Demonstration Study: Approaching Oil and Gas Pad Reclamation with Data Management: A Framework for the Future

Michael F. Curran, Benjamin J. Wolff, and Peter D. Stahl

Abstract: A database framework was constructed with the purpose of creating a restoration decision management tool by compiling oil and gas pad reclamation data to identify successful restoration practices. Pre-existing data were secured from public and private databases from two Wyoming production fields in the Greater Green River Basin: Jonah Infill and Moxa Arch. The framework includes tables for measurements of reclamation practices (e.g., soil handling methods and amendments, seeding mix and timing, and weed management), geographical and climate data (e.g., precipitation, slope, aspect, elevation, and temperature) and monitoring data (e.g., vegetation composition and structure along with soil analysis and grazing). Microsoft Access and ESRI ArcGIS were employed to build the reclamation database for consistent and reliable data storage, manipulation, and retrieval. Short-term goals of the project were to quantify disturbance and reclamation efforts and to evaluate the reclamation status of individual well pads. Long-term goals of the project are to deliver: (1) an operational framework to analyze and isolate trends leading to reclamation success and failure, (2) a strong decision management tool for limiting uncertainty and estimating associated risk under variable environmental conditions, (3) to evaluate regulatory standards for reclamation, and (4) to offer a flexible and sharable database that allows for additional data input from diverse sources. Database performance was found to be dependent on data consistency and validity. Querying populated data along with unifying imported data has revealed multiple strengths and weaknesses with the database framework.

Additional Keywords: environmental decision management, database

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Introduction

The amount of proven recoverable natural gas below the surface of Wyoming is 36.75 trillion cu ft, leaving Texas as the only state in the US with more subsurface, recoverable gas (PAW 2012). The large amount of gas available in Wyoming has helped economic growth in the state and has resulted in an average of 41% annual growth in new wells throughout the state since 1998, a trend expected to continue in the near future (Anderson and Coupal, 2009). As production fields continue to grow, surface land disturbance will continue to increase.

As the amount of land being disturbed by oil and gas drilling increases, land-use values (grazing and wildlife habitat) and watershed protection provided by the natural landscape may decline. Many areas where oil and natural gas are extracted in Wyoming are considered critical habitat areas for wildlife species such as sage grouse, mule deer, antelope, and elk. The continuance of these species depends heavily on vegetation provided in their habitat and, therefore, it is essential for vegetative restoration processes to be well understood (Holechek, 2006, Winslow et al., 2009). Natural resource development may be curtailed in the future if wildlife habitat and ecological degradation is not mitigated with positive and effective reclamation practices (Stahl and Williams, 2010). While there have been many isolated studies to examine seeding and soil handling practices on oil and gas pads, there is much lacking in terms of understanding large-scale restoration efforts of industry practitioners (Hild et al., 2009).

For this reason, a database framework has been created to house oil and natural gas pad reclamation data from public and private sources over a large scale. The database currently holds disturbance and reclamation information over eight years (2005-2012) of BP America Production Company (BP) well pads from two Wyoming production fields in the Greater Green River Basin: Jonah Infill and Moxa Arch. Keeping in mind the end goal of this project, this database was designed as an operational framework to analyze and isolate trends leading to reclamation success and failure and can serve as a decision management tool for future reclamation projects. In addition, flexibility, shareability, and scalability were key ingredients from the initial design, allowing for data input from diverse sources. The objective of this paper is to outline the construction and design processes of the database framework and provide examples of how the database can be implemented.
**Methods**

Reclamation data were secured from public and private databases across two Wyoming production fields: Jonah Infill and Moxa Arch in the Greater Green River Basin. Both areas are comprised of sagebrush-steppe habitat, are semi-arid, and experience long, cold winters. Currently, the Jonah Infill dataset consists of 116 well-pad locations, while the Moxa Arch dataset consists of 630 well-pad locations. Oil and gas pad reclamation practice data and soil and vegetation monitoring data were obtained from BP, Conservation, Seeding, and Restoration, Inc. (CSR), and the Jonah Infill Data Management System (JIDMS) over the span of eight years (2005-2012). Historic and geographic data for each site were obtained from the Wyoming Oil and Gas Conservation Commission (WOGCC). Climate data, including precipitation and temperature, were obtained from Oak Ridge National Laboratory’s (ORNL) DAYMET database. In areas where soil surveying has been completed, data tables from Natural Resource Conservation Service’s (NRCS) Soil DataMart and Soil Survey Geographic Database (SSURGO) were linked to our database.

