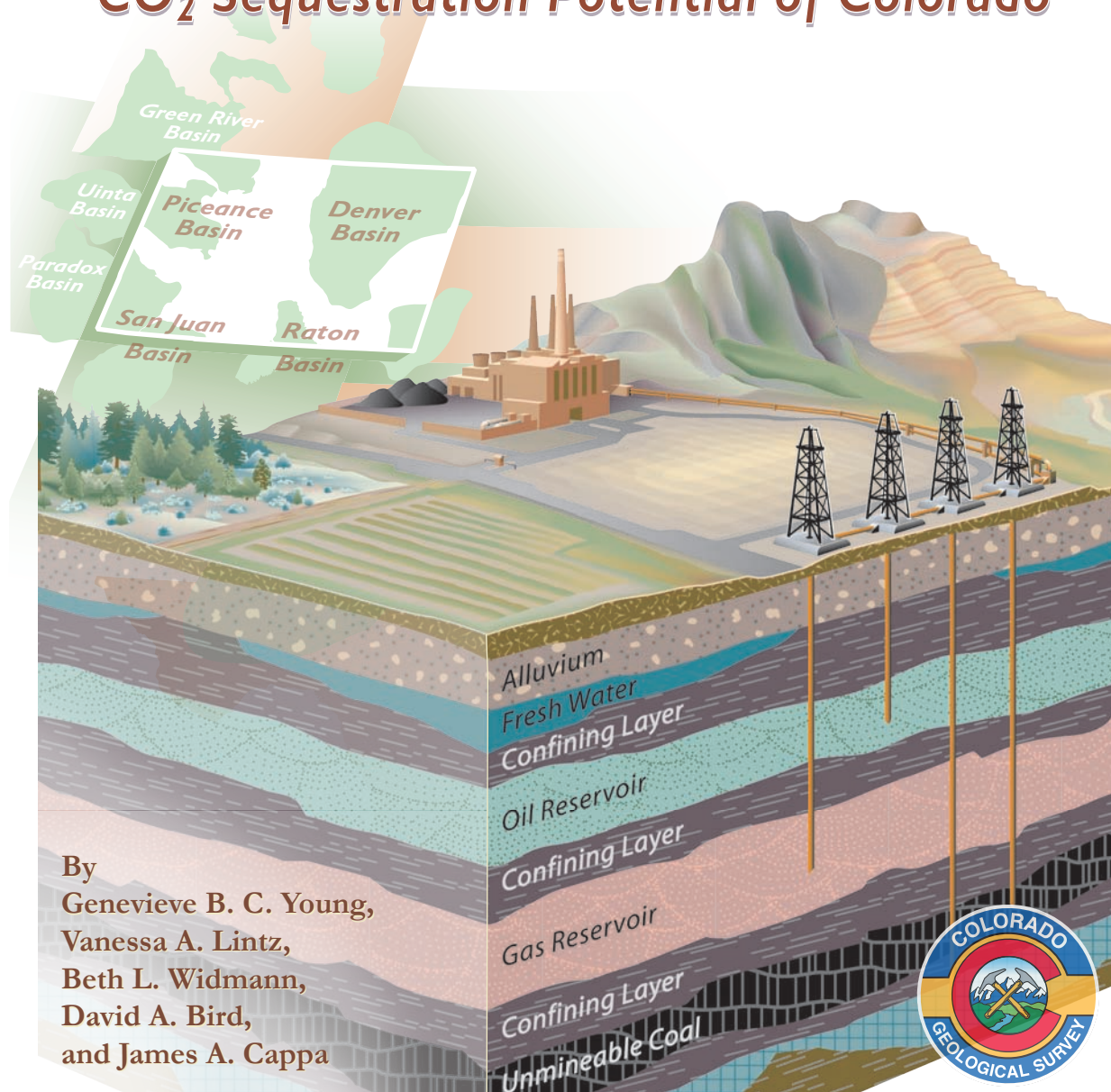


RESOURCE SERIES 45

CO₂ Sequestration Potential of Colorado



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CO₂ SEQUESTRATION POTENTIAL OF COLORADO

Abstract

The Colorado Geological Survey is a participant in the Southwest Regional Partnership on Carbon Sequestration project whose primary goal is to determine an optimum strategy for minimizing greenhouse gas intensity in the southwestern United States. The Southwest Partnership is led by the New Mexico Institute of Mining and Technology and comprises a large, diverse group of expert organizations and individuals specializing in carbon sequestration science and engineering, as well as public policy and outreach.

In 2000, CO₂ emissions were more than 92 million short tons in Colorado and are projected to increase by 2.4 percent per year through 2025. Nearly 76 percent of these emissions result from activities in the utility and transportation sectors. Power generation in the state relies primarily on coal and as a result, 42 million short tons of CO₂ or 46 percent of the total emissions in Colorado are emitted from power plants in the utility sector. These stationary point sources afford the possibility of capture and separation of CO₂ for transport to and storage at nearby “sinks”.

Although CO₂ sink potential is widely distributed across the state, characterization efforts focused on seven “pilot study regions” defined on the basis of maximum diversity in potential sequestration options relatively close to large CO₂ sources. Utilizing both geologic and mineralization options, carbon storage capacity within these regions is an estimated 720 billion short tons. With the availability of suitable technology, the pilot areas have the potential of providing a long-term storage solution based on 2000 CO₂ emission levels. The highest CO₂ sequestration capacity potential for Colorado lies within the oil, gas, coalbed, and saline aquifer reservoirs of the Denver, Cañon City Embayment, Piceance, and Sand Wash basins. Further site-specific investigations are required to determine both the technical and economic feasibility of implementing carbon storage projects in any one of these areas.

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ABBREVIATIONS

Abbreviation	Explanation	First Reference
AGRC	Automated Geographic Reference Center	1.4.3
APD	Application for permit to drill	3.1
Bcf	Billion cubic feet	1.4.2
C	Carbon	2.3
CBM	Coalbed Methane	1.4.2
CCS	Carbon Capture and Storage	8.6
CDPHE	Colorado Department of Public Health and Environment	2.2
CDWR	Colorado Division of Water Resources	1.4.2
CGS	Colorado Geological Survey	1.4
CH ₄	Methane	1.4.2
CO ₂	Carbon Dioxide	1.1
CO ₂ -ECBM	Carbon Dioxide Enhanced Coalbed Methane Recovery	4.2.2
CO ₂ -EOR	Carbon Dioxide Enhanced Oil Recovery	1.4.2
CO ₂ SIS	CO ₂ Sequestration Information System	3.3.2
COE	Cost of Electricity	8,3
COGCC	Colorado Oil and Gas Conservation Commission	1.4.2
COPD	Colorado Production Database	3.3.1
CS	Carbon Sequestration	1.1
CSEGR	Carbon Sequestration with Enhanced Gas Recovery	1.4.2
DOE	U.S. Department of Energy	1.1
ECBM	Enhanced Coalbed Methane Recovery	4.2.2
eGRID	Emissions & Generation Resource Integrated Database	1.4.1
EIA	Energy Information Administration	2.2
EOR	Enhanced oil recovery	1.4.2
EOS	Equation-of-state	3.3.4
EPA	Environmental Protection Agency	1.2

EPRI	Electric Power Research Institute	8.3
°F	Degrees Fahrenheit	
GASIS	Gas Information System	3.3.2
GDP	Gross Domestic Product	1.1
GHG	Greenhouse Gas	1.2
Giga	Billion	1.4.2
GIS	Geographical Information System	1.4.3
GSP	Gross State Product	1.2
GT	Gigatons	1.4.2
GW	Gigawatts	8.5
H ₂	Hydrogen	8.3
HHV	Higher Heating Value	8.3
HV	High volatile bituminous	4.4.2
HVA	High volatile A bituminous	4.4.2
IEA	International Energy Agency	8.3
IGCC	Integrated Gasification Combined Cycle	8.3
IPCC	Intergovernmental Panel on Climate Change	2.2
kW	Kilowatts	8.5
kWh	kilowatt-hour	6.2.3
MBtu	Thousand British Thermal Units	8.5
mD	Millidarcies	3.4.1
MIDCARB	Midcontinent Interactive Digital Carbon Atlas and Relational dataBase	1.4.2
MMBbls	Million Barrels	1.4.2
MMBtu	Million British Thermal Units	2.3
MMcfd	Million cubic feet per day	4.2.2
MMP	Minimum Miscibility Pressure	3.2
MMt	Million Metric Tonnes	1.4.1
MT	Megatons; 1 million short tons	1.4.1
MV	Medium volatile bituminous	4.4.3
MW	Megawatts	2.5
MWh	Megawatt-hour	2.5
N ₂	Nitrogen	4.2.2

NETL	National Energy Technology Laboratory	1.1
NGCC	Natural Gas Combined Cycle	8.3
NMT	New Mexico Institute of Mining and Technology	1.2
OC	Oxygen Combustion	8.3
OOIP	Original oil-in-place	3.2.1
PC	Pulverized Coal	8.3
psi	Pounds per square inch	1.4.2
PSR	Pilot Study Region	5.1
RMAG	Rocky Mountain Association of Geologists	1.4.2
Scf/ton	Standard cubic feet of gas per short ton of coal	4.4.1
Sub	Subbituminous	4.4.1
SWP	Southwest Regional Partnership	1.2
Tcf	Trillion cubic feet	4.1
TBEG	Texas Bureau of Economic Geology	1.4.2
Tons	Short Tons (2,000 pounds per ton)	
Tonnes	Metric Tonnes (2,204 pounds per tonne)	1.2
TPS	Total Petroleum System	3.4.2
TS	Terrestrial sequestration	1.3
UGS	Underground Gas Storage	1.4.2
USGS	U.S. Geological Survey	1.4.2

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

The U.S. Department of Energy's Carbon Sequestration (CS) program directly supports the President's Global Climate Change Initiative designed to reduce the carbon intensity of the U.S. economy 18 percent by 2012 (Bush, 2002). CS complements energy efficiency and low-carbon fuel greenhouse gas reduction efforts by capturing and storing greenhouse gases, primarily carbon dioxide (CO₂), which is the predominant greenhouse gas associated with global warming based on volume emitted to the atmosphere. The impact of the CS program will be to reduce the 201 tons of greenhouse gas emissions per million dollars of gross domestic product (GDP) in 2002 to 166 tons per million dollars GDP by 2012 (Scott Klara, National Energy Technology Laboratory, written communication, 2003). To place this goal in context, this reduction would be equivalent to taking an estimated 70 million cars off the road assuming 5 tons of CO₂ emissions per year for newer model cars.

In August 2003, the U.S. Department of Energy (DOE) and its National Energy Technology Laboratory (NETL) established seven regional partnerships in five geographic areas across the U.S. to become the centerpiece of the CS program (fig. 1.1). These partnerships form a nationwide network for the purpose of evaluating the most suitable carbon sequestration methods for specific areas of the country. The partnerships are comprised of 154 government and non-government organizations in 40 states, three Indian Nations, and two Canadian provinces. (More information is available at http://www.netl.doe.gov/technologies/carbon_seq/partnerships/partnerships.html)

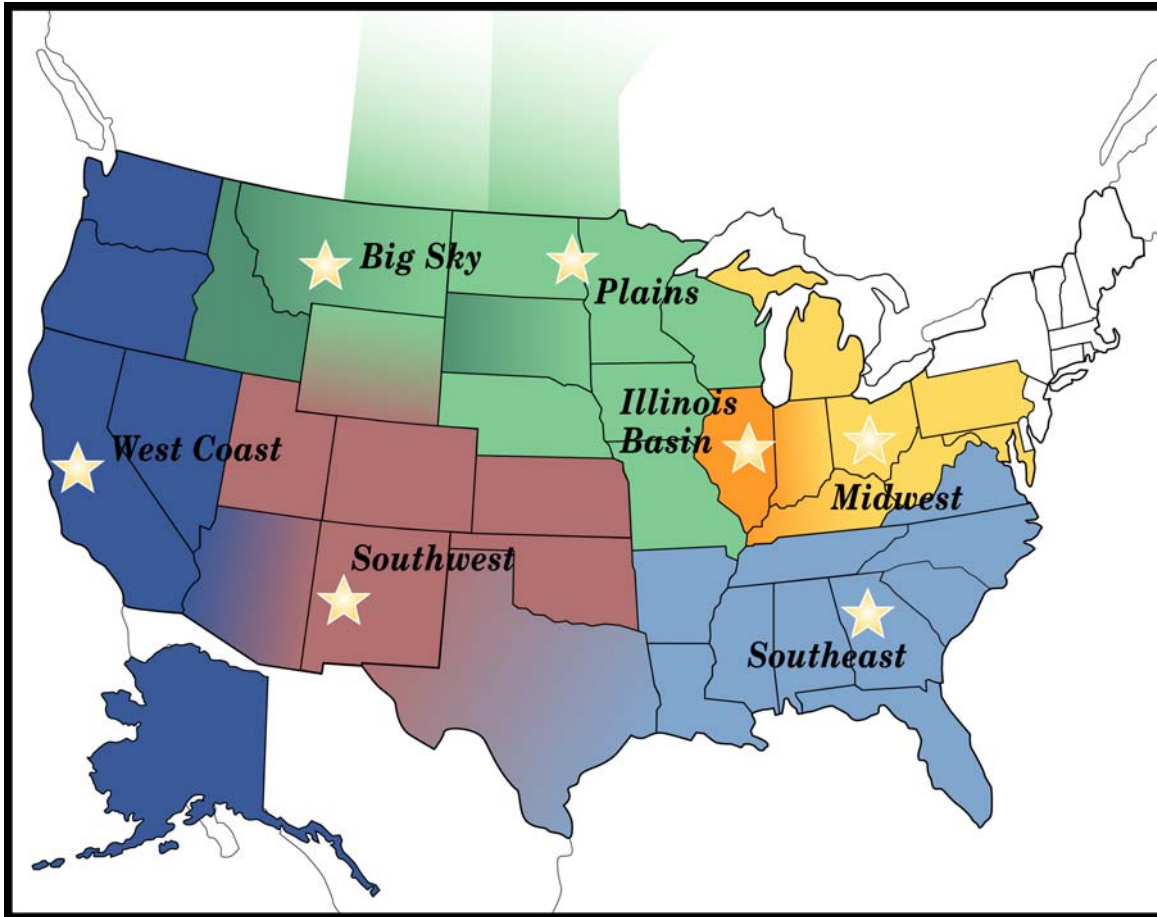


Figure 1.1: Seven regional partnerships formed by U.S. DOE and NETL in August 2003 for the evaluation of CO₂ sequestration methods (*modified from Scott Klara presentation to NETL May 2004*). The yellow stars designate the location of each partnership lead: West Coast, California Energy Commission; Southwest, New Mexico Institute of Mining and Technology; Big Sky, Montana State University; Plains, University of North Dakota, Energy and Environmental Research Center; Illinois Basin, University of Illinois, Illinois State Geological Survey; Midwest, Battelle Memorial Institute; Southeast, Southern States Energy Board.

The partnerships are tasked with (1) identifying all suitable sources and sinks for their specific regions, (2) creating action plans for regulatory, liability, environmental, and outreach issues, (3) establishing monitoring and verification protocols, (4) validating sequestration technology and availability of infrastructure, and (5) determining the benefits of sequestration within their respective regions.

DOE is utilizing a two-phased approach for the project - Phase I for planning and Phase II as a proof-of-concept or deployment phase. Phase I consisted of seven partnership projects of 18- to 24-month duration beginning in

late 2003. DOE funded each project with about \$1.5 million with an overall 40 percent cost share requirement from the partnerships. During this phase, the partnerships evaluated various sequestration technologies that have emerged over the past few years. They also initiated study of the kinds of regulations and infrastructure that might be required for wide-scale use of carbon sequestration.

Phase II is budgeted for about \$1.5 to \$2.5 million per year per partnership for a period of four years with a minimum 20 percent cost share requirement from all partners. During this phase, dozens of sequestration pilot projects recommended for small-scale validation testing under Phase I will be deployed across the country beginning in early 2006. Each of these projects will continue to focus on regulatory and infrastructure requirements, such as environmental permitting.

1.2 SOUTHWEST PARTNERSHIP REGION

The Southwest Regional Partnership's (SWP) primary goal is to determine an optimum strategy for minimizing greenhouse gas intensity in the southwestern portion of the U.S. (fig. 1.1, brown-shaded area). The SWP is led by the New Mexico Institute of Mining and Technology (NMT) and comprises a large, diverse group of expert organizations and individuals specializing in carbon sequestration science and engineering, as well as public policy and outreach. These partners include 21 state government agencies and universities, five major electric utility industries, several oil, gas and coal companies, three federal agencies, the Navajo Nation, and several non-government organizations (table 1.1).

Table 1.1: Partners in the Southwest Regional Partnership

State Partners	Industry Partners
<i>Arizona Universities & Government</i>	<i>Power Utilities</i>
Arizona Geological Survey	Pacificorp
Arizona State University	Public Service Co. of New Mexico (PNM)
	Intermountain Power Agency
<i>Colorado Universities & Government</i>	Tucson Electric Power
Colorado Geological Survey	Oklahoma Gas & Electric
	<i>Energy Providers (Oil, Gas, Coal)</i>
<i>New Mexico Universities & Government</i>	Yates Petroleum, ChevronTexaco
New Mexico Oil Conservation Division	Marathon, Occidental Permian
New Mexico Bureau of Geology	ConocoPhillips, Burlington
New Mexico Environmental Department	
New Mexico Institute of Mining and Technology	<i>Gas Infrastructure (CO₂ Pipelines)</i>
New Mexico State University	Kinder Morgan
Dine College (Navajo Nation)	
	<i>U.S. Federal Government Partners</i>
<i>Oklahoma Universities & Government</i>	Los Alamos National Laboratory
Oklahoma Geological Survey	Sandia National Laboratory
University of Oklahoma	U.S. Department of Agriculture
Oklahoma State University	
Sarkey's Energy Center	<i>Various Additional Partners</i>
	Navajo Nation
<i>Utah Universities & Government</i>	New Mexico Oil and Gas Association
Utah Geological Survey	Gas Technology Institute
University of Utah	Electric Power Research Institute
Utah State University	Interstate Oil & Gas Compact Commission
Utah AGRC	Center for Environmental Economic Develop
Utah Division of Air Quality	Advanced Resources International
Utah Energy Office	Western Governors Association
Utah Division of Oil, Gas & Mining	Petroleum Recovery Research Center
	Waste-Management Education & Research

In the absence of action, annual CO₂ emissions in the SWP region are expected to rise from 500 million tons per year (2001) to nearly 750 million tons per year by 2012 (McPherson, 2003). The region can offset much of this growth through various sequestration technologies. The region contains the principal CO₂ pipeline infrastructure in the country; it has the potential to offset natural CO₂ production from reservoirs with flue gas CO₂ sequestration from the numerous large coal-fired plants, and diverse terrestrial, geologic, and mineralization options are available in the region.

The SWP has developed the framework necessary for assessing optimum sequestration strategies for the Southwest Region. Primarily, the approach includes (1) dissemination of existing regulatory/permitting requirements, (2) educating the public about possible sequestration methodologies and assessing the public's knowledge and acceptance, and (3) evaluation and ranking of the most appropriate sequestration technologies for capture and storage of CO₂ in the Southwest Region. In addition, the Partnership has identified the potential gaps in monitoring and verification approaches needed to validate long-term storage efforts.

Figure 1.2 shows an approximate boundary for the Southwest Region and indicates major CO₂ emissions sources, existing CO₂ pipelines, and prospective geologic sequestration targets (major sedimentary basins). The Environmental Protection Agency (EPA) has funded comprehensive reviews of greenhouse gas (GHG) emissions from four of the states comprising the SWP region (U.S. Environmental Protection Agency, 2004c). The EPA-funded reviews show that 95-99 percent of all CO₂ emissions in the region are from fossil fuel combustion. In 2000, more than 320 million tons of emissions came from the nearly 70 power plants located within the region; about 25 percent of the CO₂ emissions were from the transport sector.

The economic aspects of carbon emissions in the region also play a critical role. Figure 1.3 illustrates the trends in GHG intensity (metric tonnes carbon equivalent per million gross state product (GSP) dollars) for the Southwest Partnership Region (McPherson, 2003). The national average in 2002 was 185 carbon equivalent per GSP. The Southwest Region is above average because it consumes a large amount of fossil fuels, often for the export of electricity generated in the region. Between 1993 and 2000, the regional average GHG intensity declined 22 percent, largely because of rapid economic growth.

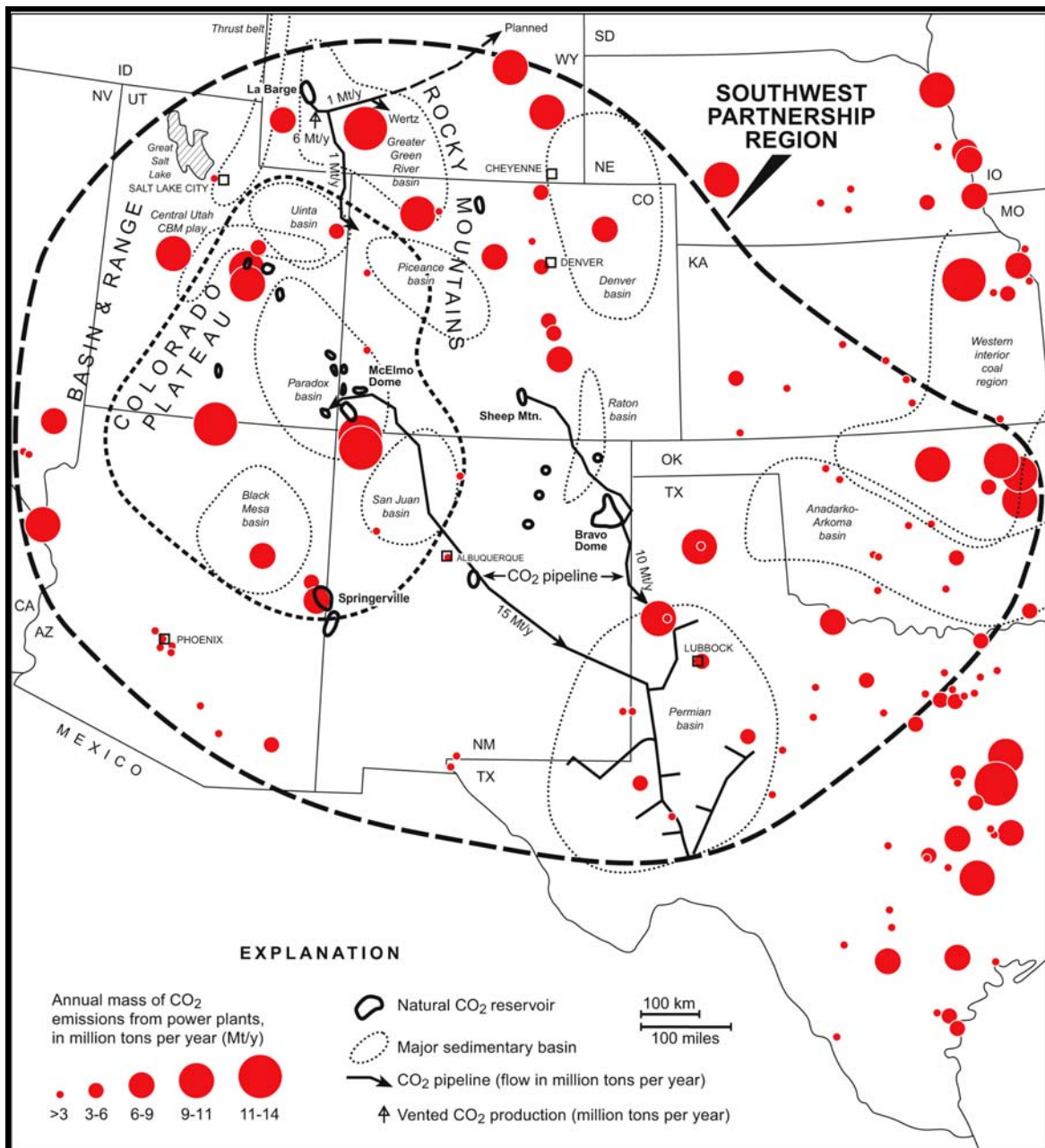


Figure 1.2: Map of the Southwest Region (Allis and others, 2003).

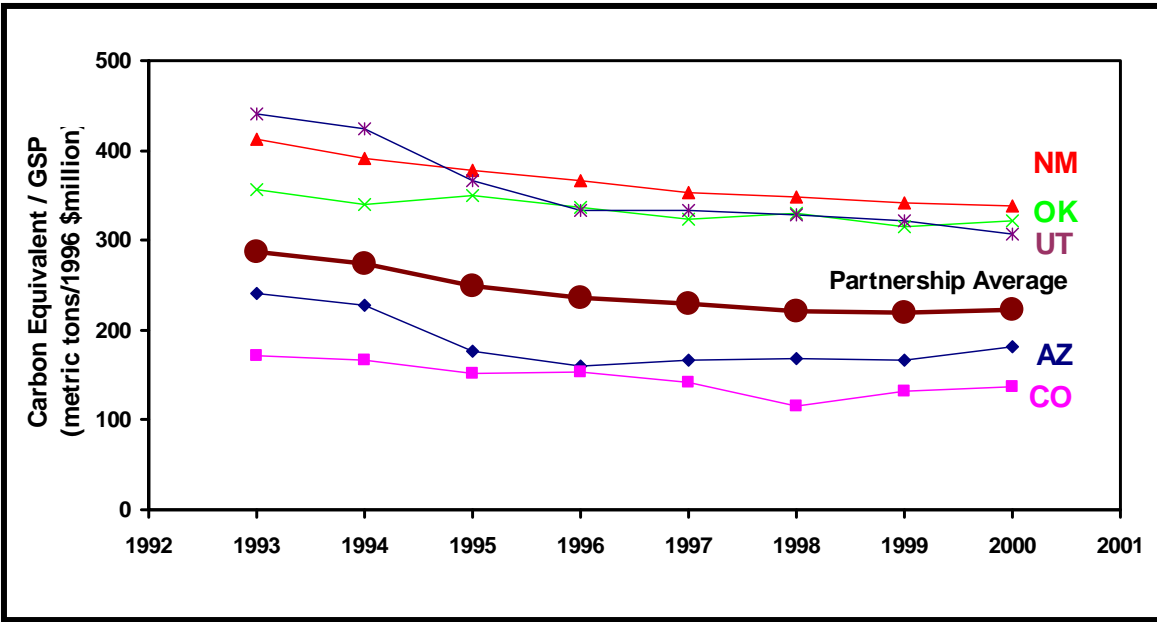


Figure 1.3: Trends in greenhouse gas intensity in the Southwest Region (Brian McPherson, NMT, written communication, 2003; modified after Allis and others, 2003). New Mexico (NM), Oklahoma (OK), Utah (UT), Arizona (AZ), and Colorado (CO), Gross State Product (GSP).

1.3 SEQUESTRATION THEMES

Carbon sequestration options assessed for the Southwest Region fall into three broad categories - geologic, terrestrial, and mineralization engineering (fig. 1.4). Geologic storage options in the region include deep unmineable coal beds, natural gas and CO₂ fields, depleted and marginal oil fields, and deep saline aquifers. One option that the Partnership has examined is the viability of supplanting the CO₂ currently produced from natural CO₂ reservoirs (used for improved oil recovery and enhanced coalbed methane applications) with anthropogenic power plant CO₂. In some parts of the Southwest Region it is important to evaluate the tradeoffs associated with using saline aquifers as CO₂ sequestration reservoirs when they might ultimately be needed as a source of potable, post-desalination water for human consumption in this rapidly growing region.

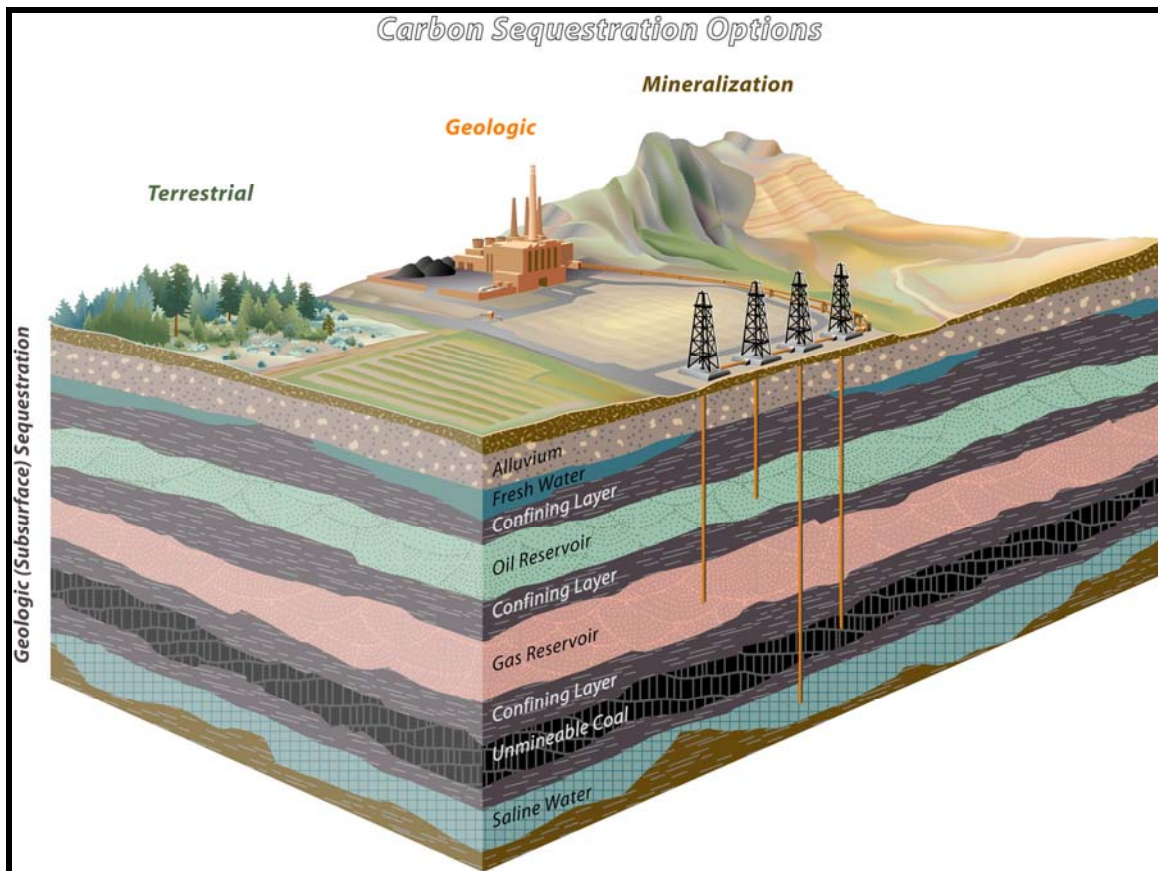


Figure 1.4: Sequestration themes evaluated for the Southwest Region (modified from Brian McPherson, NMT, written communication, 2003).

Terrestrial sequestration (TS) can play an important role in mitigating climate change. This option involves the transfer of carbon from the atmosphere to soil and vegetation via natural processes such as photosynthesis, humification, and aggregation. Although carbon dynamics have been explored at small scales, integrating TS into regional GHG management has received little attention. Exploiting terrestrial sinks is an attractive policy alternative (results can be achieved quickly, technologies are compatible with existing land management practices, delivery infrastructure is in place), but achieving the potential requires thorough economic, social, and biological analysis. Ownership includes both private and public lands managed by federal and state agencies, suggesting outreach must be broad-based, flexible, and integrated with existing programs. Land cover varies considerably, from deciduous forest to desert and coniferous forests, creating a unique potential to capture and store carbon, dictating

application of robust land management principles. Although terrestrial CO₂ sequestration appears to be a viable alternative in several parts of the Southwest Region, the Partnership recognizes that the rate of CO₂ emissions caused by drought-related forest fires and wind dispersal of cropland soil may increase under a range of dryer-than-usual climate futures.

CO₂ mineralization is a novel concept for binding CO₂ in a solid form, which eliminates the need for long-term monitoring and any concerns over the long-term fate of the CO₂. Carbon dioxide mineralization is an ongoing natural process, but an engineered process that can be implemented at a meaningful rate and scale remains an active research challenge. Although not fully realized as an operational approach, two mineralization processes are actively being investigated. One process involves extracting divalent cations from silicates using ultramafic and mafic igneous rocks (e.g., as occur in the Four Corners area of the Southwest Region). The other process involves extracting divalent cations from brines, which could be extracted either from the deep basins of the region or from the produced waters associated with the production of oil and gas. The Partnership's approach for the assessment of the CO₂ mineralization option focuses on characterizing the location and volumes of potential subsurface mineralization storage sites provided by ultramafic and mafic rocks and brines. The Partnership used available publications and databases detailing size and characteristics of the resources to estimate potential carbon storage capacity and potential value-added byproducts (which include mineral carbonates for silicate mineralization and potable water for brine mineralization).

Environmental and social consequences are associated with each of these options. Quantifying the consequences is challenging because complex interrelationships link the economy, energy production, population growth, greenhouse gas emissions, and the environment. The SWP developed a dynamic simulation model to quantitatively compare alternative sequestration technologies relative to their associated environmental risks, monitoring and verification requirements, life-cycle cost, and applicable regulatory and permitting constraints. The resultant decision model provides: (1) scenario development

where policy makers and regulators explore a range of “what if” scenarios, (2) constituency development wherein industry representatives and other partners can examine the scenario results as a test of their viability, and (3) outreach and education where the model can be taken directly to the public and used to improve their understanding of CO₂/energy cycle issues and complexity, explain the decision process, and be directly engaged in evaluating proposed sequestration options. (Refer to the SWP website for further details [http://southwestcarbonpartnership.org/.](http://southwestcarbonpartnership.org/))

1.4 CARBON STORAGE IN COLORADO

The Colorado Geological Survey (CGS) participated in Phase I of the Southwest Regional Partnership on Carbon Sequestration Project where the primary objective was to characterize the CO₂ environment throughout the southwestern region of the U.S. For the State of Colorado, this task consisted of the following three subtasks: (1) assemble CO₂ source data, (2) assemble CO₂ sink data, and (3) estimate carbon storage capacity. These results were incorporated into a geographical information system for public-access and regional-based analysis. The summary that follows briefly discusses the methodology, data sources, and findings for each of these subtasks.

1.4.1 CO₂ Source Data

In 2000, CO₂ emissions were more than 92 million short tons (MT) in Colorado and are projected to increase by 2.4 percent per year through 2025 (U.S. Environmental Protection Agency, 2004a). Nearly 76 percent of these emissions result from activities in the utility and transportation sectors. Power generation in the state relies primarily on coal and as a result, 42 MT of CO₂ or 46 percent of the total emissions in Colorado are emitted from power plants in the utility sector (U.S. Environmental Protection Agency, 2004a). With the application of the appropriate technology, these stationary point sources afford the possibility of capture and separation of CO₂ for transport and storage at nearby “sinks”.

The sequestration capacity calculations summarized below assume an anthropogenically-sourced CO₂ that has been “purified” for enhanced recovery use and/or longer-term storage. However, the combustion of fossil fuel produces a contaminated flue gas that is approximately 80 percent N₂ and only 20 percent CO₂ by volume. There is an investment required to capture, separate, transport, and sequester the CO₂. Depending on the technology selected, the average cost of carbon capture and storage is approximately \$55 per metric tonne for avoided CO₂. The high degree of variability in these costs (\$23 to \$84 per metric tonne avoided CO₂) dramatically highlights the need for site-specific analysis in the selection of an appropriate technology for fully integrated carbon capture and storage projects.

The primary source of the CO₂ emission data for this project was the *Emissions & Generation Resource Integrated Database* (eGRID), which is maintained by the Office of Atmospheric Programs at the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 2004c).

1.4.2 CO₂ Sink Potential

Although CO₂ sink potential is widely distributed across the state, data collection focused on seven primary Pilot Study Regions (fig. 1.5).

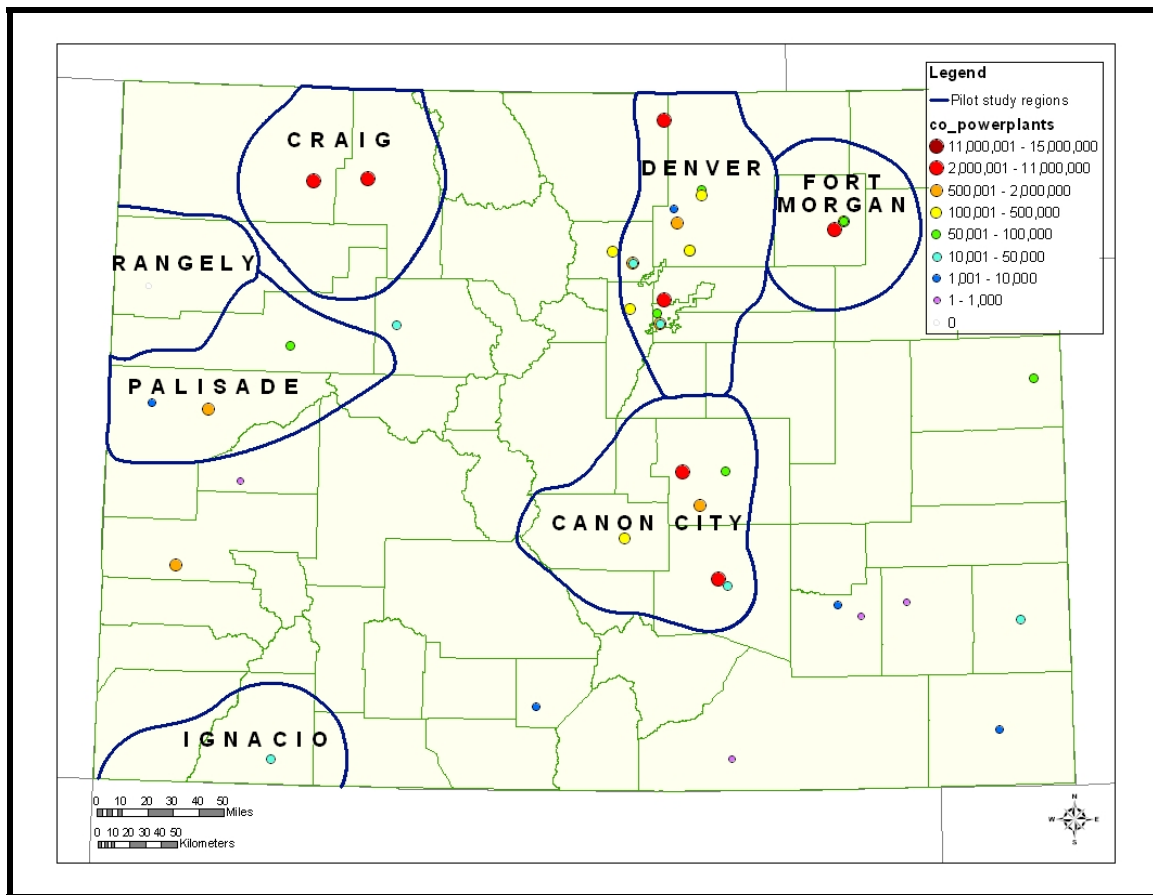


Figure 1.5: General outline of source areas identified for Colorado.

These study regions were defined based on the maximum diversity in potential sequestration options within close proximity to CO₂ sources; that is, within a 30 to 40 mile radial distance of one or more power plants. The sequestration options evaluated for Colorado include oil and gas reservoirs, underground gas storage facilities, natural CO₂ fields, coalbed reservoirs, deep saline aquifers, and advanced mineralization processes. Table 1.2 summarizes the CO₂ emissions for 2000 and the potential CO₂ sequestration capacity for each of the sequestration options in each of the pilot study regions. The emissions are not for the entire state; they represent the aggregate totals estimated for the individual pilot study regions (refer to table 2.1 in Section 2.0).

Table 1.2: CO₂ sequestration capacities in million short tons estimated for Colorado

Pilot Study Regions	2000 Emissions	Geologic			Mineralization		Total Capacity
		Oil & Gas	CBM	Saline Aquifers	Silicates	Produced Waters	
Cañon City	9.4	0	493	122,118	2,200	0	124,811
Craig	14.4	123	11,059	46,209	30,000	0	87,391
Denver	14.1	557	602	129,138	0	<0.001	130,297
Fort Morgan	4.9	164	0	43,770	0	<0.001	43,934
Ignacio	31.5	186	2,809	92,142	0	0	95,137
Palisade	0.8	116	1,798	132,330	200	<0.001	134,444
Rangely	3.4	740	1,037	102,579	0	0	104,356
Total	78.5	1,886	17,798	668,286	32,400	0	720,370

Utilizing both geologic and mineralization options, the preliminary forecast for CO₂ sequestration within the seven primary source areas is more than 720 billion tons (720 gigatons or GT). These areas have the potential of providing several hundred years of carbon storage based on 2000 emission levels. The highest CO₂ sequestration capacity potential for Colorado lies within the Denver Basin and Cañon City Embayment east of the Rocky Mountains, and within the Piceance and Sand Wash basins in northwestern Colorado.

The Denver and Rangely study regions provide the greatest potential for carbon storage utilizing oil and gas reservoirs; their combined carbon storage is estimated at 1.3 GT or nearly 70 percent of the total oil and gas sink potential for Colorado. The Craig study region is estimated to provide more than 11 GT of carbon storage due to the vast coal resources in the area. When combined with the coal resources of the Ignacio and Palisade study regions, the carbon storage potential for these three regions exceeds 15 GT or approximately 88 percent of the total coalbed methane (CBM) storage potential for Colorado. The Cañon City, Denver, and Palisade study regions have very similar carbon storage capacities estimated for the deep saline aquifers that occur in these areas. With more than 120 GT each, the carbon storage for these three regions represents more than half of the saline aquifer potential for Colorado. The Craig study

region provides the greatest mineralization potential through carbonation of silicate minerals. Preliminary estimates exceed 32 GT in storage capacity if mineralization engineering technology were commercially available.

Oil and Gas Reservoirs

There are approximately 1,400 oil and gas fields in Colorado; about 223 of these fields constitute large-volume producers; that is, cumulative production exceeds 1 million barrels (MMBbls) of oil and/or 10 billion cubic feet (Bcf) of gas. More than half of these large-volume producing fields (122) are located within 30 miles of a large CO₂ point source consisting of one or more coal-burning power plants. All of these 122 large-volume fields produce from oil and gas reservoirs that are deep enough to maintain CO₂ at supercritical conditions; that is, average reservoir depth exceeds 3,000 feet, which is sufficient to maintain CO₂ at a pressure and temperature of 1,000 psi and 90 °F, respectively. At this pressure and temperature, the density of CO₂ exceeds that of gas, oil, or water, which facilitates its containment in the subsurface.

A minimum level of data has been compiled on all oil and gas fields in Colorado, consisting primarily of location, geologic age, production, discovery date, and depth. Where data are available in the public domain, additional reservoir properties such as porosity, permeability, gas and oil composition, and fluid properties have also been compiled, particularly for those reservoirs within the seven pilot study regions. Data sources consisted of the Colorado Oil and Gas Conservation Commission (COGCC), PI/Dwights, U.S. Department of Energy, and state geological survey publications.

The estimate of CO₂ sequestration capacity for oil and gas reservoirs in the seven source areas is 1,886 MT with nearly 70 percent of that capacity contained in the Denver and Rangely source areas (table 1.2). This estimate is based on cumulative production through December 2004. Estimating CO₂ storage capacity for oil and gas reservoirs was accomplished by calculating the equivalent mass of CO₂ that is required to replace the reservoir volume voided by production. This CO₂ capacity calculation for Colorado should be considered

conservatively low due to the significant underestimation of water production from oil and gas reservoirs for the state.

Recent work by Advanced Resources International (ARI) suggests that 510 to 580 MMBbls of oil may be economically recovered from potential future enhanced oil recovery projects using CO₂ flooding (CO₂-EOR) in 12 of Colorado's major oil reservoirs (U.S. Department of Energy, 2006). These EOR projects would not only provide suitable longer-term sequestration opportunities but would also result in increased production to offset costs.

Underground Gas Storage

In 2004, Colorado had nine underground gas storage (UGS) facilities in operation, providing a total working gas storage capacity of 45.3 Bcf (American Gas Association, 2004). Most of these are located in the Denver and Piceance basins. In addition to working gas volumes, UGS facilities require base gas that in Colorado ranges from 17 to 163 percent of working gas.

Current UGS facilities in Colorado have nearly 48 Bcf committed in base gas representing a significant portion of total project investment. Some of these facilities may be suitable to base gas reductions via CO₂ replacement. Up to 4.4 MT of CO₂ would be required to offset the current base gas levels in Colorado, assuming complete replacement of existing base gas volumes. If this replacement is linked with a 30 percent increase working gas, the current 45.3 Bcf could potentially be increased to 58.9 Bcf.

Natural CO₂ Fields

Large, naturally-occurring, geologic deposits of carbon dioxide are found in three of Colorado's sedimentary basins – the Paradox, Raton, and North Park (fig. 1.2). The resources of the Paradox and Raton basins provide low-cost sources of high-pressure CO₂, primarily for EOR projects in the Permian Basin of New Mexico and Texas. In this basin alone, approximately 50 projects produce an incremental 145 MMBbls of oil per day, more than 80 percent of the North

American enhanced oil produced from CO₂ floods in 2004 (Cappa and others, 2005).

An extensive CO₂ pipeline and re-injection infrastructure system exists throughout the Permian Basin, making it attractive for expanding or starting new projects. High-pressure pipelines supply CO₂ from natural source fields at Bravo Dome in northern New Mexico, and McElmo Dome and Sheep Mountain in southern Colorado. Shell's completion of the pipeline out of McElmo Dome in 1983 significantly increased the value of the naturally occurring CO₂ reserves in Colorado. In addition to EOR applications, CO₂ is used in welding, the manufacture of dry ice, and the food and beverage industry.

Colorado's production of natural CO₂ has averaged 300 Bcf per year since the mid-1980s. Representing an annual equivalent of 18 MT, economic sources of anthropogenic CO₂ would have considerable commodity value and would have the potential to offset depletion of existing natural deposits.

Coalbed Reservoirs

Deep unmineable coal for Colorado is defined as coal-bearing formations occurring between 2,000 and 7,500 feet of depth. Coal parameters such as rank, gas content, ash and moisture content were compiled from U.S. Bureau of Mines data, Gas Research Institute reports, and state geological survey publications. The vast majority of coals in the state are bituminous in rank, which makes them suitable for enhanced coalbed methane recovery and carbon sequestration. The estimate of CO₂ sequestration capacity for coalbed methane reservoirs in the seven pilot study regions is almost 18 MT with nearly 80 percent of that capacity associated with the Iles-Williams Fork-Fort Union coals of the Sand Wash Basin (Craig Pilot Study Region) and the Fruitland coals of the San Juan Basin (Ignacio Pilot Study Region) (table 1.2). This estimate of capacity was made by applying a carbon dioxide/methane (CO₂/CH₄) replacement ratio based on coal rank and a replacement efficiency of 65 percent. In reality, the physics are far more complicated than this and require a reservoir simulator to calculate more accurately.

Deep Saline Aquifers

The criteria used to select water-bearing formations suitable for CO₂ sequestration in deep saline aquifers included lithology consisting primarily of sandstone or other rock types with sufficient porosity and permeability, depth exceeding 3,000 feet (to maintain supercritical conditions and to minimize the possibility that the formation would be developed for future water resources), salinity exceeding 1,000 ppm (again, to minimize the possibility that the formation would be developed for potable water sometime in the future), and the presence of an overlying formation that would function as a top seal to prevent vertical migration of injected CO₂. Most of the formations evaluated have had some associated oil or gas production. This implies the existence of a long-term structural or stratigraphic trapping mechanism that may decrease the possibility of migration of injected CO₂ to the surface or other unintended geological units. Data sources consisted of Colorado Oil Gas Conservation Commission (COGCC), Colorado Division of Water Resources (CDWR), and publications from the Rocky Mountain Association of Geologists (RMAG), Texas Bureau of Economic Geology (TBEG), U.S. Geological Survey (USGS), and state geological surveys.

The amount of carbon that a given formation may sequester was calculated using a volumetric method. The capacity was adjusted assuming that the efficiency of the storage process would vary between one and four percent. (The values for saline aquifers summarized in table 1.2 reflect an efficiency factor of four percent.) Thus, the estimates should be considered conservative. The calculation makes no distinction between CO₂ that is stored as an immiscible phase within a specified brine formation, CO₂ that is stored as a dissolved phase in the brine, and CO₂ that is precipitated as minerals. However, displacement of brine in the pore volume by immiscible CO₂ is the fundamental mechanism implicit in the calculations. The estimate of CO₂ sequestration capacity for deep saline aquifers in the seven pilot study regions is 668,286 MT with about 57 percent of that capacity contained in the Cañon City, Denver, and Palisade source areas (table 1.2). This capacity estimate is limited to only that portion of

these areally extensive aquifers that lie within a 30 mile radius of the primary CO₂ sources. In most cases, the carbon storage capacity of these vast deep saline aquifers will be much greater when not screened for distance. However, further study is required to develop a better understanding of the distribution of trap mechanisms needed to contain injected CO₂.

Mineralization

The primary goal of the mineral carbonation process is to sequester large amounts of carbon dioxide through carbonation of silicate minerals. Although there are numerous naturally occurring silicate minerals in the earth's crust, research for mineral CO₂ sequestration has focused primarily on olivine, serpentine, and wollastonite; silicate minerals that are rich in magnesium or calcium. In Colorado, these minerals are prevalent in mafic and ultramafic rocks such as serpentinite, peridotite, dunite, gabbro, and to a lesser extent, basalt and alkalic igneous rocks. In the industrial sector, waste materials such as coal fly ash or municipal solid waste incinerator bottom ash, asbestos waste, and metal slag are potential alternative feedstocks. Mineral silicates are a promising option for CO₂ sequestration in Colorado. Given current technology, silicate ore contained within the Cañon City, Craig, and Palisade source areas could sequester a total of 32,400 MT of CO₂ assuming 15 to 20 percent efficiency and subtracting CO₂ emitted during the sequestration process (table 1.2). Continued research and technological advances are needed before this process becomes a cost-effective and leading contender in the pool of technologies available for CO₂ sequestration.

Waters produced in association with oil and gas extraction are also a potential source of cations, particularly calcium, for mineral carbonation. However, preliminary calculations indicate that the water needed to sequester CO₂ emissions in a given region far exceeds current produced water volumes, and sequestration via this method is not likely to be practical. Even assuming 100 percent efficiency, the volume of water produced in Colorado could only sequester about 25,000 short tons of CO₂ (table 1.2).

1.4.3 Public-Access GIS Database

All characterization data gathered during completion of the initial task of the Phase I project has been compiled in a combination of Microsoft Excel™ spreadsheets and Access™ databases. A complete set of ESRI ArcMap™ shapefiles with attribute tables and metadata have also been assembled. This geographical information system (GIS) database for Colorado has been provided to Utah's Automated Geographic Reference Center (AGRC) for public access and use in further analysis by the SWP utilizing the dynamic simulation model. The GIS database for Colorado is also included on the CD with this report as well as being available via the CGS website <http://geosurvey.state.co.us>.

1.5 CGS PROJECT TEAM

The Colorado Geological Survey (CGS) comprises a diverse group of expert geoscientists and GIS specialists. The project team assembled for Phase I of the Southwest Regional Partnership on Carbon Sequestration Project is summarized in table 1.3 along with each team member's primary area of responsibility.

Table 1.3: Colorado Geological Survey project team

Team Member	Area of Responsibility
James Cappa	Colorado Point of Contact for SWP SWP Executive Steering Committee
Genevieve Young	CGS Principal Investigator and Project Manager Oil, Gas, and Coalbed Sink Characterization
Vanessa Lintz	Source and Sink Characterization; GIS
Beth Widmann	Mineralization Potential; Database Design
David Bird	Deep Saline Aquifers
Chris Martin	Coalbed Reservoir Characterization
Rachel Garrison	Oil and Gas Database
Jennifer McHarge	Oil and Gas Database
Larry Scott	Graphical Design

1.6 ABOUT THIS REPORT

This report has been prepared so that the Executive Summary may stand alone as a broad summary of the efforts conducted by CGS during participation in Phase I of the Southwest Regional Partnership on Carbon Sequestration Project. For those seeking greater detail, the chapters that follow the Executive Summary are intended to provide additional information on the source and sink characterization efforts completed by CGS. Authorship of these chapters is summarized in table 1.4.

Table 1.4: Chapter authors

Author	Chapter
Genevieve Young	1.0 Executive Summary
Vanessa Lintz	2.0 Carbon Dioxide Sources in Colorado
Genevieve Young	3.0 Oil and Gas Sinks in Colorado
Genevieve Young	4.0 Coalbed Methane Sinks in Colorado
David Bird	5.0 Deep Saline Aquifer Sinks in Colorado
Beth Widmann	6.0 Mineralization in Colorado
Genevieve Young	7.0 Carbon Capture and Storage Costs
Genevieve Young	8.0 Summary and Conclusions

Data summarized in the appendices are available on the CGS website <http://geosurvey.state.co.us/> and included on this CD. The Microsoft Access database **CoPrD** that generated the production reports in appendix 4 is also included on this CD and can be accessed via the CGS website.

2.0 CARBON DIOXIDE SOURCES IN COLORADO

2.1 INTRODUCTION

Since the onset of the Industrial Revolution, humans have challenged their limits, finding new ways to travel farther, do things more quickly, and have greater productivity. With those changes has come an ever-increasing demand for energy, one that has been met largely through the combustion of fossil fuels. As a result, large quantities of carbon that were once naturally sequestered deep underground in coal, oil, and natural gas deposits, have been released into our earth's atmosphere in the form of carbon dioxide. CO₂ is created and stored through natural processes and is an important compound present in the earth's atmosphere. As a greenhouse gas (GHG), CO₂ helps the planet to support life by keeping the climate at a tolerable temperature. However, anthropogenic sources are discharging the gas into the atmosphere faster than it can be naturally removed and stored. The newest challenge for humans is to continue creating the energy that is needed while having as small of an impact as possible on our atmosphere. One possible solution is the capture and sequestration of anthropogenic CO₂.

In 2003, the U.S. DOE made a commitment to the nation-wide study of carbon sequestration by creating the Carbon Sequestration Regional Partnership Program (U.S. Department of Energy, 2004b). Under this program the country has been divided into seven partnerships that are researching options for carbon capture, transport, and storage, with each partnership exploring the technologies that would best suit its region. The Colorado Geological Survey, as part of the Southwest Regional Partnership on Carbon Sequestration, is charged with the task of compiling data on carbon dioxide sources and sinks within Colorado.

One of the first steps in the process of carbon sequestration is the identification of CO₂ sources. According to the "Carbon Dioxide Emissions" chapter from the *Emissions of Greenhouse Gases in the United States 1997*,

nearly all of the anthropogenic CO₂ emissions produced within the U.S. are a consequence of fossil fuel combustion (Energy Information Administration, 1998). Fossil fuels are combusted in power plants to create electricity, they are burned to create heat, and they are used as transportation fuel. Only a small percentage of CO₂ emissions can be attributed to industrial processes, such as cement manufacturing, that release carbon dioxide through chemical changes in raw materials other than fossil fuels.

Sources in Colorado are responsible for approximately 1.4 percent of the fossil fuel combustion CO₂ emissions released in the U.S. annually. In 2000, CO₂ emissions in Colorado were more than 92 million short tons (U.S. Environmental Protection Agency, 2004a). This chapter examines Colorado's sources of anthropogenic CO₂ emissions to establish which of those sources produce a high enough concentration of CO₂ that can be collected and transported to storage sites. This requires looking at the amounts of CO₂ produced by an individual point source and its location relative to potential storage options. As the largest consumer of fossil fuels, power plants are responsible for much of the carbon dioxide released into the atmosphere and will offer the greatest possibilities for capture.

The final step in source identification is the prediction of CO₂ emissions into the future, as wide-scale fossil fuel dependence is likely to continue as long as there is fossil fuel production. Such predictions can be advantageous in estimating the amount of storage that may be required as well as determining the geographic areas that would benefit most from CO₂ capture and storage.

2.2 DATA AVAILABILITY

Carbon dioxide is a greenhouse gas, but it is not one of the six criteria air pollutants that are regulated by the *Clean Air Act* (U.S. Environmental Protection Agency, 1993). Neither the U.S. government nor the State of Colorado requires measurement or reporting of CO₂ emissions, and as a result, little historical documentation exists on an individual point source basis. Recently, more has

become known about atmospheric concentrations of CO₂ and their dramatic increase due to human activity. Evidence has shown that the amount of CO₂ released into the atmosphere by human activities worldwide has increased about 25 percent since the Industrial Revolution began in the mid-eighteenth century, due largely to the increase in the use of fossil fuels as an energy source (U.S. Environmental Protection Agency, 1995). While it is yet to be known exactly what effects the atmospheric changes will have and what their extent will be, interest in the release of CO₂ and its effects is growing and more is being done to gather information on its emissions. For example, the U.S. Environmental Protection Agency and the Energy Information Administration (EIA) have created voluntary reporting programs to collect data on CO₂ and other air pollutants. The most comprehensive public database that includes CO₂ numbers is the *Emissions & Generation Resource Integrated Database* (eGRID) that is maintained by the Office of Atmospheric Programs at the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 2004c). This database contains data from 24 federal data sources and includes estimated annual CO₂ emission data from 1996 to 2000 for every power plant and electric generating company in the U.S. The extent of the data available varies from year to year, with the year of 2000 data being the most recent data available, as well as being the most complete (appendices 1, 2, and 3). This project relied on the year 2000 CO₂ emissions data.

Carbon dioxide emissions from individual sources other than power plants are significantly more difficult to acquire, as is the data necessary to estimate those emissions, due to data confidentiality. The most useful data is found in estimated emissions reports done at the state or national level, such as the *Colorado Greenhouse Gas Emissions Inventory & Forecast 1990 through 2015* prepared by the Colorado Department of Public Health and Environment's (CDPHE) Air Pollution Control Division Planning and Policy Program (Colorado Department of Public Health and Environment, Air Pollution Control Division, Planning and Policy Program, 2002).

2.3 CO₂ EMISSIONS

Exhaust flue gases are produced when fossil fuels such as coal, oil, natural gas, or wood are combusted. The combustion process uses intake air which contains about 79 percent by volume of non-combustible nitrogen (N₂) gas. The next largest component of flue gas is carbon dioxide (CO₂) which can be as much as 10 to 15 percent by volume. For a typical flue gas, the balance consists of comparatively small amounts of nitrogen oxides (NO_x), sulfur dioxide (SO₂) and particulate matter.

The amount of CO₂ that is released during fossil fuel combustion is controlled by four factors. Those factors are the type of fuel consumed, the amount of fuel consumed, the carbon content of the fuel, and the fraction of the fuel that is oxidized during combustion (U.S. Environmental Protection Agency, 1995). Of the fossil fuels, coal contains the highest amount of carbon per useful unit of energy. The amount of carbon per useful unit of energy in coal is about 45 percent higher than that in natural gas and about 20 percent higher than that in petroleum (U.S. Environmental Protection Agency, 1995). Coal rank will also cause variances in the amount of carbon per useful unit of energy. Low quality coals, such as lignite, contain more carbon than high quality coals, such as anthracite. Therefore, the low quality coals will release more CO₂ during combustion.

According to the Colorado Mining Association, coal is the most widely used fossil fuel for electricity generation in the U.S. (Chris Carroll, Colorado Geological Survey, oral communication, 2004). Currently, more than 75 percent of the total electricity generated in Colorado is in coal-fired plants. The primary reason for this coal dependence is its wide availability and ready access to rail transport. The primary power plants, known as baseload plants, that operate continuously and generate the greatest amount of electricity will also consume the greatest amount of fuel. Keeping low and steady fuel costs in mind, most baseload plants are built to burn coal. Another reason for the prevalence of coal use in Colorado power plants is the close proximity to coal mining operations and high quality coal. In 2003, coal mines in Colorado produced nearly 36 million

short tons of coal, approximately 79 percent of which was bituminous coal (Cappa and others, 2004). Two of the top five CO₂ producing power plants in Colorado are located in the northwestern corner of the state, which is a major area for coal mining. The highest emitting of those plants, the Craig plant, receives much of its supply of coal directly from nearby Trapper Mining, Inc. (Tri-State Generation and Transmission Association, Inc., 2004).

As carbon dioxide emissions are not widely measured at the source, CO₂ emissions estimates from fossil fuel use are often calculated from fuel consumption data and some other known factors. This method is outlined in the U.S. Environmental Protection Agency's *State Workbook: Methodologies for estimating greenhouse gas emissions* (2nd ed.) (U.S. Environmental Protection Agency, 1995). The basic calculation for estimating CO₂ amounts is as follows:

$$\begin{aligned} \text{CO}_2 \text{ emissions (short tons)} = & (\text{fuel consumption figure}) \times \\ & (\text{carbon content coefficient}) \times \\ & (\text{oxidation factor}) \times (\text{CO}_2 \text{ factor}) \times \\ & (\text{unit conversion factor}) \end{aligned} \quad (2.1)$$

Estimation of CO₂ emissions begins with the fuel consumption figure, or the amount of fuel consumed in energy units of million British thermal units (MMBtu). The fuel consumption figure is multiplied by the carbon coefficient, which is the amount of carbon that would be emitted if it were released into the atmosphere in its entirety. The carbon content coefficient, which represents pounds of carbon (C) emitted per MMBtu of fuel consumed, reflects both the type and quality of fuel consumed. For the *Colorado Greenhouse Gas Emissions Inventory & Forecast*, the CDPHE used 56.00 as the coefficient for bituminous coal, 62.10 for anthracite coal, 31.90 for natural gas, and 44.00 for distillate fuel oil (Colorado Department of Public Health and Environment, Air Pollution Control Division, Planning and Policy Program, 2002). The oxidation factor of 0.99 that is given by the U.S. Environmental Protection Agency is based on the assumption

that 99 percent of the carbon is oxidized to carbon dioxide during combustion. Until this point all of the calculations deal with the amount of carbon in the fuel, however the real interest is in the amount of CO₂ released. The molecular weight ratio of CO₂ to carbon is 44/12; multiplying by this ratio converts the calculated amount of carbon to a calculated amount of CO₂. To make the resulting value, pounds of CO₂, more manageable, it is converted to short tons of CO₂ by the conversion factor: 1 short ton/2000 pounds.

For example, if a power plant burns 2,000,000 MMBtu of bituminous coal in a year, the estimated CO₂ emissions for that year will be:

$$\begin{aligned} \text{CO}_2 \text{ emissions (short tons)} &= (2,000,000 \text{ MMBtu}) \times \\ &\quad (56.00 \text{ pounds C/MMBtu}) \times \\ &\quad (0.99) \times (44 \text{ CO}_2/12 \text{ C}) \times \\ &\quad (1 \text{ short ton}/2000 \text{ pounds}) \\ &= 203,280 \text{ short tons of CO}_2 \end{aligned} \quad (2.2)$$

The above calculation works best when considering a single CO₂ emissions source, such as the emissions from a power plant. When estimating CO₂ emissions from fossil fuel combustion on a state level, additional information is needed. The U.S. Environmental Protection Agency's *State Workbook: Methodologies for estimating greenhouse gases* lists eight necessary steps for emissions calculations (U.S. Environmental Protection Agency, 1995):

1. Obtain required energy data
2. Estimate carbon content in fuels
3. Estimate carbon stored in products
4. Estimate carbon from bunker fuel consumption
5. Estimate carbon emitted from interstate electricity consumption
6. Calculate net potential carbon emissions
7. Estimate carbon oxidized from energy uses
8. Convert to total CO₂ emissions from energy consumption

This is the method that was followed to create the *Colorado Greenhouse Gas Emissions Inventory & Forecast* by the CDPHE (Colorado Department of Public Health and Environment, Air Pollution Control Division, Planning and Policy Program, 2002) and the Environmental Protection Agency's *Global Warming - Emissions Energy CO₂ Inventories* (U.S. Environmental Protection Agency, 2004a).

2.4 EMISSIONS BY SECTOR

The EIA has categorized energy users into five sectors: utilities, industrial, commercial, residential, and transportation. The U.S. Environmental Protection Agency and other agencies also utilize the same sector categorization. While there are some inconsistencies in how different agencies breakdown the sectors, the definitions for residential and transportation are rather constant, accounting for fossil fuel use by private residences and mobile energy users respectively. The characterization of the utilities, industrial, and commercial sectors are somewhat more indistinct and are best defined by the EIA in its *Definitions of Energy-Use Sectors and Related Terms* (Energy Information Administration, 2004a). The utilities sector consists of facilities that produce energy for sale to the public as their sole purpose. The electricity created by the utilities sector is used by the industrial, commercial, and residential sectors. In some emissions inventories, emissions for the utilities sector are split up and attributed to the end-use sectors proportional to their energy use. For the purpose of CO₂ sequestration it is necessary to estimate emissions at the source where they can be captured. The industrial sector consists of “facilities and equipment used for producing, processing, or assembling goods” (Energy Information Administration, 2004a). Often such facilities have their own on-site power plants that produce energy for the manufacturing process. Sometimes, excess power is sold to the utilities for dispersal to the public. The commercial sector consists of “service-providing facilities and equipment of businesses; Federal, State, and local

governments; and other private and public organizations, such as religious, social, or fraternal groups” (Energy Information Administration, 2004a).

Figure 2.1 shows 2000 CO₂ emissions from fossil fuel consumption produced by each sector in Colorado. This data is available from the Environmental Protection Agency’s *Global Warming - Emissions Energy CO₂ Inventories* web site (U.S. Environmental Protection Agency, 2004a).

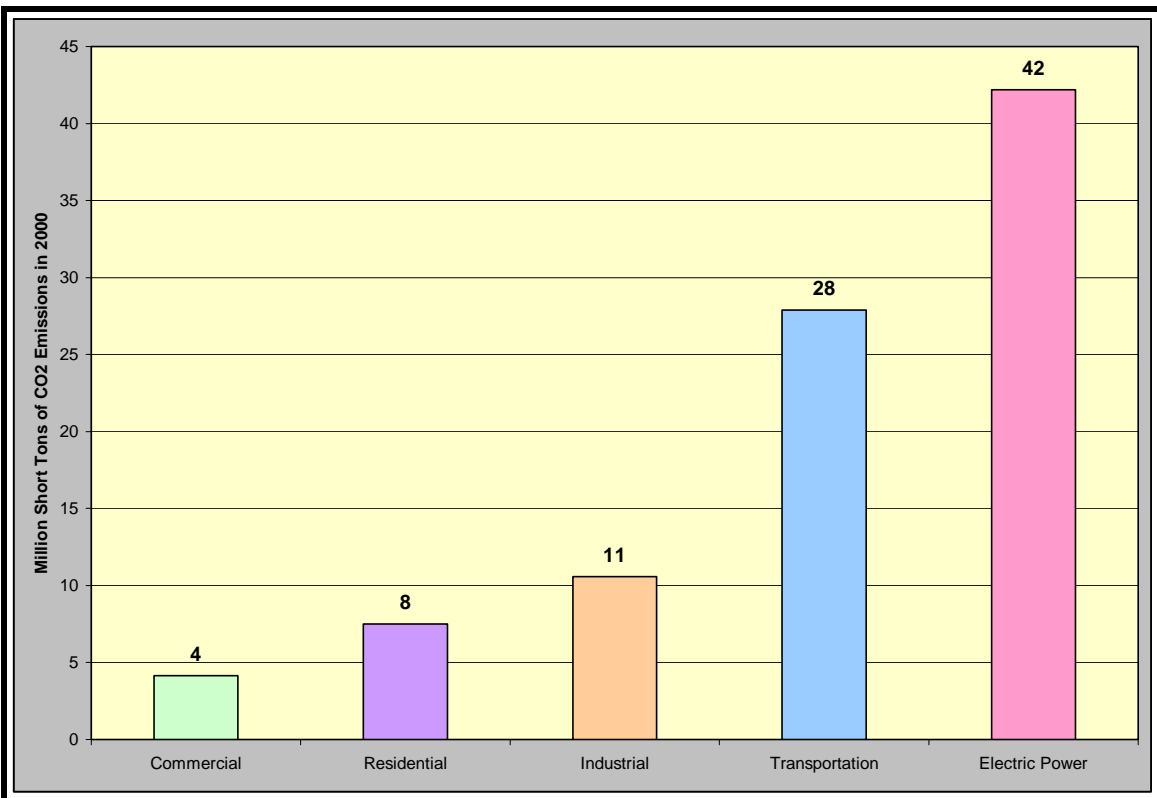


Figure 2.1: 2000 CO₂ emissions by sector from fossil fuel consumption (U.S. Environmental Protection Agency, 2004a).

The transportation sector, while a significant emitter of CO₂ in Colorado, consists of point sources that individually produce relatively small amounts of CO₂. Furthermore, the point sources are not stationary and are widely distributed, which makes collection of CO₂ more impractical. Although the sources of CO₂ in the residential sector are stationary, they are also widely dispersed, which again is not conducive to collection and transport of the greenhouse gas. Additionally, only 8 MT or 8.1 percent of the CO₂ emissions for

the state are produced directly by the residential sector. Independently, each residential source releases a negligible amount of CO₂ annually. The commercial sector is the lowest producer of CO₂ in the state, generating 4 MT or 4.5 percent of CO₂ emissions.

The remaining two sectors, utilities and industrial, are composed of stationary point sources that emit significant amounts of CO₂ per site and present the best possibility for collection. The utilities sector is responsible for the majority of CO₂ emissions in Colorado annually. In 2000, power plants produced 42 million short tons of CO₂, which was approximately 45.7 percent of the state's total emissions (U.S. Environmental Protection Agency, 2004a). The industrial sector produced approximately 11.5 percent or 10.6 million short tons of CO₂. Based on emissions amounts alone, the utilities sector will draw the most attention as possible sources of CO₂ for capture and sequestration.

2.5 COLORADO POWER PLANTS

Forty-five Colorado power plants are included in the U.S. Environmental Protection Agency's *eGRID* database (U.S. Environmental Protection Agency, 2004c). Thirty-three of the power plants are utility plants and 12 are nonutility (industrial) plants. In 2000, carbon dioxide output from these plants ranged from less than 200 short tons per year to nearly 11 million short tons per year (U.S. Environmental Protection Agency, 2004c; appendix 1). Twenty-five of the power plants in Colorado are fueled by natural gas (fig. 2.2). Fourteen plants are coal fueled and five are oil fueled. Colorado also has one distillate fuel oil plant. The coal-burning facilities are the highest producers of CO₂. Not only are they combusting the fossil fuel with the highest carbon content, they also burn the most fuel (fig. 2.3).

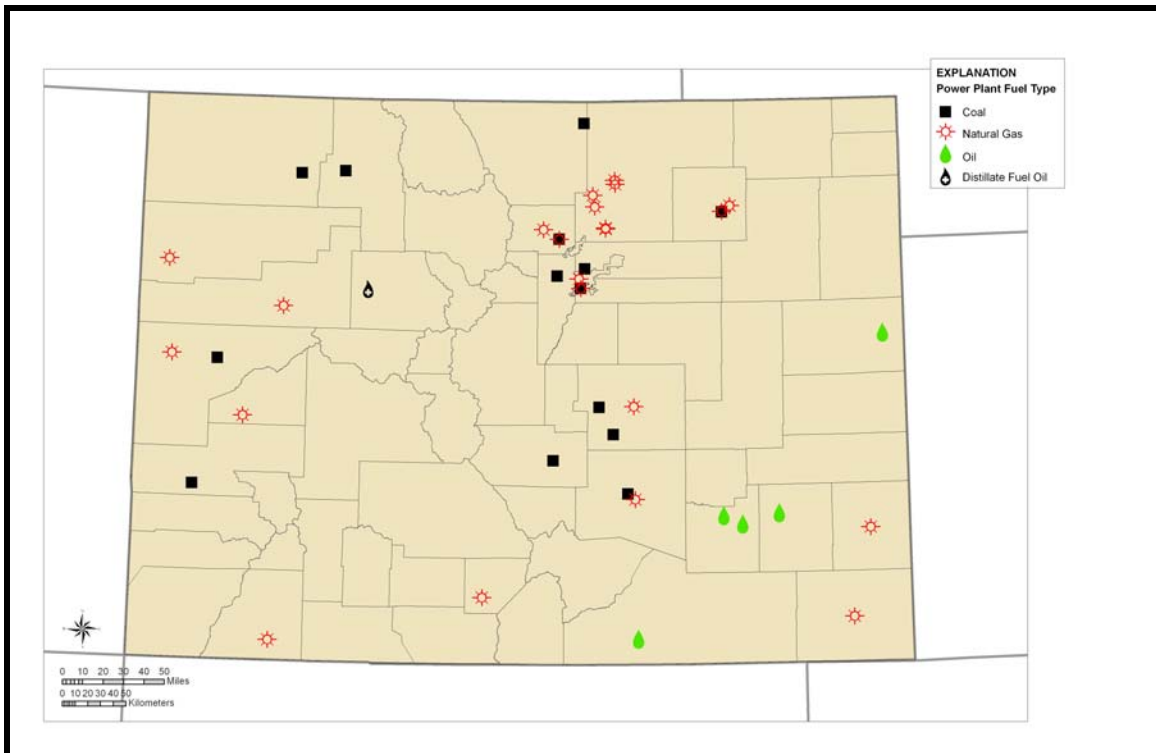


Figure 2.2: Power plants by fuel type for 2000 (U.S. Environmental Protection Agency, 2004c; appendix 1).

