Principles and Practices
of Integrating Science into Land Management
GUIDELINES

INTRODUCTION

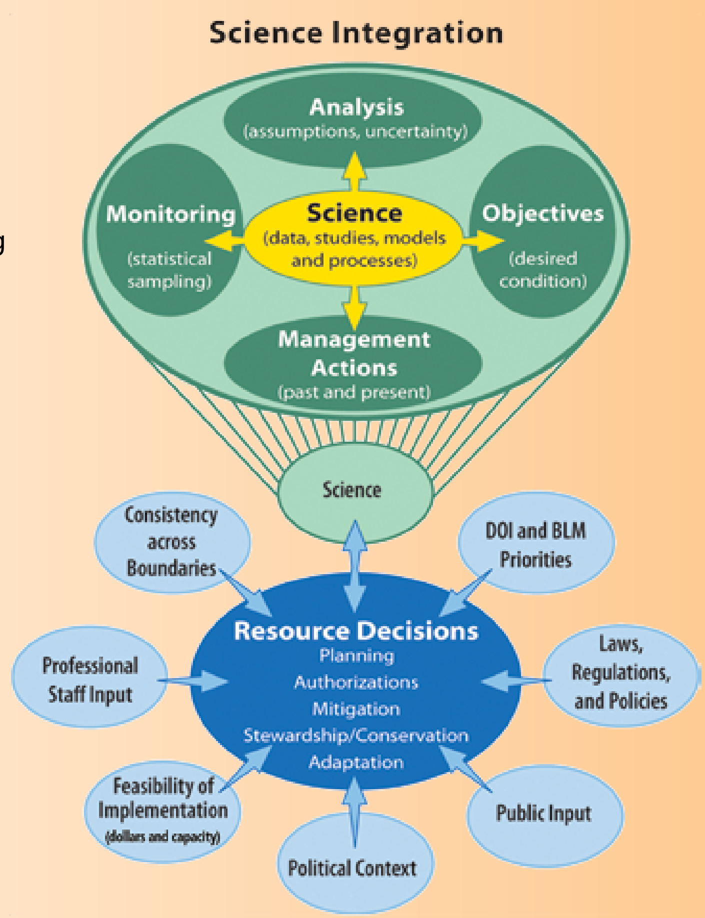
Science is the systematic study of the world based on knowledge learned through experiments and observations. The Bureau of Land Management (BLM) intends to use science deliberately and consistently in accomplishing work processes and in making land management decisions. By doing so, the BLM will enhance its ability to make well-informed decisions, increase confidence in projected outcomes, and enhance stakeholder trust.

The BLM has identified these **principles and practices** to help BLM managers:

- Use high-quality information relevant to the problem or decision being addressed, relying on peer-reviewed literature when it exists.
- Recognize the dynamic and interrelated nature of socioecological systems within which the BLM operates.
- Acknowledge, describe, and document assumptions and uncertainties.
- Use quantitative data when they exist, and applicable qualitative data, in combination with internal and external professional scientific expertise.
- Use transparent and collaborative methods that consider diverse perspectives.

BLM employees are firmly committed to finding and evaluating science for many of their work functions. These guidelines provide a framework for deliberate and consistent integration of science across all levels, offices, and programs. The following **work processes** will benefit from the consistent use of science (per the BLM's [Advancing Science Strategy]): assessing current or baseline conditions; monitoring to measure trend; performing planning; authorizing use; implementing management actions; and managing compliance. Whether the processes occur at a specific site, within a field office, or across field offices, scientific information will help the BLM perform these functions more effectively.

Similarly, a wide range of **decisions** would benefit from the consistent use of science. BLM managers consider many factors before making decisions—from professional and public input, to political and financial realities, to regulatory, administrative, and other requirements. Relevant science can add vital information to support decisionmaking. The Checklist below offers a step-by-step tool for implementing



Conceptual model showing how science is just one factor in the land management decisionmaking process.

these guiding principles and practices to integrate science consistently in the BLM's work processes and decisionmaking. It is intended to be used as a flexible tool that can adapt to the needs of different programs, projects, and areas of science. Additionally, it can help inform efforts to design or conduct new scientific research or data collection, and the process may help reveal new research needs. The Checklist acknowledges, but does not fully address, some other types of information that may also be critical to effective science integration (e.g., professional judgment, ecological knowledge obtained from traditional land users, or a permittee's direct experiences).

