OIL AND GAS POTENTIAL
AND
REASONABLE FORESEEABLE DEVELOPMENT (RFD) SCENARIOS

IN THE

GRAND MESA, UNCOMPAHGRE, AND GUNNISON (GMUG) NATIONAL FORESTS

COLORADO

Bruce Fowler
Bureau of Land Management
Geologist

Pat Gallagher
Bureau of Land Management
Petroleum Engineer

August 27, 2004

Table of Contents

SUMMARY …… 3

INTRODUCTION …… 3

OIL AND GAS RESOURCE POTENTIAL …….. 6

Geology, USGS Assessment, Gas Fields – Piceance Basin …… 7

Geology, USGS Assessment, Gas Fields – Paradox Basin …… 19

Oil and Gas Occurrence Potential ……. 23

SCENARIO FOR FUTURE OIL AND GAS EXPLORATION AND DEVELOPMENT ACTIVITY …… 29

Introduction ……. 29

Historical Development and Overview ……. 31

Present GMUG Condition ……. 33

Recent Exploration/Development Trends …… 36

Trends – Gas Price and Drilling …… 40

GMUG Reasonable Foreseeable Development (RFD) …… 44

APPENDIX 1. Classification of Oil and Gas Potential …….. 48

CONTACTS …… 49

ACRONYMS AND ABBREVIATIONS …….. 50

GLOSSARY …… 51

REFERENCES …… 52

SUMMARY

Areas of the GMUG considered to have moderate to high potential for oil and gas occurrence are the Grand and Battlements Mesas, the Upper North Fork of the Gunnison River Valley (where the Mesaverde Formation is present, excluding the West Elk and Ragged Mountains), and the southwestern portion of the Uncompaghre Forest within the Paradox Basin **(see Figure 10)**. The Piceance Basin portion (Grand Mesa and Gunnison Forests) contains oil and gas reservoirs primarily within Cretaceous Mesaverde Group rocks, while the Paradox Basin contains plays within Paleozoic formations. The most prolific area of production and development in the region occurs in the Piceance Basin within the Mamm Creek, Rulison, Grand Valley, and Parachute Fields, located about 5 miles north of the GMUG. Regional oil and gas drilling and leasing activity is shown on **Figures 1** and **2**.

Historical drilling activity in the GMUG has been sporadic, with only 106 wells drilled over a 55-year period. Of the 106 wells, 84 wells are in the Piceance Basin and 22 wells in the Paradox Basin. There are presently only 15 wells capable of production, all located within the Gunnison and Grand Mesa Forests. Based on the number of wells drilled or permitted, the GMUG represents about 11% of the historical regional activity, with the region being defined as an area that includes a 6 mile buffer around the GMUG. This translates into a forecast of 19 wells drilled and 2 wells abandoned on the GMUG over the next 15 years based solely on historical drilling activity.

Gas prices and drilling trend similarly, with gas prices predicted to escalate at 2% per year. Given this trend, it is also projected that the wells will increase at 2% over the previously drilled wells, or 2 wells per year, based on 106 existing wells drilled. This translates into 30 new wells over the next 15 years, which is an increase of 11 wells over the projection of 19 wells from just historical drilling trends.

Gunnison Energy Corporation is in the process of completing a Geographic Area Proposal that would include 15 wells north of the Spaulding Creek area on the GMNF. These 15 additional wells are added to the 30 wells projected solely on price escalation for a total forecast of 45 wells.

For the projected 45 wells and associated pipelines, a total disturbance before interim reclamation is estimated to be 153 acres, and after interim reclamation would be 86 acres and 27 miles of road. Plugging of 2 wells during the RFD period will result in a total of 3.8 acres including 1.2 miles of road reclaimed. Therefore, total disturbance after interim reclamation would be about 86 – 3.8 acres or 82 acres.

INTRODUCTION

Background. Implementing regulations of the 1987 Federal Onshore Oil and Gas Leasing Reform Act require the Forest Service to analyze the environmental effects from activities which might result from implementation of a proposed leasing program (36

CFR 228 Subpart E). A scenario of the type and amount of post-leasing activity that is reasonably foreseeable as a consequence of leasing under specified conditions provides the basis for analyzing effects from leasing. This is commonly referred to as a "Reasonably Foreseeable Development Scenario", or "RFD" and provides an activity scenario based on oil and gas resource occurrence, with development unconstrained by restrictions beyond those provided under standard lease terms and designated wilderness. Information in this report provides a context in which activity scenarios under different levels of management constraints can be developed with respect to projected oil and gas activities. The report describes the surface and subsurface geology of the GMUG, discusses potential for oil and gas resources to occur within the Forest, and gives a reasonable projection of the type and amount of oil and gas exploration and development that might occur on the Forest during the next 15 years.

This RFD was prepared using the interagency reference guide "Reasonable Foreseeable Development Scenarios and Cumulative Effects Analysis" final draft dated August 30, 2002. The guide provides recommended criteria for an adequate RFD scenario and documents the major terms and concepts associated with cumulative effects analysis and reasonable foreseeable development in the context of oil and gas resource management.

Determining Oil and Gas Resource Potential. The "Oil and Gas Resource Potential" section of this report describes areas of different potential for accumulations of oil and gas on the GMUG. Geologic criteria defined in Appendix 1 are the basis for determination of potential. An area of defined oil and gas resource potential may include adjacent non-Forest lands where the geology and exploration and development activity are significant to describing potential for oil and gas resources on the Forest. The "Oil and Gas Resource Potential" section summarizes previous studies, provides descriptions of the stratigraphy, structure, and past drilling activity in the area, with emphasis on potential reservoir rocks, source rocks, and stratigraphic and structural traps.

Projected Oil and Gas Exploration and Development Activity. Projecting expected oil and gas activity is necessary to assess potential effects of leasing forest lands for oil and gas exploration and development. The "Scenario for Future Oil and Gas Exploration and Development Activity" section of this report presents thr type and level of anticipated activity principally based on geology and past and present activity. Economics and technology, access to an area of interest, and the availability of processing facilities and transportation also play a role in exploration and development activity levels. Some of these factors, such as economics and technology, are difficult to predict due to their complexity, interactive nature, and variability in time. The "Scenario for Future Oil and Gas Exploration and Development Activity" is based on what is currently known about geology and activity and cannot be expected to include accurate predictions of future fluctuations in oil and gas markets and political factors or rapid and unpredictable changes in technology.

Relationship of Potential for Resource Occurrence to Potential for Activity. Projected oil and gas activity may not always equate with geologic potential for the existence of hydrocarbons. In some areas where all the geologic factors indicate a high

potential for oil and gas resources, other factors, such as inaccessibility, risk, high exploration costs, and low oil and gas prices, may limit the potential for exploration and development activity to occur. Consequently, an area of high potential for hydrocarbon occurrence may have a low potential for exploration and development activities. On the other hand, such factors as rapidly escalating product prices or advances in technology could lead to drilling activity in areas considered to have a low potential for oil and gas occurrence. In any case, current projections of activity are based on currently known conditions and reasonable expected changes in technology and price factors.

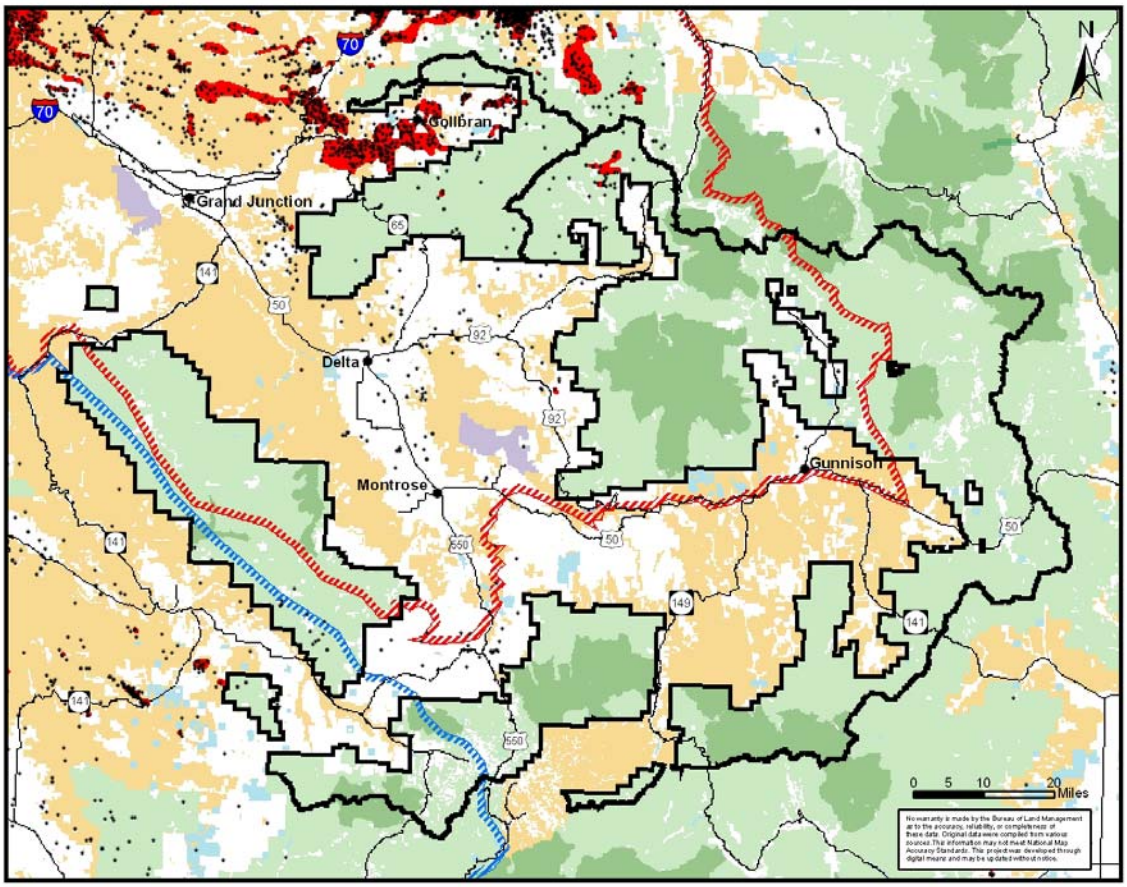


Figure 1

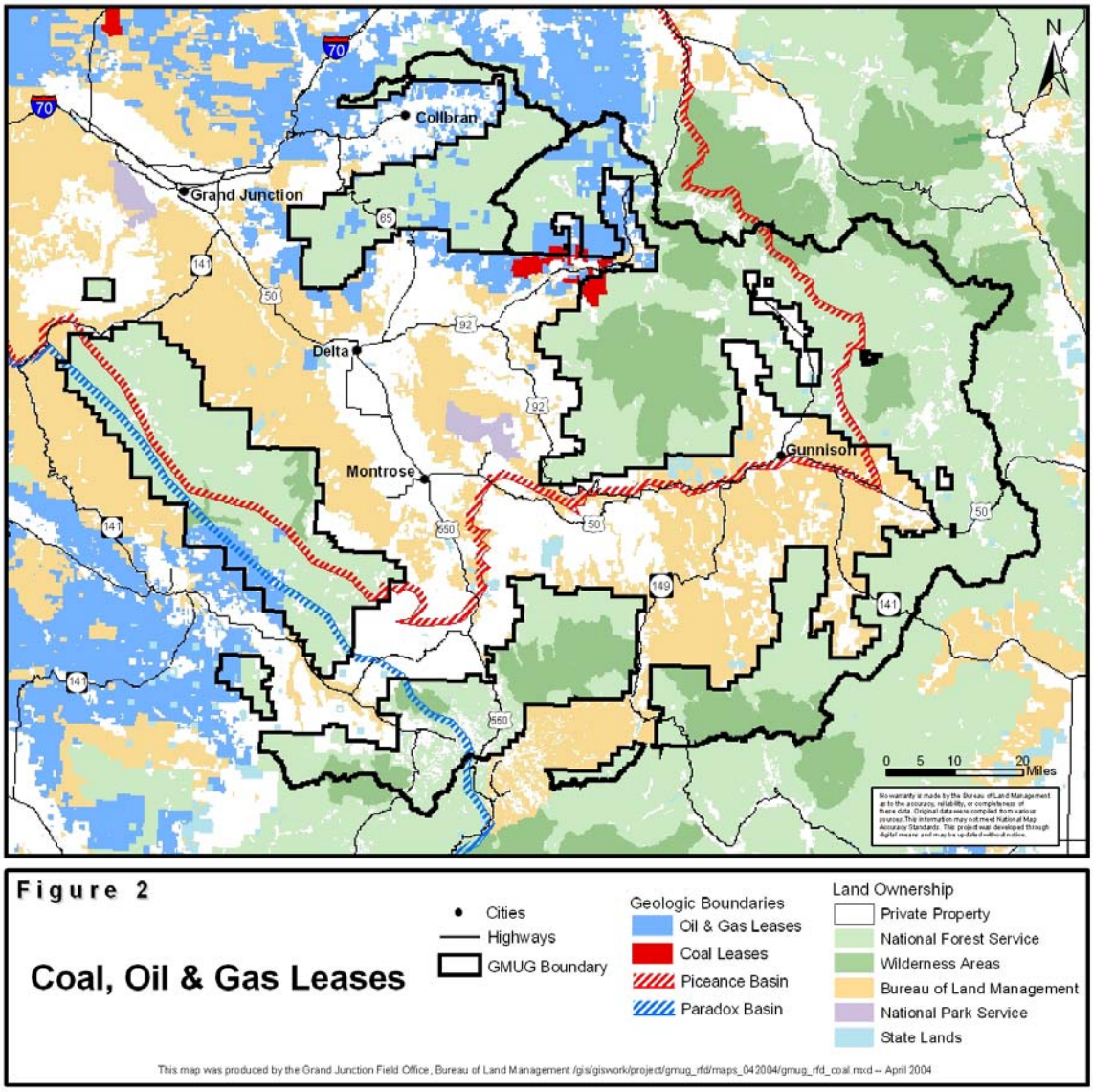
Well Locations and Oil & Gas Fields

Cities
Highways
GMUG Boundary

Geologic Boundaries
Well Locations
Oil & Gas Fields
Piceance Basin
Paradox Basin

Land Ownership
Private Property
National Forest Service
Wilderness Areas
Bureau of Land Management
National Park Service
State Lands

This map was produced by the Grand Junction Field Office, Bureau of Land Management /gis/giswork/project/gmug_rfd/maps_042004/gmug_rfd_wells.mxd -- April 2004



OIL AND GAS RESOURCE POTENTIAL

Geology

Physiography

The GMUG is located along the northeastern edge of the Colorado Plateau physiographic province. The major physiographic areas are prominent topographic features, including Grand Mesa and the Uncompahgre Plateau, portions of Battlement Mesa, northern San Juan Mountains, the Raggeds, West Elk Mountains, and Sawatch Range. The extreme eastern edge of the GMUG is the Forest boundary at the Continental Divide in the

Sawatch Range. Elevations in the Forest range from about 8,000 to over 12,000 feet. Narrow to broad valleys and drainage basins of mixed BLM-private ownership separate the mesas and mountain ranges. They include the North Fork Valley, Gunnison Basin, Uncompahgre and Gunnison River valleys. A great variety of landforms and geologic exposures are present across the area. The broad basins, mesas, badlands, and canyons dominate the north and western portion of the area while the rugged mountain ranges cover the south and east portion.

The areas with high to moderate oil and gas potential are confined to lands within the Piceance and Paradox Basins with outcrops of sedimentary rocks. This high/moderate potential area does not include the uplifted ranges, such as the San Juans and Sawatch Range.

The northern edge of the GMUG shares a boundary with the White River National Forest, and the eastern boundary runs along Huntsman ridge south to McClure Pass, and along the Raggeds Wilderness. It also extends south of the North Fork of the Gunnison River into the West Elk Mountains. GMUG also contains most of the Grand Mesa and portions of Battlement Mesa. Portions of the Uncompahgre Plateau are also in GMUG NF.

Geologic Setting and Regional Structure

Piceance Basin - The northern part of the GMUG is situated within the southeastern portion of the Piceance Basin (**Figure 1**). The basin, which extends for 100 miles to the northwest through portions of Gunnison, Delta, Mesa, Garfield, and Rio Blanco Counties, was formed during the Laramide Orogeny (late Cretaceous through Eocene). Present day configuration was not defined until the White River Uplift, which forms the present-day northeast margin of the basin, began to rise (Johnson and Flores, 2003). The southeast end of the basin is surrounded by other uplifts, including the Sawatch Range to the east, Gunnison Uplift to the south, and the Uncompahgre Uplift to the southwest. The Grand Hogback Monocline borders to the east.

Paradox Basin - The southwest part of the GMUG lies within the Paradox Basin. The Paradox Basin was formed in Middle Pennsylvanian time as a result of faulting along the pre-existing, northwest-trending Uncompahgre lineament with uplift to the northeast and corresponding basin downwarping across the fault to the southwest. Salt anticlines developed in the deeper part of the basin, with the thickest section of evaporates, as salt moved upward in response to sediment loading from the north (Scott, 2003). The basin contains the thickest sediments along the northeastern margin where it is bounded by the Uncompahgre Uplift.

