UPDATE TO
REASONABLE FORESEEABLE
DEVELOPMENT SCENARIOS
FOR OIL AND GAS ACTIVITIES
ON FEDERAL LANDS
IN THE
ROCK SPRINGS FIELD OFFICE,
WYOMING

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AND
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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
WYOMING STATE OFFICE
RESERVOIR MANAGEMENT GROUP

FINAL REPORT
February 26, 2007
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Update to Reasonable Foreseeable Development Scenarios for Oil and Gas Activities on Federal Lands in the Rock Springs Field Office, Wyoming
February 26, 2007

Prepared By:

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Introduction
The Bureau of Land Management determined a need to update the oil and gas Reasonable Foreseeable Development Scenario for the Rock Springs Field Office, Wyoming. We have gathered resource information on the potential magnitude and trend of future oil and gas activity so that staff of the Field Office can analyze associated management activities, future decisions, and environmental impact. The Field Office will use this information to update the cumulative analysis previously prepared for the EIS for the Green River Resource Management Plan for the next five years (2007-2011).

Operator Input
To aid our analysis for the Reasonable Foreseeable Development Scenario, we requested that operators active in the Rock Springs Field Office area provide their projections for the location and intensity of future oil and gas exploration and development activity for the 2007-2011 time period. We included two copies of a map of the planning area for their use. We asked them to mark townships with their 2007-2011 projection of potential for coalbed gas drilling activity on one map and potential for other types of oil and gas drilling activity (conventional oil and gas activity) on the other map. For consistency we asked them to use the following definitions when projecting 2007-2011 activities and marking those areas on the maps we provided:

- High - over 25 wells per township
- Moderate – 5 to 25 wells per township
- Low - less than 5 wells per township
- None – no drilling activity anticipated.

We received written, e-mail, and/or verbal responses from 15 companies active in the Field Office area. Follow-up calls were made to some companies to further clarify their submittals. These companies have accounted for 84 percent of the conventional wells and 74 percent of the coalbed gas wells drilled in the past five years (01/01/2002 to 01/01/2007).

Responses appeared to be tied to each company’s thoughts on areas and plays within the Field Office where they had a specific interest in developing an existing productive area or exploring for new hydrocarbon resources. In addition to marking the supplied maps, some companies also projected the total number of coalbed gas and/or conventional oil and gas wells that could be drilled in their areas of interest. Most projections seemed to assume high commodity prices, ample rig availability, the ability to obtain necessary drilling budgets, and in some exploratory cases, the ability to define new reservoirs and develop successful completion practices for presently sub-economic resources. A limited amount of information relative to potential deep drilling activity (drilling to depths greater than 15,000 feet) and associated infrastructure (e.g. future pipeline needs) was also submitted.

The companies responding to our request for information were:
• Anadarko E&P Company LP
• BP America Incorporated
• Cabot Oil & Gas Corporation
• Davis Petroleum Corporation
• EnCana Corporation
• EOG Resources Incorporated
• GMT Exploration Company
• Kodiak Oil & Gas Corporation
• Mak-J Energy Partners
• Pacific Energy
• Pinnacle Gas Resources Incorporated
• Questar Exploration and Production Company
• Shell Western Exploration & Production Incorporated
• Warren E&P Incorporated
• XTO Energy Incorporated
• Yates Petroleum Corporation.

Projects Affecting Future Development

Environmental Documents
A number of oil and gas development projects previously or currently being analyzed under NEPA within the Field Office area were reviewed. Those projects previously analyzed still have remaining well locations that may yet be drilled. Pending projects show where additional future drilling activity is likely to occur. Information on these projects helped in preparing maps to show future locations of activity. The information was also considered when projecting the total number of wells that could be drilled in the next five years.

Conventional oil and gas projects reviewed include:

• Desolation Flats
• Hiawatha Regional Energy Development
• Little Monument Natural Gas
• Monell Enhanced Oil Recovery
• Stagecoach Draw.