How To Make the Most of the Checklist

- **Keep in mind the overall complexity and scale of the issue(s) and associated management question(s) being addressed in the decisionmaking process. The Checklist can be applied to a wide range of decisions, from small-scale and routine decisions to highly complex, landscape-level management decisions. Often, you may find that steps in the Checklist are an iterative process.**
- **Many of these steps can be difficult, but consulting with relevant experts not directly involved in implementing the Checklist will help ensure that important aspects of integrating science are not missed.**
- **Work with all relevant internal and external stakeholders to document the science integration process used for addressing the management question(s).**
- **Keep up-to-date on the latest research, analytical tools, and information relevant to your discipline to make more effective use of the Checklist.**

CHECKLIST

☐ **1. DEFINE THE MANAGEMENT QUESTION(S)**, including related management objectives. All interested parties must clearly understand the management issue(s) if the five guiding principles and practices are to be successfully applied.

☐ **2. FIND** available science relevant to the management question(s). Be systematic, rigorous, and objective, and use a method that is easy for others to follow and that is well-documented.

☐ **3. EVALUATE** the potential relevance and reliability of the science identified in Step 2.

☐ **4. SUMMARIZE** the science, address any conflicting science, and identify any information gaps.

☐ **5. APPLY** your science-based conclusions to the management question(s) to decide the best course of action for achieving management objectives.

☐ **6. ASSESS** how the application of science affected public support, the sustainability and effectiveness of the decision, confidence in the course of action selected, and further learning about the system and the effects of management actions. Plan any future assessments and/or develop and implement a monitoring plan.

DETAILED GUIDELINES FOR USING THE CHECKLIST

(See the BLM's Science in Practice Portal for case studies implementing this guidance.)

1. DEFINE THE MANAGEMENT QUESTION(S), including related management objectives. All interested parties must clearly understand the management issue(s) if the five guiding principles and practices are to be successfully applied. For additional direction, please see the guidance developed for the Assessment, Inventory, and Monitoring Program and Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems, Volume II.

a) What are the management questions, and what is the larger context?

One way to frame the management question(s) is to ask what decision needs to be made and what actions management may take as a result. Based on the management question(s), explore what we know and what we need to know for the BLM to make the best decision and to choose among alternatives. Conceptual models may help you frame the management question(s). Once you have identified the management question(s) (e.g., whether to allow a certain use of the resource), consider what management objectives would further the BLM's mission (e.g., protecting the resource, providing for multiple uses of the resource).

Describing the management question as part of its larger context will help you find broadly relevant information and, ultimately, use the data more effectively. Correct interpretations of the data require that the context take into account the interrelated nature of geophysical, biophysical, cultural, and/or socioeconomic systems. These relationships become more important as the magnitude of potential impacts of a decision or alternative increases.

b) Determine if others in the BLM or our partners have already addressed the same question(s) or any similar management questions. Use the Science Partnership Resources website to determine if a partnership already exists that is focused on your management question(s). Can information from past efforts be leveraged for new purposes?

2. FIND available science relevant to the management question(s). Be systematic, rigorous, and objective, and use a method that is easy for others to follow and that is well-documented.

a) Search for relevant literature.

Government Publications. The BLM Library houses a collection of scientific documents produced by the BLM, the Department of the Interior, and other federal entities, including technical references, technical notes, National Environmental Policy Act planning and other planning documents, strategic plans, and other reports. Many are available digitally. In addition, ask your state office whether a partnership exists with a local university (e.g., ARLIS) through which you may have access to regional literature.