Stratigraphy (source rocks, reservoirs, traps, and seals) - Piceance Basin

Stratigraphic Framework

Exposed bedrock in the Piceance Basin consists of sedimentary units ranging from Upper Cretaceous (late Mesozoic) to Middle Eocene (early Cenozoic) in age. Bedrock is exposed on dissected uplands, cliffs, and hogbacks. Outcrops include (in ascending order of age) the Mancos Shale, the Mesaverde Group, Wasatch Formation, Green River Formation, and Uinta Formation. The Mesaverde Group is divided into the Iles Formation (including Rollins, Corcoran, and Cozzette sandstone members) and the overlying, massively stacked, lenticular non-marine Williams Fork Formation (including the Cameo Coal Zone). Historically, most of the Mesaverde Group gas development is primarily from the Cozzette and Corcoran sandstones. The upper portion of the Piceance Basin sequence - the Uinta, Green River, and Wasatch Formations - are found on the upland surfaces of Grand and Battlement Mesas beneath a mantle of colluvium and Tertiary basalt flows. Remnants of the Wasatch Formation outcrop along the northern flank of the West Elk Mountains. The Wasatch and Mesaverde outcrop along the slopes, and the Mancos Shale is exposed in the valleys below the Mesaverde outcrop. The sequence of buried sedimentary rocks which overlie Precambrian igneous and metamorphic rocks include (in ascending order) the Chinle Formation, Wingate Sandstone, Kayenta Formation, Entrada Sandstone, Wanakah Formation, Morrison Formation, Burro Canyon Formation, Dakota Sandstone, Mancos Shale, the Mesaverde Group, Wasatch Formation, and Green River Formation. A generalized stratigraphic column is shown on **Figure 3**.

Geologic Structure

The sedimentary rocks in the Piceance Basin portion of the GMUG generally dip to the north-northeast at about 200’-300’ per mile. A synclinal structure trending northwest-southeast is located in the northeast portion of the GMUG between Battlement Mesa and the area east of Somerset. Further northeast in the adjacent White River Forest, the rocks are folded into the Divide Creek, Coal Basin, and Wolf Creek anticlines. Some gas production occurs on top of these structures. The dip changes dramatically in the Coal Basin area along the eastern margin of the basin, with the rock layers dipping toward the west as steeply as 1000’ per mile.

AGE	FORMATION		MEMBER	THICKNESS (ft)	DOMINANT ROCK TYPES
Quaternary	*Grand Mesa*			< 100	Gravel and Till
	Lands End			< 100	Gravel and Till
Miocene	*Basalt*			170-680	Basalt
Miocene	*Unnamed*			0-100	Sandst. & Mudrock
Eocene	*Uinta*			400+	Sandst. & Mudrock
	Green River		Parachute Creek	300-1,100	Oil Shale and Marlstone
			Garden Gulch	300-700	Mudrock, Limest. & Sandst.
			Douglas Creek	100-300	SS and Shale
	Wasatch		Shire	600-4,000	Mudrock
Paleocene			Molina	50-500	Sandstone
			Atwell Gulch	700-1,800	Mudrock
Upper Cretaceous	*Mesaverde Group*	*Williams Fork (Hunter Cyn.)*	Ohio Creek	0-100	Sandst. & Congiom.
			Undifferentiated	1,500-2,000	Sandst. & Mudrock
			Bowie Shale	300-450	Mudrock, Sandst. & Coal
		Iles (Mt. Garfield)	Rollins	100-150	Sandstone
			Mancos tongue	80-120	Mudrock
			Cozzette	100-150	Sandstone
			Mancos tongue	40-80	Mudrock
			Corcoran	30-60	Sandstone
	Mancos		Juana Lopez Mbr	4,000-4,500	Mudrock and Silty Sandstone
	Dakota			80-120	Mudrock, Sandst. & Coal
L. Cretaceous	*Burro Canyon*			100-200	Sandst. & Mudrock
Jurassic	*Morrison*		Brushy Basin	200-300	Sandst. & Mudrock
			Saltwash	100-150	Sandst. & Mudrock
			Tidwell	50-120	Sandst., Mudrock & Limestone
	Wanakah			20-40	Mudrock
	Entrada			100-150	Sandstone
	Kayenta			50-80	Sandst. & Mudrock
	Wingate			250-320	Sandstone
Triassic	*Chinle*			80-120	Mudrock & Sandst.
Proterozoic (1.7-1.4 Ga)	*BLACK CANYON COMPLEX*		*GREAT UNCONFORMITY*	Feet	Schist, gneiss, pegmatite, granite, monzonite, and diorite.

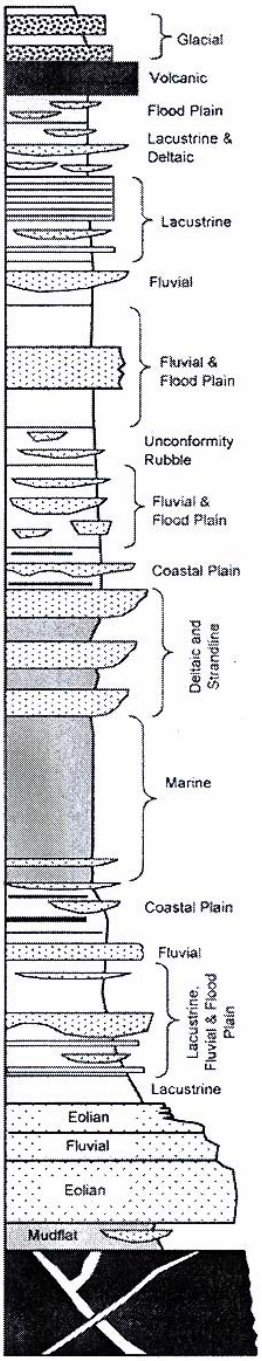


Figure 3. General Stratigraphic Column for the Grand Junction Area. Data sources: Young and Young (1968), Hintze (1988), and Scott and others (2001). Reprinted from Piceance Basin Guidebook (2003) by permission of Rocky Mountain Association of Geologists.

Source Rocks

Source rocks include coal beds and associated organic-rich carbonaceous shale rocks of the Upper Cretaceous Mesaverde Group. These rocks were deposited along the margins of the Western Interior Cretaceous Seaway in swamps and marshes associated with a deltaic and coastal plain environment. The thickest coals are found in the Cameo coal zone, which overlies the marine and marginal-marine sandstone successions in the lower part of the Mesaverde Group. Net coal thickness ranges from 20 to 80 feet. Gas expelled from coals and carbonaceous shales is interpreted as having migrated into nearby low-permeability sandstone beds of the Mesaverde Group, initiating basin-centered gas accumulations (Johnson and Roberts, 2002). The vertical migration of gas also expanded into the producing reservoir rocks of the overlying Tertiary Wasatch Formation. Peak gas generation from coals and carbonaceous rocks occurred about 47 million years ago (Johnson and Roberts, 2002). Other source rocks include the Mancos Shale, the source for gas migration into the reservoirs which occur in the lower part of the Mesaverde Group (Iles Formation). Gas migrated from the Mancos into the nearby fluvial, tidal, shoreface, and off-shore sandstone reservoirs of the Dakota Sandstone, and Corcoran, Cozzette, and Rollins Sandstone Members

The GMUG portion of the Piceance Basin shows significant variation in thermal maturity of source rocks, as measured by vitrinite reflectance analyses. Thermally mature source rocks with higher values indicate higher thermogenic gas generation based on depth of burial and higher temperatures, which occurs in the deeper part of the basin. The mature source rocks, which delineate the area of higher gas resource potential are shown on **Figure 4 and 5.**

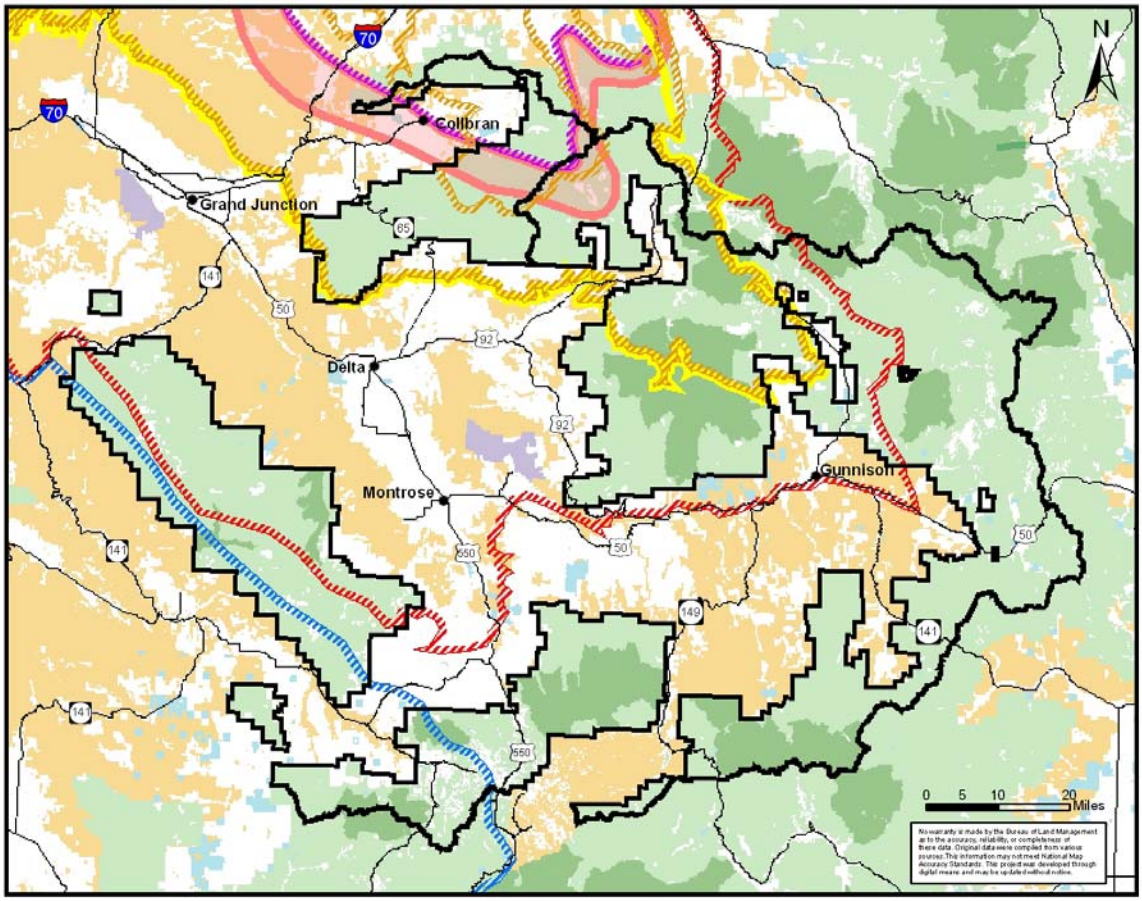


Figure 4

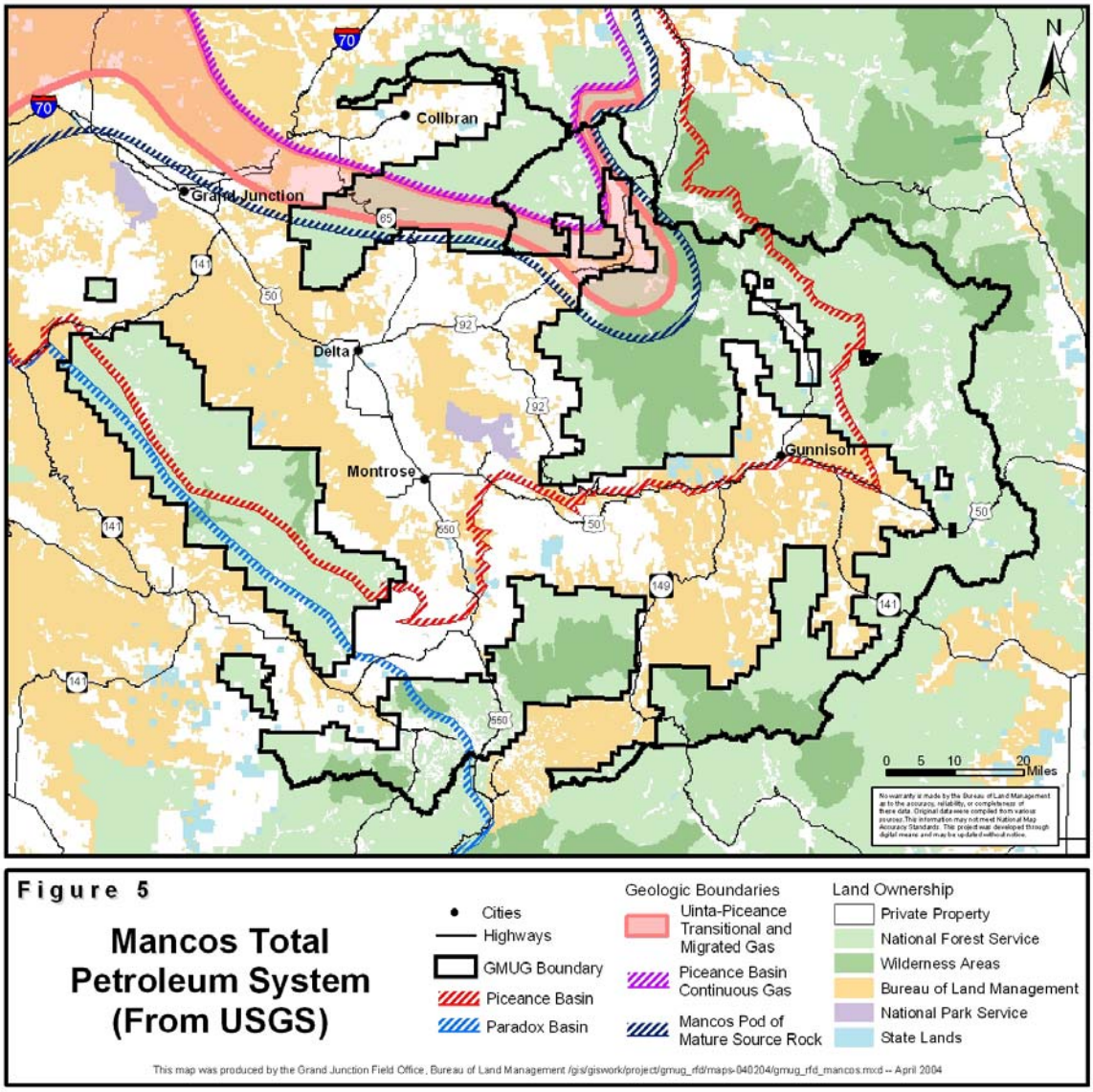
Mesaverde Total Petroleum System (From USGS)

- Cities
- Highways
- GMUG Boundary
- Piceance Basin
- Paradox Basin

Geologic Boundaries
- Uinta-Piceance Conventional Gas (Mesaverde Outcrop)
- Mesaverde Coalbed Gas
- Piceance Continuous Gas Mesaverde Pod of Mature Source Rock
- Piceance Transitional Gas

Land Ownership
- Private Property
- National Forest Service
- Wilderness Areas
- Bureau of Land Management
- National Park Service
- State Lands

This map was produced by the Grand Junction Field Office, Bureau of Land Management /gis/gisswork/project/gmug_rfd/maps_042004/gmug_rfd_mesaverde.mxd -- April 2004



Reservoir Rocks

Producing and potential reservoir rocks within the GMUG include numerous sandstones and coals ranging in age from Upper Cretaceous to Lower Tertairy **(Figure 3).** This includes the fluvial, tidal, and shoreface sandstone reservoirs of the Dakota Sandstone, tidal and shoreface deposits of the Corcoran, Cozzette, and Rollins Sandstone Members (Iles Formation), coal beds in the Cameo zone, and fluvial channel sandstones in the middle and lower part of the Williams Fork Formation and Molina Member of the Wasatch Formation. Most of the data show that the Dakota, Cozzette, and Corcoran are considered low-permeability (tight) unconventional gas reservoirs.

The fluvial sandstone reservoirs of the Williams Fork Formation are generally lenticular and classified as tight, with low permeabilities, and are therefore unconventional.

Enhanced permeability occurs with natural fracturing. The cumulative thickness of sandstones in the Williams Fork ranges from less than 200 feet near the outcrop above the North Fork Valley to an estimated 1000 feet on the north end of the GMUG. The Wasatch reservoir is the Molina Member, which is a relatively thin stratigraphic interval. The vast majority of fluvial reservoir production is from the Williams Fork, with comparatively minor production from the Wasatch. The nearest significant Wasatch production is found in the Rulison Field approximately 9 miles north of Grand Mesa Forest. There is minimal Wastach production in the Brush Creek Field located about 2 miles from the GMUG boundary.

The primary source of coal bed natural gas (CBNG) in the GMUG is the Cameo Coal Zone in the Williams Fork Formation. The northern portion of the GMUG is considered to have the highest potential for coal bed natural gas occurrence based on thicker net coal intervals and higher net gas content. However, coals that occur at depths in excess of about 5,500 feet are generally considered uneconomical because the coals tend to be more plastic and do not have the well-developed natural fracture permeability exhibited in coalbed productions regions. The USGS CBNG gas potential boundary shown on **Figure 4** is based on a depth to significant coal beds of < 7,000', with the deeper coal beds excluded. Some of the previous attempts to produce coal bed gas in the southern part of the Piceance Basin were abandoned because of high water and low gas production. Other CBNG wells contained little water, but were not very productive with respect to gas. Between 1989 and 1992, wells completed into coals and sandstones within the Grand Valley and Parachute Fields were found to have little contributing production from the coal beds, and additional attempts to complete wells into coals were abandoned. In 1986, Amoco Production Company formed the 150,000-acre Megas Unit to test the CBNG potential in the Bowie Coal Member of the Williams Fork Formation. However, the unit was terminated due to several factors, including economics, well performance, and seasonal access problems.

Traps and Seals

In the north part of the GMUG, the Williams Fork fluvial sands and paludal (coal zone) intervals contain basin-centered gas accumulations, and is considered unconventional or continuous based on the tight sands and regional extent of the reservoir. Significant production of basin-centered gas occurs to the north in the Rulison and Mamm Creek Fields. The southern edge of these fields is located about 5 miles north of the GMUG. The gas accumulations in these fluvial, lenticular sands is confined (sealed) by impermeable shales and the process of capillary seal or water block (Masters, 1979). The area of continuous gas accumulation overlies the area of mature source rocks (**Figure 4**). Additional gas accumulated in structural and stratigraphic traps in conventional reservoirs. This may include fluvial sandstones in the Wasatch and a small potential for conventional-type accumulations in Mesaverde Group fluvial channel sandstones in basin-margin areas**.** The basin-margin gas is a low permeability gas accumulation found in a shallow, permeable, water-bearing zone around the margin of the basin containing scattered gas accumulations in reservoirs with conventional or near conventional permeabilities (Johnson and others, 1987).

