Principles and Practices
of Integrating Science into Land Management

CASE STUDIES

The case studies in this series showcase examples of integrating science into Bureau of Land Management (BLM) decisions and activities. They highlight how science has helped the bureau successfully manage diverse programs across many geographical areas. These examples are not intended as programmatic guidance or policy direction; the application of science will be unique to each circumstance. Rather, they reflect the critical thinking and systematic, transparent process advocated by the BLM's "Principles and Practices of Integrating Science into Land Management: Guidelines." By using that document's recommended Checklist of actions, they demonstrate key principles and practices of effective science integration at work in a variety of fields and resource areas. Individual case studies differ in how they satisfy Checklist objectives, illustrating that the Checklist is intended to be a flexible tool—one that can be customized to meet the unique aspects and needs of different projects. Comprehensive details about individual studies (including related articles and publications) can be found on the BLM's Science in Practice Portal, through the BLM Library and the Alaska Resources Library & Information Services, and through links in these documents.

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.

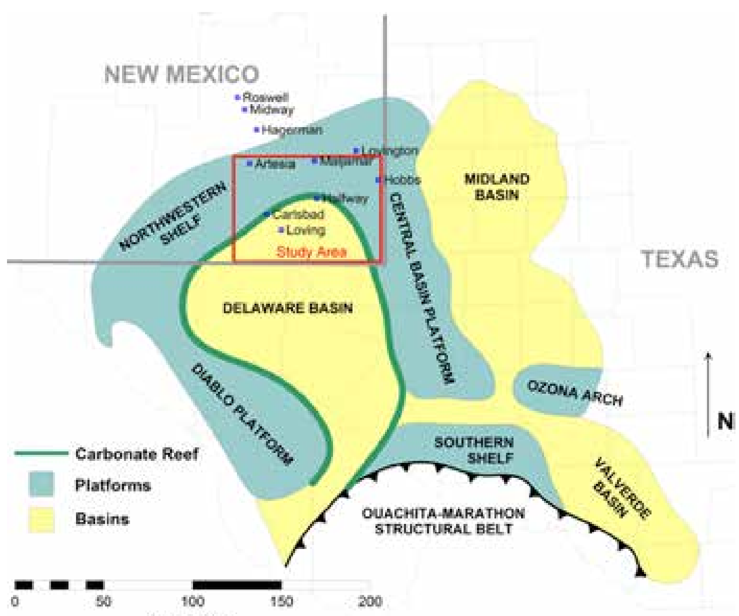
☐ **5. APPLY** your science-based conclusions to the management question(s) to decide the best course of action for achieving management objectives.

☐ **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.

Snapshot of Checklist actions from "Principles and Practices of Integrating Science into Land Management: Guidelines." The numbered actions in the case study below track with this list and show how the BLM implemented the principles and practices for integrating science into the BLM's work. Please refer to the full document for details.

CASE STUDY 4: Ensuring Water Sustainability for Resource Extraction in the New Mexico Permian Basin

1. DEFINE THE MANAGEMENT QUESTION(S). Advancements in directional drilling and well completion technologies have resulted in exponential growth in the use of hydraulic fracturing for oil and gas extraction. Within the Bone Spring Formation of the New Mexico Permian Basin, water demand to complete each hydraulically fractured well is estimated to average 7.3 acre-feet



Study area in southwest New Mexico.

(2.4 million gallons), resulting in an increase in regional water demand of more than 5,000 acre-feet per year. In addition, there are proposed changes in rules that govern the regulation and management of hydraulic fracturing on federal and Indian lands (40 CFR 3160). Both of these developments create concern about the region's ability to meet future water demand in a manner that fulfills the BLM's role of protecting human health and the environment while sustainably meeting the needs of the variety of water users and other stakeholders in the region. To address this concern, the BLM identified three key management questions:

- *How do the dynamics of the regional water supply and demand change under the different management, policy, and growth scenarios?*
- *What are the risks to water sustainability?*
- *How can the BLM mitigate those risks?*

2. FIND.

The team used a multidisciplinary approach to find available data and science, which included field and monitoring data, well logs, and technical and peer-reviewed reports. The team used this information to create an inventory of the water demand and supply in the region. Since no future surface water rights were available, it was essential to catalogue existing data such as current location, water production capacity, source formation, and depth to groundwater for each of the six groundwater sources delineated for the project. Collected data included oil, gas, and water well drilling logs from the New Mexico Office of the State Engineer as well as various hydrologic and geologic datasets and technical reports from other federal and state agencies. Extensive groundwater data were sourced through the Sandia National Laboratories of the Department of Energy (DOE), the lead organization on the project, and included pump tests and modeling results for the area in and around the DOE's Waste Isolation Pilot Plant nuclear repository that lies within the study area. In addition, the team obtained water demand data for agricultural, municipal, and industrial uses through the New Mexico Interstate Stream Commission, local irrigation and conservation districts and municipalities, and water marketers who sell water to oil and gas companies for hydraulic fracturing. The group also obtained reports and data from several other groundwater models that cover different sections of the study area. The data are being archived in a single electronic library and geodatabase for easy access by the BLM in the future.

