that at this discharge, equilibrium is most closely approached and the tendency to change is least. This condition may be regarded as the integrated effect of all varying conditions over a long period of time. Channel-forming discharge theory is often described as dominant discharge, effective discharge and the bankfull discharge (Knighton, 1998). Dominant discharge is simply a synonym for channel-forming discharge theory. Effective discharge is the product of the flow duration curve and the sediment transport rating curve; therefore, it is the discharge that moves the most sediment over time and is a key parameter in determining channel size (Wolman and Miller, 1960). Bankfull discharge fills a stream channel to the elevation of the active floodplain, thereby delineating the break between erosional (channel forming) and depositional features in a floodplain (Dunne and Leopold, 1978; FISRWG, 1998). Since this discharge leaves a geomorphic indicator, it has become the method used most often to describe channel-forming discharge theory. It is also the design discharge for natural channel designs.

## Measurements:

### A. Regional Curves of Bankfull Channel Geometry

The identification of bankfull stage and its associated dimensions and discharge are often used in stream assessment and restoration projects using natural channel design techniques. The identification of the bankfull stage is one of the first measurements made during a geomorphic assessment because the Rosgen stream classification system and stability assessments (vertical and lateral) are all dependent on knowing the bankfull stage. In addition, many of the Hydraulic and Geomorphic parameters, such as floodplain connectivity, are dependent on being able to identify and verify the bankfull stage and its corresponding dimensions (especially cross-sectional area). There are several documents that discuss how to field identify and verify bankfull. Rosgen (2009), as part of the Watershed Assessment of River Stability and Sediment Supply (WARSSS), provides a detailed description of field methods for identifying and calibrating the bankfull stage. (WARSSS is available on the EPA website at www.epa.gov/warsss) Harrelson et al. (1994) provides a more concise summary of field methods for identifying bankfull (https://www.fs.fed.us/rm/pubs_rm/rm_gtr245.pdf ).

All of these references rely on regional curves as the primary method for verifying the bankfull stage. These curves are tools that can be used to verify the bankfull stage in projects prior to restoration, as a design aid and as a tool for assessing performance. To effectively evaluate Natural Channel Design Plans, it is important to develop Regional Curves to compare bankfull design values to those expected in the region.

**Stream Functional Level 2 (Hydraulic Function)**

Hydraulic functions transport water in the channel, on the floodplain and through sediments. Hydraulic function defines how water behaves once it reaches a channel and how it interacts with the bed, banks, floodplain, hyporheic zone, etc. (Dingman 2008). It is important to note that this function works in channels of all sizes, from valley bottom swales (ephemeral channels) to large rivers. It is also present in all forms of geology and climate zones (Knighton 1998). The energy associated with moving water has the ability to do work, such as transporting sediment, which is a geomorphology function (Leopold et al. 1992).

## Parameter: Floodplain Connectivity

Harman et al. (2012) describes floodplain connectivity as how often streamflows access the adjacent floodplain. Fischenich (2006) included floodplain connectivity as part of the hydrodynamic character function, which was considered the most important of the 15 functions addressed. In high functioning alluvial valleys, all flows greater than the bankfull discharge spread across a wide floodplain. Floodplain connectivity is a driving force for many of the geomorphic and ecologic functions (Wohl, 2004; Shields et al., 2010). It is also a parameter that can easily be assessed, modified as part of a design and evaluated through monitoring, making it an excellent parameter for including a performance standard.

## Measurements:

### A. Bank Height Ratio

Bank Height Ratio (BHR) equals the depth from the top of the lowest bank to the lowest point in the stream (thalweg) divided by the depth from the bankfull elevation to the thalweg. This value works well in conjunction with entrenchment ratio to quantify floodplain connectivity.

Method: Measurements are generally obtained from either cross section survey using engineer's level or laser level and stadia rod measure elevation of upper most stream bank, deepest portion of stream, and bankfull elevation. Measure these parameters at riffles through the stream segment of interest.

Performance Standard: BHR of 1.0 means that all flows greater than bankfull are spreading onto the floodplain of C and E type (Rosgen classification) or onto bankfull bench or floodprone area of B type streams. A BHR of 2.0 means that it takes a stage 2x the bankfull stage to access the floodplain and the stream is highly incised. In the incised configuration, the stream is not capable of dissipating flood energy via the floodplain.

