APPENDIX 13—HYDROCARBON OCCURRENCE AND DEVELOPMENT POTENTIAL REPORT DEVELOPMENT SCENARIOS FOR MANAGEMENT ALTERNATIVES: 2002 TO 2021 JACK MORROW HILLS COORDINATED ACTIVITY PLAN

INTRODUCTION TO THE FLUID MINERAL PLANNING PROCESS

This Hydrocarbon Occurrence and Development Potential Report (HODP) considers current management, past hydrocarbon development, relevant research on fluid hydrocarbon potential, and industry-supplied information to evaluate the potential range of impacts on oil, gas, and coalbed methane development related to management actions for the Jack Morrow Hills Coordinated Activity Plan (JMH CAP). The planning area has existing oil and gas production and undeveloped leases that are currently held by operators. The assessment of impacts on oil, gas, and coalbed methane development is based on the production history of the area, geologic factors that control the presence of hydrocarbon resources, and management decisions that impact development activities, including—

- Occurrence of hydrocarbon source rocks, reservoir rocks with adequate porosity/permeability, and potential for accumulation of economically recoverable hydrocarbon accumulations in structural and stratigraphic traps
- Distribution of coal-bearing formations with cumulative coal seam thickness at shallow depths
- Management actions that may be implemented to protect resources and land uses, including closing areas to leasing, placing stipulations on new lease offerings, and resource protection requirements that may be required for site-specific development permits
- Market conditions and technical factors that may impact exploration and development activity due to changes in production costs, commodity prices, and feasibility of development and resource protection activities.

The Reasonably Foreseeable Development (RFD) Analysis prepared by BLM's Wyoming Reservoir Management Group in Casper represents the most likely projection of exploration and development activity for the planning area, based on current knowledge of hydrocarbon potential, BLM resource management requirements, and market conditions (Stilwell 2002). To evaluate the range of potential impacts on hydrocarbon development for the alternatives considered for the Environmental Impact Statement (EIS) for the JMH CAP, this study compares the RFD projections for development in the planning area to possible development levels that may occur under the various planning options. To fully evaluate the degree of impacts on hydrocarbon development that are related to the management alternatives, this report makes several assumptions to control for factors that impact development levels that are based on BLM actions, including—

- Stable commodity prices are favorable for continued oil and gas development in southwestern Wyoming throughout the planning period.
- Market accessibility will be provided for any significant new discoveries in the planning area, including regional pipeline capacity, and sufficient gathering and gas treatment capacity.
- Development of new trends within the planning area are considered independent events, and risk factors are not compounded to assess the cumulative probabilities of multiple discoveries.

For the Green River Resource Area Resource Management Plan (RMP) (1996) and final EIS the potential for oil and gas development for the entire resource area was assessed. Areas of high, moderate, and low potential for oil and gas accumulation were identified for projecting the expected oil-and-gas-related activity for the period 1990 through 2010. Comments received on the draft EIS for the JMH CAP and new information received during the scoping for the supplemental draft EIS for the JMH CAP were used to update the development activity estimates. Several adjustments have been made to the development potential boundaries assigned within the planning area. The revised development potentials are shown on Map A13-1. The development potential boundaries have been modified to exclude areas where no development activity is projected for the planning period. The unleased parts of the wilderness study areas (WSA) have been excluded because hydrocarbon development in the unleased parts of WSAs may not occur until congressional action has been taken to resolve their status.

The area of high development potential in the JMH CAP planning area has been enlarged from the previous evaluation for the draft EIS (Map 69). It has been expanded to the north, based on the successful discovery at the Buccaneer Unit #1 well (Section 23, T26N, R102W) and Shell Exploration & Production Company's Pacific Creek Federal B3-33 (Section 33 T27N, R103W), which is just outside the northwestern boundary of the JMH CAP planning area. Additional projected development activities between these two discoveries would expand the high potential area within the central portion of the planning area. Moderate and low development potential boundaries have been altered to correspond to the change in the high potential. Although drilling may occur in the high, moderate, and low development potential areas, most of the activity is expected to occur in the high development potential area.

EXPLORATION AND DRILLING

Previous oil and gas activity within the planning area has been undertaken to explore for and produce oil and gas resources. Oil and gas exploration in the JMH CAP planning area has occurred primarily through designation of Federal Exploratory Units. To date, 53 units have been approved or proposed. Table A13-1 lists Federal Exploratory Units known to have been located entirely or partially within the limits of the JMH CAP planning area. The locations of the five currently producing units and three non-producing (suspended) exploratory units are shown on Map A13-2. Maps A13-1 and A13-3 show the locations of oil and gas wells and abandoned wells drilled in the JMH CAP planning area, based on data from IHS Energy Group, BLM records, and the Wyoming Oil and Gas Conservation Commission. Most drilling activity has been concentrated in the south-central part of the planning area, with most of the productive wells located in the Nitchie Gulch field. A few additional producing wells and most abandoned wells are scattered across the rest of the area. The production occurs primarily along the crest of the Rock Springs Uplift, a regional geologic structure in the Green River Basin.

Early Exploration Activity

Geologic structures with mappable surface expression in Wyoming were generally located and tested through the 1940s. In the JMH CAP planning area, the only geologic structures that were early exploration targets occur along a fault system on the northern edge of the planning area. Several exploration wells were drilled to test this structural trend, but none were productive. The first test well in the planning area was drilled in 1927, in Section 16 T23N, R104W. It was a shallow (1,529 feet) Mesaverde Group dry hole drilled by Boars Tusk Oil Company, which is now defunct. Two additional nonproductive shallow Tertiary-age tests were made in the north part of the planning area in the 1940s. The first exploratory unit in this part of the planning area was the Pacific Creek unit in 1943. No economic oil and gas accumulations were discovered in this Mesaverde Group test and the unit was terminated in 1947.

After the Pacific Creek unit test, 11 more units were approved and one was proposed and later withdrawn prior to drilling. Of these exploration units only the Nitchie Gulch test found commercial accumulations of oil and gas. The Nitchie Gulch unit/field is a combination stratigraphic-structural trap, producing primarily gas from the Frontier and Dakota formations. Exploration activity was limited in the JMH CAP planning area during this early period, because the area was thought to be gas prone and market conditions favored exploration for oil during that time.

Discovery and Development, 1961–1993

Hydrocarbons were first encountered in the El Paso Natural Gas Company (now defunct) well drilled in 1954 in Section 29 T25N, R103W. This well tested gas in a number of zones in the Upper Cretaceous strata, with a maximum recovery of 240,000 cubic feet of gas per day from one zone before the well was abandoned. An additional 12 wells were drilled and abandoned before the first economic well was completed in November of 1961. Trigood Oil Company (now defunct) completed the first economic well in Section 17 T23N, R103W. Gas and some condensate (light oil) were obtained from both the Frontier and Dakota formations. This was the discovery well for the Nitchie Gulch unit/field. Between 1970 and 1984, 30 exploratory units were approved in the planning area. This period of increased exploratory activity coincided with a nationwide peak in drilling activity, mainly due to price increases for oil and gas. Hydrocarbons were found in 8 of the 30 new units (Table A13-1). Four units became significant producers. The Buccaneer, Rim Rock, Steamboat Mountain, and Treasure units are still producing. These accumulations are associated with stratigraphic traps that produce primarily gas and some natural gas liquids, also known as condensate.

No exploratory units were proposed for a 10-year period after the Essex Mountain unit terminated in 1984. This was partially due to decreasing oil and gas prices and generally low gas production volumes from many of the units other than Nitchie Gulch unit/field. In addition, the area available for exploration and development in the planning area was reduced during this time period, due to the designation of WSAs and other limitations placed on development activities. No additional areas have been offered for lease in the core area since 1992, and leasing was suspending in the rest of the planning area in 1998. Where requested by the operator, leases in the core area are held in suspension until the completion of the JMH CAP.

Recent Units

During the 1994 to 1998 period, increased emphasis on gas exploration in the region resulted in the proposal of nine exploration units. Also, discoveries southwest of JMH CAP planning area at the Stagecoach Draw and Clay Buttes fields and to the east and southeast in the Great Divide Basin increased exploration interest in the planning area. Recent exploratory unit targets have been potential gas accumulations hosted in stratigraphic traps of Cretaceous-aged strata.

Within the JMH CAP planning area, the first test of the Big Bear unit produced oil from the Rock Springs Formation. The unit was terminated due to uneconomic production rates. The Northern Lights and Jack Morrow Creek units were proposed but never received final approval.

The following three terminated exploratory units were located partly within the JMH CAP planning area, and the first well for each of these units was drilled outside the planning area:

- The Riva unit extended into the eastern part of the planning area and was terminated in June 1995. The operator tested and abandoned a Lewis Shale well in Section 36 T25N, R98W.

- The Encore unit extended into the southeastern part of the planning area and was terminated in February 1998. The operator tested and abandoned the Almond, Lewis, and Ericson formations in Section 32 T24N, R99W.
- The Jade unit was located partly in the eastern part of the planning area and was terminated in July 1998. The exploration targets were the Almond and Lewis formations. The first well was completed as a Lewis producer in Section 11 T24N, R98W. The unit was terminated as a result of uneconomic gas production rates.

The following three non-producing (suspended) exploratory units lie within the JMH CAP planning area:

- Johnson Gap (Deep) unit was approved in 1994. The first well has been proposed in Section 1 T23N, R103W.
- West 187 unit was approved in 1998. The first well has been proposed in Section 25 T23N, R105W.
- Gold Coast unit was approved in 1998 and the first test well produces from the Almond Formation and was completed in 1999.

Each of the three above exploratory units has been granted a Suspension of Operations and Production until the JMH CAP environmental analysis can be completed.

The Greasewood Wash coalbed methane unit partially extends into the JMH CAP planning area. Details for testing of this unit are discussed in Section 2.5.

Of the 53 total units, five older units are still productive; five contained productive wells, but they did not produce in economic quantities and those units have been terminated; Gold Coast is productive, but additional exploratory activity is suspended; 36 did not find hydrocarbons or economic amounts, and were terminated; four were withdrawn or canceled; and two units are suspended, awaiting completion of the JMH CAP EIS.