The Iles Formation within the Mesaverde Group includes the Corcoran, Cozzette, and Rollins Sandstone Members. The two main types of traps within these sandstones are closed anticlinal structures and basin-centered accumulations (Brown and others, 1986). The anticlinal structures include Divide Creek, Coal Basin, and Wolf Creek, which are located just east of the GMUG. Basin-centered accumulations are represented by Shire Gulch, Plateau, and Rulison Fields (Brown and others, 1986). Trends of production from fractures are controlled by subsurface faulting. Seals are the overlying unfractured marine shale tongues of the Mancos Shale. The Rollins is water wet with minimal production, and the lack of a good seal (overlying coals) allowed hydrocarbons to escape (Kirschbaum, 2002). The marine regressive limits (strandlines) of the Corcoran and Cozzette blanket reservoirs are oriented along a northeast-southwest trend in the southeast portion of the basin, which defines the stratigraphic pinchout of these units.

Because the Dakota Sandstone is classified as tight, it generally considered a continuous gas accumulation, sealed by the overlying Mancos Shale.

Coal Mine Gas

There is a potential coal mine gas resource associated with the three large coal mines located in the North Fork Valley, whose operations overlap with the GMUG. The mines are the Bowie No. 2 (operated by Bowie Resources, LLC), the Elk Creek Mine (operated by Oxbow Mining, Inc., and the West Elk Mine (Operated by Mountain Coal Company). The coal leases associated with these mines are shown on **Figure 2**.

The Bowie No. 2 and West Elk Mines have been accumulating methane (gob gas) in the mine workings as subsidence occurs after coal extraction. This has required the mines to install methane drainage wells to remove the methane from the underground workings in order to meet permissible methane levels in their underground mine ventilation system. The gas emanates primarily from the sandstones overlying the coal seams, and to some degree the coal seams themselves.

The West Elk Mine is implementing a program to install up to 58 methane drainage wells over the West Elk Mine over the next 3 years. Since 2001, about 25 methane drainage wells have been installed. Each well has about a 2 year-life, and about a third of these have been decommissioned. The West Elk Mine produces between 3 and 8 million cubic feet of gas per day from an average of 10 methane drainage wells in operation at any one time. The gas contains about 70% methane. The gas is vented to the atmosphere. No gas leases are in place in this area.

The Bowie No. 2 currently has 5 methane drainage wells drilled from the land surface into the mine. The amount of gas vented through these drainage wells is unknown. The gas is under lease at the Bowie Mine.

The Elk Creek Mine has just recently come into production. No gas is being vented at this mine. However an adjacent mine, the Sanborn Creek Mine (now sealed) vented some gas through methane drainage wells.

Although a significant volume of gas is currently vented to the atmosphere from the North Fork mines, the gas is diluted with mine air and only contains about 60%-85% methane. Therefore, it is not currently suitable for pipeline gas. Technology is being developed to enrich low BTU gob gas into pipeline quality gas. The EPA has formed the Coalbed Methane Outreach Program to disseminate technical and financial information about the use of coal mine gas (Gas Separation Technology LLC, www.gassep.com).

USGS Oil and Gas Assessment Units – Piceance Basin

The USGS oil and gas assessment project (2002) for the Piceance and Uinta Basins developed geologically based hypotheses regarding the potential for oil and gas reserves. The focus was to determine the distribution, quantity, and availability of oil and gas resources, with an emphasis on undiscovered resources underlying federal lands. The approach was to establish the framework geology, define the major total petroleum systems (TPS), define assessment units within the TPS, and assess the potential for additions to reserves.

Each TPS is a mappable accumulation of gas which was generated by a pod of mature source rock. In addition, USGS mapped the reservoirs, traps, and seals necessary for gas accumulations to exist. Within each TPS, assessment units were developed, which encompass conventional or continuous accumulations sharing similar geologic traits. Within the GMUG, the two Piceance Basin TPS designations are the Mancos and Mesaverde. An assessment unit may contain multiple plays.

Mesaverde TPS

Hydrocarbons generated from coals and carbonaceous shales in the Williams Fork Formation define the limits of the Mesaverde TPS. That portion of the GMUG underlain by the lowest coal zone in the Williams Fork is included in the Mesaverde TPS. Gas migrated into low permeability, lenticular sandstone beds, resulting in basin-centered accumulations, such as found in the Rulison and Mamm Creek Field. The TPS includes the lowest major coal zone (Cameo zone), potential reservoirs in overlying fluvial sands of the Williams Fork fluvial sands, and sands within the Wasatch Formation. There are 4 assessment units within the Mesaverde TPS which overlap the GMUG – continuous gas, transitional gas, coal bed gas, and conventional gas (**Figures 4 and 6**).

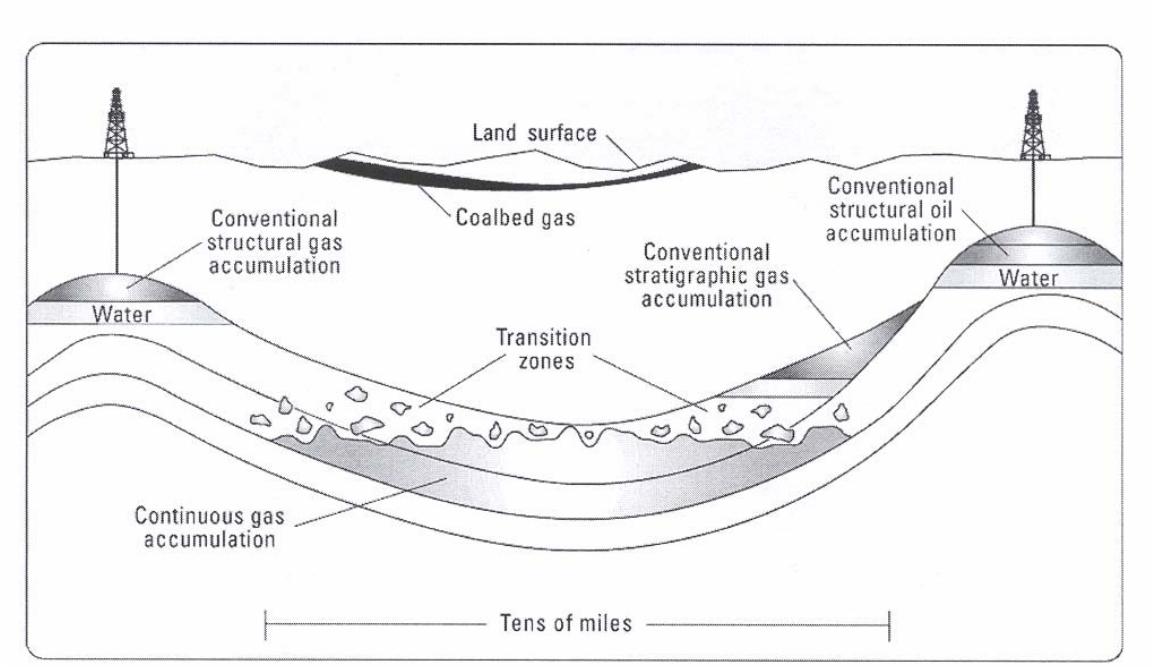


Figure 6. Schematic diagram of the types of oil and gas resources in USGS assessment

Continuous gas units include and overlie Mesaverde source rocks where thermal maturity values exceed 1.10 percent, and include basin-centered gas accumulations characterized by gas-saturated sandstone reservoirs. The primary reservoirs are the lenticular, fluvial channel sandstones in the Williams Fork and overlying Wastach Formation. Transitional units represent the transition zone surrounding the basin-centered accumulation and are characterized by a combination of gas-saturated and water-wet reservoirs, having source rocks with thermal maturity values between 0.75 and 1.10 percent. Net sand thickness in Mesaverde fluvial sands decreases significantly from the north part of the GMUG toward the margin of the basin. The transitional unit has incomplete gas saturation as compared to the continuous unit, with increased chance of penetrating water-wet reservoirs (Johnson and Roberts, 2002).

The continuous gas boundary follows the structure contours, but excludes the Divide Creek Anticline. The southeast most extension of the continuous gas is where the Rollins Sandstone subsurface elevation is 1000'-1500'.

Conventional gas units include and overlie Mesaverde source rocks where thermal maturity values exceed 0.75 percent, and basin-margin areas with values < 0.75. Reservoirs include conventional-type structural and stratigraphic traps with discrete gas-water contacts. According to USGS, there is a small potential for conventional reservoirs in the Wasatch Formation and fluvial channel sands of the Williams Fork along the basin margins.

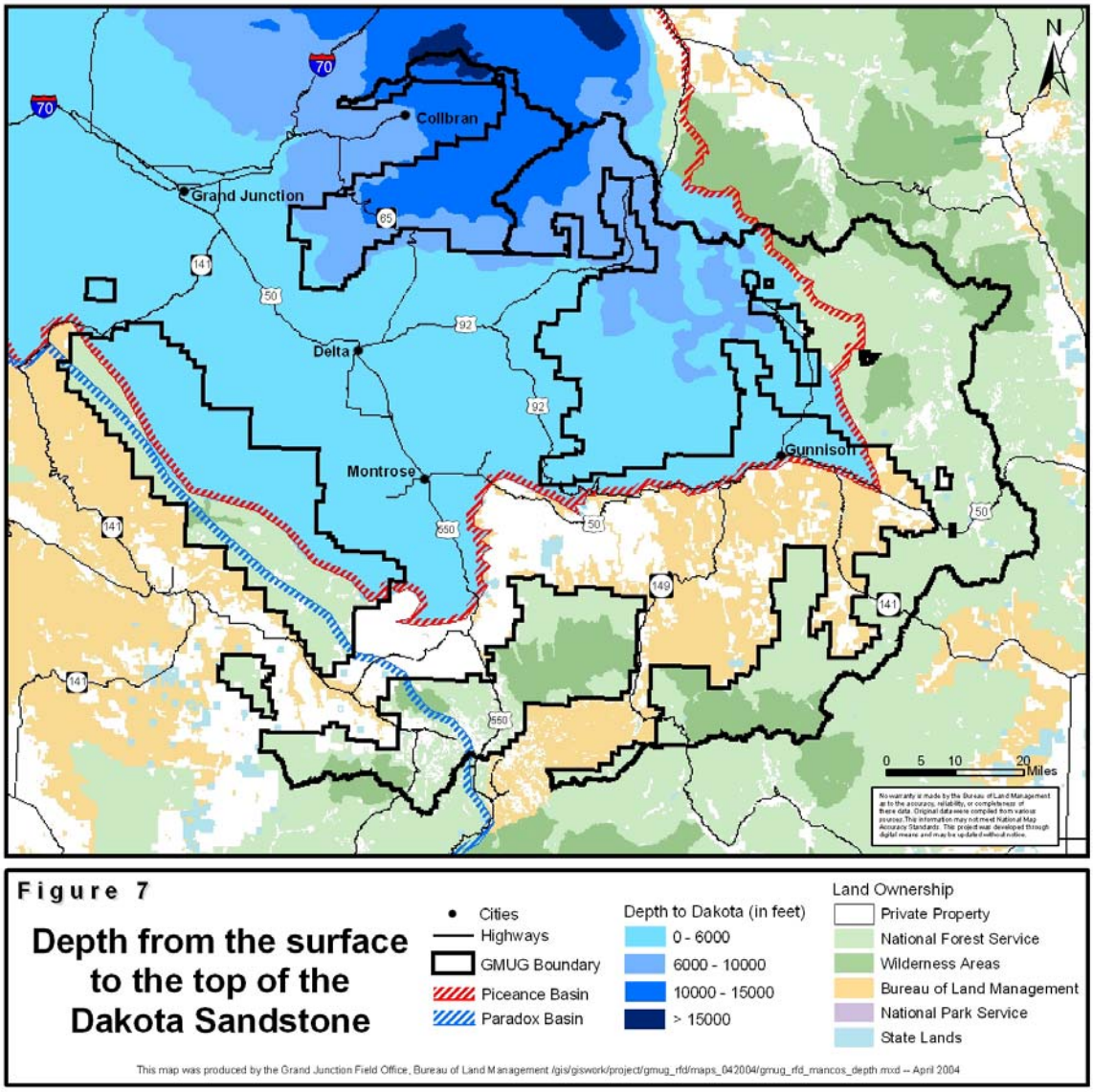
Coal bed natural gas units include the area underlain by significant coal beds within the Williams Fork Formation found at depths < 7,000', and includes coal with higher and lower thermal maturity values. The net coal thickness throughout the basin ranges from 20' to 80'. Because of the current problems associated with commercial development of coalbed gas, the potential is unknown.

Mancos TPS

Hydrocarbons generated from the Mancos Shale define the limits of the Mancos TPS, which extends to near the boundary of the Piceance Basin. Assessment units were defined based on the concept that gas generated from the Mancos Shale charged all porous sandstones and fractured beds in the Iles Formation, Mancos Shale, and Dakota Sandstone where maturities were great enough to generate gas, based on vitrinite reflectance greater than about 0.75 percent). The two assessment units which overlie the GMUG include continuous gas, and transitional and migrated gas **(Figure 5)**. No conventional gas units were identified. The continuous gas unit has thermal maturity values > 1.1 percent at the base of the Mancos, and the transitional/migration gas unit has values between 0.75 and 1.1 percent. The Mancos pod of mature source rocks is defined as > 0.60 percent.

The continuous unit includes three groups of reservoir rocks 1) lower group – Morrison Formation, Cedar Mountain Formation, and Dakota Sandstone; 2) middle group – Frontier Formation, Mancos Shale, and Mancos B; 3) upper group – sandstones of the Iles Formation (Corcoran, Cozzette, and Rollins). There is no known gas production from the middle group in the vicinity of the GMUG. The nearest production from the Dakota and Morrison is in the Shire Gulch Field, approximately 3 miles west of the GMUG. These reservoirs are usually tight and may be overpressured. Historical production comes from areas where drilling depths are less than 10,000' to lower reservoirs and less than 6,000' to upper reservoirs (Kirschbaum, 2002). The depth to the top of the Dakota Sandstone is shown on **Figure 7**.

The continuous accumulations within the transitional and migrated gas unit includes reservoirs in the Morrison Formation, Cedar Mountain, and Dakota Sandstone. Invasion by surface waters may have created conventional gas-water contacts or water-saturated reservoirs (Kirschbaum, 2002).



Gas Fields – Piceance Basin (from O&G Fields Map of Colorado, 2002, **Figure 1**)

Based on limited gas production in the GMUG, very few Piceance Basin gas fields are present. The following gas fields are located mostly outside the GMUG, but have minor overlap along the edges of the Forest:

Name	*Producing Reservoirs*
Plateau	Cozzette (primary), Corcoran, Williams Fork, Rollins
Vega	Mesaverde Group (primary), Cozzette
Sheep Creek	Cozzette (primary), Corcoran, Mancos, Mesaverde Group

The following gas fields are located entirely within the GMUG:

Grand Mesa	Mesaverde Group
Ragged Mountain	Cozzette (primary), Corcoran
Coal Basin	Cozzette (primary), Corcoran
Oil Well Mountain	Mesaverde (primary), Cozzette, Corcoran

Presently, there are only 15 wells capable of production within the GMUG, which are located in the vicinity of the Ragged Mountain and Coal Basin Units, generally in T 10 and 11 S, and R 90 and 91 W.

Through geologic inference, some of the nearby fields (within 6 miles) have the potential to expand into the GMUG. These include:

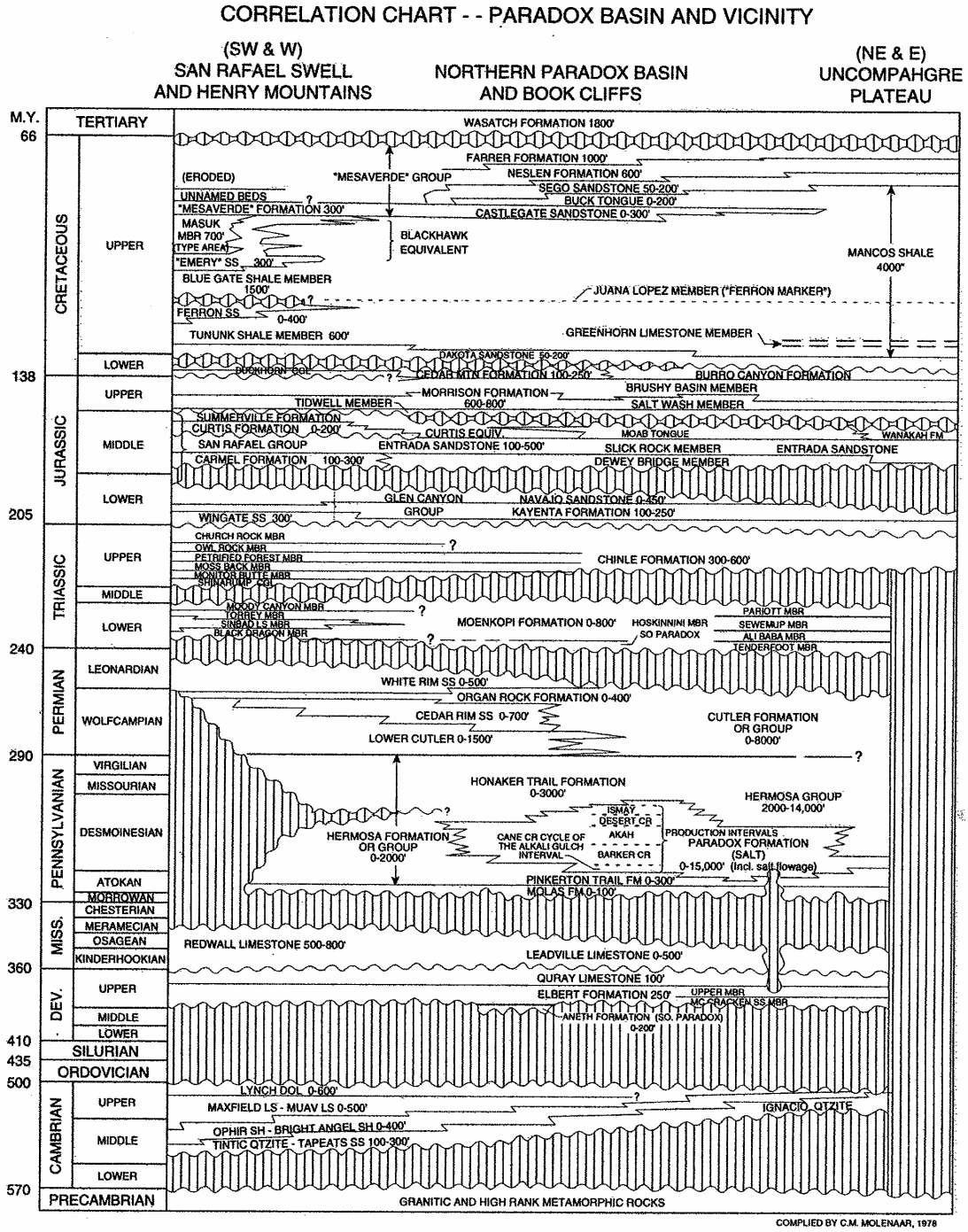
Whitewater	Dakota
Shire Gulch	Dakota (primary), Cozzette, Corcoran, Cameo
Buzzard	Mesaverde Group (primary), Cozzette, Corcoran
Brush Creek	Cozzette (primary), Corcoran, Mesaverde Group
Buzzard Creek	Mesaverde Group (primary), Cameo, Wasatch
Hells Gulch	Mesaverde Group
Mamm Creek	Williams Fork (primary), Cameo
Rulison	Williams Fork (primary), Cameo, Wasatch

As shown on **Figure 1**, most of these fields circle or encompass the northern and northeastern portion of the GMUG.

