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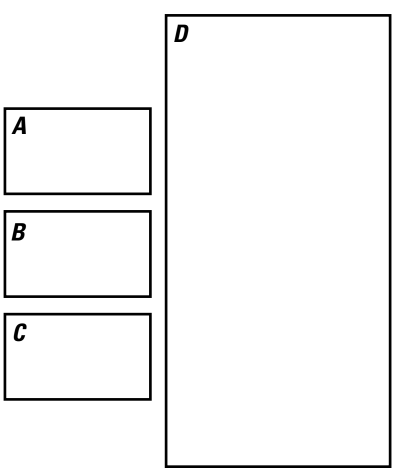
Prepared in cooperation with the Bureau of Land Management

Oil and Gas Reclamation—Operations, Monitoring Methods, and Standards

Chapter 1 of
Section A, Reclamation Activities
Book 18, Land and Resource Management

Techniques and Methods 18–A1
Version 1.1, December 28, 2023

U.S. Department of the Interior
U.S. Geological Survey



Cover. *A*, Photograph of a pronghorn (*Antilocapra americana*) using habitat with oil and gas development near Vernal, Utah. *B*, Photograph of monitoring soil and vegetation outcomes on a reclaimed oil or gas pad near Grand Junction, Colorado. *C*, Photograph of successful perennial grass establishment on a reclaimed oil and gas pad in the Book Cliffs, Utah. *D*, Photograph of a pumpjack at an active site near Farmington, New Mexico. Photographs by the U.S. Geological Survey

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
	Area	
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi^2)

Supplemental Information

Supplemental Information and resources can be found on the BLM fluid minerals website: https://www.blm.gov/programs/energy-and-minerals/oil-and-gas/reclamation.

Abbreviations

AERO	Aeolian Erosion model
AIM	Assessment, Inventory, and Monitoring Strategy
AAPD	approved APD
APD	Application for Permit to Drill
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BMP	best management practice
CFR	Code of Federal Regulations
COA	condition of approval
CPS	Conservation Practice Standard
CWA	Clean Water Act
DIMA	Database for Inventory Monitoring and Assessment
DOI	Department of the Interior
EM	environmental monitoring
EPA	U.S. Environmental Protection Agency
ES	environmental surface
ESA	Endangered Species Act
ESD	ecological site description
ESG	ecological site group
FAN	Final Abandonment Notice
FS	Forest Service
FO	field office
FWS	U.S. Fish and Wildlife Service
GIS	geographic information system
ID team	interdisciplinary team
LandPKS	Land-Potential Knowledge System
lidar	light detection and ranging
LPI	line-point intercept
NAIP	National Agriculture Inventory Program
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOC	National Operations Center
NTL	Notice-to-Lessee
NRCS	Natural Resources Conservation Service

NRI	Natural Resources Inventory
PLS	pure live seeds
PUP	Pesticide Use Permit
RCRA	Resource Conservation and Recovery Act
RHEM	Rangeland Hydrology and Erosion Model
RMP	resource management plan
ROW	right-of-way
SMA	surface management agency
STM	state-and-transition model
SUPO	Surface Use Plan of Operations
UAV	unoccupied aerial vehicle
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

Oil and Gas Reclamation—Operations, Monitoring Methods, and Standards

By Randi C. Lupardus,[1,2] Janna Simonsen,[3] Gordon Toevs,[1] Barbara Sterling,[3] Zachary H. Bowen,[1] Zoe Davidson,[3] Steven E. Hanser,[1] Emily Kachergis,[3] Alexander Laurence-Traynor,[3] Nika Lepak,[3] Rebecca K. Mann,[1] Aleta Nafus,[3] David S. Pilliod,[1] and Michael C. Duniway[1]

Abstract

This publication provides broad guidance for surface management of oil and gas development with a focus on promoting successful reclamation. Successful reclamation depends on sound best management practices, clear standards and expectations, defensible monitoring for effectiveness, and management of production facilities to minimize surface disturbance. This publication provides specific guidelines for surface management of oil and gas, including operations, standards, and monitoring. The development of this report was guided by existing Federal reclamation policy, a review of the scientific and other literature, as well as practical field experience. Expertise was pulled from multiple sources including Federal and State agencies, oil and gas contractors, and academia. The target audience for this report is primarily operators and contractors conducting oil and gas activities on U.S. Federal or Tribal lands and the surface management agencies responsible for guiding and enforcing these activities. The guidance on surface management presented here will also be useful for managing oil and gas activities on State and private lands and where private land occurs over Federal mineral estate (split estate).

Introduction

This report provides guidance on surface reclamation as it relates to planning, best management practices, monitoring, and standards for oil and gas exploration and development. Although the focus on information and methods is most pertinent to Federal lands in the Western United States, most aspects of this work are applicable to other agencies, Tribal lands, private lands, and other terrestrial systems. "The Gold Book—Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development" (the Gold Book) (U.S. Department of the Interior [DOI] and U.S. Department of Agriculture, 2007) contains practical information about the processes of oil and gas leasing and permitting, operations, bonding, and reclamation planning. Chapter 6 of the Gold Book, "Reclamation and Abandonment," briefly covers topics such as reclamation plans, well-site reclamation (interim and final), road reclamation, water-well conversion, inspection and final abandonment approval, and release of bonds. Although the Gold Book contains general guidance for structuring reclamation practices to meet reclamation standards and approve a Final Abandonment Notice (FAN),[4] it lacks the specific guidance often found in instruction memorandums and handbooks produced by surface management agency (SMA) offices, multi-jurisdictional groups, or State agencies. This report supplements the Gold Book and guidance developed for other reclamation settings (for example, Surface Mining Control and Reclamation Act of 1977 [Public Law 95–87]; Sendlein and others, 1983; Smyth and Dearden, 1998; Young and others, 2022) by providing thorough and specific guidance on reclamation surface management.

Objectives

The objective of this document is to provide specific reclamation guidelines for surface management of oil and gas, including operations, standards, and monitoring. Although resource inventory, monitoring, and protection on oil and gas sites are mandated by Federal statutes, regulations, guidelines for how to reclaim, how to monitor, and how to define standards for successful reclamation on disturbed oil and gas sites, have not been available at the national level. The effective implementation of national guidance and policy, specific to oil and gas monitoring and assessment, necessitates uniformity in monitoring protocols and standards for reclamation success. The establishment and use of consistent and standardized soil and vegetation field monitoring methods, indicators, benchmarks, standards, appropriate sample designs and analyses, and electronic data capture and storage technologies, support the implementation of (1) planning processes, (2) leasing, and (3) permitting processes and decisions. Some of these standards and processes may be applicable at local, regional, and national scales, which can be

[1]U.S. Geological Survey

[2]Northern Arizona University.

[3]Bureau of Land Management.

[4]Per 43 CFR part 3171, the operator's submittal of the FAN signifies that reclamation is complete and the site is ready for the SMA to conduct a final inspection and potential approval. Other liability releases may exist. A state agency that wants to utilize this handbook may have individualized procedures and terminology for approving reclamation.

useful when evaluating or reporting trends, or implementing adaptive management strategies. This report, like the Gold Book, will assist oil and gas companies and their contractors in conducting environmentally responsible oil and gas reclamation activities on public and private lands. Although there is an emphasis on oil and gas reclamation guidance for Federal lands in the Western United States, many of the concepts and ideas likely pertain to other fluid minerals as well as other lands and land disturbances, including wind and solar developments.

Intended Use

This document may be used from the initial planning phase—when developing a drilling application—to reclamation monitoring, which continues after plugging the well. In this document, the “Pre-development Site Assessment and Planning” section provides guidance for using digital resources, conducting a site assessment, and creating a reclamation plan. The section describes activities occurring prior to oil and gas development, including creating or gathering useful inventories and maps and writing a thorough reclamation plan that addresses benchmarks and standards. It does not cover permitting requirements or processes, as these topics are covered in existing Federal and State policy. The “Best Management Practices for Reclamation” section covers reclamation-specific best management practices (BMPs), organized by phase of the well life cycle, including for construction, interim reclamation, production, and final reclamation. The BMPs in this document are not prescriptive but are based on an annotated bibliography of current oil and gas documentation, including academic and government publications and literature (Mann and others, 2024). If an operator or contractor is interested in implementing a particular BMP, they may refer to the bibliography and associated “Science for Resource Managers Bibliography Search” tool[5] hosted by the U.S. Geological Survey (USGS) for further information. The “Reclamation Monitoring” section covers when, what, and how to monitor. The monitoring methods provided in this section are intended to create consistency across SMAs and jurisdictions. The “Reclamation Objectives, Benchmarks, and Standards” section details how data-driven benchmarks and standards can be created and evaluated against data collected with standardized methods, described herein, to assess reclamation outcomes.

Roles and Responsibilities

This section outlines SMA and operator roles and responsibilities relating to oil and gas surface management and reclamation. Although operators and others conducting reclamation are responsible for the success or failure of reclamation efforts, it is in the best interest of all parties involved to coordinate and cooperate to achieve maximize reclamation success rates. In this document the term “operators” is used to refer to both oil and gas company staff and other entities contracted to conduct reclamation activities. The phases (site construction, interim reclamation, operation, and final reclamation) are not mutually exclusive and have some overlap.

[5]Available at https://apps.usgs.gov/science-for-resource-managers/#/.

Surface Management Agencies

The Bureau of Land Management (BLM) is the largest SMA for oil and gas in the United States. The BLM manages approximately 245 million surface acres, located primarily in 12 Western States, and over 700 million acres of subsurface Federal mineral estate, and has the primary responsibility of federal oil and gas permitting. For this reason, the BLM is highlighted as a major SMA in this document. In addition, the BLM cooperates with various agencies to ensure that mutual management goals and objectives for surface protection and development activities are achieved when managing the Federal mineral estate underlying non-BLM surface lands (for example, surface managed by Forest Service [FS], Bureau of Indian Affairs [BIA], or private landowners). However, all Federal public land SMAs are responsible for protection of natural, cultural, and historic resources in accordance with applicable laws and regulations regarding surface resources. For federally funded activities or authorizations, this will include the Mineral Leasing Act of 1920 as amended, the Federal Land Policy Management Act of 1976 as amended, the National Environmental Policy Act (NEPA), the National Historic Preservation Act (NHPA), the Endangered Species Act (ESA), the Clean Water Act (CWA), and others. State governments may also have laws, regulations, and policies that govern operations.

Local SMA staff (for example, BLM field office [FO] staff) guide operators in creating a sound reclamation plan and ensure reclamation goals and expectations are clear. Other duties include inspecting reclamation progress and status, completing quality assessment and quality control of monitoring data collected by operators or contractors, and providing feedback to operators in a timely manner. Developing these general practices and policies fosters relationships and partnerships between SMAs and operators, highlights timeframes and procedures, and provides operators with information on the reclamation process.

The SMA typically creates an interdisciplinary team (ID team) to conduct environmental analysis and verify that equipment, practices, and procedures are in accordance with applicable laws, regulations, Notice-to-Lessees (NTLs), lease terms, and approved permits. The oil and gas surface inspector is an essential part of the ID team and the permitting (for example, Application for Permit to Drill [APD]) or broader reclamation planning process (for example, Master Development Plan). The ID team may include a natural resource specialist or physical scientist as the project manager and a wildlife biologist, botanist, range or forest management specialist, hydrologist, civil engineer, and representative of the SMA realty and recreation divisions. Throughout the inventory and planning processes, depending on the complexity and resources associated with the site, it may be helpful to additionally consult visual resource specialists, geologists, geomorphologists, fire managers, and other natural resource specialists.

The ID team lead may be involved in the following reclamation-related activities:

- Conducting the site assessment and the onsite inspection, typically on the same day, with the operator present;
- Determining the reclamation indicators, benchmarks, and standards used to assess reclamation success or failure; and
- Conducting environmental monitoring (EM) (according to the "How to Monitor" section) concurrent with environmental surface (ES) inspection[6] and then comparing the monitoring data to the benchmarks on the Reclamation Success Evaluation Form.[6]

Operators

Operators must comply with existing regulations for reclamation, such as those found in 43 CFRs parts 3160 and 3170[7] and 36 CFR part 228, subpart E; NTLs; and local land-management plans (for example, resource management plans [RMPs]), subject to valid existing rights. The operator is responsible for ensuring that reclamation is completed within the specified and authorized timeframes, following the

[6]Available at https://www.blm.gov/programs/energy-and-minerals/oil-and-gas.

[7]Onshore Oil and Gas Order No. 1 was codified in 43 CFR part 3171 June 16, 2023.

approved reclamation plan, and meeting or exceeding SMA-set benchmarks and standards for reclamation. As required by 43 CFR part 3171, all pads, pits, roads, and other related infrastructure are reclaimed to a satisfactorily revegetated state, with safe and stable soil conditions. Operators are also responsible for creating reclamation plans and may be required to collect and submit quantitative and qualitative reclamation monitoring data for review by SMA staff. Refer to local RMPs or other reclamation protocols for guidance on specific responsibilities and reclamation standards when developing the reclamation plan.

Reclamation Objectives, Benchmarks, and Standards

This section provides guidance on benchmarks and standards developed by SMAs to guide reclamation and determine when reclamation is successful. The benchmarks and standards described herein provide a consistent, data-driven, and practical approach to evaluating reclamation outcomes.

A major goal of reclamation is setting the site on a trajectory towards ecosystem recovery. In practice, site trajectory is not often quantified, and instead point-in-time quantitative evaluations or ocular estimates are the primary basis for FAN decisions. Therefore, it is paramount that the indicators and benchmarks used for interim and final-reclamation decisions reflect current understanding of ecological processes and account for site-specific ecological potential based on soils, topography, and climate. “Indicators” are measurable characteristics of a site and are selected to represent ecosystem processes or properties relevant to the decision or evaluation. For reclamation success, important indicators include qualitative determination of the extent and severity of soil erosion and quantitative determination of the presence or cover of plant species, including desirable and undesirable species and functional groups. “Benchmarks” are thresholds of specific indicator values, or ranges of values, that describe departure from desired conditions that can trigger adjustments to management practices, additional data collection, or indicate management success (for example, none, moderate, and extreme departure). “Standards” refer to a collection of one or more objectives assessed using benchmarks, or other information sources, and are used for specific decision processes (for example, land health standards [Kachergis and others, 2020]).

Historically, measurable soil and vegetation criteria necessary to receive FAN approval were generally lacking, necessitating operators and SMAs to rely primarily on professional judgment. Over the last two decades, standardization of monitoring methods (Herrick and others, 2017b) and newly available and accessible monitoring data,[8] collection platforms,[9] and analytical tools[10] have provided opportunities for data-driven and benchmark-based standards for soil and vegetation outcomes on reclaimed oil and gas sites (for example, Lupardus and others, 2023).

General Surface Reclamation Objectives and Standards

This section presents some general reclamation standards that are nationally applicable. Previously, individual SMA offices determined reclamation standards to meet regional requirements for topography, soils, and vegetation. Below are suggested interim and final-reclamation objectives, some of which translate directly into reclamation standards.

Interim reclamation is considered successful when the operator has met the following general objectives:

1. Recontour all areas not needed for active, long-term production and transportation operations to the original landform, where possible, or if necessary, create an interim landform that is stable, allowing sufficient flat area to set up a smaller workover rig and support equipment.
2. Minimize disturbance by spreading salvaged topsoil on the recontoured slopes as close to the well facilities and road surface as is practical, allowing for active well operations (such as a teardrop-shaped access road for trucks hauling fluids or inspecting the well).
3. Eliminate or prevent establishment of listed noxious species and reasonably eliminate or reduce non-listed invasive species (referred to here as weeds, see “Glossary” section).[11]
4. Minimize stormwater surface runoff with no major erosional features present (for example, rills or gullies).
5. Successfully establish desired vegetative community on the sides of roads, applicable cut-and-fill slopes, and a majority of the well or facility.

Final reclamation of a site is considered successful when the operator has met the following additional objectives:

6. Remove all surface equipment and structures (for example, pipes, pumpjack, tanks, signs, fences, culverts, trash).
7. Close and remediate the well pad, pit (if applicable), and road, ensuring soils are free of oil and salt contamination.

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[8]Landscape Data Commons data repository and portal available at https://landscapedatacommons.org/.

[9]Land-Potential Knowledge System (LandPKS) available at https://landpotential.org/.

[10]Landscape Toolbox available at https://www.landscapetoolbox.org/.

[11]Statutes that set law and definitions for weeds and invasive species include the Carlson-Foley Act of 1968 (Public Law 90–583), the Noxious Weed Control Act of 2004 (Public Law 108–412), the Federal Noxious Weed Act of 1974 (7 USC 2801 et seq.), the Plant Protection Act of 2000 (Public Law 106–224), Management of Undesirable Plants on Federal Lands (7 USC 2814). Weed policies include Executive Order 13112 (1999); as amended by Executive Order 13751 (2016), “Safeguarding the Nation from the Impacts of Invasive Species;” DOI Department Manuals 517 and 524; BLM Manuals 9011, 9014, and 9015 and Handbook H-9011-1; and other policies.

8. Recontour disturbed areas that were not addressed during interim reclamation, to the approximate contour that existed prior to disturbance, and establish native vegetation on any remaining disturbances or re-disturbed lands. Do not re-disturb interim-reclaimed areas where recontouring has already been completed and vegetation is established.

Three of the listed soil and vegetation objectives translate directly into standards and are included in the current ES Inspection Form[6]: noxious-weed control, erosion and stormwater control, and revegetation success. Each of these standards are assessed with benchmarks or other relevant information (see "Combining Benchmarks to Assess Standards" section).

Benchmark Groups

This section is an introduction to selecting lands of similar ecological structure and function that can be used to aggregate existing monitoring data for development of reclamation benchmarks and assessing standards for reclamation ("benchmark groups" hereafter).

Interdisciplinary Team

The initial decisions about how benchmarks and benchmark groups are organized and calculated are made by an ID team with appropriate technical support. There are tools and other technical support documents that have been developed by Federal science agencies and the BLM National Operations Center (NOC) that can assist with relating benchmarks to concepts of land potential and ecological dynamics (McCord and Pilliod, 2022). However, like most decision processes, the specific conditions of the site in question, including recent weather and site-specific soil and topographic setting, will often necessitate some professional judgement.

Unit for Comparison

A conceptually straightforward approach for developing soil and vegetation benchmarks and standards for final reclamation is to evaluate the disturbed area's condition against that of well-managed lands (that is, meeting land health standards[12]) in similar soil and climate settings (see appendix 1). To accomplish this, a benchmark group for comparison is determined using at least one of several land-classification systems based on ecological potential. The Natural Resources Conservation Service (NRCS) ecological site system[13] and associated ecological site descriptions (ESDs) (Caudle and others, 2013) and ecological site groups (ESGs) (Bestelmeyer and others, 2016) provide a potential unit for comparison. ESGs are groups of ESDs that share similarities in ecological dynamics and are slated to be available nationwide by 2026 (Thompson and others, 2020) and likely have an appropriate level of class specificity (for example, number of units in an FO) for use as benchmark groups. If ESGs are not available for a given area, see the "Insufficient Data" section. Once a benchmark group has been determined, field data that fall within the benchmark group can be compiled to create benchmarks for reclamation (see "Developing Benchmarks" section).

Using benchmark-group monitoring plot data (for example, BLM's Assessment, Inventory, and Monitoring Strategy [AIM] data grouped by ESGs) for establishing soil and vegetation benchmarks has several advantages over the more traditional use of a single, paired reference plot. By using plot data from throughout the general area, the decision processes are not influenced by the potentially subjective

[12]BLM Handbook H-4180-1 on rangeland health standards available at https://www.blm.gov/sites/blm.gov/files/uploads/Media_Library_BLM_Policy_h4180-1.pdf.

[13]Ecosystem Dynamics Interpretive Tool (EDIT) available at https://edit.jornada.nmsu.edu/.

choice of a reference plot; instead, the decision is made on the general condition of lands in the same benchmarkgroup. Standardizing within benchmark groups can also provide operators and SMA staff important information on expectations for reclamation outcomes early in the planning processes instead of relying on reference plot data collected at a later point in time. Additionally, invasive and regulated noxious ("noxious" hereafter) weeds, altered hydrology, and soil erosion may impact areas near the disturbance site; therefore, an adjacent reference plot is not always a good representation of the pre-development condition and may not entirely depict the responsibility of the operator during final abandonment. Lastly, this approach also removes the requirement of the operator or SMA to collect reference plot data when evaluating reclamation success.

Applicability of State-and-Transition Models to Benchmarks

Our current understanding of ecological dynamics within ESDs and ESGs are depicted in state-and-transition models (STMs). STMs account for the slow and often irreversible nature of degradation of many ecosystems, particularly those in arid and semiarid climates (Bestelmeyer and others, 2010). Unfortunately, there are several pieces of information and critical decisions required before STMs can be directly used for setting reclamation benchmarks. These limitations, a more in-depth description of STMs, and potential applicability are described in appendix 3.

Developing Benchmarks

Benchmarks for reclamation success are often derived based on the condition of surrounding lands with similar ecological potential but can also come from other sources, including law and policy. Examples of policy or decisions documents that can include benchmarks are State air or water-quality standards, allotment management plan objectives, RMP objectives, State noxious-weed lists, or other regional policies (fig. 1). An example of a regional policy is the greater sage-grouse habitat objectives in table 2-2 of BLM Idaho State Office (2019). However, most policy or decision documents lack the specificity to develop benchmarks for reclamation indicators.

Federal resource management agencies and other entities have a growing number of robust datasets useful for benchmark development, including data contributed by the BLM's AIM program, the NRCS Natural Resources Inventory (NRI) (collected on Tribal lands), and others (fig. 2). These data can be found on the Landscape Data Commons interagency monitoring data repository and portal[14] as well as through direct coordination with agencies. If monitoring data are not available for a particular ecological unit, a reference plot can be established and used for developing benchmarks; however, this is discouraged (see appendix 1). The BLM and others are currently developing AIM-based[15] benchmarks in many ecoregions. Contact a local resource specialist to identify the type of data or information available in the area of interest.

[14]Available at https://landscapedatacommons.org/.

[15]Available at http://www.blm.gov/aim.

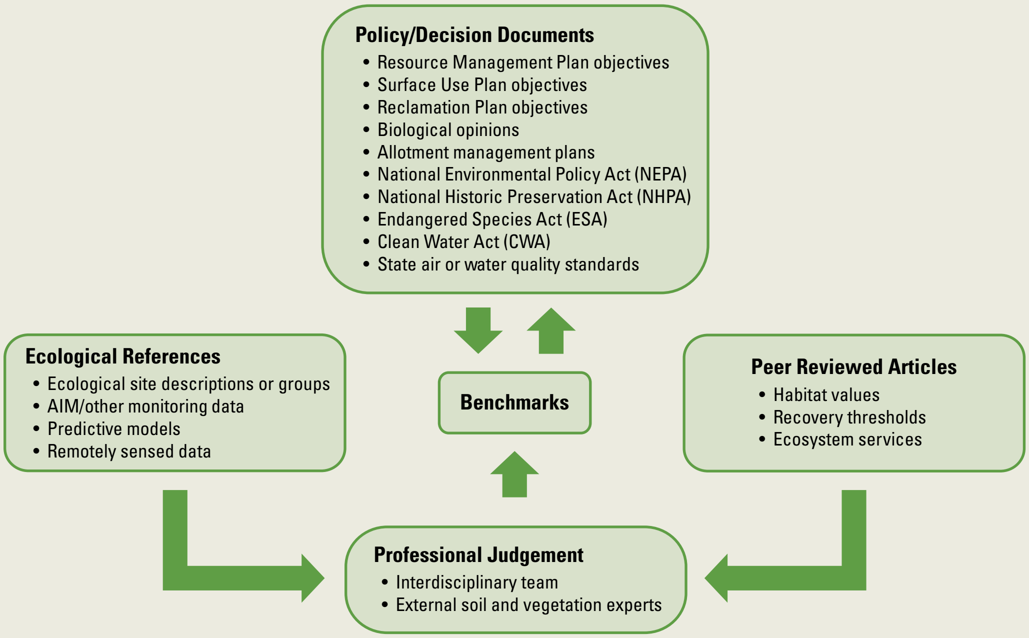


Figure 1. Diagram of example information sources used for setting benchmarks. Benchmarks are extracted from policy or decision documents, or created using other methods (for example, an ecological reference), and then placed into decision documents, such as the reclamation plan and (or) resource management plan. AIM, Assessment, Inventory, and Monitoring Strategy.

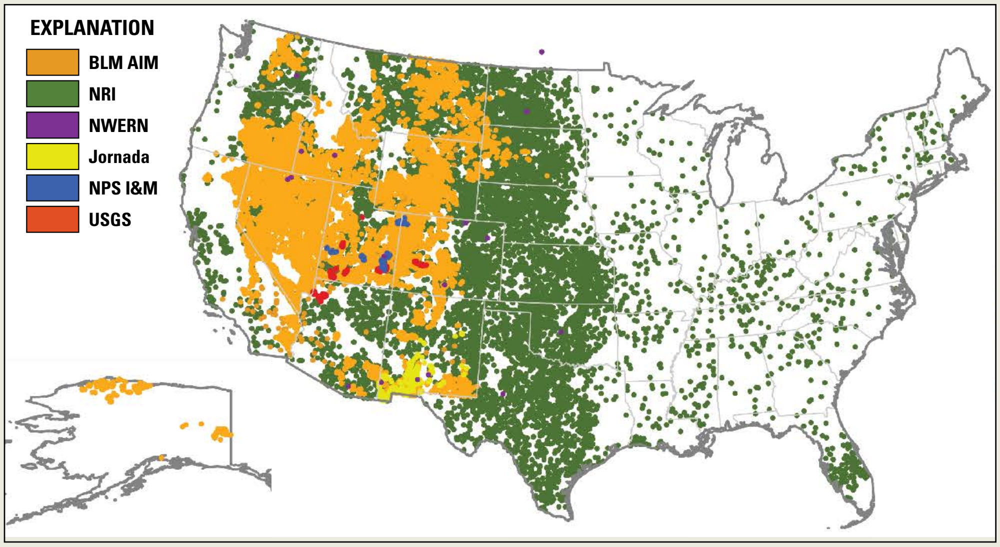


Figure 2. Map showing more than 60,000 agency monitoring plots that were established across the United States from 2014 to 2021. Data from the Bureau of Land Management's (BLM) Assessment, Inventory, and Monitoring Strategy (AIM) program, the Natural Resources Conservation Service Natural Resources Inventory (NRI), the National Wind Erosion Research Network (NWERN), the U.S. Agricultural Research Service Jornada Experimental Range, the U.S. Geological Survey (USGS), and the National Park Service (NPS) Inventory and Monitoring (I&M) network (McCord, 2021).

Benchmark Process Using BLM AIM Reference Data

This section goes through the benchmark creation process, using AIM data as the reference. The following are general steps SMA staff follow to develop benchmarks and assess standards depicted in figure 3:

1. Identify Benchmark Group. This is completed before development, during the site assessment (see "Site Assessment" section) and included in the reclamation plan. For older sites without a reclamation plan, the operator works with the SMA ID team to determine an appropriate benchmark group. If soil information and benchmark groups were not identified pre-development (for example, at existing sites), soil maps and evaluations of neighboring soils with a similar landscape setting can be used to identify the appropriate group.

2. Compile Available Data. To develop benchmark values, use available data that represent the range of conditions that exist in well-managed lands in the same benchmark group as the lease or well pad of interest ("reference data" hereafter). Attributing the reference data used in benchmark development is an active area of advancement that is described in appendix 1. Benchmark values may also be developed or informed by relevant scientific literature. SMA staff, working in collaboration with available specialists (for BLM, the State office and NOC) can help develop data summaries for each indicator of interest. These specialists may also be aware of existing benchmarks and literature that can be used. Ideally, SMAs will work towards storing and tracking benchmark group data in a single electronic location to increase accessibility and usage. When using AIM reference data for developing benchmarks, data can be linked either spatially (for mapped groups) or tabularly in the AIM data portal.

