Reasonable, Foreseeable Development: Oil, Natural Gas, and Carbon Dioxide in Canyons of the Ancients National Monument

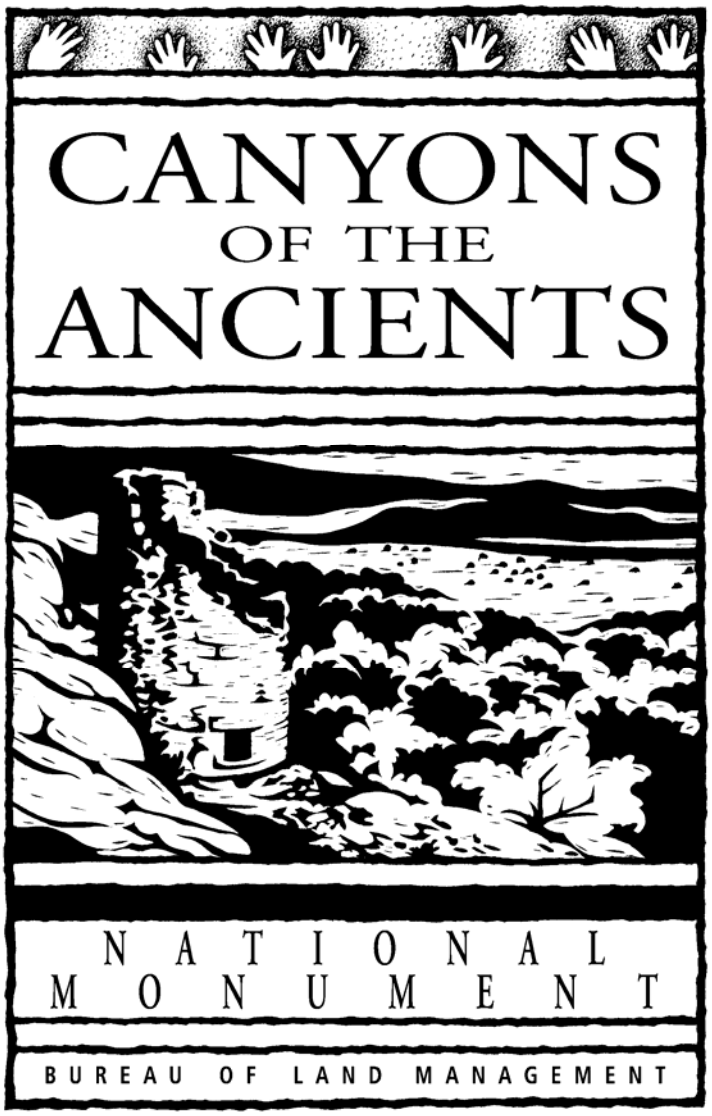

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TABLE OF CONTENTS

Executive Summary 1

Introduction 3
Factors Affecting Oil and Gas Development 3
Economics 5
Boom and Bust 6
Common Reservoirs in the Monument 6
Document Organization 7
Background and Oil and Gas Exploration and Production in the Monument 7
Petroleum Geology 11
Summary 16
Leases and Units in the Monument 16
Split-Estate 18
Units and Fields in the Monument 20
Cutthroat Unit 20
Conclusion 21
McElmo Dome Unit 25
Conclusion 28
Cache Unit 28
Conclusion 29
Flodine Park and Flodine Park East Fields 29
Conclusion 32
Cannonball Unit 32
Goodman Point Field 32
Conclusion 34
Papoose Canyon Field 34
Conclusion 38
Canyon (Shallow) Unit 38
Conclusion 38
Island Butte Field 38
Conclusion 40
Estimated Reserves 40
Conclusion 40
Reasonable Foreseeable Development Scenario: Oil and Natural Gas 45
Oil and Natural Gas Wells 45
Oil and Natural Gas Facilities 45
Seismic Surveys 46
Directional and Horizontal Drilling 46
Summary 47
Reasonable Foreseeable Development Scenario: CO_2 47
CO_2 Wells 47
Production Facilities 48
Horizontal and Directional Drilling 48
Uncertainties 49

Summary 49
Surface Impacts 49
Discussion – Access Roads, Pipelines, Wellpads and Production Facilities 50
Seismic Surveys 53
Air Quality and Emissions 54
Summary 55

Appendices

Appendix A. Selected Definitions
Appendix B. References

Figures

Figure 1. Resource Management Planning Area
Figure 2. Sedimentary basins of the Four Corners Region.
Figure 3. Seismic survey activity in the Monument, by Township, from 1970 to present.
Figure 4. Stratigraphic column of the Paradox Basin.
Figure 5. Geologic Formations
Figure 6. Block diagram of the paradox shelf-depositional environment.
Figure 7. Oil, Natural Gas and CO_2 Leases with Unit Boundaries
Figure 8. Leased and Unleased Split Estate Land
Figure 9. Desert Creek Isopach of the McClean Basin Field.
Figure 10. Leadville Structure of the McElmo Dome Field.
Figure 11. Ismay Isopach of the Cache Field.
Figure 12. Ismay Isopach of the Flodine Park and Flodine Park East Fields.
Figure 13. Ismay Isopach of the Goodman Point Field.
Figure 14. Desert Creek Isopach of the Papoose Canyon Field.
Figure 15. Desert Creek Isopach of the Island Butte Field.

Tables

Table 1. Land/Mineral status within the Monument.
Table 2. Oil and gas discoveries within the Monument.
Table 3. Monument units and their associated acreage.
Table 4. Monument units and their numbers of active and plugged wells.
Table 5. Estimated ultimate reserves for fields located within and outside the Monument.
Table 6. Twenty year projected number and location of new oil and natural gas wells.
Table 7. Twenty year projected number and location of new CO_2 wells.
Table 8. Gross existing surface disturbance in the Monument.
Table 9. Net existing surface disturbance.
Table 10. Future gross surface disturbance for oil and natural gas.
Table 11. Future gross surface disturbance for CO_2.
Table 12. Future surface disturbance for oil, natural gas and CO_2 roads and pipelines.
Table 13. Future net surface disturbance.
Table 14. Future net long-term surface disturbance.
Table 15. Future surface disturbance from Seismic Surveys.

Graphs

Graph 1. Annual number of wells drilled in the Monument from 1950 to 2003.
Graph 2. Rate/time decline graph of historic production from the McClean Basin Field.
Graph 3. Rate/time decline graph of historic production from the Cutthroat #3 well.
Graph 4. Rate/time decline graph of historic production from the Yellow Jacket Cluster.
Graph 5. Rate/time decline graph of historic production from the Papoose Canyon Field.
Graph 6. Rate/time decline graph of historic production from the Etta James well.
Graph 7. Rate/time decline graph of historic production from the Island Butte Field.
Graph 8. Rate/time decline graph of historic production from the Island Butte #6 well.
Graph 9. Oil and natural gas production history in the Monument.
Graph 10. CO_2 production history in the Monument.

Executive Summary

This Reasonable Foreseeable Development (RFD) document was prepared to support the planning efforts currently being performed for Canyons of the Ancients National Monument (the Monument). It provides the planning team with a forecast of the oil, natural gas, and carbon dioxide (CO_2) development activities that are likely to occur within the Monument over the next 20 years.

The Bureau of Land Management (BLM) Fluid Minerals staff at the San Juan Public Lands Center interviewed operators, compiled data from various sources, and developed underlying assumptions regarding future development. Management and staff reviewed guidance from the BLM's Washington Office to ensure the RFD was sufficiently rigorous for the purpose stated above.

The Monument lies within a geologic region known as the Paradox Basin. Approximately 81 percent of the Federal minerals within the Monument are leased (i.e., 143,224 acres) with 334 oil and gas (i.e., natural gas, CO_2) leases and 19 percent of the mineral estate is unleased (i.e., 34,221 acres). Numerous oil and gas fields are located within the Monument. Large portions of the Monument are underlain by the largest CO_2 gas field in the United States. This field has been producing CO_2 for Enhanced Oil Recovery from the Leadville Formation since the early 1980's. The Leadville is a limestone and dolomite formation; the CO_2 was generated when the magma that formed Sleeping Ute Mountain thermally altered the carbonate rocks. Economic deposits of oil and natural gas occur in the Ismay and Desert Creek members of the Paradox Formation at depths of about 6,000 feet. The occurrence of producible oil and gas in these formations is confined to relatively small areas of fossil algal mounds and oolitic shoals. These sedimentary bodies have high porosity and permeability; the oil and gas was trapped in these bodies as it was generated from the Gothic Shale. There are numerous fields that tap into these localized algal mounds.

Since the 1940's, 185 wells have been drilled in the Monument (COGCC 2003). This number includes oil, natural gas, and CO_2 wells. Historically, oil and gas development has caused 1,035 acres of surface disturbance (not including seismic surveys). To date, BLM estimates that 740 acres have been reclaimed, while 425 acres of surface disturbance remains in place. These 425 acres include producing wellsites, access roads, and production facilities. The reclaimed areas include wells that have been plugged and abandoned, reclaimed access roads and pipelines, and portions of active wellpads that have undergone interim reclamation.

Over the next 20 years, another 150 wells off of 121 wellpads are forecasted to be drilled in the Monument. Sixty-nine of the proposed new wells will be CO_2, requiring only 40 new wellpads. The remaining 81 wells will be oil and natural gas wells drilled from 81 new wellpads. The number of wells to be drilled over the next 20 years was estimated through analyzing operator surveys, market conditions and historical data.

The locations of the wells can be approximately determined. The development will take place on leased lands, in units, and initially stepping out from existing production infrastructure. The success rate and certainty of drilling the CO_2 wells will be higher than that of the oil and natural gas wells. The 150 new wells will require 67 miles of new access roads, and 53 miles of new

pipeline right-of-way. BLM also anticipates that five 3-D and ten 2-D seismic surveys will be conducted over the next 20 years within the Monument. Lastly, BLM estimates that eight new production and compression facilities will be built within the Monument to treat, store, and transport the produced oil, natural gas and CO_2.

Gross surface disturbance for future activities will be approximately 883 acres for wellpads, facilities, roads, and pipelines. An additional 1,102 acres of surface disturbance will occur from the seismic surveys; however, the surface disturbance associated with seismic surveys is a much lower-intensity.

Introduction

This Reasonable Foreseeable Development (RFD) was prepared to support the preparation of the Resource Management Plan (RMP) for Canyons of the Ancients National Monument (the Monument) (Figure 1). The RFD is intended for input into the RMP by:

1. Describing the level of fluid mineral exploration and production that is likely to occur over the next 20 years, and estimating the surface disturbance associated with that activity. This information will provide the planning team the basis for assessing the impacts to other resources within the Monument and a basis for identifying impacts to oil and gas resulting from any bans on development necessary to protect other resources. The analysis of impacts and associated mitigation measures will be described in the RMP and other National Environmental Policy Act (NEPA) documents.

2. The RFD also clarifies the meaning of "common reservoir" and how it may affect future leasing in the Monument.

The Proclamation establishing the Monument states:

Because most of the Federal lands have already been leased for oil and gas, which includes carbon dioxide, and development is already occurring, the monument shall remain open to oil and gas leasing and development; provided, the Secretary of the Interior shall manage the development, subject to valid existing rights, so as not to create any new impacts that interfere with the proper care and management of the objects protected by this Proclamation; and provided further, the Secretary may issue new leases only for the purpose of promoting conservation of oil and gas resources in any common reservoir now being produced under existing leases, or to protect against drainage.

Regarding Monument land currently held by leases (i.e., approximately 81 percent), the Proclamation is clear. The valid existing rights allow a lessee to extract oil and gas from any horizon capable of producing, regardless of whether it is currently being produced or a new discovery.

Factors Affecting Oil and Gas Development

An RFD scenario for oil, natural gas and CO_2 exploration and development within the Monument is relatively straightforward. The RFD must consider:

- long-term projections of oil and gas prices (economics);
- known fields, recoverable reserves, technological advances, and current well spacing (reservoir engineering and technology);
- the likelihood of significant new discoveries (geology);
- the maturity of oil and gas development within the region (history);
- pipeline capacity, pricing, and demand for CO_2 from McElmo Dome; and
- hydrocarbon potential (i.e., low, medium, or high).

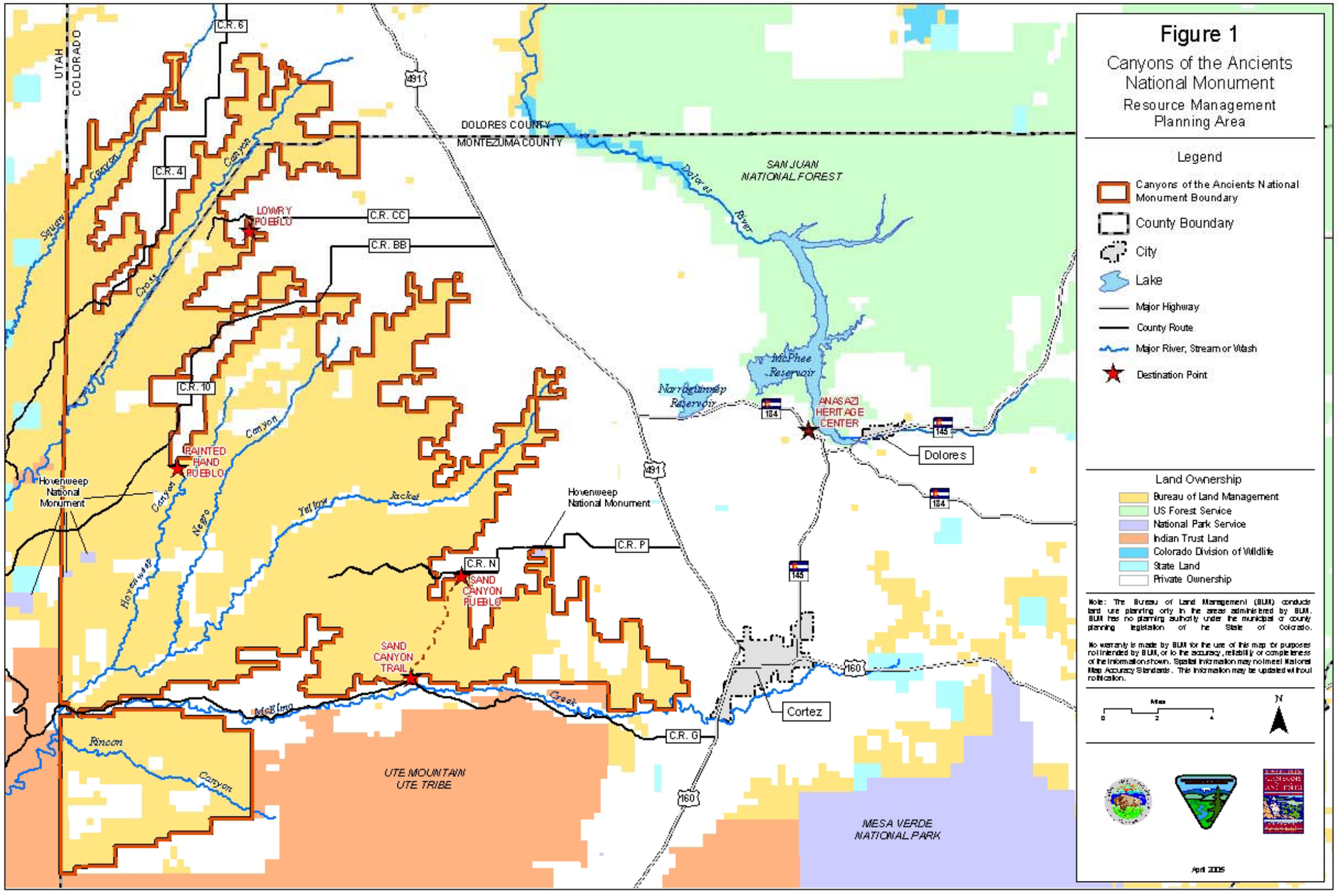
Figure 1
Canyons of the Ancients National Monument
Resource Management Planning Area
Legend
Canyons of the Ancients National Monument Boundary
County Boundary
City
Lake
Major Highway
County Route
Major River, Stream or Wash
Destination Point
Land Ownership
Bureau of Land Management
US Forest Service
National Park Service
Indian Trust Land
Colorado Division of Wildlife
State Land
Private Ownership
Note: The Bureau of Land Management (BLM) conducts land use planning only in the areas administered by BLM. BLM has no planning authority under the municipal or county planning legislation of the State of Colorado.
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April 2005
UTAH
COLORADO
DOLORES COUNTY
MONTEZUMA COUNTY
SAN JUAN NATIONAL FOREST
Dolores River
McPhee Reservoir
Narraguinnep Reservoir
ANASAZI HERITAGE CENTER
Dolores
Cortez
LOWRY PUEBLO
PAINTED HAND PUEBLO
SAND CANYON PUEBLO
SAND CANYON TRAIL
Hovenweep National Monument
UTE MOUNTAIN UTE TRIBE
MESA VERDE NATIONAL PARK
C.R. 6
C.R. 4
C.R. CC
C.R. BB
C.R. 10
C.R. N
C.R. P
C.R. G
491
184
145
160

Economics

Long-term oil and natural gas prices are likely to remain relatively high with natural gas prices over $5.00/thousand cubic feet (mcf). Currently the price of oil is $49.00/barrel (bbl), the price of natural gas is over $6.00/mcf, and the average wellhead price of CO_2 is $0.48/mcf. For comparison, in 1999, the average wellhead price of natural gas was $2.19/mcf and the average price for U.S. crude oil was $16.75/bbl. The long-term prices are dictated by supply and demand. In the U.S., natural gas demand is projected to increase, with net imports and domestic production increasing to meet this demand (Oil and Gas Journal 2003). The level of exploration and development are directly related to the price of oil and natural gas.

Experts believe that major increases in natural gas supplies will occur with the development of infrastructure from the arctic natural gas producing regions. However, these infrastructure projects are at least ten years in the future. In addition, natural gas imports from other countries will require construction of re-gasification plants for liquefied natural gas (LNG), and these construction projects will require five to ten years to complete. All these factors indicate long-term, strong natural gas prices in the U.S. Given the long-term price projections for oil and natural gas, it appears that oil and gas development within the Monument can be justified economically for the next 20 years.

The long range oil and gas price projections also support continued development of CO_2 and development in the Monument. Sustained high oil prices increase the likelihood of accelerated CO_2 development as the economics of Enhanced Oil Recovery (EOR) in west Texas and other regions become more favorable. One method of EOR is where the oil reservoir is flooded with CO_2 to produce more oil than was possible by primary recovery methods such as pumping. The CO_2 flood not only forces the oil from the area of an injection well to producing wells, but the CO_2 reduces the viscosity of the oil which makes it easier to flow.

The economics of drilling and producing a profitable well are based on numerous factors. The decision to drill a well must take into account the costs of: the permitting process, road building, site preparation, drilling and completion, and getting the product to market while considering the current and foreseeable price of the resource.

After drilling, the well is tested for production potential. If the tests show the well cannot produce economic quantities of oil and/or gas, the well is considered a dry hole. If the well is deemed a dry hole, it is usually immediately plugged and the wellpad and access road are reclaimed. On some occasions the well will be completed to recover some of the costs of drilling. The historic success rate for all Monument wells (i.e., oil, natural gas and CO_2) is approximately 60 percent and for CO_2 alone, 65 percent. These percentages are based upon all Monument wells drilled from 1947 to date.

If the well shows economic potential, it is completed. Completion is the process of preparing a well for production. The initial revenues generated by the well are devoted to paying the drilling, completion costs, and operating costs. At the time the well generates sufficient revenues to equal the aforementioned costs, the well is considered to have paid-out.

After pay-out, production revenues and operating costs determine the long term economic life of the well. As long as the revenues exceed the operating cost of the well, the well will continue to produce. Some wells have produced in excess of 40 years. Operating costs include maintenance, water disposal, recompletion, labor, transportation, separation, dehydration, compression, royalty, and taxes. Typically 12.5 percent of the gross production royalties are directly paid to the mineral rights owner. In the case of the Monument, the major mineral rights owner is the U.S. Federal Government. For example, the CO_2 production from the McElmo Dome Unit generates over $8,000,000/year in royalties for the Federal Government.

Any time during the life of the well, mechanical or other problems may arise that prematurely shorten the life of the well or initiate costly repairs. Mechanical problems or water encroachment can cause the abandonment of a well at any time. Failures during drilling also occur. That is why risk must be factored into any economic analysis. Some wells do not find economic quantities of oil and gas and must be plugged as dry holes. With drilling costs typically in the range of $700,000 to $1,500,000/well, this represents a substantial undertaking. Any unexpected occurrence that shortens the life of a well can have very negative economic impacts. When the well is depleted, or if a failure occurs, the well must be plugged and abandoned, then the surface reclaimed.

Boom and Bust: A drilling boom could have an effect on the development of the CO_2 resource. If oil prices rise, economics may warrant an additional demand for EOR and CO_2. This will require more CO_2 wells to increase production. With this scenario, pipeline capacity can be expanded and additional wells would need to be drilled. This is a finite number of wells and this scenario is discussed in the Reasonable Foreseeable Development Scenario: CO_2 section of this document. Another scenario may play out where even if oil prices increase; CO_2 market demand would drop as the oil fields being CO_2 flooded are depleted.

A drilling boom would have an impact on the rate of development of the oil and gas resource. The impact would be that the rate of development would escalate and although projected, there would be new surface disturbance. There is a possibility that unexpected new resources could be discovered (i.e., a new play), but due to the high level of past exploratory drilling in the area this is unlikely.

Common Reservoirs in the Monument

For the purposes of this RFD, the following definition of common reservoir was adopted: Common reservoir: "All or part of any oil or gas or oil and gas field that comprises and includes any area that is underlaid or that, from geological or other scientific data or experiments or from drilling operations or other evidence, appears to be underlaid by a common pool or accumulation (emphasis added) of oil or gas or oil and gas" (Texas Natural Resources Code 1978).

There are two primary producing formations (a formation is a bed or deposit composed throughout of substantially the same kind of rock) in the Monument. They are the Paradox Formation and the Leadville Formation. The Paradox Formation contains oil and natural gas in localized reservoirs (a subsurface, porous, permeable rock body in which oil and natural gas have accumulated), with production controlled by the occurrence of bioherms (algal mounds) and oolitic shoals within the Ismay and Desert Creek members. The bioherms and oolitic shoals

typically have a higher permeability and porosity than the surrounding fine-grained carbonate mud. These characteristics allow for the accumulation of natural gas and oil (traps) in concentrations which are economic for recovery. Localized reservoirs within the Ismay and Desert Creek have been delineated based on current technology. However, the extent of these reservoirs should not be viewed as a static line on a map. Emerging technologies, such as horizontal drilling, may cause the reservoir areas to be expanded as economic production becomes feasible in areas with thinner pay zones, lower permeability, lower porosity, and greater transection of localized reservoirs.

To date, known fields in the Paradox Formation exist entirely within existing leases. Requests for new leases to promote conservation of these fields are not expected. It is possible that a new field may be discovered on leased lands. It may be shown that the field extends onto unleased lands. That portion of unleased land may be eligible for leasing in order to promote conservation of a common reservoir.

The Leadville Formation underlies the entire Monument area. The presence of CO_2 appears to be present throughout the formation within the Monument and it is considered to be a common reservoir. Locally, several CO_2 wells were drilled and plugged because production rates were low; however, the geologic data shows the wells tapped into a common pool of gas. The entire Monument area could conceivably be leased in order to promote conservation of the resources of the Leadville Formation.

