U.S. Department of the Interior
Bureau of Land Management

Open File Report #169

Developing Quantifiable Management Objectives from Reference Conditions for Wadeable Streams in the Eastern Interior Field Office

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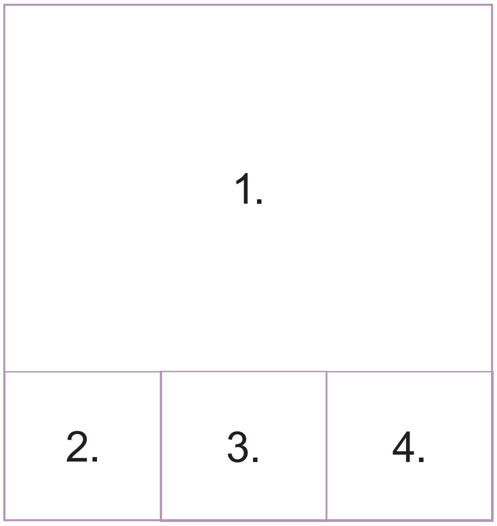

Cover Photographs

1. Champion Fork, Fortymile Planning Subunit
2. Tributary to Healy River, Fortymile Planning Subunit
3. Tributary between Willow and Sheep Creek, White Mountains National Recreation Area
4. Tributary to Big Windy Creek, Steese National Conservation Area

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May 2018

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Introduction

The Bureau of Land Management (BLM) manages over 118,000 miles of perennial stream and lotic riparian habitat, as well as almost 3 million acres of lakes throughout the State of Alaska. Nearly 9,300, or 7.9%, of those miles are located within the boundaries of the BLM Eastern Interior Field Office (EIFO). Overall, Alaska aquatic systems comprise more than 87% of the Bureau's riverine resources.

The aquatic resources in the EIFO serve as habitat for anadromous and resident fish species, in addition to a host of other aquatic species. Streams and rivers also provide many ecosystem services to the surrounding communities and the American public, ranging from recreational fishing and community drinking water sources to transportation networks and focal points for subsistence harvests. A large majority of the EIFO's aquatic resources are believed to exist in a relatively unaltered state; however, little monitoring data is available to objectively characterize current conditions or to detect changes in response to development or shifting climactic and meteorological conditions.

Section 201 of the Federal Land Policy and Management Act of 1976 (FLPMA) requires the BLM to prepare and maintain a current inventory of public land resources. The need for knowing the condition and trend of aquatic systems is underscored by increased resource uses (e.g., mining, energy development, and recreation) and landscape-level change. This information serves as the foundation for decision-making and is critical to achieving the Bureau's multiple use mission of "sustaining the health, diversity, and productivity of public lands for the use and enjoyment of present and future generations."

FLPMA also directs the BLM to manage the public lands for multiple use and sustained yield. The balance between anthropogenic uses (e.g., energy and mineral development, recreation, timber production) and ecological integrity is achieved through the preparation of land use plans (LUPs). The federal government collaborates on LUPs with state, tribal, and other local units of government and public land users. The overall objective is to identify where and under what conditions various uses of the public lands are encouraged or allowed. LUPs strive to prevent unnecessary or undue degradation and ultimately ensure the sustained yield of resources on public lands.

Land use planning requires information regarding existing and foreseeable uses; data characterizing the condition and trend of renewable resources such as fisheries and wildlife habitat, water quality, riparian vegetation; and the socioeconomics of a particular region. The BLM and its partners use this information to analyze potential trade offs among different land use scenarios, to characterize the affected environment, to develop avoidance or mitigation strategies to reduce conflict, and to assess the effectiveness of a given plan.

Land use plan monitoring is the process of (1) tracking the implementation of land use planning decisions (implementation monitoring) and (2) collecting data/information necessary to evaluate the effectiveness of land use planning decisions (effectiveness monitoring) (BLM H-1601-1, WO IM 2016-139). Similar to effectiveness monitoring, individual permitted activities (e.g., placer mining, grazing, oil and gas development) occurring at local scales require monitoring information to ensure compatibility of the action with LUP and specific permit objectives. Utilizing a standard suite of methods and study design allows the BLM to collect data once and use the information to understand resource conditions at multiple scales. Sites are also revisited periodically over time to detect natural and anthropogenic changes on the landscape. Until recently, the BLM has been unable to realize the efficiencies that this data collection approach could offer. The BLM's Assessment, Inventory, and Monitoring (AIM) Strategy issued in 2011 creates the framework to collect data to inform decision-making at multiple scales.

Specific to aquatic resources, the BLM AIM program developed a National Aquatic Monitoring Framework (AIM-NAMF, BLM TR 1735-1). Through standardizing data collection and analysis, this framework integrates both local and regional scale aquatic monitoring activities to more effectively inform BLM management decisions and planning activities. This then benefits the maintenance or improvement of resource conditions on public lands. BLM Alaska initiated AIM-NAMF data collection on lands within the EIFO-managed boundaries in 2014. The primary goals of AIM-NAMF sampling on the EIFO-managed lands included:

1. Develop quantifiable benchmarks to assess stream condition and trend;
2. Establish quantitative baseline conditions of BLM managed wadeable streams and river habitats following the applicable Alaska Statewide Land Health Standards (AK IM 2004-023);
3. Determine stressors contributing to degraded conditions, with a focus on placer mining;
4. Identify best management practices and/or changes in current management practices; and,
5. Assess the feasibility and applicability of the AIM-NAMF for implementation in Alaska.

This report presents information describing the range of aquatic habitat, streambank, and floodplain habitat conditions of wadeable waters within portions of EIFO-managed lands. These results serve as the baseline for future trend monitoring and evaluating LUP effectiveness. This report also presents three examples of how to use data collected once at various spatial scales to address important management questions or to aid in LUP development.

Methods

Sampling Methodology

To establish quantitative, baseline conditions for the chemical, physical, and biological attributes of streams within the EIFO boundaries, we selected a subset of stream reaches for sampling using a probability-based survey design. Specifically, we used a Generalized Random Tesselation Stratified (GRTS) spatially balanced, randomized survey design to select 40 sample locations from the target population of first through fourth order perennial, wadeable stream systems occurring on BLM Alaska-managed lands (Olsen 2005). The 40 sample sites were stratified by planning area (20 per planning subunit) (Figure 1). For logistical reasons, the Steese NCA and the White Mountains NRA planning subunits were combined into one unit.

BLM crews used the same methodology to collect AIM-NAMF data at 10 previously placer-mined and reclaimed streams located on EIFO-managed lands. The sampling area was centrally located within the reclaimed stream segment to minimize bias and to enhance consistency. The time since reclamation for these sites ranged from 1-50 years. These sites were selected as they generally exhibited stream conditions typical of post-mined streams where traditional reclamation techniques have been used. One targeted site, which was mined in the 1950s-60s using primarily hand tools, was also included to evaluate the recovery of habitats. One of the ten sites was reassessed following a BLM implemented stabilization project, which utilized the latest science and nationally accepted stream restoration techniques.

Data collection on lands managed by the EIFO occurred during the summer months, primarily July and August from 2014 - 2016. Field sampling followed the AIM-NAMF Field Protocol for Wadeable Lotic Systems (BLM TR 1735-2) and included the addition of two supplemental methods - (1) fish surveys and (2) surveyed channel cross-sections. Due to the need to increase sample efficiency in the field because of the high cost of helicopter operation, we reduced stream particle size counts from 210 to 105 and did not delineate dimensions of qualifying pools within a stream reach. The AIM-NAMF field methods result in the computation of over 50 instream and riparian indicators that will provide insight as to whether or not the desired conditions found in the Eastern Interior LUP and associated Alaska Land Health Standards are being achieved (Appendix 1).

Study Area

The study area spans three planning subunits covered by the Eastern Interior Resource Management Plan (EIRMP): Fortymile, Steese National Conservation Area (NCA), and the White Mountains National Recreation Area (NRA). Due to the time and cost of sampling the remote Upper Black River Planning subunit, we did not sample sites in this region. The three planning subunits where we collected data, include approximately 4.1 million acres of BLM Alaska-managed land and over 5,500 miles of perennial, wadeable streams and rivers. The majority of BLM Alaska-managed streams occurred within the Yukon Tanana Uplands (YTU) ecoregion. The YTU ecoregion is characterized as having permafrost soils, complex vegetation communities, and forests dominated by spruce and hardwood species that are susceptible to wildfire from lightning (Omernik 1987). Three of the sampled streams fell just outside the YTU ecoregion and could be classified as having similar characteristics as they may lie in the ecotone.

The YTU ecoregion contains significant levels of current and historic placer mining, and has been the focal area for several stream stabilization projects funded by the BLM’s Healthy Lands program. With the exception of placer mined stream valleys and transportation networks, the vast majority of the landscape has very little to no anthropogenic disturbances. This is due in part to the lack of highways, roads and landing strips, as well as the land classification status within past LUPs, which has limited certain types of extractive resource uses.