Table A13-1. Federal Exploratory Units

Unit Name	Effective Date	Status	Termination Date	Acres	Exploration Targets	Trap Type	Producing Formation
Big Bear	19950531	Productive Terminated	19960725	25,625	Lance, Lewis, Mesaverde, Frontier, and Dakota	Stratigraphic	Rock Springs
Big Dune	19590121	Terminated	19620501	17,675	Fort Union, Lewis, and Almond	Stratigraphic	
Boars Tusk	19790625	Productive Terminated	19861009	11,520	Frontier and Dakota	Stratigraphic	Frontier and Dakota
Buccaneer	19801216	Productive		12,160	Fort Union, Lance, and Mesaverde	Stratigraphic	Dakota
Centurion	19810428	Terminated	19810716	24,988	Lewis	Stratigraphic	
Circle Bar	19710115	Terminated	19720613	56,877	Lewis and Mesaverde	Structural closure against Continental fault	
Citation	19811130	Terminated	19820517	24,949	Mesaverde	Stratigraphic	
Continental Peak	19820617	Terminated	19820827	12,813	Granite Wash	Structural, near Continental Fault	
Dickie Springs	19700428	Terminated	19701215	13,074	Mesaverde	Structural closure against Continental fault	
Eden	19720818	Terminated	19750901	39,127	Tertiary and Mesaverde	Stratigraphic with fault control	
Encore	19970325	Terminated	19980217	4,407	Lewis, Almond, and Ericson	Stratigraphic	
Essex Mountain	19840506	Productive Terminated	19841018	10,116	Frontier	Stratigraphic	Frontier
Freighter Gap	19810209	Productive Terminated	19870711	24,656	Rock Springs	Stratigraphic	Mowry
Gold Coast	19980130	Exploratory Suspended		25,585	Confidential	Stratigraphic	
Greasewood Wash	1995	Exploratory Terminated	20011221	4,750	Rock Springs	Coalbed methane	
Greater Pacific Creek	19780310	Terminated	19801001	31,338	Frontier, Dakota, Nugget, Phosphoria, Tensleep, and Madison	Structural closure	
Harris Slough	19800812	Terminated	19810715	24,983	Lewis	Stratigraphic	
Honeycomb Buttes	19790329	Terminated	19800403	24,969	Mesaverde	Unknown	
Hourglass	19800530	Terminated	19810528	24,453	Mesaverde	Stratigraphic	
Indian Gap	19550916	Terminated	19580301	19,826	Nugget	Unknown	
Jack Morrow Creek		Exploratory Proposed		24,921	Confidential	Confidential	

Table A13-1. Federal Exploratory Units (Continued)

Unit Name	Effective Date	Status	Termination Date	Acres	Exploration Targets	Trap Type	Producing Formation
Jade	19970219	Productive Terminated	19980701	19,034	Lewis and Almond	Overpressured stratigraphic	Lewis
Johnson Gap (Deep)	19940228	Exploratory Suspended		25,970	Confidential	Stratigraphic	
Lost Valley	19780807	Productive Terminated	19851130	40,371	Lewis	Stratigraphic	Mesaverde
Monument Draw	19810917	Terminated	19811229	13,389	Granite Wash	Structural closure	
Monument Ridge	19630529	Terminated	19640201	31,644	Lewis and Rock Springs	Stratigraphic	
Morrow Creek	19541112	Terminated	19560701	25,126	Mesaverde	Structural (seismic) closure against fault	
Morrow Creek	19590917	Terminated	19600501	8,160	Lewis and Mesaverde	Stratigraphic/Structural	
Morrow Creek	19660624	Terminated	19680201	79,301	Almond	Stratigraphic	
Musketeer	19810630	Terminated	19820517	23,626	Mesaverde	Stratigraphic	
Nitchie Gulch	19621001	Producing		7,154	Frontier and Dakota	Stratigraphic/Structural	Frontier and Dakota
Northern Lights		Withdrawn		26,908	Confidential	Confidential	
Oasis	19831227	Terminated	19840515	24,677	Morrison	Stratigraphic	
Oregon Trail	19460000	Terminated		15,000	Unknown	Structural closure against Continental fault	
Pacific Creek	19430527	Terminated	19471231	23,036	Mesaverde	Structural closure against Continental fault	
Pacific Creek	19590113	Withdrawn	19610414	27,514	Mesaverde	Structural closure	
Pacific Creek II	19730927	Terminated	19750723	15,939	Ericson	Structural closure	
Packsaddle	19790227	Terminated	19790730	24,779	Frontier	Stratigraphic	
Packsaddle Canyon		Cancelled	19821015	24,927	Frontier	Stratigraphic	
Parnell Creek	19611103	Terminated	19620501	26,183	Almond	Stratigraphic	
Pinnacles	19670321	Terminated	19680601	150,024	Lewis and Almond	Stratigraphic	
Pirate	19801031	Terminated	19810227	10,165	Mesaverde	Stratigraphic	
Plunge	19600311	Terminated	19620801	21,087	Almond	Unknown	
Rim Rock	19800229	Producing		24,816	Frontier	Stratigraphic	Dakota
Riva	19941202	Terminated	19950622	13,179	Lewis	Stratigraphic	
Rock Cabin	19800627	Terminated	19820328	15,336	Lewis, Mesaverde, and Frontier	Stratigraphic	
Saddle Bag	19810528	Terminated	19821024	26,083	Rock Springs	Stratigraphic	
Sands of Time	19830311	Terminated	19830519	24,879	Lewis	Stratigraphic	
Scotty Lake	19781102	Terminated	19800721	23,240	Lewis	Stratigraphic	

Table A13-1. Federal Exploratory Units (Continued)

Unit Name	Effective Date	Status	Termination Date	Acres	Exploration Targets	Trap Type	Producing Formation
South Pass	19810323	Terminated	19830624	24,920	Lewis	Structural closure	
Steamboat Mountain	19780418	Producing		14,132	Frontier	Stratigraphic	Frontier
Treasure	19790620	Producing		24,797	Lewis	Stratigraphic	Dakota
West 187	19980225	Exploratory Suspended		4,493	Confidential	Confidential	

Drilling History

Oil and Gas Wells in Jack Morrow Hills

A total of 156 wells have been drilled, with four of those testing coalbeds. Of these wells, 66 were completed as producing wells. Two of the completed wells produce coalbed methane. The coalbed methane wells were tested, but neither has been put into production. The remaining 90 wells drilled in the planning area were abandoned. One of the wells was later converted to a water injection well.

Previous drilling targets have primarily been formations of Cretaceous age with 148 of the 156 wells drilled testing or completed in these zones. Only two wells have tested formations deeper than the Cretaceous. The Eden Unit #5-11 in Section 11 T22N, R105W was proposed as a test of Mississippian-age rocks at a depth of 19,500 feet. The well was drilled to a total depth of 18,150 feet in the Mississippian Madison Formation. A test of the Madison recovered a small amount of nonflammable gas and was abandoned. Other deep tests, further south on the Rock Springs Uplift, have tested some nonflammable carbon dioxide gas in the Madison.

The other deep test was the Indian Gap unit #1, which was drilled to a total depth of 10,066 feet in the Nugget Formation and was abandoned. No detections of hydrocarbons were reported in the older strata penetrated at this well.

One other well was drilled to test formations older than Cretaceous age. South Pass Unit #1 in Section 17 T27N, R100W was planned to test the Mississippian Madison at 22,000. Instead, the well-encountered Precambrian granite in the shallow subsurface penetrated the Wind River thrust fault and was drilled to a total depth of 22,947 feet in underlying Cretaceous-aged sediments.

Six exploration wells drilled to total depths in shallow Tertiary formations did not discover any hydrocarbons.

To date 11 units/fields have been discovered in the JMH CAP planning area. The Nitchie Gulch and Pine Canyon fields are the largest, and they extend beyond the boundaries of the planning area. The remaining nine fields are very small, with only one or two producing wells in each. Additional information about these fields is located in Wyoming Geological Association (1979 and 1992) and in IHS Energy Group, BLM, and Wyoming Oil and Gas Conservation Commission files.

Well Elevations and Depths

Surface elevations at well locations in the JMH CAP planning area range from approximately 6,400 feet to 8,100 feet above sea level. Total depths of the wells range from only 218 feet to 22,947 feet. The numbers of wells categorized by depth ranges are as follows:

- < 5,000 feet — 18 wells
- 5,000–9,999 feet — 80 wells
- 10,000–14,999 feet — 44 wells
- 15,000–19,999 feet — 13 wells
- > 20,000 feet — 1 well

Most wells with total depths between 5,000 and 10,000 feet are located in the Nitchie Gulch unit/field. Nitchie Gulch is located over the crest of the Rock Springs Uplift within the JMH CAP planning area. Wells must be drilled deeper outside the Nitchie Gulch field to reach the same target formations (Frontier and Dakota). The deepest wells that have been drilled to Cretaceous formations are located in the north and northeastern part of the JMH CAP planning area. The Buccaneer #1 (Section 23 T26N, R102W) is productive from a depth interval of 17,702 to 17,718 feet. It is the only well qualifying as a "deep producing well" (producing from a depth greater than 15,000 feet) in the JMH CAP planning area.

Drilling and Well Completion Rates

Drilling activity and successful completion rates for oil and gas wells are shown in Table A13-2. This table shows that there have been two periods of increased activity. The first was centered on the period when the Nitchie Gulch unit/field was first discovered in 1961. This field was initially developed with a well spacing of 640 acres. Drilling decreased in the 1968–1972 period because development drilling on the 640-acre spacing had been completed.

Drilling activity increased again in the mid 1970s and culminated in the drilling of 48 wells from 1978 to 1982. The increased drilling rate was caused by—

- General increase in gas prices during that period
- Improvements in drilling and completion technology that allowed for the development of areas with smaller per-well gas recovery
- Recognition of the importance of targeting stratigraphic traps that contain most of the potential gas reserves in the JMH CAP planning area
- Exploration for deeper drilling targets.