Document Organization

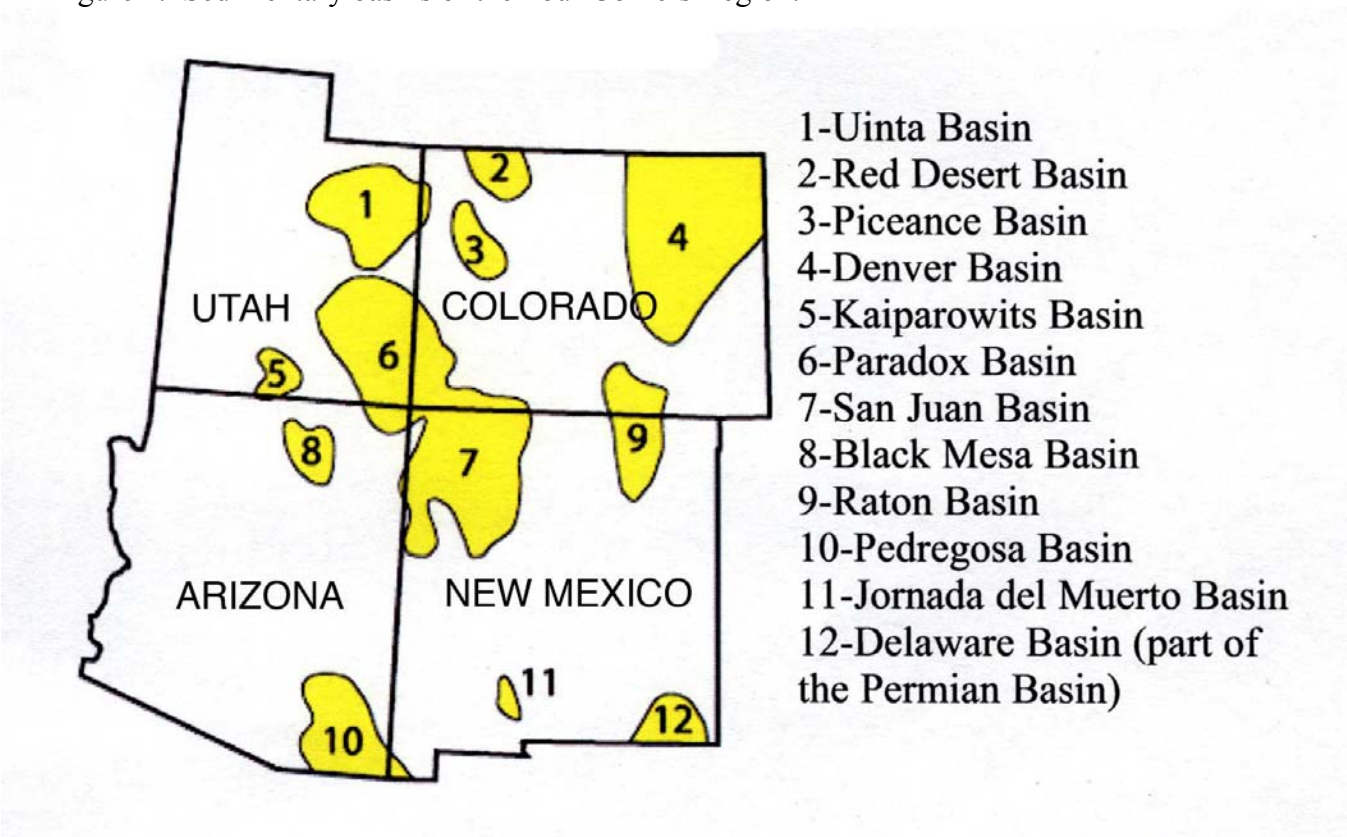
The remainder of this document presents background information relating to oil and gas, including CO_2, exploration and development in the Monument and a discussion of factors affecting fluid minerals exploration and development. After these discussions are presented, the estimates of future fluid minerals activity are presented. These estimates are for a 20 year projection, and incorporate surface disturbances, truck traffic, compressor and treatment facilities, and seismic survey activity.

Background and Oil and Gas Exploration and Production in the Monument

The Monument is located in southwest Colorado, within the geologic region known as the Paradox Basin. The Paradox Basin, along with the other sedimentary basins in the Four Corners Region, is illustrated in Figure 2 below. Elevations within the Monument range from about 4,900 feet to about 7,500 feet above sea level. The outer boundaries of the area encompass 182,876 acres of land, approximately 164,000 acres of which are in federal surface ownership and managed by the Bureau of Land Management (BLM). Of the 182,876 acres, 143,503 acres are leased for oil and gas development with 334 leases, and 39,373 acres are unleased. Of the 334 total leases, 31 are private. Table 1 shows a complete breakdown of Federal, private, leased, and unleased mineral estates.

The Monument and the underlying adjacent mineral estate contain two typical kinds of plays. One is the Leadville Formation which contains CO_2 throughout the formation. The other play typically consists of calcareous and clastic sedimentary traps which produce oil and natural gas.

Figure 2. Sedimentary basins of the Four Corners Region.



The primary reservoirs for oil and natural gas are the Pennsylvanian Desert Creek and Ismay Formations. The potential for hydrocarbons in the Monument is rated as "high". When one or more plays are present in an area, the hydrocarbon potential is rated "high". The criteria for this finding and the hydrocarbon potential assessment were taken from the current BLM planning document, H-1624-1, Planning for Fluid Mineral Resources, May 7, 1990.

Table 1. Land/Mineral status within the Monument.

Land/Minerals Status	Acres	Acres	
Federal surface/Federal minerals	164,357	Leased	132,353
		Unleased	32,004
Federal surface/Private minerals	456	Leased	279
		Unleased	177
Private surface/Private minerals	4,975	Leased	0
		Unleased	4,975
Private surface/Federal minerals	13,088	Leased	10,871
		Unleased	2,217

Through direct physical evidence and production, the CO_2 resource from the Leadville Formation is also rated as "high". This criterion for assessment was also taken from H-1624-1. CO_2 is not different from other gases except for its composition. Whereas CO_2 is composed of carbon and oxygen, natural gas is composed of carbon and hydrogen. CO_2 has many industrial

applications (e.g., EOR), while natural gas is primarily used as a fuel. The local Leadville Formation is the largest CO_2 reservoir in the country.

The United States Geologic Survey (USGS) has identified five different oil and gas plays underlying the Monument (USGS 1995). The plays are 2101 through 2105 in Geologic Province 21. A play defines the extent of a petroleum bearing formation.

Play 2101, Buried Fault Blocks, Older Paleozoic Play: This is an oil and gas play in the Leadville Formation. The reservoirs are in porous dolomite or dolomitic limestone beds. Reservoirs are as thick as 200 feet and the trapping is structural.

Play 2102, Porous Carbonate Buildup Play: This is the play where the majority of the Monument oil and gas is produced from. The reservoir is characterized by accumulations in algal mounds. Porosities in the algal mounds can approach 20 percent.

Play 2103, Fractured Interbed: The details of this play are not reported in the USGS report cited above.

Play 2104, Permian –Pennsylvanian Marginal Clastics Play (Hypothetical): This play, although only a hypothesis, is in the Permian Cutler Formation. No productive wells are producing from this interval, but gas shows and excellent source rocks are in its favor.

Play 2105, Salt Anticline Flank Play: This is a gas play in the Permian Cutler Formation. To date, the play has been only lightly explored.

Oil was first discovered in the Paradox Basin in 1908 near Mexican Hat, Utah. Shallow wells were drilled near an existing oil seep along the San Juan River. Gas (i.e., Dakota Gas) was first discovered along the southeastern edge of the Paradox Basin in 1921, at the Ute Dome in New Mexico. Dakota Gas and Pennsylvanian Gas were both discovered at Barker Dome in 1925 and 1945, respectively.

Within the Monument boundaries, several old, very mature oil and gas fields exist. The larger oil and gas fields are the Cache, Flodine Park, McClean Basin (Cutthroat), McElmo Dome, Island Butte, and Papoose Canyon Fields. There are several smaller fields, usually consisting of one or two producing wells. Oil and gas development commenced in 1948, with the drilling of the #1 McIntosh well. This well discovered natural gas in the Shinarump Formation. Field discovery dates and other information are summarized in Table 2.

Graph 1 shows the annual rate of oil, natural gas and CO_2 wells drilled within the Monument from 1950 to 2003. The fee (i.e., private mineral estate) wells are those that are producing from privately owned minerals within the Monument. The average number of wells drilled/year, as represented in Graph 1, is four wells/year. The most wells drilled in one year were 19 and there were several years of no activity. The overall success rate of all wells is 60 percent, while the success rates for CO_2, and oil and natural gas wells are 65 and 57 percent, respectively.

Historically, extensive seismic exploration has taken place in the Monument. The BLM has

Graph 1. Annual number of wells drilled in the Monument from 1950 to 2003.

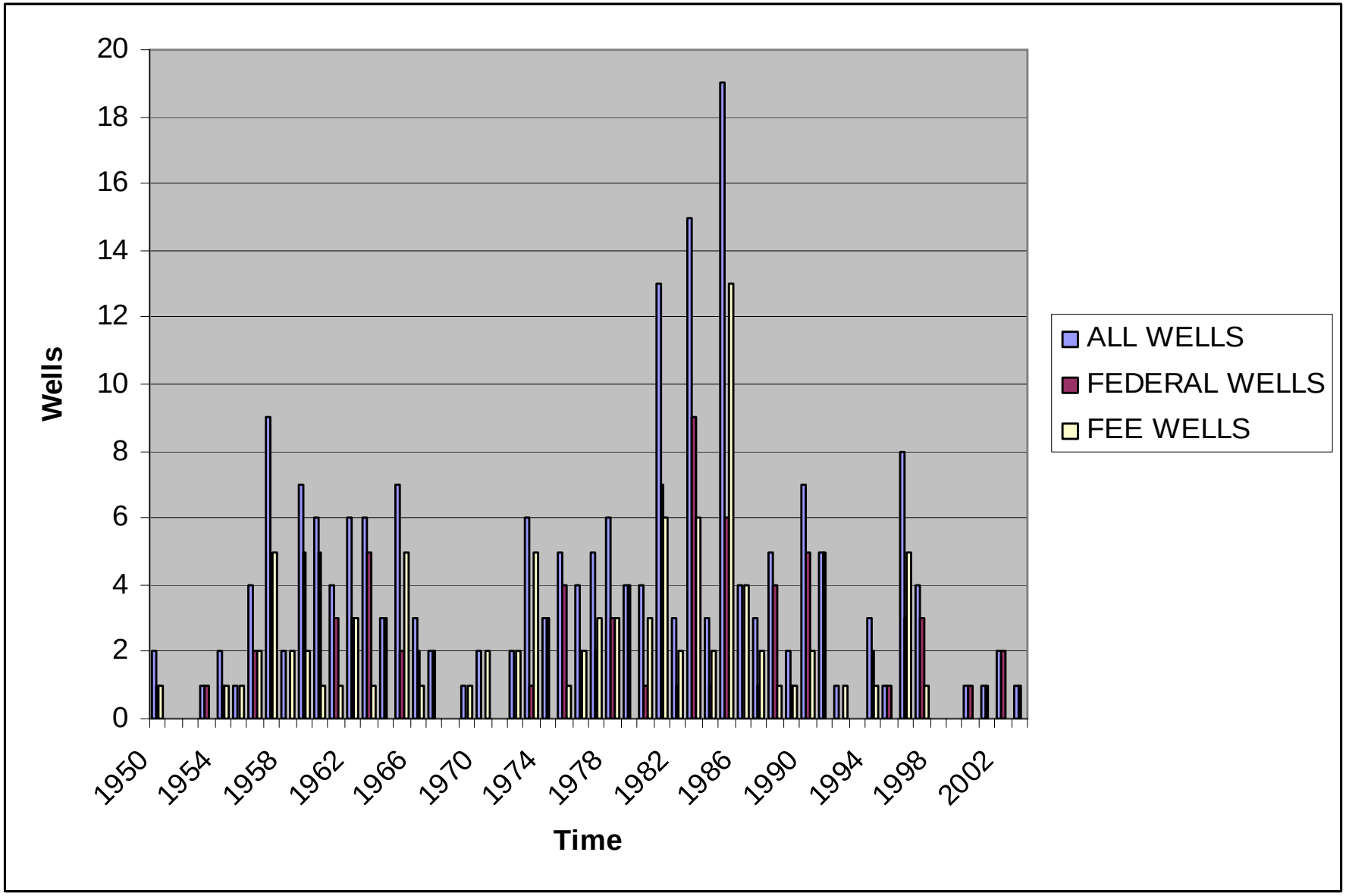


Table 2. Oil and gas discoveries within the Monument.

Field	Discovery Date	Location
McElmo Dome[1]	July 17, 1947	Sec. 24, T. 36N, R. 18W
Flodine Park[1]	April 16, 1959	Sec. 15, T. 35N, R. 20W
Goodman Point[1]	November 12, 1960	Sec. 6, T. 36N, R. 18W
Cache[2]	October 26, 1964	Sec. 2, T. 34N, R. 20W
Papoose Canyon[1]	August 14, 1970	Sec. 31, T. 39N, R. 19W
McClean Basin (Cutthroat)[1]	July 31, 1974	Sec. 15, T. 37N, R. 19W
Island Butte[3]	July 29, 1991	Sec. 20, T. 38N, R. 20W

[1] Source: Oil and Gas Fields of the Four Corners Area, 1978, Volume I Four Corners Geological Society
[2] Only a minor portion of this field falls within the Monument. Most of the Cache Field is within the Ute Mountain Ute Reservation, located south of the Monument.
[3] Source: PI Dwights Database

records of seismic surveys going back as far as 1970. Seismic lines are strings of geophones (i.e., geologic microphones). Geophones are inserted into the ground at regular intervals along a straight line to listen for seismic echoes from vibrations induced at or near ground level. Sometimes explosives are used to generate the vibrations, but usually a vibrating vibrosis truck generates the vibrations or sound waves. Three-D seismic is similar except that a series of lines are used at the same time for enhanced data collection and analysis.

At least 54 separate seismic surveys have been approved and completed in the Monument. Of the 54 surveys, three were 3-D surveys and 51 were 2-D surveys. Higher quality imaging is provided through 3-D surveys than compared to 2-D surveys. Some of these surveys used more than one seismic data collection line/survey. Most individual lines were between three and eight miles in length. Figure 3 illustrates the number of completed seismic lines in the Monument, by Township. Some seismic lines begin in one Township and end in another. When this occurs the seismic line is counted in both Townships. The highest levels of seismic activity in the Monument are coincident to the Cutthroat and Island Butte II Units.

Petroleum Geology

The Monument lies within a mature oil and gas province called the Paradox Basin. The Paradox Basin is located in southwest Colorado, southeast Utah, northwest New Mexico, and northeast Arizona (Figure 2, page 8). The Paradox Basin is typically defined by the extent of underlying Paradox evaporite deposits (i.e., gypsum, anhydrite and halite). Figure 4 illustrates a stratigraphic column for the basin.

The basin is underlain by thick deposits of Devonian and Mississippian carbonates (i.e., Ouray and Leadville Limestones), which are unconformably overlain by Pennsylvanian strata. The Pennsylvanian strata were deposited as the Paradox Basin subsided and the Uncompaghre Uplift began. The basin was isolated from the main seaway, undergoing periodic flooding and drying. This led to thick evaporite deposits forming in the basin interior (i.e., Paradox Salt). Evaporite deposits are thickest in the northeast portion of the basin, with carbonates and shales deposited contemporaneously in the southwest. Carbonates were deposited in shallow shelf environments, with bioherm and oolitic shoals in the shallowest waters, and micritic carbonates in deeper waters. As sea levels dropped, the deep basin environment became a starved basin, leading to the deposition of organic-rich shale.

Figure 3. Seismic survey activity in the Monument, by Township, from 1970 to present.

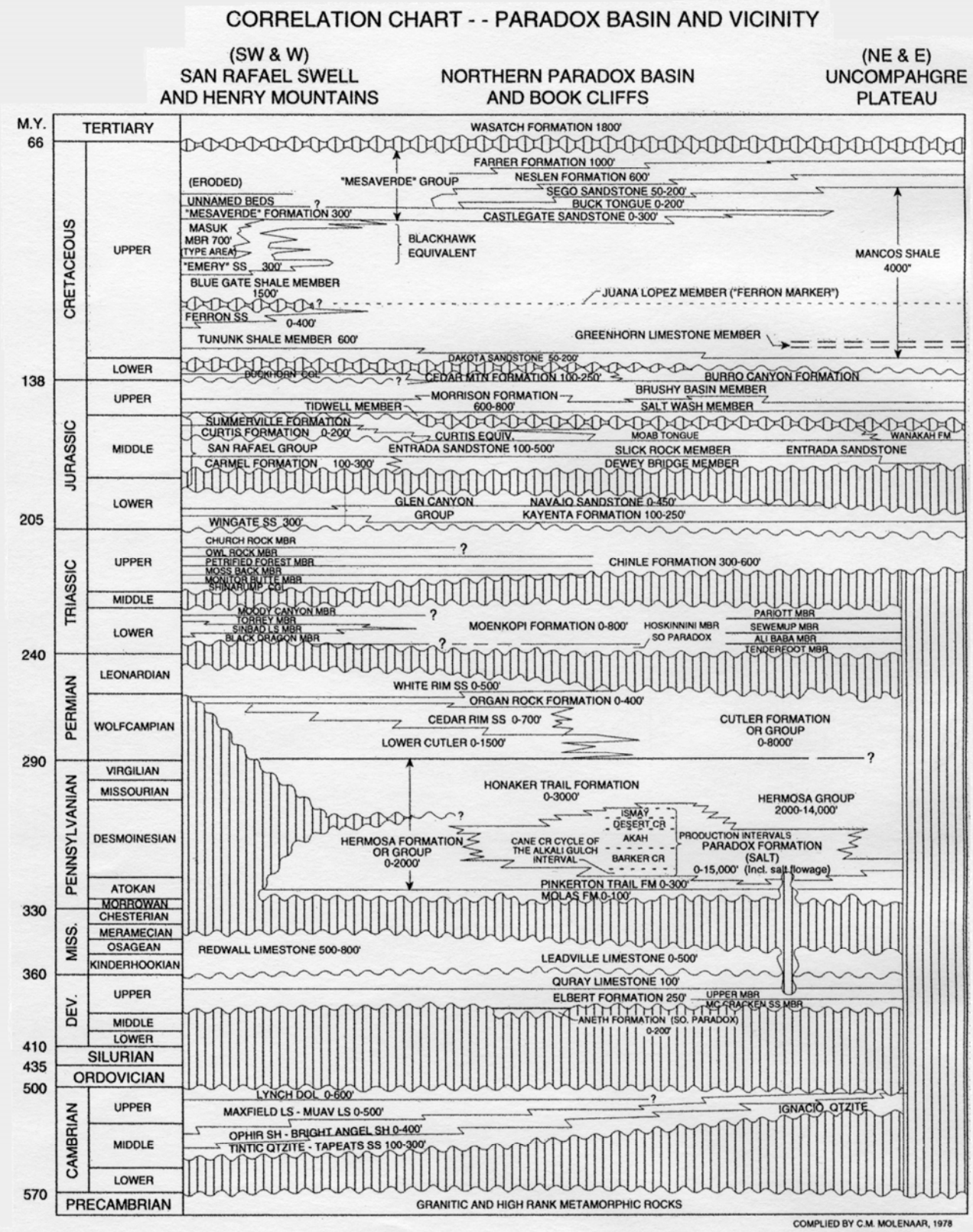
Township	20 West	19 West	18 West	17 West	16 West
39 North	5	11	2	2	1
38 North	12	19	6	3	1
37 North	7	20	9	4	1
36 North	5	14	7	4	1
35 North	6	2	0	0	0

Along the northeastern flank of the basin, the Uncompaghre Uplift shed voluminous amounts of clastics into the basin, with total thicknesses in excess of 12,000 feet adjacent to the uplift. The clastic loading on the salt beds caused early growth of salt anticlines, which are evident today in the surface geology in the region north of the Monument. Big Gypsum Valley is an example of a collapsed salt anticline. As the salt anticlines formed, the clastics thinned as they were deposited along the flanks. The shallower water provided for higher energy environments leading to better sorted, but thinner deposits along the flanks of the anticlines. These deposits are excellent hydrocarbon reservoirs, with the salt providing an updip seal.

The shedding of clastic sediments from the Uncompaghre Uplift continued into the Permian, with the deposition of the Cutler Formation. Triassic clastics of the Chinle Formation, Shinarump, and Glen Canyon Group unconformably overlie the Permian strata. Jurassic strata include the Carmel, Entrada, Summerville, Bluff, and Morrison Formations. Cretaceous rocks include the Dakota Formations and the Mancos Shale. Cretaceous or Jurassic rocks are exposed at the surface throughout the Monument (Figure 5).

Within the Monument, known reservoir rocks include the Leadville Limestone and various carbonate members of the Paradox Formation. The primary producing members of the Paradox Formation are the Desert Creek and Ismay members. Figure 6 illustrates the depositional environments of the Paradox carbonates, and also shows the rather isolated nature of the oil and natural gas reservoirs. The bioherms are the primary reservoir rock, and are surrounded by low permeability carbonate muds. The Akah and Barker Creek members are not productive members

Figure 4. Stratigraphic column of the Paradox Basin.