Academic Search Engines and Databases. Access to scientific journal databases is available through the BLM Library. The BLM librarians are available to assist with literature searches for both BLM and external documents. In addition, a number of resources are available on the BLM Library website that can help guide you in performing an effective literature search. Ask colleagues and partners about potential access to literature through other affiliations, or use online services such as ResearchGate, Google Scholar, and Academia.edu. To identify influential articles, use carefully crafted key words, and sort results by the number of times articles have been cited. (Note: Some articles are cited frequently because they are flawed, so check a few of the articles that cite them as well.) Alternatively, start a search by finding the articles referenced in relevant articles. Collaboration for Environmental Evidence provides a comprehensive guideline for conducting a systematic literature review. Remember to document search terms and search engines used.

Partner Organizations. Partner organizations play a large role in providing scientific information and support. The BLM's Science Partnership Resources website lists current partnerships and collaborations between the BLM and universities, federal science providers, state science providers, nongovernmental organizations, and many others.

b) Seek out existing tools or develop new ones for investigating the management question(s).

Decision support systems, mathematical models, conceptual models, and geospatial models can help establish a clear and common understanding of the functions of affected systems, and the relationships among these systems, as well as the potential effect of management actions applied within those systems. They can also help you identify relevant data and data gaps. They may also aid you in showing how science information can be applied to the BLM's work processes.

c) Search for relevant inventory and monitoring information, including geospatial data, if applicable to the management question(s).

Data Portals. Some websites offer maps, models, data layers, monitoring information, and support documents. Examples of data portals include: **BLM Landscape Approach Data Portal**, **BLM EGIS Portal**, **AIM TerrADat**, **USGS Geo Data Portal**, and **Data Basin.** State and field offices have also developed GIS (geographic information system) datasets and databases relevant to their area. Many more sources of geospatial and nongeospatial data are described and linked on the BLM's Science in Practice Portal, which will help BLM users find the most useful data to answer their management questions.

d) Ask colleagues in neighboring field offices about unpublished knowledge and information.

Field offices collect monitoring data and store many other types of records; for example, field notes and allotment information. Every office has different storage locations and standards for storing this information; it may not be available digitally, and it may require further analysis to be useful. You should consider these data an important part of a thorough and systematic search.

e) Locate experiential knowledge.

Systematic observations made by scientists, BLM employees, other federal employees, permittees, and members of the public can be quite useful, especially if other forms of information are not available. Long-term professional knowledge of a resource can be particularly useful, especially when observations are well-documented. Take the time to research these additional sources for information that might be used to address the management question(s).

f) Consider engaging internal and external experts.

Engaging external experts, as individuals or as part of a panel, may be productive for a variety of reasons. Experts often offer valuable alternatives for analytical approaches and decisions. This input may help establish or validate a knowledge base for highly visible, complex, or controversial management issues/questions. While experts should be viewed as credible and neutral, it is still important to recognize potential bias. Ensure that the process for engaging experts is transparent, well-documented, and responsive to public input. Doing so will help build consensus about issues and options. If timeliness is a priority, work through known experts to access and distill the most relevant and current technical information as efficiently and objectively as possible.

3. EVALUATE the potential relevance and reliability of the science identified in Step 2.

a) Is the science relevant?

- Is it relevant to the local physical, biological, geological, cultural, and/or socioeconomic conditions?

Many characteristics of how a system functions are specific to a particular location. Thus, findings from research conducted at a broad scale may or may not hold true at a local site of interest. To help determine the extent to which findings from broad-scale studies may apply to your site, record and compare key characteristics of the setting of the research studies and of your site. For example, you may want to record the soil type, climate, topography, dominant plant communities, social and economic conditions, and current and historical management practices.

- For older studies, are the data still relevant considering advances in knowledge, methodology, or both since the information was originally presented?

Some studies stand the test of time and are foundational, while others become less relevant or accurate as subsequent studies are published (e.g., the methods are no longer as valid). When referencing older studies (e.g., those more than 10–15 years old), especially in rapidly advancing fields (e.g., genetics, connectivity), document your rationale for why information is, or is no longer, relevant so that reviewers and decisionmakers can understand why it was, or was not, included in your analysis.

b) Is the science reliable?