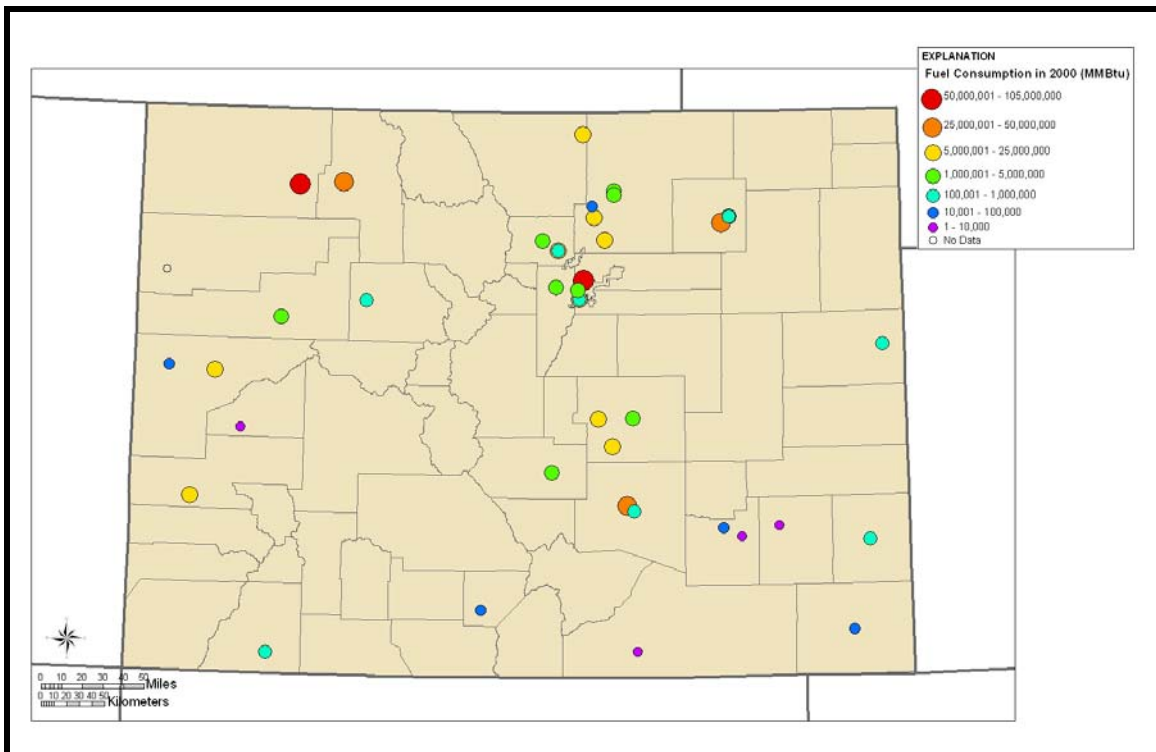


Figure 2.3: Power plants by fuel consumption in million British thermal units (MMBtu) for 2000 (U.S. Environmental Protection Agency, 2004c; appendix 1).

The top five CO₂ producers (fig. 2.4) in Colorado are all coal-fired plants with high capacities for electricity generation (appendix 1). They are baseload plants that operate continually to supply much of the electricity consumed by the public and as a result they burn large quantities of fuel. In 2000, these five power plants accounted for two-thirds of the total CO₂ emissions statewide, with the Craig plant accounting for 23 percent of that total.

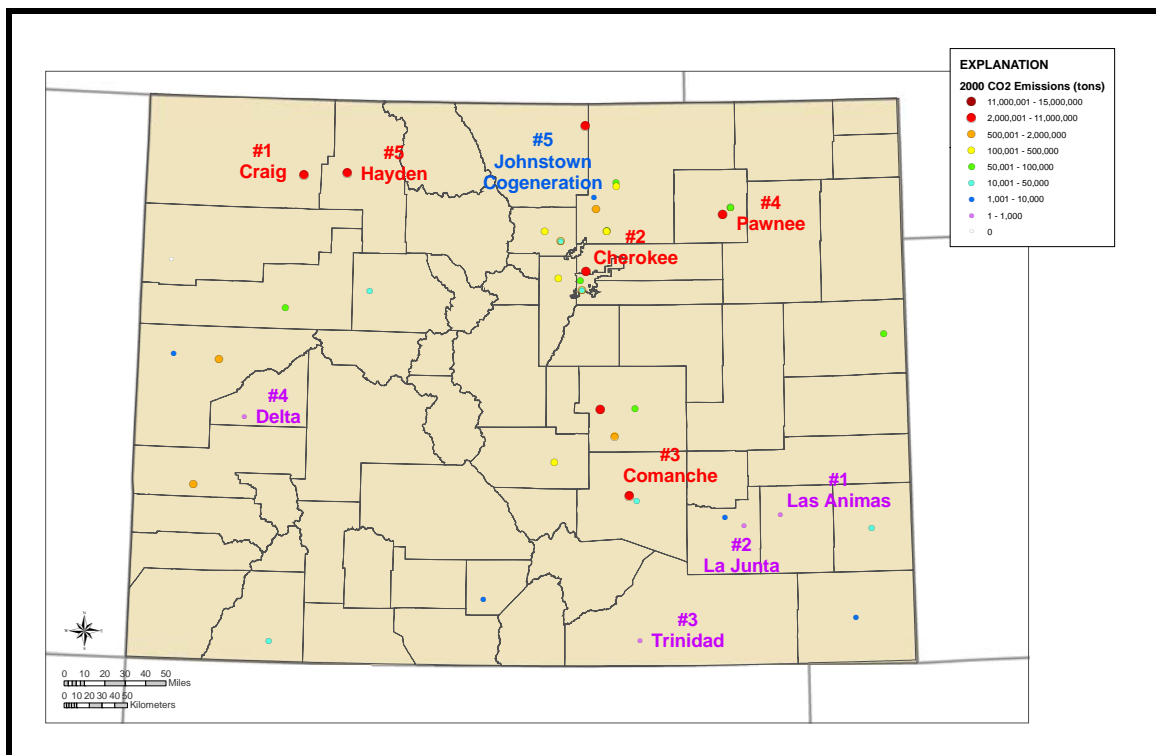


Figure 2.4: Power plants in Colorado ranked by carbon dioxide emission amounts in short tons in 2000 (U.S. Environmental Protection Agency, 2004c). The five highest producers are numbered and lettered in red; the five lowest producers are lettered in purple and blue. Refer to appendix 1 for further details.

The five Colorado producers (fig. 2.4) with the lowest CO₂ emissions burn oil and natural gas. They also consume the least amount of fuel in MMBtu per year. These plants are often small city-owned plants that service a limited area. The primary reason for these types of plants burning natural gas, in spite of fuel cost uncertainty, is that the cost to build a natural gas-fired power plant is nearly one-tenth of the cost to build a similarly sized coal-fired power plant (Chris

Carroll, Colorado Geological Survey, oral communication, 2004). The time needed to complete construction is also a consideration, as the average-sized coal-fired power plant may take four to five years to complete, while the average-sized natural gas-fired power plant may take about one year to complete. Small power plants also consume rather low amounts of fuel, so that the high cost of natural gas is not as much of a deterrent. Another factor for building natural gas plants is that in general natural gas emits less carbon per net generated energy (figure 2.5), making these plants more suitable for areas with air pollution problems. Based on 2000 emissions data for Colorado (appendix 1), the average for a natural gas power plant is 0.8 short tons CO₂ emitted per megawatt hour of net power generated compared with an average of 1.2 for coal power plants. Natural gas and oil combustion power plants are also used to meet demand when a power company's load is near its maximum or for emergency and reserve energy requirements. This is largely because they are easier to power up or down than coal-fired plants (Energy Information Administration, 2002).

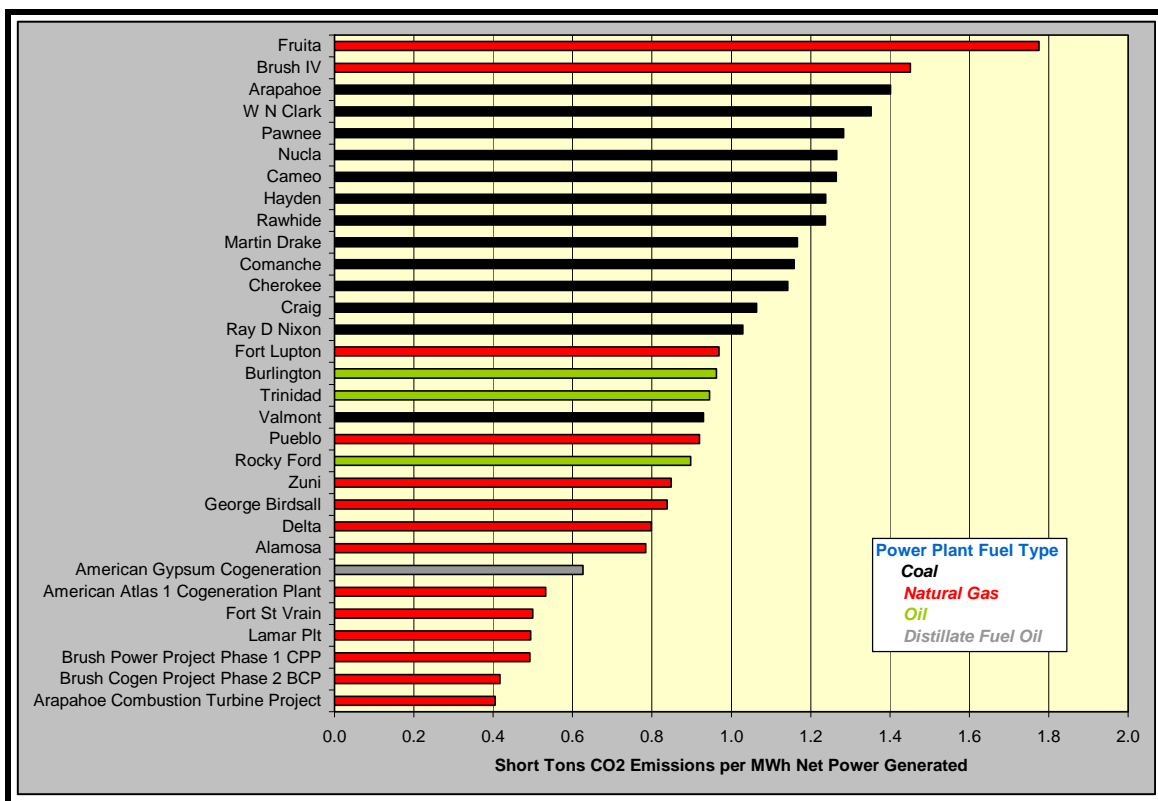


Figure 2.5: Power plants in Colorado ranked by carbon dioxide emission amounts in short tons per megawatt hours (MWh) of net power generation based on 2000 data (U.S. Environmental Protection Agency, 2004c). The color of the bar designates power plant fuel type. Refer to appendix 1 for further details.

2.6 PILOT STUDY REGIONS

A 30-mile buffer, in 10-mile increments, has been drawn around each of the power plants in Colorado and those just outside of the state borders (fig. 2.6). This is done to illustrate not only the proximity of each power plant to its neighbors, but also to show the proximity of power plants to potential storage sites. According to the NETL-sponsored GEO-SEQ website, an estimated three-quarters of the cost of geologic sequestration of CO₂ comes from the capture, storage, compression and transportation of the gas, with the remaining quarter being attributable to well-field operations (National Energy Technology Laboratory GEO-SEQ, 2004b). CO₂ transport requires a non-corrosive stainless steel pipeline, and the cost to build such a pipeline runs around \$20,000 per inch

of diameter for a one-mile stretch of pipe (Mike Hirl, KinderMorgan CO₂ Company, L.P., oral communication, 2004); these costs are double in the last couple of years to \$40,000 by late 2006 (Martin Smith, Xcel Energy, oral communication, 2007). To minimize cost, the best pipeline plans will be ones that connect power plants and sequestration sites that are in close proximity to each other.

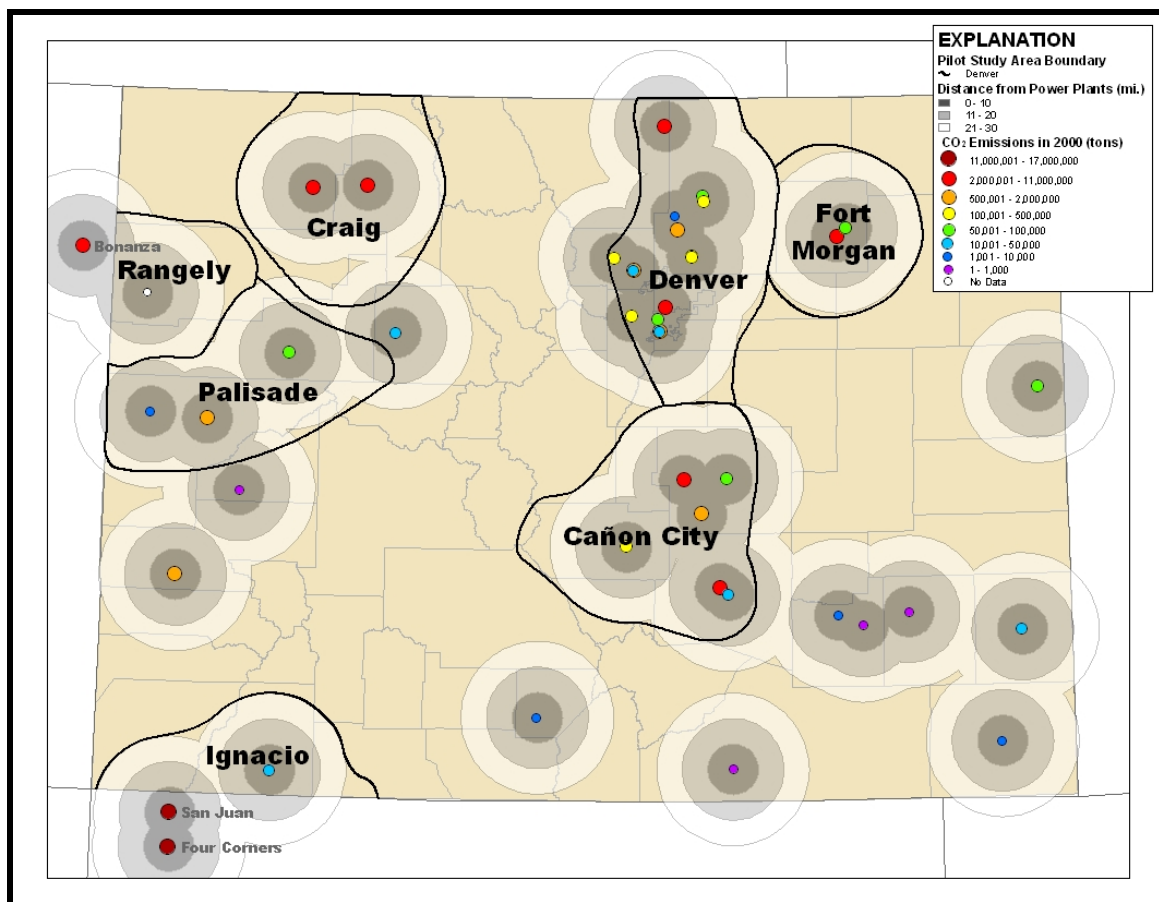


Figure 2.6: Power plants in Colorado and surrounding area, ranked by short tons of CO₂ emitted in 2000 (U.S. Environmental Protection Agency, 2004c). Buffers display area within thirty miles of the sources, broken down into ten-mile segments. The highest CO₂ emitters near the Colorado border are labeled.

When looking at the major sources of anthropogenic CO₂ in Colorado it is impractical to ignore what is just beyond the state border. A few power plants are located within thirty miles of Colorado's state boundaries and are almost as close to sequestration options in Colorado as some of the plants within the state.

Two power plants in New Mexico near Colorado's southwestern corner each release millions of tons more carbon dioxide annually than the highest producers in Colorado. The most significant of these out-of-state power plants is the Four Corners plant (fig. 2.6) in northwestern New Mexico, which produced nearly 17 million short tons of CO₂ in 2000 (U.S. Environmental Protection Agency, 2004c). (See table 2.1 for comparison with CO₂ producers in Colorado). A close second is its neighbor to the north, the San Juan power plant, which produced nearly 15 million short tons of CO₂ in 2000. Also the Bonanza power plant in eastern Utah generated over three million short tons of CO₂ in 2000.

Within Colorado, consideration of proximity of carbon dioxide sources to sinks has led to the establishment of seven areas of interest, or Pilot Study Regions, which will be the focus for further study of the state's potential sequestration options (fig. 2.6). The first criteria for an area of interest is the presence of at least one power plant that emits more than 500,000 short tons of CO₂ annually. The second criteria is the presence of one or more potential sequestration options: mineral carbonation prospects, deep saline aquifers, deep unmineable coal seams, oil fields with cumulative production greater than one MMBbls of oil, or gas fields with cumulative production greater than 10 Bcf. The Pilot Study Regions are identified as Cañon City, Craig, Denver, Fort Morgan, Ignacio, Palisade, and Rangely (fig. 2.6).

The boundaries for the Pilot Study Regions have been drawn around the 30-mile buffers for the large power plants and altered to accommodate sequestration options that exist within a reasonable distance of the 30-mile buffers or to eliminate areas inside the buffers that are unlikely to have sequestration options. For example, the eastern edge of the Cañon City study area roughly follows the 30-mile buffer for the largest emitters in the area and the western edge has been extended to include mafic rocks that may be useful for mineral carbonation. Also, the Denver study area has been truncated at the western edge of the Denver Basin due to the Front Range and a lack of sequestration options there. The Ignacio and Rangely areas have potential for significant sequestration but do not have major CO₂ emitters within Colorado;

their boundaries have been left open at the state border to indicate the presence of the major CO₂ emitting power plants in neighboring states.

Table 2.1 illustrates the cumulative CO₂ emissions for each region in 2000, the Ignacio and Rangely totals include emissions from nearby out of state plants. Two of the regions with the greatest CO₂ emissions have very few power plants. The Ignacio region had the highest CO₂ emissions in 2000, primarily from the San Juan and Four Corners power plants. The emissions from the Craig region are largely produced by the Craig facility, but the region also has significant contributions from the Hayden plant. Within the Denver region, twelve and a half million tons of the fourteen million short tons emitted in the region in 2000 were from five of the sixteen power plants in the region: Cherokee, Rawhide, Arapahoe, Fort St Vrain, and Valmont.

Table 2.1: Annual CO₂ emissions for the Pilot Study Regions

		Facility Name	2000 CO ₂ Emissions (short tons)
PILOT STUDY REGION	IGNACIO	Four Corners (New Mexico)	16,939,714
		San Juan (New Mexico)	14,512,418
		Ignacio Gasoline Plant	23,836
		Region Total	31,475,968
	CRAIG	Craig	10,466,665
		Hayden	3,926,480
		Region Total	14,393,145
	DENVER	Arapahoe	1,954,788
		Arapahoe Combustion Turbine Project	19,302
		Cherokee	5,424,678
		Fort Lupton	54,534
		Fort St Vrain	1,365,757
		Rawhide	2,430,904
		TCP 122	290,669
		TCP 150	364,528
		Thermo Greeley Inc	74,882
		Thermo Power Electric Inc	284,629
		Valmont	1,363,596
		Valmont Combustion Turbine Project	18,827
		Zuni	66,831
		Trigen Colorado Energy Corp	276,180
		Johnstown Cogeneration	1,192
		University of Colorado	116,068
		Region Total	14,107,365
	CAÑON CITY	Comanche	4,892,206
		George Birdsall	93,495
		Martin Drake	2,183,126
		Pueblo	42,105
		Ray D Nixon	1,793,609
		W N Clark	373,946
		Region Total	9,378,486
	FORT MORGAN	Manchief Electric Generating Station	1,851
		Brush Cogen Project Phase 2 BCP	115,131
		Brush Iv	41,746
		Brush Power Project Phase 1 CPP	51,926
		Pawnee	4,691,603
		Region Total	4,902,257
	RANGELY	Bonanza (Utah)	3,372,095
		Dragon Trail Gas Processing Plant	0
		Region Total	3,372,095
	PALISADE	Cameo	698,859
		American Atlas 1 Cogeneration Plant	83,169
		Fruita	4,111
		Region Total	786,138

2.7 FUTURE TRENDS

To predict the future of CO₂ emissions in Colorado, it is useful to examine the causes of fluctuations in emission amounts. Anthropogenic CO₂ emission amounts are highly correlative to the amount of energy used and are affected by economic changes, the weather, and changes in energy prices. While it would seem that population growth would be a major factor in CO₂ increases, the rate of carbon dioxide emissions seems to be more closely influenced by economic growth than population growth (Energy Information Administration, 1998). Economic growth means increased commercial expansion and industrial production, which requires greater energy use. Prosperity also influences the number of new homes and the amount of energy used by them. Currently one megawatt (MW) of power is considered adequate to meet the electricity needs of about 1,000 homes (Raabe, 2004a). Better economic conditions have also led to the more widespread use of things that were once considered luxuries, such as home air conditioning and electronic equipment strictly for entertainment. Weather conditions also have an affect on the amount of CO₂ emitted. Heating in the winter and air conditioning in the summer for the residential and commercial sectors demands greater energy output from the utilities sector, which results in higher CO₂ emissions from power plants (Energy Information Administration, 1998).

Large electric utility companies are anticipating the growth in future energy-use and the need for constructing new power plants. In February 2004, Xcel Energy, one of the largest energy providers in Colorado, chose their Comanche Generating Station near Pueblo as the future site of an additional 750-MW coal-fired generating unit (Associated Press, 2004). This addition will make the Comanche plant the second largest in the state with a net capacity of 1,410 MW when it goes on line, possibly as early as 2009. It will also likely become the second highest emitter of CO₂ in the state. Xcel is expecting to build at least one additional coal-fired power plant elsewhere, the details of which are still under consideration by the electric provider. In spite of recent price increases, coal is expected to remain the most widely used fossil fuel in the U.S.

(Energy Information Administration, 2004b). With an estimated 16.43 billion short tons of coal yet to be mined locally, Colorado will also continue to favor the use of coal as will much of the nation (Energy Information Administration, 2003).

As technology improves, future fossil fuel-fired power plants may become cleaner burning and result in reduced CO₂ emissions. In August 2003, *The Gazette* newspaper in Colorado Springs, Colorado, reported that Colorado Springs Utilities was considering plans for a 150 MW coal-burning power plant that would be “the cleanest-burning in the world when completed in 2008” (Heilman, 2003). Among the new technologies that might be implemented at this plant is the combustion of non-fossil fuel materials, such as deadwood from forests and chipped tires, in addition to fossil fuels. Another technology that can help cut down on air emissions from power plants is coal gasification. This process lowers the emissions of criteria air pollutants and allows CO₂ to be captured more easily. Initial costs are high, however, as it costs an average of \$1.8 million per MW compared to the estimated \$1.4 million per MW that Xcel expects to spend on the forthcoming Pueblo plant (Raabe, 2004b). Once built, a coal gasification plant can operate less expensively as it can burn low-cost petroleum coke. The process of capturing pollutants is also less expensive at such plants. This technology is not yet widely used and utility companies are still unsure whether or not the long-term savings will be worth the initial expense.

The use of renewable energy sources, such as wind, water, solar, geothermal and biomass, is beginning to play a larger role in power production. While not without consequences, these energy sources are considered to be “green” because they do not produce any pollutants, such as CO₂. However, even with new technologies and increasing interest in alternative fuels, renewable energy sources play only a small role in power production in Colorado and across the nation. According to data from the EIA’s *Electric Power Monthly March 2004*, only 2.5 percent of Colorado’s net electricity generation in 2003 was from renewable energy sources (Energy Information Administration, 2004c). With a total capacity of approximately 730 MW in Colorado, hydroelectric power plants are the most prominent renewable energy providers. Wind power is

another notable renewable energy source used in Colorado. Currently wind farms in operation across the state amount to a combined capacity of 240 MW. Recent proposals by Xcel Energy would boost wind-power capacity to 740 MW by 2006 (Chakrabarty, 2004). This use of renewable energy may in time take some of the burden off of the non-renewable plants, in turn having a positive effect on the reduction of CO₂ emissions.

New “cleaner” technologies and increased use of renewable energy sources are not expected to make a large impact on the rate of fossil fuel use or on the emission amounts of CO₂ within the next 20 years. Nationally, carbon dioxide emissions from energy use are expected to increase an average of 1.5 percent per year from 2000 to 2025 (Energy Information Administration, 2004b) (fig. 2.7). During the 1990s, however, CO₂ emission increases in Colorado averaged 2.42 percent, ranging from 73 million short tons in 1990 to 92 million short tons in 2000 (U.S. Environmental Protection Agency, 2004b). In the absence of mitigating action, annual state emissions could increase to 168 million short tons in 2025 assuming an average increase of 2.42 percent per year for Colorado. The majority of those emissions will continue to be released by power plants.

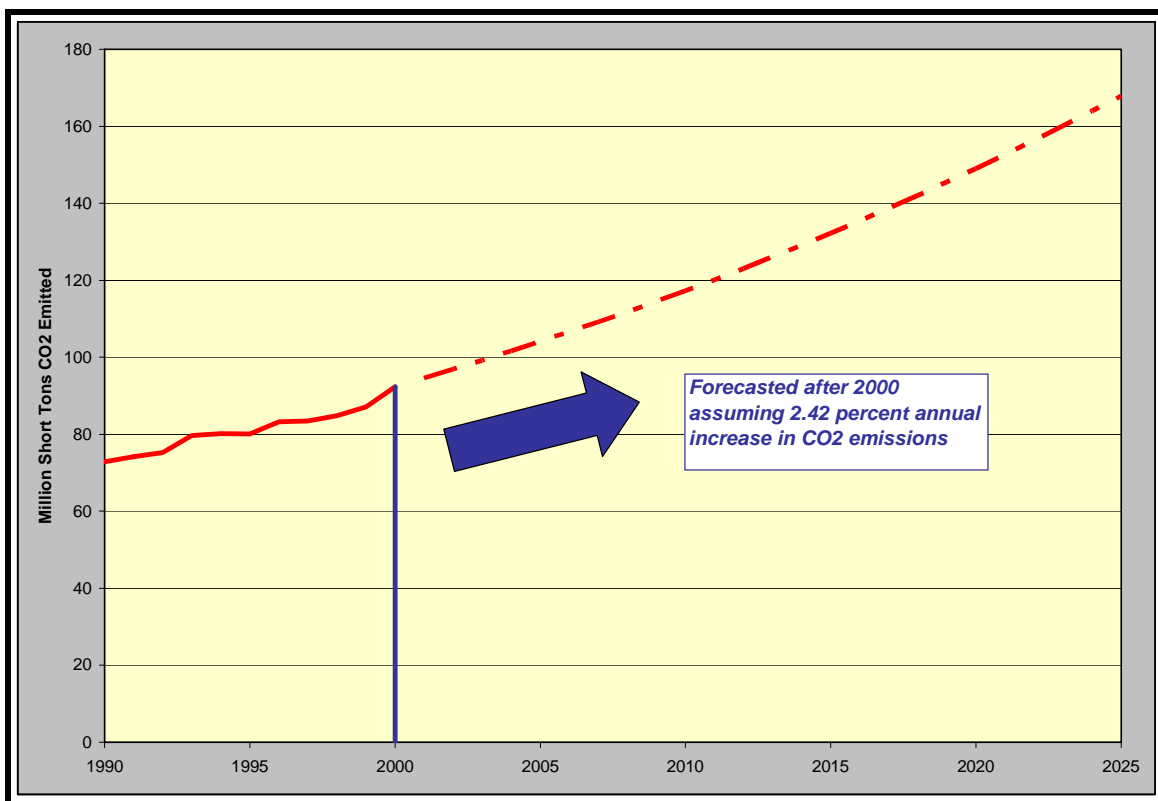


Figure 2.7: Carbon dioxide emissions growth in Colorado based on a projected increase of 2.42 percent per year after 2000. Dashed line indicates forecasted values.

2.8 CONCLUSIONS

When considering all of the anthropogenic sources of CO₂ as possible players in carbon sequestration, it is necessary to take several things into consideration. The sources most suitable to separation and capture technology will be those that are stationary and produce large concentrated amounts of CO₂. In Colorado and much of the U.S., power plants contribute the greatest amount of CO₂ to the atmosphere. Seven regions within the state will be the most favorable for further study based on the presence of both power plants that emit large amounts of CO₂ annually and potential sequestration options.

The economy, the weather, new technology, and changes in the use of renewable resources for energy production will all have an impact on CO₂ emission amounts in the future. However, fossil fuels will continue to be readily available and widely used in the near future. Technologies are being created to “clean-up” power plants, but the cost of such technologies is often high. Overall,

emission amounts are expected to continue increasing, making CO₂ sequestration even more important to our management of atmospheric quality.

3.0 OIL AND GAS SINKS IN COLORADO

3.1 COLORADO OVERVIEW

Colorado is a major oil and gas producing state with a long history of hydrocarbon exploration and development. Crude oil production began in 1881 with the discovery of the state's first oil field – the Florence field (Flis and Schwochow, 1995). Since production began in Colorado, cumulative recovery has reached 1.96 billion barrels of oil and 11.12 trillion cubic feet (Tcf) of gas through 2004 (appendix 4). An additional 4.42 Tcf of coalbed methane production has been reported since 1990 and 6.70 Tcf of naturally occurring CO₂ has been produced. In 2004, EIA ranked Colorado 11th in oil proved reserves and 6th in gas proved reserves for onshore U.S. (Energy Information Administration, 2005).

There are nearly 1,400 oil and gas fields in Colorado with an estimated 225 MMBbls of crude oil proved reserves, 14.74 Tcf of dry gas proved reserves, and 465 MMBbls of natural gas liquids proved reserves (Energy Information Administration, 2005). Nearly 65,000 wells have been drilled throughout the state with almost 30,000 of those wells classified as active and more than 3,200 applications for permit to drill (APDs) approved during 2004 alone (Colorado Oil and Gas Conservation Commission, 2005). In 2004, total production from these wells was 22.1 MMBbls of oil and 1.07 Tcf of gas (501 Bcf of which was coalbed methane) with 37 of Colorado's 64 counties producing either oil or natural gas, and often both (Cappa and others, 2005). This equates to daily production rates of 61,000 barrels of oil and 2.9 Bcf of gas.

3.2 CARBON SEQUESTRATION VIA ENHANCED RECOVERY

3.2.1 Enhanced Oil Recovery

Enhanced oil recovery (EOR) refers to techniques that allow increased recovery of oil in depleted or high viscosity oil fields. One method of EOR, carbon dioxide flooding (CO₂-EOR), has the potential to not only increase the yield of depleted or high viscosity fields, but also to sequester carbon dioxide that would normally be released to the atmosphere. In general terms, carbon dioxide is flooded into an oilfield through a number of injection wells drilled around a producing well. Injected at a pressure equal to or above the minimum miscibility pressure (MMP), the CO₂ and oil mix and form a lower viscosity liquid that more easily flows to the production well. Recovery can also be enhanced by injecting CO₂ at a pressure below the MMP, swelling the oil and reducing its viscosity. A simple schematic of the process is shown in fig. 3.1.

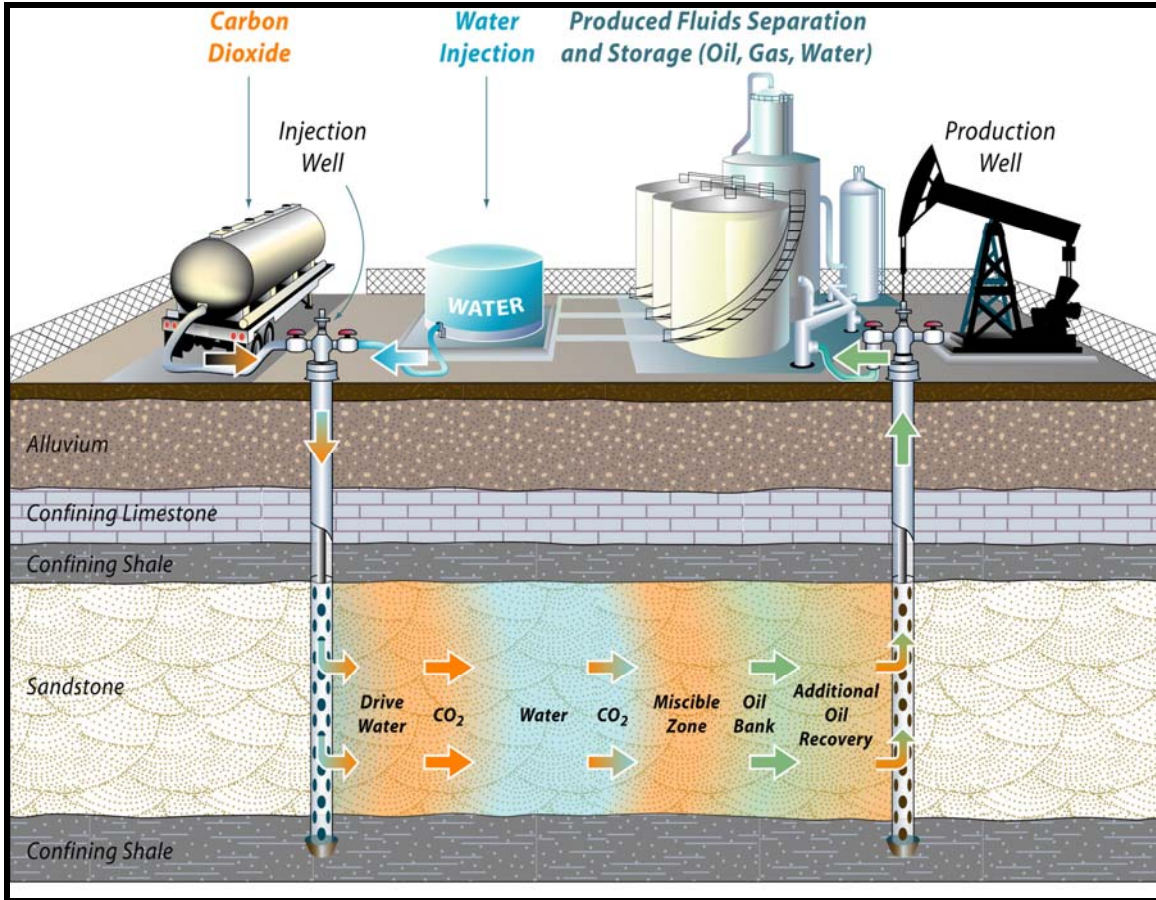


Figure 3.1: Schematic of CO₂-EOR (modified from National Energy Technology Laboratory, 2003).

Current Situation

CO₂-EOR has been used by the oil and gas industry for over 40 years, but only recently has its potential as a carbon sequestration method been realized and investigated. The U.S. has been a leader in developing and using technologies for CO₂-EOR; about 96 percent of EOR with CO₂ is performed in the U.S. (National Energy Technology Laboratory, 2003).

In 2003, NETL estimated that more than 8 million short tons (MT) of CO₂ were being used for EOR per year in the U.S. Of this total, about 10 percent (0.8 MT) is anthropogenic in origin; i.e., produced by human activities such as oil refining or fertilizer manufacturing. The rest is extracted from naturally occurring deposits such as those in the Paradox Basin of Colorado and Utah. It is

estimated that up to three-quarters of the anthropogenic CO₂ injected remains sequestered in the reservoir, amounting to about 0.6 MT per year (Stevens and others, 2001).

Benefits and Distinctions

CO₂-EOR is a promising method of sequestration for a number of reasons. First, the geologic structures that originally contained the oil and natural gas should be able to permanently contain the injected CO₂, provided the integrity of the structure is maintained. Another benefit of CO₂-EOR for sequestration purposes is the widespread distribution of depleted and operating oil and gas fields, making it likely that an oil field is near a CO₂ source. Finally, carbon sequestration from CO₂-EOR projects may provide carbon “credits” that could be traded in the emerging GHG market (Dittrick, 2006).

There are also several important distinctions between enhanced recovery and carbon sequestration, some of which are summarized in table 3.1. Enhanced recovery operations typically span a few years to several decades, whereas the goal of the CS program is to permanently store carbon for many centuries. CO₂-EOR operations are designed to maximize sweep efficiency in order to recover as much oil from the reservoir as possible. The CO₂ that has been purchased for such operations represents a valuable capital investment, and as such it is recycled as many times as necessary when breakthrough occurs at the production wells. Alternatively, long-term sequestration of CO₂ means that it should never present health or safety concerns through leakage to the surface. Wells utilized in CO₂-EOR operations are classified by the Environmental Protection Agency as Class II and there is an extensive regulatory system in place that is managed by each state where such operations occur (U.S. Environmental Protection Agency, 2002). This regulatory construct should provide an excellent roadmap for the ultimate regulation and monitoring of future carbon sequestration.

Table 3.1: Distinctions between enhanced recovery and carbon sequestration

Enhanced Recovery	Carbon Sequestration
Time scale: Years to decades maximum	Time scale: 100s to 1,000s years
Sweep efficiency paramount	Length of time required for CO ₂ to fully react with surrounding fluids/rock matrix
Sequestered CO ₂ volume highly uncertain – open issue for carbon trading	Leakage rates critical – risk associated with wellbores, reservoir seals
Regulatory construct in place	Regulatory/liability issues; long-term monitoring

Rangely Project

Chevron's Weber Sandstone miscible CO₂ flood in Rangely Field in the northern Piceance Basin is the third largest EOR producing project worldwide based on incremental recovery resulting from CO₂ injection. The Rangely project produces about 14,000 total barrels of oil per day, 70 percent of which are CO₂-EOR barrels (Jeff Roedell, Chevron U.S.A., Inc., oral communication, 2006). Carbon dioxide for this flood is purchased from the ExxonMobil Shute Creek natural gas processing facility near LaBarge, Wyoming and transported via pipeline to the field (table 3.2). By year-end 2005, the Rangely CO₂ flood consisted of 376 production wells and 265 injection wells and extended over an area in excess of 15,000 acres or 80 percent of the total field area. CO₂ injection began at Rangely in 1986 and since then, it is estimated that 1.22 Tcf of CO₂ (both purchased and recycled) has been injected into the Weber Sandstone. Leakage of CO₂ via wellbores or through the reservoir seal is considered to be negligible. Foams, gels and other strategies have been used to improve conformance and reduce premature CO₂ breakthrough. Monitoring wells are used to track movement of injectant within the reservoir, and reservoir simulations are used to estimate ultimate CO₂ sequestration at the Rangely field. By the time the project is completed in 2010, an estimated total of 29 MT (500 Bcf) of CO₂ will have been sequestered. Chevron is expecting to recover an additional 114 MMBbls of oil from using CO₂-EOR, or six percent of the original oil-in-place (OOIP) (Jeff Roedell, Chevron U.S.A., Inc., oral communication, 2006).

Table 3.2: Summary of some larger CO₂-EOR projects in the U.S. and Canada

Plant Name	Plant Type	CO ₂ Supply (tons/day)	EOR Field	Operator	Start-Up Date
Mitchell, Grey Ranch, Puckett and Terrel	Gas Processing	4.31	SACROC, TX	Pennzoil & Altura	1/1972
LaBarge	Gas Processing	2.58	Rangely, CO	Chevron	10/1986
Enid	Fertilizer	0.60	Purdy, OK	Anadarko	9/1982
Koch	Gas Processing	0.43	Paradis, LA	Texaco	2/1982
Great Plains Synfuels	Gas Processing	16.4	Weyburn, Saskatchewan	EnCana Energy	10/2000

(Source: Stevens and others, 2001; Moritis, 2002)

The CO₂-EOR project at Chevron's Rangely Field provides a valuable analog for conducting future CO₂-EOR projects in Colorado as well as advancing the state's carbon storage program.

Colorado's Oil Endowment

Although gas production has steadily increased since the mid-1980s, Colorado is a mature oil producing region that has experienced significant overall decline in its oil production since the mid-1900s (fig. 3.2). (The increase in annual oil production since 2000 is largely due to natural gas liquids, particularly from the Wattenberg field.) Many of the state's oil and gas reservoirs have already undergone secondary recovery operations such as waterflooding or gas recycling for pressure maintenance (fig. 3.3; appendix 5). It is estimated that Colorado had an original oil endowment of about 5 billion barrels (Vello Kuuskraa, Advanced Resources International, written communication, 2006). With cumulative oil production at 1.96 billion barrels and proved reserves of 225 million barrels, the remaining oil-in-place for Colorado may be nearly 3 billion barrels or about 60 percent of OOIP.

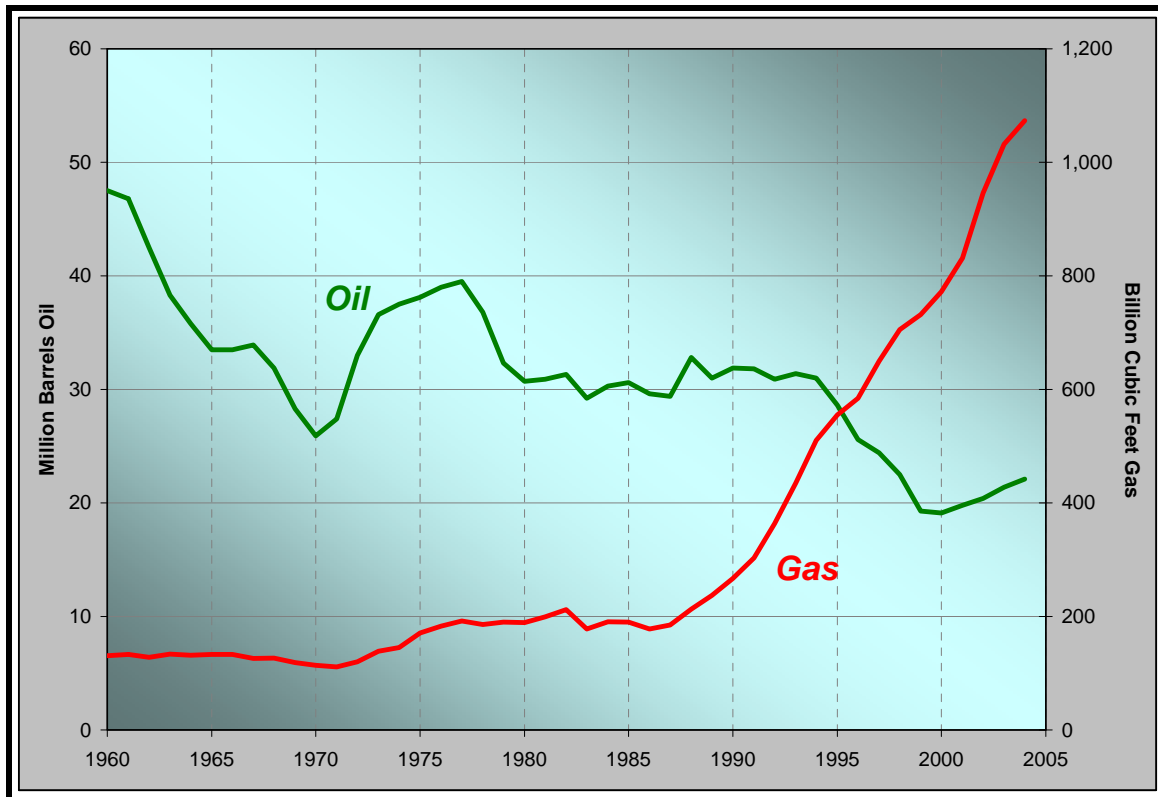


Figure 3.2: Colorado annual oil and natural gas production, including coalbed methane, 1960-2004 (Cappa and others, 2005).

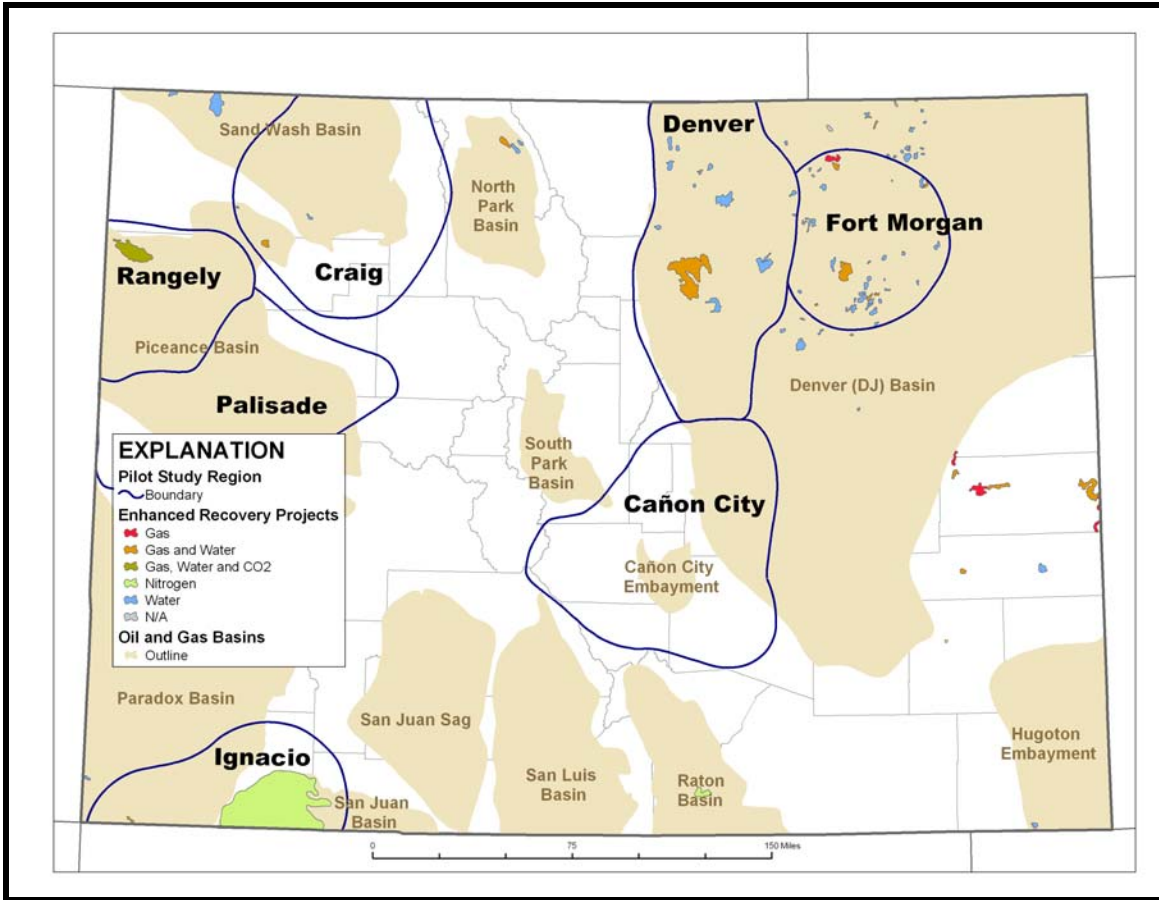


Figure 3.3: Colorado oil and gas fields with enhanced recovery projects through 2004, categorized by type and combination of injection fluids; not all projects shown are currently active (Colorado Oil and Gas Conservation Commission, 1998 and 2006). Refer to appendix 5 for further details.

Much of this endowment may be left behind or “stranded” as reservoir energy is depleted and it becomes uneconomic to recover using traditional oil recovery practices. In a recent DOE-funded study conducted by Advanced Resources International, it is estimated that a major portion of this “stranded” oil is technically and economically amenable to enhanced oil recovery (EOR) using CO₂ (U.S. Department of Energy, 2006). Depending on the technology used and the availability of low-cost CO₂, Advanced Resources estimates that 740 MMBbls of oil is technically recoverable and 510 to 580 MMBbls could be economically recoverable from potential future CO₂-EOR projects in 12 of Colorado’s major oil reservoirs (table 3.3). These 12 reservoirs are favorable for miscible CO₂-EOR based on reservoir depth, oil gravity, reservoir pressure, reservoir temperature,

and oil composition. (For a detailed discussion of the mechanisms of CO₂-EOR, both miscible and immiscible, the reader is referred to Jarrell and others, 2002).

Table 3.3: Colorado oil reservoirs favorable to CO₂-EOR

Basin	Field	Reservoir
Denver	Adena	J Sand
	Little Beaver	D Sand
	Little Beaver East	D Sand
	Spindle	Sussex
		Shannon/Sussex
	Wellington	J Sand
Las Animas Arch	Arapahoe	Morrow
	Mount Pearl	Morrow
Piceance	Rangely	Weber
		Morrison
	Wilson Creek	Sundance
Sand Wash	Iles	Sundance

(Source: U.S. Department of Energy, 2006)

3.2.2 Enhanced Gas Recovery

Although the advanced technology of injecting carbon dioxide into mature natural gas reservoirs for carbon sequestration with enhanced gas recovery (CSEGR) appears promising, it has not yet been tried in the field nor shown to be commercially feasible (Oldenburg and others, 2004). However, based on reservoir simulation and experimental studies, the process of CSEGR appears to be technically feasible (Oldenburg and others, 2004; Mamora and Seo, 2002). The mechanism of CSEGR is one of gas displacement and pressurization, as injected CO₂ moves through the reservoir's pore space displacing methane ahead of it (Oldenburg and others, 2001). This is in contrast to CO₂-EOR which relies on miscibility of the CO₂ in the oil phase as discussed above. A simple schematic of the process is shown in fig. 3.4.

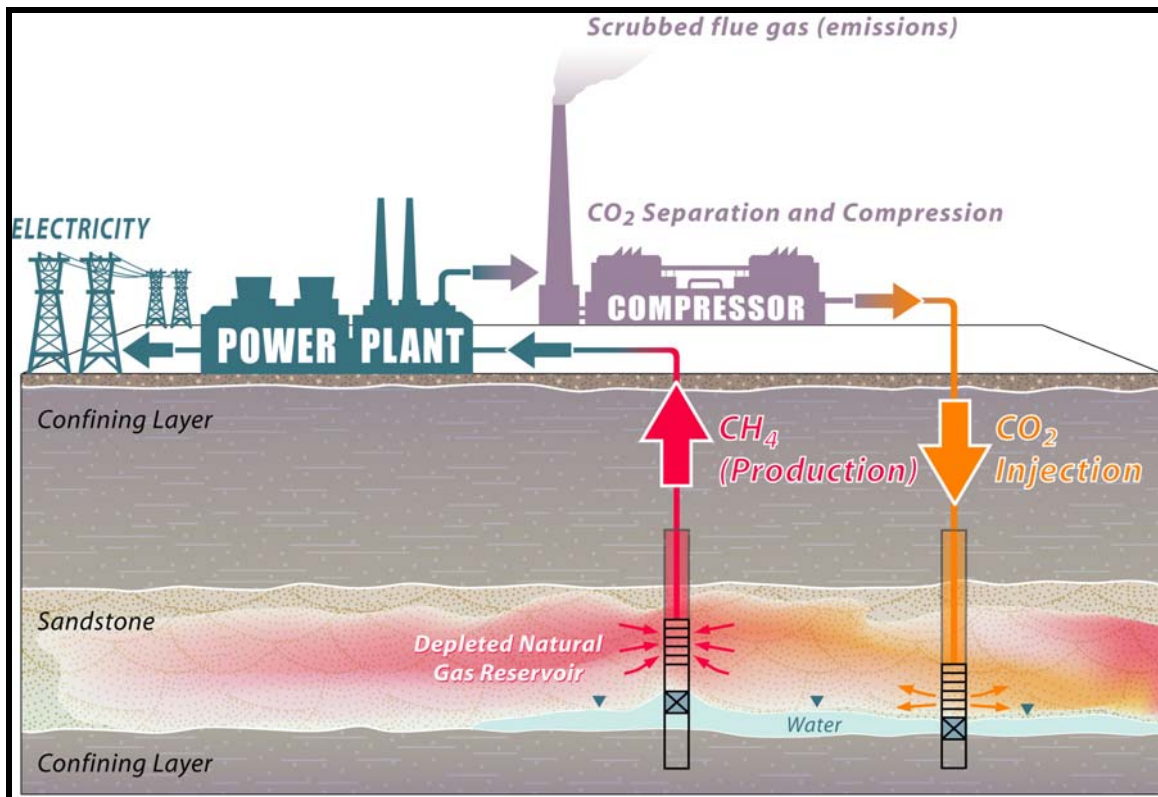


Figure 3.4: Schematic illustrating the process of carbon sequestration with enhanced gas recovery (modified from Oldenburg and Benson, 2002).

Current Situation

In 2000, Stevens and others estimated the ultimate world wide storage capacity of CO₂ in depleted natural gas reservoirs at 800 GT. As for enhanced gas recovery, the average worldwide gas recovery factor is estimated to be approximately 75 percent (Laherrere, 1997), with roughly 30 to 40 percent of the gas-in-place left behind in water-drive gas reservoirs and approximately 10 to 20 percent left behind in depletion-drive reservoirs. Even 10 percent of the original gas-in-place in a depletion-drive reservoir can represent a large volume of currently unrecoverable gas that makes potential incremental CH₄ production attractive when the alternative is field abandonment (Oldenburg and others, 2004).

Benefits and Risks

Depleted natural gas reservoirs are a promising target for geologic carbon sequestration given their proven history of gas containment and production (Oldenburg and others, 2004). A depleted natural gas reservoir can store significantly more gas than a depleted oil reservoir (assuming both have the same initial hydrocarbon pore volume) for two reasons (Mamora and Seo, 2002). First, ultimate gas recovery (about 75 percent of original gas-in-place) is typically about twice that of oil (average 35 percent of original oil-in-place). Second, gas is about 30 times more compressible than oil or water. CO₂ has a critical temperature of 88 °F and a critical pressure of 1,070 psia, above which it is no longer a gas but a liquid. Consequently, at pressures and temperatures typically encountered in the field, carbon dioxide will exhibit supercritical (liquid) behavior. However, displacement of natural gas by supercritical CO₂ has not been done in the field and is not well understood.

Analyses conducted by Oldenburg and Benson (2002) suggest that carbon dioxide can be injected into depleted gas reservoirs to enhance methane recovery for periods on the order of 10 years or so, while simultaneously sequestering large amounts of CO₂. Simulations applicable to the Rio Vista Gas Field in California show that mixing between CO₂ and CH₄ is slow relative to re-pressurization, and vertical density stratification favors enhanced gas recovery.

Although proposals have been made to inject CO₂ into natural gas reservoirs to improve recovery, or as base gas in natural gas storage fields, these schemes risk contaminating the hydrocarbon reserve and are less likely to be implemented. However, Stevens and others (2001) suggest that experience in underground gas storage and natural CO₂ production operations provide useful analogs for sequestration in depleted gas fields.

Underground Gas Storage in Colorado

In 2004, Colorado had nine underground gas storage (UGS) facilities in operation, providing a total working gas storage capacity of 45.3 Bcf (American Gas Association, 2004; appendix 6). Most of these are located in the Denver and Piceance basins (fig. 3.5). In addition to working gas volumes, UGS facilities require base gas that in Colorado ranges from 17 to 163 percent of working gas.

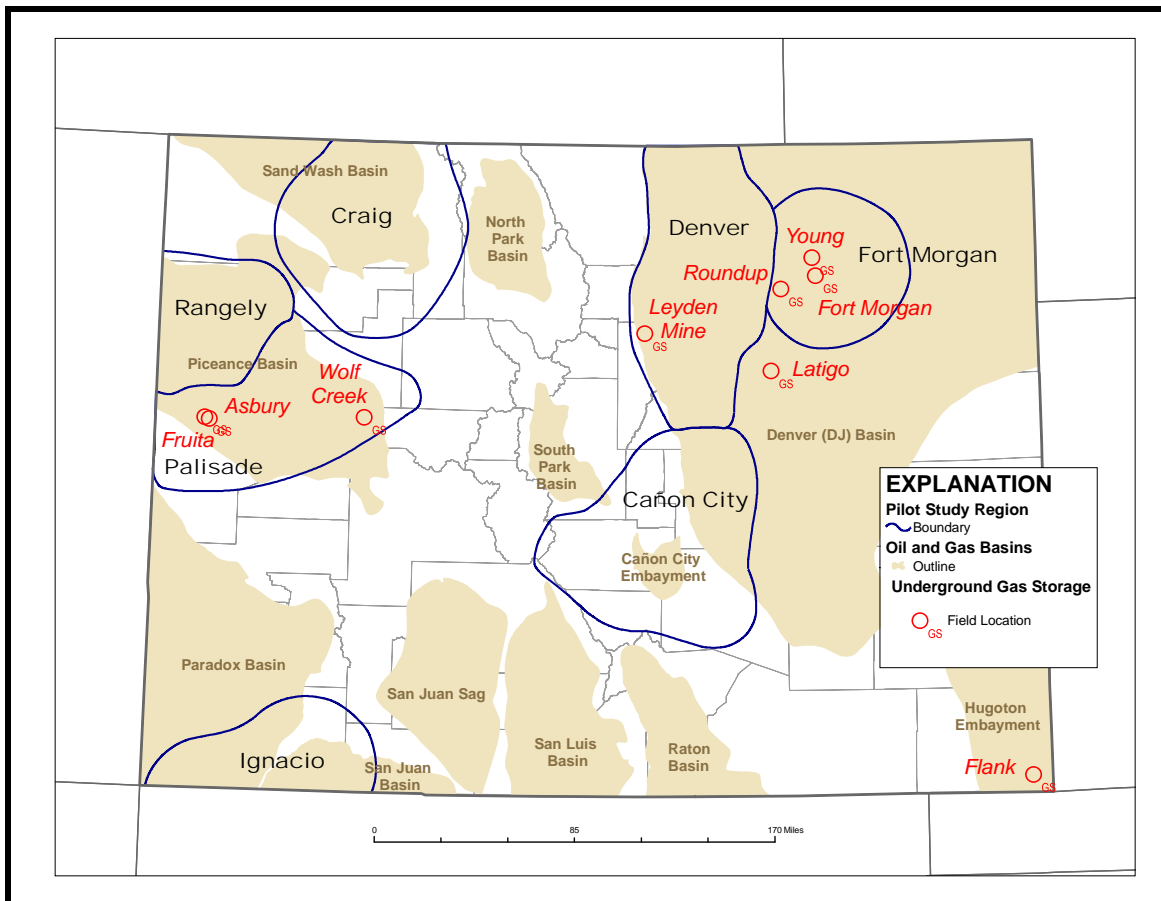


Figure 3.5: Underground gas storage facilities in Colorado (American Gas Association, 2004).

Together, gas storage and EOR represent the largest industrial experience in gas injection into geologic formations. With the exception of the Leyden Mine, all of Colorado's underground storage facilities are converted from depleted oil and natural gas fields, which is typical for UGS facilities throughout the world. Reservoir types are all sandstone except for the Leyden Mine, which

is an abandoned coal mine. The Leyden Mine was decommissioned for gas storage in 2005 and is undergoing conversion to water storage for municipal use.

In natural gas storage, the working gas (CH₄) is injected and produced seasonally while a base gas that is not extracted is used to provide pressure support (fig. 3.6). In the case of depleted gas reservoirs being used for gas storage, the base gas is commonly leftover native gas (CH₄). Another approach is to produce most of the methane from the reservoir since it can be sold for profit, replacing it with a cheaper inert gas for use as the base gas. CO₂ injection associated with CSEGR can be conducted while simultaneously producing the reservoir's methane. Particularly advantageous is the significant density change CO₂ undergoes near its critical pressure, increasing methane storage about 30 percent relative to a native gas base (Oldenburg, 2003). Furthermore, CO₂ injection may in the future be economically favorable through carbon credits or tax advantages offered to encourage carbon sequestration. Limiting the rate of mixing between methane and carbon dioxide through careful reservoir selection and operations will be critical to the use of CO₂ as a base gas (Oldenburg, 2003).

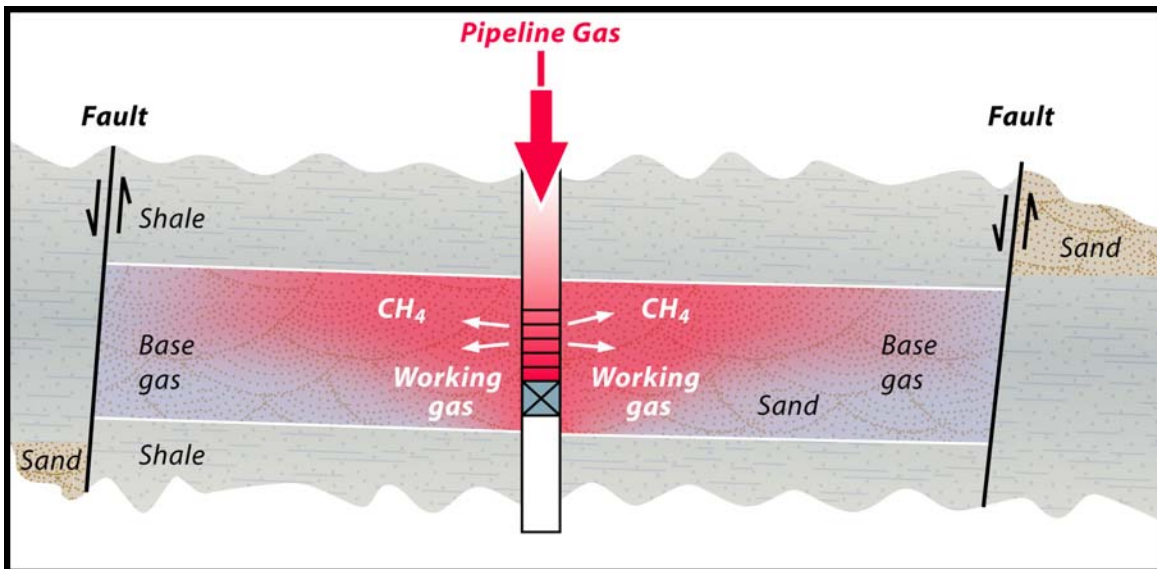


Figure 3.6: Schematic of natural gas storage reservoir showing working and base gas (modified from Oldenburg, 2003).

Current underground gas storage facilities in Colorado have nearly 48 Bcf committed in base gas representing a significant portion of total project investment. Some of these facilities may be suitable to base gas reductions via CO₂ replacement. Up to 4.4 MT of CO₂ would be required to offset the current base gas levels in Colorado, assuming complete replacement of existing base gas volumes. If this replacement is linked with a 30 percent increase in working gas, the current 45.3 Bcf could potentially be increased to 58.9 Bcf.

Natural CO₂ Fields in Colorado

Large naturally occurring geologic deposits of carbon dioxide are found in three of Colorado's sedimentary basins – the Paradox, Raton, and North Park (fig. 3.7). The resources of the Paradox and Raton basins provide low-cost sources of high-pressure CO₂, primarily for EOR projects in the Permian Basin of New Mexico and Texas. In this basin alone, approximately 50 projects produce an incremental 145 MMBbls of oil per day, more than 80 percent of the North American enhanced oil produced from CO₂ floods in 2004 (Cappa and others, 2005).

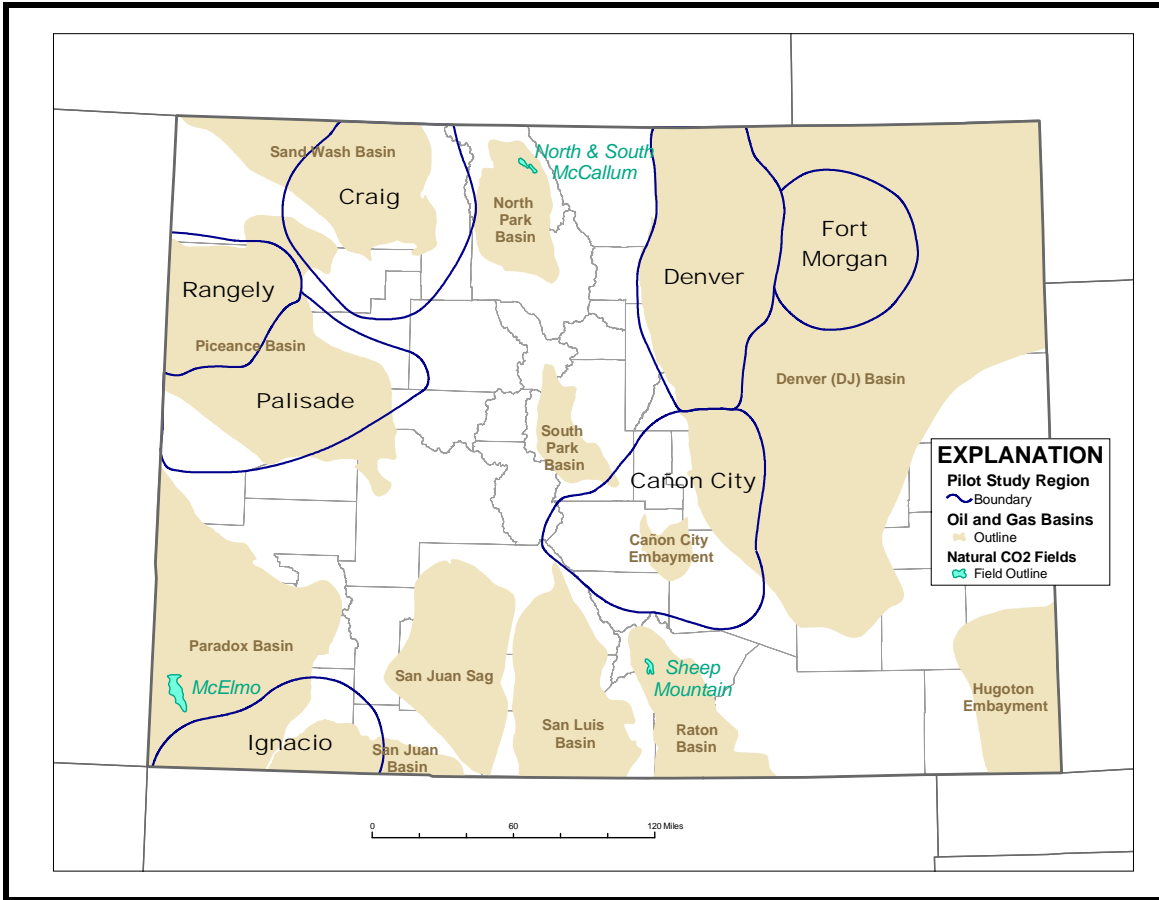


Figure 3.7: Natural CO₂ deposits in Colorado.

An extensive CO₂ pipeline and re-injection infrastructure system exists throughout the Permian Basin, making it attractive for expanding or starting new projects. High-pressure pipelines supply CO₂ from natural source fields at Bravo Dome in northern New Mexico and McElmo Dome and Sheep Mountain in southern Colorado. Shell's completion of the pipeline out of McElmo Dome in 1983 significantly increased the value of the naturally occurring CO₂ reserves in Colorado. In addition to EOR applications, CO₂ is used in welding, the manufacture of dry ice, and the food and beverage industry.

Colorado has some of the largest natural CO₂ reserves in the Rocky Mountain region (table 3.4). McElmo Dome field is the largest deposit in Colorado, contains over 17 Tcf of 98 percent-pure CO₂ that does not require processing or compression prior to injection (New Mexico Bureau of Geology and Mineral Resources, 2006). Natural CO₂ fields are useful analogs for evaluating

the safety and costs of geologic sequestration, both in terms of the long-term physical and chemical interactions of CO₂ with reservoir rocks and fluids, but also in terms of industry's field operational experience in handling and transporting large volumes of CO₂ (Stevens and others, 2001).

Table 3.4: Natural CO₂ reserves in the Rocky Mountain region

State	Basin	Field	Recoverable Reserves (Tcf)
Wyoming	Greater Green River	LaBarge-Big Piney	55
New Mexico	Northeastern NM	Bravo Dome	16
Colorado	Paradox	McElmo Dome	17
Colorado	Raton	Sheep Mountain	2.5

(Source: New Mexico Bureau of Geology and Mineral Resources, 2006; De Bruin, 2001)

Use of CO₂-EOR has resulted in CO₂ becoming a valuable commodity. The total value of carbon dioxide production in Colorado was nearly \$130 million in 2004, an increase of nearly 32 percent over the \$98 million in 2003 (Cappa and others, 2005). Carbon capture and storage technology is key to extending the availability this valuable natural resource.

3.3 METHODOLOGY

A five part methodology was used to evaluate the CO₂ sequestration potential of Colorado. The five steps were (1) compiling the production data for all fields within the state; (2) assembling an oil and gas database consisting of reservoir characterization data available within the public domain; (3) screening the oil and gas database for reservoirs with carbon storage potential; (4) calculating carbon storage capacity for screened reservoirs; and, (5) identifying the limitations in the calculations.

An important objective of this study is the ultimate compilation of a comprehensive oil and gas reservoirs database with GIS capabilities for the entire SWP region. Utah's Automated Geographic Reference Center is responsible for compiling databases and shapefiles from each of the partnership

states and maintaining a public access website (<http://atlas.utah.gov/co2sw>). In addition to oil and gas reservoirs, the SWP regional database also includes characterization data for coalbed reservoirs and deep saline aquifers.

Sandia National Laboratories developed a dynamic simulation model to quantitatively compare alternative sequestration technologies relative to their associated environmental risks, monitoring and verification requirements, life-cycle cost, and applicable regulatory and permitting constraints. This model is designed to directly access the SWP regional database to analyze these highly interdependent and complicated relationships for the purpose of assessing the financial, social, and political costs and benefits associated with various sequestration options in the region.

3.3.1 Compiling Production Data

Two primary sources were utilized to compile the production data for Colorado. The first was *Oil and Gas Fields of Colorado Statistical Summary Through 1996* (Lawson and Hemborg, 1999). This publication contains a summary of all producing, shut in, and abandoned oil and gas fields on record with the Colorado Oil and Gas Conservation Commission (COGCC) through 1996. To update the remaining production record through 2004, a combination of paper and digital files were obtained from COGCC. Only paper records exist for 1997 and 1998; whereas production data starting in 1999 is available as a download from COGCC's website (<http://oil-gas.state.co.us/>).

All of the state's annual production data was compiled into a Microsoft Access© database **Colorado Production Database (**CoPrD**)**. This allowed cumulative production values to be computed, which are not directly available from COGCC. Reports were also generated in which production was aggregated on the basis of such parameters as sedimentary basin, field, formation, county, commodity, etc. (appendix 4).

3.3.2 Assembling Oil and Gas Reservoirs Database

The development of the oil and gas reservoirs database for the SWP started with the Department of Energy's **Gas Information System (GASIS)** maintained by NETL's Strategic Center for Natural Gas (U.S. Department of Energy, 1999). **GASIS** is a national database of geological, engineering, production, and ultimate recovery data for U.S. oil and natural gas reservoirs. The SWP modified the **GASIS** database to create the **CO₂ Sequestration Information System (CO₂SIS)** to accommodate the specific requirements of the CO₂ sequestration project (fig. 3.8). As with the other states in the SWP, Colorado received that portion of the **CO₂SIS** relevant to the state for the purpose of verifying data already existing in the database and updating reservoir data from additional public sources.

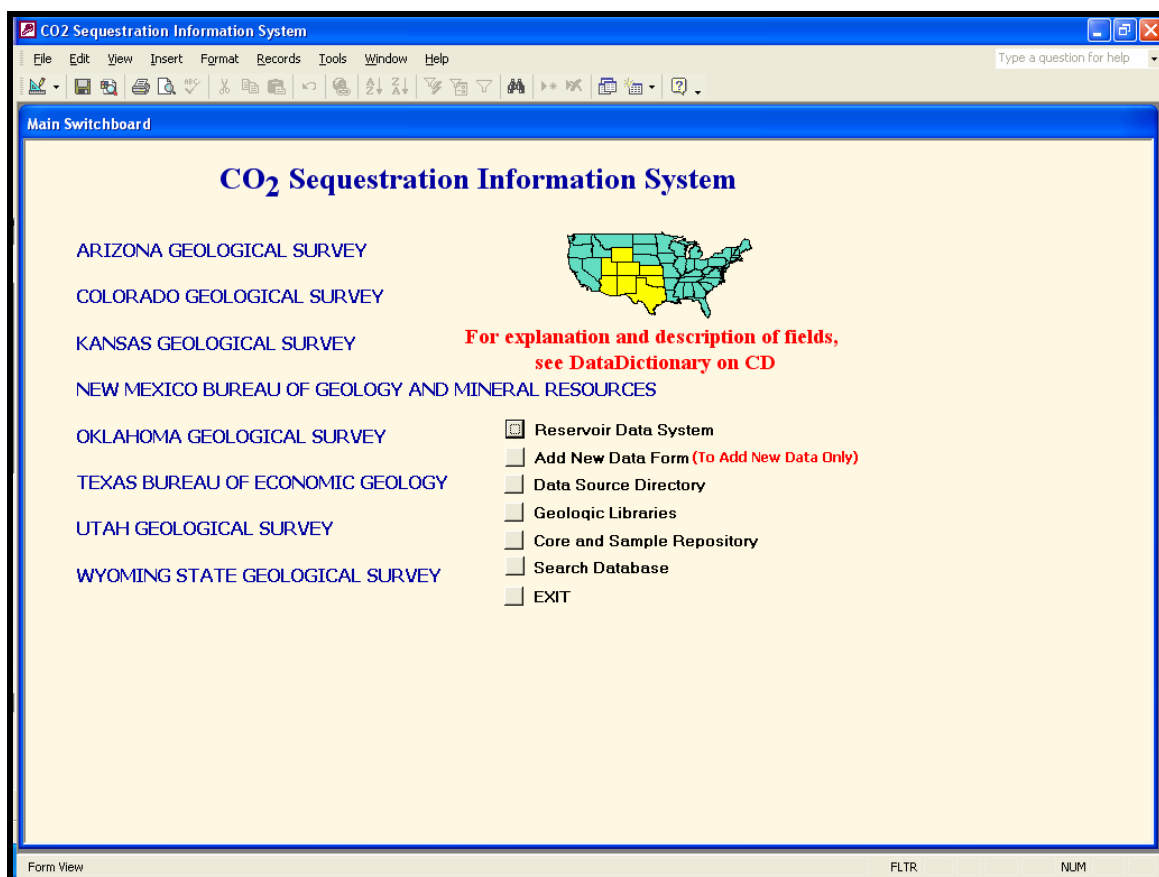


Figure 3.8: Main screen for the SWP's CO₂ Sequestration Information System.

