Bridger-Teton National Forest
Reasonably Foreseeable Development Scenario
August 2008

Background

The environmental effects of activities anticipated from implementation of a proposed oil and gas leasing program must be analyzed prior to making a leasing decision. This requirement is in accordance with the 1987 Federal Onshore Oil and Gas Leasing Reform Act and the Forest Service regulations implementing this act for National Forest System (NFS) lands, found in the Code for Federal Regulations (CFR) at 36 CFR 228 Subpart E. Bureau of Land Management implementing regulations are found at 43 CFR 3100.

A description of the type and amount of post-leasing activities that would be reasonably foreseeable over a 10 to 15-year planning horizon as a leasing decision is implemented provides the basis for analyzing the anticipated effects associated with oil and gas leasing. The assumptions upon which the projection of post-leasing activity is based and the geologic or occurrence potential of the NFS lands under consideration are also presented. This analysis is referred to as a reasonably foreseeable development scenario or (RFDS). This initial or baseline RFDS is prepared to represent a projection of post-leasing activity based on geology, occurrence potential, technology and projected economics. The lease parcels under consideration are available for leasing, based on current Forest Plan management guidance. The RFDS will be modified at a later date for each alternative considered in detail in a National Environmental Policy Act (NEPA) analysis, which will provide the basis for the analysis of the effects of the alternatives. RFD projections for the acres under consideration may be modified for each alternative based on areas that would not be available for leasing and special lease terms and conditions for resource protection (stipulations and notices) that would apply under a given alternative.

Introduction

The lease parcels within the Big Piney Ranger District that are under consideration in the BTNF Oil and Gas Leasing Supplemental Environmental Impact Statement (SEIS) are situated in Sublette County within western Wyoming, along the western flank and foothills of the Wyoming Range and in the Hoback Basin.

The RFDS projects oil and gas exploration, development, production, and reclamation activity on the lease parcels under consideration over a planning horizon that encompasses the next 10 to 15 years. The RFDS provides a basis for the analysis of the effects that discretionary management decisions have on oil and gas activity. Further understanding of the occurrence models for oil and gas resources, and advanced technologies applied to exploration, drilling, production, and field development will likely make it necessary to update the RFDS at a later date. This RFDS updates an earlier RFDS for the BTNF prepared by M. Holm in 1987, which identified most of the NFS lands administered by the BTNF as having high resource potential for economic accumulations of oil and gas.

Geologic Setting

The portion of the BTNF containing the affected lease parcels is characterized by complex geology and structure associated with the Wyoming Thrust Belt and the Hoback Basin, which is part of the Greater Green River Basin. The geologic setting is extracted from Holm (1987) and the online National Assessment of Oil and Gas (NOGA Online) for the Southwest Wyoming Province (SWWP) and the Wyoming Thrust Belt Province (WTBP) prepared by the U.S. Geological Survey (USGS) and located at the USGS Central Energy Team website: http://energy.cr.usgs.gov/oilgas/noga/**.**

During the Paleozoic and early part of the Mesozoic, the area that is now the Greater Green River Basin of the SWWP was positioned between the North American craton on the east and the open Cordilleran sea on the west. At the beginning of the Cretaceous, a major uplift of the western part of the North American craton produced a regional foreland basin situated between the Cordilleran highlands on the west and the Western Interior seaway on the east in response to tectonic and sediment loading. Between the Early Cretaceous and the close of the Paleocene, the area of the Greater Green River Basin occupied a part of this foreland basin.

During much of the Cretaceous this broad, asymmetric foreland basin was partially to completely flooded by the Western Interior seaway. All except the uppermost Cretaceous rocks in the SWWP were deposited in or adjacent to a broad seaway that periodically covered much of the Western Interior of the United States. At its maximum extent, the seaway extended a distance of more than 3,000 miles from the Arctic Ocean to the Gulf of Mexico. The sea advanced and retreated across the western part of the foreland basin, resulting in a complex pattern of marine and nonmarine deposits. Sediments associated with these environments represent marine basins (Lower Cretaceous Thermopolis Shale), coastal plains (Upper Cretaceous Mesaverde Group), and alluvial plains (Paleocene Fort Union Formation). The nonmarine deposits are represented by eastward-thinning wedges of sandstone, siltstone, shale, and coal. The marine deposits are represented by westward-thinning tongues of marine shale and siltstone By the close of the Cretaceous the western shoreline of the seaway retreated eastward as the foreland basin gradually filled in with sediments derived from the eroding uplifts of the Sevier orogenic belt (WTBP).

Archean rocks in basin margin uplifts of the SWWP occur at elevations of more than 13,000 ft, and also in the subsurface at depths of 20,000 ft below sea level, indicating more than 33,000 ft of structural relief. Paleozoic and younger rocks in the basin commonly exceed almost 4 miles in thickness, and locally exceed 6 miles in thickness; with a thickness of almost 8 miles inferred in the northeastern part of the basin.

The western margin of the SWWP is formed by the Wyoming Thrust Belt (WTB), an easterly bulge (salient) of the Sevier orogenic belt that began to form during the latest Jurassic or earliest Cretaceous and ended in the Eocene. The WTBP is characterized by multiple, overlapping low-angle (thin-skinned) thrust faults that moved detached Paleozoic and younger sediments eastward for tens of miles along thrusts that dip gently westward. North trending folds and normal faults are associated with these thrusts. Sediments have been strongly folded and thrust eastward into their present location. There are four major thrust fault systems present in the Wyoming Thrust Belt. From west to east they include the Willard-Paris, Crawford-Meade, Absaroka, and the Prospect-Darby-Hogsback thrust systems. The thrust sheets overrode one another, with the oldest (first emplaced) thrust in the west. Younger thrusts then carried previously emplaced thrust sheets for tens of miles to the east in piggy-back fashion.