Establishing Minimally Disturbed Conditions and Condition Benchmarks

The sampling of over 40 spatially balanced, random stream and river sites using the AIM-NAMF allowed us to characterize the natural range of chemical, physical, and biological variability throughout the lands managed by the EIFO. We used the natural range of variability, in the absence of anthropogenic impacts, to characterize minimally disturbed conditions (MDC) (Stoddard et al. 2006). For the purposes of this report we will refer to reference conditions as MDC. The MDC were used to develop benchmarks for select indicators (Appendix A) from which the condition of test sites can be compared to determine management success or the need for change through adaptive management.

We identified MDC by screening sampled sites for anthropogenic impacts using the Watershed

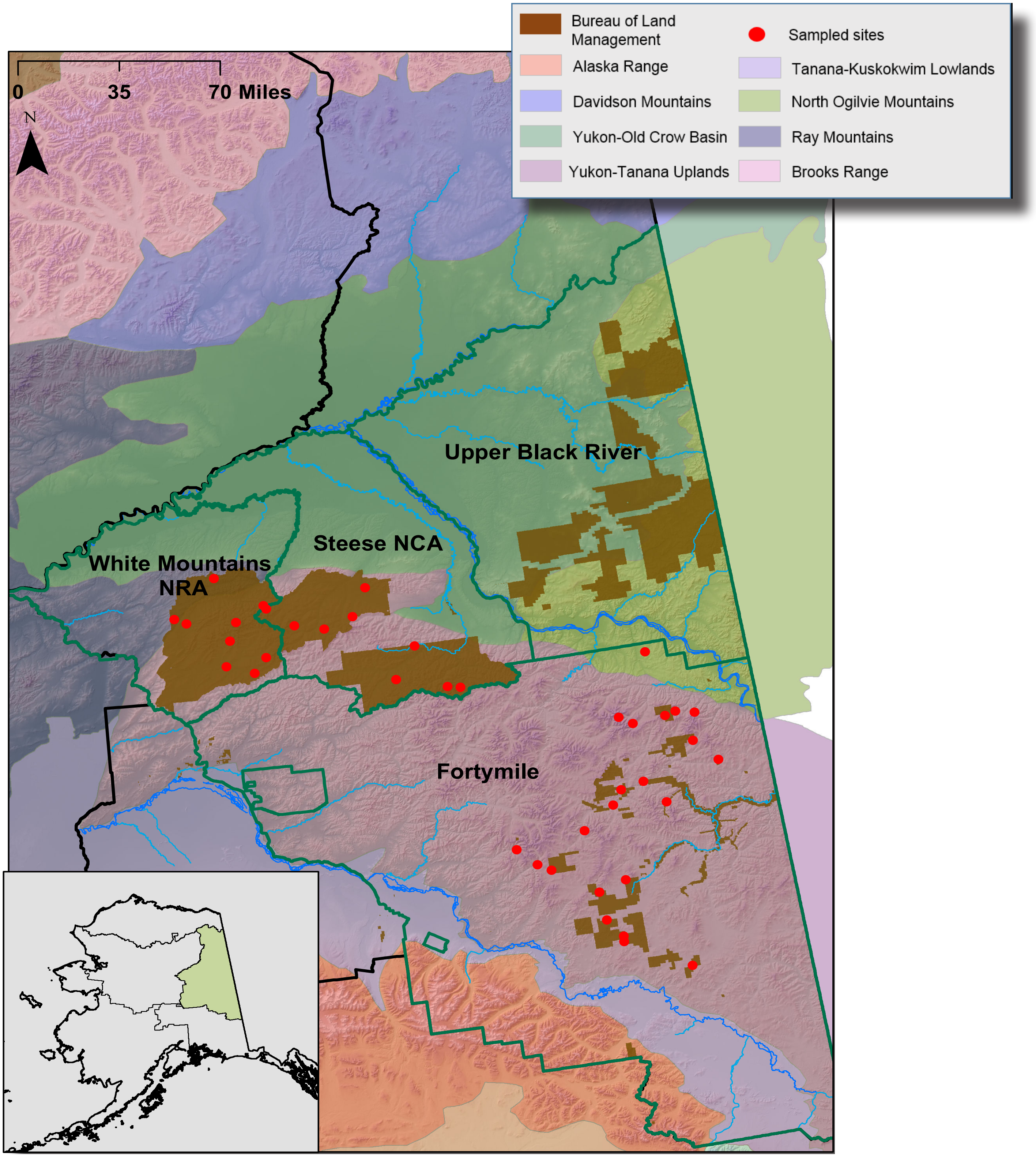


Figure 1. Map of the 2014-2016 AIM-NAMF sample sites across the Fortymile, Steese NCA and White Mountains NRA planning subunits (blue-green border). The Steese NCA and the White Mountains NRA planning units were combined into one unit for sampling.

Condition (WC) Model created by BLM Alaska (BLM 2017). The WC model evaluates 6th level United States Geological Survey (USGS) hydrologic units (HUCs) for anthropogenic disturbances using available GIS layers (e.g., mining claims, trails, and roads). The cumulative amount of disturbance per HUC is scored from 1 to 3, with HUCs scoring <1 considered to be MDC and HUCs scoring >1 progressively deviating from MDC. Sites that were within watersheds with scores >1 were further evaluated to see if the identified disturbances were upstream of sampled sites. If the disturbances were upstream of sampled points, the site was not considered to represent reference condition. In summary, watersheds with scores <1 have no known upstream impacts, thus we assumed that the processes and functions (e.g., hydrologic, thermal, and sediment regimes) occur in MDC.

We assumed that not all sites meeting the MDC criteria are in reference condition at anyone point in time because of natural occurring disturbances such as wildfire, insects/disease, floods, thermokarst dynamics, etc. Furthermore, BLM's multiple use mandate and the resulting permitting of activities that potentially impact stream and river conditions means that we need to allow for some degree of short term departure from reference conditions for some indicators at a particular site. Although we've removed sites with anthropogenic disturbance from the final MDC distribution, it is important to retain sites with naturally occurring disturbances to capture the natural range of environmental heterogeneity of the landscape and through time.

We established condition benchmarks for three of the four planning units within the EIFO boundaries using the range of MDC indicator values among the 39 sampled AIM-NAMF sites (Hughes et al. 1986; Paulsen et al. 2008). Condition benchmarks are indicator values, that establish desired conditions and are meaningful for management. The condition benchmarks are used to determine if observed values at assessed sites are within the range of desired conditions (Properly Functioning), outside the range (Non-Functioning) or somewhere in the middle (Functioning at Risk). For example, for indicators thought to increase in response to disturbance (e.g., fine sediment, turbidity, floodplain connectivity) we used the 75th and 95th percentiles of the MDC distribution to determine the maximum indicator value a site can have before it is classified as Functioning at Risk or Non-Functioning, respectively. Specifically, indicator values less than the 75th percentile represents Properly Functioning conditions, values between the 75th and 95th percentiles represent Functioning at Risk conditions, and values >95th percentile are in Non-Functioning condition. Similarly, for indicators thought to decrease in response to disturbance (e.g., pool frequency, bank stability, riparian vegetative complexity) the 25th and 5th percentiles were used to determine the minimum indicator value a site can have before it is classified as Functioning at Risk or Non-Functioning, respectively. The actual percentiles used (e.g., 95th versus 90th percentile for major departure) can change for a particular region based on BLM LUP objectives and trade offs of balancing resource use versus conservation. For example, a National Conservation Area designated for its high quality aquatic resources might require use of a higher percentile.

Results

Inventory of Perennial Streams and Rivers

We estimated the original target population of wadeable, perennial streams and rivers on lands managed by the EIFO to be 9,259 miles (USGS NHD). Of these, 3,683 stream miles (40%) are potentially part of the target population that have not yet been surveyed in the Upper Black River planning unit (Figure 2). For this report we will focus only on the 5,576 stream miles that were in the remaining planning units (Figure 3). Through site scouting and sampling, we found that about 25% of streams (1,427 miles) were non-target due to factors such as not being on BLM-managed lands, they have characteristics of a wetland instead of a stream, or they are not wadeable (Figure 3). We re-calculated the potential target population of the Fortymile, Steese, and White Mountains planning units by removing the non-target streams and rivers resulting in 4,149 miles of wadeable perennial streams and rivers. Of these 4,149 miles, 21% (874 miles) of streams were inaccessible due to terrain, so we are unable to definitively determine if these streams are part of the target population. We were able to make inference to the remaining 79% (3,275 miles) of the potential target population in the Fortymile, Steese, and White Mountains planning units.

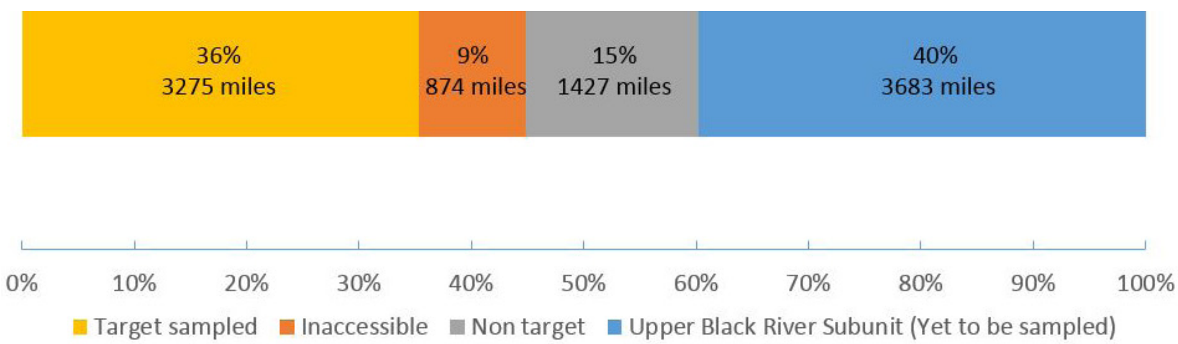


Figure 2. Breakdown of stream miles on lands managed by the EIFO that were target-sampled, inaccessible, non-target, and part of the Upper Black River subunit, but not sampled as part of this effort. Estimates are based on the National Hydrography Dataset (NHD) and field sampling.