Figure 3.9 illustrates the first screen that appears for Colorado's reservoir data system and the types of characterization data that was sought for each reservoir in the state. Appendix 7 includes the individual parameters for each of the 11 data recording forms within the **CO₂SIS** as well as the accompanying data dictionary for the database. Overall, there are about 1,400 oil and gas fields in Colorado, with many more producing reservoirs. Since production is often commingled from more than one reservoir (or formation), individual reservoirs were often combined for the purpose of data characterization. The contents of the *Colorado Production Database* were merged into Colorado's **CO₂SIS**.

CO2 Sequestration Information System

File Edit View Insert Format Records Tools Window Help

Type a question for help

Frm Reservoir Data System : Form

RESERVOIR DATA SYSTEM

Close Previous Record Next Record

UNIQUE STATE ID#: CO-000010

State: COLORADO

Field Name: ADENA

Reservoir Name: J SAND

Field/Reservoir Identification

EIA Field Code: 004194 TOTAL "Dwights" Code: 7003350

Reservoir Source: R TOTAL "Unique" Code: 050000405

Play name: MUDDY (J) SAND

Play Code: RMDB-5

Subplay Name:

Subplay Code:

USGS Province and Play Code: 39 3905 Play Code Source flag: 0

Field/Reservoir Location

Postal Code: CO API State Code: 05

Primary County: MORGAN Primary County Code: 087

Other Counties:

District: LATITUDE: 0 LONGITUDE: 0

Basin Name: DENVER BASIN Basin Code: 540

Gas Atlas Region: RM View Basin Maps

Record: 1 of 227

unique identifier used to link tables

NUM

Reservoir Type

Field Information Status

Geology

Reservoir Status and Completion Counts

Reservoir Area and Spacing

Reservoir Parameters

Gas and Fluid Properties

Drilling and Evaluation

Stimulation and Completion

Geologic Type Well

Median Recovery Well

Completion Recovery Statistics

Volumetric Data

Gas Composition

Coal Composition

Oil Analysis

Produced Water Composition

Advanced PVT Properties

Advanced PVT CO₂ Properties

Figure 3.9: Reservoir data system for the CO₂ Sequestration Information System.

Considerable effort was required to construct an up-to-date database that would provide reliable screening results and carbon storage capacity calculations. Data sources consisted primarily of peer-reviewed published

reservoir studies; some of the key publications utilized in Colorado are listed in table 3.5.

Table 3.5: Key publications used to characterize Colorado's oil and gas reservoirs

Publisher	Title	Date
Rocky Mountain Association of Geologists	Oil and Gas Fields of Colorado	1954
Rocky Mountain Association of Geologists	Oil and Gas Fields of Colorado	1961
Rocky Mountain Association of Geologists	Geologic Atlas of the Rocky Mountain Region	1972
Intercomp	Economic Feasibility of Carbon Dioxide Enhanced Oil Recovery in the Rocky Mountain Area	1980
Rocky Mountain Association of Geologists	Oil and Gas Fields of Colorado, Nebraska and Adjacent Areas	1982
Four Corners Geological Society	Oil and Gas Fields of the Four Corners Area	1983
New Mexico Bureau of Mines and Mineral Resources	Atlas of Major Rocky Mountain Gas Reservoirs	1993
U.S. Geological Survey	National Assessment of Oil and Gas website http://energy.cr.usgs.gov/oilgas/noga/	2004

3.3.3 Screening Oil and Gas Reservoirs for Carbon Storage

The **CO₂SIS** for Colorado was screened for reservoirs that may have the potential to store relatively large volumes of CO₂. Three screening criteria were used to identify favorable reservoirs. These were: production volume, reservoir depth, and proximity to a relatively large source of anthropogenic CO₂.

The preliminary screening step involved selecting reservoirs that had cumulatively produced either 1 MMBbls of oil or 10 Bcf of gas, or both. These larger-volume reservoirs were considered by the SWP to be more attractive for storing carbon due to the capital investment costs associated with project startup. A minimum reservoir depth of 3,000 feet, at the mid-point of the reservoir, was used to ensure the reservoir could maintain CO₂ at supercritical (liquid) conditions (88 °F and 1,070 psia; fig. 3.10). The final screen was a distance of about 30 miles between the mid-point of the field and a relatively large point

source of CO₂ such as a coal-fired power plant. This distance represents an investment of about \$2.5 to \$3.5 million in a CO₂-grade 4- to 6-inch diameter pipeline between a source and a single injection site (Mike Hirl, KinderMorgan CO₂ Company, L.P., oral communication, 2004).

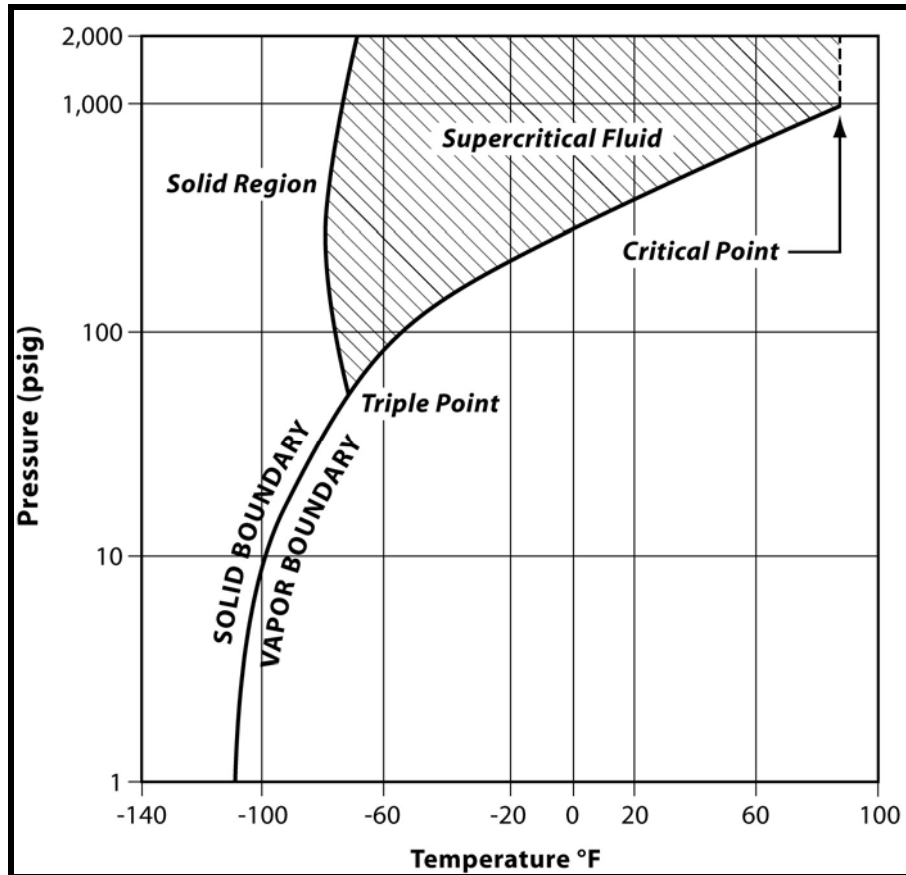


Figure 3.10: CO₂ phase equilibrium diagram showing pressures and temperatures above which CO₂ is maintained at supercritical conditions (modified from Jarrell and others, 2002).

In Colorado, 223 fields have individually produced 1 MMBbls of oil or 10 Bcf of gas. There are 181 Colorado oil and gas reservoirs in 117 fields that not only passed the production volume screen but also occur at a depth amenable to maintaining supercritical CO₂ and are located within 30 miles of a relatively large source of anthropogenic CO₂ (fig. 3.11; appendix 8).

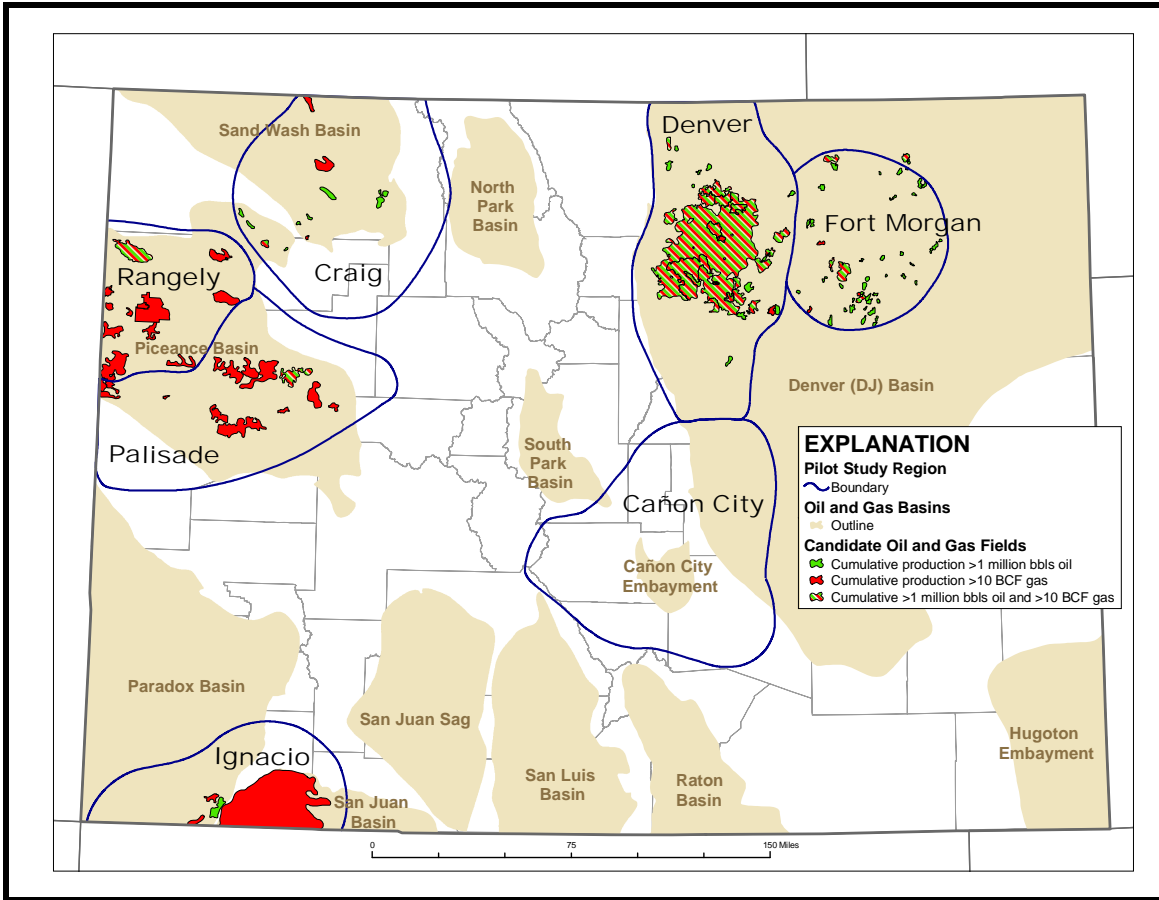


Figure 3.11: Oil and gas reservoirs that screened as candidates for carbon storage in Colorado.

3.3.4 Calculating Carbon Storage Capacity

Carbon storage capacity for oil and gas reservoirs within the SWP region was calculated based on the volume of produced oil, gas, and water from individual reservoirs. A five-step process was developed by Los Alamos National Laboratory based on criteria and data limitations identified by the Partnership. This process accounts for CO₂ sequestration in both the reservoir volume that is voided from production as well as the solubility of CO₂ in the fluids remaining in the reservoir. A program for calculating the densities of carbon dioxide, methane, and water using the equation-of-state (EOS) was developed by the New Mexico Institute of Mining and Technology. The final Microsoft Excel® spreadsheet was distributed to each state for consistent capacity calculations throughout the SWP region.

The methodology used minimum inputs of cumulative oil, gas, and water production as well as reservoir temperature, pressure, and salinity. Where temperature and pressure were not available, proxies were calculated from average depth to the mid-point of the reservoir, a temperature gradient of 1.96 °F per 100 feet, and a pressure gradient of 0.433 psi per foot. Ambient surface conditions were uniformly established at 60 °F and 14.7 psi throughout the SWP region. Other assumptions were necessitated where data was required for calculations but not available in the SWP's **CO₂SIS**. These were primarily related to formation volume factors, fluid compositions, and recovery factors. The details of the calculation process and assumptions are provided in appendix 9.

3.3.5 Limiting Factors in Calculations

Reservoir simulation is the most rigorous method for evaluating the amount of CO₂ that a given reservoir may sequester while also assessing enhanced recovery resulting from the sequestration process. Screening models, which are less data-intensive also exist (**CO₂PM**, **CO₂-PROPHET**) for the purpose of evaluating CO₂ injection requirements relative to process design and recovery potential (U.S. Department of Energy, 2004a). However, even these screening-type models require more inputs than were consistently available in the public domain. Hence, a simplified approach evolved for the purpose of estimating carbon storage potential for the maximum number of oil and gas reservoirs in the SWP region with the minimum amount of input data.

For Colorado, the assumptions utilized to calculate carbon storage capacity resulted in a conservatively low estimate for oil and gas sinks. The **CoPrD** includes annual water production only since 1999 when electronic data became available from COGCC. As a result, the cumulative water production used in Colorado's capacity calculations is significantly lower than actual withdrawal volumes. Alternatively, if the overall recovery factor for oil is closer to 35-40 percent instead of the 20 percent assumed in the calculations, the carbon storage capacity could be lower by 15-18 percent. However, this error is offset if

the cumulative water production is low by as little as a factor of three, which is likely the case.

The **CO₂SIS** for Colorado is very sparsely populated with respect to some reservoir data; for example, no formation volume factors were located in the public sources reviewed during Phase 1 of this project. However, oil gravity was compiled for about 50 percent of the screened reservoirs. Average oil density computed from this database is 51 lb/cf based on 88 samples. This compares very favorably with the assumed value of 50 lb/cf used in the capacity calculations.

3.4 POTENTIAL FOR CO₂ STORAGE IN OIL AND GAS RESERVOIRS

A candidate list of 247 oil and gas reservoirs are identified in six of the seven pilot study regions as having potential for carbon storage (fig. 3.11). (This list was combined on the basis of commingled production into 180 reservoirs for capacity calculations.) Each of these reservoirs screened successfully for production volume, depth, and proximity to an anthropogenic source of CO₂. The total carbon capacity estimated for these candidate reservoirs is 1.886 GT. Sixty-eight percent of the total oil and gas carbon capacity is associated with Rangely and Denver pilot study regions (fig. 3.12). Stratigraphic nomenclature for Colorado is provided in appendix 10.

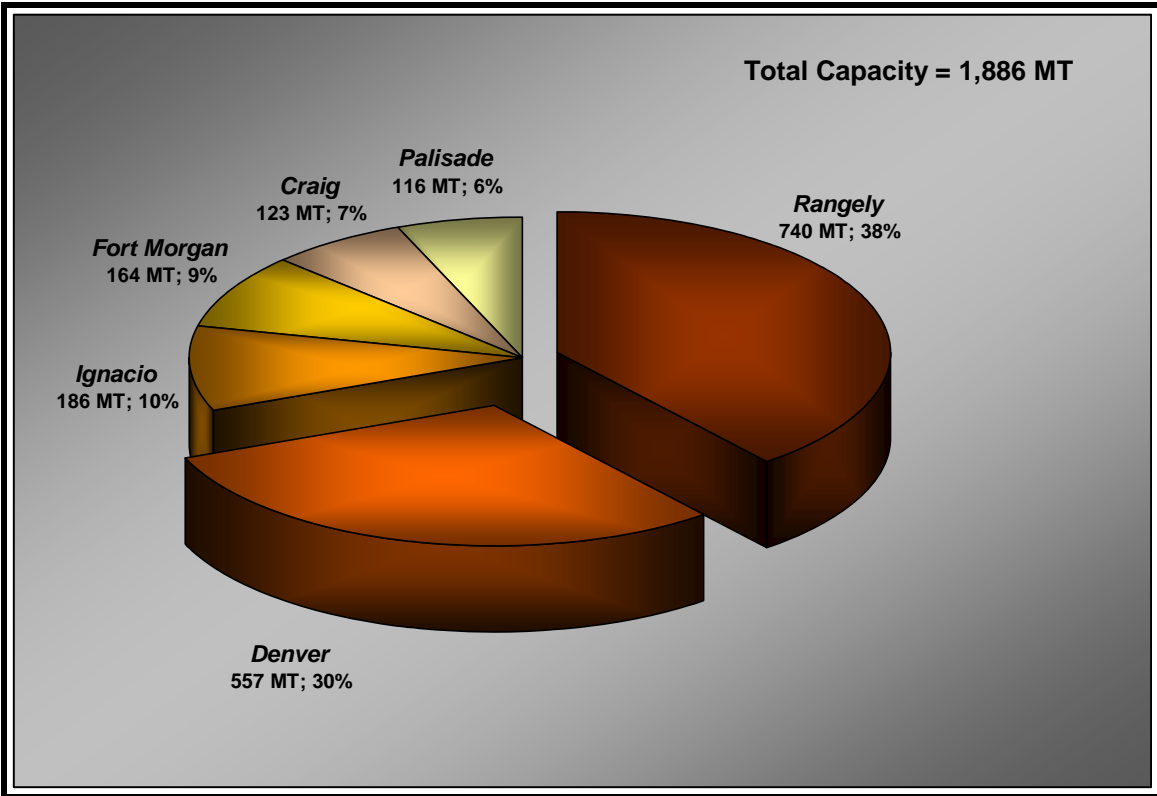


Figure 3.12: CO₂ sequestration capacities estimated for oil and gas reservoirs in Colorado's pilot study regions in million short tons (MT) and as a percentage of the total oil and gas capacity.

3.4.1 Craig Region

The Craig Pilot Study Region is comprised primarily of the eastern two-thirds of the Sand Wash Basin, the extreme northern part of the Piceance Basin, and the Axial Basin Uplift separating the two (fig. 3.11). There are thirty-nine oil and gas reservoirs in 12 fields that screened as candidates for CO₂ sequestration. The total carbon capacity calculated for this region is 123 MT (table 3.6). The largest capacity is estimated at 71 MT for the Wilson Creek field in the northernmost Piceance Basin; nearly all of this capacity is in the Morrison and Entrada reservoirs (fig. 3.13). Screened reservoir depth varies 2,300 to 9,400 feet, averaging in excess of 5,000 feet.

Table 3.6: CO₂ sequestration capacities for oil and gas fields in the Craig pilot study region, northwestern Colorado

Northwestern Colorado			Average Depth (Ft)	Total Capacity (MT)*	
Basin	Field Name	Reservoir Name		Reservoir	Field
Sand Wash	Bear River	Niobrara	4,302	1.0	1.0
	Craig North	Lewis Shale, Mesaverde	2,821	3.3	3.3
	Grassy Creek	Niobrara	5,134	0.7	0.7
	West Side Canal	Lance	2,709	0.3	
		Lewis Shale	3,769	3.8	4.2
		Mesaverde	5,830	0.1	
Piceance - Axial Basin Uplift	Buck Peak	Mancos Shale	3,288	1.0	
		Niobrara	6,822	2.9	3.9
		Shinarump	9,402	0.0	
	Danforth Hills	Dakota, Morrison	5,659	0.9	
		Entrada (Sundance)	6,525	1.1	2.9
		Shinarump, Moenkopi, Minturn, Weber	7,175	0.9	
	Iles	Morrison	2,953	0.8	
		Entrada (Sundance)	3,243	18.7	19.5
		Curtis	3,310	0.0	
	Maudlin Gulch	Dakota, Morrison, Entrada (Sundance)	6,012	6.8	
		Shinarump, Moenkopi, Phosphoria, Weber, Minturn	7,476	3.6	10.4
	Nine Mile	Dakota	7,215	0.7	0.7
	Thornburg	Dakota	2,301	0.6	
		Entrada Sandstone	2,902	0.8	3.4
		Shinarump, Weber	3,485	1.9	
	Tow Creek	Niobrara	3,201	1.9	1.9
	Wilson Creek	Niobrara	4,163	0.1	
		Morrison	6,486	46.2	
Entrada (Sundance)		6,731	23.8	71.1	
Shinarump, Minturn		8,025	1.1		
TOTALS			5,036	123.0	123.0

* MT = Million Short Tons

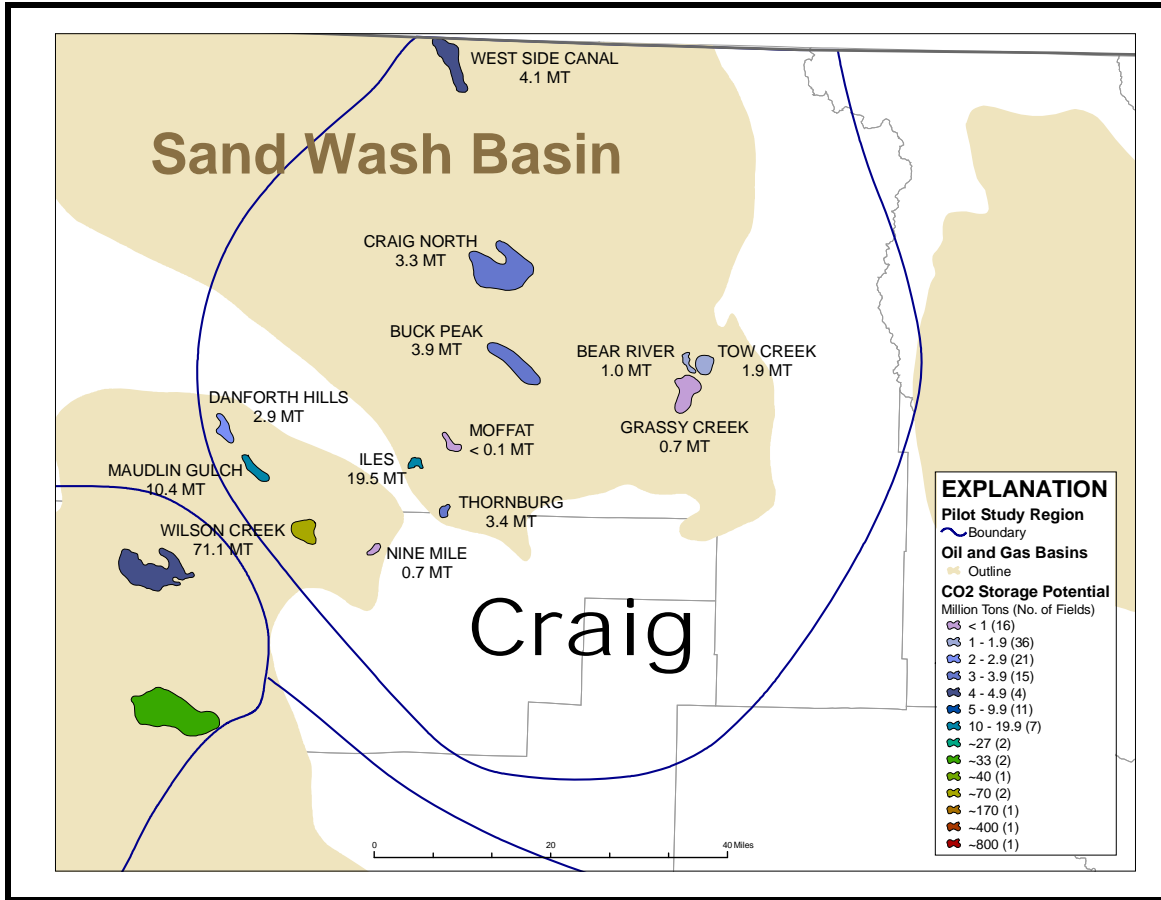


Figure 3.13: Distribution of carbon storage capacity for oil and gas reservoirs in the Craig Pilot Study Region. MT is million tons; (No. of Fields) is the number of fields statewide with the indicated carbon storage capacity.

The principal reservoirs in the Sand Wash Basin are those within the Upper Cretaceous stratigraphic interval, including the Niobrara Member of the Mancos Shale; Mesaverde Group, Lewis Shale, and Lance Formation. For these reservoirs, porosity ranges from 10 to 30 percent and permeability ranges from 0.1 to 500 mD. Reservoir thickness is highly variable, ranging from 10 to 40 feet. Cretaceous reservoirs in the deeper part of the basin have low-permeability. The trapping mechanism for nearly all accumulations is structural. Existing fields are anticlinal folds that are commonly faulted. Impermeable shales and/or faults provide the seals (U.S. Geological Survey, 2005).

The principal reservoirs in the Axial Basin Uplift and northern Piceance Basin include the Pennsylvanian Minturn Formation; Pennsylvanian-Permian Weber Sandstone; Permian Phosphoria Formation; Triassic Moenkopi and

Chinle formations; Jurassic Entrada Sandstone, Curtis and Morrison formations; Lower Cretaceous Dakota Group; and Upper Cretaceous Niobrara Formation, and Marapos Sandstone Member of the Mancos Shale. Porosity ranges from 12 to 20 percent and permeability ranges from 0.1 to 300 millidarcies (mD).

Reservoir thickness ranges 8 to 65 feet. Most hydrocarbon accumulations are in structural traps although reservoirs such as the Weber, Entrada, Shinarump, Dakota and Frontier have stratigraphic aspects (U.S. Geological Survey, 2005). Seals are provided by shales within the section.

Reservoir lithologies in the Craig Pilot Study Region are primarily sandstones interbedded with shales and reflect deposition in eolian, fluvial deltaic, strand plain and shallow margin environments. Horizontal and vertical reservoir heterogeneity varies widely due to facies variations, diagenetic effects, and faulting.

3.4.2 Denver Region

The Denver Pilot Study Region coincides with western third of the Denver Basin and includes the heavily-populated metropolitan areas concentrated along the eastern edge of the Front Range (fig. 3.11). There are eighty-two oil and gas reservoirs in 31 fields that screened as candidates for CO₂ sequestration. The total carbon capacity calculated for this region is 557 MT (table 3.7). The largest capacity is estimated at 388 MT for the Wattenberg field in the west-central part of the Denver Basin; all of this capacity is associated with production from multiple reservoirs with the Cretaceous stratigraphic interval (fig. 3.14). Screened reservoir depth varies from 1,800 to 9,200 feet, averaging in excess of 6,400 feet.

Table 3.7: CO₂ sequestration capacities for oil and gas fields in the Denver pilot study region, northeastern Colorado

Basin	Field Name	Reservoir Name	Average Depth (Feet)	Total Capacity (MT)*	
				Reservoir	Field
Denver	Aristocrat	Niobrara, Codell Ss, Sussex, Shannon, Dakota	4,436	3.6	3.6
	Banner Lakes	Dakota	7,666	1.6	1.6
	Base Line	Codell Sandstone	7,026	0.0	1.1
		Dakota	7,429	1.1	
	Black Hollow	Lyons Sandstone	8,965	7.8	7.8
	Bracewell	Sussex, Shannon	4,344	0.0	4.0
		Niobrara, Codell Sandstone, Dakota	6,845	3.9	
	Chieftain	Dakota	7,492	2.4	2.4
	Clarks Lake	Dakota	6,162	1.7	1.7
	Eaton	Niobrara, Codell Sandstone	6,910	2.8	2.8
	Fort Collins	Niobrara	3,892	0.0	
		Dakota	4,969	5.2	5.4
		Lyons Sandstone	6,190	0.2	
	Greasewood	Dakota	6,714	0.9	0.9
	Greeley	Parkman	3,607	0.1	2.9
		Niobrara, Fort Hays, Codell Sandstone	6,728	2.8	
	Hambert	Sussex	4,389	6.7	6.8
		Niobrara, Codell Sandstone	6,822	0.2	
	Irondale	Dakota	7,045	1.9	1.9
	Jamboree	Dakota	7,781	3.2	3.2
	Kersey	Niobrara, Fort Hays, Codell Sandstone	6,512	3.3	3.3
	Lanyard	Codell Sandstone	6,467	0.0	2.9
		Dakota	6,920	2.9	
	Longbranch	Dakota	7,043	3.3	3.3
	Lost Creek	Niobrara	6,093	0.0	2.2
		Dakota	6,778	2.3	
	Loveland	Sussex, Shannon	1,804	0.0	
		Niobrara, Codell Ss, Timpas, Dakota, Lakota	4,734	3.6	3.6
		Lyons Sandstone	6,896	0.0	
	Lowry	Niobrara	7,794	0.0	1.4
		Dakota	8,493	1.4	
	New Windsor	Sussex	4,254	0.2	
		Codell Sandstone	6,877	0.0	0.8
		Lyons Sandstone	8,993	0.5	
	Pierce	Lyons Sandstone	9,221	8.1	8.1
	Radar	Dakota	7,850	1.6	1.6
	Roggen	Niobrara	6,260	0.0	4.3
		Dakota	6,970	4.3	
	Space City	Dakota	7,907	2.4	2.4
	Spindle	Sussex, Shannon, Niobrara, Fort Hays, Codell Ss, Timpas, Dakota	4,695	70.6	70.6
	Third Creek	Dakota	8,303	6.1	6.1
	Trapper	Dakota	7,890	2.5	2.5
	Waite Lake	Niobrara	5,865	0.0	
		Codell Sandstone	6,152	0.0	
		Greenhorn Limestone	6,179	0.0	1.9
		Dakota	6,525	1.9	
	Wattenberg	Parkman	3,651	0.0	
		Sussex, Shannon, Niobrara, Fort Hays, Codell Ss, Greenhorn, Graneros, Dakota, Lakota, Timpas	4,367	388.0	388.0
	Wellington	Muddy (J) Sandstone	4,494	8.1	8.1
TOTALS			6,355	557.2	557.2

* MT = Million Short Tons

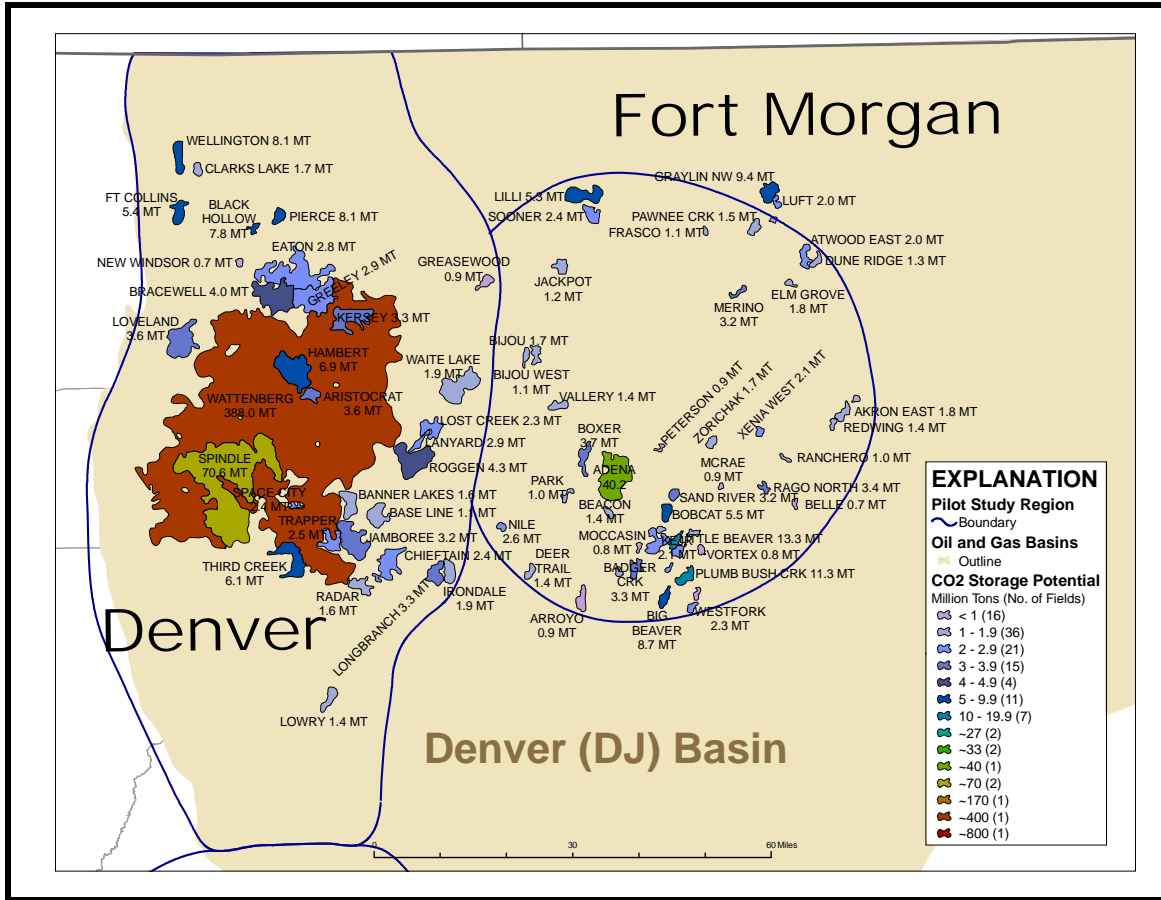


Figure 3.14: Distribution of carbon storage capacity for oil and gas reservoirs in the Denver and Fort Morgan Pilot Study Regions. MT is million tons; (No. of Fields) is the number of fields statewide with the indicated carbon storage capacity.

The principal reservoirs in the Denver region include the Lower Cretaceous Lytle Formation (Lakota) and Dakota Group (Muddy J Sandstone); and the Upper Cretaceous Benton Group (Greenhorn Limestone and Codell Sandstone Member of the Carlile Shale), Fort Hays (Timpas) Member of the Niobrara Formation, and the Pierre Shale (Shannon, Sussex, and Parkman Sandstone Members of the Pierre Shale). There is also some production from the Lower Permian Lyons Sandstone. For these reservoirs, porosity ranges from 2 to 26 percent and permeability ranges from a very tight 0.05 to 100 mD. Reservoir thickness is highly variable, ranging from 5 to 165 feet. The Cretaceous producing interval is characterized primarily by low-permeability reservoirs. The trapping mechanism for most of the accumulations is

stratigraphic; although combination structural/stratigraphic traps are not uncommon.

The lithology of most the reservoirs in this region are sandstones and siltstones with some carbonaceous shales and limestones that reflect deposition in shallow shelf, fluvial deltaic, and strand plain environments. Horizontal and vertical reservoir heterogeneity is consistently very high due to depositional and diagenetic effects.

3.4.3 Fort Morgan Region

The Fort Morgan Pilot Study Region is immediately adjacent to the Denver Pilot Study Region and is approximately half its size (fig. 3.11). There are fifty-one oil and gas reservoirs in 48 fields that screened as candidates for CO₂ sequestration. The total carbon capacity calculated for this region is 164 MT (table 3.8). The largest capacity is estimated at 40 MT for the Adena field near the center of the region, where all of this capacity is associated with the Dakota reservoir which is currently undergoing waterflood operations (fig. 3.14). Screened reservoir depth varies from 4,400 to 6,500 feet, averaging about 5,300 feet.

Table 3.8: CO₂ sequestration capacities for oil and gas fields in the Fort Morgan pilot study region, northeastern Colorado

Basin	Field Name	Reservoir Name	Average Depth (Feet)	Total Capacity (MT)*	
				Reservoir	Field
Denver	Adena	Dakota	5,561	40.2	40.2
	Akron East	D Sandstone	4,580	1.8	1.8
	Arroyo	Dakota	5,977	0.9	0.9
	Atwood East	Dakota	4,412	2.0	2.0
	Badger Creek	Dakota	5,296	3.3	3.3
	Beacon	Dakota	5,767	1.4	1.4
	Belle	Dakota	4,841	0.7	0.7
	Big Beaver	Muddy (J) Sandstone	5,015	8.7	8.7
	Bijou	Greenhorn Limestone	5,819	0.0	
		D Sandstone	6,095	1.7	1.7
	Bijou West	D Sandstone	6,158	1.1	1.1
	Bobcat	Dakota	5,142	5.5	5.5
	Boxer	Dakota	5,839	3.7	3.7
	Deer Trail	Dakota	6,220	1.4	1.4
	Dune Ridge	Dakota	4,443	1.3	1.3
	Elm Grove	Dakota	4,604	1.8	1.8
	Frasco	Dakota	5,410	1.1	1.1
	Graylin Northwest	Dakota	4,910	9.4	9.4
	Hardway	D Sandstone	4,438	0.7	0.7
	Jackpot	D Sandstone	6,461	1.2	1.2
	Kejr	Dakota	4,986	2.1	2.1
	Lilli	Codell Sandstone	5,930	0.0	
		D Sandstone	6,381	5.3	5.3
	Little Beaver	Dakota	5,201	13.3	13.3
	Little Beaver East	Dakota	5,064	2.8	2.8
	Luft	Dakota	4,868	2.0	2.0
	McRea	Muddy (J) Sandstone	4,933	0.9	0.9
	Merino	Muddy (J) Sandstone	4,980	3.2	3.2
	Middlemist	Muddy (J) Sandstone	5,508	1.4	1.4
	Moccasin	Muddy (J) Sandstone	5,417	0.8	0.8
	Nile	Dakota	6,360	2.6	2.6
	Nugget	D Sandstone	5,216	1.6	1.6
	Park	Niobrara	5,232	0.0	
		Dakota	6,098	1.0	1.0
	Pawnee Creek	Muddy (J) Sandstone	5,035	1.5	1.5
	Peterson	D Sandstone	5,173	0.9	0.9
	Phegley	D Sandstone	4,856	1.6	1.6
	Plumb Bush Creek	Muddy (J) Sandstone	4,969	11.3	11.3
	Rago North	Dakota	4,876	3.4	3.4
	Ramp	Muddy (J) Sandstone	4,915	0.7	0.7
	Ranchero	Dakota	4,746	1.0	1.0
	Redwing	D Sandstone	4,555	1.4	1.4
	Sand River	D Sandstone	5,124	3.2	3.2
	Shield	Dakota	4,845	1.0	1.0
	Sooner	Dakota	6,279	2.4	2.4
	Swan	Dakota	5,036	2.0	2.0
	Vallery	Dakota	5,904	1.4	1.4
	Vortex	Muddy (J) Sandstone	4,936	0.8	0.8
	Westfork	Muddy (J) Sandstone	4,924	2.3	2.3
	Xenia West	Dakota	4,710	2.1	2.1
	Zorichak	Dakota	4,945	1.7	1.7
TOTALS			5,274	163.7	163.7

* MT = Million Short Tons

The principal reservoirs in the Fort Morgan region include the Lower Cretaceous Dakota Group (Muddy J Sandstone) and the Upper Cretaceous Benton Group (D Sandstone, Greenhorn Limestone and Codell Sandstone Member of the Carlile Shale), and the Niobrara Formation. For these reservoirs, porosity ranges from 7 to 27 percent and permeability ranges from 1 to 1,200 mD. Reservoir thickness is highly variable, ranging from 3 to 72 feet. The trapping mechanism for most of the accumulations is stratigraphic; although combination structural/stratigraphic traps are also common.

Reservoir lithology is consistently sandstone with the exception of the Greenhorn Limestone. Depositional environments include fluvial deltaic, shallow shelf, and strand plain environments. Horizontal and vertical reservoir heterogeneity is consistently very high due to abrupt facies variations and post-depositional diagenetic effects.

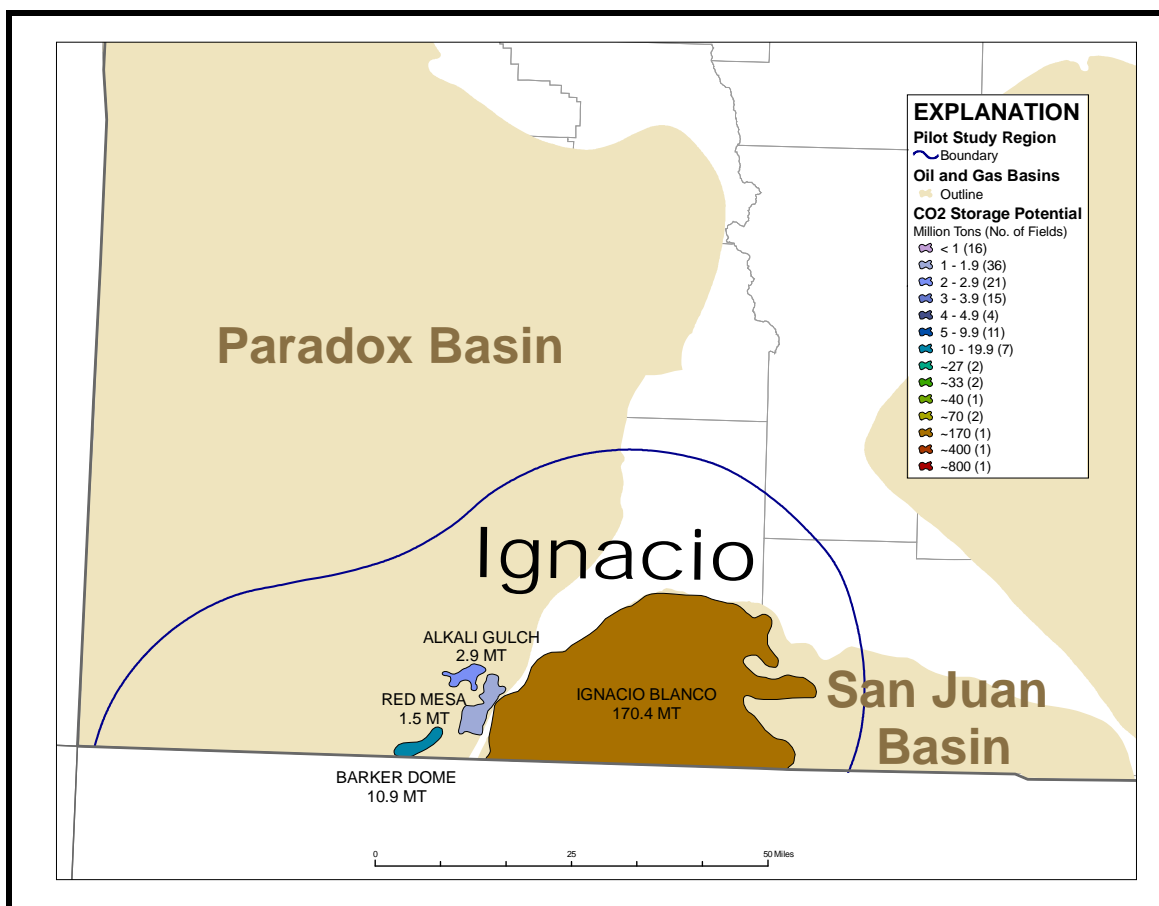
3.4.4 Ignacio Region

The Ignacio Pilot Study Region is located in the southwestern part of Colorado and includes most of the northern portion of the San Juan Basin and the southeastern part of the Paradox Basin (fig. 3.11). Ten oil and gas reservoirs in four fields screened as candidates for CO₂ sequestration. The total carbon capacity calculated for this region is 186 MT (table 3.9). The largest capacity is estimated at 170 MT for the Ignacio Blanco field in the northern San Juan Basin, where most of this capacity is associated with Cretaceous-age reservoirs (fig. 3.15). Screened reservoir depth varies from 3,100 to 9,800 feet, averaging about 5,800 feet.

Table 3.9: CO₂ sequestration capacities for oil and gas fields in the Ignacio pilot study region, southwestern Colorado

Basin	Field Name	Reservoir Name	Average Depth (Feet)	Total Capacity (MT)*	
				Reservoir	Field
Paradox	Alkali Gulch	Dakota	3,074	0.0	
		Hermosa Group	8,192	2.2	2.9
		Molas	9,752	0.6	
	Barker Dome	Dakota	3,178	0.0	
		Hermosa Group	7,683	10.9	10.9
	Red Mesa	Dakota, Morrison	3,396	1.5	1.5
San Juan	Ignacio Blanco	Mesaverde Group, Dakota, Morrison	4,963	170.4	170.4
TOTALS			5,748	185.7	185.7

* MT = Million Short Tons

**Figure 3.15:** Distribution of carbon storage capacity for oil and gas reservoirs in the Ignacio Pilot Study Region. MT is million tons; (No. of Fields) is the number of fields statewide with the indicated carbon storage capacity.

The principal reservoirs in the Paradox Basin are the Pennsylvanian Molas Formation and Hermosa Group; Jurassic Morrison Formation; and the Lower Cretaceous Dakota Sandstone. For these reservoirs, reported porosity

data is consistently very low at less than 1 percent and permeability ranges from 10 to 20 mD. Reservoir thickness is highly variable, ranging from 15 to 100 feet. The trapping mechanism is typically stratigraphic for nearly all accumulations.

Reservoir lithology is dominated by limestones and dolomites in the Paleozoic part of the section where deposition was associated with large reef complexes. Alternatively, reservoir lithology is dominated by sandstones in the Mesozoic part of the section where deposition was associated with fluvial deltaic and non-marine environments. Horizontal and vertical reservoir heterogeneity is very high particularly for carbonate reservoirs that have experienced significant post-depositional diagenetic effects.

The principal reservoirs in the San Juan Basin include the Upper Jurassic Morrison Formation; Lower Cretaceous Dakota Sandstone; and Upper Cretaceous Mesaverde Group. For these reservoirs, porosity ranges from 5 to 10 percent and permeability is generally less than 10 mD. Total reservoir thickness ranges from 100 to 150 feet. The trapping mechanism is usually structural anticlines for many accumulations.

Reservoir lithology is dominated by sandstones and siltstones where deposition was associated with fluvial deltaic and strand plane environments. Horizontal and vertical reservoir heterogeneity is related to depositional effects and is considered moderate for this basin.

3.4.5 Palisade Region

The Palisade Pilot Study Region is located in the southern half of the Piceance Basin (fig. 3.11). There are twenty-six oil and gas reservoirs in 12 fields that screened as candidates for CO₂ sequestration. The total carbon capacity calculated for this region is 116 MT (table 3.10). The largest capacity is estimated at 32 MT for the Rulison field in the east-central part of the Piceance Basin; all of this capacity is associated with Mesaverde Group production interval (fig. 3.16). Screened reservoir depth varies from 400 to 8,000 feet, averaging in excess of 3,700 feet.

Table 3.10: CO₂ sequestration capacities for oil and gas fields in the Palisade pilot study region, west-central Colorado

Basin	Field Name	Reservoir Name	Average Depth (Feet)	Total Capacity (MT)*	
				Reservoir	Field
Piceance	Bar X	Dakota, Morrison	2,496	0.9	1.8
		Entrada Sandstone	3,035	0.9	
	Bridle	Dakota, Morrison	3,118	2.6	2.6
		Entrada Sandstone	3,700	0.0	
	Buzzard Creek	Wasatch	396	0.0	1.7
		Mesaverde Group	4,503	1.6	
	Divide Creek	Mesaverde Group	3,009	8.1	8.1
	Grand Valley	Mesaverde Group	3,619	26.7	26.7
	Hunters Canyon	Dakota, Morrison	6,161	0.5	0.5
	Mamm Creek	Mesaverde Group	3,845	26.1	26.1
	Parachute	Mesaverde Group	3,810	10.6	10.6
	Plateau	Mesaverde Group	3,734	0.8	1.0
		Dakota, Morrison	7,360	0.2	
	Rulison	Mesaverde Group	4,153	32.2	32.3
		Mancos Shale	8,004	0.0	
	Shire Gulch	Mesaverde Group, Dakota, Frontier, Cedar Mtn, Mancos, Morrison	775	3.2	3.2
	Wolf Creek	Mesaverde Group	1,643	1.4	1.4
TOTALS			3,727	115.9	115.9

* MT = Million Short Tons

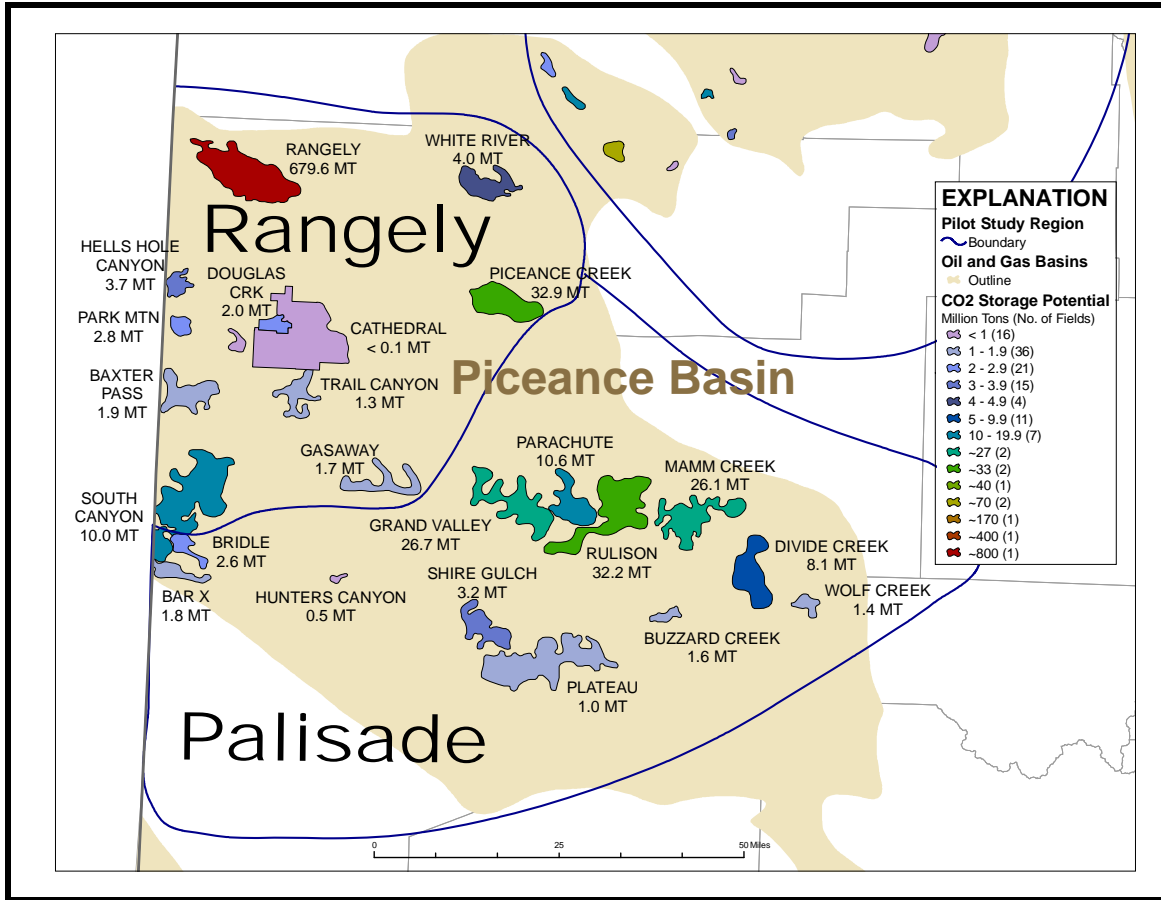


Figure 3.16: Distribution of carbon storage capacity for oil and gas reservoirs in the Palisade and Rangely Pilot Study Regions. MT is million tons; (No. of Fields) is the number of fields statewide with the indicated carbon storage capacity.

The principal reservoirs in the Palisade region include the Middle Jurassic Entrada Sandstone; Upper Jurassic Morrison Formation; Lower Cretaceous Cedar Mountain Formation of the Dakota Group; Upper Cretaceous Frontier Formation of the Mancos Group, the Mesaverde Group (Iles and Williams Fork Formations, and Ohio Creek Member); and the Paleocene Wasatch Formation. For these reservoirs, porosity ranges from 2 to 23 percent and permeability ranges from a very tight 0.05 to 0.15 mD. Total reservoir thickness is highly variable, ranging from 10 to 1,500 feet. The Cretaceous producing interval is characterized primarily by low-permeability reservoirs. The trapping mechanisms for most of the accumulations are a combination of structural and stratigraphic; specific types include lateral variations in facies and post-depositional porosity

development, anticlinal features, and structural noses; fracturing and faulting are common.

The lithology of most the reservoirs in this region are sandstones and siltstones with interbedded shales. Environments of deposition include shallow shelf, fluvial deltaic, and strand plain environments. Horizontal and vertical reservoir heterogeneity is extremely high due to depositional and diagenetic effects as well as the presence of extensive fracturing and faulting.

3.4.6 Rangely Region

The Rangely Pilot Study Region is located in the northern half of the Piceance Basin (fig. 3.11). Thirty nine oil and gas reservoirs in 10 fields screened as candidates for CO₂ sequestration. The total carbon capacity calculated for this region is 740 MT (table 3.11). The largest capacity is estimated at 680 MT for the Rangely field in the northwestern part of the Piceance Basin; all of this capacity is associated with Weber Sandstone which is currently undergoing a CO₂ miscible flood (fig. 3.16). Screened reservoir depth varies from 2,400 to 14,400 feet, averaging nearly 5,600 feet.

Table 3.11: CO₂ sequestration capacities for oil and gas fields in the Rangely pilot study region, west-central Colorado

Basin			Average Depth (Feet)	Total Capacity (MT)*	
Field Name	Reservoir Name	Reservoir		Field	
Piceance	Baxter Pass	Mancos	3,000	0.1	2.0
		Dakota, Cedar Mountain, Buckhorn, Morrison	6,303	1.9	
	Douglas Creek	Dakota	4,719	2.0	2.0
	Gasaway	Mesaverde Group	3,721	0.1	1.7
		Mancos	4,435	0.5	
		Dakota	8,370	1.0	
	Hells Hole Canyon	Williams Fork	2,437	0.0	3.6
		Mancos	3,317	0.1	
		Dakota, Cedar Mountain, Buckhorn, Morrison	6,956	3.6	
	Park Mountain	Mancos B	3,726	0.0	2.8
		Dakota, Cedar Mountain, Buckhorn, Morrison	7,196	2.8	
		Williams Fork	7,906	0.0	
	Piceance Creek	Douglas Creek	2,741	7.1	32.8
		Wasatch	2,886	24.7	
		Mesaverde Group, Ohio Creek	7,053	1.1	
		Mancos B	14,370	0.0	
	Rangely	Morrison	3,542	0.4	679.7
		Entrada Sandstone	4,298	0.0	
		Shinarump	5,287	0.1	
		Weber Sandstone	5,973	679.1	
South Canyon	Dakota, Cedar Mountain, Buckhorn, Morrison	4,669	10.0	10.0	
Trail Canyon	Mancos	2,389	0.3	1.3	
	Dakota, Buckhorn	6,414	1.1		
White River	Mesaverde Group	3,370	4.0	4.0	
	Weber Sandstone	14,194	0.1		
TOTALS			5,571	740.0	740.0

The principal reservoirs in the Rangely region include the Pennsylvanian-Lower Permian Weber Sandstone; Upper Triassic Shinarump Sandstone Member of the Chinle Formation; Middle Jurassic Entrada Sandstone; Upper Jurassic Morrison Formation; Lower Cretaceous Cedar Mountain Formation of the Dakota Group; Upper Cretaceous Emery (Mancos B) Sandstone of the Mancos Shale and the Mesaverde Group (Williams Fork Formation and Ohio Creek Member); Paleocene Wasatch Formation; and Eocene Douglas Creek Member of the Green River Formation. For these reservoirs, porosity ranges from 8 to 17 percent and permeability ranges from 0.1 to 25 mD. Total reservoir thickness ranges from 200 to 300 feet. The trapping mechanisms for most of the accumulations are a combination of structural and stratigraphic; specific types include lateral variations in facies and post-depositional porosity development, anticlinal features and structural noses; fracturing and faulting are common.

The lithology of most the reservoirs in this region are sandstones and siltstones with interbedded shales; limestones and conglomerate are less common. Environments of deposition include eolian, lacustrine, and fluvial deltaic environments. Horizontal and vertical reservoir heterogeneity is extremely high due to depositional and diagenetic effects as well as the presence of extensive fracturing and faulting.

3.5 CONCLUSIONS

CO₂ sequestration capacity for oil and gas reservoirs in the seven pilot study regions is estimated at 1,886 MT with about 70 percent of that potential capacity associated with the Denver and Rangely regions (table 3.12). Recent work by Advanced Resources suggests that 510 to 580 MMBbls of oil may be economically recovered from potential future CO₂-EOR projects in 12 of Colorado's major oil reservoirs. These EOR projects would not only provide suitable longer-term sequestration opportunities but would also result in increased production to offset costs.

Table 3.12: Value added benefits from CO₂ storage potential in oil and gas reservoirs and gas storage facilities in Colorado

Sink Type	CO ₂ Storage Potential	Value Added Benefit
Oil and Gas	Up to 1,886 MT	510-580 MMBbls CO ₂ -EOR Estimated; EGR Undefined
Natural CO₂	Up to 17.5 MT/Year	Offset Depletion of Existing Resources Currently Used for CO ₂ -EOR
Gas Storage	Up to 4.4 MT	Reduce Base Gas Requirements and Associated Costs

Colorado's production of natural CO₂ has averaged 300 Bcf per year since the mid-1980s primarily for use in Permian Basin CO₂-EOR projects. Representing an annual equivalent of 17.5 MT, economic sources of anthropogenic CO₂ would have considerable commodity value and would have the potential to offset depletion of existing natural deposits.

Current underground gas storage facilities in Colorado have nearly 48 Bcf committed in base gas, which represents 17 to 163 percent of the working gas volume and a significant portion of total project investment. Some of these facilities may be suitable to base gas reductions via CO₂ replacement. Up to 4.4 MT of CO₂ would be required to offset the current base gas levels in Colorado.

Synergistic opportunities may exist for carbon sequestration via enhanced recovery and underground gas storage projects, particularly where economic sources of anthropogenic CO₂ are made available. Such projects may serve as the required catalyst to promote longer-term carbon storage programs due in part to their potential to offset costs with revenue-generating capability. Further site-specific investigations are required to determine both the technical and economic feasibility of implementing any one of these options.

4.0 COALBED SINKS IN COLORADO

4.1 COLORADO OVERVIEW

Coalbed methane is an important resource for Colorado. Since separate reporting for coalbed methane was established in 1990, annual production growth has averaged 26 percent per year and now represents about one-half of the state's total natural gas production (fig. 4.1). Colorado coalbed methane production was 501 Bcf in 2004 and resulted in the state remaining the highest coalbed methane producer in the nation for the third consecutive year (Cappa and others, 2005). Cumulative coalbed methane recovery reached 4.5 Tcf the end of 2004.

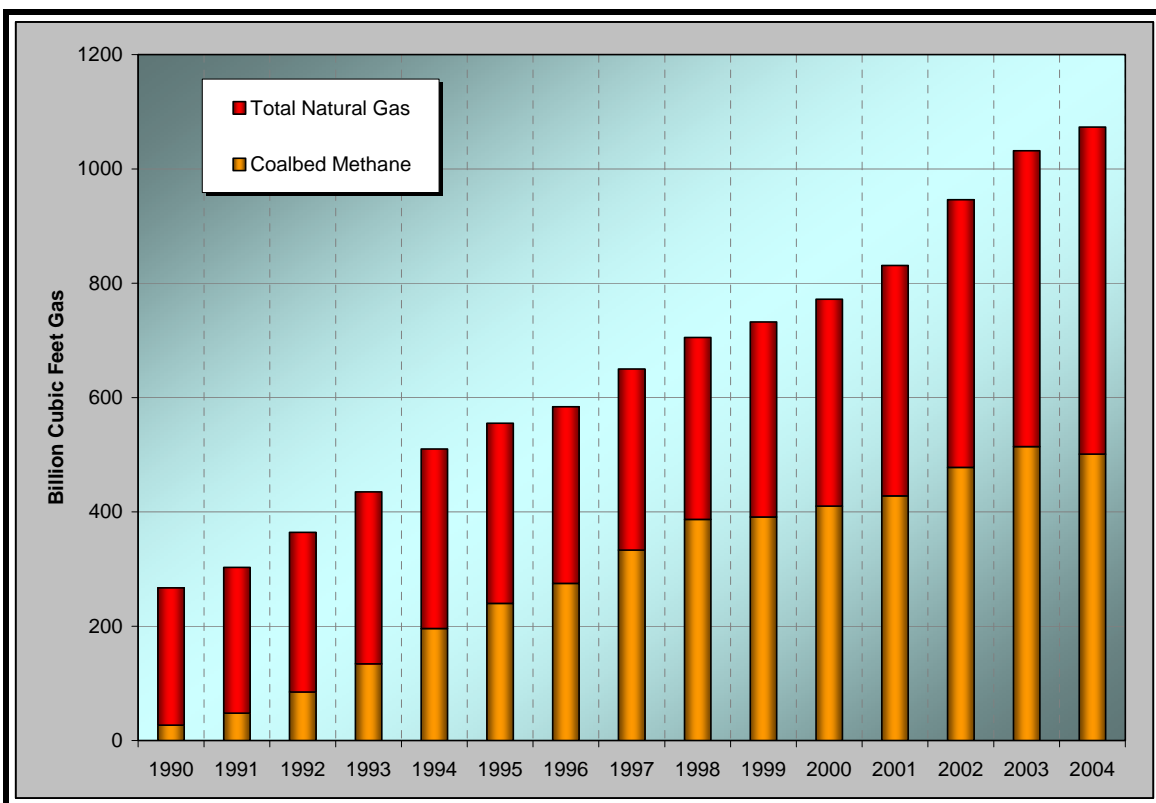


Figure 4.1: Colorado natural gas production through 2004 and contribution from coalbed methane development (Colorado Oil and Gas Conservation Commission, 2005).

Nationally, proved reserves of coalbed methane were 18.7 Tcf in 2003, accounting for 10 percent of all 2003 dry natural gas reserves in the U.S. (Energy Information Administration, 2004d). Eighty-eight percent of the U.S. proved coalbed methane reserves are in five states - Colorado, New Mexico, Wyoming, Utah, and Alabama. Among these states, Colorado ranks first in the nation for coalbed methane proved reserves with nearly 35 percent or 6.5 Tcf of the total U.S. reserves.

Of the nearly 30,000 wells currently producing in Colorado, almost 15 percent specifically target coal seam reservoirs such as the Fruitland Formation in the San Juan Basin and the Raton and Vermejo Formations in the Raton Basin. Ten of Colorado's 64 counties produce coalbed methane, which results in an average daily rate of 1.4 Bcf (Colorado Oil and Gas Conservation Commission, 2005).

4.2 CARBON STORAGE IN COALBEDS

4.2.1 Coalbed Methane Basics

In the early 1980s, the natural gas industry came to recognize coalbed methane for its unique characteristics and its potential as a low-cost source of relatively pure methane. Coal seams are unique in that they are a source rock, gas reservoir, and a trapping mechanism within the same geologic stratum. Due to their relative shallowness, coalbeds may also represent (or be in hydrologic communication with) important aquifers used for livestock or domestic purposes. Coalbed methane forms by both biogenic and thermogenic processes acting on accumulated sediments in coal-forming swamps (Law and Rice, 1993). Maturation results in methane molecules being adsorbed on the coal surface where their retention is enhanced further by hydrostatic pressure. Gas production occurs when this hydrostatic pressure is reduced by pumping water from the coal seam and allowing methane to flow to the wellbore via the natural cleat (fracture) system.

Primary recovery varies widely for coal seam reservoirs due in part to their characteristically high degree of heterogeneity compared to oil and gas reservoirs. The primary factors controlling recovery, which may range from less than 10 to nearly 70 percent, are permeability, coal thickness, gas content, and the degree to which the coal is gas-saturated relative to its maximum adsorptive capacity; that is, the ratio of desorption pressure to initial reservoir pressure (Young and others, 1992).

4.2.2 Enhanced Coalbed Methane Recovery

Enhanced coalbed methane recovery (ECBM) is the process by which carbon dioxide or nitrogen (N₂), or their combination known as flue gas, is injected into a coal seam reservoir to increase methane recovery. As indicated by their relative adsorption isotherm behavior, CO₂ has a much stronger affinity for adsorbing onto the coal surface than either methane or nitrogen (fig. 4.2). Thus, as CO₂ is injected into the coal seam reservoir, it is preferentially adsorbed onto the coal matrix while displacing methane for production. Known as CO₂-ECBM, this process is conceptualized in fig. 4.3.

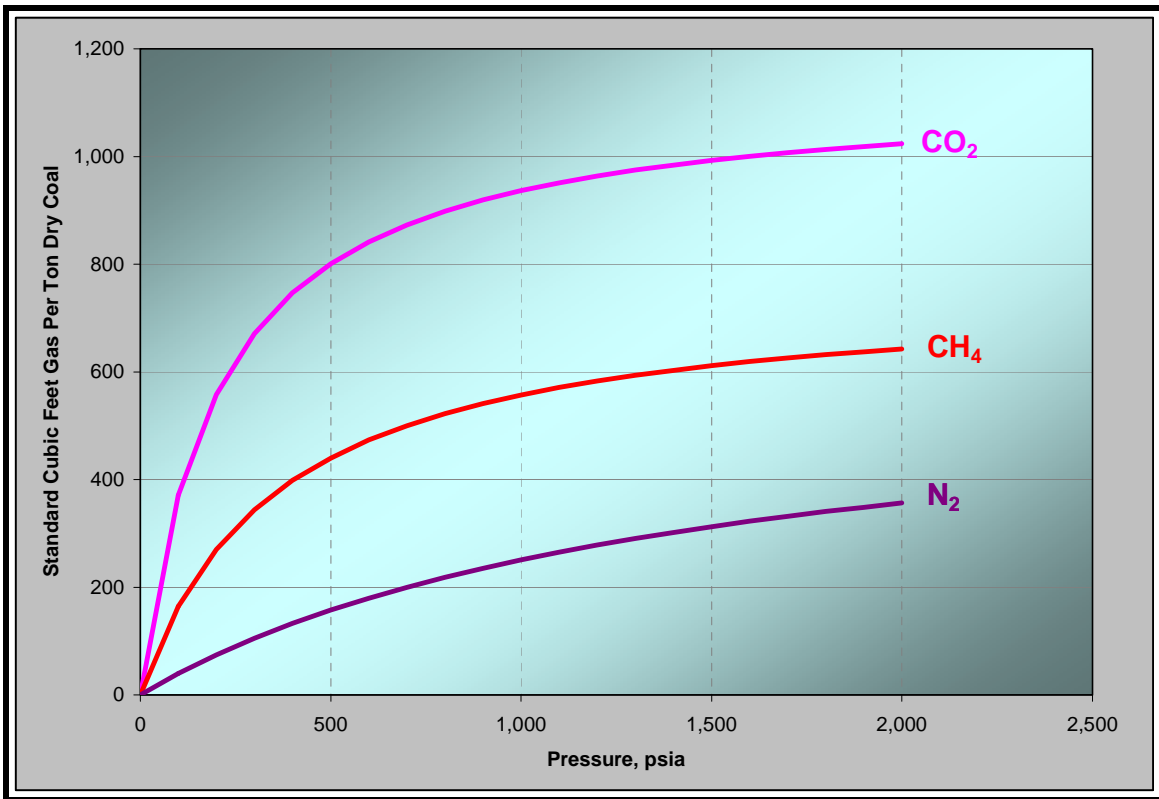


Figure 4.2: Adsorption isotherm relationships for pure CO₂, CH₄, and N₂ as measured for a San Juan Basin Fruitland dry coal sample with 18.1 percent mineral matter and at 115 °F (Arri and others, 1992).

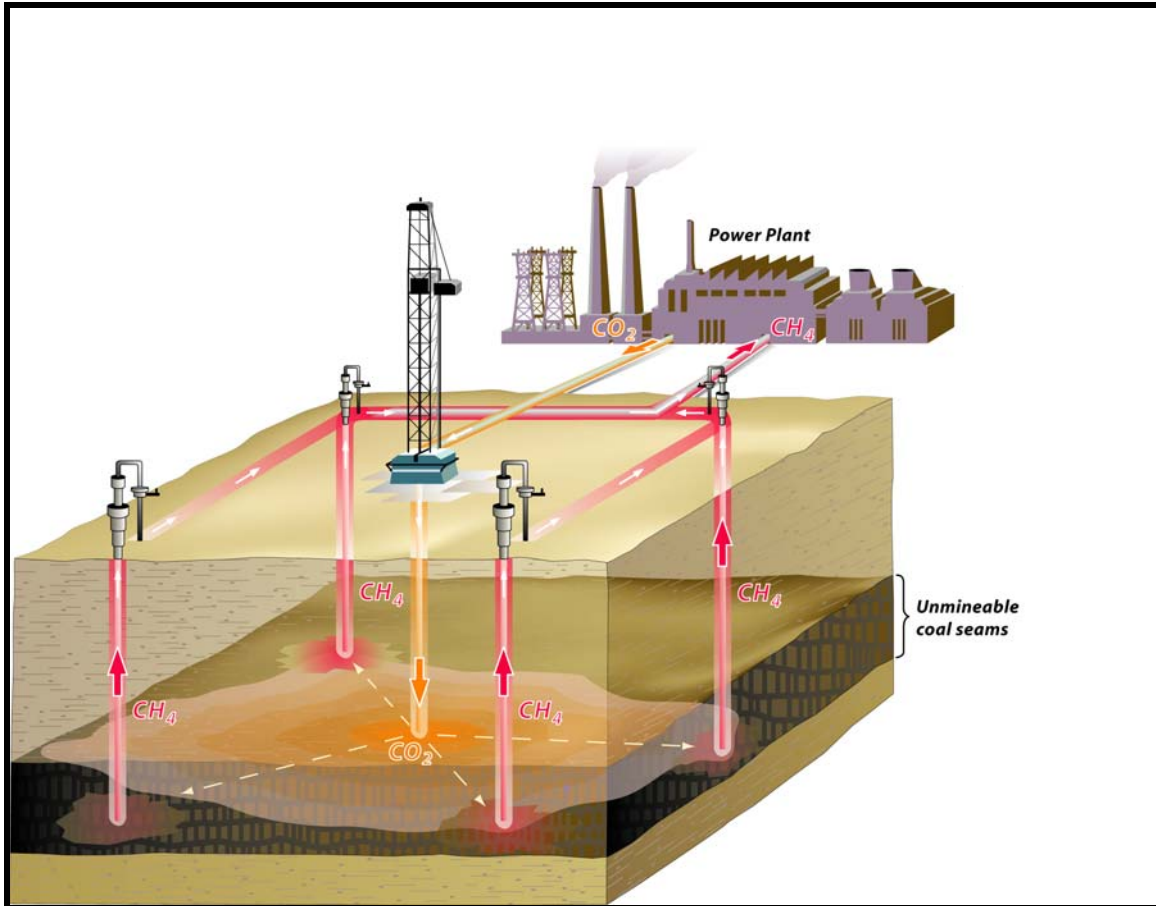


Figure 4.3: Schematic of CO₂-ECBM (modified after Reeves, 2001).

The ratio of CO₂ molecules required to displace a CH₄ molecule is a function of coal rank (fig. 4.4). For a given reservoir pressure, it is estimated that San Juan Fruitland coals (ranked medium to high volatile A bituminous) will store two or three times more CO₂ than CH₄. Alternatively, this adsorption ratio dramatically increases with decreasing coal rank, possibly exceeding 10 for lignite. [For a detailed discussion of the mechanisms of CO₂-ECBM, the reader is referred to Reeves (2001) and Reeves and Pekot (2001)].

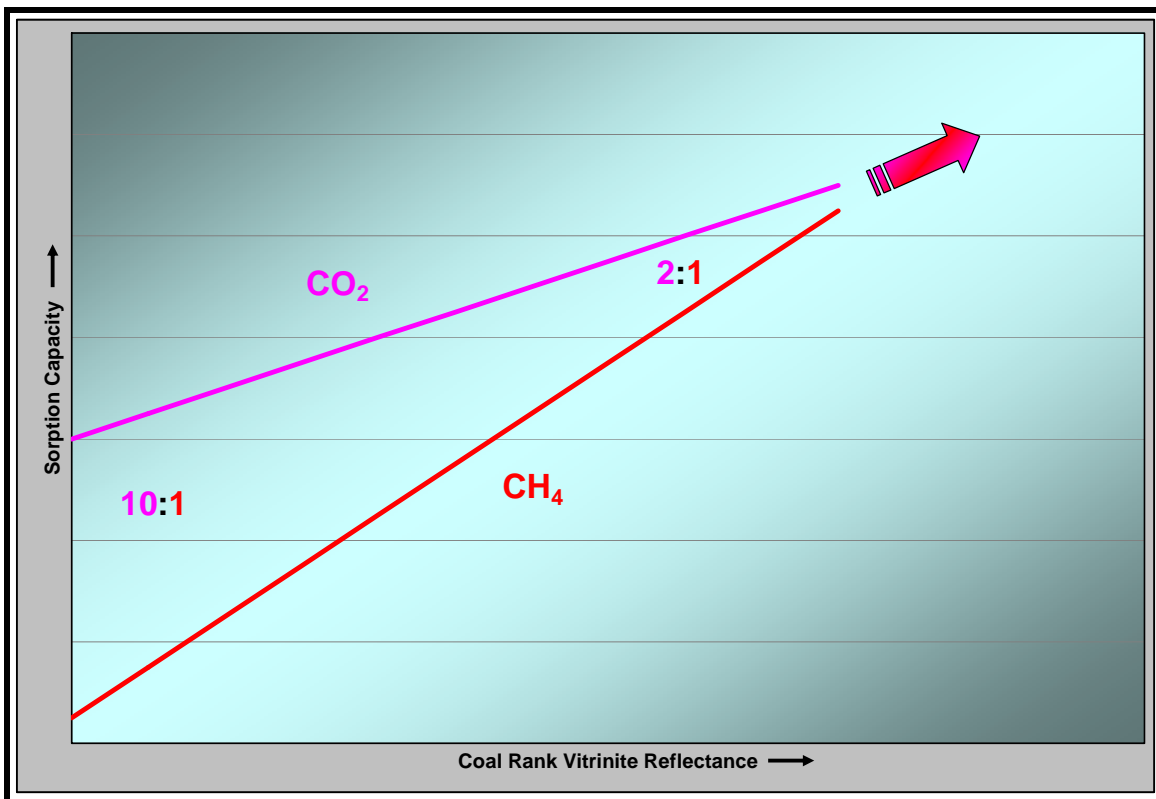


Figure 4.4: CO₂ and CH₄ sorption capacity as a function of coal rank (Bustin, 2002).