- Are the methods and analysis replicable and sound?

Assessing the potential validity and application of the information you have compiled is difficult without first understanding how it was produced.

Replicable: Sufficient detail should be clearly provided to replicate the entire study independently. Details should include the study objectives (and hypotheses to be tested, if applicable), experimental design, study location description, and sampling and analysis methods used (including statistical tests and the level of uncertainty in the results).

Sound: Replicated experimental designs should be applied wherever possible. The designs should include either randomly selected or paired controls. They should include as much as possible of the relevant spatial and temporal variability, and the interpretation of the data should clearly acknowledge the extent to which the results can and cannot be reasonably extrapolated to other areas (e.g., different soils and climate), other times (e.g., wet vs. dry years), and other conditions (e.g., a grazing study in an area with high vs. low elk populations). Some processes in social systems (e.g., learning and critical thinking) are inherently better evaluated qualitatively rather than with quantitative data. Measurable criteria for hypothesis testing, however, are critical regardless of whether quantitative or qualitative methods are used.

Resources will be available on the BLM's Science in Practice Portal website to assist you in evaluating a scientific study or journal article. Additionally, your state science coordinator and National Operations Center staff can assist you in completing this step and others. See **Lewis (2006)** and **Sundt (2002)** for a quick review on valid experimental design and statistical applications in ecology.

- Are the conclusions logical and supported by strong evidence?

It is critical that discussions and conclusions presented in the study follow directly from the study results. Record any observations or questions you have about study conclusions that do not seem to be drawn from and supported by the study results.

- Does the study or report acknowledge or cite other relevant science?

Studies that reference and briefly summarize the existing body of research on a topic demonstrate an understanding by the author(s) of the current state of knowledge and pivotal or important ideas in the field. Studies that lack this information may indicate incomplete analyses or conclusions. Relying on recent review papers that summarize the current state of knowledge on a topic can help ensure consideration of the most comprehensive and up-to-date findings available.

- Has the science been peer-reviewed, and if so, by whom?

Peer review evaluates an author's work, research, or ideas by engaging other scientific experts (peers) in the same field to check for validity, significance, originality, and clarity. Articles published in scientific journals and in the "gray" literature (e.g., agency technical reports) typically undergo some level of peer review. The current standard of peer review that is applied by most scientific journals is anonymous review by multiple independent experts in the field. The rigor of review in the gray literature is typically, but not always, less than that of scientific journals. In fact, some gray literature, such as "Interpreting Indicators of Rangeland Health, Version 4, Technical Reference 1734-6," has been subjected to a much more intensive and extensive peer review than even high-quality scientific journal articles. Identifying the extent to which a research study was reviewed, anonymously, by other independent experts in the field can help you assess its reliability.

- Who developed the information and why?

Objectivity is at the core of sound science. Conflicts of interest can bias or compromise objectivity at the level of individuals or organizations. When considering gray literature in particular, identifying who developed the information and for what purposes, along with a careful evaluation of the methods of data collection and analysis, can help you evaluate whether potential conflicts of interest may limit the usefulness of study results.

4. SUMMARIZE the science, address any conflicting science, and identify any information gaps.

a) Summarize the relevant and reliable science to create a coherent understanding of the situation.

If possible, accurately and succinctly summarize the science to create a coherent picture of the circumstances for internal and external stakeholders. This summary should include all relevant and reliable data identified during Step 3, as interpreted by professionals in the BLM and by partners with relevant knowledge. Review the management question(s) and objectives before developing this summary to ensure that you create a complete picture.

b) Acknowledge and deal with conflicting science.

During the decisionmaking process, the team will have to decide what information to use or not use. Research often yields contradictory or incomplete evidence. Stakeholders may also submit their own science information for consideration. Moreover, uncertainties frequently surround the critical issues that the BLM attempts to understand, especially given the highly complex nature of ecological and socioeconomic systems. Professional expertise in the BLM and external agencies will likely be needed to interpret and sort through the conflicting science.