Microsoft Access and ESRI ArcGIS were employed to build the reclamation database for consistent and reliable data storage, manipulation, and retrieval. Since Microsoft Access has a 2GB storage capacity, each production field was built with the same framework but kept in separate databases. The framework includes tables for measurements of reclamation practices (e.g., soil handling methods and amendments, seeding mix and timing, and weed management); historic well-pad data (e.g., spud date, additional disturbances, and plugged and abandoned date); geographical and climate data (e.g. precipitation, slope, aspect, elevation, and temperature); and monitoring data (e.g., vegetation composition and structure along with soil analysis and grazing). After completion of data input, all databases were checked for the eight characteristics of quality data according to Hoffer, et al. (2009): data accuracy, data consistency, data uniqueness, data completeness, data timeliness, data currency, data conformance, and referential integrity.

The final database framework consists of one master table which is linked by a one-to-many connection to 11 child tables, three of which have look-up tables linked to them (Fig. 1).
Figure 1. Database framework and relationships between tables are depicted. Notice that in the master and all child tables, API is used as the primary key. Tables in yellow represent monitoring tables, tables in green represent reclamation practice tables, tables in blue are geographic tables, and tables in pink are look-up tables.

The master table contains historic well data, including the American Petroleum Institute permit number (API) for the initial well on a pad, well operator, spud date of initial well, plugged and abandoned date for the final operational well, latitude and longitude coordinates, elevation, state and county, and BLM regulatory office in charge. Well pad API numbers do not change over time, and are used as unique identifiers for each pad, serving as the primary key in the master and all related child tables. Child tables are broken into three groups: (1) monitoring data, (2) geographic data, and (3) reclamation methods data. Four child tables are used to describe monitoring data: (1) one table contains quantitative vegetation cover measurements for all well pads and their undisturbed reference sites; (2) one table contains binary data showing whether or not sites passed WDEQ requirements; (3) one table contains binary data showing whether or not sites passed BLM reclamation requirements; and (4) one table shows results of any soil sampling done on well pads. Two child tables are used to provide additional geographic data: (1) one provides slope and aspect data provided by a 10-meter resolution digital elevation map (Gesch 2007, Gesch et al., 2002), and (2) one provides NRCS soil map units where applicable. Five child tables were used to house reclamation practice data: (1) a seeding table contains information about seed mix used, seed timing, and seed methodology; (2) a soil amendment table contains information about any type of
soil amendment (e.g., sulfur or gypsum) used including the rate, acreage applied to, and timing; (3) a fertilizer table contains information about any fertilizers or compost teas including rate, acreage applied to, and timing; (4) a disturbance table contains information about additional disturbances to wells since the reclamation practices first initiated; and (5) an herbicide table contains information related to herbicides sprayed on site, including herbicide used, rate, acreage applied to, and timing. The seeding, fertilizer, and herbicide tables all have look-up tables linked to them to include specific information to elaborate upon what is held in the child tables themselves (e.g., the seeding look-up table includes the pure live seed per acre and origin for each species included in a given seed mix). Since the master table and child tables are linked through the API number, this database can be considered to be a relational database with a queryable nature. This database framework enables particular geographical, climatological, reclamation practices, or monitoring data to be isolated or grouped together in queries in effort to identify trends leading to reclamation success or failure. Since the database also contains vegetation monitoring data from undisturbed reference sites, queries can be run to compare reclamation sites to undisturbed sites or to isolate information about reference sites in different geographical locations.