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

(Nuccio and Condon, 1996)

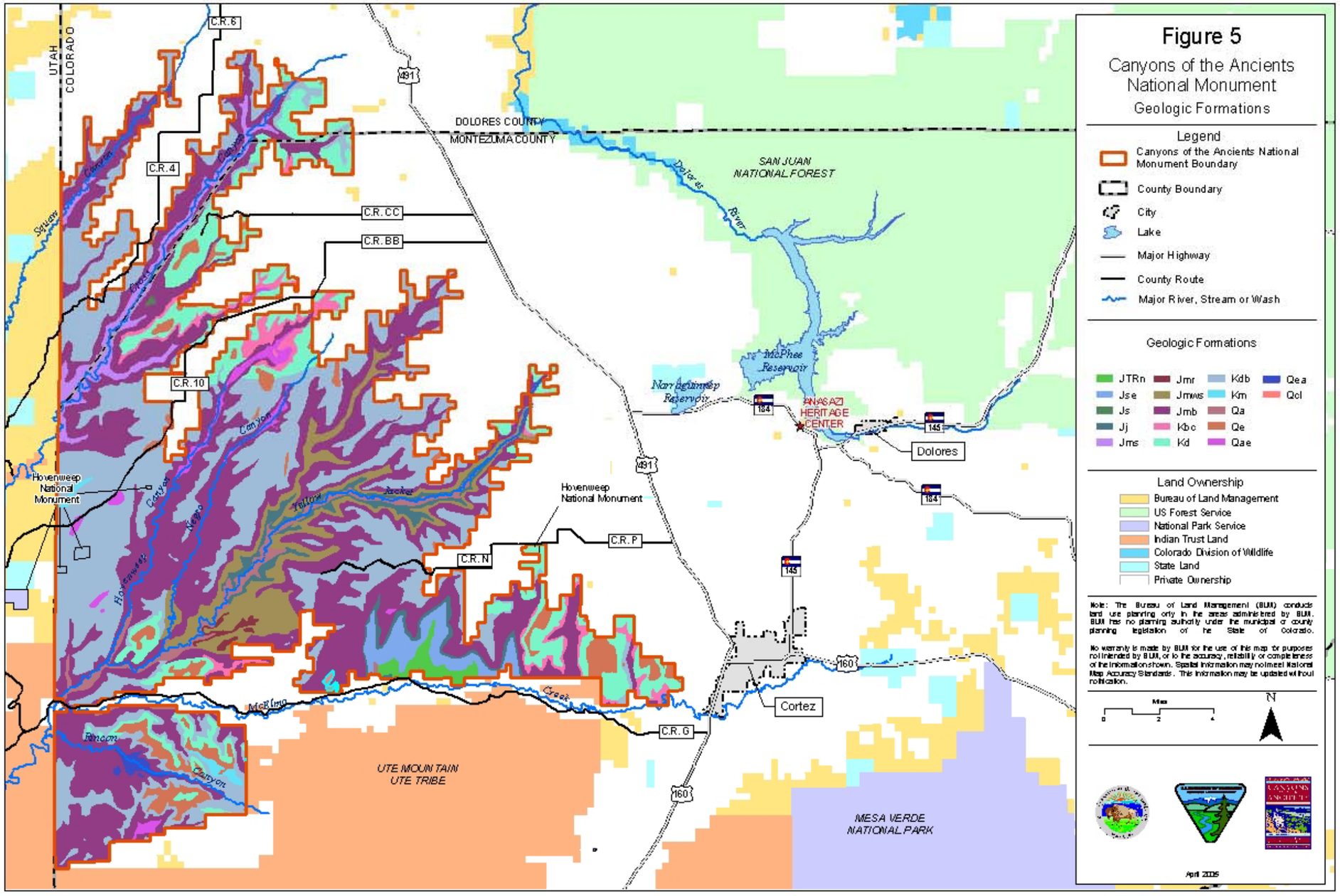


Figure 5
Canyons of the Ancients National Monument
Geologic Formations
Legend
Canyons of the Ancients National Monument Boundary
County Boundary
City
Lake
Major Highway
County Route
Major River, Stream or Wash
Geologic Formations
JTRn
Jse
Js
Jj
Jms
Jmr
Jmws
Jmb
Kbc
Kd
Kdb
Km
Qa
Qe
Qae
Qea
Qcl
Land Ownership
Bureau of Land Management
US Forest Service
National Park Service
Indian Trust Land
Colorado Division of Wildlife
State Land
Private Ownership
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Miles
0
2
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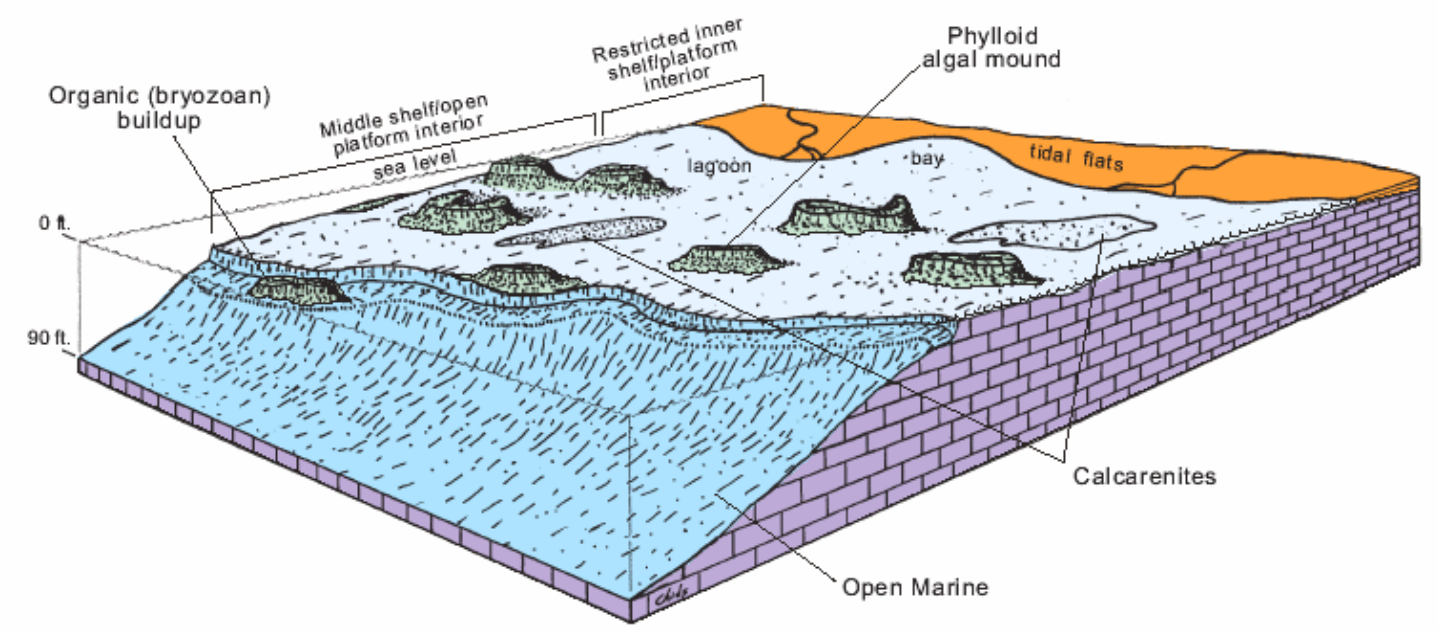
April 2005
UTAH
COLORADO
DOLORES COUNTY
MONTEZUMA COUNTY
SAN JUAN NATIONAL FOREST
Dolores River
McPhee Reservoir
Narraguinnep Reservoir
ANASAZI HERITAGE CENTER
Dolores
Hovenweep National Monument
Cortez
UTE MOUNTAIN UTE TRIBE
MESA VERDE NATIONAL PARK
McElmo Creek
Yellow Jacket
Navajo Canyon
Hovenweep Canyon
Ruin Canyon
Squaw Canyon
C.R. 6
C.R. 4
C.R. CC
C.R. BB
C.R. 10
C.R. P
C.R. N
C.R. G
491
184
145
160

Figure 6. Block diagram of the paradox shelf-depositional environment.



Source: Wray, Eby, and Chidsey 2002

of the Paradox Formation within the Monument. Some natural gas and oil shows, and very limited production has occurred from the Jurassic and Cretaceous strata; however, the hydrocarbon occurrences are very limited in extent and productivity.

Oil and gas fields within the Monument depend on localized depositional environments and diagenetic trends in carbonates of the Desert Creek and Ismay members. Although these members extend beneath the entire Monument area, only areas with higher porosity and permeability are considered exploitable oil and gas reservoirs. Many wells considered "dry holes" have encountered oil and gas shows in the Desert Creek and/or Ismay members, but they were not able to produce in paying quantities because of poor porosity and/or permeability development in the rock.

Source rocks for oil and gas are the carbonaceous shales of the Paradox Formation (Gothic Shale), and possibly the Cambrian Bright Angel Shale. These source rocks underlie the entire Monument, and the burial and thermal history indicates there is potential for hydrocarbon generation and occurrence throughout the Monument (Nuccio and Condon 1996).

There may be some future potential for natural gas discoveries in both the Permian Cutler and Pennsylvanian Honaker Trail Formations (i.e., USGS Play 2104). Testing of these formations has shown that the gas is of low quality containing 40 percent inert gas.

The oil and gas fields in the Paradox Basin are relatively small. The biggest field is the McElmo Dome CO_2 Field, in the Leadville Formation. The source for the CO_2 is thermal decomposition of the Leadville carbonates during the intrusion of the Tertiary Sleeping Ute Mountain laccolith (Cappa and Rice 1995).

Hydrogen Sulfide (H_2S) has been found in the Paradox Basin. The release of H_2S, a potentially lethal gas, may occur during oil and gas drilling operations. H_2S is encountered when drilling in the Killer Shale Formation, located in the Paradox Salt. The Paradox Salt underlies the entire Monument.

Concentrations of H_2S in this shale are typically 50 to 300 parts per million (ppm) and can be as high as 3,000 ppm. The National Institute of Occupational Safety and Health considers 300 ppm to be the level immediately dangerous to life or health. However, H_2S is not considered to be a serious problem in the Monument. While drilling, H_2S is neutralized by chemicals in the mud and is not brought to the surface as a result of the extraction process used. After the casing is set, the H_2S is isolated behind the production casing.

When necessary, the BLM requires fluid mineral operators to develop an H_2S Contingency Plan to address any H_2S problems that might occur during drilling or production operations. Within these plans, fluid mineral operators identify monitoring protocols and other mitigation measures to ensure H_2S is not released into the atmosphere. All H_2S contingency plans must be in compliance with Onshore Order Number Six.

Summary: High probabilities exist for continued development of both the CO_2 (Leadville Formation) and oil and natural gas (Paradox Formation) resources. The current production in this area is considered mature; however, there is strong potential that future reservoirs will be discovered. There is a lower likelihood that new plays may be discovered in the Permian Formation.

Leases and Units in the Monument

Approximately 81 percent of the Federal minerals within the Monument (i.e., 143,224 acres) are leased for oil and gas exploration and development, while 19 percent are currently not leased. There are 334 leases on the Monument and 41 separate lease holders. Leases entitle the lessee to develop all fluid minerals, including natural gas, oil, condensate, and CO_2. Of the 334 leases, 31 of these leases are private (i.e., non-Federal minerals). Six oil, natural gas, and CO_2 units cover the majority of the Monument. Lease operators are required to exercise due care and diligence to assure that leasehold operations do not result in undue damage to surface and subsurface resources, or any surface improvements. Leased and unleased areas of the Monument are shown in Figure 7; the unitized boundaries are also displayed.

Leases are typically 160 acres to several thousand acres, while units are made up of several leases. The definition of a unit is the joining of all or substantially all interests in a reservoir or field, rather than a single tract, to provide for efficient development and operation of a common reservoir without regard to separate property interests. Table 3 contains the units and associated acreage in the Monument. Leases may be unitized when the geologic conditions do not permit the drilling of wells at conventional locations (i.e., one well/quarter section with 160 acre spacing). Rather, well sites are selected based on geologic conditions. The unitization of leases provides the needed flexibility to properly explore, develop, and manage the reservoir. Also, as long as there is production on the unit, all the leases in the unit are held by production and will not individually expire. Table 4 lists the units and number of active and plugged wells in the Monument.

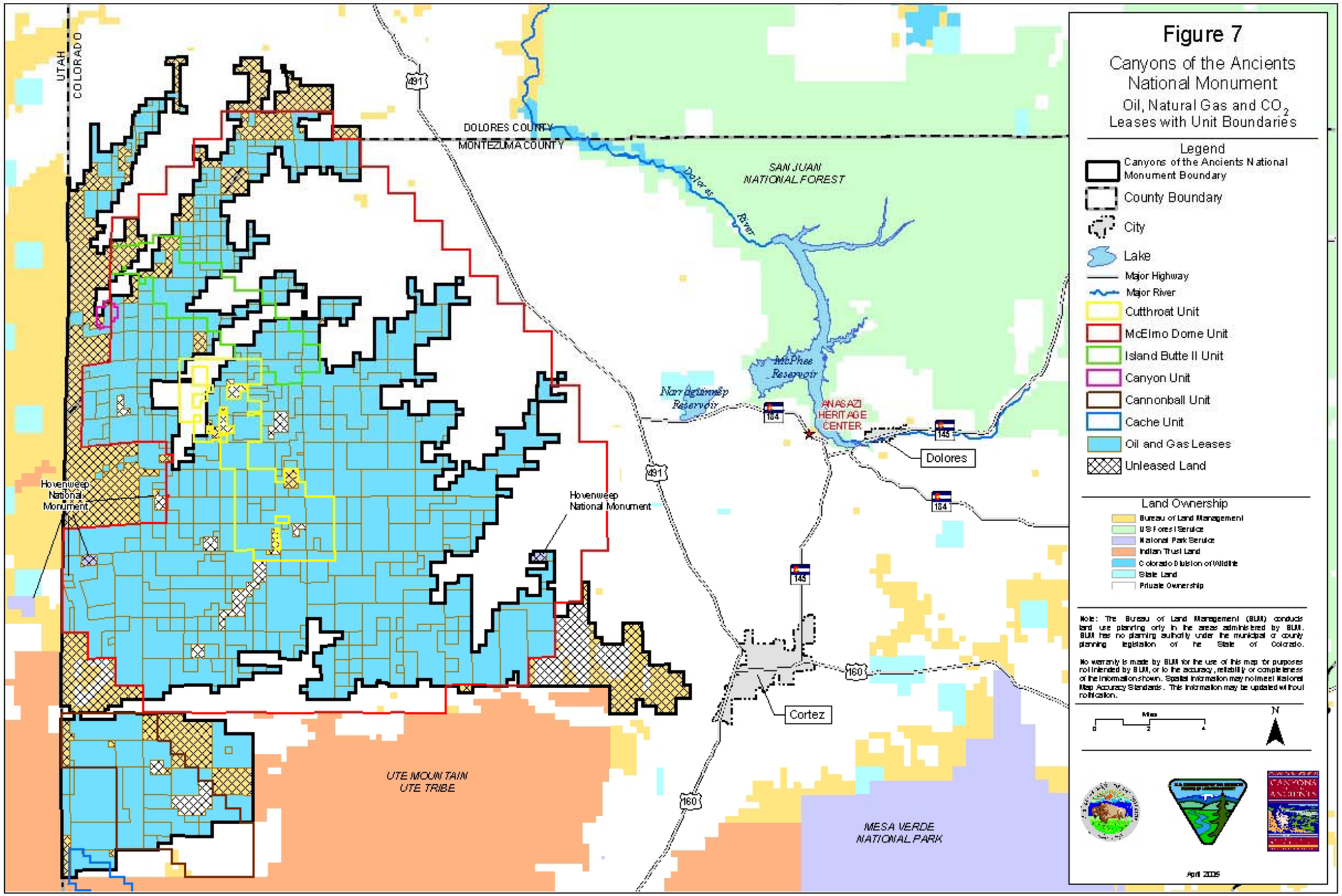


Figure 7
Canyons of the Ancients National Monument
Oil, Natural Gas and CO_2 Leases with Unit Boundaries
Legend
Canyons of the Ancients National Monument Boundary
County Boundary
City
Lake
Major Highway
Major River
Cutthroat Unit
McElmo Dome Unit
Island Butte II Unit
Canyon Unit
Cannonball Unit
Cache Unit
Oil and Gas Leases
Unleased Land
Land Ownership
Bureau of Land Management
U S Forest Service
National Park Service
Indian Trust Land
Colorado Division of Wildlife
State Land
Private Ownership
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MONTEZUMA COUNTY
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Dolores River
McPhee Reservoir
Narraguinnep Reservoir
ANASAZI HERITAGE CENTER
Dolores
Cortez
Hovenweep National Monument
Hovenweep National Monument
UTE MOUNTAIN UTE TRIBE
MESA VERDE NATIONAL PARK
491
184
145
160

Table 3. Monument units and their associated acreage.

Unit	Total Unit Acres	Unit Acres in the Monument	Unit Acres outside the Monument	% of Unit in the Monument
McElmo Dome Unit	202,674	128,573	74,096	63
Island Butte II Unit	10,005	7,093	2,912	71
Cutthroat Unit	11,850	10,369	1,481	88
Cache Unit	1,732	488	1,244	28
Cannonball Unit	15,087	11,164	3,579	74
Canyon (Shallow) Unit	344	293	51	85

Table 4. Monument units and their numbers of active and plugged wells.

Unit	Active Wells	Plugged Wells
Island Butte II Unit	6	0
Cutthroat Unit	7	5
McElmo Dome Unit	63	4
Cache Unit	4	0
Cannonball Unit	0	11
Canyon (Shallow) Unit	1	0
Monument Land Not in a Unit	44	40
TOTAL	125	60

Source: COGCC 2004

Unit operators are required to submit annual Plans of Development (POD) for review and approval from the BLM. PODs are required after production is established. PODs are required to assure proper reservoir development and to indicate what development is going to occur during the upcoming year. This includes new wells, plugging and abandonments, surface disturbance for production facilities, pipelines, compressors, tank batteries, etc. There is available undrilled acreage in all producing areas of the Monument both on units and on the individual leases.

Split-Estate: Split-estate acreage exists (e.g., Federal surface/Private subsurface) on the Monument, and is illustrated in Figure 8. The split-estate designation occurs when there is a difference between surface ownership and the underlying mineral estate. There are two different mixes of split-estate, but four different total combinations. The mixes are where the two sets of ownership are not the same and they are: Federal surface/Private minerals and Private surface/Federal minerals. The other two combinations are where there is no mixing: Federal surface/Federal minerals and Private surface/Private minerals. Private ownership is often referred to as “fee”.

Table 1 (page 8) illustrates the four combinations of land and mineral status, along with their associated acreages in the Monument. The acreage is further broken down into leased and unleased minerals. The majority of the acreage in the Monument consists of leased Federal surface/Federal minerals. Acreage of unleased Federal surface/Federal minerals also exists (i.e., 32,004). The second largest overall accounting of acreage is Private surface/Federal minerals. Over 13,000 acres fall into this category and the majority of this acreage is already under Federal lease. Federal leasing actions may have an impact on the Surface owner rights in this category.

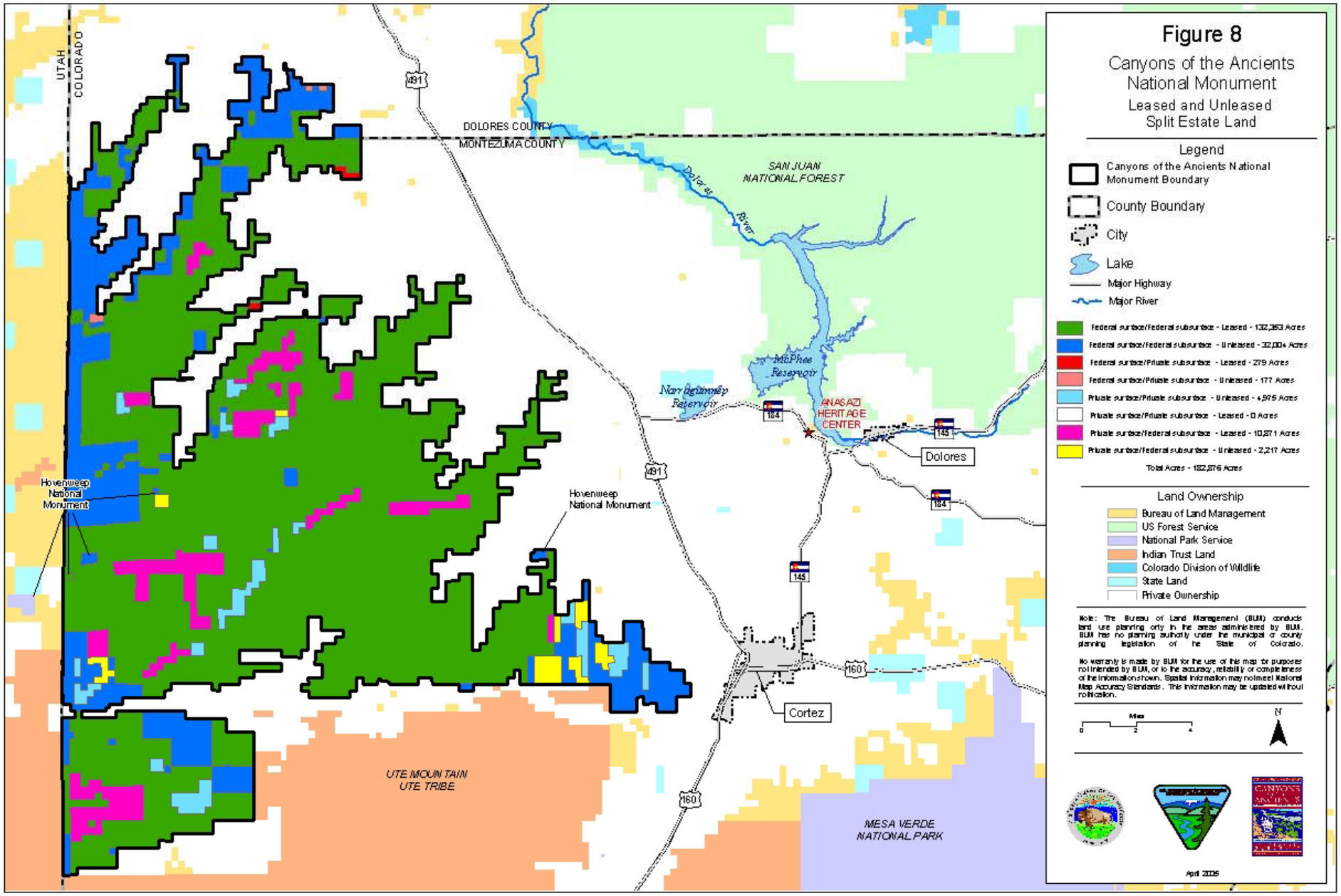
Figure 8
Canyons of the Ancients National Monument
Leased and Unleased Split Estate Land
Legend
Canyons of the Ancients National Monument Boundary
County Boundary
City
Lake
Major Highway
Major River
Federal surface/Federal subsurface - Leased - 132,353 Acres
Federal surface/Federal subsurface - Unleased - 32,004 Acres
Federal surface/Private subsurface - Leased - 279 Acres
Federal surface/Private subsurface - Unleased - 177 Acres
Private surface/Private subsurface - Unleased - 4,975 Acres
Private surface/Private subsurface - Leased - 0 Acres
Private surface/Federal subsurface - Leased - 10,871 Acres
Private surface/Federal subsurface - Unleased - 2,217 Acres
Total Acres - 182,876 Acres
Land Ownership
Bureau of Land Management
US Forest Service
National Park Service
Indian Trust Land
Colorado Division of Wildlife
State Land
Private Ownership
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The Federal surface/Private minerals category only accounts for 456 total acres. Private surface/Private minerals account for approximately 5,000 acres. Federal right-of-ways (ROWs) may have to be granted to access Private surface/Private minerals, in some cases. Again, Figure 8 illustrates the locations of leased and unleased split-estate lands within the Monument

Federal actions that take place under Private surface/Federal minerals typically require a surface owner's agreement between the surface owner and the mineral lessee prior to any activity taking place. The surface owner's agreement is a contract that specifies how development will take place and may provide for restitution of damages to property. In the event that the lessee cannot obtain an agreement, the BLM will develop a surface use plan. Regardless of the land/mineral status, environmental compliance (i.e., NEPA) must be conducted to disclose possible affects that may result from a proposed action.

Units and Fields in the Monument

The terms "units" and "fields" are not the same. Definitions for these terms are provided in Appendix A of this document. In summary, a unit is the legal or administrative boundary for an underground reservoir containing oil and/or gas, while a field is the geologic boundary. A field may be larger or smaller than the defined unit boundary, and is typically discovered prior to the formation of a unit.

Cutthroat Unit: The Cutthroat Unit, previously known as the McClean Basin Field (Figure 7, page 17), is located 20 miles northwest of Cortez, Colorado and seven miles east of the Utah-Colorado state line. Twenty two percent (i.e., 1,481 acres) of this unit is not located on the Monument. The McClean Basin Field was discovered in 1974, with paying quantities of oil produced from the Desert Creek member of the Paradox Formation. Since discovery, twelve wells have been drilled.

One of these wells, the Spargo #2, was originally drilled as an oil well. It was converted to a disposal well in 1989. This well injects water into the Hermosa Formation. The current water disposal rate from this field is 2,719 barrels (bbls)/month.

Two of the twelve wells have been directionally drilled to avoid surface use conflicts. Produced oil is trucked from the unit and the natural gas is produced to pipeline.

The Cutthroat Unit was formed in 1996 to better exploit the natural gas and oil resources in a Desert Creek biohermal mound facies play. The play is oriented north-south. These carbonate mounds were topographic highs in a fairly low relief carbonate shelf. After deposition, these algal mounds were covered with fine-grained carbonate mud, thus providing a stratigraphic trap for migrating hydrocarbon fluids. These mounds typically display high porosity and permeability due to secondary dissolution features and dolomitization.

The discovery well in this field, the Mountain Fuel Supply #2 well, was drilled to a depth of 6,017 feet in 1974. This well initially produced at a rate of 504 bbls of oil/day and 713 mcf of natural gas/day. Reservoir testing showed the average net pay to be 30 feet, and the porosity to be 11 to 17 percent.