Coalbed gas drilling projects include:

• Bitter Creek Shallow Oil and Gas
• Copper Ridge Shallow Gas
• Lower Bush Creek CBM Exploratory Pilot
• Pacific Rim Shallow Gas.
**Federal Unit Agreements**

A Federal unit agreement is a contract between the Federal Government and mineral interest owners that hold leases over a potential oil and gas reservoir or over oil reservoirs which are candidates for enhanced recovery. Federal units are intended to facilitate the orderly and timely exploration, development, and operation of multiple leases under a single operator. Units may overlie a portion of, or an entire geologic structure. An approved agreement establishes performance obligations, promotes the exploration of unproven acreage or logical enhanced recovery procedures, and permits controlled development of the unit area. This process stimulates exploration and/or development of Federal lands and encourages the drilling of the optimum number of wells needed to maximize resource recovery.

Federal oil and gas leases are incorporated into 74 active conventional oil and gas unit agreement areas that lie wholly or partially within the Field Office boundary (See attached map “Potential for Conventional Drilling Development 2007-2011”). Numerous other unit agreements have been approved but have since terminated. Active units encompass lands totaling approximately 676,252 acres in the Field Office area, or approximately 13 percent of the total Field Office area. Three of the 74 active units are pending, while all others are approved. Most of these Federal unit agreements were initially approved as exploration tools to investigate non-producing parts of the Field Office area. Some have found and developed oil and gas and are now considered to be producing units. Others are still in an exploratory stage of development. The Monell (Townships 18 and 19 north, Range 99 west) and Henry Enhanced (Townships 13 and 14 north, Range 113 west) units are the only units approved as secondary units in order to enhance the recovery of the oil resource.

Twenty-five companies operate the 74 active conventional oil and gas unit agreement areas. Companies operating more than one unit are; Questar/Wexpro (12 units), EnCana Corporation (11 units), Anadarko E&P Company LP (10 units), Cabot Oil & Gas Corporation (six units), EOG Resources Incorporated (five units), Chevron USA (three units), Whiting Oil and Gas Corporation (3 units), BP America Incorporated (three units), Kodiak Oil and Gas Corporation (two units), XTO Energy Incorporated (two units), Crown Oil & Gas Company Incorporated (two units) and Black Jack Oil Incorporated (two units). Thirteen other companies operate one unit each.

Federal oil and gas leases are incorporated into seven coalbed gas unit agreement areas that lie wholly within the Field Office area (See attached map “Potential for Coalbed Gas Drilling Development 2007-2011”). Active coalbed gas units encompass lands totaling approximately 154,796 acres in the Field Office area, or approximately three percent of the total Field Office area. Yates Petroleum Corporation operates three units and Anadarko E&P Company LP and Warren E&P Incorporated each operate two units.

**Publications**

Issues of The Rocky Mountain Oil Journal were used to indicate were oil and gas drilling activity has occurred in recent years and to point toward areas of the Field Office that might see additional exploration and development activity. This weekly publication
reports on successful and unsuccessful drilling projects and provides information on industry plans for additional exploratory and development work in the Rocky Mountain region.

Recently the U.S. Geological Survey revised their method of preparing oil and gas resource assessments. They used this new method to update their previous quantitative estimate of the undiscovered oil and gas resource for the Southwestern Wyoming province (U.S. Geological Survey; 2002, 2004, 2005, and 2006). We used this new assessment to help in better understanding the potential undiscovered technically recoverable oil and gas resources lying within the Field Office area and the potential for future development of these resources.

**Recent Historical Drilling Data**

A total of 554 conventional and coalbed gas wells were spud within the Field Office boundary in the past five years (See attached maps “Potential for Conventional Drilling Development 2007-2011” and “Potential for Coalbed Gas Drilling Development 2007-2011”). About 62 percent of these wells were drilled on Federal lands, with the other 38 percent drilled on fee or state lands.

**Conventional Activity**

In the past five years 446 conventional wells have been spud within the Rock Springs Field Office area (See attached map “Potential for Conventional Drilling Development 2007-2011”). Of these wells, 84 percent were drilled by operators who have provided input into this analysis. Present status of these wells is:

- 271 (60.8 percent) gas
- 44 (9.9 percent) oil
- 43 (9.6 percent) spud but not yet completed
- 39 (8.7 percent) abandoned
- 36 (8.1 percent) injector
- 10 (2.2 percent) service
- 3 (0.7 percent) junked and abandoned.