BHR Rating
1.0 – 1.2 Functioning
1.3 – 1.5 Functioning at Risk
> 1.5 Not Functioning

## B. Entrenchment Ratio

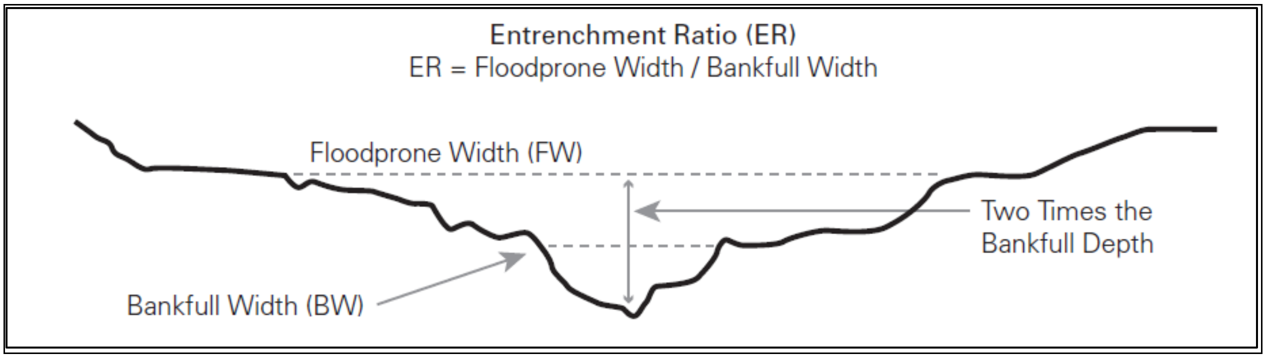
(ER = Floodprone width / Bankfull width)

Method: Using common survey equipment and techniques at cross sections established within a riffle, measure bankfull width and elevation and maximum channel depth. At an elevation of 2x maximum bankfull depth, measure the width of the floodprone area (Figure 1).

Performance Standard: Entrenchment Ratio varies by Rosgen stream type

ER Rating
B-type: Functioning >1.4; Functioning at Risk 1.2 – 1.4; Not Functioning < 1.2
C and E-type: Functioning > 2.2; Funtioning at Risk 2.0 – 2.2; Not Functioning < 2.0

**Figure 2. MEASUREMENT OF ENTRENCHMENT RATIO***



**used with permission from Harman et al. 2012*

### Stream Functional Level 3 (Geomorphology)

The function of geomorphology, as defined here, is the transport of wood and sediment to create diverse bed forms and dynamic equilibrium. The relative importance or even presence of certain Geomorphology functions varies greatly with changes in geology and climate.

### 1. Parameter: Channel Evolution

Stream evolution is useful for determining trends in stability and to determine if the stream is moving from the newly constructed condition to the reference condition.

## Measurements:

### A. Rosgen Stream Type Succession Scenarios

Rosgen (2009) identified nine different stream type succession scenarios. Since the publication of this concept, Rosgen has added three additional scenarios for a total of 12 (Table 1).

Method: Based on Rosgen Level II methods for stream type delineation (Rosgen 1996 p. 5-15). To briefly summarize this method establishes a cross section within the narrowest segment of the selected reach, where the channel can freely adjust its lateral boundaries under existing streamflow conditions. Using common survey equipment and procedure measure the channel characteristics necessary to determine the delineative criteria outlined Rosgen (1996 p. 5-2). The required information are: bankfull depths across the cross section, bankfull width, floodprone width, water surface slope, sinuosity, dominant channel material size. It will be necessary to establish a pre-disturbance reference condition as well as a post-reclamation evaluation.

Performance Standard: Function would be based on achieving the B,C, or E type channel as predicted by the succession scenario that most closely fits the existing channel type, the projected and measured post-reclamation channel, and the predicted capability of the channel based on the reference reach.