Initial production volumes for Desert Creek wells, in the Cutthroat Unit, are 226 to 429 bbls/day of light oil, and 470 to 1,150 mcf/day of natural gas. Cumulative production volumes are 5,603,914 bbls and 19,300,181 mcf. Current 12 month average production rates are 71,808 mcf and 14,949 bbls from six active producing wells (Minerals Management Service). Water production is currently 2,719 bbls/month. The estimated ultimate reserves (EURs) for the field are 5,842,632 bbls of oil and 20,734,357 mcf of natural gas. As can be seen from Figure 9, the majority of successful wells were drilled where the structure is the thickest.

Graph 2 is a rate/time decline graph of historic production from the McClean Basin Field. The graph shows initial production from this area as early as 1950. There was minimal production from this field from the 1960's through the early 1970's. The highest rates of production occurred in the early 1990's and again recently. The rates of highest production for the field occurred when the number of producing wells was the highest. The major trend to be observed on Graph 2 and on Graph 3 (Cutthroat #3 well) is that as the life of the well progresses, the oil production decreases and the water cut increases. This trend will take place until it is uneconomic to operate the well. In the case of the Cutthroat #3 well, the well produced for a period of ten years until the water/oil ratio became approximately 10,000 bbls of water to 400 bbls of oil. This is almost the opposite of the earlier production where the initial oil production of this well was 10,000 bbls of oil/month. The historic cause for abandonment of wells in the McClean Basin Field are high water production rates and/or low production rates of oil and and natural gas.

The Cutthroat Unit must be considered a very mature field. Over 96 percent of the proven reserves of oil and 93 percent of the proven reserves of natural gas have been produced. Without new production, the life of this field is estimated for at least ten more years.

The McClean Basin Field is a contiguous reservoir. It is located within the Cutthroat Unit, which is a legal designation. Although the field is approaching EUR, there is a high probability that within the unit, new structures and production will be discovered. Only 12 wells have been drilled on the unit.

Elsewhere in the Paradox Basin, hydrocarbon shows have been reported in the Upper Ismay, with a drill stem test flowing 31 mcf/day. This indicates that the Upper Ismay may have production potential nearby. To date, gas samples that have been collected from these formations indicate natural gas is present but is of low quality. It has not been developed in the Cutthroat Unit. Additional testing of the Cutler and Honaker Trail Formations may be conducted in the future.

Conclusion: Analysis shows that the proven reserves of oil and natural gas in the unit are nearly depleted. Even without the addition of new wells, production will continue for around ten more years as the wells transition to stripper well status (i.e., low production wells which pay a reduced royalty rate). Production will continue until the unit is no longer economic to produce. Untested acreage for future development is available on the unit, due to the fairly broad well spacing. Considering past history and geologic setting, there is a high probability for development of new production in this unit.

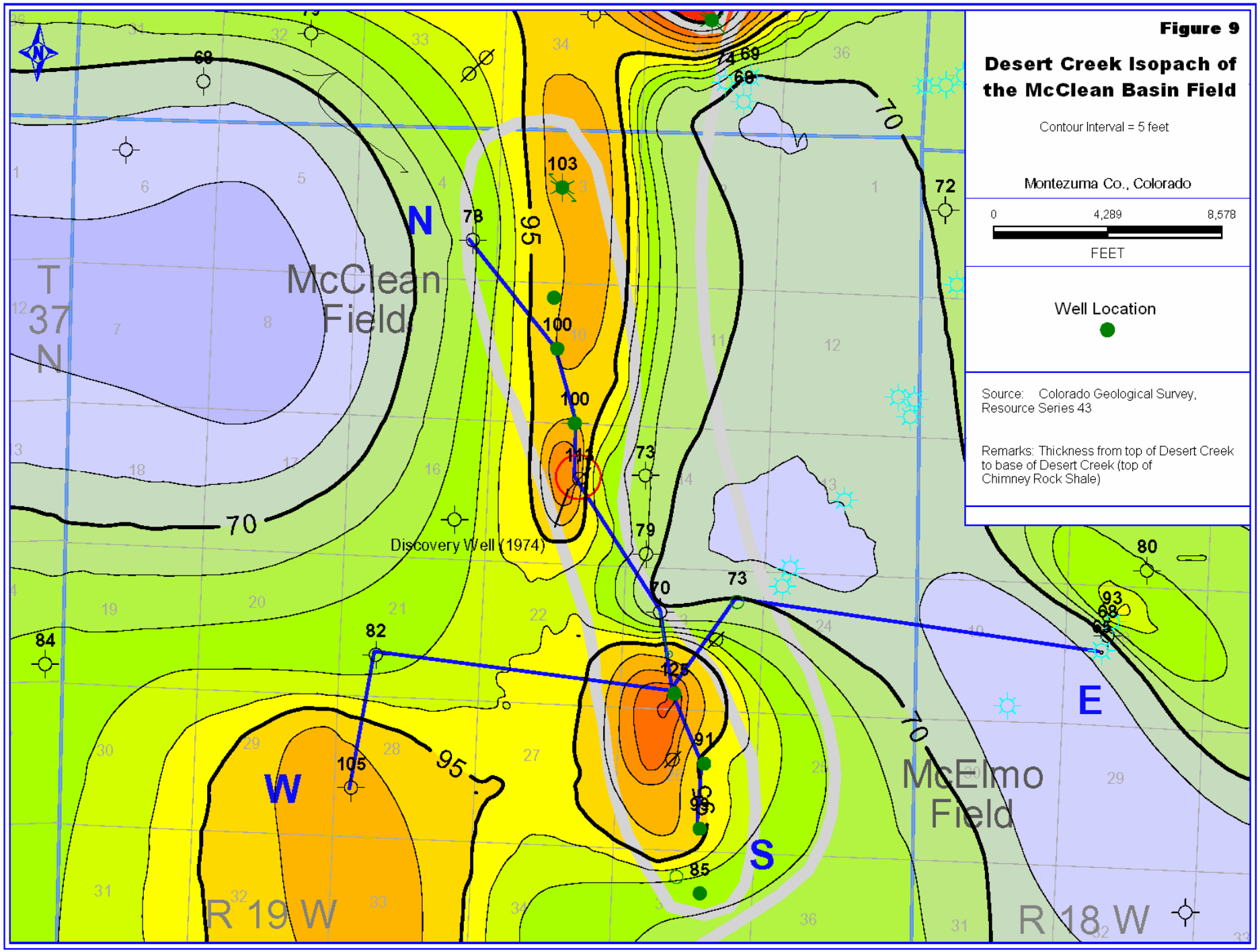
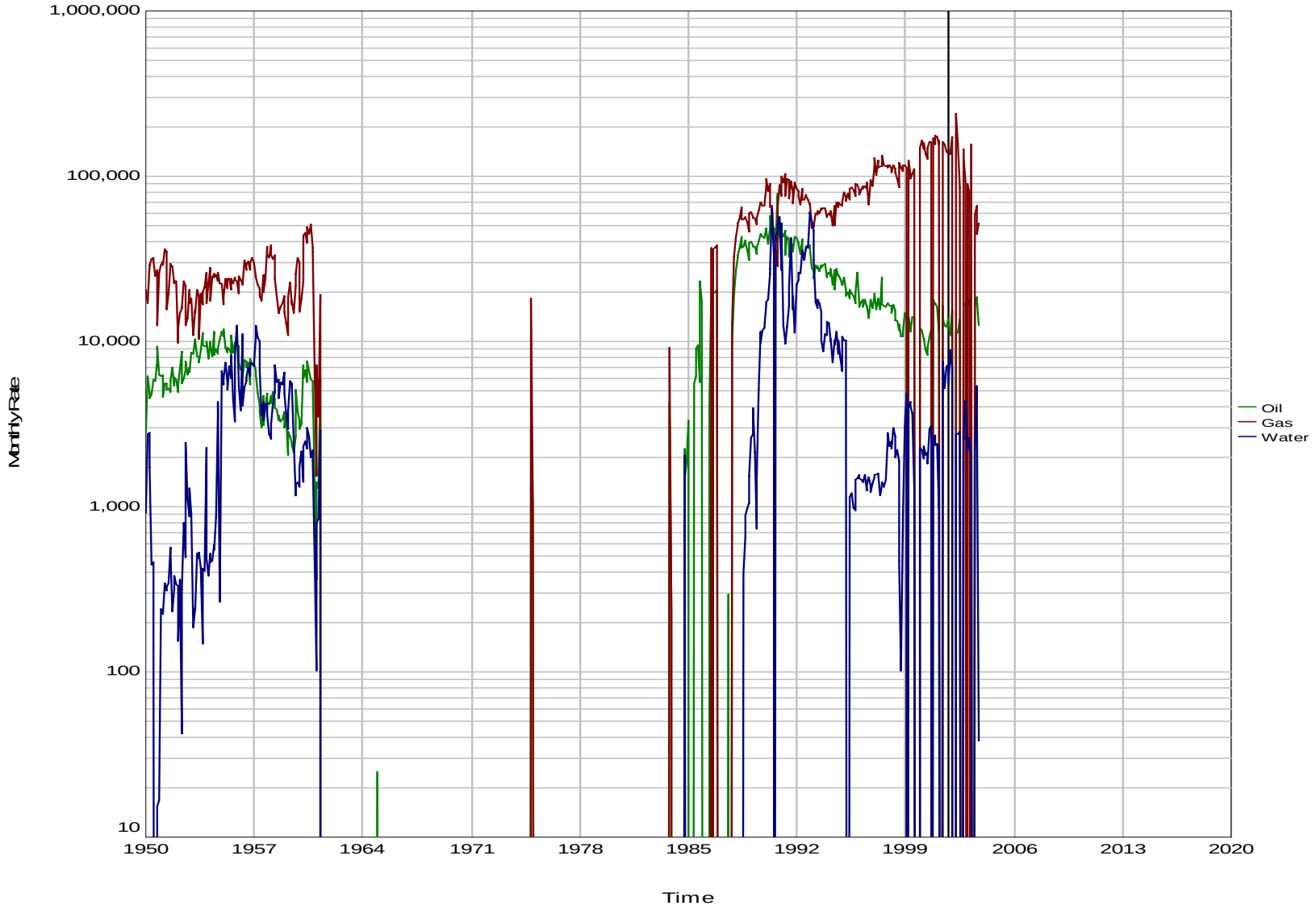


Figure 9
Desert Creek Isopach of the McClean Basin Field
Contour Interval = 5 feet
Montezuma Co., Colorado
0
4,289
8,578
FEET
Well Location
Source: Colorado Geological Survey, Resource Series 43
Remarks: Thickness from top of Desert Creek to base of Desert Creek (top of Chimney Rock Shale)
N
W
S
E
McClean Field
McElmo Field
T 37 N
R 19 W
R 18 W
Discovery Well (1974)
70
95
68
69
72
78
103
100
111
73
79
70
73
80
93
84
82
125
91
105
85

Graph 2: Rate/time decline graph of historic production from the McClean Basin Field (oil and water are reported in bbls/month, while natural gas is reported in mcf/month).



Graph 3. Rate/time decline graph of historic production from the Cutthroat #3 well (oil and water are reported in bbls/month, while CO_2 is reported in mcf/month).

McElmo Dome Unit: McElmo Dome is the most prolific CO_2 field in the U.S., with the CO_2 used for EOR in west Texas oilfields (Figure 10). The CO_2 production is from fractured dolomite. Secondary porosity from the dolomitization and fracturing are the primary means of permeability in the reservoir. In addition to the CO_2 produced from the reservoir, large amounts of water and traces of oil are produced. The current operator reports that approximately 30,000 to 65,000 bbls/month of water are produced, and 480 bbls/month of oil are produced from the unit. The produced water is disposed of to a greater depth in the Leadville Formation, beneath the CO_2-water contact. Graph 4 shows the production rates of CO_2, water, and oil from the Yellow Jacket Cluster of the McElmo Dome Unit. Production rates are shown to be constant.

The unit currently has 63 active wells. There are three salt water disposal wells in the unit with one of these, the McElmo Dome YWD-1, being located on the Monument. Eleven unit wells are classified as temporarily abandoned. Four wells were plugged and abandoned in 2003 as part of a cooperative effort between the BLM and the operator to plug nonproductive wellbores on the unit. Eight of these temporarily abandoned wellbores will be plugged in the next three years. The remaining three temporarily abandoned wells are candidates for recompletion.

The McElmo Dome Unit is very large, encompassing 202,674 acres (Figure 7, page 17). Over 128,000 acres (i.e., 63 percent) of the unit are located on Monument. The McElmo Dome Field is a structural high in the Leadville Limestone with over 500 feet of closure.

The McElmo Dome discovery well, the Stanolind #1, was drilled in 1947, and flowed 40,000 mcf/day of CO_2 from the interval of 6,805 feet to 6,965 feet. Reservoir testing showed the average net pay to be 180 feet, the porosity to be six to ten percent, and the initial reservoir pressure at 2,370 pounds/square inch (psi).

During the late 1970's and early 1980's, three operators began drilling CO_2 wells, anticipating completion of a pipeline to transport the CO_2 to west Texas oilfields. The produced CO_2 is injected under pressure to nearly exhausted or high viscosity oilfields to mix with the oil. The CO_2 dissolves into the oil, reducing the viscosity and expanding the oil. This causes the oil to flow through the formation to production wells. After recovery, the CO_2 is then separated from the oil and recycled. A minor amount of the CO_2 is converted to dry ice or compressed and sold locally.

Shell and Mobil initiated field development, and approximately six units were formed. After Shell took over operations for the entire CO_2 field, these units were combined to form the McElmo Dome Unit.

In 1984, a 500 mile pipeline from the McElmo Dome Field to west Texas was completed, and CO_2 production increased markedly. A second pipeline transports CO_2 to the nearby Aneth Field. To date, over 4.4 trillion cubic feet (tcf) of CO_2 has been produced. This is only 29 percent of the EURs. The EURs for the field are 15.3 tcf of CO_2, or enough to maintain the current production rate for another fifty years. Average production is 275 billion cubic feet (bcf)/year.

The McElmo Dome Field represents a significant resource. The current limiting factors for CO_2

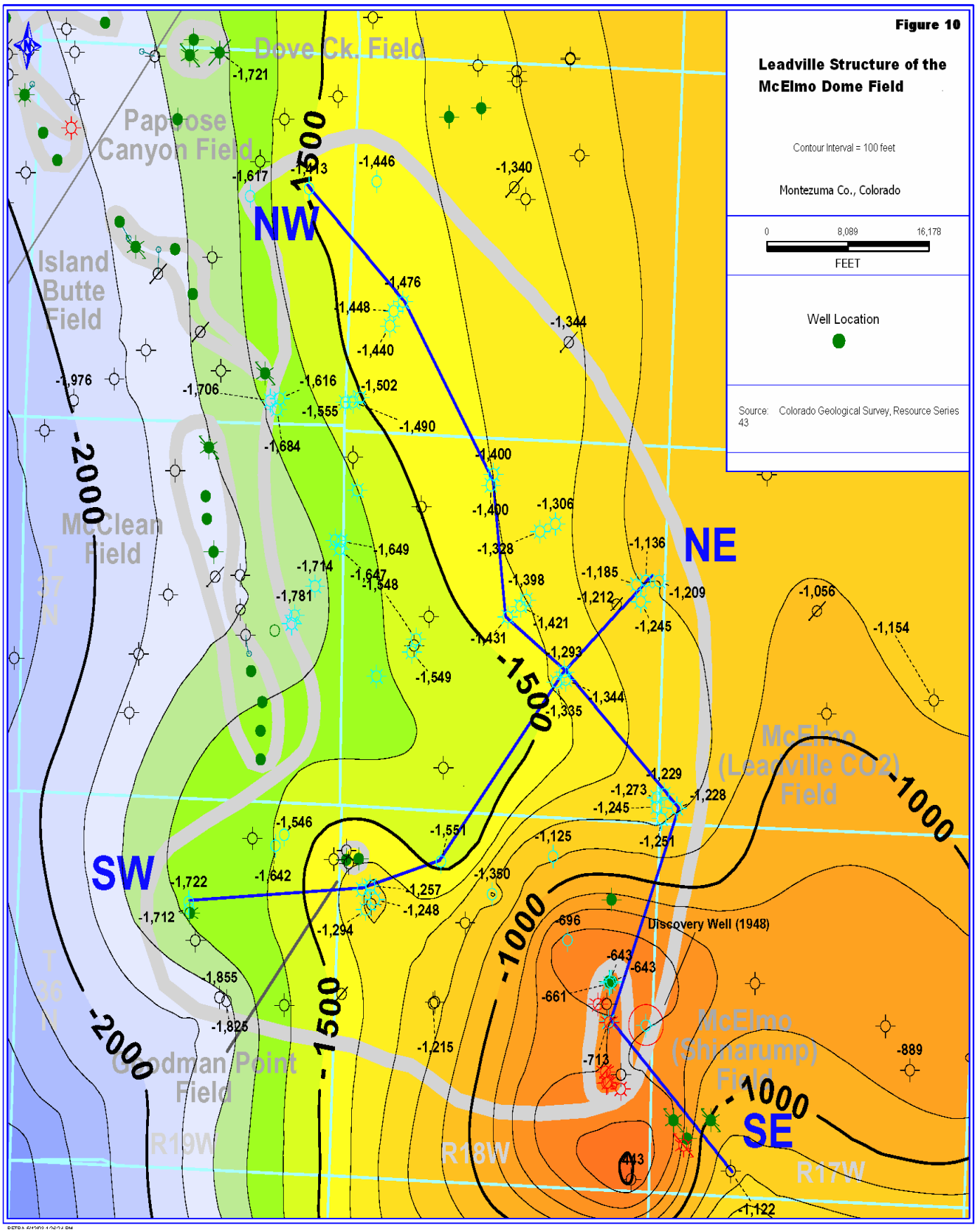
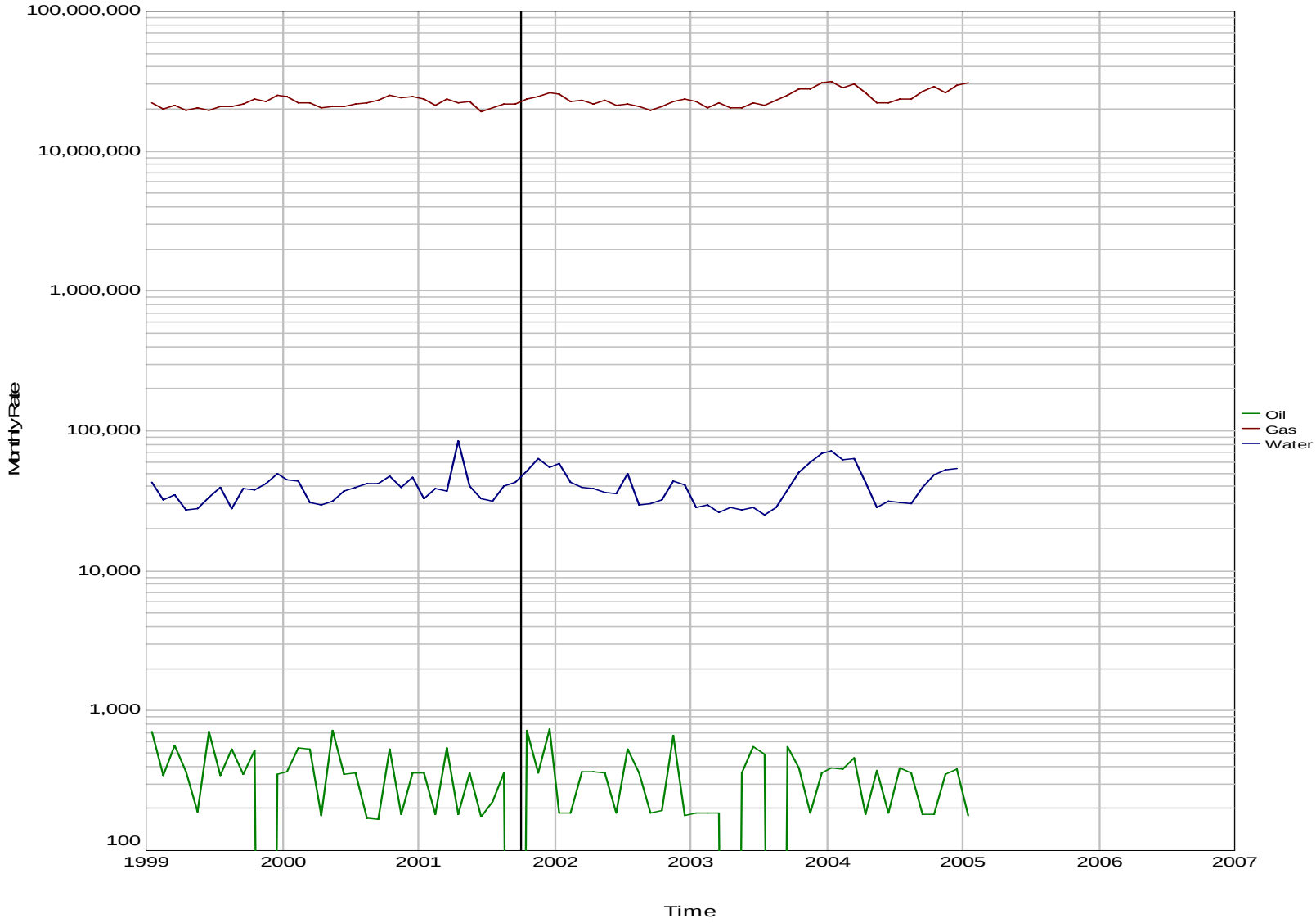


Figure 10
Leadville Structure of the McElmo Dome Field
Contour Interval = 100 feet
Montezuma Co., Colorado
0
8,089
16,178
FEET
Well Location
Source: Colorado Geological Survey, Resource Series 43
Dove Ck. Field
Papoose Canyon Field
Island Butte Field
McClean Field
Goodman Point Field
McElmo (Leadville CO2) Field
McElmo (Shinarump) Field
Discovery Well (1948)
NW
NE
SW
SE
-1500
-2000
-1000
T 37 N
T 36 N
R19W
R18W
R17W

Graph 4. Rate/time decline graph of historic production from the Yellow Jacket Cluster (oil and water reported in bbls/month, while CO_2 is reported in mcf/month).



production are pipeline capacity and market demand. There is only one pipeline that transports CO_2 from the McElmo Dome Unit and it can only carry a fixed amount of gas, with the current compression capacity. The producing wells are currently delivering approximately one bcf/day of CO_2 to west Texas oilfields, and approximately 15 million cubic feet (Mmcf)/day of CO_2 to oilfields in eastern Utah. Plans for increasing pipeline capacity are discussed in the Reasonable Forseeable Development Scenario: CO_2 section of this document.

The McElmo Dome Unit currently utilizes twelve cluster facilities for gathering and processing the CO_2, water, and oil. One to four wells flow their produced fluids to a cluster facility, where the free water is removed and the volume of the gas measured. The water is piped to a disposal well. The oil is stored in tanks and then transported by truck to refineries. The CO_2 travels to one of four central facilities where the gas is dehydrated and compressed for transmission to west Texas and Utah.

In 2003, the HF-1 well was recompleted with horizontal drilling technology. Currently, horizontal drilling technology is being tested to determine its ability to optimize CO_2 recovery in the McElmo Dome Unit. In the HF-1 well the results were promising, increasing flow from 7,000 mcf/day to 22,000 mcf/day. Sundry Notices have been submitted for horizontal recompletions in two other poor-performing wellbores. If these prove successful, additional wellbores will be evaluated for horizontal recompletion.

Directional drilling has not yet been employed for production of CO_2 from the McElmo Dome Unit. Up to four directional wells could be drilled off of one wellpad. The directional wellbores would be used to reach the Leadville Formation thousands of feet away from the surface location. Once the Leadville Formation is intersected, the drilling would be switched to horizontal to maximize penetration of the reservoir and to reach even further away from the other wells being drilled off the same pad. This combination of technologies has not been tested but, appears to be reasonable.