The Laramide orogeny, a period of crustal instability and compressional tectonics from the Late Cretaceous to middle Eocene, produced numerous uplifts and structural depressions throughout the central Rocky Mountains. The SWWP was somewhat fragmented into a number of smaller basins by basement-involved faults and basement-cored uplifts during the Laramide orogeny. Present-day structure of the SWWP is largely a result of Laramide deformation characterized by basement-involved thrust faults (thick-skinned), reverse faults, wrench faults, and strongly folded and faulted anticlines and synclines. Basement-cored uplifts bound the SWWP along its northern, southern, and eastern margins. These uplifts have overridden the sedimentary basin along high-angle basement-involved thrust faults in many locations. Major intra-basin uplifts present in the portion of the SWWP within the vicinity of the BTNF include the Moxa arch and La Barge platform.

Basins such as the Greater Green River Basin subsided rapidly and filled with thick accumulations of clastic debris eroded from the surrounding basement uplifts that were rising during the latest Cretaceous and early Tertiary. The uppermost Cretaceous and Paleocene sandstones, siltstones, shales, and coal were deposited on an extensive alluvial plain within the intermontane basin. By the beginning of the Tertiary, the Greater Green River Basin began to take form. Continued subsidence into the middle Eocene fully developed the basin and resulted in widespread deposition of lacustrine and marginal lacustrine sediments. The Hoback Basin is a Tertiary basin that occupies the northern portion of the SWWP and contains thousands of feet of relatively undeformed Tertiary conglomerates, sandstones, siltstones, shales, limestones, and some coals overlying Cretaceous and older rocks at depth. Subtle anticlinal structures are known to be present at depth (Holm 1987).

The Greater Green River Basin filled during the Eocene to Miocene with a thick succession of volcaniclastic sediments to at least an elevation surface about 4,000 ft above present-day topography. Erosion, glaciation, and dissection of the basins to present-day topography took place from the late Miocene to present.

Geologic Provinces

The lease parcels under consideration contain portions of two oil and gas assessment provinces evaluated by the USGS (USGS 1995, 2002, 2004, 2005). These provinces, oil and gas development history, and occurrence potential are addressed in a RFDS analysis prepared by the Pinedale Field Office (PFO) of the BLM in 2006. The RFDS for the PFO is incorporated by reference and forms the basis for the BTNF RFDS for the affected lease parcels.

The USGS has been reassessing domestic oil and natural gas resources in a series of priority basins in the United States using a Total Petroleum System (TPS) approach, where the assessment unit is the basic appraisal unit (rather than the oil and gas play used in a 1995 USGS study). A TPS encompasses accumulations of oil or gas across a geographic area with closely related source rocks, reservoir rocks, and trap characteristics. Assessments of undiscovered oil and gas resources in priority provinces, including the Southwestern Wyoming Province (SWWP) and the Wyoming Thrust Belt Province (WTBP), were recently completed by the USGS as part of the National Assessment of Oil and Gas and are available online (NOGA Online) at: http://energy.cr.usgs.gov/oilgas/noga/. These results were accessed during April and May 2008 for this RFDs analysis and are summarized below.

Wyoming Thrust Belt Province (Province 36) - The province is an arcuate, north-south-trending structural feature covering approximately 15,000 square miles. It extends from the Uinta Mountains on the south to the Teton Range and Snake River Plain on the north, encompassing parts of Wyoming, Utah, and Idaho. The WTBP is an easterly bulge, or salient, of the greater Cordilleran Thrust Belt of western North America that stretches over 5,000 miles from Alaska to Mexico. The wide axis of the thrust belt is roughly coincident with the eastern hingeline of a Paleozoic and Mesozoic miogeocline that had its depocenter in southeastern Idaho, where more than 60,000 ft of predominantly marine sediments of Paleozoic and Mesozoic age were deposited. This sequence was strongly folded and thrust eastward starting in latest the Jurassic in the west and ending possibly as late as the Eocene in the east, followed later by extensional faulting from Eocene to the present. The resulting transition from a thick marine section on the west to a thinner shelf section to the east provides an optimum setting for migration of hydrocarbons from source rocks to updip reservoir rocks in structural traps formed by the thrusting.

Southwestern Wyoming Province, also referred to as Southwestern Basins (Province 37) – The Southwestern Wyoming Province (SWWP) of Wyoming, Colorado, and Utah is located in the Rocky Mountain Foreland. It is an irregularly shaped area that is a composite of several basins and adjacent uplifts in Wyoming, Colorado, and Utah. The SWWP approximates the outline of the Greater Green River Basin in southwestern Wyoming, northwestern Colorado, and northeastern Utah. The USGS Southwestern Wyoming Province includes the Green River Basin, Moxa arch, Hoback Basin, Sandy Bend arch, Rock Springs uplift, Great Divide Basin, Wamsutter arch, Washakie Basin, Cherokee ridge, and the Sand Wash Basin. Hydrocarbon accumulations can be broadly placed in two categories: conventional and continuous. A conventional oil or gas accumulation is defined as a discrete accumulation with a well-defined hydrocarbon/water contact. Conventional accumulations commonly have high matrix permeabilities, obvious seals and traps, and high recovery factors. In contrast, continuous accumulations (also called unconventional) are regional in extent; commonly have low matrix permeabilities; do not have obvious seals, traps, or hydrocarbon/water contacts, generally are abnormally pressured and occur in close proximity to source rocks; and have very low recovery factors. Continuous-type accumulations include basin-centered gas, tight gas, shale gas, shale oil, fractured-reservoir gas and oil, coalbed gas, and gas hydrates. The USGS assessed undiscovered conventional oil and gas accumulations and undiscovered continuous oil and gas accumulations in the SWWP.