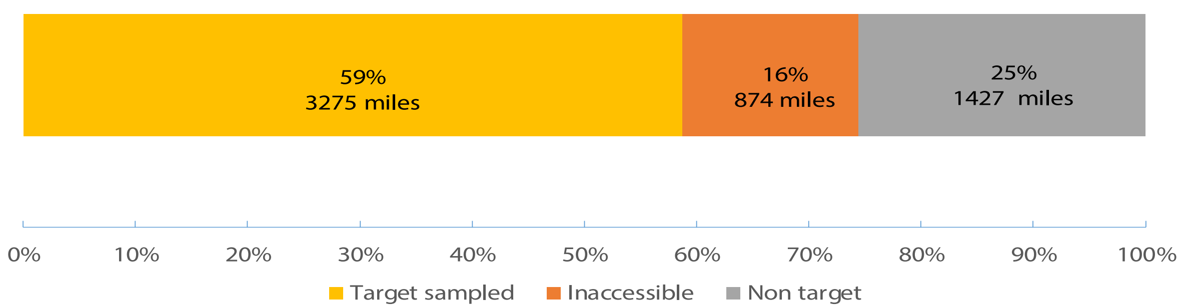


Figure 3. Breakdown of stream miles in the Fortymile, Steese, and White Mountains that were target-sampled, inaccessible, and non-target as part of the EIFO AIM implementation. Estimates are based on the National Hydrography Dataset (NHD) and field sampling.

Benchmarks and Potential Natural Conditions

To determine if the 40 randomly sampled sites represented reference conditions, each site was entered into the WC Model to see if anthropogenic disturbances occurred at or upstream of the site. We found that seven of the 40 sites fell within 6th level HUCs having a WC score >1; however, disturbances in six of those HUCs were downstream of the sampled reach. The sites were therefore deemed intact and valid reference sites (i.e., MDC). One randomly sampled site was classified as non-reference because of historic and current placer mining. Based on this screening process, we retained 39 out of 40 sites as reference sites.

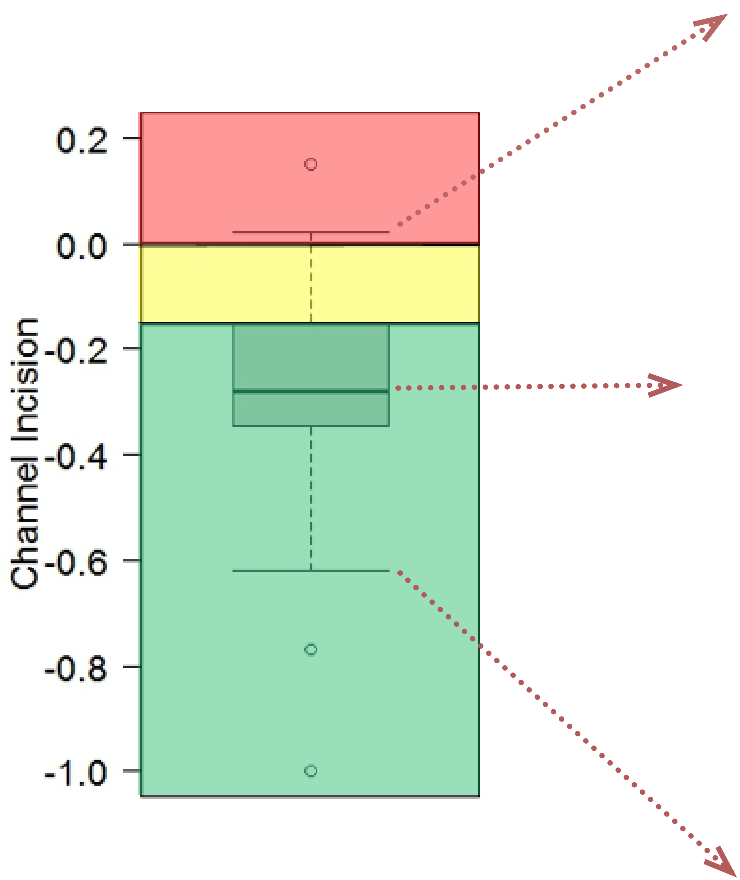
Data collected from the 39 reference sites was used to establish benchmarks for a variety of indicators that describe instream and riparian habitat quality, water quality, and watershed function. For the purposes of this report, three indicators are described in detail: (1) channel incision, (2) bank cover and stability, and (3) riparian vegetative complexity. In addition to being major components of a healthy and properly functioning stream, these three indicators are applicable to monitoring the outcomes of the EIRMP objectives and associated Alaska Land Health Standards. All of the established indicator benchmarks can be found in Appendix 1.

Alaska's Land Health Standards (LHS) helped define the desirable conditions identified in the Eastern Interior LUP and drive the need for assessment and monitoring. The watershed function LHS calls for assessments of whether stream channel characteristics are appropriate for the landscape position, while the species LHS seeks to ensure essential habitat elements are present to ensure population viability. Following the suggested indicators for each LHS, we used channel incision and bank cover and stability as examples to assess watershed function. Riparian habitat complexity was used to assess the species standard.

Channel incision results in disconnected floodplains and can negatively impact nutrient retention, dissipation of stream energy, riparian ecosystem development and maintenance, and biological diversity (Knighton 1998, Leopold et al. 1992). Channel incision is computed from the difference in elevation of the bankfull stage and the top of low bank, and can range from -1 (non incision: low bank height = to bankfull stage) to ~2 (significant incision: low bank height > bankfull stage height)(BLM TR 1735-3). We observed a minimum value of -1 and a maximum value of 0.15, with the 75th and 95th percentiles equal to -0.155 and 0.002, respectively, among the 39 reference sites (Figure 4). Overall, these benchmarks suggest a low degree of naturally occurring incision throughout the BLM-managed lands within the EIFO boundaries.

Figure 4. Channel Incision Benchmarks

The following box plot depicts the range of channel incision observed throughout the BLM-managed lands within the EIFO boundaries. The upper image depicts conditions greater than the 95th percentile of the distribution. In the image you can see that the stream is incised, meaning that the stream cannot easily access its floodplain. In the middle (50th percentile) and lower (5th percentile) images you can see that the stream is well connected to its floodplain. Incision values above the 75th and 95th percentiles of minimally disturbed conditions were used as benchmarks for Functioning at Risk and Non-Functioning ratings, respectively.



Bank cover and stability indicators assess stream bank migration and lateral channel stability, which are important components in maintaining a stream channel at dynamic equilibrium (Thorne 1982). Stable stream banks limit the addition of fine sediments to the stream and allow establishment of riparian vegetation, which provides overhead cover and inputs of woody debris.

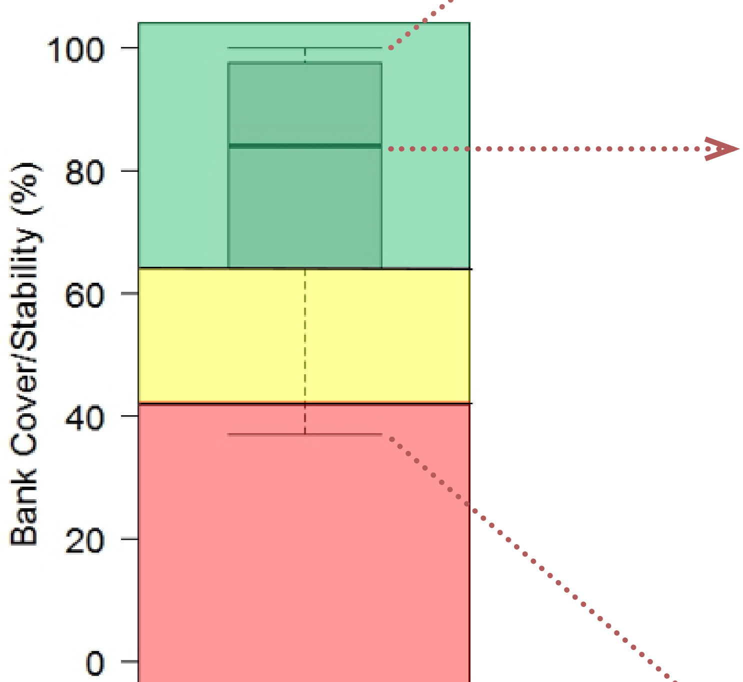
Bank cover and stability are calculated as one metric. A bank is considered stable and covered if it has greater than 50% cover and lacks features of instability (e.g., fracture, slump block). The combined bank cover and stability indicator is determined by collecting 42 bank stability and cover measurements at each site. Bank cover and stability ranges from zero to 100, with lower values indicating banks susceptible to accelerated erosion. We observed a minimum value of 37% and a maximum value of 100%, with the 25th and 5th percentiles equal to 64 and 41.9%, respectively (Figure 5). These values characterize the range of potential natural conditions throughout the field office and suggest a moderate degree of naturally occurring bank cover and stability. Bank cover and stability values need to be lower than 41.9% before they would be characterized as having 'major' departure from reference (bottom photograph in Figure 5).