Table 1. Rosgen Evolution Model by Stream Type (from Harman et al. 2012)

| Measurement Method | Functioning | Functioning At-risk | Not Functioning |
|---|---|---|---|
| 1. E→C→Gc→F→C→E | E, C | C→Gc and F→C | Gc, F |
| 2. C→D→C | C | C→D and D→C | D |
| 3. C→D→Gc→F→C | C | C→D and F→C | D, Gc, F |
| 4. C→G→F→Bc | C, Bc | C→G and F→Bc | G, F |
| 5. E→Gc→F→C→E | E, C | E→Gc and F→C | Gc, F |
| 6. B→G→Fb→B | B | B→G and Fb→B | G, Fb |
| 7. Eb→G→B | Eb, B | Eb→G and G→B | G |
| 8. C→G→F→D→C | C | C→G and D→C | G, F, D |
| 9. C→G→F→C | C | C→G and F→C | G, F |
| 10. E→A→G→F→C→E | E | E→A and F→C | A, G, F |
| 11. C→F→C→F→C | First and last C | C→F | F |
| 12. C→G→F→C→C→C | First and last C | C→G and C→C | G, F, Fourth C |

## 2. Parameter: Bank Migration / Lateral Stability

### Measurements:

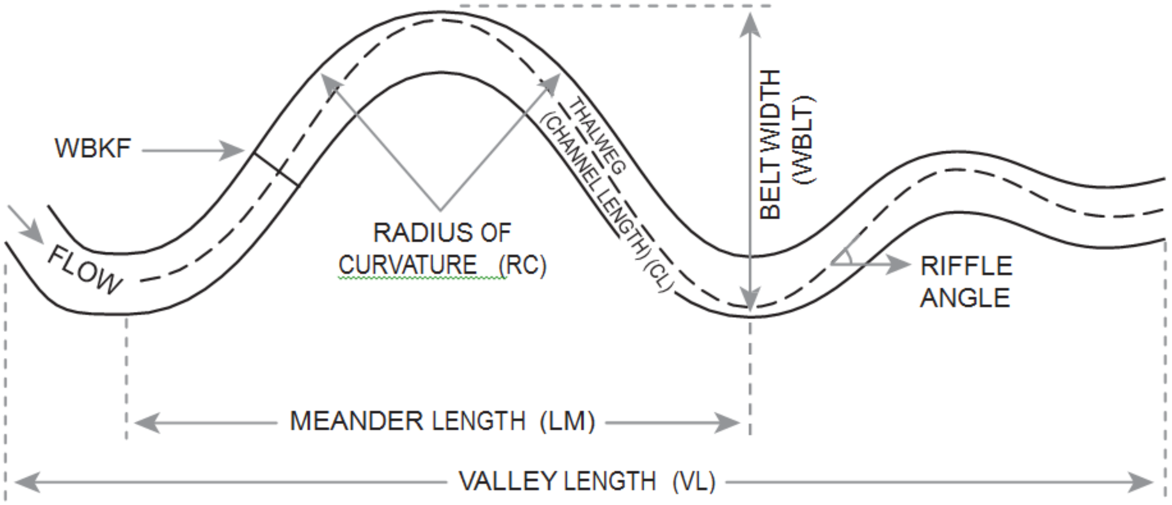
### A. Meander Width Ratio (MWR)

The measure used to determine confinement (lateral confinement). MWR = belt width / bankfull width. Streams that are confined are associated with channel enlargement, lateral accretion, high bank erosion rates, and sediment transport problems.

Method: Measure belt width as the farthest lateral extent of the stream in its valley measured from the outside to outside of opposing stream bends. Divide this by bankfull width (measured from cross section).

Performance Standard: Values for evaluating MWR are presented in Harman et. al (2012) and Rosgen (1996). These values should be adjusted based upon reference reach survey results.

**Figure 3. PATTERN MEASUREMENTS AND RATIOS, INCLUDING THE MEANDER WIDTH***



| CHANNEL PATTERN CALCULATIONS |
|---|
| RADIUS OF CURVATURE / RIFFLE WIDTH (RC / WBKF) |
| MEANDER LENGTH / RIFFLE WIDTH (LM / WBKF) |
| MEANDER WIDTH RATIO (MWR = WBLT / WBKF) |
| SINUOSITY (K) = CHANNEL LENGTH (CL) / VALLEY LENGTH (VL) |

**used with permission from Harman et al. 2012*

## B. Bank Erosion Hazard Index (BEHI) in combination with Near Bank Stress (NBS)

These measures would allow for the comparison of predicted bank erosion rates of the post-reclamation channel and a pre-disturbance reference reach.