Coalbed Methane - The Rocky Mountains region contains several provinces with coal deposits and accumulations of coal bed gas, including the SWWP and the WTBP. A significant portion of the undiscovered coal bed gas resource of the U.S. occurs in Rocky Mountain provinces. If the demand for natural gas increases significantly during the next few decades, as expected, coal bed gas will continue to be an important regional source of natural gas.

TPS Assessment Units

The Assessment Unit (AU) is the basic appraisal unit for each TPS identified within a geologic province. The AUs for each province are described below to provide a background for understanding the geologic or occurrence potentials for the AUs applicable to each lease parcel.

Wyoming Thrust Belt Province (WTBP)

WTB Conventional Oil & Gas (Cretaceous-Phosphoria)

Productive traps have been found in complexly faulted folds and in anticlinal traps on the Moxa Arch where it lies beneath thrust-faulted sediments of the Hogsback thrust fault. Seismic exploration, drilling, and new field discoveries have been most heavily concentrated in the southern-most part of the province. In the northern part of the province only minimal exploration and drilling activity has occurred. Major production has generally come from anticlinal hanging wall structures located near the leading edge of major thrust sheets, generally the Absaroka, Prospect, Darby, and Hogsback thrusts. Thrust sheets where the potential reservoir beds are in contact with organic rich Cretaceous source rocks (either directly or via a thrust fault) have been the most productive.

WTB Coalbed Methane

The coalbed methane AUs are generally defined as those areas where significant coal occurs at depths of 6,000 ft or less. Commercial production rarely extends to depths of greater than 6,000 ft. The Frontier-Adaville-Evanston Coalbed Gas TPS (WTB Coalbed Methane) is a hypothetical petroleum system consisting of Cretaceous and Tertiary strata preserved in narrow elongate synclines parallel to the trend of the major thrust faults. The coalfields having coalbed methane potential include the McDougal coalfield near the leading edge of the Wyoming Thrust Belt.

SWWP Phosphoria (Sub-Cretaceous) Conventional Oil & Gas

The boundary of the SWWP Phosphoria TPS was extended 12 miles west to the surface projection of the footwall cutoff of the Phosphoria beneath the Hogsback-Prospect thrust include subthrust accumulations.

SWWP Mowry Conventional OG and SWWP Mowry Continuous Gas

The boundary of the SWWP Mowry Composite TPS extends westward to the approximate footwall cutoffs of strata against the Hogsback and Prospect thrusts.

Southwestern Wyoming Province(SWWP)

The Mesaverde–Lance–Fort Union Composite TPS

The Mesaverde–Lance–Fort Union Composite TPS is a predominantly gas-prone system within the western part of the SWWP, west of the pinch-out of the Lewis Shale. The Composite TPS is considered as one system because all of the units were deposited in a terrestrial setting, contain similar gas-prone source rocks, and have no regional seal within the entire stratigraphic succession to inhibit the vertical migration of gas. Coals and carbonaceous shales are presumed to be the primary source rocks. Reservoir rocks are mainly fluvial sandstones. The Composite TPS encompasses about 8,410 square miles of the western part of the SWWP, and includes much of the Green River and Hoback Basins and Moxa arch. The TPS is bounded on the west by the leading edge of the Wyoming Thrust Belt, on the east by the western limit of the Lewis Shale, and on the north and south by the limits of the Mesaverde Group and the Lance and Fort Union Formations in the SWWP. The Composite TPS is divided into four assessment units: (1) Mesaverde–Lance–Fort Union Continuous Gas AU; (2) Mesaverde–Lance–Fort Union Conventional Oil and Gas AU; (3) Mesaverde Coalbed Gas AU; and (4) Fort Union Coalbed Gas AU.

Mesaverde-Lance-Ft. Union Continuous Gas

The Mesaverde–Lance–Fort Union Continuous Gas AU encompasses the deeper part of the Composite TPS where thermal maturities at the base of the Composite TPS are 0.8 percent Ro or greater. The eastern boundary is the western limit of the Lewis Shale, which fairly closely follows the 0.8 percent Ro thermal maturity at the base of the Composite TPS. Two gas fields, Jonah and Pinedale, are included in the continuous gas assessment unit.

Hydrocarbons can migrate laterally through persistent porous units or vertically through faults and fractures. Coals and organic-rich shales in the Mesaverde Group and Fort Union Formation are thought to be the principal source of oil and gas in both conventional and unconventional gas assessment units in the Composite TPS.

Gas expelled from coals and organic-rich shales migrated into nearby, low-permeability sandstone beds in the Mesaverde Group, initiating the development of a basin-centered gas accumulation. Migration was probably aided by fractures that formed as pressures increased and eventually exceeded fracture gradients during active gas generation and expulsion. Some of this gas escaped into the overlying Lance and Fort Union Formations, charging both conventional and low-permeability reservoirs in these units. Migration would have been largely vertical through faults and fractures in the thick intervals with mainly lenticular fluvial reservoirs in the TPS. The lowest lacustrine shale in the Wasatch or Green River Formation in the Mesaverde–Lance–Fort Union TPS probably also acts as a regional seal, inhibiting the vertical migration of gas and thus marking the top of the TPS.

Shale and mudstone intervals within the TPS act as local seals. A shale and mudstone interval in the upper part of the Lance Formation at Jonah field is thought to be critical to the trapping of gas. The pinch-out of lenticular sandstones into shale and mudstone can also form lateral seals. The overall trapping mechanism for continuous-type accumulations, such as the continuous gas accumulation that occurs in the Mesaverde–Lance–Fort Union Composite TPS in the more thermally mature (Ro greater than 0.80 percent) parts of the TPS, is considered to be a capillary seal or water block.