During this period well spacing was decreased to 160 acres in parts of the Nitchie Gulch unit/field and increased exploration for deeper reserves occurred in the area north and east of the field. Additional exploration would have occurred west of Nitchie Gulch unit/field, but this area had been withdrawn from leasing because of wilderness characteristics.

Improved rates of successful well completions (Table A13-2) since 1972 have been due to the industry's concentration on lower risk development drilling in the Nitchie Gulch unit/field, improvements in geologic analysis, and improvements in drilling and completion technology. Overall, 42 percent of the wells drilled in the JMH CAP planning area have been successful.

Table A13-2. Drilling Rates and Success Percentages

Time Period	Wells Drilled	Producers	Success (%)
Pre-1952	3	0	0
1953–1957	3	0	0
1958–1962	16	3	19
1963–1967	19	9	47
1968–1972	9	1	11
1973–1977	14	4	29
1978–1982	48	17	35
1983–1987	20	13	65

Table A13-2. Drilling Rates and Success Percentages (Continued)

Time Period	Wells Drilled	Producers	Success (%)
1988–1992	16	15	94
1993–1997	1	1	100
1998–2001	3	1	33
Total	**152**	**64**	**42**

Coalbed Methane Drilling and Development History

Tyler et al. (1994 and 1997) reviewed drilling history and potential of the coalbed methane resource in this part of the basin. In the JMH CAP planning area, coals of the Fort Union, Almond, and Rock Springs formations have been tested. Coalbed methane potentials and well locations are shown on Map A13-4. Saxon Exploration Company drilled two tests, the #7-11 in Section 7 T25N, R102W and the #23-15 in Section 23 T25N, R103W. Almond Formation coals (from 6,586–6,629 feet) were tested in the #7-11. The estimated gas content from Almond zone coal cuttings, ranged from 185 to 402 standard cubic feet per ton. This well was allowed to flow for 3 months, through the end of January 1991. It produced 90,300 cubic feet of gas and 442 barrels of water, with a maximum daily rate of 3,200 cubic feet of gas and 21 barrels of water. The Almond coals were abandoned and Saxon perforated a Tertiary Fort Union coal zone at 4,187 to 4,203 feet. The estimated gas content from Fort Union coal cuttings retrieved from this zone ranged from 123 to 145 standard cubic feet per ton. An injectivity/fall-off test was run on this zone and the well was abandoned.

Almond coals (from 5,637–5,673 feet) were also tested in Saxons' #23-15 well. The estimated gas content from Almond zone coal cuttings, ranged from 157 to 181 standard cubic feet per ton. This well was allowed to flow for 4 months, through the end of February 1991. It produced 612,900 cubic feet of gas and 5,902 barrels of water, with a maximum daily rate of 8,700 cubic feet of gas and 48 barrels of water. Estimated gas content from Fort Union coal cuttings was low, ranging from 4 to 30 standard cubic feet per ton. The well was abandoned without testing of any Fort Union coals.

Two other coalbed methane wells were drilled near the south boundary of the JMH CAP planning area. Triton Oil & Gas Corp. and Union Pacific Resources drilled these wells in Section 33 T23N, R102W (wells #3 and #2-33). RME Petroleum now operates both wells. Rock Springs Formation coals were tested in the 3,400 to 3,900 foot interval. The two wells went to a temporarily abandoned status in 1992, due primarily to low gas prices and disappointing test results and secondarily to environmental concern over disposal of produced water.

The Greasewood Wash unit was located east of the Nitchie Gulch unit, on the southern edge of the JMH CAP planning area. Most of the unit area was located outside the planning area, and the initial wells were drilled outside its boundary. The Greasewood Wash unit was created to explore for coalbed methane in the Rock Springs Formation. Water was pumped from the Rock Springs coals for about a year, at depths of 3,826 to 4,239 feet. As of the end of the year 2000, 600 to 700 barrels of water and 12 thousand cubic feet of gas were being produced each day from a total of five pilot test wells. This unit was terminated effective December 22, 2001. Low gas prices during the test period, large volumes of water and associated disposal costs, and carbon dioxide content of the gas may have been issues in the termination of this unit.

In 2000, the previously abandoned Treasure Unit #3 (Section 4 T23N, R101W) was reentered and converted to a water injection well. It was used to dispose of produced water from the Greasewood Wash coalbed methane unit. The unit operator has not indicated what will happen to this well's status, now that the Greasewood Wash unit has been terminated.

EVALUATION OF JMH CAP PLANNING AREA FLUID MINERAL RESOURCES AND PROJECTION OF FUTURE EXPLORATION AND DRILLING TRENDS

Several studies have been completed to assess hydrocarbon development potential for the Green River Basin, which includes the JMH CAP planning area, and geologic data from 51 of the 53 exploratory units at the planning area were also reviewed. The West 187 and Johnson Gap (deep) exploratory units are currently suspended, and technical information on the units is confidential. Some additional information has been provided through public comment and personal communication with industry representatives and other interested parties. Projections of future drilling trends are based on available information on potential hydrocarbon accumulations and the previous development of oil and gas in the planning area. The potential development activity rates will be used to assess the impacts of proposed management actions for each alternative evaluated in the final EIS for the JMH CAP.

Hydrocarbon Resource Assessments

A number of documents are available that have evaluated hydrocarbon resources for the Greater Green River Basin area. These documents were used to help evaluate the oil and gas resources present in the JMH CAP planning area and project levels of future activity. In general, the resource assessments indicate the total potential hydrocarbon resources in a region, based on geologic knowledge, data on past discoveries, or theory. Actual development activity will be determined by accessibility to resources, exploration and development costs, commodity prices, and production rates required to provide an economically viable return on investment.

Regional Geologic Information

The *Atlas of Major Rocky Mountain Gas Reservoirs* (New Mexico Bureau of Mines & Mineral Resources 1993) summarizes information on those gas reservoirs with cumulative production of at least five billion cubic feet of gas. The reservoirs and their associated plays are discussed. Some of the relevant parameters discussed are reservoir and lithologic data, production data, compositional analyses of produced gas, reservoir engineering parameters, and estimates of proved developed reserves. *Accessibility to the Greater Green River Basin Gas Supply, Southwestern Wyoming* (Barlow and Haun, Inc. 1994) provides additional discussion of plays and maps of play boundaries. It also evaluated the limitations on production and increased costs associated with access to public lands. The CD-ROM "Emerging Resources in the Greater Green River Basin" (Gas Research Institute 1996), an atlas of the Upper Cretaceous, provides geological, production, engineering, and land use data for some of the productive and potentially productive reservoirs in the JMH CAP planning area.

A three CD-ROM set "1995 National Assessment of United States Oil and Gas Resources" (U.S. Geological Survey [USGS] 1996) provides a discussion of some of the potential hydrocarbon plays in the JMH CAP planning area. Potential plays discussed are—

- Rock Springs Uplift
- Basin Margin Anticline
- Subthrust
- Deep Basin Structure
- Cloverly-Frontier
- Mesaverde
- Fox Hills-Lance

- Rock Springs Coalbed Methane
- Almond Coalbed Methane
- Lance Coalbed Methane
- Fort Union Coalbed Methane.

Advanced Resources International, Inc. (2001) prepared *Federal Land Analysis, Natural Gas Assessment, Southern Wyoming and Northwestern Colorado,* for the Department of Energy, in coordination with the BLM and Forest Service. That report estimated potential natural gas resources and reported on how they were affected by federal land use designation and related environmental stipulations. This assessment indicated that approximately 3.3 trillion cubic feet of undiscovered natural gas resources are present in the parts of the JMH CAP planning area that are available for exploration and development.

The comment letter from Barlow and Haun, Inc. (1998) was used as a reference for JMH CAP planning area plays and their potential future gas resource. For coalbed methane, only the Rock Springs Formations potential gas resource was estimated. The plays and their potential future resource are shown in Table A13-3.

Coalbed Methane Resource Assessment

The Potential for Coalbed Gas Exploration and Production in the Greater Green River Basin, Southwest Wyoming and Northwest Colorado (Tyler et al. 1997) presents a discussion of the coalbed gas resource. Information from that paper was used to prepare the map of coalbed methane development potential (Map A13-4). *The 1995 National Assessment of United States Oil and Gas Resources* (USGS 1996) also provides an assessment of coalbed methane resource potential for plays that are located in the JMH CAP planning area.

Resource Potential Estimates

For the draft EIS, two methods were used to estimate the number of wells required to develop undiscovered hydrocarbon accumulations (other than coalbed methane resources) in the JMH CAP planning area. Both methods calculated about the same number of wells from these undiscovered accumulations. These estimates are based on the size of the planning area, the thickness of deposits that may host hydrocarbon accumulations, the distribution of petroleum source rocks and distribution of existing reserves. These resource estimates indicate the total amount of petroleum hydrocarbons that may be present in the planning area and the number of wells required to produce that resource. The resource estimates and the projected number of wells required for total development of hydrocarbons do not include consideration of hydrocarbon volumes required to support exploration and development costs. The majority of wells drilled in the planning area have not been completed as producing wells because of the absence of hydrocarbons or potential production rates that would not provide enough income for operation of a producing well. The previous production history in the planning area indicates that the completion rates of all wells is about 42 percent, and exploration wells in new areas have a success rate of approximately 15 percent.

Resource Method Estimate

This method was developed from information received in the Barlow and Haun, Inc. (1998) scoping comment letter and information obtained for development of this report. Barlow and Haun determined a potential future gas resource of 2,100 billion cubic feet. Of that total, 50 billion cubic feet of gas was estimated for a potential coalbed methane in the Rock Springs Formation. A coalbed methane resource for the Almond, Lance, and Fort Union formations was not estimated. The potential gas resource, not including coalbed methane, is 2,050 billion cubic feet. A review of the existing producing wells in the JMH CAP planning area indicates that an average well (non coalbed methane) will produce 2.3 billion cubic feet of gas. To recover the estimated 2,050 billion cubic feet from wells that recover an average of 2.3 billion cubic feet would require 891 producing wells in the JMH CAP planning area.

