U.S. Department of the Interior

Bureau of Land Management

Assessment, Inventory, and Monitoring Implementation Desk Guide

PREPARING OFFICE
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List of Acronyms/Abbreviations

Acronym or Abbreviation	Full Phrase
AIM	Assessment, Inventory, and Monitoring
BDT	Balanced Design Tool
BLM	Bureau of Land Management
BpS	Biophysical Setting
CDEDT	Change and Disturbance Event Detection Tool
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CNHP	Colorado Natural Heritage Program
CSU	Colorado State University
DIMA	Database for Inventory, Monitoring, and Assessment
DOI	Department of Interior
EPA	Environmental Protection Agency
ESD	Ecological Site Description
ES&R	Emergency Stabilization and Rehabilitation
ESRI	Environmental Systems Research Institute
EVT	Existing Vegetation Type
FLPMA	Federal Land Policy and Management Act
GridMET	Gridded Surface Meteorological Dataset
GRSG	Greater Sage-grouse
GRTS	Generalized Random Tessellation Stratified
HAF	Habitat Assessment Framework
IDT	Interdisciplinary Team
IIRH	Interpreting Indicators of Rangeland Health
LandCART	Landscape Cover Analysis and Reporting Tools
LHS	Land Health Standards
LMF	Landscape Monitoring Framework
LUP	Land Use Plan
MDW	Monitoring Design Worksheet
MIM	Multiple Indicator Monitoring

MOE	Margin of Error
NAMC	National Aquatic Monitoring Center
NEPA	National Environmental Policy Act
NHD	National Hydrography Dataset
NOC	National Operations Center
NRI	National Resource Inventory
NTC	National Training Center
NWI	National Wetlands Inventory
NRCS	Natural Resources Conservation Service
OMB	Office of Management and Budget
PFC	Proper Functioning Condition
PRISM	Planning tool for Resource Integration, Synchronization and Management
QA	Quality Assurance
QC	Quality Control
RHS	Rangeland Health Standards
RMP	Resource Management Plan
SSURGO	Soil Survey Geographic Database
StreamCat	Stream-Catchment Dataset
TN	Technical Note
TR	Technical Reference
USDA	United States Department of Agriculture
VPN	Virtual Private Network

List of Website Links

2.0 AIM DESK GUIDE OVERVIEW

Climate Engine BLM Site Characterization Report	https://reports.climateengine.org/sitecharacterization
Climate Engine Web Application	https://app.climateengine.org/climateEngine
Landscape Cover Analysis and Reporting Tools (LandCART)	https://landcart-301816.wm.r.appspot.com/#/
Range Analysis Platform	https://rangelands.app/
RCMap	https://www.mrlc.gov/rangeland-viewer/

3.0 PLANNING AND PROJECT INITIATION

AIM Budget Cheatsheet	
AIM Data Use Webinars	https://www.blm.gov/aim/webinars
AIM Project Leads training	https://doitalent.ibc.doi.gov/enrol/index.php?id=1022
AIM Related Policy Summary	
AIM Resources	https://www.blm.gov/aim/resources
AIM SharePoint	
AIM Training	https://www.blm.gov/aim/training
AIM Website	https://www.blm.gov/aim
HQ 780 Budget 101	
IM 2023-043	https://www.blm.gov/policy/im2023-043
IM 2023-043: Applying AIM to Land Use Planning and NEPA	

4.0 DESIGN

AIM Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems	https://www.blm.gov/noc/blm-library/technical-reference/monitoring-manual-grassland-shrubland-and-savanna-ecosystems
AIM National Aquatic Monitoring Framework: Field Protocol for Wadeable Lotic Systems	https://www.blm.gov/documents/national-office/blm-library/technical-reference/aim-national-aquatic-monitoring-0
AIM National Aquatic Monitoring Framework: Field Protocol for Lentic Riparian and Wetland Systems	https://www.blm.gov/noc/blm-library/technical-reference/aim-national-aquatic-monitoring-framework-field-protocol-lentic
Balanced Design Tool	https://landscapetoolbox.org/balanced-design-tool
Interpreting Indicators of Rangeland Health, Version 5	https://www.blm.gov/documents/national-office/blm-library/technical-reference/interpreting-indicators-rangeland-health-0
Trend Assessment	

6.0 APPLYING AIM DATA: ANALYSIS & REPORTING

AIM Data Tools	
AIM Decision Library	
AIM Indicators Data Portal	https://www.blm.gov/AIM/AIMDataPortal
AIM Practitioners Webinars	
Analysis and Reporting Workflow and Tools	

BLM Geospatial Business Platform AIM Hub	https://www.blm.gov/AIM/PublicData
BLM Geospatial Gateway	
Climate Engine	https://www.climateengine.org/
Climate Engine Site Characterization Report	https://reports.climateengine.org/sitecharacterization
Climate Smart Restoration Tool (CSRT)	https://climaterestorationtool.org/csrt/
Evaporative Demand Drought Index (EDDI)	https://psl.noaa.gov/eddi/
Global Forest Watch	https://www.globalforestwatch.org/
LandCART	https://landcart-301816.wm.r.appspot.com/
Landscape Explorer	https://www.landscapeexplorer.org/
LANDFIRE	https://landfire.gov/
Lotic AIM Data Portal	https://www.blm.gov/aim/loticdataportal
National Design (LMF) Analyst Document	
National Design (LMF) Metadata	https://blm-egis.maps.arcgis.com/sharing/rest/content/items/ead231b9b88e4fdfbd16321d0fb0f86f/info/metadata/metadata.xml?format=default&output=html
National Fire Situational Awareness	https://maps.nwcg.gov/
National Wetlands Inventory	https://www.fws.gov/program/national-wetlands-inventory
NRI Grazing Lands On-site Survey	https://grazingland.cssm.iastate.edu/
Rangeland Indicator Calculator	https://jornada-data.shinyapps.io/rangeland-indicator-calculator/
Riparian & Wetland AIM Data Portal	https://www.blm.gov/aim/wetlanddataportal

Rangeland Analysis Platform (RAP)	https://rangelands.app/
Rangeland Condition Monitoring Assessment & Projection (RCMAP)	https://www.mrlc.gov/data/type/rcmap-time-series-trends
Riverscapes	https://www.riverscapes.net/
Sage-grouse Initiative	https://www.nrcs.usda.gov/programs-initiatives/sage-grouse-initiative
Terrestrial AIM Data Portal	https://www.blm.gov/AIM/TerrestrialDataPortal
TNC Resilient Land Mapping Tool	https://maps.tnc.org/resilientland/
UN Biodiversity Lab	http://unbiodiversitylab.org/en/

APPENDIX D: TERRESTRIAL AND LOTIC MASTER SAMPLE

BLM Solar Energy Zones	http://blmsolar.anl.gov/maps/shapefiles/
Land Ownership, BLM District and Field Offices, BLM Grazing Allotments, BLM Herd Management Areas	geocommunicator.gov
Landfire Biophysical Settings	http://www.landfire.gov/datatool.php
Omernik and EPA Ecoregions (Levels 1, 2, 3, 4)	https://www.epa.gov/eco-research/ecoregions
SSURGO Map Unit	http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627
State and County Boundaries	census.gov
Strahler Stream Order Categories	http://www.horizon-systems.com/NHDPlus/NHDPlusV2_data.php
Watershed Boundaries – HUC 6, 8, 10 and 12 Digit	http://nhd.usgs.gov/data.html

1.0 Introduction

The Bureau of Land Management (BLM) is responsible for managing approximately 245 million acres of public land in the U.S. for a variety of uses including livestock grazing, energy development, wildlife habitat, timber harvesting, and outdoor recreation, while conserving natural, cultural, and historical resources. In 2004 during a bureau-wide review, the Office of Management and Budget (OMB) found that the BLM was unable to report on the national ***condition*** of public lands with their available data and recommended that the BLM examine their monitoring activities and develop an approach which would enable ***reporting*** beyond the individual project level. In response, the BLM developed the Assessment, Inventory, and Monitoring (***AIM***) Strategy to supply monitoring data for use at multiple scales and across multiple programs. The BLM's AIM program was then built on the ***AIM Strategy*** and enables the Bureau to "prepare and maintain on a continuing basis an inventory of all public lands and their resource and other values" as required by Federal Land Policy and Management Act (FLPMA, Sec. 201a) (BLM 2022b). The AIM Strategy seeks to reach across programs, jurisdictions, stakeholders, and agencies to provide standardized information to inform land management decisions (Toevs et al 2011).

The AIM Strategy provides a standard, quantitative approach to assessing the health of uplands (terrestrial), rivers and streams (lotic), and riparian and wetland ecosystems to inform management of public lands. AIM data are a reliable, high-quality data source that meets Council on Environmental Quality and Data Quality Act Guidelines. The AIM dataset is also one of the largest available datasets to inform resource management decisions on public lands. AIM data may be used alone or in conjunction with other types of data in a "multiple lines of evidence" approach to inform decision-making. For example, AIM data can provide a snapshot of current conditions and a means of tracking resource changes over time across a ***Land Use Plan (LUP)*** Planning area or a National Environmental Policy Act (NEPA) ***project area***, while other data may provide more detailed ***analysis*** of specific areas and land uses (e.g., land health evaluations and determinations, land treatment and restoration effectiveness reports). Assessments such as BLM's Technical References (TR) Interpreting Indicators of Rangeland Health (IIRH) (TR 1734-6), Proper Functioning Condition (PFC) (TR 1737-15 and TR 1737-16), or Greater Sage-Grouse (GRSG) ***Habitat Assessment Framework (HAF)*** (TR 6710-1) should be used to augment ***status*** and ***trend*** information and should incorporate AIM ***indicators*** and methods to complete the assessments when possible. In addition, other high-quality information that describes terrestrial, lotic, and riparian and wetland conditions, including satellite-derived maps, can be used to inform assessments.

This Desk Guide illustrates how the AIM strategy is implemented through natural resource monitoring using AIM methods for a variety of applications. Further and most centrally, this Desk Guide describes how to implement an AIM project by explaining the steps from project initiation through data use and analysis. For more information on the AIM Strategy visit the AIM Website.

2.0 AIM Desk Guide Overview

The BLM ***National AIM Team*** provides and maintains this Desk Guide for use by BLM AIM State Leads, Monitoring Coordinators, Analysts, and other Program Leads (herein collectively referred to as "State Office AIM Team"), as well as AIM Project Leads, and other AIM practitioners involved in the process of data collection, data use, and management of public lands. Public and internal versions of this Desk Guide are provided on the AIM Website. The public version is intended to share information about AIM but internal links have been removed (denoted by grey highlighted text) associated with working files. The internal version is provided with live links to internal BLM working files, network directories, and SharePoint sites.

This Desk Guide describes the process to implement the six principles of the AIM Strategy by providing guidance on how to initiate and plan a monitoring project, how to create a monitoring design, how to perform data collection and management, and lastly suggests a standard workflow for data use. Implementing an AIM project is an iterative process and involves four main phases: planning and project initiation, design, data collection, and analysis and reporting (Figure and Figure 2-2). Completion of one phase helps to inform, and leads to, subsequent phases.

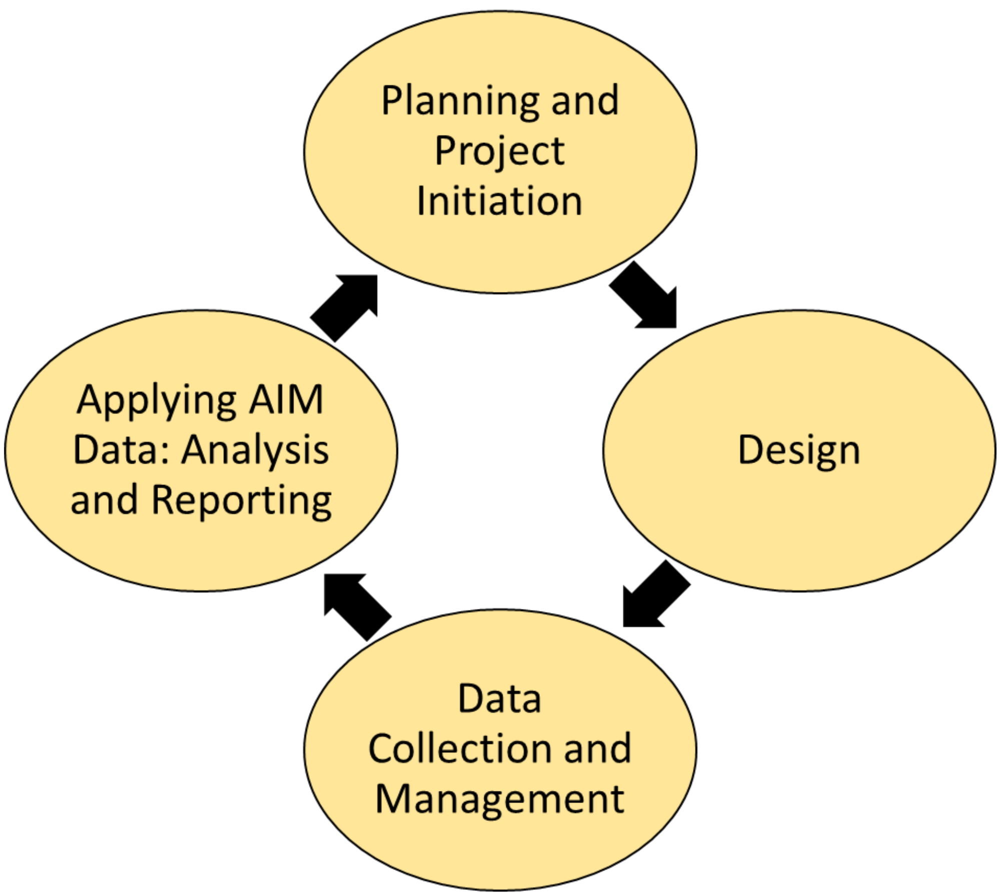

Figure 2-1. The four main phases of AIM: monitoring program planning and project initiation, design, data collection, and application of monitoring data into management.

AIM Strategy – The Six Principles

The AIM Strategy was developed to provide decision-makers with quantitative data at multiple spatial scales to assist in adaptively managing public lands at the agency-wide level. The AIM Strategy provided an alternative to developing monitoring programs for each specific use or program. The goal of the AIM strategy is "to provide the BLM and its ***partners*** with the information needed to understand resource location and abundance, condition, and trend, and to provide a basis for effective adaptive management." (Kachergis et al 2022; Toevs et al 2011). More information about the AIM principles can be found in the AIM Strategy (Toevs et al. 2011) and a recent publication updating these principles (Kachergis et al. 2022).

Resource information is needed at multiple scales to manage public lands effectively. This includes gathering information about resource extent, condition and trend, ***stressors***, and the location and nature of authorized uses, disturbances, and projects. To accomplish acquisition and assessment of this information, the AIM Strategy integrates six fundamental principles which include:

- Structured implementation to guide monitoring program development, implementation, and management decisions.
- Standardized field methods and indicators to allow data comparisons throughout BLM and its partners.
- Appropriate ***sample designs*** to minimize bias and maximize what can be learned from collected data.
- Integration with remote sensing to optimize ***sampling*** and calibrate continuous map products.
- Standardized and centralized electronic data capture, ***data management***, and stewardship to ensure data quality, accessibility, and use.
- Standardized workflows and analysis frameworks for data use that empowers land managers to make data-supported decisions.

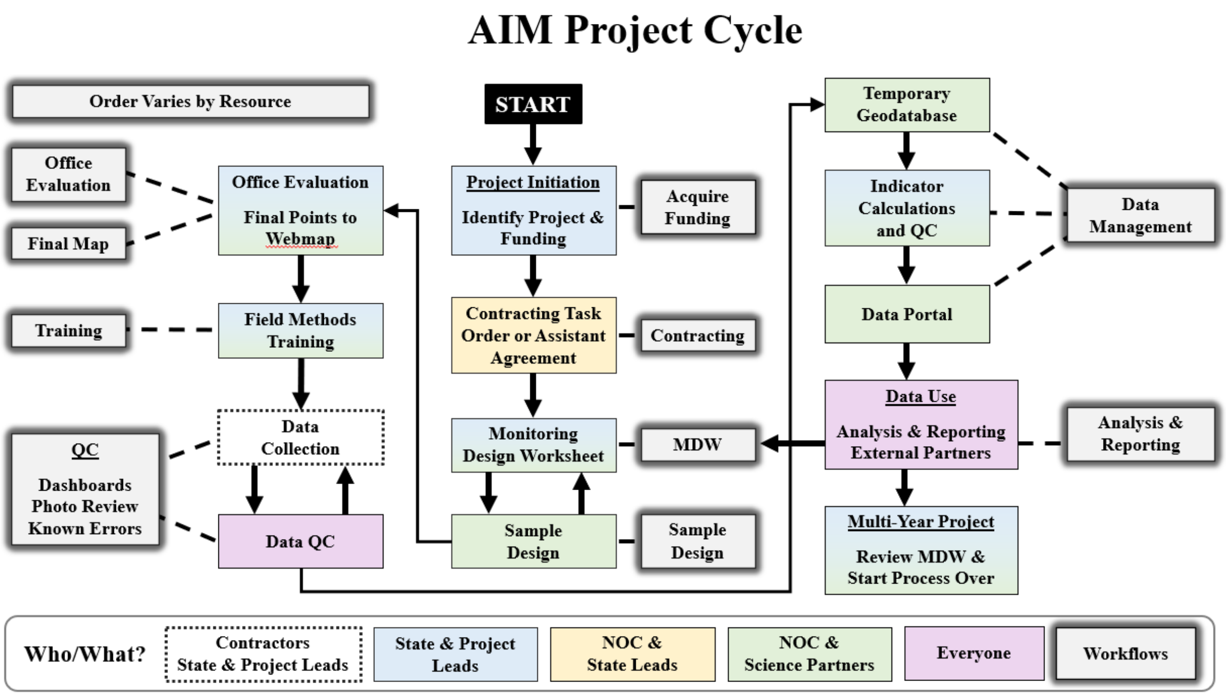

Figure 2-2. A detailed diagram of the AIM Project Cycle

AIM Data Availability and Access

As of 2024, standardized AIM data are available at more than 50,000 terrestrial, 4,500 lotic, and 850 riparian and wetland monitoring locations from Alaska to New Mexico. These data can be visualized and accessed both internally (DOI only) and externally (public only) on the AIM Data Portals link through the AIM Website.

Example Applications of AIM Data

- Evaluating the attainment of BLM ***land health standards (LHSs)*** (43 CFR §4180.2).
- Informing grazing permit decisions (43 CFR §4100).
- Tracking the spread of invasive species and prioritizing treatment areas.
- Assessing reclamation and restoration treatment effectiveness, including after fires.
- Assessing habitat conditions for species of management concern (e.g., native fishes, mule deer habitat, GRSG (Sage-grouse Habitat Assessment Instruction Memorandum 2022-056),).
- Determining the effectiveness of, and adaptively managing, LUPs (Land Use Planning Handbook H-1601-1; BLM Instruction Memorandum 2023-043).
- Assisting in the completion of national, regional, and state-based assessments to prioritize restoration, conservation, and permitted uses.

Applications of AIM data use can be found on the AIM website (see Section 3.2 for web links) and on the BLM-AIM SharePoint (for DOI users). AIM data applications are often directed by policy or integrated with other program objectives; a list of BLM Policy related to BLM program integration with AIM can be found in Table B-1.

2.1 Audience

This Desk Guide is intended to be used by all AIM practitioners from the local to the state and national levels. National teams comprise of Headquarters (HQ), ***National Operations Center (NOC)***, and ***Science Partner*** personnel. State levels usually include the State Office AIM Team. Local levels usually include AIM Project Leads, resource specialists, data collectors, and many others. A broad list of roles and responsibilities associated with these practitioners can be found in Section 9.0.

2.2 General AIM Concepts

There are some general concepts that users will encounter many times throughout the AIM process. These are briefly introduced and summarized here and will be discussed in more detail throughout this Desk Guide. Natural resource monitoring is most effective when planned and implemented as part of a coordinated approach including with District/Field Office Resource Specialists and Managers. The AIM strategy embraces this concept and encourages an Interdisciplinary Team (IDT) approach to planning AIM data collection. The AIM Project Leads should work with the relevant IDT and should support different viewpoints and fields of expertise, utilizing specialists from the Field, District, and State Office levels. It is recommended for Field or District Office resource specialists to work with a State Office resource lead or Monitoring Coordinator as well as with more local District/Field Office Managers to ensure that AIM projects meet local, state, and national management goals.

Management Questions and Management Goals

Management questions and ***management goals*** are the broad goals or desired outcomes land managers are trying to achieve with land management. Management questions relate to management actions, while management goals provide the context for why monitoring information is needed and how it will be used. These are frequently derived from planning documents and policy such as LHSs and ***resource management plans (RMPs)***. The process of developing management questions and goals should involve an IDT approach, and it is helpful to think broadly across programs and jurisdictions to identify the desired conditions in the landscape of interest. Developing management questions and goals is, in part, dependent upon resource and management concerns within a given ***study area***. Management questions and goals that are developed with an IDT have the broadest utility and support. District/Field Office Managers may also be included on an IDT, or consulted, to identify management goals and office priorities as they play an important role as decision-makers for NEPA analysis. Detailed information on management questions and goals can be found in Section 4.3, Step 1a.

Monitoring Objectives

Monitoring objectives should be developed from management goals and should include ***benchmarks***. Monitoring objectives will shape data collection efforts and subsequent utility of the data in analysis. Identifying monitoring objectives is one of the first and most important steps in the AIM process and will be the focus of a monitoring effort. Paired with management questions and goals, monitoring objectives inform all subsequent decisions, including where and how points are selected and what will be measured and at what frequency. The most useful and impactful monitoring objectives will include at least one defined benchmark. Benchmarks assist with monitoring data interpretation and help provide context to the data. Benchmarks are values (or ranges of values) for a given metric or indicator that establish desired conditions and are useful for management. Benchmark development is an iterative and ongoing process. At the outset, benchmarks are developed from any existing information such as policy, primary literature or existing monitoring data, and values may be revised as more data are collected to inform the understanding of condition. Information on setting monitoring objectives can be found in Section 4.3, Step 2b. Setting benchmarks is an important and often challenging process; an overview discussion of benchmarks can be found in Section 6.0. A more detailed discussion, beyond the scope of the main text of this Desk Guide, is included in Section 9.0 – Appendix C.

2.3 Remote Sensing Overview

Remote sensing is an integral part of the AIM process and helps inform the various phases of the AIM strategy including planning and project initiation, design, data collection, and analysis and reporting. A brief summary of the integration of remote sensing is provided here and further discussion is included within each section describing the four phases of the AIM process.

Integration with Remote Sensing

Remote sensing can be incorporated in any step of the AIM process and is frequently used for initial design creation, trip planning, ***quality control (QC)***, and data analysis and reporting. Remote sensing is being increasingly incorporated into new and existing AIM workflows. Remotely sensed data offer a broad scale complement to field surveys to develop maps of resource extent, conditions, and trends. Broadly defined, remote sensing refers to detection of information about an object (e.g. vegetation) without being in direct contact with that object. However, remote sensing in the AIM program typically refers to information recorded by passive sensors. In this context, passive remote sensing, including multi-spectral imagery (Landsat and Sentinel-2), provide information on surface reflectance at various points along the electromagnetic spectrum. These data can be used to differentiate surface cover, including various vegetation functional groups, and characterize vegetation health. For example, decreased reflectance in the near-infrared range (~850 nm) and increased reflectance in the short-wave infrared range (~1500-2000 nm) are indicative of stressed vegetation. Importantly, the data archive of these sensors continues to grow (e.g., a Landsat satellite has been in continuous orbit for more than 50 years), allowing for longer-term change detection and trend analysis. At the same time, a growing number of small satellite constellations provide greater spatial and temporal resolution (e.g., Planet Labs), some with daily revisit, providing a novel perspective on phenology and surface change monitoring. Active remote sensing, including Lidar and Radar, can provide information on the structure and physical characteristics of the surface such as the structure and density of surface vegetation. Active sensors are expected to play a more prominent role in remote sensing in the near future.

While remotely sensed data cannot yet provide the level of detail achievable in a field survey, we can model the relationship between remotely sensed data (e.g., reflectance) and field surveys to predict the occurrence of species more broadly. This is the guiding principle behind fractional vegetation cover products where a statistical relationship is developed between AIM field data and Landsat reflectance values, then used to predict fractional vegetation cover range-wide or back in time (e.g., Rangeland Analysis Platform, RCMap). Furthermore, satellite remote sensing can be used to fill gaps between field sampling over space and time (Allred et al. 2022). Once a statistical relationship is developed, models can be applied to satellite imagery from a given year to produce continuous predictions across space for that particular year. Collectively, these annual snapshots provide baseline landscape condition and trend information on a given plant functional type. When studying lotic systems, remotely sensed data can help identify watershed-level disturbances (e.g., the extent and severity of wildfires) that could drive hydrological changes and turbidity. Remote sensing can also help in mapping the extent and variability in riparian and wetland systems as the spectral signature of water differs markedly from soil and vegetation. Taken together, remotely sensed data offer a complement to vector geospatial data and field surveys like AIM to form a more complete picture of ecosystem characteristics and change.

Remote Sensing Tools – Examples of remote sensing tools commonly used alongside AIM:

- RCMap
- Rangeland Analysis Platform
- Landscape Cover Analysis and Reporting Tools (LandCART[1])
- Climate Engine BLM Site Characterization Report
- Climate Engine Web Application

[1] As of June 10, 2024, LandCART has entered a strategic pause since its dynamic architecture is no longer compatible under the current agreement with Google. However, pending future funding, LandCART will be rebooted with a modified design intended to provide a similar product to users.

3.0 Planning and Project Initiation

3.1 Overview

Planning and implementing an AIM project can be simple or complex depending on the needs and scale of the monitoring effort. This section discusses the five basic steps to plan and implement an AIM project and identifies specific people who will be involved and their roles and responsibilities in the process. Many offices may have multiple ongoing AIM efforts across different resources (terrestrial, lotic, and/or riparian and wetland) and different scales (LUP, allotment, or treatment scale). Offices wanting to implement an AIM project should learn about what monitoring has already occurred in their local field office or district office to provide context for planning continued monitoring efforts.

3.2 Tools

There are several tools that can assist with the planning and initiation phase when developing an AIM project. The primary tasks to consider when planning a project include budget, training, and sample design development.

Budget Tools – General information to assist with securing project funding:

- HQ 780 Budget 101
- AIM Budget Cheatsheet

Programmatic Policy to Support AIM Implementation:

- AIM Related Policy
- Assessment, Inventory and Monitoring (AIM) data application to Land Use Plan Effectiveness and NEPA Analysis:
    - IM 2023-043
    - IM 2023-043: Applying AIM to Land Use Planning and NEPA

Training Tools:

- AIM Project Leads Training – DOI Talent course sign-up
- AIM Training – Core Field Methods Trainings

General AIM Tools:

- AIM SharePoint
- AIM Website and AIM Data Portals
- AIM Resources
- AIM Data Use Webinars
- Remote Sensing Tools (See Section 2.3)
- Roles and Responsibilities (See Section 9.0)

3.3 The Five Basic Steps to Planning and Project Initiation

An AIM Project is typically initiated by a Field or District Office. It may also be initiated by the AIM State Lead or AIM Monitoring Coordinator who will coordinate with the local AIM Project Lead(s). The timing and level of involvement with the National AIM Team will vary by resource and project type. The following five steps to planning and initiating an AIM project are discussed in this section (Figure 3-1).

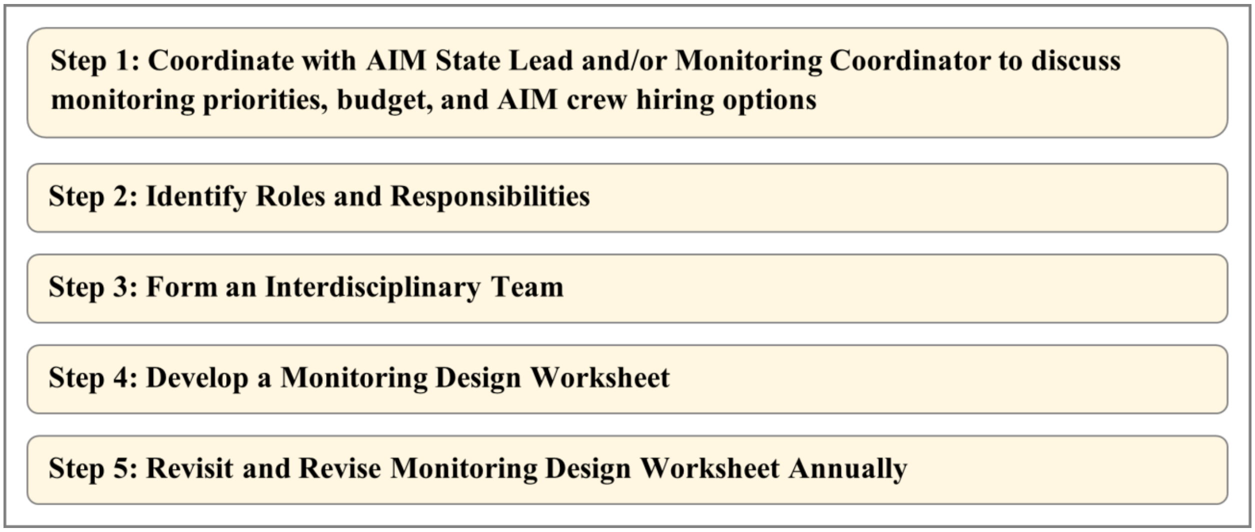

Figure 3-1. The five steps to the Planning and Project Initiation phase.

Step 1: Coordinate with AIM State Lead and/or Monitoring Coordinator to discuss monitoring priorities, budget, and AIM crew hiring options

The first step in planning and initiating AIM efforts is to identify monitoring priorities and avenues for funding AIM efforts in coordination with the appropriate Field, District, and State Offices. For more information about how AIM is integrated with other BLM program work review Section 9.0, Appendix B.

Once monitoring priorities are identified, funding request(s) should be submitted to the program(s) that benefit from the monitoring work. Budget submission processes vary by office and program; talk to your AIM State Lead and/or State Monitoring Coordinator for support in making the appropriate budget requests. Given that AIM is a standard dataset that informs questions shared across multiple programs (e.g., LHS attainment), it is often possible to pool resources from multiple programs and thus gain efficiencies in completing monitoring work.

Data can be collected by dedicated AIM crews, AIM Project Leads, specialists, or other field office staff. Typically, most AIM data are collected by dedicated AIM crews. If choosing to hire AIM crews, work with the AIM State Lead and/or Monitoring Coordinator and the local Field or District office management to explore hiring options and establish timelines for the project. AIM crew hiring can be accomplished through a variety of mechanisms including hiring BLM seasonal technicians, or hiring AIM crews through a contract or assistance agreements. Hiring costs depend greatly on the hiring mechanism and local factors. Work with the AIM State Lead or Monitoring Coordinator to estimate costs while considering the type of data collectors that will be utilized. See Section 5.3, Step 1 for more information about hiring data collectors. Refer to Figure 3-2 for general timelines of each phase of AIM implementation. Depending on the geographic region, sample period, and purpose for monitoring, the tasks in this calendar might be shifted in time. However, the general pattern of tasks top to bottom applies to the majority of AIM Projects.

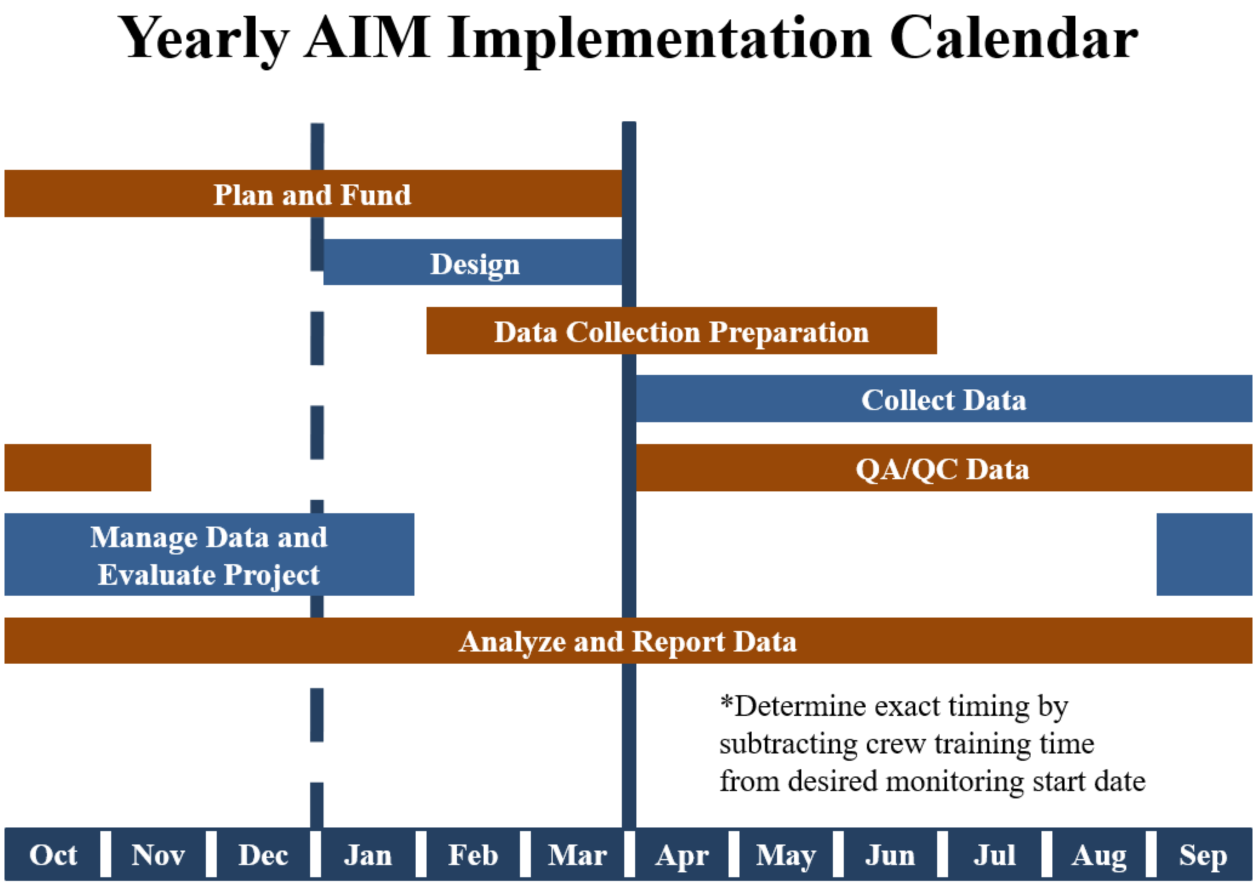

Figure 3-2. The Yearly AIM Implementation Calendar outlines the general time of year when each phase of AIM Implementation should be completed.