Jonah field is bounded on two sides by faults. Overpressuring within the field occurs at depths of from 2,500 to 3,000 ft less than outside the field, and it appears that vertical gas migration up faults and fractures is largely responsible. A thick, fine-grained fluvial interval in the upper part of the Lance Formation appears to act as a top seal.

Minimum, median, and maximum percentages of untested assessment-unit area that has potential for additions to reserves in the next 30 years are 14, 24, and 45 percent. The minimum of 14 percent assumes a continued development of the two existing fields, Pinedale and Jonah, but that no other “sweet spots” will be found. The median of 24 percent assumes that several new “sweet spots” similar to Pinedale and Jonah will be discovered and developed.

Mesaverde-Lance-Ft. Union Conventional Oil & Gas

The Mesaverde–Lance–Fort Union Conventional AU encompasses the entire Composite TPS and overlies the Continuous Assessment Unit in the deeper parts of the Composite TPS. The contact between the Mesaverde–Lance–Fort Union Continuous Assessment Unit and the overlying Conventional AU cannot be uniquely defined. The AU includes three oil fields and four gas fields that. The most recent oil field to be discovered was Ruben field in 1966. It is unlikely that many new oil fields will be discovered in the next 30 years. A median of two oil fields will be discovered and these would be comparatively small fields. The potential for future gas field discoveries is much better. The most recent gas field discovered, Stagecoach Draw field, was discovered in 1993 and is also by far the largest of the four fields discovered to date. A median of 20 new gas fields will be discovered in the assessment unit over the next 30 years

Mesaverde Coalbed Methane

The coalbed methane AUs are defined as those areas where significant coal occurs in the TPS at depths of 6,000 ft or less. Commercial production rarely extends to depths of greater than 6,000 ft. The Mesaverde Coalbed Gas AU covers part of the La Barge platform. Mesaverde coals are truncated beneath younger units along most of the Moxa arch. This AU is hypothetical as there are no producing wells and no tested cells. Interest in the coalbed methane resources of the area has been renewed recently. The lack of coalbed gas at shallow depths in the assessment unit limits the total area that can be developed for coalbed methane. The median of 10 percent of the untested assessment unit that has potential for discoveries assumes that a limited number of “sweet spots” with low water production, high permeabilities, and high gas contents will be discovered.

Ft. Union Coalbed Methane

The coalbed methane AUs are defined as those areas where significant coal occurs in the TPS at depths of 6,000 ft or less. Commercial production rarely extends to depths of greater than 6,000 ft. The Fort Union Coalbed Gas Assessment Unit encompasses areas around the margins of the TPS where significant coal is present in the Fort Union Formation at depths of 6,000 ft or less. .

The Fort Union Coalbed Gas AU includes two areas along the Moxa arch and La Barge platform. Ranks of Fort Union coals within the TPS are mostly subbituminous to high-volatile C bituminous. This compares to Fort Union coals in the Powder River Basin that are mainly subbituminous. Total coal thicknesses within the assessment unit generally average from 10 to 60 ft. The median of 10 percent of the untested assessment unit that has potential for discoveries assumes that a limited number of "sweet spots" with low water production, high permeabilities, and high gas contents will be discovered.

SWWP Phosphoria (Sub-Cretaceous) Conventional Oil & Gas

Black marine shales of the Lower Permian Phosphoria Formation generated a substantial amount of hydrocarbons during the latter part of the Mesozoic. Sixty-eight oil and gas fields in the Green River Basin, including Riley Ridge and La Barge (deep), containing some 700 wells, are reported to produce oil or gas thought to be sourced from the Phosphoria Formation from one or more of 18 formations of Cambrian through Jurassic age. The most productive reservoirs are in the Tensleep Sandstone, Sundance Formation, Nugget Sandstone, Madison Limestone, and Morrison Formation. Nearly 80 percent of the wells produce from these five formations.

Fields are conventional accumulations contained in structural traps associated with anticlines that developed during the Laramide orogeny. Oil is produced from these fields with associated gas and late-stage gas resulting from the thermal alteration (cracking) of oil.

Phosphoria oil began migrating slowly updip toward the east in the Cretaceous. Most regional migration ceased at the end of the Cretaceous when Laramide tectonism disrupted the system of carrier beds, and the Phosphoria oil was essentially locked into place. During the Laramide, newly formed anticlines provided structural traps, and Phosphoria oil in the process of migrating through the area from the thrust belt, or Phosphoria oil being generated within the province, accumulated in these structures in significant quantities to form oil fields. Locally, deeply buried Phosphoria oil started cracking to gas in the early Paleocene, and a period of late-stage gas migration began. Gas migration distances were likely relatively short and limited by structural features.

The first discovery of oil in sub-Cretaceous stratigraphic units was in 1924 and the last was in 1973. One of the first discoveries has been the largest in size or volume. Overall, the 11 sub-Cretaceous accumulations show a decrease in size over the years. In general, the trend is deeper. The first eight reservoirs discovered were at depths between about 2,000 and 4,000 ft, and the last three reservoirs discovered were at depths between about 12,000 and 14,000 ft. Future discoveries will most likely be as small or smaller and as deep or deeper than the historical trend.

Gas was first discovered in a sub-Cretaceous stratigraphic unit in 1925, and the last discovery was in 1996. One of the next to last accumulations discovered is the largest in size. Overall, the 11 accumulations show an increase in size over the years. The first four reservoirs discovered were at depths of about 4,000 ft, but the last group of reservoirs discovered was at depths between about 14,000 ft and 18,000 ft. If this trend continues, future discoveries of gas might be as large or larger and as deep as or deeper than the historical trend.