Conclusion: Future and consistent development of the McElmo Dome Unit is certain. To date, only 29 percent of the estimated reserves have been produced using current technology. Another 50 years of production, at current rates, is assured. A large amount of acreage for future development is available on the unit. There are large portions of the unit that are not being produced. Existing levels of CO_2 development will continue to both maintain current production levels and further develop proven reserves. The potential for increasing CO_2 development levels exists and is discussed under the Reasonable Foreseeable Development Scenario: CO_2 section of this document.

Cache Unit: The Cache Unit (Figure 7, page 17) is a small oilfield in the southwestern portion of the Monument. Approximately three quarters of the unit (i.e., 1,244 acres) resides on the Ute Mountain Ute Reservation located adjacent to the Monument. The Monument portion of the unit consists of 488 acres.

Production is from the Ismay member of the Paradox Formation. The Desert Creek member was tested in several wells with shows of oil and natural gas, but not in economic quantities. Twenty-eight wells have been drilled in the Cache Unit, with the extent of the producing

reservoir delineated by dry holes. There are currently four active Federal wells located within the Monument, one being an injection well.

Most of the wells were drilled in the mid-1960s. Two wells were drilled in 1980, one well drilled in 1983, and two wells drilled in 1990. The discovery well in this field, the Pan American Petroleum #1, was drilled to a depth of 4,922 feet in 1964. This well initially produced at a rate of 1,434 bbls of oil/day. Reservoir testing showed the average net pay to be 57 feet, the porosity to be 10.4 percent, average permeability to be 12.3 millidarcies with a high of 27.2 millidarcies, and the initial reservoir pressure 2,170 psi.

No new wells have been drilled since 1990. As illustrated on the Ismay Isopach of the Cache Field (Figure 11), the majority of successful wells are drilled where the structure is the thickest.

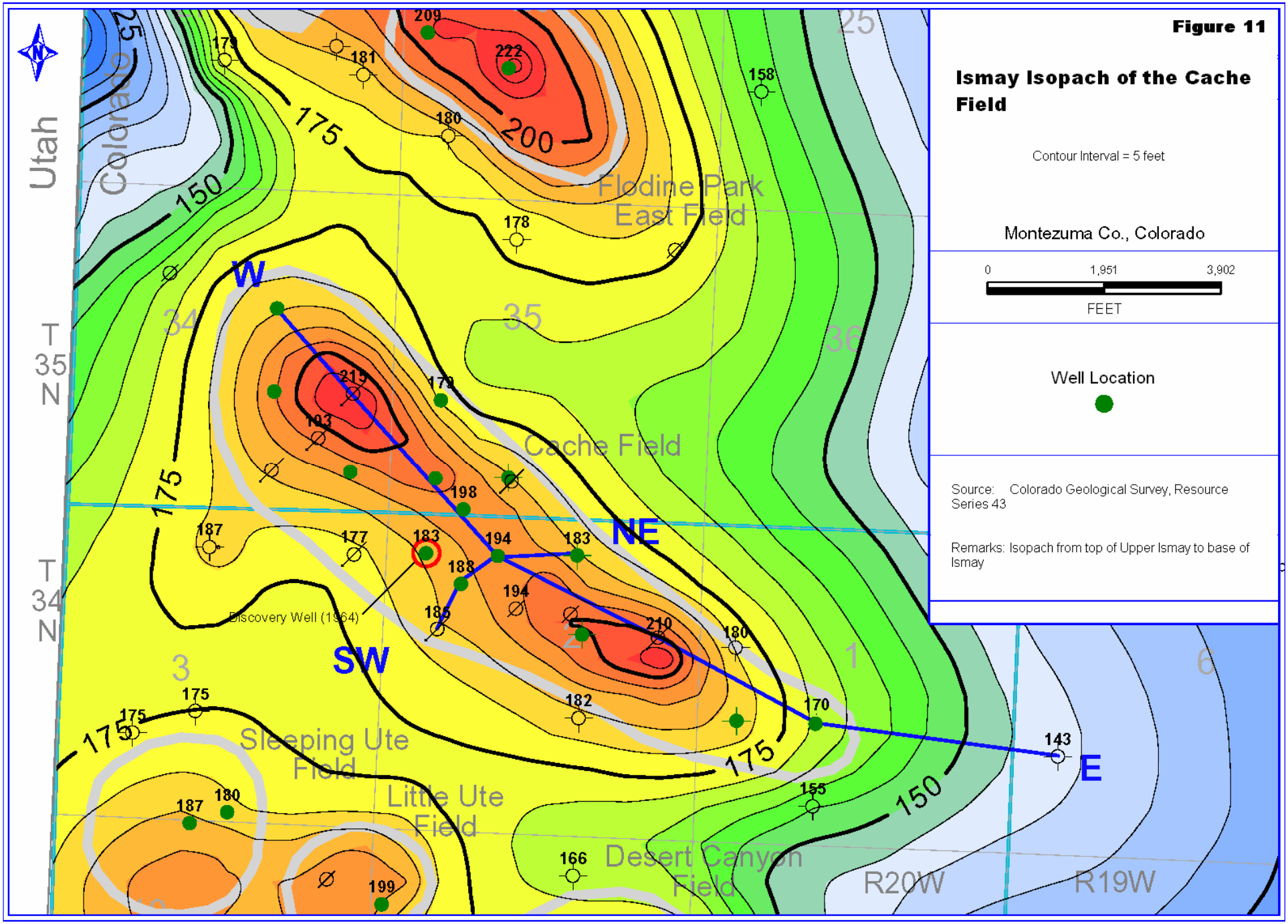
Production from the field has seen a steady decline since 1992. Current oil production is at about 650 bbls/month and natural gas production is about 440 mcf/month from the three producing Federal wells. Water production is currently 1,952 bbls/month and is reinjected. Production is sustained by water injection to drive the oil to the producing wells. Produced oil is trucked from the unit and natural gas is produced to pipeline.

Cumulative production volumes are 4,570,047 bbls of oil and 7,606,130 mcf of natural gas through December 2003. The EURs for the field are 4,703,626 bbls of oil and 7,900,021 mcf of natural gas. The historic cause for abandonment of Cache Unit wells are a combination of low oil and gas production and an increase in water production rates. The Cache Unit must be considered a very mature field. It is nearly exhausted, but may marginally produce for at least ten more years. The producing wells will qualify as stripper wells. Over 97 percent of the oil and 96 percent of the natural gas has been produced.

Conclusion: This field appears to be nearly exhausted of resources. Very limited acreage for future development is available on this small unit. To date, 28 wells have been drilled and little untested spacing is left. The life of this unit will probably be for at least ten more years at low production rates, as the wells transition to stripper well status.

Flodine Park and Flodine Park East Fields: The Monument portion of these fields are located immediately east of the Colorado-Utah border. They produce oil and natural gas from the Ismay member of the Paradox Formation (Figure 12). Minor amounts of oil have been produced from the shallow Jurassic Bluff Sandstone Formation. The fields are often described as an extension of the larger Aneth Field Complex, located across the state line in Utah, with the Flodine Park East Field being the easternmost extension of this complex.

Twenty three wells have been drilled in the Flodine Park and Flodine Park East Fields since 1959. The initial 20 wells were drilled from 1959 through 1966. The Flodine Park Field reservoir was delineated during the drilling of the initial 20 wells, with ten dry holes that defined the productive area. The most recent well drilled in the Flodine Park Field was in 1996. Produced oil is trucked from the field and the natural gas is produced to pipeline. As can be seen from Figure 12, the majority of successful wells were drilled on the thickest portion of the structure.



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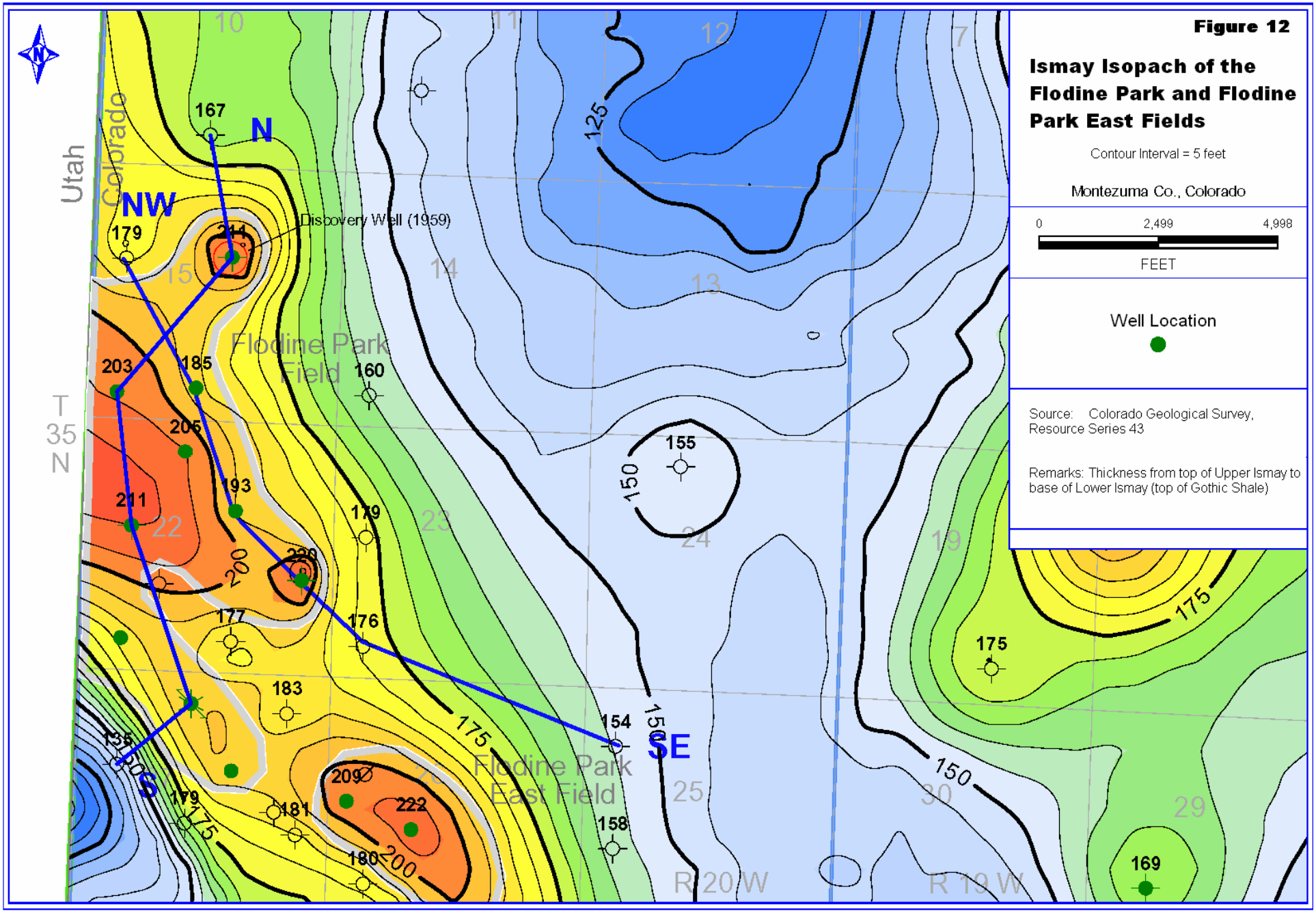


Figure 12
Ismay Isopach of the Flodine Park and Flodine Park East Fields
Contour Interval = 5 feet
Montezuma Co., Colorado
0
2,499
4,998
FEET
Well Location
Source: Colorado Geological Survey, Resource Series 43
Remarks: Thickness from top of Upper Ismay to base of Lower Ismay (top of Gothic Shale)
Utah
Colorado
T 35 N
R 20 W
R 19 W
Flodine Park Field
Flodine Park East Field
Discovery Well (1959)
NW
N
SE
S
125
150
175
200
167
179
214
203
185
160
205
193
211
179
220
177
176
183
155
154
158
135
209
222
181
180
175
169

The discovery well in this field, the Lion Oil #1 well was drilled to a depth of 6,100 feet in 1959. This well initially produced at a rate of 400 bbls of oil/day. Reservoir testing showed the average net pay to be 41 feet, the porosity to be 11 percent, average permeability to be 13 millidarcies, and the initial reservoir pressure 2,212 psi. The recoverable reserves for this field have been estimated at 14 to 39 percent of the original oil in place. The original oil in place is the volume of oil that is estimated to exist within a reservoir.

A 3-D seismic study was recently conducted in the Mail Trail Mesa area (i.e., T. 35N., R. 19W. & 20W., and T. 36N., R. 20W.) of this field and several targets were identified.

Cumulative production volumes from the Flodine Park and Flodine Park East Fields are 2,772,600 bbls oil and 16,876,098 bcf of natural gas through December 2003. The EURs for the field are 2,839,511 bbls of oil and 17,348,207 bcf of natural gas. Current monthly production rates are 1,021 bbls of oil and 8,523 mcf of natural gas, with six wells reported as active and six wells classified as inactive. The current production rate for water is 214 bbls/month. The historic cause for abandonment of Flodine Park wells is low production rates of oil and natural gas and some water encroachment. Flodine Park must be considered a very mature field. The field appears nearly exhausted, but may marginally produce for up to ten more years. Over 97 percent of the oil and 96 percent of the natural gas has been produced.

Conclusion: Although Flodine Park and Flodine Park East Fields appear to be nearly exhausted of proven resources, renewed aggressive interest in this area is evident by the recent seismic study and the staking of seven new wells. The renewed activity has resulted in the formation of the Cannonball Unit. There is available acreage in this area for continued exploration and development. Even without the addition of new wells, production will continue for another ten or fifteen years as the wells transition to stripper well status.

Cannonball Unit: Seismic exploration was conducted in the Flodine Park area in 2003. As a result, the Cannonball Unit was formed in July of 2004. This unit consists of 15,087 acres and 14 leases (Figure 7, page 17). Seventy four percent (i.e., 11,164 acres) of this unit is located on the Monument. To date, no wells have been drilled on the unit, but an application for permit to drill (APD) for the Cannonball Unit #1-18 (i.e., initial test well) has been submitted and approved.

Goodman Point Field: The Goodman Point Field is located between Cortez, Colorado and the Utah state line. This is a small oil and natural gas field with poor production records and a very short production history.

Two discovery wells are attributed to this small field. An Upper Ismay discovery well was drilled in 1960. This Upper Ismay discovery well, the Ferebee #3 well, was drilled to a depth of 5,707 feet. This well initially produced at a rate of 2,751 mcf of natural gas/day (Figure 13). Reservoir and core analysis showed the average net pay to be 24 feet, the porosity to be three percent, permeability to be 0.3 millidarcies, and the initial reservoir pressure was not recorded.

A Desert Creek discovery well, the Nabers #2, was drilled in 1961 with initial production of five bbls of oil/day and 240 to 500 mcf of natural gas/day. Reservoir testing showed the average net

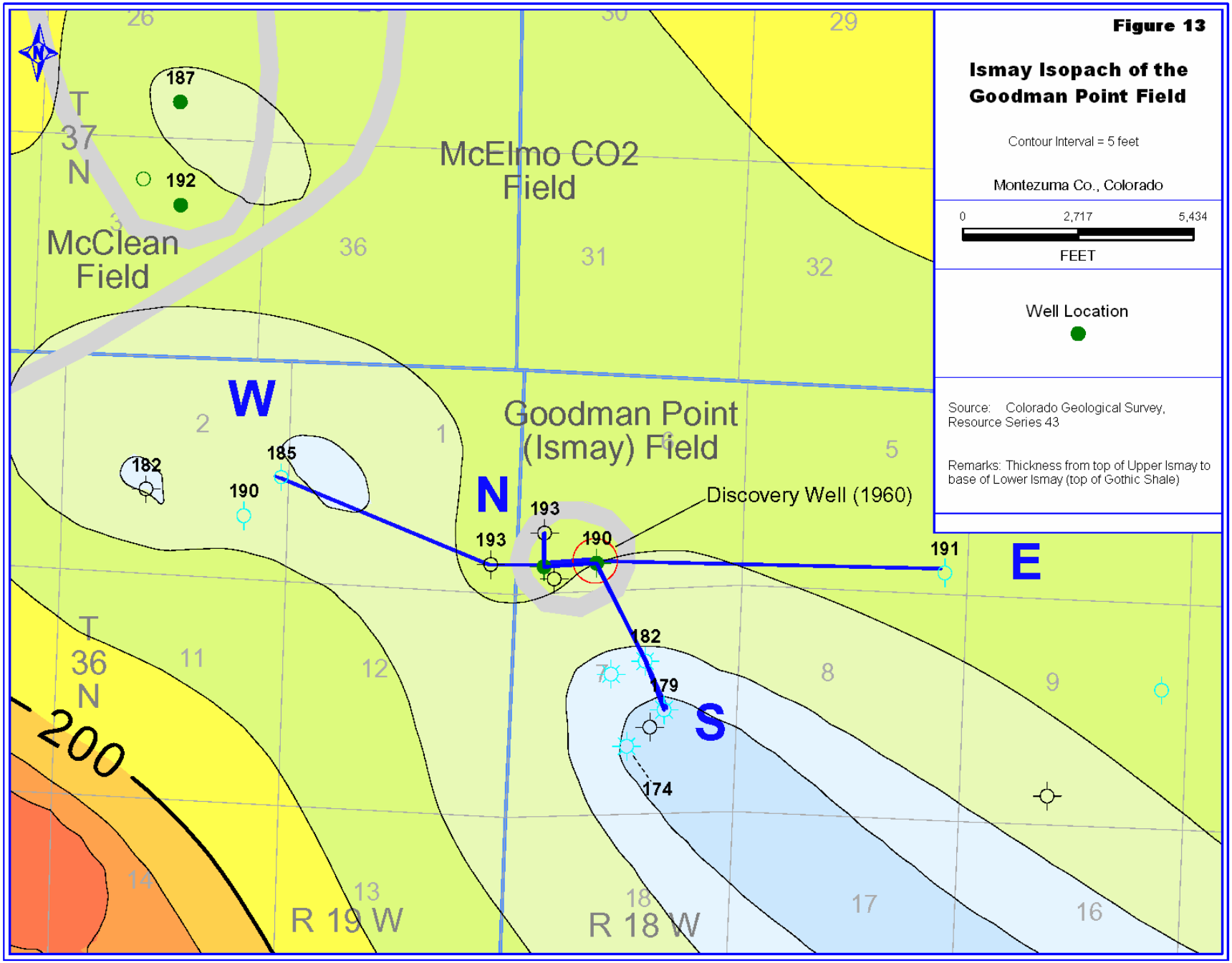


Figure 13
Ismay Isopach of the Goodman Point Field
Contour Interval = 5 feet
Montezuma Co., Colorado
0
2,717
5,434
FEET
Well Location
Source: Colorado Geological Survey, Resource Series 43
Remarks: Thickness from top of Upper Ismay to base of Lower Ismay (top of Gothic Shale)
McElmo CO2 Field
McClean Field
Goodman Point (Ismay) Field
Discovery Well (1960)
W
N
E
S
T 37 N
T 36 N
R 19 W
R 18 W
200
187
192
182
185
190
193
193
190
191
182
179
174
26
29
36
31
32
2
1
5
11
12
8
9
14
13
18
17
16

pay to be eight feet, the porosity to be 15.7 percent, average permeability to be 11.6 millidarcies and the initial reservoir pressure 3,312 psi.

Four step out development wells were drilled to delineate the reservoir, and all four were dry holes. The wells were drilled to the north, west, and southeast of the Nabers #2 well. Production occurred from 1961 through 1963. Both wells were plugged and abandoned by 1964. Cumulative production volumes have not been reported.

Conclusion: There has been no production or interest in this area for years. Future exploration is not expected to take place in the immediate area of this field.

Papoose Canyon Field: The Papoose Canyon Field is located north of the Montezuma County line, in Dolores County, Colorado and eastern Utah. Oil and natural gas are produced from the Ismay and Desert Creek zones (Figure 14); pay zones are at about 6,200 feet. The discovery well for this field was the Pribble #1, which was completed in 1970. The initial production from this well was 3,200 mcf/day. Seventy one wells have been drilled in the Papoose Canyon Field. Most wells were drilled on 160 acre spacing. Produced oil is trucked from the field and the natural gas is produced to pipeline. Produced water is trucked from the field and disposed of at an authorized facility.

Graph 5 shows the rate/time decline of historic production from the Papoose Canyon Field. The graph shows initial production from this field in the early 1970's. Decline curve analysis indicates this field is mature. Oil and natural gas production is declining and water production is rising. In the last ten years water production has increased from thousands of bbls of water/month to tens of thousands of bbls of water/month. No new wells have been drilled to maintain production or to increase proven reserves.

Graph 6 shows the rate/time decline of historic production from the Etta Thomas #36-6 well in the Papoose Canyon Field. This well was drilled in the mid-1980s and ceased producing economically in 1998. The graph shows the rapid onset of water production and increasing water cut until the well watered out. Last production is from 1998 and at that time the well was producing 4,000 bbls of water/month and 800 bbls of oil/month. The historic cause for abandonment of wells in the Papoose Canyon Field are a combination of low oil and natural gas production and an increase in water production rates.

Cumulative production from the Papoose Canyon Field, up to December 2003, was 6,459,776 bbls of oil and 35,890,976 mcf of natural gas. The EURs, derived from decline curve analysis for the field, are 6,562,572 bbls of oil and 36,510,415 mcf of natural gas. Average monthly production rates for 2003 were 3,424 bbls/month and 24,284 mcf/month. Water production is currently 24,984 bbls/month. There are currently 17 wells producing from this field.

The Papoose Canyon Field must be considered a very mature field. Over 98 percent of the oil and 98 percent of the natural gas has been produced. This field is nearly exhausted, but may marginally produce for up to ten more years. Eventually the producing wells will qualify as stripper wells.