Table A13-3. Plays and Their Potential Future Resource

Play	Play Type	Gas Resource BCF (billion cubic feet)
Fort Union and Lance	Basin-centered gas	200
Lewis Shale	Deep-water marine sandstone	150
Upper Almond Sandstone	Shore-face sandstone	100
Upper Almond Sandstone	Marine-bar sandstone	100
Lower Almond-Ericson	Basin-centered gas	500
Rock Springs Formation	Coalbed methane	50
Frontier Formation	Fluvial sandstone	100
Frontier Formation	Marine sandstone	100
Muddy Sandstone	Marine sandstone	200
Muddy Sandstone	Fluvial sandstone	100
Dakota Sandstone	Fluvial sandstone	100
Structural Accumulations	Multiple objectives	400

Checkerboard Method Stanley's (1995)

The Checkerboard Method is intended as a simple and quick way of estimating the number of undiscovered accumulations where some past activity has occurred. When this procedure was followed for the JMH CAP planning area, it was determined that 359 sections could contain producible hydrocarbons. Assuming development of each section would require 2.5 to three producing wells, 897 to 1,077 wells (not including coalbed methane wells) would be needed to develop the available resources in the JMH CAP planning area.

Wyoming State Geological Survey Report

As a cooperating agency in the preparation of the JMH CAP EIS, the Wyoming State Geological Survey (WSGS) evaluated the resource potential for the planning area. This resource evaluation provides production volume estimates based on probabilities of expansion of existing production and additional resources in the planning area. In addition, the report provides an estimate for coalbed methane resource potential in the area.

Based on the probabilities of additional discoveries in the planning area, WSGS estimates that an additional 1.255 trillion cubic feet of gas can be economically developed with current technology. The WSGS also estimates that 2.05 trillion cubic feet of coalbed methane can be produced, for a current resource estimate of 3.305 trillion cubic feet of natural gas from these sources. After publication of the WSGS report, their coalbed methane recoverable resource for present technology and potential number of wells were determined to be incorrect. The corrected information has been used when preparing assumptions and analysis for each alternative. The WSGS report also estimates that 535,000 barrels of oil and natural gas liquids could also be produced by currently available technology.

These resource estimates are based on probabilities of increased production from current trends and analogues of other producing trends in southwestern Wyoming, including Lewis Shale turbidite flows, deep mountain-front structures, and overpressured low permeability sandstones. The chance of success for additional development for extension of current production is rated at 95 percent, with an additional

95 billion cubic feet of gas (on a risk-discounted basis) being produced by an additional 38 wells. Risk factors for finding new fields that are analogues of other producing areas range from 0.25 to 10 percent, with risk-discounted production at 1.16 trillion cubic feet of gas and 535,000 barrels of oil. The predicted coalbed methane reserves are 2.68 trillion cubic feet of gas from the Fort Union and Lance formations.

The coalbed methane assessment is based on the assumptions that gas can successfully be produced from depths up to 7,000 feet. Tertiary coals of the Fort Union and Lance Formations are similar to the coal seams of the Cretaceous Rock Springs Formation, and an economical method for disposal of produced water will be developed. At present, the general industry standard maximum drilling depth for testing coal seams is 5,000 feet. The potential coal reserves identified by Cook et al. (2002) in the 5,000 to 7,000-foot depth range will probably not be tested until overlying zones have been evaluated. Work by Tyler et al. (1997) indicates that the gas contents of reported Tertiary age coals are less than those reported for the older Mesaverde Group coals of Cretaceous age. If their observation is correct, then the gas contents used by Cook et al. (2002) are optimistic and predicted reserves would be lower than their estimate. In addition, previous attempts to develop coalbed methane in this part of southwestern Wyoming have produced water with elevated total dissolved solid contents, which were reinjected into the subsurface to comply with surface water quality standards for the Colorado River Basin.

The WSGS report estimates that reserves development would require drilling of 322 conventional oil and gas wells and 543 coalbed methane wells in the study area. These resource potential estimates do not include consideration of economic factors and logistical considerations for development activity, including commodity prices and demand, development costs, regulatory requirements and non-discretionary closures within the planning area such as WSAs. The resource estimates, risk factors, and number of required wells from the WSGS report are listed in Table A13-4.

Table A13-4. Oil and Gas Potential, by Play, for the Jack Morrow Hills Area, Southwestern Wyoming, from Wyoming State Geological Survey, Open File Report 2002-1

Play Name	Target Formation	Unrisked Resource		Risk/ Recovery Factor (%)	Recoverable Resource (Present Technology)		Potential No. of Wells	Future Reserves	
Conventional Development	Frontier, Dakota	0.100	TCFG	95	95.00	BCFG	38	50	BCFG
Lewis Shale Turbidites	Lewis	0.137	TCFG	10	13.70	BCFG	49	130	BCFG
		2.300	MMBO	2	230.00				
Deep Mountain-Front Structures	Phosphoria, Madison	4.000	TCFG	2	80.00	BCFG	4	400	BCFG
Deep-Seated Thrust Structures	Frontier, Dakota	0.621	TCFG	5	31.00	BCFG	88	31	BCFG
		6.100	MMBO	5	305.00	MBO		305	MBO
Coalbed Methane	Fort Union, Lance	10.250	TCFG	20	2,049.63	BCFG	543	1,340	BCFG
Overpressured Low-perm. Sands	Frontier	40.300	TCFG	0.25	100.75	BCFG	20	705	BCFG
Overpressured Low-perm. Sands	Mesaverde	354.800	TCFG	0.25	887.00	BCFG	100	6,209	BCFG
Overpressured Low-perm. Sands	Lewis	2.400	TCFG	0.5	12.00	BCFG	8	132	BCFG
Overpressured Low-perm. Sands	Fox Hills/ Lance	14.400	TCFG	0.25	36.00	BCFG	15	252	BCFG

Note: BCFG = billion cubic feet of gas, MMBO = million barrels of oil, MBO = thousand barrels of oil, TCFG = trillion cubic feet of gas.

National Oil and Gas Assessment for Southwestern Wyoming

The USGS recently reassessed the Southwestern Wyoming Province (USGS 2002 and 2003), which contains the entire JMH CAP planning area. This is the most recent analysis for determining undiscovered hydrocarbon resources used to estimate the undiscovered resource contained within the JMH CAP planning area. The USGS used geology-based, well-documented estimates of quantities of oil and gas having the potential to be added to reserves within a future time frame—forecast span—of 30 years. This forecast span is longer than the forecast span for this analysis.

The USGS recognized 18 assessment units that lie at least partially within the JMH CAP planning area. To determine the potential resource within the JMH CAP planning area, BLM—

- Assumed a homogenous distribution of each resource within each assessment unit area
- Calculated the percent of each assessment unit lying within the JMH CAP planning area
- Multiplied that percentage by the USGS mean estimates for the entire assessment unit area to calculate JMH CAP planning area assessment unit resource values.

BLM estimates that the JMH CAP planning area contains a mean undiscovered volume of 1.02 million barrels of oil, 3.23 trillion cubic feet of gas, and 110.84 million barrels of natural gas liquids. In addition, BLM estimates that the undiscovered volume of coalbed gas is approximately 48.30 billion cubic feet of gas in Fort Union and Mesaverde coalbed gas assessment units.

DEVELOPMENT SCENARIOS

Each of the land use alternatives being evaluated in the final EIS for the JMH CAP include management actions that would affect oil and gas development activity. Information on existing oil and gas development and comments on the draft EIS were considered in the revised development estimates. The expected level of development activity is estimated for each set of management actions evaluated in the final EIS. These estimates provide the basis for evaluating impacts of the land use alternatives related to oil and gas development. The nearest proposed project is that of Kennedy Oil located south of the planning area. Currently, there is not any active coalbed methane production in the planning area or nearby parts of the Green River Basin.

Comments on Draft EIS Reasonably Foreseeable Development

Previous estimates of oil and gas development activity for the planning area were made to support the draft EIS for the JMH CAP. Comments on the draft EIS and scoping for the supplemental EIS provided additional information for estimates of development activity in the JMH CAP planning area. Diedrich (1999) projected that 88 to 111 wells could be drilled in the planning area, if all areas outside of WSAs were made available for development. Landreth (1999) indicated that the producing Frontier and Dakota wells in the Nitchie Gulch unit were being produced to their economic limit and that no additional in-fill drilling was anticipated. A number of scoping comments made for this EIS are relevant to a projection of drilling and exploration trends. Berco Resources, LLC, revealed a plan to drill up to 38 additional in-fill wells on their leasehold acreage in the Nitchie Gulch area. It only recently acquired these properties (January 1, 2001) from Hunt Oil Company, and Hunt had not indicated any interest in more in-fill wells. Berco has stated that it might develop some parts of its acreage at a well density of up to six wells per section to produce the remaining reserves. The proposed well density for this development activity is shown in Figure A13-1. Operators of the three suspended exploratory units have indicated that they still intend to test these units upon completion of the planning process.

Kerr-McGee Rocky Mountain Corporation; Odyssey Exploration, Inc.; and Bjork, Lindley, Danielson, & Little, PC, have suggested that the BLM should "project a larger number of possible wells (perhaps 300) in the entire area." No supporting information for their recommendation was included.

The U.S. Environmental Protection Agency (EPA) believes that "the impacts should evaluate a much more intense development scenario" for coalbed methane development. It points out that in the core area "the number of coalbed methane wells could be in the range of 800 wells." A spacing of 80 acres per well seems to be assumed to account for that total. No supporting information for the EPA's recommendation was included.

In addition, the operator of the terminated Greasewood Wash coalbed methane unit indicated it still has an interest in exploring for coalbed methane in Cretaceous-aged sediments in the area.