Only 10 percent of the wells spud and completed in the last five years have been abandoned. The high success rate (90 percent) in the Field Office area is mainly due to the fact that almost all completed wells were drilled as field development wells. Wells are abandoned because:

- they were “dry”—no hydrocarbons were encountered, or hydrocarbons were not present in economic quantities
- they initially were determined to be capable of producing hydrocarbons, but they became uneconomic to produce at a later date
- mechanical difficulties within a borehole prevented the operator from reaching the target formation or establishing production once total depth was reached.
Operators
There were 33 active operators within the Field Office area in the past five years. The top five operators (Anadarko E&P Company LP, EnCanna Corporation, Questar/Wexpro, BP America Incorporated, and XTO Energy Incorporated) were responsible for the spud of 68 percent of the total wells drilled. These five operators were among those providing information for this analysis. Eleven operators only drilled one well within the Field Office area in the past five years.

Producing Intervals
Wells spud and successfully completed in the last five years have been productive from 14 lithostratigraphic units. From youngest to oldest, productive completions have been made to the:

- Lance Formation - 79 wells
- Lewis Shale - 23 wells
- Almond, Ericson, Rock Springs, and Blair formations of the Mesaverde Group - 116 wells
- Baxter Shale - 15 wells
- Frontier Formation - 104 wells
- Bear River Formation/Dakota Sandstone - 20 wells
- Nugget Sandstone - 1 well
- Weber Sandstone - 8 wells
- Madison Limestone - 1 well.

Some wells produce from more than one formation. Most producing wells are considered to be gas wells. One Dakota Sandstone and two Frontier Formation wells are considered to be oil wells. The other 41 oil wells produce from the Almond Formation. The Lance Formation producing wells were primarily drilled in the Jonah Field area. The Frontier and Bear River/Dakota formation producing wells were primarily drilled in the northern and southern Moxa Arch areas and along the Rock Springs Uplift, which trends north-south in the central part of the Field Office area. All other producing units were primarily drilled in the eastern portions of the Field Office Area.

Depths
Wells spud and completed in the past five years have been drilled over a large depth range, from only 130 feet to 18,650 feet. In the Jonah Field area well depths range from about 11,800 to 13,000 feet and most wells are productive. On the southern Moxa Arch area new well depths range from 870 to 14,140 feet, but production has only occurred in the 10,400 to 13,500 foot range. In the northern Moxa Arch area new wells have been drilled from 4,084 to 11,794 feet. Production has occurred in the 6,230 to 10,654 foot range, with the majority of wells producing between 8,000 and 10,000 feet. In the Hay Reservoir area new wells have been in the 10,250 to 12,425 foot range and production has occurred from 8,298 to 11,966 feet.
In the Hiawatha area new wells have been drilled between 7,030 and 15,163 feet. Production has occurred between 4,656 and 11,316 feet. The Mesaverde Group and Almond Formation have been productive over shallower intervals and the Frontier Formation and Dakota Sandstone have been productive over the deeper intervals in this area.

At Monell, on the east side of the Field Office area, new wells have been drilled between 4,309 and 5,860 feet. Production has occurred between 4,027 and 5,016 feet, with production only coming from the Almond Formation.

Seven new wells can be classified as “deep wells” (vertical depth is greater than 15,000 feet). All new deep wells were drilled in Table Rock Field (Township 18 north, Range 98 west). All wells are gas producers in the Nugget, Weber, or Madison formations and produce in the 17,114 to 18,038 foot range.

**Directional Drilling**

Oil and gas wells traditionally have been drilled vertically throughout the Field Office area. Depending on subsurface geology, technologic advances now allow operators to deviate boreholes by anywhere from a few degrees to completely horizontal. Directional and horizontal drilling uses deviated boreholes to enable operators to reach reservoirs that are not located directly beneath the drilling rig, or to allow the borehole to contact more of the reservoir. Directional boreholes may be specifically deviated or allowed to "drift" naturally updip on the flanks of a geologic structure. In some cases directional drilling may be used specifically to protect surface resources.