Stratigraphy (source rocks, reservoirs, traps, and seals) - Paradox Basin

Stratigraphic framework

Rocks in the basin range in age from Precambrian through Cenozoic. The primary oil and gas producing formation is the Middle Pennsylvanian Paradox Formation which consists of cyclic carbonates, clastics, and evaporates deposited in a marine environment (Scott, 2003). The oldest formation with oil and gas production is the upper Mississippian Leadville Limestone. Overlying Pennsylvanian rocks include the Molas Formation and Hermosa Group, which includes the Paradox and Honaker Trail



Correlation chart for the rocks of the Paradox Basin and vicinity. Modified from Molenaar (1978).

(Nuccio and Condon, 1996)

Figure 8. Reprinted from Paradox Basin, Resource Series 43, 2003, CGS

Formations. The Paradox Formation includes all the evaporates, but production is from the interbedded carbonates. The overlying Honaker Trail consists of marine carbonates,

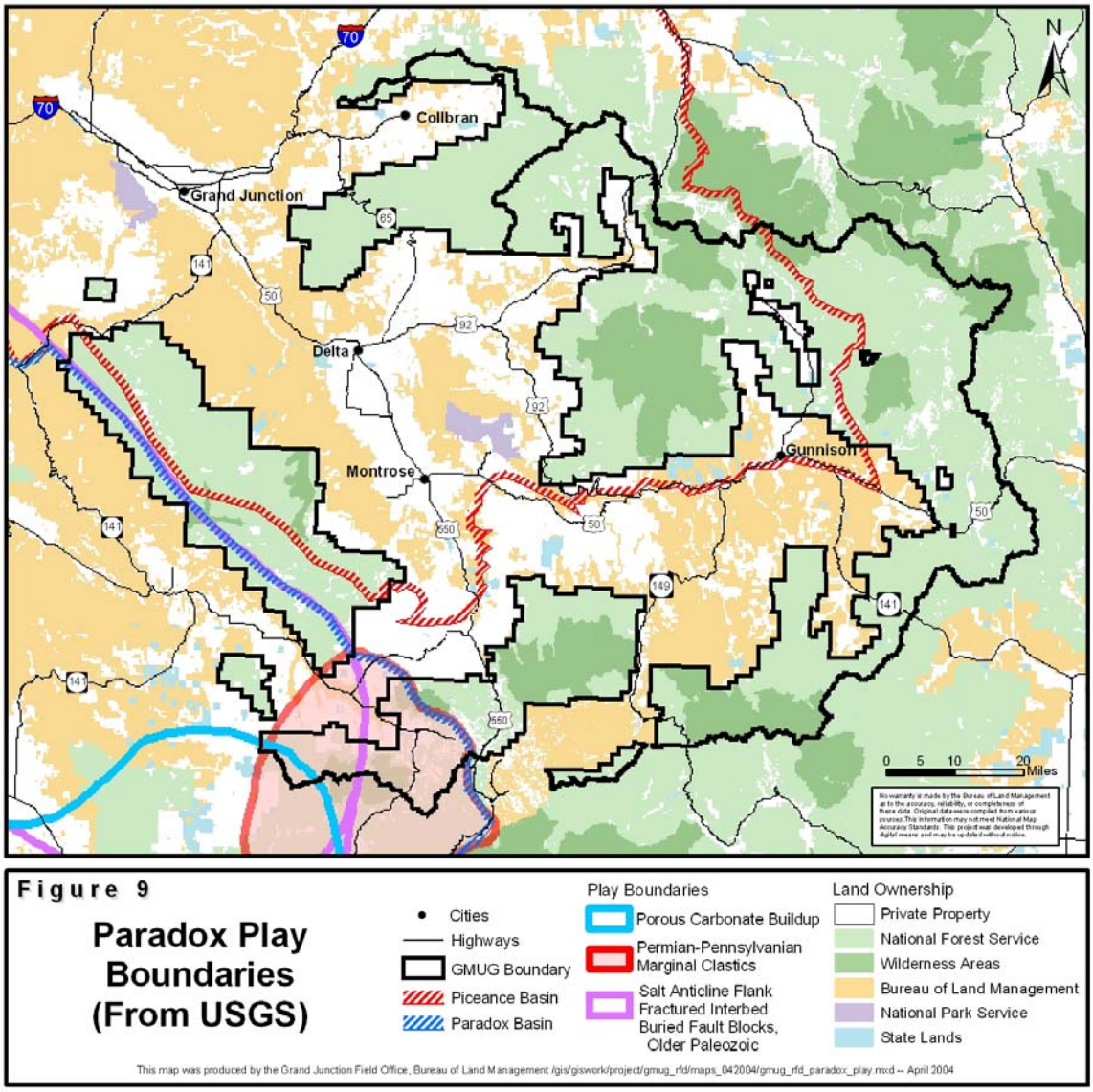
shales, siltstones, and sandstones. The Permian Cutler Formation consists of fluvial sandstones and shales. The Cutler Formation is the youngest interval of potential gas production within the GMUG. A stratigraphic correlation chart for the Paradox Basin is shown on **Figure 8**.

Geologic Structure

The structures of Paradox Basin are controlled by northeast and northwest-trending lineaments. The basin originated from faulting along the pre-existing northwest-trending Uncompahgre lineament, and the uplift resulted in basin downwarping to the southwest across the fault (Scott, 2003). The GMUG is located within a sub-basin of the larger Paradox Basin. Salt anticlines developed in portions of the basin, which appear as valleys because of the dissolution of the salt.

Source Rocks, Reservoir Rocks, Traps and Seals

The Lower Paleozoic play within the Paradox Basin consists of buried fault blocks, consisting of the McCracken Sandstone and a dolomitized limestone reservoir in the Leadville Limestone. The source rocks are also the limestone. The gas is trapped and sealed by Paradox evaporates, and faults. The second play is salt anticline flanks, which includes the Permian Cutler Formation and the Pennsylvanian Honaker Trail Formation of the Hermosa Group. Reservoirs are developed in arkosic sandstones of the Cutler and limestones with minor sandstones in the Honaker Trail that accumulated as thick sediments in synclines along the margins of salt cored anticlines. The trapping mechanism is a pinchout and updip termination against salt diapirs. The third play is fractured interbeds within the Paradox Formation, situated within the deep trough of the Paradox Basin and includes the Paradox fold and fault belt. The source rock and reservoir rock consists of fine-grained silty dolomite and dolomitic or calcareous black shale, trapped and sealed in fractures, with salt and shale interbeds (Witherbee, 1993). A fourth play includes the carbonate mounds buildup reservoirs within the Paradox Formation. Dolomitic shales are the source rocks for hydrocarbons within the carbonate mounds (Scott, 2003). The play boundaries are shown on **Figure 9** and include a broad area of the Paradox Basin except the southeast portion where it overlaps with the GMUG.



USGS Oil and Gas Assessment Project – Paradox Basin

From the USGS 1995 Basin Assessment project, five plays were identified in the Paradox Basin that overlap with portions of the GMUG **(Figure 9):**

1. Buried fault blocks, older Paleozoic - The boundary of this play follows the Basin boundary along the top of the Uncompahgre Plateau and then trends south (west of Basin boundary) near Placerville.
2. Salt anticline flanks – Within GMUG, follows same boundary as buried fault blocks play.
3. Fractured interbeds - Within GMUG, follows same boundary as buried fault blocks play.

4. Porous carbonate buildup - This play only overlaps with a very small area in the extreme southwest corner of the GMUG west of Lizard Head Wilderness
5. Permian-Pennsylvanian marginal clastics – This play covers the southwest area of the GMUG adjacent to and west of the Paradox Basin boundary.

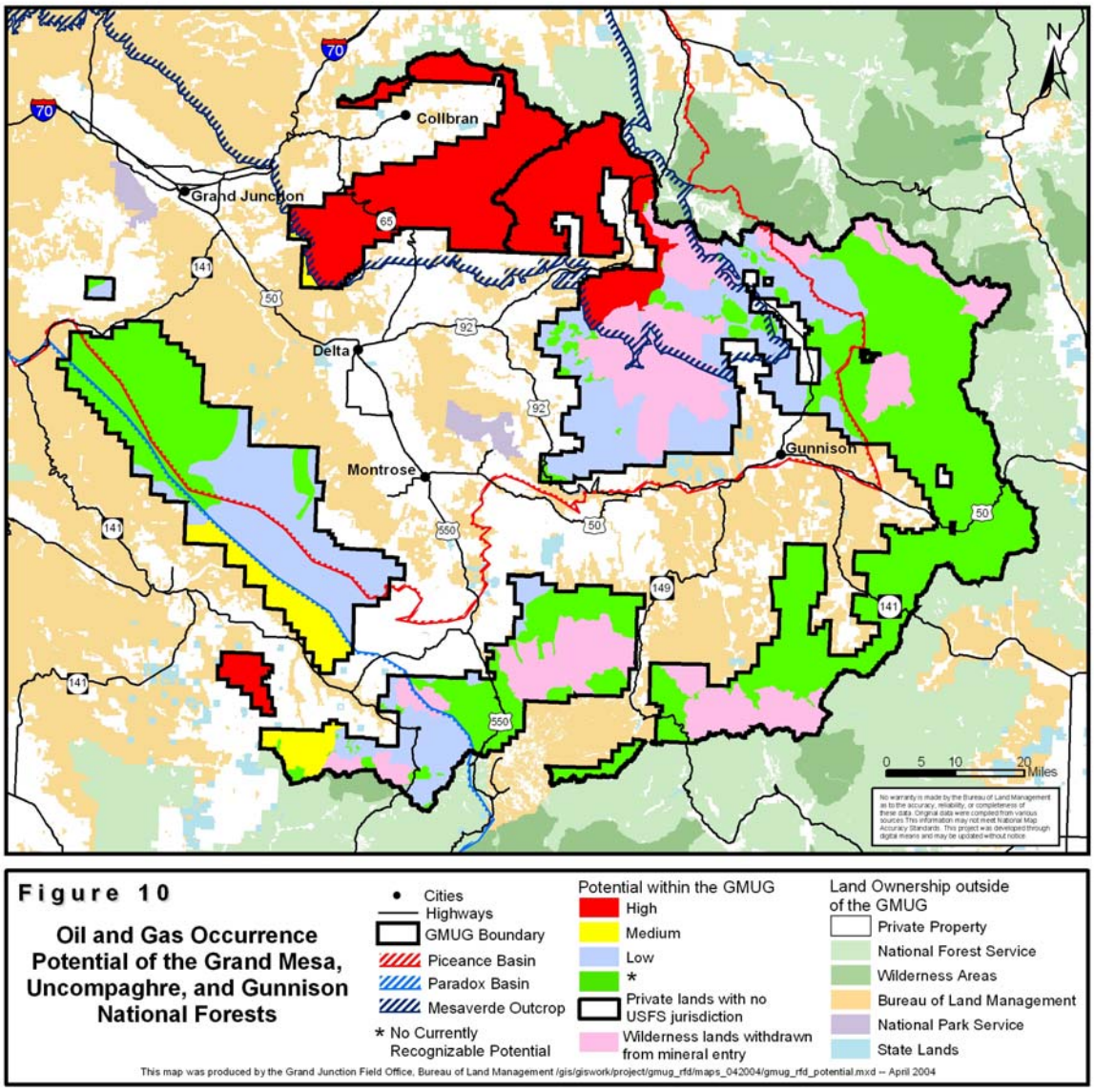
Gas Fields - Paradox Basin

The only gas field in the vicinity of the GMUG is the Hamilton Creek Field (**Figure 1**). The primary pay zone is the Permian Cutler Formation. Other objectives include the Pennsylvanian Honaker Trail Formation of Hermosa Group, and other Hermosa Group reservoirs. From the Colorado Oil and Gas Conservation Commission (COGCC) database, the well scout report data was checked for the southwest flank of the Uncompahgre Plateau. About 15 older wells were drilled on the Forest, all dry holes, shallow to deep, with no geologic tops reported. Nearby wells were also checked. The 1P-35 was drilled to 16,500' to the McCracken SS (Devonian), which is the deepest target.

The only active field near the GMUG (3 miles northwest) is the Hamilton Creek Field, on state and fee lands 10 miles west of Norwood, near the southeast corner of T45N, R15W. The producing wells appear to be located along Dry Creek and Hamilton Creek Anticlines, which also trend through the isolated forest parcel. Production is from the Cutler and/or Hermosa Formation. The 1-21 well (section 1, T44N, R15W) was spudded in 2003.

Oil and Gas Occurrence Potential

It should be noted that designated wilderness areas were not evaluated and classified for their oil and gas potential based on the legal constraint of no leasing. The oil and gas occurrence potential map shows the wilderness boundaries.



Piceance Basin Area Oil and Gas Potential (Figure 10)

<u>High Potential</u>
Generally, this includes lands within the Basin which are underlain by Mesaverde Group rocks (same as USGS boundary for Piceance conventional gas). The exception is the scattered exposures of Mesaverde rocks within the intrusive complex near the West Elk Wilderness, which have low potential because the rock layers were likely disturbed and broken during the intrusive activity. Although the high potential area includes the entire north portion of the GMUG, the following should be noted:

1. Given the presence of thermally mature source rocks within the USGS Mesaverde continuous gas assessment unit, the potential for gas resources is everywhere within its

boundary. However, developed fields such as Rulison have enhanced permeability through natural fracturing, and it is unknown whether untested areas have similar fractured reservoir systems. Much of the established production occurs in valleys cut by the Colorado River and its tributaries, and the erosion and downcutting may have opened up fractures (Law and Dickinson, 1985; Johnson, 1989).

2. Much of development is likely to consist of infill drilling coupled with minor expansion of fields into currently untested areas having similar geologic characteristics. Only those fields which currently intersect the GMUG are likely to have development within the GMUG.

3. The gas potential will be the highest in the northern area based on higher net sand thickness of the Williams Fork fluvial section. The net sand thickness decreases to the south.

4. The gas potential in the lower part of the Mesaverde Group decreases to the southeast based on the position of the strandlines of the Cozzette and Corcoran Sandstones, where these sandstone reservoirs pinch out.

5. The major plays which would be targeted in the high potential area of the GMUG include the Williams Fork fluvial sands, Cameo coal zone, and Cozzette/Corcoran reservoirs.

6. Although the USGS defined areas for mature source rocks, continuous gas, and transitional gas zones, they are generally located far north of the Mesaverde outcrop along the southern flank of Grand Mesa. The Gunnison Energy development well located 4-5 miles north of the outcrop and the coal mine gas provide evidence of high gas potential along the southern outcrop.

Medium Potential

Within the Piceance Basin area, the lands included for the medium potential category include a small area along the west flank of Grand Mesa located just outside the Mesaverde outcrop, based on potential in the Dakota Sandstone.

Low Potential

Generally, this includes lands which are located stratigraphically below the Mesaverde Group outcrop, but within the boundary of the Piceance Basin and that are underlain by at least 1000 feet of sedimentary rocks, but may not have source and reservoir rocks, or traps. The 1000-foot minimum sedimentary section is based on USGS geologic criteria for oil and gas potential. This includes sedimentary rocks which are covered with unconsolidated and volcanic deposits. The scattered exposures of Mesaverde rocks within the intrusive complex near the West Elk Wilderness are also considered to have low potential. Lands within the Basin that are mapped as plutonic (intrusive) and metamorphic rocks have no oil and gas potential (see no potential discussion). Small exposures of sedimentary rocks meeting the 1000-foot thickness criteria are located outside the Piceance Basin boundary, but are also included in this category. This

includes an area north and west of Uncompahgre Wilderness and an area just southeast of Snowmass Wilderness in the Elk Mountains.

The southeast flank of the Uncompahgre Plateau east of the Paradox Basin boundary is considered part of the Piceance Basin for purposes of this report. This area is also considered to have low potential based on the absence of Paleozoic rocks. This is supported by the absence of Paleozoic exposures in Roubideau Creek on the southeast flank of the Plateau west of Montrose. The Triassic Chinle is exposed directly above Precambrian outcrop. While the Dakota exposures on the southeast portion of the Uncompahgre indicate an adequate thickness of sedimentary rocks, there is not sufficient evidence of geologic criteria (source rocks or trap) to support a medium potential.