Riparian zones are transitional areas between terrestrial and aquatic ecosystems that provide important habitat for organisms and influence many physical and ecological processes including flood dissipation, nutrient cycling, shade, and cover to reduce thermal loading (Naiman and Decamps 1997). Maintaining an intact riparian corridor is fundamental to a stable stream channel and supports both chemical and biological stream functions (Harman et al. 2012, Perucca et al. 2007). Riparian vegetative complexity is determined by visually estimating the percent aerial cover for the three different layers, or strata, of vegetation (canopy, understory, and groundcover) and can range from zero (<10% vegetation cover) to 2.6 (> 87% vegetative cover for all three strata). We observed a minimum value of 0.66 and a maximum value of 2.16, with the 25th and 5th percentiles equal to 1.22 and 0.99, respectively (Figure 6). The wide range of values highlight the diversity of riparian conditions from forested systems to more open tundra systems. Riparian vegetative complexity values need to be below 0.99 before they would be characterized as having 'major' departure from reference (bottom photograph in Figure 6).

These stream and floodplain attributes are commonly impacted from land uses, such as placer mining, which is common on many streams within interior Alaska. By understanding the range of potential natural conditions within the Fortymile, Steese, and White Mountains subunits, the BLM can establish benchmarks for management within LUPs that can help ensure the sustained yield of aquatic and riparian resources into the future. The next section explores how AIM-NAMF data from targeted sites, which have been placer mined and reclaimed in the past, can be compared to benchmarks for the region.

Figure 5. Bank Cover and Bank Stability Benchmarks

The following box plot depicts the range of bank cover/stability measured within the BLM-managed lands within the EIFO boundaries. The upper image depicts the 95th percentile of the distribution. In the image you can see that the streambanks are well covered with a diverse mix of vegetation types and high root densities. In the middle image (50th percentile) the banks are well covered and stable. The lower image, which represents conditions less than the 5th percentile, illustrates streambanks that are actively eroding with patchy vegetation. Bank cover and stability values below the 25th and 5th percentiles of minimally disturbed conditions were used as benchmarks for Functioning at Risk and Non-Functioning ratings, respectively.



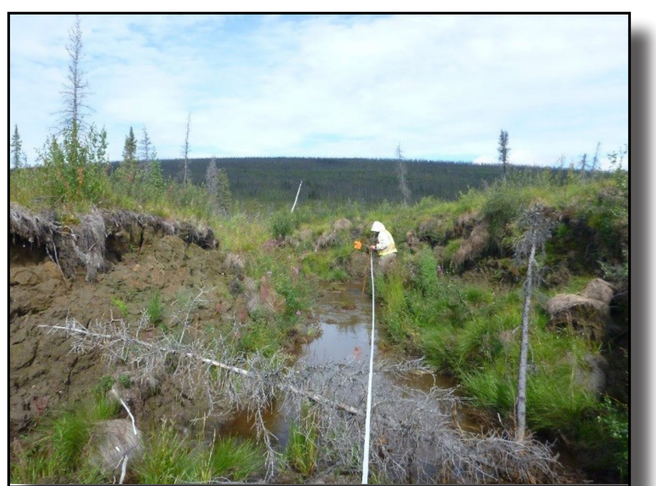
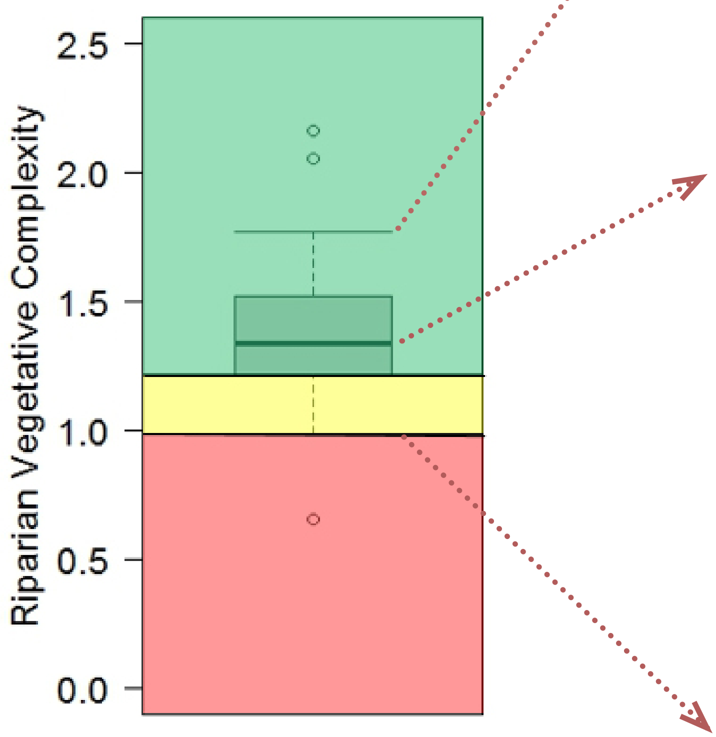


Figure 6. Riparian Vegetation Complexity Benchmarks

The following box plot depicts the range of riparian vegetation complexity measured within the BLM-managed lands within the EIFO boundaries. The upper image depicts the 95th percentile of the distribution. In the image you can see that the riparian vegetation includes a diverse canopy, understory, and groundcover of varying age classes. In the middle (50th percentile) image, the vegetation is also diverse, but is more shrub dominated. The lower (5th percentile) image illustrates a riparian community containing a lower diversity of the three vegetative strata. Values below the 25th and 5th percentiles of minimally disturbed conditions were used as benchmarks for Functioning at Risk and Non-Functioning ratings, respectively.



Applications to Land Management and Decision-making

The BLM is committed to integrating science into work processes at all levels (BLM 2015, WO IM 2017-030). BLM's NAMF program provides the tools and subsequent data to efficiently and effectively integrate science into decision-making at a variety of scales. In the section above, we described the process for developing benchmarks for the EIFO. Once developed, these benchmarks can be used in a variety of applications from the planning process (e.g., analysis of the management situation, development of potential natural conditions, LUP effectiveness monitoring) to assessments of restoration or reclamation efficacy. Below, we offer three examples to demonstrate how offices in Alaska can utilize NAMF information to improve transparency in how science is applied, increase confidence in decision outcomes, and enhance stakeholder support. The ability to use a single field method, such as AIM-NAMF, to meet multiple Bureau data needs has the capacity to increase both the efficiency and defensibility of field office monitoring and management decisions. Below are several examples ranging from landscape level to site-specific management applications of AIM-NAMF data.

Example #1
Stream Reclamation Effectiveness Monitoring Using Targeted AIM-NAMF Sampling

The standardized methods of AIM-NAMF create a consistent approach for placer mine reclamation evaluations, as well as improving stakeholder's understanding of aquatic resource condition. The regulations (43 CFR 3809) require that reclamation result in the rehabilitation of fisheries habitat, which includes "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…" (BLM H-3809-1). Since AIM-NAMF establishes baseline conditions throughout much of the lands managed by the EIFO, reclamation success can be evaluated against regional reference conditions, which adds a high level of site specificity and regional context to the analysis. These data can also be used to evaluate the efficacy of previously used methods for evaluating stream reclamation. Since 2014, the BLM has utilized an approach outlined in Harman et al. (2012) to quantify channel stability and the fundamental role of riparian vegetation in reducing erosion and dissipating stream energy. Despite being based on well established science, members of the mining community have remained skeptical of the conclusions drawn using the Harman et al. (2012) method. The following paragraphs outline the results of targeted AIM-NAMF sampling on previously reclaimed streams, and how those conditions compare to those at undisturbed streams on lands managed by the EIFO.

Traditionally used stream reclamation techniques have emphasized the creation of a pilot channel at the lowest elevation of the valley, contouring the mined ground roughly to the topography of the adjacent land, and relying on the pace of natural recovery processes to re-establish riparian vegetation, vertical and lateral stability, and to promote the recovery of instream habitats. Since the 1980s, several peer-reviewed publications, as well as agency reports, have highlighted the limited stream reclamation success achieved by miners in Alaska using these techniques (e.g., Tidwell et al. 2000, Arnette 2005, Carlson et al. 1998, Milner and Piorkowski 2004, BLM 1988a,b,c). AIM-NAMF data supported those conclusions with key stream stability indicator values well outside the range of reference condition (Table 1).

Table 1. Targeted site results for channel incision, bank cover and stability, and riparian vegetation complexity. Red cells indicate a major departure from reference condition (i.e., Non-Functioning Condition). Yellow cells indicate a moderate departure from reference condition (i.e., Functioning at Risk Condition). Green cells indicate conditions within the range of reference condition (i.e., Properly Functioning Condition).