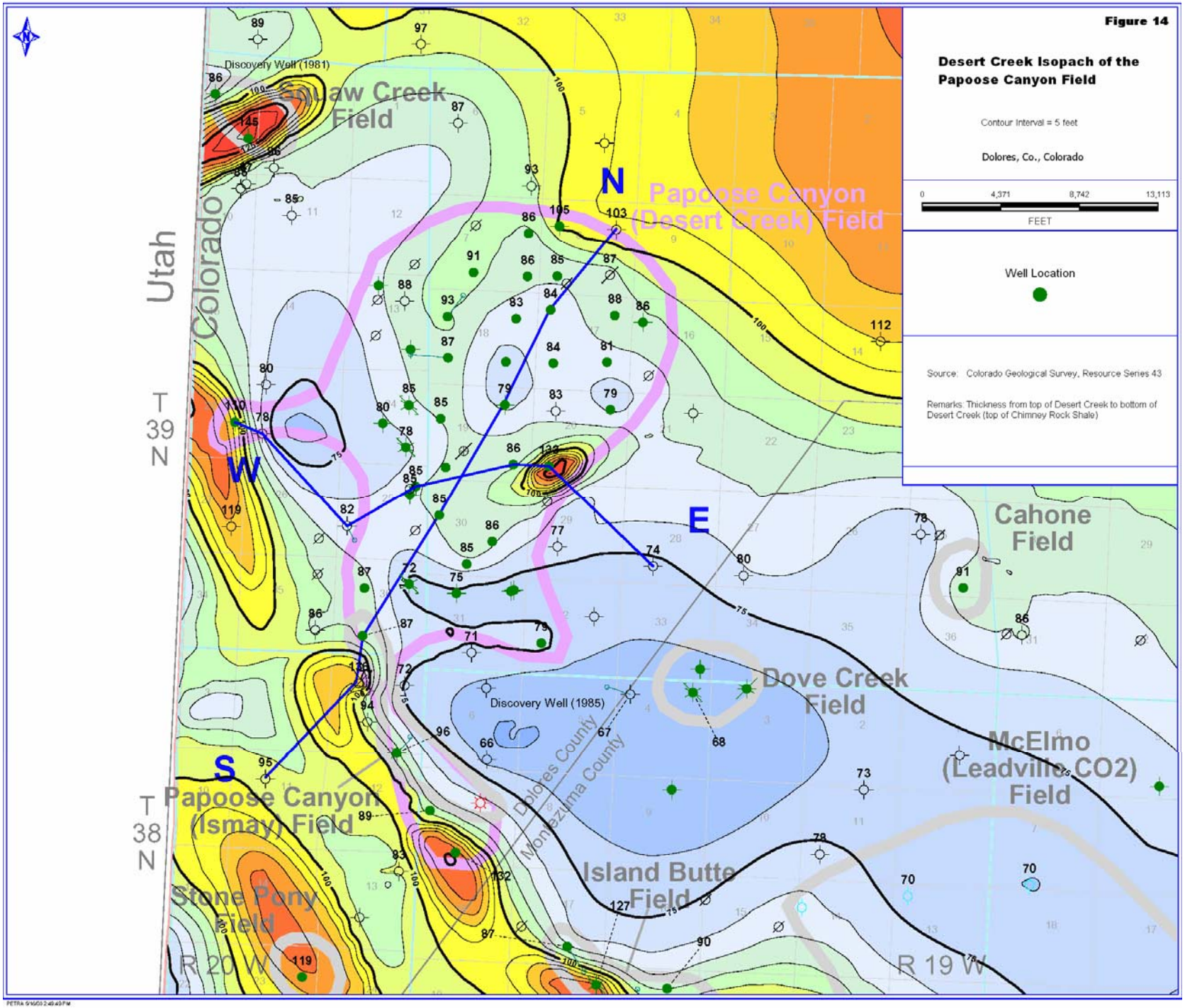
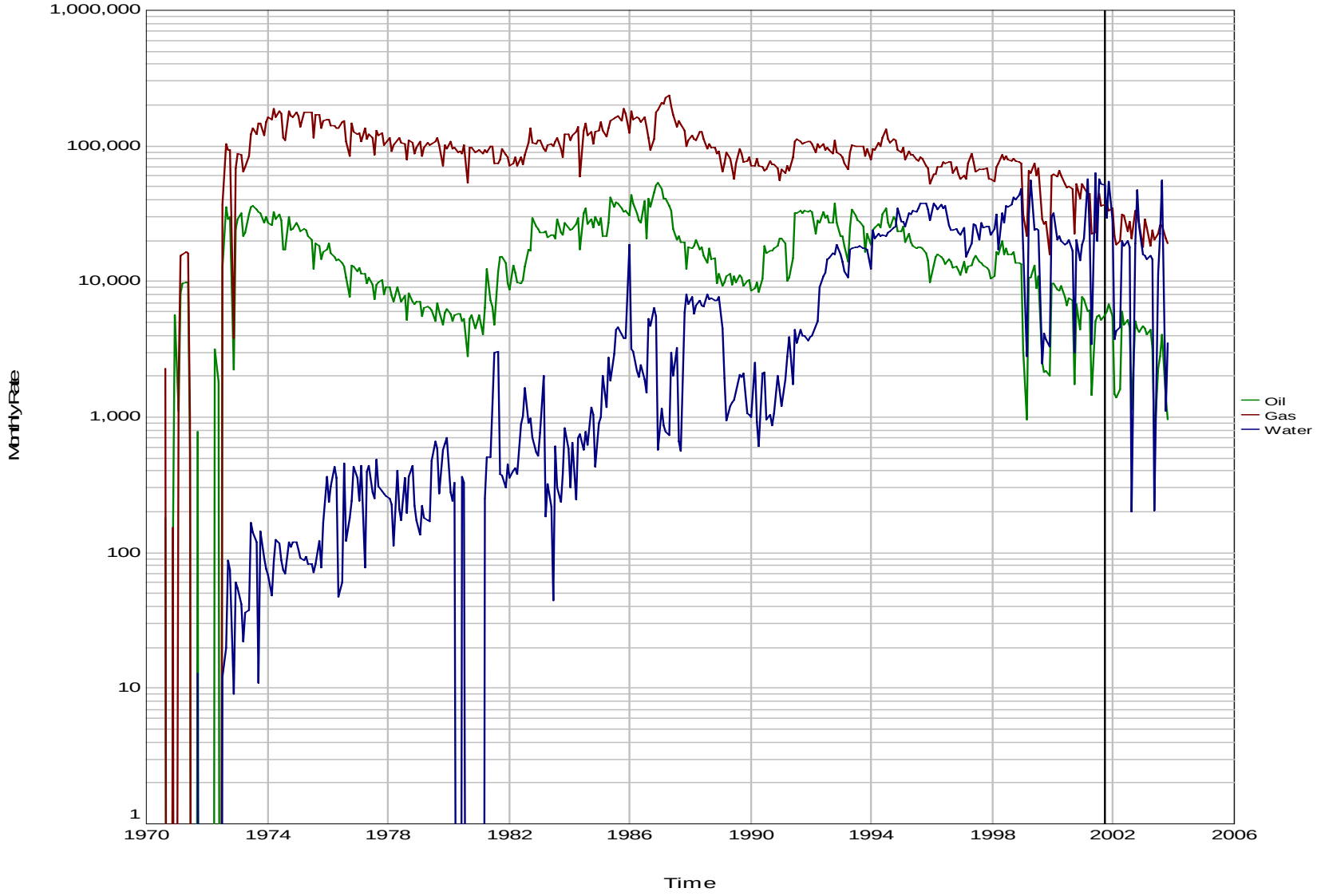
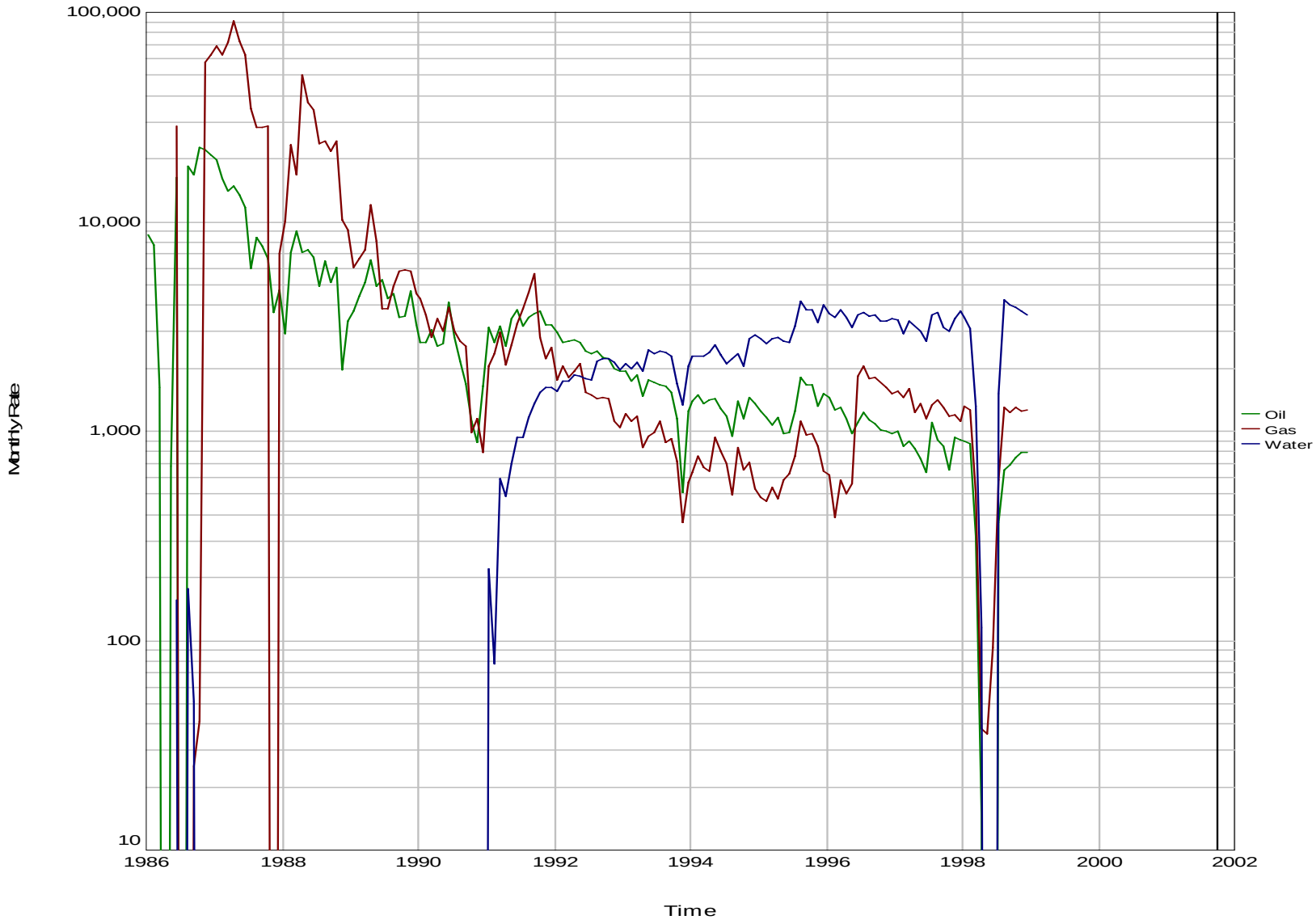


Figure 14
Desert Creek Isopach of the Papoose Canyon Field
Contour Interval = 5 feet
Dolores, Co., Colorado
0
4,371
8,742
13,113
FEET
Well Location
Source: Colorado Geological Survey, Resource Series 43
Remarks: Thickness from top of Desert Creek to bottom of Desert Creek (top of Chimney Rock Shale)
Utah
Colorado
T 39 N
T 38 N
R 20 W
R 19 W
Squaw Creek Field
Papoose Canyon (Desert Creek) Field
Cahone Field
Dove Creek Field
McElmo (Leadville CO2) Field
Island Butte Field
Papoose Canyon (Ismay) Field
Stone Pony Field
Discovery Well (1981)
Discovery Well (1985)
Dolores County
Montezuma County
N
W
E
S
O

Graph 5. Rate/time decline graph of historic production from the Papoose Canyon Field (oil and water reported in bbls/month, while natural gas is reported in mcf/month).



Graph 6. Rate/time decline graph of historic production from the Etta James well (oil and water reported in bbls/month, while natural gas is reported in mcf/month).



Conclusion: The Papoose Canyon Field appears to be nearly exhausted of resources. Limited acreage for future development is available in the currently defined field. To date, 71 wells have been drilled and some untested spacing is left. Production may continue for another ten or fifteen years as the wells transition to stripper well status.

Canyon (Shallow) Unit: Historically, the Canyon (Shallow) Unit was referred to as the Stone Pony Field (Figure 7, page 17). Currently, this unit only contains a single well. The Canyon (Shallow) Unit is 344 acres in size with 85 percent, or 293 acres located in the Monument. Originally, the unit was over 8,000 acres in size; however, in 1996 it was contracted down to its current acreage.

The term "shallow" indicates that there is more than one unit at this geographic location. Production from the Canyon (Shallow) Unit is from the Ismay member of the Paradox Formation at a depth of over 6,000 feet. The McElmo Dome Unit produces CO_2 from a much deeper depth.

The one well producing from this unit is the Canyon #1 well, and was drilled and completed in 1991. Average production from this well is 7,496 mcf of natural gas and 53 bbls of oil/month. No water production has been reported for this well. Cumulative production to date is 809,647 mcf of natural gas and 7,922 bbls of oil. Decline curve analysis indicates that this well has produced 87 percent of its reserves of natural gas. The EURs for this well are 935,645 mcf of natural gas and 8,139 bbls of oil. A dry hole was also drilled on the unit in 1991.

Conclusion: Due to the unit's small size (i.e., 293 acres on the Monument) and history, it is unlikely that any new wells will be drilled.

Island Butte Field: The Island Butte Field (Island Butte II Unit) must be considered a very mature field. Although the Island Butte Field (Figure 7, page 17; and Figure 15) is a fairly recent Ismay discovery, with eight wells drilled from 1991 through 1998, it is at the end of its estimated life. The field is located southeast of the Papoose Canyon Field. Currently, only six of these eight wells are producing. The unit is 10,005 acres in size with 7,093 acres, or 71 percent of its land area located in the Monument.

Wells produce light oil and some natural gas. Produced oil is trucked from the unit and the natural gas is produced to pipeline. Produced water is disposed of in the same water disposal well system as the Cutthroat Unit.

Currently, there are six actively producing wells. Average production rates from these six wells, over the last six months, are 7,419 mcf of natural gas and 2,424 bbls of oil (Minerals Management Service). Cumulative production from this field is 2,213,239 bbls of oil and 5,948,770 mcf of natural gas through December 2003. The EURs for the field are 2,222,143 bbls of oil and 5,956,710 mcf of natural gas. Reservoir testing showed the average net pay to be 12 feet, the porosity to be 11 percent, and the initial reservoir pressure 3,119 psi. This field appears exhausted as over 99 percent of the oil and 99 percent of the natural gas has already been produced.

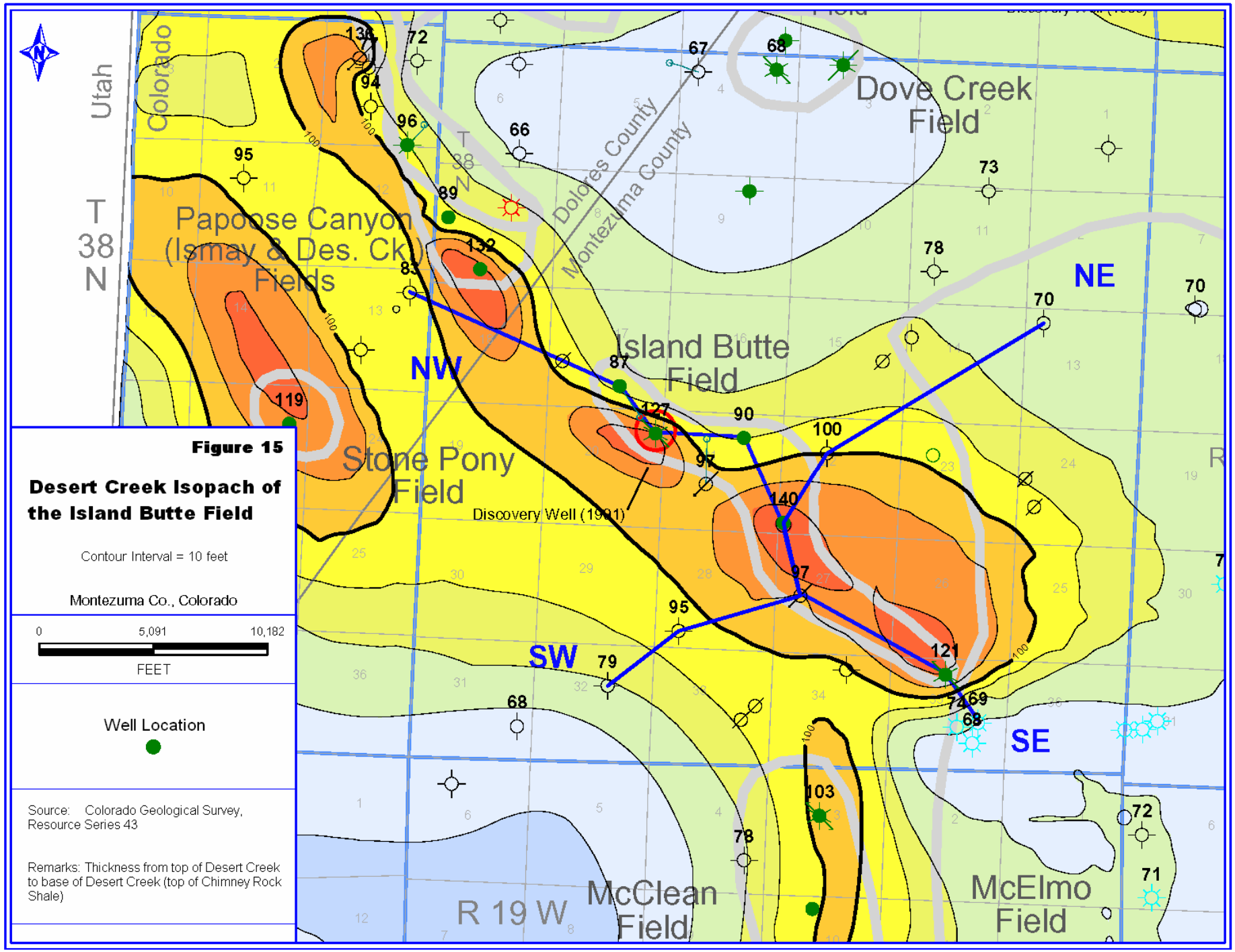


Figure 15

Desert Creek Isopach of the Island Butte Field

Contour Interval = 10 feet

Montezuma Co., Colorado

No new wells have been drilled since 1998. Initially, production rates from the wells were high then quickly dropped off, particularly for natural gas production. As illustrated in Figure 15, the majority of successful wells were drilled on thicker portions of the structure. Some interest has been expressed in testing the Cutler and Honaker Trail Formations. Natural gas samples of low quality have been collected from these formations.

Graph 7 demonstrates the rate/time decline of historic production from the Island Butte Field. The graph shows initial production from this field in the early 1990's.

In addition to the geology, the Island Butte Field's oil production is hampered by water encroachment. In the late 1990s, oil production started to decline and the water production increased. Water production peaked at 60,000 bbls/month until the Island Butte #6 well was shut-in (Graph 8). Water production is currently 2,664 bbls/month. When the cost of water separation and disposal becomes onerous the well will no longer be economic.

Conclusion: Analysis shows that the proven, known reserves of oil and natural gas in the unitare nearly depleted. Even without the addition of new wells, production will continue for another ten or more years as the wells transition to stripper well status. Production will continue until the unit is no longer economic to produce. Untested acreage for future development is available on the unit. Only six wells are currently producing off of the 7,000 acres of the unit, located on the Monument. With this said, if 3-D seismic technology is applied to the unit the extent of the known reservoir could be found to be larger than currently known. If this occurs, the productive life of the unit could be extended.

Estimated Reserves

Decline curve analysis was performed, for all but one field, to determine EURs (Table 5). These estimates include oil and gas production located throughout the fields (i.e., both on and off the Monument). All existing wells in the fields were declined, assuming that no new wells would be drilled. If new wells were drilled the projected total reserves would likely increase.

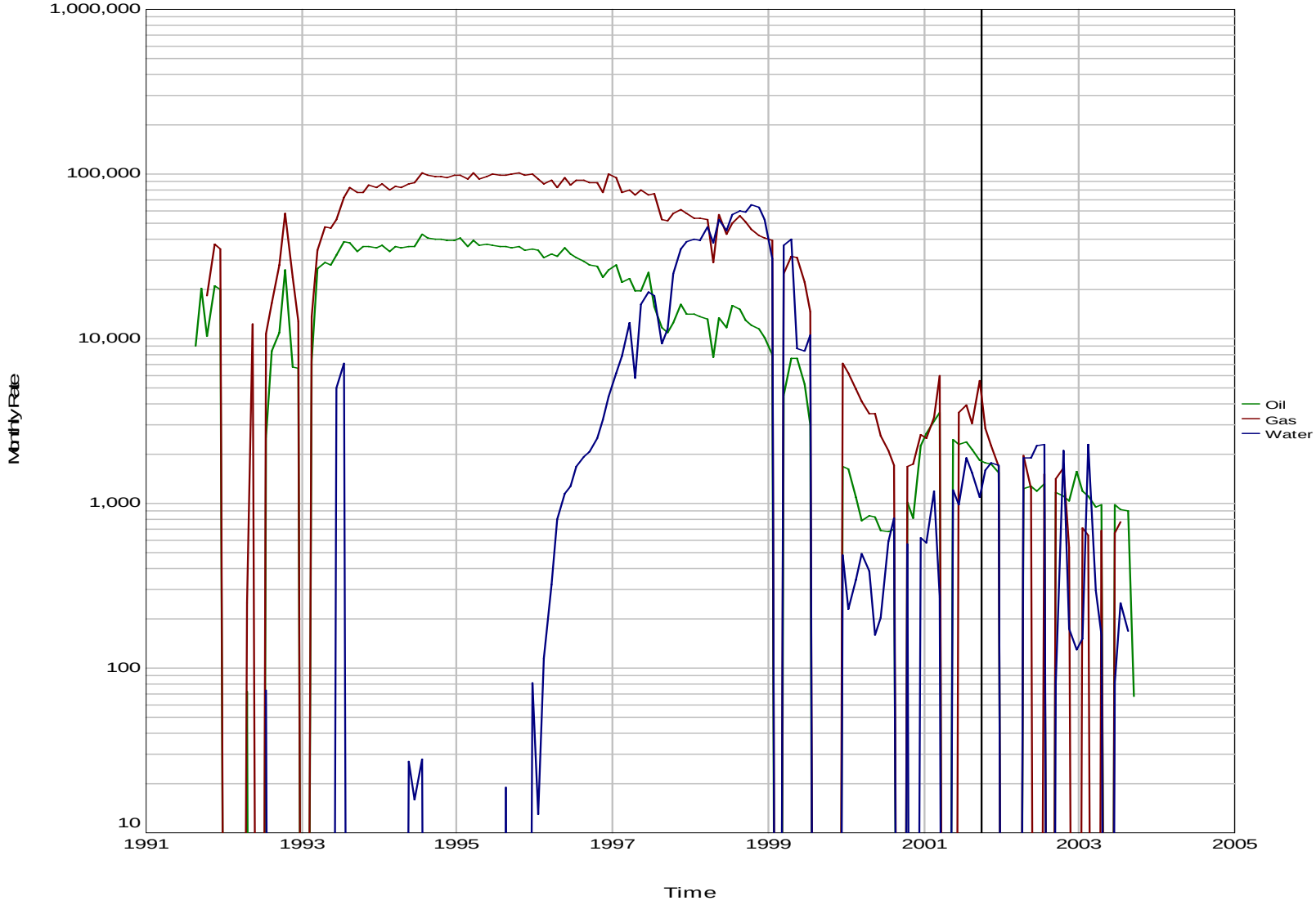
Table 5. Estimated ultimate reserves for fields located within and outside the Monument.