3. Calculate Distributions. Use statistical tools, such as the Benchmark Exploration Tool,[16] to calculate distributions and create visualizations (boxplots or histograms) for each of the indicators of interest from the reference data. From these, quantiles or percentages of the distribution are determined. It is likely necessary to screen the reference data, to ensure plots are in good condition and meet standards, and to determine if adjustments for weather are required (see "Accounting for Interannual Variability" section and appendix 1). Note that an adequate number of reference plots are needed to reliably estimate distributions and quantiles, with required numbers depending on the scale and heterogeneity of the benchmark group.

4. Identify Benchmarks. Perhaps the most important and difficult step is to identify points in the distribution of values for each indicator that will serve as benchmarks. These values are based on the distribution of indicator values from the reference and are calculated as a relative value of those target conditions (for example, greater than the 75th quantile). Review the distribution breaks for each indicator and assess whether they make sense ecologically and practically before setting the benchmarks. Consider using the lower (10th and 25th) or upper (75th and 90th) AIM reference data quantiles to set benchmarks, depending on the indicator.

5. Assess Standards. Once benchmarks (that is, quantile cutoffs) are established, monitoring data are evaluated against benchmarks to determine departures (for example, none, moderate, and extreme departure). Standards are assessed using combinations of relevant indicators and a rubric that specifies how the various benchmarks are combined to ascertain if a site is meeting or not meeting each standard. It is important for the standard to be specific, included in the reclamation plan, and used when evaluating reclamation outcomes (see "Combining Benchmarks to Assess Standards" section for more on how to evaluate outcomes).

Surface management agency staff should work to develop benchmarks for multiple groups simultaneously (fig. 4) and steps 3 and 4 are likely to be repeated every few years to update benchmarks with the newest data. Note that the

[16]Available at https://www.landscapetoolbox.org/benchmark-exploration-tool/.

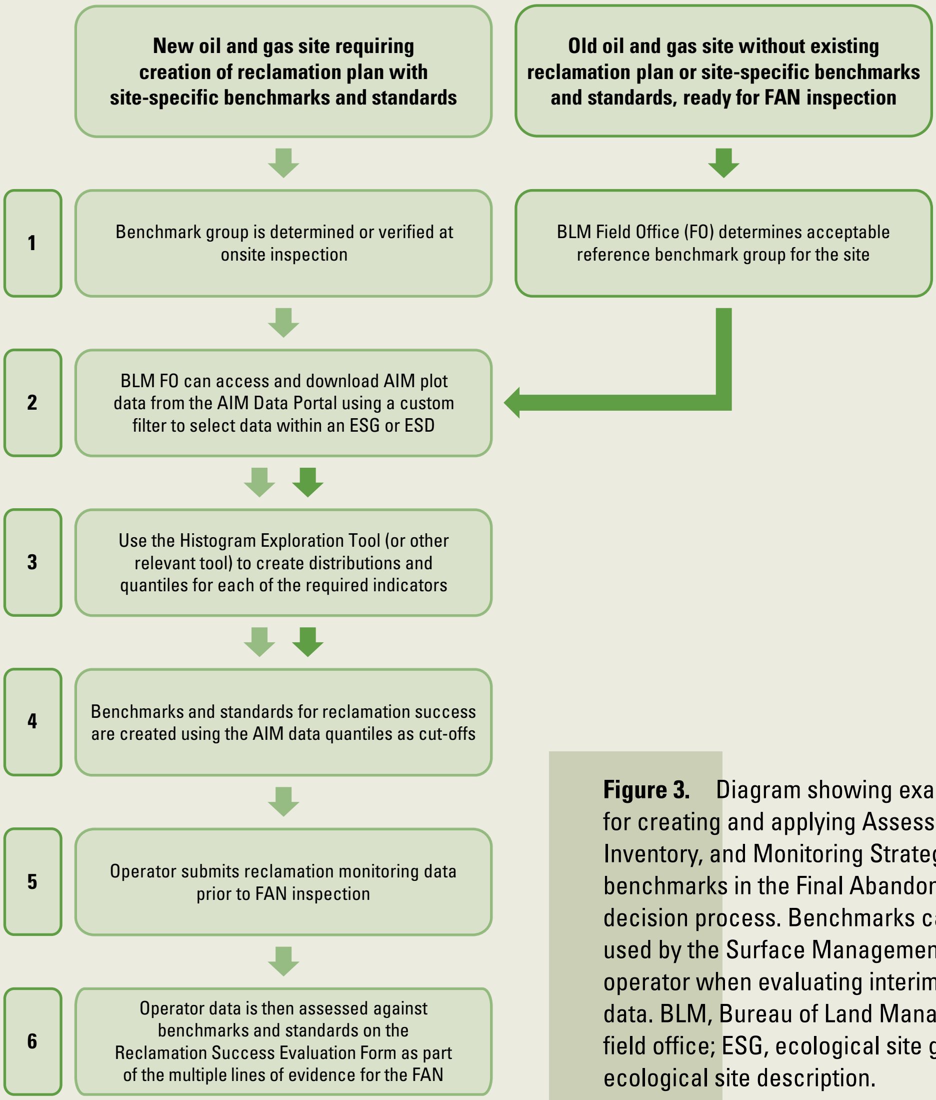


Figure 3. Diagram showing example process for creating and applying Assessment, Inventory, and Monitoring Strategy data-based benchmarks in the Final Abandonment Notice decision process. Benchmarks can also be used by the Surface Management Agency or operator when evaluating interim monitoring data. BLM, Bureau of Land Management; FO, field office; ESG, ecological site group; ESD, ecological site description.

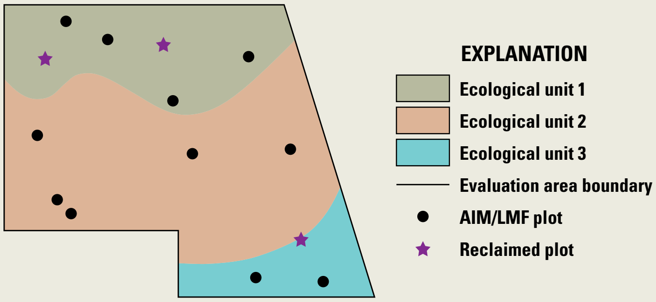


Figure 4. Conceptual example map of an evaluation area with three different types of land that belong to different benchmark groups for selected indicators. The ecological units represent distinct benchmark groups, categorized by ecological site descriptions, ecological site groups, or some other ecologically relevant grouping variable. AIM, Assessment, Inventory, and Monitoring Strategy; LMF, Landscape Monitoring Framework.

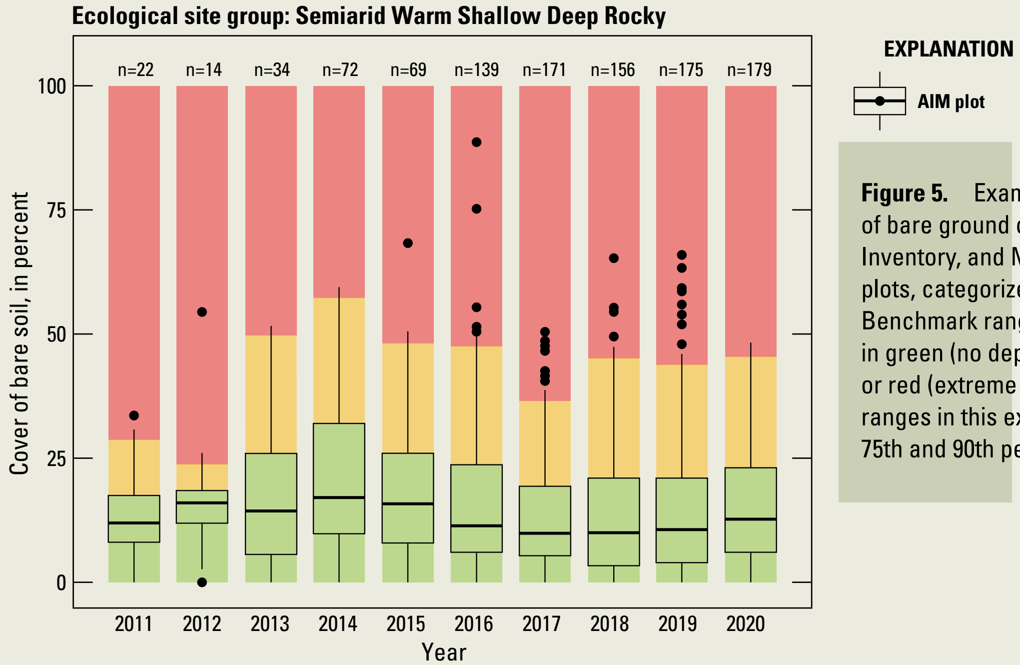


Figure 5. Example box plots showing percent cover of bare ground on unburned terrestrial Assessment, Inventory, and Monitoring Strategy (AIM) reference plots, categorized by year data was collected. Benchmark ranges are identified by areas highlighted in green (no departure), yellow (moderate departure), or red (extreme departure). Cutoffs for benchmark ranges in this example include the 10th, 25th, 50th, 75th and 90th percentiles.

Benchmark Exploration Tool[16] may be used to complete all steps when using Ecological Sites as the benchmark groups.

When an oil and gas project is in the initial permitting and planning phase, a reclamation plan is set forth, specifying a set of reclamation soil and vegetation benchmarks and standards for the project. At the end of the well life cycle, after a site has been plugged, decommissioned, and reclaimed, the SMA is responsible for evaluating indicators against set benchmarks and ensuring that the reclamation standards have been met to issue an approved FAN. At this point, which could be several decades post-disturbance, check for available up-to-date benchmarks or follow the steps presented in figure 3 to determine (or redetermine) the benchmarks and assess the standards (see “Combining Benchmarks to Assess Standards” section and appendix 5 for an example).

Lotic and Lentic Data

Guidelines for AIM benchmark development only include terrestrial AIM indicators and not lotic or lentic data or indicators. Terrestrial monitoring data (including data from ephemeral washes) are stored in the terrestrial AIM database (TerrADat), whereas data from riparian and wetland sites are stored in the Riparian and Wetland AIM Database (formerly Lentic AIM), and Lotic/Aquatic data are stored in the aquatic AIM database (AquADat) for perennial streams and rivers. Both datasets are available via the AIM website.[17] For further information on appropriate reference indicators for riparian areas see Kachergis and others (2020).

Accounting for Interannual Variability

In most lands, interannual to decadal variability in weather, including multi-year droughts, greatly affects plant growth and indicator values. Thus, benchmark values may require adjustments for FAN monitoring data collected in unusually dry or wet years. In the figure 5 example, the benchmark value for bare soil cover that distinguishes moderate from extreme departure ranges from 59 percent in a dry year to 25 percent in a wet year (even though the cutoff remains at the 90th quantile). To avoid setting the benchmark too high or too low, data can be grouped into “dry,” “normal,” and “wet” years, and if sufficient data is available, benchmarks may be established for each climate condition.

Insufficient Data

Although the availability of standardized agency monitoring data is increasing, there may be insufficient data within the benchmark group that represents the reclaimed site. One solution is to broaden the benchmark group concept and use a broader-scale benchmark group with more available data, such as U.S. Environmental Protection Agency (EPA) ecoregions.[18] When using a broader set of data, such as from the ecoregional scale, selecting appropriate percentiles for benchmarks is important as the data will span a large variety of plant communities and ecological sites. Use percentiles as a guide and ideally have an ID team discussion to establish final benchmarks. See Grant-Hoffman and others (2021) for examples of tailoring EPA ecoregion-based benchmarks to finer scales.

[17]Available at https://www.blm.gov/aim.

[18]Available at https://www.epa.gov/eco-research/ecoregions.

Pre-Development Site Assessment and Planning

In this section, the importance of adequate planning and site assessments are highlighted to develop better reclamation plans with clear expectations. This section describes appropriate digital resources and on-the-ground assessments available to operators for reclamation planning. Some of these items include existing site-specific information collected electronically from reliable sources. Others are suggested evaluations of ecosystem structure and function. On federally managed wells, these items could be used to complete the Surface Use Plan of Operations (SUPO) part of the APD (refer to 43 CFR part 3171) package, which is reviewed during the onsite inspection. The electronic inventory, described in this section, establishes a framework for successful reclamation and is useful to both operators and SMA staff. Some of this information will overlap with data and information collected for other purposes, such as NEPA documentation.

Digital Resources

Described here are the spatial and tabular data that operators consider in preparation for site mapping and the onsite inspection, including current imagery of topography, soils, vegetation, and habitats, as well as pertinent AIM data or other monitoring data.

Aerial Imagery and Footprint Delineation

Recent and relatively high-resolution imagery from fixed-wing aerial vehicles (for example, for the National Agriculture Inventory Program [NAIP]), unoccupied aerial vehicles (UAVs), or satellites is useful for broad-scope site review and checking site boundaries. Include the proposed development and all other possible alternatives of the proposed footprint on the landscape in the imagery. It is almost always best to conduct operations on degraded land, if possible, although these lands can present unique reclamation challenges for operators. The operator and SMA work together to determine drilling and infrastructure locations, not solely based upon access to the target formation, but with the additional consideration of habitats, reclamation potential, land ownership, and other surface considerations. On Federal lands, locations for drill pads, roads, and infrastructure are typically finalized during the APD process.

For federally managed wells, maps included in the SUPO require a scale no smaller than 1:24,000, according to 43 CFR part 3171. Geospatial vector and raster data include appropriate attributes and metadata with the same source for georeferenced master title plats, hardcopy plats, and maps submitted in the APD package. To aid in future reclamation planning, operators create a file of the project with geographic information system (GIS) features such as points, lines, and polygons representing the well location, exterior pad dimensions, reserve pit, cuts and fills, off-location facilities, and outer limits of the disturbance area, including the area used during construction. It is important to include a legal description and use decimal degrees for discrete point features (for example, locations of permanent photo points) if they are not already included in the geospatial dataset.

Electronic Inventories and Maps

To help develop the reclamation plan, the pre-development assessment includes a thorough inventory of the site to determine local geology, soil types, hydrology, elevation, landform, annual precipitation, timing of precipitation, temperatures (average winter minimum temperate determines plant zones), ecological site descriptions (including native plant communities), location and classification of wetland and riparian areas (see “Wetlands” sidebar), location of stock

Wetlands

Wetlands are regulated by the U.S. Army Corps of Engineers under the Clean Water Act (Section 404) and are defined as areas inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. 43 CFR part 3171 states that the operator must not conduct operations in areas subject to mass soil movement, riparian areas, floodplains, lakeshores, and (or) wetlands. Identify and analyze lotic and lentic areas using one or more geographic information system (GIS) data sources (for example, high-resolution aerial photographs, light detection and ranging [lidar] data) followed by selective inspections of representative lotic and lentic areas. Ephemeral systems differ from wetlands in that they are saturated for less than 30 continuous days and lack riparian or hydric vegetation and soils but are important enough to consider during project development. The duration of saturation is often found in an ecological site description (ESD) or soil map unit description and can assist in categorizing the resource. If any of the soil map unit components or ESDs are identified as wetlands, adhere to surface management agency avoidance buffers. If avoidance is not possible, contact the jurisdictional Army Corp of Engineers office and a wetland scientist to conduct a full field inventory.

ponds, special-status wildlife and plants, and presence and abundance of invasive and noxious species.

Other information that is useful to gather at this stage is expected livestock and wildlife grazing use, tourism and recreational activities, and other uses on the landscape, which may influence reclamation outcomes. Reviewing properties of the predominant soils expected in an area may also help assess the need for field data collection on soil parameters. Electronic inventories are used to determine ecological classification, to create maps characterizing the site (slopes, ridges, drainage ways, terraces, and surface hydrological features), and are also used during effects analysis of the NEPA process. Identifying and assessing all these location conditions can help determine reclamation needs and estimated costs, set reclamation benchmarks and standards, and set reclamation success expectations. Web resources to assist with this work are provided in table 1.

Site Assessment

Before approval of the APD (or similar process), a site assessment is conducted with the onsite inspection to further identify site-specific resource concerns and requirements. Various aspects of reclamation are typically discussed during the onsite inspection. Information and recommendations from the onsite inspection are used by the operator to develop or modify the APD and used by the BLM to determine appropriate mitigation. In previously developed areas, a reference will need to be selected for the site assessment (see appendix 1).

Trained SMA staff conduct a soil characterization as part of the site assessment, typically following the onsite inspection, and on the same day when possible. The site assessment allows for the identification of soils (including problematic soils), salvage depths for topsoil and subsoil,

Table 1. Web resources and description for pre-development inventory.

[ESD, ecological site description; ESG, ecological site group; MSC, Flood Map Service Center; FWS, U.S. Fish and Wildlife Service; USGS, U.S. Geological Survey; SSURGO, Soil Survey Geographic Database.]

Resource	Description
Ecosystem Dynamics Interpretive Tool[1]	Provides access to ESDs and ESGs as well as available state-and-transition models and other interpretations.
Federal Emergency Management Agency MSC[2]	Serves as the official public source for flood hazard information produced in support of the National Flood Insurance Program. The MSC may be used to find the official flood map for an area and access a range of other flood hazard products.
FWS Information for Planning and Consultation webtools[3]	Provides a list of threatened, endangered, and candidate species potentially impacted by activities and contact information to request an official species list and proceed with FWS review or consultation.
NatureServe database[4]	Provides maps and lists of species status under the U.S. Endangered Species Act and the Canadian Species at Risk Act for plant, fungi, lichen, and animal species, subspecies, varieties, and populations.
National Oceanic and Atmospheric Administration[5] and the National Weather Service[6]	Provides data on historical climate and forecast future weather patterns (6–12 months out).
National Wetlands Inventory[7]	Provides access information to help locate and classify wetlands and riparian areas on or near the proposed site.
USGS Land Treatment Exploration Tool[8]	Provides helpful information about past disturbances (for example, fire) and land treatments for any existing or proposed project area and generates a variety of spatial products pertinent to restoration and rehabilitation planning. These products include maps and summaries of environmental characteristics, drought forecasts, and comparisons to other similar treatments within a specified distance or area of interest.
USGS Smart Energy Development webtools[9]	Provides relevant, scientifically robust, and accessible spatial information to support energy development and management decisions, including a variety of biophysical data layers relevant to energy development and generates a summary report of data layers in an area of interest.
Web Soil Survey[10] and SSURGO Database[11]	Provides maps and information about soil as collected by the Natural Resources Conservation Service's National Cooperative Soil Survey inventory, including includes soil properties; frequency of flooding; limitations affecting site development; links to ESDs; and other information.

[1]Available at https://edit.jornada.nmsu.edu/.

[2]Available at https://msc.fema.gov/portal/home.

[3]Available at https://ipac.ecosphere.fws.gov/.

[4]Available at https://explorer.natureserve.org/.

[5]Available at https://www.noaa.gov/.

[6]Available at https://www.weather.gov/.

[7]Available at https://www.fws.gov/wetlands/.

[8]Available at https://usgs.gov/ltet.

[9]Available at https://sciencebase.usgs.gov/smartenergy.

[10]Available at https://websoilsurvey.sc.egov.usda.gov/.

[11]Available at https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo.

Avoiding Reclamation Failure

In the following scenario, an operator's reclamation plan included purchasing a generic seed mix that was readily available and collecting and storing the top 6 to 18 inches of soil (varied due to an unlevel topography), to use as topsoil during interim reclamation. After 2 years and multiple failed seeding events, the operator realized what he had stored and referred to as topsoil contained a substantial quantity of subsoil with greater rock, clay, and salt content compared to the true topsoil. This mix of topsoil and subsoil impeded root growth and penetration. The operator had to purchase additional topsoil; soil amendments; and a locally adapted, salt-tolerant seed mix to create suitable conditions for plant growth and establishment. Early planning, a thorough site assessment, and a small initial investment of time and money could have prevented the unnecessary setbacks in the operator's reclamation efforts.

and identification of plant communities to determine the ESG and appropriate seed mix for reclamation. Example information for site assessment and soil characterization are found in table 2. Specific soil characterization locations (that is, places where a hole will be dug) are selected by the SMA. Note that for large development areas that encompass multiple distinct soil, topographic, or vegetation types, multiple representative soil characterizations are completed. Identification of the NRCS soil survey map unit components provides for soil characterization refinement. Herrick and others (2017b) and the Land-Potential Knowledge System (LandPKS) application[19] (Herrick and others 2017a) have methods and resources to aid in soil identification. Following concepts of land potential or ecological potential (Duniway and others, 2010a), the ID team works with the operator to complete the site assessment by determining the soil map unit component, ecological sites (that is, ESDs or ESGs), and landform characteristics on all portions of the site (see Pellant and others [2020] and Herrick and others [2017b] for further guidance on determining soil type), including all proposed disturbance areas (for example, access road, pads, and pipelines). Additionally, inspecting road and pipeline right-of-ways (ROWs) confirms there are no additional ecological sites requiring characterization. Once the map unit component, ESD, or ESG is determined (as appropriate), those land units can then be linked to a benchmark group used to establish benchmarks and standards (see "Reclamation Objectives, Benchmarks, and Standards" section and appendixes 1 and 2).

[19]Available at https://landpotential.org/.

There are three major reasons why collection of field-based data and information at the onsite inspection is advised:

1. Soil and ecological maps require ground truthing. Published surveys and maps may not fully characterize soils, plants, and ecosystems required for successful reclamation. The NRCS soil survey map units, which are the polygons seen in soil maps, almost always contain a mix of co-occurring soil types that do not necessarily support the same kinds of plants and may differ in how they respond to reclamation (that is, differing ESDs). Thus, soil maps by themselves are not appropriate to use at the site scale without field verification. For example, many areas in the intermountain West are mapped at the soil association or soil series complex levels (Order 5 soil mapping, scale 1:250,000 to 1:1,000,000), meaning each map unit normally represents 1 to 3 named map unit components and 15 percent soil inclusions. The spatial representation of ESDs is through these same polygons; thus, to leverage the wealth of soil data and associated interpretations in the soil survey for site-level planning, field verification of the site soil types is needed.

Table 2. Example requirements for the site assessment and soil characterization.

[Based on plot characterization and observations in Herrick and others (2017b). See appendix 5 in Pellant and others (2020) for further information that may be needed for identifying ecological sites.]

Site description	Plant community notes	Soil characterization[1]

• Global Positioning System location
• Slope
• Slope shape
• Aspect
• Landscape unit/position
• Photographs
• Other observations
  ○ Management history
  ○ Wildlife use
  ○ Livestock use
  ○ Offsite influences
  ○ Additional disturbances or notes
	• Note presence of noxious or nonnative species of concern (see local regulations or specialists)
	• List dominant, subdominant, and minor plant species[2]
		• Minimum soil pit depth of 50 centimeters, or to vegetation or water limiting horizon (for example, bedrock, cemented soil horizon).
		• Record soil horizon descriptions, including
		  ○ Depths
		  ○ Rock fragments
		  ○ Textural class
		  ○ Percent clay
		  ○ Effervescence
		  ○ Color

[1]Sampling by genetic soil horizon is preferred, however standard depths may be used if personnel are not adequately trained in soil horizon identification.

[2]Dominant, functional/structural groups with the greatest size per unit area in the plant community. Subdominant, functional/structural groups within a plant community with less size per unit area than dominant plants and generally greater than 10 percent of the community composition. Minor, functional/structural groups within a plant community with less size per unit area than subdominant plants and generally greater than 1 percent and less than 10 percent of the community composition.

Photographs showing analysis of topsoil. Left, Topsoil depth is determined during the site assessment. Bottom, A soil pit reveals the depth of topsoil, which is composed of the upper soil horizons (A and O) and contains about 80 percent of the root mass. In heterogenous sites with uneven topography, topsoil is collected in multiple locations and a topsoil salvage isoline map created. Photographs by Bureau of Land Management.

2. Field-based data are necessary for effective reclamation planning. There are three goals of a pre-development site assessment, which were developed to promote timely and cost-effective reclamation activities. The first goal is to identify suitable soil salvage depths of topsoil and subsoil. Suitable topsoil depths can vary from less than 1 inch (in.) to 12 in. or more depending on location and landscape position. The second goal is to identify and avoid any problematic soils which could inhibit reclamation success and (or) require expensive supplementary soil amendments. The third goal is to determine plant communities in the existing soil conditions, match them to a corresponding ESD or ESG, and use this information to select an appropriate seed mix of locally adapted native plants. See Caudle and others (2013) and Duniway and others (2010a) for further information on ESDs.

3. Field-based data are necessary for benchmark grouping and assessment. Proper identification of the ESD or ESG is needed to establish benchmarks and standards (see "Reclamation Objectives, Benchmarks, and Standards" section and appendix 2). If the benchmark group is not properly identified during the site assessment, this may result in setting inappropriate and unrealistic reclamation targets.

The Reclamation Plan

Plans for surface reclamation are a part of the SUPO and are designed to return the disturbed area to productive use and to meet the objectives of the SMA land and resource management plan. A comprehensive reclamation plan is an important step towards achieving reclamation success. Provided here are basic guidelines for creating a suitable reclamation plan that are broadly applicable in the Western United States. Review the lease agreement and RMPs for requirements in addition to the guidance given here. The reclamation plan outlines how and when the operator plans to implement interim and final reclamation in consideration of relevant Federal regulations and policies. Operator actions are intended to stabilize soils, control noxious and undesirable species, and establish a native plant community, to ensure the site is on a long-term, positive trajectory towards recovery. Digital resources and the site assessment information (see "Digital Resources" and "Site Assessment" sections) are used to inform details of the reclamation plan. Although the operator is responsible for the creation of the reclamation plan, it is incumbent that both parties (that is, SMA and operator) review and understand surface requirements and actions of responsible parties throughout the life of the well. Figure 6 shows an example of agency (BLM) and operator responsibilities.

Basic Components

On federally managed lands, an approved APD (AAPD) must have a reclamation plan in the SUPO, according to 43 CFR part 3171. If the AAPD predates Onshore Oil and Gas Order No. 1, there may not be a reclamation plan on file, and the operator submits one in a Sundry Notice, notice of intent to plug and abandon. The BLM strongly recommends that operators file an optional Notice of Staking, prior to filing an APD, in order to receive feedback on the siting and proposed reclamation plan, as well as to process the APD in a timely manner. The structure and complexity of the reclamation plan in the APD SUPO will vary on the basis of site-specific considerations.

In addition to federally required information, include the following components:

- Proposed total disturbed acres, planned interim-reclaimed acres (including geospatial files), and planned final reclaimed acres;
- Survey plat map of the recontoured slopes for both interim and final reclamation;
- Proposed inspection timelines for surveying and monitoring and all participating parties, including contact information for the person developing the reclamation plan;
- Proposed activities and timelines for interim and final reclamation and site monitoring (guidelines for monitoring provided in "Reclamation Monitoring" section); and
- Practices necessary to reclaim all disturbed areas, including any access roads, pipelines, and other infrastructure, and proposed indicators, benchmarks, and standards (see "Reclamation Objectives, Benchmarks, and Standards" section and appendix 2).

Other specific activities to address in the reclamation plan include earth work and soil stabilization; site protection from animals and people; dust abatement; water drainage and spill containment; topsoil and subsoil removal, storage, and replacement; introduced and noxious-weed control; seedbed management and preparation; vegetation management; and pit or sump closure. Considerations for the reclamation plan may include visual aesthetics (for example, cutting trees along the well site perimeter to reduce hard edges within a wooded area), biological soil crust salvage, or reclamation to protect special-status species and their habitat requirements. Operators discuss any changes to the reclamation plan with the surface owner and consider their views prior to action. See appendix 2 for an example reclamation plan template. Associated off-lease ROWs may follow a similar reclamation plan outline. Operators provide a reclamation plan for each ROW included within the APD detailing how the ROW will comply with reclamation criteria.