Benefits and Research Needs

It is this synergism between coal's adsorptive capacity and industry efforts to maximize recovery efficiency for the country's vast coalbed methane resources that results in their attractive consideration as carbon sequestration opportunities. Advanced Resources has identified some of the most beneficial reasons for combining enhanced coalbed methane recovery with CO₂ sequestration (Kuuskraa, 2004):

1. **Offsetting Revenues.** Injecting CO₂ into coal seams can provide additional gas recovery and a revenue stream that may partially offset the costs of CO₂ storage.
2. **Increased Reserves and Recovery.** In many basins, only a portion of the gas in-place will be recovered using conventional depletion. ECBM can significantly increase this volume.

3. **Accelerated, Higher Pressure Production.** Injecting CO₂ will help accelerate gas recovery and enable the produced gas to be recovered at higher pressures.
4. **Proximity of Storage Sites to CO₂ Emission Sources.** Coal fields and reservoirs are widely distributed and often close to major power plant sites, thereby reducing CO₂ transportation costs.
5. **High Storage Capacity at Moderate Pressures.** The favorable shape of the CO₂ adsorption isotherm enables large volumes of CO₂ to be stored at relatively low (300 to 1,000 psi) pressures, reducing CO₂ compression requirements.
6. **Lower Risks of CO₂ Losses or Leakage.** Pressure and adsorption rather than a structure or a seal provides the primary trapping mechanism for CO₂ stored in coals, providing an additional level of safety.

Although a few CO₂-ECBM field tests have been conducted (and several more are planned), the technical knowledge base is still limited. A recent industry survey conducted by Advanced Resources prioritizes some of the key knowledge gaps and technological barriers identified by industry leaders currently working in this field (Kuuskraa, 2005). Recommended topics of future research should include:

- Improved understanding of linkage between coal swelling and loss of permeability/injectivity due to CO₂ or other injectants;
- Develop technologies for overcoming loss of permeability/injectivity;
- Tools to find and characterize geologically favorable settings;
- Improved understanding of relationship between ECBM and CO₂ storage in coals;
- Methods for monitoring CO₂ flow and retention; and
- Solutions to economic risk and environmental barriers.

Allison Unit

The Allison Unit was the first CO₂-ECBM field pilot in the world, and remains the only multi-well, multi-year test conducted to date. Operated by Conoco Phillips (formerly Burlington Resources), the Allison Unit is located in the northern San Juan Basin and consisted of 16 coalbed methane production wells, four CO₂ injection wells, and one pressure observation well (fig. 4.5). Approximately 370,000 tons of CO₂ were injected between 1995 and 2001. Injection targeted multiple Upper Cretaceous Fruitland coal seams at depths in excess of 3,000 feet. Incremental coalbed methane production resulting from CO₂ injection is estimated at 1.6 Bcf with 300,000 net tons of CO₂ remaining sequestered. The difference of 70,000 tons CO₂ was re-injected.

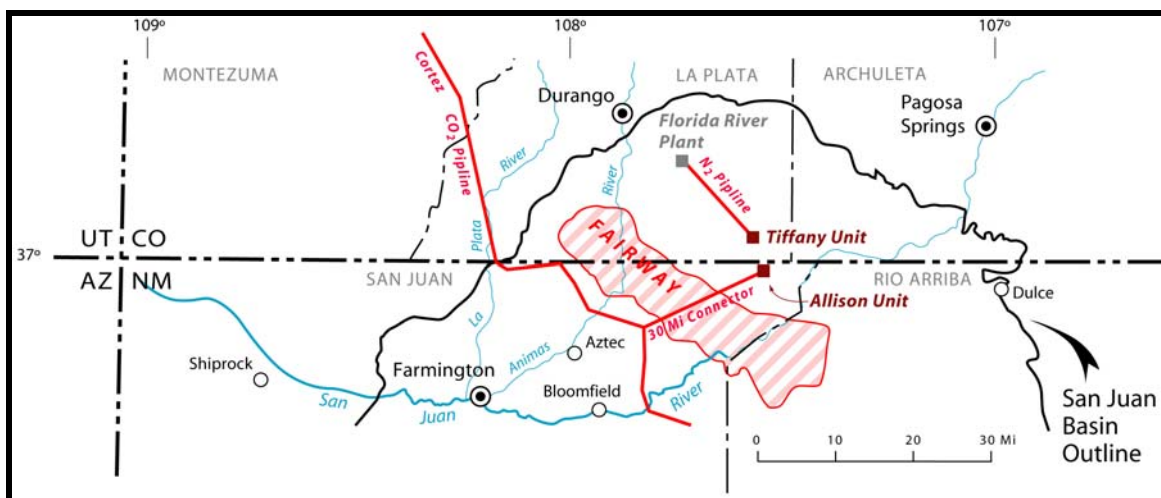


Figure 4.5: Location of Allison Unit in the San Juan Basin (modified after Reeves and others, 2003).

The Allison Unit provides a unique opportunity to better understand the CO₂-ECBM process when implemented under field conditions. A decline in CO₂ injectivity from an initial 6 million cubic feet per day (MMcfd) to approximately 3 MMcfd was noted in four of the injection wells; however, some improvement in this injectivity was later observed (up to 4 MMcfd). Detailed reservoir characterization conducted by Advanced Resources concluded that the injectivity loss was likely due to coal swelling and possibly other injectivity reducing

mechanisms (Reeves and others, 2003). Alternative well completion strategies, such as hydraulic stimulation and use of horizontal wells, were not used at the project site.

4.3 METHODOLOGY

As with the evaluation of the oil and gas sinks, a five part methodology was also used to evaluate the CO₂ sequestration potential of coalbed sinks in Colorado. These were (1) compiling production data; (2) assembling reservoir characterization data; (3) screening coalbed reservoirs for carbon storage potential; (4) calculating carbon storage capacity for screened reservoirs; and, (5) identifying the limitations in the calculations.

4.3.1 Compiling Production Data

Coalbed methane production was compiled at the same time and in the same manner as that for oil and gas reservoirs. Reports generated from **CoPrD** include these recovery volumes and can be found in appendix 4. Separate reporting for coalbed methane production in Colorado has only been available since 1990.

4.3.2 Assembling Coalbed Reservoirs Database

Input fields for coal characterization data were provided when the **CO₂SIS** database was created. Data collection efforts focused primarily on peer-reviewed publications, some of which are listed in table 4.1.

Table 4.1: Key publications used to characterize Colorado's coalbed reservoirs

Publisher	Title (Publication Number)	Date
Colorado Geological Survey	Content of Methane in Coal From Four Core Holes in the Raton and Vermejo Formations, Las Animas County, Colorado (OFR 79-3)	1979
Colorado Geological Survey	Deep Coalbed Methane Potential of the San Juan River Coal Region, Southwestern Colorado (OFR 80-2)	1980
Geological Services of Tulsa	Geologic Framework and Potential Structural Control of Methane in Coalbeds of Southeastern Piceance Creek Basin, Colorado	1980
Colorado Geological Survey	The Coal Bed Methane Potential of the Raton Mesa Coal Region, Raton Basin, Colorado (OFR 80-4)	1980
Colorado Geological Survey	The Coal Bed Methane Potential of the Sand Wash Basin, Green River Coal Region, Colorado (OFR 81-6)	1981
Colorado Geological Survey	Coal Bed Methane Potential of the Piceance Basin, Colorado (OFR 82-1)	1982
Colorado Geological Survey	Southern Ute / Department of Energy Coalbed Methane Test Wells (OFR 82-4)	1982
Colorado Geological Survey	Coal Bed Methane Desorption Data (OFR 81-4)	1983
Colorado Geological Survey	Colorado Desorption Samples – Descriptive Statistics and Gas Prediction Equations (OFR 84-2)	1984
Rocky Mountain Association of Geologists	Geology and Coal-Bed Methane Resources of the Northern San Juan Basin, Colorado and New Mexico	1988
Rocky Mountain Association of Geologists	Coalbed Methane of Western North America	1991
Colorado Geological Survey	Coalbed Gas Composition, Upper Cretaceous Fruitland Formation, San Juan Basin, Colorado and New Mexico (OFR 94-2)	1994
New Mexico Bureau of Mines and Mineral Resources	Coalbed Methane in the Upper Cretaceous Fruitland Formation, San Juan Basin, New Mexico and Colorado (Bulletin 146)	1994
Colorado Geological Survey	Spanish Peak Field, Las Animas County, Colorado (RS 33)	1998
Colorado Geological Survey	Late Cretaceous Fruitland Formation Geologic Mapping, Outcrop Measured Sections, and Subsurface Stratigraphic Cross Section, Northern La Plata County, Colorado (OFR 00-18)	2000
Colorado Geological Survey	Colorado Coal Quality Data (IS-58)	2001
Colorado Geological Survey	The Coalbed Methane Potential in the Upper Cretaceous to Early Tertiary Laramie and Denver Formations, Denver Basin, Colorado (OFR 01-17)	2001

4.3.3 Screening Coalbed Reservoirs for Carbon Storage

The **CO₂SIS** for Colorado was screened for coalbed reservoirs that may have the potential to store relatively large volumes of CO₂. Two screening criteria were used to identify favorable reservoirs - reservoir depth and proximity to a relatively large source of anthropogenic CO₂.

In Colorado, coal seams occurring at depths less than 2,000 feet are considered technically mineable. Thus, coal seams suitable for carbon storage were selected based a minimum reservoir depth of 2,000 feet. An exception to this minimum depth was made in the Raton Basin and will be discussed later in this section. Candidate coal reservoirs were also screened for a maximum depth of 7,500 feet due to the significant loss of permeability at these depths (McKee and others, 1988). The only place in Colorado where coal seam depths exceeded this maximum cutoff is in a relatively small part of the northern Piceance Basin.

Due to the continuous nature of coalbed methane accumulations, depth screening defined the areal extent of stratigraphic intervals with coalbed methane reservoirs (fig. 4.6; appendix 11). The final screen limited coalbed candidate reservoirs to those occurring within a 30 mile radial distance of a CO₂ point source.

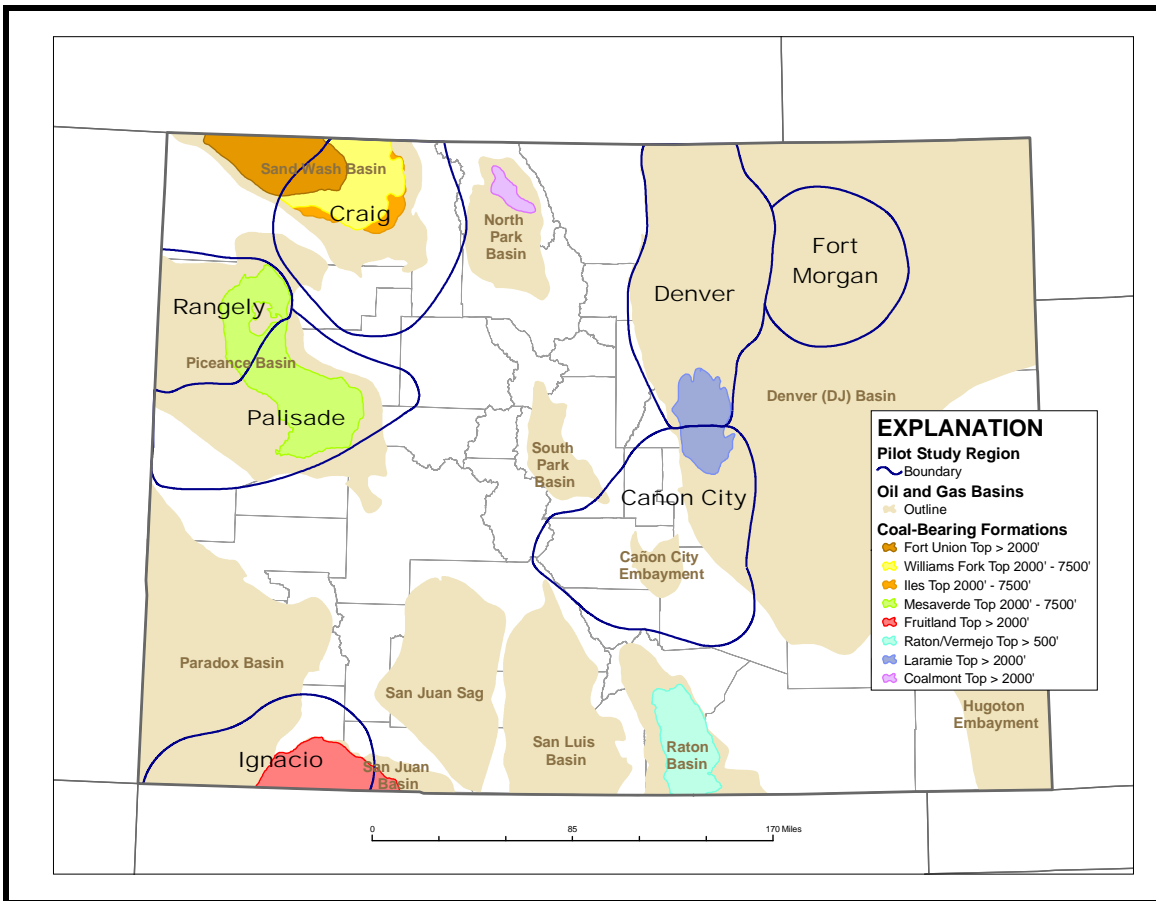


Figure 4.6: Coalbed reservoirs that screened as candidates for carbon storage in Colorado.

4.3.4 Calculating Carbon Storage Capacity

Carbon storage capacity for coalbed reservoirs within the SWP region was calculated based on coal volume, rank, depth, and a CO₂/CH₄ replacement ratio. The methodology was developed by Advanced Resources and provided a consistent capacity calculation with minimum inputs (Reeves, 2003; appendix 12). As described in appendix 12, the methodology relies on published correlations to calculate proxies for data not available in the SWP's **CO₂SIS**.

4.3.5 Limiting Factors in Calculations

Reservoir simulation is the most rigorous method for evaluating the amount of CO₂ that a given coalbed reservoir may sequester while also assessing

enhanced recovery resulting from the sequestration process. This is particularly true of coalbed reservoirs because of the limitations of decline curve analysis or material balance methods when applied to these reservoirs. Screening models, which are less data-intensive also exist (e.g., **Coal-Seq**) to evaluate CO₂ injection requirements relative to process design and recovery potential (Davis and others, 2004). However, even these screening-type models require more inputs than were consistently available in the public domain. Hence, the simplified approach that was utilized was particularly beneficial for the “broad-brush” approach required of Phase I.

There is inherent error introduced when applying homogeneous reservoir properties to heterogeneous reservoir rock, and never more so than with coalbeds. The application of an efficiency factor of 65 percent to the carbon storage capacity estimates attempts to compensate for the uncertainty in these calculations. The strength in applying the correlations described in appendix 12 is that they are based on a much larger population of data both public and proprietary and often provide a remarkably accurate first order-of-magnitude approximation. However, without detailed site-specific analysis, the “error bar” on this type of simplified approach is difficult to quantify.

4.4 POTENTIAL FOR CO₂ STORAGE IN COALBED RESERVOIRS

Coal-bearing strata are present in six of the seven pilot study regions as well as in the Raton Basin (Trinidad Pilot Study Region) (fig. 4.6). Each of the 10 coal-bearing intervals present in these areas screened successfully for depth interval and proximity to an anthropogenic source of CO₂ except for the Raton Basin. In this basin, the CO₂ emissions are considered too low to sustain a commercial sequestration project. However, carbon storage potential for the Raton is included for future consideration. The carbon capacity estimated for these candidate coalbed reservoirs exceeds 18.5 GT (table 4.2). Seventy-four percent of the total coalbed carbon capacity is associated with the Craig and Ignacio pilot study regions (fig. 4.7); 78 percent with high volatile bituminous coals (fig. 4.8).

Table 4.2: CO₂ sequestration capacities for coalbed reservoirs in Colorado

Pilot Study Region	Basin	Seam	Coal Rank**	Average Depth (Feet)	Total Capacity (MT)*	
					Rank	Pilot Region
Cañon City	Cañon City	Laramie	Sub	1,703	493	493
Craig	Sand Wash	Fort Union	HV	4,545	517	11,059
			HVA	3,828	1,278	
		Williams Fork	HV	2,863	1,726	
			HVA	5,453	4,944	
		Iles	HV	3,839	655	
			HVA	6,134	1,940	
Denver	Denver	Laramie	Sub	1,703	602	602
Ignacio	San Juan	Fruitland	HV	2,246	122	2,809
			HVA	2,676	1,419	
			MV	2,845	731	
		Menefee	HVA	5,495	537	
Palisade	Piceance	Cameo-Fairfield Coal Grp	HV	3,090	134	1,798
			HVA	3,777	567	
			MV	4,057	1,097	
Rangely	Piceance	Cameo-Fairfield Coal Grp	HVA	3,777	567	1,037
			MV	4,057	470	
Trinidad	Raton	Raton - Vermejo	HV	2,339	59	743
			MV	1,767	684	
TOTALS				1,991	18,541	18,541

* MT = Million Short Tons; ** Coal Rank: Sub, Subbituminous; HV, High Volatile Bituminous; HVA, High Volatile A Bituminous; MV, Medium Volatile Bituminous

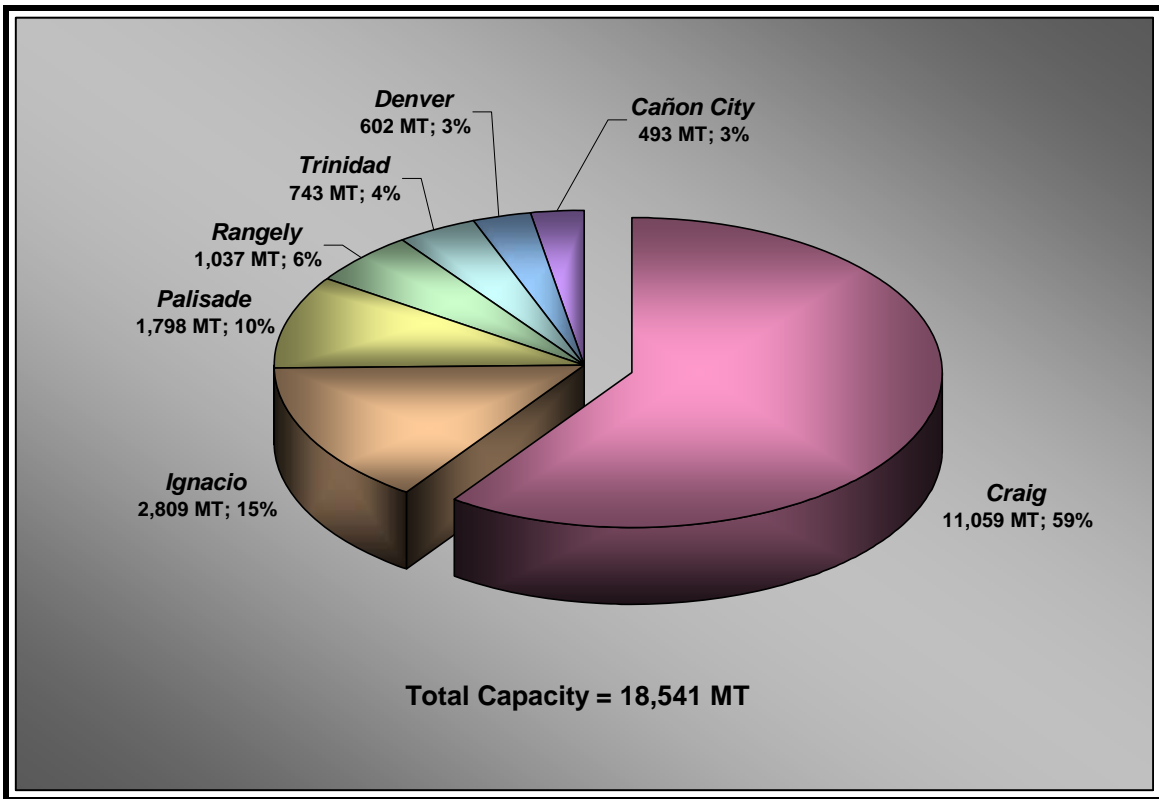


Figure 4.7: CO₂ sequestration capacities estimated for coalbed reservoirs in Colorado's pilot study regions in million short tons (MT) and as a percentage of the total coalbed capacity.

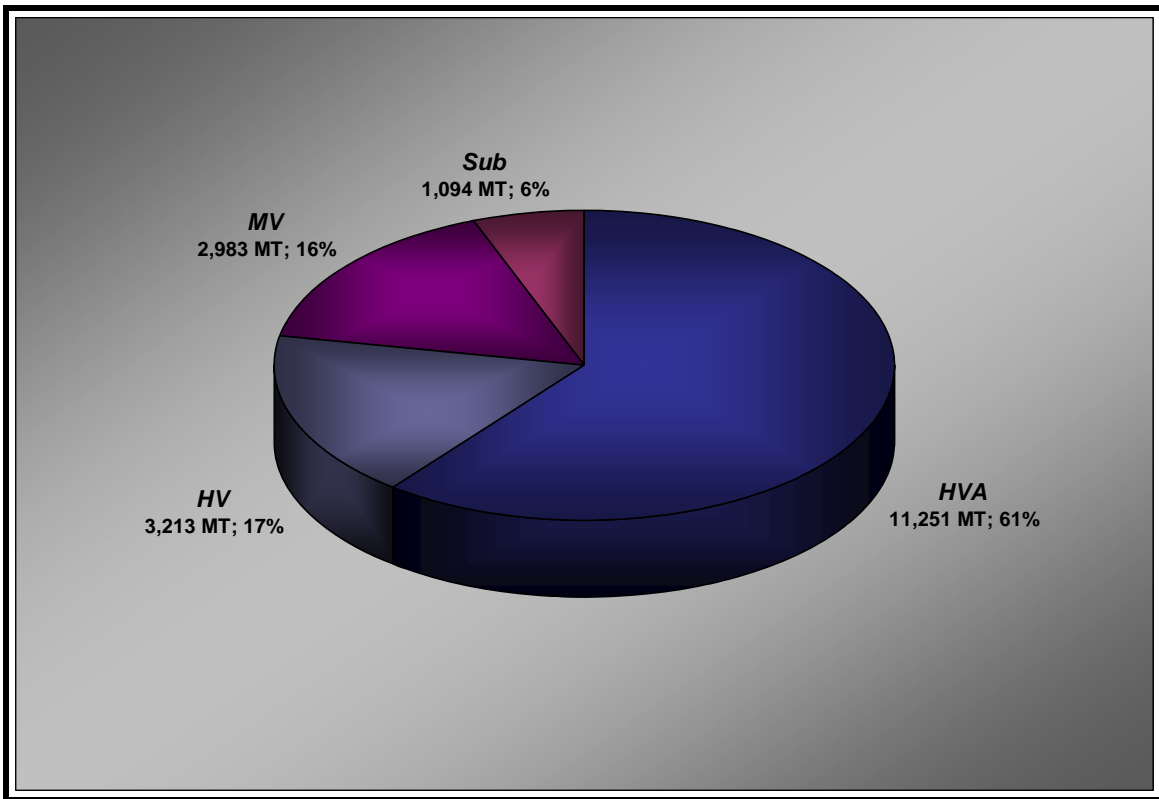


Figure 4.8: CO₂ sequestration capacities estimated by coal rank in million short tons (MT) and as a percentage of the total coalbed capacity; Coal Rank: Sub, Subbituminous; HV, High Volatile Bituminous; HVA, High Volatile A Bituminous; MV, Medium Volatile Bituminous.

4.4.1 Cañon City and Denver Regions

The Laramie Formation coalbeds straddle the boundary between the Cañon City and Denver Pilot Study Regions, covering a subsurface area in excess of 500,000 acres (fig. 4.6). These coals are Upper Cretaceous in age and subbituminous (Sub) in rank. With an average thickness of 10 feet and gas content approaching 300 standard cubic feet of gas per short ton of coal (scf/ton), the coalbed methane in-place is estimated to be 2.7 Tcf. Assuming a CO₂/CH₄ replacement ratio of 10 to 1, the CO₂ capacity is estimated at 1.1 GT (table 4.2). Approximately 45 percent of this capacity lies within the Cañon City Pilot Study Region with the remainder in the Denver region (fig. 4.9). Although there is considerable variability in recovery estimates, a replacement efficiency of 65 percent would reduce the carbon storage estimate to about 1 GT with the

potential of about 1.9 Tcf in enhanced coalbed methane recovery. This recovery factor assumes roughly 1.7 Tcf of produced CH₄ per GT of sequestered CO₂ (Reeves, 2003).

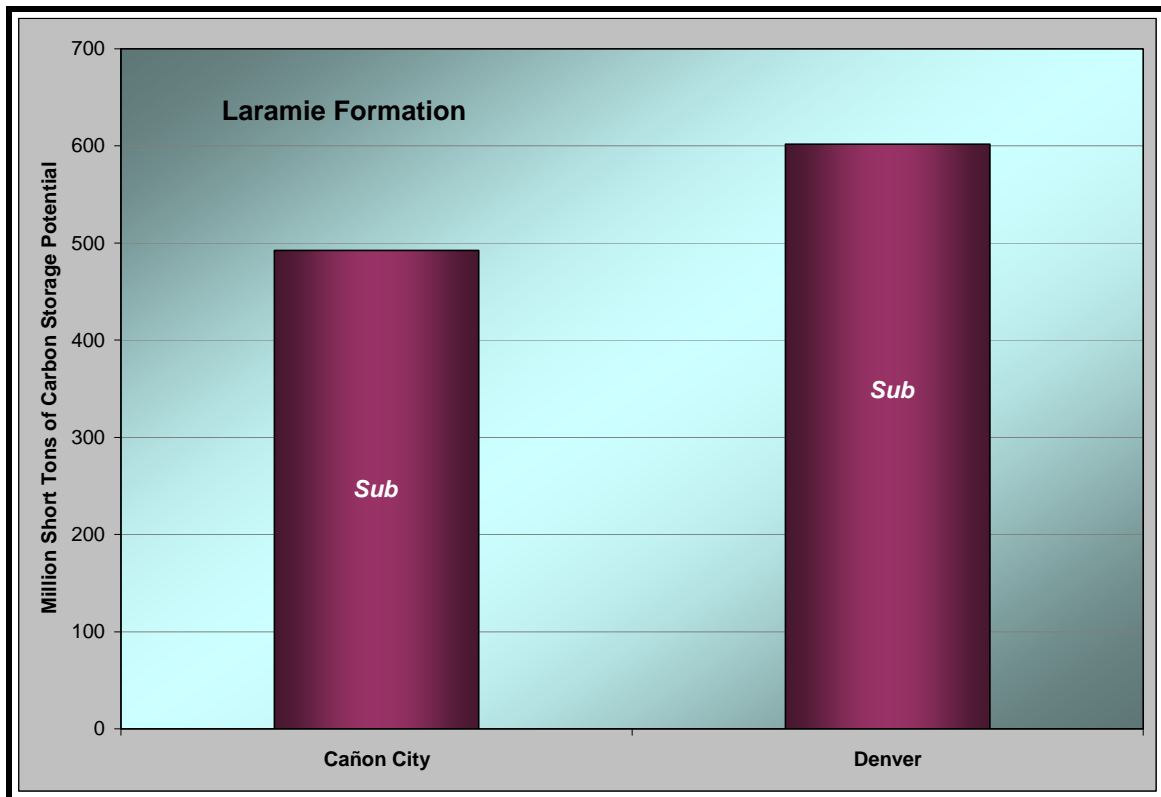


Figure 4.9: Carbon storage capacity estimated for the subbituminous Laramie Formation coals in the Cañon City and Denver Pilot Study Regions.

4.4.2 Craig Region

The Craig Pilot Study Region has three stratigraphic intervals characterized by coalbed reservoirs: the Upper Cretaceous Iles and Williams Fork Formations of the Mesaverde Group, and the Upper Cretaceous – Lower Tertiary Fort Union Formation. These coal “packages” differ in their subsurface areal extent from approximately 500,000 acres for the Iles to 750,000 acres for the Williams Fork; the Fort Union covers about 700,000 acres (fig. 4.6). Coal rank varies from high volatile A bituminous (HVA) to high volatile bituminous (HV). With a total average thickness in excess of 160 feet and gas content approaching 350

scf/ton, the coalbed methane in-place is estimated to be 62 Tcf. Assuming a CO₂/CH₄ replacement ratio of 3 to 1 for HV-ranked coals and 6 to 1 for HVA-ranked coals, the CO₂ capacity is estimated at 17.0 GT. A replacement efficiency of 65 percent would reduce the carbon storage estimate to 11.1 GT with the potential of nearly 19 Tcf in enhanced coalbed methane recovery (table 4.6). About 75 percent of this capacity is estimated for the HVA-ranked coals; 60 percent of the capacity is estimated for the Williams Fork Formation (fig. 4.10).

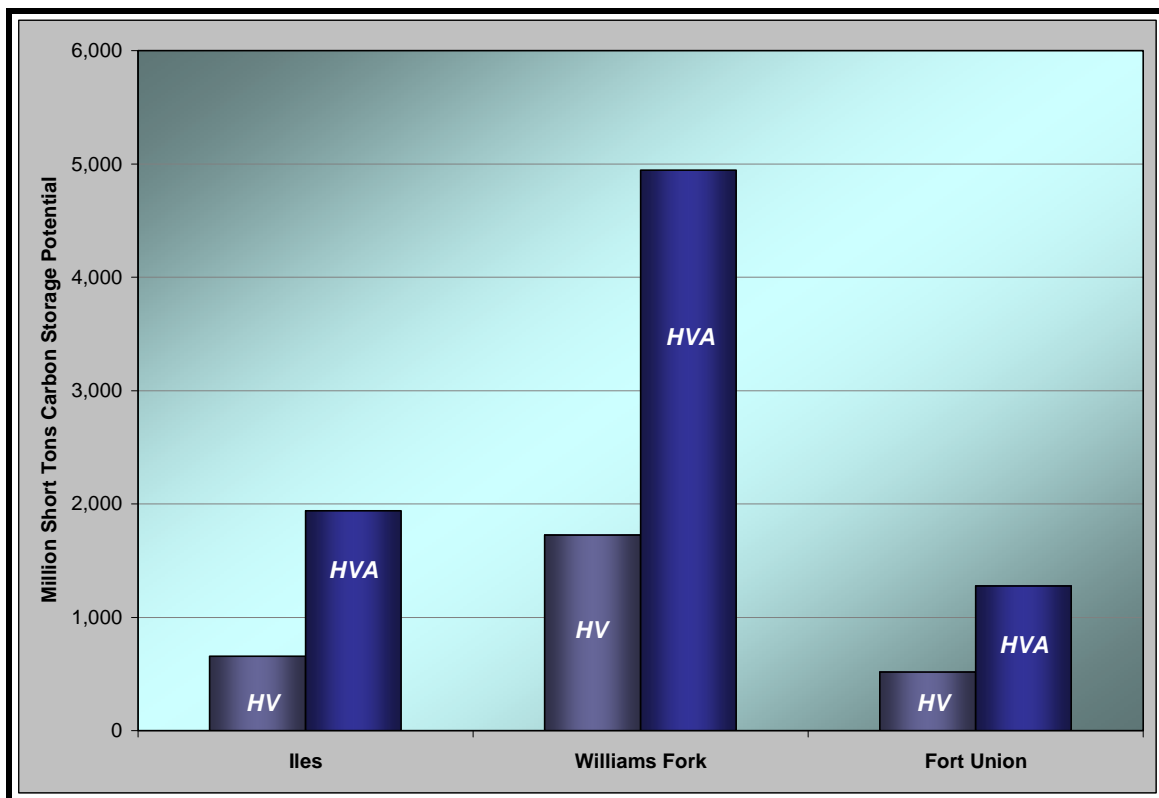


Figure 4.10: Carbon storage capacity estimated for the Iles, Williams Fork, and Fort Union coalbeds in the Craig Pilot Study Region; Coal Rank: Sub, Subbituminous; HV, High Volatile Bituminous; HVA, High Volatile A Bituminous; MV, Medium Volatile Bituminous.

4.4.3 Ignacio Region

The Ignacio Pilot Study Region has active coalbed methane development in both the Upper Cretaceous Menefee and Fruitland Formations (fig. 3.17). Both these coal intervals extend over approximately 550,000 acres each in the subsurface of

the northern San Juan Basin (fig. 4.6). The Menefee coal rank is HVA and the Fruitland coals vary from HVA to medium volatile bituminous (MV). More than 50 percent of the Fruitland coal volume is estimated to be the higher MV coal rank. With a total average thickness of 70 feet and gas content of approximately 300 scf/ton, the coalbed methane in-place is estimated to be 23 Tcf. Assuming a CO₂/CH₄ replacement ratio of 1.5 to 1 for MV-ranked coals, 3 to 1 for HV-ranked coals, and 6 to 1 for HVA-ranked coals, the CO₂ capacity is estimated at 4.3 GT. A replacement efficiency of 65 percent would reduce the carbon storage estimate to 2.8 GT with the potential of about 4.8 Tcf in enhanced coalbed methane recovery (table 4.2). Similar to the Craig region, about 70 percent of the Ignacio region's capacity is estimated for the HVA-ranked coals; 80 percent of the carbon storage capacity is estimated for the Fruitland Formation (fig. 4.11).

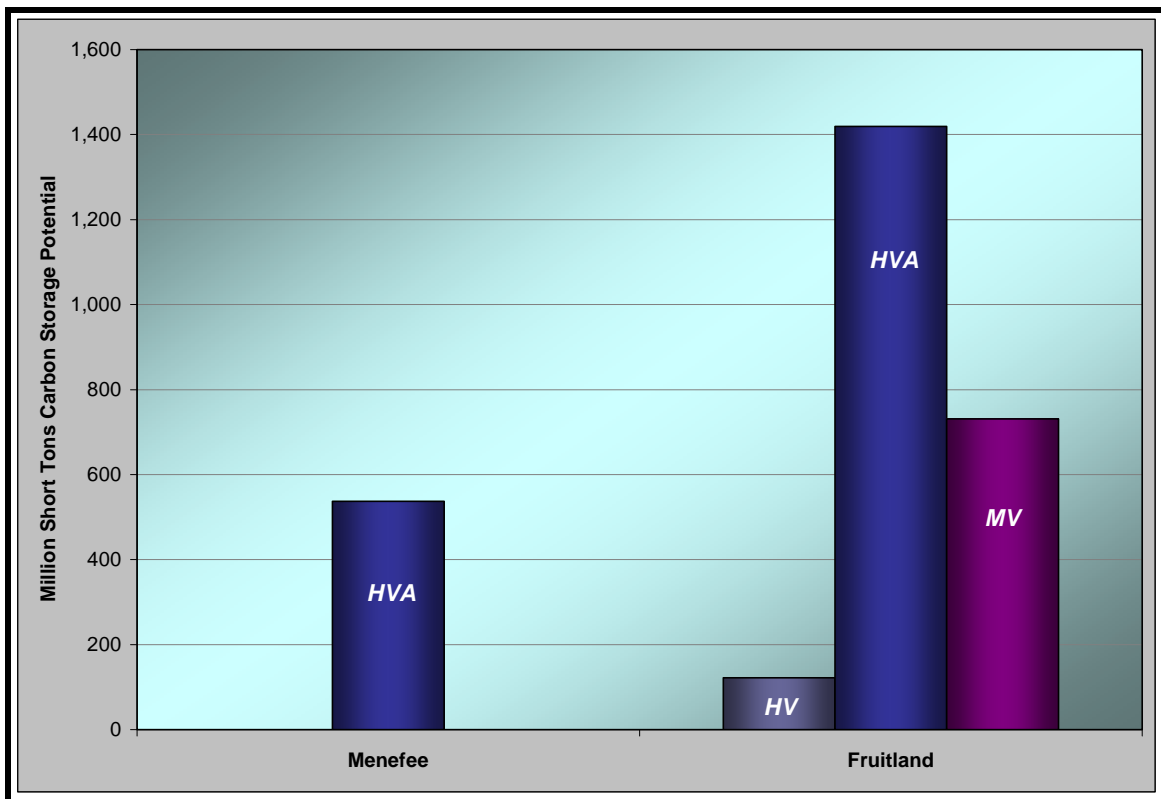


Figure 4.11: Carbon storage capacity estimated for the Menefee and Fruitland coalbeds in the Ignacio Pilot Study Region; Coal Rank: Sub, Subbituminous; HV, High Volatile Bituminous; HVA, High Volatile A Bituminous; MV, Medium Volatile Bituminous.

4.4.4 Palisade and Rangely Regions

The Cameo-Fairfield Coal Group in the Piceance Basin straddles the boundary between the Palisade and Rangely Pilot Study Regions and covers a subsurface area of nearly 1.5 million acres (fig. 4.6). This coal group lies within the Upper Cretaceous Iles and Williams Fork Formations of the Mesaverde Group (fig. 3.19). The Piceance Basin is the only area in Colorado where coal depths actually exceed 7,500 feet. Coal rank ranges from HV to MV with more than 75 percent of the coals being MV in rank. With a total average thickness of almost 55 feet and gas content exceeding 200 scf/ton, the coalbed methane in-place is estimated to be 34 Tcf. Assuming a CO₂/CH₄ replacement ratio of 1.5 to 1 for MV-ranked coals, 3 to 1 for HV-ranked coals, and 6 to 1 for HVA-ranked coals, the CO₂ capacity is estimated at 4.3 GT. A replacement efficiency of 65 percent would reduce the carbon storage estimate to 2.8 GT with the potential of about 4.8 Tcf in enhanced coalbed methane recovery (table 4.2). For the Cameo-Fairfield Coal Group, about 55 percent of the carbon storage capacity is associated with MV-ranked coals and 40 percent is associated with the HVA-ranked coals; roughly two-thirds of the capacity is located within the Palisade region (fig. 4.12).

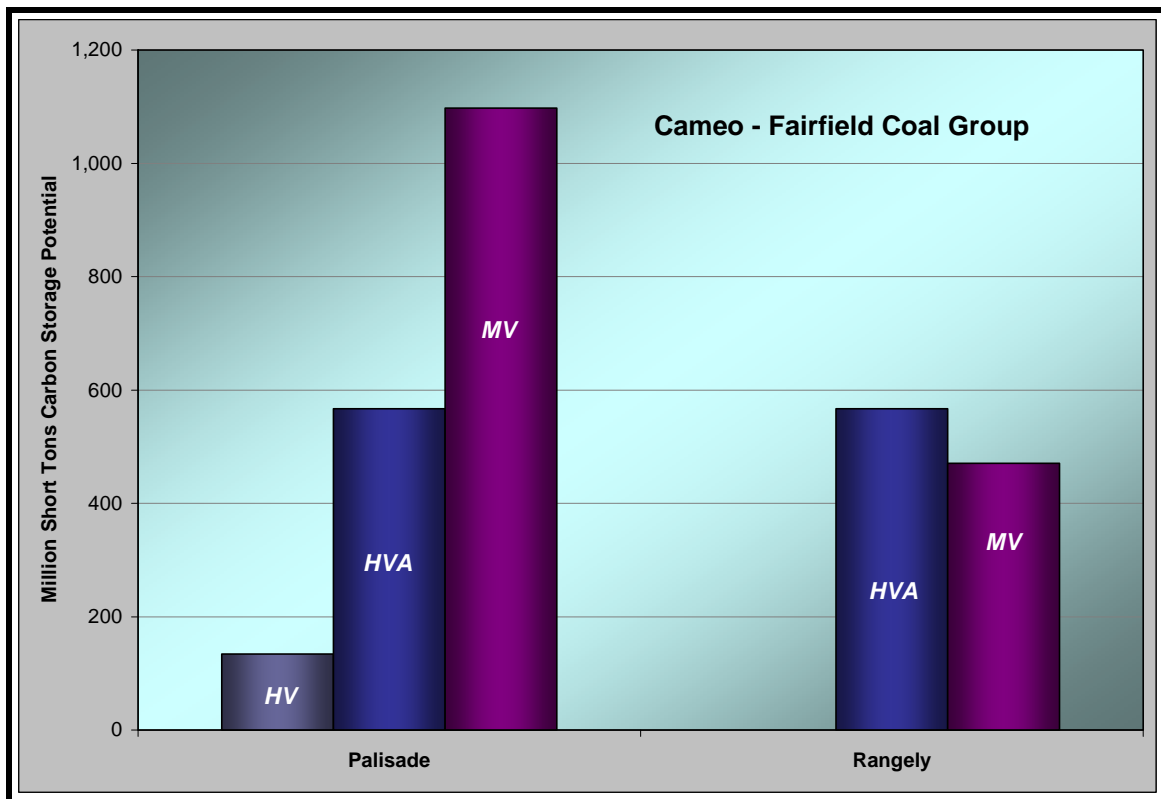


Figure 4.12: Carbon storage capacity estimated for the Cameo–Fairfield Coal Group in the Palisade and Rangely Pilot Study Regions; Coal Rank: Sub, Subbituminous; HV, High Volatile Bituminous; HVA, High Volatile A Bituminous; MV, Medium Volatile Bituminous.

4.4.5 Trinidad Region

Although there is minimal anthropogenic CO₂ available in the Raton Basin, the Trinidad Pilot Study Region was defined for the purpose of including a carbon storage estimate for the Upper Cretaceous Raton and Vermejo coals. These HV- to MV-ranked coals cover a subsurface area of nearly 600,000 acres (fig. 4.6). The Raton and Vermejo coals are under active coalbed methane development, where gas is produced from very shallow depths particularly adjacent to the Purgatoire River. As such, for this basin only, the depth cutoff was limited to 500 feet (instead of the 2,000 feet used elsewhere). With a total average thickness of about 60 feet and gas content exceeding 300 scf/ton, the coalbed methane in-place is estimated to be nearly 13 Tcf. Assuming a CO₂/CH₄ replacement ratio of 1.5 to 1 for MV-ranked coals and 3 to 1 for HV-ranked coals,

the CO₂ capacity is estimated at 1.1 GT. A replacement efficiency of 65 percent would reduce the carbon storage estimate to less than 750 MMT with the potential of about 1.3 Tcf in enhanced coalbed methane recovery (table 4.2). Nearly all of this estimated capacity is associated with MV-ranked coals (fig. 4.13).

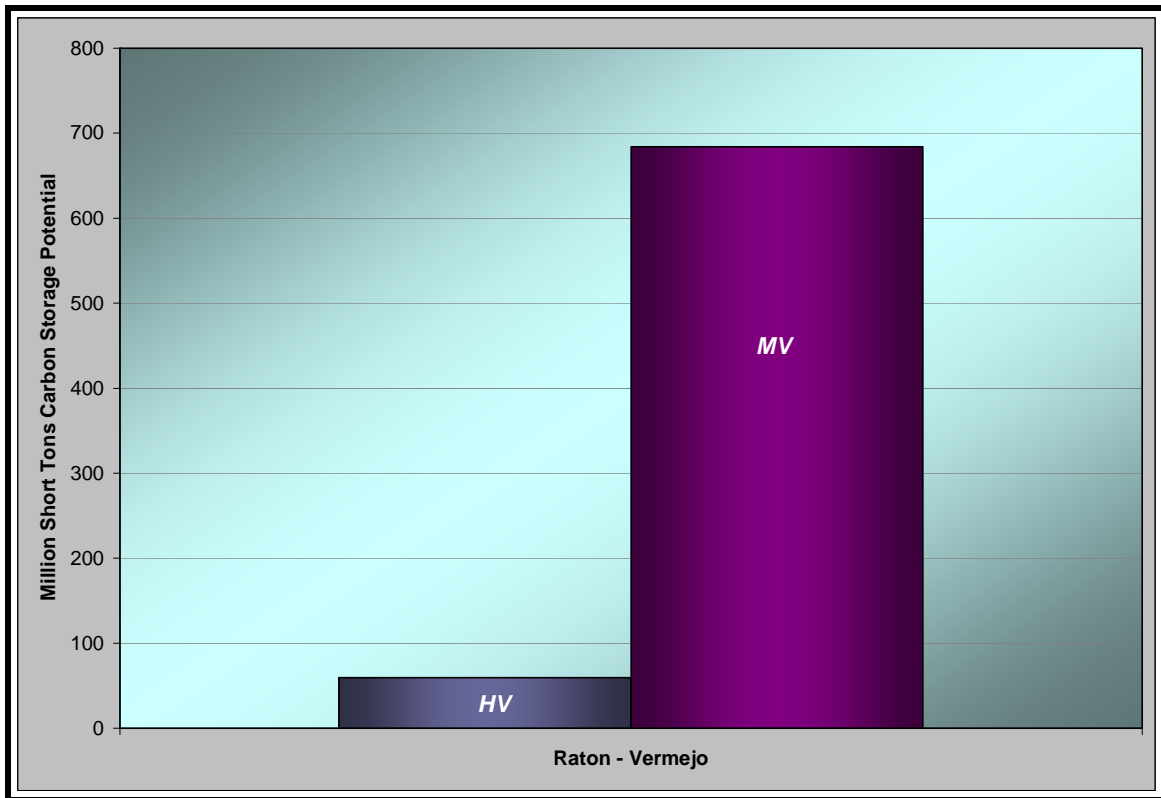


Figure 4.13: Carbon storage capacity estimated for the Raton-Vermejo coals in the Trinidad Pilot Study Region; Coal Rank: Sub, Subbituminous; HV, High Volatile Bituminous; HVA, High Volatile A Bituminous; MV, Medium Volatile Bituminous.

4.5 CONCLUSIONS

CO₂ sequestration capacity for coalbed reservoirs in the seven pilot study regions is estimated to exceed 18.5 GT with about 75 percent of that potential associated with the Fruitland coals in the Ignacio region and the Williams Fork coals in the Craig region (table 4.2). Further, if a recovery factor of 1.7 Tcf produced CH₄ per GT sequestered CO₂ is broadly applied, up to 31.7 Tcf in

ECBM recovery may be possible (table 4.3). As was noted for EOR/EGR projects, incremental coalbed methane production would be key to offsetting capital costs for such projects. However, there are technical impediments such as the changes undergone by coal in a CO₂-rich environment (matrix swelling, injectivity loss) that must be addressed before commercial-scale projects become viable.

Table 4.3: Value added benefit from CO₂ storage potential in coalbed reservoirs in Colorado

Pilot Study Region	CO₂ Storage Potential (GT)	ECBM Potential (Tcf)
Cañon City/Denver	1.1	1.9
Craig	11.1	18.9
Ignacio	2.8	4.8
Palisade/Rangely	2.8	4.8
Trinidad	0.7	1.3
TOTAL	18.5	31.7

5.0 SALINE AQUIFER SINKS IN COLORADO

5.1 INTRODUCTION

Deep saline geologic formations are those that:

- Contain pore water generally considered to be too saline for water supply development;
- Are generally too deep to be economical water supply sources;
- Possess good aquifer or reservoir properties (i.e. porosity and permeability); and
- Have sufficiently large areal extent or thickness that would allow sequestration of significant quantities of CO₂.

According to the U.S. Department of Energy (2004b), deep saline geologic formations are especially attractive sinks for carbon sequestration for two primary reasons. First, they represent the largest potential geologic sink for carbon storage, with up to 500 Gt of potential carbon storage in the U.S. (U.S. Department of Energy, 2004b) and up to 1,000 Gt worldwide (Medina and others, 2001; Friedmann, 2003). Hovorka and others (2000) identified a number of potential deep saline geologic formations meeting the necessary criteria over a large portion of the U.S. (fig. 5.1).

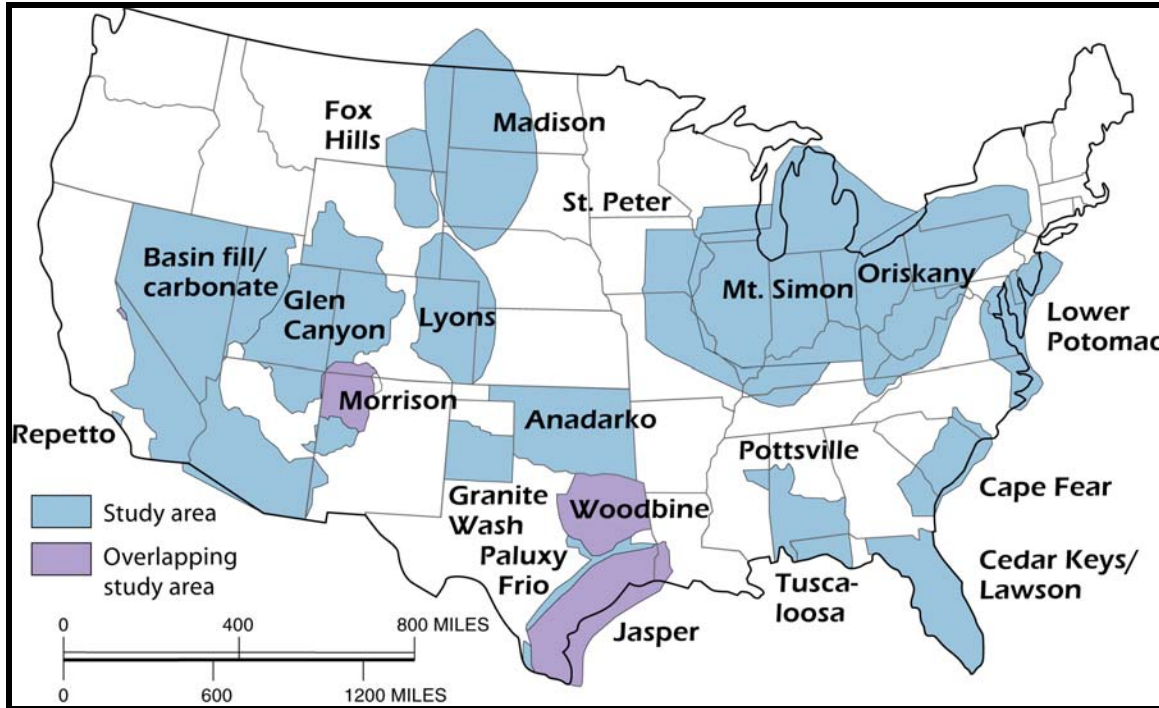


Figure 5.1: Deep saline geologic formations evaluated nationwide by Hovorka and others (2000) as potential sequestration targets.

Second, most large CO₂ point sources, i.e., power plants, have a saline geologic formation lying at some depth beneath them, and therefore sequestration in saline formations is “compatible with a strategy of transforming large portions of the existing U.S. energy and industrial assets to near-zero carbon emissions via low-cost carbon sequestration retrofits” (U.S. Department of Energy, 2004b).

Another factor favoring deep saline geologic formations is that precedents have been set and infrastructure is already in place in many locations. The U.S. currently injects 75 million cubic meters of industrial waste annually into deep geologic formations (Leistra, 2002). Saline waters produced as a byproduct of oil and gas extraction are reinjected at numerous oil and gas fields nationwide. By early 2004, 877 reinjection wells had been permitted in Colorado alone (Colorado Oil and Gas Conservation Commission, 2004a). Due to the abundance of deep saline geologic formations throughout the U.S., two-thirds of the nation’s power

plants and industrial centers may be able to inject CO₂ without the need for constructing additional pipelines (Leistra, 2002).

CGS compiled a list of deep saline geologic formations that it considers to be the best candidates for carbon sequestration. From an initial inventory of dozens of potential candidate formations, the list was narrowed to 25 formations possessing the necessary characteristics that qualify them as potentially favorable sites for carbon sequestration.

As discussed in previous sections of this report, an essential preliminary criterion, based on the costs of pipeline construction and CO₂ delivery, is that the formations lie within 30 miles of significant CO₂ emitters, i.e., coal-burning power plants. For that reason, the search has focused on the seven Pilot Study Regions (PSRs) possessing power plants with relatively high carbon emissions (fig. 5.2).

One of the desirable aspects of these regions is that the majority of them are situated over large sedimentary basins (fig. 5.2) consisting of consolidated sedimentary rocks, which possess characteristics favorable for sequestration. The Cañon City region is the only exception; less than half of the region is underlain by sedimentary rock with most of the region underlain by crystalline, i.e. igneous or metamorphic, rock.

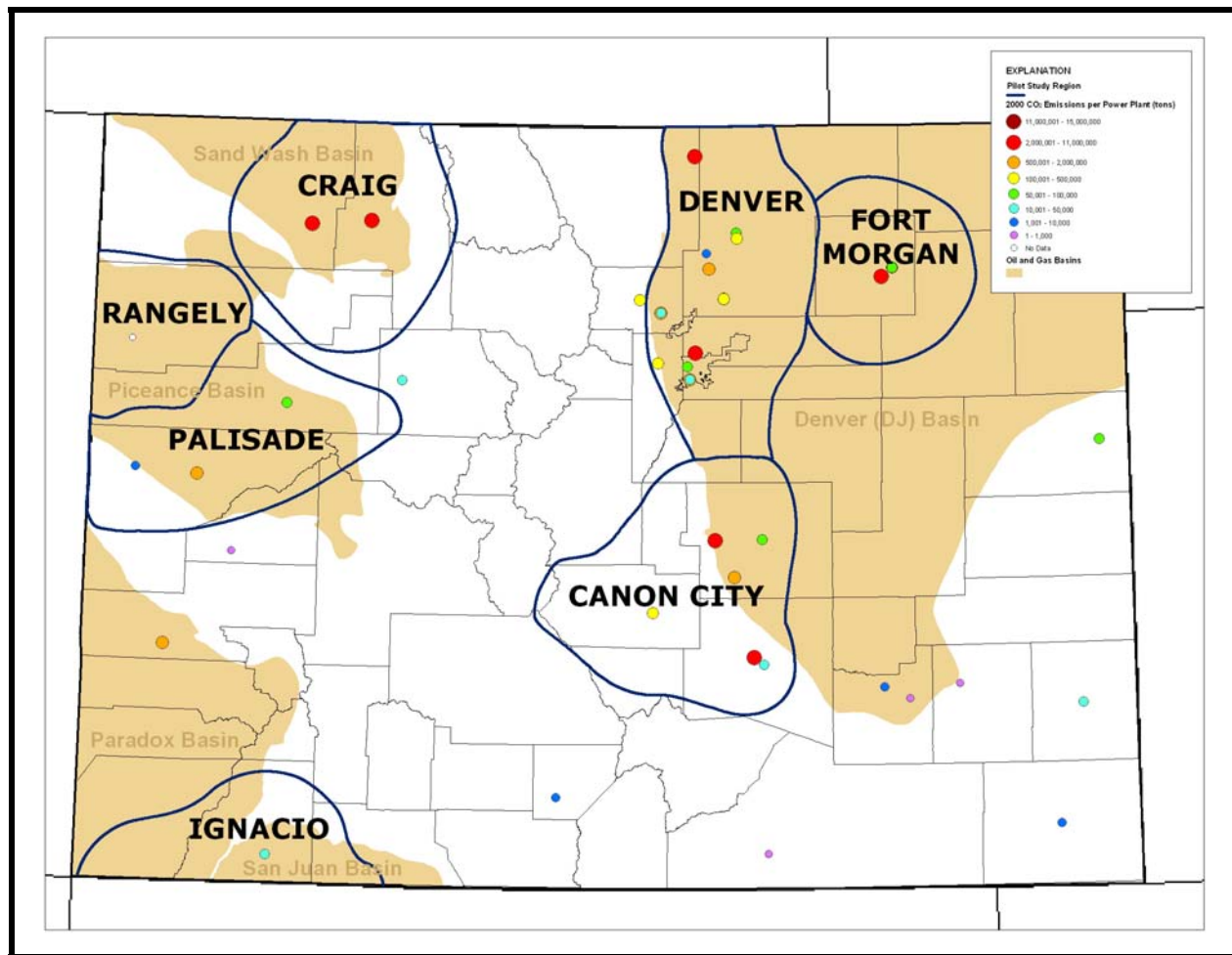


Figure 5.2: Locations of Pilot Study Regions, the consolidated sedimentary basins underlying each region, and power plants in Colorado (from Lintz, 2004; USEPA, 2004).

5.2 THEORETICAL BASIS

The injection of carbon in the form of CO₂ at sufficient depth and under specified conditions will theoretically allow its long-term storage, and will isolate it to prevent its migration into overlying or adjacent strata where it could contaminate aquifers or escape to ground surface. To minimize vertical or lateral migration from the sequestering formations, the optimal method of delivery will be to inject the CO₂ as a supercritical fluid, which can generally be achieved at depths of 800 meters or more (2,625 feet) (Pope and others, 2003). As fig. 4.10 shows, CO₂ exists as a supercritical fluid where temperature and pressure exceed 88° F and

1,075 pounds per square inch (psi), respectively. Supercritical CO₂ has a density of about 0.60 to 0.75 grams per cubic centimeter (g/cc) while the density of saline formation fluid ranges from 1.0 to 1.2 g/cc, so confining pressure is required to contain the CO₂ and prevent its escape. Supercritical CO₂ will be both less dense and less viscous than saline waters, thus the injected CO₂ must be addressed as a multiphase system (Sminchak and others, 2001).

A considerable amount of research has been done on the subject of carbon sequestration in deep saline geologic formations, and several modeling studies have been done (Pope and others, 2003; Gupta and others, 2001; McPherson and Lichtner, 2001; Hovorka and others, 2001; Gunter and others, 1997; Holtz, 2002; Nghiem, 2002; Pruess and García, 2002; Pruess and others, 2001; Sass and others, 1999a; Sass and others, 1999b; Sass and others, 2001; Sass and others, 2002; Vikas, 2002; Xu and others, 2001; White and others, 2003), some with time scales out to 100,000 years. Sass and others (2002) used pressure vessels to simulate conditions in geologic formations at depths exceeding 800 meters to characterize the chemical reactions that could occur due to CO₂ injection. White and others (2002) developed a numerical model of the Farnham Dome, Utah CO₂ reservoir as a natural analog of an artificial CO₂ reservoir. They used a model that included the reactive chemical transport code *CHEMTOUGH2* (White, 1995) to evaluate top seal permeability, capillary pressure, and chemical reactions between CO₂ gas, reservoir brine, and a simulated mineral suite. In a subsequent study, White and others (2003) used the *CHEMTOUGH2* code to model the chemical and physical response to CO₂ injection into non-dome geological formations, i.e., those lacking traditional trapping structures. One of the most important issues is whether the CO₂ will dissolve into the aquifer, or will merely displace the water in the formation. Uncertainty remains as to whether the existing models have adequately answered this question.

5.3 PREVIOUS AND PROPOSED PROJECTS

The world's first commercial-scale carbon sequestration project is in a deep saline geologic formation - in the Sleipner Project in the North Sea, operated by Statoil, the Norwegian State Oil Company (Korbol and Kaddour, 1995; Kongsjorden and others, 1997; International Energy Association Greenhouse Gas R&D Programme, 2006). Carbon dioxide is generated as an unwanted by-product of natural gas production, stripped off, then injected into a large, deep saline reservoir, the Utsira Formation, 800 meters below the seabed. The unusually high CO₂ content of the natural gas (about nine percent) requires that the CO₂ be stripped off to attain a concentration of 2.5 percent before the natural gas is sold to customers. After stripping, the CO₂ is injected into a small "structural closure" in the 200 meter-thick, saline water-bearing Utsira Formation, a massive sandstone unit lying about 2,500 meters above the gas producing formation. The project sequesters 1 million metric tonnes of carbon dioxide per year which is equivalent to the output of a 150-megawatt coal-fired power plant. Statoil also plans to inject CO₂ at an annual rate of 700,000 tonnes at its Snøhvit gas field in the North Sea. CO₂ will be injected 2,600 meters beneath the seabed at the edge of the gas reservoir.

A similar project is under consideration by a consortium involving Exxon and the Indonesian State Oil Company in the Natuna gas field, one of the largest in the world, in the South China Sea (Chan and others, 2003). The project plans to inject up to 100 million metric tonnes of CO₂ annually into a sub-seabed aquifer (Hanisch, 1998).

Other projects to evaluate experimental wells to inject and monitor CO₂ stored in saline formations are in early stages of development (Chan and others, 2003). The Battelle Memorial Institute is performing seismic surveys to characterize a site in West Virginia for a CO₂ injection well. The Texas Bureau of Economic Geology is demonstrating the use of conventional wells to inject and monitor CO₂ in a brine formation (Chan and others, 2003). A university consortium is investigating the feasibility of sequestering carbon dioxide by injecting it into calcareous sediments below the sea floor. Pressurized tanks in a

laboratory will be used to create a range of pressures, temperatures, and sediment compositions to simulate the conditions below the sea floor (National Energy Technical Laboratory, 2004a).

5.4 GEOCHEMICAL AND PHYSICAL CONSIDERATIONS

A variety of chemical and physical transformations are expected to accompany the injection of CO₂ into a deep saline geologic formation (Pruess and others, 2001), including such processes as:

- Miscible or immiscible displacement of native fluids;
- Dissolution of injected fluids into reservoir fluids;
- Changes in effective stress with associated porosity and permeability modifications and the possibility of inducing seismic activity;
- Chemical interactions between injected fluids and aquifer fluids, and between injected fluids and solids; and
- Non-isothermal effects.

For geochemical and physical modeling of the injection process, key considerations include (Pruess and others, 2001):

- Thermodynamics of sub- and supercritical CO₂, and pressure-volume-temperature properties of mixtures of CO₂ with other fluids, including (saline) water, oil, and natural gas;
- Fluid mechanics of single and multi-phase flow when CO₂ is injected into aquifers, oil reservoirs, and natural gas reservoirs;
- Coupled hydrochemical effects due to interactions between CO₂, reservoir fluids, and primary mineral assemblages; and
- Coupled hydromechanical effects, such as porosity and permeability change due to increased fluid pressures from CO₂ injection.

The details of geochemical and physical processes have been studied and documented to great extent by other investigators (Hovorka and others, 2000;

Pope and others, 2003; Hovorka and others, 2001; Sass and others, 2002; White and others, 2003; Allis and others, 2001; Moore and others, 2003; Bond and others, 2001) and will not be repeated here, although a few of the more important and common expected reactions deserve mention.

If conditions in the aquifer do not allow the CO₂ to persist in a supercritical state, the CO₂ will go into solution in quantities of up to 50 grams of CO₂ per kilogram of typical formation water (Czernichowski-Lauriol and others, 1996). The solubility of CO₂ in water is shown on fig. 5.3 (Tim Carr, Kansas Geological Survey, written communication, 2004), which shows that CO₂ solubility increases rapidly from pressures of zero up to around 1,000 to 1,500 psi, above which the solubility increases more slowly as shown by the flatter slopes of the curves; normally called the “bubble point” in oil field parlance. The solubility curves also demonstrate that CO₂ is more soluble at lower temperatures.

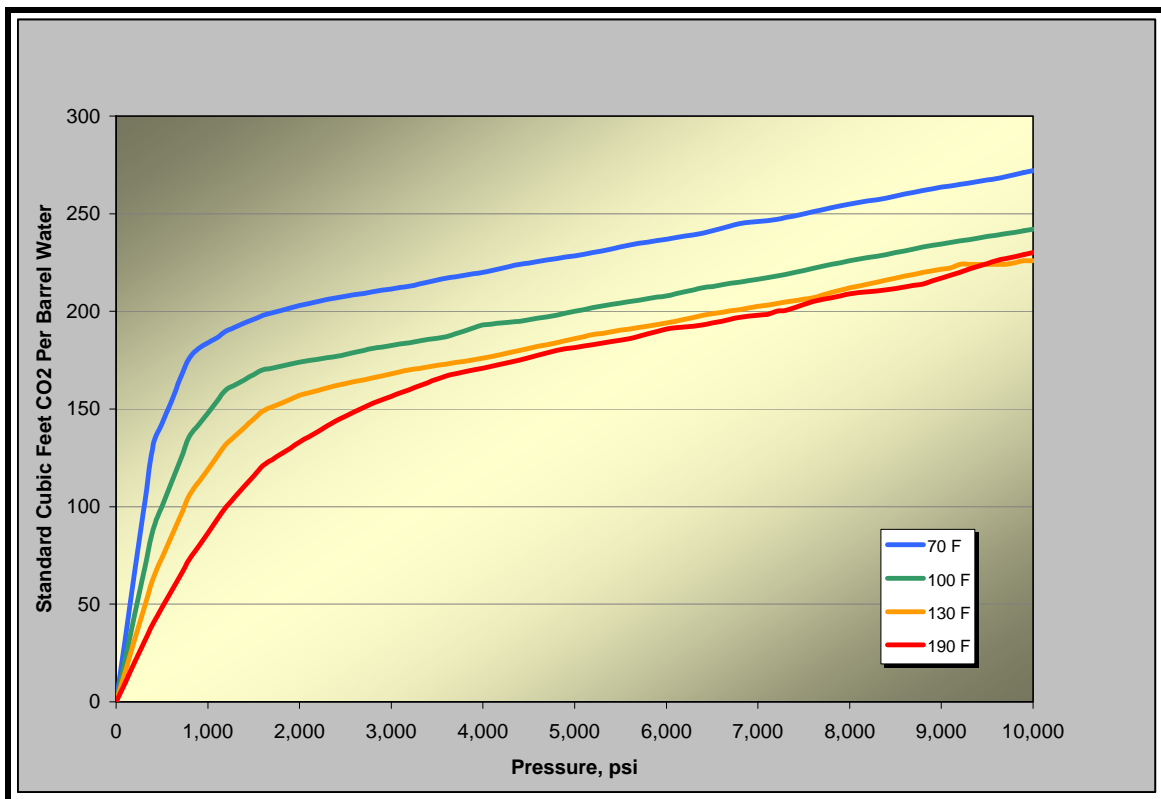
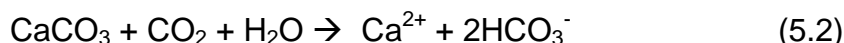


Figure 5.3: CO₂ solubility in water at various temperatures as a function of pressure (Tim Carr, Kansas Geological Survey, written communication, 2004).

The dissolution of CO₂ into ground water will cause acidification of the ground water due to the formation of carbonic acid:



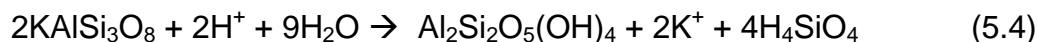
The acidification of the ground water could disturb the natural, long-term hydrogeochemical equilibrium that has existed in the formation, and could set into motion a wide assortment of water-rock interactions. One of the most probable chemical reactions that can be expected to occur is dissolution of calcite that is present either as a primary mineral or as cement. The reaction consumes acid and releases calcium and bicarbonate ions into solution as (Appelo and Postma, 1994):



Concurrently with this reaction, if dissolved sulfate is present in the ground water, then thermodynamics might favor the precipitation of sulfate minerals, such as gypsum, by:



Aquifer acidification can also enhance the dissolution of common rock-forming silicate minerals, such as potassium feldspar (Appelo and Postma, 1994):



This reaction releases potassium ions into solution, but also forms aqueous silicic acid and a relatively insoluble and immobile clay precipitate, in this case kaolinite. Thus the dissolution of silicates forming a clay precipitate is an example in which dissolution of aquifer materials may not result in an increase in aquifer porosity.

As these reactions demonstrate, dissolution of carbonates and silicates will buffer acidification, but will also release dissolved solids to the ground water,

further increasing its salinity, and concurrently increasing the porosity of the formation (Melcer and Gerrish, 1996). However, any increased porosity caused by dissolution may be offset by the release of cations that could form various carbonate, sulfate, or silicate precipitates. The competition between these reactions will determine the potential for additional storage, and the balance is likely to be time dependent, as the approach to equilibrium will involve transport as well as kinetics (Pope and others, 2003).

Mineral trapping is the process of CO₂ reacting with minerals in the rock and “locking up” carbon in a very stable form. This process may provide a substantial and important mechanism for long-term carbon sequestration in saline aquifers (Hitchon, 1996). Geochemical models suggest that significant quantities of injected CO₂ can be removed by water-rock reactions, particularly those that form Ca, Fe, and Mg carbonates (Xu and others; 2001; Gunter and others, 1993; Bachu and others, 1994; Perkins and Gunter, 1996). Research by Moore and others (2003) suggests that reactions between injected CO₂ and the host rocks can also be expected to form mineral precipitates such as zeolites, kaolinite, quartz, dolomite, hematite, calcite, anhydrite, gypsum, and with sufficiently high CO₂ fugacity, dawsonite.

5.5 CRITERIA FOR TARGET SELECTION

CGS has identified seven pilot study regions as priority areas in which to narrow the search for favorable geologic sequestration sites. Due to costs associated with carbon capture and transport, the partnership assumes that only those sequestration candidates lying within 30 miles of the carbon source will be economically feasible, although at least one study suggests that pipelines up to 100 kilometers (62 miles) could be economical (Smith and others, 2001). Therefore, the selection of the Pilot Study Regions is based solely on the criterion that the areas must be within 30 miles of large carbon-producing power plants (fig. 5.2). Within these seven areas, favorable formations have been identified based on several factors. After the initial criterion of proximity to carbon

emitters is met, the selection of specific geologic formations for sequestration is based on the criteria discussed in the following sections.

5.5.1 Absence of Water Supply Development

Injection of CO₂ should preferably be done in deep geologic formations that are not now, or ever will be, used as a source of water supply. Thus, the formations will generally lie at significant depth that renders them uneconomic for ground-water exploitation using current technology. The Ground Water Atlas of Colorado (Topper and others, 2003) was an ideal starting point for this exercise because it inventories all of the aquifers in the state. The lowermost formations in each basin that were designated by the Colorado Division of Water Resources as ground-water aquifers are assumed, for this investigation, to be the deepest formations that are used for ground-water exploitation, and thus form the limiting upper boundary of potential candidates for carbon sequestration. The deepest water well existing in each basin also indicates the deepest exploitation of ground-water resources, depths below which are assumed to be beyond economically exploitable limits.

5.5.2 Salinity

All of the geologic formations being considered for sequestration in Colorado are water bearing below 800 meters. Sequestration should be limited to formations with salinity greater than 1,000 parts per million (ppm) to minimize the probability that the formations will be exploited in the future as an aquifer for municipal or agricultural water supplies. The ideal scenario for preventing contamination of future water resources would be to limit CO₂ injection to formations with salinity greater than 10,000 ppm. However, this is not a standard bound by law. In fact, the literature contains examples of erroneous assertions that injection into aquifers with salinity less than 10,000 ppm is prohibited by Federal regulations under the National Pollution Discharge Elimination System (NPDES). However, variances to the NPDES regulation can be obtained if the geologic formation has

a low probability of being developed as a drinking water source due to extreme depth or other factors. Examples are common in Colorado for reinjection of produced waters (E. DiMatteo, Colorado Oil & Gas Conservation Commission, oral communication, 2004).

Examination of the produced waters database at the Colorado Oil & Gas Conservation Commission (2004b) reveals 1,624 analyses for formation salinity. All of the analyses exceed 1,000 ppm, and 108 analyses (6.7 percent) exceed 10,000 ppm. Although there may be instances where the salinity locally is less than 1,000 ppm, the assumption is statistically valid that the entire volume of each formation has a salinity exceeding 1,000 ppm.

5.5.3 Depth

To maintain the CO₂ in a supercritical state, it must be injected at sufficient depth such that the overlying hydrostatic pressure is at least 74 bars, or 1,075 psi. To allow for a margin of error, researchers are using the convention that injection depth must be at least 800 meters (Hovorka and others, 2000). Depths of approximately 1,000 – 1,200 meters provide the optimal density-pressure environment. At depths greater than 1,200 meters, the density of CO₂ does not significantly increase.

5.5.4 Porosity and Permeability

To ensure adequate porosity and permeability, which will theoretically maximize the storage capacity, only formations that consist primarily of sandstone, or those that have had oil and gas production, were selected. A formation with oil and gas production is assumed to have adequate reservoir characteristics to be a favorable host for CO₂ sequestration. Hovorka and others (2000) set minimum criteria that included permeability of 1 Darcy, and minimum thickness of 100 meters in their search for favorable geologic formations. Only one of Colorado's formations meets Hovorka and others (2000) permeability criterion of 1 Darcy, but about half of the units meet the thickness criterion of 100 meters.

5.5.5 Top Seal

To ensure that the CO₂ will not migrate vertically and potentially contaminate overlying aquifers, the most desirable scenario is to have an impermeable geologic unit or structure overlying the sequestering unit to provide a trap. Thus, only those formations in which a top seal could be identified were included as sequestration targets.

5.6 CALCULATION OF SEQUESTRATION CAPACITY

The sequestration capacity of a specific brine formation was calculated using the following volumetric equation:

$$G_{CO_2} = A \times h_g \times \phi_{tot} \times \rho_{CO_2} \times E \quad (5.5)$$

where G_{CO_2} is the mass of CO₂ that is sequestered, A is the geographical area of the brine formation that is assessed, h_g is its gross thickness, ϕ_{tot} is the average porosity over the gross thickness, ρ_{CO_2} is the density of CO₂ evaluated at the temperature and pressure that represents the storage conditions anticipated for a specific brine formation, and E is the CO₂ storage efficiency factor that reflects a fraction of the total pore volume that is expected to be filled by CO₂. This calculation makes no distinction between CO₂ that is stored as an immiscible phase within a specified brine formation, CO₂ that is stored as a dissolved phase in the brine, and CO₂ that is precipitated as minerals. However, displacement of brine in the pore volume by immiscible CO₂ is the fundamental mechanism implicit in the calculations. Another critical point is that there is no accounting for the lack of void space available for storing CO₂; that is, the pore space is already fully saturated with brine so that void space would have to be created through production before injecting CO₂ for storage.