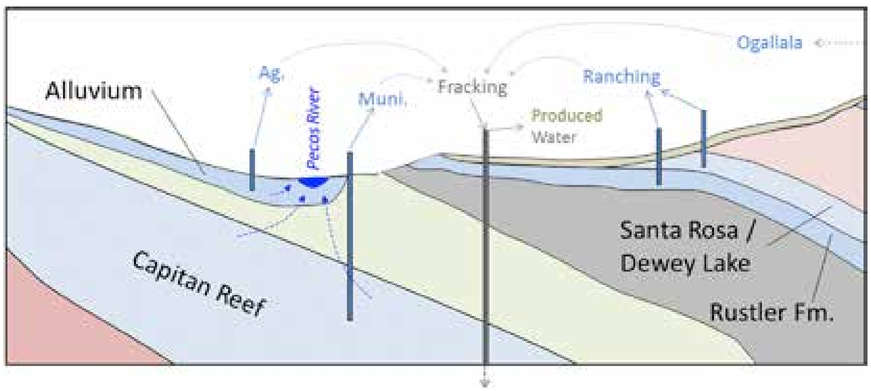
Team members Michael Schuhen (Sandia National Labs) and Patricia Blair (intern) perform field verification (top) and water sampling (bottom).

3. EVALUATE.

The scientific challenge was to bring together disparate data in a manner that exposed the temporal and spatial dynamics of the water supply sources in the context of increasing demands and changing policy and management scenarios. The group conducted field verification and testing to evaluate the existing data, ensuring that the data were accurate and up-to-date. Well owners were asked for permission to access their wells to take depth to groundwater measurements and to verify the drill-hole construction and its source formation to confirm information listed on the public well log. Water samples were also taken to characterize the source water quality and chemistry. These data were analyzed together with other data in the region to develop correlations between depth to water, water chemistry, and source formation. In return for their cooperation, well owners received a formatted report of the data and description of their well(s), along with a photographic record of the well condition. Several wells that were deemed as high value in terms of the usefulness of their data are currently being fitted with long-term monitoring equipment to monitor water levels over time. Field verification and testing will continue, serving the important roles of assuring data quality and improving data availability and understanding in the locations of greatest need.

4. SUMMARIZE.

The data were used to develop a conceptual model that describes the inflows, outflows, and storage mechanisms of water in the study area. Conceptual models provide a visual map of a dynamic system. This conceptual model shows the relationships between the surface and groundwater, the primary uses of the water from each source, and how each source may be used to support hydraulic fracturing. While simplistic in nature, the underpinnings of a conceptual model require a thorough understanding of the data and the relationships among the various components. Once created, the conceptual model becomes the foundation for mathematical models of system dynamics that provide decision support.



The conceptual model of the dynamics of the regional water supply and demand.

Beyond the conceptual model, historical and current field data are also being compiled in a Geographical Information System to produce maps of spatially varying parameters such as water levels and chemistry. These maps provide both a means of visualizing the data and a visual check on the data by allowing for quick identification of data outliers and/or anomalies. The maps and underlying data also provide a baseline against which future measurements and monitoring activity may be compared to identify trends that could be detrimental to the long-term management objectives for the region.

5. APPLY.

Application of the science is through the creation of a system dynamics (SD) decision support model. SD models are a type of numerical model that emphasizes the temporal dynamics between disparate but connected systems. An example of a simple SD model would be the dynamics between predator and prey, whereby the population of each group is dynamically dependent on the population of the other group. Here, the SD model will simulate the dynamics illustrated in the conceptual model based on the collected historical and field data. For this study, the key dynamic is the relationship between groundwater pumping and water levels and its long-term effects on water availability and cost. The model simulates increased drilling activity and water demand relative to each formation and water source to identify the areas, users, and formations that are most vulnerable, and it estimates the risk to water sustainability. The model also performs cost/benefit analyses for each management and future demand scenario. To ensure the model is performing correctly, the model is calibrated against historical data. Users and decisionmakers interact with the model through a graphical user interface that allows the user to change input parameters and see graphical representations of the output.

6. ASSESS.

The SD model simulates forecasted increases in drilling activity and water demand relative to each water source to identify areas that are most vulnerable and to estimate risk to water sustainability. The BLM can also use the model to produce cost/benefit analyses for using alternative sources of water, such as the treatment and use of saline groundwater or produced water from the oil extraction process. The model is grounded in the current level of scientific understanding of the region to provide results that are as representative as possible. Key to this is the model's ability to handle uncertainty. Users are able to input one or more uncertain parameters into the model in the form of a probability distribution function. The model then calculates probabilistic representations of the range of outputs that show the most likely outcome as well as the potential for extreme outcomes that may need to be avoided. This ability allows decisionmakers to explore and better understand the conditions that may render their actions harmful or ineffective, providing a means to manage the system adaptively as real-life conditions change over time. The model integrates the dynamics of the regional water supply and demand under different management, policy, and growth scenarios and allows decisionmakers to identify risks to water sustainability and develop alternatives to mitigate those risks.

MESSAGE FROM THE PROJECT TEAM: This project began because of a concern about the region's ability to meet future water demands, given that water demand for oil extraction and other uses is expected to grow. Studies to date have focused on individual aspects of the water demand and supply problem. Here the team was able to bring together diverse data sources to develop a collective understanding of the system across the region, informing and supporting decisionmakers. The output from this project is not meant to be a static report of the current state of affairs but rather a foundation that may be used and expanded as more information becomes available and the BLM's understanding of the system improves. Working with local well owners added a community outreach aspect to the project that continues to provide transparency and a mechanism for the research team to understand their needs and concerns. The integrated nature of this project is also reflected in the makeup of the research team, which consists of subject matter experts from the BLM, Sandia National Laboratories, private contractors, academia, and the U.S. Geological Survey (USGS).

Project Lead Dave Herrell (BLM)(right) oversees the opening of an abandoned well as part of the field verification process. Tim Evans (USGS) and Rudy Milligan (Intercontinental Potash) are also pictured.

For more information, contact: **Dave Herrell (Soil and Water Program Lead)**.

Photos by BLM staff unless otherwise noted.

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