Agency	Phase	Operator
• Answer operator questions about siting and reclamation • Set date for onsite inspection • Assemble interdisciplinary team • Biological opinions • Review Surface Use Plan (APD only) • Consider Conditions of Approval (COA) • Determine which lease stipulations apply to the project	**1. Notice of Staking (NOS)/ Application for Permit to Drill (APD)**	• Detailed Location Assessment (avoid sensitive areas: wetlands, cultural sites) • Review Resource Management Plan (RMP) • Submit NOS to BLM (subsequent APD to follow) • Submit APD to BLM-includes Drilling and Reclamation Plan in the Surface Use Plan of Operation (SUPO)
• Confirm drilling location and perimeter of site • Discuss reclamation seed mix composition and sourcing, potential resource concerns or stipulations on lease • Determine indicators, benchmarks, and standards for benchmark group(s) • Suggest changes to the NOS or APD proposal	**2. Onsite inspection and site assessment**	• Confirm soils, ecological site, and the reference for benchmark group assessment (with natural resource specialist and interdisciplinary team) • Determine depth and amount of topsoil available (incorporate into SUPO) • Develop electronic inventories, collect any additional field inventories, and refine the reclamation plan
• National Environmental Policy Act (NEPA) review and request additional necessary information from operator • Repeat onsite if necessary • Decision on permit to drill (pending NEPA completion)	**3. Permit review**	• Respond to BLM request for additional information in a timely manner • Provide BLM with inventory data collected during the Onsite
• Construction of the drill site, road, and infrastructure should be inspected within 2 weeks of receiving construction notification, weather permitting • Ensure meeting requirements in APD during inspection	**4. Construction and well completion**	• Notify BLM construction will begin (one week prior) • Have APD in hand for inspection • Salvage topsoil (protect and stabilize) • Weed management begins • Minimize surface runoff and erosion
• Environmental Surface (ES) Inspection is conducted to verify interim reclamation compliance within 6 months of well completion • If not meeting the APD interim reclamation plan, then potential enforcement action • Verify operator interim monitoring data and collect any additional monitoring data (if necessary)	**5. Production and interim reclamation**	• Recontour and till all areas not needed for production and transportation, respread salvaged topsoil, reseed and add amendments • Control erosion, water drainage, weeds, and dust • Conduct interim monitoring after establishment of vegetation
• Review the reclamation plan upon receiving plugging notification and conduct ES Inspection within 6 months of plugging to verify final reclamation has been initiated and meets the APD (may require several visits with monitoring) • If not meeting the APD final reclamation plan, then potential enforcement action	**6. Well plugging and final reclamation**	• Submit Notice of Intent to Plug and Abandon • Plug the well and flush or remove pipelines • Return the pad, material storage piles, cut-and-fill slopes, roadways, sediment retainers, and storm water control features to natural contours that blend with adjacent undisturbed areas and reestablish plant communities • Discuss proposed changes to the reclamation plan
• Review reclamation plan, RMPs, COAs, lease agreements, and evidence (monitoring data) submitted from the operator • Complete Final ES Inspection, monitoring, and Reclamation Success Evaluation Form • Submit FAN decision	**7. Final Abandonment Notice (FAN)**	• When considering submission of FAN, contact the field office to schedule an informal site visit to discuss potential resource concerns • Submit the FAN, addendum to the reclamation plan (if required), and monitoring data to the BLM
• If FAN approved-operator released from further obligations at the well site and associated surface disturbance • If FAN denied-operator allowed time to recomplete reclamation, then conduct an additional ES inspection after the operator has met all conditions for FAN approval	**8. Reclamation completion**	• If the FAN was denied, the operator may recomplete reclamation and re-submit the FAN or appeal to the district/state agency office

Figure 6. Diagram showing example surface reclamation phases and activities of surface management agency (Bureau of Land Management [BLM]) and operator.

Reclamation plan updates are submitted to the SMA through a Sundry Notice and are reviewed by SMA staff prior to final-reclamation activities. This ensures the operator is using the best available science for reclamation activities.

Collecting Additional Field Inventories for Reclamation Planning

Some inventories and maps are required by the operator for APD approval (see 43 CFR part 3171) whereas others are optional to operators for reclamation planning. Listed below are optional qualitative and quantitative pre-development data that can further inform reclamation planning.

- Soil physical and chemical analyses can be used to identify characteristics that may influence salvage, stockpiling, replacement, and revegetation. Characteristics of interest may include texture, water holding capacity, pH, electrical conductivity, sodium adsorption ratio, heavy metal contents, and other variables. For example, ranking soils with a soil suitability table can inform probability of reclamation success and guide use of soil amendments. See table 3 for an example of Wyoming's soil suitability thresholds.
- Information collected on historical and current activities and disturbances on and near the site can further guide reclamation planning.
- Plant inventory data can be used in conjunction with soil characterization data to identify the ESD and ecological state, which can be used to identify other potential risks for site management as well as appropriate seed mixes. If multiple ESDs are represented within the survey area, a seed mix that includes species from both ESDs, based on seed and soil compatibility, may maximize success.
- Plant inventory data can also highlight noxious and invasive species found on the site and help determine if pre-development treatments are necessary. Note that some FOs have added species to their introduced and noxious-weed lists that are not on State or county lists.
- Soil cover data can be used to identify the abundance of biological soil crusts (biocrusts) on the site and inform if salvaging and reclaiming with biocrusts is viable. Successful reclamation of vegetation does not ensure biocrust recovery, therefore, sites dominated with biocrusts pre-development may require implementation of biocrust restoration techniques (see "Biological Soil Crusts" sidebar).

Table 3. An example soil suitability table used to identify suitable topsoil material.

[From the Wyoming Department of Environmental Quality (2015), attachment B2. Suitability is determined case by case if pre-development values for topsoil are in the marginal or unsuitable range. EC, electrical conductivity; mmhos/cm, millimhos per centimeter; %, percent; mm, millimeter; % vol, percent volume.]

Parameter and method	Suitable range	Marginal range	Unsuitable range
pH (acidity or alkalinity)[1]	5.5–8.5	5.0–5.5 8.4–9.0	<5 >9.0
Salt content by EC (mmhos/cm)[1]	0–8	8–12	>12
Texture[2]	Loams <40% clay, <90% sand or silt	Clay, silty clay, sand	--
Sodium ion activity (sodium adsorption ratio)[3]	0–10	10–12, clay soils 10–15, other soils	>12 >15
Gravel (>2 mm) (% vol)[4]	<25%	25–35%	>35%
Available water-holding capacity (cm^3/cm^3)	>0.10	0.05–0.10	<0.05

1pH and EC can be determined with simple field meters.

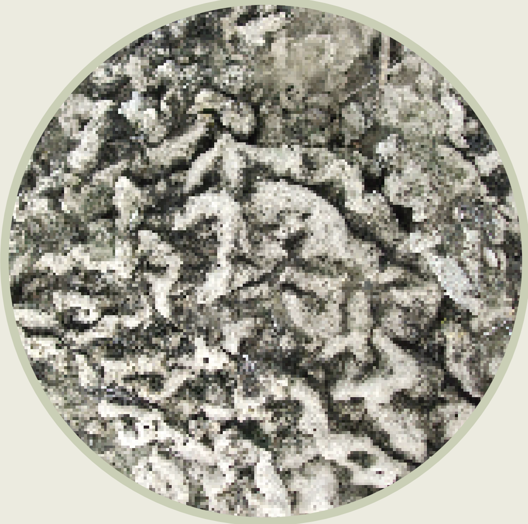
2Texture by feel can be done using the textural triangle and flow chart.

3Sodium adsorption ratio is determined by a soil laboratory.

4Gravel content by volume can be ocularly estimated by sieving a soil sample through a 2-mm (10-mesh) sieve. Suitability depends on values for pre-development soils.

Biological Soil Crusts

Biological soil crusts, also known as cryptobiotic soils or biocrusts, are associations between topsoil particles and communities of hetero- and auto-trophs such as cyanobacteria, algae, lichens, bryophytes, bacteria, fungi, and archaea. Biocrusts serve important ecological functions such as stabilizing soils, increasing soil fertility, and providing seed germination sites (Weber and others, 2016). Reestablishment of biocrusts, particularly lichens and mosses, can be very slow. Therefore, the addition of biocrusts inoculum during reclamation can jumpstart recovery and be a critical step in the restoration process (Bu and others, 2018; Antoninka and others, 2020). Inoculum can be applied by broadcasting with a hydroseeder (Blankenship and others, 2020; Lorite and others, 2020; Zhou and others, 2020) or with rangeland restoration and farm equipment (Doherty and others, 2020) at large scales. For more information on biocrusts, see Belnap and others (2001) and Belnap and Lange (2003). For methods on storage and handling of biocrusts in dryland systems, see Tucker and others (2020).



Photographs showing examples of biological soil crusts. Photographs by U.S. Geological Survey.

Best Management Practices for Reclamation

This section covers timing considerations for reclamation activities as well as the SMA's (typically BLM) responsibilities and operator's best management practices for site construction, interim reclamation, operating phase, and final reclamation, based on a thorough review of government and academic literature. For lands with specific management allocations, resource objectives, and management actions for conservation, refer to local RMPs and (or) SMA FO staff.

Reclamation Information Sources

The recommendations and BMPs provided below are based on information compiled from publicly available technical articles related to reclamation of oil- and gas-impacted lands. The majority of these articles have been catalogued in the "Science for Resource Managers Bibliography Search" tool. The bibliography includes journal articles, government reports, technical reports, proceedings, theses, and dissertations available through 2020. Although most of the articles included in the bibliography directly address reclamation of oil- and gas-impacted landscapes, several articles addressing reclamation of mining-impacted landscapes were also considered and included if they were relevant to the scale and scope of oil and gas. Further details on the methods used for the bibliography's systematic literature search and screening processes are documented in Mann and others (2024).

Surface Management Agency Review of Operator Activities

It is the SMA's responsibility to inspect the operator's reclamation procedures and activities and compare them to the approved authorizations; to ensure accordance with 43 CFR part 3171, regulations, and statutes; to ensure reclamation is conducted in a timely and effective manner; and to issue written orders and enforcement actions (table 4).

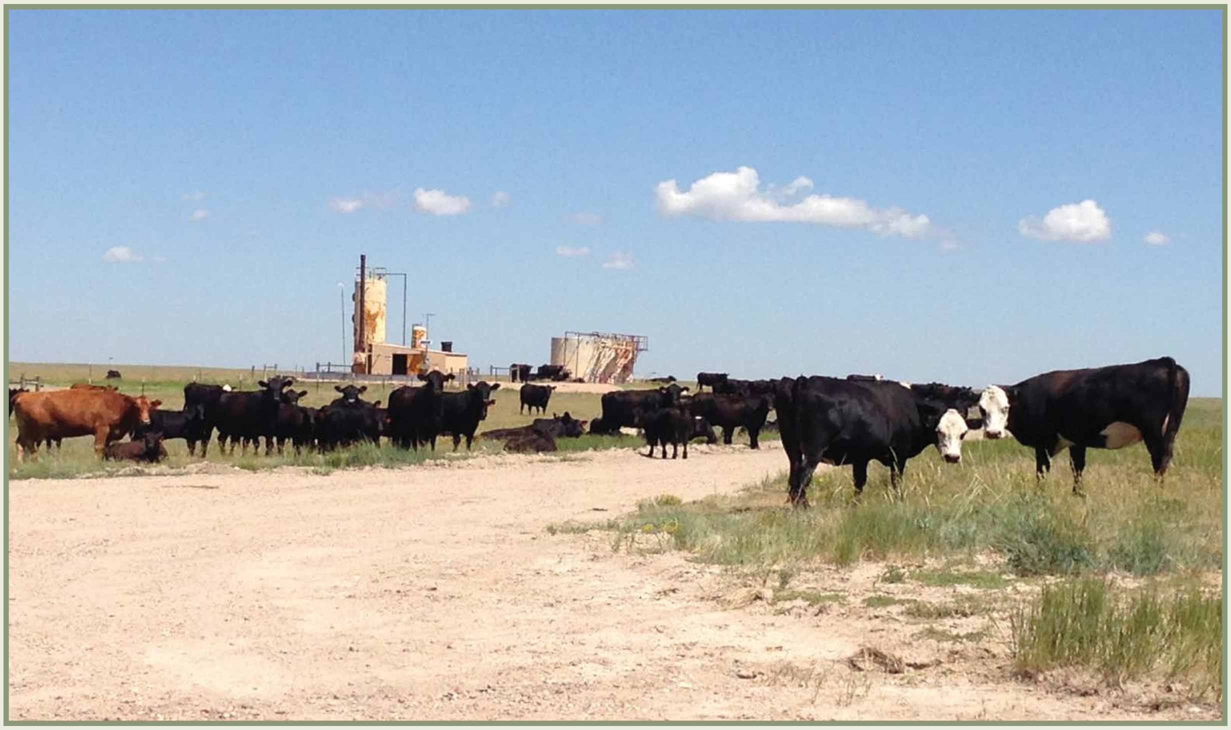


Table 4. Example operator practices suggested for review by the surface management agency.

[Practices organized by reclamation phase; phases are not mutually exclusive. AAPD, Approved Application for Permit to Drill; ROW, right-of-way; SUPO, Surface Use Plan of Operations; SMA, surface management agency; FAN, Final Abandonment Notice.]

Phase	SMA staff ensure these reclamation practices are reviewed or inspected and enforced
Pre-Construction	Identify or confirm ecological sites (or groups) and soils for the disturbance area, including ROWs associated with the AAPD.
Construction	Approved seed mix includes an adequate number of native species and functional groups and is certified as weed free (complete prior to interim reclamation).
	Prior to topsoil salvage, stripping depths are marked in the field with labeled stakes indicating topsoil salvage depths across the area.
	Topsoil is stripped and stored onsite, kept separate from subsoil or other excavated material, during construction of well pads, pipelines, roads, and other surface facilities.
	Soils are properly located, oriented, and labeled as the site is developed.
	Stockpiles are vegetated as soon as practicable with temporary cover.
	Noxious weeds and invasive species are controlled per statute, regulation, and policy.[1]
	There is adequate erosion and stormwater control and it is installed properly.
	The site is free of spills and leaks that could impact reclamation efforts and areas requiring remediation have been adequately addressed.
	There is dust abatement on areas with exposed bare soil.
Interim	Approval is granted before air drying pits or using chemicals to aid in fluid evaporation, stabilization, or solidification.
	The specific reclamation plan is adhered to for topsoil source, type, handling, storage, and respreading. If operator plans to live-haul offsite, or to keep stockpiled soil in berms surrounding the pad for the life of the well, these actions are specifically addressed and approved on a site-by-site basis.
	Soil is replaced in the reverse order of collection, by returning any subsoil first, followed by topsoil.
	Every effort has been made to minimize sitting times and to reduce the production-phase footprint (for example, by reclaiming as much area as possible except a small area around well pad, tanks, and other necessary infrastructure).
	The interim-reclaimed area has been recontoured to the natural slope or topography of the site and has reestablished drainage properties.
	The drilling pad has been reduced to the minimum area required for production, with all other areas reclaimed as depicted in the AAPD SUPO.
	Interim reclamation is completed within 6 months of well completion (weather permitting; for example, it is not recommended to reclaim during periods of heavy rainfall, excessive heat, or freezing temperatures).
Production	Noxious species are controlled, and herbicide is applied by licensed applicators.
	There is proper erosion and stormwater control.
	The site is free of spills and leaks that could impact reclamation efforts.
	There is dust abatement on areas with exposed bare soil.
	Fences are adequately maintained.
Final	Reclamation plan is adhered to for topsoil handling.
	The site is recontoured to the natural slope or topography and has reestablished drainage properties.
	Soil is replaced in the reverse order of collection, by returning any subsoil first, followed by topsoil.
	Earthwork for final reclamation is completed within 6 months of well plugging (weather permitting).
	Approval is granted before air drying pits or using chemicals to aid in fluid evaporation, stabilization, or solidification.
	Erosion control and vegetation reestablishment are completed within the timeline approved by the SMA.
	Reclamation is satisfactory after the FAN has been submitted. If not satisfactory, inform the operator of the issues needing resolution.

[1]See footnote 11 in the text.

Timing Considerations for Reclamation Practices

The timing of reclamation activities is crucial to the ecological recovery of a site, from initial groundbreaking through final reclamation. Keep time-sensitive activities in mind during reclamation planning and do not deviate from the approved reclamation plan timeline unless approved in writing by the SMA. Plan for disruptive events such as native seed supply shortages, extreme weather events, machinery malfunctions, and noxious-weed spread. If delays are anticipated due to unforeseen circumstances, ensure the SMA is notified in a timely manner, and, if warranted, submit a Sundry Notice requesting a new timeline for activities with sufficient rationale for the change.

Operators determine sources and quantities of required seed mixes, obtain certificates of seed analysis, and submit seed analysis results to the SMA prior to seed purchase and construction activities. This will ensure seed availability and the absence of prohibited noxious and undesirable species in the seed mix. Do not leave stockpiled soils and (or) other disturbed ground that is not required for production unseeded or otherwise unprotected, because barren soil is susceptible to erosion and noxious-weed infestation without competition.

If the operator is permitted to wild harvest seed as part of the approved reclamation plan, collect seed prior to the construction phase. Collection of native seed can be a viable technique for ensuring a locally adapted seed source, however it requires a considerable amount of time, planning, permitting, harvesting, and proper storage prior to construction activities.

Soil preparation and seeding events are also time-sensitive activities essential to successful reclamation. Operators typically conduct drilling operations when a drill rig is available, which can lead to interim reclamation activities occurring outside of the optimal timeframes for plant growth and establishment. Planning is necessary to ensure seeding is conducted both immediately following final seedbed preparation and when environmental conditions are optimal. For example, dormant seeding involves putting down seed while the ground is cold enough to prevent germination until the following spring. If seeded too early and seeds germinate in late fall or early winter, the immature seedlings may not survive winter conditions, necessitating additional seeding. Similarly, seeding during extended dry periods may also lead to seeding failure (see “Establishing Desired Vegetation” section). Use forecasting tools to time seeding with favorable precipitation when possible (see table 1). When developing the reclamation plan for the APD, the operator incorporates the appropriate timeframe for seedbed preparation and seeding during optimal environmental conditions. Operators work with the SMA to identify and address any time-sensitive activities.

Photographs of composting oily tank bottoms with wood chips (right) and exposed liners that were not adequately removed or buried (bottom). Bioremediation efforts reduce oil field wastes and spills and reduce costs and potential liability associated with landfill disposal. Photographs by Bureau of Land Management.

Contaminated Structures and Materials

Minimizing or eliminating contamination of soils and water during pad development, drilling, and production is critically important for reclamation success. Remediation actions are extremely costly, time consuming, not always successful, and may prevent revegetation efforts during reclamation. Investigate all aspects of an operation that may cause pollution so that every phase of the operation is designed to avoid environmental contamination. The SUPO includes detailed information about the location of buried pit and tank materials (including plastic liners, hydrocarbons, hydraulic fracturing chemicals). Since oil and gas exploration and production waste are exempt from Federal hazardous waste regulations (EPA, 2002) covered under the Resource Conservation and Recovery Act (RCRA), individual States may regulate disposal for these wastes. Practices can vary widely from State to State, although the RCRA intends for those States to take adequate measures to ensure that solid waste (as defined in 40 CFR part 257.2) is disposed of without affecting human health or the environment. This includes accounting for hydrogeologic systems that may allow for the migration of contaminants. Contaminants affecting reclamation can usually be broken down into five broad categories:

1. Salts.—Electrical conductivity, sodium adsorption ratios, exchangeable sodium percentages, and chlorides.
2. Hydrocarbons.—Total petroleum hydrocarbons, oil and grease, and benzene.
3. Metals.—Arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver.
4. pH.—Strong acids and bases
5. Chemicals.—Hydraulic fracturing fluid additives such as per- and poly-fluoroalkyl substances (PFAS), polyacrylamide, and glutaraldehyde.

When contamination does occur on a site, pollutants must be properly controlled, removed, and reported (BLM NTL- 3A[20]). Analyze contaminants according to appropriate testing protocols. The concentration of each of the listed contaminants is important in determining how the environment will be affected and, as a result, it is critical that they are tested for and managed accordingly. Utilize a soil suitability table (discussed in the "Collecting Additional Field Inventories for Reclamation Planning" section) to evaluate whether containments in categories 1, 3, and 4 exceed thresholds and (or) are inhibiting vegetation growth at the site. Some pollutants may be removed from the system using topsoil excavation, chemical amendments, or bioremediation efforts. Wastewater spills (also known as brine spills, Lauer and others, 2016; Dornbusch and others, 2020), are prevalent on unconventional oil and gas development sites during pipeline transport to injection sites and during filling or emptying of storage tanks and have the potential to inhibit vegetation growth. If brine and other contaminants are not

[20]Available at https://www.ntc.blm.gov/krc/uploads/172/NTL-3A%20Undesirable%20Events.pdf.

completely removed or adequately buried, future issues may arise with leaching or persistent contamination resulting in indefinite vegetation die-off. Maintaining healthy soils will support nutrient cycling, water infiltration, microbial activity, and plant growth—all essential components of successful reclamation. Please review the Gold Book, the EPA hazardous waste webpage "Management of Oil and Gas Exploration and Production Waste,"[21] and other agency policy and resources for further guidance on mitigation and remediation of environmental contamination (for example, BLM Instruction Memorandum WY 2012-007[22]).

Construction

Topics covered in this section include guidelines for minimizing disturbance, topsoil storage and handling, erosion control, drainage and hydrology, vegetation handling, and introduced and noxious-weed management during the construction phase. For construction guidelines unrelated to reclamation, please review the Gold Book or BLM Manual Section 9113 on roads.[23]

[21]Available at https://www.epa.gov/hw/management-oil-and-gas-exploration-and-production-waste.

[22]Available at https://www.blm.gov/policy/im-wy-2012-007.

[23]Available at https://www.blm.gov/sites/blm.gov/files/uploads/mediacenter_blmpolicymanual9113.pdf.

Minimizing Disturbance

Minimizing surface disturbance during construction eases the workload associated with interim and final reclamation. Locating well pads on relatively level ground and clustering wells and production facilities toward the entrance of the pad and slightly toward the cut slope is preferred, while considering erosional potential. Clustering infrastructure minimizes the footprint of the final-reclamation area and maximizes the area receiving interim reclamation. Plan to keep removal and disturbance of vegetation and soils to a minimum through construction site management, including using previously disturbed areas. Avoid placing tanks or other facilities on the fill or in the cut, as this prevents recontouring during interim reclamation and makes reclamation more difficult with increased erosion potential and decreased revegetation potential.

Reducing the severity of soil disturbance can also reduce costs and increase success of interim and final reclamation. Identify site or soil conditions that may require specific timing, equipment, or treatment measures to minimize soil disturbance. For example, minimize soil compaction and rutting on roads and staging areas by using heavy equipment only on dry ground. Further, conducting mechanical treatments along topographic contours, minimizing or avoiding heavy equipment use on slopes greater than

Streamlining Recovery

Soil and vegetation removal can be avoided when drilling shallow wells and using wooden mats during drilling and completion activities. This method has been shown to minimize disturbances to soil and plant resources, speeding up recovery to 1 year post disturbance (Mitchem and others, 2009).

Photograph showing wooden mats laid to access a well, instead of building traditional road and well pad infrastructure, to minimize disturbances to soil and plants. Photograph from Mitchem and others (2009).

Photograph showing tanks placed on fill. Infrastructure placed on the fill or in the cut prevents recontouring of the site during interim reclamation. Photograph by Bureau of Land Management.

Photographs showing plowing and pulling to put minor pipelines in the ground in order to disturb much less ground and vegetation than excavating and trenching. Photographs by Bureau of Land Management.

Photographs showing bucket augers and rock or wheel saws used to bury lines and pipes with a minimal disturbance footprint where plowing and pulling can't be used. Pipelines and communication-line right-of-way soils are temporarily windrowed, re-spread over the disturbance as sections of construction are completed, and compacted to prevent erosion. Photographs by Bureau of Land Management.

20 percent, and reducing the amount of time between soil disturbance and reclamation can all serve to reduce soil damage and improve reclamation success.

Other considerations for minimizing disturbance include using the following:

- Elongated or irregular-shaped drill sites to fit topographic features and reduce cut-and-fill slopes.
- Enclosed drilling systems or tanks instead of open pits (for example, a closed-loop system).
- Centralized infrastructure such as water management systems (Poseidon tanks, temporary surface lines, treatment facilities), production facilities (centralized tank batteries), and bioremediation facilities.
- Directional drilling (multiple wells on a pad). Take special consideration when locating larger multi-well pads, as they can be challenging to reclaim owing to compaction from larger rigs and drilling and (or) hydraulic fracturing equipment, more cut and fill to level the location, and less likelihood of reestablishment of vegetation in the interior of the location.
- Common corridors for roads
- Repeated elements of color, form, line, and texture for aesthetics and to reduce harsh visual impacts (for example, avoid using straight roads and constructing on steep terrain or on top of ridges).
- Placement of production facility to maximize area where interim reclamation can be completed. Place facilities away from cut-and-fill slopes, and near the access road, to avoid interfering with interim reclamation.

Management of Vegetation

During construction, the operator considers how to handle existing site vegetation and how to prevent and manage introduced and noxious weeds.[11] In the pre-development phase, all weed infestations are inventoried, mapped, and potentially pre-treated. State or county weed control specialists can assist with the identification and control of these species. Check with an agency weed coordinator to identify species managed regionally.

Photographs showing air spraying (top) and washing (right) of vehicles and machinery to remove weed seed before moving them from areas containing noxious and invasive weeds. Photographs by Bureau of Land Management.

BMPs for Vegetation Removal

- Masticate trees and large shrubs prior to construction. Mulch generated from mastication can be mixed with topsoil to incorporate organic matter. If excessive mulch is generated from mastication, mulch can be stockpiled separately from topsoil so that the mulch can be redistributed over seeded reclamation areas for a protective cover.
- If trees and brush are not masticated prior to construction, separate vegetation from topsoil. If not separated, topsoil salvaging is more difficult. The stockpiled vegetation can be placed on top of seeded reclamation areas as a protective cover. If this method is used, consider reseeding efforts if revegetation is not occurring in a timely manner.

BMPs for Weed Prevention and Management

- If noxious weeds are identified, remove them immediately, preferably prior to construction.
- Check the ecological conditions of adjacent lands, as they may affect reclamation outcomes and require further precautions. For example, placing a well pad in a location suffering from invasive weed dominance may increase the risk of weed spread with disturbance. Proximity to areas seeded to nonnative agronomic plants can also increase risk of undesired species introduction.
- To prevent the spread of undesirable species by equipment, the operator ensures contracted construction vehicles are clean and free of mud, soil clods, and vegetation prior to working onsite. This prevents undesirable plant species from infesting the site. Clean vehicles, removing all soil and plant parts, before leaving the project site to prevent onsite weeds from spreading to other work sites. This is easily implemented when wash stations are nearby and treated for weeds.
- On large, multi-well sites, construction and reclamation activities may overlap, allowing some areas of the site to be reclaimed while other areas are still under construction. Concurrent reclamation is only conducted where practicable, and the remaining disturbed areas are reclaimed at the end of the drilling program. This provides for a smooth transition

from weed removal to reseeding and protecting. A combination of weed removal techniques (for example, mowing and herbicide application), work best if applied prior to seed set. This sometimes requires a mass kill of all vegetation in the infested area. If construction and interim reclamation occur in separate seasons, a competitive seed mix may help to prevent reestablishment of noxious species and limit soil erosion prior to interim reclamation.

Topsoil Storage and Handling

Most soils have three major horizon designations (A, B, C) with topsoil at the surface (A) composed of minerals from parent material with organic matter incorporated. Some soils have an additional organic horizon (O) that is above the topsoil and composed of mostly organic matter such as decomposing leaves. Topsoil in this document refers to the upper soil horizons (A and O), which are essential for supporting plant growth. Microorganisms, organic matter, nutrients, and plant roots are found in the topsoil. Topsoil also has physical and chemical characteristics which differentiate it from subsoil, including texture, pore space, structure, and color. The magnitude of these differences and the thickness of topsoil can vary widely depending on soil forming factors. Owing to the large range in topsoil thicknesses across ecosystems, pre-development measurements of topsoil thickness are essential for successful reclamation on new operations. Typically, plant rooting depth is 2 feet (ft), with the topsoil often occupying only the top few inches, although topsoil thickness can be 12 in. or more in productive systems and less than 2 in. in arid and semiarid environments.