The first wildcat well drilled to test a sub-Cretaceous stratigraphic unit was completed in 1910. Following that, at least one well was completed for almost every year through 1938, and from 1939 through 2000, one or more wells were completed each year. Three periods of intensified exploration are apparent: 1918 through 1931 during which an average of 4 wells per year were drilled (9 in 1926), 1949 through 1964 during which an average of 15 wells per year were drilled (31 in 1959), and 1968 through 1988 during which an average of 19 wells per year were drilled (32 in 1980). Since 1988, about five wildcats per year have been drilled on average in this TPS.

The availability and high density of seismic line data or 3-D data greatly increases the potential for identification of a covered anticline. The area is considered mature in regard to petroleum exploration. The days of discovering an anticline using simple field geology are most likely over. Sub-Cretaceous accumulations are commonly discovered by drilling deeper in anticlines already producing from Cretaceous or younger units. On average, sub-Cretaceous oil was identified 8 years after the initial field discovery, and deep gas accumulations were identified 15 years after the initial discovery. Future discoveries of sub-Cretaceous accumulations will most likely be in the deeper parts of known anticlines, and finding these will depend on the willingness of oil and gas companies to drill deeper in these structures.

Considering the declining sizes of discovered sub-Cretaceous oil accumulations over time, the exploration maturity of the area, and the low probability of finding covered or subsurface anticlinal structures, the minimum number of undiscovered oil accumulations of minimum size or larger in the Sub-Cretaceous AU was estimated to be two. The maximum estimate of eight undiscovered oil accumulations represents the highest number that could be justified under “best case” conditions. The median estimate was set at four. The prospects for discovering additional sub-Cretaceous gas accumulations seem more promising because the sizes of discovered accumulations are increasing with time, and the latest discovery was made in 1996. The estimated minimum number of undiscovered gas accumulations in the Sub-Cretaceous AU of minimum size or larger was set at 5, the maximum of 45 undiscovered gas accumulations represents an optimistic forecast for future discoveries; the estimated median was set at 17.

SWWP Mowry Conventional Oil & Gas and SWWP Mowry Continuous Gas

The Mowry is a composite system because there are multiple source rocks present within about a 1,000-ft stratigraphic interval. The Mowry Composite TPS is present within all of the SWWP. There are multiple source rocks including the Mowry and Thermopolis Shales and their equivalents (marine units), and the Bear River and Frontier Formations and Dakota Sandstone (terrestrial facies). Reservoirs are sandstones in the Frontier Formation, Bear River Formation, Dakota Sandstone and equivalents, and the Muddy Sandstone Member of the Thermopolis Shale. Traps are stratigraphic, structural, and basin centered, and seals are diagenetic, capillary, or lithologic, including marine, estuarine, and terrestrial shale. Accumulations are both basin-centered and conventional.

Marine and terrestrial source rocks were buried within the foreland basin and overridden by thrusts between approximately 100 and 80 million years ago. Petroleum was generated during this time, and oil and gas migrated updip from the west through carrier beds and were trapped in stratigraphic pinch-outs or contemporaneous intrabasinal structures, such as the Moxa arch. By the Late Cretaceous and continuing into the Eocene, compressional tectonics created major basin-bounding and intrabasin structures. Basin fill (Cretaceous to Eocene) buried the Mowry Composite TPS source rocks to a depth and thermal regime that allowed petroleum generation within the province, resulting in continuous accumulations of oil and gas in the basin centers and parts of the Moxa arch, and conventional accumulations where stratigraphic pinch-outs and structural traps were present at the margins of subbasins.

The Mowry Conventional Oil and Gas AU covers the entire province and includes mainly intrabasinal and basin margin structures and stratigraphic traps, but also includes traps located stratigraphically below the basin-centered accumulations of the Mowry Continuous Gas AU. The areas that have potential for additions to reserves in the next 30 years contain relatively small fields with local structural closure or small stratigraphic traps within the Rock Springs uplift. Historically, 11 conventional oil fields and 29 conventional gas fields have been found in the province. No conventional accumulations above the minimum size cutoff have been discovered since the mid-1980s. A median well drainage area of 120 acres is based on current and anticipated well-spacing. Infill drilling is expected to have a better success ratio than the historical ratio of 76 percent, stepout drilling is expected to have a similar success ratio (76 percent), and in undrilled areas, the ratio is expected to be less than the historical success ratio.
The continuous gas AU underlies an area of about 11.5 million acres where the approximate limit of gas saturation is defined by: (1) areas of overpressure, (2) bottom hole temperature greater than 200°F, (3) vitrinite reflectance greater than 0.8 percent, (4) low permeabilities, and (5) absence of gas/water contacts in the reservoirs. These conditions are generally reached at depths of 8,000 to 12,000 ft in the province because of the interrelationship of heat flow, source rock maturity, and overpressuring due to gas generation in low-permeability rocks.

The USGS estimates that a median value of about 9 percent of the untested assessment unit is thought to have potential for additions to the reserves over the next 30 years. It would follow that over a 15-year RFD planning horizon, half of the untested area with potential may be evaluated.

SWWP Hilliard-Baxter-Mancos Conventional OG and SWWP Hilliard-Baxter-Mancos Continuous Gas

The Hilliard-Baxter-Mancos TPS is divided into two assessment units: (1) the Hilliard-Baxter-Mancos Conventional Oil and Gas Assessment Unit and (2) the Hilliard-Baxter-Mancos Continuous Gas Assessment Unit. These two assessment units overlap through a broad zone near the basin margins.

The Hilliard-Baxter-Mancos interval was deposited in offshore to nearshore marine settings in the foreland basin during an extended period of time in the Late Cretaceous when the shoreline was predominantly west of the TPS. The stratigraphic interval included in the TPS ranges from about 3,500 to 6,000 ft thick and contains thick intervals of organic-rich marine shales that are potential source rocks and thick silty and sandy nearshore to offshore marine intervals that are potential reservoir rocks. This TPS has been sparsely explored, but some promising discoveries have been made.