Using Remote Sensing to Inform Monitoring Priorities

In addition to field data, consider available remote sensing data sources to inform monitoring planning and to provide needed indicators for land management. For example, many monitoring applications use remote sensing products to locate monitoring sites within areas of interest. Remote sensing products, such as fractional vegetation cover data, provide indicator estimates that may help with project planning such as total plant foliar cover and bare ground across landscapes and through time.

Remote Sensing Products

Remote sensing products can be useful to identify disturbance and recent changes in vegetation. For example, an Analyst may be interested in identifying recent disturbance in the vicinity of a planned AIM monitoring location that might not be captured in an aerial photo as even the most recent photos could have been collected several years earlier. The Change and Disturbance Event Detection Tool (CDEDT) can be used to efficiently identify and vectorize surface disturbances using Sentinel-2 imagery (Figure 3-3). This could identify areas that would benefit from additional field monitoring such as those increasingly dominated by invasive species.

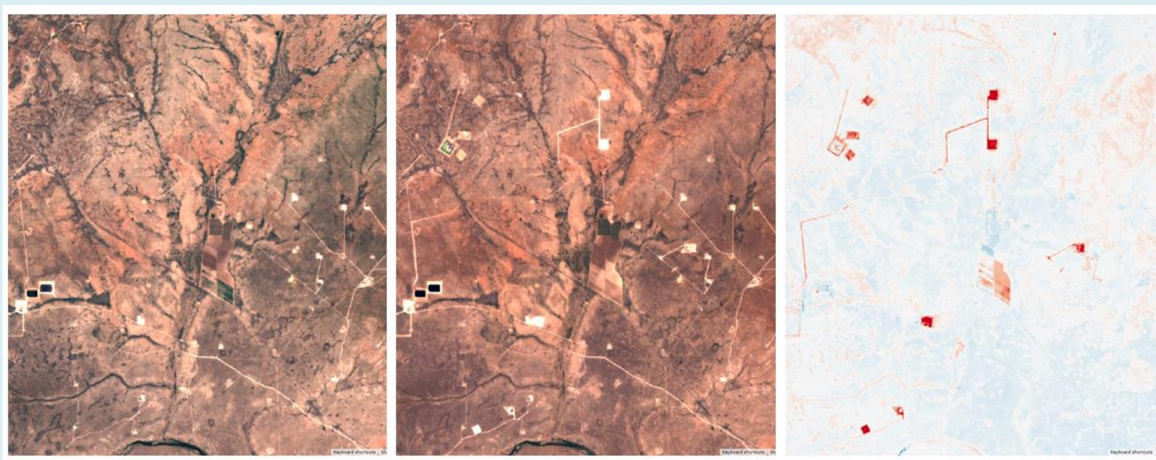

Figure 3-3. Remote sensing product shows oil and gas development near Carlsbad, New Mexico between August 2022 (left) and August 2023 (center), and a differenced image highlighting changes in the area in red (right).

Step 2: Identify Roles and Responsibilities

The second step in the process is identifying the roles and responsibilities for each member or group involved in an AIM project, which is essential to the success and longevity of any monitoring effort. Individuals and groups involved in an AIM project include: (1) National AIM Team members; (2) the AIM State Lead and/or Monitoring Coordinator; (3) District/Field Office AIM Project Lead; (4) the IDT; and (5) the AIM crew. See Section 9.0, Appendix A for more information and detailed descriptions of these roles.

Step 3: Convene an Interdisciplinary Team

The AIM strategy is intended to be used across programs and resources. The AIM Project Leads are considered the point of contact for local AIM monitoring efforts and are encouraged to collaborate with other resource specialists in their office to begin planning workload, funding, and identifying management goals for Lotic, Terrestrial, and/or Riparian & Wetland AIM efforts. This process ensures engagement across the district or field office and that monitoring is meeting the needs of all stakeholders. The IDT is also an essential group for establishing benchmarks used during design, analysis, and reporting steps. It is recommended that the team collaborate on the process of setting benchmarks concurrent to any AIM effort. This collaboration will ensure monitoring designs will answer management goals, design creation can proceed quickly, and data can be analyzed efficiently.

Step 4: Develop a Monitoring Design Worksheet

The ***Monitoring Design Worksheet (MDW)*** is a template used to guide and document objectives to develop successful monitoring efforts. The MDW communicates sample design specifications to the National AIM Team for creating a monitoring design and to other BLM personnel to learn more about local AIM monitoring. Completing the worksheet is essential when planning a design but will also inform subsequent data analyses. In Section 4.3, the steps to complete a MDW will be covered, including how to properly track management goals, monitoring objectives, specific data needs, the appropriate sample design to employ, and all design specifications details.

Step 5: Revisit and Revise Monitoring Design Worksheet Annually

Once created, MDWs should be reviewed and revised annually. Monitoring in an adaptive management framework requires that data are analyzed regularly. Reviewing data that were collected and whether the data are addressing management goals can help practitioners decide if adjustments to the monitoring approach are necessary. In addition, it’s a good way to get new IDT members up to speed on ongoing AIM efforts.

Remote Sensing Helps Inform MDW Revisions

The first step in the MDW is to develop management goals related to resource conditions and trends. A major disturbance in a LUP Planning design study area may trigger new management goals for that area that may necessitate a short- or long- term modification to implementation of the original sample design or even the creation of a project level design. Remote sensing can be used to inform the planning process. For example, while vector fire perimeters can identify field sampling plots that may have burned, a burn severity image can provide more detail on the extent and severity of fire to the landscape, as well as whether monitoring plots were directly affected. Remotely sensed data can also identify other surface disturbances that are often not captured in other vector geospatial datasets.

4.0 Design

4.1 Overview

When starting a new or reviewing an existing AIM sample design, consult with your IDT to identify specific management questions and goals of interest. Once these questions are identified, an appropriate monitoring plan can be developed to make necessary technical decisions using an AIM sample design. AIM encourages the use of appropriate sample designs for the management questions at hand. For example, restoration questions may require a Before–After - Control–Impact approach, LUP/RMP evaluations often require a random design, and a grazing specific question might be approached with a Key Area/Designated Monitoring Area. The most common AIM sample designs are a combination of random and ***targeted sample points***. ***Spatially balanced random designs*** are a random draw of points or stream reaches on the landscape intended to report conditions across the landscape. *Targeted* designs are points that are manually selected to ensure data is collected at a very specific non-random location. A random design is usually drawn by the National AIM Team (see Step 5), and targeted points are usually selected by the Project Lead. The development of a random, targeted, or combination designs should be driven by management goals and documented carefully through the MDW. The National AIM Team is available to provide guidance and support for deciding and implementing any appropriate sample design.

The process of designing a monitoring and assessment effort can be broken down into a series of steps (Figure 4-1). This design section lists the steps in the order that they are normally completed, but there is no "single" way to design a monitoring program; the steps should be viewed as an iterative process. As an IDT work through steps in the design process, decisions made earlier in the process may require modification. By completing the MDW during the design process, the IDT can ensure the completeness of the design. A link to the MDW template can be found in Section 4.2 (see below).

Each step in the design process (Figure 4-1) is tied to a step in the MDW. Once a MDW is drafted, the Project Lead should coordinate with the appropriate State Lead and National AIM Team to review and update as necessary. Completion of the worksheet is an iterative process, and it can be revised and updated throughout the life cycle of an AIM project. To request further assistance, contact the appropriate resource personnel at the BLM NOC.

4.2 Tools

There are several tools that can assist with the design phase of an AIM project however the primary tool used to plan a project is the MDW. While the National AIM Team will typically create designs using the completed MDW (see Section 4.3, Step 5), terrestrial treatment or allotment level designs may also be created by AIM Project Leads using the Balanced Design Tool (BDT) (formerly known as the "Shiny Tool").

Monitoring Design Worksheet Tools – Monitoring Design Worksheet tools include worksheet instructions, a completed example document, and a blank MDW template. These resources can be found on the AIM Resources webpage (see Section 3.2):

- Monitoring Design Worksheet Instructions
- Monitoring Design Worksheet Template
- Example Monitoring Design Worksheet
- Balanced Design Tool (BDT) – A web-based tool to draw sample designs following the GRTS algorithm using user input parameters such as study area, ***stratification***, and ***sample size***.
- Trend Assessment

Resource Library Webpages – includes links to Terrestrial, Lotic, and Riparian & Wetland AIM Core Methods Protocols, AIM Data Management Protocols (QC procedures), AIM Design and Site Evaluation Protocols, and other supplemental protocols:

- AIM Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems
- AIM National Aquatic Monitoring Framework: Field Protocol for Wadeable Lotic Systems
- AIM National Aquatic Monitoring Framework: Field Protocol for Lentic Riparian and Wetland Systems
- Interpreting Indicators of Rangeland Health, Version 5

4.3 The Six Steps to Completing a Monitoring Design Worksheet

The MDW is designed to document all the decisions that inform the completed monitoring design. It serves as the metadata document for the design and is a valuable tool for design development and eventual analysis of the data collected through the design.

Step 1: Develop management goals; select additional ecosystem attributes and indicators to monitor

- Step 1a: Develop management goals related to resource condition and (if necessary) resource trend
- Step 1b: Select indicators to monitor and additional ecosystem attributes

Step 2: Set study area and reporting units; develop monitoring objectives

- Step 2a: Set the study area, reporting units, define the target population, document the geospatial layers used to describe these areas, and select the appropriate design or the existing sample designs to be used for revisits
- Step 2b: Develop monitoring objectives related to resource condition and/or resource trend

Step 3: Select criteria for stratifying the study area (only if necessary)

Step 4: Select and document supplemental monitoring methods; estimate sample sizes; set sampling frequency; and develop implementation rules

- Step 4a: Select and document supplemental monitoring methods (optional/if required)
- Step 4b: Collect and evaluate available data to determine sampling sufficiency and the validity of the strata (if available)
- Step 4c: Estimate sample sizes (in coordination with National AIM Team)
- Step 4d: Define revisit parameters if using a revisit design (use the revisit frequency table to document decisions made in this section)
- Step 4e: Develop implementation rules

Step 5: Select monitoring locations

Step 6: Data management plans

Figure 4-1. The Six Steps to Completing a Monitoring Design Worksheet.

Step 1: Develop management goals; select additional ecosystem attributes and indicators to monitor

Step 1a: Develop management goals related to resource condition and (if necessary) resource trend

One of the first and most important steps in the AIM process is identifying the management goals of a monitoring effort. Management goals should provide the context for why monitoring information is needed and how it will be used.

After gaining management approval, assemble an IDT to review existing documents which describe management history, planned management actions, previous data collection efforts, and relevant policy. Some examples of documents that should be included in this review are:

- BLM Land Health Handbook (4180)
- Land Health Standards (LHSs)
    - Ecological processes
    - Watershed function
    - Water quality and yield
    - Threatened and endangered and native species
- Sage-grouse habitat management goals
- Resource Management Plans (RMPs)
- Commitments in NEPA documents or biological opinions

Based on this review, consider what ***management goals*** the IDT should synthesize. Examples of management goals include statements like “maintain suitable sage-grouse habitat” and “improve stream condition post-treatment.” Provide citations to the relevant supporting background documents. Since many of these documents relate back to the LHSs for the area, LHSs are a good place to start.

During this step, it is helpful to think broadly across programs and jurisdictions to identify the desired conditions in the landscape of interest. Multiple management goals should be addressed by a monitoring effort but should also be balanced with available resources (e.g., ***sample points***, AIM crews, funding). Identifying all management goals at the initial planning stage can increase efficiency in sampling efforts by ensuring the necessary data required to address all management goals is collected in a single site visit.

When making land management decisions, resource condition trend is often an important objective for reporting. Trend can be detected using randomized designs in which each location is sampled only once, but designs which involve revisiting locations are more sensitive to changes in trend. The need for a revisit design and ratio of revisits to non-revisits (new sampling locations) should be determined by the objectives and how they balance resource conditions and trend (see Step 4c).

Step 1b: Select indicators to monitor and additional ecosystem attributes

The core and contingent AIM methods were selected because they are relevant across BLM managed ecosystems and because the data they collect can be used to address many BLM monitoring and assessment requirements, including LHSs. For example, vegetation cover and composition data might be useful to address habitat, grazing, and fire recovery objectives.

Review and select monitoring methods that relate to management goals. For LUP/RMP related management goals, all ***core methods*** are required at the initial site visit. Exceptions can be made for a reduced set of the core methods at subsequent sample visits, depending on the resource (Terrestrial, Lotic, or Riparian and Wetland). For other types of management goals, core methods should be considered, but are not required. Core and ***contingent methods*** should be selected to meet management goals, documented in the MDW, and communicated to the National AIM Team (via MDW or Survey123 form schema, contact your State Lead if details are needed). If there are management goals which will not be satisfied by the core and contingent methods, consider adding ***supplemental methods***. Documentation of supplemental methods occurs in Step 4.

Step 2: Set study area and reporting units; develop monitoring objectives

Step 2a: Set the study area, reporting units, define the target population, document the geospatial layers used to describe these areas, and select the appropriate design or the existing sample designs to be used for revisits

First, identify the ***study area*** or geographic extent of the resource to report on. The study area should include the entire landscape area or extent of the resource that will be monitored to meet management goals. Some common study areas are field offices, grazing allotments, watersheds, habitat areas, or streams.

Next, determine the desired ***reporting units*** (e.g., grazing allotment, watershed, field office, district, state). Reporting units are the geographic areas for which indicator estimates will be computed and thus there is a minimum required sample size. The scale and distribution of reporting units therefore helps determine the point density and distribution requirements. Reporting units are typically smaller than the study area and nested within it, but depending on the management goals, a reporting unit and the study area can be the same. Generally, reporting units are administrative areas where AIM data need to be summarized for a particular analysis. Although it is highly recommended that reporting units be identified during design planning, they can be defined at any point during an AIM project's life cycle because they do not affect how AIM data are collected. The number of acres (for terrestrial or riparian and wetlands) or stream kilometers (for lotic) in each of the reporting units is documented in Step 3.

Define the ***target population***. The target population refers to the overall resource being monitored. A target population must be limited to only places where sampling locations may be placed and fall entirely within the study area. The definition of the target population should contain specific information about the resource of interest: its spatial extent, ownership status, and size (e.g., all streams versus just first order streams). Examples of target populations include: all BLM lands within a study area; all perennial, wadeable streams on BLM land; all riparian and wetland areas on BLM land; or sage-grouse habitat on BLM lands (Herrick et al. 2017). A ***sample frame*** is a representation of the target population such as a geospatial feature or a list of features. Sample points are selected from the sample frame which represents the target population.

Once the study area, reporting units, and target population are established, document the geospatial layers used to delineate these polygons. When creating sample designs in study areas that contain existing or historical sample designs, consider the historic layers, or consolidate layers along the historic perimeter lines that were used to generate points in the original sample design for terrestrial, lotic, and riparian and wetland resources. Lotic sample designs may refer to the ***master sample***. See Section 9.0, Appendix E for more information. Information about the number of acres (terrestrial) or stream kilometers (lotic) in the study area will be added in Step 3.

Selecting the Appropriate Designs
Based on your target population and management goals determine the appropriate design that will be needed to properly analyze data (See Section 6.0 for data analysis options). Some common design types, or selection methods, that might be appropriate include Generalized Random Tessellated Stratified (GRTS) design, random systematic, simple random designs, and targeted, but are generally defined as either Random or Targeted. A combination of random and targeted designs may be needed to fully address all management goals.

Random designs are used to make inference to a target population. Standard LUP/RMP AIM designs, or other large-scale analyses, use the GRTS algorithm to generate statistically valid, spatially balanced, and random sampling locations (Stephens and Olsen 2004). These designs randomly distribute points throughout the sample frame in a spatially balanced manner, considering pre-determined ***strata*** when applicable. This type of design allows inference to be made to the entire area for which the design was created and avoids the bias created from selecting locations of interest directly. Other types of random designs may be appropriate for different use cases (e.g., systematic random, simple random).

Targeted designs are encouraged when random designs do not sufficiently address the management goals (e.g., desire to understand grazing impacts in a certain allotment or specific area of interest). A targeted approach may also be preferred in areas where there is not a sample frame available which adequately represents the target population, as in the case of outdated ***National Wetlands Inventory (NWI)*** mapping or unrefined treatment implementation polygons. Targeted points can be valuable for addressing location specific monitoring questions (e.g. restoration or treatment effectiveness). However, data from targeted points cannot be used to make statistical inferences beyond the sampled locations.

Targeted points may be new locations that need to be identified or they may be existing locations, such as an existing design point that is sampled out of sequence or a long-term trend point that has been sampled in the past. For new targeted points, identify the ruleset for locating the points. Some common rulesets include manually placing a point on a map within a feature of interest or placing points in the field based on the presence of a feature of interest that can’t be identified from the office (e.g., a sage-grouse nest).

Lastly, if developing a design that will have revisits (i.e., monitoring locations will be resampled), additional information will be required to create an appropriate revisit design. Targeted and Random points can be resampled to assess trend. By default, GRTS designs run by the National AIM Team can easily incorporate revisits at various intensities to better assess trend. Planning a revisit design includes assessing which existing sample points will be incorporated into the sample design, how many points should be revisited, and the revisit interval (see Step 4d for more information about revisit designs).

Lotic sample designs may refer to the master sample. See Section 9.0, Appendix E for more information. Information about the number of acres (terrestrial) or stream kilometers (lotic) in the study area will be added in Section 4.3, Step 3.

Step 2b: Develop monitoring objectives related to resource condition and resource trend

Monitoring objectives are quantitative statements that provide a means of evaluating whether management goals were achieved. Monitoring objectives should be specific, quantifiable, and attainable based on ecosystem potential, as well as resource availability, and the sensitivity of the methods. Quantitative monitoring objectives may be available in a variety of places, or they may be developed in the monitoring planning process.

Objectives guide how and where to focus sampling efforts so that there are sufficient data to address management goals and ensure sample designs are meeting the project needs. While many projects take place across a large area (e.g., within the boundary of an LUP/RMP, Field Office, or District Office), sample designs can also be created for much smaller projects such as restoration treatment areas. If more points are needed in specific areas, targeted points can be used, or an ***intensification*** sample design can be drawn over part of an existing sample design to ensure that enough necessary information can be obtained within those areas.

Begin by listing management goals that were set in step 1 in column 1 of the **Resource Condition and Trend Objectives Tables** found in the MDW (see Section 4.3, Step 1). While filling out the table, each management goal should have one or more corresponding monitoring objectives. *Projects with differing objectives among reporting units will need to complete separate* **Resource Condition and Trend Objectives Tables** *for each reporting unit*. Ideally monitoring objectives should be set prior to data collection, but in some cases, these can be determined during the analysis phase or as needed for different data uses and applications.

Monitoring objectives should include at a minimum:

- The *indicator(s)* that will be monitored (e.g., percent cover by perennial grasses, stream bank stability and cover, percent bare ground)
- Quantitative *benchmark(s)* for each indicator
- *Reporting unit,* or area, where the objective is being assessed

The most robust monitoring objectives include:

- The *threshold* or proportion of the resource (or points in some cases) that is required to meet the benchmark.
- A *time frame* for evaluating the indicator(s)

- Desired ***confidence level*** (e.g., 90% confidence)

Combining both the minimum and most robust components into one objective will be the most informative and should follow a basic monitoring objective formula template (Figure 4-2). An example of a monitoring objective for the goal to “maintain suitable sage-grouse habitat” might be “sagebrush cover should be between 25% and 50% for at least 75% of sage-grouse habitat in the field office with 80% confidence this year.”

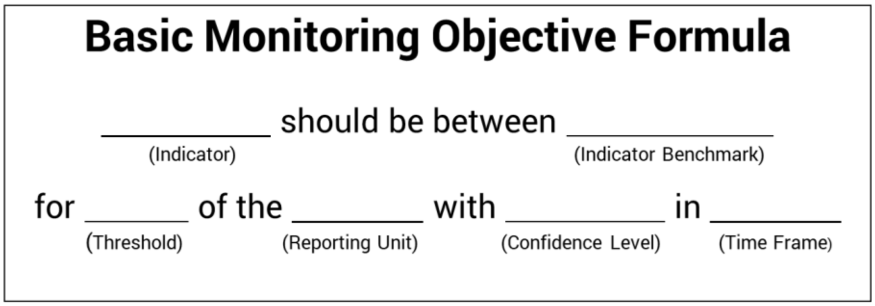

Figure 4-2. The basic monitoring objective formula is a template used to develop specific quantifiable, and attainable monitoring objectives based on ecosystem potential, as well as resource availability.

Monitoring objectives should also be developed to describe the desired change in indicator values over a specified time frame (Figure 4-3). These monitoring trend objectives might be short-term (e.g., evaluating recovery of a study area following a disturbance) or long-term (e.g., evaluating vegetative changes within an allotment in response to changes in grazing management).

Trend monitoring objectives should include at a minimum:

- *Indicator(s)* being monitored for change over time
- *Desired direction* (increase, decrease, or no change) and *percent or amount* of change
- *Reporting unit*, or area, where the objective is being assessed
- *Time frame* for assessing the change

The most robust trend monitoring objectives include:

- The *threshold* or proportion of the resource in which change is desired
- Desired *confidence level* (e.g., 90% confidence)

Rather than just focusing on the status of an indicator with the monitoring objectives, a trend monitoring objective focuses on a *change* in an indicator *over a time frame*. The time frame for assessing change could be the amount of time following or preceding a particular event (e.g., change in management or a disturbance), a comparison between two time frames (e.g., 2015-2019 compared to 2020-2024), or a fixed interval (e.g., trend over the next 10 years). For robust trend analyses it is beneficial to specify the magnitude of desired change – this is equivalent to a benchmark for trend and is the specific amount or range that the indicator should change to meet stated objectives.

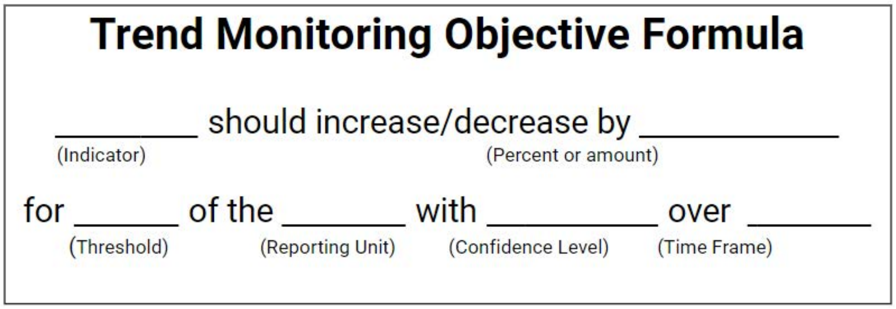

Figure 4-3. The trend monitoring objective formula is a template used to develop objectives addressing desired change in indicator values over a specified time frame.

When considering an area with multiple monitoring locations, some amount of failure to achieve a benchmark is often acceptable. Natural events such as floods, droughts, fire, and disease result in natural variability across a landscape. For this reason, monitoring objectives also include the proportion of the landscape that is required to meet a given benchmark and desired confidence level. For example, achieving a benchmark density of plants on 80% of seeded acres can indicate success, even if 20% of the acres did not meet the benchmark value. If monitoring information shows that an insufficient amount of the resource has met a benchmark, then management actions may be triggered.

It is also important to consider ecological potential or spatially defined administrative requirements. Not every benchmark is appropriate to apply across all sampling locations (e.g., the expected percent cover by perennial grasses would be lower in deserts than grasslands and so the benchmark value range for deserts would be lower than in grasslands). To accommodate this, separate benchmarks may be defined for ***benchmark groups*** so that they can be applied correctly. Benchmark groups may be defined using traits like habitat status, ***ecological site***, or human use. See Section 6.0 for more information.

The IDT should document benchmarks, benchmarks sources, and the proportion of the resource that is required to meet the benchmarks for each indicator of interest in columns 3-5 of the **Resource Condition and Trend Objectives Tables** found in the MDW. This exercise will quickly reveal indicators which will require professional judgement, the development of ***ecological site descriptions (ESDs)***, or other resources to aid in future data interpretation.

Benchmarks, along with associated required landscape proportions, provide a way to objectively operationalize policy statements such as “take appropriate action” to make “significant progress toward fulfillment” of LHSs.

Remote Sensing Informs Monitoring Objectives

Back-in-time fractional vegetation cover datasets can inform the development of meaningful target benchmarks. While far from being baseline monitoring data, these back-in-time data are often the best indicator of site potential and change, especially where no on-the-ground monitoring has been completed. By comparing key AIM indicators over the past several decades, one can identify the degree to which the vegetation community has become degraded, as well as whether different sites have diverged in extant vegetation but share similar ecological potential. Moreover, these datasets may offer a reasonable target benchmark for restoration after a more recent disturbance, such as wildfire (Figure 4-4).

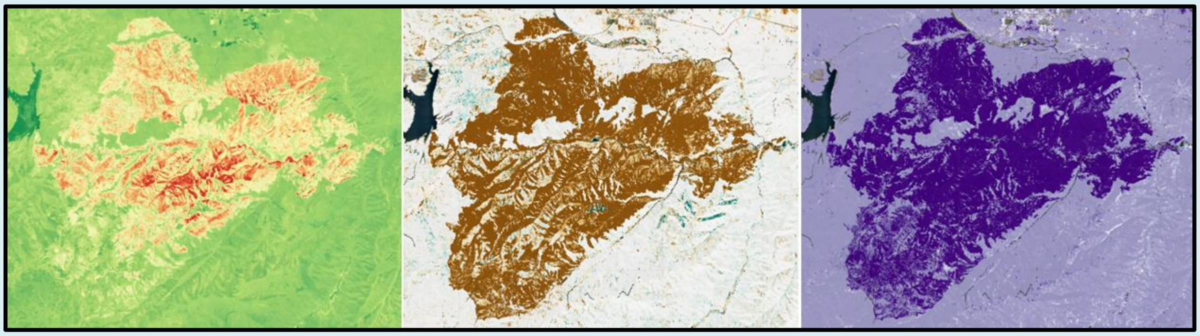

Figure 4-4. Remote sensing informs monitoring objectives on the Dollar Ridge Fire which burned nearly 70,000 acres in central Utah in 2018. The ClimateEngine.org App was used to identify the burn severity of the fire using the difference in Normalized Burn Ratio (yellow to red indicates increasing severity, left). The RCMAP fractional vegetation cover product was used to identify the loss of shrub cover (dark brown, center) and the subsequent increase in bare soil (dark purple, right) after the fire.

Example monitoring objectives, with benchmarks and required proportions:

- Soils Land Health Standard: In the grazing allotment, maintain soil aggregate stability of 4 or greater on 80% of lands with 80% confidence over 10 years.
- Watershed Function within LUP Area: Maintain bank stability of greater than or equal to 75% for 80% of perennial wadeable streams in the planning area with 95% confidence over 10 years.
- Sage-Grouse Habitat within LUP Area: In all designated sage-grouse habitat, the desired condition is to maintain all lands ecologically capable of producing sagebrush (but no less than 70%) with a minimum of 15% sagebrush cover or as consistent with specific ecological site conditions over 5 years.

Step 3: Select criteria for stratifying the study area (only if necessary)

First, identify whether strata are necessary. If so, identify which strata will be utilized, how many sample points will be collected in each strata, and the amount of resource that will be represented by each stratum.

Stratification is the sub-setting of the sample frame into smaller units and can be used to distribute sample points across the landscape or resource and/or to ensure that areas of interest, including reporting units, are sufficiently sampled (i.e., have adequate sample sizes for reporting). In contrast to reporting units, strata must be defined prior to design creation as they will affect AIM data collection. ***Stratification is not required and if deemed necessary it must be justified through documentation.*** Strata may be justified when a non-stratified design would not provide enough samples to statistically analyze and report, for example:

- In sage-grouse habitat a non- stratified sample would not provide enough samples within habitat areas to report on that area individually so the sample frame should be stratified by "sage-grouse habitat" and "non sage-grouse habitat" to ensure that enough sampling occurs in sage-grouse habitat.
- Streams may be grouped by ***Strahler stream order*** categories so that categories with shorter stream lengths will be sampled with enough locations for statistical analysis and reporting.

Each stratum receives its own allocation of points, which may or may not be proportionate to the resource extent or area on the landscape and may differ between strata. This means that each stratum is guaranteed to be sampled, even if it is a small portion of the target population. Stratification can consider properties of the study area like physiography, management boundaries, ownership, or other attributes of the resource that need to be described to meet the monitoring objectives. Stratification decisions should be captured in the Sample Design Table.

The design process will typically start with the creation of a simple, unstratified design across a broad area (e.g., LUP/RMP). The "draft" design will then be reviewed by the Project Lead and IDT to determine if the design is adequate or if different point allocations are necessary in certain areas. If more points are needed in specific areas, stratification may be used or an ***intensification*** can be added to the design in the future to ensure that enough necessary information can be obtained within those areas.

Additional strata may be included in the design if deemed necessary. However, adding strata should be done with considerable thought, as sample sizes, required resources, and the complexity of data analysis increase with each additional stratum.

Additional stratification or point allocation approaches include but are not limited to:

- RMP boundaries
- Strahler stream order categories
- Habitat areas for sage-grouse or other species of special concern such as T/E fish species

Terrestrial Designs

The general recommendation for terrestrial monitoring designs is to minimize stratification; either forgoing stratification or utilizing as few strata as are required to meet monitoring objectives. New terrestrial monitoring designs are usually not stratified. If stratification is necessary, the recommendation is to stratify by ***physiographic properties*.** Physiographic properties are not typically used as reporting units. Stratifying by physiographic properties can help allocate sample points to underrepresented or more variable portions of the landscape without sacrificing the ability to describe the whole landscape.

If strata will be used, AIM Project Leads are asked to provide a polygon shapefile of the strata with an attribute field containing the stratum name. These polygons should be clipped to the target population, typically a combination of the study area and most current BLM ownership layer.

If a design is stratified, the stratum count should be minimized to keep the design simple and manageable. For example, combine all LANDFIRE ***biophysical setting (BpS)*** groups which are dominated by Wyoming Big Sagebrush into a single stratum. Early terrestrial designs were typically stratified by BpS groups. BpS groups represent natural vegetation potential on the landscape based on biophysical environment and historic disturbance regimes. Ecological sites and watersheds have also been used to stratify terrestrial designs. Document these groupings in the Stratification Lookup Table found in the appendix of the MDW.

If any strata are less than 3,000 acres or 1% of the study area, it is recommended that they be grouped with other strata so that the resulting stratum is greater than 3,000 acres or 1% of the study area. If several polygons are grouped to obtain the final strata, be sure to document how those decisions were made, and which polygons were combined to create the groups.

Lotic Designs

The general recommendation for stream and river monitoring designs is to limit the use of strata unless minimum sample sizes are insufficient to report on specific areas or species of interest. However, all designs will be stratified by Strahler Stream Order, grouped into three categories with grouping depending on location:

- Lower 48: small streams (1st and 2nd order), large streams (3rd and 4th order), and rivers (5th order and above).
- Alaska: small streams (1st order), large streams (2nd and 3rd order), and rivers (4th order and above).

If any of the stream or river strata contain less than 1% of the total stream kilometers or result in less than three sample points, we often recommend grouping that stratum with another stratum.

Riparian & Wetland Designs

Similar to Terrestrial and Lotic AIM, the general recommendation for Riparian & Wetland monitoring designs is to limit the use of strata unless minimum sample sizes are insufficient to report on specific areas or species of interest. However, for many designs the National AIM Team recommends stratifying by wetland size to ensure adequate sampling of small wetland features on the landscape. Small wetland features account for less of the resource on the landscape so stratifying by riparian and wetland size ensures adequate representation of small features. If stratification by size is not used, points more often fall in large wetland complexes. Work with the National AIM Team to determine if stratification by wetland size works well for the study area.

Remote Sensing Informs Stratification

Remote sensing can supplement other geospatial data layers to better inform if, and how, to stratify field plots. For example, elevation datasets could allow the user to stratify based on elevation, aspect, or landscape position or thematic datasets such as LANDFIRE ***Existing Vegetation Type*** can be used to stratify by vegetation groups. Fractional vegetation cover datasets could help inform how one might stratify sampling plots based on vegetation communities. For example, various fractional vegetation cover datasets could be downloaded and stacked into one raster. Next, an unsupervised classification (e.g., Iso Cluster) in a GIS could be used to identify clusters of different vegetation types. Alternatively, a principal components analysis of these layers would help emphasize the variation in vegetation composition across the focal area.

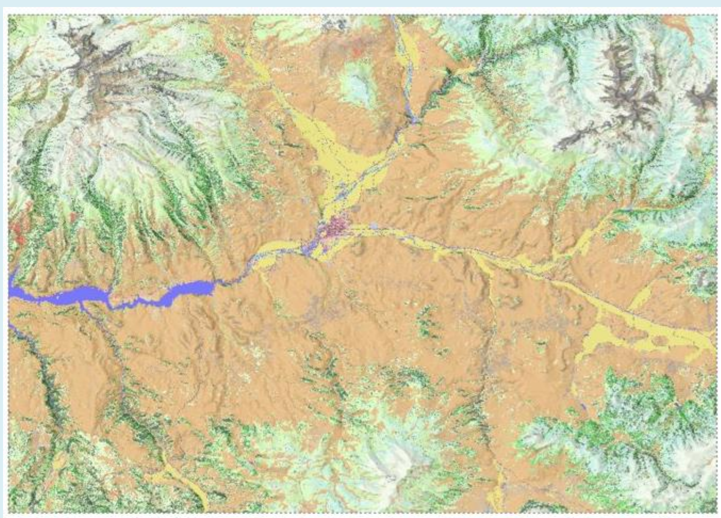

Figure 4-5. Remote sensing informs stratification using Landfire EVT layer depicting sagebrush steppe (dark orange) within the Gunnison Valley, Colorado, transitioning to various forest and alpine cover types at higher elevation.