Drilling and completion costs for directional and horizontal boreholes are higher than for conventional vertical boreholes. The risk of losing all or parts of the deviated or horizontal borehole due to technical drilling difficulties is also higher. Because of these factors, industry generally prefers not to drill directional or horizontal boreholes unless other concerns make this option necessary. An exception to this general rule can be made if industry can determine that reservoir conditions are suitable for using this type of borehole to contact more of the reservoir (increase drainage area) and increase productivity. In this case, the potential for increased productivity may offset the additional drilling costs and risks, making this type of borehole the preferable drilling option.

Eustes (2003) has identified a number of items that have the potential to raise drilling costs for these types of wells. Additional drilling costs can occur when:

- special directional drilling equipment (mud motor, measurement while drilling tools, and extra personnel) is required
- a larger rig is needed to drill, which would also require larger mud pumps
- casing and tubing design needs modification to overcome problems with ovality and bending stress
- borehole risk is higher due to tectonic stresses
- slower rate of penetration requires more drilling time on the location and/or
• torque and drag on borehole equipment is greater.

In recent years directional well drilling has increased within the Field Office area. In the past five years 99 directional wells (22 percent of total conventional wells) were spud. These locations are concentrated in three parts of the Field Office: the Northern Moxa Arch, the Jonah field, and the southeast part of the Field Office area. Only one directional well has been drilled outside of these three areas.

In the Northern Moxa Arch area, the successful productive completion rate of directional boreholes has been 95 percent for the 22 wells spud. All of these producing wells make gas and produce from the Frontier Formation, with a few wells also completed in the Baxter Shale. These wells were drilled from 7,847 to 9,133 feet in true vertical depth.

The part of Jonah Field in the Field Office area has had a 96 percent successful completion rate for the 55 directional boreholes spud. One directional well had to be “junked and abandoned” due to borehole complications encountered during the drilling or completion process. All producing directional wells make gas and produce from the Lance Formation. These wells were drilled from 10,889 to 12,956 feet in true vertical depth.

In the southeast part of the Field Office area, the successful productive completion rate of directional boreholes has been 100 percent for the 22 wells spud. Most of these wells make gas. Two wells are oil wells, and one has been completed as an injection well. Wells produce from seven different lithostratigraphic units (Lance, Lewis, Mesaverde, Baxter, Frontier, Dakota, and Weber). These wells were drilled from 5,168 to 18,400 feet in true vertical depth. Only one well in the Field Office area has been directionally drilled to greater than 15,000 feet.

The high success rates in these areas are mainly due to the fact that almost all wells drilled have been field development wells. Industry prefers not to drill wildcat wells directionally, since details of geology and potential reservoir characteristics are not yet known and directional drilling adds an extra element of risk and increased costs.

In most wells, the borehole should be vertical when it passes through the reservoir. An S-shaped borehole profile is used rather than the usual slant profile. To drill an S-shaped borehole a well is started vertical, it is then directed into a slant or angled portion until it reaches a position above the target reservoir, and is then brought back to vertical before the target reservoir is reached. A vertical orientation is maintained through the target reservoir until total depth is reached.

In southwestern Wyoming, industry does not appear to have used horizontal boreholes to avoid sensitive surface features or areas of environmental concern. Other types of directional boreholes are used to meet these concerns, as discussed above. Horizontal borehole drilling and completion costs are higher than those for a vertical or other type of directional borehole. A number of reasons to drill horizontal boreholes have been identified by Eustis (2003). They are:
• ability to intersect many fractures
• minimize premature entry of water or gas into the borehole
• increased drainage area
• ability to intersect layered reservoirs at high dip angles
• improve coal gas production
• increase productivity
• improve injection of water, steam, and etc.

The benefits from increased production can, in some cases, outweigh the added cost of drilling this type of well.

Horizontal boreholes have not been commonly used within the Field Office area. Horizontal boreholes appear to have only been used to contact more of the reservoir (increase drainage area), which increases productivity. Ten horizontal wells have been spud in the Field Office area. Nine wells have been completed and each has been successful.