The capacity calculations do not assume that 100 percent of the pore space in the rock formations will be available for storage. Adjustments are made using the CO₂ storage efficiency factor (E) which accounts for net to effective

porosity, areal displacement efficiency, vertical displacement efficiency, gravity effects, and microscopic displacement efficiency. Monte Carlo simulations estimate a range of 1 to 4 percent for the efficiency factor; these values provide a 15 to 85 percent confidence range (U.S. Department of Energy, 2007).

The formation data and the source(s) used in the calculations are shown below.

- Reservoir temperature (from Dixon, 2002; Dixon, 2004);
- Reservoir pressure (entered as hydrostatic pressure, calculated based on the average depth to the approximate midpoint of the formation [from IHS Energy, 2004], and incorporating the assumption that the overlying strata are fully saturated);
- Salinity (from Colorado Oil and Gas Conservation Commission, 2004b, or other published information);
- Formation thickness;
- Formation surface area (projected to ground surface, and only that portion that is contained within the boundaries of the pilot study region; compiled from a combination of sources including well log data, geologic maps, and IHS Energy, 2004); and
- Porosity (from published information).

5.7 SUMMARY AND RANKING OF FORMATIONS

Twenty-five formations have been identified in the seven pilot study regions where significant carbon-emitting power plants are located. The Denver and Fort Morgan regions of the Denver Basin contain four candidates each, the Palisade and Rangely regions of the Piceance Basin contain three each, the Craig region of the Sand Wash Basin contains two, the Ignacio region in the San Juan Basin contains six, and the Cañon City region contains three (fig. 5.2).

The sequestration capacities for each geologic formation evaluated in this study are summarized in table 5.1. The formations are ranked in order from highest to lowest, based on the calculated tons of CO₂ that each unit can

potentially hold. Appendix 13 provides a tabulation of the aquifer characteristics used to calculate carbon storage capacity in Colorado.

Table 5.1: CO₂ sequestration capacities (million short tons) for deep saline aquifers in Colorado

Rank	Formation	Pilot Study Region	Based on an Efficiency Factor of		
			100 Percent	1 Percent	4 Percent
1	Fountain	Cañon City	2,628,140	26,281	105,126
2	Fountain	Denver	1,875,541	18,755	75,022
3	Weber	Palisade	1,791,624	17,916	71,665
4	Weber	Rangely	1,441,773	14,418	57,671
5	Morrison	Palisade	1,335,066	13,351	53,403
6	Hermosa	Ignacio	1,178,649	11,786	47,146
7	Morrison	Rangely	982,553	9,826	39,302
8	Morrison	Denver	844,908	8,449	33,796
9	Weber	Craig	665,463	6,655	26,619
10	Morrison	Fort Morgan	516,332	5,163	20,653
11	Entrada	Craig	489,771	4,898	19,591
12	Morrison	Ignacio	436,317	4,363	17,453
13	Morrison	Cañon City	328,255	3,283	13,130
14	Lyons	Denver	311,644	3,116	12,466
15	Mesaverde	Ignacio	308,439	3,084	12,338
16	Fountain	Fort Morgan	273,036	2,730	10,921
17	Entrada	Denver	196,355	1,964	7,854
18	Lyons	Fort Morgan	186,986	1,870	7,479
19	Entrada	Ignacio	185,462	1,855	7,418
20	Dakota	Palisade	181,554	1,816	7,262
21	Dakota	Rangely	140,147	1,401	5,606
22	Leadville	Ignacio	132,219	1,322	5,289
23	Entrada	Fort Morgan	117,885	1,179	4,715
24	Lyons	Cañon City	96,560	966	3,862
25	Dakota	Ignacio	62,472	625	2,499
Total Sequestration Capacity			16,707,152	167,072	668,286

One of the surprising findings of this study is that the highest ranked formation in the state, the Fountain, lies in the Cañon City PSR (table 5.1). This

is unexpected, as less than half of the areal extent of the Cañon City PSR is available for sequestration due to a large presence of crystalline rocks. Although the areal extent of the Fountain Formation is relatively small (1,300 square miles) compared to others evaluated in this investigation, its tremendous thickness of more than 3,400 feet allows for relatively high sequestration capacity. The Fountain Formation in the Denver PSR also has the distinction of being the second highest ranked formation in the state.

The relatively low ranking of the formations in the Ignacio PSR deserves clarification. The low rankings are misleading because the basin spans the border of Colorado with Arizona, New Mexico, and Utah, but the sequestration capacity shown in table 5.1 is only for the portion of the formations that lie in Colorado. In fact, the overall size of the basin is much larger than the Colorado portion that was evaluated in this study. The amount of sequestration capacity contributed by the portion of the basin lying in adjacent states will add greatly to the total sequestration capacity of the overall basin, and should increase the attractiveness of the region beyond what table 5.1 implies.

Table 5.2 shows how the seven Pilot Study Regions rank when the total sequestration capacities of each formation within the region are summed. The Palisade PSR is the top-ranked region, followed closely by the Denver and Cañon City PSRs. The Ignacio region becomes a somewhat more attractive target when its six formations are considered collectively rather than individually, and the inclusion of the remainders of the Ignacio PSR formations that lie outside Colorado should further enhance the region's favorability as a sequestration site.

Table 5.2: Combined CO₂ sequestration capacities (million short tons) for saline aquifers for the pilot study regions

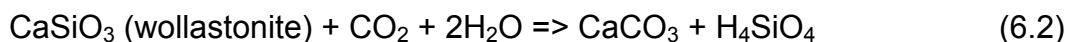
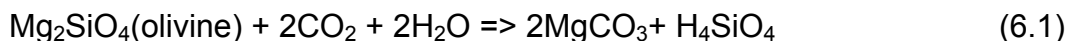
Rank	Pilot Study Region	Based on an Efficiency Factor of		
		100 Percent	1 Percent	4 Percent
1	Palisade	3,308,243	33,082	132,330
2	Denver	3,228,447	32,284	129,138
3	Cañon City	3,052,955	30,530	122,118
4	Rangely	2,564,474	25,645	102,579
5	Ignacio	2,303,558	23,036	92,142
6	Craig	1,155,235	11,552	46,209
7	Fort Morgan	1,094,239	10,942	43,770

6.0 MINERALIZATION IN COLORADO

6.1 CO₂ MINERALIZATION USING SILICATES

Several techniques for CO₂ sequestration have been proposed and can be categorized under the headings geologic, terrestrial, or oceanic sequestration. Terrestrial sequestration encourages the absorption of CO₂ by plants and agricultural techniques; ocean sequestration involves deep-water injection and dissolution of CO₂ in saline waters or nutrient enhancement in depleted waters. Techniques for geologic sequestration include storage in oil and gas fields, which can be used for enhanced oil or coalbed methane recovery; storage in deep saline geologic formations; and mineral carbonation. All but the last geologic method offer temporary storage and will require long-term monitoring to minimize the possibility of leakage and potential health risks. While temporary storage may ultimately prove to be desirable, CO₂ is not the lowest energy state of carbon and is therefore inherently unstable. The mineralization technique involves the reaction of CO₂ with a silicate mineral or brine to form a stable carbonate, which is a more thermodynamically stable form of carbon. This offers geologically long term and safe disposal of CO₂ in an above-ground setting that precludes the need for monitoring. Additionally, the mineralization option is estimated to have a CO₂ storage capacity comparable to other sequestration methods proposed to date (Kohlmann, 2001). Mineral carbonation is environmentally a relatively low risk application compared with other sequestration methods; however, the environmental risks associated with mining of the feedstock and disposal of the carbonate product must not be overlooked. Additionally, current mineralization technologies carry a somewhat higher price tag than other sequestration options. Ultimately, the viability of any given sequestration technique will depend on future detailed assessment of a multitude of economic and environmental factors.

Rainwater is known to naturally dissolve CO₂ from the atmosphere and react with minerals on the ground to form carbonate. The silicate mineral carbonation concept is based on a similar naturally occurring hydrothermal process whereby magmatic CO₂ reacts at depth with the silicate minerals in the surrounding host rock to form carbonate. Relatively high pressure and temperature help drive this reaction. For example, the reactions between dissolved CO₂ and the silicate minerals olivine and wollastonite are as follows:



To date, research has focused on mineral carbonation using olivine, serpentine, and wollastonite because these minerals are abundant and have relatively high concentrations of magnesium or calcium, which allow for greater sequestration of CO₂. Studies have shown that MgO has a greater capacity for carbonation than does CaO; complete carbonation of one ton of CO₂ requires 4.7 tons of CaO but only 3.3 tons of MgO (Huijgen and Comans, 2003). However, rocks containing silicate minerals with high (generally greater than 15 to 20 weight percent) Mg, Ca, Fe²⁺, K, or Na singular or combined content may have sufficient carbonation potential for local sequestration projects. Additionally, solid alkaline waste materials, such as asbestos waste, metal slag, and coal fly and municipal incinerator ash are abundant and contain substantial calcium.

The mineral carbonation reaction is exothermic (ex: $\Delta H_r(\text{olivine}) = -90\text{kJ/mol}$; (Goldberg and others, 2001)) but is very slow to occur at room temperature and pressure. Increasing the speed of the reaction is necessary if mineral carbonation is to be considered a practical sequestration method. Thus, some form of pre-treatment of either the feedstock material or CO₂ gas and/or novel reaction process approaches are required. This may be accomplished in many ways, some of which include purification of the flue gas CO₂, addition of catalyst solutions, and/or feedstock size reduction, magnetic or gravity separation, heat or mechanical activation of the feedstock, and passivating

reaction layer exfoliation. Unfortunately, pre-treatment typically involves consumption of energy, which leads to a delicate balancing game of CO₂ sequestered versus CO₂ produced during the sequestration process. The difference between these two values is referred to as CO₂ avoided:

$$CO_2 \text{ avoided} = CO_2 \text{ sequestered} - CO_2 \text{ emitted during mineral carbonation} \quad (6.3)$$

Clearly, if a process results in net negative CO₂ avoided, more CO₂ was produced than was captured and the process is untenable. Only if CO₂ avoided meets to-be-determined acceptable positive values while maintaining cost efficiency will a given mineralization technology be worthy of consideration. Research utilizing several different mineral feedstocks has shown that the average CO₂ avoided is about 75 percent of CO₂ sequestered (O'Connor and others, 2004).

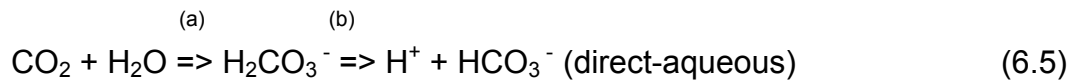
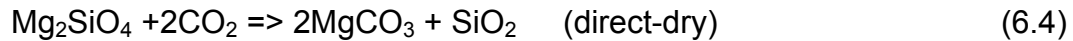
6.1.1 Methods

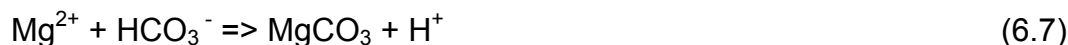
There are numerous technologies existing or postulated that involve the absorption of CO₂ either as a primary goal or as a consequential step in another process (table 6.1).

Table 6.1: Partial listing and selected references for mineral carbonation techniques and sequestration options

Method/ Technology	Process	Starting Material	Reference
NaHCO ₃ , NaCl	Direct – aqueous	Mg, Fe, Ca	O'Connor and others, 2004
Carbonic acid	Direct – aqueous	Mg, Ca	O'Connor and others, 1999
CO ₂ -solid	Direct – dry	Mg, Ca	Lackner and others, 1997
HCl	Indirect	Mg, Ca	Lackner and others, 1995; Haywood and others, 2001
Molten salt	Indirect	Mg, Ca	Wendt and others, 1998
Acetic acid	Indirect	Mg, Ca	Kakizawa and others, 2001
Dual alkali	Indirect	Na	Huang and others, 2001
Concrete	Industrial	Wet (uncured) concrete	Shao and others, 2004
Concrete	Industrial	Waste concrete	Fujii and others, 2001
Coal fly ash	Waste	Ash	Fauth and others, 2002
Incinerator ash	Waste	Ash	Devoldere and others, 2000
Slag	Waste		Fauth and others, 2002
Basalt	Injection	Porous zones	O'Connor and others, 2003

Mineral carbonation may be carried out using either a direct or indirect method. Direct carbonation is a process in which mineralization takes place through a single or simultaneous reaction. This may be achieved in a “dry” environment whereby CO₂ gas is reacted directly with a solid feedstock (equation 6.4), or in an “aqueous” environment using feedstock that is suspended in a solution such as carbonic acid (equations 6.5-6.7). Research suggests that the direct aqueous route may currently be the most promising technique for mineral CO₂ sequestration. The reactions for olivine are as follows:

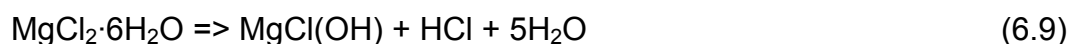




Alternatively, indirect or multi-phase carbonation uses an acid such as HCl to disassociate silica from the feedstock mineral. The resulting solution is then heated to drive off excess H₂O and an elemental oxide or hydroxide is formed. Carbonation then takes place with the introduction of CO₂. Serpentine, a hydrated Mg-silicate, forms magnesium carbonate in the following manner:



The above reaction can take place within one hour at a temperature of 100°C (Huijgen and Comans, 2003). Increasing the temperature to 250°C drives off excess water, recovers HCl, and forms the hydroxide (equations 9 and 10):



Carbonation is then free to occur with the addition of CO₂ (equation 11):



The energy consumed during the heating step and the corrosive nature of many of the acid or salt solutions used for indirect carbonation make it less favorable than the direct aqueous method, described below.

6.1.2 Direct Aqueous Mineralization

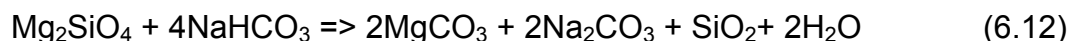
Carbonic Acid Reaction

As stated previously, direct aqueous mineralization involves the use of crushed or ground feedstock suspended in solution. Carbonic acid (formed through the dissolution of CO₂ gas in distilled water) was one of the earlier carrier solutions considered (O'Connor and others, 1999). Equations 6.5 through 6.7 illustrate the reaction pathways for this process using olivine as the mineral feedstock. It was

found that reaction (b) in equation 5, in which the bicarbonate ion (HCO_3^-) was formed, occurred very fast. However, the formation of carbonic acid (reaction 5a) took far longer and was thus noted as the rate determining, or limiting, step for aqueous dissolution (Nguyen and Ha, 1984). Additionally, it was theorized that while the use of an acid solution promotes the disassociation of silica from the elemental cation (equation 6.6), it may actually be a limiting factor in the precipitation of carbonate (equation 6.7). Thus, the use of a buffered solution carrier was proposed (O'Connor and others, 2000).

Sodium Bicarbonate – Sodium Chloride Reaction

Dramatic improvements to the rate of aqueous mineral carbonation were made by incorporating a buffered solution of sodium bicarbonate and sodium chloride. This solution, slightly alkaline in nature ($\text{pH} \approx 7.7\text{-}8.0$), encourages both dissolution of the cation and precipitation of carbonate. Tests showed that the maximum solution concentration at 25°C and 1 atm is 0.64 moles (M) NaHCO_3 and 1 M NaCl (O'Connor and others, 2004). Using olivine as an example, the reaction pathway is illustrated below:



Note that NaCl does not participate directly in this reaction. Its function is merely to enhance the solubility of magnesium. Carbonation efficiency using the sodium solution ranges from 15 percent to as much as 92 percent (O'Connor and others, 2004). However, the greatest efficiencies are only achievable through various pretreatment steps, some of which are too energy intensive to be cost effective or to return a positive net reduction of CO_2 (CO_2 avoided). Excluding pretreatment, current technology should allow for at least 60 percent carbonation (achieved in less than two hours) given a fairly high quality olivine feedstock. The addition of a recycle loop, in which unreacted material is passed through the system a second time, could increase total carbonation to about 80 percent (William O'Connor, Albany Research Center, oral communication, 2004).

Current research continues to focus on maximizing carbonation efficiency while minimizing cost and energy consumption.

6.1.3 Experimental Research

Numerous experiments and papers have addressed the feasibility and merits of mineral carbonation. One of the more detailed of these is an in-depth study of the carbonation potential of several different mineral silicates associated with nine mafic and ultramafic regions in the U.S. (O'Connor and others, 2004). These regions were selected for their abundance of silicate minerals such as olivine, serpentine, pyroxene, talc, and wollastonite. Numerous rock samples were collected for evaluation. Initial pretreatment involved crushing all samples to 80 percent minus 400 mesh (-37 μm). Throughout the study, this pretreatment was considered the base-line, or standard. Additional treatments, or activating steps, included ultra-fine grinding to increase available reaction surfaces, and heat-treatment (630° C) to drive off excess water in hydrated silicate forms such as serpentine. Most experiments utilized the NaHCO₃/NaCl carrier solution, although it was found that distilled water (i.e., carbonic acid route) was the better solution for the Ca-silicates such as wollastonite. The optimum reaction conditions for each silicate mineral used as feedstock varied considerably; conditions for some of the better performers are listed in table 6.2.

Table 6.2: Optimum conditions for the mineral carbonation process using Mg- and Ca-silicate feedstocks (O'Connor and others, 2004)

Mineral Feedstock	T, °C	P _{CO₂} , atm	Carrier Solution
Olivine	185	150	0.64 M NaHCO ₃ , 1 M NaCl
Wollastonite	100	40	Distilled water
Heat Treated Serpentine	155	115	0.64 M NaHCO ₃ , 1 M NaCl

The results of these experiments have provided a great deal of information about the mineralization process and are summarized in table 6.3. Wollastonite proved to have the greatest amenability to mineralization, and although localized wollastonite resources may have niche applications, nation-wide wollastonite resources are not considered sufficient to meet more regional demands. Conversely, the abundance of serpentine in the ultramafic regions of the U.S. is more than adequate to sequester current and near-future CO₂ emissions. However, the carbonation potential for inactivated serpentine is far lower than that of wollastonite or olivine, requiring as much as 30 tons of ore per single ton of CO₂ sequestered. To increase carbonation potential, serpentine must be heat-treated to drive off chemically bound water, or mechanically activated, which involves particle size reduction to maximize available reaction surface through rod and ball milling or ultra-fine grinding. This incurs a significant energy penalty that could amount to as much as \$0.23 per kilowatt-hour (kW·h) per ton of CO₂ sequestered – a price too high to render this method viable. The heat treatment step also consumes a great deal of energy and can produce as much CO₂ in emissions as CO₂ sequestered, resulting in zero net CO₂ avoided.

Olivine emerged as the best candidate for the mineral carbonation process (O'Connor and others, 2004). Although not as abundant as serpentine, olivine offered adequate CO₂ sequestration with low ore tonnage, low energy consumption penalties, and relatively low costs. Without any extra activation steps, 2.9 tons of crushed olivine ore can sequester one ton of CO₂ at an estimated price of \$69 per ton of CO₂ sequestered. This figure does not take into account the cost of CO₂ capture or transportation, but does include the cost of mineral extraction and pretreatment. This translates to \$0.06 per kW·h per ton of CO₂ sequestered, far less than the energy costs associated with the serpentine method. If the amount of CO₂ emitted during the carbonation process is taken into account, the final price tag increases to an estimated \$78 per ton of CO₂ avoided.

Table 6.3: Summary of experiments conducted by O'Connor and others (2004) highlighting the effects of pretreatment on CO₂ sequestration and cost

[Standard (std) pretreatment involves grinding to 400 mesh. Additional activation (act) steps include ultra-fine grinding or heat pretreatment. The price per ton of CO₂ avoided takes into account mining of the feedstock, transportation, and mineral carbonation, but does not include CO₂ capture or transport]

Silicate Mineral	Ore/CO ₂ sequestered (ton/ton)		CO ₂ Avoided (MT*)		\$ /ton CO ₂ avoided		\$ /kW·h/ton CO ₂	
	std	act	std	act	std	act	std	act
Olivine	2.9	2.2	13	7	78	167	0.06	0.06
Serpentine	30.2	6.4	8	0	537	---	0.49	0.23
Wollastonite	6.5	3.4	62	43	112	110	0.09	0.06

*All tonnages reported are standard English (short) tons. MT = million short tons

A much needed breakthrough in cost effective mineral carbonation may be found by in situ observation of the reactions involved in CO₂ mineralization using a newly developed microreaction system that can simulate various conditions (Wolf and others, 2004). Utilizing the microreaction system, McKelvy and others observed the formation of silica-rich layers on mineral surfaces of olivine feedstock during the carbonation process (Michael McKelvy, Arizona State University, written communication, 2004). The silica layers, also called passivating layers, thicken with increased reaction time, then fracture and exfoliate to expose fresh olivine surfaces. If the passivating layers are not allowed to fracture and exfoliate, mineral carbonation will cease when all mineral surfaces have been coated with silica. Therefore, current investigations are focusing on increasing the mineral surface available for carbonation by increasing passivating layer exfoliation. This could substantially enhance total mineral carbonation while still avoiding some of the high costs of other pretreatment steps (e.g., mechanical activation).

6.1.4 Environmental Issues and Cost Recovery

One of the more favorable aspects of the mineralization process is that it offers safe and geologically long-term storage of CO₂ as a stable mineral carbonate.

Many of the other storage methods rely on entrapment of CO₂ as a gas or supercritical fluid and thus, cannot offer this same degree of enduring confinement; long-term monitoring will be required to minimize CO₂ leakage and potential health risks. However, the mineralization process is not free of risk. While certainly offering relatively permanent assimilation of CO₂, the use of carrier solutions and the energy consumed to promote mineral carbonation may have serious environmental impacts. For example, some of the mineralization methods proposed require the use of acid or salt solutions, such as HCl, which may be classed as hazardous. Additionally, the large volumes of solution needed to keep the mineralization reaction moving forward are problematic. The HCl method, if implemented for a single 3 MT CO₂ processing plant, would consume nearly one third of the annual world HCl production (Newall and others, 2000). In general, the recycling of reaction components other than CO₂ and the associated feedstock mineral is critical for cost-effective process development. Even using buffered or low-volume carrier solutions, the energy expended simply to crush, grind, and/or preheat potential feedstock minerals may result in substantial CO₂ emissions, effectively negating the entire process. As mentioned previously, a sodium carrier solution combined with a minimally pretreated feedstock appears to produce results that are relatively cost effective without significant adverse environmental affects.

Another environmental concern relates directly to the operations associated with mining of the feedstock. The scale of the mining operation needed to produce mineral carbonation feedstock is consistent with current-day, large-scale mining of metals such as copper or gold. These industries have been scrutinized for decades and the associated environmental issues are well understood, and in most cases, well-regulated. It should not prove difficult to develop a mine plan that minimizes environmental impact. Of greater concern is the amount of material produced during the mineralization process. Newall and others (2000) estimated that sequestration of one ton of CO₂ would produce 1.9 tons of dry carbonate and 0.9 tons of silica sludge. This estimation assumes a relatively pure olivine feedstock. Less pure feedstocks would generate an

unknown amount of additional waste resulting from any non-reactive components in the feedstock. Storage of these materials poses some difficulty. While quarried areas of the mine could accommodate much of the waste material, studies show that over the course of the mine life, waste products would eventually exceed the volume of extracted feedstock by as much as 50 percent (Newall and others, 2000). Moreover, while not considered toxic, both the carbonate dust and dried silica dust are potential respiratory irritants. The carbonate dust would need to be kept relatively dry as the fine particles would dissolve, thus releasing the entrapped CO₂, if exposed to excess water. In order to overcome this disposal issue and at the same time recover some of the costs incurred, it will be necessary to find or develop marketable products that would utilize the excess waste material. For example, both magnesium and calcium carbonate may be used as filler or pigment materials for paint, paper, and plastics. Additionally, gravity and magnetic separation techniques instigated during the crushing process could improve the quality of the feedstock and may yield relatively high tonnages of metal ore, such as iron, chromium, nickel, and manganese. And yet, high production volumes of carbonate, metals, and any other value-added product may adversely impact the value of current resources by essentially over-saturating any potential market. Clearly, these are issues that must be investigated in more detail. Ideally, a mining, storage, and marketing plan could be developed to be both environmentally sound and economically rewarding without swamping local markets.

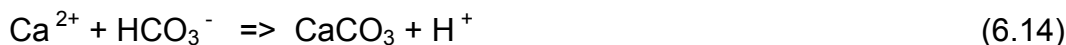
In keeping with these environmental and economic objectives, several researchers (e.g., Shao and others, 2004; Fauth and others, 2002; Fujii and others, 2001; Delvodore and others, 2000) have looked into the possibility of using industrial waste as a feedstock. While it is beyond the scope of this study to evaluate these numerous techniques, it is important to note that some of these methods have the potential to improve the environment and reduce total sequestration costs by utilizing unwanted and potentially hazardous materials that are in abundant supply. Several such options include asbestos waste (chrysotile), coal fly ash, municipal incinerator bottom ash, waste concrete, and

wet (uncured) concrete. These are primarily niche markets that will likely be quickly overwhelmed by the magnitude of CO₂ being produced.

6.2 CO₂ MINERALIZATION USING PRODUCED WATERS

In a recent Department of Energy (DOE) white paper, produced waters are defined as “*any water that is present in a reservoir with [a] hydrocarbon resource and is produced to the surface with the crude oil or natural gas*” (Veil and others, 2004). This definition was also expanded to include water produced from coalbed methane horizons in order to initiate flow and recovery of the methane. In the U.S., the average produced water to oil ratio is more than seven barrels for every single barrel of oil extracted (Lee and others, 2002), and in some cases can be far greater. Considering that U.S. oil production exceeded 3.23 billion barrels in 2003 (Energy Information Administration, 2004b), it quickly becomes apparent that water production is a very large factor in the oil and gas industry. It is both challenging and costly for companies to deal with this enormous volume of water as it cannot simply be allowed to flow freely from the drill site. Produced water is typically not potable and may contain a multitude of hazardous constituents – both naturally occurring and drilling-related. Currently, oil and gas companies are charged with the task of either re-injecting the water to a depth below the target reservoir or treating the water appropriately to meet various discharge or industrial use regulations. Recent studies by Bond and others (2004, 2001) explore the possibility of using produced water to sequester CO₂ as a stable, benign mineral carbonate.

The produced waters mineral sequestration concept involves binding calcium and magnesium ions inherent to the water with bicarbonate ions formed through hydration of the CO₂ gas. As with the silicate mineralization method, the rate limiting step in this process is the formation of bicarbonate. This is remedied with the use of an enzyme, carbonic anhydrase, which acts as a catalyst to hydrate CO₂. The reaction is as follows:



Preliminary laboratory experiments have successfully demonstrated the feasibility of this method. However, there are a number of factors that influence the rate and efficiency of the mineralization process and these must be further scrutinized before reliable sequestration potential can be determined. Probably the most important factor is the use of the carbonic anhydrase enzyme, which dramatically increases the rate of mineralization. Small quantities of human carbonic anhydrase II were obtained for experimental purposes. This enzyme can be economically mass-produced fairly readily through bacterial over-expression once a demand is established (Gillian Bond, New Mexico Tech, written communication, 2004). Ion content, in particular Ca and Mg, of the produced water is also an important factor. High calcium concentration is preferred as the calcium ions precipitate more readily than the magnesium ions, which can actually inhibit precipitation. Mineralization efficiency is as high as 80 percent in one to two hours of reaction time, and with the addition of a recycle loop, or second pass, efficiency is expected to be near 100 percent. Future technological improvements may be able to optimize magnesium precipitation as well. Lastly, increased temperature (~55° C) was found to positively affect mineralization, and optimum pH was determined to be six or higher. Cost and energy requirements for this process have not yet been addressed. As with the silicate mineralization procedure, carbonation using produced waters results in fairly large quantities of carbonate material, which, though not hazardous, must be utilized or stored. Environmental and market considerations for the final carbonate product are thus similar to those discussed above in the silicate mineralization section. Additionally, while effective in sequestering modest amounts of CO₂, the produced waters method does not greatly reduce the volume of the produced water nor does it remove significant quantities of potential toxins such as heavy metals. Following mineral carbonation, the

resulting water must still be re-injected or properly treated to meet disposal criteria, so there is little apparent cost value to the oil and gas industry. Continued research is needed to determine the ultimate viability of the produced water mineralization method as it relates to large-scale CO₂ sequestration.

6.3 CO₂ MINERALIZATION IN COLORADO

Colorado has numerous CO₂ sequestration options, ranging from geologic, to terrestrial, to mineral carbonation. CGS has identified seven regions in Colorado that are potential candidates for future geologic or mineral sequestration pilot studies (fig. 6.1). These regions were identified on the basis of proximity to significant CO₂ sources and diversity of CO₂ storage options (table 6.4).

Polygons surrounding the Rangely and Ignacio regions have been left open to indicate proposed extension of each region into the corresponding neighboring state where large power plants contribute significantly to local CO₂ emissions.

Three of Colorado's regions offer mineral carbonation via silicate rocks: Craig, Cañon City, and Palisade. Waters produced coincident with oil and gas extraction are potential candidates for the mineral carbonation process in all but the Cañon City region.

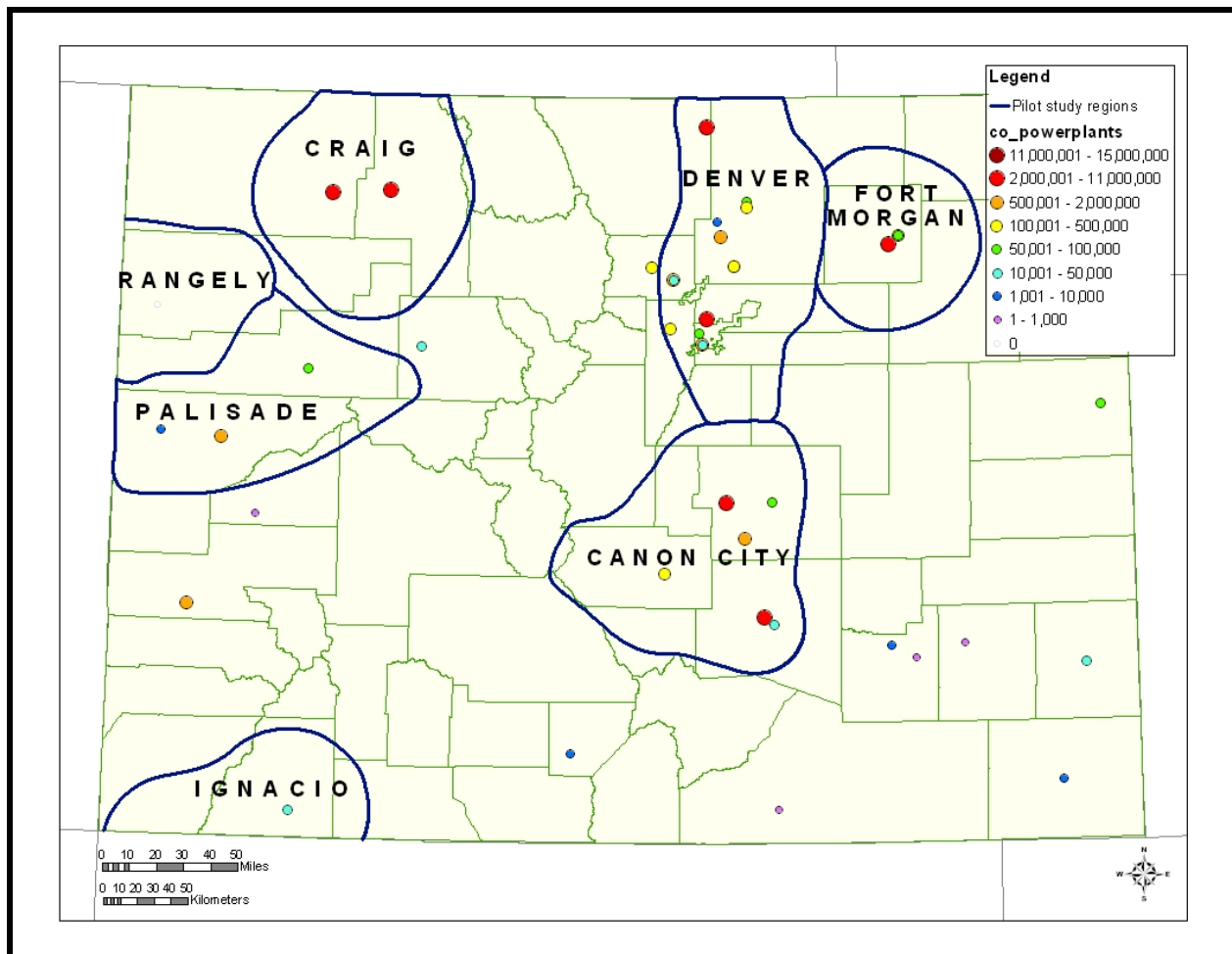


Figure 6.1: General outline of potential pilot study regions in Colorado. The Craig, Cañon City, and Palisade regions offer silicate mineralization options. Produced waters are available for sequestration in all but the Cañon City region.

Table 6.4: Potential pilot study regions in Colorado, selected on the basis of proximity to major CO₂ emission point sources and CO₂ storage diversity

Pilot study region	2003 power plant CO ₂ emissions* (tons)	Sequestration options				
		Mineralization		Geologic		
		Silicates	Produced Waters	Oil and Gas	Coalbed methane	Saline aquifers
Cañon City	12,087,551	X		X		
Craig	9,945,794	X	X	X	X	X
Denver	7,259,920		X	X	X	X
Fort Morgan	4,673,512		X	X		X
Ignacio	28,562,916		X	X	X	X
Palisade	410,712	X	X	X	X	X
Rangely	4,246,149		X	X	X	X

*Preliminary figures, subject to revision. Data includes emissions from 2 plants in northern New Mexico (Ignacio) and one plant in eastern Utah (Rangely).

6.3.1 Silicate Rocks

In Colorado, feedstock options for the mineralization process include basalt, gabbro, and syenite with minor amounts of pyroxenite, diabase, dunite, and diorite. Although these resources are quite small relative to those in other parts of the country, they may prove adequate to handle local CO₂ emissions. Basalt is the most abundant of the potential feedstocks in Colorado. Outcrops are found primarily throughout the central part of the state along a northwest trend (fig. 6.2). There are also basalt flows east of the Front Range in the southern part of the state. The vast majority of these flows are Miocene in age. The combined MgO, CaO, and FeO content for these rocks averages 15 to 20 weight percent (appendix 14). This is significantly lower than in the high purity experimental feedstocks (such as olivine), which can have as much as 49 weight percent MgO (O'Connor and others, 2004). This does not automatically eliminate basalt as a potential mineralization candidate. Rather, it merely indicates that a greater

tonnage of ore must be utilized to sequester the same amount of CO₂ as would be assimilated by a more pure feedstock. Depending on which mineralization process is deemed optimal by future research, this may or may not be economical.

Mafic and ultramafic rocks are of higher quality for CO₂ sequestration than basalt, but in Colorado, are much less widespread (fig. 6.2). They crop out as small stocks, plugs, and dikes that are Precambrian or Cambrian in age. Of the larger mafic bodies, gabbro is the dominant rock type, and has a combined MgO, CaO, and FeO content that averages 25 to 30 weight percent. While still of lower quality than the experimental feedstocks, gabbro has a greater capacity for CO₂ storage than does basalt. Similarly, syenite has lower Na₂O and K₂O concentrations than do source materials used for the mineralization process in which soda ash (Na₂CO₃) is formed, but still may be practical for local sequestration projects. Syenite crops out at only a handful of locations in south-central Colorado. It should be noted that carbonation with the sodium and potassium ions results in a highly soluble material, such as soda ash, that will require immediate industrial use or ensured long-term dry storage. The mineralization reaction is reversed with the addition of water, and thus, CO₂ will be released back into the atmosphere if the product is not kept dry.

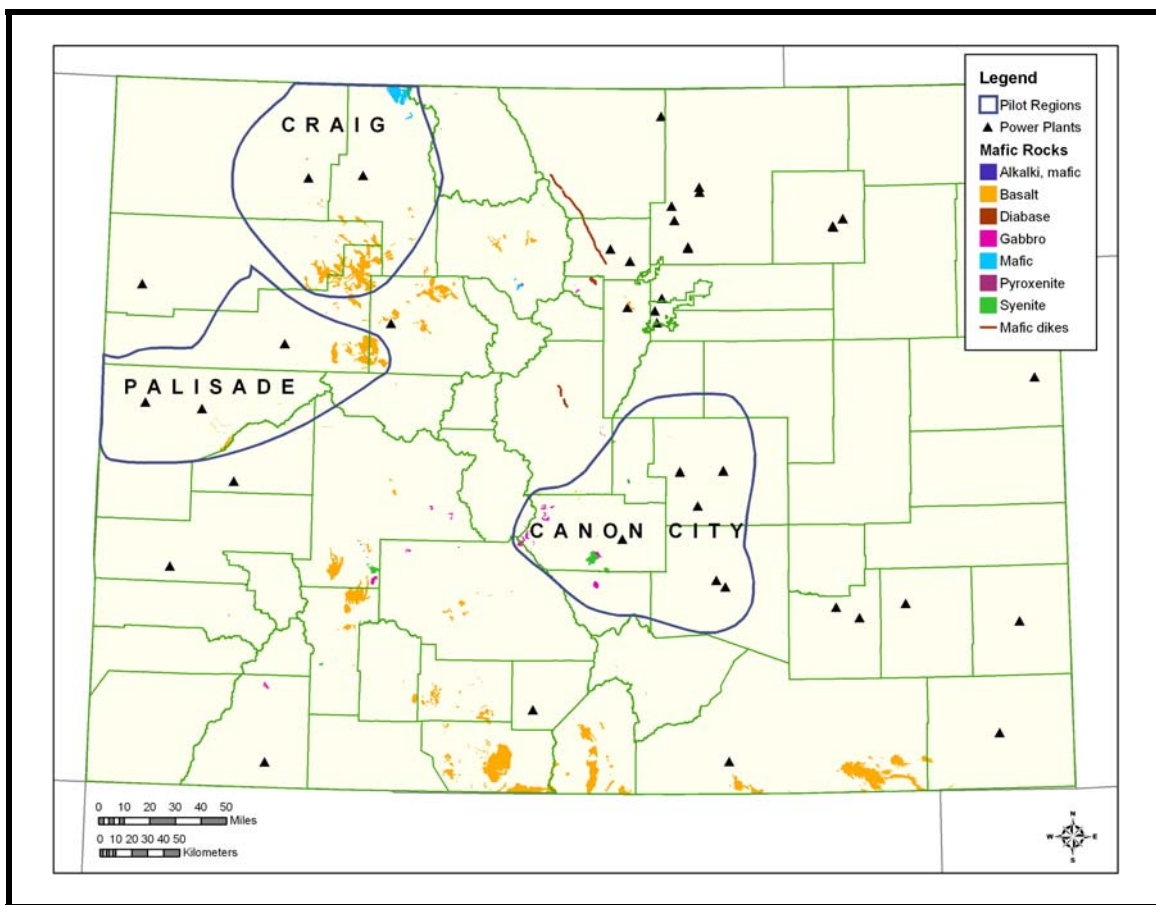


Figure 6.2: Map showing silicate mineralization pilot study regions and areal distribution of mafic and ultramafic rocks, basalt, and alkalic igneous rocks in Colorado that may be used as feedstock.

Three Colorado regions have potential for mineral carbonation using silicate rocks as feedstock. Total sequestration potential was calculated for each region on the basis of the following factors and assumptions:

- Ore resources within about 40 miles of the CO₂ point source(s) as shown on 1:250,000-scale geologic maps (fig. 6.2)
- Mining depth of 200 feet for basalt; 500 feet for all other rocks
- Average specific gravity of 2.8 for syenite; 3.0 for all other rocks
- Geochemistry extracted from the U.S. Geological Survey PLUTO database (U.S. Geological Survey, 2004a) and averaged for similar rock types

Craig Region

The Craig region is located in northwestern Colorado and is centered on the Craig and Hayden coal-fired power plants, both of which are among the state's top five CO₂ emitters. CO₂ emissions from these plants totaled over 9.9 million tons in 2003.

Bimodal basalt is prevalent in the southern part of the region and represents 1,459 billion tons of potential feedstock. To the northeast, mafic and ultramafic rocks (primarily gabbro) could provide 60.9 billion tons of material. Assuming 100 percent efficiency, these rocks could sequester more than 256 billion tons of CO₂. Basalt and (ultra)mafic rocks would be consumed at a rate of 6.0 and 4.1 tons per ton of CO₂ sequestered, respectively.

Experiments conducted by O'Connor and others (2004) suggest that the reaction efficiencies for basalt and gabbro are far below 100 percent using current technology. In fact, they are probably as low as 15 to 20 percent, respectively, significantly lower than pure olivine feedstock, which yields 60 to 80 percent efficiency. Actual CO₂ sequestration potential is therefore greatly reduced. Additionally, an energy penalty must be added to account for the CO₂ produced during the mineralization process. As mentioned previously, CO₂ avoided is the difference between total CO₂ sequestered and CO₂ that is produced during mineralization, which averages about 75 percent of total CO₂ sequestered for several mineral feedstocks investigated. This translates to actual sequestration potential of about 29 billion tons of CO₂ for the Craig region (table 6.5). The large gap between theoretical potential and potential based on current technology clearly indicates there is a great deal of room for technological advancement.

Table 6.5: CO₂ mineral sequestration potential and ore demands for the Craig pilot study region

Feedstock	Ore available (MT)	CO ₂ seq. potential (MT) 100% effic.	CO ₂ seq. potential (MT) 15-20% effic. ¹	2003 CO ₂ emissions (tons)	Ore demand/year (MT) ²
Mafics*	60,886	14,820	2,223		272
Basalt	1,458,822	241,789	27,201		533
Total	1,519,708	256,609	29,424	9,945,794	

1 – Estimated potential assuming 15% efficiency for basalt, 20% efficiency for mafics, and accounting for CO₂ produced during mineralization. MT = million short tons

2 – Ore required to sequester total 2003 CO₂ emissions

* Primarily gabbro, also diabase, pyroxenite, diorite, and dunite

Cañon City Region

The Cañon City region is west of Pueblo in the central part of Colorado. There are four coal-burning plants and two natural gas plants within or near this region. A total of 12 million tons of CO₂ were produced from three of the coal plants in 2003; the remaining three did not operate during that year. A proposed 750-megawatt (MW) coal-fired power plant for the area is projected to be operational by 2009 (Associated Press, 2004) and is expected to contribute significantly to local CO₂ emissions in the years following.

Silicate rocks crop out primarily in the western half of the pilot study region and are predominantly gabbro and syenite in composition, although minor basalt and pyroxenite are also present. Mafic and ultramafic rocks represent more than 35 billion tons of potential feedstock for the mineralization process. Similarly, syenite bodies in the area could provide nearly 31 billion tons of feedstock. Basaltic rocks would provide a mere 1.7 billion tons of material. Ore tonnage requirements per ton of CO₂ sequestered would be 4.1 for mafic and ultramafic rocks, 4.7 for syenite, and 6.5 for basalt.

Total theoretical CO₂ sequestration potential for the area is over 15 billion tons, assuming 100 percent efficiency. As mentioned previously, actual reaction efficiencies for the rocks in this region are currently as low as 15 to 20 percent.

This, in combination with consideration of CO₂ emitted during the mineralization process, indicates an estimated sequestration potential closer to 2.3 billion tons using current technology (table 6.6).

Table 6.6: CO₂ mineral sequestration potential and ore demands for the Cañon City pilot study region

Feedstock	Ore available (MT)	CO ₂ seq. potential (MT)	CO ₂ seq. potential (MT)	2003 CO ₂ emissions (tons)	Ore demand/ year (MT) ²
		100% effic.	15-20% effic. ¹		
Mafics*	35,360	8,551	1,283		333
Basalt	1,775	273	31		699
Alkalic ign. [^]	30,912	5,570	836		447
Total	68,046	14,394	2,149	12,087,551	

1 – Estimated potential assuming 15% efficiency for basalt, 20% efficiency for mafics, and accounting for CO₂ produced during mineralization. MT = million short tons

2 – Ore required to sequester total 2003 CO₂ emissions

* Primarily gabbro, also diabase, pyroxenite, diorite, and dunite

[^] Primarily syenite

Palisade Region

The town of Palisade is located in the central part of western Colorado. There are four power plants in the vicinity, but only one is coal-fired. The Cameo plant was responsible for all 410,712 tons of plant-generated CO₂ emitted in the region in 2003.

Basalt is the only feedstock option in the Palisade region. Total ore available is estimated at 9.7 billion tons, which indicates a maximum sequestration potential of 1.6 billion tons of CO₂. Actual sequestration potential is closer to 182 million tons when current reaction efficiencies and CO₂ emissions are taken into account (table 6.7).

Table 6.7: CO₂ mineral sequestration potential and ore demands for the Palisade pilot study region

Feedstock	Ore available (MT)	CO ₂ seq. potential (MT) 100% effic.	CO ₂ seq. potential (MT) 15% effic. ¹	2003 CO ₂ emissions (tons)	Ore demand/year (MT) ²
Basalt	9,776	1,620	182	410,712	22

¹ – Estimated potential assuming 15% efficiency and accounting for CO₂ produced during mineralization. MT = million short tons

² – Ore required to sequester total 2003 CO₂ emissions

6.3.2 Produced Waters

The majority of produced waters in Colorado originate from the principal oil and gas basins: Denver, Raton, San Juan, and Piceance (fig. 6.3). State-wide production of water amounted to nearly 294.3 million barrels in 2003 (extracted data from Colorado Oil and Gas Conservation Commission, 2004b), more than half of which was from the Purgatoire River, Rangely, and Ignacio Blanco oil and gas fields (table 6.8). An evaluation of all produced water in the state reveals that calcium concentrations are highly variable (appendix 15), ranging from trace amounts to as much as 62,000 ppm. Magnesium is similarly variable and may reach over 7,000 ppm. Nearly all of the produced waters contain more than 1,000 ppm total dissolved solids (TDS). Maximum TDS is over 340,000 ppm; mean TDS for 2,001 samples is 25,319. Average geochemistry may be calculated for various fields or basins, but the high degree of variability, even within a single well, suggests that other factors will need to be considered. If all the water produced from all the various formations in a given region is combined for use at a single mineralization plant, then a simple average, weighted by volume per producing horizon, may suffice. If, however, it is deemed more practical to collect high-calcium water only from selected horizons then several permutations may be necessary and acceptable collection methods will need to be developed.

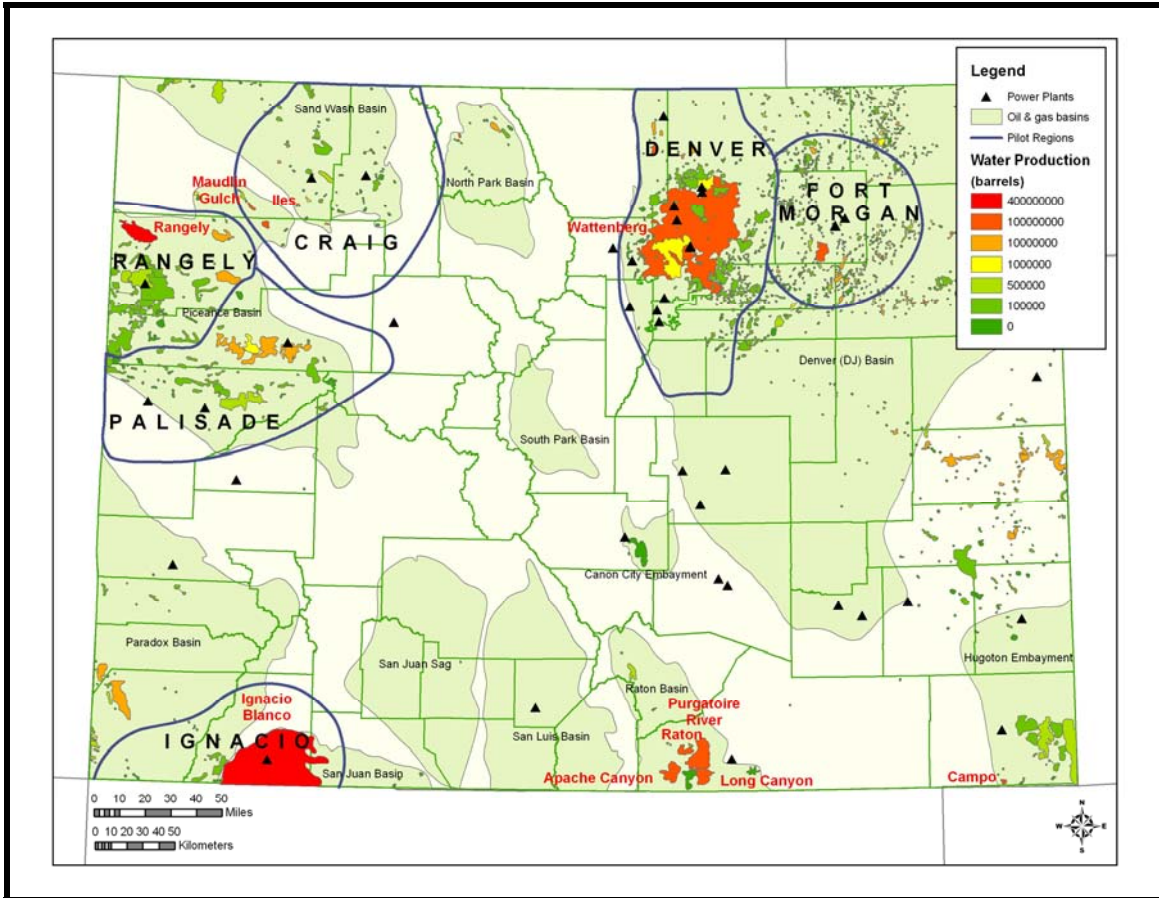


Figure 6.3: Oil and gas fields in Colorado, ranked on the basis of water production from 1999 through 2003. The top 10 water producing fields for 2003 are labeled in red (see also, table 6.8).

Table 6.8: Top 10 water producing oil and gas fields in Colorado in 2003

[Note that only five of these top fields coincide with proposed pilot study regions (see also fig. 6.3). Mbbls = thousand barrels]

Rank	Field	Water (Mbbls)	Pilot study region
1.	Purgatoire River	80.2	---
2.	Rangely	77.6	Rangely
3.	Ignacio Blanco	25.6	Ignacio
4.	Raton	10.3	---
5.	Iles	8.3	Craig
6.	Apache Canyon	4.5	---
7.	Long Canyon	4.5	---
8.	Maudlin Gulch	3.7	Craig
9.	Campo	3.6	---
10.	Wattenberg	3.3	Denver

Six Colorado regions have potential for mineral carbonation using produced waters as a cation source. Total sequestration potential was calculated for each region on the basis of the following factors and assumptions:

- Includes water resources from all fields within about 40 miles of the region's CO₂ point source(s) (fig. 6.3)
- Assumes 100 percent mineralization with the Ca and Mg cations, energy requirements are not considered
- Water geochemistry extracted from the U.S. Geological Survey produced waters database (U.S. Geological Survey, 2004b) and averaged by principal producing formations and by pilot study region

Ignacio Region

The Ignacio region of southwestern Colorado is considered to extend into New Mexico since nearly all of the CO₂ emitted in this region originates from two coal-fired plants in the northwest part of that state. Emissions from these two plants exceeded 28.5 million tons of CO₂ in 2003, making this the highest CO₂-emitting region proposed by CGS for future pilot studies. The largest Colorado field in the

area is Ignacio Blanco, which has produced significant volumes of oil, gas, and coalbed methane (CBM) from several different stratigraphic horizons. Water has been produced from many of these same horizons, but has been most prolific from the Cretaceous Dakota Sandstone, Mancos Shale, and Mesaverde Group and the Pennsylvanian Hermosa Group. Water production in this region has totaled 122.5 million barrels from 1999 through 2003. Water chemistry indicates that the Hermosa Group tends to have the highest calcium content, whereas the Mancos Shale is relatively low in calcium (table 6.9).

Table 6.9: Average geochemistry for principal water-producing horizons in the Ignacio region

[All units in milligrams per liter]

Formation	HCO ₃	Ca	Cl	Mg	K	Na	K+Na	SO ₄	TDS	n*
Dakota	732	653	4,921	33	129	3,050	3,179	1,114	10,441	16
Hermosa	1,043	5,366	105,136	1,250	1,133	60,374	61,508	2,134	175,872	9
Mancos	2,505	214	18,638	225	0	12,452	12,452	194	33,142	8
Mesaverde	1,310	777	17,743	443	0	11,221	11,221	2,063	33,557	8

*number of samples included in calculation of average values

Denver Region

The Denver region is east of the Rocky Mountain Front Range and occupies the western part of the Denver Basin. Several power plants contributed to CO₂ emissions totaling 7.3 million tons in 2003. Wattenberg field is the largest in the region and is a source of oil and natural gas. Production of water is predominantly from the Cretaceous Dakota and Pierre Formations and the Permian Lyons and Ingleside Formations. Total water production in the region amounted to 44.2 million barrels from 1999 to 2003. Calcium content in waters from the Denver region is relatively low, averaging 264 ppm, regardless of producing formation (table 6.10).

Table 6.10: Average geochemistry for major producing horizons in the Denver region

[All units in milligrams per liter]

Formation	HCO ₃	Ca	Cl	Mg	K	Na	K+Na	SO ₄	TDS	n*
Dakota	938	241	6,804	62	213	4,544	4,758	720	13,182	60
Ingleside	540	342	112	26	0	786	786	1,991	3,522	6
Lyons	831	272	14,937	155	272	12,656	12,928	7,262	36,048	156
Pierre	860	200	8,780	38	73	5,765	5,838	108	15,430	27

*number of samples included in calculation of average values

Rangely Region

Similar to the Ignacio region, the Rangely region is a multi-state pilot study region, and is located in northwestern Colorado in the northern part of the Piceance Basin. The Bonanza power plant in eastern Utah is responsible for nearly all power plant emissions in the region, amounting to more than 4.2 million tons in 2003. There are over 50 fields in this region that produce oil, gas, and CBM. The Rangely field is the top water producer and is also an important oil and gas reservoir. There are numerous producing horizons in the Piceance Basin and water chemistry is highly variable. The Jurassic San Rafael Group and the Pennsylvanian-Permian Weber Sandstone have the highest calcium concentrations (table 6.11). The Mancos Shale, as in the Ignacio region, tends to produce waters that are very low in calcium. Produced waters have exceeded 400 million barrels over the course of the last five years.

Table 6.11: Average geochemistry for waters produced from the Denver region

[All units in milligrams per liter]

Formation	HCO ₃	Ca	Cl	Mg	K	Na	K+Na	SO ₄	TDS	n*
Dakota	1,515	481	14,861	206	25	9,892	9,917	926	27,527	34
Mancos	1,424	119	7,842	47	68	5,518	5,586	282	14,641	31
Mesaverde	2,524	267	15,182	103	572	10,212	10,784	249	28,686	29
Morrison	1,612	751	15,353	137	29	10,006	10,035	1,131	28,428	21
San Rafael	1,656	1,329	24,547	188	754	14,820	15,574	1,256	43,807	17
Wasatch	1,008	594	6,665	52	46	4,116	4,162	410	12,409	37
Weber	541	3,313	50,850	656	242	28,558	28,800	1,210	85,100	74

*number of samples included in calculation of average values

Palisade Region

The Palisade region occupies the southern part of the Piceance Basin in western Colorado. Relative to the other proposed pilot study areas, CO₂ emissions in the Palisade region are relatively low; only 0.4 million tons in 2003. The majority of the 50 plus fields in this region produce oil and/or natural gas. Roughly a dozen of these fields also produce CBM. Water production from 1999 through 2003 exceeded 7.4 million barrels. Geochemical analyses indicate that the Cretaceous Dakota Sandstone and Mesaverde Group; and the Jurassic San Rafael Formation produce waters high in calcium (table 6.12).

Table 6.12: Average geochemistry for major producing horizons in the Palisade region

[All units in milligrams per liter]

Formation	HCO ₃	Ca	Cl	Mg	K	Na	K+Na	SO ₄	TDS	n*
Dakota	1,875	1,156	26,273	462	23	15,658	15,681	186	45,110	7
Mesaverde	1,464	475	6,507	57	14	4,251	4,264	270	12,568	26
Morrison	457	2,231	30,621	472	0	16,625	16,625	84	50,276	5
San Rafael	1,856	1,318	21,674	419	0	13,167	13,167	1,503	38,995	10

*number of samples included in calculation of average values

Fort Morgan Region

In 2003, the two power plants in the Fort Morgan region emitted 4.7 million tons of CO₂. There are several hundred small oil and gas fields in this region, which is situated in the central part of the Denver Basin in northeastern Colorado. Nearly all production is from the D Sand and the Muddy J Sand of the Cretaceous Dakota Group. Cumulative water production since 1999 is over 70.2 million barrels, but average calcium concentration in these waters is very low (table 6.13), which renders this region lowest on the list of proposed pilot study areas for produced water mineralization.

Table 6.13: Average geochemistry for waters produced from the Fort Morgan region

[All units in milligrams per liter]

Formation	HCO₃	Ca	Cl	Mg	K	Na	K+Na	SO₄	TDS	n*
Dakota	1,625	36	3,188	13	10	2,768	2,778	258	7,343	110

*number of samples included in calculation of average values

Craig Region

More than 9.9 million tons of CO₂ were emitted in 2003 by two power plants in the Craig region, which is situated in northeastern Colorado. About 50 fields produce oil and gas from the Sand Wash Basin in this region. Three fields also produce CBM. Cumulative water production for the past five years is well over 111 million barrels. Two of Colorado's 2003 top ten water producing fields are located in the Craig region: Iles field and Maudlin Gulch field. Waters with the highest calcium content originate from the Cretaceous Mancos Shale, Triassic Chinle Formation, and Pennsylvanian-Permian Weber Formation (table 6.14).

Table 6.14: Average geochemistry for major producing horizons in the Craig region

[All units in milligrams per liter]

Formation	HCO ₃	Ca	Cl	Mg	K	Na	K+Na	SO ₄	TDS	n*
Chinle	1,900	291	4,348	59	17	3,412	3,429	539	9,703	21
Dakota	952	81	1,529	18	7	1,433	1,439	385	3,964	56
Lewis-Lance	1,652	60	1,160	12	7	1,420	1,427	105	3,696	22
Mancos	1,472	709	4,363	84	31	2,848	2,878	781	9,645	28
Mesaverde	2,414	120	1,795	16	35	2,266	2,301	567	6,136	35
Morrison	691	151	4,941	37	10	3,663	3,674	923	10,117	104
San Rafael	1,630	57	1,533	11	7	1,713	1,720	301	4,477	14
Weber	929	496	12,960	91	41	9,261	9,302	2,625	25,938	18

*number of samples included in calculation of average values

6.3.3 Theoretical Sequestration

Assuming 100 percent efficiency and no costs or energy requirements, the sequestration potential for each region can be seen below in table 6.15. The Rangely pilot study region offers the highest annual sequestration potential. Water production is the highest of all the regions and calcium concentrations are elevated. Although the Ignacio region is host to some of the most calcium-rich water in the state, water production is significantly lower than in the Rangely region, and CO₂ sequestration potential is thus cut by more than one third. Water production in the Fort Morgan region is moderate but calcium concentrations are so low that CO₂ sequestration through produced water is not worth considering in this area.

Table 6.15: CO₂ sequestration potential utilizing produced waters as a source for mineral carbonation

Rank	Pilot study region	Avg. annual production* (Mbbls)	Avg. Ca (mg/L)	Avg. Mg (mg/L)	CO ₂ seq. potential (tons) ¹
1.	Rangely	80.2	979	199	15,090
2.	Ignacio	24.5	1,752	488	9,019
3.	Craig	22.2	246	41	1,003
4.	Denver	8.8	264	70	483
5.	Palisade	1.5	1,295	352	401
6.	Fort Morgan	14.0	36	13	117

* Annual average calculated using production from 1999 through 2003. Mbbls = thousand barrels; mg/L = milligrams per liter

¹—Theoretical potential assuming 100% efficiency

6.3.4 Limitation of Calculations

The produced water mineralization technique is still in the early stages of experimentation and implementation. It has been shown to be successful at both the bench and lab scale but has not yet been implemented on a larger scale. Cost and energy requirements for this process are, as yet, unknown. Additionally, cation concentrations used herein are inherently skewed since they are based on a simple arithmetic average of tens to hundreds of samples per pilot study region but do not take into account the volume of water produced by individual formations. Since water production is often reported as commingled, it becomes difficult to assign a volume or geochemical signature to any given formation. Average cation concentrations could vary considerably based on the cation concentration in the dominant water producing horizon of a region, field, or even single well. Additionally, calculation of long term mineralization capacity is tenuous at best. Unlike the feedstock for silicate mineralization, for which a known volume can be calculated, water production is not constant (Veil and others, 2004). The volume of water produced in association with oil and gas fields increases over time, and can ultimately exceed oil and gas extraction to such an extent as to render a well or field uneconomical and cause it to be abandoned. Conversely, large volumes of water must be pumped out of coalbed

methane horizons in order to initiate flow of the methane gas. Thus, water production is initially high but decreases significantly once the methane is liberated. Considering all of these variables, any real estimate of CO₂ sequestration potential is, accordingly, highly speculative.

In comparing sequestration potential of silicate minerals and produced water, it is readily apparent that the silicate minerals can consume far more CO₂ than the produced water. A large, but reasonable silicate mining operation could provide sufficient cation quantity to accommodate annual CO₂ emissions within the specified region. Sequestration of the same amount of CO₂ would require an enormous volume of water to provide the necessary cations. In the Rangely region, for example, 80 million barrels of water can theoretically sequester 15,124 tons of CO₂. This is far below the 4.2 million tons of CO₂ emitted in that region in 2003. It would take over 22 billion barrels of water to mineralize this much CO₂. This is closer to total U.S. water production in 2003 (Veil and others, 2004). Therefore, produced water mineral carbonation, while an intriguing approach to CO₂ sequestration, does not appear to be practical for large-scale CO₂ sequestration efforts in Colorado. However, the technology may be suitable for some niche applications.

6.4 CONCLUSIONS

Numerous technologies have been proposed to aid in the reduction of CO₂ emissions. Mineral carbonation, though currently more costly than many other technologies, is the only method that actually sequesters CO₂ as a geologically stable mineral carbonate rather than as a potentially mobile gas or subcritical/supercritical fluid. Two pathways to mineral carbonation have emerged: silicate mineralization, which has been evaluated and tested for nearly a decade, and produced water mineralization, a relatively new technology just starting to gain momentum. Although the silicate method holds promise as an effective means to sequester CO₂, it must be further refined to minimize cost and

energy consumption and environmental impact assessments (EIAs) need to be performed.

The current cost estimate for silicate mineralization is \$78/ton of CO₂ avoided. This takes into account the cost of mining the silicate feedstock, the cost of the mineralization process itself, and the cost of the energy required to complete the process. Assuming that technology could be developed to render silicate mineralization a viable solution to the CO₂ problem, Colorado would have adequate resources to implement mineral carbonation in several regions. The Craig region, in the northwestern part of the state, is most promising for silicate mineralization, and could sequester as much as 29.4 billion tons of CO₂ given current technology.

No cost estimates have been calculated for the produced water mineralization method. Preliminary calculations indicate that the volume of water necessary to sequester CO₂ emissions in a given region would far exceed current production levels. The Rangely region, also in northwestern Colorado, has the highest produced water mineralization potential, but even with annual production of about 80 million barrels, could only sequester up to 11,333 tons of CO₂ per year. Produced water mineralization does not appear to be a viable sequestration method for Colorado at this time.

7.0 CARBON CAPTURE AND STORAGE COSTS

7.1 INTRODUCTION

Throughout the previous sections of this report, reference is made to the availability of CO₂ for storage in suitable geologic environments. All of the sequestration capacity calculations assume that the CO₂ is anthropogenic in origin and has been “purified” for enhanced recovery use and/or longer-term storage. This assumption carries with it a cost – the investment required to capture, separate, transport, and sequester the CO₂, as well as some consideration of the energy required (and associated emissions) to achieve this goal. Although beyond the scope of the Phase I project, this section is intended to briefly summarize some of the available cost information and the issues that impact those costs.

7.2 FLUE GAS

The “carbon footprint” of a coal-fired power plant is about twice that of a natural gas-fired power plant; that is, approximately 2,000 pounds CO₂ per MWh versus 1,000 pounds CO₂ per MWh, respectively. Even so, the seeming volatility in natural gas prices and supply diminishes some of the attractiveness of natural gas as a stable feedstock for baseload power generation. In spite of recent price increases, coal is expected to remain the most widely used fuel for power generation in the U.S. (Energy Information Administration, 2004b). With an estimated 16.43 billion short tons of coal yet to be mined locally, Colorado will continue to favor the use of coal as will much of the nation (Energy Information Administration, 2003).

As discussed in Section 2.0 of this report, coal combustion produces a large amount of anthropogenic CO₂ during flue gas production. Flue gas can be captured for sequestration purposes and injected without an investment in purifying the concentration of CO₂. However, the composition of the flue gas is

only about 10 to 15 percent CO₂ with the balance being comprised of non-combustible N₂ and some minor amounts of pollutants. For this reason, sequestered volumes of CO₂ would be less than 20 percent of each unit volume of unpurified flue gas injected for storage.

Further, without purification, the use of flue gas for enhanced oil recovery projects would be significantly impeded because the N₂ concentration has a detrimental effect on the minimum miscibility pressure (MMP); that is, the threshold that must be met to increase recovery more efficiently. The dilutants in the flue gas increase the pressure at which the CO₂ and oil become miscible to approximately 6,500 psi while the MMP for pure CO₂ is only about 1,250 psi.

7.3 CO₂ CAPTURE TECHNOLOGY

The Electric Power Research Institute (EPRI) identifies several advanced technology options for CO₂ capture associated with power generation (Neville Holt, EPRI, written communication, 2007). These include:

- Post-combustion removal of CO₂ from flue gas by amine or other sorbent scrubbing for natural gas combined cycle (NGCC) or pulverized coal (PC) plants
- Pulverized coal combustion with oxygen and recycle CO₂ to give a concentrated CO₂ stream [OxyFuel or oxygen combustion (OC)]
- Coal gasification with shift reactor and removal of CO₂ from syngas prior to combustion of hydrogen (H₂) in combined cycle (IGCC); (Syngas is synthesis gas composed primarily of carbon monoxide and hydrogen.)
- Coal gasification and syngas combustion with oxygen and recycle CO₂ to give a concentrated CO₂ stream; for example, Clean Energy Systems

Critical research and engineering design is required to fully integrate gasification and combustion technologies with CO₂ capture options. Integrated

Gasification Combined Cycle and CO₂ removal are offered commercially but have not operated in a mature integrated manner. Issues yet to be addressed include IGCC costs particularly with low rank coals, integration, H₂ turbines and CO₂ storage. Advanced PC and CO₂ post-combustion are each offered commercially but CO₂ removal has only operated at a small scale and has not been fully integrated. The issues with this technology include CO₂ capture cost, integration, and CO₂ storage. OxyFuel combustion is still in the developmental stage and not ready for deployment.

Klara (2006) has recently compared the costs and performance of various types of fossil energy power plants assuming a 90 percent capture rate for CO₂ (table 7.1). The average cost of electricity (COE) using IGCC technology with CO₂ capture is 7.13 cents per kilowatt-hour (¢/kWh), an increase of 30 percent over the 5.48 ¢/kWh without capture. The increase in the COE using PC technology (either sub- or supercritical) with CO₂ capture is about 70 percent; that is, 8.49 ¢/kWh with capture versus 4.98 ¢/kWh without capture. The use of NGCC technology with CO₂ capture increases the COE from 6.75 ¢/kWh to 8.99 ¢/kWh or about 33 percent, marginally higher than IGCC with CO₂ capture.

Table 7.1: National cost and performance comparison of fossil energy power plants using various technologies¹

Power Plant Technology²	Capital Cost (TCR³ \$/kW)⁶	Efficiency (HHV⁵, Percent)	Cost of Electricity⁴ (Cents/kWh)⁶
Avg IGCC	1,692	39.0	5.48
Avg IGCC with CO ₂ Capture	2,245	31.5	7.13
PC Subcritical	1,474	36.3	4.99
PC Subcritical with CO ₂ Capture	2,626	23.9	8.63
PC Supercritical	1,508	38.5	4.97
PC Supercritical with CO ₂ Capture	2,635	26.9	8.35
NGCC	568	50.6	6.75
NGCC with CO ₂ Capture	988	43.4	8.99

¹ Source: Klara, 2006² Power Plant Technology: IGCC, Integrated Gasification Combined Cycle; PC, Pulverized Coal; NGCC, Natural Gas Combined Cycle³ TCR, Total Capital Requirement (includes equipment, materials, labor, indirect construction costs, engineering, contingencies, cost of money, real estate, royalty allowance, preproduction costs, and initial inventories); 2006 dollars⁴ Assumes January 2006 dollars; 13.8 percent levelization factor; coal cost \$1.34/10⁶ Btu, gas cost \$7.46/10⁶ Btu, IGCC capacity factor 80 percent, PC capacity factor 85 percent, NGCC capacity factor 65 percent⁵ HHV, Higher Heating Value⁶ \$/kW, Dollars per kilowatt; Cents/kWh, Cents per kilowatt-hour

However, not all IGCC technology is created equal; the gasifier or boiler design utilized in the process impacts IGCC performance (table 7.2). While averaging an increase of 30 percent, the increase in the COE with CO₂ capture ranges from a low of 24 percent with GE Energy's design (5.69 ¢/kWh without capture up to 7.05 ¢/kWh with capture) to a high of 38 percent with Shell's design (5.61 ¢/kWh without capture up to 7.72 ¢/kWh with capture).

Table 7.2: IGCC performance comparison¹

Gasifier/Boiler Design	Capital Cost	Efficiency	Cost of Electricity ³
	(TCR ² \$/kW) ⁵	(HHV ⁴ , Percent)	(Cents/kWh) ⁵
GE Energy	1,730	38.6	5.69
GE Energy with CO ₂ Capture	2,166	32.6	7.05
Conoco Phillips E-Gas	1,576	38.5	5.15
Conoco Phillips E-Gas with CO ₂ Capture	2,068	31.3	6.63
Shell	1,770	40.3	5.61
Shell with CO ₂ Capture	2,500	30.6	7.72

¹ Source: Klara, 2006² TCR, Total Capital Requirement (includes equipment, materials, labor, indirect construction costs, engineering, contingencies, cost of money, real estate, royalty allowance, preproduction costs, and initial inventories); 2006 dollars³ Assumes January 2006 dollars; 13.8 percent levelization factor; coal cost \$1.34/10⁶ Btu, capacity factor 80 percent⁴ HHV, Higher Heating Value⁵ \$/kW, Dollars per kilowatt; Cents/kWh, Cents per kilowatt-hour

EPRI recently compiled a range in estimated CO₂ capture costs published between 2000 and 2004 in studies conducted by the Department of Energy's National Energy Technology Laboratory (U.S. DOE), the International Energy Agency (IEA), and EPRI (Neville Holt, EPRI, written communication, 2007). Although the costs summarized in table 7.3 reflect current technology, there is no consistent basis for calculating the COE. Assumptions that lead to lower COE and particularly a lower capital cost component of the COE lead to lower avoided costs for CO₂ capture. EPRI cautions the following when reviewing the data in table 7.3:

- A lower capital charge rate; e.g., U.S. DOE and EPRI use 15 percent, whereas IEA uses 11 to 12 percent
- A higher assumed capacity factor; e.g., U.S. DOE and EPRI use 80 percent and IEA uses 85-90 percent
- A larger capacity plant with economies of scale; e.g., IEA assumes 800 MW versus the U.S. DOE/EPRI 500 MW plant
- A lower fuel cost; e.g., IEA uses natural gas at \$2 per gigajoule

For the data summarized in table 7.3, a newly constructed IGCC plant yields the lowest average cost of \$25 per metric tonne (mt) for avoided CO₂ whereas the highest average cost of \$59/mt results from retrofitting an existing PC power plant. (Avoided CO₂ is sequestered CO₂ less CO₂ emitted during capture.)

Table 7.3: Range of estimated CO₂ capture costs with current technology from U.S. DOE, IEA, and EPRI 2000-2004 studies¹

	New NGCC ²	New PC ²	Existing PC ²	New IGCC ²	
	with Post-Combustion Capture			with Shift and Pre-Combustion Capture	
				GE Q ³	Shell ³
Avoided CO ₂ , US\$/mt ⁴	37 – 74	29 – 55	45 - 73	13 - 25	24 - 37
% COE increase with capture ⁵	37 - 69	42 – 84	150 - 290	20 - 40	31 - 55
% more input/MWh with capture ⁶	11 - 22	24 – 40	43 - 77	16 - 25	18 - 25

¹ Source: Neville Holt, EPRI, written communication, 2007

² NGCC, Natural Gas Combined Cycle; PC, Pulverized Coal; IGCC, Integrated Gasification Combined Cycle; New, New plant construction with capture option; Existing, Retrofit existing plant with capture option

³ GE Q, GE Energy with Quench Gasifier; Shell, Shell Gasifier

⁴ mt, metric tonnes

⁵ COE, Cost of Electricity

⁶ MWh, Megawatt-hour

7.4 TRANSPORTATION AND STORAGE

The COE used for calculating avoided CO₂ should also include the estimated cost of transportation, storage/sequestration and monitoring. EPRI recommends using a nominal \$10/mt for these additional costs, which yields an average cost of \$55/mt for avoided CO₂ across all technologies represented in table 7.3. The high degree of variability in these costs (\$23 to \$84/mt avoided CO₂) dramatically highlights the need for site-specific analysis in the selection of an appropriate technology for fully integrated carbon capture and storage projects.

As part of a DOE-funded program, Smith and others (2001) provided an engineering and economic assessment of CO₂ injection for various scenarios.