It should be noted that a significant area of the Basin located north of Blue Mesa Reservoir and northeast of Gunnison near the West Elk Wilderness has large exposures of volcanic rocks. These are lavas and breccias at numerous widely scattered volcanic sources surrounded by coalescing aprons of volcaniclastic debris (Tweto and others, 1976). Scattered outcrops of Cretaceous rocks are exposed within and around the perimeter of the volcanic cover, which suggests that the sedimentary section, which includes potential oil and gas reservoirs and source rocks, underlies the volcanic rocks. The evidence is indirect because there are no known wells which penetrate the volcanic rocks in this area to confirm the presence and thickness of Cretaceous rocks. Based on this, the area mapped as volcanics within the Piceance Basin is included in the low potential category.

<u>No Currently Recognizable Potential</u> – Generally, this includes both lands located outside the Piceance Basin boundary and that are not underlain by at least 1000 feet of sedimentary rocks, with an absence of source and reservoir rocks, and traps. Based on the geologic map, some sedimentary exposures located outside the basin do not have sufficient thickness to have oil and gas potential. The igneous intrusives and minor exposures of metamorphic rocks within the Piceance Basin have no currently recognizable potential, which includes the West Elk Mountain exposures of igneous intrusives. The granitic intrusive rocks are exposed on the peaks and slopes of Mt Gunnison, Landsend Peak, Beckwith Peak, and others. The existing Cretaceous section of rocks was intruded during the Tertiary period, which pushed up the sediments, which were subsequently eroded away. The sedimentary rocks adjacent to the intrusives are considered to have a low potential based on the geologic formation exposed. It should be noted that a large portion of the intrusive rocks are located in the vicinity of wilderness areas.

The northeast flank of the Uncompahgre is not underlain by at least 1000 feet of sedimentary rocks and therefore has no currently recognizable potential. The exposures are pre-Cretaceous, with intermittent Precambrian exposures, and a progressive thinning of the sedimentary section toward the north.

<u>Changes from 1993 RFD Potential Boundaries - Piceance Basin area</u>

The O&G potential boundaries in the 1993 RFD have not significantly changed for the Grand Mesa and Gunnison Forests. For unknown reasons, the earlier RFD shows an area on the top of Grand Mesa as medium potential rather than high. Also, the earlier RFD appeared to rely on USGS Prospectively Valuable (PV) boundaries to delineate the boundaries between the potential categories, particularly between low and none. With GIS technology and the availability of digital geologic maps, the boundaries have been refined, which may be of most importance in the area where the high potential terminates against the West Elks intrusive complex.

There are some differences between the RFDs in the potential boundaries in the Uncompahgre Forest (outside Paradox Basin). Most notably, the southeast flank of the Uncompahgre Plateau east of the Paradox Basin boundary which was ranked as medium in the earlier RFD is now considered to have low potential for the reasons stated above. Less notably, an area north of Uncompahgre Wilderness previously ranked as low (based on PV boundary) is now considered to have no currently recognizable potential, with a much smaller area of low.

Paradox Basin Area Oil and Gas Potential (Figure 10)

High Potential
This includes the isolated parcel in T44N, R13&14W based on the trend of the Hamilton Creek Anticline extending into this parcel and close proximity to Hamilton Field production.

Medium Potential
This includes the lands along the southwestern flank of the Uncompahgre Plateau (adjacent to and west of the play/basin boundary), and the area just northwest of Lizard Head Wilderness (within the Basin) which overlap with the USGS plays – buried fault block, salt anticline flanks, and fractured interbeds, and are underlain by a sedimentary section at least 1000 feet thick. The boundaries of these three plays coincide within the GMUG. They follow the Basin boundary along the top of the Uncompahgre Plateau and then trend south near Placerville. The presence of Paleozoic rocks along the southwestern flank of the Uncompahgre Plateau is confirmed by the presence of the Permian Cutler Formation along the San Miguel River southeast of Norwood. A large portion of this area has been leased for oil and gas, and there are scattered plugged and abandoned wells.

Low Potential
Generally, this includes the remaining lands within the Basin outside the medium area that are underlain by a sedimentary section at least 1000 feet thick, but may not have source and reservoir rocks, or traps. Most of this area has not been leased for oil and gas, and has not been drilled. A small area along the west flank of the Uncompahgre (north of medium potential area) is near Precambrian exposures and is rated as low. The scattered exposures of Cretaceous and other sedimentary rocks within and outside the play and basin boundaries and north of the intrusive and volcanics complex in the southern portion

of Uncompahgre Forest (northeast and southwest of Ridgway) are also considered to have low potential based on the projected thickness of the sedimentary section. The sedimentary rocks within that portion of the USGS-identified marginal clastics play located northeast of Lizard Head Wilderness up to the basin boundary also have low potential.

No Currently Recognizable Potential

Generally, this includes both lands located outside the Paradox Basin boundary and that are not underlain by at least 1000 feet of sedimentary rocks. Based on the geologic map, some sedimentary exposures are found outside the basin, but presumably consist of a thinner section. The plutonic rocks within the Paradox Basin have no currently recognizable potential, which includes the area near Lizard Head and Mt Sneffels Wilderness areas.

The northwest flank of the Uncompahgre is not underlain by at least 1000 feet of sedimentary rocks and therefore has no currently recognizable potential. Exposures are pre-Cretaceous, with intermittent Precambrian exposures, and a progressive thinning of the sedimentary section toward the north.

Changes from 1993 RFD Potential Boundaries - Paradox Basin area

The O&G potential boundaries in the 1993 RFD are generally similar, with one notable exception. The areas with medium potential were rated as high in the earlier RFD.

SCENARIO FOR FUTURE OIL AND GAS EXPLORATION AND DEVELOPMENT ACTIVITY

Introduction

Areas of the GMUG considered to have moderate to high potential for oil and gas occurrence are the Grand and Battlements Mesas, the Upper North Fork of the Gunnison River Valley (where the Mesaverde Formation is present, excluding the West Elk and Ragged Mountains), and the southwestern portion of the Uncompaghre Forest within the Paradox Basin. These areas are covered in part by the Grand Valley, Paonia and Norwood Ranger Districts.

The Paonia Forest Ranger District covers the portion of the GMUG surrounding the North Fork of the Gunnison River. It extends north and west to the Delta County – Mesa County line. The north edge of the district shares a boundary with the White River National Forest. The eastern boundary runs along Huntsman ridge south to McClure Pass, and along the Raggeds Wilderness. It also extends south of the North Fork of the Gunnison River into the West Elk Mountains and Black Mesa.

The Grand Valley Forest Ranger District encompasses most of the Grand Mesa. The eastern boundary is the Mesa County – Delta County line. The district extends to the north to include a portion of Battlement Mesa, and shares a boundary with the White River National Forest.

The Norwood Forest Ranger District partially extends over the Uncompahgre Plateau.

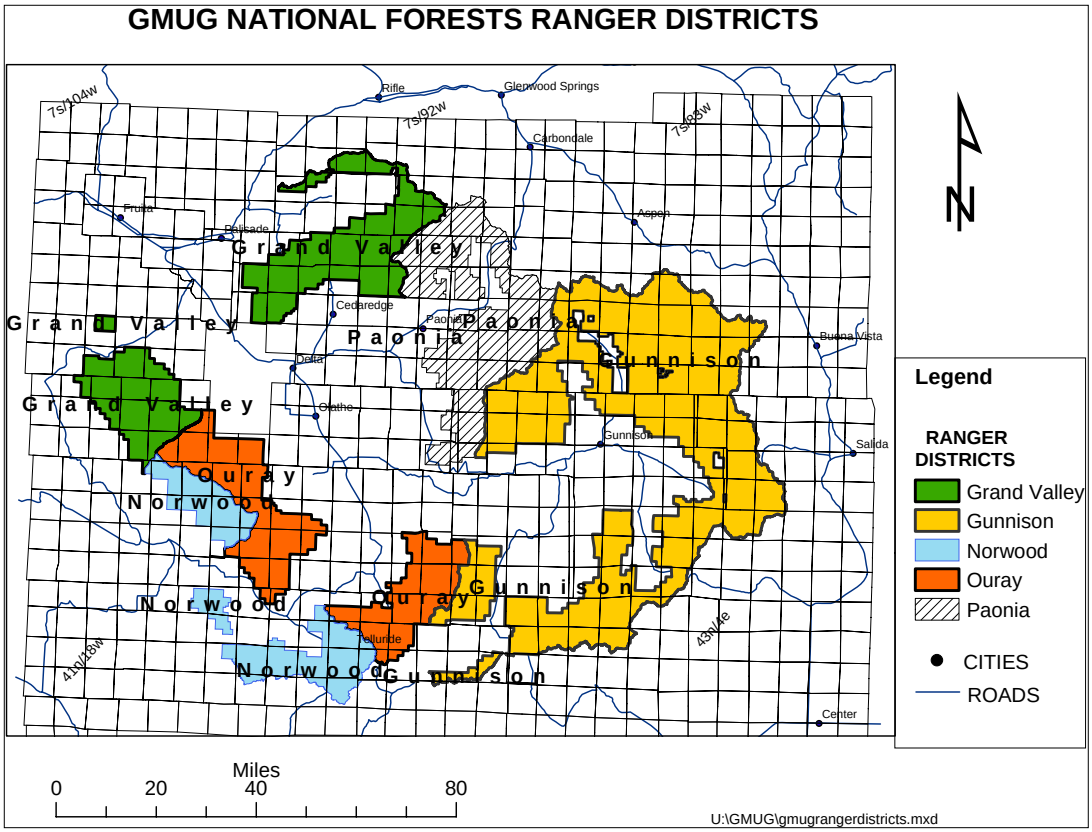


Figure 11. Plat of GMUG Forest Ranger Districts.

Historical Development and Overview

Study Area

USGS estimates that the Uinta-Piceance contains 22 TCFG and 149 MMBO. The Paradox Basin contains 52 TCF and 660 MMBO (EPCA 2003). For the purpose of this study, the study area is defined as an area that includes a 6 mile buffer around the GMUG and the GMUG. According to PID, the study area contains 953 drilled or permitted wells from which 182,000 BO, 212,540,000 MCFG and 3,212,000 BW[1] have been produced. Of the 953 wells, 503 are gas completions (54%), 270 wells are abandoned never completed, 10 are oil wells, 104 wells are permitted not yet drilled, 57 wells are being tested and 19 of the gas wells are abandoned after production. Presently, 252 wells are capable of production.[2] The overall success ratio is 60%[3] of all wells drilled since 1926. However, during recent years, well success had improved. Most of the development is to the north of the Grand Mesa National Forest. Well abandonment after production averages about 19 wells over 54 years or about 1 well every 3 years.

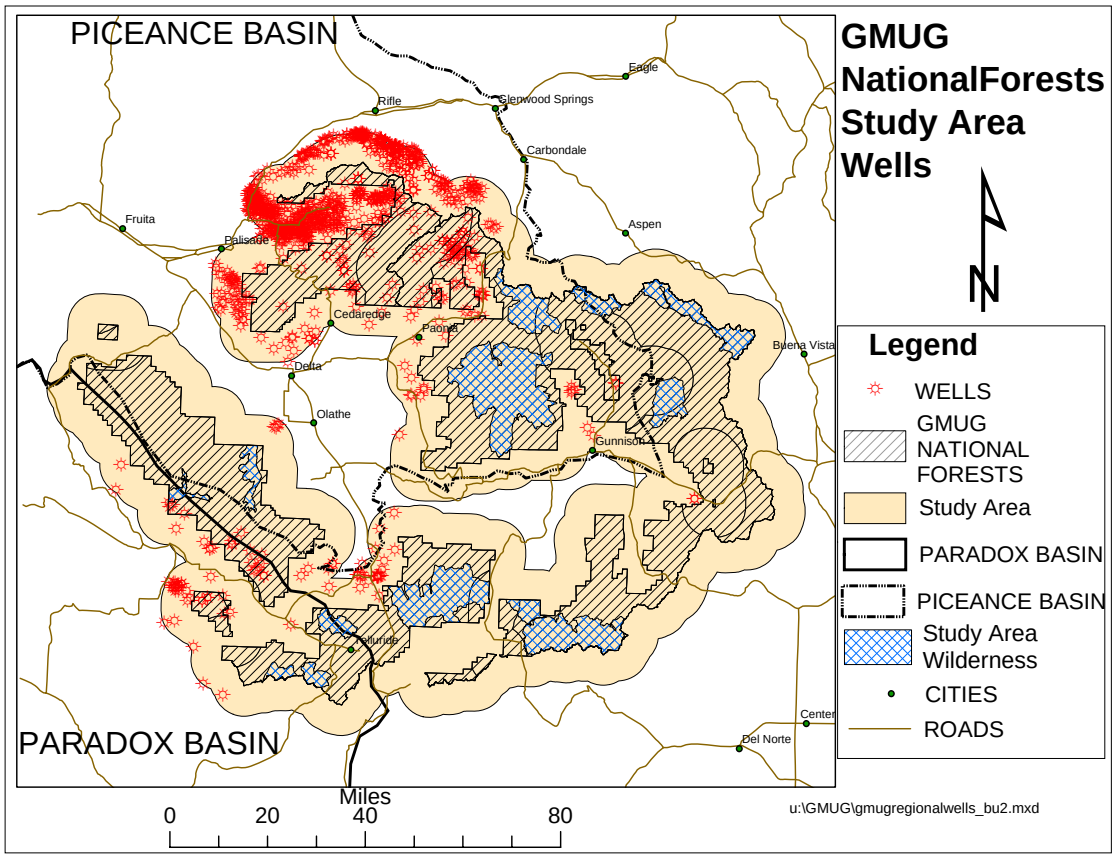


Figure 12. Plat of GMUG National Forests Study Area Including Wells and Wilderness.

[1] U:\GMUG\gmugbuffer.mdb
[2] U:\GMUG\co_wellsbuffer.shp, data from PID
[3] (503+10)/(953-104) = 60%

Decline curve analysis was used to estimate the oil and gas resource potential for the GMUG. Monthly production from wells in the study area was obtained from PID. Production from only later completed wells was used to emphasize later enhancements in drilling and completion technologies that more closely represent wells drilled currently. The production from the study area wells spud after 1990 were given a common start date of Year 0 and added together. The summed gas, oil and water production for the study area was divided by the summed production well count to yield an average monthly well production (production normalization). A plot of monthly volumes on a logarithmic scale versus time (decline curve) was developed (See Figure 13). The result is a single decline curve for each product (i.e., gas, oil and water) that approximates what an average well might produce. The sharp decrease in production at Year 10 is probably due to recent production not yet entered in PID and is therefore not included in this analysis. From the projected decline curve and using PowerTools version 5.0 analytical software to perform a decline curve analysis, a typical well would have an IP of about 10,000 MCF per month of gas and decline to an economic limit[4] of 300 MCF per month. At this, a typical well would ultimately produce about 794,767 MCF. Oil production would mostly be associated condensate for this typical well and would have an IP of about 46 BOPM and ultimately produce 3,525 BO. Water production would be about 7,265 BW over the life of the well. The life of this well would be about 35 years[5]. Gas contains about 1,000,000 BTU/MCF and oil contains about 5,000,000 BTU/BO (Gas Processors Suppliers Association Handbook). Based on ultimate recoveries, this typical well would produce 17,625 MMBTU from the oil and 794,767 MMBTU from the gas. As such, one can see that this typical well is clearly a gas well as it will produce 45 times as many BTUs from gas as it will from oil. As such, the wells will herein be referred to as gas wells.

[4] The economic limit is the point in time when the revenue from the production stream will balance such variables as the costs and taxes paid for that production. As these variables and resource dollar values change, so do oil and gas resource estimations.

[5] U:\GMUG\gmugregion1990laterspud.mdb

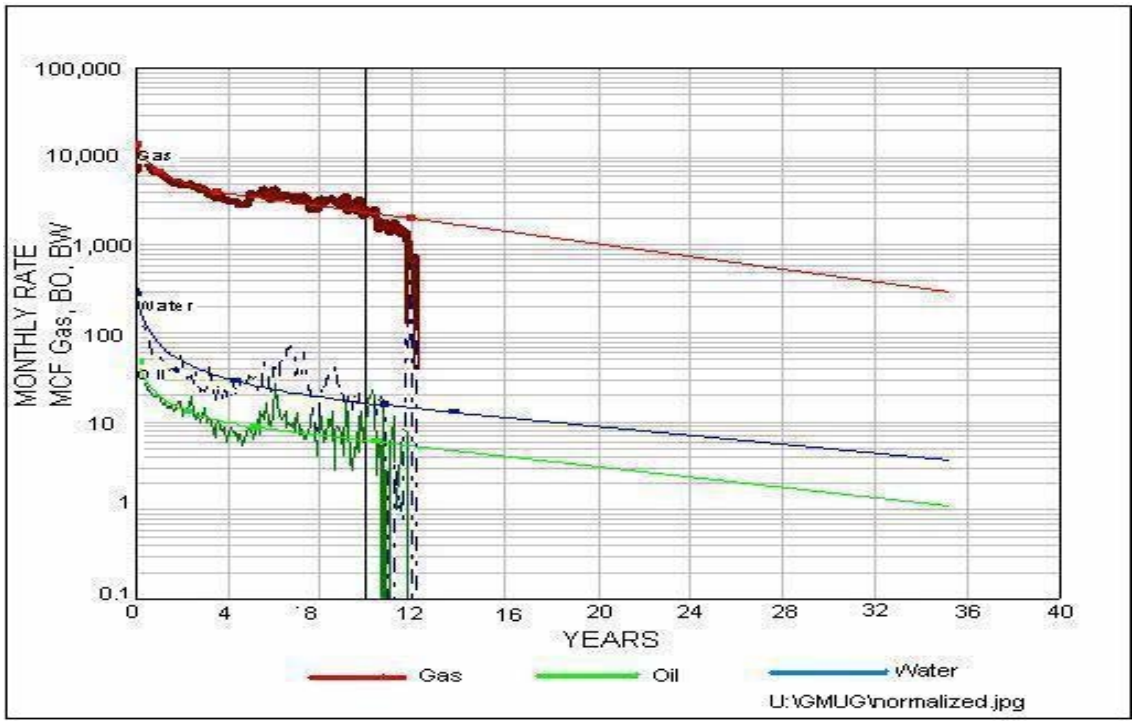


Figure 13. Normalized monthly production from wells completed since 1990 in the area of the GMUG National Forests. The normalized production is used to calculate well resources.