**Coalbed Gas Activity**
In the past five years (01/01/2002 and 01/01/2007) 110 coalbed gas wells have been spud within the Field Office area (See attached map “Potential for Coalbed Gas Drilling Development 2007-2011”). Of these wells, 74 percent were drilled by operators who have provided input into this analysis. Present status of these wells is:

- 30 (27.3 percent) producing gas
- 64 (58.2 percent) shut-in or temporarily abandoned gas
- 7 (6.4 percent) “notice of intent” or “subsequent report” of abandonment filed
- 7 (6.4 percent) spud but not yet completed
- 1 (0.9 percent) “notice of intent” for disposal
- 1 (0.9 percent) monitoring.

At present, only 6.4 percent of the wells are in the abandonment process. Operators in this area are still in the initial stages of trying to determine the economic viability of the coalbed gas play. Many completed wells have not yet produced any gas. All coalbed gas wells have been drilled with vertical wellbores.

**Operators**
There were seven active coalbed gas operators within the Field Office area in the past five years. They were:

- Warren E&P Incorporated – 34 wells
- Infinity Oil & Gas of Wyoming – 27 wells
- Anadarko E&P Company LP – 24 wells
- Pinnacle Gas Resources Incorporated – 14 wells
- Yates Petroleum Corporation – 7 wells
• Shell Western Exploration & Production Incorporated – 2 wells
• El Paso Exploration & Production Company – 2 wells.

Producing Intervals
Coalbed gas wells spud and successfully completed in the last five years have been productive from three lithostratigraphic units. Lance Formation coals have been completed in three wellbores, Fort Union Formation coals (including the Big Red and Tierney coals) have been completed in 19 wellbores, and Mesaverde Group/Almond Formation coals have been completed in 79 wellbores. The productive wells with Fort Union Formation coals are in the northeast and north-central parts of the Field Office area. The Lance and Mesaverde/Almond coals are productive in wells in the southeastern part of the Field Office area.

Depths
Coalbed gas wells spud and completed in the past five years have been drilled over a depth range of 878 feet to 7,890 feet. The Fort Union Formation coalbed gas wells in the northeast part of the Field Office area have well depths in the range of 878 to 6,410 feet, with the top of the first productive coal ranging from 868 to 5,196 feet. The two Fort Union Formation coalbed gas wells in the north-central part of the Field Office are 7,307 and 7,875 feet in depth, with the top of the first productive coal at 5,644 and 5,667 feet.

In the southeast part of the Field Office, total depths range from 1,928 to 7,890 feet. The Lance Formation coalbed gas wells range from 1,779 to 3,150 feet in depth, with the top of the first productive coal ranging from 1,049 to 2,716 feet. Mesaverde Group/Almond Formation wells range from 1,928 to 7,890 feet, with the top of the first productive coal at 1,336 to 6,190 feet.

Projections of Future Activity
Two maps were prepared to show our assessment of the potential for conventional oil and gas and coalbed gas exploration and development activities for the next five years (see attached maps “Potential for Conventional Drilling Development 2007-2011” and “Potential for Coalbed Gas Drilling Development 2007-2011”). We used the same definitions for estimates of potential future activity that were used when we asked for operator input into this analysis.

Each map was prepared by first outlining areas of the Field Office where an assessment of future potential would not be made. These areas include the Jack Morrow Hills (a Resource Management Plan amendment was recently made for this area) and areas that would be unavailable for oil and gas leasing and development (wilderness study areas and the mechanically mineable trona area).

Map of Potential for Conventional Drilling Development 2007-2011
Operator input was first considered and accepted unless it was in conflict with submittals from other operators or other information was available to indicate a certain township should have a different potential designation than that submitted. All Federal
conventional unit agreements and all conventional wells spud in the past five years were placed on this map to help see where recent activities have occurred and where they would be most likely to occur in the next five years. Environmental document information, published data, and our knowledge of the region were all useful in helping determine where future activities could likely occur. These types of data were especially useful for making determinations of potential for future activities in townships that operators did not indicate a potential. The Southwest Wyoming Province boundary (U.S. Geological Survey; 2002, 2004, 2005, and 2006) was used on the northern part of the Field Office area to separate areas of no potential for development from other areas with some potential for development.