Calculations include costs for capture, compression, pipeline transmission, and injection (including capital and present worth of operating costs for 25 years at 4.1 percent interest). For a CO₂ injection well 2,000 meters deep (6,562 feet) and a 15-kilometer pipeline originating from a PC plant with flue gas desulfurization, the calculated cost ranges from \$63.26 to \$63.56 per metric tonne of CO₂ avoided (table 7.4).

Table 7.4: Cost comparisons for various CO₂ transmission/sequestration scenarios¹

Well Depth (m/ft)	Cost of CO ₂ Avoided for Various Scenarios (\$/metric tonne)				
	15 km (9.3 mi) and Normal Terrain	100 km (62.1 mi) and Normal Terrain	400 km (249 mi) and Normal Terrain	15 km (9.3 mi) and Rocky/Hilly Terrain	15 km (9.3 mi) and Urban Terrain
<i>Pulverized Coal with Flue Gas Desulphurization Power Plants²</i>					
1,000/3,281	62.48	NA	NA	NA	NA
2,000/6,562	63.26	66.05	76.49	63.56	63.45
3,000/9,843	65.40	NA	NA	NA	NA
<i>Integrated Coal Gasification Combined Cycle Power Plants³</i>					
2,000/6,562	39.77	NA	NA	NA	NA

¹ Source: Smith and others, 2001

² Sequestration cases estimated for a 500 MW (megawatts of electrical output) plant burning pulverized coal with flue gas desulfurization and CO₂ capture by amine absorption.

³ Sequestration cases estimated for a 500 MW IGCC plant and CO₂ capture by physical absorption.

NA = cost estimate not prepared for this case

Abbreviations: m =meter, ft=feet, km= kilometer, mi=mile, NA=not available

The cost only increases about four percent for a pipeline of 100 kilometers (\$66.05/tonne CO₂ avoided), but a more significant increase of about 21 percent occurs with a pipeline of 400 kilometers (\$76.49 per tonne CO₂ avoided). For the same conditions with an IGCC power plant, the cost is much less at \$39.77 per tonne CO₂ avoided, assuming flat terrain. A cost of \$30 per tonne of CO₂ may be achievable in the long term (Lackner, 2003).

7.5 CARBON TAX

Another cost component to be considered is the effect of potential carbon taxes on fuel and technology selection. The U.S. currently generates about 320 gigawatts (GW) of coal-fired power; more than half of the installed capacity (184 GW) is generated from existing +300 MW boilers that are less than 35 years old. The paid off capital on most U.S. coal-fired power plants is a great economic and strategic advantage for the nation. According to a recent study by the National Energy Technology Laboratory (Klara, 2006), a carbon tax of approximately \$200/mt would be required to bring the COE generated from an existing PC plant to that of a new IGCC plant with carbon capture. (\$200 per metric tonne of carbon is approximately equivalent to \$50 per short ton of CO₂.) Even with an additional capital investment of \$500/kW to retrofit existing PC technology for capture, a carbon tax of \$180/mt would be required to bring its COE to that of a new PC plant with carbon capture. Based on natural gas at \$6/MBtu, a new NGCC plant with an 80 percent capacity factor and CO₂ venting has a lower COE than a new IGCC plant with carbon capture until the carbon tax exceeds \$200/mt. The large increase in capital costs during 2006 means that all of these carbon tax estimates must increase to maintain the competitiveness of IGCC technology.

Although no national carbon tax yet exists, the Energy Information Administration (2007) recently proposed a national allowance cap-and-trade system to regulate greenhouse gas emissions (GHG). Under this proposal, suppliers of fossil fuel and other covered sources of GHGs would be required to submit government-issued allowances based on the emissions of their respective products. Energy-related carbon dioxide is among the gases covered in this proposal. As the excerpt below indicates, if the proposed emissions fee (i.e., carbon tax) becomes policy, it will be considerably less punitive than the cost of fully integrated carbon capture and storage projects.

“The program would establish annual caps based on targeted reductions in greenhouse gas intensity, defined as emissions per dollar of Gross Domestic Product (GDP). The targeted reduction in GHG intensity would be 2.6 percent annually between 2012 and 2021, then increase to 3.0 percent per year beginning in 2022. To limit its potential cost, the program includes a “safety-valve” provision that allows regulated entities to pay a pre-established emissions fee in lieu of submitting an allowance. The safety-valve price is initially set at \$7 (in nominal dollars) per metric tonne of carbon dioxide equivalent in 2012 and increases each year by 5 percent over the projected rate of inflation, as measured by the projected increase in the implicit GDP price deflator. In 2004 dollars, the safety-valve rises from \$5.89 in 2012 to \$14.18 in 2030.”

Carbon taxes will be born by the American consumer, being paid via utility bills. The tax revenues will in turn be utilized by power generating companies to invest in the capital improvements necessary to further reduce greenhouse gases.

7.6 FUTURE CONSIDERATIONS

All power generation options will be needed in a carbon-constrained world including coal, natural gas, nuclear, and renewables. However, increasingly more restrictive carbon constraints will shift power generation portfolios away from coal assets toward the often more costly renewable and nuclear options in the absence of technological advances in carbon capture and storage (CCS). To keep coal in the energy mix and competitive, advanced IGCC technology is required in combination with multiple, fully integrated CCS demonstrations on the scale of one million metric tonnes CO₂ sequestered per year.

Carbon capture and storage is costly for both IGCC and PC plants. CCS costs add approximately 40 to 50 percent to the COE for IGCC and 70 to 90 percent for PC with bituminous coals. IGCC technology equipped with CO₂

capture allows coal to play a key role as a lower cost option that reduces both electricity prices and carbon intensity.

Advanced technologies for IGCC may provide significant benefits for U.S. consumers and the economy:

- Environment and the Economy – Provides competitive coal options to adjust to growing domestic energy demand and new environmental challenges
- Consumer Cost Savings – Provides clean energy from fossil fuel at an affordable price
- Energy Independence – Provides diversity to fuel mix, flexibility in end-product options, and a pathway to a hydrogen economy

8.0 SUMMARY AND CONCLUSIONS

8.1 SOURCES

- **CO₂ Emissions** In 2000, CO₂ emissions were more than 92 MT in Colorado. These emissions are projected to increase by 2.4 percent per year reaching 168 MT in 2025.
- **Power Generation** The CO₂ sources most suitable to separation and capture technology will be those that are stationary and have the capability to produce large concentrated amounts of CO₂. Nearly 75 percent of the CO₂ emissions in Colorado result from the utility and transportation sectors. Power generation in the state relies primarily on coal and as a result, 36 MT of CO₂ or 42 percent of the total emissions in Colorado are emitted from power plants in the utility sector. These stationary point “sources” afford the possibility of capture and separation of CO₂ for transport and storage to nearby “sinks”.

8.2 SINKS

- **Geologic Environments** Geologic storage options for CO₂ in Colorado include deep saline aquifers, depleted and marginal oil fields, natural gas and CO₂ fields, deep unmineable coal beds, and advanced mineralization engineering. Although all of these options are widely distributed across the state, efforts summarized in this report focused on seven primary Pilot Study Regions. These regions were defined based on maximum diversity in potential sequestration options within 30 to 40 miles of one or more power plants. Subsurface options were further screened for depths sufficient to maintain injected CO₂ as a supercritical fluid.
- **Saline Aquifers** CO₂ sequestration capacity for deep saline aquifers in the seven pilot study regions is estimated to range from 167 GT to more

than 668 GT based on a one to four percent efficiency factor in the storage process, respectively. This represents a three- to 12-fold increase over the combined storage estimates for oil, gas, coal, and mineralization options. Further, deep saline aquifers may provide several centuries' worth of carbon storage potential if the process is only one percent efficient. The storage potential is widely distributed throughout all of the pilot study regions with eastern Colorado (Denver, Fort Morgan, and Cañon City) providing 44 percent, northwestern Colorado (Palisade, Rangely, and Craig) providing 42 percent, and southwestern Colorado (Ignacio) providing the remaining 14 percent.

- **Oil and Gas Reservoirs** CO₂ sequestration capacity for oil and gas reservoirs in the seven pilot study regions is estimated at 1,886 MT with about 70 percent of that capacity potential associated with the Denver and Rangely regions. Capacity estimates were made only for those reservoirs that have cumulatively produced more than 1 MMBbls of oil or 10 Bcf of gas through 2004.
- **Enhanced Oil Recovery** Recent work suggests that 510 to 580 MMBbls of oil may be economically recovered from potential future CO₂-EOR projects in 12 of Colorado's major oil reservoirs. These EOR projects would not only provide suitable longer-term sequestration opportunities but would also result in increased production to offset costs.
- **Natural CO₂ Deposits** Colorado's production of natural CO₂ has averaged 300 Bcf per year since the mid-1980s primarily for use in Permian Basin CO₂-EOR projects. Representing an annual equivalent of 17.5 MT, economic sources of anthropogenic CO₂ would have considerable commodity value and would have the potential to offset depletion of existing natural deposits.
- **Underground Gas Storage** Current underground gas storage facilities in Colorado have nearly 48 Bcf committed in base gas, which represents 17 to 163 percent of the working gas volume and a significant portion of total project investment. Some of these facilities may be suitable to base gas

reductions via CO₂ replacement. Up to 4.4 MT of CO₂ would be required to offset the current base gas levels in Colorado.

- **Coalbed Reservoirs** CO₂ sequestration capacity for coalbed reservoirs in the seven pilot study regions is estimated to exceed 18.5 GT with about 75 percent of that potential associated with the Fruitland coals in the Ignacio region and the Williams Fork coals in the Craig region.
- **Enhanced Coalbed Methane Recovery** If a recovery factor of 1.7 Tcf produced CH₄ per GT sequestered CO₂ is broadly applicable, up to 31.7 Tcf in ECBM recovery may be possible. However, there are technical impediments such as the changes undergone by coal in a CO₂-rich environment (matrix swelling, injectivity loss) that must be addressed before commercial-scale projects become viable.
- **Mineralization** Mineral carbonation, though currently more costly than many other technologies (\$78/ton of CO₂ avoided), is the only method that actually sequesters CO₂ as a geologically stable mineral carbonate rather than as a potentially mobile gas or supercritical fluid. Assuming that technology could be developed to render silicate mineralization a viable solution to the CO₂ problem, Colorado would have adequate resources to implement mineral carbonation in several regions. The Craig region, in the northwestern part of the state, is most promising for silicate mineralization, and could sequester as much as 29.4 GT of CO₂ with current technology. Produced water mineralization does not appear to be a viable sequestration method for Colorado at this time. Preliminary calculations indicate that the volume of water necessary to sequester CO₂ emissions in a given region would far exceed current production levels.

8.3 COSTS

- **Flue Gas versus Pure CO₂** All of the sequestration capacity calculations provided in this report assume an anthropogenically-sourced CO₂ that has been “purified” for enhanced recovery use and/or longer-term storage.

However, the combustion of fossil fuel produces a contaminated flue gas that is approximately 80 percent N₂ and only 20 percent CO₂ by volume. There is an investment required to capture, separate, transport, and sequester the CO₂.

- **IGCC versus PC** Carbon capture and storage is costly for both IGCC and PC power generation technology. CCS costs add approximately 40 to 50 percent to the COE for IGCC and 70 to 90 percent for PC with bituminous coals. The average cost of CCS is approximately \$55/mt for avoided CO₂ for both technologies. However, the high degree of variability in these costs (\$23 to \$84/mt avoided CO₂) dramatically highlights the need for site-specific analysis in the selection of an appropriate technology for fully integrated carbon capture and storage projects.
- **Carbon Tax** It is estimated that a carbon tax of approximately \$200/mt would be required to bring the COE generated from an existing PC plant to that of a new IGCC plant with carbon capture. Although no national carbon tax yet exists, a national allowance cap-and-trade system to regulate GHG emissions has recently been proposed. If this proposal becomes policy, the emissions fee of \$7 per metric tonne of CO₂ equivalent in 2012 will be considerably less punitive than the investment required for fully integrated carbon capture and storage projects.

8.4 LOOKING FORWARD

All power generation options will be needed in a carbon-constrained world including coal, natural gas, nuclear, and renewables. However, increasingly more restrictive carbon constraints will shift power generation portfolios away from coal assets toward the often more costly renewable and nuclear options in the absence of technological advances in carbon capture and storage. To keep coal in the energy mix and competitive, advanced IGCC technology is required in combination with multiple, fully integrated CCS demonstrations on the scale of one million metric tonnes CO₂ sequestered per year.

Synergistic opportunities may exist for carbon sequestration demonstrations via enhanced recovery and underground gas storage projects, particularly where economic sources of anthropogenic CO₂ are available. Such projects may serve as the required catalyst to promote longer-term carbon storage programs due in part to their potential for offsetting costs with revenue-generating capability. Although saline aquifers do not provide the same economic recovery incentives, they do represent the largest potential in terms of long-term storage options; conceivably centuries' worth of CO₂ emissions.

Further site-specific investigations are required to determine both the technical and economic feasibility of implementing any one of these options. In these analyses, it will be as important to consider the short-term costs as the long-term benefits.

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Appendix 1

Colorado Power Plant Data 1995 Through 2003

(This project relied on year 2000 CO₂ emissions data.)

Facility Name	Operator	County	Facility Type	Fuel Type*
Alamosa	Public Service Co of Colorado	Alamosa	utility	NG
American Atlas 1 Cogeneration Plant	American Atlas #1 Ltd	Garfield	utility	NG
American Gypsum Cogeneration	Centex Eagle Gypsum Co LLC	Eagle	utility	DFO
Arapahoe	Public Service Co of Colorado	Denver	utility	COL
Arapahoe Combustion Turbine Project	Black Hills Capital	Denver	utility	NG
Brush Cogen Project Phase 2 BCP	Colorado Cogeneration Operat	Morgan	utility	NG
Brush IV	Brush Power LLC	Morgan	utility	NG
Brush Power Project Phase 1 CPP	Brush Power LLC	Morgan	utility	NG
Burlington	Tri-State G & T Assn Inc	Kit Carson	utility	OIL
Cameo	Public Service Co of Colorado	Mesa	utility	COL
Cherokee	Public Service Co of Colorado	Denver	utility	COL
Comanche	Public Service Co of Colorado	Pueblo	utility	COL
Craig	Tri-State G & T Assn Inc	Moffat	utility	COL
Delta	City of Delta	Delta	utility	NG
Dragon Trail Gas Processing Plant	EnCana Oil & Gas (USA) In	Rio Blanco	non-utility	NG
Fort Lupton	Public Service Co of Colorado	Adams	utility	NG
Fort St Vrain	Public Service Co of Colorado	Weld	utility	NG
Fruita	Public Service Co of Colorado	Mesa	utility	NG
George Birdsall	City of Colorado Springs	El Paso	utility	NG
Hayden	Public Service Co of Colorado	Routt	utility	COL
Ignacio Gasoline Plant	Ida West Operating Services	La Plata	non-utility	NG
Johnstown Cogeneration	Colorado Interstate Gas Co	Weld	non-utility	NG
La Junta	City of La Junta	Otero	utility	OIL
Lamar Plt	City of Lamar	Prowers	utility	NG
Las Animas	City of Las Animas	Bent	utility	OIL
Manchief Electric Generating Station	TransCanada PipeLines Ltd	Morgan	non-utility	NG
Martin Drake	City of Colorado Springs	El Paso	utility	COL
Nucla	Tri-State G & T Assn Inc	Montrose	utility	COL
Pawnee	Public Service Co of Colorado	Morgan	utility	COL
Pueblo	Aquila Networks-Colorado	Pueblo	utility	NG
Rawhide	Platte River Power Authority	Larimer	utility	COL
Ray D Nixon	City of Colorado Springs	El Paso	utility	COL
Rocky Ford	Aquila Networks-Colorado	Otero	utility	OIL
South Bear Creek	Trigen	Baca	non-utility	NG
TCP 122	Thermo Cogeneration Partner	Weld	non-utility	NG
TCP 150	Thermo Cogeneration Partner	Weld	non-utility	NG
Thermo Greeley Inc	Thermo Cogeneration Partner	Weld	non-utility	NG
Thermo Power Electric Inc	Thermo Power & Electric Inc	Weld	non-utility	NG
Trigen Colorado Energy Corp	Trigen	Jefferson	non-utility	COL
Trinidad	City of Trinidad	Las Animas	utility	OIL
University of Colorado	University of Colorado	Boulder	non-utility	NG
Valmont	Public Service Co of Colorado	Boulder	utility	COL
Valmont Combustion Turbine Project	Black Hills Capital	Boulder	non-utility	NG
W N Clark	Aquila Networks-Colorado	Fremont	utility	COL
Zuni	Public Service Co of Colorado	Denver	utility	NG

*Fuel Type: Natural Gas (NG); Distillate Fuel Oil (DFO); Coal (COL); Oil (OIL)

Sources:

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Facility Name	1995		1996			1997		
	Fuel Consumption (MMBtu)*	CO ₂ Emissions (tons)***	Fuel Consumption (MMBtu)*	Net Generation (MWh)**	CO ₂ Emissions (tons)***	Fuel Consumption (MMBtu)*	Net Generation (MWh)**	CO ₂ Emissions (tons)***
Alamosa			52,291	2,331	3,372	36,750	1,703	2,292
American Atlas 1 Cogeneration Plant								
American Gypsum Cogeneration								
Arapahoe	12,861,312	1,319,402	17,573,476	1,270,549	1,803,168	18,298,437	1,268,016	1,875,259
Arapahoe Combustion Turbine Project								
Brush Cogen Project Phase 2 BCP								
Brush IV								
Brush Power Project Phase 1 CPP								
Burlington			34,266	2,812	2,925	63,666	5,175	5,292
Cameo	4,014,102	411,762	7,011,036	464,774	774,386	6,242,247	468,336	640,227
Cherokee	37,926,238	3,913,836	46,828,546	4,571,834	4,816,897	51,091,399	4,635,456	5,236,332
Comanche	46,175,001	4,733,286	49,343,506	4,319,080	5,040,763	51,469,776	4,424,635	5,277,724
Craig	83,662,277	8,583,339	81,525,021	8,637,791	8,345,927	103,308,668	8,757,887	10,594,910
Delta			14,339	1,043	875	7,656	592	466
Dragon Trail Gas Processing Plant								
Fort Lupton			142,111	9,811	8,419	220,696	14,104	13,076
Fort St Vrain			2,170,704	78,988	128,822	3,192,550	130,258	189,512
Fruita			15,112	367	927	29,861	1,427	1,800
George Birdsall			71,204	2,967	4,473	55,876	3,148	3,235
Hayden	44,481,214	4,563,036	39,052,668	3,168,009	4,006,359	41,008,552	2,727,872	4,207,095
Ignacio Gasoline Plant								
Johnstown Cogeneration								
La Junta						1,415	-1,540	101
Lamar Plt			1,159,875	81,490	65,076	1,128,274	75,824	65,327
Las Animas						840	-237	70
Manchief Electric Generating Station								
Martin Drake	16,610,607	1,714,292	15,362,384	1,276,910	1,575,994	17,876,232	1,456,381	1,834,005
Nucla	4,964,406	508,906	8,400,765	653,630	856,499	9,463,148	704,248	970,915
Pawnee	43,722,191	3,599,281	30,654,570	2,931,983	3,140,855	36,882,139	3,112,183	3,780,852
Pueblo			802,508	47,889	56,643	171,749	10,669	10,096
Rawhide	21,288,073	2,184,156	23,931,922	1,983,681	2,455,415	22,245,623	1,812,626	2,282,401
Ray D Nixon	15,595,452	1,599,359	15,295,314	1,483,999	1,611,538	15,860,186	1,479,998	1,627,249
Rocky Ford			23,286	1,735	1,987	19,135	1,259	1,591
South Bear Creek								
TCP 122								
TCP 150								
Thermo Greeley Inc								
Thermo Power Electric Inc								
Trigen Colorado Energy Corp								
Trinidad			122,662	6,275	16,928	102,442	11,818	14,125
University of Colorado								
Valmont	12,713,682	1,304,170	13,782,405	1,148,241	1,407,740	13,525,128	1,077,141	1,383,465
Valmont Combustion Turbine Project								
W N Clark			2,825,280	226,792	395,016	3,078,081	240,849	317,026
Zuni		53,409	716,986	13,820	42,625	892,679	20,417	53,409

*Million British Thermal Units; **Megawatt Hours; ***Short Tons

Facility Name	1998			1999			2000		
	Fuel Consumption (MMBtu)*	Net Generation (MWh)**	CO ₂ Emissions (tons)***	Fuel Consumption (MMBtu)*	Net Generation (MWh)**	CO ₂ Emissions (tons)***	Fuel Consumption (MMBtu)*	Net Generation (MWh)**	CO ₂ Emissions (tons)***
Alamosa	133,303	133,303	8,480	140,706	4,164	8,217	62,602	5,307	4,162
American Atlas 1 Cogeneration Plant	1,312,011	1,312,011	75,965	1,317,816	168,872	76,301	1,436,430	156,200	83,169
American Gypsum Cogeneration	703,133	703,133	50,012	198,821	22,568	14,029	216,666	25,309	15,841
Arapahoe	15,644,438	15,644,438	1,604,848	17,753,398	1,222,398	1,821,341	19,061,659	1,395,220	1,954,788
Arapahoe Combustion Turbine Project							324,790	47,651	19,302
Brush Cogen Project Phase 2 BCP	2,185,733	2,185,733	126,553	1,722,169	253,476	99,713	1,988,465	276,165	115,131
Brush IV				199,139	8,455	11,530	720,999	28,772	41,746
Brush Power Project Phase 1 CPP	1,727,795	1,727,795	100,038	504,177	59,315	29,192	896,835	105,510	51,926
Burlington	260,101	260,101	20,763	207,484	16,969	16,563	726,457	60,231	57,991
Cameo	6,720,276	6,720,276	690,204	6,159,357	470,478	631,134	6,809,388	552,783	698,859
Cherokee	52,621,096	52,621,096	5,394,279	49,839,542	4,683,924	5,059,395	53,153,707	4,747,647	5,424,678
Comanche	48,293,445	48,293,445	4,952,655	48,698,865	4,563,839	4,991,905	47,750,916	4,223,847	4,892,206
Craig	98,400,808	98,400,808	10,094,903	93,670,345	8,643,861	9,537,560	102,345,002	9,844,040	10,466,665
Delta	3,376	3,376	201	5,967	424	364	8,167	610	487
Dragon Trail Gas Processing Plant	45,780	45,780	2,651	52,154	4,485	3,020			
Fort Lupton	487,179	487,179	28,617	240,725	15,210	14,078	937,139	56,283	54,534
Fort St Vrain	3,320,968	3,320,968	62,618	13,736,680	1,619,175	816,550	22,981,629	2,733,681	1,365,757
Fruita	61,931	61,931	3,779	44,646	1,932	2,606	68,297	2,315	4,111
George Birdsall	461,814	461,814	26,739	335,704	20,717	19,519	1,589,852	111,505	93,495
Hayden	37,904,837	37,904,837	3,892,536	37,789,598	2,965,760	3,877,204	38,315,608	3,170,860	3,926,480
Ignacio Gasoline Plant	373,879	373,879	21,647	369,355	42,568	21,386	411,684	46,836	23,836
Johnstown Cogeneration	142,422	24,035	8,246	232,424	24,349	13,457	20,579	2,145	1,192
La Junta							4,031	-389	322
Lamar Pit	674,739	674,739	39,067	671,483	78,998	38,879	552,390	64,987	32,145
Las Animas	844	844	67				2,404	-105	192
Manchief Electric Generating Station							30,968	511,660	1,851
Martin Drake	18,364,433	18,364,433	1,884,028	18,109,151	1,484,262	1,857,794	21,414,712	1,870,734	2,183,126
Nucla	8,062,481	8,062,481	827,455	8,678,484	644,906	890,005	8,116,536	657,042	831,311
Pawnee	36,599,944	36,599,944	3,746,993	45,855,909	3,982,368	4,695,495	45,856,525	3,655,268	4,691,603
Pueblo	147,869	147,869	8,859	248,753	14,311	14,754	676,623	45,761	42,105
Rawhide	21,733,381	21,733,381	2,229,845	25,800,967	2,119,443	2,647,172	23,693,012	1,964,843	2,430,904
Ray D Nixon	16,798,672	16,798,672	1,723,551	11,987,856	1,140,133	1,221,127	17,873,391	1,742,251	1,793,609
Rocky Ford	9,820	9,820	784	12,771	824	1,019	76,573	6,813	6,113
South Bear Creek							34,713	1,276	2,010
TCP 122				4,935,788	631,686	285,780	5,020,238	672,258	290,669
TCP 150				6,061,844	779,048	350,978	6,295,877	836,756	364,528
Thermo Greeley Inc	145,305	145,305	8,413	1,211,920	182,536	70,170	1,293,310	190,419	74,882
Thermo Power Electric Inc	4,390,186	4,390,186	254,190	4,351,391	597,111	251,943	4,915,905	620,640	284,629
Trigen Colorado Energy Corp	2,968,516	2,968,516	304,964	2,410,353	276,095	246,894	2,729,523	291,689	276,180
Trinidad	17,933	17,933	1,846				5,920	498	471
University of Colorado	1,247,365	1,247,365	72,305	1,300,978	152,546	75,357	2,004,511	138,185	116,068
Valmont	15,843,165	15,843,165	1,610,195	7,657,547	749,078	775,591	13,605,707	1,465,787	1,363,596
Valmont Combustion Turbine Project							316,779	32,588	18,827
W N Clark	2,916,050	2,916,050	300,571	5,288,528	228,420	162,151	3,627,908	276,551	373,946
Zuni	456,579	456,579	27,408	187,817	15,980	11,233	1,123,495	78,769	66,831

*Million British Thermal Units; **Megawatt Hours; ***Short Tons

Facility Name	2001			2002			2003		
	Fuel Consumption (MMBtu)*	Net Generation (MWh)**	CO ₂ Emissions (tons)***	Fuel Consumption (MMBtu)*	Net Generation (MWh)**	CO ₂ Emissions (tons)***	Fuel Consumption (MMBtu)*	Net Generation (MWh)**	CO ₂ Emissions (tons)***
Alamosa									
American Atlas 1 Cogeneration Plant									
American Gypsum Cogeneration									
Arapahoe	17,735,668		1,814,511	21,320,716		2,186,585	14,267,284		1,463,818
Arapahoe Combustion Turbine Project	554,634		32,963	1,050,306		62,417	2,513,789		149,356
Brush Cogen Project Phase 2 BCP									
Brush IV	1,559,595		92,686	999,064		59,372	617,457		36,589
Brush Power Project Phase 1 CPP	989,397		58,799	815,340		48,454	73,134		4,346
Burlington									
Cameo	4,433,623		454,802	4,239,544		434,629	4,003,029		410,712
Cherokee	51,612,292		5,256,124	46,704,244		4,760,723	53,713,602		5,468,411
Comanche	50,711,977		5,193,993	55,542,284		5,693,376	58,553,101		6,002,038
Craig	104,490,454		10,695,496	103,949,552		10,665,230	103,928,628		10,662,644
Delta									
Dragon Trail Gas Processing Plant									
Fort Lupton									
Fort St Vrain	32,077,430		1,906,388	38,837,254		2,308,040	30,145,618		1,791,509
Fruita									
George Birdsall									
Hayden	41,282,448		4,235,576	43,214,614		4,433,177	38,444,372		3,943,756
Ignacio Gasoline Plant									
Johnstown Cogeneration									
La Junta									
Lamar Pit									
Las Animas									
Manchief Electric Generating Station	10,337,732		615,304	8,863,253		527,435	5,014,277		298,424
Martin Drake	22,472,532		2,262,644	21,534,007		2,193,004	22,674,075		2,321,713
Nucla	8,487,590		869,057	9,001,127		922,997	8,224,788		842,991
Pawnee	51,115,319		5,240,962	38,786,012		3,968,366	45,594,820		4,673,512
Pueblo									
Rawhide	26,060,472		2,673,805	24,622,206		2,511,670	27,320,920		2,761,266
Ray D Nixon	18,642,388		1,844,762	18,513,968		1,891,496	18,373,520		1,881,900
Rocky Ford									
South Bear Creek									
TCP 122									
TCP 150									
Thermo Greeley Inc									
Thermo Power Electric Inc									
Trigen Colorado Energy Corp									
Trinidad									
University of Colorado									
Valmont	13,887,790		1,424,890	13,293,779		1,362,314	15,257,755		1,565,445
Valmont Combustion Turbine Project	534,254		31,747	600,002		35,656	255,868		15,198
W N Clark									
Zuni	1,629,191		96,953	859,668		51,087	601,898		35,766

*Million British Thermal Units; **Megawatt Hours; ***Short Tons

Appendix 2

Colorado Power Plant Generator Data

Facility Name	Prime Mover Type*	Primary Fuel*	Generator Status*
Alamosa	GT	DFO	OP
Alamosa	GT	DFO	OP
American Atlas 1 Cogeneration Plant	CA	WH	OP
American Atlas 1 Cogeneration Plant	CT	NG	OP
American Atlas 1 Cogeneration Plant	CT	NG	OP
American Atlas 1 Cogeneration Plant	CT	NG	OP
American Gypsum Cogeneration	IC	DFO	CS
American Gypsum Cogeneration	IC	DFO	CS
American Gypsum Cogeneration	GT	NG	OP
American Gypsum Cogeneration	GT	NG	OP
Arapahoe	ST	BIT	OP
Arapahoe	ST	BIT	OP
Arapahoe	ST	BIT	OP
Arapahoe	ST	BIT	OP
Arapahoe Combustion Turbine Project	GT	NG	CS
Arapahoe Combustion Turbine Project	GT	NG	CS
Brush Cogen Project Phase 2 BCP	CT	NG	OP
Brush Cogen Project Phase 2 BCP	CA	WH	OP
Brush IV	GT	NG	SB
Brush IV	GT	NG	SB
Brush Power Project Phase 1 CPP	CT	NG	OP
Brush Power Project Phase 1 CPP	CT	NG	OP
Brush Power Project Phase 1 CPP	CA	WH	OP
Burlington	GT	DFO	SB
Burlington	GT	DFO	SB
Cameo	ST	BIT	OP
Cameo	ST	BIT	OP
Cherokee	ST	BIT	OP
Cherokee	ST	BIT	OP
Cherokee	ST	BIT	OP
Cherokee	ST	BIT	OP
Cherokee	IC	DFO	SB
Cherokee	IC	DFO	SB
Comanche	ST	BIT	OP
Comanche	ST	BIT	OP
Craig	ST	BIT	OP
Craig	ST	BIT	OP
Craig	ST	BIT	OP
Delta	IC	NG	OP
Delta	IC	NG	OP
Delta	IC	DFO	OP
Delta	IC	DFO	OP
Delta	IC	DFO	OP
Delta	IC	NG	OP
Delta	IC	NG	OP
Dragon Trail Gas Processing Plant	IC	NG	CS
Dragon Trail Gas Processing Plant	IC	NG	OP
Fort Lupton	GT	NG	OP
Fort Lupton	GT	NG	OP
Fort St Vrain	CA	WH	OP
Fort St Vrain	CT	NG	OP
Fort St Vrain	CT	NG	OP
Fruita	GT	NG	OP
George Birdsall	ST	NG	OP
George Birdsall	ST	NG	OP
George Birdsall	ST	NG	OP
Hayden	ST	BIT	OP
Hayden	ST	BIT	OP
Ignacio Gasoline Plant	ST	NG	OP

Facility Name	Prime Mover Type*	Primary Fuel*	Generator Status*
Johnstown Cogeneration	GT	NG	CS
La Junta	IC	DFO	OS
La Junta	IC	DFO	SB
La Junta	IC	DFO	SB
La Junta	IC	NG	SB
La Junta	IC	NG	OS
La Junta	IC	NG	SB
La Junta	IC	NG	SB
La Junta	IC	NG	SB
La Junta	IC	NG	SB
Lamar Plt	ST	NG	OS
Lamar Plt	ST	NG	OS
Lamar Plt	ST	NG	OP
Lamar Plt	IC	DFO	OP
Lamar Plt	IC	DFO	OP
Las Animas	IC	DFO	OP
Las Animas	IC	DFO	OP
Las Animas	IC	NG	RE
Las Animas	IC	NG	OP
Las Animas	IC	NG	OP
Las Animas	IC	NG	OP
Manchief Electric Generating Station	GT	NG	SB
Manchief Electric Generating Station	GT	NG	SB
Martin Drake	ST	BIT	OP
Martin Drake	ST	BIT	OP
Martin Drake	ST	BIT	OP
Nucla	ST	BIT	OP
Nucla	ST	BIT	OP
Nucla	ST	BIT	OP
Nucla	ST	BIT	OP
Pawnee	ST	BIT	OP
Pueblo	ST	NG	OP
Pueblo	IC	DFO	OP
Pueblo	IC	DFO	OP
Pueblo	IC	DFO	OP
Pueblo	IC	DFO	OP
Pueblo	IC	DFO	OP
Pueblo	IC	DFO	OP
Rawhide	ST	SUB	OP
Ray D Nixon	ST	BIT	OP
Ray D Nixon	GT	NG	OP
Ray D Nixon	GT	NG	OP
Rocky Ford	IC	DFO	OP
Rocky Ford	IC	DFO	OP
Rocky Ford	IC	DFO	OP
Rocky Ford	IC	DFO	OP
Rocky Ford	IC	DFO	OP
South Bear Creek	GT	NG	CS
TCP 122	CA	WH	OP
TCP 122	CT	NG	OP
TCP 122	CT	NG	OP
TCP 150	CA	WH	OP
TCP 150	CT	NG	OP
TCP 150	CT	NG	OP
TCP 150	CA	WH	OP
Thermo Greeley Inc	GT	NG	OP
Thermo Power Electric Inc	CT	NG	OP
Thermo Power Electric Inc	CT	NG	OP
Thermo Power Electric Inc	CA	WH	OP

Facility Name	Prime Mover Type*	Primary Fuel*	Generator Status*
Trigen Colorado Energy Corp	ST	SUB	OP
Trigen Colorado Energy Corp	ST	SUB	OP
Trigen Colorado Energy Corp	ST	SUB	OP
Trigen Colorado Energy Corp	ST	SUB	OP
Trinidad	ST	BIT	OS
Trinidad	IC	NG	OP
Trinidad	IC	NG	OP
Trinidad	IC	DFO	OP
Trinidad	IC	DFO	OP
Trinidad	IC	DFO	OP
University of Colorado	CT	NG	OP
University of Colorado	CT	NG	OP
University of Colorado	CA	WH	OP
Valmont	ST	BIT	OP
Valmont	GT	NG	OP
Valmont Combustion Turbine Project	GT	NG	CS
W N Clark	ST	BIT	OP
W N Clark	ST	BIT	OP
Zuni	ST	NG	OP
Zuni	ST	NG	OP

*Definitions in Appendix 3

Source: *Emissions & Generation Resource Integrated Database (eGRID)* – Retrieved February 2004, from the U.S. Environmental Protection Agency Web site: <http://www.epa.gov/cleanenergy/egrid/index.html>

Appendix 3

Colorado Power Plant Definitions

Facility Type	Description
Utility	Power plant that has a “designated franchise service area for the sale of electricity” and is “subject to regulatory authority”
Nonutility	Power plant that does not have a “designated franchise service area for the sale of electricity” and is not “subject to any regulatory authority”. Nonutility status also applies to plants that are owned jointly by utility and nonutility companies, but are operated by the nonutility company.

Prime Mover	Description
CA	Combined cycle steam turbine with supplementary firing
CT	Combined cycle combustion turbine
GT	Combustion (gas) turbine
IC	Internal combustion (diesel)
ST	Steam turbine – boiler

Primary Fuel	Description
BIT	Bituminous coal
DFO	Distillate Fuel Oil
NG	Natural Gas
SUB	Subbituminous Coal
WH	Waste Heat

Generator Status	Description
CS	Cold storage
MR	Proposed for deactivation shutdown status
OP	Operating
OS	In commercial operation, but out of service
RE	Retired
SB	Cold stand-by (long-term storage)
SD	Sold to nonutility

Source: Technical Support Document Emissions & Generation Resource Integrated Database (eGRID) May 2003, Retrieved May 10, 2004 from the U.S. Environmental Protection Agency web site:
<http://www.epa.gov/cleanenergy/egrid/pdfs/egrid2002techsupport.pdf>

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Abarr					
Niobrara	0	1,298,761	0	0	0
Field Total	0	1,298,761	0	0	0
Abbott					
J Sand	57,522	0	0	0	1,529,734
Muddy (J)	502,105	93,927	0	0	0
Field Total	559,627	93,927	0	0	1,529,734
Abbott North					
J Sand	0	0	0	0	0
Muddy (J)	6,293	0	0	0	0
Field Total	6,293	0	0	0	0
Able					
Dakota, Muddy (J)	175,414	0	0	0	0
J Sand	25,230	0	0	0	509,313
Muddy (J)	193,509	0	0	0	0
Field Total	394,153	0	0	0	509,313
Abundance					
J Sand	0	0	0	0	0
Muddy (J)	196	0	0	0	0
Niobrara	7,658	100	0	0	0
Field Total	7,854	100	0	0	0
Acme					
D Sand	3,357	0	0	0	0
Field Total	3,357	0	0	0	0
Acrobat					
D Sand	1,062	10,545	0	0	0
Field Total	1,062	10,545	0	0	0
Adena					
D Sand	3,535,635	18,727,978	0	0	540,503
J Sand	260,581	136,465	0	0	14,954,422
Muddy (J)	59,081,925	70,843,089	0	0	0
Niobrara	0	0	0	0	0
Field Total	62,878,141	89,707,532	0	0	15,494,925
Adena South					
D Sand	2,912	33,491	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	585,078	661,737	0	0	0
Field Total	587,990	695,228	0	0	0
Adobe					
J Sand	0	0	0	0	0
Muddy (J)	22,799	21,228	0	0	0
Field Total	22,799	21,228	0	0	0
Agate					
D Sand	30,034	5,400	0	0	0
Field Total	30,034	5,400	0	0	0
Airport					
Mississippian	6,703	0	0	0	0
Mississippian, Osage	0	0	0	0	0
Field Total	6,703	0	0	0	0
Akron					
J Sand	0	0	0	0	0
Muddy (J)	0	133,156	0	0	0
Field Total	0	133,156	0	0	0
Akron East					
D Sand	3,322,263	1,864,310	0	0	268,803
Field Total	3,322,263	1,864,310	0	0	268,803

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Alamo					
Marmaton	5,977	7,366	0	0	0
Field Total	5,977	7,366	0	0	0
Alkali Gulch					
Barker Creek	0	9,593,503	0	0	0
Dakota	135	0	0	0	0
Desert Creek	0	139,241	0	0	0
Gallup Ss	351	0	0	0	0
Ismay, Desert Creek	1,847	526,385	0	0	68
Molas	0	7,448,551	0	0	0
Paradox	0	15,077,359	0	0	0
Field Total	2,333	32,785,039	0	0	68
Alkali Gulch West					
Ismay	850	775,749	0	0	15
Field Total	850	775,749	0	0	15
Alkali Lake					
Dakota	3,978	0	0	0	0
Niobrara	5,874	492	0	0	0
Field Total	9,852	492	0	0	0
Allen					
D Sand	426,734	212,026	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	2,883	960,562	0	0	0
Field Total	429,617	1,172,588	0	0	0
Alpha					
J Sand	0	0	0	0	0
Muddy (J)	0	68,691	0	0	0
Field Total	0	68,691	0	0	0
Amber					
D Sand	347,619	2,016,516	0	0	148,882
J Sand	0	0	0	0	0
Muddy (J)	44,822	56,484	0	0	0
Field Total	392,441	2,073,000	0	0	148,882
Amber South					
D Sand	8,222	329,180	0	0	0
Field Total	8,222	329,180	0	0	0
Ambush					
J Sand	37,967	653,132	0	0	101
J Sand	6,791	106,296	0	0	0
Muddy (J)	144,350	1,715,825	0	0	0
Field Total	189,108	2,475,253	0	0	101
American					
Mississippian	462,967	154	0	0	52,741
St Genevieve	18,493	0	0	0	0
Field Total	481,460	154	0	0	52,741
Anasazi					
Ismay	215	35,773	0	0	0
Field Total	215	35,773	0	0	0
Andy's Mesa					
Cutler	22,353	18,489,503	0	0	54,342
Cutler, Arkose	3,340	2,785,550	0	0	28,210
Cutler, Hermosa	22,990	22,980,860	0	0	57
Honaker Trail	29,643	24,587,411	0	0	42,441
Ismay	4,403	1,503,712	0	0	1,288
Navajo	0	0	0	0	0
Field Total	82,729	70,347,036	0	0	126,338

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Antelope					
Sussex	2,541	0	0	0	0
Field Total	2,541	0	0	0	0
Antelope Flats					
D Sand	3,078	0	0	0	0
Field Total	3,078	0	0	0	0
Antler					
D Sand	112,517	303,918	0	0	2
J Sand	9,251	44,566	0	0	0
Muddy (J)	39,641	180,253	0	0	0
Field Total	161,409	528,737	0	0	2
Anton					
J Sand	0	0	0	0	0
Muddy (J)	6,861	0	0	0	0
Field Total	6,861	0	0	0	0
Anvil					
D Sand	45,389	368,262	0	0	0
Field Total	45,389	368,262	0	0	0
Apache Canyon					
Dakota, Entrada, Niobrara	0	0	0	0	0
Dockum	0	1,389	0	0	6,566
Niobrara	0	85,675	0	0	11
Raton Coal	0	12,667	7,043,773	0	4,556,304
Raton Sand	0	167,129	0	0	119,551
Raton Sand, Vermejo Coal	0	35,934	0	0	14,074
Raton, Vermejo Coal	0	1,877	501,053	0	320,496
Vermejo Coal	0	65,612	25,783,445	0	12,225,851
Field Total	0	370,283	33,328,271	0	17,242,853
Apex					
J Sand	0	0	0	0	0
Muddy (J)	48,683	40	0	0	0
Field Total	48,683	40	0	0	0
Apollo					
J Sand	3,914	120	0	0	11,488
J Sand	5,443	0	0	0	34,065
Muddy (J)	43,736	2,830	0	0	0
Field Total	53,093	2,950	0	0	45,553
Appaloosa					
J Sand	97,778	0	0	0	1,911,098
Muddy (J)	309,502	0	0	0	0
Field Total	407,280	0	0	0	1,911,098
Arapahoe					
Morrow	22,739,934	41,952,693	0	0	6,036,285
Morrow B	13,107	119,212	0	0	1,553
Morrow V7	39,816	109,829	0	0	400,481
Field Total	22,792,857	42,181,734	0	0	6,438,319
Arapahoe East					
Morrow	1,336,099	485,925	0	0	38,971
Field Total	1,336,099	485,925	0	0	38,971
Arbor					
D Sand	115,834	58,597	0	0	7,370
Field Total	115,834	58,597	0	0	7,370

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Archer					
Marmaton	44,244	8,787	0	0	0
Marmaton, Fort Scott Ls	1,007	0	0	0	0
Mississippian	485,854	145	0	0	0
Mississippian, Osage	0	0	0	0	0
Mississippian, Osage, Warsaw	0	0	0	0	0
Mississippian, Spergen	0	0	0	0	0
Morrow	2,858	6,571,402	0	0	2,451
Osage	155,298	10,491	0	0	0
Shawnee	180,868	0	0	0	0
Topeka A	0	0	0	0	0
Topeka Ls	303,325	1,984	0	0	0
Topeka Ls, Fort Scott Ls	4,425	0	0	0	0
Topeka, Lansing, Ft Scott	0	0	0	0	0
Warsaw	5,907	0	0	0	0
Warsaw, Osage	30,907	0	0	0	0
Field Total	1,214,693	6,592,809	0	0	2,451
Arford					
J Sand	0	0	0	0	0
Muddy (J)	3,492	81,300	0	0	0
Field Total	3,492	81,300	0	0	0
Aristocrat					
Codell Ss	4,669	171,813	0	0	2,483
J Sand	3,043	198,207	0	0	2,490
Muddy (J), Niobrara, Codell Ss	16,348	564,451	0	0	0
Niobrara, Codell Ss	265,194	7,343,380	0	0	80,679
Niobrara, Codell Ss, Sussex	185,752	4,600,878	0	0	32
Sussex	431,705	11,796,713	0	0	32,512
Sussex, Shannon, Niobrara, Codell Ss	23,280	1,216,954	0	0	0
Field Total	929,991	25,892,396	0	0	118,196
Aristocrat Northeast					
Sussex	23,798	1,643,799	0	0	7,051
Field Total	23,798	1,643,799	0	0	7,051
Armadillo					
Marmaton	9,417	3,857	0	0	0
Field Total	9,417	3,857	0	0	0
Armel					
Niobrara	0	135,086	0	0	0
Field Total	0	135,086	0	0	0
Armstrong					
D Sand	39,956	5,571,026	0	0	0
Dakota	44,846	80,901	0	0	0
J Sand	0	0	0	0	0
J Sand, O Sand	0	0	0	0	0
Muddy (J)	181,912	985,661	0	0	0
Muddy (J), Dakota	3,170	1,280	0	0	0
O Sand	0	0	0	0	0
Field Total	269,884	6,638,868	0	0	0
Arriba					
Lansing	37,609	0	0	0	0
Marmaton	2,367	0	0	0	0
Field Total	39,976	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Arrow					
Dakota	0	731	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	1,104	231,226	0	0	0
Field Total	1,104	231,957	0	0	0
Arrowhead					
Morrow	437	1,045,508	0	0	226
Morrow	13,310	2,618,476	0	0	10,958
Field Total	13,747	3,663,984	0	0	11,184
Arroyo					
D Sand, Muddy (J)	467,042	1,005,351	0	0	0
J Sand	1,354	0	0	0	0
Muddy (J)	994,644	1,418,930	0	0	0
Field Total	1,463,040	2,424,281	0	0	0
Asbury Creek					
Buckhorn	0	0	0	0	0
Cedar Mountain	0	6,689	0	0	0
Dakota	0	2,406,841	0	0	0
Field Total	0	2,413,530	0	0	0
Ashley					
D Sand	57,268	63,400	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	61,920	587,698	0	0	0
Field Total	119,188	651,098	0	0	0
Astronaut					
Marmaton	58,407	1,757	0	0	0
Field Total	58,407	1,757	0	0	0
Atwood					
J Sand	1,615	1,555	0	0	0
Muddy (J)	536,341	199,753	0	0	0
Field Total	537,956	201,308	0	0	0
Atwood East					
D Sand	2,496,488	6,840,356	0	0	124,119
J Sand	0	0	0	0	0
Muddy (J)	47	159,773	0	0	0
Field Total	2,496,535	7,000,129	0	0	124,119
Ault					
Niobrara	5,983	0	0	0	0
Field Total	5,983	0	0	0	0
Aztec Wash					
Gallup Ss	53,564	4,139	0	0	0
Field Total	53,564	4,139	0	0	0
Aztecan					
Morrow	1,935	1,180,947	0	0	19,864
Field Total	1,935	1,180,947	0	0	19,864
Azure					
D Sand	675,118	88,643	0	0	120,748
Field Total	675,118	88,643	0	0	120,748
Azure East					
D Sand	50,413	2,111	0	0	0
Field Total	50,413	2,111	0	0	0
Baby Doe					
D Sand	1,169	66,294	0	0	0
Unkown					
Field Total	1,169	66,294	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Bacon Lake					
Niobrara	1,552	0	0	0	0
Field Total	1,552	0	0	0	0
Badger Creek					
D Sand	4,937,107	1,976,963	0	0	67,431
J Sand	29,608	0	0	0	415,886
Muddy (J)	1,522,478	593,693	0	0	0
Field Total	6,489,193	2,570,656	0	0	483,317
Badger Creek West					
J Sand	0	0	0	0	0
Muddy (J)	550,390	260,676	0	0	0
Field Total	550,390	260,676	0	0	0
Baker					
J Sand	0	0	0	0	0
Muddy (J)	10,718	0	0	0	0
Field Total	10,718	0	0	0	0
Baldy Creek					
Corcoran	0	0	0	0	0
Corcoran, Cozzette, Rollins	0	0	0	0	0
Corcoran, Mancos	0	0	0	0	0
Cozzette	0	0	0	0	0
Cozzette, Corcoran	0	0	0	0	0
Mesaverde	0	438,742	0	0	0
Mesaverde, Mancos Sh	0	5,922	0	0	0
Rollins	0	0	0	0	0
Rollins, Cozzette, Corcoran	0	0	0	0	0
Field Total	0	444,664	0	0	0
Bandana					
Niobrara, Codell Ss	1,835	0	0	0	0
Field Total	1,835	0	0	0	0
Banner					
Dakota	145	4,315	0	0	5
J Sand	70,572	1,005,409	0	0	7,510
Muddy (J)	88,915	942,140	0	0	0
Field Total	159,632	1,951,864	0	0	7,515
Banner Lakes					
D Sand	229,832	2,707,872	0	0	8,933
D Sand	651,543	6,631,869	0	0	6,180
D Sand, Muddy (J)	48,035	765,387	0	0	32
J Sand	4,234	78,401	0	0	0
J Sand	7,687	344,759	0	0	3,990
Muddy (J)	29,935	221,912	0	0	0
Muddy (J)	41,231	1,040,990	0	0	0
Field Total	1,012,497	11,791,190	0	0	19,135
Banta Ridge					
Castlegate	0	3,841	0	0	881
Dakota	5,234	215,244	0	0	140
Mancos B	29,282	2,909,461	0	0	6,307
Mancos Sh	101	778,775	0	0	829
Mesaverde	0	1,982,304	0	0	0
Field Total	34,617	5,889,625	0	0	8,157

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Bar X					
Dakota	0	265,100	0	0	0
Dakota	50,161	1,168,858	0	0	134
Dakota, Morrison	21,094	4,010,715	0	0	0
Entrada Ss	598	8,668,111	0	0	0
Morrison	0	113,613	0	0	0
Morrison	3,544	1,504,335	0	0	163
Morrison, Salt Wash	0	0	0	0	0
Salt Wash	0	1,275	0	0	0
Field Total	75,397	15,732,007	0	0	297
Barbwire					
D Sand	13,828	139,131	0	0	887
D Sand, Muddy (J)	573	6,783	0	0	0
J Sand	17,166	518,067	0	0	28,158
Muddy (J)	142,270	2,316,293	0	0	0
Field Total	173,837	2,980,274	0	0	29,045
Barefoot					
Dakota, Muddy (J)	77,045	0	0	0	0
J Sand	22,149	0	0	0	142,417
Muddy (J)	208,908	9,970	0	0	0
Field Total	308,102	9,970	0	0	142,417
Barker Dome					
Barker Creek	50	110,461	0	0	6
Dakota	677	622,367	0	0	386
Desert Creek	634	317,749	0	0	276
Hermosa	889	113,001	0	0	792
Hermosa, Ismay	1,349	650,157	0	0	25
Ismay	2,833	900,410	0	0	854
Ismay, Desert Creek	21,746	6,014,741	0	0	1,319
Paradox	93,452	111,725,260	0	0	44,361
Field Total	121,630	120,454,146	0	0	48,019
Barrel Ranch					
D Sand	288,796	758,821	0	0	4,583
D Sand, Muddy (J)	84,661	235,755	0	0	0
J Sand	37,613	187,836	0	0	1,487
Muddy (J)	642	32,535	0	0	0
Field Total	411,712	1,214,947	0	0	6,070
Barrel Springs					
Morrow	30,255	9,225,296	0	0	1,855
Morrow Upper	0	115,898	0	0	0
Field Total	30,255	9,341,194	0	0	1,855
Barrel Springs North					
Morrow	4,562	2,947,038	0	0	1,571
Field Total	4,562	2,947,038	0	0	1,571
Barrow					
D Sand	24,382	476,353	0	0	0
Field Total	24,382	476,353	0	0	0
Base Line					
Codell Ss	990	110	0	0	0
D Sand	996,449	5,804,708	0	0	5,799
D Sand	47,974	163,373	0	0	0
D Sand, Muddy (J)	6,681	46,769	0	0	0
J Sand	458	59,839	0	0	794
Muddy (J)	1,686	161,551	0	0	0
Field Total	1,054,238	6,236,350	0	0	6,593

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Bassett					
D Sand	1,778	3,153	0	0	0
Field Total	1,778	3,153	0	0	0
Battle Canyon					
J Sand	2,064	7,460	0	0	11,301
Muddy (J)	994,336	3,482,772	0	0	0
Field Total	996,400	3,490,232	0	0	11,301
Battleship					
Dakota	2,977,878	0	0	0	263,445
Dakota, Lakota	3,601	0	0	0	0
Frontier	45,669	1,390	0	0	0
Lakota	45,936	0	0	0	4,497,698
Field Total	3,073,084	1,390	0	0	4,761,143
Baxter Lake					
Codell Ss	15,197	9,962	0	0	0
Niobrara	4,367	19,835	0	0	0
Niobrara	121,031	290,584	0	0	45
Niobrara	7,096	6,693	0	0	0
Niobrara, Codell Ss	192,330	444,181	0	0	170
Niobrara, Codell Ss, Lyons Ss	4,829	7,115	0	0	0
Field Total	344,850	778,370	0	0	215
Baxter Pass					
Buckhorn	7	86,992	0	0	1,172
Cedar Mountain	919	1,054,997	0	0	0
Dakota	5,289	3,799,196	0	0	2,534
Dakota	20,614	10,487,403	0	0	33,131
Dakota, Morrison	2,171	1,151,347	0	0	0
Madison	0	0	0	0	0
Mancos B	0	0	0	0	0
Mancos B	0	132,714	0	0	1,181
Mancos Sh	0	17,425	0	0	0
Mancos Sh	0	414,501	0	0	145
Mesaverde	0	263,128	0	0	213
Mesaverde	0	139,568	0	0	10,164
Mesaverde Coal	0	1,836	0	0	5,497
Mississippian	0	8,923	0	0	0
Morrison	202	128,004	0	0	128
Field Total	29,202	17,686,034	0	0	54,165
Baxter Pass South					
Morrison	0	301,509	0	0	0
Field Total	0	301,509	0	0	0
Bazooka					
Warsaw	18,383	0	0	0	218,933
Field Total	18,383	0	0	0	218,933
Beacon					
D Sand	1,398,369	4,545,323	0	0	150,428
D Sand, Muddy (J)	1,928	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	28	2,979	0	0	0
Field Total	1,400,325	4,548,302	0	0	150,428
Bead					
D Sand	13,812	0	0	0	0
D Sand	80,358	4,719	0	0	2,795
Field Total	94,170	4,719	0	0	2,795

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Beall Creek					
J Sand	0	0	0	0	0
Muddy (J)	1,895,494	1,424,112	0	0	0
Field Total	1,895,494	1,424,112	0	0	0
Bear Creek					
Vermejo Coal	0	0	0	0	291,497
Field Total	0	0	0	0	291,497
Bear Gulch					
Codell Ss	0	0	0	0	0
D Sand	114,653	842,543	0	0	539
D Sand, Muddy (J)	7,989	39,685	0	0	0
Dakota	216	7,582	0	0	37
J Sand	12,637	214,271	0	0	1,987
Muddy (J)	230,549	2,915,474	0	0	0
Niobrara	0	0	0	0	0
Niobrara, Codell Ss	0	0	0	0	0
Field Total	366,044	4,019,555	0	0	2,563
Bear Gulch Southwest					
D Sand	224	9,805	0	0	136
D Sand, Muddy (J)	2,793	93,388	0	0	0
J Sand	220	9,760	0	0	136
Field Total	3,237	112,953	0	0	272
Bear River					
Niobrara	1,260,188	1,645,292	0	0	158
Field Total	1,260,188	1,645,292	0	0	158
Beaver Bend					
J Sand	0	0	0	0	0
Muddy (J)	0	392	0	0	0
Field Total	0	392	0	0	0
Beaver Creek					
D Sand	56,984	121,515	0	0	45
Field Total	56,984	121,515	0	0	45
Becker					
J Sand	0	0	0	0	0
Muddy (J)	24,349	11,822	0	0	0
Field Total	24,349	11,822	0	0	0
Bedroll					
J Sand	10,586	0	0	0	12,720
Muddy (J)	10,126	0	0	0	0
Field Total	20,712	0	0	0	12,720
Bee Lake					
Muddy	0	0	0	0	0
Muddy (J)	2,008	0	0	0	0
Field Total	2,008	0	0	0	0
Beecher Island					
Niobrara	0	33,154	0	0	0
Niobrara	138	69,210,353	0	0	467,877
Field Total	138	69,243,507	0	0	467,877
Beeson					
Morrow	285,359	7,585	0	0	687,590
Field Total	285,359	7,585	0	0	687,590
Bell Rock					
Mesaverde	0	86,478	0	0	0
Field Total	0	86,478	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Belle					
J Sand	18,300	0	0	0	304,847
Muddy (J)	1,073,511	246,306	0	0	0
Field Total	1,091,811	246,306	0	0	304,847
Bellyache					
Marmaton	10,745	0	0	0	0
Field Total	10,745	0	0	0	0
Bennett					
D Sand	260,079	1,988,882	0	0	0
D Sand, Muddy (J)	5,644	71,819	0	0	0
J Sand	6,610	146,997	0	0	5,830
Muddy (J)	9,349	235,035	0	0	0
Field Total	281,682	2,442,733	0	0	5,830
Bent's Fort					
Morrow	25,738	1,459,570	0	0	0
Field Total	25,738	1,459,570	0	0	0
Bent's Fort					
Cherokee	170	4,846	0	0	0
Field Total	170	4,846	0	0	0
Berry Patch					
Morrow	9,907	1,654,627	0	0	0
Field Total	9,907	1,654,627	0	0	0
Berthoud					
Codell Ss	3,641	3,770	0	0	0
D Sand	115,336	59,047	0	0	0
Dakota	11,628	0	0	0	0
Dakota, Lyons Ss	160,433	0	0	0	0
Dakota, Muddy (J)	151,805	910	0	0	0
Lakota, Dakota, Muddy	166	0	0	0	0
Lyons Ss	311,149	99,835	0	0	0
Lyons, Lakota	23	0	0	0	0
Muddy (J), Lyons Ss	729	1,360	0	0	0
Niobrara	9,368	1,686,731	0	0	0
Field Total	764,278	1,851,653	0	0	0
Beryl					
D Sand	169,806	85,848	0	0	691
J Sand	251	27,322	0	0	5,721
Muddy (J)	28,172	80,026	0	0	0
Field Total	198,229	193,196	0	0	6,412
Beta					
Mississippian	0	173,948	0	0	0
Morrow	45	483,906	0	0	0
Morrow	4,679	5,237,296	0	0	0
Field Total	4,724	5,895,150	0	0	0
Big Beaver					
J Sand	185,937	0	0	0	5,993,997
Muddy (J)	12,921,596	1,711,149	0	0	144,619
Field Total	13,107,533	1,711,149	0	0	6,138,616
Big Bend					
D Sand	71,706	238,961	0	0	0
D Sand, Muddy (J)	10,520	28,593	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	6,276	300	0	0	0
Field Total	88,502	267,854	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Big Gulch					
Frontier	4,182	2,679,950	0	0	0
Mesaverde	0	1,307,102	0	0	8,640
Williams Fork Coal	0	0	15,394	0	1,016,060
Williams Fork, Cameo	0	7,042	8,106	0	1,515,404
Williams Fork, Cameo Coal	0	4	0	0	121,607
Field Total	4,182	3,994,098	23,500	0	2,661,711
Big Hole					
Fort Union Coal	0	0	0	0	0
Lewis Sh	47,718	6,805,161	0	0	30,596
Mancos Sh	966	246,856	0	0	1,015
Mesaverde	19,496	159,899	0	0	3,305
Williams Fork	618	3,094	0	0	179
Field Total	68,798	7,215,010	0	0	35,095
Big Ridge					
Mancos B	0	0	0	0	0
Mancos Sh	148	8,597	0	0	0
Field Total	148	8,597	0	0	0
Big Sandy					
J Sand	0	0	0	0	0
Muddy (J)	967,969	2,490,008	0	0	0
Field Total	967,969	2,490,008	0	0	0
Bijou					
D Sand	1,596,427	6,847,198	0	0	0
Greenhorn Ls	1,261	900	0	0	0
Field Total	1,597,688	6,848,098	0	0	0
Bijou South					
D Sand	1,945	51,224	0	0	0
D Sand, Muddy (J)	3,829	291,169	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	3,204	1,219,191	0	0	0
Field Total	8,978	1,561,584	0	0	0
Bijou West					
D Sand	1,210,870	3,118,283	0	0	0
Field Total	1,210,870	3,118,283	0	0	0
Bingo					
J Sand	4	0	0	0	0
Muddy (J)	76,637	0	0	0	0
Field Total	76,641	0	0	0	0
Bird Haven					
D Sand	276,156	1,490,677	0	0	1,389
J Sand	41,268	277,785	0	0	19,336
Field Total	317,424	1,768,462	0	0	20,725
Birdseed					
D Sand	71,321	52,778	0	0	17,054
Field Total	71,321	52,778	0	0	17,054
Bison					
J Sand	292,805	0	0	0	8,446,583
Muddy (J)	5,915,561	3,254	0	0	0
Field Total	6,208,366	3,254	0	0	8,446,583
Black Hollow					
Lyons Ss	11,177,951	330,412	0	0	7,454,655
Field Total	11,177,951	330,412	0	0	7,454,655

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Black Hollow Northwest					
Codell Ss	422	0	0	0	0
Niobrara, Codell Ss	1,685	0	0	0	0
Field Total	2,107	0	0	0	0
Black Jack					
J Sand	0	0	0	0	0
Muddy (J)	1,049,066	95,442	0	0	0
Field Total	1,049,066	95,442	0	0	0
Black Kettle					
Marmaton	7,728	91,157	0	0	0
Marmaton, Keyes	0	0	0	0	0
Field Total	7,728	91,157	0	0	0
Black Mountain					
Lewis Sh	47	18,864	0	0	667
Lewis Sh, Mesaverde	1,182	250,765	0	0	0
Mesaverde	0	3,787	0	0	49
Field Total	1,229	273,416	0	0	716
Blade					
J Sand	71,992	0	0	0	565,842
Muddy (J)	2,925,958	6,921	0	0	0
Field Total	2,997,950	6,921	0	0	565,842
Bledsoe Ranch					
Codell Ss	0	0	0	0	0
Marmaton	2,098,926	3,281,513	0	0	385,969
Morrow	1,159,059	1,167,579	0	0	7,237,767
Field Total	3,257,985	4,449,092	0	0	7,623,736
Blizzard					
Niobrara	0	9,824	0	0	0
Field Total	0	9,824	0	0	0
Blood Spring					
J Sand	1,670	0	0	0	38,114
Muddy (J)	2,833	0	0	0	0
Field Total	4,503	0	0	0	38,114
Blue Cloud					
Dakota	57	143,856	0	0	0
Mancos B	0	578,859	0	0	225
Mancos Sh	0	2,183,970	0	0	0
Field Total	57	2,906,685	0	0	225
Blue Gravel					
Lewis Sh	178	1,302,959	0	0	35,586
Lewis Sh,	3,463	8,718,681	0	0	0
Field Total	3,641	10,021,640	0	0	35,586
Blue Sky					
Almond	12,481	2,249,926	0	0	6,654
Lewis Sh	15	0	0	0	0
Lewis Sh,	0	146,870	0	0	0
Mesaverde	2,368	234,735	0	0	0
Field Total	14,864	2,631,531	0	0	6,654
Bluebell					
D Sand	68,884	1,475,324	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	66,397	16,443	0	0	0
Field Total	135,281	1,491,767	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Bluebell South					
D Sand	1,560	0	0	0	0
Field Total	1,560	0	0	0	0
Bluebird					
J Sand	3,137	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	973,992	0	0	0	0
Muddy (J)	22,063	0	0	0	0
Field Total	999,192	0	0	0	0
Bluejay					
D Sand	43,563	18,961	0	0	8,916
Field Total	43,563	18,961	0	0	8,916
Bobcat					
D Sand	7,481,643	5,664,749	0	0	2,813,723
J Sand	0	0	0	0	0
Muddy (J)	2,664	2,043	0	0	0
Field Total	7,484,307	5,666,792	0	0	2,813,723
Bobcat West					
J Sand	0	0	0	0	0
Muddy (J)	31,133	33,545	0	0	0
Field Total	31,133	33,545	0	0	0
Bolero					
Cherokee	40,903	17,143	0	0	0
Field Total	40,903	17,143	0	0	0
Bombing Range					
D Sand	293	132	0	0	667
D Sand, Muddy (J)	15,896	107,841	0	0	0
Dakota	2,364	96,656	0	0	1,525
Dakota, Muddy (J)	3,268	83,966	0	0	0
J Sand	66,306	824,481	0	0	19,918
Muddy (J)	461,714	4,365,940	0	0	0
Niobrara	588	580	0	0	0
Field Total	550,429	5,479,596	0	0	22,110
Bonanza					
J Sand	0	0	0	0	0
Muddy (J)	1,268,018	1,808,818	0	0	0
Field Total	1,268,018	1,808,818	0	0	0
Bonanza North					
J Sand	88,229	302,877	0	0	81,871
Muddy (J)	185,698	592,573	0	0	0
Field Total	273,927	895,450	0	0	81,871
Boneyard					
D Sand	87,830	52,680	0	0	0
Field Total	87,830	52,680	0	0	0
Bonham					
J Sand	0	0	0	0	0
Muddy (J)	271,013	60,239	0	0	0
Field Total	271,013	60,239	0	0	0
Bonito					
D Sand	1,975	75,630	0	0	0
Field Total	1,975	75,630	0	0	0
Bonny					
Lakota	0	0	0	0	88,200
Niobrara	0	39,519,258	0	0	5,497,262
Field Total	0	39,519,258	0	0	5,585,462

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Boom					
J Sand	15,659	0	0	0	230,368
Muddy (J)	43,857	22,618	0	0	0
Field Total	59,516	22,618	0	0	230,368
Boondocks					
Dakota	0	3,116	0	0	0
Field Total	0	3,116	0	0	0
Boot Hill					
D Sand	102,971	67,477	0	0	0
Field Total	102,971	67,477	0	0	0
Boot Jack					
J Sand	0	0	0	0	0
Muddy (J)	9,745	3,620	0	0	0
Field Total	9,745	3,620	0	0	0
Border					
D Sand	22,905	517,945	0	0	34,096
J Sand	122,364	24,060	0	0	194,459
Muddy (J)	1,379,731	2,148,499	0	0	0
Field Total	1,525,000	2,690,504	0	0	228,555
Boreas					
D Sand	1,366	3,185	0	0	0
Field Total	1,366	3,185	0	0	0
Boulder					
Dakota	0	51,741	0	0	0
Pierre Sh	804,531	308	0	0	0
Field Total	804,531	52,049	0	0	0
Boulder Valley					
Codell Ss	106,721	817,052	0	0	5,213
J Sand	369	78,508	0	0	1,215
Muddy (J)	335	158,305	0	0	0
Muddy (J), Niobrara, Codell Ss	16,916	235,084	0	0	0
Niobrara	25,125	151,207	0	0	4,544
Niobrara, Codell Ss	84,181	669,270	0	0	3,721
Field Total	233,647	2,109,426	0	0	14,693
Bounty					
D Sand	38,203	0	0	0	260
J Sand	0	0	0	0	0
Muddy (J)	97,556	67,852	0	0	0
Field Total	135,759	67,852	0	0	260
Bow					
J Sand	2,771	0	0	0	6,654
Muddy (J)	128,566	1,372,941	0	0	0
Field Total	131,337	1,372,941	0	0	6,654
Bowl					
D Sand	173,876	287,630	0	0	120,321
Field Total	173,876	287,630	0	0	120,321
Bowstring					
D Sand	20,914	133,229	0	0	0
Field Total	20,914	133,229	0	0	0
Box Elder Creek					
J Sand	3,244	64,040	0	0	0
Muddy (J)	27,542	563,311	0	0	0
Field Total	30,786	627,351	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Boxer					
D Sand	3,999,579	10,470,141	0	0	514,253
J Sand	10,374	0	0	0	1,900
Muddy (J)	148,977	160,144	0	0	0
Field Total	4,158,930	10,630,285	0	0	516,153
Boyero					
Marmaton	773	0	0	0	0
Field Total	773	0	0	0	0
Bracewell					
Codell Ss	2,183,397	16,445,905	0	0	58,564
J Sand	571	10,814	0	0	50
Muddy (J)	1,553	70,432	0	0	0
Muddy (J), Codell Ss	33,868	110,293	0	0	0
Niobrara	40,491	540,834	0	0	3,220
Niobrara, Codell Ss	773,009	5,673,541	0	0	22,282
Shannon	4,170	264,718	0	0	131
Sussex	6,487	1,265	0	0	0
Field Total	3,043,546	23,117,802	0	0	84,247
Bradbury					
J Sand	0	0	0	0	0
Muddy (J)	374	48	0	0	0
Field Total	374	48	0	0	0
Braid					
J Sand	12,000	0	0	0	201,915
Muddy (J)	36,060	0	0	0	0
Field Total	48,060	0	0	0	201,915
Branding Iron					
D Sand	6,323	0	0	0	7
Field Total	6,323	0	0	0	7
Brandon					
Lansing, Kansas City	520,307	0	0	0	88,510
Mississippian	11,070,503	15,640	0	0	7,573,981
Mississippian, Pennsylvanian	11,971	0	0	0	39,971
Mississippian, Spargen	0	0	0	0	0
Morrow	14,419	3,499,804	0	0	580
Warsaw	17,350	0	0	0	437,035
Field Total	11,634,550	3,515,444	0	0	8,140,077
Brave					
D Sand	5,305	18,341	0	0	0
Fort Hays	0	0	0	0	0
J Sand	2,532	62,403	0	0	0
Muddy (J)	17,996	128,161	0	0	0
Niobrara	561	2,921	0	0	0
Field Total	26,394	211,826	0	0	0
Bravo					
J Sand	0	0	0	0	0
Muddy (J)	320	687	0	0	0
Field Total	320	687	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Bridle					
Cedar Mountain	1,440	1,718,583	0	0	0
Dakota	781	7,209,805	0	0	0
Dakota	0	522,903	0	0	0
Dakota, Cedar Mountain	0	0	0	0	0
Dakota, Morrison	873	9,807,026	0	0	0
Entrada Ss	11,521	0	0	0	0
Morrison	5	1,178,609	0	0	0
Field Total	14,620	20,436,926	0	0	0
Briggsdale					
J Sand	0	0	0	0	0
Muddy (J)	651	33,834	0	0	0
Field Total	651	33,834	0	0	0
Bristle					
Greenhorn Ls	2,591	0	0	0	0
Field Total	2,591	0	0	0	0
Britannia					
J Sand	13,808	392	0	0	2,308
Muddy (J)	65,053	42,215	0	0	0
Field Total	78,861	42,607	0	0	2,308
Brittney					
D Sand	52,472	355,580	0	0	135
Field Total	52,472	355,580	0	0	135
Broken Bow					
Fort Scott Ls	6,529	0	0	0	0
Mississippian	166,449	0	0	0	120,829
Mississippian, Spergen	0	0	0	0	0
Unknown	4,490	476	0	0	0
Field Total	177,468	476	0	0	120,829
Broken Fork					
J Sand	13,595	0	0	0	267,129
Muddy (J)	210,721	0	0	0	0
Field Total	224,316	0	0	0	267,129
Broker					
D Sand	2,382	58,959	0	0	0
Field Total	2,382	58,959	0	0	0
Bromley					
D Sand	166,341	805,569	0	0	2,487
D Sand, Muddy (J)	2,681	13,462	0	0	0
J Sand	3,805	75,255	0	0	1,675
Field Total	172,827	894,286	0	0	4,162
Bronco					
J Sand	0	0	0	0	0
Muddy (J)	4,015	186,368	0	0	0
Field Total	4,015	186,368	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Bronco Flats					
Cameo Coal	0	97,620	171,406	0	35,099
Cameo Coals, Mesaverde	0	1,075	0	0	3,784
Cedar Mountain	0	562,413	0	0	586
Corcoran	0	316,676	0	0	0
Cozette	0	52,532	0	0	0
Cozzette, Corcoran	0	171,849	0	0	0
Cozzette, Corcoran, Cameo C	0	63,810	11,109	0	2,461
Dakota	55	2,313,170	0	0	5,017
Dakota, Morrison	0	24,740	0	0	0
Mancos Sh	0	89,332	0	0	0
Mesaverde	0	385,529	0	0	16
Mesaverde Coal	0	0	23,626	0	0
Morrison	0	0	0	0	0
Field Total	55	4,078,746	206,141	0	46,963
Brook					
J Sand	747	60,174	0	0	1,160
Field Total	747	60,174	0	0	1,160
Brule'					
J Sand	0	0	0	0	0
Muddy (J)	1,475	0	0	0	0
Field Total	1,475	0	0	0	0
Brun					
Wabaunsee	0	87,432	0	0	0
Field Total	0	87,432	0	0	0
Brush Creek					
Corcoran	300	217,172	0	0	8,405
Corcoran, Mesaverde	0	198,760	0	0	0
Cozette	0	11,603	0	0	640
Cozzette, Corcoran	0	18,826	0	0	0
Cozzette, Corcoran, Mesaverde	0	112,693	0	0	0
Mesaverde	436	1,572,550	0	0	13,983
Wasatch	0	101,818	0	0	40
Wasatch G	0	46,843	0	0	0
Field Total	736	2,280,265	0	0	23,068
Buck					
D Sand, Muddy (J)	5,876	0	0	0	0
Field Total	5,876	0	0	0	0
Buck Peak					
Mancos Sh	1,243,839	1,105,577	0	0	0
Mesaverde	0	514,310	0	0	0
Niobrara	3,456,977	6,574,983	0	0	130,850
Shinarump	8,501	3,214	0	0	0
Trout Creek	0	0	0	0	0
Field Total	4,709,317	8,198,084	0	0	130,850
Buckaroo					
J Sand	5,472	0	0	0	2,690
Muddy (J)	330,017	0	0	0	0
Field Total	335,489	0	0	0	2,690
Buckboard					
Niobrara	20	6,455,406	0	0	39,430
Field Total	20	6,455,406	0	0	39,430