Step 4: Select and document supplemental monitoring methods; estimate sample sizes; set sampling frequency; develop implementation rules

Step 4a: Select and document supplemental monitoring methods (optional/if required)

Supplemental methods are measurable ecosystem components that are specific to a given ecosystem, land use, or management objective and not widely applicable across management goals. These methods are not part of the AIM field methods protocols because they may not be cross-programmatic. The AIM program does not provide standardized methods, training, or data management processes for supplemental methods. When these specific ecosystem components are needed to address management goals they can be sampled along with AIM core and contingent methods. When determining supplemental monitoring methods, consider the following guidelines:

- Decide whether supplemental indicators are necessary to meet management goals that were set in Step 1. Keep in mind that adding supplemental indicators will require additional work in the field and beyond.
- If supplemental indicators are necessary to meet management goals and monitoring objectives, first evaluate the core and contingent methods to determine if these supplemental indicators can be calculated using a core or contingent method. This may be done with the help of the National AIM Team.
- If a necessary indicator cannot be calculated from the core or contingent methods, select a supplemental method. Select supplemental methods that are used by other monitoring programs or state/national regulatory agencies and are documented clearly in a peer-reviewed source such as a method manual or journal article. Other desirable characteristics of supplemental indicators and methods include relevance to LHSs, ability to be measured objectively and consistently in many ecosystems by different observers, scalability, and applicability to multiple objectives. Document the rationale for including the supplemental indicator as well as a citation for the method. The National AIM Team strongly advises against creating new methods or modifying existing methods.

Data storage, training and in-field support processes must be identified for supplemental methods prior to collecting data since the AIM Program does not provide this structure for supplemental methods. Many supplementals may be supported by non-AIM programs or state offices.
Tasks required to implement supplemental methods include:

- Identify or establish data management protocol and tools for the supplemental method, including data recording, electronic data capture, data storage, ***quality assurance (QA)*** and quality control (QC), and analysis and reporting.
- Identify or establish calibration standards for the supplemental method.
- Identify capacity to provide technical support for the supplemental method (e.g., who will answer questions about it during the field season?).
- Plan sufficient training for successful implementation of the supplemental method. This training cannot occur during a core methods training, but it is recommended that it follow soon after so that AIM crew members can integrate what they learned during the core methods training.
- Practice the supplemental method in the field to establish compatibility with AIM plot or reach layout and requirements (e.g., not walking on left side of a terrestrial transect, collecting water quality before instream lotic sampling begins).
- Consider the additional time required for an AIM crew to complete the supplemental method at each sampling location. If the additional time required to collect supplemental methods limits the AIM crew's ability to visit the desired number of plots or reaches, then the desired number of plots or reaches might need to be reduced.

Step 4b: Collect and evaluate available data to determine sampling sufficiency and the validity of the strata (if available)

This step addresses the following question: "How much data should be collected across the study area to address the management goals and monitoring objectives?" Analysis of existing data and monitoring objectives will provide information about the number of points required to detect whether an objective for a particular indicator has been met (e.g., the number of sites needed to determine whether 70% of areas with the potential to support sagebrush have greater than 15% sagebrush cover).

Consider sample size requirements in terms of the management goals and the available information needed for the decision. If one indicator requires more samples than the others, then one may be able to rely on the evidence from the other indicators to make a decision. If many indicators are showing insufficient information, then more monitoring points are likely needed.

LUP Planning and many other AIM efforts seek to estimate the proportion of a resource (in acres for terrestrial and riparian and wetland ecosystems and kilometers for perennial streams) within the project area that are meeting or not meeting objectives, within a certain level of confidence. Given the goals of estimating conditions, the general recommendation for such monitoring efforts is to take an approach that minimizes the likelihood of not detecting a difference in conditions when a difference actually exists (i.e., Type II errors).

From a statistical standpoint, the sample size required (e.g., number of plots or stream reaches) to determine the proportion of the resource that is achieving the desired conditions will depend on three factors: 1) the amount of existing AIM-compatible data, 2) estimated proportion of data meeting an objective, and 3) the desired confidence level.

- For many new AIM projects, data are already available from other AIM monitoring efforts. Always evaluate and consider using existing data when determining sample sizes.
- Depending on monitoring objectives and previous sample date and condition, National and other AIM datasets may be used to offset sample size requirements for new monitoring objectives. At a minimum, these data can be used to help assess the proportions of a resource that are meeting an objective and help estimate the required sample size for monitoring objectives.
- If a high degree of confidence (e.g., 95%) is desired in the condition estimates derived from the data, then larger sample sizes are required. To balance the desire to minimize Type II errors (i.e., failure to detect a difference) with the need for a realistic workload, the specific recommendation is to establish sample sizes using an 80% ***confidence interval***. If monitoring data are to be used to support a contested management decision, higher percent confidence interval with smaller margin of error (MOE) may be necessary.

To determine how much data is needed to address management goals and monitoring objectives, consider the following:

- Identify the indicators of interest and the proportion of the landscape that is likely in a given condition category (e.g., percentage of the landscape consisting of suitable or

unsuitable habitat). It can be helpful to look at existing data to estimate the proportion of sites currently meeting monitoring objectives as a starting point.
- Select an appropriate confidence level for the monitoring objective.

With the information identified above, the initial sample sizes can be estimated with sample sufficiency tables (see Section 9.0 for more information).

If increased precision and accuracy of the design is needed, a greater number of points will be necessary. If it is likely that additional points may be desired during the design implementation, additional ***oversample points*** should be added to the design during design creations. If there are sufficient points in the original design, oversample points may be sampled to increase the sampling intensity of the design at a later date. If adding more points is not feasible because of resource limitations, an alternative approach is to accept a lower level of confidence for some reporting units. In these cases, data from other sources (e.g., remote sensing, use data) can be valuable for a multiple lines of evidence approach.

After each year of sampling, designs should be reviewed to assess whether the current sampling intensity is appropriate or if increased intensity is needed to obtain a larger sample size. At the end of each revisit design cycle, designs should be evaluated to determine to continue revisiting the design or whether a new design should be created.

Step 4c: Estimate sample sizes in coordination with the National AIM Team

Determine if significant amounts of comparable, high quality monitoring data already exist, if so, the required sample size may be smaller than when such data are not available as those existing points may be able to be incorporated into eventual analyses.

For unstratified designs, all sampling effort is simply dedicated to the target population/sample frame. For stratified designs, the default method for allocating sampling effort is to ***proportionally allocate points*** based on the area/length that each stratum covers, e.g., a stratum that makes up 20% of the target population would receive 20% of the total points to be sampled. If stratification is used, ensure sufficient sample sizes for each stratum. For example, all strata should have at least 3 monitoring points.

The recommendation is to start with the proportional allocation approach and then adjust sample sizes up or down as needed per stratum. The number of sample points may need to be increased in areas that cover a small percentage of the study area to achieve a sample size sufficient to provide information for management decisions. For example, black sagebrush areas often occupy a small portion of the landscape but provide important sage-grouse habitat, and thus will need to be well represented in a design that is focused on sage-grouse habitat.

If the desired number of points in one stratum is increased, the effort allocated to other strata may have to be reduced to keep the total number of points sampled the same. Allocating zero points to any strata will limit the ability to draw inference to the entire landscape because the target population consists of only areas that may be sampled and strata with zero points are therefore dropped from the target population. Exclude points from a stratum only if you are willing to drop it from the target population because 1) the stratum is not part of the target population defined by the management goals (e.g., open water in a terrestrial monitoring effort) or 2) the stratum is being monitored as a part of a separate monitoring effort and should not be monitored as part of this project. In either case, update the polygons representing the target population to exclude those areas.

Point weights are the area (in acres or hectares) or length (in stream kilometers) represented by an individual sample location. ***Weights*** are used to generate statistical estimates of resource status or condition across the landscape (i.e., proportional estimates). Specifically, weights are used to adjust the relative influence that each point has on the final estimates; points with larger weights have more influence, and points with smaller weights have less. The weight of each point depends on the specifics of the design, how it was implemented (following data collection each point should have an ***evaluation status*** or ***final designation*** that categorizes if it was sampled and if not, why it was not sampled), and the reporting area of interest. Changing sample sizes in a given stratum will affect point weights and therefore should be done with care. As sample sizes are increased in a stratum, the area/length represented by each point is reduced, thus the point weights and relative influences are reduced. Designs will have an initial point weight which assumes perfect implementation without point rejections and reporting on the entire target population. Each reporting unit and data subset will need to be recalculated at the time of analysis

Instructions for filling out the remainder of the Sample Design Table

When stratification is used, fill in the first row of the **Sample Design Table** with information regarding the entire sample frame.

- *Proportional area or length:* Divide the number of acres or stream km represented by each stratum by the total number of acres or stream kilometers in the entire study area to get proportional areas/lengths. This will be 100% for an unstratified design.
- *Proportional points per stratum:* Calculate the proportional number of points per stratum by multiplying the proportional number of acres or stream km by the total number of points to be sampled. This will be the total number of points for an unstratified design.
- *Final Points per stratum (optional):* If a proportional allocation of points will not satisfy the monitoring objectives, adjust the number of points that will be monitored for each stratum. Calculate the number of sites to sample in each stratum, taking into account the amount and quality of existing or legacy monitoring information, the amount of resource that needs to be monitored, statistical considerations, funding and personnel limitations. If points are allocated in a way that is highly disproportionate across strata, justification for the disproportionality should be documented alongside the table. Final point numbers normally refer to the total number of sampling locations visited within one sampling cycle (e.g., over 5 years). If specifying point number for a different time frame, this should be specified in the sample design table.
- *Point weights:* Once all the other columns in the **Sample Design Table** (found in the MDW) have been finalized, point weights can be calculated as the total number of acres or stream km within the stratum, divided by the number of points to be monitored for that stratum. For assistance in completing this section contact the National AIM Team, particularly for more complex revisit designs.

Step 4d: Define revisit parameters if using a revisit design (use the Revisit Frequency Table to document decisions made in this section)

Revisit designs are a specialized kind of design which help to maximize trend detection. Revisits can be selected from Targeted and Random designs. However, in a random revisit design, there are two kinds of points which are treated differently in implementation: revisit and non-revisit. During the implementation of a revisit design, revisit points are sampled multiple times at set intervals while non-revisit points are sampled just once. Resampling the same locations helps to detect changes over time while adding the non-revisit points increases spatial coverage. It is possible to detect trend with a design that does not include any revisit points. Revisit designs require a few more decisions than strictly non-revisit designs do, including revisit frequency/interval, number of revisit cycles, and the number of revisit points versus non-revisit points to sample.

Determine the revisit frequency/interval and the number of years sampled per cycle

Most monitoring efforts need to be spread out across several years to accommodate AIM crew capacity and to ensure that interannual variability is captured by the monitoring data. Once the total number of sample points and the point weights have been calculated, determine how many years of sampling might be necessary to achieve the desired sample size. For example, a 20–year design with a 5-year revisit frequency would consist of five revisit ***panels***, where each point is assigned a specific year in which it should be sampled. All points in the same panel will be sampled every five years for a total of four data collection efforts (cycles) at each point over the 20–year design. In contrast, when specific geographic areas are sampled in only one or two years rather than during every year of the design, bias from climate variability can affect condition estimates. However, it may be appropriate in Lotic sample designs to sample only a proportion of the years in each sampling cycle based on logistical and funding limitations (e.g., two years sampled out of five).

Detecting change in condition through time (i.e., trend) is a common monitoring objective that requires setting an interval for revisiting points over time. Questions to consider when setting revisit frequency include:

- What revisit frequency makes sense relative to the disturbance or management event? For example, ES&R monitoring dictates annual re-visits for three years, whereas monitoring stream geomorphic changes following livestock removal might occur on a 3 to 5-year basis, and changes in upland condition might occur over 5-10 years.
- How resistant and/or sensitive to disturbance are the areas that are being monitored? How resilient are those areas following disturbance events? Consider establishing more frequent revisit intervals in areas that are more sensitive or less resilient to disturbance than in areas that are highly resistant and resilient.
- How variable and/or sensitive are the indicators utilized to evaluate the management goals? Consider more frequent revisit intervals for indicators that are particularly sensitive to inter-annual variability in abiotic conditions.
- What resources will be available (e.g., funding and personnel)?

The default revisit interval for RMP effectiveness monitoring is every 5 years, unless natural conditions or management actions occur that would elicit landscape-scale responses on shorter timescales. A revisit interval of less than three years is discouraged due to the rate at which most changes will occur. For more detailed background on the consequences of different revisit intervals see the National AIM Team's Trend Assessment write up on power for trend (see Section 4.2 for Trend Assessment PDF link).

Set number of cycles and the total duration of the design
A cycle is a defined time frame over which all panels are visited once, e.g., a design with five single-year panels would have a cycle duration of five years. The number of cycles in each revisit design depends on both the revisit frequency (or cycle duration) and total design duration such that numbers of cycles equals design duration divided by revisit frequency. In a typical design the standard number of cycles is four with a total design duration of 20 years (using a 5-year revisit frequency).

Set the proportion of design points which will be revisited
Depending on objectives, only a subset of points may need to be revisited. Trend assessments are usually most effective when combining a mix of revisit and non-revisit points. AIM generally recommends 70-80% of the points sampled within a year or cycle are points that are being revisited. However, this greatly depends on management goals, existing sample size and resource extent, landscape scale heterogeneity, type and scale of trend detection needed, and field sampling effort available. Factors to consider when determining the proportion of design points which will be revisited include:

- Revisitation involves resampling points and helps to explain changes over time. Higher proportions of revisit points mean more statistical power available to detect trend.
- Non-revisit points add new sampling locations across the landscape and help to explain spatial variability in resources. Higher proportions of non-revisit points mean higher precision of condition estimates.
- If trend assessment is a priority and existing trend data are unavailable, a higher proportion of revisits will be beneficial. Conversely, if management goals are more focused on precise condition assessment at a single point in time, a higher number of non-revisits points will be preferred.
- Some monitoring efforts may not include revisitation at all, depending on various project constraints or monitoring objectives.

The proportion of revisits to non-revisits is influenced by many factors and it can be difficult to make a broad suggestion for all types of projects and designs. The National AIM Team is still working to refine the recommendations but please contact the relevant State Lead, State Analyst, or NOC AIM Analyst to discuss a specific design.

Step 4e: Develop implementation rules

Implementation rules are those that guide the rejection, movement, and merging of points. Standard rules are outlined in the Lotic Evaluation and Design Management Protocol, Riparian & Wetland Design Management and Plot Evaluation Protocol, and Terrestrial Data Management Protocol. Review the standard implementation rules to identify whether they need to be customized to meet the monitoring objectives. If so, consult with the National AIM Team when developing the additional criteria to ensure the design will remain statistically valid. Proper design implementation also involves documenting the fate, or outcome, of each point in a given design (see Section 5.3, Step 1). Documentation of point fate should be tracked using the Terrestrial, Lotic, or Riparian & Wetland Office Evaluation WebMaps.

Step 5: Select monitoring locations

In this step the final sample design, or monitoring locations, are selected, reviewed, and documented. The AIM Project Leads and the State Office AIM Team (with support from National AIM Team staff) must be sure to document how the design(s) were created, any additional notes, information on the sample frame, review of revisions, and why. If the design process or sample sufficiency analysis resulted in different sample sizes than those identified in Section 4.3, Step 4b, document those changes here as well. Various design types, or selection methods, might be used, it is important to document each (e.g., GRTS design, random systematic, shiny tool random designs, targeted, etc.). Regardless of whether or not the National AIM Team will select the points, the design information should be documented in the appropriate National AIM Design Database. Consult with the National AIM Team if help is needed implementing this step.

Standard LUP/RMP AIM designs use the GRTS algorithm to generate statistically valid, spatially balanced, and random sampling locations (Stephens and Olsen 2004). These designs can be used to make inference to the conditions across the landscape which is why they are an ideal tool for LUP/RMP evaluations or other large scale analyses.

Tools to select random points

Several tools are available to complete statistically valid monitoring designs. For new designs, the standard approach is for the National AIM Team to use the survey package in R to draw GRTS designs. R is a programming language for statistical computing. For designs that incorporate previously sampled points the standard approach is modified to spatially balance new points around existing sample locations and revisit a proportion of existing locations.

For Terrestrial projects in small geographic areas (e.g., <10,000 acres), one-year designs, or designs that exclude some areas of the landscape and that don't need to balance around existing points, there is the web-based BDT hosted by ***the Jornada*** Landscape Toolbox. Designs created using the BDT use the same GRTS code as standard AIM designs, are statistically valid, and produce data that can be uploaded to the National AIM Database. The Terrestrial National AIM Team recommends that the design files be uploaded to the SharePoint for any designs created using the BDT for future analysis needs. Designs that have not been created by the National AIM Team should still be stored in the National Design Database, but to do so design creation files and decisions must be documented and supplied to the National AIM Team. A list of necessary information and files can be found in the Design Review and Finalization section.

For Lotic and Riparian & Wetland projects, all GRTS designs, no matter how small or short term, are run through the National AIM Team.

Design review and finalization

Once a draft design has been created, the National AIM Team will share the design with the AIM State and Project Leads for review. The draft design should be reviewed to make sure it will meet design criteria described in Section 4.3, Steps 1 through 4.

Questions to ask when reviewing a draft design include:

- Are there enough points in all areas for which data are needed?
    - Consider whether stratification is needed if there are not enough points within an area.
    - Consider rejection rates. Areas with high rejection rates may require additional oversample points. It can be complicated to add points to a design at a later date so ensure there are sufficient numbers to cover all rejections.
- Are there any areas that were left out of the design that should have been included? Was this due to the randomness of the design or are updated GIS files needed to represent the full extent of the design area?
- Is there any inappropriate clumping of points (i.e., too many points) in (a) certain area(s)?

For assistance, work with the National AIM Team to further refine the sample design.

Once final monitoring locations are selected, the National AIM Team will assist the AIM State and Project Leads with documenting several components of the design. Targeted points can often be documented in the MDW, but in some cases targeted point selection should be documented in the National Design Database. For these targeted points and any random design not run by the National AIM Team please provide the below information to the National AIM Team for input into a design database. Lack of documentation limits the ability to properly analyze data from a design and could prohibit its use in some analyses.

- What tool, or selection method, was used to create the design.
- Who ran the design or selected locations.
- What (if applicable) modifications were made to the initial point selection.
- Where files to inform the design/selection are stored (e.g., geospatial files).
- If modifications were made, please include an updated and final version of the Sample Design Table as well.

Step 6: Data management plans

Review the standard QA and QC procedures for AIM efforts to ensure understanding of the roles and responsibilities for data management. These QA and QC procedures can be found in the data management protocols for each resource and are found on the resource specific library pages (see Section 4.2). General information on QA and QC can be found in Section 5.3, Step 4.

Data management for BLM AIM efforts is supported by the National AIM Team through standardized electronic data capture and management. More information is available on the AIM website under Data Management and Stewardship, and in the resource-specific Data Management Protocols linked on the AIM Resources page (see Section 3.2 for web links).

5.0 Data Collection and Management

5.1 Overview

There are four main steps to data collection which include preparation, field methods trainings, data collection, and data ingestion. These steps include details about AIM crew hiring, field methods training, evaluation and rejection of points, etc. Each of which has important associated quality assurance (QA) and quality control (QC) procedures. The State Office AIM Team, AIM Project Leads, resource specialists, other field office staff, data collectors, and National AIM Team members are a critical part of the data collection process. Whether or not they are collecting data, everyone has a role to play in data quality.

The AIM principles include QA and QC for each step of the data collection process, ensuring quality data that practitioners can use with confidence. Quality assurance and quality control are the responsibility of all participants and occur throughout the data collection process. Quality assurance is a proactive process intended to minimize the occurrence of errors and includes strategies like standardized required trainings, data collector calibration, and electronic data capture tools with built-in data rules and documentation. Quality control is a retrospective process which identifies errors after data have been collected. The ability to correct errors during the QC process is limited because points cannot be revisited with the exact conditions that occurred during the original data collection event. Quality control tools include error review scripts and dashboards, data review dashboards, and manual review by data collectors, AIM Project Leads, the State Office AIM Team, and/or the National AIM Team Data Managers/Analysts.

5.2 Tools

There are several tools that can assist with the data collection and management phase of an AIM project. Reference the following data and design management protocols for each resource found on the AIM Resources webpage (see Sections 3.2).

Data and Design Management Protocols:

- Lotic AIM Evaluation and Design Management Protocol
- Lotic AIM Data Management and Quality Assurance and Control Protocol
- Terrestrial Data Management Protocol
- Riparian & Wetland AIM Design Management and Plot Evaluation Protocol
- Riparian & Wetland AIM Data Management Protocol

5.3 The Four Steps to Data Collection

AIM data collection occurs during the appropriate seasonal expression of the ecosystems being sampled. It is often accomplished by dedicated AIM crews and by resource specialists in field offices. There are four main steps to data collection which include preparation, field methods trainings, data collection, and data QC and ingestion prior to data use (Figure 5-1). The following steps are discussed here in further detail.

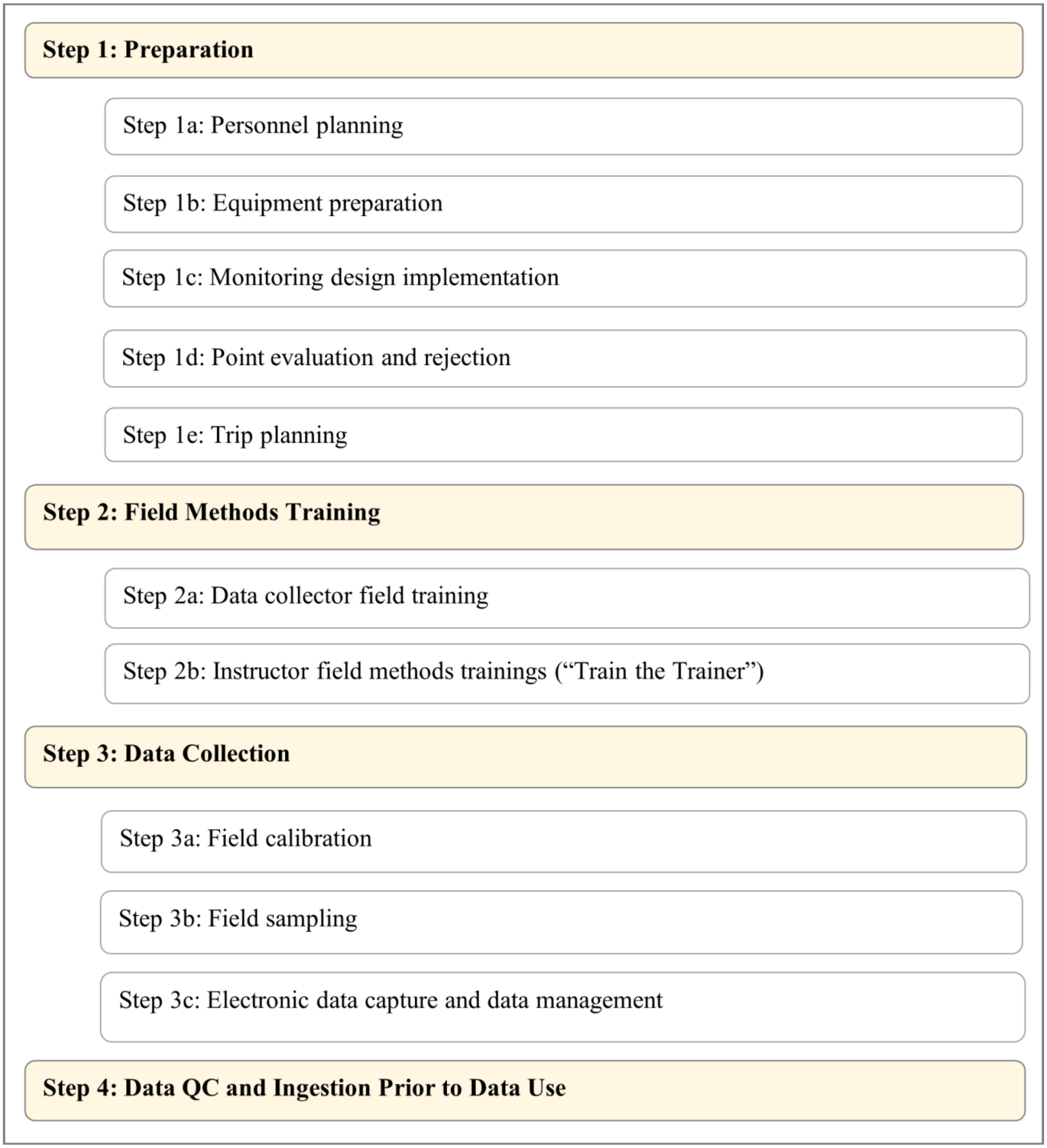

Figure 5-1. The Four Steps to Data Collection.

Step 1: Preparation

Once a sample design has been completed (see Section 4.0 for more information), the next step is to prepare for field season data collection of the sample points in the design. Data collection preparation includes planning who will collect the data, understanding your monitoring design and implementation rules, completing office evaluation, and planning data collection trips (also called "hitches"). For data to be ingested into the National AIM Database, data collectors must meet data ingestion requirements (e.g. training attendance and calibration requirements). For specific data ingestion requirements refer to the Data Management Protocols for Terrestrial, Lotic, and Riparian & Wetland AIM found on the AIM Resources webpage (see Section 3.2 for web links).

Step 1a: Personnel planning

Data can be collected by anyone including BLM staff or dedicated AIM crews, typically consisting of two- or three-person teams. If data will be ingested into the national databases, data collectors will need to meet data ingestion requirements that include training standards (see Step 2 for more information about field training). Hiring dedicated AIM crews can be accomplished through a variety of mechanisms including contracting, BLM seasonal hiring, or use of assistance agreements. Work with the AIM State Lead and your local Office to determine hiring options. The hiring process may require setting up an assistance agreement, hiring BLM technicians, or creating a contract.

- A new contract or agreement may need over a year to put into place.
- To hire under an existing contract may take almost a year to appropriately plan and fund.
- Timelines and opportunities to hire technicians through the BLM seasonal process will be determined by local HR.

General guidance to determine how many AIM crews might be needed:

- A Terrestrial AIM crew with 2-3 people can monitor approximately 50 plots per season.
- A Lotic AIM crew with 2-3 people can monitor 25-35 reaches per season.
- A Riparian & Wetland AIM crew with 3 people can monitor 25-35 plots per season.

The AIM crews will need to be onboarded with adequate time to acquire DOI Talent and ***GeoPlatform.gov*** accounts, attend any required pre-course training and field methods trainings, and prepare for the first data collection trip/hitch. DOI Talent is required for pre-coursework completion, GeoPlatform.gov accounts are required for use during the field training so they must be active and functional before attending the in-person field training. Data collector training requirements are outlined at www.blm.gov/aim/training.

Step 1b: Equipment preparation

Data collection requires the use of specific instruments and equipment. Refer to the appropriate data methods manual and/or current equipment list for equipment associated with the AIM Core Methods to ensure all necessary equipment has been purchased. If contingent or supplemental methods are planned, additional equipment may be needed. Set up and calibrate equipment prior to data collection to ensure functionality. It is also recommended to check gear prior to each collection trip. Data collectors are required to collect all core and contingent data on a mobile device (tablet) with the current operating system, ArcGIS Field Maps, and Survey123 AIM data collection forms. Field methods protocols for each resource are available on the blm.gov/aim website and hardcopies will be provided at the required training.

Step 1c: Monitoring design implementation

AIM promotes the use of appropriate monitoring designs to address the required data needs at hand. Each design (e.g., targeted or random) may have specific assumptions and implementation rules. Targeted designs have fairly straightforward implementation rules so in this section we will focus on the specific implementation rules to maintain statistical validity and meet desired sample size of a common AIM design (a spatially balanced random sample). Random monitoring designs utilize randomly selected monitoring locations (i.e., points) that are evenly distributed across the landscape, so the order of the selected points is critical to maintaining that spatial and temporal balance. It is critical that the points are sampled in order, all attempts are made to sample the number of points planned, and non-sampled points are properly documented.

Step 1d: Point evaluation and rejection

Sample point evaluation involves screening for safety, accessibility, and ability to sample. Point evaluation may be conducted by the Project Lead, AIM Crew Manager, or the AIM Crew Lead. Office point evaluation should be completed before the start of the field season or immediately before the start of a scheduled field trip (i.e., hitch) and generally determines if AIM crews should attempt to sample a point or if the point will be rejected without being visited. Additional point evaluation occurs in the field, which could lead to point rejection in the field at the time the AIM crew visits to sample. All point evaluation should be documented and follow a list of rules (Rejection criteria) that have been previously determined in Section 4.3, Step 4e.

Proper documentation of point evaluation is a key component to implementing a sample design. For every point assessed in a design the evaluation status must be documented according to each specific resource's definition. Points are designated as either sampled or not sampled. Sampled point data will contribute to inferences about the target population. Not sampled sites can either be outside of the target population (non-target) or not sampled for various other reasons but still may be part of the target population. Non-target locations can be used to adjust our estimate of the true target population. However, points not sampled for other reasons may limit the amount of the target population we can report on and may cause bias in the results. All rejected points should be given a reason such as non-target, inaccessible, and reattempt needed. Documenting the outcome of each point should be based on previously established and documented criteria.

Documenting rejection criteria, or the list of rejection rules, allows for a consistent approach for tracking points which are not part of the target population (non-target), are unsafe to sample, or are for other reasons unsampleable. When consistently applied, the use of rejection criteria will preserve the ability to make statistical inferences from the data while maximizing efficiency and promoting safety during field sampling. Specific non-target rejection criteria have been developed for terrestrial, lotic, and riparian and wetland resources. See the Terrestrial Data Management protocol, the Lotic Design Management Protocol, or the Riparian & Wetland Design Management Protocol, for more information. Rejection criteria that are used to implement a specific design must be carefully considered during analysis and reporting because they can limit the inferences that can be drawn from the data. For example, in Terrestrial AIM, if all plots on slopes greater than 50% are rejected, then the monitoring data only describes the resource status on slopes less than 50%.

Remote Sensing Point Evaluations and Rejections

In conjunction with other GIS data layers, remotely sensed data can be used to help evaluate candidate points before they are visited in the field. For example, imagery indices that highlight water (e.g., the normalized difference water index, a ratio of near-infrared to shortwave-infrared reflectance) could help determine if an AIM point lands in a non-target body of water and needs to be rejected or shifted.

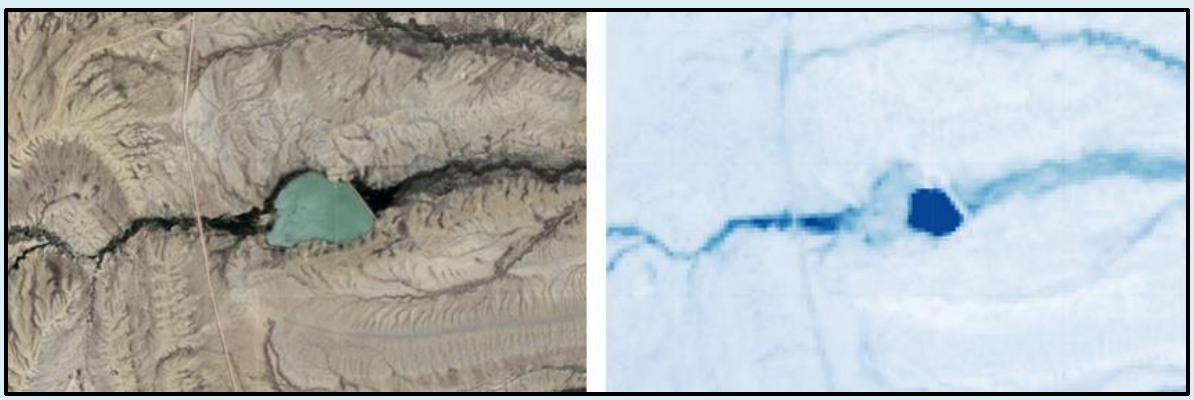

Figure 5-2. Remote sensing point evaluations and rejections using aerial imagery. The aerial photo on the left depicts an impounded body of water at the time the photograph was taken. Aerial imagery can be used to confirm features on the ground related to point selection. However, the Normalized Difference Water Index, derived from Landsat, can be used to confirm the extent of the water on the landscape (dark blue) during a particular window in time (Carbon County, Wyoming). The ClimateEngine.org Web Application was used to develop this image.

Rejection criteria is applied during two phases, in the office prior to field visiting, and during the field visit. In the office sample points should be reviewed against rejection criteria using ancillary data sources. This might include reviewing topographic maps and aerial imagery, obtaining site information from field office personnel, contacting private landowners to obtain access permissions and instructions, etc. Points remaining after the office evaluation are ready to be visited in the field. While in the field the AIM crew should review the rejection criteria to determine if the point should be sampled or rejected. If a point is rejected in either the office or the field, it is important to document the reason(s) for rejection as this information is incorporated into data analysis.

Step 1e: Trip planning

It is best to visit and evaluate sample points in the assigned order whenever possible to preserve the statistical validity of the design. Balancing logistics and travel efficiencies with sampling points in order can be tricky, the goal is both to avoid spatial patterns in the data and ensure that by the end of a field season all potential points have been evaluated. Ask for help from the State Monitoring Coordinator or National AIM Team regarding questions about implementing the design.