Targeted Site	Time Since Reclamation	Channel Incision	Bank Cover and Stability	Riparian Vegetative Completely
Franklin Creek	1	0.01	15	0
Ketchum Creek-Sherlud	1	-0.11	0	0
Ketchum Creek-Wilkinson	1	-0.02	0	0.07
South Fork Harrison Creek	3	0	2	0.19
North Fork Harrison Creek	4	-0.14	6	0.06
Ketchum Creek	5	0.52	43	0.76
Volcano Creek	7	-0.15	5	0.89
Kokomo Creek	11	-0.2	47	1.04
Jack Wade Creek	~20	-0.16	5	0.5
Franklin Creek	~55	0.09	38	1.25

As noted in the table above, the majority (6 of 10) of the assessed streams were found to have channel incision values that were within the Functioning at Risk category based on a moderate departure from reference condition (-0.16, Figure 7, page 14). Minimum and maximum values for channel incision were -0.2 and 0.52 respectively. Only one site, Kokomo Creek, was found to be within the Properly Functioning Condition category for channel incision.

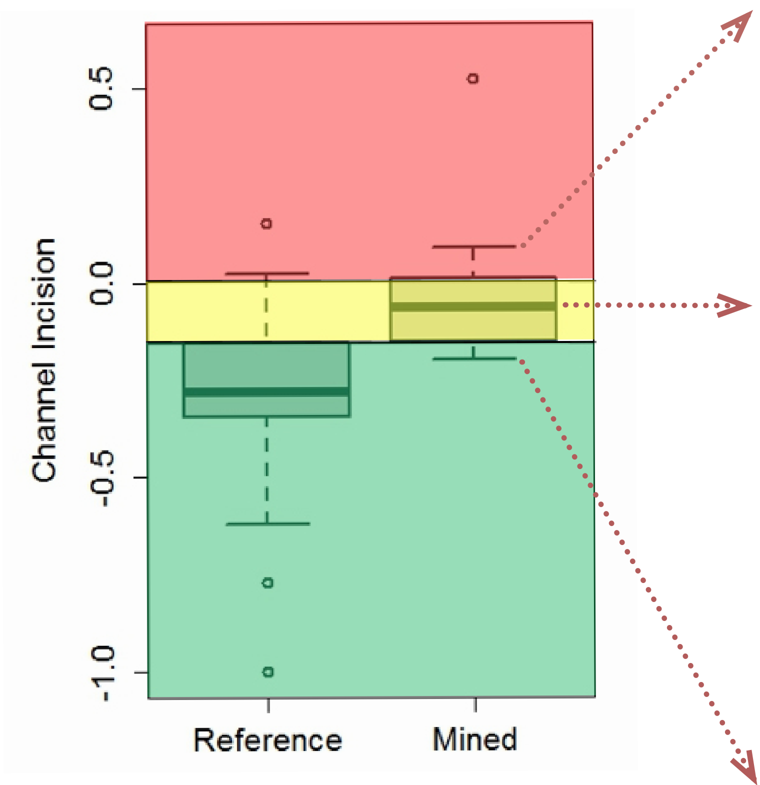
The majority (8 of 10) of reclaimed reaches were found to have bank cover and stability values that were within the Non-Functioning category based on a major departure from reference condition (<41.9%, Figure 7). Minimum and maximum values for bank cover and stability were 0% and 47%, respectively. Even after 11 years of post-reclamation recovery, bank cover and stability values still indicated a moderate departure from reference condition at one site (Kokomo Creek) (Figure 8, upper image, page 15).

The majority (8 of 10) of reclaimed reaches were found to have riparian vegetation complexity values that were within the Non-Functioning category based on a major departure from reference condition (<0.99, Figure 9, page 16). Minimum and maximum values for riparian vegetation complexity were 0 and 1.25, respectively. These results are largely due to the reliance on natural recovery processes to reestablish near stream riparian habitat, which is difficult based on the loss of growth medium during mining, the short growing season, concentrated run-off during spring break-up of channel ice, and channel adjustments following reclamation. Only one reclaimed stream reach was within the Functioning at Risk category based on a moderate departure from reference condition with a value of 1.04.

The data show that there is a moderate-to-major loss of stream function on placer mined streams which persists well after reclamation has been completed. These results suggest that reclamation techniques that are reliant on natural processes are inadequate at rehabilitating fisheries habitat, which is a required performance standard (43 CFR 3809.420), as well as meeting LUP objectives and associated Land Health Standards. These results were also complementary to data collected using the Harman et al. (2012) framework, which has also indicated that reclaimed streams are often disconnected from their floodplains, laterally unstable, and have poor riparian vegetation recovery well after initial reclamation has been completed.

Figure 7. Channel Incision at Reclaimed Sites Compared to Benchmark Values

The following box plots depict the range of channel incision measured at reclaimed placer mined sites compared to the range of reference condition within the BLM-managed lands within the EIFO boundaries. The upper image depicts conditions greater than the 95th percentile of the reclaimed distribution, which represents a deeply incised channel that is disconnected from the floodplain. In the middle image (50th percentile) the stream is Functioning at Risk with slight incision, while the lower image (5th percentile) is well connected to its floodplain and within the range of properly functioning condition.



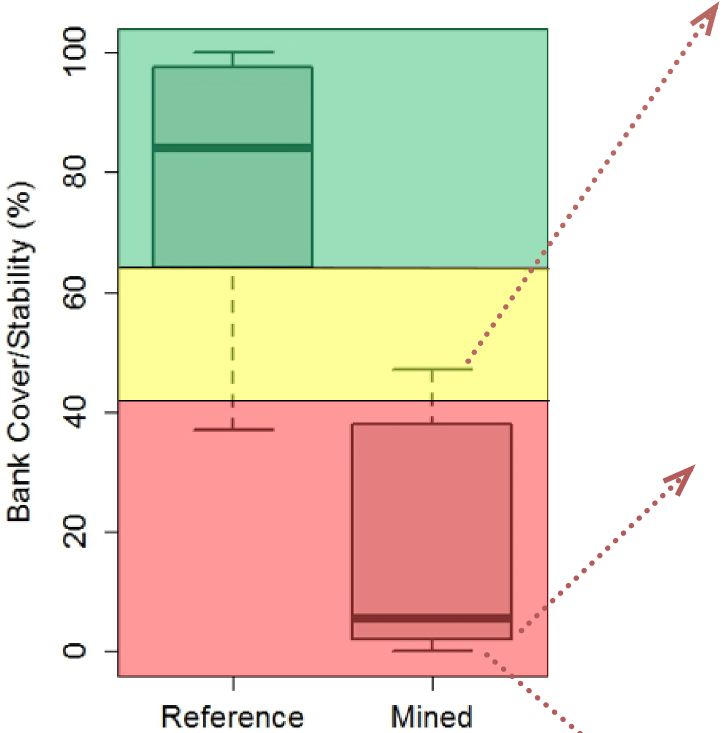
Upper Photograph
Ketchum Creek, Steese Planning Unit, Eastern Interior planning area, five years since reclamation

Middle Photograph
Ketchum Creek, Steese Planning Unit, Eastern Interior planning area, one year since reclamation

Lower Photograph
Kokomo Creek, Steese Planning Unit, Eastern Interior planning area, eleven years since reclamation.

Figure 8. Bank Cover and Bank Stability Box Plots

The following box plots depict the range of bank cover and bank stability measured at reclaimed placer mined sites compared to the range of reference condition within the BLM-managed lands within the EIFO boundaries. The upper image depicts conditions greater than the 95th percentile of the reclaimed distribution, which is within the Functioning at Risk range of the reference distribution roughly 11 years after reclamation. In the image you can see that the streambanks are moderately covered with herbaceous species and sparse early age class willow species. In the middle image (50th percentile) the banks are dominated by unconsolidated gravel and cobble, with evidence of scour. The lower image (5th percentile) illustrates unstable streambanks dominated by sand with some cobble and gravel. The vast majority of surveyed reclamation sites were Non-Functioning for this indicator.



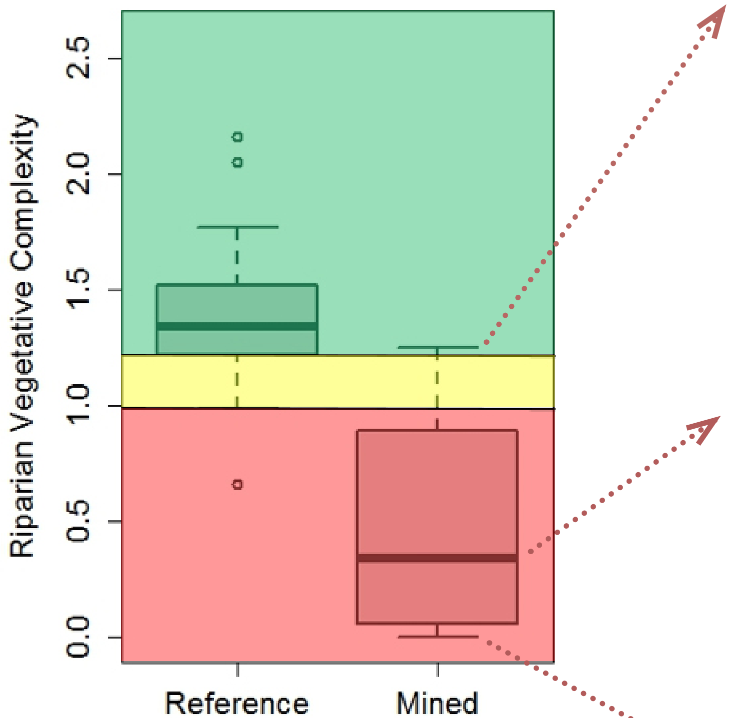
<u>*Upper Photograph*</u>
Kokomo Creek, Steese Planning Unit, Eastern Interior planning area, eleven years since reclamation.