Conventional traps include anticlines and the stratigraphic pinch-out of sandstone into finer grained mudstone and shale. Seals are most commonly mudstone and shale, but seals can also form from the termination of sandstone bodies against faults. The overall trapping mechanism for continuous-type accumulations, such as the continuous gas accumulation that occurs in the more thermally mature parts of the TPS, is thought to be a capillary seal or water block.

The Hilliard-Baxter-Mancos Conventional Oil and Gas Assessment Unit covers the marginal areas of the SWWP and includes one oil field and eight gas fields. The first field discovered was Bunker Hill in 1937, and the most recent discovery was Craven Creek field in 1974. All of the fields are on structures around the shallow margins of the basin, and it is likely that most structures have already been discovered. Because of these factors, the potential for future discoveries in this AU are not considered great. Estimates of minimum, median, and maximum number of gas accumulations that will be discovered in the next 30 years are 1, 2, and 4, respectively.

The Hilliard-Baxter-Mancos Continuous Gas Assessment Unit covers about 10.5 million acres of the Southwestern Wyoming Province and it produces from five fields. The assessment unit is largely untested with only 157 tested cells identified for this vast area for a median percentage of total assessment unit tested of 0.1 percent. Only wells that had drill-stem tests or completions in the Hilliard-Baxter-Mancos interval or that bottomed in the Hilliard-Baxter-Mancos interval were considered tests. Wells drilled to the underlying Frontier Formation are not included as Hilliard-Baxter-Mancos tests because there is no indication that the operators tested for gas in the overlying Hilliard-Baxter-Mancos interval. Of these 157 identified tests, only 12 had established production for a historical success ratio of 8 percent. Minimum, median, and maximum area per cell of untested cells having potential for additions to reserves in the next 30 years are 20, 80, and 180 acres, respectively.. Minimum, median, and maximum percentages of untested area that has potential for additions to reserves in the next 30 years are 2, 14, and 36, respectively.

Oil and Gas Exploration and Development History

Oil and gas exploration and development in Sublette County dates back to the discovery of oil in the LaBarge field area in the early 1900's. A summary prepared by BLM (2006) indicates that the first production from the LaBarge field was obtained in the spring of 1924. By 1929, the Dry Piney and LaBarge field was producing about 2,000 barrels per day. Acceleration of drilling activity has coincided with periods of increased demand, such as World War Two (oil demand), the energy boom of the 1970s (oil and increasing gas demand), and the current high level of gas drilling activity that has been occurring in recent years. This recent acceleration is at least partly in response to increased knowledge of the area, improved gas prices, and improvements in techniques used to drill and complete wells. Increased drilling activity has been concentrated within the Jonah Field, which began in earnest in 1997, and the Pinedale Anticline which began in 2000.

Oil and gas fields that include some of the NFS lands in the vicinity of the lease parcels are the Soda, Riley Ridge, Lake Ridge, Fogarty Creek, and Maki Creek fields. Other fields in the vicinity of the lease parcels, but located outside the National Forest boundary, include the Mickelson Creek and Merna fields.

Only two exploratory wells have been drilled on the subject leased lands. Gulf Oil Corporation drilled a 7,851 foot test in 1961 and Davis Oil Company drilled an 11,928 foot test in 1978. Both wells were not productive and were abandoned.

A total of 73 other wells have been drilled in surrounding management areas. Three small fields have been discovered in these areas. Maki Creek has produced from the Mesaverde Group in two (presently shut-in) wells. Soda Field has produced from the Frontier Formation in four (presently shut-in) wells. The Cabin Creek Unit well (Section, 33, Township 37 North, Range 114 West) recovered oil and gas from the Madison Limestone. This well was determined to be uneconomic to produce by the operator and it was abandoned, but the Wyoming State Geologic Survey carries it as an abandoned field.

Additional wells produce carbon dioxide rich gas from the Madison Limestone at Lake Ridge and Fogarty Creek fields and are capable of producing at Riley Ridge Field. Madison production from these fields comes from a large reservoir delineated by Stilwell (1989). Pending leases WYW173043, WYW173044, WYW173278, WYW173279, and WYW173280 lie within the limits of this reservoir, although not at the best locations for near-term development.

Field Name	Discovery Date	No. of wells	Gas MCF (cum)	Oil BBLS (cum)
Mickelson Creek	1960	19	7,790,896	244,513
Fogarty Creek	1979	22	3,242,767,935	69,542
Maki Creek	1980	2	525,005	13,062
Riley Ridge	1980	8	1,415,851	14,027
Lake Ridge	1981	6	1,386,769,421	6,500,063
Merna	2001	2	99,659	364
Soda	1982	4	382,910	19,443

The above table shows that gas is the primary production target and that existing fields have a relatively small number of wells.

Projections of Future Activity

The occurrence potential categorizes the likelihood of encountering hydrocarbon-bearing rocks at depths that can be feasibly drilled and produced. This interpretation is based on the following information: RFDs analysis prepared by BLM; geology and structure; USGS oil and gas assessment provinces and applicable Total Petroleum System (TPS) mapping/assessment units/results for each province; existing leases and units held by production; oil and gas fields; producing wells; shut-in wells; plugged and abandoned wells; and existing leases not held by production. This supporting information is presented in a series of unnumbered Figures attached to this report.