43 CFR part 3171 requires segregation of spoil materials to ensure topsoil integrity and separation from subsoil material. This requirement, as well as proper storage practices, facilitates the maintenance of soil ecologic functions and dynamics inherent to topsoil. For instance, non-living organic material found in topsoil not only improves soil physical properties such as porosity and water holding capacity but also provides binding sites for soil nutrients and is a critical source of energy for soil microorganisms which contribute to the cycling of minerals, nutrients, and carbohydrates to plants and other soil organisms. The living and non-living organic materials, inherent to well-maintained native topsoil, contribute to soil carbon storage capacity, soil stability, and the overall regenerative capacity of the soil. Keeping topsoil separate from subsoil increases its reclamation potential by reducing the dilution of its biological components and reducing contamination by salts, clays, and other soil components that are often elevated in deeper soil horizons and substrates.

The biological activity of stockpiled topsoil can greatly decline with time as well as with handling (moving or disturbing) owing to reduced plant inputs combined with continued microbial decomposition of organic matter. Storing soil at shallow depths and establishing native plants on the surface can maintain soil health, limit invasion by nonnative plant species, and minimize soil erosion. To ensure maintenance of topsoil health and support successful final reclamation, SMA personnel visually inspect the storage of topsoil.

Concurrent Reclamation

Onsite concurrent reclamation refers to placing salvaged soil, from a newly constructed or scraped area, directly onto a previously disturbed area to avoid stockpiling and double handling. This type of concurrent reclamation is best suited to large, multi-well sites and is adopted from the mining industry, which commonly conducts mining in phased areas. Concurrent reclamation is always recommended where practicable to minimize the time soil is in piles so that microbes and seeds remain viable (see “Soil Stockpiles” sidebar). Offsite concurrent reclamation is less common, owing to its numerous complexities. If an operator is approved to live-haul topsoil to a nearby well pad undergoing reclamation, the soils must be similar in required quantity and quality, moist, free from noxious and introduced species, and immediately re-spread and seeded. A reliable source of topsoil for the newly disturbed site is also required. All plans for concurrent reclamation are addressed in the reclamation plan.

BMPs for Topsoil Handling

Topsoil Identification

- Prior to submitting the APD, operators investigate the depth of topsoil at several points throughout the disturbance area and use these data to inform stripping depths to be incorporated into the APD SUPO. Note that lower slopes and swales contain deeper topsoil, whereas upper slopes, knolls, and ridge tops typically have thinner topsoil. On heterogenous sites with varying topography, create a topsoil salvage isoline map to keep track of depths across the site.
- Include the entire A (and O where relevant) horizons, as identified by surveys during the Site Assessment, in the topsoil thickness.
- After determining the depth of topsoil at the site, the APD SUPO identifies how much topsoil would be salvaged from the disturbed area (for example, in cubic feet or yards) and show the horizontal and vertical dimensions of the topsoil area that would contain the amount salvaged.

Soil Salvaging

- It is recommended to use an experienced equipment operator for soil salvaging. Avoid stripping topsoil too deeply or mixing subsoil with topsoil during the salvage operation. However, where the topsoil is only a few inches thick, equipment operators may find it difficult to scrape accurately, and special measures may need to be taken to prevent soil-horizon mixing. Combining topsoil and subsoil because of operator error or equipment limitations may inhibit reclamation success.
- Limit push distances (for example, <200 ft) to reduce soil-horizon mixing and soil handling time. Consider placing subsoil stockpiles and designated topsoil in areas with low soil erosion risk, near or around the perimeter of the pad.
- As soon as construction and drilling equipment are removed from the site and no further drilling is planned in the foreseeable future, topsoil may be respread in a designated interim-reclaimed area to avoid topsoil stockpiling. Except for the portion of the topsoil required for final reclamation, do not re-disturb the interim-reclaimed area for the life of the well (see “Soil Stockpiles” sidebar).

Soil Storage

- Make an account of segregated stockpiled materials, so that the amount saved for interim reclamation is known and to track topsoil loss due to erosion.
- Label all stockpiled soils and take photographs that capture labeling, location, and orientation (labels may become lost or damaged with time).
- Subsoil may be stored in stockpiles and used as berms.
- During road construction, operators may temporarily store topsoil on the side of the road and then redistribute it within the disturbances along the road. If an operator knows in advance that a road will not be reclaimed, such as when a county plans to adopt an oil and gas road, it is highly recommended to salvage this valuable topsoil if free from noxious and other species of concern.

Photograph showing topsoil that has not been handled properly. The pile of topsoil is an insufficient quantity for reclamation and left vulnerable to erosion. Photograph by Bureau of Land Management.

- All topsoil is respread across interim-reclaimed areas immediately following well completion (that is, within 6 months). The final-reclamation plan identifies where topsoil would be acquired from the interim-reclaimed areas to be used in the final reclamation. Do not use topsoil as a construction material or for any use other than as a seed bed for reclamation.

Ensuring Topsoil Pile Stability and Biotic Viability

- Stockpiled topsoil is immediately seeded (within the first appropriate seeding window) and protected from erosion.
- Ridging, pitting, and other soil-roughening techniques can maximize soil surface area and aeration on the stockpiles when used in combination with soil erosion prevention methods.
- Windrowing is a useful practice when temporarily storing topsoil for interim reclamation. Windrowing entails reducing pile height (<4 ft), which exposes a greater surface area of soil, allowing for increased moisture collection and creating preferable conditions for meso- and microfauna.
- Although seeding stockpiled topsoil with fast-growing sterile nonnative annual or early-succession native species may aid in preventing erosion and weed infestations, and may contribute organic material to the stockpiles, seeding with native species is always preferred. Planting with nonnative species can shift the composition and function of microbial communities in the soil, making it difficult to reestablish native species. Quick-growing nonnative grasses, cover crops, and nurse crops do not provide long-term stability and will not achieve revegetation standards.
- Topsoil for ROWs is treated in the same manner as other reclamation areas on the well site, requiring segregation of subsoil from topsoil. Excavated soils for pipelines and utility lines are temporarily windrowed and re-spread over the disturbance as sections of construction are completed, and areas seeded to prevent weed infestations and erosion.

Erosion Control

This section focuses on BMPs for minimizing site erosion during construction. Erosion control is important for conserving onsite soil resources as well as for maintaining air quality and preventing damage to adjoining lands and waters. When appropriate measures are not taken to control erosion, construction can cause damage to local habitat quality, plant and wildlife health, water quality, cultural resources, and properties near the construction site. Disturbed areas are at risk of accelerated erosion by wind and water during earthwork. Loose, dry soils are susceptible to movement by wind, either as saltating sand particles (that is, particles bouncing along the soil surface) or as finer soil particles entrained in wind and transported offsite. Both types of wind transport are a concern: saltating sands can abrade or bury plants and cause further soil erosion and entrained fine particles can lead to loss of site fertility and soil water holding capacity as well as impact air quality. Similarly, unprotected soil surfaces, especially stockpiled soils, are at risk of accelerated water erosion due to raindrop impact and overland flow. Raindrop impact will damage soil structure and clog soil pores, leading to decreased infiltration which furthers accelerated erosion risk. Erosion owing to overland flow is more easily recognized, can lead to loss of topsoil, and is indicative of overall poor site hydrologic function. It is especially important to focus water erosion prevention in drainage channels, on steep slopes, and along roads.

BMPs for Erosion Control

- Reduce slope angles during earthwork to reduce runoff flow velocities and erosive potential and reduce slope length to decrease the potential for concentrated flow and erosion owing to rills and other forms of channeling.
- Determine the best erosion-control features for a site by considering the angle and length of the site slope, vegetation cover, surface impermeability, amount and connectivity of bare ground, and precipitation characteristics of the site.
- Protect stockpiled top- and subsoil from erosion by placing on a stable, level surface; avoiding compaction; seeding within the first appropriate seeding window; and using silt fences, trenches, or other erosion-control practices.
- To prevent erosion during construction, diversion terraces and ditches, mulch, riprap, fiber matting, temporary sediment traps, broad-based drainage dips, water bars, lateral furrows, biodegradable wattles, weed-free straw bales, or silt fences are employed as necessary to reduce offsite transport of sediments. These structures are installed during construction and left in place and maintained until the site undergoes interim reclamation.
- Erosion-control matting disperses raindrop impact, holds soil and seeds in place, and then biodegrades as vegetation is established. The mats can provide a stable seedbed for one or more growing seasons. Multiple types of mats are available with different levels of durability, stability, biodegradability, and ecological sensitivity.
- Polypropylene erosion control blankets are designed to facilitate accelerated vegetative growth for short term erosion control, as they typically degrade over a period of 1 year. The rows of lightweight woven material help to hold seeds and soil in place until vegetation can take root. These blankets are ideal for use on moderate slopes.
- On steeper slopes, excelsior double-net matting and (or) blankets (mesh on both sides) with synthetic fibers are a cost-effective solution for steeper slopes. Although the mats can last for multiple years, it is important to check the structural integrity of the mats and remember to clean up the netting when it is no longer needed. These mats do come in biodegradable options; however, they are typically more expensive and not as durable as the synthetic mats.
- If erosion rates are relatively slow and time permits, successful revegetation can serve as erosion control. Typically, the use of temporary erosion prevention techniques can preserve soils until seeded species can establish. Some natural materials include weed-free jute, hay, straw, or mesh from native grasses.
- Any protective soil cover, including vegetation, plant litter, and biocrusts, can protect soil surfaces from raindrop impact. Plant bases, rocks, embedded litter, and other barriers or durable soil-roughness elements can slow overland flow and help retain sediment.
- Hydromulching with tackifiers is also a recommended method for soil stabilization on steep slopes, rough terrain, or areas that are difficult to access (see “Soil Amendments” section).
- Water should drain off roads as quickly as possible without eroding the surface. A target crown of 5 percent (±1 percent) assures that the road surface will shed rain and water used in dust mitigation. A crown of less than 4 percent can lead to water ponding on the road, which will quickly turn into potholes. A crown of more than 6 percent will exacerbate erosion during runoff and may cause truck trailers to slip off the road.
- Water should not pond next to the road, as this leads to water ingress, road material softening, and loss of reclamation materials such as topsoil. Include culverts, ditches, and miter drains in the road geometry to channel this water away, while also understanding and managing where the water goes.
- The specific type of water barrier used on the well site depends on the suspended particulate size in the runoff, and the quantity and velocity of water flow. Some common forms of surface flow controls

Photograph showing riprap and straw bales used to protect soil at culverts from fast moving water. Note that the rock is sized large enough so that the force of flowing water does not wash it away. Photograph by Bureau of Land Management.

Photograph showing erosion blankets placed over a steep hillside as a cost-effective soil stabilization method. Photograph by Bureau of Land Management.

include reshaping embankments; building retention ponds for sediment, siltation, and (or) water; or setting up sediment barriers (for example, brush barriers, silt fences, or ditches). Local geology, groundwater hydrology, embankment design, and other geohydrologic factors are considered in the overall design owing to subsurface pore water pressure, and seepage and piping concerns around, through, and beneath the well pad.

- Check all erosion structures for damage after heavy rainfall or strong winds. Erosion will increase with increasing storm intensity and duration.

Interim Reclamation

Areas of the site that are not required for oil or gas production activities undergo interim reclamation as soon as possible after disturbance. Reclamation continues until interim benchmarks and standards are achieved and can include greater than 80 percent of the disturbed area. Conducting successful interim reclamation can reduce costs and increase the effectiveness of final reclamation. During interim reclamation, disturbed areas are recontoured to blend with the surrounding topography, soils are stabilized, and native vegetation is established. Topsoil redistributed across unused

Photographs showing waddles that require maintenance owing to water flow (left) and disintegration (bottom). Regular maintenance ensures proper function. Photographs by Bureau of Land Management.

Photographs showing microtopography "pits," approximately 1 foot in size, during a precipitation event (left) and the resulting vegetative growth (bottom). Photographs by Bureau of Land Management.

areas during interim reclamation helps retain soil viability for future final reclamation. This section describes current interim-reclamation BMPs for operators. Topics covered include suggested guidelines for earthwork, establishing desired vegetation, soil amendments, introduced and noxious-weed management, and erosion prevention.

Earthwork

Earthwork is the first step in interim reclamation and includes the movement and recontouring of terrain. 43 CFR part 3171 requires that earthwork for interim reclamation is completed within 6 months of well completion. Wherever possible, the interim-reclaimed slope is recontoured back to the natural topography, so that these areas do not require further earthwork during final reclamation. With this method, excess topsoil is located close to the production pad so only a portion of the interim-reclaimed area will need to be re-disturbed during final reclamation. BMPs for earthwork will evolve as more research is conducted and data is collected.

BMPs for Topsoil Handling

- Avoid mixing topsoil with subsoil during reclamation.
- When replacing topsoil, take care to maintain soil structure during spreading. Using scrapers and handling soil (subsoil and topsoil) when it is too wet can lead to compaction.
- When drill seeding, final preparation of soil provides a firm, relatively uniform seedbed. Firm soil prevents planting seed too deeply, whereas compacted soil results in restrictive layers that limit root development and water penetration.
- When broadcast seeding, various options for soil roughening and microtopography creation include furrowing, pitting, mounding, imprinting, and soil ripping. Surface microtopography can enhance seed germination and plant establishment and growth by creating protected microsites for water and plant litter accumulation. These techniques alone do not mitigate erosion risk (and can exacerbate risks) and are combined with appropriate erosion prevention materials.
- To minimize degradation of topsoil, operators respread all topsoil on the interim-reclaimed areas allocating a portion of the interim-reclaimed area (labeled as such) with enough topsoil for final reclamation. At most productive wells, final reclamation occurs decades after initial construction, which is too long to maintain biotic life in topsoil that is stored in piles.
- Pipelines and communication-line ROWs are installed with the least degree of disturbance to topsoil. Where topsoil removal is necessary, segregate topsoil from subsoil, windrow, and re-spread over the disturbance as sections of construction are completed.

BMPs for Soil Ripping and Tilling

- Deep ripping further disturbs the soil, yet it is often required to mitigate compaction. In deeply compacted soils, subsoil tillage can often restore drainage properties and allow root growth into subsoil. Soils are typically ripped 12 to 18 in., with a maximum furrow spacing between rips of 24 in., but may be deep ripped 24 in. and cross ripped on especially compacted sites. If topsoil requires tillage, do not rip deeper than the replaced topsoil depth. Run across slope or perpendicular to prevailing wind to reduce erosion risk. Conduct soil tillage when soil is in the recommended moisture content range for earthwork. Deep ripping is only viable on certain soil types (for example, it is less effective on very dry or heavy clayey soils) and will provide little benefit if other subsoil constraints such as elevated salinity, sodicity, or acidity are also present. An alternative option is to use a winged subsoiler, which has been shown to ameliorate compacted clayey forest soil.

- Most sites will need a pre-seeding till. One or more passes with a cultipacker or roller harrow is recommended (see appendix 4). A common rule for ensuring good seed-to-soil contact is that, depending on soil type, a 170-pound (lb) person should leave a footprint 1/2 in. deep in the topsoil. To avoid subsidence along pipelines, moderate compaction limits the development of large depressions without inhibiting vegetation growth.

- During periods of adverse soil-moisture conditions, suspend reclamation activities. Disturbing adversely dry soils can increase the risk of accelerated wind erosion. When conditions are adverse for prolonged periods, contact the SMA authorized officer.

Soil Stockpiles

There are typically two types of soil stockpiles on an oil and gas site: topsoil and subsoil spoil. Historically, both topsoil and subsoil spoils were stored long term onsite in large piles. Although this is still common for some subsoil spoils, the unique biological properties of topsoil can be lost depending on stockpile depth, storage time, and location (Harris and others, 1989; Rokich and others, 2000; Grundy and others, 2003; Hall and others, 2009; Boyer and others, 2011; Rivera and others, 2012; Golos and others, 2016; Dhar and others, 2019; Mackenzie and Naeth, 2019; Block and others, 2020; Gorzelak and others, 2020). It is a best management practice to re-spread and reseed topsoil as quickly as possible in interim-reclaimed areas, with a designated area containing enough topsoil to cover the pad during final reclamation. When interim reclamation is postponed, as with some exploratory wells, windrowed topsoil is seeded to protect this valuable reclamation asset from erosion and invasion and is not re-disturbed until interim reclamation, to prevent loss of soil organic matter and structure (Mason and others, 2011).

Entire interim-reclamation area is recontoured and seeded

Photograph showing interim-reclaimed areas, differentiating between the area that will be re-disturbed during final reclamation and the area that will not be re-disturbed during final reclamation. Note, there is no stockpiled soil. Photograph by Bureau of Land Management.

Photographs showing soil ripping to loosen highly compacted soils. Leaving a roughened texture traps moisture and seed. Photographs by Bureau of Land Management.

Establishing Desired Vegetation

Establishment of desired vegetation on oil and gas sites requires consideration of several important components. These components include designing the seed mix, preparing the seedbed, timing the seeding, and using site appropriate seeding methods. The type of seed mix and number of seeds in the mix are determined in the pre-development reclamation planning phase and reflect the benchmarks and standards for site reclamation (see "Reclamation Objectives, Benchmarks, and Standards" section). By using a seed mixture that includes a diversity of native plants, the operator will increase the likelihood of establishing a native community that can resist droughts and other climatic issues, support desired ecological processes, increase the probability of meeting benchmarks, and reduce costs associated with poor reclamation performance. Typically, a greater proportion of pad footprint that is successfully reclaimed during interim reclamation results in less land requiring re-disturbance during final reclamation.

This section provides operators with BMPs to support successful establishment of desired vegetation. This section also aids SMAs in the development of effective and appropriate seed menus.

BMPs for Seed Quality

- Conduct reclamation with native seeds that are representative of the species and functional groups determined present at the onsite inspection, in addition to other species identified in the ESD or ESG. There may be instances where earthwork has resulted in soil conditions that greatly depart from pre-disturbance, which may necessitate altering the seed mix (for example, elevated salts in soils require salt-adapted native species).
- Use genetically appropriate (for example, from the same seed zone) native seed, of known origin, where possible, as native plant materials from local populations have been found to survive and establish better than non-local

Photograph showing seeding between facilities to maximize the interim-reclaimed area footprint. Interim reclamation occurs as close to facilities as possible, leaving only a small buffer for fire prevention. Photograph by Bureau of Land Management.

native seed. Do not use invasive nonnative plant species for reclamation under any circumstances.

- Use a seed mix with plants that support local pollinators, where possible, including native nectar- and pollen-producing plants that flower at different times throughout the growing season.
- Create a list of contingency species in the case that supply is lacking for some species on the main seed list. Ensure that the seed mix provider will not substitute species at their own discretion.
- To prevent infestation of noxious or other undesirable species during reclamation, determine that seed mixes are free of noxious and invasive weeds with a certified seed laboratory inspection test (labeled as such by a State seed certification program). Operators may also request details about other non-target species in the mix to identify potential species of concern.
- Use seed that contains no more than 2.0 percent of “other crop” seed by weight and does not contain noxious, prohibited, or restricted weed seeds according to State seed laws in the respective State(s). Consult the site-specific benchmarks to guide the number of perennial species in the seed mix.
- Ideally, purchase seed that is either Certified (blue tag) or Source Identified (yellow tag) by a seed certifying agency. Consult experts (for example, the BLM Plant Conservation and Restoration Program, local seed cooperatives) when developing a site seed mix, and ensure all seed mixes are incorporated into the APD SUPO. Seed mixes are approved by the SMA prior to seeding.
- Use viability-tested, certified seed for the current year, with a preferred minimum germination rate of 80 percent and a minimum purity of 90 percent. If using locally collected, native seed, plan well in advance as supplies are typically limited and native seed is sometimes expensive and difficult to source.
- When using wild-harvested seed, work with the SMA to identify appropriate seed-harvesting locations with compatible soils and environmental conditions and comply with any required seed-collection protocols. Wild-harvested materials require testing similar to purchased seed to ensure materials are free of noxious species. The Technical Protocol for native seed collection, on the BLM Seeds of Success website,[24] provides useful guidelines for wildland seed collections.

BMPs for Seed Storage

- Seed purchased during the planning phase will require proper storage and protection from exposure to undesirable seed until interim and final reclamation.
- Review the Center for Plant Conservation seed banking guidelines for storage of orthodox, intermediate, and recalcitrant seeds,[25] as only orthodox seed is stored conventionally. For many species with intermediate and recalcitrant seeds, consider alternative planning (for example, planting nursery germinated plants, using cuttings, or doing collections with short term storage). Refer to U.S. Department of Agriculture (USDA) Agriculture Handbook 727, “The Woody Plant Seed Manual”[26] for more information on storage of woody seed.
- Properly label seed containers from wild collections with species name, source location, environmental information, date of collection, and collector information.

[24]Available at https://www.blm.gov/programs/natural-resources/native-plant-communities/native-plant-and-seed-material-development/collection.

[25]Available at https://saveplants.org/best-practices/difference-between-orthodox-intermediate-and-recalcitrant-seed/.

[26]Available at https://www.fs.usda.gov/nsl/nsl_wpsm.html.

BMPs for Timing of Seeding

- If possible, conduct seeding immediately after final seedbed preparation (that is, within 24 hours). If interim reclamation occurs outside the appropriate window for seeding, it is important to protect exposed soils from accelerated erosion (see "BMPs for Erosion Control" section).
- Use dormant seeding for appropriate seeds that require cold stratification. Dormant seeding is typically conducted late in the fall, after the growing season but before soils freeze, allowing species to break dormancy and germinate in the spring. Some shrubs and forbs can be broadcast onto snow during the winter.
- Seed in early spring only if spring and summer soil moisture is reliable and if soils dry sufficiently in early spring to allow for earthwork without damaging the seedbed.
- Avoid summer seeding in arid regions unless the region has predictable summer monsoonal precipitation and summer soil-moisture conditions are conducive to seedling germination and establishment.

BMPs for Seed Application

- Calculate seeding rates in mixes using State or other regionally relevant guidance, including the NRCS Field Office Technical Guide[27] and NRCS Technical Notes.[28] The NRCS-recommended drill-seeding rate for large seeded species is 20 pure live seeds (PLS) per square foot and 30 to 40 PLS per square foot for small seeded species. Sagebrush is typically seeded at 1/4 to 1 lb PLS per acre and native annual species are seeded at 1 ounce to 2.5 lb PLS per acre, depending on seed size.
- Once a rate is estimated, double it for "critical" (steep or unstable) sites and for broadcast seeding, though it is not recommended to seed at rates beyond what has proven successful and cost effective.
- Follow agency seeding methods for a specific seed mix, as recommended seeding depths can vary. Suggested seeding depth depends on the seed species and seeding method. For example, for many grasses and large-seeded forbs, seeding 1/4 to 1/2 in. works best with positive depth control drilling. For small-seeded shrubs and forbs, seeding 1/8 in. or less, in combination with broadcast seeding (followed by a cultipacker), has been shown to work well. When the SMA does not have guidance for specific mixes, reference published research, the seed supplier, or other credible sources.
- Drill seeding is only recommended for slopes less than 33 percent owing to machinery constraints, and hydroseeding is often preferred for steeper slopes. Drill seeding works most efficiently on the contour and perpendicular to prevailing winds. The application of the seed mix requires at least two passes over the disturbed area, where the first pass rips the surface and spreads the seed and a second pass drags the area.

[27]Available at https://www.nrcs.usda.gov/resources/guides-and-instructions/field-office-technical-guides.

[28]Available at https://www.nrcs.usda.gov/plant-materials/publications.

Photographs showing drill seeding in semi-flat areas. Drill seeding is not used for long steep slopes. Photographs by Bureau of Land Management.

- If multiple seed applications are planned in mesic locations (> ~12 in. of annual precipitation), the seeding rate is reduced so that the total seed rate, combining all application methods, does not exceed 50 to 100 seeds per square foot (10–16 lb per acre).
- If the site contains multiple terrains, design one mix for drilling and another for broadcasting to seed effectively.
- To ensure the best possible outcomes, calibrate seed drills or broadcast seeders, and use properly designed seed box agitators and (or) carrier materials to prevent complications associated with small and (or) wind-dispersed seed.
- If trees and shrubs are transplanted onsite, plant during dormancy and not during summer (unless irrigation is provided). When transplanting live adjacent vegetation (for example, scoop and plant) only collect from within an approved area (for example, the area determined within an APD or ROW decision) and plant immediately after digging the planting holes to reduce drying of the backfill. Pruning the above-ground stem(s) reduces transpiration and increases the likelihood of survival.
- If establishing shrubs is a reclamation priority, review information available from the BLM's "Integrated Vegetation Management Handbook"[29] and the FS report "Restoring Western Ranges and Wildlands."[30] Shrub planting and seeding success is highly variable and often low owing to competition from nonnative annual grasses and fire. The BLM Emergency Stabilization and Rehabilitation Program supports both planting and seeding approaches, but typically drill seeds its shrubs no deeper than 1/4 in. and uses preemergent herbicide treatments prior to seeding.

Soil Amendments

Soil amendments are materials used to ameliorate poor soil conditions by improving physical, chemical, or biologic properties. Some soil amendments are added to the surface to reduce erosion and conserve moisture (for example, mulch), whereas others are mixed into the soil to improve soil quality for vegetation growth and establishment (for example, compost). When choosing an amendment, factors to consider include soil texture, organic matter, salinity, sodicity, and pH, as well as longevity of the amendment. On sandy soils, soil amendments are often used to increase the water and nutrient holding capacity, whereas on clayey soils they are often added to improve soil aeration, drainage, and rooting depth. The longevity of the amendment depends on project goals. For example, organic amendments that decompose slowly may provide long-term increases in soil organic matter, whereas rapidly decomposing amendments may provide quick, short-term improvements in soil physical properties. Choose a combination of amendments that balance rapid and long-lasting improvements. Although this section differentiates between organic and inorganic soil amendments, soil amendments are typically combined.

BMPs for Soil Amendments

Organic Amendments

- As part of seedbed preparation, spread weed-free mulch over the seedbed, crimping straw or hay into the soil with a straight disk, crimper, or imprinter to ensure the materials do not blow or wash away. Straw and native hay are common soil amendments used as mulch in oil and gas reclamation.
- In soils with little to no topsoil nutrients or organic matter, apply an organic amendment with a carbon-to-nitrogen ratio of about 30:1 to improve conditions for plant growth. Organic matter prevents swelling and dispersion of sodium in soils and provides an energy source for microbial populations. Note that native plants in the arid west are adapted to dry, nutrient-poor conditions, and nitrogen-rich fertilizers can favor the establishment of nonnative species over native species. Limit fertilizer applications in newly seeded areas where invasive annual species are becoming established.
- When feasible, ensure that organic materials have been tested and are free from heavy metals, introduced and noxious-species seed, and other contaminants. Although fresh manure is often more cost effective, composted materials contain more stable carbon compared to fresh manure. Compost is also light and easy to transport, is weed free, and has much lower salt content than fresh manure, which is important when applying it to salty soils and dry environments.
- Hydromulching is recommended on terrain or slopes that are not accessible with typical machinery. It involves spraying a seed, mulch, and soil-binding tackifier mixture onto the soil. Some tackifiers reduce the ability of water to infiltrate the soil, potentially limiting seed germination, therefore it is not a recommended practice where other methods can be used.

Inorganic Amendments

- Short-lived chemical amendments, such as sulfuric acid and elemental sulfur, have been shown to increase establishment of desired plants where soils are high in soluble salts (that is, saline soils, indicated by high soil electrical conductivity), though results are mixed.

[29]Available at https://www.blm.gov/sites/blm.gov/files/uploads/Media_Library_BLM_Policy_Handbook_H-1740-2.pdf.

[30]Available at https://doi.org/10.2737/RMRS-GTR-136-V1.