<u>*Middle Photograph*</u>
North Fork Harrison Creek, Fortymile Planning Unit, Eastern Interior planning area, four years since reclamation.

<u>*Lower Photograph*</u>
Ketchum Creek, Steese Planning Unit, Eastern Interior planning area, one year since reclamation.

Figure 9. Riparian Vegetation Complexity Box Plots

The following box plots depict the range of riparian vegetation complexity measured at reclaimed placer mined sites compared to the range of reference condition within the BLM-managed lands within the EIFO boundaries. The upper image depicts the 95th percentile of the reclaimed distribution. In the image you can see that the riparian vegetation has limited structural diversity; however, conditions are within the Functioning at Risk portion of the reference distribution. In the middle image (50th percentile) vegetation is largely absent and the floodplain is made up of small cobbles and gravels, which make it difficult for riparian vegetation to establish itself. The lower 5th percentile contains basically no vegetation near the stream channel even four years after reclamation. The majority of reclaimed sites have limited riparian vegetation near the stream and are Non-Functioning.



__Upper Photograph__
Kokomo Creek, Steese Planning Unit, Eastern Interior planning area, eleven years since reclamation

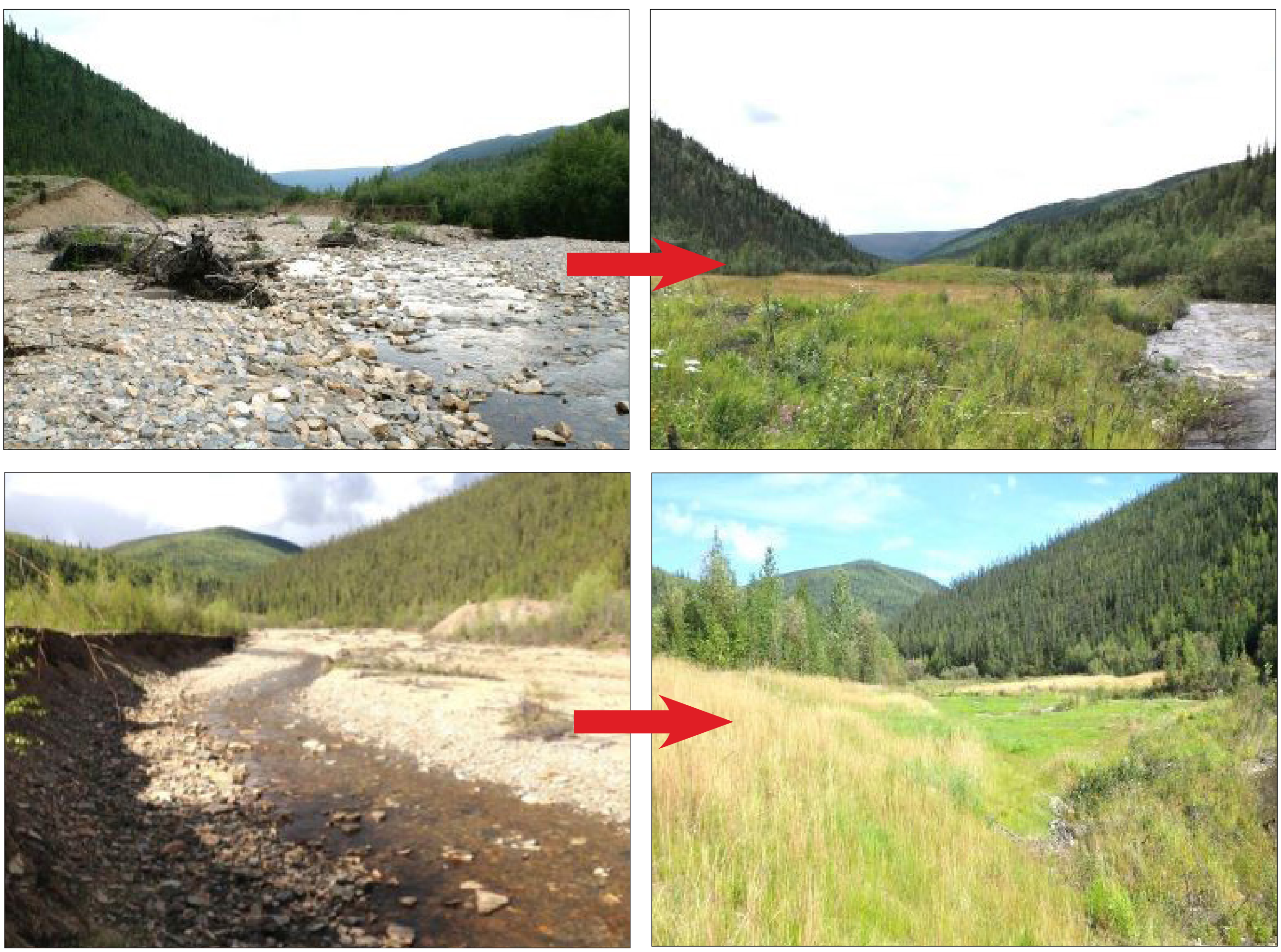
__Middle Photograph__
Jack Wade Creek, Fortymile Planning Unit, Eastern Interior planning area, ~20 years since last disturbance

__Lower Photograph__
North Fork Harrison Creek, Steese Planning Unit, Eastern Interior planning area, four years since reclamation

<u>Example #2</u>
Evaluating the Effectiveness of Natural Channel Design Techniques to Reclaim Placer Mined Streams

As demonstrated in Example #1, satisfying the requirement to rehabilitate fisheries habitat on streams that have been placer mined is difficult and often not achieved, even decades after reclamation has been completed. To improve stream reclamation success in Alaska, the BLM has developed multiple demonstration projects that serve as examples for the mining community regarding the integration of the latest science and proven techniques for reclaiming streams. These techniques, including the Rosgen geomorphic channel design approach, have been used for nearly 20 years in North America and are part of the NRCS National Engineering Handbook (NRCS 2007). The first project that was completed involved over 1600 ft of stream reconstruction on Jack Wade Creek, which is within the Fortymile Wild and Scenic River section. This site was assessed using targeted AIM-NAMF data prior to construction and one year afterward. The images below illustrate the conditions prior to and one year after construction.

Photographs 1, 2, 3, & 4. Jack Wade Creek (MP 85 on Taylor Highway). Left images illustrate conditions after being mined and left to reclaim naturally for over 20 years. Right images show conditions one year after implementing the latest science regarding natural channel design.



In addition to the photographs above, Table 2 shows the conditions of the Jack Wade Creek site following 20 years of natural recovery after mining ended, as well as conditions after implementation of the BLM project in early 2015. These results strongly contrast with AIM-NAMF data collected from past reclamation projects using traditional techniques. By applying the latest science and techniques commonly used outside of Alaska, the BLM was able to move stream conditions from largely non-functioning to functioning for most indicators within a few weeks at this previously mined site. Riparian vegetation complexity remained non-functioning due in part to the transplanting of vegetation mats, which had the shrubs cut back thereby removing the canopy cover, and the predominately herbaceous vegetation on the site. Recent monitoring has noted improved structural diversity within the transplanted areas and young willows emerging along the stream point bars. A project completed in 2017 utilized uncut transplants to create the streambanks and floodprone benches of the stream. This site is shown in the photographs below and will be evaluated using AIM-NAMF beginning in 2018.

Table 2. AIM-NAMF results for several key indicators at a site that was previously mined and left to naturally recover for over 20 years, before the BLM implemented a stabilization project in 2015.

Targeted Site	2014 (Prior to Construction)	2015 (One Month After Construction)
Channel Incision	-0.16	-0.21
Bank Cover and Stability	5	83
Riparian Vegetative Complexity	0.5	0.45

Photographs 5 & 6. Left image depicts pre-reclamation conditions at the site, which contained limited streambank vegetation, no pool habitats, and unstable streambanks. The image on the right was taken on Day 5 of the stream reclamation project, which took less than two weeks to complete. The streambanks were transplanted with vegetation from the next mining cut and stream habitats were created via the construction of pools and riffles.

Continued monitoring of these sites using AIM-NAMF will improve the BLM's understanding of recovery timelines and the effectiveness of reclamation techniques in Alaska. The effectiveness of reclamation on placer mined streams is being further explored in a separate technical report, which will utilize AIM-NAMF datasets and cover both the EIFO and Central Yukon Field Office. This focused report will also explore factors that limit reclamation success in Alaska and introduce techniques that can significantly increase the likelihood of successfully rehabilitating fisheries habitat during reclamation. We anticipate having this report available in late 2018.