Method: The methods to determine both Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) are explained in detail in Rosgen (2009). The BEHI variables include measures of the stream bank height, bankfull height, root depth and density, bank angle, surface protection, bank material, and stratification of bank material. Based on the measurements of these variables the segment of bank is given a score (very low, low, moderate, high, very high and extreme). One BEHI rating would be calculated for each length of stream bank exhibiting common characteristics.

The NBS parameter uses one of seven possible methods to determine near bank stress.

Performance Standard: By plotting the ratings of both the BEHI and NBS ratings on the appropriate curve the bank erosion rate can be estimated (see Rosgen 2009, Figure 5-34 & 35). Relationships between BEHI and NBS are provided in Rosgen (2009) for streams found in sedimentary and /or metamorphic geology (in Colorado) as well as for streams in glacial and/or volcanism areas (in Wyoming) (Rosgen 2009). Functional performance standards are provided in Harman et al. (2012).

## C. Riparian Vegetation

Riparian zones are the vegetated region adjacent to streams and wetlands that are critical to providing channel stability, cover/shade, wood recruitment to the channel, and a source of carbon (Sweeney, 1993; Hession et al., 2000; Sweeney et al., 2004; Hoffman, 2006; Sweeney and Blaine, 2007). Therefore, the restoration of riparian vegetation as part of a Level–3 assessment and design approach provides the vegetative structure to support many of the Level 3, 4 and 5 functions.

Method: Several techniques exist for evaluating riparian zones. These techniques include measuring the width, species composition, density, canopy cover, successional status, and age-class distribution. Since the goal for riparian reclamation is to achieve sufficient vegetative cover to effectively reduce erosion and dissipate stream energy, it is recommended that a Proper Functioning Condition Assessment be completed (see BLM 1737-15 & 16). It is also suggested that plot data on greenline vegetation cover and composition (both reference and reclamation reaches) be collected (see BLM 1737-23). The latter can be used to develop meaningful post reclamation objectives.

## D. Bed Form Diversity

The rehabilitation of fish habitat is linked to the recovery of instream habitat diversity.

Method: Several measurement methods exist to evaluate bed form diversity such as percent riffle, pool-to-pool spacing, and depth variability. These measures are easily derived from a longitudinal profile of the study reach. Performance standards are provided in Harman et al. (2012), but may require site specific adjustment based on Alaska specific datasets and baseline data submitted by the operator.

**Stream Functional Level 4 (Physicochemical)**

Physicochemical functions include temperature and oxygen regulation, and processing of organic matter and nutrients.

1. **Parameter: Water Quality**

**Measurements:**

## A. Basic Water Quality Parameters

- Dissolved Oxygen
- Temperature
- Turbidity
- pH
- Conductivity

Method: These parameters are easily measured in the field with the most important parameters being temperature, pH, and turbidity. Functional values should be established based on reference conditions and Alaska Statute.

**Stream Functional Level 5 (Biology)**

Biology is located at the top of the Pyramid because these functions are dependent on all the underlying functions. These functions include the biodiversity and the life histories of aquatic and riparian organisms. Biology functions can affect lower-level functions, e.g., beaver activities; however, as with the other levels, the dominant cause-and-effect relationship is upward. A healthy aquatic ecosystem must have sufficient water contributed from the watershed, the right levels of hydraulic forces, proper bed form diversity and channel stability, suitable temperature and oxygen regimes, and so on.

1. **Parameter: Macroinvertebrate Communities**

**Measurements:**

## A. Taxonomic Metrics and Biological Indices

It is generally accepted that benthic macroinvertebrates or aquatic insects are sentinels for environmental impacts (see Hare 1992, Rosenberg and Resh 1993) since they:

1. are one of the most common and diverse groups of freshwater animals;
2. are sedentary and thus characteristic of local conditions;
3. exhibit a range of responses to environmental stress;
4. occupy the benthos and thus are closely linked with sediments (trace metal sink);
5. can accumulate metals and yet are tolerant of low-to-moderate metal concentrations; and
6. have metal concentrations that appear to coincide with those in the environment.