Assessment of Existing Production

Cumulative gas production and estimated ultimate gas production was determined for most wells that produce or have produced in the JMH CAP planning area (Table A13-5). Cumulative production was available for one coalbed methane well. Projected production could not be estimated for either coalbed methane well, or for the two oil shut-in wells (Gold Coast #16-6 and Big Bear Unit 11-7). A total of 128.411 billion cubic feet of gas has been produced through 2001. Projected ultimate production from existing wells is estimated to be 144.363 billion cubic feet of gas, assuming that active wells would be abandoned when production declined to 20,000 cubic feet of gas per day. Subtracting cumulative gas production from projected ultimate production indicates that an additional 15.952 billion cubic feet of gas can be recovered from existing gas wells in the JMH CAP planning area.

An abandonment date was recorded for abandoned wells or has been determined using decline curve analysis for currently producing wells (Table A13-5). The decline curve analysis indicates that 31 of the 44 presently producing wells will reach the economic production threshold of 20,000 cubic feet of gas per day before the end of 2021. Estimated abandonment dates will be used to determine when the surface at each well will be reclaimed.

Of the 64 wells completed as producers, 44 are still producing or are capable of producing. Analysis of producing and abandoned wells indicated that the average well would produce 2.3 billion cubic feet of gas with a well life of 26 years. There is significant variation in total production and well life; some wells produce relatively small amounts of gas for a short period, while the maximum total production from individual wells has exceeded 10 billion cubic feet of gas for four wells located in the JMH CAP planning area. Each of these high-volume producing wells has a projected productive life of more than 50 years.

The overall success rate for exploration and production wells combined in the planning area is about 54 percent. This rate was determined by comparing wells drilled in the period 1978–1997 against the number completed as producers. During this period, 46 producing gas wells were completed out of the 85 wells drilled. Recent success rates have been high and are expected to remain relatively high due to (1) continued improvements in geologic analysis and in drilling and completion technology and (2) expected in-fill drilling and step-out drilling from producing areas. Field development drilling success rates in the Green River Basin have been enhanced by the use of exploration technology, including three-dimensional seismic surveys. Nondrilling exploration technologies, such as seismic surveys, increase the drilling success rate by identifying favorable areas for producing wells and excluding areas from consideration that have lower development potential. The use of these technologies decreases the number of unsuccessful wells drilled and may result in a net decrease in total wells drilled in an area, along with decreases in surface disturbances and other impacts associated with drilling.

Most drilling activity has been concentrated in the south-central part of the JMH CAP planning area (Nitchie Gulch unit/field), with additional exploratory wells scattered across the rest of the area. If allowed, in-fill drilling would occur in the Nitchie Gulch field (up to 38 wells), and activity would spread out and down the flanks of the Rock Springs Uplift. Exploration drilling is expected to occur in areas where exploratory unit proposals have been made but have not yet been tested. Development of the play related to Shell's Pacific Creek Federal B3-33, could extend drilling into the JMH CAP planning area, in the vicinity of T26N, R103W. Scattered exploratory wells will continue to be drilled throughout the area, and if successful, field delineation will occur. The lowest rates of activity are expected to be on the north edge of the planning area, where targets are deep and lie below granites of the Wind River Thrust.

Figure A13-1. Proposed Drilling Density for Nitchie Gulch Field

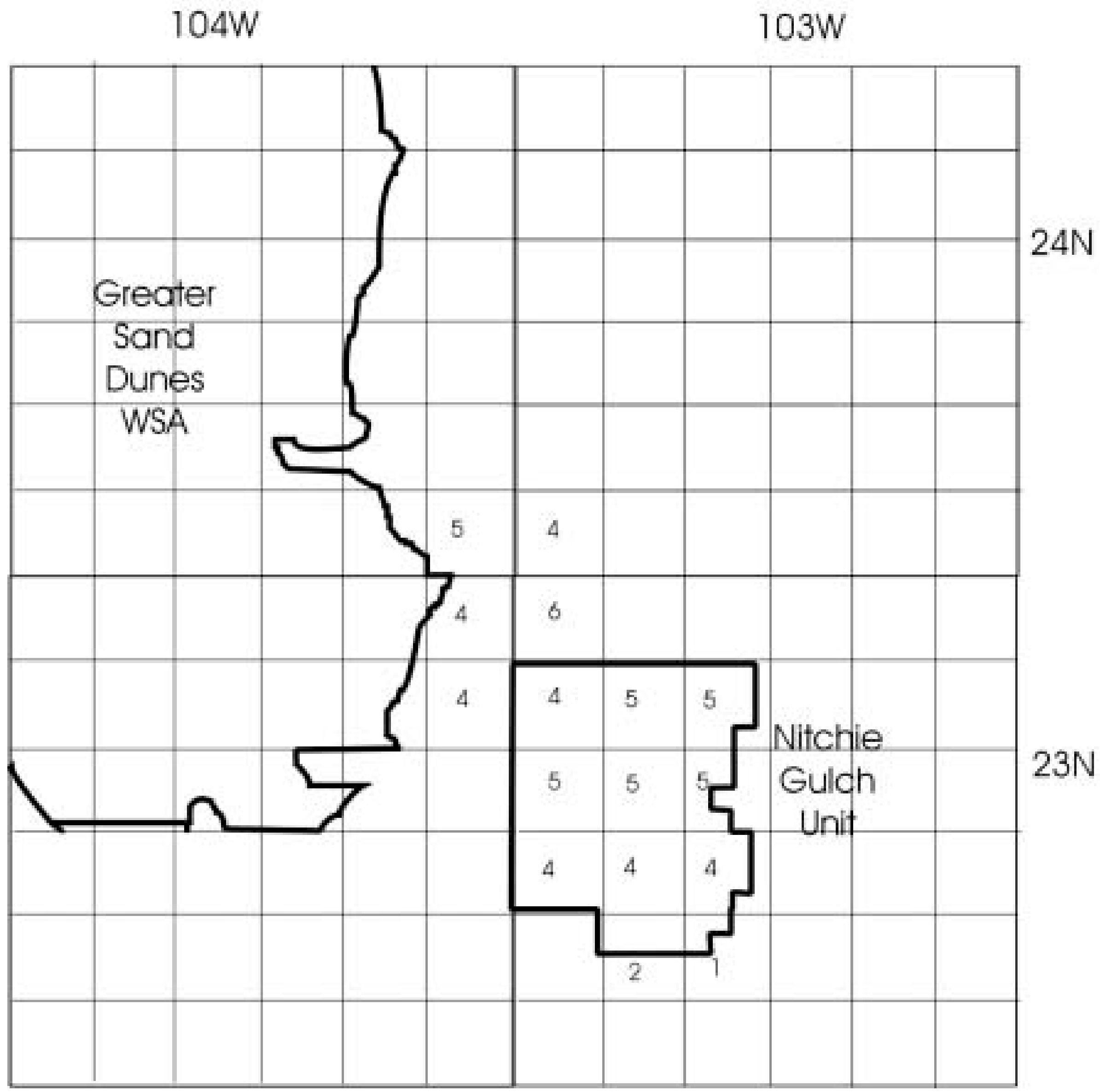


Table A13-5. Production Summary for Oil and Gas Wells in Jack Morrow Hills

Section	Township	Range	Well Name	Well Number	Producing Formation	Oil Initial Production (Barrels/Day)	Gas Initial Production (MCF/Day)	Present Status	Cumulative Gas Production (MMCF)	Ultimate Gas Production (MMCF)	Year Abandoned
3	23N	102W	STEAMBOAT	1	Frontier	0		GSI	519	519	2002
			MOUNTAIN UNIT								
33	23N	102W	UPRC	3	Rock	0	0	TA	1	Unknown	Unknown
					Springs coal						
33	23N	102W	UPRC	2-33	Rock	0	3	TA	0	Unknown	Unknown
					Springs coal						
3	23N	103W	AMOCO FEDERAL	13-3	Frontier	0	1,400	P&A	203	203	1983
4	23N	103W	DUNCAN FEDERAL	1-4	Frontier	0	526	P&A	383	383	1983
5	23N	103W	NORTH	2-5	Dakota	0	1,060	GSI	595	610	2002
			NITCHIE FEDERAL								
5	23N	103W	NORTH	3-5	Frontier	0	290	GSI	9	9	1991
			NITCHIE FEDERAL								
5	23N	103W	GOVERNMENT	1-5	Frontier	0	2,615	PGW	2,212	2,377	2013
6	23N	103W	NORTH NITCHIE	2-6	Frontier	0	1,200	PGW	2,610	3,062	2018
6	23N	103W	NORTH NITCHIE	2-6	Dakota	0		P&A	812	812	1988
6	23N	103W	NORTH NITCHIE	20-6	Frontier	0	20	P&A	278	278	1995
6	23N	103W	NORTH NITCHIE	30-6	Frontier/	0	2,332	PGW	1,918	2,227	2015
					Dakota						
6	23N	103W	GOVERNMENT	1	Frontier/	0	1,895	PGW	2,709	3,439	2042
			ANDERSON		Dakota						
7	23N	103W	NITCHIE	14-7	Frontier	0	1,096	PGW	2,462	2,743	2014
			GULCH UNIT								
7	23N	103W	NITCHIE	19-7	Dakota	0	440	PGW	1,684	1,927	2015
			GULCH UNIT								
7	23N	103W	NITCHIE	6-7	Frontier	0	3,240	PGW	15,794	16,469	2020
			GULCH UNIT								
8	23N	103W	NITCHIE	22-8	Dakota	0	440	PGW	1,056	1,680	2026
			GULCH UNIT								
8	23N	103W	NITCHIE	15-8X	Frontier	0	180	PGW	649	724	2007
			GULCH UNIT								
8	23N	103W	NITCHIE	7-8	Frontier	0	120	PGW	9,977	10,513	2031
			GULCH UNIT								

Table A13-5. Production Summary for Oil and Gas Wells in Jack Morrow Hills (Continued)