<u>Example #3</u> *Landscape Scale - Developing LUP Objectives*

The BLM's Land Use Planning Handbook (BLM H-1601-1) requires specific decisions to be made during the development of Resource Management Plans (RMPs). For fisheries, riparian, and water resources, the handbook requires the identification of desired conditions and outcomes. LUPs are required to identify desired width/depth ratios, streambank conditions, channel substrate conditions, and large woody material characteristics, among other metrics. Many LUPs satisfy handbook requirements through the use of descriptive objectives that often lack measurable criteria or include criteria derived from published literature rather than an assessment of actual conditions within the planning area. In some cases, LUPs establish objectives that are based on literature, agency publications, and/or professional judgment. In 2016, BLM issued policy that linked AIM data collection to LUP effectiveness monitoring. This policy underscored the need for offices to begin implementation of AIM-NAMF, not only for the development of LUP objectives, but also to improve their understanding of baseline conditions within the planning area. Consistent with this policy, BLM staff implemented AIM-NAMF in preparation for LUP development within the Bering Sea-Western Interior planning area in Alaska.

Using the baseline conditions established through AIM-NAMF implementation within the planning area, BLM fisheries and hydrology staff will use the AIM-NAMF Indicator Benchmark Tool to establish measurable thresholds for the planning area and/or specific areas within the planning area, such as aquatic resource based Areas of Critical Environmental Concern (ACECs). The AIM-NAMF Indicator Benchmark Tool allows staff to establish indicator benchmarks using three approaches. The first approach utilizes predicted natural conditions. Predicted natural conditions account for natural environmental gradients by using physiographic predictors (e.g., geology, climate, topography) to make site-specific predictions of the conditions that should occur in the absence of anthropogenic impacts. This method is commonly associated with water quality indicators and macroinvertebrates. The second approach utilizes percentiles of regional reference conditions, which does not consider natural environmental gradients other than coarse ecoregional categories and coarse stream size categories. This approach establishes default benchmarks based on the 25th and 5th percentiles of the data set for indicators that are expected to decrease with disturbance (e.g., Riparian Vegetation Complexity, LWD Frequency, and Instream Habitat Complexity, and the 75th and 95th percentiles of the data set for indicators that are expected to increase with disturbance (e.g., Channel Incision and Percent Fines (Kaufmann et al. 1999; Stoddard et al. 2005). The last approach that can be used to establish benchmarks in the planning area involves the use of best professional judgment. This method should be used where no other policy guidance or baseline monitoring data are available.

The Bering Sea-Western Interior draft RMP is utilizing the second approach to establishing benchmark aquatic habitat objectives in the planning area. The planning team has simplified the percentiles of regional reference condition approach by emphasizing the concept of managing for Potential Natural Condition or PNC. The team defines PNC as the portion of a metric's distribution excluding outliers and the upper or lower tail of the distribution (based on the indicator's response to stressors). Outliers or the upper or lower tail of the distribution represent impairment from a functioning condition as a result of disturbance. These disturbances could include: wildfire, insects/disease, thermokarst dynamics, etc. A conceptual table depicting potential indicators and benchmarks for the Bering Sea-Western Interior draft RMP is illustrated below (Table 3) and will be refined after baseline conditions are established for the planning area in 2020.

Table 3. Conceptual table depicting benchmarks for an RMP.

Indicator	Predicted Response to Stress	Units	Benchmark	Percentile	Small Streams	Large Streams
Percent Overhead cover	Decrease	%	Moderate	25th	47.2	22.5
			Major	5th	26.1	11.5
Bank Overhead Cover	Decrease	%	Moderate	25th	69	55.1
			Major	5th	32.1	25.2
Veg Complexity	Decrease	None	Moderate	25th	1.03	0.99
			Major	5th	0.6	0.73
Bank Cover and Stability	Decrease	%	Moderate	25th	65.4	68
			Major	5th	55	59.2
Channel Incision	Increase	None	Moderate	75th	-0.09	0.11
			Major	95th	0.22	0.22
% Fines	Increase	%	Moderate	75th	45	44
			Major	95th	66	81

Example #4 *Landscape Scale - LUP Effectiveness Monitoring*

Land use plan effectiveness monitoring is the process of collecting data/information necessary to evaluate the effectiveness of land use planning decisions (BLM H-1601-1). In contrast to monitoring on a local, project specific scale as demonstrated in Example 1, by monitoring resource condition and trend over a larger land base the BLM is able to evaluate its progress toward the achievement of desired outcomes on a landscape scale basis (e.g. planning subunit). In the EIRMP, monitoring resource conditions using NAMF data collection will help refine desired future condition objectives (BLM 2016a, 2016b, 2016c, 2016d). Indicators like floodplain connectivity, streambank stability, fine sediment, pool frequency, and riparian vegetation condition were previously based on professional judgment and literature from the Pacific Northwest region, therefore planning area-specific baseline conditions will provide the site specificity that is important for long-term trend evaluations. Implementation of NAMF includes an initial assessment of baseline conditions, which can be used to describe the range of natural variability within the planning area. However, by resampling 50% of these sites after a period of time (5-10 yrs), the BLM is able to assess aquatic resource condition trends or changes over time in response to changing landscape conditions.

BLM offices with LUPs that include NAMF-based desired future condition objectives are well positioned to complete effectiveness monitoring. Offices that have used professional judgment, peer-reviewed literature or agency reports to develop desired future condition objectives will need to crosswalk their plan with NAMF indicators to establish appropriate benchmarks for LUP effectiveness monitoring. The EIRMP outlines several specific objectives for the management of aquatic habitats with the caveat that they represent interim goals that will be refined through monitoring of reference aquatic systems (e.g., NAMF). The EIRMP goes on to say that refined targets will be established based on the upper percentile of values collected from reference sites in the planning area (BLM 2016a, 2016b, 2016c, 2016d). As an example, several of the EIFO RMP's objectives are outlined in

Table 4 (below) with a direct crosswalk to the measurable equivalent based on NAMF data collected in the planning area.

Table 4. RMP & NAMF Crosswalk Example

Indicator	EIRMP ROD Objectives (12/2016)	NAMF Equivalent
Streambank Stability	Streambank stability greater than 95 percent for A and B and E channel types; greater than 90 percent for C channel types within 80 percent of any stream reach. Streambank stability would be evaluated using the BLM Multiple Indicator Monitoring technique or other appropriate methodology.	Streambank Stability and Cover: Percent of banks both stable and covered is > 64% based on the 25th percentile of the NAMF dataset.
Riparian and Riparian Conservation Area Vegetation	Percent of riparian vegetation in the greenline dominated by late seral community types or anchored rocks/logs is greater than 80 percent (good-excellent ecological condition). Over 80 percent of the plant community type along the streambank provides high bank stability, deep fibrous roots, good resistance to streambank erosion or is comprised of anchored rocks/logs. The riparian vegetation provides adequate shade, large wood debris recruitment, and connectivity.	Riparian Vegetation Complexity: Aggregate measure of the average vegetative cover provided by three different vegetative height ratings for small streams and large streams is > 1.22 based on the 25th percentile of the NAMF dataset.
Turbidity	Stream stability levels facilitate balanced sediment aggradation and degradation within the watershed, thereby maintaining seasonally consistent turbidity levels. Turbidity levels would not exceed those outlined in the Alaska Water Quality Standards (18 AAC70).	Average water clarity as measured by the suspended solids in the water column (units: NTU, n=3) for small streams and large streams is < 2.3 based on the 75th percentile of the NAMF dataset. This information would be used in conjunction with the Alaska Water Quality Standards.
Channel Substrate Condition	Percent Surface Fines (< 6 mm): A & B Rosgen Channel Types (RCTs) < 10% / C & E RCTs < 20%	Percent of 105 particles with a b-axis <6mm (units %, min = 0, max=100, n=105) for small and large streams is < 9.8% based on the 75th percentile of the NAMF dataset.

Although not ideal, it is reasonable to crosswalk and assess LUP objectives in the absence of a baseline AIM-NAMF assessment within the planning area. As illustrated in the table above, it is also reasonable to use AIM-NAMF data to refine LUP objectives based on actual conditions within the planning area.

Gaining Efficiencies through Technology and Collaboration

Working across the vast landscape of Alaska, with its diversity of habitats and freshwater organisms, will require the adoption of existing technologies such as electronic data capture and storage, and remote sensing, as well as leveraging other agency resources with similar mission areas. Using technology to collect, store, and manage data are key aspects of AIM-NAMF, which also allows for the integration of supplemental indicators to address local data needs. Supplemental data collection is improving our ability to assist placer miners with stream design, while fish inventory efforts are expanding our knowledge of fish distribution, which is important for effectively managing subsistence resources. New technologies such as environmental DNA (eDNA), which allows the BLM to detect the presence of aquatic species based on the DNA collected in a water sample, are also important to success. The Alaska NAMF will integrate eDNA sampling as a way to revolutionize inventory of both resident and migratory fish species; a very efficient and cost-effective method compared to what are traditionally intensive fish surveys.