Use the following steps when planning for a trip:

- With the set of office-accepted sample points, AIM Projects Leads, AIM Crew Managers, and AIM Crew Leads/crews should develop a plan to visit groups of points efficiently. When points are part of ***Random Sample Designs***, planning must include consideration of point order in the monitoring design.
- Once a hitch is planned the AIM crew should review all the office evaluation notes to ensure they are prepared to visit the points identified for that hitch. If necessary, contact BLM staff or private landowners responsible for overseeing access to obtain access permission, gate keys or combinations, and access instructions.
- Obtain maps (paper-based maps and/or electronic base layer for Field Maps) of all the areas slated for sampling. Seek local knowledge for information regarding current road conditions, places to camp and get water, etc.
- Print all necessary information and upload digital copies onto tablets, as a backup in case of electronic failure.
- Update ArcGIS Survey123 data collection forms before heading out into the field (see Step 3).

Step 2: Field Methods Training

Step 2a: Data collector field training

Field methods trainings are essential to data QA; therefore, the BLM requires data collectors to attend approved AIM protocol trainings for data to be ingested into the National AIM databases. Project managers should ensure that data collectors receive proper training on the core methods. The field methods trainings provide standardized instruction for each of the AIM Resources to ensure data collection consistency. Trainings include protocol instruction for all core methods as well as applicable contingent and ***covariate*** methods, supervised practice, calibration, general guidance about implementing a sample design, and how to use data collection applications. Electronic data collection is critical to collecting high quality data. Attendees are required to have an appropriate AGOL account and bring a mobile device (tablet) with the current operating system, ArcGIS Field Maps, and Survey123 AIM data collection forms to the field training. If smaller or more local trainings are needed, work with the National AIM Team prior to data collection to ensure data collectors meet the program requirements.

All dedicated AIM data collectors (including AIM crews, seasonal BLM staff, and contractor/agreement staff) must complete an AIM Field Methods training during the year in which data will be collected. Permanent non-seasonal BLM staff collecting AIM data must have successfully completed AIM Field Methods Training within the last three years and review protocol updates every year as a refresher.

Step 2b: Instructor field methods trainings ("Train the Trainer")

State and Field Office BLM staff are critical instructors to support the number of regional Field Methods trainings that are needed. To ensure that regional trainings are consistent across the BLM, the National AIM Team hosts Instructor Field Methods Trainings (Train the Trainer) for Terrestrial and Lotic resources. This training is directed towards state and regional core methods instructors. It provides specialists in different regions the skills that they need to be able to host locally adapted regional core methods field courses. Topics include a field protocol refresher, calibration, and discussion of successful training approaches. For more information visit the AIM Training website (see Section 3.2 for web links).

Step 3: Data Collection

Once field season preparation and training are complete, data collection may begin. Data collectors should verify that they have all required equipment and electronic devices are set up to collect AIM data before going into the field (See Step 1). Data collectors are required to always carry a physical copy of the appropriate methods manual and electronic data management protocol for references.

The State Office AIM Team is responsible for ensuring proper calibration for data collectors and scheduling early-season and end-of-season check-ins (or as required by the specific resource) with the National AIM Team to review data and provide updates on the project status. For AIM State and Project Leads, it is helpful to have the AIM crew produce an end-of-season implementation report.

Step 3a: Field calibration

Data collection begins with the first data collection calibration event. Prior to collecting data, data collectors must calibrate following the resource-specific calibration requirements. The National AIM Team reserves the right to reject data if field calibration is not complete or does not follow the rulesets outlined in resource specific data management protocols.

Step 3b: Field sampling

Once data collectors are successfully calibrated, field data can be collected following the methods identified in the MDW. After collecting the field data and before leaving the field site, all field data should be reviewed for quality and completeness. When returning from the field, data collectors should review the data and evaluation statuses and consult with resource specialists regarding any questions or concerns as soon as possible. It's recommended that local resource specialists periodically go out into the field with the data collectors to ensure proper implementation of methods and help with site-specific questions. Reaching out to the State Monitoring Coordinator or the National AIM Team with questions is always encouraged.

Step 3c: Electronic data capture and data management

All AIM resources use ArcGIS Field Maps and ArcGIS Survey123 applications for digital capture of data in the field. ArcGIS Field Maps (Field Maps) is used to navigate to sample points and to document field evaluation status. ArcGIS Survey123 (Survey123) is used to collect monitoring data. It is critical to launch each Survey123 form from Field Maps so that all data subsequently collected is related to the point's spatial coordinates and unique record identifier.

Different types of mobile devices can run Survey123 and Field Maps. Review the latest version of each resource's equipment lists and technology manuals for the minimum required specifications.

Terrestrial

The National Terrestrial AIM Team strongly encourages individual field offices to purchase their own tablets; iPads or newer model Android tablets, such as Samsung tablets, are highly suggested. Tablets older than three years should be avoided or replaced. Keeping tablets updated will ensure proper Survey123 and Field Maps application functionality. All data should be collected and submitted using these applications. When necessary, paper data sheets are acceptable to record information in the field but should be transferred immediately to the tablet and uploaded. Instances where this might happen could include physical technology failure, power loss, and software issues. Reference the Terrestrial Data Management Protocol (see Section 4.2 for web link). If collecting data on paper data sheets is required for more than a single plot, immediately contact the Project Lead and/or the AIM Terrestrial Data Lead for guidance and assistance.

Lotic

All Lotic AIM data should be collected using electronic data capture applications. Printable data forms are available but should only be used in extremely rare circumstances, such as complete failure of iPads. If collecting data on paper data sheets is required for more than a single plot, immediately contact the Project Lead and/or the AIM Lotic Data Lead for guidance and assistance.

The Lotic Technology and Applications Manual provides detailed guidance on required technology. This document provides step-by-step instructions on tablet and application settings, required downloads for field sampling, and advice for troubleshooting common issues in the field. The AIM crews should read this document along with the Data Management Protocol before collecting data and consult it during the field season as issues arise.

Riparian & Wetland

All Riparian & Wetland AIM data should be collected using the electronic data capture applications. Printable data forms are available and should be carried as a back-up while conducting surveys. If collecting data on paper data sheets is required for more than a single plot, immediately contact the Project Lead and/or the AIM Riparian & Wetland Data Lead for guidance and assistance.

Detailed guidance on required technology can be found in the Riparian & Wetland AIM Technology Manual, found in the appendix of the Data Management Protocol. This document provides step-by-step instructions on tablet and application settings, required downloads for field sampling, and advice for troubleshooting common issues in the field. The AIM crews should read this document along with the Data Management Protocol before collecting data and consult it during the field season as issues arise.

Step 4: Data QC and Ingestion Prior to Data Use

Data QC occurs at multiple stages and include various parties. At the sample locations and after data has been collected, data collectors should QC their own data before uploading the forms (e.g., data completeness and correctness). Once uploaded and no longer in a field setting, there are QC steps and tools to further ensure data quality. State and local BLM staff or AIM Crew Managers should utilize available QC tools (e.g., Data Review Dashboards) to ensure data accuracy and completeness. Additionally, the NOC will QC the data for issues such as improper location identifiers, missing data or forms, etc. and reach out to the appropriate Project Lead. If errors are identified quickly enough, there may be opportunities to correct the issues so that data is not lost or compromised. This could involve revisiting a location to verify data, or to re-collect the data properly. Where applicable (i.e., Terrestrial or Riparian & Wetland AIM plots), data collectors should be tracking their unknown species codes to make sure they do not reuse a code. Duplicate codes must be corrected before data can be finalized.

When an error is identified a known error form (Terrestrial and Riparian & Wetland) or QC Comments form (Lotic) must be completed to document and track the error. Everyone involved in AIM data collection should be monitoring the known errors during the season to help resolve issues. Data cannot be ingested into the final AIM databases until all data has been checked and all errors have been resolved. The NOC performs field data ingestion by transferring the data from the field tools to the final database so that official indicators can be calculated, and data can be used for analyses.

6.0 Applying AIM Data: Analysis & Reporting

6.1 Overview

There are numerous ways that AIM data can be used to inform land management and land management decisions. This section presents a standardized workflow to address the most common ways to use AIM and other natural resource data (Figure 6-1). While the workflow presented here is AIM-specific, it is intentionally similar to the steps outlined in BLM Technical Note (TN) 453, which specifically focuses on land health evaluations and authorizations of permitted uses, and the workflow associated with LUP effectiveness evaluations. AIM data can be analyzed for an entire sample design area as specified in a MDW or opportunistically, using the data that fall within a particular area of interest. For assistance with any of these steps, or additional analyses, please contact the State Office and National AIM Teams.

In addition to standard workflows, examples of AIM data being used to inform decision-making can be very helpful. Several current AIM data-use examples are described on the AIM Resources and AIM Data Use Webinars webpage (see Section 3.2 for web links), and in the AIM Decision Library (see Section 6.2 below).

6.2 Tools

There are many tools available for use in analyzing and reporting AIM data. A list of tools with brief descriptions of their use has been compiled and is referenced throughout the document.

Analysis & Reporting Resources:

- Analysis and Reporting Workflow and Tools – Workflow for using AIM data in decision-making. Based on BLM Technical Note 453 and lists tools used for AIM data analysis.
- AIM Decision Library – (BLM Internal Resource)
- AIM Practitioners Webinars – (BLM Internal Resource)
- AIM Data Use Webinars – (see Section 3.2)
- AIM Resources – (see Section 3.2)
- AIM SharePoint – (see Section 3.2)
- Rangeland Indicator Calculator

AIM Data Access Resources:

- AIM Data Portals (DOI Internal) – Resource web maps provide users access to field collected data, calculated indicator data, and site photos for Terrestrial, Lotic, and Riparian & Wetland AIM sampling locations.
    - Terrestrial AIM Data Portal – Includes ***TerrADat*** and Landscape Monitoring Framework (LMF) layers (see Figure 6-2).
    - Lotic AIM Data Portal
    - Riparian & Wetland AIM Data Portal
    - AIM Indicators Data Portal – Calculated indicator data only for all resources.

- AIM Data Tools (BLM Internal) – This folder on the BLM's network drive contains multiple ways of accessing and interacting with AIM data, including layer files for ArcMap and ArcPro, current AIM indicator data in MS Excel format by state and by AIM resource, Python scripts, accessing data in R, AIM SDE connection files (i.e., ArcGIS Enterprise Geodatabases), pre-configured map documents, and links to AIM web resources and web maps including the benchmark tools.
- BLM GeoSpatial Gateway (BLM Internal) – This is the internal SharePoint site for sharing national datasets within the BLM. See the hydro and vegetation category links to AIM program descriptions, data, metadata, and pre-configured map documents.
- BLM Geospatial Business Platform AIM Hub (Public Access) – The BLM Geospatial Business Platform hosts BLM data and metadata for public access and offers AIM calculated indicator data to view and download. This portal is updated several months after the BLM internal datasets are updated. Field collected data is available by request.

National Terrestrial AIM Dataset (aka, Landscape Monitoring Framework) Resources:

- National Design (LMF) Metadata (Public Access)
- National Design (LMF) Analyst Document (BLM Internal)
- NRI Grazing Lands On-site Survey

Remote Sensing Tools:

- ClimateEngine
- Climate Engine Site Characterization Report
- Climate Smart Restoration Tool (CSRT)
- Evaporative Demand Drought Index (EDDI)
- Global Forest Watch
- LandCART
- Landscape Explorer
- LANDFIRE
- National Fire Situational Awareness
- National Wetlands Inventory
- Rangeland Analysis Platform (RAP)
- Rangeland Condition Monitoring Assessment & Projection (RCMAP)
- Riverscapes
- Sage-grouse Initiative
- TNC Resilient Land Mapping Tool
- UN Biodiversity Lab

6.3 The Ten Steps to the Standard AIM Data Use Workflow

The ten steps for AIM data use are outlined in Figure 6-1 and organized into three phases of analysis:

- Preparing for an Analysis
- Conducting an Analysis
- Interpreting and Communicating the Results

This workflow guides the AIM data user through the initial stages of identifying goals and obtaining data, selecting the appropriate analysis, conducting an analysis, visualizing data, and interpreting the results. Throughout the workflow, multiple lines of evidence such as other datasets (e.g., local data or remote sensing) should be used in conjunction with AIM data. The same workflow presented here is often useful to analyses of non-AIM natural resource data. Additionally, once data analysis is complete, and results are reviewed (Interpreting and Communicating the Results) reevaluating whether additional data or analyses could help better answer the management questions is recommended. Returning to the steps in "Preparing for an analysis" allow for a structured way to approach this step.

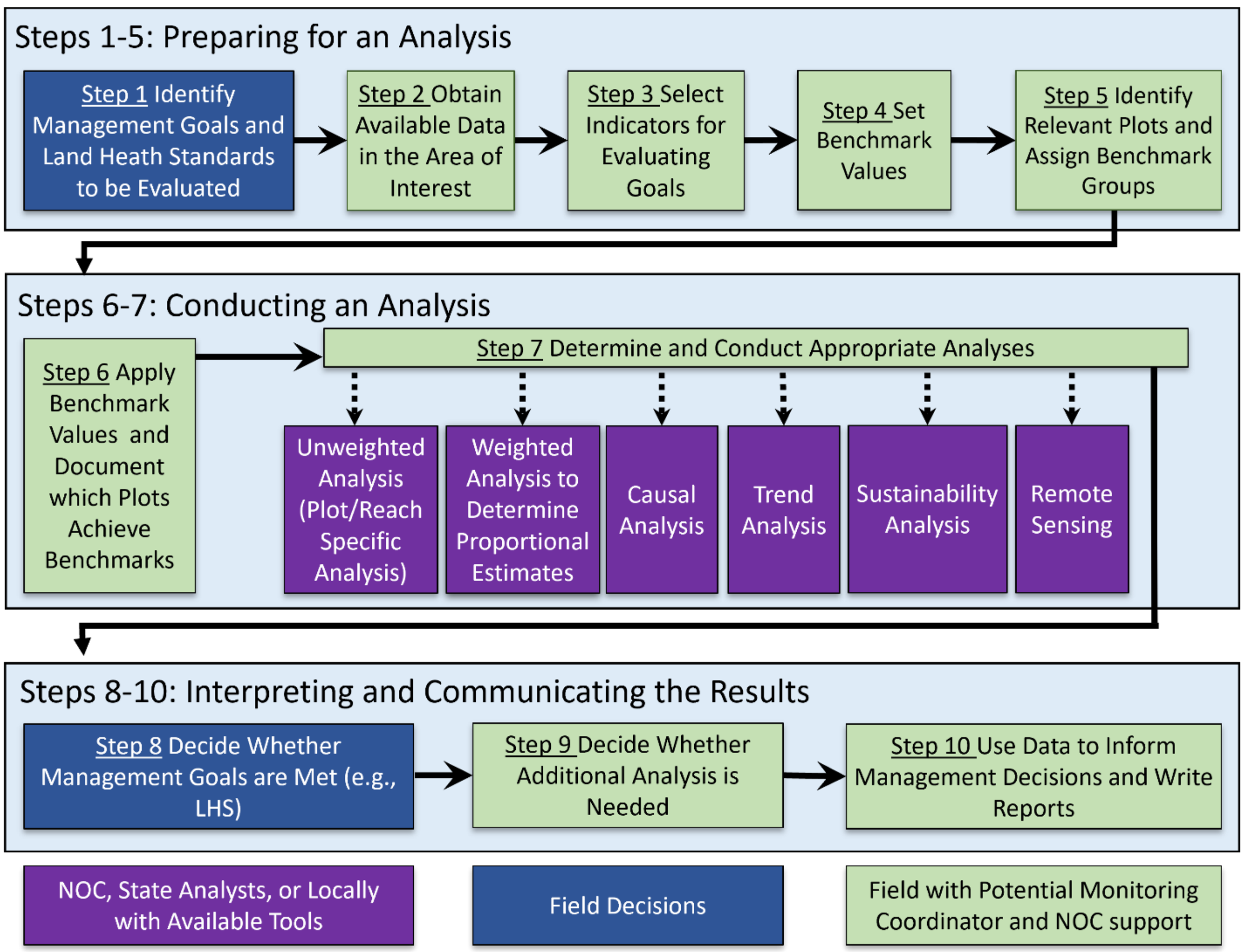

Figure 6-1. Analysis and Reporting Workflow

Steps 1-5: Preparing for an Analysis

Steps 1 through 5 overlap with the steps in the MDW and information for these steps of the analysis workflow may be found in the relevant MDWs. Review these worksheets and other relevant management documents to identify the relevant management goals, indicators, benchmarks, and benchmark groups to use in your analysis. If an analysis is being conducted which doesn't have a corresponding MDW, or the worksheet is out-of-date, steps 1-5 will need to be completed with the planned analysis questions in mind.

For a more detailed look at these individual analyses, refer to Step 7 below.

Step 1: Identify management goals and Land Health Standards to be evaluated

Management goals and/or questions will guide the analysis regardless of whether the initial sample design or data was collected for the current analysis. If available and applicable, refer to the MDW for the original management goals and monitoring objectives. If the management goal at hand is listed, review and reference this document throughout the next seven steps as needed. If an MDW with original management goals and monitoring objectives is not available, or original the goals and objectives do not meet the current data analysis needs, the first step should be to outline the management goals or questions to be evaluated and outline the monitoring objectives. A full MDW is not required, but following the structured workflow for developing management goals, selecting indicators, identifying study area, and outlining monitoring objectives can be extremely helpful (See Section 4 Design, Steps 1 and 2). Other helpful documents include LUPs, LHSs (available in BLM TN 453 Appendix 1), other policy and NEPA documents, and Biological Opinions (See Section 4.3, Step 1a).

Step 2: Obtain available data within the area of interest

Gather all available data within the area of interest for the management goals identified in Step 1. Use the AIM data portals (described below) to visualize your data to better understand the amount and type of data that has been collected in your analysis area and each reporting unit. This will help to inform each successive step below, with a focus on Step 7 (see Section 6.3.2).

The section below will focus on AIM data types, but other applicable data should also be used, including long-term monitoring datasets (e.g., MIM, PFC, IIRH, frequency transects, photo plots, etc.), covariate data (e.g., precipitation and climate data from Planning tool for Resource Integration, Synchronization and Management (PRISM), Gridded Surface Meteorological Dataset, Stream-Catchment Dataset (StreamCat), local weather stations), and short-term monitoring or use data (e.g., grazing utilization, recreational use information, etc.).

There are three main types of AIM data:

- *Calculated indicators* of ecosystem health for uplands (terrestrial ecosystems), streams and rivers (lotic ecosystems), and riparian and wetland areas. These are also known as AIM indicators or AIM indicator data. For Terrestrial and Riparian & Wetland AIM data, there are plot-level indicators and species-by-plot indicators (Species Indicators).
- *Raw data* are the direct measurements recorded in the field using AIM methods as described in the AIM protocols. These are used to calculate AIM indicators.
- *Site photos* showing each AIM monitoring location each time it was visited.

AIM data can be accessed using several different tools, each designed for a specific purpose or audience, review the tools section above for all data access options. The BLM AIM databases are updated annually after field data is finalized, indicators are calculated, and QC is completed. If there are data needs prior to this update or for help interpreting AIM indicators, contact the State Office AIM Team or relevant NOC AIM Team members.

Overview of the National Terrestrial AIM Dataset aka Landscape Monitoring Framework

The National Terrestrial AIM Dataset, aka the Landscape Monitoring Framework (LMF), is collected using the Natural Resource Conservation Services (NRCS) National Resource Inventory (NRI) methodology which mirrors the data collected by the BLM using the AIM Monitoring Manual for Grassland, Shrubland, and Savannah Ecosystems 2nd Edition. Each year the data were collected specific instructions for data collectors can be found on the NRI Grazing Lands On-site Survey webpage. Also see Interpreting Indicators of Rangeland Health, Version 5. Additional LMF resources can be found in Section 4.2 and 6.2.

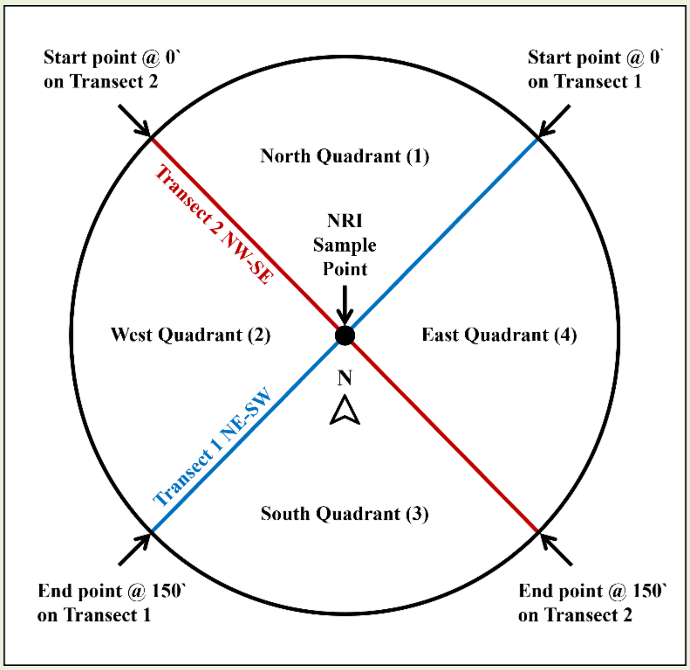

Figure 6-2. Standard plot layout for Natural Resource Conservation Services (NRCS) National Resource Inventory (NRI) points. This plot layout is used for terrestrial National AIM Design Points (aka LMF). The data are housed in the terrestrial database labeled as the "LMF" layer. Data are collected along 2 intersecting 150ft transects in a cross shape oriented 45 degrees from magnetic north.

The monitoring locations are selected using spatially balanced, random sampling approaches to provide an unbiased representation of land conditions. However, these data should not be used for statistical or spatial inferences without knowledge of how the sample design was drawn or without calculating spatial weights for the points based on the sample design. The LMF sample design information can be found in the National Terrestrial Design Database.

<u>Analysis Implications:</u>
Terrestrial National (LMF) data can be used together with AIM data. A few key considerations when using the National Design data include:

- The National Design uses a BLM-wide (excluding AK) sample design intensified on Greater Sage-grouse habitat. Points are paired within randomly selected Public Land Survey System quarter sections
- Only Rangeland locations are sampled – forested plots (> 20% tree cover) are rejected
- LMF plot area is 17,671ft^2 compared to 29,588ft^2 from a standard terrestrial AIM plot with a 25 meter spoke design and 5 meter trample zone – this can affect species inventory
- Data collectors do not record standing dead, cyanobacteria, duff, embedded litter, or rock fragment size classes

Step 3: Select indicators for evaluating goals

Each indicator selected for analysis should be directly applicable to the management goal(s) of the analysis. First, review the standard indicators calculated by the National AIM Team in the relevant resource's database. Many existing resources are available to crosswalk these indicators to common management goals, such as LHSs. These resources include Appendix 1 of BLM TN 453, the HAF TR and associated state RMP-amendments, as well as peer-reviewed literature (see Table 6-1 for a few example indicators).

When selecting indicators to address your management goals, it may be helpful to focus on indicators which reflect the primary threats to ecosystem function in your specific management area. For example, for the management goal of sustaining upland soils, there are many indicators which can speak to different aspects of that goal. In an area where soil loss and wind erosion are major factors in landscape degradation it may be best to focus on indicators such as bare soil amount, canopy gaps, and perennial cover. On the other hand, in other ecosystems where the primary concern to soil health is maintaining infiltration and permeability rates it might be better to focus on indicators such as cover of deep-rooted perennial grass.

Other considerations for indicator selection include: the analysis scale, the availability of benchmarks, ability to detect trend, and indicator transparency and interpretability by the public and stakeholders. It may be necessary to revisit this step after determining the type of analysis (Step 7) to ensure indicators will be applicable or that essential indicators were not missed.

The standard indicators calculated by the National AIM Team comprise only a subset of the potential indicators that can be calculated from data collected using AIM methods. If additional custom Terrestrial indicators are needed for a particular analysis but are not available from any of the AIM databases, use the Rangeland Indicator Calculator or contact the relevant National AIM Team Analyst or State Analyst for assistance (see Section 6.2 for more information).

Terrestrial Indicators	**Lotic Indicators**	**Riparian & Wetland Indicators**
Bare ground	pH	Bare ground
Nonnative invasive species	Specific conductance	Nonnative invasive species
Plant species of management concern	Temperature (instantaneous)	Plant species of management concern
Vegetation cover and composition	Pool dimensions	Vegetative cover and composition
Vegetation height	Streambed particle sizes	Vegetation height
Species richness	Floodplain connectivity	Species richness

Terrestrial Indicators	Lotic Indicators	Riparian & Wetland Indicators
Proportion of large gaps between plant canopies	Large wood	Woody vegetation structure
Soil aggregate stability*	Benthic macroinvertebrates	Hydrophytic cover
Density*	Priority noxious vegetation	Litter/thatch cover
	Bank stability and cover	Water cover
	Canopy cover	Hummocks*
	Turbidity*	pH*
	Total nitrogen* and phosphorus*	Specific conductance*
	Bank angle*	Total nitrogen* and phosphorus*
	Thalweg depth profile*	
	Pool tail fines*	
	Greenline vegetation composition*	

* Contingent indicator: measurable ecosystem component having the same cross-program utility and definition as core indicators but that is measured only where applicable. Contingent indicators are not expected to be informative or cost effective for every monitoring application and, thus, are only measured when there is reason to believe the resulting data will be important for management purposes.

*Table 6-1***.** *AIM terrestrial, lotic, and riparian & wetland indicators commonly used in analyses to evaluate management goals.*

Step 4: Set benchmark values or define condition/descriptive categories

A fundamental piece of making defensible management decisions is using a clear and understandable rationale for how data is used to draw conclusions. For example, the BLM Rangeland Health Standards (RHS) Handbook states that land health evaluations require a "consistent, defensible approach to drawing conclusions; an approach that is logical and provides a pathway between data, indicator, standard and conclusion". To do this there needs to be some way of connecting the data to the conclusions. Benchmarks can act as a bridge to connect data to conclusions. Benchmarks help turn policy statements such as “take appropriate action” or “make significant progress toward fulfillment of LHSs” into specific, measurable objectives.

Benchmarks are indicator values, or ranges of values, that describe desired conditions. When indicator values are outside the desired range, this may require additional data be collected or reviewed or may prompt management action. When indicator values are inside the desired range, this may indicate management success (Webb et al., 2020). Benchmarks provide a quantitative way of classifying AIM indicator data into two or more categories. Specific benchmark values are often applied to indicator data from points which have similar ecological potential or may respond to management actions similarly (benchmark groups) and thus reflect the condition of that area relative to its potential. Applying benchmarks which are specific to the ecological potential of each site allows for an easy comparison of sites across large areas and summaries of condition at the scale of the reporting unit. For instance, when applying benchmarks for bank overhead cover (canopy) to stream reaches, a stream in an arid desert or canyonland may have different potential to support canopy growth than a stream in forested mountains. Grouping points into ecologically meaningful benchmark groups will allow benchmarks to vary across points in relation to their ecological potential while still allowing summary of condition across a heterogeneous landscape.

Benchmarks are most often set with the intent to compare monitoring data to desired or reference conditions. However, in the absence of quantitative information regarding desired/reference conditions, descriptive benchmarks can also be used to categorize indicator data. Descriptive benchmarks should be set by a resource specialist and/or IDT to ensure benchmarks are not arbitrary. These benchmarks may aid in exploratory data analysis or improve data visualizations. For a detailed description of setting benchmarks, see Section 9.0 and BLM TN 453, Appendix 2 (Kachergis et al. 2020).

For some data uses an analysis might only consist of reviewing continuous data, summary statistics, or running regressions. For these specific purposes, benchmarks are not needed, skip this step, continue to the first part of Step 5 to identify relevant plots/reaches and then jump to Step 7 (see Section 6.3.2).

Step 5: Identify relevant plots/reaches and assign benchmark groups

Before beginning analysis, ensure that the applicable plots/reaches to address the monitoring objective(s) are selected and then assign each plot to a benchmark group. For the analysis it may not be appropriate to include all points collected in the area of interest. For example, if there are points across an entire field office but the desire is to evaluate a sage-grouse habitat objective, only the points that are within sage-grouse habitat should be considered for that objective. Another example is if the intent is to conduct a weighted analysis to evaluate overall stream condition in the field office, it may be appropriate to limit the analysis to random plots and only data collected in a subset of years, excluding repeat visits.

Benchmark groups are groups of monitoring points that have the same benchmark value for evaluating the success of a particular monitoring objective. In general, benchmark groups are areas or groups of monitoring sites which have similar climate, topography, geology, vegetation, hydrology, and soils and thus are expected to respond similarly to disturbance and management actions. Therefore, the same benchmarks are likely to be appropriate for all plots/reaches within that benchmark group. These groups may be determined by a geospatial layer (e.g., level IV ecoregion), plot/reach characteristics (e.g., stream width, stream gradient, soils, landforms, ecological site, wetland type), or some other defining feature. After selecting the points to use in the analysis, assign each to the appropriate benchmark group.

Steps 6-7: Conducting an Analysis

The National AIM Team, State Office AIM Team, partners, geospatial ecologists, and GIS specialists may be able to assist with Steps 6 through 7 (Figure 6-1) or provide guidance and support as needed. When contacting the State or National AIM Analysts, including the following information will help understand your needs and expedite next steps and planning:

- A succinct statement of the analysis objective
- Deadline for analysis results
- Points of contact
- Monitoring objectives or a list of classified points – this may be in the form of a completed benchmark tool (described below)
- A list of points to include or exclude in the analysis and some justification for excluded points (if not all points within each reporting unit)
- Spatial layers describing reporting units

Step 6: Apply benchmark values and document which plots achieve benchmarks

Applying benchmarks simply means converting continuous indicator values (e.g., 35% cover) into categories (e.g., “meeting objectives”, “minimal departure from reference” etc.). These categories are most helpful when they represent the status of the sampled point relative to their ecological potential or the desired condition of that point. However, these categories could also represent purely descriptive categories (e.g., “high”, “medium”, “low”) to aid in interpretation of the data. Benchmarking helps to bridge the gap from data to management application by directly tying indicator values to our management goals so that we can use that data to inform our decisions.

In Step 5 (see Section 6.3.1) benchmark values and benchmark groups have been created, applying benchmarks to the data that fell within the benchmark group informs how well each plot is doing relative to its potential and enables summarization of those categories to the landscape level. For example, if we had data from a loamy ecological site and some from a sandy site, we’d want to apply different benchmarks to the sample locations that fell in the loamy vs sandy areas. If we did not apply separate benchmarks, and only looked at the indicator values across all sites, the naturally higher bare ground of a sandy site and the lower bare ground values of a loamy would create a biased view of the data.

The output from this step is a table of each point and each indicator categorized by comparing the indicators values to the benchmark value or range for the corresponding benchmark group. This table can be summarized into figures or graphs displaying the number of points in each condition category for each indicator. It may also be helpful to calculate summary statistics (mean, standard deviation etc.,) for each benchmark group. These may be your final results or can be used in further analysis such as weighed analysis. There are several tools that can help with this step listed in the

Step 7: Determine and conduct appropriate analyses

There are many ways to use AIM data including but not limited to: the individual point scale, landscape scale analyses, and combining AIM data with other types of information. In this section we highlight several common analysis types used by AIM practitioners. This is by no means an exhaustive list of all the potential analysis types and statistical tests, but a general introduction to analyses that are most commonly used. We’ve grouped this section by these analysis categories:

- Unweighted
- Weighted
- Trend
- Causal
- Sustainability
- Remote sensing

These analysis types can be accomplished in many ways (e.g., regression, summary statistics, t-test, etc.). Table 6-2 can be used to determine which analysis type and specific methods are the best option based on various considerations:

- Inputs such as general number of sample points available, benchmarks, and type of sample design of available data
- Time and resources available
- Analysis objectives or use cases
- Available remote sensing data or tools

With all these considerations, we recommend balancing the time investment to accomplish an analysis with the current use case. A data exploration might start as a simple summary of data, and as the data is incorporated into decisions a more robust approach might be needed. Remote sensing, local data, and other lines of evidence should be considered throughout the process of determining appropriate analyses. Throughout this section different analyses are listed but order and step number are no indication of priority. For help determining and conducting appropriate analyses, contact the State Office AIM Team or relevant NOC AIM Team members.

Analysis Type	Possible Analysis Methods	Description	Inputs	Time Commitment	Skills needed	Example Use Cases
Unweighted Analysis **(Step 7a-1)**	Point counting	A categorical analysis summarizing the number of points in different condition categories	One or more targeted or random points, Benchmarks	Low	Excel use	Data exploration; small area assessments; simple Environmental Assessments; data summaries; describing status of indicators for an Environmental Assessment or Environmental Impact Statement; using data to set benchmarks
	Summary statistics	Summary statistics (e.g., mean, median, standard deviation), generally grouped by some meaningful unit such as stream size or ecological site group.	Multiple targeted or random points	Medium	Excel use, or R coding or other statistical programs.	
	Indicator value review	List indicator values to review and compare without statistics.	One or more targeted or random points,	Low	Database access only	
Weighted Analysis **(Step 7a-2)**	Proportional Extent Estimates	A categorical analysis summarizing the number of acres/stream kilometers in different condition categories	Multiple random AIM points; Benchmarks, remote sensing data	High	R coding (package built for R), deep understanding of GRTS designs	Broad scale assessments; more controversial Environmental Assessment or Environmental Impact Statement; Sage Grouse Habitat Assessment Framework
	Summary statistics	Summary statistics (e.g., mean, median, standard deviation), generally grouped by some meaningful unit such as stream size or ecological site group.	Multiple random AIM points; remote sensing data	Medium	Excel use, or R coding or other statistical programs.	

Analysis Type	Possible Analysis Methods	Description	Inputs	Time Commitment	Skills needed	Example Use Cases
Trend Analysis **(Step 7b)**	Regression	Measuring change in indicator values over time	Many random or Targeted AIM points; remote sensing data	Medium	Excel use, or R coding or other statistical programs.	To assess progress towards meeting standards; understand changes in resource conditions over time; understand whether changes in management are producing the desired effects or initial/additional management actions are needed to change current ecological trends. Specific examples may include, evaluating trend of an allotment for a grazing permit renewal or reporting long term trend for affected environment sections of NEPA documents.
	Comparing two or more time frames	Indicator review, summary statistics for points, or remotely sensed areas measured at two different time frames. Review and compare without statistics, or compare with a t-test, ANOVA, or similar. Can also be performed in conjunction with a weighted analysis.	One or more random or targeted AIM points; remote sensing data	Medium	Excel use, or R coding or other statistical programs.	