Results

Simple queries have revealed inconsistencies in monitoring methods and timing across years in each field. For example, modified Daubenmire squares were used to monitor sites in the Jonah Infill in 2008 and 2009, whereas in 2010 and 2011 sites were monitored using a line-transect method. In 2011, all sites in the Jonah Infill were monitored between July 6 and July 10, whereas in 2010 most Jonah sites were monitored between June 1 and June 7.

Other simple queries have allowed us to quantify reclamation efforts in each field. For example, in 2007, 10 well pads with a total of 60 acres (24.3 ha) of disturbance were seeded with an early seral mix and 20 well pads with a total of 75 acres (30.3 ha) of disturbance were seeded with a late seral mix in the Jonah Infill. Using our seeding look-up table, we are able to determine the amount of seed per species used in each seed mix used for reclamation efforts in the Jonah Infill (Table 1).
In 2007, two seed mixes were used in the Jonah Infill. Early Seral mix was seeded on 60 acres (24.3 ha) across 10 well pad locations, while Late Seral mix was seeded on 75 acres (30.3 ha) across 20 well pad locations. The information from our seeding look-up table allows us to rapidly find information about each seed mix.

<table>
<thead>
<tr>
<th>Species Early Seral 2007</th>
<th>PLS/Acre</th>
<th>Species Late Seral 2007</th>
<th>PLS/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluebunch Wheatgrass</td>
<td>2.00</td>
<td>Gardner Saltbush</td>
<td>4.00</td>
</tr>
<tr>
<td>Needle and Thread</td>
<td>3.00</td>
<td>Wyoming Big Sagebrush</td>
<td>1.00</td>
</tr>
<tr>
<td>Western Wheat</td>
<td>3.00</td>
<td>Rubber Rabbitbrush</td>
<td>0.50</td>
</tr>
<tr>
<td>Sandberg Bluegrass</td>
<td>0.75</td>
<td>Needle and Thread</td>
<td>1.00</td>
</tr>
<tr>
<td>Indian Ricegrass</td>
<td>3.00</td>
<td>Indian Ricegrass</td>
<td>2.50</td>
</tr>
<tr>
<td>Bottlebrush Squireltail</td>
<td>1.00</td>
<td>Bluebunch Wheatgrass</td>
<td>2.00</td>
</tr>
<tr>
<td>Blue flax</td>
<td>1.00</td>
<td>Black Sage</td>
<td>0.40</td>
</tr>
<tr>
<td>White Yarrow</td>
<td>0.20</td>
<td>Blue Flax</td>
<td>0.75</td>
</tr>
<tr>
<td>Penstemon Strictus</td>
<td>0.50</td>
<td>White Yarrow</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Penstemon Strictus</td>
<td>7.15</td>
</tr>
</tbody>
</table>

More complex queries have revealed inconsistencies in regulatory requirements between and amongst agencies. In 2011, 0 of 116 sites in Jonah were considered to pass the Jonah Interagency Office’s (JIO) reclamation criteria, while 67 sites passed the Wyoming Department of Environmental Quality’s Storm Water Pollution Prevention Plan (SWPPP). In the Moxa Arch, 317 of 630 sites passed Kemmerer BLM reclamation criteria, while 340 passed WDEQ SWPPP criteria. Queries to evaluate JIO versus Kemmerer BLM standards were conducted and revealed that all 317 sites passing Kemmerer BLM requirements in Moxa Arch would be considered failures against JIO criteria, while 63 sites in Jonah would be considered successful against Kemmerer BLM criteria.

Statistical analyses are currently being performed and evaluated to determine which reclamation practices and combinations of reclamation practices are leading to the various levels of reclamation success in given areas in wet and dry years. Seeding, soil amendments, fertilization, and weed management practices are being isolated by themselves and grouped with one another before being examined alongside monitoring, geographic, and climate data in an effort to identify best management practices. Analyses are also being performed to understand successional patterns on reclaimed oil and natural gas pads. However, trend analysis has proven to be difficult over the short time period our database accounts for, especially because monitoring timing and technique vary amongst years.
Discussion

The framework of this database system is sound and will allow for advancements in the field of oil and gas pad reclamation in the future as more data are gathered over longer time periods. The framework is flexible and sharable to allow for plenty of additional data from diverse sources. Although this framework has strong potential to be used as a decision management tool in the future, we have found several weaknesses in the database that need to be addressed moving forward. Currently, the three most limiting factors to our database are: (1) the storage capacity of Microsoft Access, (2) the minimal amount of reclamation practice data, and (3) inconsistent monitoring data.