A summary and description of commonly used comparative measures or metrics is available in Barbour et al. (1999) and Karr and Chu (1998). Both of these publications suggest use of the following metrics for assessing the health of aquatic macroinvertebrate assemblages: Total taxa richness, EPT taxa richness, Ephemeroptera taxa richness, Plecoptera taxa richness, Trichoptera taxa richness, % EPT abundance, % Ephemeroptera abundance, % Chironomidae abundance, Intolerant taxa richness, % tolerant organisms, Hilsenhoff Biotic Index, % contribution of the dominant taxon, clinger taxa richness, % clinger abundance, % collector filterer abundance, and the % scraper abundance.

Method: Protocols from the BLM National Aquatic Monitoring Center should be followed for sample collection. Samples should be collected from reference streams in addition to the project area prior to mining and post reclamation.

**2. Parameter: Fish Communities**

**Measurements:**

### A. Taxonomic Metrics

Fish are ubiquitous in Alaska and are an important component of the ecosystem and culture. Harman et al. (2012) state that:

A healthy, functioning fish community occurs when the following conditions are present:

1. Continuous upstream streamflow sources, as removal of impoundments and excessive water consumption for human activities will provide adequate streamflow throughout the year;
2. Floodplain connectivity and bankfull channel, dissipate energy of large storm events to prevent excessive scouring of substrates used for reproduction (pools), and prevent sediment inundation of substrate habitat;
3. Healthy hyporheic zones, which provide habitat for food resources;
4. Bed form diversity and in-stream structures, which create diverse habitats for feeding and reproduction, dissipate stormflow energy; provides opportunities for organic carbon storage and retention, provide substrates such as large woody debris, and provide scour pools for reproduction, feeding and shelter;
5. Channel stability, which prevents sediment inundation of habitat and excessive turbidity that is contributed from channel erosion;
6. Riparian community, which provides allochthonous carbon inputs for food resources, provides shade for cooler temperatures and provides vegetative roots for available habitat; and
7. Adequate dissolved oxygen, which is required for fish survival and health.

Methods: Electrofishing techniques using block nets with three pass depletion should be used to sample fish populations. A pre-mining survey should be conducted, as well as sampling in reference areas. Species composition, abundance, richness, and Simpson's Diversity Index (Simpson 1949) can used to evaluate fish sampling data and functional status.