Analysis Type	Possible Analysis Methods	Description	Inputs	Time Commitment	Skills needed	Example Use Cases
Causal Analysis **(Step 7c)**	BACI, Regression	Using data to understand associations between conditions and change drivers and/or determine the cause of a change over time	Random or targeted AIM points or remote sensing estimates from before and after a disturbance or treatment, ideally with control/untreated data	High	R coding or other statistical programs., an understanding of treatment sample designs	Determining the cause of not meeting standards
Sustainability Analysis **(Step 7d)**	ANOVA/ Regression	An analysis comparing different management actions or different levels of intensity of treatment or management (e.g., grazing) with the intent to understand how those actions will affect future resource use and availability.	Multiple AIM points or remote sensing data from multiple different management treatments/levels of intensity, ideally using a specific experimental design	High	R coding or other statistical programs and statistics	Determine the effect of current resource use on future resource use to ensure a sustainable land uses.
	Qualitative assessment	Non-statistical approach of gathering multiple lines of evidence to inform future expectations.	Scientific literature, remote sensing data, review of previous trend analysis and adaptive management decisions.	Low	Ideally ID Team	

Analysis Type	Possible Analysis Methods	Description	Inputs	Time Commitment	Skills needed	Example Use Cases
Remote Sensing **(Step 7e)**	Site Characterization Report	Summary report of vegetation condition and climate history for a BLM administrative unit. Including summary statistics and trend analysis.	Tabular spatial location.	Low	Access to Google Earth Engine tools	Broad scale assessment: data can be used to contextualize BLM decision making reports (Figure 6-4).
	Condition and Trend Analysis	Highly dependent of remote sensing tool being used. See step 7e for a list of common remote sensing products used in conjunction with AIM data.	Spatial location,	Low to high	Access and understanding of remote sensing tools.	

Table 6-2. Common Analysis Types. A list of commonly used analysis types and methods to help determine an appropriate analysis approach to address specific management goals. Descriptions, inputs, time commitment, skills, and example use cases are listed to help understand possibilities. The skills needed for all analysis types include access to the AIM database and ability to view or download data. The skills needed column suggests R coding because code and packages exist for common AIM data uses and analyses however a variety of statistical programs can be used. The State Office and National AIM Teams are available to help working through this table and provide the skills needed to accomplish desired analyses.

Step 7a: Unweighted versus weighted analyses

Weighted and unweighted analyses can be used to summarize resource conditions across an area. Weighted analyses refer to analyses which use sample design information to add a weight to individual points (measured in hectares or stream kilometers) to statistically infer to the larger landscape. Unweighted analyses, in contrast, do not account for any sample design information or potential overlap of multiple sample designs. As a result, inference is limited to the area in which the data was collected (the plot(s) or reach(es)) and can't be extrapolated to non-sampled areas. Whether inference is being drawn to the larger landscape or individual points it is beneficial determine the proportion of points or resource that must meet benchmarks or desired values (See Section 4, Step 2 Developing Monitoring Objectives). Both weighted and unweighted analyses have benefits, but analysis objectives, available data types, inputs, and time limitations might determine which analysis is more appropriate for use.

Unweighted analyses can be conducted when there is not adequate sample size to complete a weighted analysis, there is limited time or capacity to do a weighted analysis, or there is no underlying sample design information. Unweighted analyses may also be more appropriate when conducting very broad scale or preliminary analyses when time to analyze large numbers of sample designs is limited. Unweighted analyses may result in spatial bias and an under estimation of variance, particularly in analyses with several complex designs. Care should be taken when selecting points for unweighted analyses. Because of these limitations, it may be best to use unweighted analyses alongside other lines of evidence such as remote sensing estimates, other long-term monitoring datasets, and professional judgement.

Weighted analyses account for the number of acres or stream kilometers that each monitoring site represents, otherwise known as a weight. When selecting this analysis approach, it is important to consider the underlying sample designs. Targeted points or points which were implemented non-randomly cannot be used to make a statistical inference beyond those plots and thus cannot be used in a weighted analysis. Weighted estimates are appropriate only for data coming from random sample designs. In comparison to an unweighted analysis, a weighted estimate will help to compensate for any unequal point weighting or spatial bias from point clustering. It is particularly important to follow a weighted analysis approach when combining points from vastly different sample designs (such as when combining AIM and LMF).

Weighted analysis, in this section, refers to proportional extent estimates of indicators of resource condition. However, weighted analysis can refer to several other analysis types such as those where sample points are weighted but not categorized (See Step 7a-2) or other inputs (e.g. indicators) may be weighted (See Interpreting and Communicating the Results, Composite Indicators and Indices).

<u>Unweighted Analysis</u>

Unweighted analyses are used for management decisions without explicitly accounting for the weight of each plot or stream reach. Often unweighted analysis is the first step to any analysis and used for data exploration and help determine if additional analysis will be needed to fully answer the management questions (discussed in Step 8 and 9). Two commonly used unweighted analyses are calculated indicator summary statistics and point counting analysis. A special use case of these two methods is when data from only a single reach or plot is used to address a management goal. When using unweighted analyses, it is helpful to put the data in the context of benchmark expectations because this enables comparison between areas of differing ecological potential.

- *Indicator Summary Statistics:* Calculating summary statistics using AIM indicator data such as means, standard deviations, percentiles, and counts, can be an important first step in understanding data. This can also help with setting benchmarks or summarizing baseline conditions (see Section 9.0, Appendix C for more information). When using summary statistics for an analysis rather than condition categories, consider whether benchmarks might differ among points. If so, consider grouping summary statistics by benchmark groups (or some other ecologically meaningful unit) or converting indicator values to a ratio of observed value to benchmark value to normalize across those unique benchmark groups. If benchmarks do not differ, using ungrouped indicator values is appropriate. An important part of summarizing indicator data is how the data is visualized. For examples of methods to visualize indicator summaries (see Interpreting and Communicating the Results).
- *Point Counting Analysis:* To do an unweighted analysis, benchmarks are applied to the data and then the number of sites in each condition are counted. As with any unweighted analysis, keep in mind how sites were selected and examine for any spatial clustering of points because that may influence results and interpretation of the data. Points may be subject to spatial bias when sample design weights are not considered (see Step 7b-2: weighted analysis). There are benchmark tools available for terrestrial and lotic resources that can assist in completing unweighted analyses (see Section 6.2, Analysis and Reporting Workflow and Tools). A point counting analysis does not allow for inference to areas beyond that which was sampled. To assess the percent of the landscape in each condition, a weighted analysis is required. Since this approach is relatively quick and easy to conduct it can be used to identify areas you would like to look at more closely (e.g., for treatment/restoration prioritization planning).
- *Single Point Analysis:* Some management decisions or questions can be addressed with data from one monitoring location. AIM data from a single point can be analyzed using a simple data summary table or figure to present the relevant indicator data. Monitoring objectives and benchmarks can also be applied to individual points to get an understanding of condition and trend at that point. For example, in evaluating the effectiveness of restoration or land treatments at a specific location, it may be sufficient to use condition at a single plot/reach to decide whether management was successful. In some cases, only one point may be available for analysis in your area of interest. Even if only one point is available or needed to answer management questions, monitoring data including AIM data from a broader area can be used to give context to the indicator values and condition of an individual point. In some cases, it may be appropriate to use individual measured values from a sampled point (e.g., pin drops for line point intercept, transect values, stream bank values, etc.) to obtain summary statistics (e.g., mean, variance) for the point. However, spatial autocorrelation may result in biased estimates, and inference is limited to the area in which the data was collected (the plot(s) or reach(es)) such that estimates cannot be extrapolated to non-sampled areas. Single point data is often used as part of a multiple lines of evidence approach.

Weighted Analysis

There are two common approaches for weighted analysis with AIM data: calculating proportional extent estimates and weighted indicator summary statistics. Both approaches weight the sample point within the area of interest (can include one or more designs) and usually require at least 10 monitoring points for accurate estimates. The main difference between the two is that extent estimates require benchmarks. Sage-grouse habitat assessments and LUP effectiveness are common applications where weighted analyses are expected. Although many land management decisions will not require a weighted analysis, weighted analyses are defensible so, when possible, a weighted approach should be considered.

Considerations for a weighted analysis include:

- Policy requires reporting on the percent of a resource with a specific condition or data range
- Reporting on a large area or area with a large amount of stream km
- Where a known level of confidence is desired.
- If a complex or controversial decision must be made

Point weights can be calculated from the total extent or amount of a monitored resource (area of interest such as acres or kilometers) divided by the number of monitoring points sampled.

$$\text{weight} = \frac{\text{area of interest}}{\text{number of points sampled}}$$

For example, assuming a single unstratified sample design, in a 10,000-acre grazing allotment with 10 evaluated points, the weight of each point is 1,000 acres (10,000 divided by 10). For a stratified sample design, the extent of the resource in the given stratum would be divided by the number of points in that stratum. Similarly, this approach can be taken with multiple overlapping designs. Weights are used to generate unbiased resource status or condition across the landscape. Specifically, the weight is used to adjust the relative influence each point has on the final results; points with larger weights have more influence, and points with smaller weights have less influence. The weight of each point depends on the design and how it was implemented as well as the reporting area of interest. Figure 6-3 shows the formula to calculate the relative weights of sample points that were clustered in an area of interest. Weighting allows for a more unbiased analysis of a design that contains stratification or allows for the use of multiple, sometimes overlapping, designs. However, calculating weights can be complex, especially if multiple sample designs are being combined, as it depends on all the underlying sample designs and the stratification of those designs. To collaborate on a weighted analysis, contact your State Lead/Coordinator, State Analyst, and/or the National AIM Team.

During collaboration you will work with the Analyst to:

- Ensure all the required documents are complete and all the required data has been received
- QC the design database and point tracking information
- QC the monitoring objectives and reporting area polygons(s)
- Calculate weights
- Calculate proportional estimates and confidence intervals

- Generate figures and tables with the results
- Send a summary of the results back to the individual requesting the analysis

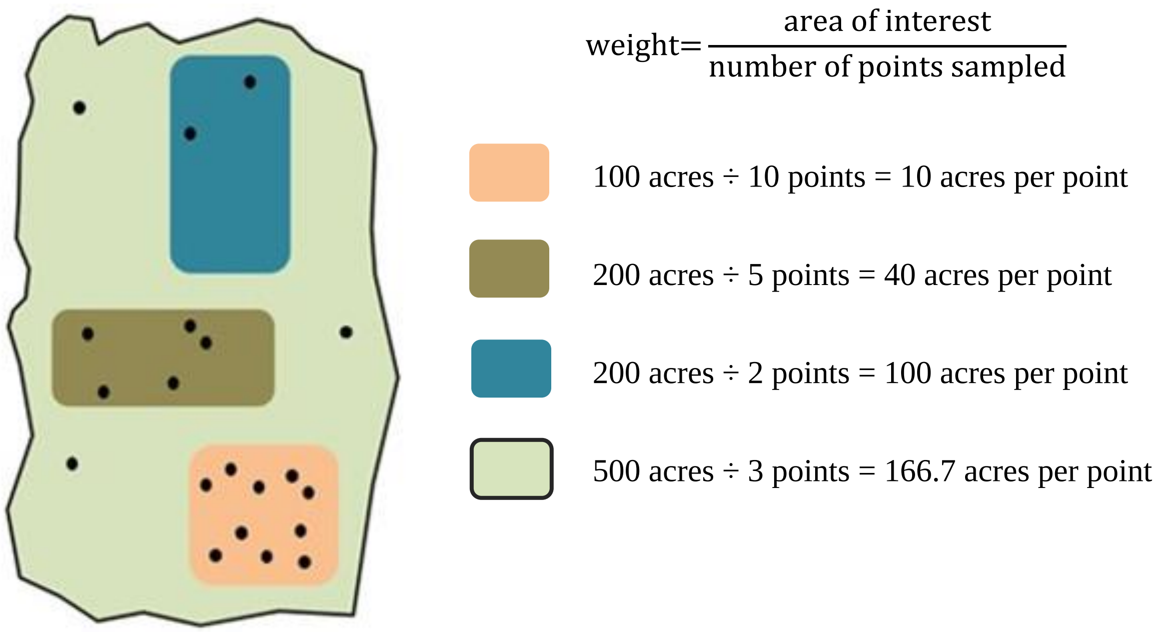

Figure 6-3. Weighted points within an area of interest. Weighting points reduce the bias associated with differing densities of points from a stratified design or from combining multiple random sample designs. Weights are assigned to each point within a group using the formula within the figure.

- *Proportional Extent Estimates:* Calculating proportional extent estimates is one analysis option to consider if the AIM data were collected using a spatially random sample design. Proportional extent estimates use the weight each sample point within the area of interest (can include one or multiple designs) to calculate the percentage of the resource in a given condition on the landscape, with known level of confidence. To assign conditions benchmarks must be used and each point assigned to a benchmark group. An example result of this type of weighted analysis is: “75% (+/- 8%) of brood-rearing sage-grouse habitat is in suitable condition.”
- *Other Weighted Analyses:* Without benchmarks a weighted analysis may still be an option. Sample weights in combination with raw indicator values (i.e. continuous data) to produce outputs such as weighted indicator summary statistics, cumulative distribution functions, and/or model-based analyses which include design weights. These approaches, like proportional extent analyses, take into account the spatial distribution and sampling probabilities in a given area to improve the accuracy of summary statistics and confidence intervals and help to account for any spatial bias in the data.

Step 7b: Trend analyses

Many management goals require an analysis of trend. In a trend analysis, data from two or more time periods are compared to determine whether there has been a change in that time frame. A trend analysis may be used for a variety of goals such as determining treatment effectiveness or evaluating landscape condition and whether a management action or change in management actions might be needed. Trend analysis can incorporate a variety of approaches. It can be analyzed using a weighted or an unweighted approach, can be used to compare changes in indicator values or changes in condition categories, can be a formal analysis or an exploratory analysis to ensure conditions or values are moving in the correct direction, as well as many more approaches. Most LUP AIM designs have a five-year cycle to enable a trend analysis that controls for effects caused by high interannual variability in weather conditions between years.

Parametric (linear regression) and nonparametric (Mann Kendall) approaches can be used to assess the rate and direction of change over time of raw indicator values and incorporate additional variables such as precipitation or other climate information. Trend analyses can also be completed at the individual point scale to assess change over time at a single point. The proportion of the landscape in different condition categories can be compared for two or more time frames using a weighted analysis approach. Remote sensing is also valuable when analyzing trend since estimates often cover greater spans of time compared to monitoring data and can help provide context for results or be used to look at trend more directly. Table 6-2 suggest several options for trend analyses.

Step 7c: Causal analyses

Causal analysis can help determine what is potentially causing changes in ecological conditions as well as to understand the effects active or planned management action have on an ecosystem. For example, a causal analysis might be used to determine whether grazing is contributing to a degraded ecosystem or it might be used to predict the anticipated effect of a restoration treatment or to determine whether that treatment was effective. Causal analysis is often done using two general approaches. One common approach is a general correlation analysis where the ecosystem attributes and associated conditions are correlated to potential covariates (causal factors). Another approach is a more structured design approach to help control for impacts and isolate the cause in patterns seen within an ecosystem such as a Before-After-Control-Impact (BACI). When assessing condition causes, consider whether you are trying to look at the general trends and interactions of those trends on the landscape, or trying to isolate one impact (treatment, restoration).

Ecology is complex and many covariates can contribute to, or appear to be correlated with, an ecosystem response. To look at one or a few variables at a time, an experimental design created for that purpose can be very helpful. In one common and useful experimental design, the Before-After-Control-Impact (BACI) design, data from both control and impacted (areas where management action has been taken) areas are collected before and after a management action or resource use. This framework can be applied post-hoc to most AIM points if there are enough pre and post disturbance points as well as undisturbed points which could be used as controls. Sites with similar climate, weather, and ecological potential, for instance, in the same ecological site, should be selected to minimize non-treatment effects and then subset into control and treatment groups. In this example, all locations would have similar climate and ecological potential, which will allow for more direct conclusions about the management action at the impacted locations. Before-After-Control-Impact design approaches or analyses are often used to evaluate the effectiveness of a vegetation treatment or restoration action.

Frequently, however, we do not have before, after, and control data and more correlative analysis could be used. While it is important to remember correlation does not mean causation, this approach can provide strong evidence for causation and context about our management actions. To assess correlation a regression analysis or, more commonly, a multivariate regression analysis is used. These analyses include both potential causal factors such as management types (e.g., grazing intensity, herbicide treatment, etc.) and ecological data (e.g., soil type, annual precipitation, etc.) to understand the interactions between the two types of variables. There are sometimes complex interactions between current uses or disturbance, management actions, historical uses, climate, soils, and topography making it difficult to isolate a single potential causal factor to examine its effects. For example, it may be difficult to determine whether ecological degradation is caused by drought or grazing, because it is likely that both factors play significant roles. Although regression analyses can help identify correlation between covariates and their contributions to the observed effects it is recommended to consider additional analyses and multiple lines of evidence to determine cause (see Figure 6-4 for a remote sensing example of using additional lines of evidence).

Wild Horse and Burro "Hit Areas" for Further Investigation

Wild horse and burro populations are known to have a major impact on vegetation, particularly within riparian areas. However, quantifying the impact of wild horse and burro population on vegetation through AIM data alone remains challenging. The inclusion of remote sensing data may provide another line of evidence for assessment. Where available, high-quality LiDAR data can be used to quantify vegetation structure and density. In addition, comparisons between current and historic high-resolution imagery may provide some information on wild horse and burro population impact by identifying increases in "game trails" (Figure 6-4). While such trails may also result from other causes, such as increased recreation, they may also be indicative of increased wild horse and burro use and could be used to highlight areas for further field monitoring.

Figure 6-4. Wild horse and burro populations impact riparian vegetation. A substantial increase in game trails can be seen along Jerry Creek in the Little Book Cliffs Wild Horse Range near Palisades, CO from September 30, 1980, to August 30, 2018.

There are many situations where BLM might use AIM and other data to "determine cause" and AIM uses and builds on existing guidance. Tech Note 453 (Section 3.0) describes approaches to determine potential causes or correlations between nonachievement of Land Health Standards. Tech Note 453 also emphasizes the need to look at multiple scales to determine whether a pattern or correlation is associated with your management question, or a larger impact seen across the landscape. Similarly, BLM Handbook H-4180-1 (the Rangeland Health Standards) describes a process for using landscape-scale analyses to illuminate relationships between conditions and causes.

Causal analyses may require larger amounts of data, resources, planning, and analysis time. Reach out to the State Office or National AIM Team for support. Before attempting a causal analysis be clear on the goals of the analysis, most causal assessments are done to ensure and demonstrate that management actions are not the reason for undue harm to the ecosystem, both for current and future use. It is often important to understand the effect a management action might have on future resource use; in these cases, a sustainability analysis (step 7d) is recommended.

Step 7d: Sustainability analyses

A sustainability analysis examines the effect of current resource use on future resource use. For example, how does the current level of livestock grazing change forage availability for livestock grazing in the future? The multiple use/sustained yield mandate of the BLM implies that the bureau should conduct this kind of analysis for permitted uses, but in practice this is a very difficult kind of analysis. A sustainability analysis might require a sample design in which plots are placed in areas where different levels of resource use can be maintained over a relatively long period of time but other variables can be kept constant. This approach is not always feasible, and in these cases, we recommend using multiple lines of evidence, scientific literature, and past experience with adaptive management practices to ensure the sustainability of our ecosystems and land uses. Please contact the National AIM Team for assistance.

Step 7e: Remote Sensing Analyses

AIM methods are consistent across all BLM lands and between other agencies, which allows AIM data the ability to be combined with other agencies' data, other field monitoring information, information from satellites, and other aerial sensors to generate satellite derived maps of many different indicators. Most remote sensing products use these various datasets within empirical models to predict vegetation, soil, and water indicators continuously or thematically across a landscape. While remote sensing models can be very helpful, they are best used alongside monitoring data in a multiple lines of evidence approach when used in decision making.

The AIM program has shared our data with numerous groups. Although the number of products that include AIM data and/or are commonly used in conjunction with AIM data is too numerous to list, a comprehensive list of some of the most common remote sensing tools can be found in Section 6.2.

Guiding principles for using satellite-derived maps:

- Use maps within a decision-making framework.
- Use maps to better understand and embrace landscape variability.
- Keep error and uncertainty in perspective.
- Think critically about contradictions.
- See Allred et al., 2022 for more details.

Example analyses using remote sensing include:

- Treatment/restoration planning and prioritization (remote sensing products can be used to identify areas that warrant further investigation).
    - E.g., are there certain regions within reporting units that are of more concern than others?

    - Using the preponderance of evidence approach are there certain areas with several indicators in degraded condition?
- Rapid assessment of vegetation growth trend (Figure 6-5).
- Change detection: disturbances, dynamics, and treatment effectiveness.

There are many different remote sensing models and tools and choosing the appropriate product for your analyses is an important step in any remote sensing analysis. For more background on different remote sensing products or for support in remote sensing analysis contact the National AIM Team Remote Sensing Specialist or Analysts, and/or the State Office AIM Team. Commonly used remote sensing tools are those that provide fractional vegetation cover estimates. Technical Note 456: Evaluation of Fractional Vegetation Cover Products provides an analysis of three commonly used remote sensing products and discusses appropriate uses of each for natural resource programs and decision making. This is a rapidly evolving field and new remote sensing tools and products are continually being made available.

Site Characterization Report

The BLM has worked with Climate Engine to create site characterization reports to provide efficient information about BLM lands that can be used to contextualize decision making documents. No geospatial skills or software are required. A user can simply select a BLM unit of interest (at the State, District/Field Office or allotment level) and a site characterization report is generated for the selected area of interest. The information includes maps of the main plant functional types for the current year. Information on vegetation condition and trend is summarized for the selected area of interest, such as an allotment. The mean cover for each plant functional type is provided as well as the slope estimate from a Theil-Sen regression. Information on herbaceous vegetation production is included as well as climate summaries for the last four decades.

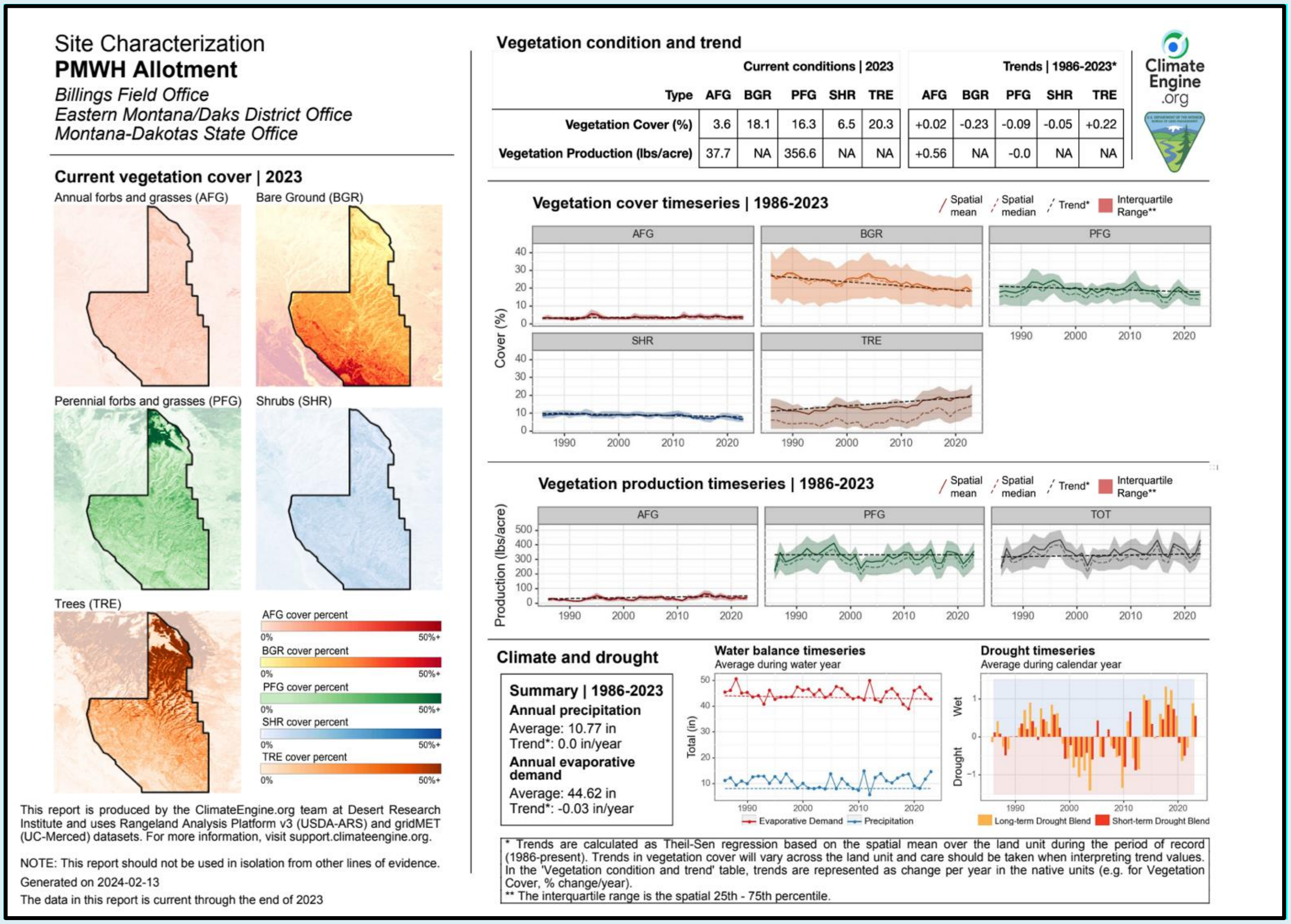

Figure 6-5. The Climate Engine Site Characterization Report (Section 6.2) for the Pryor Mountain Wild Herd Area. Spatial data provides on the left provides information about the RAP Plant Functional Types for the most recent year. The vegetation condition and trend provides a global mean of each type within the polygon and the trend slope for each type as well (top right). The time series graphs (center) provide information over the entire period of record (1986-present). Climate and drought indices are summarized for the extent of the polygon of interest as well (bottom right). Note: the spatial scale reflects the BLM administrative unit selected.

Steps 8-10: Interpreting and Communicating the Results

The final analysis phase (Steps 8 through 10) is to document, visualize, and interpret the analysis results in the context of management goals. Interpreting results is the responsibility of the data user. The AIM Project Leads, and District/Field Office specialists are the experts on each District/Field Office's management goals, field data, and management history. Local and historical knowledge should be used at this step to contextualize the analysis results.

Data Visualization

How data is visualized plays an important role in communicating results and helps to interpret complex analyses. There are a vast number of ways to display data, below are some examples that have been used to display AIM data in decision making (see Section 6.2 for more information).

Boxplots and Histograms

When summarizing continuous indicator data across a reporting unit it is helpful to visualize the data's distribution (i.e., the range and frequency of difference values). Boxplots and histograms are good methods for this (Figure 6-6). Boxplots, also known as box-and-whisker plots, are helpful because they display several key summary statistics such as: the median, interquartile range, overall range, as well as any potential outliers. The box extends from the 25th percentile to the 75th percentile (the interquartile range) and is split by the median (50th percentile). Whiskers either extend to the minimum and maximum values, or to 1.5 times the interquartile range. When paired with point data, they can also display the sample size which may influence how the data is interpreted. Areas with very little data (e.g., < 30 points) are likely to give less precise estimates.

Boxplots can also be used to compare data distributions from one area (or group of sites/a single site) to another area. This can be a helpful exploratory technique for contextualizing your data.

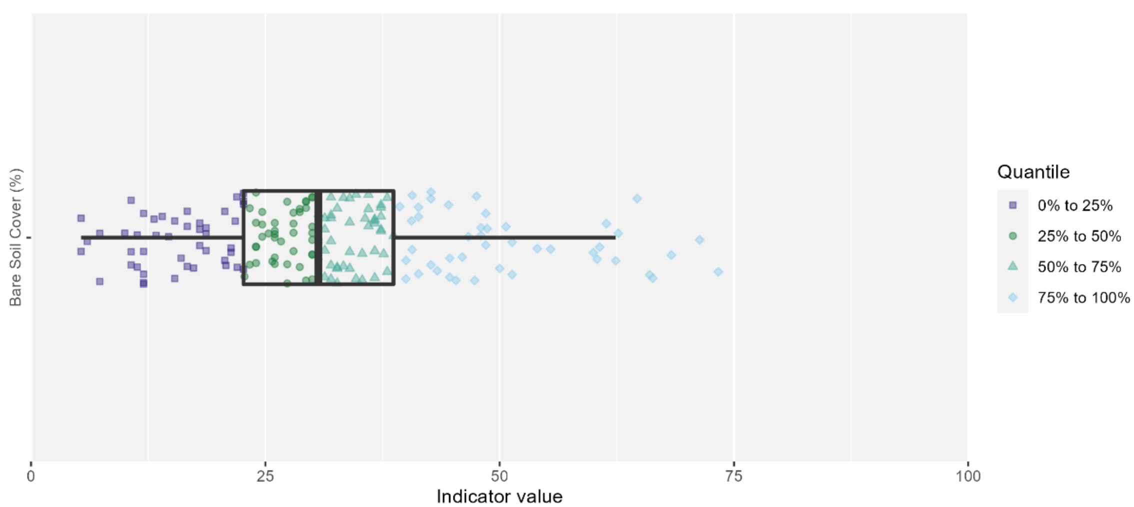

Figure 6-6. Example of a single indicator summary visualized with a boxplot, points, and color-coded by quantile.

Points and Error Bars

Points with associated error bars are a useful method for communicating categorical data such as proportional extent estimates from a weighted analysis. In this case, the points represent the estimate from a statistical analysis and the error bars represent confidence intervals describing the uncertainty around each estimate (Figure 6-7). The larger the confidence interval, the less precise the estimate and the greater the uncertainty. Whenever error bars are provided in a figure, the caption should state what level of confidence they represent.

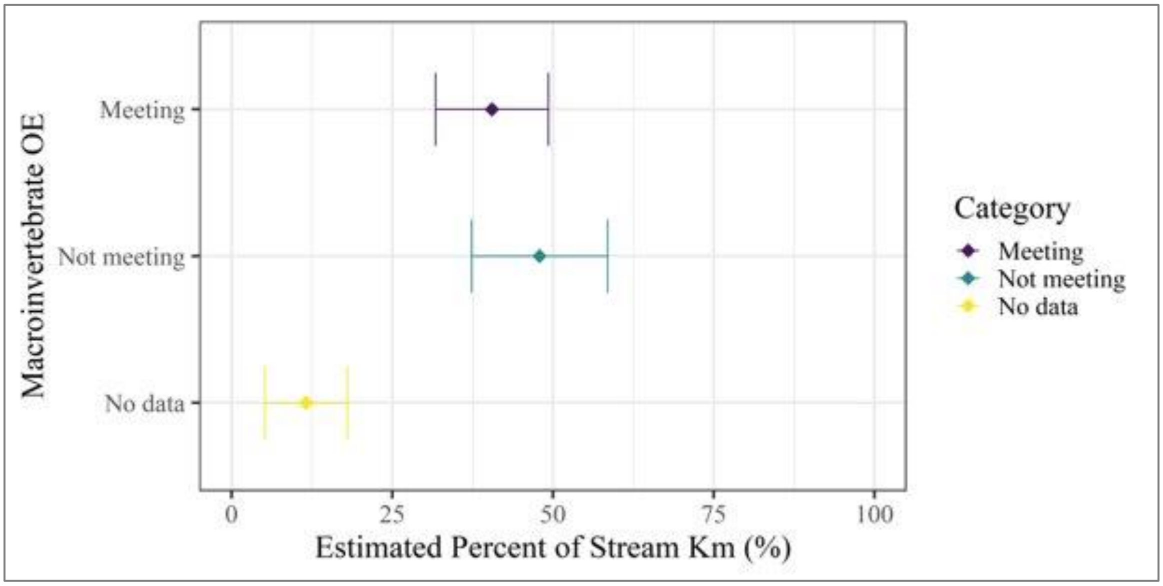

Figure 6-7. Proportional extent estimates and ± 90% Confidence Intervals represented by color coded points with error bars.

Stacked Bar Plots

A stacked bar plot (Figure 6-8) is another way to display data and conveys some of the same information as points and error bars (Figure 6-4) but doesn't display confidence intervals. Instead of the bars or points displayed separately for good/fair/poor conditions, bars are stacked for each indicator reported on. This is more appropriate for point counting rather than weighted analysis because confidence intervals cannot be displayed on these plots. Stacked box plots are a concise way to visualize data across indicators, years, or field offices (Figure 6-5).