- Apply gypsum (calcium sulfate) amendments to mitigate sodic soil conditions, provide available sources of calcium and sulfur to plants, impede phosphorus movement, improve soil aeration and water percolation, and correct aluminum toxicity. When considering the use of gypsum as a soil amendment, reference the NRCS Conservation Practice Standard (CPS) "Amending Soil Properties with Gypsum Products" (Code 333).[31] To remediate sodic soils, use NRCS CPS "Saline and Sodic Soil Management" (Code 610).[32] Work gypsum into the soil with tilling equipment or spray it onto topsoil prior to seeding or planting. Note that, although calcium sulfate moves deeper into the soil than other calcium sources, such as lime, it is still an additional source of salt. Gypsum is also known to break up compact soil, especially clay soil, without changing the pH.
- Use dolomitic and calcitic limestones, composed of magnesium and calcium carbonates, to help neutralize acidic soils, increase nutrient turnover, improve soil structure, and reduce high levels of aluminum, manganese, and iron that occur in acidic conditions.
- Address soil hydrology problems with inorganic amendments like vermiculite and perlite. In sandy soils with low water retention, an amendment like vermiculite can increase soil water retention. In clay soils with low permeability, choose an amendment with high permeability, like perlite.

Interim Weed Management

This section describes weed management during interim-reclamation activities, immediately following well completion (see "Glossary" section for definition of a "weed"). The same BMPs are relevant during production and final-reclamation phases.

[31]Available at https://www.nrcs.usda.gov/sites/default/files/2022-08/Amending_Soil_Properties_with_Gypsum_Products_333_CPS_June_2015_Final.pdf.

[32]Available at https://www.nrcs.usda.gov/sites/default/files/2022-09/Saline_Sodic_Soil_Management_610_CPS_10_2020.pdf.

Photographs showing crimped mulch (left) and hydromulching (bottom) to hold soil in place from wind and water erosion, retain soil moisture, and provide protection for seeds and seedlings. Photographs by Bureau of Land Management.

BMPs for Interim Weed Management

- Weeds are best controlled before flowering of mature plants.
- Use grazing or browsing livestock to manage weedy species prior to seed set. Any targeted grazing is carried out in accordance with current SMA requirements and in coordination with the SMA range program and grazing permittee (if applicable).
- Use a cover crop of a sterile annual or short-lived perennial to prevent establishing a nonnative seed bank and preserve soil resources while awaiting seeding and establishment of desired species. These are often nonnative species specially developed for such applications. Cover crops are not a long-term solution for weed control and are only used at the discretion of the SMA in areas with a pronounced presence of noxious or invasive species.
- Use herbicides only after considering the effects of environmental variables (for example, wind, humidity, temperature inversions, heavy rainfall) and effectiveness of all potential methods, including combinations of other biological and mechanical methods of control. Other short term weed control measures include mechanical removal through mowing, chemical removal through the application of appropriate herbicide, and control through increasing desired plant species.
- Only agency-approved herbicides can be used and require an approved Pesticide Use Permit (PUP). All SMAs require reporting of the Pesticide Application Records under the stipulations of the PUP, which are reported to the EPA. The PUP describes relevant BMPs and applicator authorities and provides a record of the authorization to apply pesticides on public lands. Hire a licensed applicator to apply as little herbicide as possible, within label guidelines or approval rates, whichever is less, to achieve desired results.
- Take an ecological approach to plant management when dealing with weedy species long term. Although there is clear policy for noxious species, requiring their removal and control for the life of the well, not all other weedy species necessarily inhibit successful reclamation, and may contribute to short-term site stabilization, reestablishment of organic soils from litter, and successful ecological outcomes. Non-invasive annual plant species can sometimes provide soil cover until seeded species take over and may also act as a nurse plant by shading native seedlings and protecting them from desiccating. However, in harsh environments a weedy prevalence can inhibit native species and slow the trajectory towards recovery. As a rule of thumb, if weedy species are still dominant (>75 percent of relative cover) after 3 years, control measures and reseeding are likely necessary.

Erosion Control

Many erosion-control BMPs listed in the construction section also apply to interim reclamation. However, additional techniques and structures are often needed during interim reclamation when compacted soils are loosened and stockpiled soils are re-spread.

BMPs for Erosion Control

- When reclaiming, note that erosion is more likely to occur on sites with limited vegetation and excessive exposed bare ground. Measures to prevent accelerated erosion while vegetation is establishing during interim reclamation include deep ripping or imprinting compacted areas to allow water infiltration, then firming the soil and properly installing erosion prevention structures (for example, mulch, wattles, sediment fences). Often, multiple erosion control methods are required in combination.
- Manage erosion during interim reclamation by evaluating the landscape and providing the proper controls based on need. For example, focus on stabilizing the soil in high-flow areas like ditch bottoms and pipeline trenches. If runoff from the surrounding landscape affects the site, then berms, diversions, woody armoring, or sediment fencing that diverts larger flows may be required.
- When timing for earthwork and seeding do not align, additional erosion control measures are needed to limit soil loss. Ideally, these measures will provide dual protection from erosion and weeds. Continuous fiber fabrics are sometimes used for erosion protection but might not be able to suppress aggressive weeds, and the mesh may hinder weed removal efforts. Fast-growing, sterile cover crops may temporarily protect seedbeds until the optimal season for seeding, but their use is controversial (see "Interim Weed Management" section).

Production-Phase Soil and Vegetation Maintenance and Monitoring

The production phase has little to no reclamation activity aside from general management and monitoring. Typical management activities include weed control, erosion mitigation, waste mitigation, and, in some instances, continued efforts to establish desired vegetation on interim-reclaimed areas. Often, the SMA will require an interim-reclamation inspection to ensure that all interim reclamation checklist items are met satisfactorily, including those on the operator's proposed reclamation plan and any conditions of approval (COAs) in the approved permit (for example, the APD). Monitoring allows both parties to effectively evaluate the progress of revegetation efforts, erosion control, and noxious-species control. The operator will follow their reclamation plan and COAs, including approved monitoring methods (see "Reclamation Monitoring" section).

Photograph showing woody plant material used to provide texture and armoring, keep vehicles off the reclamation area, trap soil movement, and create micro-sites for vegetation. Photograph by Bureau of Land Management.

Weed Control

During interim reclamation, only the well and a small area around the well, required for normal production operations, are not reclaimed. This area is kept clear of vegetation and requires active bare-ground control for the life of the well. An influx of native and nonnative annual species is normal during the first few growing seasons following interim reclamation. These early colonizing species can help prevent erosion and provide shelter and microclimates for perennial species germination. Using broad-spectrum herbicides on these colonizing species will damage seeded species and potentially require reseeding. Sometimes mowing and chemical treatments are used to control seed development during the later growing seasons or if invasive species dominate the site. Most seed mixes contain broadleaf forbs and shrubs, and thus broadleaf-targeted chemical control is not generally recommended. If a broad-spectrum herbicide is the only viable option, operators may later interseed or plant shrub seedlings in patches (islands) to facilitate recovery. Noxious weeds are often removed or sprayed before they can spread or produce seed. The agreed-upon reclamation plan outlines all such topics in the weed-management and control strategy.

Erosion and Dust Mitigation

Follow the stormwater and dust-management plan and monitor any areas of erosion or instability after weather events (heavy rainfall or strong winds). Check for movement of matting, topsoil, and mulch. Uncontrolled erosion can degrade a reclamation project rapidly, putting the integrity of the land at risk. If erosion points are worsening, repair the surface, replace topsoil, reseed, re-mulch, and incorporate control measures that slow and divert water runoff or mitigate soil exposure to wind. Maintain roads with erosion- and dust-control measures in place. Operators must comply with State regulations for attainment and nonattainment areas. Review the USDA “Southern Plains and Southwest Climate Hubs Dust Mitigation Handbook”[33] for more information.

Vegetation Establishment

Successful establishment of vegetation in interim-reclaimed areas during the production phase is necessary for meeting interim-reclamation goals, including maintaining topsoil viability and controlling invasive species and erosion, which aid in successful final reclamation. Fencing is often useful in limiting herbivory by domestic livestock, wild horses and burros, and certain wildlife species, but it requires periodic monitoring and maintenance. Actual construction specifications depend on the types of livestock excluded and wildlife species present in the area. Flagged top wires, fence markings, smooth bottom wires, and other specifications may be necessary for collision avoidance. Refer to chapter 4 of BLM Handbook H-1741-1 on fencing for guidance. Exclosure fences are most effective when left in place until vegetation is established and mature. For unfenced interim reclamation, or when removing fencing, monitor the revegetated areas to assure vegetation is withstanding herbivory. When the exclosure fencing is removed, a tech fence (livestock barrier)

[33] Available at https://dust.swclimatehub.info/.

is often installed around infrastructure (for example, the pump jack) to protect livestock and wildlife from injury. Refer to SMA policies regarding wildlife protections and fencing, and other applicable resources (Paige, 2015).

Post-Operation Final Reclamation

This section describes BMPs for final reclamation. Final-reclamation activities begin once all onsite structures are removed and the well is plugged. All pads, pits, and roads are reclaimed to a satisfactorily revegetated, safe, and stable condition, unless an agreement is made with the SMA or landowner to keep the road or pad in place. Pits containing fluid must not be breached (cut) and pit fluids are removed or solidified before backfilling. When pits are allowed to air dry, or chemicals are used to aid in fluid evaporation, stabilization, or solidification, prior SMA approval is required according to 43 CFR part 3171. Many of the practices for final reclamation are the same as previously described in the “Interim Reclamation” section, including those for soil decompaction, subsoil and topsoil replacement, contouring and tilling, seed mixes, methods and timing, soil amendments, erosion prevention, and weed management. Practices described in this section are specific to final reclamation.

Earthwork

Per 43 CFR part 3171, all final reclamation earthwork on federally managed wells must be completed within 6 months of plugging the well. Reclamation measures begin as soon as possible and continue until successful reclamation is achieved, allowing for variability in environmental conditions. Final reclamation includes restoring both the ecological function and the aesthetic aspects of the site. Earthwork generally requires returning the entire site and any associated ROWs to natural contours that blend with adjacent undisturbed areas. This may require re-disturbing interim-reclaimed areas that have functioned as the long-term storage area for topsoil. Avoid disturbing interim-reclaimed areas whenever possible.

BMPs for Earthwork

- Flush and remove pipelines, where possible, to ensure potential contamination does not occur in the future.
- Remove exposed surface pipelines and associated infrastructure.
- Fill and compact the pipe removal trenches, then respread the topsoil and revegetate.
- If a pit is present, sufficiently dry the pit and remove contaminants and containment structures. Comply with regulations (including NTL-7) and policies regarding liners.
- Recontour the site and replace soils in the order they were removed, with the bottom rocker soil layers first, followed by topsoil or other suitable growing media. Adapt the layering to problematic soil layers by putting those lower in the soil profile, so revegetation is not inhibited. Additional soil testing (for example, for salinity) is recommended. Severely degraded soils may require removal or additional soil amendments to establish conditions suitable for plant growth. The area may also require an alternate seed mix.
- Soil tillage and recontouring are usually necessary after removal of imported mineral material on roads and the pad, as well as any unnecessary infrastructure. Prior to topsoil re-spreading, areas with the highest soil compaction, including the access road and well pad, will likely require a deep rip (to 12- or 24-in. depth).

Photograph showing topsoil spread on the sides of roads (in borrow ditches) that has been seeded and maintained to prevent erosion and control weeds. Photograph by Bureau of Land Management.

- Remove culverts and reestablish natural drainage systems (and do not fill former drainages). This may require the temporary use of erosion-control features (do not use plastics).

- Expect noticeable changes in soil texture, structure, and quality when reclaiming roads. Roads are frequently difficult to reclaim because they are often highly compacted, are graveled, have erosion scars (for example, rills and gullies), are conduits for weeds, and lack access to saved topsoil. Vegetation efforts may be damaged by motorists if roads are not effectively closed. Unless the road has a very small footprint, simply ripping and seeding is usually not sufficient. Further, long access roads will likely pass through multiple habitats, requiring identification of the different physical properties and aspects of soils and requiring differing revegetation strategies. As with well pad reclamation, gravel and other surface material are removed prior to topsoil and revegetation activities.

- The operator calculates the amount of topsoil required to cover the final-reclamation area and only re-disturbs the necessary area of interim-reclaimed land (see "Topsoil" section).

- If the slope from the production pad to the edge of disturbance is steeper than the natural contour, the slope will need to be stripped of topsoil (to be stockpiled temporarily) and the whole site recontoured for final reclamation.

Photographs showing a road pre-reclamation (right), post-reclamation (below), and 1 year post-reclamation (bottom right). Successful reclamation of roads requires removal of any surfacing material, such as gravel, caliche, or crushed rock, prior to ripping and applying topsoil. Photographs by Bureau of Land Management.

Topsoil

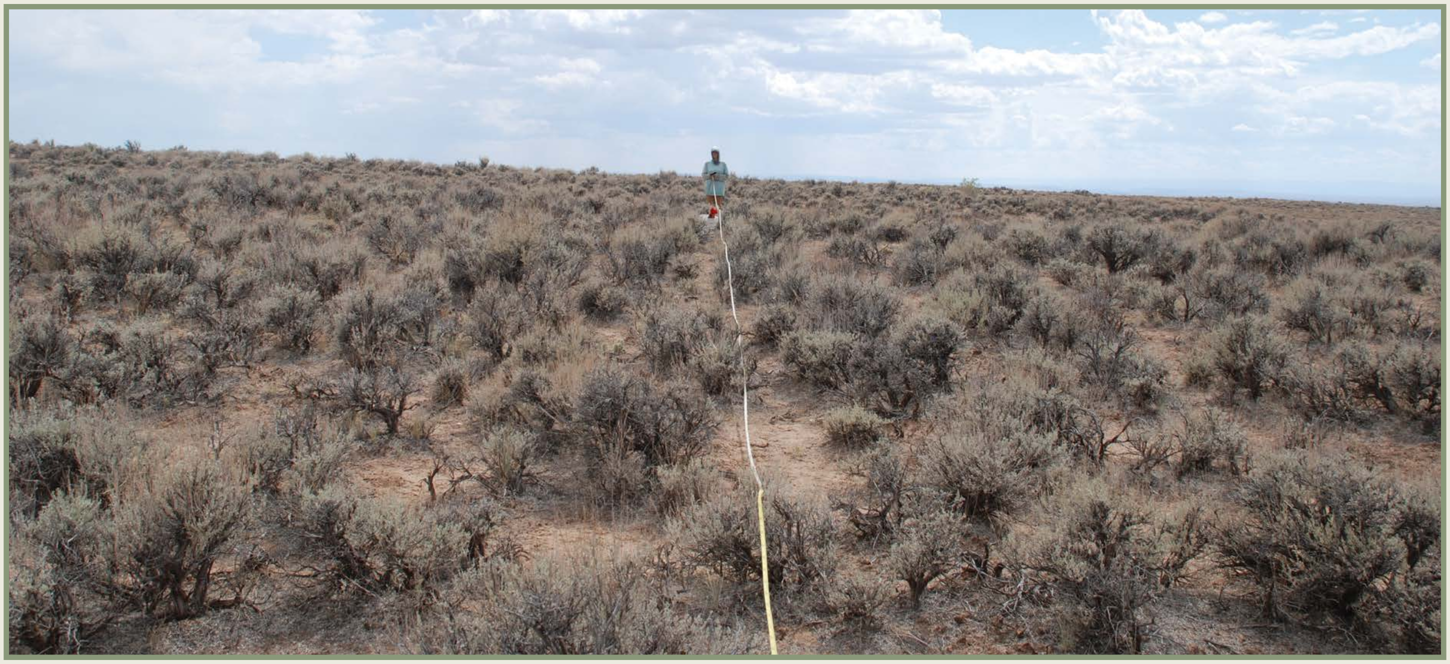
All saved topsoil is typically respread during interim reclamation, leaving no stockpiled topsoil for final reclamation. The labeled surplus of topsoil in the interim-reclaimed area is the source of topsoil for final reclamation. On older sites or sites without segregated soils, topsoil will need to be salvaged from a large portion of the interim-reclaimed area, and (or) topsoil and other amendments brought to the site. Determination of the area to be re-disturbed will depend on the size of the final-reclamation area, the size of the interim-reclaimed area, the success of interim reclamation (that is, the success in establishing desired plants), and the availability of other weed-free sources of topsoil.

BMPs for Topsoil

- As in the construction phase, if interim-reclaimed areas need recontouring or ripping, remove topsoil and stockpile it onsite while ripping and recontouring occurs. After earthwork is completed, spread topsoil over the entire disturbed area. Note that the depth of respread topsoil is reduced owing to the larger area covered (well pad plus any re-disturbed interim-reclaimed areas).
- On older, level well sites with well-established native plant communities in interim-reclaimed areas, the operator may propose to bring in topsoil from another source and (or) add soil amendments to reclaim the well pad instead of re-disturbing areas with successful interim reclamation. However, the topsoil must match the surrounding soil, be free of weeds, and be approved by the SMA.
- Prior to replacing topsoil, loosen highly compacted soils on the well pad and roads by either deep ripping or using a winged subsoiler to fracture compacted soils in place.
- If topsoil kept in a berm or borrow ditch along the side of the road was not properly protected from erosion it will likely be insufficient for supporting revegetation.

Revegetation

Revegetation for final reclamation mirrors practices used during interim-reclamation and production phases. When the interim-reclaimed area is re-disturbed to access stored topsoil, the reclamation timeline for vegetation is reset. Operators carefully review interim-reclamation successes and failures to identify site-specific BMPs for final reclamation. The operator may submit reclamation plan revisions to the SMA for review, including adjustments to the seed mix. When revegetation fails repeatedly, the first step is to test soils for toxicities, deficiencies, and compaction (that is, bulk density or penetration resistance). Review the section on soil amendments if issues with soil toxicity or deficiencies are found. If soils are highly compacted, they may require an additional deep rip. If soils are deemed healthy and uncompacted, review the seed mix with the ID team or other FO staff to ensure the mix is suitable for the soils. Also, check that the seed is viable and that seeding methods are appropriate for the site and seed mix. If vegetation grows in the first season and then dies off, check for signs of overgrazing (for example, cattle dung, signs of trampling, tops of annual species eaten). If overgrazing is an issue, an exclosure fence may be required. If extreme drought is a concern (for example, 1 in 20 year drought event or worse), a temporary solution such as watering may allow for the germination and establishment of vegetation. However, use extreme caution and ensure the system replicates typical drought conditions, as plants can quickly develop a dependency on watering. By watering less frequently, but for a longer period, the root system will be forced to search deeper for more water and will survive well on less total water. In arid and semiarid landscapes, seeded species must be trained to survive and thrive with very little water. In general, a closely monitored site with adjustments and intervention is more likely to reach reclamation success.



Reclamation Monitoring

This section provides recommended monitoring methods to assess reclamation outcomes on reclaimed oil and gas sites. Meeting reclamation objectives may take many years following initial commencement of reclamation, whereas long-term recovery of soils and vegetation may take decades (Monroe and others, 2020; Lupardus and others, 2023). It is necessary to monitor and manage reclaimed sites carefully to avoid costly retreatment and an extended reclamation timeline. The goals of reclamation are to return the land topography to the approximate pre-disturbed state, stabilize soils, control noxious and undesirable species, and establish a native plant community, thereby putting the site on a long-term, positive trajectory. Monitoring is used to ensure reclamation goals are achieved by providing robust and timely data on reclamation outcomes.

This section also describes which biological, physical, and chemical indicators to inventory and monitor on oil and gas sites and how to collect this information. The BLM's AIM program and compatible protocols detect change in the key ecosystem sustainability attributes on which virtually all land uses depend: biotic integrity, soil and site stability, and hydrologic function (Toevs and others, 2011). When using these methods for data collection, reclamation monitoring indicators are compared against reclamation benchmarks derived from AIM and other compatible monitoring data collected in areas with similar soils and climate (for example, benchmark groups; see example in Lupardus and others, 2023). The following set of methods were selected because they are well documented, are widely used, allow minimal bias in data collection, and have structured training and implementation protocols in place. Use of consistent and AIM-compatible methods will produce data that are comparable among offices and will allow for leveraging of the AIM program and other compatible terrestrial data for analysis and reporting at multiple scales and for defensibility of inspection and enforcement actions.

Who Monitors and When

Vegetation and soil outcome monitoring begins post-reclamation (interim and final) and is typically the responsibility of the operator until a FAN is approved. The SMA may collect its own monitoring data to verify the operator-submitted data are accurate or to assess post-final abandonment trends. While conducting ES and EM inspections, agency staff also assess interim and final reclamation to ensure operators are following agreed-upon COAs and the reclamation plan or identify and resolve unforeseen problems. High-priority sites are inspected annually, whereas lower priority sites are inspected less frequently. SMA staff visually inspect lower priority sites at least every couple of years during interim and final reclamation and may collect quantitative monitoring data. See SMA policies for guidance (for example, BLM "Inspection and Enforcement Documentation and Strategy Development Handbook" [H-3160-5] and BLM Instruction Memorandum "Annual Oil and Gas Inspection and Enforcement Strategy Matrices Instructions and Strategy Goals").

Where to Monitor

Monitoring occurs within the boundaries of the disturbed area and is tracked with a GIS polygon. The BLM, BIA, FS, and other SMA State, regional, district, or field offices may track these disturbance polygons. Nationally, the BLM and USGS Surface Disturbance and Reclamation Tracking Tool (SDARTT)[34] digitized many disturbance polygons using

[34]Available at https://blm.sciencebase.gov/landing.html.

standardized methodology. It is important to inspect the proposed interim-reclamation polygon using GIS technologies to accurately evaluate compliance with the approved permit and reclamation plan or other overarching NEPA documents (for, example environmental impact statements or RMPs). The monitoring plot covers the disturbance area as much as possible (see “Establishing a Monitoring Plot” section). Where field-generated or remotely sensed boundaries do not coincide with the authorized disturbance, a violation of the permit likely has occurred, and enforcement action may be required.

Indicators for Monitoring

Indicators, as used here, are measurable components of the reclaimed site’s plant community and soil conditions that are used to define standards for reclamation (see “Reclamation Objectives, Benchmarks, and Standards” section). For simplicity, we break down the complexity of the topic by considering three questions: (1) Is the indicator meaningful to the inspection decision? (2) Can you accurately measure the indicator with sufficient precision to assess meaningful differences among sites or changes through time given resources and capacity? And (3) Do the data, understanding, or policies exist to create a defensible and quantitative benchmark for the chosen indicator? All three questions are equally important and should be answered with a “yes” for inclusion of the indicator in a monitoring method and in the creation of a reclamation standard.

The precision of indicator values can depend on an understanding of the monitoring methods being used, the training of the staff, and reasonable time and resource expectations for monitoring. For example, the typical 150-point line-point intercept (LPI) approach (Herrick and others, 2017b), with three transects of 50 points each, are best used to detect cover greater than ~3–5 percent, owing to uncertainty of estimates of low-cover values. The number of points is adjustable, allowing for collection of more points in low-cover situations or where a higher level of precision is required, depending on monitoring detection-level needs. For example, reliable estimates might require more than 150 points, or the addition of supplemental methods (for example, Pilliod and Arkle, 2013), for detecting cover of a specific seeded species when cover is less than 3 percent. All indicators require a defensible method or reference. Generally, indicators available from the AIM dataset and methods addressed in existing regulatory documents (or described in other rangeland scientific resources) are supported. Avoid subjective or poorly described qualitative indicators and avoid novel or undocumented methods. Indicators typically considered for reclamation monitoring are listed in tables 5 and 6.

Supplemental indicators are sometimes required to address site-specific COAs, when there are additional management concerns and standards, or when reclamation is unsuccessful. Supplemental indicators may include, for example, measurements of soil toxins, salts, and (or) acidity (Soil SurveyStaff, 2014); wildlife populations (Coates and others, 2021; Spencer and others, 2021); lotic (BLM, 2021) and lentic systems (BLM, 2015; Gonzalez and Smith, 2020). Always check with the local SMA or other responsible party such as the BLM State office, State natural resources departments, or BIA Indian Energy Service Center (IESC), to ensure that all requested indicators are included.

Indicator—Basal Cover

Basal cover is the proportion of the soil surface covered by plant bases and is often very low in arid and semiarid ecosystems (<~5 percent). Despite these low values, basal cover is used as a primary indicator for reclamation standards in many field offices (for example, 60–80 percent basal cover compared to reference). Detecting such infrequent cover components with high precision is very difficult and therefore not recommended when monitoring for the Final Abandonment Notice (FAN). Although foliar cover is more sensitive to measurement timing, foliar-cover-based indicators are typically better captured using standard methods with less effort. Below is a comparison of basal and foliar cover modified from Bonham (2013).

Basal cover—

- Varies little seasonally and annually compared to foliar cover (less sensitive to measurement date and drought/precipitation)
- More appropriate for permanent plots
- Potentially related to water erosion caused by overland flow and rills

Foliar cover—

- Related to wind and water erosion (caused by raindrop impact)
- Typically requires less effort to achieve desired levels of precision
- More closely related to remote-sensing-based indices of cover
-

How to Monitor

The following section describes methods for monitoring oil and gas sites. Monitoring is suggested at multiple points along the production and reclamation timeline and often at multiple points after final reclamation, until standards are met. These assessment and monitoring data can guide reclamation management decisions throughout the well life cycle, thereby improving reclamation outcomes.

In this document, data-collection intensity is organized by tiered monitoring approaches. Tier 1 includes a lower intensity assessment of soils and vegetation conditions, used by both operators and agency staff to quickly document the progress of reclamation efforts with basic botanical training (table 5). Tier 2 is a higher intensity approach that provides species-level LPI data and requires more time, training, and botanical knowledge (table 6). SMA staff may use the Tier-1 approach to document reclamation progress and to quality control Tier-2 data collected by the operator. Additionally, the Tier-1 and Tier-2 data can be used to model erosion risk by wind and water (see "Soil-Erosion Models as Estimates of Risk" sidebar). At the same time or prior to submitting a FAN, the operator submits reclamation data to the SMA for review. Although Tier 2 is the recommended assessment approach for FAN decisions, either Tier 1 or Tier 2 may be implemented for FAN decisions if deemed appropriate by the SMA (for example, through an instruction memorandum or permitting office).

In addition, the reclaimed area being monitored is characterized for general geographic, topographic, climate, and management conditions, as described in the "Site Assessment" section (table 2). As many of these conditions will likely change post-development, it is recommended to repeat the plot characterization of the monitored area post-interim and post-final reclamation.

Tier-1 Monitoring Approach

The Tier-1 monitoring approach is a structured set of forms, observations, photographs, and simplified soil and vegetation-cover measurements (table 5). Although Tier-1 monitoring is recommended at specific points post-reclamation, it can be used at any point in the well life cycle, except when more detailed (Tier-2) data are required. The primary point-intercept indicators recommended for collecting Tier-1 data do allow using a limited set of plant functional groups and thus can be performed using the "stick" method (Riginos and Herrick, 2010) with minor modifications to make

Table 5. Tier-1 data components including point-intercept, vegetation height, and canopy gap descriptions.

[Based on the stick method (Riginos and Herrick, 2010), though these data can also be collected along transects. Functional/structural groups, plot observations, and connections of indicators to ES inspection categories based on Pellant and others (2020). ES, environmental surface; veg., vegetation; m, meter; cm, centimeter.]

Method	Description	Minimum indicator(s)	ES inspection category		
			Noxious	Erosion	Veg.
Point intercept	1-m stick is used to make all measurements. Stick is marked at 10, 30, 50, 70, and 90 cm for data collection using point-intercept method.	Bare-soil cover		x	
		Total foliar cover			x
		Perennial cover			x
		Introduced-annual cover			x
Vegetation height	Stick is raised vertically to determine maximum height of vegetation within a 30-cm- (1-foot-) diameter circle tangent to center of stick.	Average height of herbaceous and woody vegetation			x
Canopy-gap intercept	Record if entire 1-m and each half stick (50 cm) fall entirely within canopy gaps (any perennial or annual plants).	Percentage of 1-m and 50-cm sticks falling entirely within canopy gaps.		x	
Functional/ structural groups	Visual ranking of dominance of predefined plant functional groups and species, including noxious and invasive species	Noxious-species presence	x		
		Relative abundance of plant functional groups, including seeded species			x
Plot erosional observation	Visual inspection with photographs for signs of erosion.	Flow patterns, gullies, rills, plant pedestaling, and wind-scoured and depositional areas		x	
Photo points	Repeated photographs of a landscape or plot are used to qualitatively monitor how vegetation and soils change over time.	Photographs are used as additional evidence to support benchmarks and standards determinations.	x	x	x

the data AIM compatible (see table 5), by using pace- or step-point transects or with traditional transects using the LandPKS mobile application[35] (see "Data-Collection Platforms" section). This application was designed to rapidly generate indicators that are compatible with those yielded by the standard BLM AIM and NRCS NRI methods, but with less effort, detail, or need for training and expertise (Herrick and others, 2017a). In addition, Tier-1 (and Tier- 2) data components include permanent photo points (see the Permanent Photo Point Protocol;[36] Herrick and others, 2017b; or the LandPKS application for example methods) and semi-quantitative plot observations of plant functional groups and soil erosion (table 5; Pellant and others, 2020). The LandPKS application data-collection method currently supports vegetation cover by very simple functional groups, with anticipated improvements by 2024 to allow for (among other things) improved photograph collection, a limited number of user-defined plant functional groups or species of interest, and plot erosional observations (table 5). Collection of the quantitative data by an experienced data collector using the LandPKS application on a mobile phone typically requires about 30 minutes per plot (30 sticks and 150 points) but slightly less if working in pairs.