Areas with a high occurrence potential are characterized by the presence of proven source and reservoir quality rocks that have experienced a favorable thermal maturation history for the generation and trapping of significant hydrocarbon accumulations. Areas with moderate occurrence potential are those characterized by geophysical or geological indications of the presence of source and reservoir quality rocks which may have undergone a favorable thermal maturation history for the generation and trapping of hydrocarbon accumulations. Areas with low occurrence potential are characterized by an absence of one or more key characteristics (source rocks, reservoir rocks, thermal maturation, and/or trap presence). Areas with no known hydrocarbon occurrence potential are those areas without source rocks, reservoir rocks, favorable thermal maturation history, or traps essentially excluding the occurrence of hydrocarbons in the area.

A high level of exploration and production of natural gas from continuous (basin-centered) gas accumulations would continue during the 10 to 15-year planning horizon in the Southwest Wyoming Province (SWWP). Energy companies will continue to search diligently for other Jonah-type fields in the central and northern portions of the project area. It is likely that additional new target areas (new lease areas) on NFS lands will be explored rather than ignored during the 10 to 15 year planning horizon. The northern lease parcels (Sheet 1 of 3) represent an area that may have favorable targets for continuous gas accumulations. Where existing access is good, and few lease stipulations and notices have been applied to lease parcels within the SWWP Mesaverde–Lance–Fort Union Continuous Gas Analysis Unit (AU), a good opportunity for an exploratory program, referred to in this RFD as the Beaver-Horse Exploratory Gas Wells (1 to 5 exploratory wells), would exist.

The Mesaverde–Lance–Fort Union Continuous Gas AU is producing regionally in the Jonah and Pinedale Anticline fields. A proposal to test a portion of this AU just north of the northernmost block of lease parcels (those parcels shown on Sheet 1 of 3) is currently being evaluated by the Big Piney Ranger District of the BTNF. That proposal, by Plains Exploration and Production Company Inc. (PXP) would involve exploratory drilling of 1 to 3 wells from one wellpad located in T.36N. R.113W., Section 8. The Merna field (T.36N. R.112W. Section 28) is located less than 10 miles east of the PXP Eagle Prospect.

Within the planning horizon of 10 to 15 years, it is reasonably foreseeable that this system (Mesaverde–Lance–Fort Union) will be tested by an exploratory program located somewhere on the northernmost block of lease parcels (those parcels shown on Sheet 1 of 3), given the high interest in the Jonah and Pinedale Anticline fields. An exploratory program for continuous gas accumulations could be based on 1 to 5 bottomhole locations drilled initially from a single multi-well pad. One well pad 8 acres in size would be adequate for drilling 1 vertical and 4 directional boreholes (bottomhole locations), each about 10,000 to 14,000 feet deep. Anticipated surface disturbance associated with this exploratory program could be comparable to the PXP exploratory program, affecting 11-12 acres over the short term (pad and access) and 6 acres over the long term, if the exploratory wells are productive. If planned exploratory wells are successful, development likely would proceed on 40 to 80-acre spacing for bottomhole locations drilled from multi-well pads.

Most of the subject 44,720 acres lie within a reasonable foreseeable development analysis area prepared by Stilwell and Crockett (2006) for the Pinedale Field Office Planning Area. Their analysis was used to project the number of wells that could be drilled on the subject leased land in the next 10-15 years (assuming those land would not be restrained by management-imposed restrictions). Approximately 528 leased acres lie within the Kemmerer Field Office Planning Area and the same assumptions and projections were made for those lands. Analysis indicated that 27 wells could be drilled on the subject leased lands in the next 20 years. Some small number of these wells could be coalbed gas wells. The projection of 27 wells should be considered as the most likely number of wells that could be drilled.

Coalbed gas wells in this area would likely be undistinguishable from wells producing from sandstone or shale formation. Most of the coal zones are within the Mesaverde Group or the Bacon Ridge Formation, which are known to be overpressured. Being overpressured, these zones would not require de-watering to create a pressure gradient to release the gas as is the case in the Powder River Basin. Coalbed gas in the Powder River is produced from shallow, low pressure zones. Large volumes of produced water would not be anticipated for any wells within the project area.

There is some geologic uncertainty as to whether any oil or gas exists under the leased tracts. Rose (2001) reported that new field wildcats during the 1980's in the U.S. were 13-18% successful. These types of wells have relatively low probability of success due to the high risk associated with finding an economically productive reservoir. Using probability theory presented by Rhoads (2003), a calculation of probability of success of obtaining at least one successful well after 27 attempts would be between 97.7 and 99.5 percent, using success rates reported by Rose (2001). It appears very likely that if 27 new field wildcats are drilled in the subject leased area, then at least one new field discovery may be made. It is very likely that a new discovery would be in the small field size (less than one million barrels of oil equivalent or less than six billion cubic feet of gas) with six or fewer producing wells since Root and Attanasi (1993) estimated the 89% of the ultimate number of discovered fields in the lower 48 states would be in the small field category. As stated earlier, the few fields discovered in the immediate area are considered to be small in size and help confirm that any new discovery will likely also be small in size.

Realistic upper and lower ranges of the number of potential future wells drilled can also be projected from the historical record and exploration proposals made for the leased area. There is a very high probability (probably greater than 19 in 20) that at least two new wells could be drilled and a very low probability (probably much less than 1 in 20) that at least 200 new wells could be drilled in the next 20 years on the subject leased lands.

It is possible that additional new target areas (new lease areas) on NFS lands will be drilled rather than ignored during the 10 to 15 year planning horizon. The central and southern lease parcels (Sheets 2 and 3) represent areas that may have favorable targets for infill and well replacement drilling, and drilling to greater depths near existing fields. However, the central and southern lease parcels adjoin many existing leases and units already held by production.

Moderate development potential is anticipated on the La Barge Platform. Drilling densities would be anticipated to vary from relatively dispersed, with up to 4 bottomhole locations per square mile, to local areas with more intense drilling activity. On average, given the acreage included in the parcels, most parcels would likely have 0 to 2 wells drilled over the 10 to 15-year planning horizon. Parcels WYW173278, WYW173279, and WYW173280 would each be likely to have 2 wells drilled over the 10 to 15-year planning horizon.