GMUG

The GMUG consist of approximately 3.2 million acres[6]. Of the GMUG, about 1,555,000 acres are in the Piceance-Uinta Basin and about 347,000 acres are in the Paradox basin[7]. The remainder is not within any geologic basin. Drilling on the GMUG started in June 1949. As of February 2004, a total of 106 wells have been drilled on the GMUG. Of the 106 wells, 84 wells are in the Piceance Basin and 22 wells in the Paradox Basin. According to PID, 29 wells are gas producers, 19 wells are permitted not drilled, 58 have been abandoned never completed, and 1 has been abandoned after production. At the end of 2003, a total of 6,684 BO, 3,539,201 MCFG and 30,026 BW had been produced from the GMUG[8]. On the GMUG, there are presently 15 wells capable of production. Since inception, the overall success ratio is 34%[9].

Present GMUG Condition

This section will focus primarily on the current oil and gas, and related activities occurring on the Paonia and Grand Valley Ranger Districts of the GMUG. Information

[6] U:\GMUG\gmug_bdy.lyr
[7] U:\GMUG\gmug\pr20bndg\gmugpiceance.lyr; paradoxgmugintersect.lyr
[8] U:\GMUG\gmugwells3.shp (data from PID)
[9] (29+1)/(106-19)) = 34%

on activity on the Norwood Ranger District is included where available. Only the areas where oil and gas activity is occurring are discussed.

Existing Gas Production: There are 15 [10]currently productive natural gas wells on the Paonia RD generally in T 10 and 11 S, and R 90 and 91 W. These wells are concentrated in T 10 and 11 S, R 90 W. Twelve of the wells are currently on line and capable of production, three are have been shut-in since drilling. Two operators, BDS International/Paradox Partners, and Riviera Drilling and Exploration operate the wells. The wells are known as: 11-90-9 (Henderson No. 1), 10-91-1-25, 10-91-1-26, 10-90-8 (10-8), 10-90-21-7 (21-7), 10-90-16-4, 10-90-30-4, 10-90-31, 10-90-32, 10-90-33, 10-90-34, 11-90-3, 11-90-7, 11-90-10, 11-90-17. The 11-90-3, 11-90-10 and the 11-90-17 are shut in, are not on a pipeline, and do not have production equipment on them.

Wells 10-90-16-4, 10-90-30-4, 10-90-31, 10-90-32 and 10-90-33 are part of the Ragged Mountain Unit. Well 10-8-11-90 is part of the Coal Basin Unit. The rest of the wells are lease wells. In general, production from these units has been sporadic. For year 2000, PID reports production from the GMUG as 119,737 MCF[11]. Since then, production has dropped off primarily due to operator/pipeline owner disputes.

In 2003, BDS performed recompletion activities on three wells (10-8, 1-25 and 1-26). A compressor was installed on the existing gas gathering system at the 30-4 well in 2002. Wells operated by Riviera Drilling have not produced since early 2003.

There are five drilled wells on the Grand Valley District. None of these are actively producing, there are no pipelines in place to any of these locations. The wells are known as the Leon Lake No. 1, Leon Lake No. 2, USA 1-17SC, USA 1-16SC, and Old Man Mountain No.1 (Now called the Federal No. 1, operated by Tom Brown). The other wells are operated by Maralex Resources and Gunnison Energy Corporation.

Gunnison Energy has applied to recomplete the Leon Lake 2 by sidetracking. The Forest Service gave approval for this work in January 2003. Gunnison Energy has also applied to plug and abandon the Leon Lake No. 1. The map below represents the wells capable of production with the exception of the Leon Lake No. 1 well.

[10] U:\GMUG\GMUG.mdb
[11] U:\GMUG\GMUG.mdb

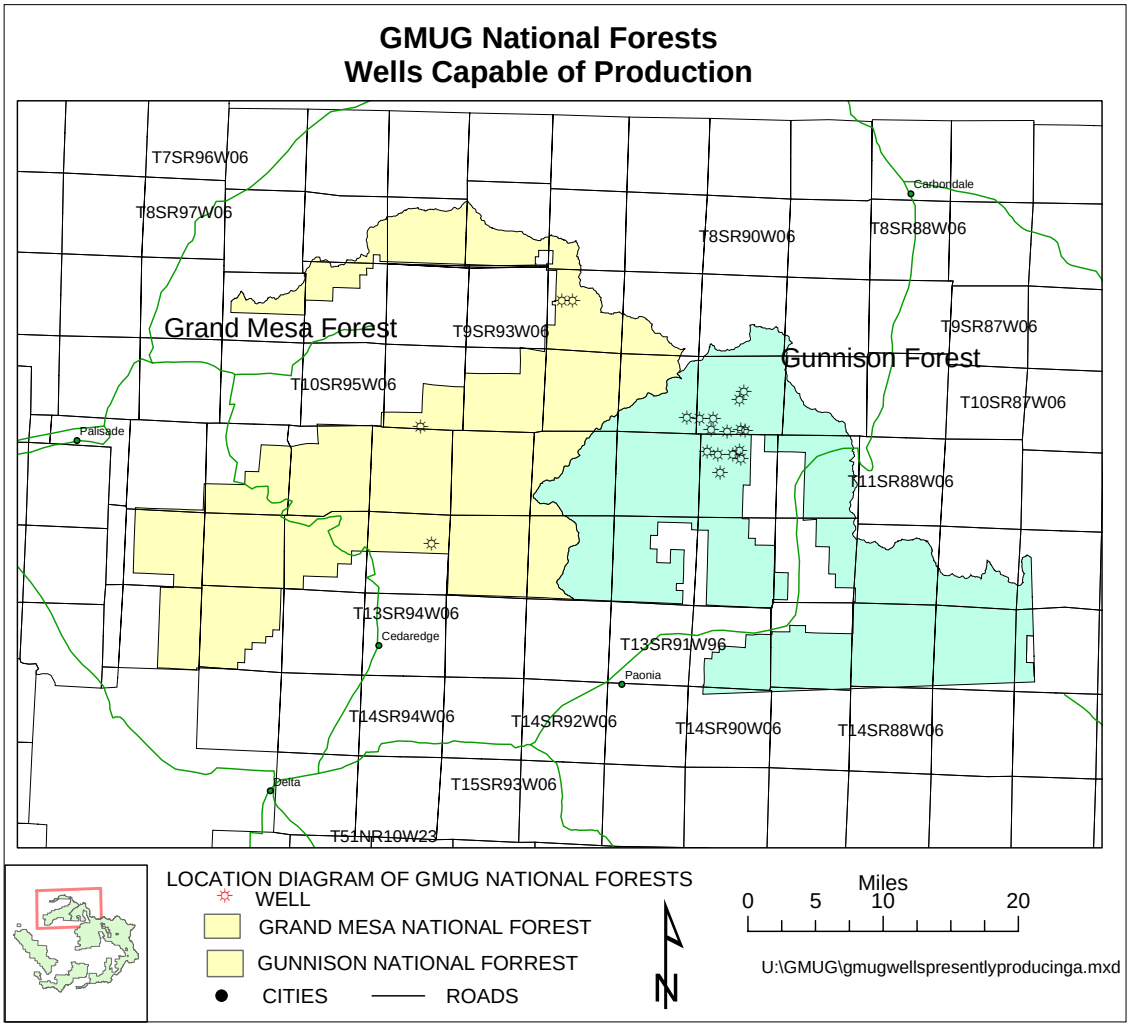


Figure 14. Plat of currently productive wells in the GMUG National Forests

Recent Exploration/Development Trends

Recent drilling activity and proposed exploration or development activities in the vicinity of the GMUG may influence the projected development in portions of the GMUG. As of March 2004, the following was noted:

Gunnison Energy Corporation (GEC) – Eight APDs (6 FS and 2 BLM) were submitted in 2003 and are approved for exploration in an area north of Paonia, Somerset, in the Surface Creek area northeast of Cedaredge. Four wells were drilled on fee lands east of Cedaredge in 2003. Based on significant gas found in Mesaverde Group sands in the Spaulding Peak No. 1-24 well (northeast of Cedaredge), GEC is proposing 4 additional development wells on fee lands just south of the Forest boundary. They will be identified as the 1-23, 2-23, 2-24, and 3-24 wells. The wells would be located around the producing Spaulding Peak well, spaced 160 acres apart. If productive, gathering lines and a compressor would be constructed to connect the wells into the existing Rocky Mountain Natural Gas pipeline at Cedaredge. Drill pads would measure 180' x 250', and reclaimed back to 150' x 200' size when production begins. The other 3 drilled wells are currently being tested. Through an agreement between GEC and several special interest groups, GEC has agreed to postpone plans for recompleting the Leon Lake No. 2 well into the coal beds for coal bed natural gas exploration. GEC also has an interest in the potential for producing coal mine gas from vent holes at its closed Sanborn Creek Mine. GEC is also in the process of completing a Geographic Area Proposal that would include 15 wells north of the Spaulding Creek area on the GMNF. The wells are projected to be drilled in years 2006 and 2007.

BDS International Corporation (BDS) has submitted six production well APDs in the Ragged Mountain Unit, which would be connected to the existing gathering system. An application from SG Interests proposes a pipeline to connect fee wells into the existing Ragged Mountain Gas Gathering System.

Strachan Exploration Inc submitted APDs in 2003 for 2 wells in section 2, T9S, R92W to explore Mesaverde Group reservoirs. The wells would be located near Hightower Mountain in the adjacent White River national Forest about 1-2 miles from the GMUG.

EnCana Oil and Gas operates the Hunter Mesa Unit in the Mamm Creek Field. The unit extends into White River Forest. The operator has proposed two exploration wells along the southern edge of the unit in section 15, T8S, R93W, approximately 1 mile from the GMUG. An APD was also submitted in 2003 for a well in section 11.

EnCana also operates the Orchard Unit and recently completed a well into Mesaverde Group reservoirs in section 16, T8S, R96W, located about 5 miles from the GMUG. A new APD in 2004 proposes a well in section 28, about 4 miles from the GMUG boundary.

CDX Rockies LLC submitted an APD in 2002 for exploration in the Cameo coal zone at a location about ¼ mile outside the GMUG.

Evertson Oil Company drilled 5 exploration wells in 2003 to test the Dakota Sandstone potential. They are located in the Whitewater Basin area, about 1-2 miles from the extreme west edge of Grand Mesa Forest. The drilling produced mixed results, with 3 of the wells being plugged. The other wells were completed for connecting up to the nearby Transcolorado Pipeline.

Mesa Hydrocarbons submitted an APD in 2001 for a proposed well in section 7, T9S, R92W, which would target the Mesaverde Group reservoirs. The well is located < 1 mile from the GMUG boundary. Another APD (section 15, T9S, R93W) in the Buzzard Creek Field was submitted by EnCana in 2002.

Willsource Enterprises submitted several APDs in 2002 along the flank of the Divide Creek Anticline (Mesaverde Group target), the nearest located about 2 miles from the GMUG boundary in section 20, T9S, R90W.

SG Interests drilled three wells on private lands in Section 20, T 11S, R 89W, and section 13, T 11 S, R 90W. SG Interests reports that the well testing has shown encouraging results from the coal seams, and they are awaiting test results from the sandstones.

Recent interest has been expressed in drilling wells on existing leases on the GMUG in the Hamilton Creek Field (Paradox Basin)

Recent Unit Agreement Summaries. There are five Federal oil and gas units that contain lands within the GMNF and GUNF. The Ragged Mountain, Coal Basin, Old Man Mountain, Leon Lake and Bull Mountain are established units, while the Aransas, Narrows, Collier Creek and Acapulco proved unsuccessful and have been terminated.

AMOCO Production Company formed the Megas Unit during 1986 to test the degasification potential and develop CBNG from the Bowie coal member of the Mesaverde in the southern Piceance basin. The unit area included over 150,000 acres and was one of the largest units approved in Colorado. The lands included in the unit were considered by AMOCO to be optimum for the production of CBNG. The unit was subsequently terminated due to several factors, which included economics, well performance and seasonal access problems.

Pipelines. The Ragged Mountain Unit has a gas gathering System in place for the 12 producing wells. The gathering system connects to the Northwest Gas Pipeline that runs north off of the GMUG and onto the White River National Forest. BDS International/Paradox Partners own and operate the gas gathering system and pipeline.

The Paonia RD has received an application from SG Interests for a pipeline to connect to the existing Ragged Mountain Gas Gathering system. This pipeline is proposed to connect three wells on private lands in Section 20, T 11S, R 89W, and section 13, T 11 S, R 90W to the system. SG Interests reports that the well testing has shown encouraging results from the coal seams, and they are awaiting test results from the sandstones.

BDS has proposed connecting the production wells for which APDs have been submitted to the existing gathering system.

Riviera Drilling has also expressed interest in connecting the 11-90-3, 11-90-10 and the 11-90-17 to the existing gathering system. The Forest Service does not have a formal proposal for this.

GEC has expressed interest in a pipeline running from the Sanborn Creek Mine in section 8, T 13 S, R 90W north to connect to a gas gathering system. The hook in point would be at the 30-4 well.

Lands Currently Under Lease According to the USFS, there are about 70,500 acres of land on the Paonia RD currently under lease for oil and gas. There are about 37,000 acres of land on the Grand Valley RD currently under lease for oil and gas (Piceance Basin). There are about 52,000 acres under lease on the Uncompahgre Plateau (Paradox Basin). There are currently 168 leases in the GMUG (131 leases within the Piceance and 37 leases and within the Paradox).[12]

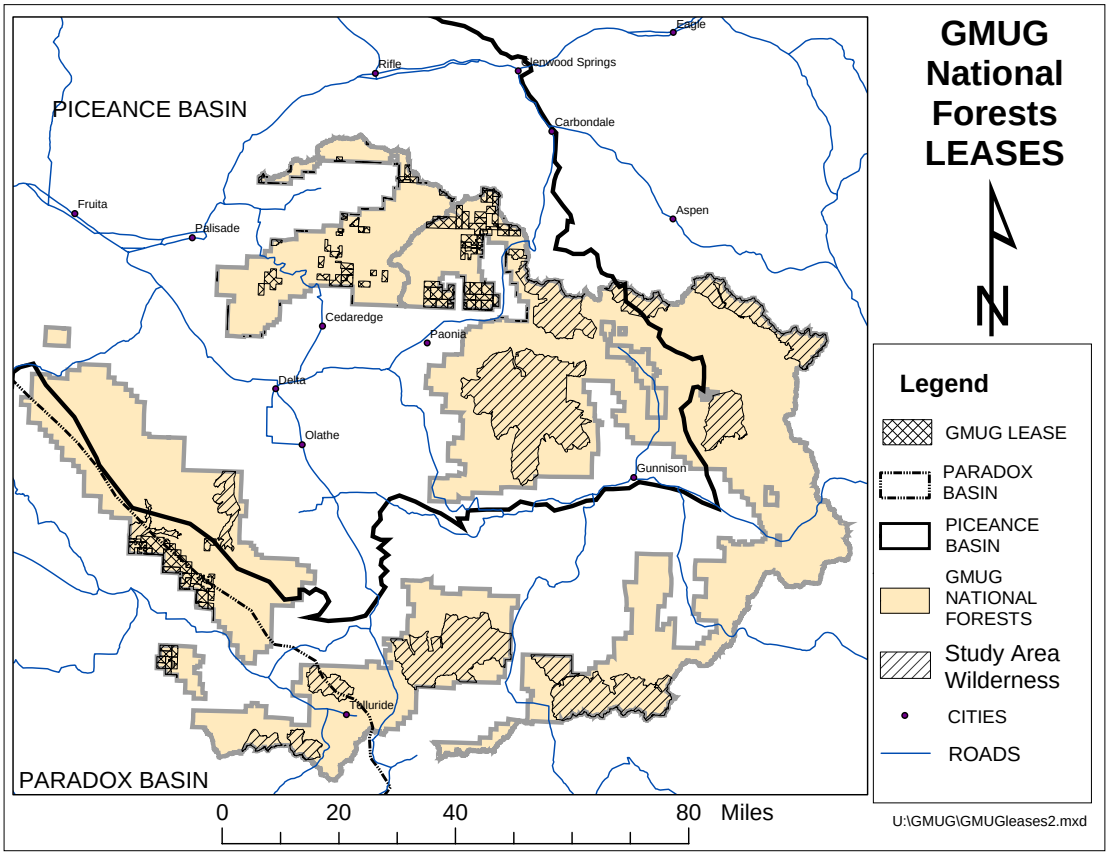


Figure 15. Plat of currently active leases in the GMUG National Forests

[12] U:\GMUG\gmugleaseintersectpiceance2.lyr and gmugleaseintersectparadox2.lyr

Pending Leases According to the USFS, the GMUG currently has 131 individual oil and gas lease parcel requests, totaling about 177,800 acres, which represents 65% of the leased acreage. Fifty-three of these requests are on the Paonia RD, encompassing 75,800 acres. Sixty-two of the requests are on the Grand Valley RD, encompassing about 84,000 acres. Sixteen requests are on the Norwood RD, and encompass 18,000 acres.