[35]Available at https://landpotential.org/learning/collections/oil-gas-mining/.

[36]Available at https://www.blm.gov/programs/energy-and-minerals/oil-and-gas.

Tier-2 Monitoring Approach

The Tier-2 approach requires measurements of indicators using transects and a subset of the AIM terrestrial protocols (Herrick and others, 2017b; table 6) and an electronic data capture system (see "Data Capture and Storage" section). The Tier-2 LPI, height, and canopy gap methods allow for estimation of additional indicators, species-level cover, multiple gap sizes, native species richness, and plant diversity, which can then be compared to agency terrestrial monitoring

Table 6. Tier-2 methods, method descriptions, suggested indicators, and relationships to Environmental Surface Inspection Form categories.

[Final selection of indicators will be ecosystem dependent. Site assessment (table 2) is conducted if not previously completed. Connections of indicators to ES inspections categories based on Pellant and others (2020). Environmental Surface (ES) Inspection Form available at https://www.blm.gov/programs/energy-and-minerals/oil-and-gas. Veg., vegetation; cm, centimeter.]

Method	Description	Minimum indicator(s)	ES inspection category		
			Noxious	Erosion	Veg.
Line-point intercept	Measurement of vegetation and soil surface cover by dropping a narrow pin (or pointer) at fixed intervals (that is, points) along transects.	Bare-soil cover		x	
		Total foliar cover			x
		Perennial cover			x
		Introduced-annual cover			x
		Species evenness (dominant species cover/total foliar cover)			x
		Noxious-species cover	x		
Species inventory	Plot-level vegetation species inventory to provide an estimate of species richness.	Noxious-species presence	x		
		Number of perennial species			x
Vegetation height	Height of tallest leaf or stem of woody and herbaceous vegetation (living or dead) within a 15-cm radius recorded for points along a transect.	Average height of herbaceous and woody vegetation			x
Canopy-gap intercept	Proportion of soil surface in intercanopy gaps (any perennial or annual plant)	Proportion of a line covered by large intercanopy gaps (>50 cm, >100 cm, or >200 cm)		x	
Plot erosional observation	Visual inspection with photographs for signs of erosion.	Flow patterns, gullies, rills, plant pedestaling, and wind-scoured and depositional areas		x	
Photo points	Repeated photographs of landscape or plot are used to qualitatively monitor how vegetation and soils change over time.	Photographs are used as additional evidence to support benchmarks and standards determinations	x	x	x

data benchmarks, including AIM data. This is in addition to the other indicators available in Tier 1 and modeled erosion risk by wind and water (see "Soil-Erosion Models as Estimates of Risk" sidebar). Supplemental indicators of interest may require additional methods for data collection and analyses. Finally, as in Tier 1, the plot observation form and photo point protocol are included to further document site conditions.

Using the species-level LPI method and the gap-intercept method and completing the species inventories described in Tier 2 will provide operators and SMAs with the most complete information and options for data analysis. These methods provide a flexible set of information that can be used to estimate any number of indicators that may be required in the future for FAN-related benchmarks and standards and that will support further analysis of reclamation-practice effectiveness. However, accurately identifying each plant species in the LPI and species-inventory protocols is time consuming and requires training. With the collection and analysis of Tier-2 data, the indicators that are most critical for determining reclamation effectiveness will be identified, allowing the data-collection requirements for Tier 2 to be streamlined (that is, become suitable for applications such as LandPKS).

Evidence of Soil Erosion

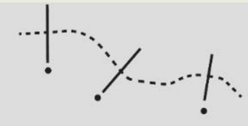
Although the erosion models (see "Soil-Erosion Models as Estimates of Risk" sidebar) and AIM data components provide information on the risk of erosion, they do not include measures of past or active erosion (Duniway and others, 2010b). Including a simple rubric for qualitative and semi-quantitative observations of water and wind erosion or deposition evidence can help fill in this critical information in both Tier-1 and Tier-2 data collections. The erosion classes for each indicator are descriptive, assigned without comparison to reference data, can be completed without explicit understanding of land potential (see appendix 7 in Pellant and others, 2020), and are planned for the next version of the LandPKS application, along with a "Describing Indicators of Rangeland Health" technical note publication that will provide further instruction.

Establishing a Monitoring Plot

As described in the "Where to Monitor" section, the monitoring plot covers the entire disturbance area and is mapped using GIS. When determining the most appropriate plot layout and transect length, make the decision based upon the monitoring polygon area, shape, and seed row direction. The goal is to acquire a good representation of the reclamation area while reducing bias and lack of inference from non-random or convenient plot placement. A minimum of three parallel transects dispersed across the disturbed area with either 10 sticks (Tier 1; table 5) or 50 LPI points (Tier 2; table 6) per transect is recommended (table 5; Herrick and others, 2017b). If there are clear rows of vegetation or furrows from drill seeding, orient the transects perpendicular to seeding rows. If there are no discernable rows of vegetation, follow a systematic orientation for oblong or rectangular pads with transects parallel to the long axis of the pad or random orientation if there is no clear long axis. For small pads (<0.5 hectare [ha] [1.23 acre]) 25-meter [m] transects with about 2.5-m stick spacing (Tier 1) or 0.5-m LPI spacing (Tier 2) are recommended; for large pads (>0.5 ha [~1.23 acre]) 50-m transects with 5-m and

Table 7. Descriptions of parallel and linear transect layouts for plots.

[Adapted from Herrick and others (2017b). Solid line is the transect and dashed line is the feature. m, meter; ft, foot; ha, hectare.]

Transect layout	Description	Visual
Parallel-transect design	Standard transect length is 25 m (75 ft). Parallel transects are evenly spaced. Transects may run perpendicular to the slope, perpendicular to seed rows, if present, or perpendicular to a randomly selected azimuth. On larger disturbances, use 50-m transects (for example, >~0.5 ha)	
Linear-feature design	Standard transect length is 25 m (75 ft). A multiple-transect design is often used to maximize replication at landscape scale. Length may vary depending on linear-feature size, extent, or potential impact.	

1-m spacing (stick and LPI, respectively) are recommended. Transect spacing is adjusted to equally cover the area of interest. It is not recommended to use the spoke design, which skews measurements toward the center. When monitoring a linear feature (for example, a pipeline or road) use the linear feature transect layout (table 7). If an operator is collecting data for submission to the SMA, the data must be collected using an approved plot layout. Note that the SMA may require additional monitoring on large sites with multiple ecological systems. For further descriptions and method updates for well pad transect setup, see the BLM Library.[37]

When to Monitor and Inspect

When BLM is the SMA, there are two national BLM Inspection forms: ES Inspection Form 3160-33 and EM Inspection Form 3160-35.[6] The BLM may use one or both forms during a single inspection, depending on the purpose of the visit. The number and types of inspections will vary by SMA and with staff availability. Field or State offices have the option to augment the standard surface-inspection form with locally unique criteria, survey reports, and photographs, while still submitting standardized electronic data, so analysis and oversight is accessible to entities at various levels and scales. During an ES or EM inspections, it is strongly recommended that the SMA staff (preferably a member of the ID team) conduct rapid monitoring (Tier 1) to assess reclamation progress. The type of reclamation monitoring (Tier 1 versus Tier 2) conducted by the operator at each phase of the well life cycle may vary by SMA and office requirements. All operator-collected monitoring data is submitted to the SMA. Table 8 lists the different types of Federal inspections and monitoring relevant to reclamation and provides example details on timing, purpose, and available inspection forms.

Site visits with monitoring are needed for tracking progress and completing surface inspections. Reclamation inspections are conducted to ensure compliance with the applicable reclamation requirements, including those outlined in an AAPD's or Sundry Notice's SUPO, including applicable COAs, 43 CFR part 3171, pertinent lease terms and conditions, and orders or instructions of the SMA authorized officer. Vegetation and soil monitoring data are used to guide the SMA when completing inspection forms and as evidence to support the decision for final abandonment of a site. The optimum period for vegetation monitoring varies depending on the ecosystem or habitat type and timing of vegetation growth. Ideally, data submitted for FAN decisions will be collected during or immediately after the growing season of the dominant perennial species, as this will provide the best opportunity for meeting reclamation objectives. Additionally, the SMA and operators should understand the seasonality of vegetation growth when interpreting monitoring data and making FAN determinations. For more information and guidance on surface inspections for Federal leases, or to determine appropriate windows for monitoring, contact your local SMA.

During the post-interim and post-final-reclamation phases the operator monitors their site regularly to ensure soil is stable and revegetation is on a positive trajectory (using Tier-1 monitoring). When and how often to monitor depend on the seasonality of the flora under investigation.

[37]Available at https://www.blm.gov/noc/blm-library/technical-reference/monitoring-manual-grassland-shrubland-and-savanna-ecosystems.

Table 8. Example timeline for reclamation-related inspections and monitoring.

[Onsite inspection form, Environmental Surface (ES) Inspection Form, Environmental Monitoring (EM) Inspection Form, and Reclamation Success Evaluation Form available at https://www.blm.gov/programs/energy-and-minerals/oil-and-gas. SMA, surface monitoring agency; APD, Application for Permit to Drill; BLM, Bureau of Land Management; BMP, best management practice; FO, field office; FAN, Final Abandonment Notice.]

Well status and activities	Inspection timing and purpose	SMA inspection forms	SMA assessment or monitoring[1]	Operator assessment or monitoring
Onsite inspection	After Notice of Staking (optional), but before approval of the APD. Used to determine site suitability. Site assessment conducted by BLM and operator, together.	Onsite	Site assessment	Site assessment, Tier-1 monitoring optional
Construction	Newly constructed locations are typically inspected by BLM within 2 weeks of receiving construction notification (weather permitting). Evaluation of BMPs.	ES, EM	--	--
Drilling	While drilling and well completion are underway, EM is not typically conducted.	ES	--	--
Well completion/ interim reclamation	Conducted 6 months after well completion or well plugging to ensure operator properly completed earthwork for interim reclamation, unless FO granted a variance to 43 CFR part 3171 requirements.	ES	--	--
Production/ interim reclamation	Subsequent/follow-up interim reclamation inspections and monitoring are conducted periodically until the well, facility, and (or) road achieves successful interim reclamation with stable soils and established native vegetation. Areas that will not be disturbed again should be on a trajectory towards meeting reclamation benchmarks and standards.	ES, EM	Tier-1 or Tier-2 monitoring (determined by the SMA and submitted to the SMA)	Tier-1 or Tier-2 monitoring (determined by the SMA and submitted to the SMA)
Well plugging	A surface inspection is conducted 6 months after well plugging to ensure earthwork completion (unless the FO granted a variance to the 43 CFR part 3171 requirements). Potential addendum to the reclamation plan (for example, new seed mixes and BMPs) discussed to ensure reclamation activities will meet current benchmarks and standards (based on best available data and science).	ES	--	Tier-1 or Tier-2 monitoring optional
Final reclamation	After final reclamation has been completed, BLM inspectors conduct subsequent/follow-up final-reclamation inspections periodically to ensure operators are on a trajectory towards meeting reclamation benchmarks and standards.	ES, EM	Tier-1 or Tier-2 monitoring (determined by the SMA)	Tier-1 or Tier-2 annual monitoring and reporting strongly encouraged
FAN	When the operator submits a FAN, monitoring data are also submitted to determine reclamation success and to support a decision to approve the FAN. BLM will review the operator's monitoring data and inspect the site to determine if reclamation success has been achieved in accordance with the standards.	ES, EM, Reclamation Success Evaluation	Tier-1 or Tier- 2 monitoring recommended (determined by the SMA)	Tier-1 or Tier-2 monitoring (determined by the SMA and submitted with or prior to FAN)

[1]Tier-1 monitoring includes ocular cover estimates, erosion observations, and photo points and Tier-2 monitoring includes simplified Assessment, Inventory, and Monitoring Strategy line-point intercept monitoring method derived from Herrick and others (2017b).

Interpreting and Reporting Data

This section describes how to interpret data relative to defined standards using a multiple lines of evidence approach. It also describes how to compile and report monitoring results to support a FAN inspection and final decision. A full example of the process is available in appendix 5.

Combining Benchmarks to Assess Standards

Standards refer to a collection of one or more objectives that are assessed using benchmarks, and potentially other information sources, for specific decision processes (for example, land health standards; Kachergis and others, 2020). Historically, reclamation standards were established from local, or regional policy and plans, depending on the office. For oil and gas surface management, final reclamation standards are used for the approval of the FAN and inform the entire reclamation process.

Assessment of standards for final reclamation has four components, framed here as questions:

- What are the indicators that will assess the standard?
- What are the reference data or information sources by which those indicators will be evaluated?
- What are the benchmarks for each indicator?
- How are individual benchmark evaluations analyzed together to assess the reclamation standard?

The process for assessing standards using benchmarks does not lower the standards laid out in existing, applicable regulatory documents, land use plans, field development NEPA documents, or site-specific requirements. For example, if a development has or is occurring on designated critical habitat for a federally listed species with habitat-specific reclamation standards, the benchmarks and standards described here are adapted to ensure specific habitat requirements are incorporated into any new standards.

For assessments based on benchmark departures, there are three standards included in the current ES inspection form[6] relevant to the soil and vegetation objectives described here: noxious-weed control, erosion and stormwater control, and revegetation success. Each of these standards is assessed with benchmarks by tallying the number of indicators that fall into the different departure classes. In general, extreme benchmark departure (>90th or <10th quantile) for any indicator should not occur and would result in not meeting standards on the inspection (see example in table 9). Similarly, if all indicators fall into the no-departure (>25th or <75th quantile) range of values, the Reclamation Success Evaluation Form[6] supports a passing inspection. The goal of reclamation is to set a system on a trajectory to recovery, but full system recovery is not a requirement of reclamation, therefore moderate departures (10th–25th or 75th–90th quantile) may still indicate a positive trajectory and successful reclamation. Professional judgement is needed to determine what proportion of "moderate departure" is acceptable for meeting the standard and is ideally determined by an ID team and not a single individual.

A critical part of this process is comparing the indicators calculated from operator-submitted data to reference benchmarks on the Reclamation Success Evaluation Form.[6] The Reclamation Success Evaluation Form was created to

Table 9. Example indicators and departure classes for the "Semiarid Warm Shallow Deep Rocky" ecological site group derived from AIM-data distribution.

[In this example, no departure is >25th or <75th quantile, moderate departure is 10th–25th or 75th–90th quantile, and extreme departure is <10th or >90th quantile, depending on the indicator. cm, centimeter; %, percent.]

Indicator	No departure	Moderate departure	Extreme departure
Bare soil cover	<23%	23–36%	>36%
Cover of canopy gaps >100 cm	<45%	45–58%	>58%
Herbaceous height	>15 cm	11–15 cm	<11 cm
Total foliar cover	>40%	30–40%	<30%
Foliar cover of perennial species	>35%	25–35%	<25%
Foliar cover of nonnative annual species	<5%	5–20%	>20%
Number of perennial species	>14	9–14	<9
Species evenness, based on compositional cover (species cover/total foliar cover)	Any single species <70%	Any single species 70–85%	Any single species >85%
Number of noxious species	Zero	Zero	Greater than zero

support decisions on ES-inspection checklist items including noxious-weed control, erosion, and revegetation success. As no single indicator fully describes the erosion or revegetation success items, multiple indicators are rated for these attributes (table 10). Regardless of the path used to create benchmarks, their development and application is documented with a brief, clear justification.

If the operator has been collecting Tier-1 or Tier-2 final reclamation data prior to the FAN submission, the trends in these data can also support a FAN decision. For sites in designated critical habitat for a federally listed species or other special circumstances, review the agreed-upon reclamation plan and local RMPs or COAs for further requirements. In addition, other lines of evidence can be used to support the determinations, including estimates from erosion models and remote sensing (see "Soil-Erosion Models as Estimates of Risk" and "Remote-Sensing Data" sidebars), photographs, professional judgment, and (or) other information. An SMA staff member compiles this documentation in a Reclamation Success Evaluation Report that includes the completed Reclamation Success Evaluation Form, along with all other relevant evidence of achievement of reclamation goals and objectives (see appendix 5 for an example). The evaluation of reclamation-standard achievement is then summarized.

Table 10. An example completed Reclamation Success Evaluation Form, section A13.

[N, no departure; M, moderate departure; E, extreme departure; AIM, Assessment, Inventory, and Monitoring Strategy; COA, condition of approval; %, percent; RMP, resource management plan).]

A13. Revegetation Success			
Indicator	**Rating**	**Benchmark or other justification**	**Comments**
Total foliar cover	N	AIM benchmark (75th)	Total foliar cover is 77%
Perennial cover	M	AIM benchmark (25th)	Perennial cover is 25%
Introduced-annual cover	E	Referred to COA <25%	Site contains 53% cheatgrass, need to reduce
Species evenness	N	AIM benchmark (75th)	All species below 70% cover
Perennial-species richness	E	Referred to local RMP	Only 3 species onsite (minimum 9 required)
Attribute total departures	1/5 M 2/5 E	**Decision and rationale**	Fail. Need to increase number of native species onsite and eliminate noxious cover.

Soil-Erosion Models as Estimates of Risk

Soil-erosion models can be used to augment the qualitative evidence for erosion and sediment movement captured in the describing indicators of the rangeland health rubric, parameterized with the gap, LPI, and height data as well as the Tier-1 stick-method data. The Aeolian Erosion model (AERO) uses canopy gap distribution, vegetation height, soil cover, and estimated soil-texture and windspeed distributions to provide estimates of horizontal and vertical mass flux (Edwards and others, 2022). Similarly, the Rangeland Hydrology and Erosion Model (RHEM) uses soil and vegetation cover and estimates soil texture and rainstorm distributions to provide estimates of runoff and soil loss by water (Hernandez and others, 2017). Both AERO and RHEM translate the vegetation cover, soil cover, and height data into risks of accelerated erosion, which can further support reclamation-outcome decisions.

Remote-Sensing Data

Ecosystem-condition data from remote sensing are becoming increasingly available and useful for estimating ecosystem conditions in times or at scales where field data are not available (Rigge and others, 2020; Savage and Slyder, 2022). Remotely sensed products can take the form of aerial photography collected as part of national imaging programs (such as NAIP), imagery collected for specific purposes, or satellite data. Remotely sensed data are not considered a replacement for field data or local knowledge and are best used in combination with other information sources (Allred and others, 2021). In particular, the 30-m resolution of most west-wide and national cover products precludes their use for absolute estimates of cover for areas smaller than about 100 acres (40 ha) and necessitates field data collection for the FAN decision. However, these products do have utility for understanding trends, even for small areas.

To understand trends in reclaimed lands, use both pre-development data as well as trends in cover from comparable benchmark groups (pixels), unimpacted by oil and gas, as multiple lines of evidence (for example, Waller and others, 2018; Fick and others, 2021; Monroe and others, 2022). In the context of reclamation, remotely sensed data collected across time may be useful for understanding trends (for example, Waller and others, 2018) as well as for a robust estimate of land conditions of comparable benchmark groups undisturbed by oil and gas (for example, Nauman and others, 2017). Further, the long history of the USGS LandSat sensor facilitates land-cover estimates as far back as 1984, which may allow for estimates of pre-development cover. These pre-development estimates, and post-reclamation annual estimates, provide a powerful tool for estimating trends (Monroe and others, 2020). However, climate change and prolonged droughts can make these simple before-and-after comparisons problematic (Fick and others, 2021).

As of 2023, several publicly available remote-sensing products and online tools[1] will likely meet many oil and gas monitoring needs, if combined with field data and local knowledge. There are many innovative applications in remote sensing of soil and vegetation, with methods for different geographic scales and resolutions, although many require specialized training or equipment or are proprietary. For example, very high resolution imagery collected using UAVs has become more common owing to availability of equipment, increased ease of use, and new software that makes the post-processing easier. Additionally, there are photograph-interpretation tools available that can be used to estimate functional group- and species-level cover (Schrader and Duniway, 2011; Curran and others, 2019). The Landscape Toolbox[2] and Ramaseri Chandra and others (2022) contain some of the most common methods, models, and indices used to monitor, model, or track reclamation success.

[1]Tools include Landscape Cover Analysis and Reporting Tools (LandCART) (available at https://www.landcart.org/); Rangeland Analysis Platform (available at https://rangelands.app/); Rangeland Condition Monitoring Assessment and Projection (RCMAP) Fractional Component Time-Series Across the Western U.S. 1985-2020 (available at https://www.mrlc.gov/data/type/rcmap-time-series-trends).

[2]Available at https://www.landscapetoolbox.org/.

Data Capture and Storage

McCord and others (2022) determined that well-designed electronic data-capture and storage systems are a critical component of monitoring programs that facilitate quality assurance and ensure timely data availability for decision processes. Important components of data capture include ease of use, adaptability to a variety of field tablets or computers, functionality of forms for field methods, and seamless integration with data-storage systems. Key components of data storage include data fidelity; integration with analysis and summary tools; and accessibility by stakeholders, decision makers, and partners.

Data-Collection Platforms

Current options for electronic data capture and storage, which are independent of oil and gas data-management systems, include Esri ArcGis Online Survey123,[38] the Database for Inventory Monitoring and Assessment (DIMA), and LandPKS.[39] Survey123 is an application that allows both collection of Tier-2 monitoring data and completion of other inspection forms by SMA staff. Survey123 requires a mobile device such as a tablet (iPad, Android, or similar) and an ArcGIS Online mobile account. DIMA is a custom Microsoft Access database that can be used to collect LPI, height, gap, and species-inventory data as part of Tier-2 data collection (Courtright and Van Zee, 2011). The current version of LandPKS (ver. 3.7.5) supports data collection for Tier-1 but not Tier-2 data. However, updates underway to the LandPKS application will allow for collection of additional functional-group cover data (for example, non-native annuals), a few priority species cover data (user specified), and other functionality. Importantly, LandPKS allows for rapid data collection on smart phones or tablets and does not require an ArcGIS online account. Follow agency policies for use of data-collection software and data-management protocols.

[38]Available at https://www.esri.com/en-us/arcgis/products/arcgis-survey123/overview.

[39]Available at https://landpotential.org/.

Training

Training is another critical component of monitoring programs to ensure data fidelity (McCord and others, 2022). For the Tier-1 methods, training videos for collecting data using the stick method are available from LandPKS.[40] Videos for LPI, height, gap, and species inventory of the Tier-2 methods are also available from the Jornada Experimental Range program.[41] At a minimum, field-crew leaders should receive hands-on training in the protocols listed in table 6 and go through re-training every 3 years. Operators should hire or contract a qualified monitoring team to collect quantitative data. It is recommended that all field-crew members attend the core-methods training sessions. Terrestrial training opportunities are offered annually through the BLM National Training Center in partnership with the NOC and other SMAs, and training is also often available through State or regional offices.

[40]Available at https://landpotential.org/learning/oil-gas-mining/.

[41]Available at https://jornada.nmsu.edu/.

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Glossary

A

Application for Permit to Drill (APD) Package of information submitted to the SMA by an operator after they have acquired a Federal lease. The requirements of an APD are specified in 43 CFR part 3171.

B

benchmark Indicator value, or range of values, that describes desired conditions that, when departed from, trigger adjustments to management practice, trigger additional data collection, or indicate management success.

benchmark group Land-potential-based or ecologically based land classification or map with monitoring plot data that are grouped together and share the same benchmarks and standards for reclamation evaluation.

best management practice (BMP) Practice that provides for state-of-the-art mitigation of specific impacts that result from surface operations. BMPs are voluntary unless they have been analyzed as a mitigation measure in the environmental review for a Master Development Plan, APD, right-of-way (ROW), or other related facility and included as a COA.

C

condition of approval (COA) Site-specific requirement included in an approved APD or Sundry Notice that may limit or amend the specific actions proposed by the operator. COAs minimize, mitigate, or prevent impacts to public lands or other resources. BMPs may be incorporated as a COA.

E

ecological site Natural Resources Conservation Service (NRCS)-maintained land classification system. A site is a distinctive type of land with specific soil and physical characteristics that differ from other types of land in its ability to produce distinctive types and amounts of vegetation and its ability to respond similarly to management actions and natural disturbances.

ecological site description (ESD) NRCS reference document with information and data pertaining to a particular ecological site.

ecological site group (ESG) Group of ecological sites that share similarities in potential ecological states and dynamics, providing larger spatial scale land-potential classes and maps for management.

I

indicator Measurable component of the reclaimed site plant community and soil condition that is used as part of a standard for reclamation.

O

onsite inspection Inspection of the proposed drill pad, access road, flowline route, and any associated ROW or Special Use Authorization needed for support facilities that is conducted before the approval of the APD or SUPO and construction activities.

R

reclamation Process of assisting the recovery of severely degraded ecosystems to benefit native plants and animals through the establishment of habitats, populations, communities, or ecosystems that are similar but not necessarily identical to surrounding naturally occurring ecosystems.

reclamation plan Plan for the surface reclamation or stabilization of all disturbed areas. This plan addresses interim (during production) reclamation for the area of the well pad that is not needed for production, as well as final reclamation before abandonment of the well location.

reclamation standard Collection of one or more benchmarks, and potentially other information sources, used for specific reclamation decision processes.

S

surface management agency (SMA) Federal or State agency having jurisdiction over the surface overlying Federal or Indian oil and gas.

Surface Use Plan of Operations (SUPO) Describes access road(s) and drill pad layout, construction methods that the operator plans to use, and proposed means for containment and disposal of all waste materials; provides for safe operations and adequate protection of surface resources, ground water, and other environmental components; includes adequate measures for stabilization and reclamation of disturbed lands; describes any BMPs the operator plans to use; and describes where the surface is privately owned. Includes a certification of Surface Access Agreement or an adequate bond.

W

weed Plant that causes economic losses or ecological damage, creates health problems for humans or animals, or is undesirable where it is growing. When a weed is regulated by Federal, State, or local government, it is designated as a **listed noxious weed**. When a weed is unregulated, yet known to establish, persist, and spread widely in natural ecosystems, often outside the plant's native range (nonnative), it is designated as an **invasive weed**. In this document, the term "weed" refers specifically to species designated as invasive or listed as noxious.

Appendix 1–5

Appendix 1. Picking an Appropriate Ecological Reference

What is a Reference?