<u>Summary of Potential Surface Disturbance</u>:

Drilling and well pads: With the estimate that 27 wells could be drilled in the next 10-15 years, up to 10 of those wells could be exploratory wells and 17-25 would be development wells should a field(s) be discovered. If a discovery is made with one of the initial exploratory wells, then more of the 27 projected wells (i.e., 25) would be associated with development.

A limit of 10 exploratory wells is deemed reasonable because of the limited acreage available to explore. Industry would loose interest in this area if no production is found after the 10 exploratory wells. Should additional acreage be leased, or technology and new information indicate deeper economic reserves are possible; a few additional wells may be drilled to test those zones.

The 10 exploratory wells would be single well pads and if nonproductive, would be reclaimed upon completion of the drilling process. The pads would be approximately 400 ft. by 350 ft. or 3.2 acres in size (including cut and fill slopes).

Should one of the exploratory wells discover a new field, the well pad would be expanded to accommodate additional wells or a second larger pad (approximately 8 acres in size) constructed and 5 development wells drilled from that location; 1 straight hole and 4 directional. Similar pads and drilling processes would continue until the outer limits of the field are defined. *Should reservoir characteristics require closer well spacing, additional wells could be directionally drilled from those pads.*

Pads would temporarily impact 32 acres (10 exploratory wells x 3.2 acres) and approximately 24 acres (3 multi-well pads x 8 acres), for a total disturbance of 56 acres.

Roads: Access roads would typically be single lane roads (14 ft. driving surface) with turnouts as needed. It is estimated that approximately 0.7 miles of road would be needed to access each of the 27 well pads for a total of 18.9 miles. With a 40 foot construction width, approximately 3.4 acres would be impacted per location. For the 27 wells that would result in impacts to 91.8 acres. In the north block of parcels, due to the density of existing roads most of the impact would involve reconstruction rather than new construction.

Pipelines: Pipelines would generally be laid within the road prism and therefore would not add to the surface disturbance acreage.

Also, non-productive wells and associated access roads would be reclaimed within one year of completing the well, and vegetation re-established within a couple growing seasons. As such the total acreages identified above would be cumulative for the 10-15 year period and not anticipated to occur at any give point in time. If wells are productive the pad is reduced to the area needed for production which typically decreases the area by half or more. Also, all but the 14 ft. driving surface of the access road would be reclaimed.

Principal Assumptions for Post-Leasing Activities on the BTNF

Lack of pipeline capacity may make any marginally productive discoveries uneconomic to develop and may temporarily constrain drilling activity over several years for better discoveries, until additional gathering and sales pipelines come online.

Drilling and production activity will be related to the future price for natural gas. Supporting factors include an increase of about 50 percent in the U.S. demand for natural gas by 2020, and future anticipated prices for natural gas through 2020 that make it possible for unconventional resource plays to achieve rates of return on investments adequate to support anticipated levels of activity.

It is unlikely that projected future crude oil prices will significantly increase drilling and production activity on the affected lease parcels.

Geophysical (seismic) exploration in western Wyoming will continue to be an important exploration tool to delineate or identify potential targets within the Thrust Belt province. Geophysical operations in the vicinity of the affected lease parcels will most likely be conducted using heli-portable techniques which have very minimal and short term affects.

Drilling activities during the 10-15 year planning period are most likely to be primarily for continuous type gas reservoirs and secondary for conventional reservoirs.

An exploratory program for continuous gas accumulations could be based on 1 to 5 bottomhole locations drilled initially from a single wellpad. If initial exploratory wells are successful, development likely would proceed on 40 to 80-acre spacing for bottomhole locations from multi-well pads.

Close well spacing and hydraulic fracturing is necessary to produce gas accumulations in fields with producing zones consisting of numerous, stacked and discontinuous sandstones.

For continuous type reservoirs, one well pad 8 acres in size would be adequate for drilling up to 16 directional boreholes (bottomhole locations), each about 10,000 to 14,000 feet deep. Eight directional wells could reach all 80-acre drilling locations in a section, while 16 directional wells could reach all 40-acre drilling locations. After all bottomhole locations are drilled from a well pad, the footprint of the well pad would be reduced to 2 acres through interim reclamation activities. An estimated 0.7 mile corridor within each section would contain the well pad access road system and gathering lines and would disturb a 40-foot width.

Coalbed natural gas development potential for the subject leases is 2.3% moderate, 70% low, 23.7% very low, and 4% no potential.

Anticipated Post-Leasing Activities (RFDs) for the BTNF

At the analysis stage for both exploration and development projects, the appropriate environmental protection measures (such as best management practices, mitigation, and standard operating procedures) and reclamation measures would be identified through the analysis process. All measures would be incorporated in the Surface Use Plans of Operation (SUPOs) and development plans. Key elements that would be considered in future site-specific analyses include:

- Noxious weed prevention and control
- Road maintenance standards
- Erosion control measures
- Spill prevention measures and controls
- Wildlife mitigation
- Water quality protection measures
- Reclamation of all surface disturbances
- Plugging and closure of all drill holes and wells
- Visual quality protection
- Waste management options

Guidance and sources of information would follow current Federal and state laws, regulations, and policies in effect at that time; they include, but would not be limited to:

36 CFR 228 Subpart E
Federal Onshore Oil and Gas Orders
1990 Forest Plan (and future revisions or amendments)
BLM and Forest Service Oil and Gas Gold Book, 4th edition (Operators Guide)
Forest Service Handbook, FSH 2509.25, Watershed Conservation Practices
Forest Service Roads Engineering Guidance

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