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Buckeye					
J Sand	0	0	0	0	0
Muddy (J)	9,466	3,151	0	0	0
Field Total	9,466	3,151	0	0	0
Buckhorn					
J Sand	509	69,681	0	0	0
Muddy (J)	605	118,123	0	0	0
Field Total	1,114	187,804	0	0	0
Buckingham					
D Sand	506,340	1,539,116	0	0	1,392
Field Total	506,340	1,539,116	0	0	1,392
Buckingham West					
D Sand	426,289	365,732	0	0	0
Field Total	426,289	365,732	0	0	0
Buckskin					
D Sand	2,417	10,870	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	19,389	2,515,333	0	0	0
Field Total	21,806	2,526,203	0	0	0
Buckskin East					
J Sand	3,428	534,890	0	0	0
Muddy (J)	53,095	3,958,221	0	0	0
Field Total	56,523	4,493,111	0	0	0
Bud					
D Sand	35,047	4,665	0	0	7,470
Field Total	35,047	4,665	0	0	7,470
Buffalo					
J Sand	0	0	0	0	0
Muddy (J)	5,148	151	0	0	0
Niobrara	0	24,278	0	0	0
Field Total	5,148	24,429	0	0	0
Buffalo Creek					
Marmaton	2,210	155	0	0	0
Field Total	2,210	155	0	0	0
Buffalo Grass					
Niobrara	0	6,945,190	0	0	226,597
Field Total	0	6,945,190	0	0	226,597
Buffalo Slough					
D Sand	37,139	42,641	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	28,016	20,026	0	0	0
Field Total	65,155	62,667	0	0	0
Bugle					
D Sand	350,199	1,417,724	0	0	42
D Sand, Muddy (J)	77,581	208,029	0	0	0
Field Total	427,780	1,625,753	0	0	42
Bull Fork					
Cozette	7	15,457	0	0	385
Cozette, Williams Fork	198	180,945	0	0	1,999
Mesaverde	565	616,797	0	0	3,090
Mesaverde	0	0	0	0	0
Wasatch	434	340,313	0	0	6,877
Williams Fork	1,263	461,746	0	0	12,726
Williams Fork	0	157,144	0	0	0
Field Total	2,467	1,772,402	0	0	25,077

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Bull Mountain					
Niobrara	49,332	85,136	0	0	0
Field Total	49,332	85,136	0	0	0
Bullseye					
D Sand	0	25,207	0	0	0
Field Total	0	25,207	0	0	0
Bullwacker					
J Sand	0	0	0	0	0
Muddy (J)	4,780	5,002	0	0	0
Field Total	4,780	5,002	0	0	0
Bunting					
D Sand	3,520	0	0	0	0
Field Total	3,520	0	0	0	0
Burr					
D Sand	463,055	192,718	0	0	0
Field Total	463,055	192,718	0	0	0
Buscadero					
Lansing, Kansas City	136,365	223,789	0	0	1,714
Mississippian	100,458	0	0	0	1,941
Mississippian, Spergen	20,292	0	0	0	43,907
Morrow	0	2,804	0	0	0
Field Total	257,115	226,593	0	0	47,562
Busy Bee					
D Sand	390,539	526,532	0	0	36,373
D Sand, Muddy (J)	16,580	43,207	0	0	1,317
J Sand	3,818	2,068	0	0	479
Field Total	410,937	571,807	0	0	38,169
Butler Creek					
Corcoran	16	235	0	0	44
Cozette	16	300	0	0	53
Frontier	29,609	14,871	0	0	0
Field Total	29,641	15,406	0	0	97
Buzzard					
Cameo	0	6,661	0	0	0
Corcoran	95	93,201	0	0	1,214
Cozette	683	1,018,040	0	0	9,874
Cozzette, Corcoran	102	16,497	0	0	258
Cozzette, Mesaverde	0	647	0	0	0
Mesaverde	164	2,724,649	0	0	883
Williams Fork	0	2,979	0	0	57
Field Total	1,044	3,862,674	0	0	12,286
Buzzard Creek					
Cameo	95	21,127	0	0	52
Cameo Coal	0	0	5,512	0	13
Corcoran	89	126,893	0	0	1,567
Cozette	525	2,258,783	0	0	15,243
Mesaverde	641	8,710,614	0	0	8,398
Mesaverde Coal	0	0	52,998	0	0
Wasatch	0	159,852	0	0	39
Williams Fork	1,669	797,752	0	0	12,729
Field Total	3,019	12,075,021	58,510	0	38,041
Byers					
J Sand	69,282	39,708	0	0	27,745
Muddy (J)	540,025	348,788	0	0	0
Field Total	609,307	388,496	0	0	27,745

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Caballero					
D Sand	44,546	32,289	0	0	6,000
Field Total	44,546	32,289	0	0	6,000
Caballo					
D Sand	2,667	5,928	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	6,754	75,959	0	0	0
Field Total	9,421	81,887	0	0	0
Cabin Creek					
D Sand	2,101	21,590	0	0	0
J Sand	5,812	12,322	0	0	326,250
Muddy (J)	32,293	7,782	0	0	0
Field Total	40,206	41,694	0	0	326,250
Cable					
J Sand	1,727	49,468	0	0	530
Muddy (J)	6,665	136,777	0	0	0
Field Total	8,392	186,245	0	0	530
Cache					
Ismay	4,583,965	7,629,976	0	0	831,480
Field Total	4,583,965	7,629,976	0	0	831,480
Cactus					
J Sand	0	0	0	0	0
Muddy (J)	1,046	20	0	0	0
Field Total	1,046	20	0	0	0
Cahone					
Honaker Trail	84,804	209,970	0	0	3,166
Field Total	84,804	209,970	0	0	3,166
Caledonia					
D Sand	557,867	3,659,855	0	0	3,286
D Sand, Muddy (J)	78,080	343,772	0	0	42
J Sand	11,410	253,092	0	0	1,119
Muddy (J)	125,593	1,633,942	0	0	0
Field Total	772,950	5,890,661	0	0	4,447
Calf Canyon					
Dakota	160	774,352	0	0	0
Mesaverde	0	312,275	0	0	0
Niobrara	0	25,224	0	0	0
Field Total	160	1,111,851	0	0	0
Calhoun					
J Sand	84,010	0	0	0	2,727,931
Muddy (J)	297,099	4,563	0	0	0
Field Total	381,109	4,563	0	0	2,727,931
California Park					
Niobrara	1,748	471	0	0	0
Field Total	1,748	471	0	0	0
Calumet					
D Sand	11,117	42,828	0	0	218
D Sand, Muddy (J)	2,176	11,388	0	0	0
Field Total	13,293	54,216	0	0	218

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Cameo					
Cameo Coal	0	0	0	0	0
Corcoran	0	0	0	0	0
Dakota	0	529,838	0	0	0
Mesaverde Coal	0	0	152	0	0
Rollins	0	347	0	0	4,551
unknown	0	0	0	0	0
Field Total	0	530,185	152	0	4,551
Camino					
Codell Ss	7,346	54,821	0	0	386
D Sand	82,168	39,766	0	0	0
Field Total	89,514	94,587	0	0	386
Camp Creek					
J Sand	11,665	2	0	0	47,080
Muddy (J)	244,538	12,668	0	0	0
Field Total	256,203	12,670	0	0	47,080
Camp Creek West					
J Sand	0	0	0	0	0
Muddy (J)	40,698	0	0	0	0
Field Total	40,698	0	0	0	0
Camp Gulch					
Dakota	0	260,257	0	0	0
Field Total	0	260,257	0	0	0
Campana					
J Sand	5,210	535,497	0	0	1,980
Muddy (J)	48,930	1,861,957	0	0	0
Field Total	54,140	2,397,454	0	0	1,980
Campo					
Lansing	4,720,458	1,805,368	0	0	19,202,832
Neva Ls	16,112	25,560	0	0	1,493
Wolfcamp, Neva, Lansing	0	0	0	0	0
Field Total	4,736,570	1,830,928	0	0	19,204,325
Canadian River					
Dakota	462,136	8,510,646	0	0	0
Dakota, Lakota	0	0	0	0	0
Lakota	0	0	0	0	0
Muddy	0	0	0	0	0
Muddy (J)	0	247,667	0	0	0
Niobrara	39,277	176	0	0	0
Field Total	501,413	8,758,489	0	0	0
Canal					
D Sand	14,483	6,193,148	0	0	2,313
Field Total	14,483	6,193,148	0	0	2,313
Cannon					
J Sand	0	0	0	0	0
Muddy (J)	22,200	3,400	0	0	0
Field Total	22,200	3,400	0	0	0
Cantina					
D Sand	95,459	211,244	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	15	10,369	0	0	0
Field Total	95,474	221,613	0	0	0
Cantle					
D Sand	76	30,728	0	0	0
Field Total	76	30,728	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Carbonera					
Buckhorn	0	15,432	0	0	0
Dakota	0	227,475	0	0	468
Dakota, Buckhorn	0	53,038	0	0	33
Dakota, Cedar Mountain	121	1,544,341	0	0	0
Field Total	121	1,840,286	0	0	501
Caretaker					
D Sand	117,176	1,559,597	0	0	60
Field Total	117,176	1,559,597	0	0	60
Caribou					
J Sand	53,143	0	0	0	1,191,714
Muddy (J)	741,743	0	0	0	0
Field Total	794,886	0	0	0	1,191,714
Carlstrom					
Niobrara	7,741	4,194	0	0	0
Field Total	7,741	4,194	0	0	0
Carousel					
J Sand	12,778	0	0	0	49,168
Muddy (J)	63,406	1,783	0	0	0
Field Total	76,184	1,783	0	0	49,168
Cartwheel					
J Sand	0	0	0	0	0
Muddy (J)	4,121	8,588	0	0	0
Field Total	4,121	8,588	0	0	0
Casement					
D Sand	0	10,607	0	0	0
Field Total	0	10,607	0	0	0
Casino					
J Sand	1,009	0	0	0	0
Muddy (J)	690,038	32,296	0	0	0
Field Total	691,047	32,296	0	0	0
Castle					
Dakota	0	0	0	0	0
Field Total	0	0	0	0	0
Castle Peak					
Cherokee	102,653	0	0	0	35,919
Morrow	327,593	461,545	0	0	295,615
Morrow V7	12,199	12,372	0	0	33,548
Field Total	442,445	473,917	0	0	365,082
Cathedral					
Castlegate	0	257,707	0	0	274
Dakota	44	2,032,839	0	0	106
Emery	13	552,174	0	0	450
J Sand	0	602	0	0	0
Mancos A	0	158,278	0	0	112
Mancos A, B	3,261	891,732	0	0	540
Mancos B	1,091	5,396,566	0	0	7,119
Mancos Sh	33,323	38,915,304	0	0	4,214
Mancos, Emery	0	6,033	0	0	0
Mesaverde	373	2,559,208	0	0	0
Morrison	0	620,977	0	0	230
Field Total	38,105	51,391,420	0	0	13,045

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Cauldron					
J Sand	24,464	44,746	0	0	453,735
Muddy (J)	112,041	323,434	0	0	0
Field Total	136,505	368,180	0	0	453,735
Cavalry					
Keyes	75,121	3,775	0	0	276,381
Lansing	3,818	0	0	0	1,560
Lyons Ss	0	0	0	0	0
Mississippian	1,671,095	58,339	0	0	1,773,338
Mississippian, Keyes	0	0	0	0	0
Morrow	15,409	2,554,360	0	0	0
St Louis	60,942	0	0	0	22,388
St Louis, Spergen	3,490	0	0	0	0
Field Total	1,829,875	2,616,474	0	0	2,073,667
Cayuse					
J Sand	0	0	0	0	0
Muddy (J)	91,971	80,662	0	0	0
Field Total	91,971	80,662	0	0	0
Cedar Bench					
Dakota	0	58,907	0	0	5,710
Field Total	0	58,907	0	0	5,710
Cedar Creek					
D Sand	616,383	1,029,652	0	0	23,105
D Sand, Muddy (J)	526,926	686,861	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	5,905	22,283	0	0	0
Field Total	1,149,214	1,738,796	0	0	23,105
Cedar Creek North					
D Sand	767,282	2,498,907	0	0	31,940
J Sand	12,047	11,011	0	0	0
Muddy (J)	1,999	128	0	0	0
Field Total	781,328	2,510,046	0	0	31,940
Cedar Valley					
D Sand	16,642	84,064	0	0	0
Field Total	16,642	84,064	0	0	0
Centennial					
J Sand	0	0	0	0	0
Muddy (J)	17,285	4,769	0	0	0
Field Total	17,285	4,769	0	0	0
Center Pivot					
D Sand	271,382	1,062,915	0	0	5,887
J Sand	0	3,182	0	0	390
Field Total	271,382	1,066,097	0	0	6,277
Chalice					
J Sand	18,612	1,088,294	0	0	9,522
Muddy (J)	83,757	4,238,717	0	0	0
Field Total	102,369	5,327,011	0	0	9,522
Champion					
J Sand	4,682	315	0	0	72,134
Field Total	4,682	315	0	0	72,134
Chance					
J Sand	0	0	0	0	0
Muddy (J)	2,446	0	0	0	0
Field Total	2,446	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Channel					
D Sand	18,930	0	0	0	0
Field Total	18,930	0	0	0	0
Channing					
Marmaton	0	16,293	0	0	0
Morrow	8,125	7,382,350	0	0	3,267
Field Total	8,125	7,398,643	0	0	3,267
Chaparral					
D Sand	11,127	1,269,864	0	0	0
J Sand	11,795	0	0	0	2,369
Muddy (J)	29,975	0	0	0	0
Field Total	52,897	1,269,864	0	0	2,369
Chappel					
D Sand	0	4,245,455	0	0	0
Field Total	0	4,245,455	0	0	0
Chess					
J Sand	11,604	0	0	0	60,114
Muddy (J)	141,415	24,860	0	0	0
Field Total	153,019	24,860	0	0	60,114
Cheyenne Wells					
Mississippian	1,256,816	0	0	0	0
Mississippian, Spergen	93,132	0	0	0	104,407
Morrow	88,785	7,227	0	0	0
Osage	754,989	13,303	0	0	0
Shawnee	450,715	0	0	0	1,069,342
Spergen	577,200	200,752	0	0	1,819,774
Warsaw	19,378	0	0	0	130,200
Warsaw, Osage	0	0	0	0	30,251
Field Total	3,241,015	221,282	0	0	3,153,974
Chieftain					
D Sand	98,552	361,423	0	0	585
D Sand, Muddy (J)	91,906	700,901	0	0	0
J Sand	122,747	1,846,511	0	0	18,939
Morrow	1,238	24,621	0	0	0
Muddy (J)	886,041	14,653,469	0	0	0
Field Total	1,200,484	17,586,925	0	0	19,524
Chileno					
D Sand	659	513,007	0	0	0
Field Total	659	513,007	0	0	0
Chimney Canyon					
J Sand	0	0	0	0	0
Muddy (J)	77,513	579,197	0	0	0
Field Total	77,513	579,197	0	0	0
Chinook					
D Sand	145,583	1,043,423	0	0	988
J Sand	12,384	90,971	0	0	2,820
Muddy (J)	145,662	1,187,423	0	0	0
Field Total	303,629	2,321,817	0	0	3,808
Chipeta					
Tocito	202	0	0	0	0
Field Total	202	0	0	0	0
Chivington					
Morrow	107	60,073	0	0	0
Field Total	107	60,073	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Chromo					
Greenhorn Ls	0	0	0	0	0
Mancos Sh	171,207	6,342	0	0	0
unknown	0	0	0	0	0
Field Total	171,207	6,342	0	0	0
Cimarron					
J Sand	0	0	0	0	0
Muddy (J)	2,282,108	0	0	0	0
Field Total	2,282,108	0	0	0	0
Cinch					
J Sand	0	0	0	0	0
Muddy (J)	22,728	32,977	0	0	0
Field Total	22,728	32,977	0	0	0
Cinder Buttes					
Dakota	1,245	226,029	0	0	0
Entrada, Bluff, Morrison	0	0	0	0	39,180
Gallup Ss	0	42,130	0	0	0
Mesaverde	0	3,626	0	0	0
Field Total	1,245	271,785	0	0	39,180
Circle					
J Sand	0	0	0	0	0
Muddy (J)	288	0	0	0	0
Field Total	288	0	0	0	0
Clarks Lake					
D Sand	62,364	72,319	0	0	0
J Sand	96,937	0	0	0	1,546,565
Muddy	66,862	0	0	0	364,483
Muddy (J)	1,975,090	918,638	0	0	152,160
Field Total	2,201,253	990,957	0	0	2,063,208
Clay Basket					
D Sand	308	1,000	0	0	0
J Sand	18,264	24,624	0	0	147,060
Muddy (J)	94,757	66,601	0	0	0
Field Total	113,329	92,225	0	0	147,060
Clay Creek					
Cherokee	754	0	0	0	0
Mississippian	34,398	0	0	0	0
Field Total	35,152	0	0	0	0
Clear View					
Raton, Vermejo Coal	0	0	254,515	0	364,013
Field Total	0	0	254,515	0	364,013
Cliff					
D Sand	6,084,822	12,931,338	0	0	559,117
J Sand	0	0	0	0	0
Muddy (J)	7,061	111,868	0	0	0
Field Total	6,091,883	13,043,206	0	0	559,117
Clifford					
Arbuckle	0	0	0	0	0
Cedar Hills	0	0	0	0	34,438
Cherokee	61,451	0	0	0	0
Marmaton	243,645	60,931	0	0	9,350
Morrow	2,338,383	533,126	0	0	2,104,752
Field Total	2,643,479	594,057	0	0	2,148,540

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Clover Leaf					
J Sand	0	0	0	0	0
Muddy (J)	287,456	1,056,204	0	0	0
Field Total	287,456	1,056,204	0	0	0
Clyde					
Keyes	7,855	14,479	0	0	0
Marmaton	79,053	0	0	0	0
Morrow	38,264	6,992,839	0	0	1,352
Field Total	125,172	7,007,318	0	0	1,352
Clyde North					
Morrow	714	0	0	0	0
Field Total	714	0	0	0	0
Coachman					
D Sand	1,131	3,451	0	0	0
Field Total	1,131	3,451	0	0	0
Coal Basin					
Corcoran	21	59,393	0	0	2,847
Cozette	23	59,192	0	0	2,851
Cozzette, Corcoran	1	40,430	0	0	0
Mesaverde	1,463	458,493	0	0	571
Williams Fork	25	30,243	0	0	2,717
Field Total	1,533	647,751	0	0	8,986
Coal Gulch					
Cedar Mountain	793	1,153,283	0	0	0
Dakota	0	246,146	0	0	0
Dakota	1,105	1,466,465	0	0	363
Mesaverde	0	21,316	0	0	0
Mesaverde Coal	0	0	214,767	0	0
Field Total	1,898	2,887,210	214,767	0	363
Coalbank Creek					
Niobrara	8,511	0	0	0	0
Niobrara, Codell Ss	4,642	325	0	0	0
Field Total	13,153	325	0	0	0
Coalmont					
Niobrara	203,467	85,337	0	0	99
Field Total	203,467	85,337	0	0	99
Cobb Lake					
Niobrara	1,699	7,095	0	0	221
Field Total	1,699	7,095	0	0	221
Cocklebur Draw					
Hermosa	0	2,546,153	0	0	268
Field Total	0	2,546,153	0	0	268
Cody					
J Sand	56,472	0	0	0	596,792
Muddy (J)	1,339,150	146,206	0	0	0
Field Total	1,395,622	146,206	0	0	596,792
Cole					
D Sand	14,429	1,014,449	0	0	3,018
Field Total	14,429	1,014,449	0	0	3,018
Collins Ranch					
Spergen	8,013	30,336	0	0	0
Field Total	8,013	30,336	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Colorow Gulch					
Frontier	977	10,502	0	0	0
Shinarump	53,846	730,026	0	0	0
Field Total	54,823	740,528	0	0	0
Colt					
Morrow	42	527,590	0	0	0
Field Total	42	527,590	0	0	0
Columbine					
J Sand	0	0	0	0	0
Muddy (J)	34	78,416	0	0	0
Field Total	34	78,416	0	0	0
Comanche					
Mississippian	84,877	4,686	0	0	8,264
Mississippian, Osage	0	0	0	0	0
Osage	9,919	0	0	0	0
Field Total	94,796	4,686	0	0	8,264
Comanche Creek					
D Sand	2,067,150	7,161,645	0	0	3,821
D Sand, Muddy (J)	66,459	337,323	0	0	1
J Sand	66,178	122,209	0	0	75
Muddy (J)	140,080	1,712,106	0	0	0
Field Total	2,339,867	9,333,283	0	0	3,897
Concho					
J Sand	68,432	0	0	0	2,911,701
Muddy (J)	381,334	0	0	0	0
Field Total	449,766	0	0	0	2,911,701
Cone					
J Sand	0	0	0	0	0
Muddy (J)	154,330	38,551	0	0	0
Field Total	154,330	38,551	0	0	0
Conestoga					
J Sand	0	0	0	0	0
Muddy (J)	573	16	0	0	0
Field Total	573	16	0	0	0
Cookie Jar					
J Sand	24,088	83,727	0	0	0
Muddy (J)	18,851	45,029	0	0	0
Field Total	42,939	128,756	0	0	0
Coon Creek					
Cherokee	1,008	0	0	0	0
Field Total	1,008	0	0	0	0
Coon Hollow					
Corcoran	0	6,238	0	0	453
Corcoran, Cozzette, Rollins	0	17,959	0	0	0
Cozzette	0	6,531	0	0	452
Mesaverde	91	795,838	0	0	0
Rollins	0	6,225	0	0	452
Rollins, Cozzette, Corcoran	0	1,692	0	0	0
Field Total	91	834,483	0	0	1,357
Cope					
J Sand	0	0	0	0	0
Muddy (J)	208,342	100	0	0	0
Field Total	208,342	100	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Coral					
D Sand	2,530	595	0	0	0
Field Total	2,530	595	0	0	0
Corral Creek					
Dakota	1,684	1,612,658	0	0	7,729
Dakota, Morrison	23	943,719	0	0	0
Mancos B	2,646	391,320	0	0	3,789
Mancos Sh	3,444	1,194,774	0	0	15,432
Mesaverde	1,053	25,408	0	0	4,577
Morrison	0	2,766	0	0	14
Wasatch	0	0	0	0	0
Williams Fork	100	11,334	0	0	1,020
Field Total	8,950	4,181,979	0	0	32,561
Cotton Valley					
D Sand	111,177	304,037	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	26,007	2,447,591	0	0	0
Field Total	137,184	2,751,628	0	0	0
Cottonwood					
J Sand	0	0	0	0	0
Muddy (J)	85,295	13,970	0	0	0
Field Total	85,295	13,970	0	0	0
Cottonwood South					
D Sand	97,931	163,874	0	0	0
J Sand	12,252	0	0	0	381,685
Muddy (J)	64,476	17,808	0	0	0
Field Total	174,659	181,682	0	0	381,685
Cougar					
D Sand	5,758	28,484	0	0	311
D Sand, Muddy (J)	12,247	390,107	0	0	0
J Sand	2,765	340,225	0	0	3,748
Muddy (J)	15,954	2,203,021	0	0	0
Field Total	36,724	2,961,837	0	0	4,059
Council					
Niobrara	0	39,025	0	0	0
Field Total	0	39,025	0	0	0
County Line					
D Sand	119,019	868,138	0	0	0
Field Total	119,019	868,138	0	0	0
Cowboy					
Lansing	26,727	0	0	0	0
Morrow	59,609	0	0	0	10,491
Field Total	86,336	0	0	0	10,491
Coyote					
D Sand	0	122,049	0	0	0
Field Total	0	122,049	0	0	0
Coyote Wash					
Dakota	0	262,483	0	0	0
Field Total	0	262,483	0	0	0
Crackerjack					
D Sand	5,395	42,120	0	0	0
Field Total	5,395	42,120	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Craig					
Frontier	466	1,521,129	0	0	0
Mesaverde	0	213,873	0	0	0
Mesaverde Coal	0	0	0	0	0
Morapos	0	0	0	0	0
Niobrara	250,858	189,074	0	0	38
Field Total	251,324	1,924,076	0	0	38
Craig North					
Lewis Sh	1,312	1,850,327	0	0	2,798
Lewis Sh,	4,815	6,701,034	0	0	0
Lewis Sh, Mesaverde	11,398	2,439,689	0	0	3,614
Mesaverde	19,396	12,957,357	0	0	0
Field Total	36,921	23,948,407	0	0	6,412
Craig Ranch					
Morrow, Atoka	14,622	5,051	0	0	0
Field Total	14,622	5,051	0	0	0
Crawford					
Dakota	1,187	0	0	0	0
Field Total	1,187	0	0	0	0
Crazy Horse					
D Sand	10,743	824,864	0	0	0
Field Total	10,743	824,864	0	0	0
Crest					
D Sand	2,989	0	0	0	0
Field Total	2,989	0	0	0	0
Cricket					
D Sand	14,769	32,881	0	0	4,796
Field Total	14,769	32,881	0	0	4,796
Crist					
Niobrara	0	0	0	0	0
Field Total	0	0	0	0	0
Crow					
D Sand	620,479	2,859,963	0	0	21,675
J Sand	29,997	104,896	0	0	11,573
Field Total	650,476	2,964,859	0	0	33,248
Crow Creek					
Niobrara	9,427	27,341	0	0	0
Field Total	9,427	27,341	0	0	0
Crystal					
D Sand	31,153	75,150	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	5,711	0	0	0	0
Field Total	36,864	75,150	0	0	0
Curtis					
Niobrara	250,159	96,353	0	0	0
Field Total	250,159	96,353	0	0	0
Cutlass					
D Sand	1,514	3,352	0	0	0
J Sand	2,879	258,236	0	0	0
Muddy (J)	7,893	619,393	0	0	0
Field Total	12,286	880,981	0	0	0
Cypress					
J Sand	0	0	0	0	0
Muddy (J)	113,982	99,527	0	0	0
Field Total	113,982	99,527	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Dagger					
J Sand	2,843	58,794	0	0	582
Muddy (J)	8,810	89,693	0	0	0
Field Total	11,653	148,487	0	0	582
Dailey					
D Sand	0	15,585	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	0	212,899	0	0	0
Field Total	0	228,484	0	0	0
Dale					
D Sand	331,802	998,610	0	0	0
J Sand	15,673	154,476	0	0	453,315
Muddy (J)	474,857	2,304,747	0	0	0
Field Total	822,332	3,457,833	0	0	453,315
Dale North					
J Sand	0	0	0	0	0
Muddy (J)	173,917	240,267	0	0	0
Field Total	173,917	240,267	0	0	0
Dance					
D Sand	15,376	82,367	0	0	2,462
J Sand	0	0	0	0	0
Muddy (J)	51,456	441,926	0	0	0
Field Total	66,832	524,293	0	0	2,462
Dance South					
D Sand	54,460	1,009,544	0	0	3,277
Field Total	54,460	1,009,544	0	0	3,277
Dandy					
J Sand	15,451	3,745	0	0	392,840
Muddy (J)	55,080	1,977	0	0	0
Field Total	70,531	5,722	0	0	392,840
Danforth Hills					
Dakota	251,719	88,903	0	0	0
Dakota, Morrison	0	0	0	0	0
Minturn	51,594	626,976	0	0	0
Moenkopi, Shinarump	154,224	543	0	0	0
Morapos, Mancos	0	0	0	0	0
Morrison	1,149,479	154,756	0	0	282,570
Shinarump	566,472	42,720	0	0	186,389
Sundance	1,743,532	38,070	0	0	4,663
Weber Ss	635,378	2,219	0	0	17,687
Field Total	4,552,398	954,187	0	0	491,309
Danforth Hills North					
Moenkopi	727	565	0	0	0
Moenkopi, Shinarump	24	0	0	0	0
Morrison	453,793	133,611	0	0	1,891
Weber Ss	9,846	0	0	0	490
Field Total	464,390	134,176	0	0	2,381
Danskin					
J Sand	9,124	169,553	0	0	0
Field Total	9,124	169,553	0	0	0
Dapper					
Niobrara	0	1,741,967	0	0	0
Field Total	0	1,741,967	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Darby Creek					
D Sand	1,720,148	2,756,746	0	0	0
J Sand	4,195	0	0	0	51,250
Muddy (J)	110,639	218,184	0	0	0
Field Total	1,834,982	2,974,930	0	0	51,250
Dart					
J Sand	11,301	0	0	0	45,490
Muddy (J)	314,592	22,633	0	0	0
Field Total	325,893	22,633	0	0	45,490
De Nova					
J Sand	0	0	0	0	0
Muddy (J)	135,976	3,347	0	0	0
Niobrara	1,215	21,894,363	0	0	35,843
Field Total	137,191	21,897,710	0	0	35,843
Deadeye					
D Sand	4,464	20,694	0	0	0
D Sand	855,354	4,438,278	0	0	1,951
D Sand, Muddy (J)	284,029	1,658,746	0	0	0
J Sand	0	0	0	0	0
J Sand	0	477	0	0	0
Muddy (J)	47,400	158,098	0	0	0
Muddy (J)	0	2,611	0	0	0
Field Total	1,191,247	6,278,904	0	0	1,951
Deadman					
Frontier	963	202,864	0	0	0
Field Total	963	202,864	0	0	0
Dealer					
Dakota, Muddy (J)	66,459	0	0	0	0
J Sand	16,118	0	0	0	943,810
Field Total	82,577	0	0	0	943,810
Dearfield					
D Sand, Codell SS	2,653	74,145	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	6,471	29,939	0	0	0
Field Total	9,124	104,084	0	0	0
DeBeque					
Mesaverde	112	943,158	0	0	77
Williams Fork	0	0	0	0	0
Williams Fork, Cameo	0	0	0	0	0
Field Total	112	943,158	0	0	77
Deep Pockets					
J Sand	29,610	32,572	0	0	1,129
Muddy (J)	11,441	10,536	0	0	0
Field Total	41,051	43,108	0	0	1,129
Deer Trail					
D Sand	61,846	469,057	0	0	0
J Sand	2,984	277,807	0	0	0
Muddy (J)	325,251	9,703,541	0	0	0
Field Total	390,081	10,450,405	0	0	0
Del Norte					
Tertiary Volcanics	1,855	0	0	0	0
Volcanics	0	0	0	0	0
Field Total	1,855	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Delaney Butte					
Dakota	10,600	0	0	0	0
Frontier	2,331	358	0	0	0
Niobrara	2,015	1,015	0	0	0
Field Total	14,946	1,373	0	0	0
Desert Canyon					
Ismay	60,741	132,098	0	0	0
Field Total	60,741	132,098	0	0	0
Desperado					
D Sand	610	2,460	0	0	0
Field Total	610	2,460	0	0	0
Diablo					
D Sand	869	2,717	0	0	0
Field Total	869	2,717	0	0	0
Dike					
D Sand	123,731	2,992,264	0	0	0
Field Total	123,731	2,992,264	0	0	0
Dike Mountain					
Dakota, Entrada Ss	0	0	0	7,248,020	0
Field Total	0	0	0	7,248,020	0
Dill Gulch					
Niobrara	27,718	1,921	0	0	0
Field Total	27,718	1,921	0	0	0
Dino					
Spergen	153,507	11,942	0	0	36,025
Field Total	153,507	11,942	0	0	36,025
Dinosaur					
Mancos B	0	0	0	0	0
Mancos Sh	107	0	0	0	0
Field Total	107	0	0	0	0
Dipper Gap					
D Sand	137,615	4,083,965	0	0	32,278
Field Total	137,615	4,083,965	0	0	32,278
Ditch					
D Sand	19,276	373,081	0	0	0
Field Total	19,276	373,081	0	0	0
Divide					
D Sand	3,875,467	2,974,417	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	590,613	1,058,632	0	0	0
Field Total	4,466,080	4,033,049	0	0	0
Divide Creek					
Cameo Coal	0	0	10,780	0	7,276
Cameo Coal	0	0	15,758	0	501
Corcoran	0	44,944	0	0	595
Cozette	0	84,077	0	0	1,643
Cozette, Corcoran	0	0	0	0	0
Cozette, Rollins	0	44,773	0	0	0
Mesaverde	0	1,899,819	0	0	0
Mesaverde	68	60,512,121	0	0	484
Mesaverde Coal	0	0	1,498,291	0	0
Mesaverde Coal	0	0	201,692	0	0
Rollins	0	27,510	0	0	1,597
Williams Fork	0	856,289	0	0	0
Field Total	68	63,469,533	1,726,521	0	12,096

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Doherty					
J Sand	0	0	0	0	0
Muddy (J)	83,849	2,828,040	0	0	0
Field Total	83,849	2,828,040	0	0	0
Dolley					
D Sand	311,895	1,673,572	0	0	320
Field Total	311,895	1,673,572	0	0	320
Doodlebug					
D Sand	1,286	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	370	48,718	0	0	0
Field Total	1,656	48,718	0	0	0
Dorado					
D Sand	28,447	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	159,125	0	0	0	0
Field Total	187,572	0	0	0	0
Double Eagle					
D Sand	119,537	373,411	0	0	1,475
Honaker Trail	265	448,156	0	0	102
Field Total	119,802	821,567	0	0	1,577
Double Take					
Lansing	17,366	0	0	0	0
Field Total	17,366	0	0	0	0
Doubletree					
D Sand	95,371	469,790	0	0	283
J Sand	1,079	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	141,397	240,660	0	0	0
Muddy (J)	104,359	5,396,018	0	0	0
Field Total	342,206	6,106,468	0	0	283
Douglas Creek					
Dakota	1,165	162,422	0	0	1,320
Dakota	1,510	13,915,367	0	0	451,432
Mancos A	0	60,999	0	0	94
Mancos B	3,405	4,976,607	0	0	5,999
Mancos Sh	1,331	37,078,250	0	0	307
Field Total	7,411	56,193,645	0	0	459,152
Douglas Creek North					
Castlegate	0	17,691	0	0	2
Dakota	10,218	2,756,420	0	0	1,093
J Sand	0	0	0	0	0
Mancos B	938	2,862,877	0	0	10,381
Mancos Sh	16,308	26,653,125	0	0	90
Mesaverde	0	627,475	0	0	0
Mesaverde, Mancos Sh	0	16,997,106	0	0	0
Morapos, Mancos	0	132,673	0	0	0
Morrison	3,680	30,963	0	0	0
Weber Ss	47,634	0	0	0	1,907
Field Total	78,778	50,078,330	0	0	13,473

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Douglas Creek South					
Buckhorn	0	6,819	0	0	0
Buckhorn, Morrison	0	116,204	0	0	0
Castlegate	0	1,105,104	0	0	1,225
Cedar Mountain, Morrison	0	709,991	0	0	0
Dakota	216	2,686,782	0	0	63
Dakota, Buckhorn	0	0	0	0	0
Dakota, Cedar Mountain	0	163,296	0	0	0
Mancos A	0	139,697	0	0	102
Mancos B	436	4,935,520	0	0	13,697
Mancos Sh	0	3,144,273	0	0	468
Mesaverde	0	1,930,628	0	0	0
Morapos	0	403,099	0	0	1,080
Morrison	0	72,128	0	0	192
Niobrara	0	75,633	0	0	7
Field Total	652	15,489,174	0	0	16,834
Douglas Creek West					
Mancos B	0	297,850	0	0	815
Mancos Sh	182	714	0	0	0
Field Total	182	298,564	0	0	815
Douglas Lake					
Lyons Ss	12,548	0	0	0	0
Niobrara	4,517	2,685	0	0	0
Field Total	17,065	2,685	0	0	0
Douglas Pass					
Dakota	2,825	6,674,789	0	0	1,875
Dakota, Morrison	0	107,025	0	0	0
Field Total	2,825	6,781,814	0	0	1,875
Dove Creek					
Desert Creek	373	0	0	0	0
Molas	84,309	946,234	0	0	0
Field Total	84,682	946,234	0	0	0
Dragon Trail					
Emery	0	373,591	0	0	2,118
Mancos A	186	345,363	0	0	8,822
Mancos A, B	0	196,406	0	0	372
Mancos B	28,954	35,695,884	0	0	113,505
Mancos Sh	52,783	230,182,613	0	0	2,137
Mancos Sh, Mesaverde	229	6,824,894	0	0	0
Mancos, Emery	0	747,321	0	0	0
Mesaverde	0	975,491	0	0	0
Morapos	0	0	0	0	0
Field Total	82,152	275,341,563	0	0	126,954
Dragon Trail North					
Mancos B	0	129,955	0	0	623
Mancos Sh	17,394	542,591	0	0	0
Field Total	17,394	672,546	0	0	623
Dragoon					
D Sand	1,159,858	5,542,947	0	0	683
D Sand, Muddy (J)	37,403	1,060,221	0	0	0
J Sand	8,215	62,469	0	0	5
Muddy (J)	297,439	1,741,217	0	0	0
Field Total	1,502,915	8,406,854	0	0	688

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Drifter					
D Sand	1,317	55	0	0	0
Field Total	1,317	55	0	0	0
Dry Creek					
Niobrara	102,673	243,967	0	0	1
Field Total	102,673	243,967	0	0	1
Dry Fork					
Cedar Mountain	0	164,212	0	0	1,230
Cozette	0	512	0	0	0
Dakota	0	793,677	0	0	1,230
Dakota, Cedar Mountain	0	864,193	0	0	0
Mesaverde	0	17,490	0	0	0
Field Total	0	1,840,084	0	0	2,460
Dry Gulch					
J Sand	0	0	0	0	0
Mesaverde	41	26,853	0	0	0
Muddy (J)	132	0	0	0	0
Field Total	173	26,853	0	0	0
Duck Creek					
Wasatch	1,004	0	0	0	0
Field Total	1,004	0	0	0	0
Dugout					
D Sand	5,784	0	0	0	0
Field Total	5,784	0	0	0	0
Duke					
Niobrara	0	1,782,955	0	0	12,809
Field Total	0	1,782,955	0	0	12,809
Dull Knife					
J Sand	0	0	0	0	0
Muddy (J)	15,537	0	0	0	0
Field Total	15,537	0	0	0	0
Dune Ridge					
D Sand	1,766,353	2,059,012	0	0	56,535
J Sand	0	0	0	0	0
Muddy (J)	18	453	0	0	0
Field Total	1,766,371	2,059,465	0	0	56,535
Dust Bowl					
Marmaton	1,164	0	0	0	0
Mississippian	0	0	0	0	0
Field Total	1,164	0	0	0	0
Dust Devil					
Morrow	35	236,535	0	0	0
Field Total	35	236,535	0	0	0
Eagle					
D Sand	303	0	0	0	0
Fort Hays	0	0	0	0	0
J Sand	209	0	0	0	0
Muddy (J)	16,724	21,435	0	0	0
Niobrara	0	200	0	0	0
Field Total	17,236	21,635	0	0	0
East Prong					
D Sand	31,523	10,842	0	0	0
Field Total	31,523	10,842	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Eastward					
D Sand	6,782	0	0	0	0
Field Total	6,782	0	0	0	0
Eaton					
Codell Ss	2,078,959	9,465,218	0	0	21,699
Niobrara	59,140	208,549	0	0	33
Niobrara, Codell Ss	521,088	2,312,639	0	0	8,031
Niobrara, Fort Hays, Codell	4,572	36,632	0	0	897
Field Total	2,663,759	12,023,038	0	0	30,660
Echo Canyon					
D Sand	16,099	26,214	0	0	0
Field Total	16,099	26,214	0	0	0
Eckley					
Niobrara	0	45,090,906	0	0	183,289
Field Total	0	45,090,906	0	0	183,289
Egret					
D Sand	307,780	858,522	0	0	4
J Sand	0	0	0	0	0
Muddy (J)	516	43,638	0	0	0
Field Total	308,296	902,160	0	0	4
Electra					
J Sand	6,493	15,936	0	0	0
Muddy (J)	49,634	174,267	0	0	0
Field Total	56,127	190,203	0	0	0
Elephant					
Morrow	0	395,784	0	0	0
Field Total	0	395,784	0	0	0
Elk Springs					
Dakota	0	24,126	0	0	0
Leadville	0	0	0	0	0
Minturn	0	0	0	0	0
Phosphoria	0	0	0	0	0
Weber Ss	627,449	13,030	0	0	882,300
Field Total	627,449	37,156	0	0	882,300
Elm Grove					
D Sand	1,296,210	3,801,724	0	0	2,950,235
J Sand	7,001	16,308	0	0	217,680
Muddy (J)	108,290	417,302	0	0	0
Field Total	1,411,501	4,235,334	0	0	3,167,915
Ember					
J Sand	7,227	0	0	0	519,653
Muddy (J)	40,049	0	0	0	0
Field Total	47,276	0	0	0	519,653
Emblem					
J Sand	0	0	0	0	0
Muddy (J)	1,282	3,147	0	0	0
Field Total	1,282	3,147	0	0	0
Emerald					
J Sand	21,499	23,207	0	0	429,348
Muddy (J)	760,662	945,999	0	0	0
Field Total	782,161	969,206	0	0	429,348

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Empire					
Greenhorn Ls	1,787	0	0	0	0
Greenhorn Ls	791	0	0	0	0
J Sand	0	0	0	0	0
Field Total	2,578	0	0	0	0
Encampment					
St Louis	107	0	0	0	0
Field Total	107	0	0	0	0
Enigma					
J Sand	654	4,281	0	0	1,550
Muddy (J)	7,014	11,273	0	0	0
Field Total	7,668	15,554	0	0	1,550
Epiphany					
J Sand	54,412	0	0	0	2,188,980
Muddy (J)	377,478	332	0	0	0
Field Total	431,890	332	0	0	2,188,980
Erin					
J Sand	0	0	0	0	0
Muddy (J)	11,395	0	0	0	0
Field Total	11,395	0	0	0	0
Ermine					
Codell Ss	3,950	2	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	29,495	16,377	0	0	0
Field Total	33,445	16,379	0	0	0
Eureka Creek					
Marmaton	94,655	0	0	0	86,942
Field Total	94,655	0	0	0	86,942
Evacuation Creek					
Dakota	0	0	0	0	0
Dakota, Morrison, Saltwash	0	146,580	0	0	0
Mancos B	0	1,336,590	0	0	4,894
Mancos Sh	0	2,912,305	0	0	0
Morrison	0	0	0	0	0
Salt Wash	0	0	0	0	0
Field Total	0	4,395,475	0	0	4,894
Fairway					
J Sand	28,564	308,274	0	0	21,180
Muddy (J)	348,967	2,780,395	0	0	0
Field Total	377,531	3,088,669	0	0	21,180
Falcon					
D Sand	83,997	61,221	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	166,547	168,098	0	0	0
Field Total	250,544	229,319	0	0	0
Fallow					
Marmaton	101,315	21,343	0	0	189,402
Field Total	101,315	21,343	0	0	189,402
Faro					
Dakota, Muddy (J)	41,520	0	0	0	0
J Sand	13,938	0	0	0	213,091
Muddy (J)	263,636	0	0	0	0
Field Total	319,094	0	0	0	213,091

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Farside					
Morrow	71,333	6,755	0	0	254,606
Field Total	71,333	6,755	0	0	254,606
Fawn Creek					
Mesaverde	56	33,663	0	0	0
Williams Fork	82	0	0	0	25
Field Total	138	33,663	0	0	25
Feather					
J Sand	0	0	0	0	0
Muddy (J)	28,952	0	0	0	0
Field Total	28,952	0	0	0	0
Featherstone					
Morrow	630	312,023	0	0	519
Field Total	630	312,023	0	0	519
Fence Post					
D Sand	187,580	1,230,609	0	0	3,697
D Sand, Muddy (J)	4,997	81,532	0	0	0
Field Total	192,577	1,312,141	0	0	3,697
Feral					
Niobrara	0	489,725	0	0	0
Field Total	0	489,725	0	0	0
Ferret					
J Sand	9,077	409,529	0	0	2,927
Muddy (J)	16,852	647,530	0	0	0
Field Total	25,929	1,057,059	0	0	2,927
Fever Pitch					
Morrow	782	1,585,741	0	0	2,098
Field Total	782	1,585,741	0	0	2,098
Fiesta					
J Sand	657	0	0	0	0
Muddy (J)	174,831	0	0	0	0
Field Total	175,488	0	0	0	0
Firecreek					
J Sand	1,138	31,898	0	0	273
Muddy (J)	8,249	176,029	0	0	0
Field Total	9,387	207,927	0	0	273
First Creek					
Sussex	72,050	23,951	0	0	1,049
Field Total	72,050	23,951	0	0	1,049
First-One					
D Sand	141,987	13,548	0	0	272,062
J Sand	19,264	0	0	0	98,399
Muddy (J)	59,176	0	0	0	0
Field Total	220,427	13,548	0	0	370,461
Firstview					
Morrow	0	0	0	0	0
Field Total	0	0	0	0	0
Fish Creek					
Niobrara	52,203	18,638	0	0	0
Field Total	52,203	18,638	0	0	0
Flag					
D Sand	67,436	51,942	0	0	0
Field Total	67,436	51,942	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Flank					
Atoka	0	16,898	0	0	0
Cherokee	5,008	6,970,636	0	0	0
Keyes	0	56,907	0	0	0
Marmaton	0	0	0	0	0
Morrow	2,672,202	6,354,932	0	0	77,614
Morrow B	79,169	0	0	0	0
Red Cave	0	357,614	0	0	18,019
Topeka A	0	0	0	0	0
Topeka Ls	0	445,149	0	0	0
Wabaunsee	0	16,401	0	0	0
Field Total	2,756,379	14,218,537	0	0	95,633
Flank North West					
Cherokee	2,538	702,455	0	0	4,947
Keyes	0	1,813,617	0	0	4,457
Field Total	2,538	2,516,072	0	0	9,404
Flat Praire					
D Sand	28,849	70	0	0	0
Field Total	28,849	70	0	0	0
Fleming					
J Sand	0	0	0	0	0
Muddy (J)	0	2,392	0	0	0
Field Total	0	2,392	0	0	0
Flickertail					
D Sand	9,417	33,810	0	0	0
Field Total	9,417	33,810	0	0	0
Flint					
J Sand	0	0	0	0	0
Muddy (J)	1,197	1,780	0	0	0
Field Total	1,197	1,780	0	0	0
Flintlock					
J Sand	0	0	0	0	0
Muddy (J)	13,356	1,855	0	0	0
Field Total	13,356	1,855	0	0	0
Flodine Park					
Desert Creek	271,903	1,192,369	0	0	0
Ismay	2,305,520	8,528,079	0	0	53,777
Paradox	616	21,452	0	0	0
Field Total	2,578,039	9,741,900	0	0	53,777
Flodine Park East					
Ismay	248,899	1,409,006	0	0	213
Field Total	248,899	1,409,006	0	0	213
Florence-Canon City					
Niobrara	236	0	0	0	0
Niobrara, Codell Ss	513	0	0	0	0
Pierre B	2,050	0	0	0	0
Pierre Sh	15,356,561	19,995	0	0	0
Field Total	15,359,360	19,995	0	0	0
Focus Ranch					
Igneous Sill, Intrusive	10,113	0	0	0	0
Field Total	10,113	0	0	0	0
Football					
J Sand	0	0	0	0	0
Muddy (J)	11,214	5,400	0	0	0
Field Total	11,214	5,400	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Ford					
J Sand	0	0	0	0	0
Muddy (J)	926	0	0	0	0
Field Total	926	0	0	0	0
Forge					
D Sand	112,647	38,207	0	0	0
Field Total	112,647	38,207	0	0	0
Fort Collins					
Dakota	2,279	0	0	0	178,312
J Sand	17,821	0	0	0	524,574
Lyons Ss	346,372	15,728	0	0	101,025
Muddy	426,658	68	0	0	9,171,524
Muddy (J)	5,321,638	461,025	0	0	2,586,528
Niobrara	24,232	718	0	0	30,406
Field Total	6,139,000	477,539	0	0	12,592,369
Fort Morgan					
D Sand	160,836	9,729,497	0	0	0
J Sand	0	0	0	0	0
Field Total	160,836	9,729,497	0	0	0
Fortification Creek					
Lewis Sh	5,790	823,921	0	0	24,931
Mesaverde	1,099	1,332,961	0	0	582
Field Total	6,889	2,156,882	0	0	25,513
Fortuna					
Lansing	3,324	1,902	0	0	0
Field Total	3,324	1,902	0	0	0
Fosston					
J Sand	0	0	0	0	0
Muddy (J)	1,995	245,545	0	0	0
Niobrara, Codell Ss	4,534	24,179	0	0	0
Field Total	6,529	269,724	0	0	0
Fosston Southwest					
J Sand	0	0	0	0	0
Muddy (J)	2,294	9,618	0	0	0
Niobrara, Codell Ss	1,337	16,762	0	0	0
Field Total	3,631	26,380	0	0	0
Foundation Creek					
Cedar Mountain	7,120	964,371	0	0	0
Dakota	6	239,994	0	0	112
Dakota, Morrison	0	11,123	0	0	0
Mancos B	0	33,451	0	0	75
Mancos B	0	1,749,535	77,933	0	7,180
Mancos Sh	0	135,884	0	0	0
Mancos Sh	32	4,391,081	0	0	74
Field Total	7,158	7,525,439	77,933	0	7,441
Four Mile Creek					
Lance	0	311,059	0	0	0
Lewis Sh	1,315	363,320	0	0	3,252
Field Total	1,315	674,379	0	0	3,252
Fox Field					
D Sand	2,925	283,372	0	0	0
Field Total	2,925	283,372	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Franks					
J Sand	10,450	480	0	0	33,720
Muddy (J)	12,127	8,699	0	0	0
Field Total	22,577	9,179	0	0	33,720
Frasco					
D Sand	6,254	0	0	0	0
D Sand, Muddy (J)	124,563	222,337	0	0	0
J Sand	10,349	10,420	0	0	810,891
Muddy (J)	1,278,606	586,372	0	0	0
Field Total	1,419,772	819,129	0	0	810,891
Fremont Butte					
D Sand	8,538	44,450	0	0	0
Field Total	8,538	44,450	0	0	0
Frenchman Creek					
J Sand	0	0	0	0	0
Muddy (J)	107	358,159	0	0	0
Field Total	107	358,159	0	0	0
Frenchman Creek South					
J Sand	0	0	0	0	0
Muddy (J)	0	22,038	0	0	0
Field Total	0	22,038	0	0	0
Friday					
D Sand	13,447	581,041	0	0	0
Field Total	13,447	581,041	0	0	0
Fringe					
D Sand	122,901	323,502	0	0	0
Field Total	122,901	323,502	0	0	0
Frontera					
Morrow	3,666,721	5,615,867	0	0	528
Morrow A	36,702	241,730	0	0	0
Morrow B	1,091,093	4,077,541	0	0	38,774
Field Total	4,794,516	9,935,138	0	0	39,302
Frontier					
J Sand	0	0	0	0	0
Muddy (J)	210,474	327,587	0	0	0
Field Total	210,474	327,587	0	0	0
Fruita					
Morrison	0	607,228	0	0	0
Field Total	0	607,228	0	0	0
Full House					
D Sand	78,585	421,699	0	0	1,200
Field Total	78,585	421,699	0	0	1,200
Full Moon					
Mississippian	47,348	0	0	0	13,520
Field Total	47,348	0	0	0	13,520
Fury					
J Sand	810	0	0	0	4,725
Muddy (J)	148,607	50,767	0	0	0
Niobrara	4,443	4,467	0	0	5,225
Field Total	153,860	55,234	0	0	9,950

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Galeton					
Codell Ss	29,657	78,881	0	0	47
J Sand	312	9,375	0	0	0
Muddy (J)	0	77	0	0	0
Niobrara, Codell Ss	15,297	87,420	0	0	83
Field Total	45,266	175,753	0	0	130
Gall					
D Sand	5,068	7,432	0	0	0
Field Total	5,068	7,432	0	0	0
Gambler					
D Sand	28,595	208,385	0	0	374
D Sand, Muddy (J)	47,915	242,700	0	0	0
J Sand	301	2,946	0	0	45
Field Total	76,811	454,031	0	0	419
Gambrel					
J Sand	654	30,365	0	0	742
J Sand	1,276	29,651	0	0	0
Muddy (J)	3,037	357,446	0	0	0
Muddy (J)	1,672	201,552	0	0	0
Field Total	6,639	619,014	0	0	742
Garcia					
Pierre Sh, Niobrara	0	1,561,000	0	0	0
Pierre, Apishapa	0	0	0	0	0
Field Total	0	1,561,000	0	0	0
Gardner					
Gardner					
Codell Ss	4,253	3,179	0	0	0
Field Total	4,253	3,179	0	0	0
Garmesa					
Buckhorn	0	0	0	0	0
Dakota	0	1,802,645	0	0	0
Dakota, Morrison	0	2,001,213	0	0	0
Entrada Ss	0	3,349,998	0	0	0
Morrison	0	0	0	0	0
Salt Wash	0	0	0	0	0
Salt Wash, Dakota	0	98,558	0	0	0
Field Total	0	7,252,414	0	0	0
Garnet					
D Sand	202,062	185,281	0	0	104,504
Field Total	202,062	185,281	0	0	104,504
Gary					
D Sand	17,119	5,454	0	0	0
Field Total	17,119	5,454	0	0	0
Gary North					
D Sand	301,122	207,830	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	5,904	1,151,560	0	0	0
Field Total	307,026	1,359,390	0	0	0
Gary West					
D Sand	0	0	0	0	0
Muddy (J)	45,968	1,810	0	0	0
Field Total	45,968	1,810	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Gasaway					
Corcoran	0	89,549	0	0	967
Cozette	0	117,113	0	0	5,150
Cozzette, Corcoran	0	19,536	0	0	0
Dakota	16	11,000,460	0	0	43,956
Lloyd Ss	0	64,660	0	0	5,592
Mancos B	942	753,667	0	0	9,935
Mancos Sh	4,986	3,201,356	0	0	9,767
Mesaverde	1,413	950,170	0	0	0
Rollins	150	122,516	0	0	7,061
Sego	807	871,266	0	0	17,722
Williams Fork	0	7,184	0	0	2,281
Field Total	8,314	17,197,477	0	0	102,431
Gaslight					
J Sand	0	0	0	0	0
Muddy (J)	650	108,216	0	0	0
Field Total	650	108,216	0	0	0
Gazelle					
J Sand	8,208	69,046	0	0	1,692
Muddy (J)	45,617	1,032,086	0	0	0
Field Total	53,825	1,101,132	0	0	1,692
Gemini					
D Sand	58,445	2,807,257	0	0	0
Field Total	58,445	2,807,257	0	0	0
Gilliam Draw					
Dakota	3,588	248,715	0	0	0
Field Total	3,588	248,715	0	0	0
Gillsonite Draw					
Castlegate	2,411	1,274,739	0	0	0
Mancos B	2,983	3,763,226	0	0	0
Mesaverde	25,875	0	0	0	0
Field Total	31,269	5,037,965	0	0	0
Gingham					
D Sand	20,961	0	0	0	0
Field Total	20,961	0	0	0	0
Goat Hill					
D Sand	11,207	46,730	0	0	0
J Sand	13,840	1,200	0	0	320,150
Muddy (J)	788,415	1,425,565	0	0	0
Field Total	813,462	1,473,495	0	0	320,150
Golden Spike					
Mississippian	1,752,255	0	0	0	1,542,377
Mississippian, Osage	0	0	0	0	0
Mississippian, Spergen	0	0	0	0	0
Spergen	302	250	0	0	0
St Louis, Spergen	14,092	1,173	0	0	0
Field Total	1,766,649	1,423	0	0	1,542,377
Goodman Point					
Desert Creek	1,401	552	0	0	0
Field Total	1,401	552	0	0	0
Goodrich					
J Sand	0	0	0	0	0
Muddy (J)	5,436	1,770	0	0	0
Field Total	5,436	1,770	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Goose					
D Sand	142,725	307,793	0	0	0
Field Total	142,725	307,793	0	0	0
Gopher					
Codell Ss	0	0	0	0	0
Morrow	31,594	0	0	0	0
Field Total	31,594	0	0	0	0
Goss Mohawk					
D Sand	395	3,902	0	0	0
Field Total	395	3,902	0	0	0
Grail					
D Sand	251,002	618,827	0	0	0
Field Total	251,002	618,827	0	0	0
Grand Mesa					
Mesaverde	0	741	0	0	0
Williams Fork, Cameo	0	426,630	0	0	1,362
Field Total	0	427,371	0	0	1,362
Grand Slam					
Mesaverde	287	307,359	0	0	666
Williams Fork	295	183,150	0	0	7,378
Field Total	582	490,509	0	0	8,044
Grand Valley					
Cameo	0	0	0	0	0
Cameo Coal	0	54,188	717,994	0	47
Codell Ss	0	97,580	0	0	518
Corcoran	0	15,559	0	0	0
Cozette	0	15,563	0	0	0
Cozz, Crcrn, Rlns, Cmeo, Wmfrk	0	287,340	0	0	1,499
Cozzette, Corcoran	0	40,502	0	0	550
Mesaverde	25,358	38,366,067	0	0	26,194
Mesaverde Coal	0	0	12,056,804	0	0
Rollins	0	14,940	0	0	0
Rollins, Cameo	0	0	0	0	0
Rollins, Williams Fork	154	213,558	0	0	0
Wasatch	0	476,106	0	0	0
Williams Fork	18,123	18,185,618	378,128	0	124,025
Williams Fork, Cameo	24,362	157,073,036	5,608,400	0	2,195,443
Williams Fork, Cameo Coal	0	303,672	0	0	4,374
Williams Fork, Cameo Ss	23	184,812	0	0	0
Field Total	68,020	215,328,541	18,761,326	0	2,352,650
Grande					
Raton Coal	0	0	0	0	0
Vermejo Coal	0	625	1,280	0	56,099
Field Total	0	625	1,280	0	56,099
Grande West					
Raton Coal	0	37,264	23,786	0	31,114
Vermejo Coal	0	925	11,011	0	19,952
Field Total	0	38,189	34,797	0	51,066
Granny					
D Sand	6,936	361,244	0	0	0
Field Total	6,936	361,244	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Grassy Creek					
Niobrara	1,163,127	325,483	0	0	1
Field Total	1,163,127	325,483	0	0	1
Gravel					
D Sand	809	0	0	0	0
Field Total	809	0	0	0	0
Graylin Northwest					
D Sand	11,639,411	9,524,585	0	0	515,686
J Sand	32,308	19,891	0	0	235,467
Muddy (J)	1,772,513	2,285,699	0	0	0
unknown	0	0	0	0	0
Field Total	13,444,232	11,830,175	0	0	751,153
Greasewood					
D Sand	6,480	188,227	0	0	0
D Sand	1,093,995	2,085,723	0	0	600
Field Total	1,100,475	2,273,950	0	0	600
Greasewood Flats					
D Sand	11,642	640,465	0	0	0
Field Total	11,642	640,465	0	0	0
Greasewood South					
D Sand	222,977	1,609,245	0	0	0
Field Total	222,977	1,609,245	0	0	0
Great Divide					
Almond	0	0	0	0	0
Lewis Sh	39,559	5,796,217	0	0	22,799
Mesaverde	1,640	175,567	0	0	0
Field Total	41,199	5,971,784	0	0	22,799
Great Expectations					
Morrow	704	863,129	0	0	9,362
Field Total	704	863,129	0	0	9,362
Greeley					
Codell Ss	1,017,405	7,608,976	0	0	37,546
Niobrara	11,290	69,593	0	0	0
Niobrara, Codell Ss	1,132,397	9,290,803	0	0	25,920
Niobrara, Fort Hays, Codell Ss	9,775	148,875	0	0	459
Parkman	134,848	23,343	0	0	673,741
Richards Ss	1,342,000	359,734	0	0	0
unknown	0	0	0	0	0
Field Total	3,647,715	17,501,324	0	0	737,666
Greenwood					
Keyes	0	7,642	0	0	0
Lansing	0	286,121	0	0	491
Morrow	309,006	146,440	0	0	0
Red Cave	69	1,652,107	0	0	1,678
Topeka A	0	82,473	0	0	0
Topeka C	0	111,723	0	0	2,791
Topeka Ls	396	19,456,129	0	0	126,661
Topeka Ls, Lansing	0	6,455,071	0	0	0
Toronto	0	88,823	0	0	3
Field Total	309,471	28,286,529	0	0	131,624
Gringo					
J Sand	0	0	0	0	0
Muddy (J)	1,521	1,143	0	0	0
Field Total	1,521	1,143	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Grizzly Creek					
Niobrara	1,112	0	0	0	0
Shannon	230	0	0	0	0
Field Total	1,342	0	0	0	0
Grizzly Creek Southeast					
Niobrara	1,612	0	0	0	0
Field Total	1,612	0	0	0	0
Grouse					
Mississippian	847,561	14,791	0	0	0
Mississippian, Spergen	22,614	0	0	0	506,500
Morrow	262,668	120,688	0	0	328,959
Spergen	602,567	28,727	0	0	1,175,227
Spergen, Osage	0	0	0	0	0
Field Total	1,735,410	164,206	0	0	2,010,686
Grover					
J Sand	0	0	0	0	0
Muddy (J)	19,112	134,282	0	0	0
Field Total	19,112	134,282	0	0	0
Guidon					
D Sand	9,312	40,898	0	0	54
J Sand	2,467	150,987	0	0	257
Muddy (J)	18,567	1,484,875	0	0	0
Field Total	30,346	1,676,760	0	0	311
Gullible					
J Sand	27,800	0	0	0	595,728
Muddy (J)	125,593	0	0	0	0
Field Total	153,393	0	0	0	595,728
Gun Barrel					
D Sand	4,721	0	0	0	0
J Sand	3,266	53,701	0	0	824
Muddy (J)	6,165	152,591	0	0	0
Field Total	14,152	206,292	0	0	824
Gunsmoke					
J Sand	0	0	0	0	0
Muddy (J)	29,310	955	0	0	0
Field Total	29,310	955	0	0	0
Hadfield					
D Sand	2,433	14,276	0	0	0
Field Total	2,433	14,276	0	0	0
Hambert					
Codell Ss	39,026	1,298,207	0	0	12,306
Niobrara, Codell Ss	18,834	593,033	0	0	3,525
Sussex	1,074,509	47,540,749	0	0	72,773
Field Total	1,132,369	49,431,989	0	0	88,604
Hamil Ranch					
Dakota	14,512	0	0	0	0
O Sand	0	0	0	0	0
Field Total	14,512	0	0	0	0
Hamilton Creek					
Cutler	52	4,467,708	0	0	14,912
Hermosa	4,511	3,698,385	0	0	43,801
Honaker Trail	0	129,122	0	0	0
Field Total	4,563	8,295,215	0	0	58,713

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Hamm Canyon					
Hermosa	10,889	845,710	0	0	83
Field Total	10,889	845,710	0	0	83
Hammer Head					
J Sand	160,634	0	0	0	1,586,810
Field Total	160,634	0	0	0	1,586,810
Hancock Gulch					
Dakota	1	184,221	0	0	0
Dakota	0	5,892	0	0	0
Dakota, Morrison	0	1,150,398	0	0	0
Morrison	0	83,465	0	0	1,118
Field Total	1	1,423,976	0	0	1,118
Handle					
D Sand	8,104	16,675	0	0	0
Field Total	8,104	16,675	0	0	0
Happy Dog					
D Sand	11,480	557,982	0	0	0
Field Total	11,480	557,982	0	0	0
Hardway					
D Sand	1,056,798	545,636	0	0	314,160
Field Total	1,056,798	545,636	0	0	314,160
Harker Ranch					
Morrow	1,203,385	9,989,944	0	0	366,688
Morrow 3	0	214,009	0	0	1,124
Field Total	1,203,385	10,203,953	0	0	367,812
Harlech					
Codell Ss	22,340	73,331	0	0	0
J Sand	742	4,688	0	0	0
Muddy (J)	2,089	52,316	0	0	0
Niobrara, Codell Ss	64,129	327,183	0	0	90
Field Total	89,300	457,518	0	0	90
Harness					
Morrow	40	1,562,239	0	0	0
Field Total	40	1,562,239	0	0	0
Harrisburg					
J Sand	0	0	0	0	0
Muddy (J)	483,026	0	0	0	0
Field Total	483,026	0	0	0	0
Haswell					
Morrow	401,483	3,230,146	0	0	16,663
Field Total	401,483	3,230,146	0	0	16,663
Hawkeye					
D Sand	4,180	72,909	0	0	331
J Sand	15,855	397,518	0	0	1,912
Muddy (J)	167,405	3,358,090	0	0	0
Field Total	187,440	3,828,517	0	0	2,243
Hawthorne					
D Sand	7,636	2,390	0	0	0
Field Total	7,636	2,390	0	0	0
Haxtun					
J Sand	0	0	0	0	0
Muddy (J)	0	36,696	0	0	0
Field Total	0	36,696	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Hay Gulch					
Dakota	1,687	0	0	0	0
Field Total	1,687	0	0	0	0
Heart					
Codell Ss	1,894	0	0	0	0
Mesaverde	141	936,639	0	0	93
Niobrara	4,226	630	0	0	0
Field Total	6,261	937,269	0	0	93
Hector					
J Sand	0	0	0	0	0
Muddy (J)	112,354	78,643	0	0	0
Field Total	112,354	78,643	0	0	0
Hells Gulch					
Mesaverde	0	150,397	0	0	0
Field Total	0	150,397	0	0	0
Hells Hole Canyon					
Buckhorn	913	391,279	0	0	6,331
Castlegate	0	0	0	0	0
Dakota	69,915	30,006,782	0	0	38,131
Dakota, Buckhorn	912	450,795	0	0	93
Dakota, Cedar Mountain	1,343	601,506	0	0	0
Mancos A	0	511,746	0	0	3,605
Mancos B	95,499	485,521	0	0	15,894
Mancos Sh	49,741	243,253	0	0	0
Mesaverde	0	369,048	0	0	0
Morrison	6,289	697,585	0	0	2,310
Williams Fork	0	3,357	0	0	33,436
Field Total	224,612	33,760,872	0	0	99,800
Hereford					
Codell Ss	1,606	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	3,451	8,200	0	0	0
Niobrara	35,357	17,562	0	0	184
Niobrara, Codell Ss	4,468	3,136	0	0	0
Field Total	44,882	28,898	0	0	184
Hiawatha					
Entrada Ss, Nugget Ss	0	18,701,607	0	0	14,146
Fort Union	97,219	33,707,281	0	0	11,408
Fort Union, Lance	124,236	9,401,427	0	0	845
Fort Union, Lewis Sh	2,803	791,534	0	0	412
Fort Union, Wasatch	41,319	36,360,084	0	0	620
Fox Hills	275	141,195	0	0	221
Lance	1,048	1,120,389	0	0	938
Lance, Fort Union, Wasatch	2,869	973,162	0	0	0
Lewis Sh	7,603	2,731,166	0	0	3,575
Mesaverde	358	125,707	0	0	214
Nugget Ss	0	36,502,725	0	0	42,969
Wasatch	4,455,317	121,551,284	0	0	130,442
Wasatch F	2,061	824,737	0	0	0
Wasatch, Fort Union, Lewis Sh	11,579	3,631,159	0	0	0
Wasatch, Fort Union, Mesaverde	6,199	7,021,989	0	0	0
Field Total	4,752,886	273,585,446	0	0	205,790

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO₂ (Mscf)	Water (Barrels)
Hiawatha West					
Almond, Fort Union	0	0	0	0	0
Fort Union	33,296	24,879,176	0	0	11,703
Fort Union, Lance	28,334	12,199,319	0	0	618
Fort Union, Lance, Lewis Sh	42,348	7,242,904	0	0	0
Fort Union, Wasatch	202	226,345	0	0	145
Fox Hills	513	383,198	0	0	259
Lance	27,025	25,006,787	0	0	2,366
Lance, Fort Union, Wasatch	834	336,685	0	0	213
Lance, Fox Hills	2,736	2,665,138	0	0	621
Lance, Lewis Sh	45,477	24,664,681	0	0	0
Lance, Wasatch	3,488	2,513,583	0	0	0
Lewis Sh	9,937	4,452,860	0	0	13,433
Mesaverde	411	110,874	0	0	237
Mesaverde, Fort Union	8,946	350,033	0	0	234
Nugget Ss	0	0	0	0	0
Wasatch	39,344	41,138,603	0	0	11,158
Wasatch A	1,473	250,625	0	0	1,568
Wasatch, Fort Union, Lewis Sh	13,811	2,535,490	0	0	629
Wasatch, Fort Union, Mesaverde	8,083	11,637,118	0	0	62
Field Total	266,258	160,593,419	0	0	43,246
Hidden Arrow					
Mississippian	47,800	0	0	0	390,884
Field Total	47,800	0	0	0	390,884
Hidden Valley					
Niobrara	18,775	5,650	0	0	0
Field Total	18,775	5,650	0	0	0
High Plains					
Morrow	2,478	0	0	0	0
Field Total	2,478	0	0	0	0
High Pockets					
J Sand	153,504	0	0	0	3,210,844
Muddy (J)	595,966	0	0	0	0
Field Total	749,470	0	0	0	3,210,844
High Rock					
Atoka	360	0	0	0	0
Field Total	360	0	0	0	0
Highland					
Hygiene	0	0	0	0	0
Niobrara	2,500	10,940	0	0	0
Niobrara, Codell Ss	841	0	0	0	0
Shannon	358	0	0	0	0
Timpas, Codell	0	0	0	0	0
Field Total	3,699	10,940	0	0	0
Highline Canal					
Dakota	0	89,288	0	0	0
Salt Wash	0	184,129	0	0	0
Field Total	0	273,417	0	0	0
Hinge					
D Sand	204,891	500,032	0	0	0
Field Total	204,891	500,032	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Hirst					
J Sand	0	0	0	0	0
Muddy (J)	40,599	6,104	0	0	0
Field Total	40,599	6,104	0	0	0
Hoffman Creek					
D Sand	19,110	18,362	0	0	889
D Sand, Muddy (J)	102,181	281,617	0	0	0
J Sand	15,869	0	0	0	889
Muddy (J)	12,379	907,618	0	0	0
Field Total	149,539	1,207,597	0	0	1,778
Holland					
Niobrara	31,673	130,919	0	0	0
Niobrara, Codell Ss	125,867	971,166	0	0	0
Field Total	157,540	1,102,085	0	0	0
Holland West					
Niobrara	2,595	20,529	0	0	0
Niobrara, Codell Ss	18,617	92,698	0	0	0
Field Total	21,212	113,227	0	0	0
Holster					
D Sand	434,581	2,192,133	0	0	4,179
D Sand, Muddy (J)	169,141	2,407,077	0	0	0
J Sand	11,768	295,370	0	0	4,461
Muddy (J)	41,282	1,036,087	0	0	0
Field Total	656,772	5,930,667	0	0	8,640
Hombre					
J Sand	569	19,748	0	0	0
J Sand	16,820	0	0	0	135
Muddy (J)	972,967	2,575,714	0	0	0
Muddy (J)	268,321	694,058	0	0	0
Field Total	1,258,677	3,289,520	0	0	135
Home Run					
J Sand	0	0	0	0	0
Muddy (J)	2,360	0	0	0	0
Field Total	2,360	0	0	0	0
Homestead					
D Sand	81,343	70,993	0	0	260
J Sand	0	22,412	0	0	0
Muddy (J)	109	90,791	0	0	0
Field Total	81,452	184,196	0	0	260
Hone					
J Sand	0	0	0	0	0
Muddy (J)	519,627	81,402	0	0	0
Field Total	519,627	81,402	0	0	0
Hoolahan					
D Sand	57,999	0	0	0	43
Field Total	57,999	0	0	0	43
Horn					
J Sand	0	0	0	0	0
Muddy (J)	717	431	0	0	0
Field Total	717	431	0	0	0
Horse Creek					
D Sand	56,452	242,061	0	0	0
J Sand	261	39,274	0	0	882
Muddy (J)	387	82,772	0	0	0
Field Total	57,100	364,107	0	0	882