Trends

Gas Price and Demand trends

According to the EIA, the largest increase in the lower 48 onshore natural gas production is projected to come from the Rocky Mountain Region. Moderating the projected gas price a bit would be expected growing gas imports from Canada and Alaska as well as increasing use of Liquefied Natural Gas imports. The natural gas resource base is sufficient in the early years of the forecast to support the increase in drilling activity. In later years, rising costs of gas well development reduce drilling activity, and resource depletion reduces reserve additions. As a result, total reserves are projected to decline. The projected incline of gas price is at an average of about 2% per year not adjusted for inflation. It can be seen from the graph that Colorado's well head gas price trends follow closely with the national trend. The gas spike in the 1980s was due to deregulation. Other anomalies are primarily due to anomalous weather, supply and demand, use of other sources of energy, etc.

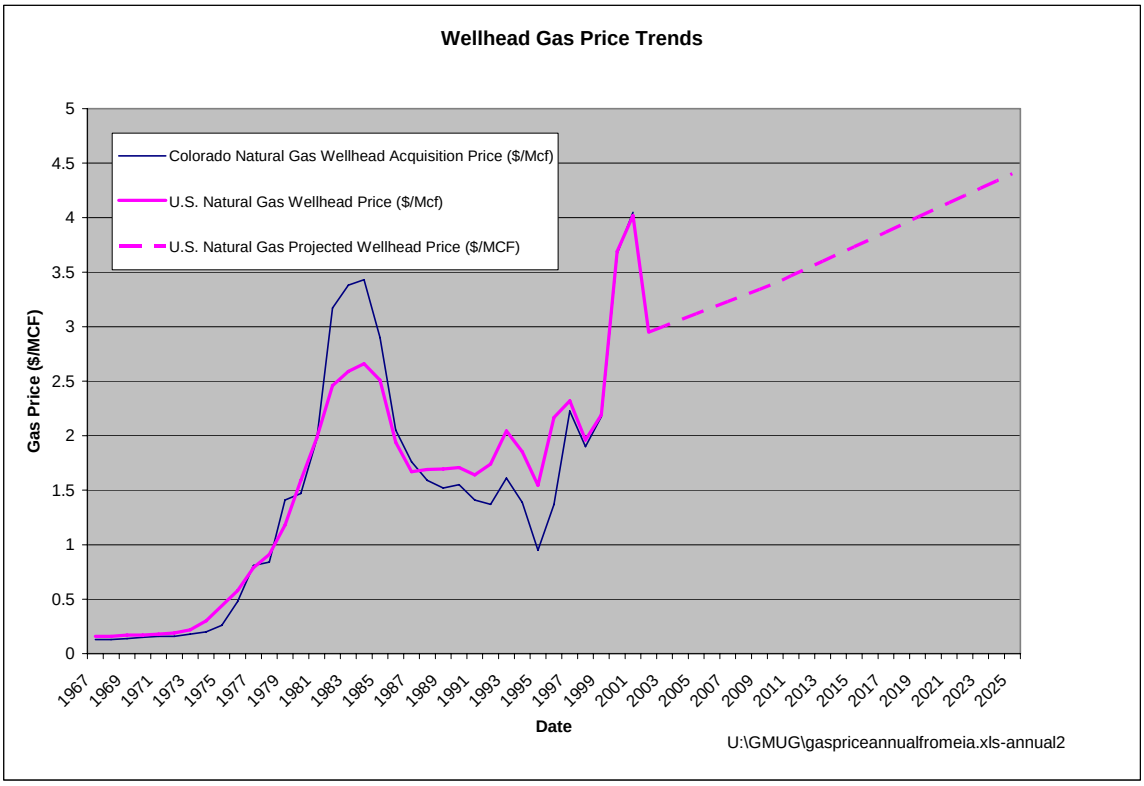


Figure 16. Plot of National and Colorado Gas Price ($/MCF) versus Date through year 2003 with a projection line through year 2025 which reveals the historical and projected national and Colorado wellhead gas prices from EIA

According to the EIA, total domestic natural gas consumption is projected to increase from 2002 to 2025 an average of 32 TCF per year as compared with 22.6 TCF in 2002.

This represents about a 41%[13] increase in gas consumption over 23 years, or about a 2% increase per year in consumption.

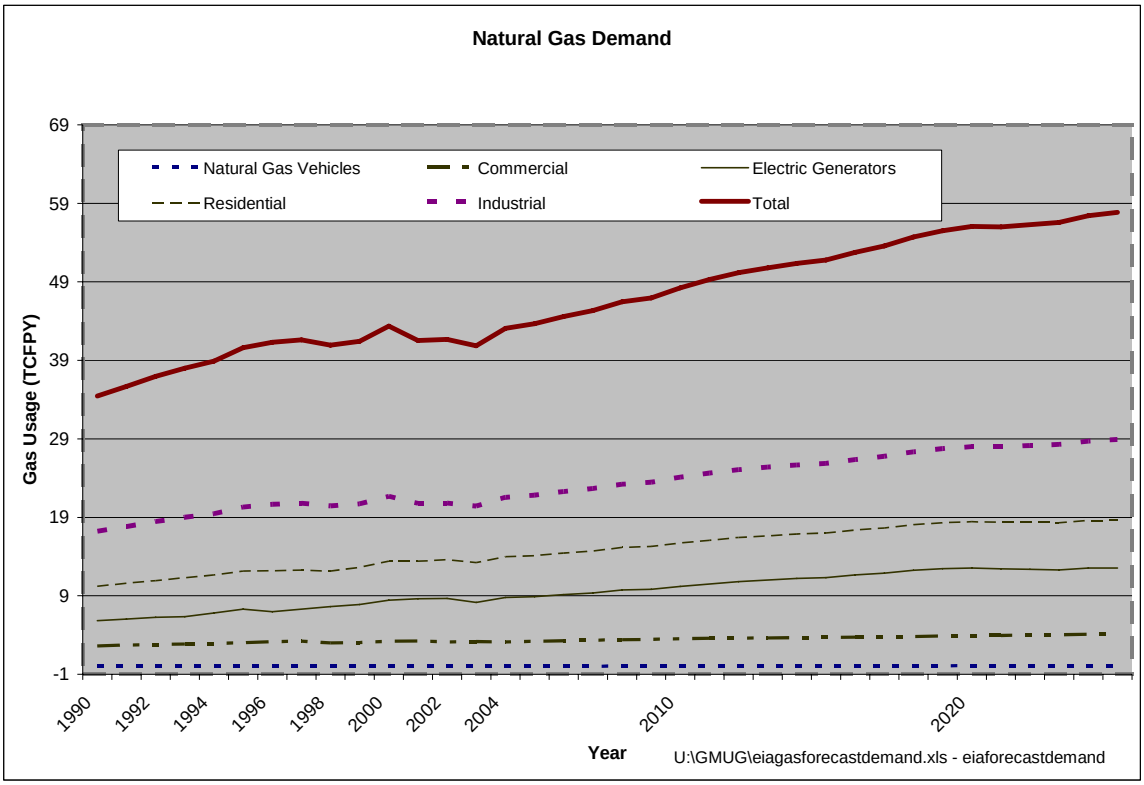


Figure 17. Plot of industrial, commercial, residential, electric generation and natural gas vehicles usages versus year

Drilling and Abandonment Trends

Observing Figure 18, shows that drilling in the study area has been fairly stable. Conversely, Figure 19 shows that drilling on just the GMUG has been very sporadic. As such, the drilling, completion and abandonment data from just the GMUG is not reliable to analyze separately.

Completion Trends

A general drilling increase as well as increasing success as indicated by a progressively lessening gap between spuds and completions in later years is the trend for the GMUG is shown in Figure 19. As mentioned in the "Study Area" section, overall completion success has been at approximately 60%. However, during the last 10 years, 212 wells were drilled and 10 wells were drilled and abandoned without production resulting in a success ratio of 95%[14].

[13] (100*(32 -22.6)/22.6)=41%
[14] (212-10)/212*100=95%, data from U:\GMUG\spudcomplbuffer.xls - GMUGbufferdata

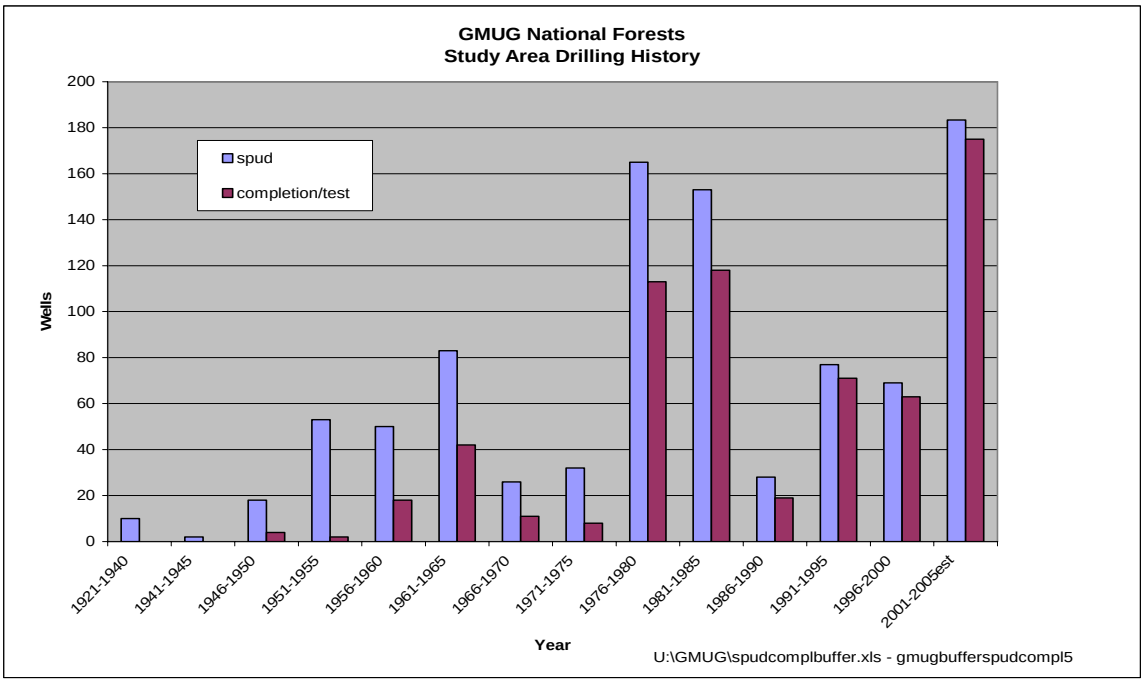


Figure 18. Bar graph showing the number of wells spud and completed in the study area

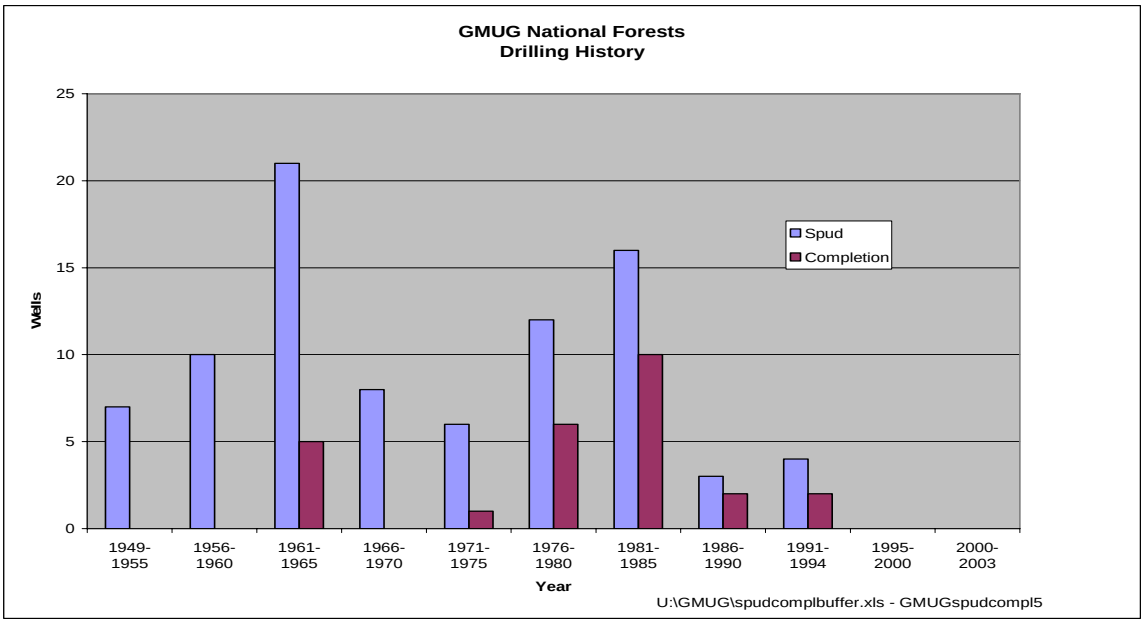


Figure 19. Bar graph showing the number of wells spud and completed in the GMUG National Forests

Forecast Based On Historical Drilling Activity

Based on historical drilling activity and using a Forecast function in Microsoft Excel, by the year 2019, an additional 168 wells are projected to be drilled, or 11 wells/year and an additional 120 wells or 8 wells/year are projected to be abandoned. Based on the number of wells drilled or permitted, the GMUG represents about 11%[15] of the study area activity. Based on just the drilling trends discussed here, 11% of 168, or 19 wells are projected to be drilled and 11% of 8, or 2 wells abandoned on the GMUG over the next 15 years.

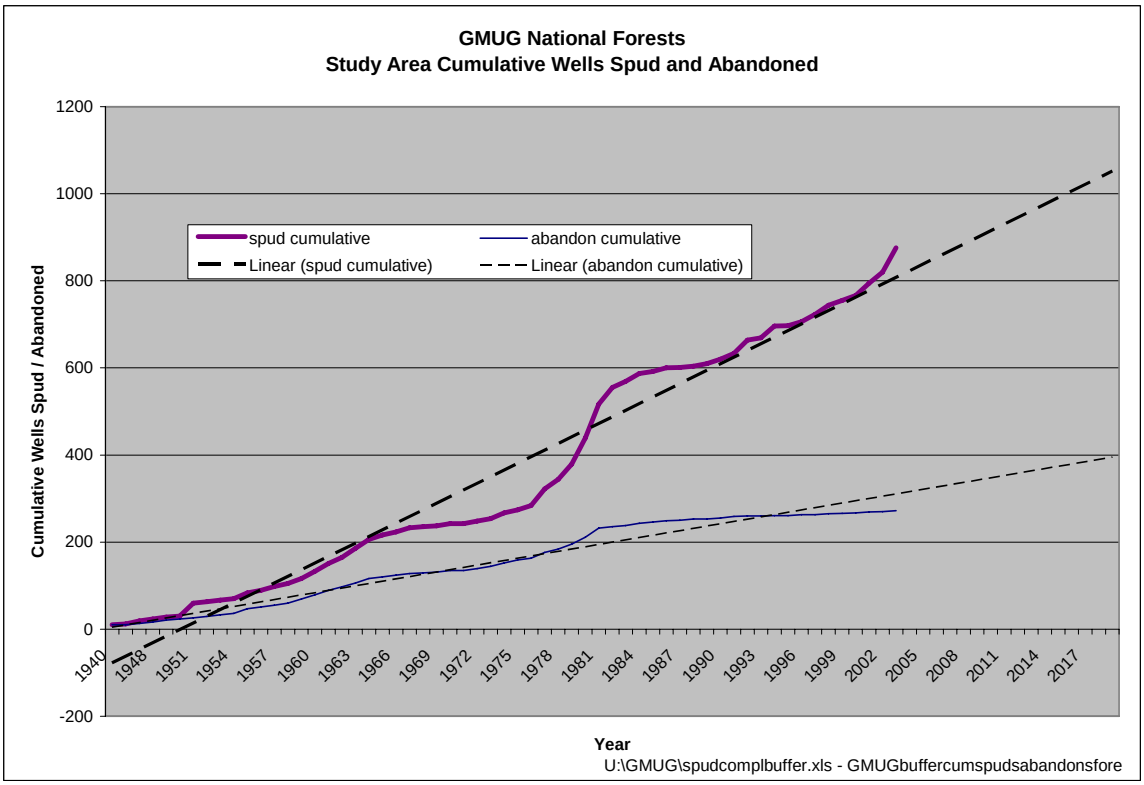


Figure 20. Plot of cumulative wells spud and abandoned within the Study Area of the GMUG National Forests, including a trend line.

[15] (106/953)*100=11%

GMUG Reasonable Forseeable Development

Historical trends, USGS resource estimates, current activity, existing leases, pending wells, pending leases, and proposed pipelines were considered in formulating the RFD. The projection of drilling activity, both wildcat and development is based primarily on the escalation of gas price which corresponds closely to the historical drilling activity and will mostly be confined to the high and medium potential areas. The low potential areas may have little or no activity and the no potential areas are forecast for no activity. Proposed pipelines, and wells were also considered.

Increasing gas prices, gas consumption and rig availability both favor continued exploration for gas nationally. In addition, 6 pending wells and 131 pending leases exist for the GMUG area. If these leases are finally issued, it would almost double the existing 168 leases. In addition, the largest single GMUG lessee, Gunnison Energy, was formed solely to develop their 30,000 acres within the GMUG. They remain optimistic of the area. As mentioned previously, Gunnison Energy has recently filed 6 APDs on the GMUG (approved), 2 APDs on adjacent BLM land (approved), and 4 fee wells adjacent to the GMUG, along with a pipeline proposal. BDS has filed APDs for 6 wells on the GMUG. However, those APDs are on hold pending a sale of the BDS property.

Based on the number of wells drilled or permitted, the GMUG represents about 11%[16] of the study area activity (106/953). From the drilling trends section above, 168 wells are forecast to be drilled and 8 wells are forecast to be abandoned within the study area over the 15 year RFD time period. Based upon the GMUG being 11% of the study area activity, this corresponds to forecast of 19 wells drilled and 2 wells abandoned on the GMUG over the next 15 years based solely on historical drilling activity.

As shown on Figure 21, one can see that gas price and drilling trend similarly. As mentioned previously, EIA estimates that gas price will escalate at 2% per year. Since the GMUG has had 106 wells drilled and it is assumed that the proposed Gunnison Energy wells will be drilled bringing the total to 112 wells, it is estimated that the wells will increase at 2% over the previously drilled wells, or 2 wells per year. Over 15 years, 30 wells are estimated to be drilled based solely on price escalation. This is an increase of 11 wells over the projection of 19 wells from just historical drilling trends. Abandonment trends are estimated at 2 wells over the analysis period.