Our analysis has indicated that minimum activity levels for the next five years (2007-2011) will be comparable to the number of wells drilled in the past five years (446 wells). We estimated a maximum number of wells that could be drilled by assigning an average number of wells drilled per township for each category of potential (high, moderate, and low). We assigned an average of 35 wells drilled per township in areas of high development potential, seven wells per township in areas of moderate potential, and one well per township in areas of low potential. When these averages were calculated for all lands assigned to each category of development potential, a total of 693 new wells was estimated.

Map of Potential for Coalbed Gas Drilling Development 2007-2011
Operator input was first considered and accepted unless it was in conflict with submittals from other operators, clarified in later conversations with operators, or other information was available to indicate a certain township should have a different potential designation than that submitted. All Federal coalbed gas unit agreements and all coalbed gas wells spud in the past five years were placed on this map to help see where recent activities have occurred and where they would be most likely occur in the next five years. Environmental document information, published data, and our knowledge of the region were also useful in helping determine where future activities could likely occur. These types of data were especially useful for making determinations of potential for future activities in townships that operators did not indicate a potential. Southwest Wyoming Province coalbed gas assessment unit boundaries (U.S. Geological Survey; 2002, 2004, 2005, and 2006) were used to separate areas of no potential for development from other areas with some potential for development in certain parts of the Field Office area. In other areas, operator information was used to include some lands that were not included in coalbed gas assessment areas. In other areas we assigned a “no coalbed gas potential” to some areas within coalbed gas assessment unit boundaries because we determined that there would be no development activity in those areas over the next five years.

Our analysis has indicated that minimum activity levels for the next five years (2007-2011) will be comparable to the number of coalbed gas wells drilled in the past five years (110 wells). We estimated a maximum number of coalbed gas wells that could be drilled by assigning an average number of wells drilled per township for each category of potential (high, moderate, and low). We assigned an average of 26 wells drilled per township in areas of high development potential, six wells per township in areas of moderate potential, and one well per township in areas of low potential.
moderate potential, and 0.6 wells per township in areas of low potential. When these averages were calculated for all lands assigned to each category of development potential a total of 198 new coalbed gas wells was estimated.

Summary
We examined the available information on the Rock Springs Field Office area (operator input, environmental documents, unit agreement activity, publications, historical drilling data, and professional knowledge of the area) and used that data to prepare two maps that indicate areas of potential conventional oil and gas and coalbed gas development for 2007-2011. We also estimated a range of wells that could be drilled during this period for both categories of wells. We estimated that conventional drilling would range from 446 to 693 new wells during this period and coalbed gas drilling would range from 110 to 198 new wells.

References


No warranty is made by the Bureau of Land Management for use of the data for purposes not intended by BLM.

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January, 2007

POTENTIAL FOR CONVENTIONAL DRILLING DEVELOPMENT
2007-2011

High Potential - Greater Than 25 Wells Per Township
Moderate Potential - Five to 25 Wells Per Township
Low Potential - Less Than Five Wells Per Township
No Potential - No Wells

2007-2011 Wyoming Basinwide Province
Conventional Units
Mechanically Mineable Trona Areas (MMTA)
Northern Moxa Arch
Southern Moxa Arch

Wyoming State Office
Reservoir Management Group
Potential For Coalbed Gas Drilling Development
2007-2011

Coalbed Gas Wells Spud Between 01/01/2002 and 01/01/2007

High Coalbed Gas Potential—Greater Than 25 Wells Per Township
Moderate Coalbed Gas Potential—Five To 25 Wells Per Township
Low Coalbed Gas Potential—Less Than Five Wells Per Township
No Coalbed Gas Potential—No Wells
Coalbed Gas Assessment Unit Outer Boundary
Coalbed Gas Units
Wilderness Study Areas
Jack Morrow Hills
Mechanically Movable Trona Area (MMTA)