Section	Township	Range	Well Name	Well Number	Producing Formation	Oil Initial Production (Barrels/Day)	Gas Initial Production (MCF/Day)	Present Status	Cumulative Gas Production (MMCF)	Ultimate Gas Production (MMCF)	Year Abandoned
8	23N	103W	NITCHIE	7-8	Dakota			P&A	1,136	1,136	1995
			GULCH UNIT								
9	23N	103W	NITCHIE	11-9	Frontier	0	1,507	PGW	1,642	1,998	2021
			GULCH UNIT								
16	23N	103W	NITCHIE	17-16	Frontier	0	542	GSI	750	1,006	2015
			GULCH UNIT								
16	23N	103W	NITCHIE	17-16	Dakota	0	1,265	PGW	3,697	4,594	2028
			GULCH UNIT								
17	23N	103W	NITCHIE	1-17	Frontier	0	1,000	GSI	1,172	1,172	2002
			GULCH UNIT								
17	23N	103W	NITCHIE	1-17	Dakota	0	1,000	PGW	1,309	1,575	2017
			GULCH UNIT								
17	23N	103W	NITCHIE	4-17	Frontier	0	14,000	P&A	16,388	17,014	2020
			GULCH UNIT								
17	23N	103W	NITCHIE	4-17	Dakota	0	12,300	PGW	1,824	1,824	2002
			GULCH UNIT								
18	23N	103W	NITCHIE	12-18	Frontier	0	227	GSI	2,832	4,132	2012
			GULCH UNIT								
18	23N	103W	NITCHIE	8-18	Frontier	0	3,600	PGW	10,561	11,479	2032
			GULCH UNIT								
19	23N	103W	NITCHIE	20-19	Frontier	0	450	PGW	968	1,019	2004
			GULCH UNIT								
19	23N	103W	NITCHIE	5-19	Frontier	0	950	P&A	1,812	1,812	1982
			GULCH UNIT								
20	23N	103W	NITCHIE	13-20	Frontier	0	1,572	PGW	4,081	4,338	2012
			GULCH UNIT								
20	23N	103W	NITCHIE	2-20	Frontier	0	1,750	P&A	1,191	1,191	1987
			GULCH UNIT								
20	23N	103W	NITCHIE	2-20	Dakota	0	1,380	P&A	369	369	1985
			GULCH UNIT								
21	23N	103W	NITCHIE	21-21	Frontier	0	436	PGW	348	390	2005
			GULCH UNIT								

Table A13-5. Production Summary for Oil and Gas Wells in Jack Morrow Hills (Continued)

Section	Township	Range	Well Name	Well Number	Producing Formation	Oil Initial Production (Barrels/Day)	Gas Initial Production (MCF/Day)	Present Status	Cumulative Gas Production (MMCF)	Ultimate Gas Production (MMCF)	Year Abandoned
21	23N	103W	NITCHIE	21-21	Dakota	0	1,300	PGW	1,306	1,574	2015
			GULCH UNIT								
21	23N	103W	NITCHIE	3-21	Dakota	0	1,864	PGW	443	552	2010
			GULCH UNIT								
22	23N	103W	FEDERAL	2-22	Dakota	0	1,538	PGW	3,335	4,588	2042
26	23N	103W	FEDERAL	4-26	Frontier	0	15	P&A	3	3	1978
27	23N	103W	UPRR 1-27	1	Dakota	0	1,415	PGW	1,089	1,096	2002
28	23N	103W	NITCHIE	16-28	Frontier	0	1,460	PGW	2,240	2,579	2016
			GULCH UNIT								
28	23N	103W	NITCHIE	16-28	Dakota	0	1,400	PGW	2,134	2,440	2019
			GULCH UNIT								
28	23N	103W	PINE CANYON	1-28	Frontier	0	100	PGW	66	66	2002
			FEDERAL								
28	23N	103W	PINE CANYON	1-28	Dakota	0	4,000	GSI	446	446	2002
			FEDERAL								
1	23N	104W	JAMIESON “A”	1	Frontier	0	1,150	P&A	738	738	1999
2	23N	104W	WINSTON	1	Frontier/	0	800	P&A	601	601	1982
			FEDERAL		Muddy						
3	23N	104W	FEDERAL	9-3	Frontier	0	156	P&A	0	0	UNKNOWN
11	23N	104W	SAND DUNES	1	Frontier	0	476	P&A	544	544	1999
			FEDERAL								
11	23N	104W	GOVT AMAX	11-10	Frontier	0	330	P&A	152	152	1966
12	23N	104W	ROGERS FEDERAL	20-12	Frontier	0	750	PGW	877	1,084	2013
12	23N	104W	ROGERS	1-12	Frontier	0	1,140	PGW	6,138	6,619	2018
13	23N	104W	GOVERNMENT	7-13	Frontier	0	344	P&A	345	345	1990
26	23N	104W	NITCHIE	1-26	Frontier	0	24	P&A	0	0	1977
			GULCH FED								
28	24N	101W	TREASURE UNIT	4	Frontier	0	360	PGW	112	112	2002
33	24N	101W	TREASURE UNIT	1	Muddy	0	4,309	PGW	615	615	2002
13	24N	102W	FREIGHTER	1	Mowry Sand	0	1,362	P&A	164	164	1986
			GAP UNIT								
8	24N	103W	ESSEX MOUNTAIN	1-8	Frontier	0	240	PGW	194	259	2007

Table A13-5. Production Summary for Oil and Gas Wells in Jack Morrow Hills (Continued)

Section	Township	Range	Well Name	Well Number	Producing Formation	Oil Initial Production (Barrels/Day)	Gas Initial Production (MCF/Day)	Present Status	Cumulative Gas Production (MMCF)	Ultimate Gas Production (MMCF)	Year Abandoned
10	24N	103W	RIM ROCK	1	Muddy	0	1,569	PGW	829	1,204	2022
16	24N	103W	RIM ROCK UNIT	2	Frontier/	0	906	PGW	388	462	2007
					Muddy						
21	24N	103W	FEDERAL	21-1	Dakota	0	2,126	PGW	1,058	1,968	2044
31	24N	103W	NORTH NITCHIE	30-31	Frontier	0	2,689	GSI	2,640	2,716	2006
31	24N	103W	NORTH NITCHIE	10-31	Frontier	0	1,252	P&A	265	265	1991
31	24N	103W	NORTH NITCHIE	30-31F	Frontier	0	5	P&A	0	0	1990
32	24N	103W	NORTH NITCHIE	10-32	Dakota	0	601	P&A	218	218	1992
33	24N	103W	FEDERAL	13-33	Frontier	0	76	P&A	92	92	1980
34	24N	103W	FEDERAL	13-34	Frontier	0	185	P&A	8	8	1980
24	24N	104W	FEDERAL	44-24	Frontier	0	278	P&A	40	40	UNKNOWN
25	24N	104W	NORTH NITCHIE	40-25	Frontier	0	423	PGW	428	521	2009
35	24N	104W	GOODSTEIN	1-35	Frontier	0	638	PGW	461	488	2003
			FEDERAL								
36	24N	104W	NORTH NITCHIE	40-36	Frontier	0	2,271	PGW	2,909	3,620	2027
36	24N	104W	NORTH NITCHIE	20-36	Frontier	0	695	PGW	959	1,065	2009
36	24N	104W	NORTH NITCHIE	30-36	Frontier	0	2,282	PGW	1,375	1,415	2005
6	25N	102W	GOLD COAST	16-6	Almond	5	425	GSI	0	Unknown	Unknown
7	25N	102W	BIG BEAR UNIT	11-7	Rock	23	116	GSI	17	Unknown	Unknown
					Springs						
23	26N	102W	BUCCANEER UNIT	1	Muddy	0	1,027	PGW	1,232	2,679	2039

Abbreviations: MCF – thousand cubic feet; MMCF – million cubic feet; GSI – shut-in gas well; TA – temporarily abandoned; P&A – plugged and abandoned; PGW – producing gas well

Activity Estimate for Alternative 1

In selecting and leasing exploration areas and drilling wells, oil and gas companies consider the potential for economic accumulations for oil and gas, the cost of leasing and drilling, and the market prices for the produced commodities. Factors used to estimate the size of potential reserves include geologic data from nearby wells, geophysical data used to interpolate conditions between well control, and production history and occurrence of oil and gas shows in the region. Excluding parts of the planning area that have been removed from leasing and development based on regulatory and statutory requirements (such as WSAs and areas with surface slopes exceeding 25 percent), 469,251 acres are currently available for development.

Previous exploration activity in the JMH CAP planning area and nearby areas, and the use of non-drilling exploration technologies such as three-dimensional seismic surveys indicate that the success rate for new exploration wells in the planning area will be approximately 15 percent. Resource estimates for the planning area are based on data from wells in the planning area and economic oil and gas accumulations found in other areas that occur in geologic settings that are similar to the planning area. Available resource estimates indicate that approximately 2 trillion cubic feet of recoverable gas may be present in the planning area that is not associated with coalbed methane. The planning area is characterized by a fairly complex geologic setting, with the potential for multiple types of oil and gas accumulations, including stratigraphic, structural, and basin-centered accumulations.

More than 150 wells have been drilled in the planning area; however a significant portion of the planning area has not been fully explored, as existing wells have been concentrated on exploitation of existing discoveries, and more than half of the wells drilled in the planning area are less than 10,000 feet in total depth. This is typical of exploration and development patterns for oil and gas producing areas, with initial exploration activities based on shallow targets with structural expression at the land surface, followed by exploration for deeper targets that are based on inferences about potential occurrences. Based on considerations of the number of potential accumulation types, the geologic complexity of the area, and the prevalence of oil and gas occurrences in the planning area, a maximum average exploration well density of one well for every four sections is projected for the planning area. This would result in drilling of 156 exploration wells in the planning area. This represents the maximum foreseeable development in the available parts of the planning area during the planning horizon, based on the commodity prices that support a high level of interest in development over the planning period. This level of exploration activity, along with seismic data acquired during exploration programs, would provide sufficient information for stratigraphic correlation and structural mapping of oil and gas reservoirs in the plays that are potential development targets in the planning area.