## Literature Cited:

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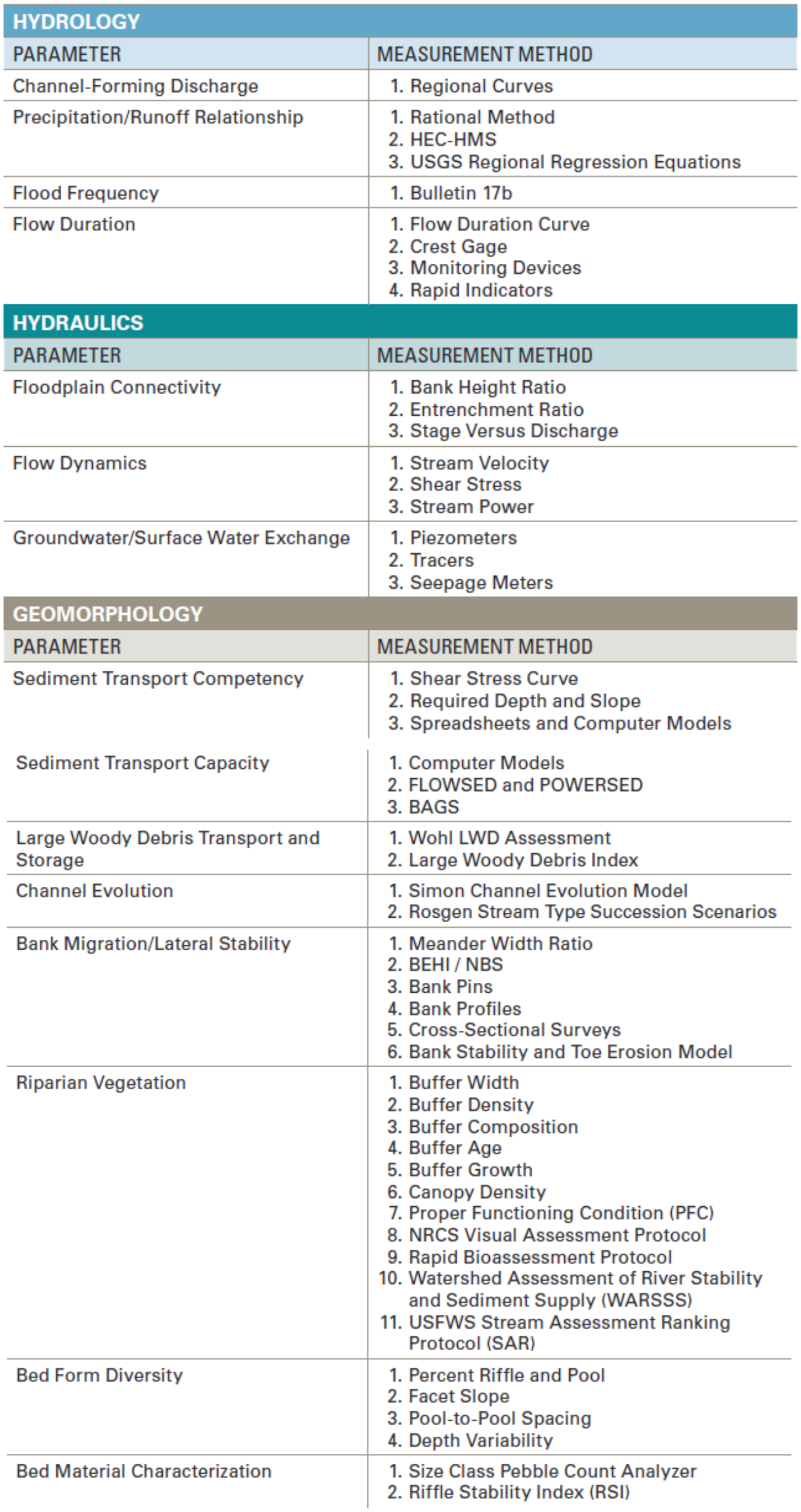
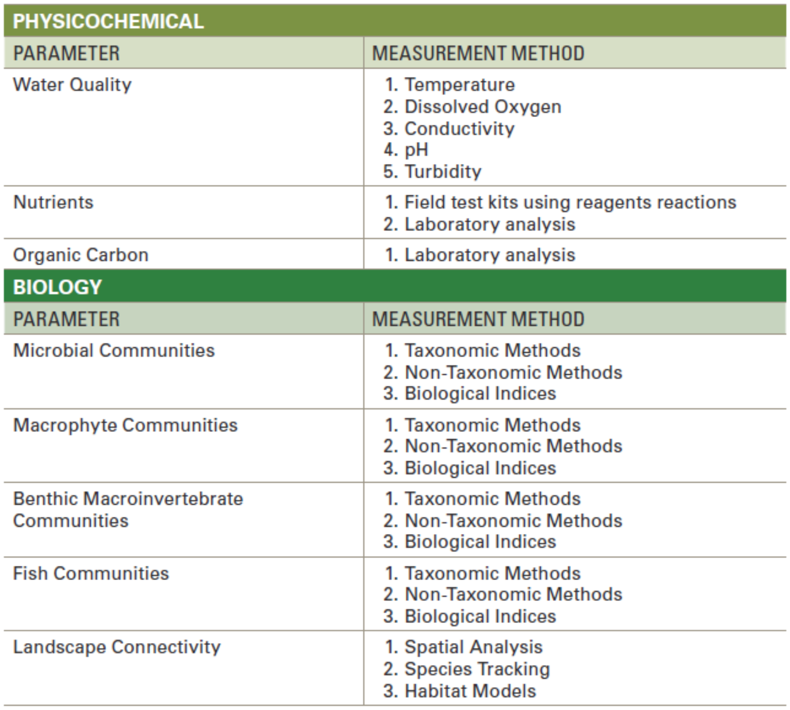
## Appendix A. Parameters and Measurements Methods (from Harman et al. 2012).