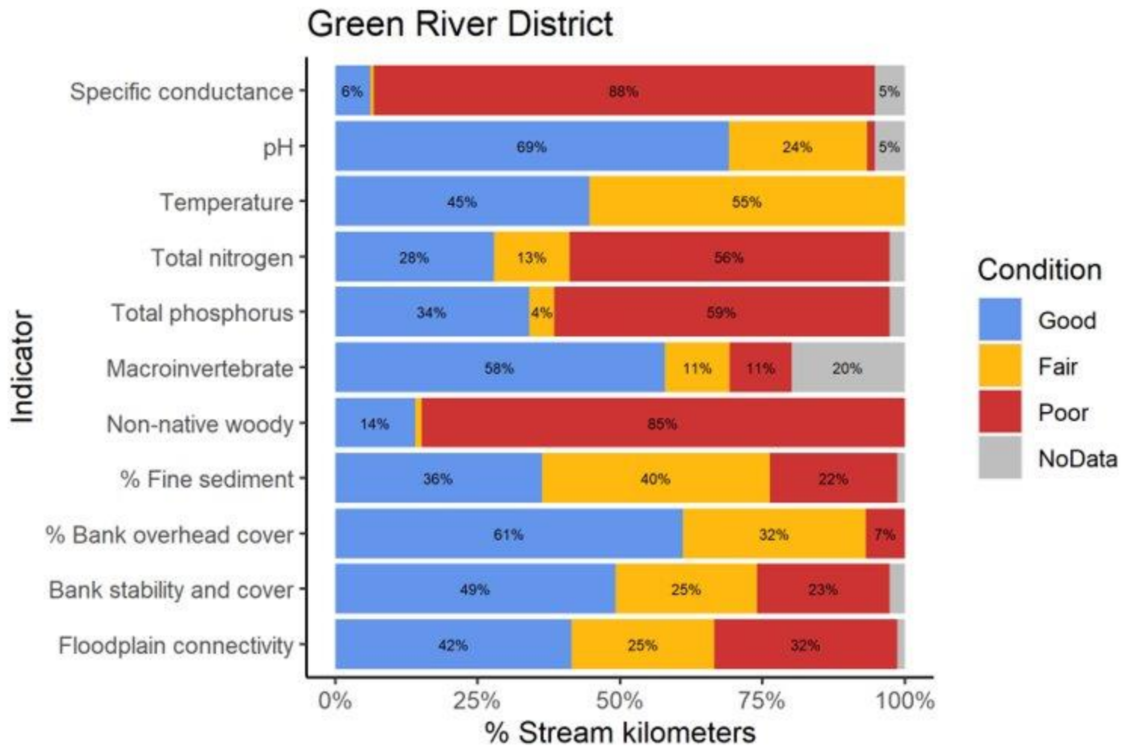

Figure 6-8. Stacked bar plot showing the percent of stream kilometers in good, fair, or poor condition for a selection of lotic indicators.

Maps and Photos

Displaying AIM data spatially can help to put indicator data in the context of the surrounding landscape and helps to illustrate any spatial patterns in conditions. Maps are also particularly important for weighted analyses as they can display the area within each reporting unit that is within the statistical inference of that analysis and inversely, areas which that analysis cannot extrapolate to. Maps may show the individual plots color-coded by indicator values or categories (Figure 6-9) or the reporting areas may be color-coded.

Condition Category	Proportion of Landscape
Suitable	65%
Unsuitable	35%

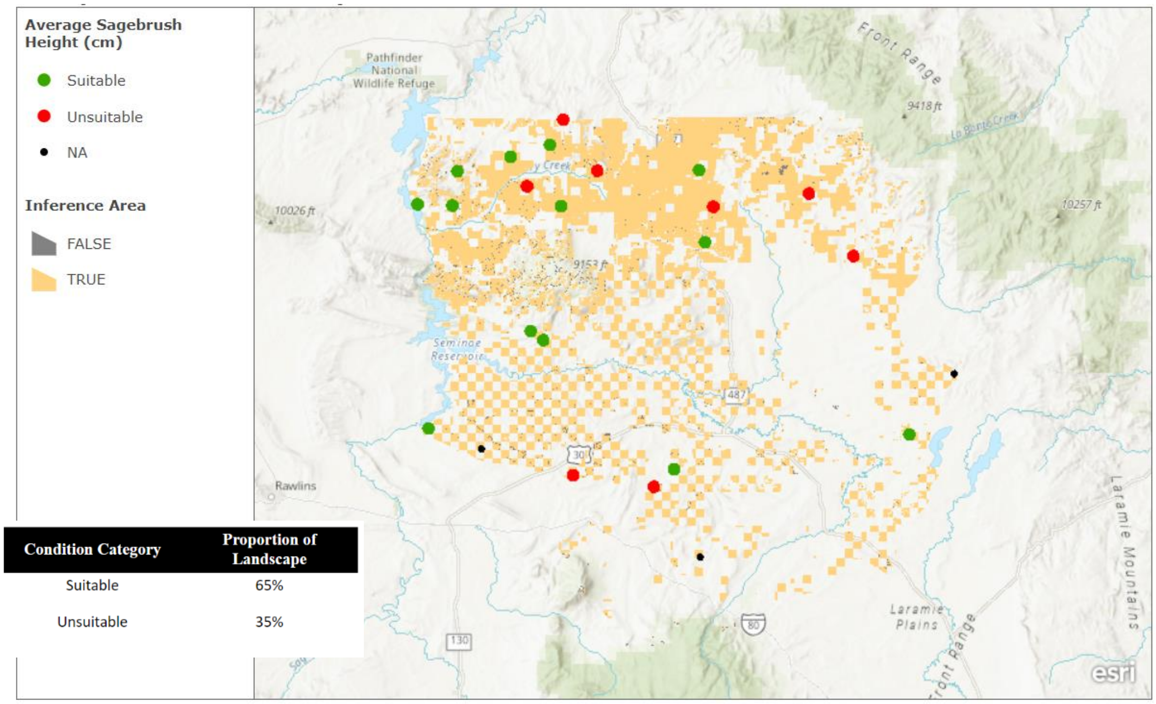

Figure 6-9. Results of a weighted analysis displayed spatially. Points display monitoring locations color coded by benchmark categories. Areas colored in yellow are within the inference area of the analysis whereas areas in gray are parts of the reporting unit that the analysis cannot infer to.

Photos can be helpful during the initial stages of data exploration to corroborate indicator data and benchmark group assignments as well during the reporting results phase to illustrate conditions across a reporting unit. These photos are informative with case studies that have management changes or where restoration and reclamation efforts have been applied (Figures 6-10 and 6-11).

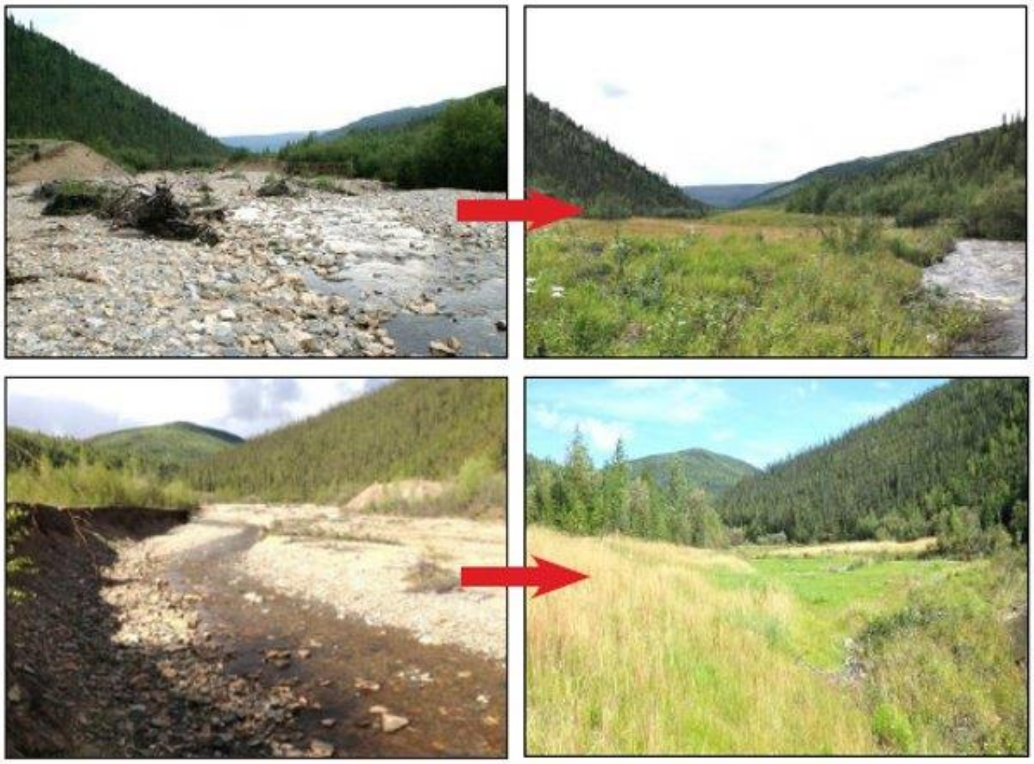

Figure 6-10. Example of using before and after photos in a stream restoration effort.

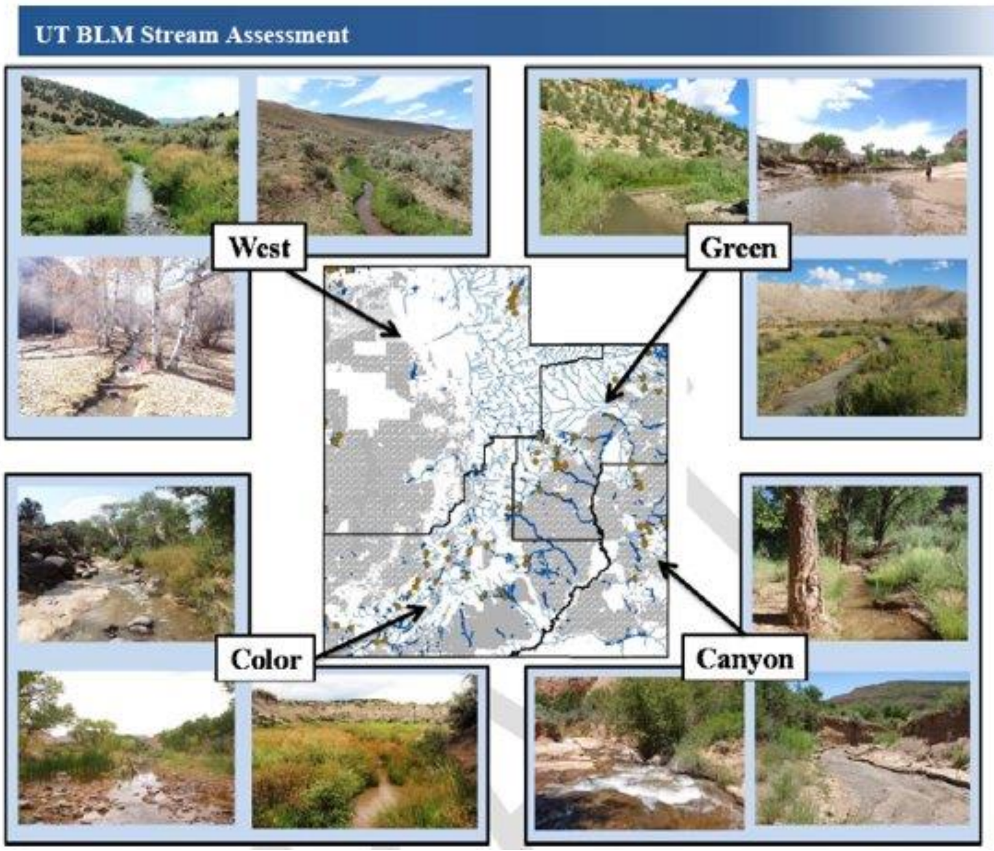

Figure 6-11. Example of using photos alongside a map in a lotic report.

Dashboards and StoryMaps

Dashboards, StoryMaps, and their underlying web maps provide an interactive display of data and can be versatile compared to static reports (Figure 6-12). They can allow for quick data review and comparisons (Figure 6-13) as well as display of contextual data such as remote sensing information, climate data, additional monitoring data, disturbance layers, and other GIS data that can help to interpret AIM data.

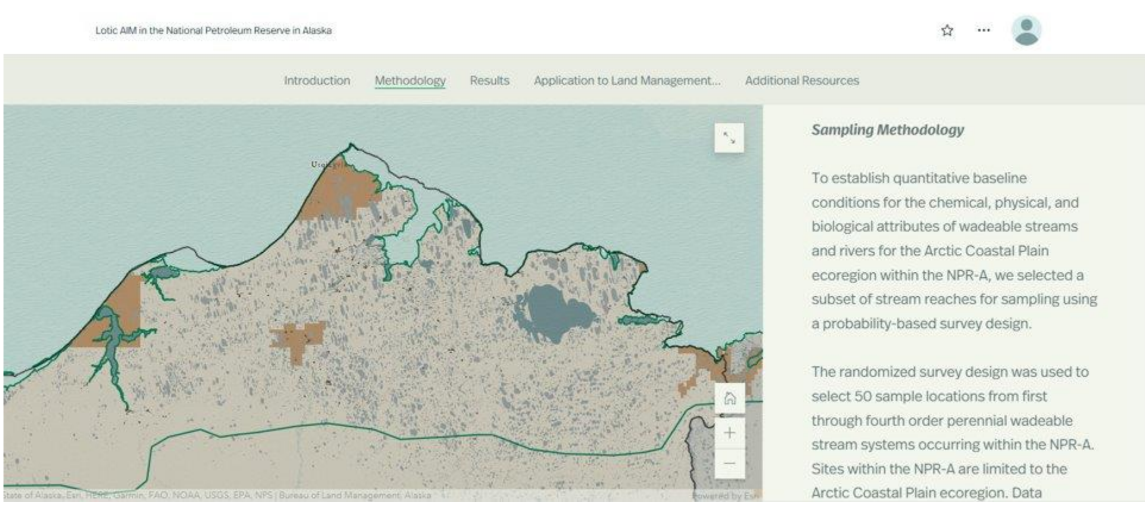

Figure 6-12. Example of a StoryMap for lotic systems in the National Petroleum Reserve in Alaska. This StoryMap displays the analysis process of establishing baseline conditions, developing quantifiable benchmarks, plans for collecting pre-disturbance data, and assessing long term trends for lotic systems in the National Petroleum Reserve. A link for this StoryMap can be found in the AIM Decision Library (see Section 6.2).

Composite Indicators and Indices

When communicating analysis results it may make sense to combine several indicators into a single index (or composite indicator) to simplify map symbology or improve the ease of connecting indicators to management goals. For example, to assess the management goal of evaluating upland soil health you may use data from many indicators including: bare soil cover, soil stability, cover of deep rooted perennial bunch grasses, proportion of large canopy gaps etc., to simplify reporting of all these indicators, they can be combined and weighted such that more influential or important indicators make up a higher proportion of the final composite indicator. There are many potential methods to do this such as swing weighting, weighted means, harmonic means, or ratios of different indicators. The Watershed Condition Comparison tool (Figure 6-13) uses composite indicators to display ecological conditions across AIM points.

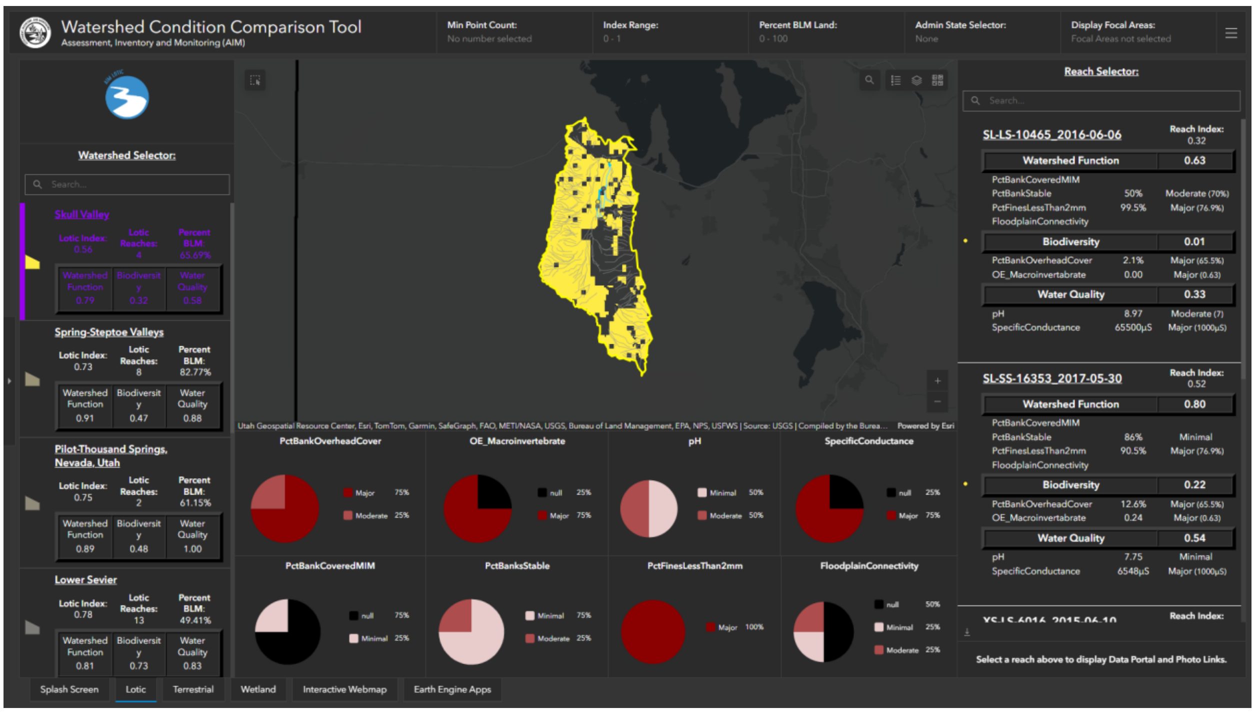

Figure 6-13. The Watershed Condition Comparison Tool is a dashboard which displays AIM data, allowing for quick comparisons of the ecological conditions across AIM points. The tool utilizes composite indicators where multiple indicators are combined into a single score or index at the reach/plot and watershed scale. A link for this dashboard can be found in the AIM SharePoint (see 6.2 Tools).

Step 8: Decide whether management goals have been met

The next step is to determine whether management goals have been met and ensure multiple lines of evidence are included to support your decisions. This step is often most productive when working through each goal with an IDT, ensuring all available data and analyses have been considered, and results are contextualized and presented in a digestible manner. Multiple lines of evidence can include remote sensing data, other monitoring data, and photos. Figure 6-4 shows an example of how remote sensing can provide context and support for a management decision. Refer to TN 453 (e.g., p.16), 455, and 459 for examples of how to work through a management decision.

Step 9: Decide whether additional analysis is needed

After reviewing results of the initial analysis, it may be that additional analyses or data are required to ensure the correct interpretation is made or to more fully answer the analysis question. For example, one may start with summary statistics for a group of points but realize that without benchmarks the context to interpret the results as it relates to the management goals is limited. Therefore, the Analyst may decide to expand the analysis to include proportional extent estimates. Other times, the initial analysis may beckon additional analytical questions. For instance, perhaps a trend analysis was successfully completed and showed conditions in certain indicators declining over time. A natural question to ask is “Why?” To answer that, one might try to perform a causal analysis to take into account the effects of covariates on those changes in time.

Step 10: Use data to inform management decisions and write reports

After completing the above analysis steps, the final steps are to use the results of the analysis to inform management decisions and document the results via written reports. To inform management decisions, utilize the conclusions you drew from step 8. For instance, if after using a multiple lines of evidence approach you determine management goals were met, perhaps no novel management decisions are required. However, if some goals are not met, consider the resources and habitat impacted and what management actions would be most likely to help improve conditions. For example, if stream bank stability and stream bank cover were in poor condition in the area of interest due to cattle impacts, perhaps the cattle grazing density or cycles should be modified to help improve stream bank conditions.

Writing up results as part of a report can look very different depending on many factors. Your management goals might determine how data must be presented, for example a grazing permit renewal for an allotment compared to a Land Use Plan Evaluation that might be much larger in spatial extent. Your analysis type and data might also play into how data is presented in a report. There are several tools available to help write up and explain results to inform management decisions. For example, some analysis tools such as the LCAT tool, or the Site Characteristic Report, can provide boxplots, summary tables, or other useful visuals that can be copied and pasted directly into documents. There are also metadata documents about the data and indicators to help explain the data and in some cases should be referenced. There are also several example use cases and reports that can be used as templates that can be found in the AIM Decision Library (see Section 6.2).

7.0 Glossary

This glossary presents terms and their definitions commonly used within the AIM program and among AIM practitioners and data users. Some of the definitions make reference to terms also defined in the glossary. In such cases, ***bold italics*** are used to alert the reader that a term can be found elsewhere in the glossary. Hyperlinks are not included in this glossary, several can be found in the tools sections within each major section, on the blm.gov/aim website, or via internet search.

AIM: The Assessment, Inventory, and Monitoring (AIM) program which implements an approach for integrated, cross-program assessment, inventory, and monitoring of renewable resources at multiple scales of management as well as standardized, broadly applicable monitoring methods and tools consistent with the ***AIM Strategy***.

AIM Strategy: The AIM Strategy addresses renewable resource data collection specific to vegetation, associated habitats for wildlife, and the supporting ecological components of soil and water. In general, the strategy is intended to: (1) document the distribution and abundance of natural resources on public lands; (2) determine resource conditions; and (3) identify natural resource trend or change. (Toevs et al 2011).

Analysis: The process of turning data into information to answer a question.

Base Points: The original set of points in a panel of a design which are intended to be sampled in a given year.

Benchmark: An indicator value, or range of values, that establishes desired condition and is useful for management. Benchmarks are used to compare observed indicator values to desired conditions. Benchmarks for a given indicator may vary by potential, thus different ***benchmark groups*** may be necessary within a project area so that points are understood as meeting or not meeting an objective relative to potential.

Benchmark Group: A geographic area or group of monitoring points that have the same benchmark for evaluating the success of a particular monitoring objective. For example, if there are points across the entire field office but evaluating sage-grouse habitat is the objective, only the points that are within sage-grouse habitat should be considered for that objective. Likewise, the ecoregion, ecological site, the evaluation area, or stream type must be considered for determining whether an objective is met when benchmarks vary by ecoregion or ESD.

Biophysical Setting (BpS): A remote sensing-derived layer that is conceptually similar to reference states of Ecological Sites. BpS represents the vegetation that may have been dominant on the landscape prior to Euro-American settlement. BpS is based on both the current biophysical environment and an approximation of the historical disturbance regime. BpS describe the following physical characteristics of a BpS environment: vegetation, geography, biophysical characteristics, succession stages, and disturbance regimes (and major disturbance types).

Change and Disturbance Event Detection Tool (CDEDT): A free application in Google Earth Engine, this tool allows the user to search for two dates of imagery from a set of common remotely sensed data (e.g. Sentinel-1, 2 or aerial photography). The tool calculates the change in a suite of remote sensing indices (e.g. the Normalized Difference Vegetation Index or NDVI),and allows the user to vectorize the pixels of these indices.

Colorado State University's (CSUs) Colorado Natural Heritage Program (CNHP): An AIM ***Science Partner*** that provides science support for the Riparian & Wetland AIM program through research and development of the field methods protocol, training support, data stewardship, indicator development, and sample design and analysis support.

Condition: The status of a resource in comparison with a specific indicator reference value or benchmark (adapted from BLM Rangeland Resource Assessment-2011). When describing condition, a condition category may be assigned (e.g., Suitable, Marginal, Unsuitable or Minimal, Moderate, or Major departure) relative to the benchmark or reference value.

Confidence Interval: Range of values that likely includes the true value of a ***population*** mean. Confidence intervals help understand uncertainty in indicator estimates. The ***confidence level*** indicates the probability that the confidence interval includes the true value and is chosen by the monitoring data user. For example, an 80% confidence level indicates that 80% of sampling events will result in estimates that fall within this range; 20% will not (Elzinga et al. 1998).

Confidence Level: The percentage of times you expect to get close to the same estimate if you repeat the experiment or have resampled the population in the same way.

Contingent Methods: Standardized procedures for collecting data with the same cross-program utility and definition as core methods but measured only where applicable. Data from contingent methods are centrally stored and processed with data from core methods. Contingent methods are not informative everywhere and thus are only measured when there is reason to believe they will be important for management purposes.

Core Methods: Standardized procedures for collecting data that are applicable across many different ecosystems, management goals, and agencies.

Covariate: A measured or derived parameter used to account for natural spatial or temporal variation in a core, contingent, or supplemental method or indicator; covariates provide context for monitoring data and are recommended wherever BLM implements monitoring.

Data Management: Organizing and storing data so that they can be accessed and used to create information for management decisions.

Database for Inventory, Monitoring, and Assessment (DIMA): (now obsolete) a MS Access application developed by the Jornada Experimental Range to collect field data, manipulate data in the office, and run preliminary reports. As of 2022, the Jornada no longer supports DIMA, and the AIM program has transitioned to Environmental Systems Research Institute (ESRI) products for data collection.

Ecological Site: An ecological site is defined as a distinctive kind of land with specific soil and physical characteristics that differ from other kinds of land in its ability to produce a distinctive kind and amount of vegetation and its ability to respond similarly to management actions and natural disturbances.

Ecological Site Description (ESD): Information and data pertaining to a particular ecological site is organized into a reference document known as an Ecological Site Description (ESD). ESDs function as a primary repository of ecological knowledge regarding an ecological site. ESDs are maintained on the Ecosystem Dynamics Interpretive Tool, which is the repository for information associated with ESDs and the collection of all site data. (NRCS, 2017)

Emergency Stabilization and Rehabilitation (ES&R): BLM Program that implements planned actions to stabilize and prevent unacceptable degradation to natural and cultural resources, to minimize threats to life and property resulting from the effects of a fire, or to repair/replace/construct physical improvements necessary to prevent degradation of land or resources.

Existing Vegetation Type (EVT): LANDFIRE's Existing Vegetation Type represents the current distribution of the terrestrial ecological systems classification, developed by NatureServe for the western hemisphere, through 2016. A terrestrial ecological system is defined as a group of plant community types (associations) that tend to co-occur within landscapes with similar ecological processes, substrates, or environmental gradients.

Evaluation Status: Categorization of a potential monitoring point identified in a monitoring design. The evaluation status of the point has implications for how points are used in analyses and the subsequent inference to reporting units. The terrestrial sample design database, this is referred to as Final Designation. Points are designated as either sampled or not sampled. Not sampled sites should be given a reason such as non-target, inaccessible, and reattempt needed. Additional and more specific categories are described in the Terrestrial Data Management Protocol and the Lotic and Riparian and Wetland Field Protocols.

Final Designation: See Evaluation Status.

Geographic Information System (GIS): A Geographic Information System is a computer system that analyzes and displays geographically referenced information. It uses data that is attached to a unique location.

GeoPlatform.gov: A Federal Geographic Data Committee (FGDC)-sponsored system that allows AIM contractors and partners to collect data using AIM mobile applications and upload AIM data via ArcGIS Online (AGOL). GeoPlatform.gov uses Login.gov to authenticate users.

Habitat Assessment Framework (HAF): Applicable to sage-grouse, a method to consistently evaluate suitability of sage-grouse habitat across the range and at multiple scales.

Indicator: A component of a system whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (e.g., biotic integrity) that is too difficult, inconvenient, or expensive to measure.

Intensification: An effort that increases the density of monitoring locations within an area of special interest to increase the accuracy (mean estimate closer to the population mean) and precision (smaller confidence interval) of indicator estimates. Typically performed in anticipation of special management decisions (e.g., permit renewal) that require greater accuracy and precision than provided by existing monitoring designs within the same area. Alternatively, performed because special areas have few or even no monitoring locations.

The Jornada: A ***United States Department of Agriculture (USDA)***-ARS unit, the Jornada Experimental Range has partnered with BLM to develop and support AIM since 2006. The Jornada works with BLM Field, District, and State offices as well as the NOC and HQ office to implement AIM and analyze AIM data and has over 100 years of experience in rangeland monitoring data collection and application.

Land Health Standards (LHS): Statements of physical and biological condition or degree of function required for healthy sustainable rangelands.

Landscape Monitoring Framework (LMF): A dataset with a national-scale sample frame that along with ***TerrADat*** make up the Terrestrial National AIM Database. A joint venture between BLM, ***Natural Resources Conservation Service (NRCS)***, and Iowa State University. Data are collected following the National Resource Inventory (NRI) protocol (National Resources Inventory 2016).

Land Use Plan (LUP): Also known as a ***Resource Management Plan (RMP)***, that forms the basis for every action and approved use on BLM-managed lands.

Lotic AIM Database: National Lotic AIM Database, formerly known as AquADat, contains all field data and calculated indicators from 2013 onward.

Management Goal: Broad goals or desired outcomes land managers are trying to achieve with land management. Management goals provide the context for why monitoring information is needed and how it will be used. Often, these are derived from planning documents and policy. Examples include maintaining forage production for livestock or high-quality habitat for wildlife.

Master Sample: A large number of pre-selected, random sample locations from which project-level designs can be selected. Across the western U.S (12 states), Terrestrial AIM master sample locations consist of 1 point per 35 hectares, and aquatic AIM master sample locations are 1 point per 0.5 km of stream length. These points can be used for comparable and complementary monitoring among separate monitoring organizations and across geographic scales. The Master Sample retains the principles of Randomization and Spatial Balance. Further reading: Larsen, D.P., A.R. Olsen, and D.L. Stevens. 2008. Using a master sample to integrate stream monitoring programs. JABES 13: 243-254.

Monitoring Design Worksheet (MDW): A step-by-step template to document and plan an AIM monitoring effort. This worksheet serves many purposes including documenting decisions and reasons for completing monitoring, providing the necessary information for drawing sample points, and completing analyses once data are collected. The MDW is an important reference document used during and after the completion of each monitoring project.

Monitoring Objective: Quantitative statements that provide a means of evaluating whether management goals were achieved. Monitoring objectives should include: 1. indicator; 2. benchmark for the indicator; 3. a time frame for evaluating the indicator, and 4. the reporting unit(s).

National AIM Team: The AIM team supporting national implementation of AIM data collection, AIM database stewardship, and data use. The National AIM Team is composed of BLM staff at the NOC and Headquarters, and Science Partner staff at the USDA's Jornada Station, ***CSU's CNH***P, and ***USU's NAMC***. BLM staff on the National AIM Team are largely housed in the Division of Resource Services (DRS) at the ***NOC***. The DRS provides a technical interface between national policy and field operations through scientific and specialized products, resource data stewardship, and technical program support.

National Aquatic Monitoring Center (NAMC): NAMC was created in 1992 at Utah State University (USU)in partnership with the US Forest Service (USFS) and the BLM. NAMC's mission is to develop scientifically sound methods to assess ecological integrity and transfer that knowledge to stakeholders involved in the conservation and restoration of stream, lake, and wetland ecosystems. They provide Science Partner support for AIM efforts for rivers and streams such as research and development of field protocol updates, training support, and analysis support.

National Hydrography Dataset (NHD): The NHD is a national geospatial dataset that represents surface water on the landscape. The NHDPlus medium resolution data (1:100,000 scale) is broken into stream segments each of which is associated with several attributes including the Strahler Stream Order, and whether the segment has been designated as perennial, intermittent, an artificial path, etc.

National Operations Center (NOC): National Operations Center, is a BLM Center that provides operational and technical program support to BLM State, District, and Field offices as well as collaborators.

National Wetlands Inventory (NWI): The NWI is a national geospatial dataset of wetland and deepwater habitats across the United States. The NWI dataset is maintained by the US Fish & Wildlife Service (USFWS). Wetlands are delineated using aerial imagery and a subset of the data are ground truthed. Data are submitted to USFWS to meet data quality standards and then uploaded to the master NWI dataset.

Oversample Points: Extra sample points which are selected at the time of the base sample draw. These points are used to supplement the ***base points*** when a base point is rejected or not sampled (see ***Evaluation Status***). These are points to account for failures/rejections of base points to ensure we meet sample sizes.

Panel: A set of sample points that have the same revisit pattern across years. For example, an AIM design might be divided into 5 panels, each one visited in a different year. All points within a single panel visited in 2017 would then be visited in 2022, 2027, and so on. The points visited 2017 through 2022 together make up the entire sample design.

Partners: The collective reference to agency partners, science partners, and data collection partners, including any entity outside of the BLM that assists with implementation of the AIM Strategy (e.g., training, data collection, data analysis, etc.).

Percent (Proportion) Achieving Desired Conditions: The desired percentage of a resource with one or more indicator values that meet benchmark value(s). For instance, a desired percentage may be (80%) of the landscape with <20% bare ground, or 80% of sage-grouse summer habitat scored as suitable (based on multiple indicators). Percentages are derived from weights (see ***Weight***) of monitoring points or plots, where a point or plot weight indicates the extent of the resource represented by a point or plot.

Percentiles of Regional Reference: An approach to setting benchmarks that uses reference sites or points grouped by a landscape classification schema (e.g., ecoregions) to create a distribution of reference site indicator values. Benchmarks can then be set by assuming that sites in reference condition should fall within certain percentiles of the reference site distribution of a similar physiographic region. For example, the 90th and 70th percentiles of reference site floodplain connectivity values for the Colorado Plateau can be used to separate “major departure,” “moderate departure,” and “minimal departure” from reference conditions, respectively. For Lotic AIM, this approach can be used for indicators that lack models to compute ***predicted natural conditions***. For Terrestrial and R&W AIM, this approach is dependent on identifying and establishing a group of regional reference points.

Physiographic Properties: Physical characteristics of a landscape that can be used to understand the potential of that landscape. These properties can be used as supplemental information, or covariates, for interpreting indicators. Slope, aspect, landform, and soil type are all physiographic properties.

Population: The entire “universe” to which the results of sampling apply. The population is defined by many factors: the area of interest, objectives, and constraints.

Project Area: Describes the broadest boundary outline of an AIM project. Usually, the boundary of a field office, district office, or other administrative boundary. A project area contains the target population (e.g., BLM land within a field office boundary). (see ***Study Area)***.

Predicted Natural Conditions: An approach to setting benchmarks where the conditions expected to occur at a plot or reach in the absence of anthropogenic impairment are derived from empirical models. Such models use geospatial predictors (e.g., soil, climate, and topographic attributes) to account for natural environmental gradients. Observed field values are compared to potential natural indicator values and any deviation is assumed to result from anthropogenic impacts. This approach is advantageous because it provides spatially explicit predictions of expected conditions with known levels of accuracy and precision. Due to data limitations and the current state of the scientific literature, this approach is only available for a few Lotic AIM indicators.

Quality Assurance (QA): A proactive process employed to maintain data integrity. QA is a continuous effort to prevent (e.g., training, calibration, proper technique), detect (e.g., on-plot data review, client-side data validation), and correct measurement errors (e.g., readjustments in response to data review).

Quality Control (QC): A reactive process to detect measurement errors during data collection and after the data collection process is complete.