Since Microsoft Access is compatible with larger databases, such as SQL Server, the storage capacity problem can be eliminated by upgrading to a larger server, at which point our databases can be combined into a single database and allow input of mass amounts of additional data entry from diverse sources. Currently, a multi-tiered database system is being developed to allow for electronic forms to be used to populate the database on the front-end, while a password protected back-end will ensure data quality and protection. The use of forms on the front-end will save time and money associated with data entry and labor, as well as improve data accuracy by eliminating the multiple steps that are presently being used to get data from the paper into the database.

Combining our databases into a single database and increasing the amount of reclamation practices being used by additional sources will allow for better understanding of best management practices across geographic space. By including reclamation practice and monitoring data from additional production fields, we will also increase our understanding of how different climates, soil types, and land forms affect reclamation success. While this database currently focuses solely on oil and natural gas pad reclamation, the framework allows for reclamation data from other projects (e.g., roads, pipelines, coal mines) to be added to the database system. Although this database has focused on reclamation, it is capable of incorporating wildlife data if geospatial information is available for certain individuals or populations. Additionally, successional trends on drastically disturbed sites will be better understood as the temporal scale of this database system increases.

More studies need to be conducted to improve monitoring techniques and timing. Without consistent monitoring techniques and timing, our ability to perform statistical analyses and identify
best management practices is limited. Inconsistent monitoring timing is, at least in part, due to lack of man-power and the vast spatial scale of these oil and gas fields. The Wyoming Reclamation and Restoration Center at University of Wyoming (WRRC) is currently attempting to develop a predictive model to aid in determining best monitoring timing to capture data during the peak growth stage of a given growing season. This may prove beneficial for regulatory agencies, operators, and reclamation contractors to schedule monitoring during periods best suited to fit current regulatory criteria. It may also guide monitoring to be conducted at times outside of peak growing season to account for periods of the year that are paramount to wildlife.

While the database currently contains only vegetation density and richness measurements, vegetative structure measurements have not been thoroughly studied (Hild et al., 2009). Incorporating this type of data along with reclamation practice, climate, and geography information may aid in future decision making by bettering our understanding of best reclamation management practices in specific areas. Identifying areas where reclamation can be achieved using proper management practices versus areas where reclamation success is difficult or improbable to occur can also be used as risk management in the future. For example, determining areas likely and unlikely to achieve reclamation success prior to disturbance in large natural gas fields can be a useful risk management tool in critical wildlife habitat areas where future land disturbance decisions can be proactive to prevent development on land where reclamation is unlikely to mitigate disturbance in a reasonable time.

During a time when natural resource exploration and development are increasing at record levels, our ability to understand and identify best management practices of land reclamation is paramount. With improved data collection, additional data, and more time, the framework of this data management system has potential not only to enhance our understanding of reclamation, but also to serve as a decision management and risk assessment tool for operators, reclamation contractors, and regulatory agencies. The flexible and sharable nature of our database framework allows for increased data from additional sources to be input rapidly and immediately. Increasing the data content in our database system will enhance our overall understanding and ability to quantify the amount of land disturbance and reclamation efforts, as well as evaluate the status of reclamation over a broad scale.
Since the inception of the database, the United States Fish and Wildlife Service (USFWS) have demonstrated interest in this database and will be using it to evaluate industry-wide reclamation efforts when making their listing decision for the Greater sage grouse as an endangered species. Currently, thirteen operating oil and natural gas companies have shared or have agreed in principle to share reclamation data with WRRC. After thoroughly examining all data, additional tables may be added to the current framework if necessary. The contributions from all companies will broaden our knowledge of reclamation and enhance future management decisions.

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**Literature Cited**