Reference conditions are thought to provide important context in land management because they represent a set of conditions where ecological processes and functions are maintained (for example, Pellant and others, 2020; Bureau of Land Management [BLM] Handbook H-4180-1[1] on rangeland health standards). Thus, reference conditions are used to characterize expected natural conditions for assessed sites, from which goals or benchmarks are set for land-management actions or decisions (reviewed in Stoddard and others, 2006). Reference conditions reflect and lie within a range of variability for environmental conditions, processes, and functions. The "ecological reference" condition can be defined from historic conditions (for example, pre-European settlement in North America) or the best available conditions found in the present-day landscape under natural disturbance regimes (Herrick and others, 2019). Using historic or pristine conditions as a reclamation target (or reference) is likely unrealistic and beyond what is required in "Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development" (the Gold Book) (U.S. Department of the Interior and U.S. Department of Agriculture, 2007). A more practical concept for a reclamation "reference standard" is the condition of well-managed lands with similar ecological potential. To accomplish this requires (1) the ability to identify lands with similar ecological potential, (2) the availability of needed ecological monitoring data, and (3) the ability to screen available data to limit included lands to those in a properly functioning condition (for example, as inferred from structural and functional indicators) (Pellant and others, 2020). The characteristics that describe well-managed lands (or the inverse) vary among different soil and climate settings and through time owing to variation in weather. For many landscapes, identifying and removing data collected from degraded lands is easier than identifying well-managed lands themselves. For example, it is relatively easy to remove indicator values that clearly represent poor conditions, such as areas with high cover of weedy species, road densities, or livestock use. Finally, benchmarks that define the reclamation standards are often achieved with some degree of departure from the typical reference conditions, thereby allowing for some variability between sites and antecedent conditions. BLM Handbook H-4180-1 suggests reference conditions as the starting point for setting benchmarks and evaluating whether land health standards are achieved. A similar approach is recommended for defining site-specific reclamation standards.

Types of References

It is recommended to use benchmarks developed from a large sample of reference conditions. When this is not possible, there are single reference options available. Only use single plot comparisons when no other option is available, as single plot comparisons lack statistical validity and are subject to potential bias.

Using a Single Reference Site (Adjacent Reference Site or Pre-Development)

Pros—

- Using a single, paired-reference plot from nearby, comparable, and undisturbed land to create benchmarks and standards has been common for decades, therefore it is familiar to surface management agency (SMA) staff and operators
- If pre-development data are used as the reference, there are no subjective decisions made to match appropriate reference sites.

Cons—

- Reclamation success evaluations that use a single paired-plot or site for reference are very dependent on the selection of a suitable site and therefore entail a high potential for bias.
- Pre-development/post-reclamation monitoring data comparisons are likely to be confounded by decadal fluctuations in climate as well as changes in allotment livestock management and other factors.
- The paired-reference site or pre-development land condition may not meet minimum land health requirements.

[1]Available at https://www.blm.gov/sites/blm.gov/files/uploads/Media_Library_BLM_Policy_h4180-1.pdf.

Using a Large Sample of Reference Conditions

Pros—

- Increasing the number of reference sites from one to 100 or more can greatly reduce the bias and uncertainty in benchmark estimates. The existing BLM Assessment, Inventory, and Monitoring Strategy (AIM) data can provide a robust line of evidence for setting benchmarks.
- The use of many terrestrial AIM plots (ideally >30) allows for a robust estimate of indicator-value distributions, which are then used to set benchmarks. The benchmark for a given indicator is set based on a point in the distribution, often a percentile, that is informed by the screening approach used.
- Data from successfully reclaimed well pads are also used to estimate or inform benchmarks for reclamation. Soils following reclamation often cannot be returned to a previous condition in any reasonable amount of time, even if best management practices are followed. Therefore, data from reclaimed areas that support ecosystem processes and functions can provide more realistic management goals for reclamation, even if they differ from pre-development conditions. Additionally, the general goal of reclamation, and Final Abandonment Notice (FAN) approval, is not full restoration of the previous ecosystem but setting up for eventual ecosystem recovery. Thus, incorporating data that describe these known conditions could allow for increased precision in benchmarks (for example, reduced quantile ranges for meeting benchmarks).

Cons/challenges—

- Reference data are sometimes insufficient for a particular benchmark group.
- The needed land-management or ecological knowledge to screen reference plot data is often lacking.

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Appendix 2. Reclamation Plan Example

This appendix provides an example reclamation plan based on soil and climate settings similar to many surface management agency (SMA) lands. In areas with site-specific challenges, plans may need additional information to achieve the standards and objectives of reclamation. Examples include detailed reclamation plats with irregular re-contours to support visual and ecological benefits; soil test results; soil amendments; and soil or earthwork techniques for high slopes. Over the lifetime of a site, if changes or additions to a reclamation plan are appropriate, operators will propose them in writing prior to implementation for SMA approval.

Example Reclamation Plan

Reclamation Objectives

The objectives of interim reclamation, which reestablishes vegetation, ecological function, and other natural resource values during the productive life of an energy facility (for example, a well pad), are to establish vegetative cover and a landform sufficient to maintain healthy, biologically active topsoil; to control erosion and sediment transport; and to minimize loss of habitat, forage, and visual resources throughout the project life. Interim reclamation is judged successful when benchmarks for standards are met and disturbed areas not needed for long-term production operations have been recontoured, stabilized, and revegetated with a self-sustaining, vigorous, diverse, native (or otherwise approved) plant community sufficient to minimize visual impacts, provide forage, stabilize soils, and impede the invasion of noxious weeds.

The long-term objective of final reclamation is to establish a land condition approximating that of the defined ecological reference. This includes reclaiming the landform, natural vegetative community, hydrologic systems, visual resources, and wildlife habitats. Reclamation objectives are provided to promote an understanding of performance standards and best management practices (BMPs), to ensure implementation is effective and cost-efficient. Objectives, benchmarks, and standards also inform and facilitate understanding of SMA Inspection and Enforcement strategies.

Reclamation Indicators and Benchmarks

To help evaluate the standards, Tier-2 reclamation monitoring will be conducted on soil and vegetation indicators selected for comparison to benchmark values. Indicators will include bare soil cover, cover of canopy gaps larger than 1 meter (m), total foliar cover, foliar cover of perennial species, foliar cover of nonnative annual species, number of perennial species, and species evenness (based on species cover and total foliar cover). Bureau of Land Management (BLM) Assessment, Inventory, and Monitoring Strategy (AIM) data were not available for the ecological site or the ecological site group (ESG), so the benchmark group was determined using the U.S. Environmental Protection Agency (EPA) Level IV ecoregion (Semiarid Benchlands and Canyonlands; table 2.1). Experts examined the distribution of indicator values for AIM plot data available in this benchmark group (1,562 plots) and selected ranges of values that represent no departure, moderate departure, and extreme departure from the central tendency of observed indicator values in the reference plots. In table 2.1, the "no departure" benchmark column is based on the 75th quantile for indicators where smaller values are desired (less than the 75th quantile) and the 25th quantile for indicators where larger values are desired (at least the 25th quantile). The third column allows for moderate departure (10th–25th or 75th–90th percentiles, depending on indicator) and the fourth column is extreme departure (less than 10th or greater than 90th percentile, depending on indicator). These benchmark ranges are then used to develop the site standards for reclamation.

Reclamation Performance Standards

It is the responsibility of the operator and holder of the right-of-way to meet the following reclamation performance standards. Successful compliance with standards is determined by the SMA-authorized officer. If revegetation is unsuccessful, subsequent treatments and reseedings will be necessary to meet standards.

Benchmark-Based Reclamation Standards

- No noxious species are present (no departure).
- No extreme departure in bare soil cover, cover of canopy gaps larger than 2 m, or herbaceous height, and no signs of erosion indicators in Class 5. No more than two signs of erosion in Classes 3 and 4 combined.
- No extreme departure in total foliar cover, foliar cover of perennial species, foliar cover of introduced annual species, number of perennial species, or species evenness.

Table 2.1. Example indicators and benchmark-departure classes for the U.S. Environmental Protection Agency Level IV ecoregion (Semiarid Benchlands and Canyonlands).

[Derived from Assessment, Inventory, and Monitoring Strategy data distribution (located within the Colorado Plateau; n = 1,562). The operator and surface management agency staff (interdisciplinary team) work together to complete the table after the site assessment has been completed. In this example, no departure is >25th or <75th quantile, moderate departure is 10th–25th or 75th–90th quantile, and extreme departure is <10th or >90th quantile, depending on the indicator. cm, centimeter; %, percent]

Indicator	No departure	Moderate departure	Extreme departure
Bare Soil Cover	<27%	29–41%	>41%
Cover of canopy gaps >100 cm	<50%	60–67%	>67%
Total foliar cover	>34%	24–34%	<24%
Foliar cover of perennial species	>30%	20–30%	<20%
Foliar cover of nonnative annual species	<5%	5–24%	>24%
Number of perennial species	>14	10–14	<10
Species evenness, based on compositional cover (species cover/total foliar cover)	Any single species <70%	Any single species 70–85%	Any single species >85%
Number of noxious species	Zero	Zero	Greater than zero

General Reclamation Standards

- In agricultural areas, irrigation systems and soil conditions are reestablished in ways that ensure successful cultivation and harvesting of crops.
- Water naturally infiltrates into the soil rather than running off the surface.
- In areas where locally undesirable weeds are documented as a concern, operators will develop a site-specific treatment plan to meet the local objectives for management of those species.
- After a well is drilled and completed, the well location and surrounding areas(s) are cleared of and maintained free of all debris, materials, trash, and equipment not required for production.
- No hazardous substances, trash, or litter are buried or placed in pits. Hydrocarbons in pits are remediated or removed.
- Upon well completion, pits are dried prior to soil testing, then backfilled and closed per State standards.

Interim reclamation is judged successful by the SMA, when the following additional standards are met:

- Disturbed areas not needed for long-term production operations have been recontoured, stabilized, and revegetated with a self-sustaining, vigorous, diverse, native (or otherwise approved) plant community sufficient to minimize visual impacts, reestablish wildlife habitat or forage production, stabilize soils, and impede invasion by noxious weeds.

Final Reclamation is judged successful by the SMA, when the following additional standards are met:

- All disturbed areas, including well pads, production facilities, roads, pipelines, and utility corridors, have been recontoured to approximate the original landforms.
- All recontoured disturbance has been stabilized and revegetated with a self-sustaining, vigorous, diverse, native (or otherwise approved) plant community sufficient to minimize visual impacts, reestablish wildlife habitat or forage production, stabilize soils and impede the invasion of noxious weeds.
- Seeded species have had at least three growing seasons to establish root systems and to reach sufficient cover thresholds. Hence, it will likely take more than 3 years to release a site post-reclamation, particularly if fences or gates are let down and overgrazing occurs or if the site experienced drought that caused the vegetation cover to decline.

Pre-Development Activities

Pre-disturbance reclamation work involves the operator and SMA working together to complete a site assessment and collect additional electronic and field inventories. Complete the site assessment and soil characterization as described in Herrick and others (2017b) or as modified by an SMA-approved soil-prediction tool (Herrick and others 2017a). The minimum acceptable soil-characterization protocol requires digging a soil pit to a minimum of depth of 50 centimeters (cm) and recording soil-horizon depths and textures for each horizon (including topsoil depth). Identify areas of challenge or low reclamation potential on the site. Identify and quantify weeds and undesirable plant species within an SMA agreed-upon distance from the project area, including all access roads, pipelines, or other areas with proposed surface disturbance. Also consider collecting the following field inventories during the site assessment for the best possible reclamation results:

- Baseline soil testing is useful in areas of low reclamation potential and (or) prior to the use of soil amendments. If soil is tested, provide the results of the testing to the SMA for use in analysis and planning. Soil testing may include texture, pH, organic matter, sodium adsorption ratio, cation exchange capacity, alkalinity and salinity, and basic nutrients (nitrogen, phosphorus, potassium).

- Baseline vegetation inventories, including weed, listed, and rare plant inventories, inform planning and evaluation of reclamation success. A thorough inventory includes all affected areas such as roads, pipelines, and pads.

Monitoring and Reporting

- Inform the SMA when reclamation is planned, has been completed, or is reported successful or the site is ready for final inspection.

- Post-disturbance vegetation monitoring data are collected using a combination of Tier-1 and Tier-2 monitoring (described in this report) and follows the agreed-upon reclamation timeline (see table 2.2). The SMA may require more frequent monitoring, if necessary. If 20 percent or more of a successfully reclaimed area is re-disturbed, vegetative monitoring will be reinitiated.

- Operators will use Tier-1 and Tier-2 monitoring and resulting data to complete annual reports on reclamation progress at all disturbed sites across the field offices. SMA staff will also use Tier-1 and Tier-2 monitoring to confirm reclamation progress.

- Tier-1 monitoring of interim-reclaimed areas occurs the second year after reclamation efforts are initiated, within the growing season. Tier-1 monitoring will continue until monitoring data indicate the site is approaching reclamation benchmarks. Tier-2 monitoring is then used, no sooner than after three growing seasons post-reclamation, to confirm whether interim-reclaimed areas are meeting benchmarks and standards for reclamation. Once benchmarks and standards are met for an interim-reclaimed area, monitoring is postponed until final reclamation monitoring begins. When recontouring is minimal, only a portion of the interim-reclaimed area (containing excess topsoil) is re-disturbed for final reclamation, however all parts of the well pad are included in monitoring for final reclamation.

- Tier-1 final-reclamation monitoring occurs the second year after reclamation efforts are initiated, within the growing season. Tier-1 monitoring will continue until monitoring data indicate the site is approaching reclamation benchmarks. Tier-2 monitoring is then used, no sooner than after three growing seasons post-reclamation, to confirm whether all reclamation areas (interim and final) are meeting benchmarks and standards for reclamation. Once benchmarks and standards for reclamation are met and Final abandonment is approved, no further monitoring is required of the operator.

- Tier-2 monitoring is completed by the operator and reported in conjunction with the Final Abandonment Notice. SMA staff may confirm results with their own Tier-1 or Tier-2 monitoring data.

- The Reclamation Success Evaluation Form and Report are completed using Tier-2 monitoring data as supporting information. The report will cover soil and vegetation reclamation quality, which will aid in supporting compliance decisions on the Environmental Surface (ES) Inspection Form,[1] specifically regarding sections on erosion and stormwater control (for example, items L5, U5, E5, P5, IR6, A6), revegetation success (for example, items IR15, A13), and noxious-weed and vegetation control (for example, items L3, R3, U3, IR2, A4). The report will document compliance with all aspects of the reclamation objectives, benchmarks, and standards, identify whether they are likely to be achieved in the near future without additional actions, and identify actions that have been or will be taken to meet the objectives and standards.

[1]Available at https://www.blm.gov/programs/energy-and-minerals/oil-and-gas

Reclamation Timeline

Table 2.2. Example timeline for reclamation monitoring and reclamation inspection activities.

[SMA, surface management agency; TBD, to be determined; ES, environmental surface; EM, environmental monitoring.]

Well status and activities	Season or date ±3 months	SMA inspection	SMA assessment or monitoring	Operator assessment or monitoring
Onsite inspection	March 2022	Onsite	Site assessment	Site assessment
Production/interim reclamation	August 2022	EM, ES (every third year with monitoring)	Monitor every third year until benchmarks are met	Monitor annually or until monitoring confirms benchmarks are met
Notice of intent to plug and abandon	TBD	EM	--	Monitor interim-reclaimed areas
Final reclamation	TBD	ES (every third year with monitoring)	--	Monitor annually or until monitoring confirms benchmarks are met
Final surface abandonment	TBD	ES, SMA final-reclamation form	Monitor to confirm operator-submitted data	Monitoring data submitted with Final Abandonment Notice

Initial Construction

The Application for Permit to Drill (APD) contains a reclamation plat (for example, fig. 2.1) and other diagrams that contain site-specific details about acres to be reclaimed, areas of topsoil storage, earthwork reshaping plans, stormwater BMPs, and changes agreed to at the onsite inspection. This plat (fig 2.1) does not show a configuration of reshaped topography as required by 43 CFR part 3171, as other figures in the APD show the recontouring. The plan includes stabilization measures implemented in disturbed areas, including pipelines and roads, at the time of initial site construction (within 72 hours after initial surface disturbance). Some example stabilization measures include pre- and post-construction BMPs; contouring; texturing; mulching; temporary seeding; topsoil berming, tracking, and storage; and controls for weeds, stormwater, and spills.

Visual Resource Management

- During production and interim reclamation, all permanent above-ground facilities will be painted in a non-reflective finish to blend with the natural environment. Colors will be selected at the proposed project location using the BLM Environmental Color Tool,[2] considering viewers' likely observation points and the time of year with the greatest number of viewers. Selected colors will be one to two shades darker than those naturally occurring in the background landscape.
- Projects will be located to take advantage of existing vertical and natural features, such as landforms or existing stands of vegetation, to provide visual screening. They will not be located on exposed locations like ridgelines and hilltops. Edge feathering and other recontouring techniques will be used to blend the disturbed area with surrounding terrain and to reduce edge effects.
- Linear disturbances (roads and pipelines) will follow the natural contours of the landscape as much as possible.

Minimum Disturbance

To reduce the disturbance and reclamation footprint, liquid gathering systems will be used to collect and pipe produced fluids from each remote well location to a centralized production and collection facility located outside of wildlife habitat and closer to a major highway of pipeline. A centralized fracturing pad (located offsite) will serve the proposed well pad, as well as nine others, and water will be piped into the well pad, thereby eliminating the construction of frac tanks and reducing the use of haul trucks. This effort will reduce dust and tailpipe emissions, noise, visual concerns, wildlife disruption, and habitat fragmentation.

Directional drilling and deep burying of utilities and flowlines (immediately adjacent to roads) by plowing and pulling (rather than excavating and trenching), where possible, will reduce the overall disturbance and reclamation footprint.

[2]Available at https://www.blm.gov/sites/blm.gov/files/docs/2021-06/BLM_Gov_website_quick_links_color_tool%20%281%29.pdf.

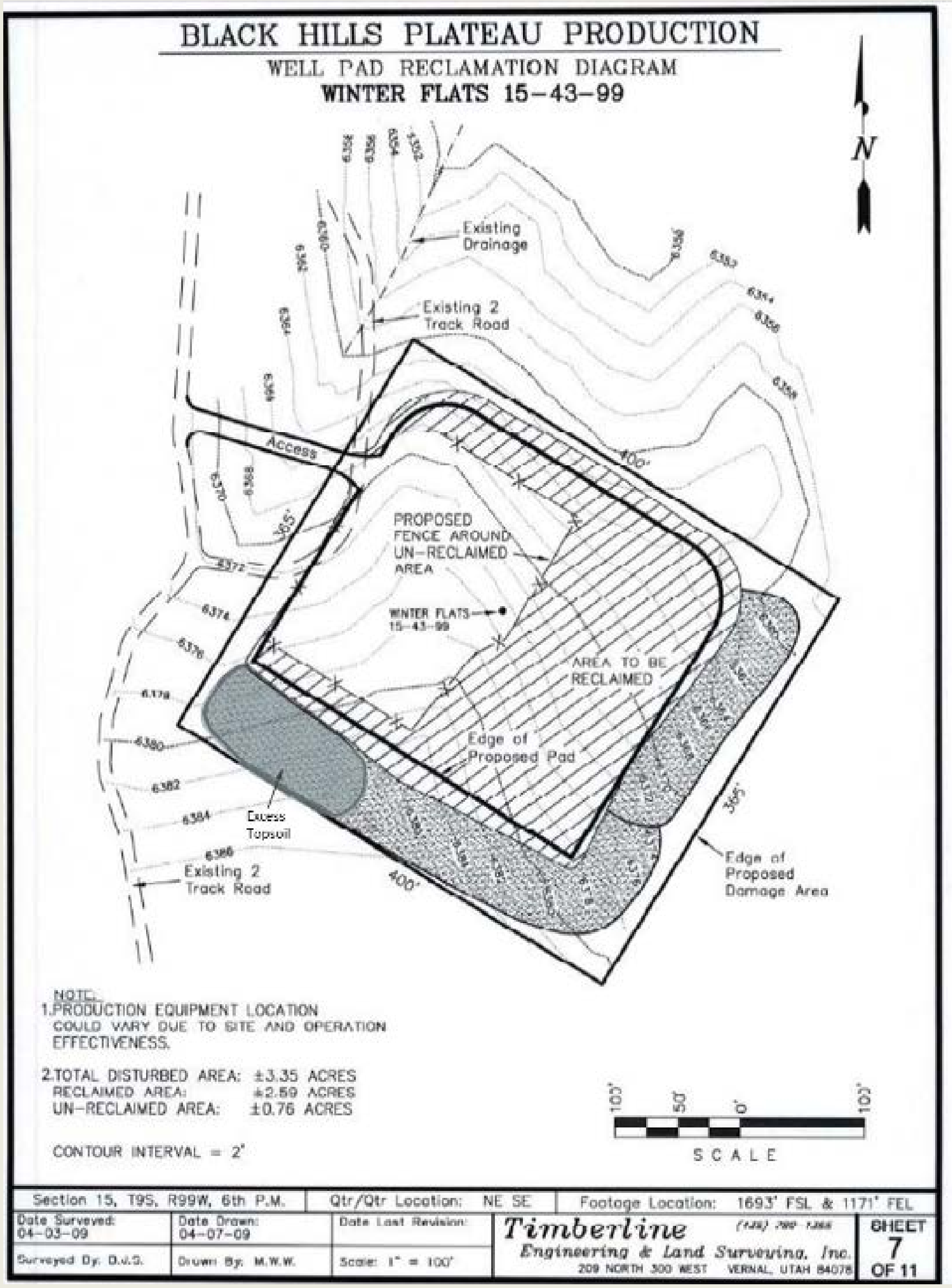

Figure 2.1. Reclamation plat submitted with an Application for Permit to Drill. Used with permission from Timberline Engineering & Land Surveying, Inc.

Interim Reclamation

Before interim-reclamation activities begin, permit holders will contact the designated SMA staff at least 72 hours beforehand, to schedule a field visit to inspect the disturbed area, review the existing reclamation plan, and agree upon any revisions to the plan. Within 6 months after completion or after a year has passed with no new wells drilled, interim reclamation will reduce well pads and roads to the minimum size needed for production and reshape disturbed lands to approximately natural contours. Since the drilling is phased to coincide with wildlife considerations, part of the interim reclamation will take place at the time of construction. Slopes will be recontoured and textured to accommodate stability, stormwater/spill controls and visual resource benefits. Temporary seeding or other components of the reclamation plan may be required to stabilize the materials, maintain biotic soil activities, and minimize weed infestations.

Stabilization and Stormwater

- As the disturbance is greater than 1 acre, a general construction permit will be acquired from the State Department of Public Health and Environment. Permit compliance requires the design and implementation of a stormwater management plan to systematically monitor the site, establish directed run-on and runoff management, and implement site-specific adaptive BMPs that reduce erosion and sediment transport. Measures must remain current and functional.
- The stormwater plan will be documented in the plat.
- Evaluating site-specific factors will help determine combinations of BMPs to apply during various project stages and construction activities based on monitored conditions. BMPs may include measures such as run-on and runoff protections (such as berms, culverts, diversions), sediment catchments, anchored weed-free straw bales or wattles, and revegetation of the surface. Other BMPs could include well-roughened seedbeds, crimped-in or hydrologically applied mulches, or gently contoured slopes and swales.
- Mulch may be used to control erosion, create ecologic microsites for vegetation success, and retain soil moisture. It may include native hay, small-grain straw, wood fiber, live mulch, cotton, jute, or synthetic netting such as erosion control blanketing. Mulch will be free from mold and fungi and be certified free of noxious or invasive weed seeds. Straw mulch fibers should be long enough to facilitate crimping and provide maximum cover.

Dust Abatement

- Fugitive dust will be prevented and abated as needed, whether created by vehicular traffic, equipment operations, or wind events. SMA approval will be acquired before application of surfactants, binding agents, or other dust-suppression chemicals on roadways within public lands. Speed-control measures will be acquired on all project-related unpaved roads. More stringent dust control may be required in areas adjacent to Federal- or State-listed threatened, endangered, or sensitive plant species.

Vegetation Clearing

- Before construction or other surface-disturbing activities, well-pad, access-road, and pipeline alignment will be cleared of brush and trees. As designated by the SMA, stumps will be buried or scattered in an area, such as the toe slope, or used to create a berm for stormwater or topsoil protection. Vegetation removal will be minimized and vegetation smaller than 2 inches (in.) in diameter will be collected with topsoil. All trees directly outside the staked limit of disturbance will remain undamaged and left standing unless removal is specifically directed by the SMA.

Topsoil Management

- At the time of construction, topsoil and vegetation will be stripped following tree and brush removal, stored separately from subsoil or other excavated material, and replaced prior to final seedbed preparation. No topsoil will be stripped when soils are saturated or are frozen below stripping depth. Topsoil will include all suitable growth medium present at a site and extend to the depth indicated by the site assessment. In areas of thin soil, site-specific topsoil management may be appropriate. Soil profile descriptions are included to inform stripping and topsoil depths as well as seeding details.

- A portion of the interim-reclaimed area will contain a surplus of topsoil that will be evenly spread across this area, clearly labeled, and documented with a photograph. When the site does not require complete recontouring, only this portion of the interim disturbed area will be re-disturbed during final reclamation to provide topsoil for the well pad area. Wherever topography allows, subsoil will be windrowed to the shallowest practical depth around the entire perimeter of the well pad to create a small berm that infiltrates, redirects, and manages stormwater. Along roads, where topsoil will be stored long-term, topsoil is segregated and windrowed to the shallowest practical depth for later spreading across the disturbed corridor as part of final reclamation. Along pipelines, topsoil will be re-spread over the disturbance as sections of construction are completed.
- Topsoil will be immediately seeded, with the SMA-approved native seed mix, to maintain soil microbial activity, reduce erosion, and minimize weed establishment.

Pit Closure

- Pit remediation and reclamation will be completed upon compliance with State standards of contaminant concentrations in accordance with 43 CFR part 3171.
- It is recommended that the latest version of the EPA's "Hazardous Waste Test Methods" (SW-846)[3] analytical methods be used for contaminant testing and that analyses of samples be performed by laboratories that maintain State or Federal accreditation programs.
- Immediately upon well drilling and (or) completion, hydrocarbons or trash in the pit will be removed. The pit will be left to dry, pumped dry, or solidified in-situ with an SMA-approved method prior to backfilling. When dry, the pit will be backfilled in compacted lifts no deeper than 4 feet (ft) to prevent subsidence under any surface pressures.

Facility Installation and Recontouring

- Installed facilities will be planned and placed to facilitate safety and maximize areas available for reclamation, such as clustered at the access end of the pad. Equipment installed in a manner that interferes with the proper interim reclamation of disturbed areas will be appropriately relocated. Centralizing and co-locating facilities to serve multiple pads will further minimize longterm disturbance.
- Access to facilities may be provided by a teardrop-shaped road through the production area (if not needed as a work area), so the driving area may be clearly defined, and the teardrop center seeded.
- Unnecessary equipment and materials, including gravel and road base, will be removed from areas to be reclaimed.
- Soil tillage will be conducted when soil moisture is in the recommended moisture content range for earthwork. Deeply compacted soils will be ripped in two passes at perpendicular directions to a depth of 18 to 24 in., at a furrow spacing of no more than 2 ft. A winged subsoiler will be used when deep ripping is not necessary.
- Portions of a site not needed for operational or safety purposes will be reshaped to as close to pre-disturbed condition as possible to blend with natural topography. Recontoured cut-and-fill slopes will be no steeper than 3 to 1 unless adjacent natural topography is steeper. Fill slopes will be restored to cuts and blended or contoured into large natural-looking berms that provide visual and stormwater benefits.
- If damage to reclaimed areas occurs as a result of well operations and maintenance, including workover operations, affected areas will be reclaimed again. As appropriate to avoid soil compaction and to protect topsoil and seedbeds, vegetation and topsoil will be removed prior to workover operations and then restored and reclaimed following operations.

[3]Available at https://www.epa.gov/hw-sw846.

Topsoil Application, Seedbed Preparation, and Seeding

- Following recontouring, salvaged topsoil will be evenly redistributed in locations as close as possible to where it was removed (that is, subsoil followed by topsoil). Topsoil will also be replaced on its respective slopes (for example, oak brush soil and piñon woodland soils will not be mixed).
- Before reseeding, all surfaces will be ripped and left rough. If more than one season has elapsed between final seedbed preparation and seeding, and if the area is to be broadcast-seeded or hydroseeded, this step will be repeated within 24 hours before seeding to break up any soil crust.
- Seedbed preparation techniques may include pitting and (or) mounding to form surface microtopography scaled to the site and materials. Seedbeds will be constructed in irregularly aligned rows oriented perpendicular to the natural flow of runoff downslope. Blankets, matting, or wattles may also be required to prevent erosion.
- Seed mixes and planting techniques will be approved in advance. No seeding will occur until seed tags and (or) other official documentation of the correct seed mix are submitted and approved by the SMA. After seeding, the operator will provide written notice to the SMA describing the completed work and any amendments to the reclamation plan.
- Seed will contain no noxious, prohibited, or restricted weed seeds and no more than 0.5 percent by weight of other weed seeds. Seed may contain up to 2.0 percent of "other crop" seed by weight, but a lower percentage is recommended.
- To maintain quality, purity, germination, and yield, only tested, certified seed for the current year, with a minimum germination rate of 80 percent and a minimum purity of 90 percent will be used unless otherwise approved by the SMA in advance of purchase. Seed will be viability tested in accordance with State law(s) within 9 months before purchase.