This level of exploration activity should result in about 23 discovery wells, based on past success rates for exploration in this portion of the Green River Basin. The average number of wells in currently producing units within the JMH CAP planning area is nearly four. Based on the average number of wells per producing unit, development of the new discoveries will include 70 development wells, and development drilling in existing producing areas is expected to result in drilling of 38 additional producing wells, resulting in a total of 108 new development wells. The total estimated drilling activity is 264 wells drilled, with 132 wells placed in production. This would result in discovery and placement into production of approximately 15 percent of the available oil and gas resource in the planning area that is not associated with coalbed methane. The development activity estimates and associated production volumes for each alternative are listed in Table A13-6.

Activity Estimate for Alternative 2

The preservation management action would result in no new leasing in sensitive areas and would provide compensation for existing rights. If exchanges for existing leases are executed, no new drilling and completion of production wells would occur in the sensitive areas. In parts of the planning area without sensitive resources, leasing and development could occur, consistent with the planning requirements of the Green River RMP. With successful exchange of existing leases, total development activity under this alternative is expected to include the following activities. Approximately 86 exploration wells would be drilled in the rest of the planning area at the projected density for exploration activity, resulting in 13 new producing wells. Development of the new discoveries would be expected to require drilling of 39 new producing wells, along with 38 wells drilled to expand existing production, resulting in 77 new development wells. A total 163 new wells would be drilled, with 90 new wells placed in production.

Activity Estimate for Alternative 3

This management alternative controls leasing and levels of drilling activity to prevent irreversible adverse impacts on sensitive resources in the planning area. Past drilling rates are assumed to be the target activity level for development controls. A statistical analysis was developed to determine the number of wells that could be drilled during the 20-year period, assuming that the entire JMH CAP planning area was available for development. Since the early 1980s, large parts of the planning area have not been available for development or have had development restrictions, distorting that period's data. Past activity shows that the highest 5-year rate was during the 1978–1982 period, when 48 wells were drilled (Figure A13-2). Few land use restrictions were in place at that time and most of the area was open for development. Assuming that existing requirements for protection of other resources would allow drilling activity at a level near the maximum rate observed for a 5-year period, a maximum rate of drilling activity can be projected. At a rate of 46 wells per 5-year period, an additional 205 wells could be drilled in the JMH CAP planning area, including 115 exploration wells and a total of 90 development wells, with 107 new wells placed into production.

This alternative is based on the RFD analysis (Stilwell 2002), with additional adjustments for areas where oil and gas development will not occur to comply with the Wilderness Act, and is considered to reflect the most likely development scenario that would occur in the planning area if current management practices were continued in the planning area, along with development of planning criteria for new development activity in the core area.

Activity Estimate for the Proposed JMH CAP

The Proposed JMH CAP provides for controls on leasing and levels of drilling activity to prevent irreversible adverse impacts on sensitive resources in the planning area. The overall level of activity would be managed through an implementation, monitoring, and evaluation management strategy (Appendix 17), which would reinstate all suspended leases within 3 years of signing the Record of Decision (ROD), close a portion of the planning area to new leasing consideration, and offer leases in other areas with stipulations to protect sensitive resources. New lease offerings in portions of the planning area would be based on such factors as operational need, resource recovery, geology, and ability to mitigate impacts. Appropriate mitigation measures would be based on observations of resource indicators, such as wildlife populations and distribution, and non-development factors, such as disease and drought.

Past drilling rates are assumed to be the target activity level for development controls. These factors indicate that similar development activity levels may occur as projected for Alternative 3. Past activity shows that the highest 5-year rate was during the 1978–1982 period, when 48 wells were drilled. Few land use restrictions were in place at that time, and most of the area was open for development. Assuming that existing requirements for protection of other resources would allow drilling activity at a level near the maximum rate observed for a 5-year period, a maximum rate of drilling activity can be projected. At a rate of 46 wells per 5-year period an additional 205 wells could be drilled in the JMH CAP planning area, including 115 exploration wells and a total of 90 development wells, with 107 new wells placed into production.

This alternative is based on the modified RFD analysis (Stilwell 2002) with additional adjustments described in Alternative 3.

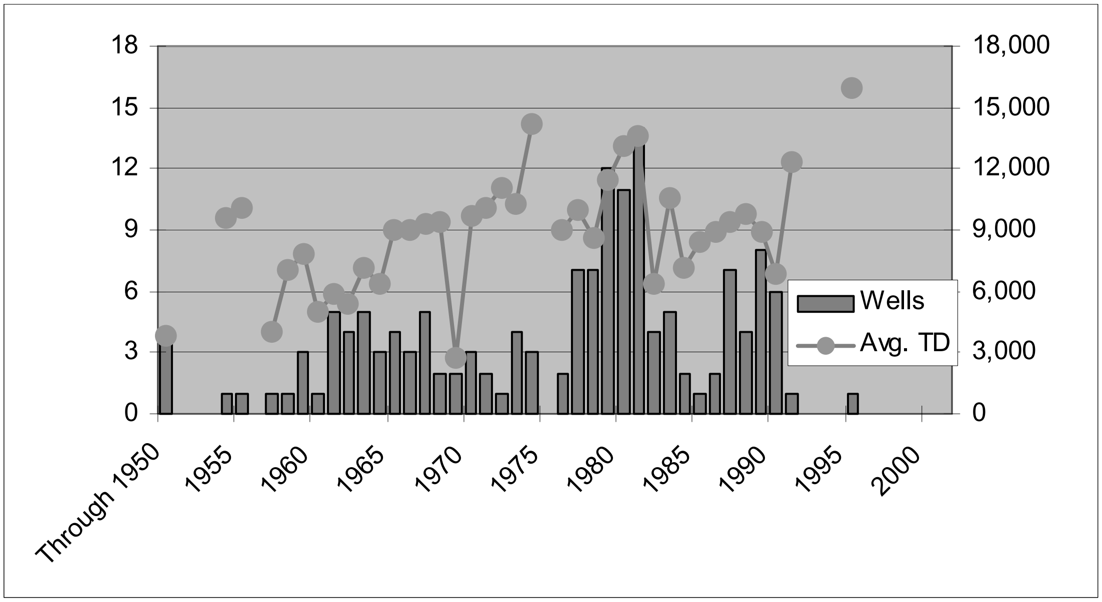
Activity Estimate for the No Action Alternative

Under the No Action Alternative, 38 development wells would be drilled to in-fill production activity at Nitchie Gulch, and existing leases could be explored and developed within the core area. The planning area outside the core area would be available for further leasing and development activity. Because more than 60 percent of the core area is currently leased, activity could occur on those leases at the completion of the planning process. However, a significant number of the leases would expire during the planning period unless the leases were developed and held by production. If half the existing leases were successfully developed, the overall activity level would be similar to that expected under Alternative 1, with some reduction in activity due to unavailability of portions of the core area when existing leases expire. Based on the predicted drilling and completion rates for the planning area, the total estimated drilling activity would be 221 wells drilled, with 114 wells placed in production. This would include 126 exploration wells and 95 development wells drilled in the planning area.

Table A13-6. Estimated Oil and Gas Development Activity by Management Alternative for the JMH CAP Planning Area

Alternative	Exploration Wells	Development Wells	Well Total	New Producing Wells
1	156	108	264	132
2	86	77	163	90
3	115	90	205	107
Proposed JMH CAP	115	90	205	107
No Action	126	95	221	114

Figure A13-2. Drilling Trends at the JMH CAP Planning Area



Coalbed Methane Development

Resource Potential

The industry has expressed interest in continuing to explore for potential coalbed methane reserves in the JMH CAP planning area. Map A13-4 shows areas of future potential for continued exploratory and development activity, assuming that all lands would be available for lease and development. Information in Tyler et al. (1997) was used to prepare Map A13-4. The eastern lobe of this map outlines the area of Cretaceous-aged (Rock Springs and Almond coals) coalbed methane potential, while the western lobe outlines the area of Tertiary-aged (Fort Union coals) potential.

Preliminary testing of the Fort Union, Almond, and Rock Springs Formations has not been successful in the area. Development has not continued, primarily because of low gas prices and disappointing test results and, secondarily, because of environmental concern over disposal of produced water. The Rock Springs appears to have the highest potential for success, because those coals are thickest and gas content is favorable. The comment letter of Barlow and Haun, Inc. (1998) indicates a potential gas reserve of 50 billion cubic feet. Almond coals have high estimated gas contents (as indicated in the #7-11 and #23-15 wells). New estimates by Cook et al. (2002) indicate that 2.68 trillion cubic feet of Fort Union coalbed methane may be present as an extractable resource in the planning area.

Activity Estimate for Alternative 1

No coalbed methane project has been determined to be economic in the Wyoming part of the Greater Green River Basin. The Greasewood Wash coalbed methane unit was terminated in December 2001 and all unit wells are proposed for abandonment. Testing is occurring in the Cow Creek field area, some 80 miles southeast. Other projects are proposed in the Greater Green River Basin, but none near the JMH CAP planning area. Discussion with industry indicates that the planning area has only exploratory interest for coalbed methane resources in the near term. Any action subsequent to an initial phase of exploration is so speculative as to preclude reasonable analysis at this time.

An initial phase of exploration could include up to 50 wells. Based on their evaluation of the performance of wells at the Greasewood Wash coalbed methane unit, WSGS staff have indicated that as many as 25 closely spaced wells would be required to effectively dewater the coal and determine maximum gas production rates (Cook and DeBruin, personal communication, 2002). Only at that level of activity could economic viability be estimated. Assuming that 50 coalbed methane wells would be drilled in the early part of the planning period allows for exploratory testing at two potential locations in the JMH CAP planning area. Potential locations for testing would be first expected in the Cretaceous-aged coals in the southwestern part of the eastern lobe, where depths are shallowest. At least small quantities of gas would probably be produced from any test, and successful completion of two exploratory projects could result in gas production rates of several hundred thousand cubic feet of gas per day.

To project drilling activity, it was assumed that an initial exploratory test phase could occur as early as 2003. Up to 25 wells would be drilled over a short period of time. A second phase (up to 25 additional wells) could begin as early as 2005. Economic factors could affect actual project timing or limit activity levels. For this alternative, it was assumed that all 50 wells would be drilled.