Random Sample Design: Randomly selected sample locations used to collect measurements and estimates of condition within a study area where every member of the target population has a known probability of being selected. Results from random sample designs can be extrapolated to provide a statistically valid assessment of condition and trends across an entire population, or study area, with known levels of precision and accuracy (Gitzen et al. 2012). Random sample designs can be simple, stratified, and/or spatially balanced to ensure geographic spread across a sampling area (Stevens and Olsen 2004). See relevant reference documents for implementing landscape-scale or population-scale random sample designs (e.g., BLM 2015, Herrick et al. 2009). Random sample designs can also be used to provide context for nonrandomly selected targeted sites. *See also* ***Sample Design*** *and* ***Spatially Balanced Random Design.***

Reporting: Communicating the results of monitoring data analysis in a manner that can be used to understand conditions, address management goals, or as part of the adaptive management process.

Reporting Unit: A subset of the study area where information, such as indicator means and confidence intervals, is needed. A study area can have various reporting units. Reporting units may be different than stratification. Knowing the units ahead of time helps ensure adequate sampling. Watersheds, allotments, and GRSG habitat units are all examples of reporting units.

Resource Management Plan (RMP): Interchangeable with ***LUPs***, which form the basis for every action and approved use on BLM-managed lands.

Sample Design: Sample locations used to collect measurements and estimates of condition within a study area. Developed using the ***MDW***. See also **Random Sample Design,** ***Spatially Balanced Random Design*** and ***Targeted Sample Point***.

Sample Frame: A representation of the target population that is often a geospatial feature (e.g., ***SMA layer***, ***NHD***, wetland mapping). If a geospatial layer is not available, the sample frame can be a described using a list of the elements of interest we want to explore through a sample survey.

Sample Point (Reach or Plot): Location where monitoring information has been collected or data collection is planned. For Terrestrial and Riparian & Wetland AIM, this is a plot. For Lotic AIM, this is a stream reach. In some documents, the term sample point is used to refer to both.

Sample Size: The number of points or plots in the target population that need to be sampled within a stratum to ensure a desired level of precision and accuracy for data analysis. The sample size across the study area is a function of several factors: 1. existing or legacy monitoring information; 2. statistical considerations (e.g., what analyses are needed, what is the desired confidence level and confidence interval); 3. funding and personnel limitations (e.g., how many points per year can be accomplished). The sample size may influence the types of analyses that can be performed and the confidence level of the results.

Sampling: Using selected members to estimate attributes of a larger population.

Sampled Population: The portion of the target population that was actually sampled.

Science Partner: BLM National AIM Team Science Partners are agreement holders or contractors that provide support for AIM efforts such as research and development of protocol updates, training support, and/or analysis support (see Jornada, CNHP & NAMC definitions).

Spatially Balanced Random Design: Samples are evenly spaced across the study area and ordered to maximize spatial dispersion of any sequence of units. These designs are often used to make inference to conditions across large scale areas including LUP/RMP evaluations.

Status: A measured indicator value or range of values.

Strahler Stream Order: A hierarchical numeric system used to classify stream size. Stream size as determined by this method is used in most if not all lotic designs as a stratum. First order streams are small headwater streams. When two first order streams come together a second order stream is formed, when two second order streams come together a third order stream is formed, and so on. Two different order streams (e.g., first and second) coming together do not create a higher order stream (e.g., third), the stream below the confluence of the two different orders will remain the same order as the larger order stream (e.g., second order). Common groupings of stream orders for Lotic AIM strata are SS- Small streams (1-2 order streams), LS- Large streams (3-4 order streams), and RV-Rivers (5+ order streams).

Strata: Subgroups or subunits of a study area used to divide up sampling efforts. Strata can be used to ensure adequate sample sizes for parts of the study area of management concern or may be used to increase precision when extrapolating data over large areas. Strata can be defined as relatively uniform parts of the landscape (e.g., flood basin or hill summit) with similarities or can be general areas that need adequate sample sizes (e.g., sage-grouse habitat, streams with T&E fish species).

Stratification: Stratification refers to dividing a population or study area up into sub-groups or subunits called ***strata*** for the purposes of sampling or data analysis. Reasons to stratify: 1. variability in indicators is different across strata; 2. ensure features of interest (e.g., habitats);

especially uncommon ones, within the study area are adequately represented in the sample population. Examples of strata include biophysical settings (see BpS), stream order (see Strahler stream order), management unit boundary, and ecological sites.

Stressor: Environmental or ecological stressors are pressures or dynamics impacting ecosystem components or processes that may be natural or caused by human and associated activities. Stressors may impede or compromise plant or animal performance, productivity, or increase susceptibility to other forms of pressures like disease or pests.

Study Area: (a.k.a. ***Project Area***). Defines the extent of the population and is the maximum area to draw conclusions about.

Supplemental Design: Additional points that were drawn for a pre-existing design because all pre-existing points have been used and the needed sample sizes have not been met.

Supplemental Method: Field methods that provide additional indicators necessary to address specific management questions, beyond what the BLM standardized core and contingent methods provide. They may be collected alongside AIM when core and contingent methods are insufficient to inform a particular management goal but are not duplicative of these methods. Supplemental methods should follow existing, peer-reviewed protocols and be identified using a thoughtful screening process.

Surface Management Agency (SMA) Layer: The SMA layer is a ***Geographic Information System (GIS)*** dataset that depicts Federal land for the United States and classifies this land by its active Federal surface managing agency. The purpose of this dataset is to fulfill the public and Government's need to know what agency is managing Federal land in a given area, and for use by BLM Staff for use in analysis and reports. This dataset is useful as a tool to determine and illustrate the boundaries of a particular Federal agency's "managing" area and to quantify these areas in terms of geographic acreage.

Target Population: Refers to the resource to be described. In statistical surveys, the target population refers to the group of individuals that one seeks to make inference about. Sample points are selected from within the population. The definition of the target population should contain specific information including resource of interest, its spatial extent, its ownership status, and its size. The definition should be specific enough that one could determine whether a sample point is part of the target population. In some cases, membership in the target population might be determined after data have been collected at the sample point (e.g., sage-grouse seasonal habitat). Examples of the target population include: all BLM lands within a reporting unit; all perennial, wadeable streams on BLM land: sage-grouse habitat on BLM lands.

Targeted Sample Points: Sample locations that are manually selected with the judgement of the project manager to ensure data is collected to estimate condition and trends at nonrandom sites. These sites are usually selected to address specific management goals such as document a reference condition, establish a repeat monitoring area, monitor known habitat of a rare plant or animal species, or track changes that result from management actions like grazing or restoration (e.g., critical designated monitoring area) (Burton et al. 2011). For targeted sample points, statistical inference cannot be drawn beyond the sample area.

TerrADat: Terrestrial AIM Data (TerrADat) is a national terrestrial monitoring database. As of 2022, TerrADat is a multi-scaled dataset built around the state level, that along with ***LMF*** make up the Terrestrial AIM Database.

Trend: The direction of change in ecological status or resource value rating observed over time.

Weight: A weight is the area (in acres or hectares) or length (in stream kilometers) represented by each plot. For an unstratified sample design, all plots have the same weight, equal to the extent of the sample area divided by the number of plots. For a stratified sample design, plot weights are calculated for each stratum, as the extent of that stratum divided by the number of plots in it. Plot weights are used to convert from plot-based estimates to area-based estimates. As an example, imagine an aquatic AIM sample design in which stratum A has 100 km & 25 plots; stratum B has 25 km & 25 plots. Each plot in stratum A has weight = 4; in stratum B, weight = 1. If average bank stability is 80% in stratum A and 40% in stratum B, an unweighted average across plots is 60%. A weighted average accounts for the different spatial extents of the strata: (4×80% + 1×40%)/5 = 72%. This is the simplest case, in more complicated cases we may need to consider multiple sample designs, reporting units in which the proportional extents represented by the strata differ from those of the sample design, and how sample designs were implemented (see ***Evaluation Status***).

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9.0 Appendices

Appendix A: Roles and Responsibilities

This appendix defines many of the roles and responsibilities of AIM practitioners which may include the National AIM Program Lead, the National AIM Team, the State Office AIM Team, District and Field Offices, AIM Crew Managers and Leads, and AIM data collectors.

A.1 National AIM Team

A.1.1 Headquarters: National AIM Program Lead

The National AIM Program Lead operates out of BLM Headquarters and provides technical support and services to the Branch of Assessment and Monitoring, National AIM Team, the State Office AIM Team, and the District and Field Offices.

Specific roles and responsibilities include:

- Developing and maintaining up-to-date policies, objectives, priorities, and general procedures for assessment, inventory, and monitoring of natural resources at a national level.
- Developing agency budget guidance pertaining to assessment, inventory, and monitoring of natural resources and recommending funding allocations to state offices and centers.
- Monitoring AIM program implementation expenditures and performance in compliance with government accountability requirements.
- Coordinating with State Office Program Leads and other National Program Leads to ensure consistent implementation of AIM-related policies.
- Providing technical expertise and appropriate resources across the BLM to ensure proper consideration and implementation of AIM related policies.
- Coordinating with other Federal agencies, Tribal, and State agencies, and national and international organizations on AIM activities.
- Working with the BLM's NOC and National Training Center (NTC) to develop science initiatives, tools, and training materials relevant to the AIM program and related policies.
- Facilitating reviews of new and proposed legislation, regulations, and policies as needed to determine how they affect the policies and objectives of BLM relevant to assessment, inventory, and monitoring.
- Reviewing RMPs and associated documents related to AIM activities, policies, and procedures.
- Communicating with Division Chiefs about resource conditions and trends nationally to ensure they have current information.

A.1.2 National Operations Center: Branch of Assessment and Monitoring

The NOC Branch of Assessment and Monitoring provides technical support for a variety of natural resource assessment and monitoring approaches for the BLM. The Branch includes the AIM Section (i.e., National AIM Team) as well as several non-AIM Section technical support programs including wildlife, range, forestry, hydrology, soils, and other natural resource programs.

Specific roles and responsibilities include:

- Providing technical support and expertise across the BLM and to partners to ensure consistent implementation of assessment, inventory, and monitoring activities.
- Providing technical support and data analysis for program-specific inventory, assessment, and monitoring efforts, which may utilize the AIM principles and/or methods (e.g., wildlife, sage-grouse, range)
- Providing technical support for standardized inventory, assessment, and monitoring activities that complement the AIM core indicators and methods including qualitative assessment approaches and use-based monitoring.
- Connecting remote sensing science with BLM assessment, inventory, and monitoring, and support integration of remote sensing products with land management decision-making.
- Coordinating with the National AIM Team and other program-specific monitoring efforts as necessary.

A.1.3 National AIM Team: NOC AIM Section and Science Partners

The National AIM Team is comprised of the NOC AIM Section (within the NOC Branch of Assessment and Monitoring) and the AIM Science Partners. The National AIM Team is responsible for day-to-day AIM operations including, but not limited to, data management, training support, developing or advancing BLM monitoring practices, analysis support, and communications. The AIM Science Partners responsibilities vary by resource program but, in general, AIM Science Partners are responsible for tying AIM data and methods to current science, leading research and development to support sound methods and workflows, communicating AIM to external agencies and researchers, and providing support to AIM data analysis and reporting.

Specific roles and responsibilities include:

- Providing technical support and expertise across the BLM and to partners to ensure consistent implementation of assessment, inventory, and monitoring activities, particularly the AIM core and contingent indicators.
- Developing and implementing consistent training on AIM methods and related activities, in cooperation with the NTC, to meet BLM workforce needs.
- Developing, managing, and maintaining internal and external systems for standardized renewable resource AIM data, including electronic data capture, data QA and QC, data access, and analysis and reporting.
- Preparing, reviewing, and evaluating BLM and other scientific technical references, user guides, technical notes, and other documents supporting the policies and objectives of BLM assessment, inventory, and monitoring activities in coordination with National Program Leads.
- Coordinating with Headquarters, regional, state, district, and/or field office personnel to ensure that AIM implementation is successful (e.g., answering questions regarding the AIM strategy, monitoring plans, access to resources for projects, etc.).

- Applying specialized statistical expertise to select state, district, and/or field office monitoring points based on their monitoring plans and analyze data for land-management decision making.
- Providing standard approaches to analyze and report information for land-management decision-making across BLM.
- Working collaboratively with partners to expand the AIM strategy across agency and state boundaries.
- Connecting BLM to science that supports implementation of the AIM Strategy.
- Coordinating with the NOC Branch of Assessment and Monitoring and other program-specific monitoring efforts as necessary.

A.2 State Office AIM Team

The State Office AIM Team is comprised of State Program Leads, State Monitoring Coordinators, State Analysts, and other State resource specialists (e.g., Geospatial Ecologists) who work with the National AIM Team and District and Field Offices to implement AIM data collection at the State, District, and Field Office levels. The State Office AIM Team is primarily responsible for providing support to District and Field Offices in AIM project implementation, training, funding procurement, contract/agreement management, and analysis and reporting.

Specific roles and responsibilities include:

- State level AIM support can come in various forms, each state is responsible for ensuring that the below responsibilities are covered: Communicating and assisting in implementing the policies, priorities, and procedures for assessment, inventory, and monitoring of renewable ecological resources within the state, working with BLM staff at the state leadership, district, and field levels.
- Overseeing implementation and reporting of inventory, assessment, and monitoring policies and procedures within the state, for uplands, streams and rivers, and riparian and wetland areas. To ensure high-quality data collection AIM program implementation should include:
    - Managing the hiring of AIM crews for AIM monitoring data collection through assistance agreements, BLM staffing, or contracts.
    - Coordinating with Field and District to plan and implement monitoring (e.g., designs, pre- and in-season data, and field support)
    - Identify individuals to receive Train-the-Trainer training to sustain a training cadre within your state.
    - Coordinating methods training.
    - Facilitating early season and end-of-season AIM crew check-ins.
    - Finalizing data QC and certifying data finalization for ingestion by the NOC.
    - Support District and Field Offices in reporting to ensure resource specialists can clearly communicate conditions and trends with line officers.
- Acting as a liaison to ensure communication to and from the National AIM Team and among BLM offices and BLM staff at different levels (e.g., adjacent District/Field Offices; AIM Project Leads and District/Field Office Managers) so that the National AIM Team is receiving communication from the field and the field is receiving communication from the National AIM Team.

- Developing state level policies as needed to ensure inventory, assessment, and monitoring policy objectives are met, including collection of information and application of information to land management decision-making.
- Coordinating AIM program work plan and budgeting efforts and recommending funding allocations that will best meet monitoring needs within the state.
- Tracking AIM program expenditures and reporting performance and accomplishments for their state. This includes conducting periodic program reviews to assess the adequacy and effectiveness of staffing levels, budget, training, and other resources to achieve program policies and priorities.
- Collaborating with other State Office Program Leads involved in managing renewable resources to ensure inventory, assessment, and monitoring data collection and information application are integrated with their respective programs. Communicating standard inventory, assessment, and monitoring protocols and data management procedures through required protocol training and regular calibration to keep field and district offices current on policies and direction changes. Training should include AIM core and contingent methods and local supplemental methods as applicable.
- Partnering with NOC and Headquarters AIM staff in execution of the AIM principles and methods.
- Maintaining cooperative working relationships with State and Federal agencies, universities, and local groups relative to the assessment, inventory, and monitoring of natural resources.
- Providing technical expertise and support to state leadership and district and field offices to ensure current information about condition and trends of renewable resources is included in land management decision-making, LUPs, and public land use authorizations.
- Reviewing new and proposed legislation, regulations, polices, and court rulings as needed to determine how they affect the implementation of this policy in their state.
- Communicating with Branch Chiefs, Deputy State Directors, and State Directors about state-level resource conditions and trends to ensure they have the current information.

A.3 District and Field Offices

A.3.1 District and Field Office AIM Project Leads

The AIM Project Leads are District or Field Office resource specialists, such as Range Management Specialists, Ecologists, Aquatic Ecologists, Hydrologists, Botanists, or Fisheries Biologists, who are assigned specific duties directly related to AIM projects or data collection occurring within their District or Field Office area. Project Leads are usually assigned this role by District/Field Office management in coordination with the State Office AIM Team (i.e., AIM State Lead or Monitoring Coordinator). An AIM Project Lead may also be the lead resource specialist representing BLM data collection efforts in a District/Field Office by an IDT, and is unrelated to data collection assigned under an AIM contract or assistance agreement.

Specific roles and responsibilities include:

- In coordination with District and Field Office IDT and the State Office AIM Team:
    - Planning AIM activities based on multiple renewable resource needs (e.g., LUP effectiveness, treatment effectiveness, wildlife habitat).

    - Documenting interdisciplinary monitoring objectives, methods, and designs in a MDW in coordination with IDTs, the State Program Lead, and the National AIM Team (when designs will be provided by the National AIM Team).
- Implementing inventory, assessment, and monitoring activities of renewable resources within areas under their authority. AIM implementation tasks vary with the AIM crew hiring mechanism, but may include:
    - Assembling field equipment; contributing to AIM core indicator and supplemental methods training and support in coordination with State Office; providing a local orientation; conducting field visits and calibration; providing local supervision or contact throughout the field season; overseeing AIM crew QA and QC of data; reviewing preliminary indicator data; and resolving errors in data in coordination with the State Office and National AIM Teams.
- Analyzing and interpret data using an interdisciplinary approach to ensure that resource interrelationships are considered.
- Ensuring that land management decisions, LUPs and public land use authorizations fully incorporate available AIM information about the conditions and trends of renewable resources. When local data analysis capacity is not available, this may involve requests for state or National AIM Team assistance.
- Coordinating, as appropriate, with Federal, Tribal, and State agencies, adjoining BLM district and field offices, and BLM stakeholders relative to inventory, assessment, and monitoring of renewable resources.
- Communicating with line officers about resource conditions and trends to ensure they have the current information within their district or field office.

A.3.2 AIM Crew Managers and Leads

The AIM Crew Managers and AIM Crew Leads are data collection partners hired to collect AIM data under an AIM contract or assistance agreement by the State Office AIM Team. The AIM Crew Managers and Leads also work with the National AIM Team to complete required AIM training and data QC. Periodically they also communicate with AIM Project Leads when organizing hitch planning to conduct office evaluations and discuss site access issues.

Specific roles and responsibilities include:

- Office evaluating points
- Organizing field trips / hitch plans
- Coordinating with field office staff
- Performing data QC checks throughout the field season
- Participating in AIM core methods training
- Calibrating on data collection methods
- Collecting field data following standardized methods and following QA procedures
- Communicating with supervisory staff regularly to facilitate safety oversight
- Communicating with Project Lead regarding data collection and data submission processes
- Properly processing, storing, and documenting samples collected in the field
- Maintaining field equipment and vehicle

A.3.3 AIM Data Collectors

The AIM Data Collectors are data collection partners hired by, and working directly for/with, the AIM Crew Managers and Leads under an AIM contract or assistance agreement. They report directly to the AIM Crew Manager and facilitate data collection and QC for AIM projects.

Specific roles and responsibilities include:

- Participating in AIM core methods training
- Calibrating on data collection methods
- Collecting field data following standardized methods and following QA procedures
- Communicating with Project Lead regarding data collection and data submission processes
- Properly processing, storing, and documenting samples collected in the field
- Performing data QC checks throughout the field season
- Maintaining field equipment and vehicle
- Performing pre-season prep as needed
- Submitting data submission and ensuring QC checks are completed
- Finalizing data

Appendix B: Setting Benchmarks

B.1 Overview

Setting benchmarks for indicators is a necessary but often challenging step in defining monitoring objectives. Benchmarks are an indicator value, or range of values, that establish desired conditions and should be based on the ecological potential of the resource and/or conditions to sustain desired ecosystem structure, function, and services. Benchmarks are therefore a key part of defining different condition categories which are then used to analyze and help interpret monitoring data. The process of setting benchmarks should ideally be completed by the IDT concurrently when planning an AIM monitoring effort and is included as part of the MDW. During the planning process, it is impossible to foresee all possible uses of the data so frequently benchmarks will be set by the IDT during the analysis stage. Benchmarks may be set by policy or may need to be created through other reference material. For example, the BLM has policy that sets several benchmarks for sagebrush cover and other vegetation characteristics to maintain habitat for the GRSG as part of the RMP amendment process (e.g., Stiver et al. 2015). These benchmarks were based on peer reviewed research demonstrating the beneficial conditions for sage-grouse. Another common approach is to use the conditions observed at individual or groups of reference sites to set benchmarks. For example, the EPA has partnered with BLM and other agencies to identify a network of "least-disturbed" sites. Benchmarks are then defined in terms of departure of sampled sites from the range of indicator values across a network of "reference" sites. Networks of reference sites can be used to account for natural variability among sites and through time (Hawkins et al. 2010).

Benchmarks will often vary across the landscape based on natural environmental gradients, therefore variability in ecological potential should be considered when setting benchmarks (Webb et al., 2020). The goal is to ensure comparison among assessed sites to those with similar potential. Thus, similar biophysical areas with similar ecological potential should have similar benchmarks – these are your benchmark groups. In contrast, areas with large differences in ecological potential may have large differences in benchmarks. There are numerous approaches for accomplishing this that range from landscape classification systems to modeling continuous ecological gradients. Ecological site descriptions (Caudle et al. 2013), grouping least-disturbed sites by ecoregion or stream size (Hughes et al. 1986; Hawkins et al. 2000), or grouping sites by Rosgen stream type are examples of landscape classification. An alternative to classifying the landscape into categories is to use site-specific empirical models (e.g., Hill et al. 2013; Olson and Hawkins 2012) which model continuous environmental gradients. This modeling approach assesses the site potential at individual sites rather than by groups of sites.

Benchmarks may also vary based on management goals. For example, a post-treatment management goal for an ***Emergency Stabilization and Rehabilitation (ES&R)*** treatment may differ from a goal for a land health standard that is evaluated on an ecological site within a grazing allotment. An alternative to employing varying benchmarks based on management goals is to vary the proportion of the landscape required to meet the benchmark (aka threshold). This approach enables land managers to strive for a consistent set of conditions but make management decisions about the percentage of resources that meet those conditions based on their management goals. For example, a larger proportion of the landscape may be required to meet benchmarks in a Wilderness Study Area compared to a motorized recreation area.

For more information about Benchmarks, see BLM Rangeland Health Standards (BLM 2001); BLM Interpreting Indicators of Rangeland Health (Pellant et al. 2020); Chapter 4: Management Objectives in Measuring and Monitoring Plant Populations (Elzinga et al. 1998, see thresholds); Stoddard et al. 2006; Hawkins et al. 2010; Karl and Herrick 2010, and Webb et al (2020). For more information on setting benchmarks using AIM data, see Appendix 2 of BLM TN 453 (Kachergis et al. 2020).

B.2 Approaches for Setting Benchmarks

The key to setting benchmarks is to clearly document and justify the approach taken. Below, is an overview of common approaches to setting benchmarks (Figure B-1). These approaches vary in their potential for bias, ability to quantify bias, ease of communication, applicability to the management question, and geographic availability. However, all can be defensible if used appropriately and the reasoning is well-documented. Often, a combination of these approaches is required to cover different monitoring indicators or to provide multiple lines of evidence and increase confidence in the benchmark. Best professional judgment, including review by an IDT, should inform any benchmark setting approach (Figure B-1). This section steps through the process of setting benchmarks and is organized into three subsections (Figure B-1): Best Professional Judgement (applies throughout all benchmark decisions), Policy (priority when available, but often limited), and Non-Policy based approaches. Within Non-Policy based approaches there are three general, sometimes overlapping, categories discussed in this section: determining ecological potential (i.e., predictive natural conditions and ecological site descriptions), screening monitoring data to include the range of natural conditions and exclude disturbance, and using values or ranges from peer reviewed literature.

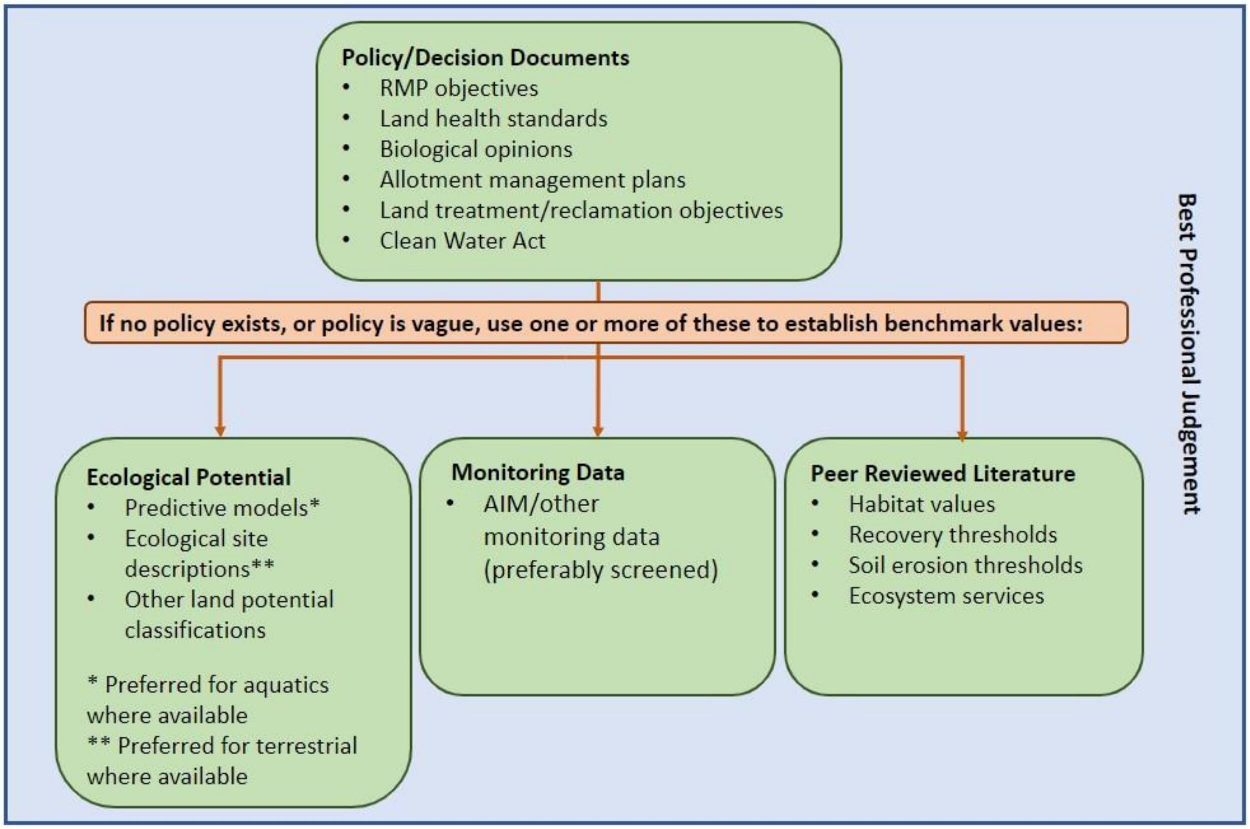

Figure B-1. Approaches for setting benchmarks.

B.2.1 Best professional judgment

Best professional judgement is important throughout the benchmark process. The knowledge base and experience of natural resource professionals is foundational to setting benchmarks. This knowledge is invaluable, especially when it comes from multiple professionals (IDT) with many years of experience working with ecological complexity and land management decision-making. (Knapp et al. 2011). Best professional judgement is used to identify the approach to setting benchmarks, to review information for appropriateness and applicability, and to validate the results. It should always be used as one of several lines of evidence. Best professional judgement is a vital part of the entire benchmarking process. Choices made should be well thought through and documented to show that a reasoned approach was taken.

Best practices for using benchmarks based on best professional judgement:

- Use site photos as a tool when discussing benchmarks. For example, look at sites within the reporting unit that both meet and don't meet the suggested benchmarks to verify how the selected benchmark compares to a visual inspection of a site
- Work in IDTs and be prepared to provide resumes in the event that the approach is challenged in court
- Be aware of individual or group bias and take steps to minimize bias
- Use best professional judgement to evaluate potential sources of benchmarks for applicability to the specific location(s) being assessed
- Use best professional judgement to review the analysis results to confirm that the benchmarks were appropriate.

- Document the process and rationale used

B.2.2 Policy based approaches to setting benchmarks

Policy or decision documents outline legal commitments by the BLM to either 1) meet specific standards or values (e.g., Biological Opinions, RMP amendments for GRSG, state agency water quality standards) or 2) follow a specific approach to identify standards or values that must be met (e.g., reference conditions in the Land Health Manual and Handbook, site stabilization criteria for ES&R treatments). When policy benchmark values are identified, they are typically based on one or more of the other information sources identified in non-policy based approached to setting benchmarks. If the science underlying the policy is out of date, it may be necessary to utilize these non-policy-based approaches to validate why the benchmarks set by the policy were not applicable.

Best practices for the implementation of policy benchmarks:

- Ensure the policy is the most recent policy
- Ensure the policy is applicable to the geographic area of interest
- Ensure that any new science that has emerged since the policy was established is employed to inform or refine benchmarks

B.2.3 Non-policy based approaches to setting benchmarks

When policy-based benchmark values are not available or the policy cannot be used to identify useful benchmark values, other approaches are needed. Many of these approaches overlap and best professional judgement will be an important component in identifying the approach that should be taken. It may be necessary to use several of these benchmark approaches to fully address all the scales of the analysis or management goals.

When policy does not exist, the approach to setting benchmarks starts with defining the state where ecological processes and functions are maintained (i.e., reference or desired conditions) and in line with management goals. Reference conditions can be used to identify the range of values for expected natural conditions across the landscape. There can be many definitions of reference conditions (Stoddard et al. 2006) so it is critical that the IDT starts by clearly defining the term. Reference condition, for example, may be used to refer to historic conditions (e.g., pre-European settlement in North America) or to least-disturbed conditions that represent the best available conditions found in the present-day landscape under natural disturbance regimes. Reference sites "do not need to be pristine or historically unused lands" (Pellant et al. 2020) but should include the range of conditions or values that enable you to determine whether your management questions are being answered. Once reference or desired condition ranges are determined specific values within those ranges should be selected as benchmarks.

The approach used to identify benchmarks, as well as the definition of reference or desired conditions, may depend on available data and resources. Some potential data and resources include site potential and historical conditions, availability of minimally disturbed sample sites, and applicable scientific research. Benchmark setting approaches will be discussed under three general groups: Ecological Potential, Monitoring Data, and Peer-Reviewed literature.

Ecological Potential

Ecological potential-based approaches to setting benchmarks generally reflect conceptual ideas of what might be ecologically possible in the identified ecosystem given abiotic conditions. They may be developed with the goal of predicting how an ecosystem is likely to respond to change. This type of information may take a lot of effort to develop and are frequently produced through external agencies or organizations. There are many types of ecological potential based approaches. In this section we will discuss two of these approaches that have been commonly used with AIM data: predicted natural conditions and Ecological Site Descriptions (ESDs). Predicted Natural Conditions are typically developed for aquatic systems and ESDs are typically developed for terrestrial systems.

Predictive Models

Field data from a network of reference sites can be combined with geospatial data (e.g., temperature, precipitation, slope, bedrock geology) to create empirical models that can be used to calculate site specific predictions of reference conditions across the landscape (Figure B-2). Predictive models are used to estimate reference conditions continuously across the landscape, account for gradients in resource potential, make site-specific predictions, and have known levels of error in their predictions. Predicted natural values are used to set benchmarks based on the site-specific predictions and associated error of the model and then evaluated in comparison to the observed value at that site (Figure B-3). No model, however, is perfect and it is important to understand the applicability and error of the modeled values when using them as benchmarks.

Models have been developed that predict reference conditions for lotic macroinvertebrates, nutrients, specific conductivity, stream temperature, and some instream habitat variables for selected geographic regions (e.g., Hill et al. 2013, Olson and Hawkins 2012); similar models for terrestrial ecosystems are in development.

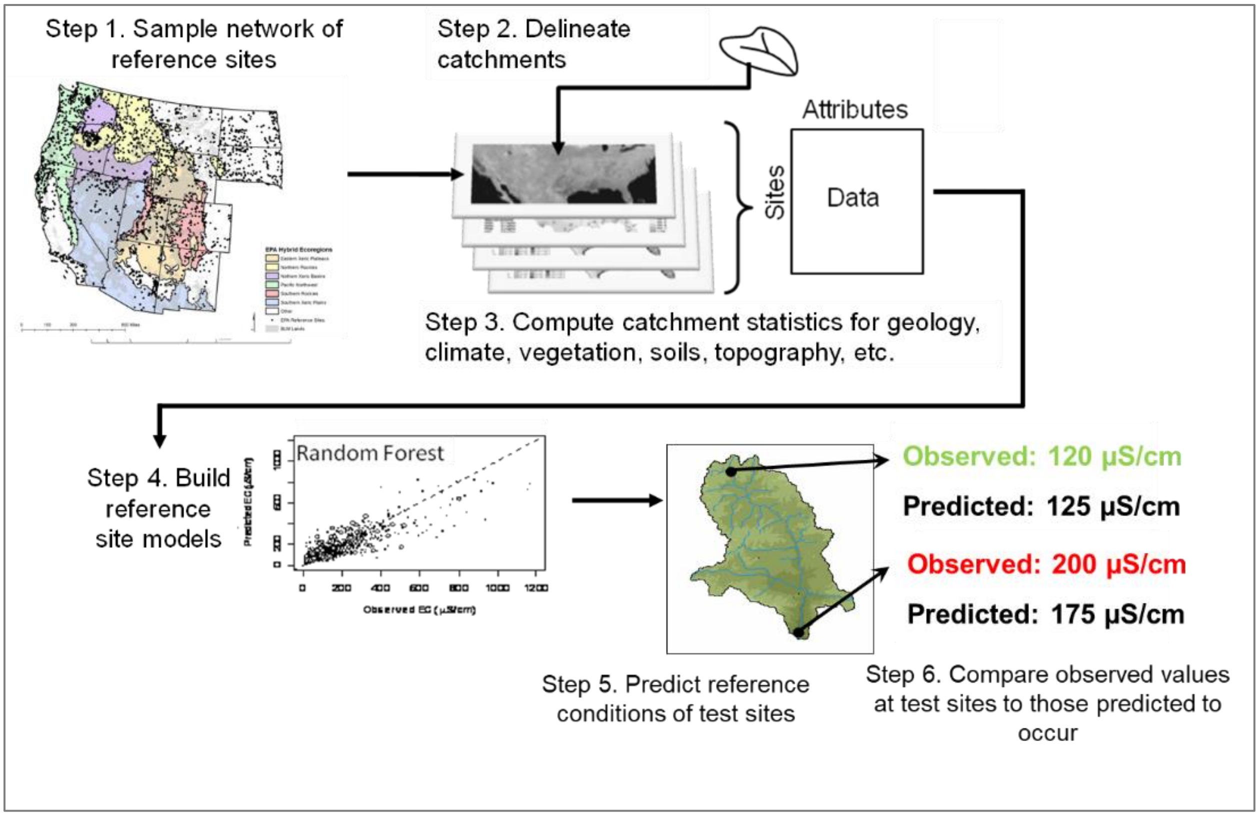

Figure B-2. A schematic diagram of a predictive model for the Lotic AIM specific conductance indicator.