Invasive, Noxious, and Nonnative Species

- The operator will develop a weed-management and control strategy in compliance with the BLM and Forest Service's "Noxious and Invasive Weed Management Plan for Oil and Gas Operators."[4] Weedy species considered "nurse plants" for reclamation purposes that will not be actively managed the first few years after reclamation are addressed in the control strategy.
- Beginning the first growing season after any reclamation, an intensive weed-monitoring and control program will be implemented.
- Operators will regularly monitor and promptly control noxious weeds and other invasive plant species. Annual weed-monitoring reports will be submitted to the SMA officer by December 1 (and may be combined with reclamation reports).
- A Pesticide Use Permit will be approved by the SMA prior to the use of herbicides.
- All heavy equipment brought onto public lands will be cleaned before and after use to reduce the potential for introduction of noxious weeds or other undesirable nonnative species. If field wash stations will be used, a plan for the collection and disposal of wash fluids will be provided to the SMA.

Site Protection

- If required, the reclaimed area will be fenced to SMA livestock or wildlife standards to exclude livestock grazing until seeded species are firmly established, have stabilized soils, and meet percent-cover requirements.

[4]Available at https://www.nrc.gov/docs/ML1108/ML110820649.pdf.

- Since the well pad is located within deer and elk habitat, fences for livestock exclusion will not exceed 40 in. These four-strand fences will have smooth top and bottom wires. Distance from the ground to the bottom smooth wire will be no less than 16 in. Distance from the top wire to the second wire will be no less than 12 in. Middle wires will be barbed, with 6-in. spacing.
- The operator will use guidance provided in the “Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development” (the Gold Book) and in BLM Handbook H-1741-1 on fencing (p. 16), or electric fencing may be approved by the SMA.

Short-Term Interim Reclamation

If the drilling and (or) development phase lasts longer than expected (for example, >5 months), short-term interim reclamation will be implemented.

- Stabilization measures would begin at the time of construction, or at least within 72 hours after initial surface disturbing activities to stabilize materials, maintain biotic soil activities, and minimize weed infestations.
- Seeding of topsoil berms or windrows, cut-and-fill slopes, and temporarily disturbed areas along roads and pipelines will be done at the time of disturbance and (or) construction. Seedbed preparation is not generally required for topsoil storage piles or other areas of temporary seeding if seeding is immediate. Operators acquire SMA pre-approval of seed mix.
- Follow interim-reclamation BMPs for weed management, soil amendments, revegetation, and erosion control.

Final Reclamation

- When the notice of intent to plug and abandon is submitted, an inspection will be held with the SMA to review the existing reclamation plan or agree to an amended plan (for example, interim seed mix was unsuccessful long term and a new mix needs to be selected based on availability). Note, the operator may submit an addendum for updated techniques as they become available (for example, new native seed mixtures). Any changes to the reclamation plan require SMA approval prior to implementation.
- Final reclamation will be completed within 6 months of well plugging (weather permitting).
- A dry-hole marker will be placed below the surface, to prevent raptor predation upon small game.
- All equipment and materials, including gravel, road base, and sub-surface anchors, will be removed from areas to be reclaimed.
- Topsoil and vegetation will be salvaged and stored for redistribution following recontouring.
- Deeply compacted areas including roads and well pads will be ripped to a depth of 18 to 24 in., with spacing of 18- to 24-in. between deep rips. The access road and location will be recontoured to blend with natural topography, with fill materials returned to cuts and pushed up over backslopes.
- All disturbed areas, including roads, pipelines, pads, and production facility areas will be recontoured to what existed prior to initial construction or to contours that blend with the surrounding landscape. Interim-reclaimed areas are to remain undisturbed except for the marked location containing excess topsoil.
- Salvaged soils will be returned in the reverse order they were collected (that is, subsoil followed by topsoil)
- Salvaged topsoil will be evenly spread over the well pad and designated interim-reclaimed area, prepared, and seeded according to approved methods and seed mixes. No depressions will be left where water could pond, with the following exceptions: microtopography created to support reclamation success (for example pitting), terminal stormwater containments designed to silt in over time, or other approved stormwater- or snow-storage basins.
- In areas where mitigation of visual contrasts is needed, or to create irregularly shaped openings or mosaic patterns for wildlife, additional tree removal and “feathering” may be appropriate.

- In locations containing woody debris (such as cleared trees), slash, and large rocks, these will be redistributed in natural looking patterns onto reclaimed areas to imitate colors and textures closer to the natural landscape and to help create microclimates to encourage vegetation growth.

- Water breaks and terraces will not be included in final reclamation. In cases of special approval (for example, where necessary to prevent erosion of fill material), these structures will be removed, with the disturbed-area seedbed prepared and reseeded after the rest of the site is successfully revegetated and stabilized.

- Final abandonment of pipelines and flowlines will include purging, proper disposal of fluids, and then plugging at specific intervals. All surface lines and any lines that may be exposed in the foreseeable future owing to water or wind erosion, soil movement, or anticipated subsequent use, are removed. Deeply buried lines may remain in place unless otherwise directed by the SMA.

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Herrick, J.E., Karl, J.W., McCord, S.E., Buenemann, M., Riginos, C., Courtright, E., Van Zee, J., Ganguli, A.C., Angerer, J., Brown, J.R., Kimiti, D.W., Saltzman, R., Beh, A., and Bestelmeyer, B., 2017a, Two new mobile apps for rangeland inventory and monitoring by landowners and land managers: Rangelands, v. 39, no. 2, p. 46–55, https://doi.org/10.1016/j.rala.2016.12.003.

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Appendix 3. Ecological Sites and State-and-Transition Models

Ecological sites and ecological site groups (ESGs) classify lands based on concepts of land potential (soils, topography, and climate) (Duniway and others, 2010a; Caudle and others, 2013; Bestelmeyer and others, 2016) and describe the natural range of variability and ecological dynamics that have been documented in state-and-transition models (STMs). These STMs are a tool for classifying plots or areas that fall within an ecological site description (ESD) or ESG into recognized states with known ecological functions and services, and with information on known drivers of transitions into other states.[1] The ecological site system and contained interpretive information has been extensively used for range assessments and vegetation management decisions, particularly the STM, and managing for desired conditions (states). In general, management objectives include soil and vegetation conditions to be in or on a trajectory towards a desired state in the STM, which is often the historic climax of a plant community (for example, State 1 in fig. 3.1; also termed "reference") but can also be an alternative state that meets rangeland health standards (for example, States 2 or 3). Recovery of reference states following significant disturbances, like oil and gas development, may take decades or not be achievable. However, full restoration of reference-state conditions is not typically required for successful interim reclamation or issuance of a Final Abandonment Notice (FAN).

The complete removal of soil and alteration of topography that occurs during construction of oil and gas well pads and infrastructure generally results in altered land potential and the post-operation ecological dynamics may not be represented by the existing STM (Bestelmeyer and others, 2015). Successful final reclamation, recent and interim reclamation, and a disturbed

[1]https://edit.jornada.nmsu.edu/.

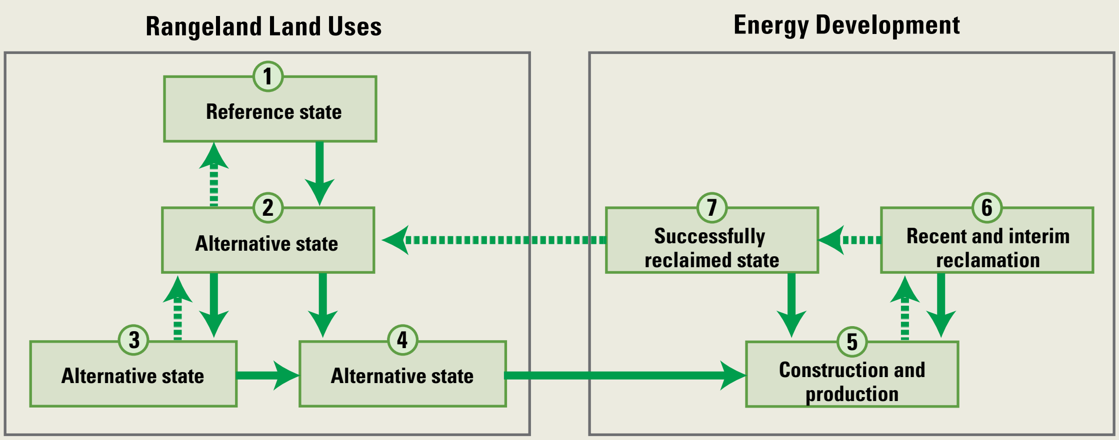

Figure 3.1. Diagram showing a generic state-and-transition model (STM) for rangeland land uses (left; States 1–4) and an example of how ecological dynamics of highly disturbed lands following energy development relates to the rangeland STM (right, States 5–7). Modified from Bestelmeyer and others (2015). Transition pathways are indicated with solid arrows and restoration pathways are indicated by dashed arrows. In this example, any state can potentially be developed for energy production, but restoration from a successfully reclaimed state is likely to restore to only one state in the rangeland land-use model.

site (for example, a recently constructed location) can be considered “states” in an STM, with transitions and restoration pathways identified and described for the ESDs and ESGs where these types of land uses are common (fig. 3.1). The exercise of developing soil and vegetation benchmarks as part of the reclamation standards is essentially describing the conditions that define the “successfully reclaimed state” in the example, with the expectation that with time and appropriate management these successfully reclaimed states can recover to the target state. The goal of a state-and-transition model is to provide a framework for vegetation management; its creation requires considerable ecological knowledge and experience to define the ecosystem properties associated with states, thresholds, and transitions (Bestelmeyer and others, 2004).

There are several pieces of information and decisions required before an ESD or ESG STM can be used for setting reclamation benchmarks. First, it is necessary to identify the ecological state from the STM that most closely represents a target for reclamation. Information about recovery pathways from highly disturbed lands (lands necessitating reclamation) is not currently included in most STMs, meaning there is not likely a state describing the soil and vegetation conditions of a successfully reclaimed site (for example, box 7 in fig. 3.1). To use currently published STMs, the operator and surface management agency (SMA) interdisciplinary team (ID team) will need to determine which ecological state most closely matches a reasonable management objective for reclamation, which may or may not be the reference state. Finally, benchmark values for each indicator will need to be determined based on data available from the ESD or ESG (and potentially augmented with available monitoring data). Furthermore, professional judgement is needed to determine the similarity in site conditions used for benchmarks. Use of STMs is further complicated owing to ESD reports typically containing only vegetation production data, necessitating estimations or conversion of ESD-reported production values to cover values for compatibility with the monitoring methods used in reclamation.

Developing new or updating existing STMs using monitoring data and quantitative analysis is an active area of research (for example, Nauman and others, 2022) with new databases that link national monitoring program data with ESD and ESG data and provide further opportunities for developing robust reclamation benchmarks[2] (McCord, 2021). With sufficient post-reclamation monitoring data and tracking of trends over time, STMs with benchmarks that describe the suite of conditions associated with a successfully reclaimed site, are possible (fig. 3.1).

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[2]https://landscapedatacommons.org/.

Appendix 4. Reclamation Equipment

Figure 4.1. Photographs showing reclamation equipment. *A*, *B*, Caterpillar-type (continuous track) bulldozers are limited by how far and how fast they can move soil. *C*, Wheeled tractor scrapers and earthmovers can move a lot of soil quickly over greater distances. *D*, Loaders can move small amounts of soil into trucks. *E*, Trackhoes recontour roads or respread topsoil on steep road cuts and fills. *F*, Adjustable offset discs are used to rip and decompact soil. *G*, Rolling harrows quickly prepare seedbeds for seeding. *H*, Cultipackers gently firm soil where seed has been broadcast, ensuring shallow seed placement and good seed-to-soil contact. *I*, Push spreaders and handcrank broadcast seed spreaders are used to spot treat problematic areas needing reapplication. Photographs by Bureau of Land Management.

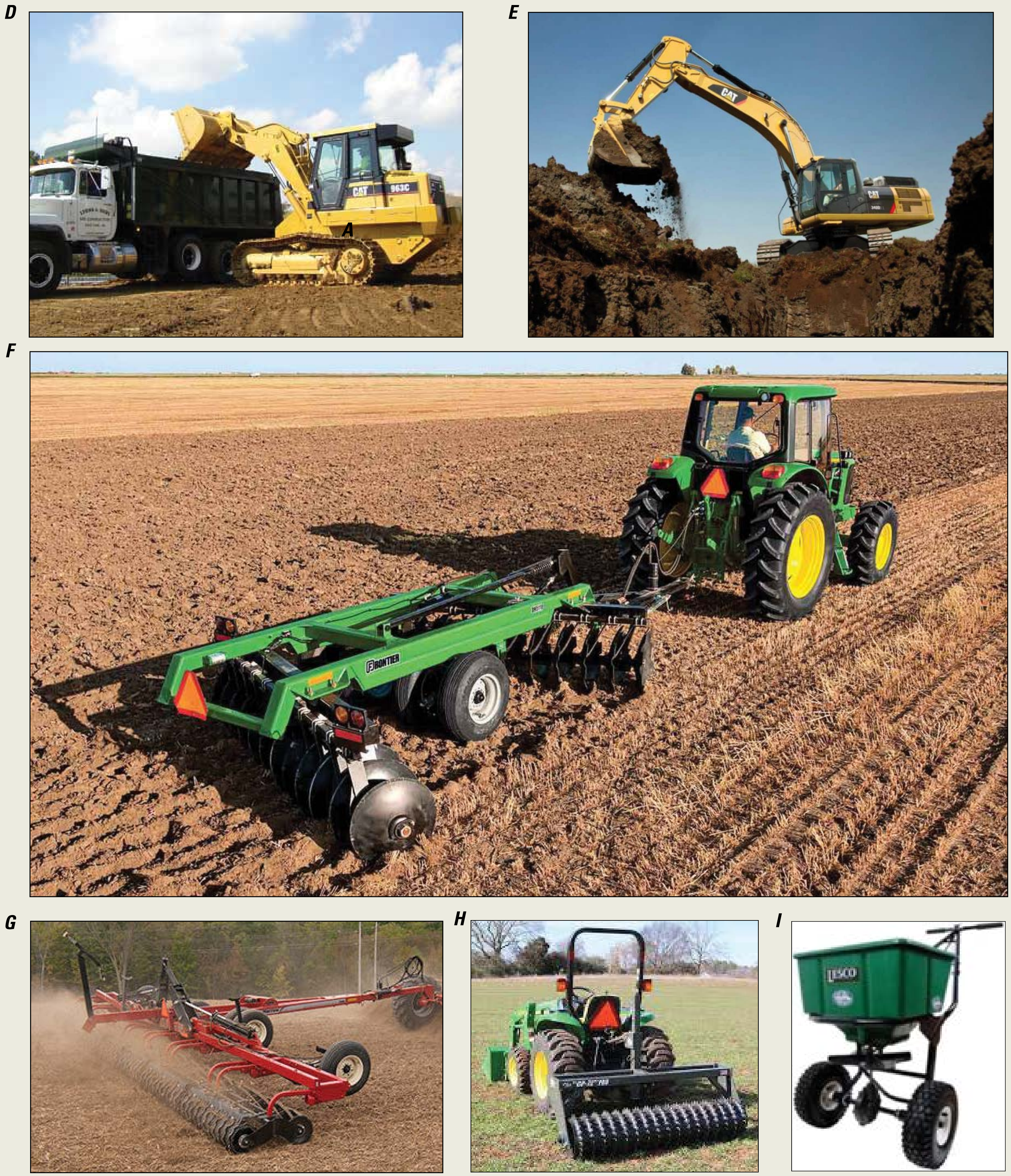

Figure 4.1. —Continued.

Appendix 5. Reclamation Success Evaluation Report

Surface management agency (SMA) staff will develop a report that includes the completed Reclamation Success Evaluation Form, along with all other relevant evidence that supports achievement or failure of reclamation goals, objectives, and standards. Below is an example of how the Assessment, Inventory, and Monitoring Strategy (AIM)-derived benchmarks, along with other locally relevant benchmarks, are used to substantiate the met or not met compliance decision on the applicable forms (for example, the Environmental Surface [ES] Inspection Form and the effectiveness of mitigation on the Environmental Management [EM] Inspection Form[1]). The report clearly records all aspects of the evaluation and analysis and interpretation of available information, including inventory and monitoring data. Additional evidence can also be presented to determine whether reclamation standards were met.

Section 1. Benchmarks and Standards

Include a brief summary of benchmark and standard review.

Then include a table of benchmark departures and list the standards and their assessments (see table 5.1).

Benchmarks (Completed)

Table 5.1. Example table of benchmarks derived from Assessment, Inventory, and Monitoring Strategy data distribution using U.S. Environmental Protection Agency Level IV ecoregion (Semiarid Benchlands and Canyonlands).

[Located within the Colorado Plateau (n = 1,562). In this example, no departure is >25th or <75th quantile, moderate departure is 10th–25th or 75th–90th quantile, and extreme departure is <10th or >90th quantile, depending on the indicator. cm, centimeter; %, percent.]

Indicator	No departure	Moderate departure	Extreme departure
Bare soil cover	<23%	23–36%	>36%
Cover of canopy gaps >100 cm	<45%	45–58%	>58%
Herbaceous height	>15 cm	11–15 cm	<11 cm
Total foliar cover	>40%	30–40%	<30%
Foliar cover of perennial species	>35%	25–35%	<25%
Foliar cover of introduced annual species	<5%	5–20%	>20%
Number of perennial species	>14	9–14	<9
Species evenness, based on compositional cover (species cover/total foliar cover)	Any single species <70%	Any single species 70–85%	Any single species >85%
Number of noxious species	Zero	Zero	Greater than zero

[1]Available at https://www.blm.gov/programs/energy-and-minerals/oil-and-gas.

Standards

In this section, the standards for noxious-weed control, erosion, stormwater control, and revegetation are assessed using benchmarks and results described.

For example

A.4. Noxious-Weed Control:

- No noxious species present (no departure)

A.6. Erosion and Stormwater Control:

- No extreme departure in bare soil cover or cover of canopy gaps larger than 100 or 200 centimeters, and no signs of erosion indicators in “Describing Indicators of Rangeland Health” Class 5.
- No more than two signs of erosion in “Describing Indicators of Rangeland Health” Classes 3 and 4 combined.

A.13. Revegetation Success:

- No extreme departure in total foliar cover, foliar cover of perennial species, foliar cover of introduced annual species, number of perennial species, or species evenness.

Section 2. Results of Well-Pad Data Collection (Completed)

In this section, results of the field data collected are reported and indicators classified relative to the established benchmarks (table 5.2)

Table 5.2. Example table of indicator results of final reclamation on well-pad using Tier-2 data collection and binned relative to benchmarks (table 5.1).

[In this example, no departure is >25th or <75th quantile, moderate departure is 10th–25th or 75th–90th quantile, and extreme departure is <10th or >90th quantile, depending on the indicator. cm, centimeter; %, percent.]

Indicator	No departure	Moderate departure	Extreme departure
Bare soil cover	22%		
Cover of canopy gaps >100 cm	17%		
Herbaceous height	32 cm		
Total foliar cover	77%		
Foliar cover of perennial species		25%	
Foliar cover of introduced annual species			53%
Number of perennial species			<9
Species evenness, based on compositional cover (species cover/total foliar cover)	53%		
Number of noxious species			Greater than zero

Section 3. Reclamation Success Evaluation Form (Completed)

In this section, the complete evaluation is documented using the Reclamation Success Evaluation Form[1] (table 5.3).

Table 5.3. Example completed Reclamation Success Evaluation Form.

Reclamation Success Evaluation Form			
Facility or well name/number: Falcon 4-21 07-103-39484			**Date:** 8/11/21
Evaluator name: Tammy Jones		**Benchmark unit:** Semiarid Warm Shallow Deep Rocky Ecological Site Group	
Departure from Expected		**Code**	**Instructions**
None to slight		**N**	(1) Assign indicator ratings, record method for rating, and comments
Moderate		**M**	(2) Total departures per attribute
Extreme to total		**E**	(3) Provide rationale for pass/fail based on preponderance of evidence
Attribute	**Authority Reference***	**Description**	
A4. Noxious- Weed Control	AAPD—SUPO, PUP, reclamation plan	Determine if any weeds exist and if control measures are adequate.	
A6. Erosion and Stormwater Control	AAPD—SUPO, 43 CFR part 3171	Determine if erosion-control features such as diversion ditches, silt fences, berms, sediment ponds, and any other controls from the permit are present, installed properly, and effective. Determine if any of the structures need removal before approval of a Final Abandonment Notice.	
A13. Revegetation Success	COA, local policy	Determine if final reclamation has resulted in a desirable plant community.	

*May be, for example, the Approved Application for Permit to Drill Surface Use Plan of Operations; Pesticide Use Permit; 43 CFR part 3171; condition of approval; or reclamation plan.

A4. Noxious-Weed Control			
Indicator	**Rating**	**Benchmark or other justification**	**Comments**
Noxious cover	E	Referred to SUPO	Fail. Any noxious is an automatic fail
Attribute total departures	1/1 E	**Decision and rationale**	Fail. Site does not have reclamation plan or pre-development data. Previous conditions are unknown, but RMP states that sites should be free from noxious species.
A6. Erosion and Stormwater Control			
Indicator	**Rating**	**Benchmark or other justification**	**Comments**
Bare soil	N	AIM benchmark (75th)	Bare soil cover is 22%
Intercanopy gaps >100 cm	N	AIM benchmark (75th)	6% is in normal range
Soil erosion	N	Observation form	One Class 3, no Class 4 or 5
Attribute total departures	0/3	**Decision and rationale**	Pass. No large canopy gaps, excessive bare soil, or erosion. Met all standards.
A13. Revegetation Success			
Indicator	**Rating**	**Benchmark or other justification**	**Comments**
Total foliar cover	N	AIM benchmark (75th)	Total foliar cover is 77%
Perennial cover	M	AIM benchmark (25th)	25% perennial cover
Introduced-annual cover	E	Referred to COA <25%	Site contained 53% cheatgrass
Species evenness	N	AIM benchmark (75th)	All species below 70% cover
Perennial-species richness	E	Referred to local RMP	Only 3 species onsite (minimum 9 required)
Herbaceous height	N	AIM benchmark (25th)	Average herbaceous height much greater than 25th percentile(32 cm)
Attribute total departures	1/6 M 2/6 E	**Decision and rationale**	Fail. Need to increase number of native species onsite and get noxious and introduced cover down.

Section 4. Additional Evidence to Support Benchmarks and Standards

This section contains materials to support the decision process. This can include completed site assessments and soil characterizations,[2] ground photos, remote sensing, summarized data, and data visualizations (fig. 5.1).[3]

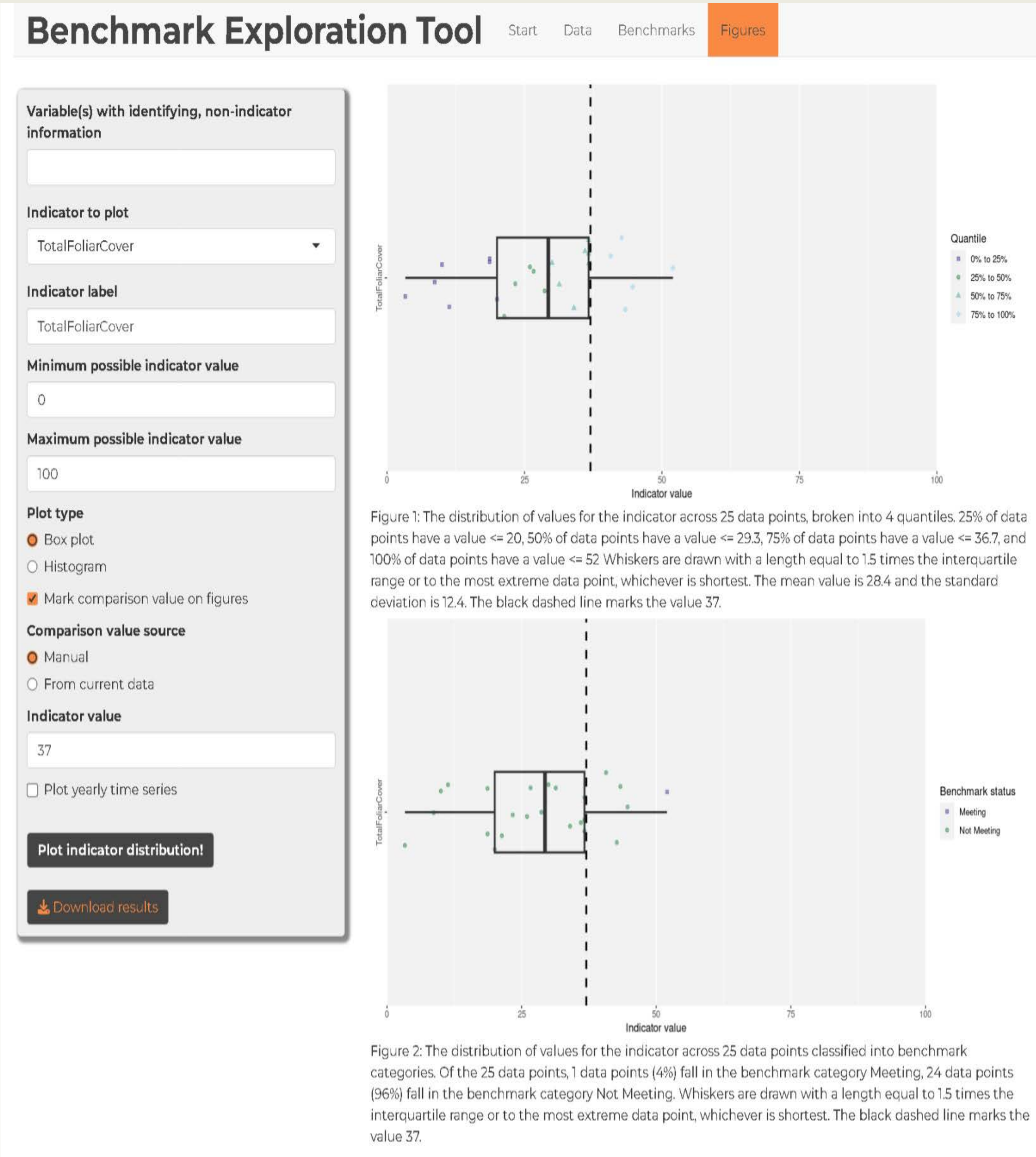

Figure 5.1. Screen capture showing an example of data visualized using the Benchmark Exploration Tool. The dashed line represents total foliar cover on the well pad, and the box plot represents the reference data total foliar cover distribution.

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[2]Based on plot characterization and observations in Herrick and others (2017b).

[3]Available at https://www.landscapetoolbox.org/benchmark-exploration-tool/.

Section 5. Decision and Rationale

This section contains a summary of all sections of the report to support the inspection decision listed on the Reclamation Success Evaluation Form. For example, “The presented evidence suggests that this site has not been sufficiently reclaimed and is not on a trajectory towards eventual restoration according to the established benchmarks and standards listed in the reclamation plan. Benchmarks and standards used in the assessment were updated by the Bureau of Land Management field office in 2022.”

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Herrick, J.E., Van Zee, J.W., McCord, S.E., Courtright, E.M., Karl, J.W., and Burkett, L.M., 2017b, Core methods, v. 1 *of* Monitoring manual for grassland, shrubland, and savanna ecosystems: Las Cruces, New Mexico, USDA-ARS Jornada Experimental Range, 77 p.

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