Field	Ultimate Oil (bbls)	Ultimate Gas (mcf)
McElmo Dome	[2]	15,300,000,000[1]
McClean Basin (Cutthroat)	5,842,632	20,734,357
Cache	4,703,626	7,900,021
Island Butte	2,222,143	5,956,710
Flodine Park	2,839,511	17,348,207
Papoose	6,562,572	36,510,415
Canyon (Shallow)	7,922	935,645
Goodman Point	N/A[3]	N/A[3]

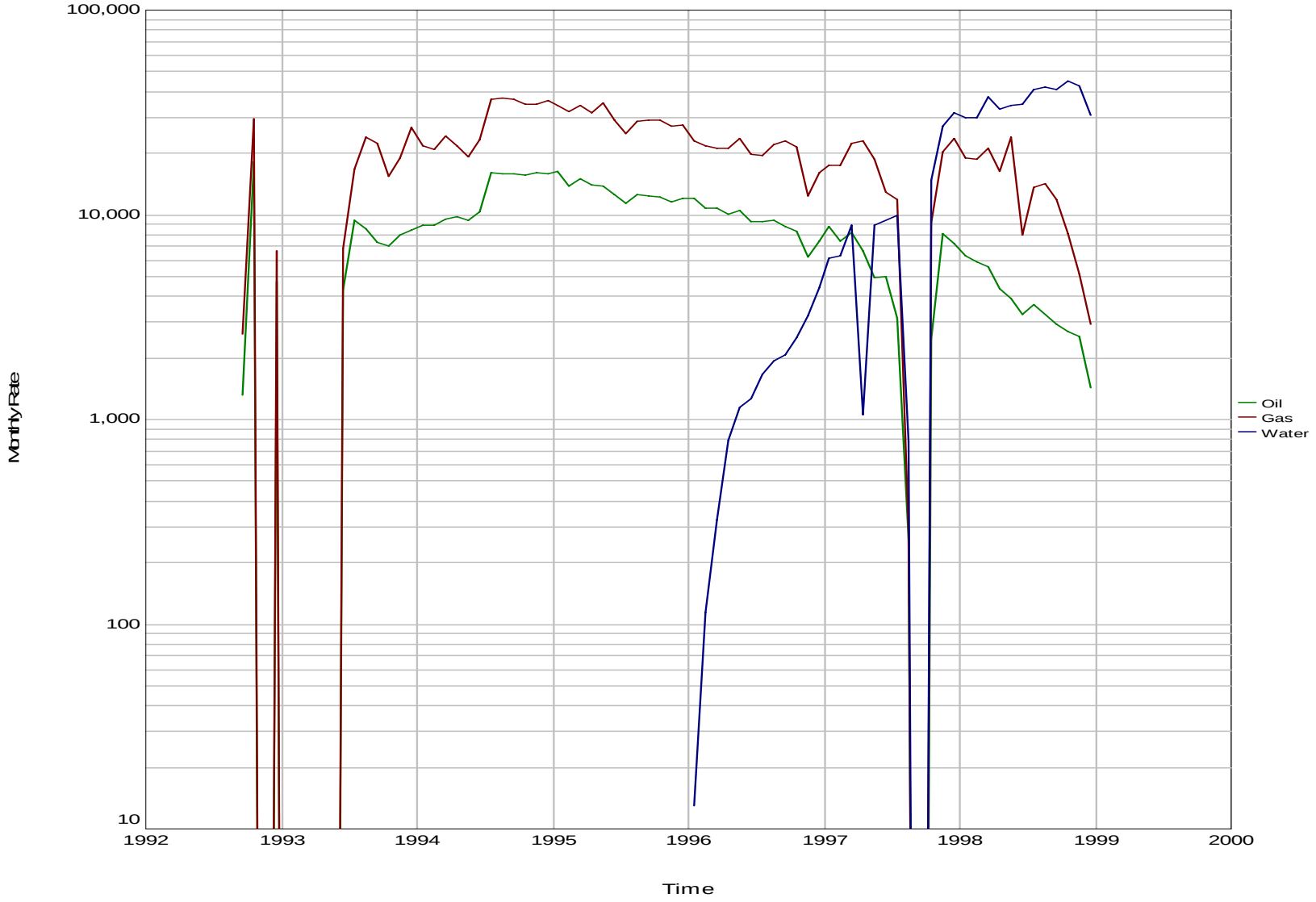
[1] EUR based on operator estimate.
[2] This field is a CO_2 reserve, with only trace amounts of oil produced.
[3] No active wells are located in this field to calculate EUR; cumulative production was never reported.

Conclusion: Graphs 9 and 10 illustrate the overall production history for oil, natural gas and CO_2 in the Monument. At different rates of time, production at each field in the Monument will decline until they are all depleted. The largest fluid mineral resource in the Monument is CO_2,

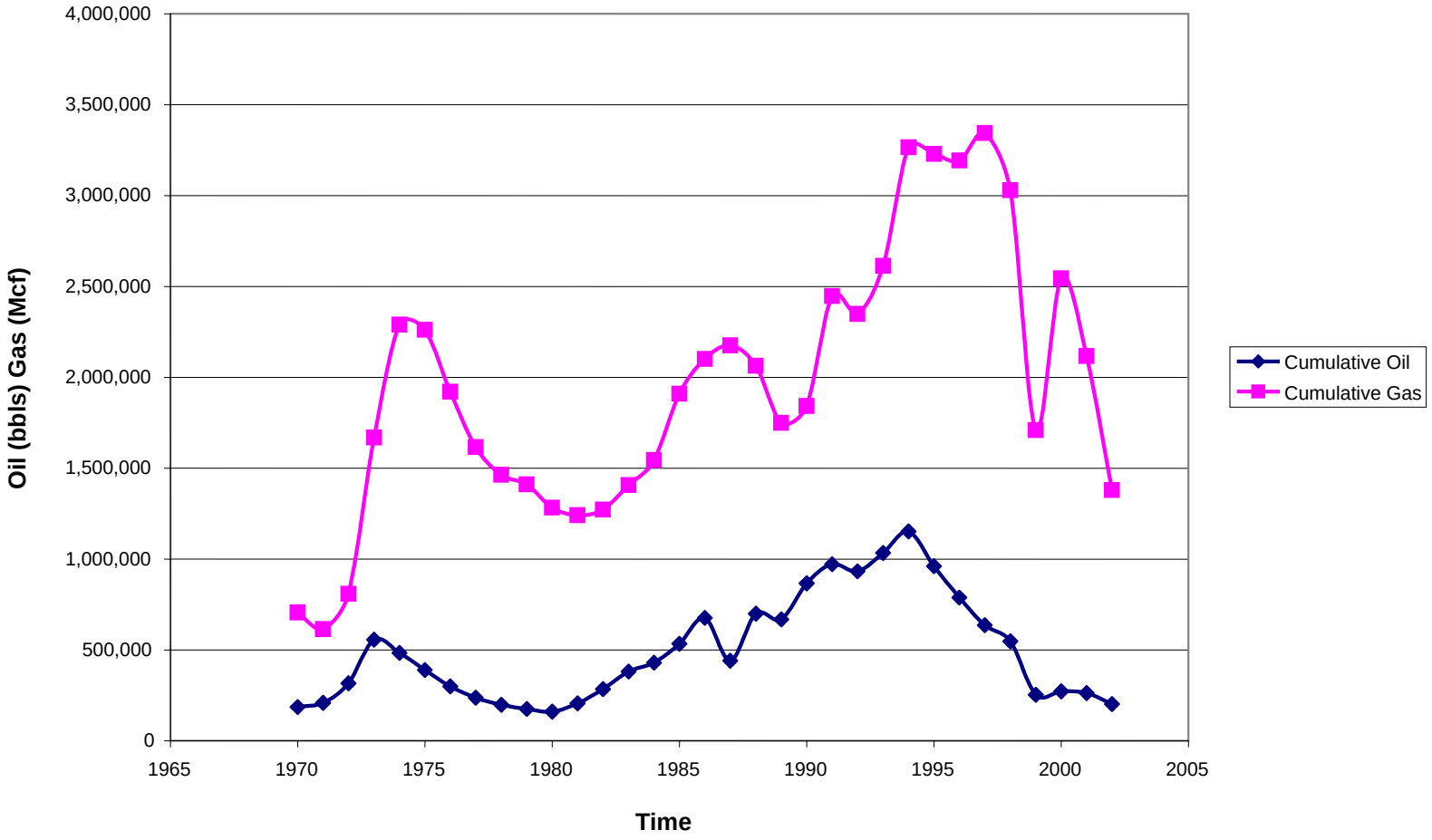
Graph 7. Rate/time decline graph of historic production from the Island Butte Field (oil and water reported in bbls/month, while natural gas is reported in mcf/month).



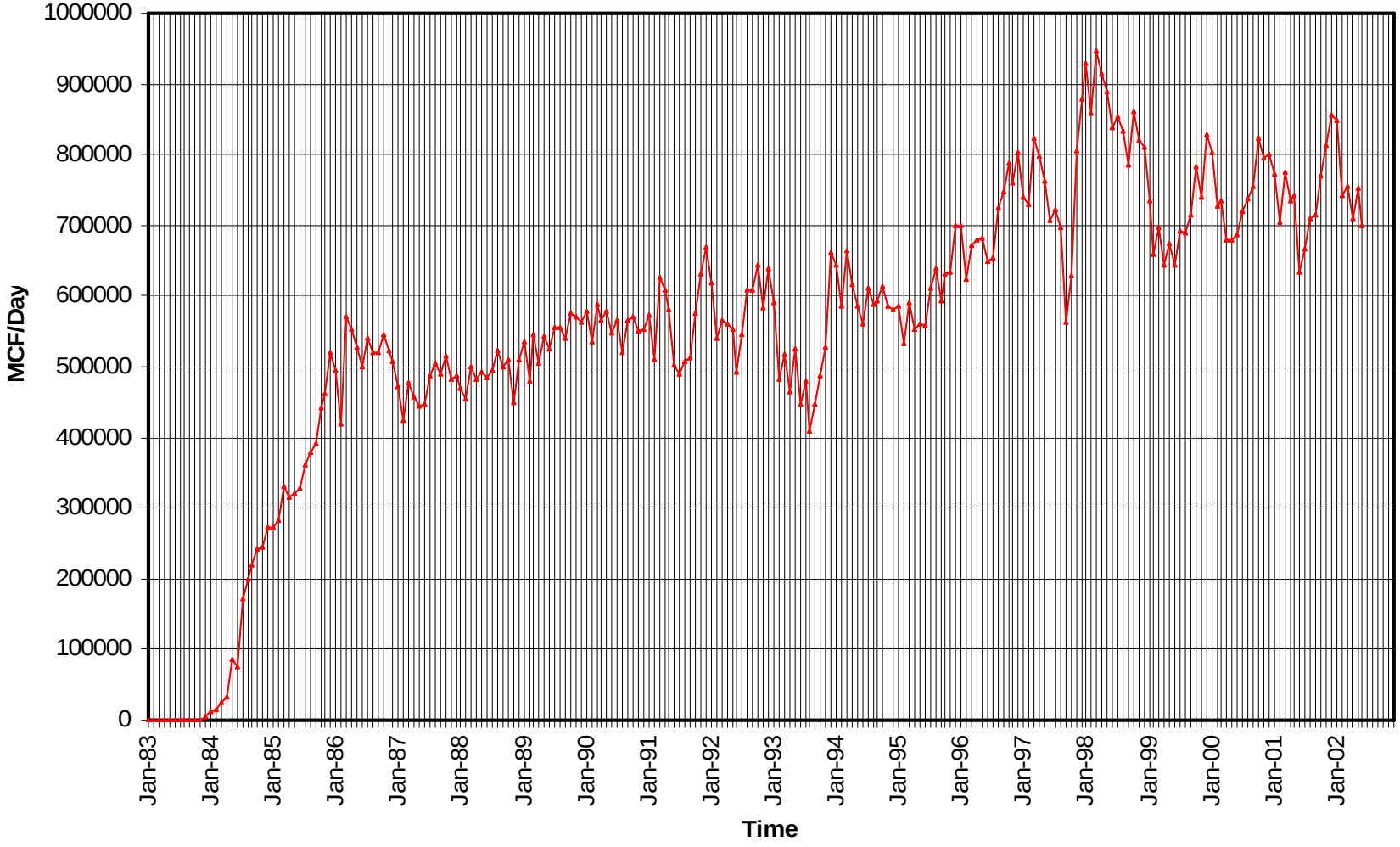
Graph 8: Rate/time decline graph of historic production from the Island Butte #6 well (oil and water reported in bbls/month, while natural gas is reported in mcf/month).



Graph 9. Oil and natural gas production history in the Monument.



Graph 10. CO_2 production history in the Monument.



located in the McElmo Dome Field. As domestic oil fields age in the U.S. and/or the price of oil rises, the use of EOR technology and subsequent demand for CO_2 from the McElmo Dome Field will increase. Therefore, increased production of CO_2 from the McElmo Dome Unit is expected over time.

Reasonable Foreseeable Development Scenario: Oil and Natural Gas

Several sources of data were used in developing the RFD. Some of these include an operator survey conducted by the BLM, geologic information and historic levels of activity (i.e., exploration and development).

Oil and Natural Gas Wells: The BLM estimates a maximum of 81 new oil and natural gas wells will be drilled over the next 20 years. The majority of these wells will be drilled into either the Ismay or Desert Creek members of the Paradox Formation. The Cutler and Honaker Trail Formations may be tested also.

Historical drilling rates averaged approximately two new oil/natural gas wells/year. Over a 20 year period, it is reasonable to expect an increase in oil and natural gas activity (i.e., exploration and development), resulting in a total of four new oil/natural gas wells/year. Therefore, BLM conservatively estimated that a total of 81 new oil and natural gas wells will be drilled in the Monument during the next 20 years.

Some wells may be located in existing fields, to fully develop the reservoirs. Many of the wells will be located near existing fields in hopes of finding other similar sedimentary traps. Other wells will test undeveloped areas, based on seismic data or other information. Well location in exploration programs will be relatively far apart. An increase in density would be expected if some of the new wells successfully find a new reservoir and development begins. Table 6 presents a reasonable estimate of where future oil and natural gas wells may be drilled in the Monument.

Assuming a success rate of 57 percent for 81 projected wells, production could result in up to 23 million bbls of oil and 72 bcf of natural gas. This volume of reserves is based upon the combined average production of one well located in the Cutthroat Unit and another in the Island Butte II Unit.

Oil and Natural Gas Facilities: An additional four new processing facilities may be required to support future oil and natural gas development. Current facilities are located central to current production. The current facilities are tank batteries, separators, and metering equipment. Much of this infrastructure is twenty or more years old and is probably at the end of its useful service life. If current production continues, these facilities may be refurbished to extend their life.

It would be reasonable to expect that new facilities would be required to support new production. The new facilities would need to be central to new production, serviceable, and incorporate state of the art technologies. The locations of these facilities are predicted to be within the Monument boundary. However, some of these facilities could be located on private surface. These facilities may include water disposal wells (i.e., converted oil and gas wellbores), gas dehydration, and compression facilities. Oil will be trucked to refineries in the Four Corners region.

Table 6. Twenty year projected number and location of new oil and natural gas wells.

Field/Unit	# of New Wells	Location
Cache Unit	No Estimate[2]	Sections 34, 35, 36, T.35N., R.20W., and Sections 1, 2, 3, T.34N., R.20W.
Island Butte II Unit[1]	21 Total • 18 Ismay/Desert Creek • 3 Cutler/Honaker Trail	T.38N, R.19W. Small amounts of available acreage in T.38N., R.20W., and T.38N., R.18W.
Cutthroat Unit[1]	22 Total • 18 Ismay/Desert Creek • 4 Cutler/Honaker Trail	T.37N., R.19W. Small amounts of available acreage in T.38N., R.19W., T.37N., R.18W., T.36N., 19W., and T.36N., 18W.
Papoose Canyon Field	6	T.39N., R.19W. and T.39N., R.20W.
Flodine Park Field/Cannonball Unit	12	Sections 10, 11, 14, 15, 22, 23, 26, 27, T35N, R20W.
Monument-wide	20 Wildcat Wells	Monument-wide
TOTAL	81	

[1] Operator projected all total wells without specifying whether they were in Island Butte II or the Cutthroat Unit. Therefore, 18 were assigned to each using the following calculation: [(63 wells at 57 percent success) ≅ 36 wells, divided by 2 = 18 wells)].

[2] No recent development on this unit. The 20 projected wildcat wells cover any future potential development in this unit.
Only seven exploratory wells are projected in the Cutler/Honaker Trail Formation (i.e., ten percent of total proposed).

Seismic Surveys: Current oil and natural gas operators indicate that up to five more 3-D seismic and ten more 2-D seismic surveys will be conducted in the Monument over the next 20 years.

Based on recent 3-D seismic surveys, it is estimated that each future 3-D seismic survey will cover, on average, 15 square miles. For future 2-D seismic, it is estimated that the average seismic line will be five miles in length. This estimate is based on the knowledge that given the typical reservoir dimensions in the Paradox Formation, 2-D seismic lines have historically ranged from two to eight miles in length.

Directional and Horizontal Drilling: Currently, vertical wellbores are the preferred drilling and completion method for oil and natural gas wells on the Monument. Compared to directional and horizontal drilling, vertical wellbores are typically less expensive and pose fewer risks. For example, pumps located in curved wellbores, as used in directional drilling, experience more friction and have higher maintenance costs. Also, when pumping is required to produce oil, maintenance costs are typically lower when using vertical wellbores, compared to directional and horizontal drilling.

Directional drilling can be applied to all producing formations in the Monument. The separation between the surface locations and the bottomhole locations are typically between 1,000 and 2,000 feet. The shallower the target formation, the less directional distance can be obtained.

At least four wells have been drilled into the Desert Creek member of the Paradox Formation directionally. This approach has typically been applied to avoid surface use conflicts (e.g.,

impacting archaeological sites). Much of the Monument is incised with canyons and directional drilling can be employed to reach targets underneath areas where vertical drilling is not possible.

Success with horizontal drilling in the mature fields may increase drilling or redrilling activity because of the extra reserves captured with this new technology. In some cases this technology will utilize existing vertical wellbores (i.e., recompletions), because the operators have a clearer picture of localized geology in the producing fields. By redrilling wells with a horizontal leg, the operator can accelerate and capture more reserves than a vertical well. In the case of new development, fewer wells would be required with horizontal wellbores. Since a horizontal wellbore intersects a thousand or more feet of the producing formation compared to vertical penetration, more oil or natural gas can be accessed and produced.

The success of horizontal drilling is dependent on the geology of the reservoir. To date, it has not been tested in the existing oil and natural gas reservoirs in the Monument. Horizontal wellbores are not as conducive for pumping. Operators will have to weigh these risks prior to opting for expensive horizontal completions verses using traditional vertical completions.

Summary: It is estimated that up to 81 new oil and natural gas wells will be drilled in the next 20 years. Fifty-three miles of pipeline and 67 miles of access roads will be constructed to serve these wells. Untested acreage is available for this development. The overall number of wells is dependent on the success rate of these future wells. The historical success rate has been 57 percent. Four new oil and natural gas treatment and compression facilities will be built to support future oil and natural gas production within the Monument.

In addition, there will be five 3-D and ten 2-D seismic surveys conducted to support oil and natural gas exploration activities. Produced oil and water will continue to be transported by truck to refineries and disposal wells. Natural gas will be produced via pipeline.

Reasonable Foreseeable Development Scenario: CO_2

The current operator estimates 15.3 Tcf of recoverable reserves, or enough to continue current production rates for about 50 years in the McElmo Dome Unit. The unit operator provided the BLM with a general expectation of activities for the next 20 year period. A review of historical activity and economic markets indicate their scenario to be reasonable.

CO_2 Wells: Two new wells/year (i.e., 40 wells) need to be drilled to maintain current production levels. All future development is expected to occur within the existing McElmo Dome Unit over the next 20 years (Figure 7, page 17). Table 7 provides a reasonable estimate of the location and amount of CO_2 wells to be drilled in the Monument over the next 20 years.

CO_2 miscible drive is an effective tertiary recovery method for oil. It is quite successful in the west Texas oilfields, and demand is likely to increase as the price of oil remains high. Recently, the Oil and Gas Journal reported that the CO_2 pipeline cannot meet the demand for CO_2 in west Texas, and that some operators are looking elsewhere than the McElmo Dome Unit for CO_2 supplies (Oil and Gas Journal, 2004). In addition, there are efforts underway to expand EOR technology into Kansas, and New Mexico. Should these efforts prove successful, the pace of drilling will increase, as will the number of surface facilities required to gather and process the

Table 7. Twenty year projected number and location of new CO_2 wells.

Unit	# of New Wells	Location
McElmo Dome[1]	69	Sections 35 and 36, T.38N., R.19W., Sections 30 and 31, T.38N., R.18W.; Sections 12, 13, and 24, T.37N., R.19W.; Sections 6 and 7, T.37N., R.18W; Sections 2, 4, 10, 13, 15, 19, 20, 22, and 23, T.37N., R.18W; Section 36, R.37N., R.17W., and Section 31, T.37N., R.16W; and Sections 7 and 8, T.36N., R.18W.

[1] Projected locations are based on the assumption that new production will be targeted in close proximity to existing cluster facility locations.

CO_2. Current development is "in-field" development, which maximizes the use of existing infrastructure and is less capital intensive.

The existing Cortez pipeline capacity could be increased to 1.4 bcf/day with the addition of two compressor stations along the pipeline route. This represents a 40 percent increase over current capacity. Should CO_2 demand in Texas, New Mexico, and/or Kansas require this expansion, 14 new wells would need to be drilled initially to increase supplies. In the long-term, an additional 15 wells would need to be drilled over the next 20 years to maintain that production rate, resulting in a net increase of 29 wells. Therefore, in addition to the 40 wells required to maintain current production, the total number of new wells will be as high as 69 in the next 20 years. With increases to the capacity of the Cortez pipeline, the average number of CO_2 wells would rise to over three wells/year.

Production Facilities: Short-term development will not require additional surface facilities because they will continue drilling near existing cluster facilities to maximize the utility of these installations. However, over the next 20 years, four additional cluster facilities will be built to service new areas of development. Cluster facilities include gas dehydration units to remove moisture from the CO_2 before it enters the transmission pipeline, and compressors for transporting the gas to west Texas. The water from dehydrators and the water produced from the wells are disposed of by injection wells located near the cluster facilities. The produced water is injected into the Leadville Formation and the oil trucked from the facilities. Cluster facilities also include separators and storage tanks for the oil produced from the CO_2 wells. The equipment at the cluster facilities is housed within buildings.

Horizontal and Directional Drilling: Successful horizontal recompletions of existing wellbores may reduce the need to drill new wells. The operator has submitted two Sundry Notices to re-enter existing vertical wellbores, and drill horizontally into the Leadville Formation. The initial attempt was successful by increasing production from 7,000 mcf/day to 22,000 mcf/day. If the second attempt proves successful, re-entry to drill horizontal legs could be applied on a larger scale. This may result in higher production and less surface disturbance. Horizontal recompletions will be limited due to the small number of wells that have casing diameters large enough for this technology.

Directional drilling has not yet been employed as a new technology for production of CO_2 from the McElmo Dome Unit. The current operator has discussed using a combination of both directional and horizontal drilling to minimize surface impacts. Up to four directional wells

could be drilled off of one wellpad. The directional wellbores would be used to reach the top of the Leadville Formation, thousands of feet away from the surface location. Once the Leadville Formation is intersected, the drilling would be switched to horizontal. This would be done to maximize penetration of the reservoir and to reach even further away from the other wells being drilled off the same pad. Both directional and horizontal drilling are considered viable alternatives for the McElmo Dome Unit.

Uncertainties: Past development history shows a success rate of 65 percent for CO_2 wells. This percentage considers all wells drilled in the CO_2 field since the late 1970's. The geology of McElmo Dome Unit is more clearly understood now and as a result, the success rate is anticipated to be much higher. Extremely high oil and gas prices will significantly alter the economics of all drilling in the Monument. Sustained high prices and demand for oil might drive the need for more CO_2 used for EOR.

Summary: Up to 69 new wells from up to 40 new well pads will be drilled for CO_2 in the McElmo Dome Unit over the next 20 years. These 69 wells include 40 wells to continue current production levels over the next 20 years. In addition, if the existing Cortez pipeline capacity is increased to 1.4 bcf/day an additional 14 wells will need to be drilled initially, plus another 15 wells over the next 20 years to maintain production levels. These 29 wells needed to accommodate expansion of pipeline capacity would require new well pads, and up to four new cluster facilities within the Monument.

Surface Impacts

Surface disturbance is classified as short term and long term, and the cumulative acreage is expressed as gross acreage and net acreage. Surface disturbance associated with seismic surveys is reported separately because it is typically a much lower impact.