[16] (106/953)*100=11%

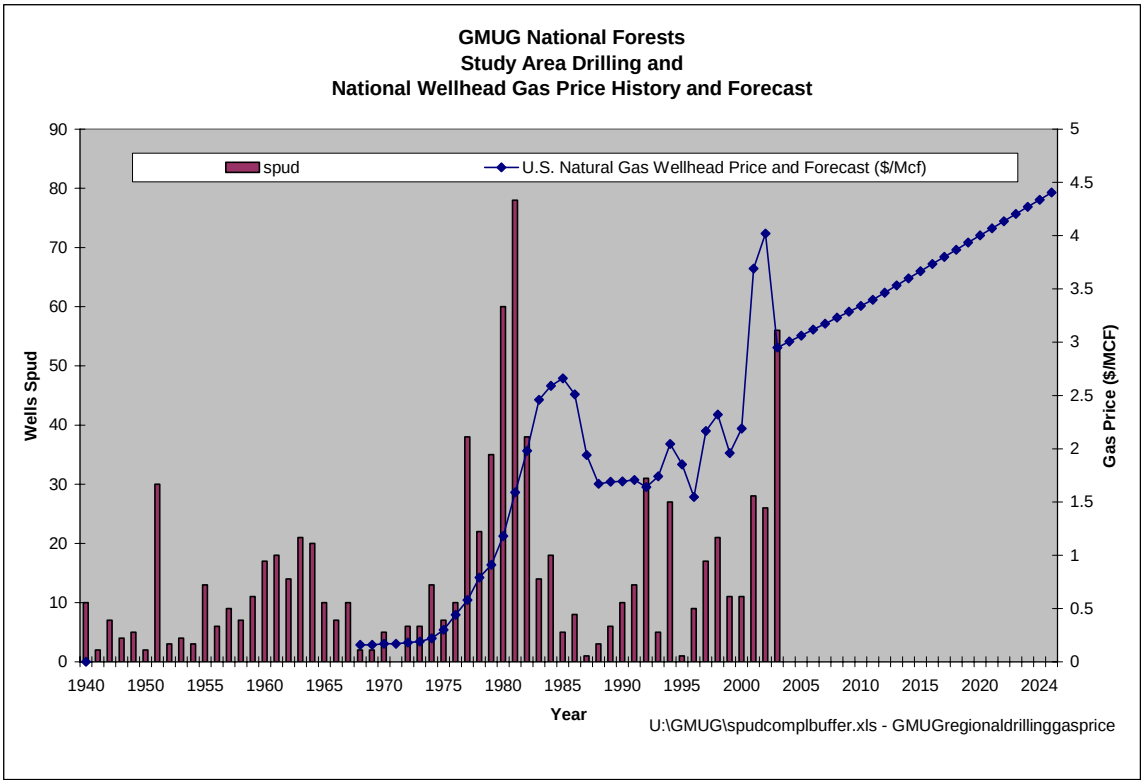


Figure 21. Bar graph showing the wells spud in the study area and plot showing historical and projected gas price

For the purposes of this RFD, it is assumed that undrilled wells with currently approved APDs are covered under the existing plan and RFD forecast. As such, these wells are not covered in this plan. Since the 6 exploratory GMUG wells proposed by GEC have approved APDs, these wells are not included in this RFD forecast. However, the 15 wells proposed by GEC for the Spalding Peak area are covered under a Geographic Area Proposal but are not yet approved under individual well APDs. As such, these wells are included in this RFD forecast. The pending leases, while an indicator of potential activity, are just speculation at this point and are not a factor in determining potential drilling. The six BDS GMUG wells will also not be considered since they are on hold and are just another indicator of activity.

RFD Projections

1. Drilling on the GMUG will escalate linearly with gas prices at about 2% per year or 2 wells per year or 30 wells over the analysis period of 15 years. In addition, 15 wells recently proposed by GEC for the Spaulding Peak area are added to this forecast for a total forecast of 45 wells.

2. The six presently approved GEC wells and associated compressor and pipeline are not part of this RFD forecast. However, the 15 wells recently proposed by GEC under a Geographic Area Proposal are included in this RFD forecast.

3. Based on the study area's historical activity, 2 wells are forecast to be abandoned over the next 15 years.

4. Of the 45 forecasted wells, it is anticipated that 27 would be drilled on the GMNF, 12 would be drilled on the GUNF, and 6 would be drilled on the UNNF. Most wells would be drilled in the high potential area, some in medium, and little or none in the low potential area.

5. There is forecast to be no drilling in no-currently-recognizable potential areas

6. It is anticipated that the impacts associated with Coal Bed Natural Gas (CBNG) are no different than those associated with natural gas produced from sandstone reservoirs. As such, CBNG development was not analyzed separately and is included in the forecast development. It is projected that few wells will be completed solely as CBNG due to possible technical and/or economic constraints.

7. While GEC reports less well pad disturbance, the surface disturbance for the wells in this RFD will be based upon disturbance from federal wells drilled in the nearby Grand Valley, Rulison and Parachute fields (Glenwood Springs Final Supplemental Environmental Impact Statement). A typical single-well pad, associated road and pipeline will have an initial disturbance of 3.4 acres. (Glenwood Springs Draft Supplemental Environmental Impact Statement) reveals that an average location requires about 0.6 miles of road. After a well is drilled as a producer, much of the disturbed site is immediately reclaimed (interim reclamation). The interim reclamation is estimated to be 1.9 acres per well. Thus, for the projected 45 wells and associated pipelines, a total disturbance before interim reclamation would be 153 acres and after interim reclamation would be 86 acres and 27 miles of road. Plugging of 2 wells during the RFD period will result in a total of 3.8 acres including 1.2 miles of road reclaimed. Therefore, total disturbance after interim reclamation would be about 86 – 3.8 acres or 82 acres.

8. Most, if not all, of the wells will be vertically drilled due to the exploratory nature of this area. However, because of the access problems and potential surface area preclusions because of steep slopes and surface restriction stipulations, it is possible that wells will be directionally drilled. There are no significant

additional impacts with directional drilling as compared to vertical drilling. Actually, less impacts would occur with directional drilling because of fewer locations resulting in less drill pads and road disturbance.

9. From the normalized decline curve analysis above and the study area's success, it is estimated that each successful well will average 795,000 MCFG and 3,500 BO over a span of 35 years. Based on 45 wells drilled and a 95% success ratio, the resultant drilling will result in an additional 34 BCF of gas resources and 150 MBO of oil resources.

Appendix 1.

CLASSIFICATION OF OIL AND GAS POTENTIAL

(revised December 19, 1994, from BLM Handbook H-1624-1, May 7, 1990)

HIGH	Demonstrated existence of source rock, thermal maturation, reservoir strata possessing permeability and porosity, and traps. Demonstrated existence is defined by physical evidence or documentation in the literature.
MEDIUM	Geophysical or geological indications that the following may be present: source rock, thermal maturation, reservoir strata possessing permeability and porosity, and traps. Geologic indication is defined by geological inference based on indirect evidence.
LOW	Specific indications that one or more of the following may not be present: source rock, thermal maturation, or reservoir strata possessing permeability and porosity, and traps.
NO CURRENTLY RECOGNIZABLE POTENTIAL	Demonstrated absence of source rock, thermal maturation, reservoir rock, and traps. Demonstrated absence is defined by physical evidence or documentation in the literature.

Note: Inclusion of an area in a USGS oil and gas play defined in the national assessment should be considered in determining potential for oil and gas resources. However, because the USGS assesses speculative plays, play definition alone should not be the only criterion for determining potential.

Contacts.

BDS International/Paradox Partners: Bob Fluornoy, 972-808-9322. (Operates 5 wells in the Ragged Mountain and Coal Basin Units, operates gas gathering system and pipeline).

Riviera Drilling: Sam Thurner, 970-921-3457 (Operates 10 wells in the Ragged Mountain and Coal Basin Units)

SG Interests: Rob Guinn, 713-951-0100 (Company recently drilled 3 wells on private lands in Gunnison County, east of GMUG. Has applied for pipeline permit to connect to existing system)

Gunnison Energy Corporation: Tony Gale, 303-296-4222. (Holds 8 permits for exploration drilling in North Fork Valley. Also interested in pipeline from Sanborn Creek Mine to existing system).

Bowie Resources LLC. Greg Hunt, 970-929-5277. (Operate Bowie No. 2 coal mine, have 5 methane drainage holes on GMUG, more on BLM and private).

Oxbow Mining Inc. Kathy Welt, 970-929-5834. (Operate Sanborn Creek and Elk Creek Mine. Methane venting occurred from Sanborn Creek Mine. She also is public relations director for Gunnison Energy).

West Elk Mine. Phil Schmidt, 970-929-2217. (Operate west Elk Mine, large multi-year program to install methane drainage wells into coal mine).

Delta County. Bruce Bertram, 970-874-5905. Local Government Designee for oil and gas operations, has been overseeing drilling on private land in Delta County.

Gunnison County: Neal Starkebaum, 970-641-0360. Gunnison County Planner, has been working on county permits for oil and gas drilling.

BLM. Lynn Lewis, 970-240-5305. Lynn has been working with us on APDs in the North Fork Valley.

Acronyms and Abbreviations

Acronym	Definition
APD	Application for Permit to Drill
B	Barrels
B	1,000,000,000
BDS	BDS International Corporation
BLM	Bureau of Land Management
BTU	British Thermal Unit
CBNG	Coal Bed Natural Gas
CF	Cubic Feet
EIA	Energy Information Administration
EPCA	Energy Policy and Conservation Act
G	Gas
GEC	Gunnison Energy Corporation
GMNF	Grand Mesa National Forest
GMUG	Grand Mesa, Uncompahgre and Gunnison National Forests
GUNF	Gunnison National Forest
IP	Initial Production
M	1,000
O	Oil
PID	Production Information/Dwights Plus Database
RFD	Reasonable Forseeable Development
SEIS	Supplemental Environmental Impact Statement
T	1,000,000,000, or 1MB
UNNF	Uncompaghre National Forest
USFS	United States Forest Service
USGS	United States Geologic Survey
W	Water

Glossary

Basin-centered accumulation – For this report, the basin-centered gas is a continuous gas accumulation found in the structurally deeper part of the Piceance Basin.

Basin-margin accumulation – For this report, the basin-margin gas consists of potential accumulations of gas found along the southern and eastern margins of the basin.

Continuous gas accumulations – Also called unconventional, petroleum accumulations that are regional in extent, commonly having low matrix permeabilities; no obvious seals, traps, or hydrocarbon-water contacts; are abnormally pressured; are in close proximity to source rocks; and have low recovery factors.

Conventional gas accumulations – Discrete petroleum accumulation with a well-defined hydrocarbon-water contact, commonly having high matrix permeabilities, obvious seals and traps, and high recovery factors.

Play – A set of known or postulated oil and gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathway, timing, trapping mechanism, and hydrocarbon type.

Reservoir rock – A connected layer of porous rock, such as sandstone or carbonates, containing varying amounts of oil, gas, and/or water, based on variations in permeability, porosity, and water saturation.

Source rock – Rocks, such as coal, carbonaceous shale, or shale which provide the source for gas generation and subsequent migration into reservoir rocks.

Strandlines – Former shorelines which became elevated above the water level of the sea. Within the Piceance Basin, this refers to the seaward limit of Mesaverde Group (sandstones) regressive cycles.

Thermal maturity values – Thermal maturity in source rocks is measured by the % vitrinite reflectance in oil (%Ro). The vitrinite reflectance is a measure of the reflectivity of polished vitrinite (coal) particles under oil. This provides a measure of the thermal methane generation of source rocks. Immature source rocks have lower values (less gas generated), while mature source rocks have higher values, indicating that source rocks have been heated sufficiently to generate larger quantities of methane.

Transitional gas accumulations – Petroleum accumulations in the transition zone adjacent to the area of continuous gas accumulation; gas saturations are less complete based on less mature source rocks; thus, a higher percentage of water-saturated reservoirs.

Water-wet reservoirs – Reservoirs that have a significant amount of water and may be watered-out, such that the cost of water removal would exceed the value of any gas produced.

References

Allen, E.G., and Lutz, G.A., compilers, 1976, Leasable Mineral and Waterpower Land Classification Map, Montrose Quadrangle: U.S. Geological Survey Open File Report 76-371.

Allen, E.G., DeCicco, D.A., and Lutz, G.A., compilers, 1979, Leasable Mineral and Waterpower Land Classification Map, Leadville Quadrangle: U.S. Geological Survey Miscellaneous Investigations Series map I-1108.

Ambrose, C.M., 1998, Penetration Charts of Selected Colorado Oil and Gas Fields: Colorado Geological Survey Resource Series 34.

Butler, W.C., compiler, 1994, Significant Parts of 13 Papers from Eight Published Volumes Showing the Quantitative Estimates of Coalbed Methane Resources in the Piceance Basin, Colorado: Department of Energy, Naval Petroleum and Oil Shale Reserves, Advisory Team Meeting.

Chronic, H., 1980, Roadside Geology of Colorado: Mountain Press Publishing Company.

Colorado Oil and Gas Conservation Commission, 2004, Scout Cards, Completion Reports, and Other Oil and Gas Well Data for Piceance and Paradox Basin Areas.

Decicco, D.A., Pera, E.M., and others, compilers, 1977, Leasable Mineral and Waterpower Land Classification Map, Moab Quadrangle: U.S. Geological Survey Open File Report 77-612.

Doelling, H.H., 1983, Observations on Paradox Basin Salt Anticlines: Grand Junction Geological Society, Northern Paradox Basin – Uncompahgre Uplift, pp. 81-90.

Ellis, M.S., and Freeman, V.L., 1984, Geologic Map and Cross Sections of the Carbondale 30’ x 60’ Quadrangle, West-Central Colorado: U.S. Geological Survey, Coal Investigations Map C-97-A.

Elston, D.P., and Shoemaker, E.M., 1961, Preliminary Structure Contour Map on Top of Salt in the Paradox Member of the Hermosa Formation in the Salt Anticline Region, Colorado and Utah: U.S. Geological Survey, Oil and Gas Investigations Map OM 209.

Energy Information Administration: Annual Energy Outlook With Projections To 2025 – Forecast Comparison and Market Trends sections.
http://www.eia.doe.gov/oiaf/aeo/gas.html (pp1-12)
http://www.eia.doe.gov/oiaf/aio/forecast.html (pp1-6)

Gas Processors Suppliers Association Handbook, 1972 edition: Figure 16-1

Hemborg, H.T., 2000, Gas Production Characteristics of the Rulison, Grand Valley, Mamm Creek, and Parachute Fields, Garfield County, Colorado: Colorado Geological Survey Resource Series 39.

Johnson, R.C., 1989, Geologic History and Hydrocarbon Potential of late Cretaceous-Age, Low-Permeability Reservoirs, Piceance Basin, Western Colorado: U.S. Geological Survey Bulletin 1787-E.

Pearl, R.H., and Murray, D.K., compilers, 1974, Colorado Stratigraphic Correlation Chart: Colorado Geological Survey.

Pera, E.M., Smedley, J.E., and others, compilers, 1977, Leasable Mineral and Waterpower Land Classification Map, Grand Junction Quadrangle: U.S. Geological Survey Open File Report 77-304.

Petroleum Information/Dwights LLC d/b/a IHS Energy Group (PID). Copyright 2002: Rocky Mountain Production Region – US Production data and US Well data

Resource Enterprises, Inc., 1985, Piceance Basin, Structure Contour Map of the Rollins Sandstone.

Rocky Mountain Association of Geologists, 1972, Geologic Atlas of the Rocky Mountain Region, pp. 282-284.

Rocky Mountain Association of Geologists, 2003, Piceance Basin 2003 Guidebook.

Scott, P.K., 2003, Paradox Basin, Colorado, Maps, Cross Sections, and Database for Oil, Gas, and CO2 Fields: Colorado Geological Survey Resource Series 43.

Steven, T.A., and Hail, Jr., W.J., 1989, Geologic Map of the Montrose 30’ x 60’ Quadrangle, Southwestern Colorado: U.S. Geological Survey, Miscellaneous Investigations Map I 1939.

Tremain, C.M., 1984, Coal bed Methane Resources of Colorado: Colorado Geological Survey Map Series 19.

U.S. Department of Agriculture, Forest Service, 1993, Final Oil and Gas Leasing Environmental Impact Statement: Appendix E – Reasonable Foreseeable Development Activity Within the Grand Mesa, Uncompahgre and Gunnison National Forests.

U.S. Department of Agriculture, Forest Service, and U.S. Department of the Interior, Bureau of Land Management, 2003, Environmental Assessment Gunnison Energy Corporation’s Proposed Exploratory Gas Drilling Project.

U.S. Department of Interior, Bureau of Land Management, Glenwood Springs Final Supplemental Environmental Impact Statement, 1999: Table 4.8-1

U.S. Department of Interior, U.S. Department of Agriculture, U.S. Department of Energy, 2003, Scientific Inventory of Onshore Federal Lands' Oil and Gas Resources and Reserves and the Extent and Nature of Restrictions or Impediments to their Development (EPCA), Janurary 2003: Section 3.1.2 (p 3-2)

U.S. Department of Interior, Bureau of Land Management, Glenwood Springs Draft Supplemental Environmental Impact Statement, June 1998: Table I-2-1.

U.S. Geological Survey Uinta-Piceance Assessment Team, 2002, Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado 2002.

Williams, P.L., 1964, Geology, Structure, and Uranium Deposits of the Moab Quadrangle, Colorado and Utah: U.S. Geological Survey, Miscellaneous Investigations Map I 360.

Wray, L.L., Apeland, A.D., and others, compilers, 2002, Oil and Gas Fields Map of Colorado: Colorado Geological Survey, Map Series 33.