| HYDROLOGY | |
|---|---|
| PARAMETER | MEASUREMENT METHOD |
| Channel-Forming Discharge | 1. Regional Curves |
| Precipitation/Runoff Relationship | 1. Rational Method<br>2. HEC-HMS<br>3. USGS Regional Regression Equations |
| Flood Frequency | 1. Bulletin 17b |
| Flow Duration | 1. Flow Duration Curve<br>2. Crest Gage<br>3. Monitoring Devices<br>4. Rapid Indicators |
| **HYDRAULICS** | |
| PARAMETER | MEASUREMENT METHOD |
| Floodplain Connectivity | 1. Bank Height Ratio<br>2. Entrenchment Ratio<br>3. Stage Versus Discharge |
| Flow Dynamics | 1. Stream Velocity<br>2. Shear Stress<br>3. Stream Power |
| Groundwater/Surface Water Exchange | 1. Piezometers<br>2. Tracers<br>3. Seepage Meters |
| **GEOMORPHOLOGY** | |
| PARAMETER | MEASUREMENT METHOD |
| Sediment Transport Competency | 1. Shear Stress Curve<br>2. Required Depth and Slope<br>3. Spreadsheets and Computer Models |
| Sediment Transport Capacity | 1. Computer Models<br>2. FLOWSED and POWERSED<br>3. BAGS |
| Large Woody Debris Transport and Storage | 1. Wohl LWD Assessment<br>2. Large Woody Debris Index |
| Channel Evolution | 1. Simon Channel Evolution Model<br>2. Rosgen Stream Type Succession Scenarios |
| Bank Migration/Lateral Stability | 1. Meander Width Ratio<br>2. BEHI / NBS<br>3. Bank Pins<br>4. Bank Profiles<br>5. Cross-Sectional Surveys<br>6. Bank Stability and Toe Erosion Model |
| Riparian Vegetation | 1. Buffer Width<br>2. Buffer Density<br>3. Buffer Composition<br>4. Buffer Age<br>5. Buffer Growth<br>6. Canopy Density<br>7. Proper Functioning Condition (PFC)<br>8. NRCS Visual Assessment Protocol<br>9. Rapid Bioassessment Protocol<br>10. Watershed Assessment of River Stability and Sediment Supply (WARSSS)<br>11. USFWS Stream Assessment Ranking Protocol (SAR) |
| Bed Form Diversity | 1. Percent Riffle and Pool<br>2. Facet Slope<br>3. Pool-to-Pool Spacing<br>4. Depth Variability |
| Bed Material Characterization | 1. Size Class Pebble Count Analyzer<br>2. Riffle Stability Index (RSI) |

## Appendix A (cont). Parameters and Measurements Methods (from Harman et al. 2012).



| PHYSICOCHEMICAL | |
|---|---|
| PARAMETER | MEASUREMENT METHOD |
| Water Quality | 1. Temperature<br>2. Dissolved Oxygen<br>3. Conductivity<br>4. pH<br>5. Turbidity |
| Nutrients | 1. Field test kits using reagents reactions<br>2. Laboratory analysis |
| Organic Carbon | 1. Laboratory analysis |
| **BIOLOGY** | |
| PARAMETER | MEASUREMENT METHOD |
| Microbial Communities | 1. Taxonomic Methods<br>2. Non-Taxonomic Methods<br>3. Biological Indices |
| Macrophyte Communities | 1. Taxonomic Methods<br>2. Non-Taxonomic Methods<br>3. Biological Indices |
| Benthic Macroinvertebrate Communities | 1. Taxonomic Methods<br>2. Non-Taxonomic Methods<br>3. Biological Indices |
| Fish Communities | 1. Taxonomic Methods<br>2. Non-Taxonomic Methods<br>3. Biological Indices |
| Landscape Connectivity | 1. Spatial Analysis<br>2. Species Tracking<br>3. Habitat Models |