The definitions are:

Short-term: An activity that leads to a one-time disturbance of the land surface, with no anticipated follow-on activity required. For example, a subsurface pipeline requires the digging of a trench, pipeline construction and burial. After the backfill is placed over the pipeline, reclamation begins and the pipeline can be abandoned in place with no additional surface disturbing activities anticipated. Seismic activity is similar. The surface disturbance occurs once, and no follow up activities are anticipated along the source lines. Reclamation is conducted immediately following the surface-disturbing activity.

Long-term: An activity that leads to long-term occupancy of the land surface, such as access roads, wellpads, and gas treatment/compression facilities. In all these cases, the surface is disturbed and occupied by the facilities or roads for years or decades. Reclamation occurs only after the wells and access roads are no longer needed for continued oil and gas production.

Gross acreage: This is the total acreage of surface disturbance associated with oil and gas operations. It incorporates all short-term and long-term disturbances, and for this RFD, it has two components. The existing surface disturbance that occurred prior to initiating the RFD, and

the future projected surface disturbance for all oil and gas activities. Tables of existing and future disturbance follow this discussion.

Net acreage: The net acreage of surface disturbance consists of only those areas that are not reclaimed at any one time. The net acreage is always less than the gross acreage because of ongoing reclamation activities. When calculating the future surface disturbance, the short-term disturbances are subtracted (i.e., existing gross – existing reclaimed + future gross – future reclaimed = net acreage).

Reclamation: Involves recontouring the land to its original configuration, stabilizing the soil surface through re-vegetation and noxious weed control. Reclamation is the starting point for restoring the land to pre-development conditions.

Discussion – Access Roads, Pipelines, Wellpads and Production Facilities: To date, oil and gas development has lead to a gross surface disturbance of 1,165 acres within the Monument (Table 8). This acreage was calculated based on the 185 wells that have been drilled in the Monument in the past. The average historic wellpad area was estimated to be 2.75 acres each.

Table 8. Gross existing surface disturbance in the Monument.

Development Type	Number	Acres/Site	Gross Disturbance (acres)
Wells	185	2.75	509
Access Roads (30' wide)	139	2.00	278
Access Roads (40' wide)[1]	46	2.70	124
Pipelines	93	2.00	186
CO_2 Treatment Facilities	12	4.00	48
CO_2 Central Facilities[2]	4	5.00	20
TOTAL	N/A	N/A	1,165

[1] 25 percent of existing roads are 40' wide to accommodate passing on hills.
[2] Existing central facilities include Yellow Jacket, Hovenweep, Moqui, and Sand Canyon.

Future CO_2 wellpads are estimated to be 3.3 acres in size to accommodate the possibility of more than one well/pad. There is no distinction between acreage necessary to drill a vertical or directional wellbore. These estimates assume an average access road distance of 0.55 miles, and that 25 percent of the wells require a separate pipeline right-of-way. Seventy-five percent of existing roads are estimated to be 40 feet wide to accommodate oncoming traffic. The average road distance was calculated from all the wells drilled over the last ten years. Pipelines are typically located along roads. When this is the case, the typical disturbance is initially 50 feet wide. Once the pipeline is laid, 20 feet of the disturbance is immediately reclaimed. Past production facilities are approximately four acres in size. Future facility locations are anticipated to be the same size.

The current net surface disturbance (i.e., gross – reclaimed area) is estimated to be approximately 425 acres (Table 9). The net disturbance includes the existing wellpads, access roads, and compression/treatment facilities. It was estimated that all abandoned wells, associated access roads, and pipelines have been reclaimed, and are therefore no longer included in the net surface disturbance acreage.

Table 9. Net existing surface disturbance.

Development Type	Gross Existing Disturbance (acres)	Plugged & Abandoned (acres)	Drilled & Abandoned (acres)	Interim Reclamation (acres)	Reclamation to Date (acres)	Existing Net Disturbance (acres)
Wells	509	66	203	89	358	151
Access Roads	402	48	148	N/A	196	206
Pipelines	186	N/A	N/A	N/A	186	0
Treatment Facilities	48	N/A	N/A	N/A	0	48
Central Facilities	20	N/A	N/A	N/A	0	20
TOTAL	1,165	N/A	N/A	N/A	740	425

An additional 883 acres of gross surface disturbance are projected over the next 20 years for future oil, natural gas and CO_2 activities and facilities (Tables 10 and 11). New roads and pipelines to service successful wells will account for 120 miles of new linear surface disturbance or 548 acres (Table 12). Of the 120 miles, 67 miles will be for roads, and 53 miles for pipelines.

The future net surface disturbance within the Monument is estimated to be approximately 681 acres (Table 13). This accounts for future reclamation of some existing and future projected wells, pipelines, access roads and facilities. To derive this figure, the following assumptions were made:

- All future dry holes will be immediately reclaimed, including wellpads and access roads;
- All future pipelines installed within the Monument will be immediately reclaimed;
- Thirty wells will be plugged and abandoned over the next 20 years, and the associated wellpads and access roads will be reclaimed;
- All future producing wells will have approximately one-third of the wellpad area reclaimed during the producing life of the well; and
- There will be no interim reclamation of the production facilities.

In summary, there are now 425 acres of net existing surface disturbance. Future gross disturbance will be 883 acres, and future reclamation will account for 312 acres over the next 20 years (Table 14). Future reclamation includes wellpads reclaimed after drilling and abandonment, or abandonment due to exhaustion of resources; roads associated with development and abandonment; and interim reclamation due to contraction of drilling pads to, only the necessary area needed to safely produce and maintain the well.

Table 10. Future gross surface disturbance for oil and natural gas.

Development Type	Number	Acres/Site	Gross Disturbance (acres)
Oil and Gas Well Pads	81.00	2.1	170.10
Pipelines[1]	11.54	2.0	23.08
30' wide Access Road[2]	20.25	2.0	40.50
50' wide Access Road[3]	60.75	3.3	200.48
Treatment Facilities	4.00	3.0	12.00
Treatment Facility Pipelines[4]	4.00	18.2	72.80
TOTAL	N/A	N/A	519.00

[1] Assumes 25 percent of successful wells will require a separate pipeline to tie in to existing infrastructure. The remaining 75 percent of successful wells will route pipelines along access roads. Average width of pipeline is assumed to be 30' [(81 wells)(57 percent) x 25 percent = 11.54 wells w/pipelines]. 57 percent of wells are estimated to be successful.
[2] Assumes 25 percent of 81 access roads are ~0.55 miles long and 30' wide w/o pipeline.
[3] Assumes 75 percent of 81 access roads are ~0.55 miles long and 50' wide with pipeline.
[4] Assumes each pipeline will be an average of five miles long and 30' feet wide (18.2 acres).

Table 11. Future gross surface disturbance for CO_2.

Development Type	Number	Acres/Site	Gross Disturbance (acres)
CO_2 Well Pads	40	3.5	140.00
Pipelines[1]	10	2.0	20.00
30' wide Access Road[2]	10	2.0	20.00
50' wide Access Road[3]	30	3.3	99.00
Treatment Facilities	4	3.0	12.00
Treatment Facility Pipelines[4]	4	18.2	72.80
TOTAL			363.80

[1] Assumes 25 percent of wells will require a separate pipeline to tie in to existing infrastructure. The remaining 75 percent of new wells will route pipelines along access roads. Average width of pipeline is assumed to be 30' [(40 wells) x 25 percent = 10 wells w/pipelines]. Estimate is 100 percent of wells will be successful.
[2] Assumes 25 percent of 40 access roads are ~0.55 miles long and 30' wide without pipeline.
[3] Assumes 75 percent of 40 access roads are ~0.55 miles long and 50' wide with pipeline.
[4] Assumes each pipeline will be an average of five miles long and 30' feet wide (18.2 acres).

Table 12. Future surface disturbance for oil, natural gas and CO_2 roads and pipelines.

Disturbance Type	Linear Miles	Acres
Roads[1] (long-term)	67	359
Pipelines[2] (short-term)	53	189
TOTAL	120	548

[1]Assumes 75 percent of the roads are 50' wide and 25 percent to be 30' wide.
[2]Assumes all pipelines are 30' wide and includes treatment facility pipelines.

Table 13. Future net surface disturbance.

Development Type	Existing Net Disturbance (acres)	Future Long-Term Disturbance (acres)	Plugged & Abandoned (acres)[1]	Future Net Disturbance (acres)
Existing Wells	151	N/A	83.0	68.0
CO_2 Well Pads	N/A	93.8	0.0	93.8
Oil and Natural Gas Well Pads	N/A	65.0	0.0	65.0
Pipelines	0	0.0	N/A	0.0
Access Roads	206	245.3	89.0	362.3
Treatment Facilities	48	24.0	N/A	72.0
Central Facilities	20	0.0	N/A	20.0
TOTAL	425	428.1	172.0	681.1

[1]Assumes reclamation of (30) "existing" wells and access roads over 20 years.

Most of the new surface disturbance will occur on the mesa tops, because access to canyon bottoms is restricted by the topography. Additionally, all the estimates for surface disturbance reflect the maximum for wellpads and treatment facilities. This should provide for a reasonable estimate of the upper limit of surface disturbance.

Seismic Surveys: Future seismic surveys in the Monument were estimated based upon input from several operators and reviewing past activity. The surface disturbance values reported here are only future estimates. Table 15 presents the associated surface disturbance from the 15 seismic surveys that are projected to occur over the next 20 years. These values were based on the North Mail Trail Seismic Survey EA (BLM 2002), which evaluated impacts associated with a vibroseis 3-D survey. Shot-hole surveys are expected to have a similar level of surface disturbance. Ten 2-D and five 3-D seismic surveys are proposed. Seismic surveys typically employ drilling, shooting charges (or vibroseis), and data collection via cables of geophones laid across the surface. Reclamation takes place immediately after the survey is completed. The seismic lines (disturbance) are roughly ten feet wide. Two-D surveys are conducted along single lines and 3-D surveys are laid out in a grid pattern. Both methods are employed to determine the

Table 14. Future net long-term surface disturbance.

Development Type	Gross Disturbance (acres)	Dry Holes[1]	Dry Hole Reclamation (acres)[2]	Interim Reclamation (acres)[3]	Long-term Disturbance (acres)
CO_2 Well Pads	140.0	0.0	0.0	46.2	93.8
Oil and Natural Gas Well Pads	170.1	34.8	73.1	32.0	65.0
All Pipelines	189.0	N/A	N/A	189.0	0.0
Access Road[4]	360.0	34.8	69.6	45.1	245.3
Treatment Facilities	24.0	N/A	N/A	N/A	24.0
TOTAL	883.1	N/A	142.7	312.3	428.1

[1] 43 percent of future oil and natural gas wells are estimated to be dry based on an overall success rate to date of 57 percent. For oil and natural gas [81 wells x 43 percent = 34.8 dry holes].
[2] Includes reclamation of well pads associated with dry holes.
[3] Assumes 33 percent of producing well sites will be reclaimed after drilling. Also, all pipelines are expected to be reclaimed soon after construction [81 wells - 34.8 wells = 46.2 producing wells], [(46.2 x 2.1 acres)(33 percent) = 32.0 interim acres] and [(46.2 x 2.1 acres)(67 percent) = 65.0 long-term acres]
[4] 25 percent of access roads are assumed to have average dimensions of 0.55 miles x 30' [(.55 mi = 2,904ft) x 30ft = 87,120ft^3]/43,560ft^3 = 2 acres. Ex: 34.8 x 2 $\cong$ 69.6 acres.
75 percent of access roads are assumed to have average dimensions of 0.55 miles x 50'. [(.55 mi = 2904ft) x 50ft = 145,200ft^3]/43,560ft^3 = 3.3 acres. Ex: 46.2 is (57 percent of 81 wells) x 3.3 (.75) = 114.35 acres. The 50' wide access roads will be reclaimed to 30' wide (45.1 acres reclaimed). Ex: 46.2 is (57 percent of 81 wells) x (3.3 - 2) (.75) = 45.1 acres.

Table 15. Future surface disturbance from seismic surveys.

Type of Seismic Surveys	Number	Miles^2/Survey	Average Length (miles)	Disturbance (acres)	Duration	Total Disturbance (acres)
3-D Seismic	5	15	N/A	900	Short-term	900
2-D Seismic	10	N/A	5	202	Short-term	202
TOTAL	15	15	5	1,102	N/A	1,102

depth and configuration of the underlying rock strata. The difference is that the output of a 2-D survey would be a cross section and 3-D would provide output similar to a topographic map.

The total estimated surface disturbance for future seismic surveys is 1,102 acres. This disturbance is short-term and will be immediately reclaimed after the surveys.

Air Quality and Emissions

The oil produced in the Monument is transported by truck to refineries in Bloomfield, New Mexico or Utah. A truck can carry 180 bbls of oil/trip. In 2002, average oil production in the Monument was 6,725 bbls/day, requiring approximately 37 truck trips/day to haul the produced oil. These truck trips occur on roads throughout the Monument. Many of the roads are unpaved, and the dust emissions can be estimated by multiplying the number of truck trips times the miles of gravel roads traveled/trip, and correcting for wet days, when dust is not emitted. Trucks

hauling produced water to disposal wells must also be counted in the emission inventory. Due to lack of better information from the current operators, it is estimated that, at the current level of production, approximately 40 truck trips/day are required for water gathering. At total of 77 truck trips/day are made throughout the Monument for oil and water transportation. Additional impacts will result from other uses such as recreation, residents, and agricultural activities.

Over the next 20 years, it is estimated that additional trips will be required for drilling and operating new wells. An average of 100 truck trips/day for the next 20 years is reasonable, and will account for increases in oil and water production, drilling rig transportation and supply, and other support services for constructing and operating wells (e.g., workover rigs). With respect to CO_2 production, the water is gathered by pipeline, with no associated trucking.

Natural gas production is gathered via flowline to a central compression facility, where it is dehydrated and then compressed for transport to other states. Compression power required for transmission is 1,100 horsepower (hp)/mcf/day of produced natural gas (Williams 2003).

Based on this figure, the compression power needs for 2002 were 400 hp to handle the production rate of 3,800 mcf/day. Peak compression requirements correspond to peak production, which occurred from 1994 through 1997, with over 8,500 mcf/day of natural gas produced. This required over 1,000 hp of compression power capacity. Although it is unlikely that this compression capacity remains installed at Monument facilities, the existing facilities can be upgraded to accommodate increased production, should this occur. Likewise, with decreasing production, horsepower requirements will decline and existing facilities will be modified to this demand.

For the purposes of this RFD, we estimated that eight new treatment and compression facilities will be built to accommodate ongoing production in the Monument. Four of these will support oil and natural gas production, and four will support CO_2 production. These eight new facilities will only be constructed when needed. The situation may arise where the production source is too far away from existing facilities for them to be of use. Other treatment and compression facilities may be constructed near the Monument boundaries, particularly if new oil and natural gas fields are discovered; however, these were not considered in our evaluation.

Compression and treatment facilities for CO_2 are electric powered.

A dry ice and compressed CO_2 plant near the Monument derives their power from low yield natural gas wells located on their leases, which are in the Monument. Emissions from this operation should be considered in an emission inventory.

Summary

The BLM estimates that 150 new wells will be drilled in the Monument over the next 20 years from approximately 121 wellpads. An additional eight compressor and gas treatment facilities will be required by the operators to transport gas from the Monument to interstate pipelines. Taking into consideration valid leases, an expanding market, and available acreage to drill, the BLM accepts these estimates as reasonable. Forty new CO_2 wells will certainly be drilled. An additional 29 CO_2 wells have a high probability of being drilled to expand pipeline capacity. Up

to 81 additional oil and natural gas wells may be drilled due to market demand and increasing prices. Initially future development will take place in the Flodine Park/Cannonball Unit area where a 3-D seismic study was recently completed.

Over the next 20 years, gross surface disturbance will be 883 acres and net disturbance will be 681 acres. This includes access roads, pipelines, wellpads and treatment/compressor facilities. Access roads and pipelines will account for 120 miles of linear surface disturbance (i.e., 548 acres). The 681 acres of net disturbance is 0.4 percent of the total land area in the Monument.

For air impacts, truck traffic and compression of gas are the primary emission sources. Over the next 20 years, these sources are expected to increase over their current levels. Truck trips will increase from 77/day to 100/day as more wells are drilled and begin operating. Although 150 new wells would require many more truck trips, we estimate that many existing wells would cease producing during the next 20 years, and that some of the 150 new wells would not be economic producers. The 100 trips/day accounts for drill rig transportation, as well as oil and water hauling.

Compressor emissions will increase as natural gas production increases. Given the projection of up to three new oil and natural gas wells/year, compression power needs will likely remain within the historic maximum of 1,000 hp for natural gas compression. CO_2 compression emissions will increase considerably if a natural gas electrical generating station is built to power compressors. New facilities will only be constructed when and if needed. The situation may arise where the production source is too far away from existing facilities for them to be of use. Other treatment and compression facilities may be constructed near the Monument boundaries, especially if new oil and gas fields are discovered.

Selected Definitions

Application for Permit to Drill (APD): The form and supplemental materials an oil, gas or CO_2 operator must submit for official approval to drill to drill for Federal fluid minerals.

bbl: A barrel which equals 42 gallons.

bbls: Barrels, each equal to 42 gallons.

bcf: A billion cubic feet.

Complex: A large scale field association.

D&A: A well which was drilled and abandoned.

Dry Hole: Any well that does not produce oil or gas in commercial quantities. A dry hole may flow water, gas, or even oil, but not in amounts large enough to justify production.

Note: a distinction can be made between no-show and non-economic wells that are abandoned. A no-show is a well drilled where no hydrocarbons are encountered. A non-economic well encounters hydrocarbons, but the volume or flow rate is not significant enough to warrant production.

Enhanced Oil Recovery (EOR): The introduction of artificial drive and displacement mechanisms into a reservoir to produce a portion of the oil unrecoverable by primary production methods.

Estimated Ultimate Reserves (EUR): An estimate of the ultimate amount of oil or gas that a well or field will produce. The method of determining these amounts can be based upon different analytical methods.

Fee: A term for distinguishing private lands (fee) from Federal or State lands.

Field: A geographical area in which a number or oil and gas wells produce from a continuous reservoir. A single field may have may have several separate reservoirs at varying depths.

Formation (fm): A bed or deposit composed throughout of substantially the same kind of rock; often a lithologic unit.

Injection well: A well through which fluids are injected into an underground stratum to increase reservoir pressure and to displace oil.

mcf : A thousand cubic feet.

Millidarcies: A unit of measure of permeability.

P&A: Plugged and abandoned.

psi: Pounds per square inch.

Permeability: A measure of the ease with which a fluid flows through the connecting pore spaces of a rock.

Pool: A subsurface accumulation of oil or gas in a porous and permeable rock.

Porosity: The ratio of the volume of empty space to the volume of solid rock in a formation indicating how much fluid a rock can hold.

Proven Reserves: Estimated quantities of liquids (i.e., oil and/or gas) that geological and engineering data demonstrate, with reasonable certainty, to be recoverable in future years from known reservoirs under existing economic and operating conditions.

Recompletion: After the initial completion of a well, the action and techniques of re-entering the well and redoing or repairing the original completion to restore the wells productivity.

Recoverable reserves: The quantity of oil or gas determined to be economically recoverable and available for delivery from a well or wells.

Reserves: The unproduced but recoverable oil or gas in a formation that has been proved by production.

Reservoir: A subsurface, porous, permeable rock body in which oil and gas have accumulated.

Right-of-Way (ROW): The legal right of passage over public land and privately owned property.

Split-estate: The situation that exists when surface rights ownership and the mineral rights ownership are not the same.

Stripper well (Stripper): A well nearing depletion that produces a very small amount of oil or gas, usually ten barrels/day or less.

Sundry Notice: Sundry Notices and Reports on Wells, Form 3160-5, A Department of the Interior/BLM form for operators to request permission to perform activities or to report the accomplishment of work relating to oil and gas activities.

Unit: The joining of all or substantially all interests in a reservoir or field, rather than a single tract, to provide for development and operation without regard to separate property interests. Also can be the area covered by a Unitization Agreement.

Unit area: The area described in an agreement as constituting the land logically subject to exploration and/or development under such an agreement (43 CFR).

Unitized land: Those lands and formations within a unit area which are committed to an approved agreement or plan (43 CFR).

Water Disposal Well: A well drilled or used for disposal of brines (production water) or other fluids in order to prevent contamination of the surface by such wastes.

Wildcat: An exploratory well drilled for oil and gas on a geologic feature not yet proven to be productive, or in a zone that has never produced, or is known to be productive in the general area.

References

Bureau of Land Management. 2002. North Mail Trail 3D Seismic Survey, Environmental Assessment CO-SJFO-01-081EA. San Juan Public Lands Center, Canyons of the Ancients National Monument.

Bureau of Land Management. 1990. BLM Handbook H-1624-1, Planning for Fluid Mineral Resources.

Cappa, J.A. and D.D. Rice. 1995. Carbon dioxide in Mississippian rocks of the Paradox Basin and adjacent areas, Colorado, Utah, New Mexico, and Arizona. *US Geological Survey Bulletin 2000-H.* Reston, VA.

Colorado Oil and Gas Conservation Commission website at http://oil-gas.state.co.us. 2003.

Four Corners Geological Society. 1978. *Oil and gas fields of the Four Corners area*. Volume I.

Gustafson, V.O. 1981. Petroleum geology of the Devonian and Mississippian rocks of the Four Corners Region. *Geology of the Paradox Basin.* Rocky Mountain Association of Geologists, Denver.

Kinder Morgan, Letter dated December 29, 2003; received January 2, 2004.

Minerals Management Service. Oil and Gas Operations Report (OGOR), Oil and Gas production is reported via: OGOR MMS Form 4054, Parts A, B, and C.

Nuccio, V.F., and Condon S.M., 1996. Burial and thermal history of the Paradox Basin, Utah and Colorado, and petroleum potential of the Middle Pennsylvanian Paradox Formation in Huffman, A.C. Jr., Lund, W.R., and Godwin, L.H., eds., Geology and resources of the Paradox Basin: *Utah Geological Association and [Durango, Colorado] Four Corners Geological Society Guidebook 25.* p. 57-76.

Oil and Gas Journal, June 30, 2003, Volume 101.

Oil and Gas Journal, January 5, 2004, Volume 102.

Personal Communication with Questar on Planning for Canyons of the Ancients National Monument. January 23, 2004.

Personal Communication with Robert L. Bayless on the Reasonable Foreseeable Development Scenario for Canyon of the Ancients National Monument. January 16, 2004.

Personal Communication with D.J. Simmons on Future Exploration and Development in Canyons of the Ancients National Monument. December 16, 2003.

Personal Communication with Pat Gallagher, BLM Colorado State Office on the Williams Production Company. 2003

PI/Dwights Plus on CD. 2003. IHS Energy. Houston, TX

Robert L. Bayless, Producer LLC, Letter dated November 19, 2003.

Scott, P.K. 2003. Paradox Basin, Colorado: Maps, Cross sections, and Database for oil, gas, and CO_2 Fields. *Colorado Geological Survey Resource Series 43*, Denver, CO.

Shell Oil Company. 1982. Structure on Leadville. *Structural Contour Map.*

Texas Natural Resource Code. 1978. § 86.002(4).
University of Texas at Austin. 1991. A Dictionary for the Petroleum Industry, First Edition, Petroleum Extension Service. Division of Continuing Education.

U.S. Geological Survey. 1995. Stratigraphic Column of the Paradox Basin Province (021). *USGS 1995 Geological Report*.

Wray, L.L., D.E. Eby, and T.C. Chidsey. 2002, Heterogeneous shallow-shelf carbonate buildups in the Paradox Basin, Utah and Colorado: Targets for increased oil production and reserves using horizontal drilling techniques. *Semi-Annual Technical Progress Report, October 6, 2001 – April 5, 2000.* US DOE, National Petroleum Technology Office. Tulsa, OK.