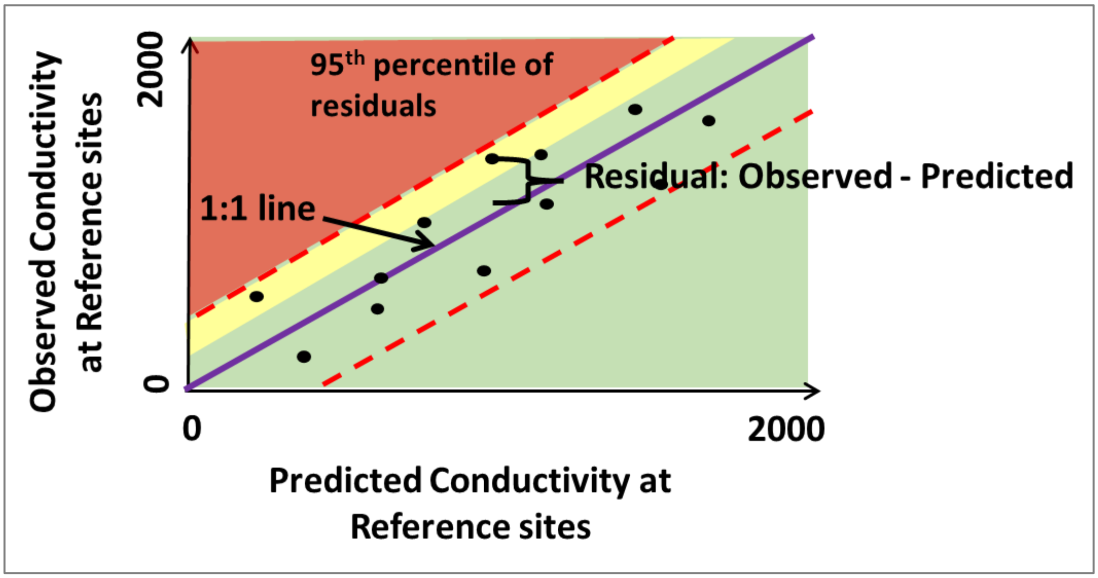

Figure B-3. Figure showing the relationship of predicted to observed values in reference to a 1:1 line. Benchmarks can be set based on predicted values and associated model error. Benchmarks are then created from the predicted value plus the percentile of residuals. If the model were perfect, the observed value at the reference site would be equal to the model-predicted value and all points would fall on the 1:1 line. The benchmark for each site is the predicted value plus the *percentile of residuals. These benchmarks can then be compared to the observed value to assign condition categories.*

Best practices for the implementation of benchmarks based on predictive models:

- Review and consider all available models. The State Office or National AIM Teams can help suggest models and determine their applicability.
- When choosing models, consider the following:
    - Ensure the compatibility among field methods used in the sampling of reference site networks with local AIM monitoring data.
    - Understand how reference conditions were defined and used to develop a given model.
    - Ensure that reference data used to create a specific model are applicable to the geographic area of interest.
    - Consider the quality of the model benchmarks: how well can the model predict reference conditions and how large is the model error used to set the benchmarks?
- When reviewing resulting benchmarks from a model:
    - Consider if the model was applicable to a given site (the National Aquatic Monitoring Center provides output to assist with this for the generically used models in Lotic AIM).
    - Think critically about the degree of departure from reference condition that is allowable while still maintaining ecosystem structure and function.
    - Model accuracy and precision can vary across the landscape so consider that the model may under- or over-predict site specific values in different areas.

<u>Ecological Site Descriptions</u>

Ecological Site Descriptions (ESDs) provide information about different types of land, including their potential or reference condition, that can be used to set benchmarks. An ecological site is “a conceptual division of the landscape that is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances (Caudle et al. 2013)”. An underpinning assumption is that soils, climate, geomorphology, and plant species can be grouped with sufficient precision to inform reference conditions and associated changes. Ecological site descriptions are developed by the USDA-NRCS and other partners using a variety of information sources, including professional judgment, peer-reviewed studies, and field data.

Best practices for the implementation of benchmarks based on ESDs:

- Given high variation in quality, be sure to consider the ESD itself as well as the information that it is based on.
- Based on the ESD’s state-and-transition model of ecosystem dynamics, the reference state (or the appropriate community within it given recent disturbance) is frequently used to set benchmarks.
- When available, reference sheets from Interpreting Indicators of Rangeland Health (Pellant et al. 2020) are ideal sources of benchmarks.
- Ensure compatibility among field methods used in ESD and reference sheet documentation with AIM data and consider adjusting benchmarks accordingly to

address incompatibility. Contact the National AIM Team for past research on how different methodologies compare.

More information about the conceptual underpinnings of ESDs and their treatment of reference conditions is available from Caudle et al. 2013 and Pellant et al. 2020.

Monitoring Data: Screened for Reference or Desired Conditions

Another type of approach to set benchmarks is to use available monitoring data to understand the range of variability in values across a landscape. This monitoring data may be classified as reference data or may just be general monitoring data. When using available monitoring data it is key to define reference or desired condition before developing benchmarks to ensure they will appropriately address management goals. In contrast to Ecological Potential which may take a lot of effort to develop and are frequently produced through external agencies or organizations, these monitoring data approaches may be more straightforward, are accomplished with existing data, and can generally be done by local, state, or National AIM teams.

When using monitoring data to determine benchmarks the general approach is to

- Compile monitoring data to use for setting benchmarks
- Screen out recent disturbance to determine the range of expected natural conditions available
- Group data into benchmark groups (e.g., site with similar ecological potential)
- Compare the range (or specific percentiles) to the sites where you desire to apply benchmarks or determine conditions.

During this approach it is important to avoid circular reasoning. To accomplish this, you will need two sets of sites. A set of sites to set benchmarks that is different from and covers a much broader area than where the assessment of condition is sought, and a set of sites where condition is being assessed and benchmarks will be applied. It is important to avoid using the same dataset to both set and apply benchmarks as this does not give any information about the condition of those sites. For example, if benchmarks are set at the 25th percentile of the data distribution, and all sites below that percentile are considered to not meet your benchmark then when you apply that benchmark to the same set of data you will of course have 25% of your sites not meeting your benchmark.

To set benchmarks using available monitoring data, screen the available data to include only reference or desired conditions and exclude all sites that will be used for comparison to benchmarks. This screening should be based on what you previously defined as reference or desired conditions. For example, if you define desired condition as best available unburned areas, then the screening process should be limited to unburned areas and try to remove overly disturbed sites. Throughout this section we referred to the set of screen sites as “reference site networks”. Some common methods to screen data include:

- Filtering data by indicator values know to be related to disturbance.
- Using GIS layers to spatially filter sites such as road layers, treatment polygons, and recent fires.
- Use of aerial imagery to remove disturbed areas.
- Examination of AIM site photos.

A reference site network is the dataset formed from the remaining sites after filters and screens have been applied and can be used in a number of ways to develop benchmarks. The simplest way is to create indicator distributions which should characterize the range of likely conditions. This “natural range of variability” of reference conditions acknowledges the dynamic nature of ecosystems resulting from natural disturbance events such as drought, floods, disease, fire, mass wasting events, and grazing by native ungulates. Additionally, reference sites are typically grouped by categorical variables such as physiographic boundaries (e.g., level III ecoregions; Rosgen stream types; ecological sites) to account for differences in reference site potential and subsequent frequency distributions resulting from factors such as climate and topography (i.e., benchmark groups).

Once sites have been placed into benchmark groups and distributions have been created, percentiles of the resulting distributions can be used to set benchmarks, against which monitoring data can be compared and deviations from reference conditions identified (Figure B-4). For example, the 5th to 25th percentile of reference distribution for percent fine sediment can define the benchmark to differentiate acceptable vs. unacceptable sediment values. The specific percentile used may depend on the level of degradation found in your reference sites – if almost all of your sites are impaired to some extent, then choose a more conservative percentile (i.e., a lower percentile for indicators which increase with degradation or a higher percentile for indicators which decrease with degradation).

Lotic AIM currently uses this approach and can provide values for several instream physical habitat indicators (i.e., fine sediment, bank cover, bank stability, canopy cover), typically grouping sites and resulting benchmarks by ecoregion and stream size to account for differing ecological potentials. For example, the 90th and 70th percentiles of reference site fine sediment values for streams in the Southern Xeric Basin ecoregion can be used as benchmarks to classify the condition of a monitoring site as having “major”, “moderate”, or “minimal” departure from reference conditions, respectively (Figure B-5). In other words, a site would be categorized as having major departure from reference conditions if the fine sediment value for a sample site is greater than that observed among 90% of reference sites in the Southern Xeric Basin ecoregion. In contrast, the site would be categorized as moderate departure if the site is less than 90% of reference sites but greater than 70% and minimal departure if less than 70% of reference site distribution. This approach does not have known levels of accuracy and precision, which lessens our understanding of if we may be over or under protecting a resource compared to a model approach.

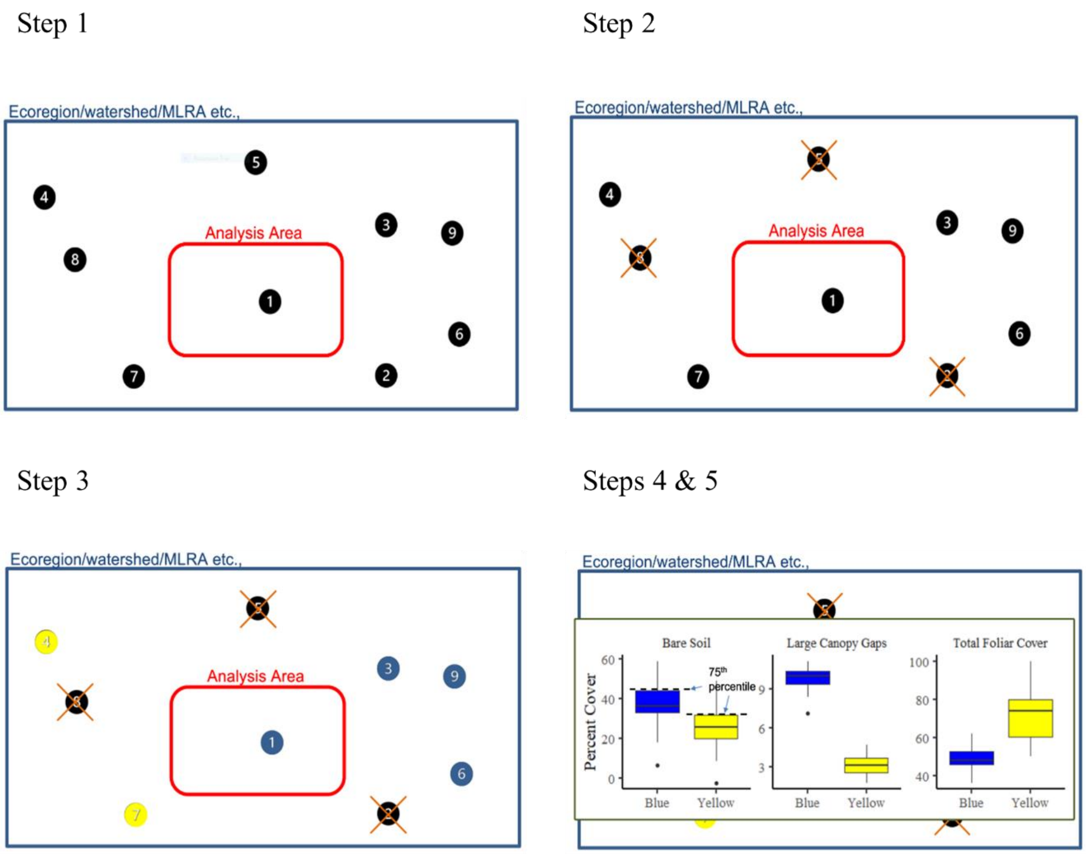

Figure B-4. Overview of setting/informing benchmarks using AIM data Steps 1-5. Step 1 is to select available data, Step 2 is to filter data to represent desired or "reference" conditions, Step 3 is to apply benchmark groups, Step 4 is to visualize data and Step 5 is to select and appropriate percentile for benchmark values.

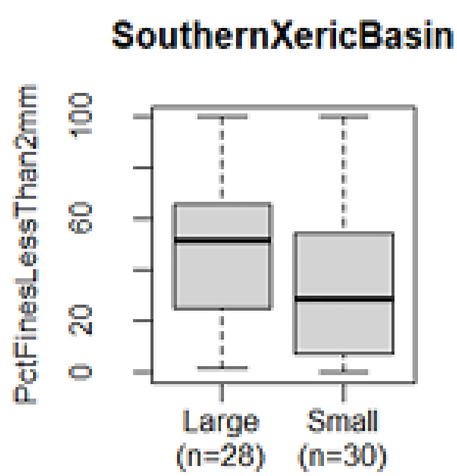

Figure B-5. Reference distributions for percent fine sediment less than 2mm for the Southern Xeric Basin ecoregion. Distributions shown are for large streams (left) and small streams (right) separately as determined by bankfull width.

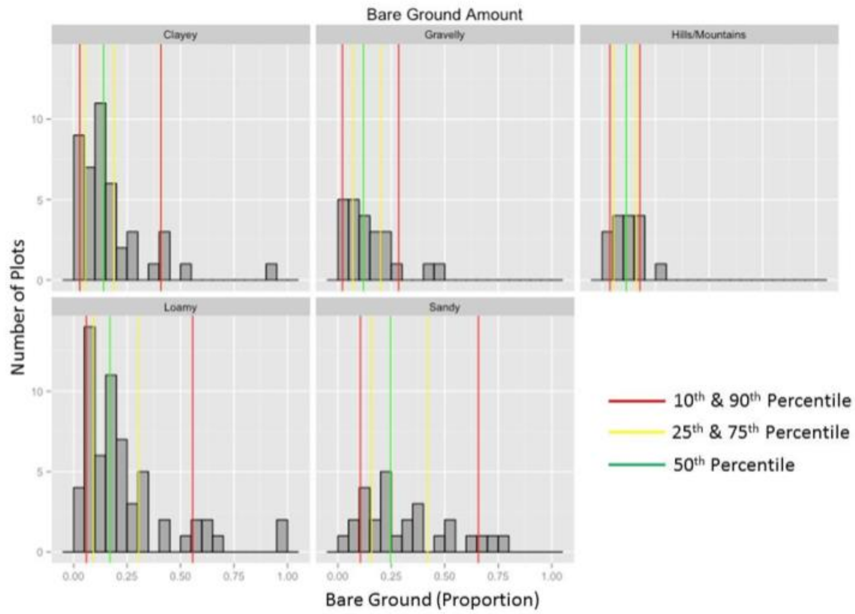

Figure B-6. Example histograms of bare ground for all unburned Terrestrial AIM plots in an ecoregion, split by type of land. This information can be helpful for setting benchmarks. For example, if it was decided that the lower 25% percentile of bare ground values represent desired conditions, the benchmark for clayey areas would be about 5% bare ground. The benchmark for sandy areas would be about 15% bare ground. Other information sources like professional judgment or peer reviewed articles should be used to validate and/or justify adjustments to these benchmarks.

Best practices for the implementation of benchmarks based on monitoring data:

- Understand and document how screening processes were used to define reference condition and subsequently develop indicator distributions.
- If using a non-BLM/external dataset, ensure the compatibility among field methods used in the sampling of reference site networks with previous monitoring data.
- Ensure that reference data used are applicable to the geographic area of interest. For example, ensure the reference dataset has similar climate, elevation, slope, stream size etc., to your area of interest.
- Think critically about the degree of departure from reference that is allowable while still maintaining ecosystem structure and function.
- Consider how your screening process may impact the potential range of conditions for choosing a benchmark value. For example, if the range contains mostly pristine sites, it may not be realistic to set a benchmark at the most pristine end of the range, and you might need to select a benchmark in the middle of the range. Alternatively, if the range includes mostly best available sites with some degradation, you may want to a benchmark that represents the least degraded sites.
- A sample size of 30 or more is optimal for developing representative distributions.
- Separate reference sites into ecologically similar groups to help account for natural variability but balance the number of groups with meeting minimal sample sizes.

- Consider indicator distributions: highly skewed or narrow reference distributions (e.g., very small interquartile range or difference in indicator values between the 25th and 75th percentiles), or distributions with upper or lower limits, may need to be handled differently.
- Site photos and aerial imagery can be a useful tool in both selecting reference sites and selecting appropriate percentiles.

For more information and examples related to this approach see Technical Notes 453 as well as Technical Note 455: “Applying and Interpreting Assessment, Inventory, and Monitoring (AIM) Data at the Field Office Level: An Example”, Technical Note 459: “An Application of Terrestrial Assessment, Inventory, and Monitoring (AIM) Data to Set Benchmarks in the Malheur Field Office, Oregon”, Open File Report #129 Developing Quantifiable Management Objectives from Reference Conditions for Wadeable Streams in the National Petroleum Reserve, and Open File Report #169 Developing Quantifiable Management Objectives from Reference Conditions of Wadeable Streams in Eastern Interior Field Office.

Peer Reviewed Literature

Scientific research that addresses how ecosystem structure, function, and services (including habitat) relate to indicator values can be very useful for setting benchmarks. Good sources for peer reviewed studies include Google Scholar, Journal Map, the Articles section of the AIM Sharepoint (see Section 3.2), and the BLM Library. The National AIM Team may also be able to direct you to relevant literature.

Best practices for the implementation of benchmarks based on peer-reviewed articles:

- Ensure compatibility among field methods and that results are applicable to the geographic area of interest.
- Ensure literature is current and from a reputable peer-reviewed journal.
- Look for replication or corroboration of findings among multiple studies.
- Cite the utilized studies and provide a rationale for why other pertinent studies were not included.

Appendix C: Sample Sufficiency Tables

C.1 Overview

The number of AIM points on a landscape is often determined by factors such as funding or available resources but the number of sample points and variability of the conditions across the landscape can impact how confident you are in your condition estimates. Sample sufficiency tables can also be used by AIM practitioners to better understand how the total sample sizes will affect the confidence intervals. These tables can be used in two ways, to logically inform your initial sample size, or to more statistically inform a new design where data already exists. In the case of informing an initial sample size it is recommended that the 50/50 split of meeting/not meeting a benchmark is used. This simulates the “worst case” where your data is split in conditions 50/50 so it is likely to require the highest sample size to meet your confidence level for a decision. This also needs to be balanced with other logistical limitations to sample sizes such as funding or data collection capacity. In the case where there is enough data available to estimate the proportions of the resource that are and are not meeting monitoring objectives these tables can be used to refine the necessary sample sizes to have the needed confidence in the results of your monitoring objective. The statistical foundations on which these tables are based can only be applied to proportional estimates of resource condition, where point weights are used in the calculations. Therefore, these tables should not be applied to a plot-counting approach.

The sample sufficiency tables displays the margin of error (MOE) associated with the sample sizes for a range of confidence levels (i.e., 80%, 85%, 90%, 95%). MOEs are half of a confidence interval. Complimentary landscape percentages (e.g., 5/95, 10/90, 20/80) have the same MOE, so if the proportions of the resource that are meeting and are not meeting the objective are complementary, then simply multiply the MOE by two to derive the width of the entire confidence interval. In some scenarios, the proportions of the resource that are and are not meeting the objective may not be complementary (e.g., 70% meeting, 20 not meeting, 10% unknown) and thus the MOE will differ for the different proportional categories. Confidence intervals are bounded by 0 and 100%.

C.2 Table Use Instructions

To use the tables, practitioners will first need to know the proportions of the landscape that are estimated to be meeting and not meeting the benchmark for a given indicator, and the number of sampled points (i.e., current sample size) that were used to calculate those estimates. Second, practitioners will need to know the level of confidence that they would like to have surrounding their final proportional estimates.

To obtain a MOEs, select the table that corresponds to the desired confidence level. Next, find a sample size that corresponds to the number of points that were used to derive proportional estimates of resource condition. Follow this row to the right until reaching the column that most closely matches the percentages of the resource that were observed to be meeting and not meeting the specified benchmark. The value displayed in this cell is the estimated MOE for the proportion based on the current sample size.

C.3 Example

An IDT wants to understand what sample size they need to be 80% confident that they are meeting one of their objectives with a reasonably narrow confidence interval. The current sample size (N) for the reporting unit is 10 points. Data collected at these 10 points were used to estimate that 80% of the resource is meeting their objective and 20% is not. Using Table D-1, the IDT determined that the MOE for their data is 17.1% for both proportions of the landscape, meaning that the width of their confidence interval is 34.2%. Since this value is quite large, the IDT decided to try to reduce the width of the confidence intervals to 15% or less. They used the table to determine that they should attempt to sample 40 additional points to achieve a total sample size of 50, which will hopefully reduce the MOEs to 7.3%, and the width of the confidence intervals to 14.6%. Tables D-2 through D-4 provide examples of what sample sizes are needed to be 80%, 85%, 90% and 95% confident, respectively.

Sample size (N)	Percentage of the resource either meeting/not meeting, or not meeting/meeting a benchmark									
	5/95	10/90	15/85	20/80	25/75	30/70	35/65	40/60	45/55	50/50
5	14.0	19.2	22.9	25.6	27.8	29.4	30.6	31.4	31.9	32.0
10	9.3	12.8	15.2	17.1	18.5	19.6	20.4	20.9	21.2	21.4
15	7.5	10.3	12.2	13.7	14.8	15.7	16.3	16.8	17.0	17.1
20	6.4	8.8	10.5	11.8	12.7	13.5	14.0	14.4	14.6	14.7
25	5.7	7.8	9.3	10.5	11.3	12.0	12.5	12.8	13.0	13.1
30	5.2	7.1	8.5	9.5	10.3	10.9	11.4	11.7	11.8	11.9
35	4.8	6.6	7.8	8.8	9.5	10.1	10.5	10.8	10.9	11.0
40	4.5	6.2	7.3	8.2	8.9	9.4	9.8	10.0	10.2	10.3
45	4.2	5.8	6.9	7.7	8.4	8.8	9.2	9.5	9.6	9.7
50	4.0	5.5	6.5	7.3	7.9	8.4	8.7	9.0	9.1	9.2
55	3.8	5.2	6.2	7.0	7.6	8.0	8.3	8.5	8.7	8.7
60	3.6	5.0	6.0	6.7	7.2	7.6	8.0	8.2	8.3	8.3
65	3.5	4.8	5.7	6.4	6.9	7.3	7.6	7.8	8.0	8.0
70	3.4	4.6	5.5	6.2	6.7	7.1	7.4	7.6	7.7	7.7
75	3.2	4.5	5.3	6.0	6.4	6.8	7.1	7.3	7.4	7.4
80	3.1	4.3	5.2	5.8	6.2	6.6	6.9	7.1	7.2	7.2

Table C-1. Margin of error estimates for an 80% confidence level. The highlighted cell in this table corresponds to the example above.

Sample size (N)	Percentage of the resource either meeting/not meeting, or not meeting/meeting a benchmark									
	5/95	10/90	15/85	20/80	25/75	30/70	35/65	40/60	45/55	50/50
5	15.7	21.6	25.7	28.8	31.2	33.0	34.3	35.3	35.8	36.0
10	10.5	14.4	17.1	19.2	20.8	22.0	22.9	23.5	23.9	24.0
15	8.4	11.5	13.7	15.4	16.7	17.6	18.4	18.8	19.1	19.2
20	7.2	9.9	11.8	13.2	14.3	15.1	15.8	16.2	16.4	16.5
25	6.4	8.8	10.5	11.7	12.7	13.5	14.0	14.4	14.6	14.7
30	5.8	8.0	9.6	10.7	11.6	12.2	12.7	13.1	13.3	13.4
35	5.4	7.4	8.8	9.9	10.7	11.3	11.8	12.1	12.3	12.3
40	5.0	6.9	8.2	9.2	10.0	10.6	11.0	11.3	11.5	11.5
45	4.7	6.5	7.8	8.7	9.4	9.9	10.3	10.6	10.8	10.8
50	4.5	6.2	7.3	8.2	8.9	9.4	9.8	10.1	10.2	10.3
55	4.3	5.9	7.0	7.8	8.5	9.0	9.3	9.6	9.8	9.8
60	4.1	5.6	6.7	7.5	8.1	8.6	8.9	9.2	9.3	9.4
65	3.9	5.4	6.4	7.2	7.8	8.2	8.6	8.8	8.9	9.00
70	3.8	5.2	6.2	6.9	7.5	7.9	8.3	8.5	8.6	8.7
75	3.6	5.0	6.0	6.7	7.2	7.7	8.0	8.2	8.3	8.4
80	3.5	4.9	5.8	6.5	7.0	7.4	7.7	7.9	8.1	8.1

Table C-2. Margin of error of percentage estimates for an 85% confidence level.

Sample size (N)	Percentage of the resource either meeting/not meeting, or not meeting/meeting a benchmark									
	5/95	10/90	15/85	20/80	25/75	30/70	35/65	40/60	45/55	50/50
5	17.9	24.7	29.4	32.9	35.6	37.7	39.2	40.3	40.9	41.1
10	12.0	16.5	19.6	21.9	23.7	25.1	26.2	26.9	27.3	27.4
15	9.6	13.2	15.7	17.6	19.0	20.2	21.0	21.5	21.9	22.0
20	8.2	11.3	13.5	15.1	16.3	17.3	18.0	18.5	18.8	18.9
25	7.3	10.1	12.0	13.4	14.5	15.4	16.0	16.4	16.7	16.8
30	6.7	9.2	10.9	12.2	13.2	14.0	14.6	15.0	15.2	15.3
35	6.2	8.5	10.1	11.3	12.2	12.9	13.4	13.8	14.0	14.1
40	5.7	7.9	9.4	10.5	11.4	12.1	12.6	12.9	13.1	13.2
45	5.4	7.4	8.8	9.9	10.7	11.4	11.8	12.2	12.3	12.4
50	5.1	7.1	8.4	9.4	10.2	10.8	11.2	11.5	11.7	11.8
55	4.9	6.7	8.0	9.0	9.7	10.3	10.7	11.0	11.1	11.2
60	4.7	6.4	7.6	8.6	9.3	9.8	10.2	10.5	10.6	10.7
65	4.5	6.2	7.3	8.2	8.9	9.4	9.8	10.1	10.2	10.3
70	4.3	5.9	7.1	7.9	8.6	9.1	9.4	9.7	9.8	9.9
75	4.2	5.7	6.8	7.6	8.3	8.8	9.1	9.4	9.5	9.6
80	4.0	5.6	6.6	7.4	8.0	8.5	8.8	9.1	9.2	9.2

Table C-3. Margin of error of percentage estimates for a 90% confidence level.

Sample size (N)	Percentage of the resource either meeting/not meeting, or not meeting/meeting a benchmark									
	5/95	10/90	15/85	20/80	25/75	30/70	35/65	40/60	45/55	50/50
5	21.4	29.4	35.0	39.2	42.4	44.9	46.7	48.0	48.8	49.0
10	14.2	19.6	23.3	26.1	28.3	29.9	31.2	32.0	32.5	32.7
15	11.4	15.7	18.7	20.9	22.7	24.0	25.0	25.7	26.1	26.2
20	9.8	13.5	16.1	18.0	19.5	20.6	21.4	22.0	22.4	22.5
25	8.7	12.0	14.3	16.0	17.3	18.3	19.1	19.6	19.9	20.0
30	7.9	10.9	13.0	14.6	15.8	16.7	17.4	17.8	18.1	18.2
35	7.3	10.1	12.0	13.4	14.6	15.4	16.0	16.5	16.7	16.8
40	6.8	9.4	11.2	12.6	13.6	14.4	15.0	15.4	15.6	15.7
45	6.4	8.9	10.6	11.8	12.8	13.5	14.1	14.5	14.7	14.8
50	6.1	8.4	10.0	11.2	12.1	12.8	13.4	13.7	13.9	14.0
55	5.8	8.0	9.5	10.7	11.6	12.2	12.7	13.1	13.3	13.3
60	5.6	7.6	9.1	10.2	11.1	11.7	12.2	12.5	12.7	12.8
65	5.3	7.4	8.8	9.8	10.6	11.2	11.7	12.0	12.2	12.2
70	5.1	7.1	8.4	9.4	10.2	10.8	11.2	11.6	11.7	11.8
75	5.0	6.8	8.1	9.1	9.9	10.4	10.9	11.2	11.3	11.4
80	4.8	6.6	7.9	8.8	9.6	10.1	10.5	10.8	11.0	11.0

Table C-4. Margin of error of percentage estimates for a 95% confidence level.

Appendix D: Terrestrial and Lotic Master Samples

D.1 Development, Evolution, and Implications of the AIM Master Sample

Master Sample (MS) points, an attempt to standardize and simplify the sampling design generation process, are equivalent to other randomly located sampling locations and do not need to be treated differently in analyses. Both the Lotic and Terrestrial AIM teams produced a Master Sample in 2016. The Master Samples were random designs run on all BLM-managed lands (terrestrial) and all BLM Streams and Rivers (lotic) in which millions of points were pre-generated and attributed with the most common reporting units and potential stratification criteria (see Table E-1, e.g., field office boundaries, GRSG habitat, LANDFIRE BpS). Project-level GRTS designs could be run to select a subset from the Master Sample points for an AIM project-level design. Ultimately, the complications of changing geospatial data and re-processing time combined with increased access to processing power negated many of the benefits of the Master Sample. For these reasons, the Master Sample is no longer used by default with its use depending on both the resource and use-case.

How was the Master Sample used and what years:

- *General:* The Master Sample was used to select points where the attributes were correct and applicable from the years 2016 to current.
- *Terrestrial:* The Master Sample was used from 2016 through 2019 as the basis for terrestrial sampling designs
- *Lotic:* Most project-level designs during years 2016 to current use the Master Sample unless Master Sample points did not have appropriate spatial coverage. In 2016 all pre-attributed information was used, but as the geospatial layers changed the MS were re-attributed prior to selecting a design.

How is the Master Sample still used:

- *Terrestrial:* The Master Sample is no longer used for new terrestrial projects because it forced unnecessary limitations on sampling designs (e.g., minimum stratum areas)
- *Lotic:* The Lotic designs still benefit from the use of the master sample primarily for data management purposes. However, in many cases the MS cannot be used because of inadequate point coverage (e.g., new BLM land, incorrect perennial attribution by the ***National Hydrography Dataset (NHD)***).

What's important to know if you have a MS draw from and what's the impact:

- *Terrestrial:* Likely no impact. Master Sample points can like other randomly generated points in sampling designs. Rarely, a design's documented strata may not completely cover the sample frame. In that case, use the sample frame in the analysis instead.
- *Lotic:* No impact. Data users should always check the data sources associated with point selection and stratification.

D.2 Details and Metadata

For detailed master sample metadata please contact the National AIM Team. General details and basic data sources are included below.

<u>Terrestrial master sample details:</u>

- *Spatial extent*: BLM lands within the 13 contiguous western states
- *Base layers used to identify BLM lands*: ***Surface Management Agency (SMA)*** database published July 2015 by the NOC
- *Survey design approach*: GRTS sampling; unweighted point selection with no *a priori* stratification
- *Point density*: 1 point per 35 hectares for a total of 2 million possible sample locations
- *Example attributes used for stratification schemes in sampling designs*: BLM Field/District Offices, BLM Allotments, LANDFIRE BpS, and GRSG habitat.

<u>Aquatic master sample details:</u>

- *Spatial extent*: 13 contiguous western states with BLM land
- *Base layers used to identify BLM streams and rivers*: USGS NHD version 2.0, medium resolution (1:100,000) and Surface Management Agency (SMA) data layer published July 2015 by the NOC
- *Survey design approach*: GRTS sampling; unweighted point selection with no *a priori* stratification
- *Point density*: one point per 0.5 km of perennial stream for a total of over 67,000 possible sample locations
- Attributes listed in Table E-1 may have been used as strata if relevant and current, otherwise the Master Sample would have been re-attributed with current information before a design was run.

Attribute	Original Source	Download Date
Land Ownership, BLM District and Field Offices, BLM Grazing Allotments, BLM Herd Management Areas	geocommunicator.gov	9/1/2015
State and County Boundaries	census.gov	9/1/2015
BLM Solar Energy Zones	http://blmsolar.anl.gov/maps/shapefiles/	9/1/2015
SSURGO Map Unit	http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053627	9/1/2015
Omernik and EPA Ecoregions (Levels 1, 2, 3, 4)	https://www.epa.gov/eco-research/ecoregions	9/1/2015

Landfire Biophysical Settings	http://www.landfire.gov/datatool.php	9/1/2015
Strahler Stream Order Categories	http://www.horizon-systems.com/NHDPlus/NHDPlusV2_data.php	4/14/2014
Watershed Boundaries – HUC 6, 8, 10 and 12 Digit	http://nhd.usgs.gov/data.html	9/1/2015
BLM existing LUP Planning Areas, BLM In Progress LUP Planning Areas, BLM Historic LUP Planning Area	BLM Internal	8/28/2015
BLM Wilderness Areas, BLM Wilderness Study Areas, National Monument, National Conservation Area Boundaries, BLM Wild and Scenic Rivers, BLM EIS Boundaries for Use in Analysis, Sage Grouse Focal Areas, Sage Grouse Priority Habitat, Sage Grouse General Habitat	BLM Internal	9/1/2015
Elevation	BLM Internal	9/1/2015

Table D-1. Geospatial layers used to attribute the Master Sample and the download location and date for each layer.