Collaborating with other agencies tasked with understanding the condition of aquatic resources in Alaska is also critical in times of reducing budgets and increasing operational costs. Since AIM-NAMF methods are compatible with those used by the Alaska Department of Environmental Conservation (ADEC) and the U.S. Environmental Protection Agency, the BLM has been able to significantly benefit from their efforts. For example, in 2015 the BLM and ADEC began collaborating on stream and river monitoring in the National Petroleum Reserve, resulting in the assessment of dozens of sites on BLM-managed land at no cost to the Bureau. These data represented half of the total data needed to assess the condition of wadeable aquatic habitats of the Arctic Coastal Plain region of the National Petroleum Reserve in Alaska.

Improving data analysis efficiencies through the use of technology is also a high priority for the BLM. AquADat is a BLM database, which stores AIM-NAMF data and is maintained by the BLM National Operations Center. AquADat automates indicator calculations and allows BLM staff to export AIM-NAMF data using MS Excel. The data are queryable and provide field specialists with the tools necessary to understand how a particular site of interest relates to the conditions in the surrounding ecoregion or office. The accompanying AquADat Benchmark Tool provides field and state office staff with the ability to set resource condition objectives and thresholds in the development of LUPs. Establishing specific and measurable objectives is essential to future effectiveness monitoring and detecting change across the landscape over time. The Benchmark Tool also allows for watershed or area-specific objectives or thresholds based on the requirements of sensitive species or the management prescriptions for the area.

The ability to partner with collaborating agencies in Alaska, as well as electronically capture, store, and analyze core and supplemental data, has made AIM-NAMF an integral part of the BLM Alaska Water and Aquatics Program. Integrating science and new technologies and leveraging resources to meet the mission is central to how BLM Alaska is meeting the needs of the people we serve and ensuring resource use and sustainability into the future.

Next Steps in Alaska

The utility of using NAMF-derived measurable benchmarks to a wide range of activities ranging from the evaluation of placer mines to the development of a LUP, has shown very promising results on lands within the EIFO boundaries. Based on these results, the application of the NAMF in Alaska has shown promising results. From application to activities like placer mining to the development of LUPs, the integrated data collection that the NAMF affords is both cost-effective and based on sound science. Implementation of NAMF statewide is underway and BLM Alaska has already leveraged resources by the Alaska Department of Environmental Conservation using their AKMAP program to expand the dataset beyond BLM lands in the future. Discussions are also underway with other federal land managers, such as the National Park Service, regarding NAMF expansion to NPS-managed lands. In the future, AIM-NAMF efforts will also include non-wadeable waters and lake habitats.

Additional data analysis is also underway to better understand the range of natural conditions in Alaska. With large ranges of variability seen with some of the AIM-NAMF indicators throughout the lands managed within the EIFO boundaries, it's important to understand why. We have begun efforts to screen outliers, build models to account for some of this variation, (e.g., watershed area as a predictor of fine sediment) and look at basic assessments of distribution.

We are also collaborating with other agencies and universities to build freshwater macroinvertebrate multi-metric indices (MMI), observed to expected (O/E) ratios, and various water quality prediction models (e.g. temperature, specific conductance). Once these additional models and analyses are complete, we will be able to further enhance our understanding of the landscape as well as management decisions at multiple scales.

The NAMF has established itself as a key component of BLM Alaska's Water and Aquatics Program. Collecting data once to inform management questions at multiple scales, over time, represents one of the most cost-effective approaches for maintaining an up-to-date inventory as required by FLPMA.

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Appendix

Alaska's Land Health Standards & AIM NAMF Instream and Riparian Indicator Benchmarks for the lands managed by the Eastern Interior Field Office

Appendix 1 - Alaska's Land Health Standards & AIM NAMF Instream and Riparian Indicator Benchmarks for the lands managed by the Eastern Interior Field Office

Data Type	Indicator	Description	Predicted response to stress	Units	Range of Values (Min and Max)		5th percentile	25th percentile	75th percentile	95th percentile	Alaska Application Notes
Biodiversity and Riparian Habitat Quality	Bank Overhead Cover	Average percent overhead cover provided by stream banks (left and right), vegetation or other objects measured at the scour line of the left and right banks across 11 transects	Decrease	%	2.9	94.1	35.5	51.8			
	Vegetative Complexity	Aggregate measure of the average vegetative cover provided by three different vegetative height categories: Canopy (>5m), Understory (0.5-5m), and Ground (<0.5m). Each vegetative height category is then divided into two vegetation types (e.g. woody or nonwoody). Proportional cover is binned into four classes (0.875, 0.575, 0.25, and 0.05) per vegetation type, summed across the three heights, and then averaged across the left and right banks of 11 transects.	Decrease	None	0.66	2.16	0.99	1.22			
	Riparian Vegetative Understory Cover	Measure of the average riparian vegetative cover provided by understory vegetation (0.5-5m). Proportional cover is binned into four classes (0.875, 0.575, 0.25, and 0.05) and then averaged across the left and right banks of 11 transects.	Decrease	None	0.25	0.85	0.29	0.34			Only available for 2016 to present; values subject to change as more data is collected
	Riparian Vegetative Ground Cover	Measure of the average riparian vegetative cover provided by the ground cover vegetation (<0.5m). Proportional cover is binned into four classes (0.875, 0.575, 0.25, and 0.05) and then averaged across the left and right banks of 11 transects.	Decrease	None	0.24	0.81	0.25	0.31			Only available for 2016 to present; values subject to change as more data is collected
	Native Woody Vegetative Cover	Percent of 22 vegetation plots with native woody vegetation present	Decrease	%	100	100	100	100			Only available for 2016 to present; values subject to change as more data is collected
	Sedge/Rush	Percent of 22 vegetation plots with sedges and rushes present	Decrease	%	41	100	41	64			Only available for 2016 to present; values subject to change as more data is collected
	Invasive Invert Species	Presence or absence of invasive macroinvertebrates	Increase	(P)resent or (A)bsent	**Under development**						
	O/E Macroinvertebrate	Biological condition is assessed using an observed/expected (O/E) index. O/E models compare the macroinvertebrate taxa observed at sites of unknown biological condition (i.e., 'test sites') to the assemblages expected to be found in the absence of anthropogenic stressors (see Hawkins et al. 2000 for details). Model specific metadata can be found at www.usu.edu/buglab/.	Decrease	None							
	MMI Macroinvertebrate	Biological condition was assessed using a MMI (Multimetric Index) model.	Decrease	None							

Data Type	Indicator	Description	Predicted response to stress	Units	Range of Values (Min and Max)		5th percentile	25th percentile	75th percentile	95th percentile	Alaska Application Notes
Water Quality	Specific Conductance	Measured specific conductance value. The specific conductance is conductivity standardized to 25 degrees C.	Increase	µS/cm	26.9	734			196.6	413	
	pH	Measured pH value	Increase or decrease	SU	6.3	8.2					EPA Guidance suggests the following benchmark values for moderate to major departure: Acidic: <7 and < 6.5; and Alkaline: > 8.5 and > 9.0
	InstantTemp	Instantaneous water temperature measurement	Increase	°C	2.2	14.2			8	10.1	
	Turbidity	Average water clarity as measured by the suspended solids in the water column	Increase	NTU	0.13	30.7			2.3	12.4	
Watershed Function and Instream Habitat Quality	% Pools	Percent of the sample reach (linear extent) classified as pool habitat as assessed using the core pool method	Decrease	%	**Under development**						
	Residual Pool Depth	Average residual pool depth as assessed using the core pool method	Decrease	m							
	Pool Frequency	Frequency of pools in the reach as assessed using the core pool method	Decrease	# pools/km							
	% Fines < 2mm	Percent of 110 particles with a b-axis < 2 mm	Increase	%	0	100			6.8	24.1[a]	
	% Fines < 6mm	Percent of 110 particles with a b-axis < 6 mm	Increase	%	0	100			9.4	30.9[a]	
	Bank Cover	Percent of 42 erosional banks with greater than 50% cover provided by perennial vegetation, wood or mineral substrate > 15 cm	Decrease	%	37	100	49.6	71.5			
	Bank Stability	Percent of 42 banks lacking visible signs of active erosion (e.g., slump, slough, fracture)	Decrease	%	74	100	77.9	92.5			
	Bank Cover Stability	Percent of 42 banks both stable (lacking visible signs of active erosions (e.g., slump, slough, fracture)) and covered (greater than 50% cover provided by perennial vegetation, wood or mineral substrate > 15 cm)	Decrease	%	37	100	41.9	64			
	Bank Cover Vegetation	Average bank cover composed of vegetation	Decrease	%	29	76	32.3	48			Only available for 2016 to present; values subject to change as more data is collected
	Channel Incision	Logarithm of the difference between average bankfull height and average floodplain height (log(FloodplainHeight - BankHeight + 0.1))	Increase	None	-1	0.15			-0.16	-0.002	
	Instream Habitat Complexity	Aggregate measure of average cover provided by boulders, overhanging vegetation, live trees and roots, LWD, small woody debris, and stream banks for stream fishes measured at 11 plots. Proportional cover was binned into four classes (0.875, 0.575, 0.25, and 0.5), averaged across transects, and then summed across six types of cover.	Decrease	None	0.09	0.61	0.2	0.4			
	Thalweg Depth CV	Indicator of bed heterogeneity computed as the coefficient of variation of 100-300 thalweg depth measurements	Decrease	None	0.17	0.9	0.22	0.26			

[a]Percentiles used to denote major departure from reference for fine sediment were 85% and not 95% because of the presence of outliers