Acknowledging, describing, and reflecting on conflicting evidence is important in gaining a better understanding of a topic. If the BLM is to maintain credibility and make sustainable and effective decisions, it is critical that you clearly establish what the tradeoffs are and document the process and criteria used for determining whether or not to use different science data. In general, the courts have upheld BLM decisions when this thought process is well-documented, transparent, and logical.

c) Identify any gaps in science that are relevant to the management question(s).

In most cases there will be information gaps. If the gaps are critical to understanding a situation, the BLM should acknowledge the gaps and base decisions on high-quality information that exists, after consulting **science partners** for advice. In other cases, acknowledging the gap may be sufficient. In all cases, you should communicate these gaps to **science partners** and encourage future efforts to fill the gaps.

5. APPLY your science-based conclusions to the management question(s) to decide the best course of action for achieving management objectives.

a) Document how the team used science to answer the management question(s), or (if applicable) how science was applied to different aspects of work processes listed on page 1 of these guidelines.

Document and communicate the process used to find, evaluate, and integrate the information. Cite scientific references in written documents to support statements, conclusions, and decisions. Document the role played by science in the ultimate decision by describing how it was considered among the other decision factors, and explaining reasons for any departures from the science. Doing so will increase the strength of the BLM's decisions.

b) Describe, consider, and document assumptions and uncertainties.

A key component of applying science is to acknowledge any limitations of the information itself when applied to the issue at hand. By clearly explaining the limits of the science documented during Step 3, the BLM can help establish understanding and practical expectations among stakeholders. These limits or gaps often highlight topics that need further research.

c) Communicate effectively throughout the process.

Communicate clearly with colleagues, partners, and stakeholders about how science can be used to address a particular management question or questions. This outreach will help ensure that high-quality information and technological tools are being used. An open and collaborative approach can help build trust with stakeholders and will reinforce the effectiveness of land management decisions based on science.

6. ASSESS how the application of science affected public support, the sustainability and effectiveness of the decision, confidence in the course of action selected, and further learning about the system and the effects of management actions. Plan any future assessments and/or develop and implement a monitoring plan.

Integrating science into land management is a long-term, iterative process. Therefore, monitoring remains foundational to help ensure that management actions follow the prescribed standards and guidelines (implementation), verify that desired results are achieved (effectiveness), determine if assumptions are sound (validation), and understand condition changes over time (status and trend). Monitoring, together with research, provides a basis for adaptive management. A monitoring plan should specify the goal, protocols, and criteria used, along with reporting formats and timelines. More guidance and tools regarding monitoring are provided in the BLM's Assessment, Inventory, and Monitoring (AIM) Strategy.

GLOSSARY

Conceptual Model – a visual representation of concept components, which helps people understand or simulate what the concepts represent and how the individual components link together.

Geospatial Data – data with a geographic (locational) component; in resource management, geospatial data are often used to display locations on a map and help managers visualize and assess needs.

Hypothesis – a proposed explanation, based on scientific method, for observable or measurable results.

Peer Review – evaluation of scientific, academic, or professional work by others in the same discipline; often performed to ensure that a scholarly work meets necessary standards before it is accepted or published.

Professional Judgment – a formal opinion or evaluation based on specialized knowledge, discernment, and/or comparison when forming a statement or reaching a conclusion; often conforms to technical or ethical standards of a discipline requiring intensive academic preparation; often includes both objective and subjective considerations.

Qualitative Data – data that approximate quality and are not based on standard scientific measures, such as descriptions or personal observations (e.g., habitat conditions are fair).

Quantitative Data – data that are measurable through standard scientific measures (e.g., sagebrush cover is 15 percent, with a confidence interval of +/- .05).

Science – the systematic study of the world based on knowledge learned through experiments and observations.

Scientific Method – the process of systematic observation, measurement, and experimentation to form, test, and modify scientific hypotheses.

Socioeconomic System – a combination of interacting social and economic factors.