If exploration tests show that coalbed methane development is economically feasible, well life could be 10 to 20 years based on information on coalbed methane wells in the Powder River Basin. Because no information is available to determine well productivity or success rates, it was assumed that none of the 50 wells would be abandoned before 2021. In addition to the 50 well sites, other facilities, such as access roads, gas gathering and water disposal pipelines, water injection wells, electrical utilities, and compressors, will be constructed to aid in production of any gas developed. Because there is not currently any existing coalbed methane production in the region, the potential production rates for the 50 wells could not be estimated. Coalbed methane wells produce at low rates, and any producing wells would not contribute significant production to the larger gas volumes expected from other gas wells in operation during the planning period. If economically successful exploration projects for coalbed methane were completed in the planning area, then the actual production rates and the acreage of areas available for coalbed methane development could be used to estimate production rates.

Activity Estimate for Alternative 2

Under this alternative, it is assumed that no new leases will be offered in areas with sensitive resources. Because a significant part of the planning area with potential for coalbed methane development contains sensitive resources, it is assumed that only one coalbed methane exploration project would be completed in the planning area, with up to 25 wells installed to dewater and test production in the exploration project.

Activity Estimate for Alternative 3

The development activity estimate for Alternative 1 would also be assumed to occur under this alternative. Although the additional resource protection requirements that would be implemented under this alternative would increase development costs and might decrease interest in development of coalbed methane resources by industry, the initial two exploration projects and 50 wells anticipated for Alternative 1 could be carried out within the planning area. Cook et al. (2002) estimate that more than 400,000 acres of the planning area are underlain by coal with potential for coalbed methane development; therefore, a significant area with development potential could be leased and explored outside the sensitive resource areas. Any reduction in development related to access restrictions and costs associated with mitigation requirements would probably impact later development activity, which cannot be estimated from currently available information, since there is no development history for coalbed methane production in the planning area.

Activity Estimate for the Proposed JMH CAP

The development activity estimate for Alternative 1 would also be assumed to occur under this alternative. Although the additional resource protection requirements that would be implemented under this alternative would increase development costs and might decrease interest in development of coalbed methane resources by industry, the initial two exploration projects and 50 wells anticipated for Alternative 1 could be carried out within the planning area. Cook et al. (2002) estimate that more than 400,000 acres of the planning area are underlain by coal with potential for coalbed methane development; therefore, a significant area with development potential could be leased and explored outside the sensitive resource areas. Any reduction in development related to access restrictions and costs associated with mitigation requirements would probably impact later development activity, which cannot be estimated from currently available information, since there is no development history for coalbed methane production in the planning area.

Activity Estimate for the No Action Alternative

Under the No Action Alternative, the planning area outside the core area would be open to leasing and development, consistent with the planning guidelines of the Green River RMP, including timing and access restrictions on development activity to protect sensitive resources. New leases for coalbed methane development would not be offered in the core area, which is currently the highest interest area for coalbed methane development. Because other significant coalbed methane potential areas exist outside the core area, it is assumed that two exploration projects and 50 wells would still be installed under this management action, similar to Alternatives 1 and 3.

IMPACTS OF DEVELOPMENT ACTIVITIES

Costs of Time Delays Related to Restrictions

Barlow and Haun (1994) project an increased demand for clean-burning, affordable natural gas in the area of the planning area. This increased demand, coupled with a slower drilling response time caused by a high level of restriction on activity, does not allow for timely development of drilling programs. This adversely impacts economics for companies trying to develop the resource. Seasonal access restrictions increase the time needed to acquire seismic data, drill individual wells, and develop discovered fields. These delays do not necessarily prevent an individual operator from developing the resource, although development may be stifled if limitations are considered to be onerous. Restrictions do at least increase costs of field development and slow the industry's response time to attractive increases in product prices. These time delays, coupled with the many other restrictions on activity in the planning area, are expected to discourage interest in the area, and limit the drilling of wells in some areas. Barlow and Haun (1994) found that "cumulative costs associated with access in the NEPA process can add $9,500 to $21,000 on a per well basis."

Surface Disturbance

These general guidelines for access roads, drill pads, and pipelines and power lines are used to determine acres of surface disturbance associated with oil and gas exploration and development drilling activities.

Access roads:

- 40 feet total width disturbance
- 12- to 14-foot-wide travelway
- 4.8 acres initial disturbance per linear road mile

- 4.0 acres initial disturbance per access road (less than 1 mile disturbed per well)
- 4.0 acres long-term disturbance per producing well (no stabilization or revegetation of barrow ditch)
- 4.0 acres of access road stabilized per abandoned dry well, after 3 years
- 4.0 acres of access road stabilized after abandonment of each producing well, after 3 years.

Road standards would be in conformance with guidelines issued in BLM Manual 9113 (Roads) and in Surface Operating Standards for Oil and Gas Exploration and Development (1989).

Drill pads:

- 3.0 acres initial disturbance per average well pad
- 0.7 acres long-term disturbance per producing well
- 2.3 acres stabilized per producing well, after 3 years
- 3.0 acres stabilized per abandoned dry well, after 3 years
- 0.7 acres stabilized after abandonment of each producing well, after 3 years.

Pipelines and power lines:

- 6.0 acres initial disturbance per producing well
- 5.5 acres stabilized per producing well, after 3 years
- 0.5 acres long-term disturbance per producing well
- 0.5 acres stabilized after abandonment of each producing well, after 3 years.

The projected surface disturbance for each of the alternatives by year during the planning period are listed in Table A13-7. The surface disturbance areas include reclamation of completed drill pads and abandoned wellhead areas.

Surface Disturbance for Coalbed Methane Wells

The disturbance guidelines for coalbed methane access roads, drill pads, and pipelines and power lines are the same as those used for non-coalbed methane exploration and development drilling activities. Actual disturbance caused by coalbed methane drilling activity is likely to be less than normal (as described below), but disturbance guidelines have not been changed, since there is so little history available to determine what actual disturbance is likely to be in the JMH CAP planning area.

With likely well spacing at 40 acres, road length needed to reach each drill site should be less than the 1 mile previously assumed for normal wells. For this type of producing well, fewer service visits are needed. As a result, two-track unimproved roads or trails could be used for access to most wells.

Use of truck-mounted drilling rigs is expected for drilling Rock Springs Formation tests that will less than 3,000 feet in depth. For wells drilled to a total depth below 3,000 feet, a full-sized rig would be required. For tests drilled in the Almond or Fort Union Formations to total depths of 1,200 feet, smaller, truck-mounted rigs may be used. These smaller rigs can drill wells that use smaller pads with smaller surface disturbance area than the drilling rigs that will be used for drilling deeper wells.

If wells are productive, wellhead facilities are expected to occupy a smaller surface area than normal wells. A weatherproof covering will be placed over the wellhead facilities. No additional structure will be constructed at the well site for gas-water separation facilities. A down hole pump will be used to produce water from the producing interval(s). Methane gas will flow to the surface using the space between the production casing and the water tubing. No pump jacks will be put at the wellheads. The long-term surface disturbance, at each productive well location where no cut and fill construction techniques are utilized, is likely to encompass a negligible area, less than 0.1 acres. Well site production facilities typically would not be fenced or otherwise removed from existing uses.

Pipeline trenches for well gathering lines are expected to disturb portions of 40-foot-wide corridors and be reclaimed after construction is completed. Trenches will be constructed along well access roads wherever possible. Separate gathering lines, averaging one-quarter to one-half mile long each, will be buried in the trenches and will transport methane gas to production facilities and produced water to injection wells.

Typically, gas production from each well will be individually measured and mechanically or electronically recorded at a central collection point or pod facility. Gas gathering lines for each 5 to 10 wells will be tied together at the pod facility. Here gas is commingled into the gas gathering system, which will transport it to a compressor station. An improved road, averaging one-half mile in length, will be constructed to each pod facility and will disturb an area no wider than 50 feet. Each pod facility will disturb about 0.25 acres.

Coalbed Methane Produced Water-Gathering System and Discharge Facilities

Expected water production rates are unknown, although Greasewood Wash coalbed methane unit production (in the Rock Springs) averaged 120 to 140 barrels of water per day from each well testing at the end of 2000. The two Almond coal tests, to the north of the planning area, produced water at average rates of 21 and 48 barrels per day.

Any water produced from the Rock Springs Formation (most likely exploratory target) is expected to be of poor enough quality that disposal into subsurface formations will be required. Water produced from the Rock Springs coals, in the area, has not been of acceptable quality for surface disposal. No data were available from the Almond and Fort Union coal tests to determine their water quality. If water obtained from any coals in the JMH CAP planning area were of suitable quality for surface disposal, discharge would only be allowed at point sources that had been approved through the National Pollutant Discharge Elimination System and BLM permitting procedures, including Wyoming Department of Environmental Quality basin water quality limits.

Table A13-7. Cumulative Acres of Surface Disturbance (by Year) for Oil and Gas Development in Jack Morrow Hills for Each Management Alternative

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
No Action	207	408	608	755	885	952	990	1,032	1,083	1,147	1,215	1,284	1,344	1,410	1,466	1,532	1,590	1,646	1,697	1,752	1,801
Alternative 1	207	429	650	811	955	1,038	1,091	1,147	1,224	1,313	1,399	1,491	1,574	1,652	1,720	1,795	1,858	1,929	1,999	2,071	2,136
Alternative 2	207	377	545	676	783	828	844	863	902	953	1,001	1,055	1,100	1,140	1,160	1,191	1,223	1,259	1,292	1,326	1,353
Alternative 3	207	398	587	732	854	914	944	978	1,032	1,099	1,151	1,210	1,260	1,318	1,366	1,425	1,476	1,534	1,589	1,636	1,675
Proposed JMH CAP	207	398	587	732	854	914	944	978	1,032	1,099	1,151	1,210	1,260	1,318	1,366	1,425	1,476	1,534	1,589	1,636	1,675

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