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Horse Gulch					
Dakota	224,083	0	0	0	0
Field Total	224,083	0	0	0	0
Horseshoe					
Corcoran	0	62,086	0	0	2,330
D Sand	6,404	15,432	0	0	0
Field Total	6,404	77,518	0	0	2,330
Horsetail					
D Sand	257,563	6,010,361	0	0	37,461
J Sand	0	0	0	0	0
Muddy (J)	11,489	36,521	0	0	0
Field Total	269,052	6,046,882	0	0	37,461
Horsethief Creek					
Corcoran	0	0	0	0	0
Wasatch	0	141,282	0	0	0
Field Total	0	141,282	0	0	0
Hot Dog					
J Sand	0	0	0	0	0
Muddy (J)	524	0	0	0	0
Field Total	524	0	0	0	0
Hotspur					
J Sand	65,490	0	0	0	610,847
Muddy (J)	148,677	0	0	0	0
Field Total	214,167	0	0	0	610,847
Houlet					
Niobrara	218	0	0	0	0
Field Total	218	0	0	0	0
House Creek					
Cutler	0	25,383	0	0	0
Field Total	0	25,383	0	0	0
Hoy Gulch					
J Sand	0	0	0	0	0
Muddy (J)	8,104	7,502	0	0	0
Field Total	8,104	7,502	0	0	0
Huckabee					
J Sand	0	0	0	0	0
Muddy (J)	1,656	0	0	0	0
Field Total	1,656	0	0	0	0
Hugo					
Arbuckle	0	0	0	0	0
Lansing, Kansas City	0	0	0	0	0
Marmaton	164,491	9,855	0	0	301,048
Mississippian	5,026	0	0	0	74,141
Field Total	169,517	9,855	0	0	375,189
Hunter					
J Sand	0	0	0	0	0
Muddy (J)	29,007	330,005	0	0	0
Field Total	29,007	330,005	0	0	0
Hunters Canyon					
Cedar Mountain	320	262,351	0	0	0
Cedar Mountain, Morrison	0	215	0	0	0
Dakota	0	4,077,130	0	0	0
Mesaverde	0	9,360,341	0	0	0
Field Total	320	13,700,037	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Hurry Up					
J Sand	0	0	0	0	0
Muddy (J)	15,618	0	0	0	0
Field Total	15,618	0	0	0	0
Hyde					
D Sand	2,427,384	542,335	0	0	1,563,878
Field Total	2,427,384	542,335	0	0	1,563,878
Ice					
Keyes	632	273,171	0	0	317
Morrow V7	0	334,217	0	0	22,036
Spergen	222	116,228	0	0	115
Field Total	854	723,616	0	0	22,468
Icon					
J Sand	0	0	0	0	0
Muddy (J)	792	40,484	0	0	0
Field Total	792	40,484	0	0	0
Ignacio Blanco					
Bluff	0	0	0	0	0
Bluff, Entrada	0	0	0	0	0
Dakota	0	0	0	0	0
Dakota	807	334,904,350	142,606	0	560,641
Dakota, Gallup	0	6,693	0	0	280
Dakota, Morrison	0	25,321,927	0	0	285
Dakota, Sanastee	0	1,687	0	0	0
Entrada Ss	0	0	0	0	19,840
Entrada, Bluff, Morrison	0	0	0	0	0
Fruitland	0	59,539	0	0	26
Fruitland	1,661	11,066,423	66,371	0	176,487
Fruitland Coal	0	114,437	8,376,709	0	964,405
Fruitland Coal	663	110,752,852	4,019,542,527	0	144,033,931
Fruitland, Pictured Cliffs	891	40,389,833	2,258	0	7,305
Gallup Ss	0	109,498	0	0	0
J Sand	97	15,240	0	0	1,080
Kirtland	0	0	0	0	0
Kirtland Sh	0	15,082	0	0	0
Lewis Sh	455	2,923,971	0	0	6
Mancos B	0	401	0	0	0
Mancos Sh	0	17,796	0	0	0
Mesaverde	0	588,302	0	0	11,525
Mesaverde	52,177	862,646,024	0	0	674,220
Mesaverde Coal	0	0	753	0	1,702
Mesaverde, Dakota	0	3,903,056	0	0	1,041
Mesaverde, Sanastee	0	39,929	0	0	0
Morrison	0	0	0	0	0
Nacimiento	0	43,883	0	0	0
Niobrara	0	57,690	0	0	0
Pictured Cliffs	0	0	0	0	0
Pictured Cliffs	73,174	74,748,608	15,031	0	95,245
Pictured Cliffs, Mesaverde	51	3,274,926	0	0	38,240
Pictured Cliffs, Mesaverde, Dakota	0	491,602	0	0	0
Pierre B	140	0	0	0	2,610
Point Lookout	0	421,645	0	0	243
Sanastee	0	4,806	0	0	0
Field Total	130,116	1,471,920,200	4,028,146,255	0	146,589,112

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Iles					
Curtis	70,582	0	0	0	0
Morrison	1,344,211	59,941	0	0	20,765
Morrow	0	0	0	0	0
Mowry	147,470	0	0	0	0
Sundance	17,982,161	1,990,485	0	0	50,640,041
Field Total	19,544,424	2,050,426	0	0	50,660,806
Impala					
J Sand	0	0	0	0	0
Muddy (J)	5,401	5,757	0	0	0
Field Total	5,401	5,757	0	0	0
Incline					
J Sand	23,552	0	0	0	175,560
Muddy (J)	218,845	0	0	0	0
Field Total	242,397	0	0	0	175,560
Independence					
Sussex	830	1,170	0	0	0
Field Total	830	1,170	0	0	0
Indian					
Keyes	217	0	0	0	0
Field Total	217	0	0	0	0
Indian Bead					
Mississippian	71,929	564	0	0	0
Field Total	71,929	564	0	0	0
Indian Cave					
J Sand	2,362	12,418	0	0	75
Muddy (J)	276,798	866,344	0	0	0
Field Total	279,160	878,762	0	0	75
Indian Run					
Dakota	13	1,140	0	0	0
Field Total	13	1,140	0	0	0
Indio					
Morrow	489	225	0	0	0
Field Total	489	225	0	0	0
Intrepid					
J Sand	0	0	0	0	0
Muddy (J)	42,772	1,329	0	0	0
Field Total	42,772	1,329	0	0	0
Irish Creek					
Fort Union	1,640	201,174	0	0	3,408
Mesaverde	0	26,824	0	0	0
Field Total	1,640	227,998	0	0	3,408
Irondale					
D Sand	1,290,018	5,169,040	0	0	3,992
D Sand, Muddy (J)	482,266	2,276,884	0	0	0
J Sand	5,881	49,522	0	0	69
Muddy (D)	54,186	271,824	0	0	0
unknown	24,298	550,845	0	0	0
Field Total	1,856,649	8,318,115	0	0	4,061
Ironhorse					
D Sand	16,468	45,581	0	0	0
J Sand	2,327	1,951	0	0	0
Muddy (J)	108,916	136,036	0	0	0
Field Total	127,711	183,568	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Island Butte					
Desert Creek	2,210,128	5,942,528	0	0	208,333
Ismay	21	77,506	0	0	0
Field Total	2,210,149	6,020,034	0	0	208,333
Jace					
Mississippian	4,417	0	0	0	0
Morrow	1,024,195	778,893	0	0	75,234
Morrow 3	1,177	36,902	0	0	1,494
Morrow V6	67,327	9,399	0	0	0
Morrow V7	11,786	3,123	0	0	0
Field Total	1,108,902	828,317	0	0	76,728
Jack Draw					
D Sand	515	4,992	0	0	0
Field Total	515	4,992	0	0	0
Jack Rabbit					
J Sand	0	0	0	0	0
Muddy (J)	113,679	28,601	0	0	0
Field Total	113,679	28,601	0	0	0
Jackknife					
J Sand	0	0	0	0	0
Muddy (J)	4,705	23,000	0	0	0
Field Total	4,705	23,000	0	0	0
Jackpot					
D Sand	768,396	1,670,498	0	0	723
D Sand	804,871	863,351	0	0	0
Niobrara	27	0	0	0	0
Field Total	1,573,294	2,533,849	0	0	723
Jackpot South					
D Sand	32,906	96,420	0	0	0
D Sand, Muddy (J)	56,794	178,572	0	0	0
Field Total	89,700	274,992	0	0	0
Jackson					
D Sand	62,146	12,228	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	24,551	8,473	0	0	0
Field Total	86,697	20,701	0	0	0
Jade					
D Sand	841	0	0	0	0
Niobrara	163	0	0	0	0
Timpas	0	0	0	0	0
Field Total	1,004	0	0	0	0
Jalapeno					
Lansing, Kansas City	9,741	0	0	0	0
Field Total	9,741	0	0	0	0
Jamboree					
D Sand	576,706	4,611,001	0	0	5,291
D Sand, Muddy (J)	236,563	2,904,404	0	0	2
J Sand	93,297	2,119,682	0	0	8,828
Muddy (J)	445,585	14,807,030	0	0	0
Field Total	1,352,151	24,442,117	0	0	14,121
Jasper					
D Sand	122,396	915,556	0	0	0
J Sand	19,773	2,879	0	0	2,390
Muddy (J)	307,952	611,299	0	0	0
Field Total	450,121	1,529,734	0	0	2,390

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Jayhawk Draw					
J Sand	26,042	0	0	0	65,981
Field Total	26,042	0	0	0	65,981
Jeeper					
D Sand	114,874	5,717	0	0	290,684
Field Total	114,874	5,717	0	0	290,684
Jesse					
J Sand	15,174	0	0	0	181,185
Muddy (J)	70,279	0	0	0	0
Field Total	85,453	0	0	0	181,185
Jitter					
D Sand	181,115	300	0	0	0
Field Total	181,115	300	0	0	0
Joes					
D Sand	2,769	0	0	0	0
Field Total	2,769	0	0	0	0
Johnny Moore Mountain					
Niobrara	36,189	64,693	0	0	0
Field Total	36,189	64,693	0	0	0
Johnson Hill					
J Sand	0	0	0	0	0
Muddy (J)	106	8,634	0	0	0
Field Total	106	8,634	0	0	0
Johnson Hill East					
J Sand	0	0	0	0	0
Muddy (J)	42,074	400,348	0	0	0
Field Total	42,074	400,348	0	0	0
Johnson Hill North					
J Sand	53,320	43,296	0	0	89,156
Muddy (J)	1,896,343	3,473,471	0	0	0
Field Total	1,949,663	3,516,767	0	0	89,156
Johnsons Corner					
Codell Ss	9,461	171,792	0	0	0
J Sand	23,866	275,061	0	0	861
Muddy (J)	27,547	565,009	0	0	0
Muddy (J), Codell Ss	742	16,408	0	0	0
Muddy (J), Niobrara, Codell Ss	22,860	191,931	0	0	60
Niobrara	6,208	136	0	0	73
Niobrara, Codell Ss	5,843	40,261	0	0	513
Field Total	96,527	1,260,598	0	0	1,507
Johnstown					
Codell Ss	16,202	51,162	0	0	0
J Sand	0	36,119	0	0	50
Niobrara	3,435	27,545	0	0	0
Shannon	38,186	50,758	0	0	0
Field Total	57,823	165,584	0	0	50
Jubilee					
D Sand	172,567	167,228	0	0	0
Field Total	172,567	167,228	0	0	0
Judson Hills					
D Sand	6,700	109,117	0	0	0
Field Total	6,700	109,117	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Jupiter					
J Sand	45,525	232,126	0	0	202,635
Muddy (J)	134,222	748,953	0	0	0
Field Total	179,747	981,079	0	0	202,635
Justice					
J Sand	57,888	0	0	0	2,103,250
Muddy (J)	415,454	0	0	0	0
Field Total	473,342	0	0	0	2,103,250
Kachina					
Dakota	0	0	0	0	0
Dakota, Muddy (J)	1,277,347	93	0	0	0
J Sand	104,745	0	0	0	4,027,075
Muddy (J)	204,995	460	0	0	0
Field Total	1,587,087	553	0	0	4,027,075
Katie					
J Sand	650	34,796	0	0	1,404
Muddy (J)	19,332	111,687	0	0	0
Skull Creek	1,310	2,925	0	0	0
Field Total	21,292	149,408	0	0	1,404
Keg					
J Sand	0	0	0	0	0
Muddy (J)	234	0	0	0	0
Field Total	234	0	0	0	0
Kejr					
D Sand	2,245,210	579,631	0	0	11,778
J Sand	55,138	8,071	0	0	1,239,571
Muddy (J)	762,987	169,949	0	0	0
Field Total	3,063,335	757,651	0	0	1,251,349
Kejr South					
D Sand	4,203	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	273,380	115,467	0	0	0
Field Total	277,583	115,467	0	0	0
Kelim					
Niobrara	2,231	0	0	0	193
Niobrara, Codell Ss	39,834	0	0	0	163
Field Total	42,065	0	0	0	356
Keno					
D Sand	326,988	0	0	0	105,306
J Sand	18,044	0	0	0	8,887
Field Total	345,032	0	0	0	114,193
Kenzie					
Dakota	33,672	0	0	0	0
O Sand	0	0	0	0	0
Field Total	33,672	0	0	0	0
Keota					
J Sand	20,923	0	0	0	119,804
Lyons Ss	12,816	0	0	0	0
Muddy (J)	1,262,408	598,576	0	0	0
Field Total	1,296,147	598,576	0	0	119,804
Kernan Canyon					
Dakota	150	0	0	0	0
Field Total	150	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Kersey					
Codell Ss	790,996	6,776,956	0	0	31,051
Niobrara, Codell Ss	1,642,256	12,436,204	0	0	46,524
Niobrara, Fort Hays, Codell Ss	22,702	277,909	0	0	1,013
Field Total	2,455,954	19,491,069	0	0	78,588
Kettle					
D Sand	9,993	0	0	0	0
Field Total	9,993	0	0	0	0
Key					
J Sand	18,209	0	0	0	3,056
Muddy (J)	771,521	606,613	0	0	0
Field Total	789,730	606,613	0	0	3,056
Keystone					
D Sand	10,648	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	5,865	6,302	0	0	0
Field Total	16,513	6,302	0	0	0
Kicking Bird					
Morrow	0	549,998	0	0	0
Field Total	0	549,998	0	0	0
King Lake					
Codell Ss	7,852	962	0	0	174
Field Total	7,852	962	0	0	174
Kiowa Creek					
D Sand	17,927	1,221,154	0	0	533
Dakota	0	0	0	0	0
Dakota	9,578	964,203	0	0	0
J Sand	1,202	160,876	0	0	1,001
Lakota	1	33,212	0	0	24,283
Muddy (J)	16,122	2,472,689	0	0	0
Niobrara, Codell Ss	5,758	0	0	0	0
Timpas, Codell	0	0	0	0	0
Field Total	50,588	4,852,134	0	0	25,817
Kit Carson					
Morrow	4,321	0	0	0	0
Field Total	4,321	0	0	0	0
Kitchel Lake					
Codell Ss	265	900	0	0	0
Field Total	265	900	0	0	0
Kitty					
D Sand	1,637	1,082	0	0	429
D Sand, Muddy (J)	51,049	70,396	0	0	117
J Sand	1,247	1,086	0	0	346
Muddy (J)	64,537	169,713	0	0	0
Field Total	118,470	242,277	0	0	892
Knoll					
J Sand	0	0	0	0	0
Muddy (J)	0	13,831	0	0	0
Field Total	0	13,831	0	0	0
Knox					
D Sand	46,562	49,418	0	0	0
Field Total	46,562	49,418	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Kokopelli					
Mesaverde	64	153,800	0	0	0
Williams Fork	1,448	378,995	0	0	3,041
Field Total	1,512	532,795	0	0	3,041
Krauthed					
D Sand	768,794	6,347,826	0	0	11,474
D Sand	913	960	0	0	0
D Sand, Muddy (J)	6,280	227,816	0	0	0
J Sand	2,286	119,720	0	0	1,851
Muddy (J)	1,615	53,681	0	0	0
Field Total	779,888	6,750,003	0	0	13,325
Krieger					
D Sand	34,764	155,294	0	0	0
Field Total	34,764	155,294	0	0	0
Ladder Creek					
Mississippian	2,315,154	42,288	0	0	2,889,904
Mississippian, Osage	0	0	0	0	0
Mississippian, Pennsylvanian	0	0	0	0	0
Mississippian, Spergen	69,941	0	0	0	912,300
Morrow	0	13,542	0	0	0
Osage	97,547	0	0	0	0
Spergen	345,335	37,586	0	0	1,109,924
St Louis, Spergen	2,596	0	0	0	0
Warsaw	4,426	0	0	0	0
Field Total	2,834,999	93,416	0	0	4,912,128
Ladle					
J Sand	0	0	0	0	0
Muddy (J)	27	5,279	0	0	0
Field Total	27	5,279	0	0	0
Lady K					
D Sand	18,817	5,525	0	0	437
Field Total	18,817	5,525	0	0	437
Ladybug					
Mississippian	40,638	0	0	0	8,925
Field Total	40,638	0	0	0	8,925
Laird					
Lansing, Kansas City	6,327	1,200	0	0	0
Field Total	6,327	1,200	0	0	0
Lake Canal					
Codell Ss	5,731	1,308	0	0	0
D Sand	3,149	0	0	0	0
J Sand	0	0	0	0	0
Lyons Ss	2,717	0	0	0	0
Muddy (J)	2,111	34,738	0	0	0
Niobrara, Codell Ss	17,271	38,560	0	0	0
Field Total	30,979	74,606	0	0	0
Lakeside					
D Sand	110,591	1,082,977	0	0	2,576
J Sand	8,216	235,436	0	0	1,804
Muddy (J)	109,051	1,273,150	0	0	0
Field Total	227,858	2,591,563	0	0	4,380
Lamar					
Marmaton	18,574	0	0	0	1
Field Total	18,574	0	0	0	1

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Lamb					
D Sand	118,950	3,546,542	0	0	0
Field Total	118,950	3,546,542	0	0	0
Lamborn Draw					
D Sand	3,305	1,335	0	0	0
Field Total	3,305	1,335	0	0	0
Lame Beaver					
J Sand	16,578	0	0	0	53,406
Field Total	16,578	0	0	0	53,406
Lance					
J Sand	0	0	0	0	0
Muddy (J)	56,120	13,229	0	0	0
Field Total	56,120	13,229	0	0	0
Lance Creek					
D Sand	9,768	210,797	0	0	0
Field Total	9,768	210,797	0	0	0
Lantern					
J Sand	0	0	0	0	0
Muddy (J)	1,018	0	0	0	0
Field Total	1,018	0	0	0	0
Lanyard					
Codell Ss	2,137	1,395	0	0	0
D Sand	3,443,150	4,851,195	0	0	2,170,308
J Sand	147	27,222	0	0	2,348
Muddy (J)	2,841	64,106	0	0	0
Field Total	3,448,275	4,943,918	0	0	2,172,656
LaPorte					
Lyons Ss	141	0	0	0	0
Field Total	141	0	0	0	0
LaPoudre					
Codell Ss	49,713	153,197	0	0	557
J Sand	3,583	11,150	0	0	2,834
Muddy (J), Niobrara, Codell Ss	9,909	59,067	0	0	0
Niobrara, Codell Ss	23,369	108,017	0	0	0
Sussex	65,976	49,504	0	0	4,580
Field Total	152,550	380,935	0	0	7,971
LaPoudre South					
Codell Ss	84,604	381,126	0	0	1,458
J Sand	6,086	212,125	0	0	1,382
Muddy (J)	22,747	731,993	0	0	0
Muddy (J), Codell Ss	115	1,135	0	0	0
Niobrara	4,566	12,037	0	0	98
Niobrara, Codell Ss	237,751	991,000	0	0	10,349
Niobrara, Codell Ss, Sussex	1,806	2,121	0	0	0
Shannon	6,714	0	0	0	0
Sussex	307,812	11,721	0	0	34,550
Sussex, Shannon	1,792	0	0	0	2,884
Field Total	673,993	2,343,258	0	0	50,721
Lariat					
D Sand	794,121	256,554	0	0	79,206
Dakota	0	0	0	0	0
J Sand	34	108,970	0	0	2,333
Field Total	794,155	365,524	0	0	81,539

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Lark					
J Sand	0	0	0	0	0
Muddy (J)	42,289	18,120	0	0	0
Field Total	42,289	18,120	0	0	0
Lasso					
J Sand	0	0	0	0	0
Muddy (J)	2,156	10,800	0	0	0
Field Total	2,156	10,800	0	0	0
Last Chance					
J Sand	0	0	0	0	0
Muddy (J)	697,833	33,050	0	0	0
Field Total	697,833	33,050	0	0	0
Latch String					
D Sand	55,373	15,055	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	543	76,202	0	0	0
Field Total	55,916	91,257	0	0	0
Lathrop					
Raton, Vermejo Coal	0	0	0	0	1,513,623
Vermejo Coal	0	0	0	0	729,303
Field Total	0	0	0	0	2,242,926
Latigo					
J Sand	0	0	0	0	0
Lyons Ss	0	0	0	0	0
Muddy (J)	355,461	7,304,739	0	0	0
Field Total	355,461	7,304,739	0	0	0
Lay Creek					
Mesaverde	25	7,199,629	0	0	26,320
Field Total	25	7,199,629	0	0	26,320
Leader					
J Sand	0	0	0	0	0
Muddy (J)	158,231	1,320,760	0	0	0
Field Total	158,231	1,320,760	0	0	0
Leader East					
J Sand	0	0	0	0	0
Muddy (J)	618	420,528	0	0	0
Field Total	618	420,528	0	0	0
Leather					
D Sand	26,846	45,431	0	0	0
Field Total	26,846	45,431	0	0	0
Lee					
D Sand	62,537	261,098	0	0	0
D Sand, Muddy (J)	880	112,256	0	0	0
Field Total	63,417	373,354	0	0	0
Left Hand					
Keyes	12,153	2,659,183	0	0	0
Marmaton	43,756	54,504	0	0	0
Morrow	48	369,707	0	0	0
Field Total	55,957	3,083,394	0	0	0
Levee					
J Sand	0	0	0	0	0
Muddy (J)	15,853	13,522	0	0	0
Field Total	15,853	13,522	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Lewis Creek					
D Sand	3,922	854,343	0	0	0
J Sand	18,707	9,704	0	0	1,494,860
Muddy (J)	5,421,136	3,275,775	0	0	0
Field Total	5,443,765	4,139,822	0	0	1,494,860
Liberty					
J Sand	23,971	19,545	0	0	95,168
Muddy (J)	1,010,237	2,146,781	0	0	0
Field Total	1,034,208	2,166,326	0	0	95,168
Liberty South					
J Sand	6,368	3,540	0	0	8,300
Muddy (J)	161,986	119,009	0	0	0
Field Total	168,354	122,549	0	0	8,300
Liberty West					
J Sand	63,488	88,689	0	0	676,788
Muddy (J)	986,624	1,471,988	0	0	0
Field Total	1,050,112	1,560,677	0	0	676,788
Lido					
J Sand	1,797	229,896	0	0	0
Muddy (J)	5,286	763,298	0	0	0
Field Total	7,083	993,194	0	0	0
Lightfoot					
J Sand	0	0	0	0	0
Muddy (J)	1,235	0	0	0	0
Field Total	1,235	0	0	0	0
Lilli					
Codell Ss	29,747	207,839	0	0	39
D Sand	3,515,842	32,232,802	0	0	36,220
Field Total	3,545,589	32,440,641	0	0	36,259
Lilli-West					
D Sand	17,270	0	0	0	0
Field Total	17,270	0	0	0	0
Limon					
Marmaton	4,303	1,786	0	0	0
Field Total	4,303	1,786	0	0	0
Lindon					
J Sand	135,815	0	0	0	4,954,484
Muddy (J)	4,110,555	10,462	0	0	0
Field Total	4,246,370	10,462	0	0	4,954,484
Line Camp					
D Sand	2,118	3,804	0	0	0
Field Total	2,118	3,804	0	0	0
Lingo					
Marmaton	933	0	0	0	0
Mississippian	0	0	0	0	0
Field Total	933	0	0	0	0
Lipan Wash					
Dakota	79	675,082	0	0	0
Field Total	79	675,082	0	0	0
Lisbon Southeast					
Leadville	8,819	1,734,480	0	0	762
Mississippian	156,103	14,461,209	0	0	0
Field Total	164,922	16,195,689	0	0	762

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Little Beaver					
D Sand	50,998	13,597	0	0	0
D Sand	14,166,801	8,363,984	0	0	2,264,711
J Sand	0	0	0	0	0
J Sand	11,639	32,565	0	0	0
Muddy (J)	19,046	1,140,424	0	0	0
Muddy (J)	3,302,795	11,214,059	0	0	0
Field Total	17,551,279	20,764,629	0	0	2,264,711
Little Beaver East					
D Sand	3,671,941	2,375,114	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	598,333	218,655	0	0	0
Field Total	4,270,274	2,593,769	0	0	0
Little Bud					
Keyes	3,180	9	0	0	0
Field Total	3,180	9	0	0	0
Little Creek					
Raton, Vermejo Coal	0	0	0	0	13,461,759
Vermejo Coal	0	0	0	0	1,121,423
Field Total	0	0	0	0	14,583,182
Little Dude					
Marmaton	273	0	0	0	0
Field Total	273	0	0	0	0
Little Hoot					
D Sand	646,221	9,635,610	0	0	23
D Sand, Muddy (J)	19,560	2,528,034	0	0	0
J Sand	0	56,640	0	0	0
Muddy (J)	1,768	683,564	0	0	0
Field Total	667,549	12,903,848	0	0	23
Little Hoot South					
D Sand	6,237	0	0	0	0
D Sand, Muddy (J)	10,620	7,230	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	9,247	704	0	0	0
Field Total	26,104	7,934	0	0	0
Little Snake					
Fort Union	0	386,045	0	0	0
Lewis Sh	1,189	131,132	0	0	2,105
Lewis Sh,	2,703	131,702	0	0	0
Field Total	3,892	648,879	0	0	2,105
Little Tree					
D Sand	10,811	0	0	0	0
Field Total	10,811	0	0	0	0
Little Ute					
Ismay	188,325	496,062	0	0	3,860
Field Total	188,325	496,062	0	0	3,860
Loam					
D Sand	210,477	2,142,646	0	0	942
D Sand	306,268	1,230,226	0	0	0
Field Total	516,745	3,372,872	0	0	942
Lobo					
D Sand	7,131	6,369	0	0	236,620
D Sand, Muddy (J)	66,806	123,498	0	0	0
J Sand	10,260	181,232	0	0	583,302
Muddy (J)	354,696	765,994	0	0	0
Field Total	438,893	1,077,093	0	0	819,922

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Loco					
J Sand	0	0	0	0	0
Muddy (J)	1,687	698,299	0	0	0
Field Total	1,687	698,299	0	0	0
Lodestone					
J Sand	0	0	0	0	0
Muddy (J)	0	10,061	0	0	0
Field Total	0	10,061	0	0	0
Lodge					
J Sand	132	78	0	0	0
Muddy (J)	21,191	10,423	0	0	0
Field Total	21,323	10,501	0	0	0
Logan					
J Sand	0	0	0	0	0
Muddy (J)	218,868	702,263	0	0	0
Field Total	218,868	702,263	0	0	0
Logan North					
J Sand	0	0	0	0	0
Muddy (J)	131,905	620,143	0	0	0
Field Total	131,905	620,143	0	0	0
Logan Wash					
Corcoran	0	116,050	0	0	45
Corcoran, Cozzette, Rollins	33	8,361	0	0	0
Cozzette	0	75,794	0	0	45
Cozzette, Corcoran	0	32,046	0	0	0
Mesaverde	179	1,737,261	0	0	0
Rollins	0	0	0	0	0
Williams Fork	0	471,001	0	0	9,368
Field Total	212	2,440,513	0	0	9,458
Loma					
Marmaton	72,325	0	0	0	246,022
Mississippian	178,925	98,819	0	0	450
Mississippian, Spergen	6,633	0	0	0	0
Spergen	26,883	0	0	0	35,132
Field Total	284,766	98,819	0	0	281,604
Lone Pine					
Dakota	2,588,144	690,517	0	0	1,566,535
Entrada Ss	0	0	0	0	13,300
Lakota	190,025	5,785	0	0	12,959,968
Morrison	1,231	0	0	0	14,321
Field Total	2,779,400	696,302	0	0	14,554,124
Lone Star					
J Sand	11,439	0	0	0	631,620
Muddy (J)	92,377	0	0	0	0
Field Total	103,816	0	0	0	631,620
Lone Tree					
J Sand	83,128	64,571	0	0	611,065
J Sand	40,116	33,600	0	0	61,342
Muddy (J)	2,368,445	3,172,829	0	0	0
Muddy (J)	634,534	1,008,883	0	0	0
Field Total	3,126,223	4,279,883	0	0	672,407

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Lone Valley					
J Sand	45,228	7,508	0	0	545
Muddy (J)	890,626	379,410	0	0	0
Field Total	935,854	386,918	0	0	545
Lonesome Coyote					
J Sand	0	0	0	0	0
Muddy (J)	24,921	68,893	0	0	0
Field Total	24,921	68,893	0	0	0
Long Canyon					
Dakota	0	2,333	0	0	41,110
Dakota, Purgatoire	0	0	0	0	0
Fort Hays	0	4,242	0	0	70
Niobrara	0	6,516	313	0	319
Raton Sand	0	80,945	0	0	53,086
Raton, Vermejo Coal	0	0	1,055,608	0	420,347
Vermejo Coal	0	2,369,311	55,345,910	0	27,745,186
Field Total	0	2,463,347	56,401,831	0	28,260,118
Long South					
D Sand, Muddy (J)	153,381	184,478	0	0	0
Field Total	153,381	184,478	0	0	0
Longbranch					
D Sand	411,440	2,449,533	0	0	174
Dakota	4,257	22,027	0	0	1,773
J Sand	39,754	1,158,896	0	0	1,471
Muddy (J)	526,744	22,977,252	0	0	0
Field Total	982,195	26,607,708	0	0	3,418
Longhorn					
J Sand	0	0	0	0	0
Muddy (J)	17,491	174	0	0	0
Field Total	17,491	174	0	0	0
Longhorn Gulch					
Morrow	223	1,174,737	0	0	0
Field Total	223	1,174,737	0	0	0
Longknife					
Niobrara	0	567,837	0	0	0
Field Total	0	567,837	0	0	0
Longmont					
Niobrara, Codell Ss	13,304	50,395	0	0	0
Sussex	6,043	0	0	0	0
Field Total	19,347	50,395	0	0	0
Longs Peak					
J Sand	24,439	0	0	0	0
Muddy (J)	10,591	0	0	0	0
Field Total	35,030	0	0	0	0
Lookout					
Mississippian	10,768	0	0	0	0
Mississippian, Spergen	0	0	0	0	0
Morrow	11,248	6,505,533	0	0	2,129
Spergen	350	250,846	0	0	0
Field Total	22,366	6,756,379	0	0	2,129
Lost Boy					
J Sand	0	0	0	0	0
Muddy (J)	21,075	0	0	0	0
Field Total	21,075	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO₂ (Mscf)	Water (Barrels)
Lost Creek					
D Sand	1,356,647	4,284,984	0	0	21,802
D Sand, Muddy (J)	713	102	0	0	0
Dakota	50	5,663	0	0	0
Dakota, Muddy (J)	380	77,443	0	0	0
J Sand	3,114	1,051,970	0	0	26,439
Muddy (J)	28,068	8,590,758	0	0	0
Niobrara	119	0	0	0	0
Field Total	1,389,091	14,010,920	0	0	48,241
Lost Steer					
D Sand	19,901	236,989	0	0	261
Field Total	19,901	236,989	0	0	261
Loula					
J Sand	0	0	0	0	0
Muddy (J)	3,703	3,050	0	0	0
Field Total	3,703	3,050	0	0	0
Love Ranch					
Mesaverde	8,494	4,283,528	0	0	1,006,814
Field Total	8,494	4,283,528	0	0	1,006,814

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Loveland					
Codell Ss	78,854	65,667	0	0	110
Codell Ss	996	16,753	0	0	0
D Sand	219	0	0	0	0
Dakota	29,421	135,316	0	0	0
Dakota, Muddy, Niobrara	526	0	0	0	0
Dakota, Niobrara	157,251	153,256	0	0	0
Fuson	0	0	0	0	0
Hygiene	0	0	0	0	0
J Sand	3,398	73,405	0	0	0
J Sand	295	5,033	0	0	0
Lakota	905	14,482	0	0	0
Lakota, Niobrara	0	0	0	0	0
Lyons Ss	5,939	0	0	0	0
Muddy (J)	44,097	72,827	0	0	0
Muddy (J)	8,754	27,964	0	0	0
Muddy (J), Niobrara	75,362	433,011	0	0	0
Muddy (J), Niobrara, Codell Ss	229,357	1,807,753	0	0	0
Muddy (J), Niobrara, Codell Ss	83,874	613,660	0	0	0
Niobrara	1,456,976	6,343,764	0	0	173
Niobrara	147,118	557,340	0	0	0
Niobrara, Codell Ss	307,946	1,838,382	0	0	664
Niobrara, Codell Ss	53,775	593,472	0	0	0
Niobrara, Codell Ss, Dakota	557,151	351,898	0	0	0
Niobrara, Timpas	2,000	43,065	0	0	0
Niobrara, Timpas	2,499	36,957	0	0	0
Niobrara, Timpas, Codell	35,367	416,079	0	0	0
Niobrara, Timpas, Codell	6,156	72,488	0	0	0
Niobrara, Timpas, Codell, Lakota	0	0	0	0	0
Shannon	0	229,309	0	0	0
Sussex	10,575	4,850	0	0	0
Timpas	606	9,409	0	0	0
Timpas	0	0	0	0	0
Timpas, Codell	0	0	0	0	0
Timpas, Lakota	193	4,198	0	0	0
Topeka Ls	1,291	22,582	0	0	0
Field Total	3,300,901	13,942,920	0	0	947
Lower Horse Draw					
Dakota	192	932,951	0	0	38,651
Dakota, Morrison	800	1,473,700	0	0	1
Entrada Ss	234	178,102	0	0	7,892
Mancos A	0	1,119,659	0	0	369
Mancos B	45,442	23,003,245	0	0	78,100
Mancos Sh	64,190	66,875,002	0	0	2,244
Morrison	234	156,961	0	0	8,129
Field Total	111,092	93,739,620	0	0	135,386

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO₂ (Mscf)	Water (Barrels)
Lowry					
D Sand	100	0	0	0	0
D Sand, Muddy (J)	15,913	123,469	0	0	0
J Sand	70,027	248,108	0	0	64,323
J Sand	17,700	31,432	0	0	0
Muddy (J)	1,571,800	3,754,041	0	0	0
Muddy (J)	55,035	92,934	0	0	0
Niobrara	14,857	0	0	0	3,814
Field Total	1,745,432	4,249,984	0	0	68,137
Lubers					
Atoka	3,099	200,754	0	0	0
Morrow	0	51,407	0	0	0
Field Total	3,099	252,161	0	0	0
Luft					
D Sand	2,579,569	2,734,347	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	225,642	343,447	0	0	0
Field Total	2,805,211	3,077,794	0	0	0
Lunar					
J Sand	0	0	0	0	0
Muddy (J)	5,260	15,992	0	0	0
Field Total	5,260	15,992	0	0	0
Luster					
J Sand	0	0	0	0	0
Muddy (J)	810,231	773,052	0	0	0
Field Total	810,231	773,052	0	0	0
Mac Creek					
Williams Fork	10,932	705,455	0	0	9,886
Field Total	10,932	705,455	0	0	9,886
Mack Creek					
Burro Canyon	0	13,171	0	0	0
Morrison	0	238,007	0	0	0
Field Total	0	251,178	0	0	0
Mako					
Codell Ss	1,275	2,792	0	0	0
Niobrara	7,779	658	0	0	5
Field Total	9,054	3,450	0	0	5
Mallard					
Lance	212	0	0	0	0
Lansing	30,777	0	0	0	0
Lansing, Mississippian	74	0	0	0	0
Mississippian	390	0	0	0	0
Morrow	0	157,240	0	0	265
Field Total	31,453	157,240	0	0	265
Malpais					
D Sand	30,121	732,462	0	0	5,112
Field Total	30,121	732,462	0	0	5,112

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Mamm Creek					
Cameo Coal	73	11,073	0	0	333
Cameo Coals, Mesaverde	179	74,895	0	0	0
Corcoran	4,491	897,055	0	0	41,700
Cozette	95	17,460	0	0	2,942
Cozzette, Corcoran, Mesaverde	156	47,321	0	0	421
Mesaverde	179,007	37,604,854	0	0	234,195
Mesaverde Coal	0	0	54,435	0	0
Rollins	133,767	22,652,827	0	0	655,852
Williams Fork	1,342,225	199,006,170	1,225,425	0	6,059,108
Williams Fork Coal	130	9,992	0	0	167
Williams Fork, Cameo	0	219,806	0	0	2,537
Field Total	1,660,123	260,541,453	1,279,860	0	6,997,255
Manassas					
Atoka	838	25,240	0	0	0
Field Total	838	25,240	0	0	0
Mancos River					
Gallup Ss	166	0	0	0	0
Mancos Sh	25,851	0	0	0	0
Field Total	26,017	0	0	0	0
Mandan					
J Sand	26,163	16,008	0	0	349,970
Muddy (J)	56,970	18,201	0	0	0
Field Total	83,133	34,209	0	0	349,970
Mandella					
D Sand	109,637	914,217	0	0	1,299
J Sand	5,120	198,951	0	0	41
Muddy (J)	11,653	747,670	0	0	0
Field Total	126,410	1,860,838	0	0	1,340
Mangy Dog					
Codell Ss	3,946	0	0	0	0
Field Total	3,946	0	0	0	0
Manila					
D Sand	4,361	160,267	0	0	0
J Sand	989	84,099	0	0	0
Muddy (J)	10,773	291,430	0	0	0
Field Total	16,123	535,796	0	0	0
Mantle					
J Sand	0	0	0	0	0
Muddy (J)	3,410	479,104	0	0	0
Field Total	3,410	479,104	0	0	0
Maple					
D Sand	6,917	463,745	0	0	0
Field Total	6,917	463,745	0	0	0
Marble Wash					
Hermosa	19,978	54,772	0	0	0
Ismay	992,343	1,661,902	0	0	102,239
Lower Ismay	488	0	0	0	38,049
Field Total	1,012,809	1,716,674	0	0	140,288
Marguerite					
Morrow	0	33,194	0	0	0
Field Total	0	33,194	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Maria					
D Sand	287,019	2,163,911	0	0	3,091
D Sand, Muddy (J)	82,169	907,037	0	0	0
Dakota	1,864	13,817	0	0	73
J Sand	38,995	454,777	0	0	2,562
Muddy (J)	52,791	335,778	0	0	0
Field Total	462,838	3,875,320	0	0	5,726
Marks Butte					
D Sand	0	225,366	0	0	0
Field Total	0	225,366	0	0	0
Marks Butte North					
Leonard	105,636	1,544	0	0	99,768
Field Total	105,636	1,544	0	0	99,768
Masters					
D Sand	25,053	355,617	0	0	0
D Sand	331,618	1,070,747	0	0	0
D Sand, Greenhorn	4,979	18,786	0	0	0
Field Total	361,650	1,445,150	0	0	0
Maudlin Gulch					
Dakota	4,474,374	948,354	0	0	2,745,118
Entrada Ss	771,491	30,057	0	0	0
Minturn	47,421	535,694	0	0	0
Moenkopi	252,749	0	0	0	33,472
Moenkopi, Shinarump	422	0	0	0	0
Morapos, Mancos	0	0	0	0	0
Morrison	442,254	21,735	0	0	2,897,294
Morrison, Entrada Ss	2,125,865	330,105	0	0	0
Morrison, Sundance	35,156	246	0	0	0
Phosphoria	1,164,072	0	0	0	281,922
Shinarump	874,819	1,193	0	0	4,251,292
Sundance	46,322	0	0	0	4,784,144
Weber Ss	2,312,684	799	0	0	1,940,801
Field Total	12,547,629	1,868,183	0	0	16,934,043
Maverick					
D Sand	11,232	48,600	0	0	0
Field Total	11,232	48,600	0	0	0
Maxwell					
Morrow V1	0	216,962	0	0	0
Field Total	0	216,962	0	0	0
May					
J Sand	259	0	0	0	1,372
Muddy (J)	438,256	446,587	0	0	0
Field Total	438,515	446,587	0	0	1,372
Mayberry					
Almond	0	0	0	0	0
Mesaverde	1,548	114,112	0	0	0
Field Total	1,548	114,112	0	0	0
Mayfield					
Marmaton	46,501	0	0	0	146,837
Mississippian, Spergen	0	5,649	0	0	0
Morrow	229,097	4,061,600	0	0	379,200
Morrow V5	768	0	0	0	133
Shawnee	967,157	142,630	0	0	2,392,768
Field Total	1,243,523	4,209,879	0	0	2,918,938

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
McCallum					
Dakota	1,808	118,152	0	10,548	9,838
Dakota, Lakota	4,864,143	919,496	0	360,869,437	0
Lakota	14,696	316,336	0	1,993,390	34,421
Morrison	2,050,553	467,767	0	155,731,347	101,145
Muddy	2,388	0	0	0	1,165
Muddy (J)	51,736	0	0	276,313	0
Niobrara	231	0	0	0	0
Pierre B	705,923	92,083	0	198	5,225,482
Pierre Sh	2,394,825	596,502	0	917,866	17,605
Field Total	10,086,303	2,510,336	0	519,799,099	5,389,656
McCallum South					
Dakota	431	181,247	0	16,351	794
Dakota, Lakota, Muddy (J)	727,288	0	0	163,937,667	0
Lakota	4,672	175,846	0	2,214,108	4,192
Lakota, Dakota, Muddy	3,275	0	0	1,362,680	0
Niobrara	1,855	0	0	0	0
Pierre B	0	0	0	0	0
Pierre Sh	83,857	119,958	0	0	2,860
Field Total	821,378	477,051	0	167,530,806	7,846
McClave					
Atoka	0	327,952	0	0	0
Marmaton	7,208	1,765	0	0	0
McClave Ss	17,455	13,955,251	0	0	39
McClave Ss	56,642	36,279,008	0	0	43
McClave Ss	87	119,813	0	0	0
Morrow	39,644	12,761,649	0	0	438
Morrow	8,027	4,825,793	0	0	87
Morrow	261	419,198	0	0	0
Field Total	129,324	68,690,429	0	0	607
McClean					
Desert Creek	4,840,043	16,809,201	0	0	411,124
Field Total	4,840,043	16,809,201	0	0	411,124
McElmo					
Leadville	38,874	0	0	2,255,510,263	2,117,426
Mississippian	32,168	7,991,864	0	2,443,894,878	3,247
Shinarump	1,097	1,137,201	0	496,084	626
Field Total	72,139	9,129,065	0	4,699,901,225	2,121,299
McHatton					
Niobrara	28,225	182	0	0	352
Field Total	28,225	182	0	0	352
McKenzie					
D Sand	19,876	160,100	0	0	0
J Sand	85	10,258	0	0	0
Muddy (J)	4,721	352,693	0	0	0
Field Total	24,682	523,051	0	0	0
McRea					
J Sand	0	0	0	0	0
Muddy (J)	1,414,297	665,577	0	0	0
Field Total	1,414,297	665,577	0	0	0
Meadow Springs					
J Sand	0	0	0	0	0
Muddy (J)	2,454	0	0	0	0
Field Total	2,454	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Meander					
Shinarump	23,973	8,383	0	0	0
Field Total	23,973	8,383	0	0	0
Menefee Mountain					
Dakota	50,091	255	0	0	0
Field Total	50,091	255	0	0	0
Merino					
J Sand	79,461	19,656	0	0	2,726,633
Muddy (J)	4,342,481	1,490,287	0	0	0
Field Total	4,421,942	1,509,943	0	0	2,726,633
Merino Northeast					
J Sand	0	0	0	0	0
Muddy (J)	91,257	18,246	0	0	0
Field Total	91,257	18,246	0	0	0
Mesa View					
Almond	0	0	0	0	0
Mesaverde	313	26,343	0	0	0
Field Total	313	26,343	0	0	0
Mesagar					
Dakota	25	2,324,412	0	0	556
Dakota	0	24,419	0	0	0
Mancos Sh	0	14,749	0	0	0
Morrison	0	319,314	0	0	260
Sego	0	0	0	0	0
Field Total	25	2,682,894	0	0	816
Mescalero					
J Sand	0	0	0	0	0
Muddy (J)	17,190	109	0	0	0
Field Total	17,190	109	0	0	0
Messer					
J Sand	0	0	0	0	0
Muddy (J)	3,639	0	0	0	0
Field Total	3,639	0	0	0	0
Messex					
J Sand	10,089	0	0	0	413,630
Muddy (J)	619,208	748,879	0	0	0
Field Total	629,297	748,879	0	0	413,630
Messex West					
D Sand	126,324	39,476	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	35,096	45,623	0	0	0
Field Total	161,420	85,099	0	0	0
Meteor					
Morrow	36,100	39,677	0	0	264
Morrow V11	17,466	0	0	0	38,657
Morrow V7	214	0	0	0	68,608
Field Total	53,780	39,677	0	0	107,529
Michigan River					
Dakota	158,062	155,876	0	0	0
Lakota	16,623	0	0	0	0
Niobrara	588	0	0	0	0
Field Total	175,273	155,876	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Middlemist					
J Sand	0	0	0	0	0
Muddy (J)	2,161,537	1,249,872	0	0	0
Field Total	2,161,537	1,249,872	0	0	0
Midnight					
J Sand	0	0	0	0	0
Muddy (J)	44,670	0	0	0	0
Field Total	44,670	0	0	0	0
Midway					
D Sand	0	1,653,544	0	0	0
Lansing	0	17,283	0	0	0
Morrow	2,132	644,287	0	0	0
Topeka A	0	57,124	0	0	0
Topeka B	0	84,669	0	0	4
Topeka Ls	18	10,640,855	0	0	1,061
Unkown	0	6,293	0	0	0
Field Total	2,150	13,104,055	0	0	1,065
Mildred					
Niobrara	0	13,051,173	0	0	116,552
Field Total	0	13,051,173	0	0	116,552
Mini					
D Sand	657	0	0	0	0
Field Total	657	0	0	0	0
Minto					
J Sand	25,300	0	0	0	1,723,575
Muddy (J)	2,291,541	1,123,891	0	0	0
Field Total	2,316,841	1,123,891	0	0	1,723,575
Minto North					
J Sand	7,420	22,048	0	0	133,260
Muddy (J)	508,640	344,699	0	0	0
Field Total	516,060	366,747	0	0	133,260
Mirage					
J Sand	11,367	0	0	0	60,336
Muddy (J)	48,874	0	0	0	0
Field Total	60,241	0	0	0	60,336
Missouri Creek					
Mancos A	0	338,555	0	0	55
Mancos Sh	0	3,142,368	0	0	0
Field Total	0	3,480,923	0	0	55
Moccasin					
J Sand	0	0	0	0	0
Muddy (J)	1,152,206	1,128,407	0	0	0
Field Total	1,152,206	1,128,407	0	0	0
Mockingbird					
Marmaton	1,563	0	0	0	0
Field Total	1,563	0	0	0	0
Model					
Lyons Ss	0	53,000	0	0	0
Wingate	0	0	0	0	0
Field Total	0	53,000	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Moffat					
Dakota	4,450	0	0	0	495,478
Entrada Ss	0	0	0	0	0
Mancos Sh	5,873,929	40,160	0	0	80
Mesaverde, Dakota	2,597,181	44,643	0	0	0
Minturn	2,990	0	0	0	0
Niobrara	117,023	14,031	0	0	200
Shinarump	35,336	0	0	0	383,392
Weber Ss	754,228	148,798	0	0	0
Williams Fork Coal	0	0	34,473	0	564,459
Field Total	9,385,137	247,632	34,473	0	1,443,609
Monahan Lakes					
J Sand	0	0	0	0	0
Muddy (J)	15,155	956,518	0	0	0
Niobrara	1,430	650	0	0	0
Field Total	16,585	957,168	0	0	0
Monte					
J Sand	66,872	0	0	0	1,821,552
Muddy (J)	1,729,132	0	0	0	0
Field Total	1,796,004	0	0	0	1,821,552
Montrose Dome					
Hermosa	0	58,092	0	0	0
Field Total	0	58,092	0	0	0
Moore					
D Sand	52,306	25,229	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	12,065	0	0	0	0
Field Total	64,371	25,229	0	0	0
Moose					
D Sand	138,804	0	0	0	62,890
Field Total	138,804	0	0	0	62,890
Morningside					
D Sand	1,709	645,093	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	7,438	752,140	0	0	0
Field Total	9,147	1,397,233	0	0	0
Mosley					
D Sand	1,663	195,714	0	0	0
Field Total	1,663	195,714	0	0	0
Mount Hope					
D Sand	0	0	0	0	0
D Sand, Muddy (J)	0	0	0	0	0
Dakota	11,471	0	0	0	0
J Sand	0	0	0	0	0
Muddy	13,963	8,974	0	0	636,237
Muddy (J)	91,827	388,173	0	0	0
Muddy (J), Dakota	6,961,373	6,493,256	0	0	0
Niobrara	0	0	0	0	0
O Sand	13,901	0	0	0	0
Field Total	7,092,535	6,890,403	0	0	636,237

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Mount Hope East					
D Sand	2,016,844	3,034,588	0	0	0
D Sand, Muddy (J)	131,245	77,780	0	0	0
Dakota	102,383	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	337,228	1,572,017	0	0	0
O Sand	0	0	0	0	0
Field Total	2,587,700	4,684,385	0	0	0
Mount Hope North					
D Sand	337,533	481,219	0	0	78,375
D Sand, Muddy (J)	494,872	962,008	0	0	0
J Sand	3,110	0	0	0	79,875
J-2 Sand	0	0	0	0	0
Muddy (J)	14,869	166,957	0	0	0
Field Total	850,384	1,610,184	0	0	158,250
Mount Pearl					
Keyes	192,579	521,606	0	0	1,686
Lansing	665	2,238	0	0	0
Marmaton	14,814	30,260	0	0	0
Morrow	11,908,372	23,032,363	0	0	0
Morrow A	1,783	0	0	0	0
Morrow B	3,225,564	19,677,627	0	0	5,087,975
Morrow V7	0	1,439,726	0	0	9,811
St Louis	25,525	0	0	0	0
Field Total	15,369,302	44,703,820	0	0	5,099,472
Mountain View East					
D Sand	52,733	13,156	0	0	14,545
J Sand	0	0	0	0	0
Muddy (J)	9,913	3,392	0	0	0
Field Total	62,646	16,548	0	0	14,545
Mouthpiece					
D Sand	15,365	34,450	0	0	0
Field Total	15,365	34,450	0	0	0
Muddy Creek					
D Sand	26,272	18,694	0	0	0
D Sand, Muddy (J)	56,486	220,441	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	26,694	196,960	0	0	0
Field Total	109,452	436,095	0	0	0
Musket					
J Sand	0	0	0	0	0
Muddy (J)	54,555	0	0	0	0
Field Total	54,555	0	0	0	0
Muskrat					
J Sand	0	0	0	0	0
Muddy (J)	4,358	800,953	0	0	0
Field Total	4,358	800,953	0	0	0
Mustang					
D Sand	476,952	918,467	0	0	0
Field Total	476,952	918,467	0	0	0
Nabar					
J Sand	0	0	0	0	0
Muddy (J)	56,143	117,253	0	0	0
Field Total	56,143	117,253	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Nacho					
D Sand	7,296	159,256	0	0	19
D Sand	0	0	0	0	0
Field Total	7,296	159,256	0	0	19
Narrows					
D Sand	275	193	0	0	0
Field Total	275	193	0	0	0
Navajo					
Gallup Ss	57,519	49	0	0	0
Mancos Sh	212	0	0	0	0
Field Total	57,731	49	0	0	0
Nay Ranch					
Niobrara	2,255	4,194	0	0	0
Field Total	2,255	4,194	0	0	0
NE Riverside II					
D Sand	559,171	3,655,052	0	0	260
Field Total	559,171	3,655,052	0	0	260
Neenoshe					
Marmaton	0	11,032	0	0	0
Morrow	728	4,387,042	0	0	0
Field Total	728	4,398,074	0	0	0
Nelson Reservoir					
Greenhorn Ls	601	1,440	0	0	0
Field Total	601	1,440	0	0	0
New Day					
Niobrara	474	0	0	0	0
Field Total	474	0	0	0	0
New Hope					
Corcoran	28	33,598	0	0	2,538
Cozzette	0	3,398	0	0	0
Field Total	28	36,996	0	0	2,538
New Raymer					
D Sand	165,413	13,909	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	293,276	243,464	0	0	0
Field Total	458,689	257,373	0	0	0
New Windsor					
Codell Ss	143	78	0	0	0
Lyons Ss	911,954	29,997	0	0	0
Sussex	299,436	20,380	0	0	2,476
Field Total	1,211,533	50,455	0	0	2,476
Night Fire					
Morrow	3,737	0	0	0	2
Field Total	3,737	0	0	0	2
Nighthawk					
D Sand	64,506	400,536	0	0	4,353
Field Total	64,506	400,536	0	0	4,353
Nile					
D Sand	3,431,413	3,569,024	0	0	1,593,697
J Sand	0	0	0	0	0
Muddy (J)	216	44,063	0	0	0
Field Total	3,431,629	3,613,087	0	0	1,593,697
Nimbus					
D Sand	12,242	45,475	0	0	0
Field Total	12,242	45,475	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Nina View					
Permian	0	0	0	776,121	0
Field Total	0	0	0	776,121	0
Nine Mile					
Dakota	1,165,753	308	0	0	0
Field Total	1,165,753	308	0	0	0
Noonen Ranch					
D Sand	26,799	4,704	0	0	0
J Sand	26,574	37,667	0	0	31,886
Muddy (J)	553,805	554,896	0	0	0
Field Total	607,178	597,267	0	0	31,886
Noonen Ranch South					
J Sand	0	0	0	0	0
Muddy (J)	70,424	420,894	0	0	0
Field Total	70,424	420,894	0	0	0
Noria					
J Sand	0	0	0	0	0
Muddy (J)	34,092	0	0	0	0
Field Total	34,092	0	0	0	0
North Big Hole					
Lewis Sh	15,273	495,762	0	0	6,264
Field Total	15,273	495,762	0	0	6,264
North Buffalo					
Morrow	14,016	0	0	0	0
Field Total	14,016	0	0	0	0
North Dust Bowl					
Mississippian, Pennsylvanian	0	6,140	0	0	2,647
Morrow	0	238	0	0	0
Morrow V5	0	11,104	0	0	12,031
Field Total	0	17,482	0	0	14,678
North Riverside					
D Sand	13,505	257,190	0	0	756
Niobrara	65,464	107,497	0	0	14,942
Field Total	78,969	364,687	0	0	15,698
North Shore					
J Sand	0	0	0	0	0
Muddy (J)	330,627	79,037	0	0	0
Field Total	330,627	79,037	0	0	0
Nugget					
D Sand	2,492,916	1,207,542	0	0	43,779
Field Total	2,492,916	1,207,542	0	0	43,779
Nunn					
Codell Ss	1,191	2	0	0	0
Field Total	1,191	2	0	0	0
Oak Creek					
Shinarump	59,806	0	0	0	0
Field Total	59,806	0	0	0	0
Oasis					
D Sand	287,952	24,844	0	0	48
Field Total	287,952	24,844	0	0	48

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Oil Well Mountain					
Cameo Coal	60	0	26,210	0	3,668
Cameo Coal	8	7,442	1,878	0	799
Corcoran	37	6,511	0	0	1,569
Corcoran	2	11,239	0	0	676
Cozette	4	11,010	0	0	684
Cozzette	1	493	0	0	1,037
Cozzette, Corcoran	0	271	0	0	0
Cozzette, Corcoran, Mesaverde	11	13,221	0	0	270
Mesaverde	561	162,068	0	0	0
Mesaverde	471	78,536	0	0	0
Field Total	1,155	290,791	28,088	0	8,703
Old Baldy					
D Sand	469	0	0	0	115
J Sand	254	0	0	0	71
Niobrara	0	27,938,487	0	0	66,210
Field Total	723	27,938,487	0	0	66,396
Old House					
J Sand	592	0	0	0	715
Muddy (J)	10,547	0	0	0	0
Field Total	11,139	0	0	0	715
Old Road					
D Sand	436	54,056	0	0	0
Field Total	436	54,056	0	0	0
Omar					
D Sand	2,261	1,680	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	449	6,937	0	0	0
Field Total	2,710	8,617	0	0	0
Onyx					
J Sand	0	0	0	0	0
Muddy (J)	696	5,119	0	0	0
Field Total	696	5,119	0	0	0
Opal					
D Sand	80,676	514,844	0	0	0
Field Total	80,676	514,844	0	0	0
Open View					
J Sand	1,039	16,378	0	0	1,708
Field Total	1,039	16,378	0	0	1,708
Orchard					
D Sand	561,589	2,225,917	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	3,391	72,255	0	0	0
Field Total	564,980	2,298,172	0	0	0
Orchard West					
Greenhorn Ls	257	0	0	0	0
Field Total	257	0	0	0	0
Oriole					
D Sand	5,717	282,088	0	0	0
Field Total	5,717	282,088	0	0	0
Orion					
D Sand	5,051	289,811	0	0	0
D Sand, Muddy (J)	15	0	0	0	0
Field Total	5,066	289,811	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Otis					
D Sand	0	1,216,193	0	0	0
Niobrara	0	0	0	0	0
Field Total	0	1,216,193	0	0	0
Outpost					
D Sand	332	5,076	0	0	0
Field Total	332	5,076	0	0	0
Overlook					
J Sand	7,310	0	0	0	580,503
Muddy (J)	31,670	0	0	0	0
Field Total	38,980	0	0	0	580,503
Owl Creek					
Codell Ss	155,959	962,172	0	0	295
Niobrara, Codell Ss	175,412	1,463,868	0	0	2,220
Field Total	331,371	2,426,040	0	0	2,515
Oxbow					
J Sand	9,107	0	0	0	95,528
Muddy (J)	130,714	0	0	0	0
Field Total	139,821	0	0	0	95,528
Oyster					
Keyes	0	52,684	0	0	0
Morrow	336	3,595,885	0	0	0
Morrow V7	0	580,463	0	0	9,559
Field Total	336	4,229,032	0	0	9,559
Pack					
D Sand, Muddy (J)	0	44,842	0	0	0
Field Total	0	44,842	0	0	0
Padroni					
D Sand	22,438	4,024,801	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	112,872	1,681,849	0	0	0
O Sand	0	0	0	0	0
Field Total	135,310	5,706,650	0	0	0
Padroni West					
D Sand	83,826	15,117	0	0	0
Dakota	3,857,477	131,750	0	0	0
J Sand	12,130	0	0	0	113,486
J Sand, O Sand	2,151	0	0	0	0
Muddy (J)	430,742	171,187	0	0	0
O Sand	330,613	0	0	0	7,216,690
Field Total	4,716,939	318,054	0	0	7,330,176
Pagoda					
Shinarump	994	3,805,181	0	0	0
Field Total	994	3,805,181	0	0	0
Paleface					
Atoka	221	0	0	0	0
Field Total	221	0	0	0	0
Palomino					
D Sand	17,452	6,980	0	0	0
Field Total	17,452	6,980	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO₂ (Mscf)	Water (Barrels)
Papoose Canyon					
Desert Creek	6,278,983	32,656,530	0	0	665,300
Desert Creek	0	0	0	0	0
Hermosa	10,315	52,051	0	0	0
Ismay	4,535	2,391,836	0	0	10,530
Ismay, Desert Creek	215,848	936,635	0	0	973,625
Field Total	6,509,681	36,037,052	0	0	1,649,455
Parachute					
Cameo Coal	61	224,471	595,272	0	130
Cameo Coals, Mesaverde	44	97,119	0	0	326
Crcn, Cozz, Cameo Sd, Wmfk	5	40,910	0	0	0
Mesaverde	2,483	16,457,680	0	0	1,305
Mesaverde Coal	0	0	4,615,731	0	0
Rollins	0	63,411	0	0	33
Rollins, Williams Fork	59	65,315	76,149	0	218
Wasatch	3,124	39,778,334	0	0	7,215
Wasatch G	0	1,226,519	0	0	0
Williams Fk, Rollins, Cameo	0	183,454	0	0	2,328
Williams Fork	3,542	5,129,499	612,996	0	98,960
Williams Fork Coal	157	419,519	0	0	2,901
Williams Fork, Cameo	28,107	72,888,668	4,095,362	0	821,956
Williams Fork, Cameo Coal	806	252,095	0	0	63
Field Total	38,388	136,826,994	9,995,510	0	935,435
Park					
D Sand	13,902	1,171,234	0	0	0
J Sand	35,178	0	0	0	54,979
Muddy (J)	1,179,067	805,979	0	0	0
Niobrara	10,008	0	0	0	0
Field Total	1,238,155	1,977,213	0	0	54,979
Park Mountain					
Buckhorn	660	489,363	0	0	3,262
Cedar Mountain	102	63,514	0	0	0
Dakota	87,279	25,662,050	0	0	43,879
Dakota, Buckhorn	2,116	337,636	0	0	42
Dakota, Morrison	15	17,231	0	0	35
Mancos B	2,971	18,541	0	0	0
Morrison	74	37,763	0	0	213
Williams Fork	0	263	0	0	14,000
Field Total	93,217	26,626,361	0	0	61,431
Pass Creek					
Marmaton	353	0	0	0	0
Field Total	353	0	0	0	0
Patrol					
J Sand	29,547	0	0	0	0
Muddy (J)	158,112	691	0	0	0
Field Total	187,659	691	0	0	0
Patrol North					
D Sand	10,199	36,039	0	0	0
Field Total	10,199	36,039	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Pawnee					
J Sand	5,162	13,769	0	0	85,200
Muddy (J)	17,383	79,722	0	0	0
Field Total	22,545	93,491	0	0	85,200
Pawnee Buttes					
J Sand	0	0	0	0	0
Muddy (J)	1,625	0	0	0	0
Field Total	1,625	0	0	0	0
Pawnee Creek					
J Sand	16,725	14,445	0	0	76,876
Muddy (J)	2,230,519	1,552,804	0	0	0
Field Total	2,247,244	1,567,249	0	0	76,876
Pawnee Creek North					
J Sand	0	0	0	0	0
Muddy (J)	7,171	57,322	0	0	0
Field Total	7,171	57,322	0	0	0
Pawnee Hills					
D Sand	24,860	1,103,532	0	0	0
Field Total	24,860	1,103,532	0	0	0
Pawnee Pioneer					
Richards Ss	132,502	0	0	0	123,593
Field Total	132,502	0	0	0	123,593
Peace Pipe					
D Sand	14,523	147,555	0	0	0
J Sand	222	62,166	0	0	1,650
Muddy (J)	88,350	4,464,705	0	0	0
Field Total	103,095	4,674,426	0	0	1,650
Peachtree					
Dakota	0	37,724	0	0	771
Dakota, Morrison	0	825	0	0	0
Morrison	0	240,873	0	0	1,657
Field Total	0	279,422	0	0	2,428
Peacock					
D Sand	322,327	1,263,809	0	0	2,755
J Sand	3,621	1,010,896	0	0	835
Field Total	325,948	2,274,705	0	0	3,590
Peak View					
D Sand	341,128	1,455,123	0	0	432
D Sand, Muddy (J)	2,459	46,848	0	0	0
J Sand	131	706	0	0	0
Muddy (J)	49,451	167,494	0	0	0
Field Total	393,169	1,670,171	0	0	432
Peavy					
D Sand	0	98,019	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	360,644	676,963	0	0	0
Field Total	360,644	774,982	0	0	0
Pebble					
D Sand	166	46,151	0	0	1,652
J Sand	53,898	20,194	0	0	65,569
Muddy (J)	553,753	320,744	0	0	0
Field Total	607,817	387,089	0	0	67,221
Peck Ditch					
Mancos Sh	10,460	17,415	0	0	0
Niobrara	1,601	4,390	0	0	0
Field Total	12,061	21,805	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Peconic					
Niobrara	0	11,160	0	0	0
Field Total	0	11,160	0	0	0
Peetz Northwest					
D Sand	87,630	2,194,933	0	0	16,422
J Sand	0	0	0	0	0
Field Total	87,630	2,194,933	0	0	16,422
Peetz Table					
J Sand	17,540	0	0	0	185,270
Field Total	17,540	0	0	0	185,270
Peetz West					
D Sand	21,460	1,548,775	0	0	0
J Sand	40,612	76,742	0	0	519,421
Muddy (J)	1,716,280	2,051,184	0	0	0
Field Total	1,778,352	3,676,701	0	0	519,421
Pelt					
Niobrara	15,125	529,282	0	0	0
Field Total	15,125	529,282	0	0	0
Pennypacker					
Morrow	149	100,751	0	0	0
Morrow V7	4,162	1,582,336	0	0	2,571
Field Total	4,311	1,683,087	0	0	2,571
Peoria					
J Sand	19,150	23,608	0	0	530,605
Muddy (J)	48,142	25,274,247	0	0	0
Field Total	67,292	25,297,855	0	0	530,605
Peoria (Gas)					
J Sand	4,726	225,260	0	0	5,315
Muddy (J)	0	0	0	0	0
Field Total	4,726	225,260	0	0	5,315
Peoria North					
J Sand	0	0	0	0	0
Muddy (J)	850,487	2,910,239	0	0	0
Field Total	850,487	2,910,239	0	0	0
Peregrine					
Niobrara	0	375,680	0	0	1,235
Field Total	0	375,680	0	0	1,235
Persigo Wash					
Buckhorn	0	0	0	0	0
Cedar Mountain	0	7,993	0	0	0
Dakota	0	29,922	0	0	0
Morrison	2	12,065	0	0	0
Field Total	2	49,980	0	0	0
Peterson					
D Sand	1,176,154	390,088	0	0	1,394,611
Field Total	1,176,154	390,088	0	0	1,394,611
Pheasant					
J Sand	2,138	35,798	0	0	56
Muddy (J)	5,483	305,442	0	0	0
Field Total	7,621	341,240	0	0	56
Phegley					
D Sand	2,576,682	457,134	0	0	1,403
Field Total	2,576,682	457,134	0	0	1,403

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Philadelphia Creek					
Mancos B	0	1,249,532	0	0	2,644
Mancos Sh	756	7,596,885	0	0	0
Field Total	756	8,846,417	0	0	2,644
Phuma					
Niobrara	0	108,154	0	0	0
Niobrara	0	1,659,880	0	0	26,674
Field Total	0	1,768,034	0	0	26,674
Piceance Creek					
Cameo	0	737,509	0	0	12,105
Corcoran	0	0	0	0	0
Cozette	0	0	0	0	0
Douglas Creek	32	56,565,428	0	0	654
Iles	333	620,874	0	0	6,848
Mancos B	33	20,505	0	0	0
Mesaverde	36,599	7,944,568	0	0	657,064
Ohio Creek	356	388,316	0	0	47,720
Rollins	1,007	632,595	0	0	12,675
Sego	0	0	0	0	0
Wasatch	123,985	179,581,726	0	0	80,880
Wasatch A	2,345	6,749,312	46,114	0	9,746
Wasatch A, B	420	598,806	0	0	1,202
Wasatch A, G	729	1,503,262	0	0	12,530
Wasatch D	44	398,501	0	0	138
Wasatch F	86	102,392	0	0	82
Wasatch G	1,274	6,282,063	0	0	456,609
Williams Fork	0	0	0	0	0
Williams Fork	620	696,746	0	0	10,458
Williams Fork, Cameo	0	379,169	0	0	19,466
Field Total	167,863	263,201,772	46,114	0	1,328,177
Piceance Creek South					
Douglas Creek	450	2,546,961	0	0	0
Green River	114	0	0	0	0
Field Total	564	2,546,961	0	0	0
Pierce					
Lyons Ss	12,093,716	493,157	0	0	6,272,549
Field Total	12,093,716	493,157	0	0	6,272,549
Pike					
Fort Hays	0	0	0	0	0
Niobrara	799	0	0	0	0
Field Total	799	0	0	0	0
Ping					
J Sand	47,143	1,888	0	0	42,055
Muddy (J)	20,731	3,858	0	0	0
Field Total	67,874	5,746	0	0	42,055
Pinnacle					
Dakota	991	57,991	0	0	0
Shinarump	139,161	64,789	0	0	50
Field Total	140,152	122,780	0	0	50
Pinneo North					
D Sand	48,000	82,539	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	16,192	513	0	0	0
Field Total	64,192	83,052	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Pintail					
J Sand	0	0	0	0	0
Muddy (J)	2,690	5,479	0	0	0
Field Total	2,690	5,479	0	0	0
Pinto					
D Sand	87,864	191,420	0	0	11,200
J Sand	57,905	0	0	0	8,080
Muddy (J)	139,785	9	0	0	0
Field Total	285,554	191,429	0	0	19,280
Pinto North					
D Sand	4,246	9,061	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	6,262	49,312	0	0	0
Field Total	10,508	58,373	0	0	0
Pinyon Ridge					
Cameo Coal	0	0	0	0	0
Cameo Coal	0	29,622	4,735	0	249,100
Mesaverde	14,858	0	0	0	0
Mesaverde	0	0	0	0	0
Mesaverde Coal	0	0	77,922	0	0
Mesaverde Coal	3,147	0	176,690	0	0
Williams Fork	0	0	0	0	0
Williams Fork	0	14,372	569	0	45,115
Williams Fork Coal	0	0	0	0	0
Field Total	18,005	43,994	259,916	0	294,215
Pitch					
J Sand	0	0	0	0	0
Muddy (J)	5,182	213	0	0	0
Field Total	5,182	213	0	0	0
Plains					
J Sand	89,137	0	0	0	510,975
Muddy (J)	389,467	496	0	0	0
Field Total	478,604	496	0	0	510,975
Plainsman					
D Sand	116,042	1,122,110	0	0	2,105
D Sand	6,450	2,225	0	0	0
Mesaverde	0	0	0	0	0
Niobrara	4,900	4,764	0	0	0
Field Total	127,392	1,129,099	0	0	2,105

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Plateau					
Cameo	0	43,589	0	0	32
Cameo Coal	0	3,340	1,431	0	8,265
Corcoran	2,538	2,686,268	0	0	81,070
Corcoran, Cozzette, Rollins	0	52,246	0	0	38
Corcoran, Mesaverde	0	0	0	0	0
Cozzette	1,151	1,170,759	0	0	43,681
Cozzette, Corcoran	937	792,183	0	0	1,237
Cozzette, Mesaverde	0	18,377	0	0	0
Dakota	0	1,587,027	0	0	4,354
J Sand	0	17,990	0	0	0
Mesaverde	12,420	29,532,767	0	0	1,079
Mesaverde Coal	0	0	14,346	0	0
Morrison	0	47,542	0	0	0
Muddy (J)	0	44,800	0	0	0
Ohio Creek	0	0	0	0	0
Rollins	135	410,046	0	0	20,647
Rollins, Corcoran	0	130,384	0	0	0
Rollins, Cozzette, Corcoran	0	579,520	0	0	1,938
Wasatch	28	37,893	0	0	243
Williams Fork	0	24,433	0	0	0
Field Total	17,209	37,179,164	15,777	0	162,584
Platner					
D Sand	14,518	78,012	0	0	0
Field Total	14,518	78,012	0	0	0
Playa					
Topeka C	0	10,663	0	0	0
Topeka Ls	0	13,894,618	0	0	7,267
Field Total	0	13,905,281	0	0	7,267
Pleasant Ridge					
J Sand	15,593	0	0	0	0
Muddy (J)	288,782	253,014	0	0	0
Field Total	304,375	253,014	0	0	0
Pleasant Valley					
J Sand	0	0	0	0	0
Muddy (J)	59,774	20,856	0	0	0
Field Total	59,774	20,856	0	0	0
Plumb Bush Creek					
J Sand	0	0	0	0	0
Muddy (J)	18,859,916	2,166,793	0	0	0
Field Total	18,859,916	2,166,793	0	0	0
Poco					
J Sand	0	0	0	0	0
Muddy (J)	281	0	0	0	0
Field Total	281	0	0	0	0
Pod					
J Sand	70,464	0	0	0	3,830,954
Muddy (J)	1,154,930	882	0	0	0
Field Total	1,225,394	882	0	0	3,830,954
Poe					
D Sand	45,899	995,872	0	0	0
Field Total	45,899	995,872	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Point Bar					
D Sand	104,356	1,670	0	0	580,307
Field Total	104,356	1,670	0	0	580,307
Point Lookout					
Dakota	0	0	0	0	0
Point Lookout	0	23,000	0	0	0
Field Total	0	23,000	0	0	0
Point of Rocks					
D Sand	9,093	620	0	0	0
Field Total	9,093	620	0	0	0
Poison Spring					
D Sand	242,447	56,289	0	0	0
Field Total	242,447	56,289	0	0	0
Pole Gulch					
Lance	0	63,436	0	0	0
Lance, Lewis	0	4,425	0	0	0
Lewis Sh	3,128	4,555,966	0	0	2
Lewis Sh, Mesaverde	2,913	4,550,302	0	0	0
Field Total	6,041	9,174,129	0	0	2
Pollen					
J Sand	11,047	0	0	0	0
Muddy (J)	257,365	1,265,874	0	0	0
Field Total	268,412	1,265,874	0	0	0
Pommel					
D Sand	84,651	767,920	0	0	704
Field Total	84,651	767,920	0	0	704
Pommel West					
D Sand	170,648	1,242,184	0	0	885,770
J Sand	905	14,508	0	0	8,100
Field Total	171,553	1,256,692	0	0	893,870
Poncho					
J Sand	0	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	898,318	1,209,948	0	0	0
Muddy (J)	669,134	855,413	0	0	0
Field Total	1,567,452	2,065,361	0	0	0
Poncho South					
J Sand	9,283	5,894	0	0	1,020
Muddy (J)	83,624	27,666	0	0	0
Field Total	92,907	33,560	0	0	1,020
Pony					
J Sand	0	0	0	0	0
Muddy (J)	22,152	42,919	0	0	0
Field Total	22,152	42,919	0	0	0
Pony Express					
Niobrara	0	352,466	0	0	952
Field Total	0	352,466	0	0	952
Porter					
D Sand, Muddy (J)	700	15,040	0	0	0
J Sand	4,429	731,670	0	0	1,940
Muddy (J)	33,096	3,289,533	0	0	0
Field Total	38,225	4,036,243	0	0	1,940

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Pow Wow					
J Sand	94,528	112,899	0	0	601,779
Muddy (J)	632,730	138,516	0	0	0
Field Total	727,258	251,415	0	0	601,779
Powder Wash					
Fort Union	2,689,030	174,829,462	0	0	128,484
Fort Union, Wasatch	119,061	291,947	0	0	0
Wasatch	5,417,094	97,637,694	0	0	12,196
Field Total	8,225,185	272,759,103	0	0	140,680
Powell					
D Sand	395	78,925	0	0	0
Wasatch	0	3,240	0	0	7
Field Total	395	82,165	0	0	7
Powell Park					
Corcoran	0	0	0	0	0
Cozette	0	0	0	0	0
Fort Union	189	251,532	0	0	0
Mancos B	0	0	0	0	0
Mancos Sh	0	7,376	0	0	0
Mesaverde	3,102	16,354	0	0	0
Wasatch	1,016	323,877	0	0	639
Williams Fork	5,470	87,235	0	0	6,352
Field Total	9,777	686,374	0	0	6,991
Prairie Canyon					
Dakota	145	4,234,235	0	0	0
Dakota, Morrison	43	2,435,650	0	0	0
Morrison	0	218,705	0	0	0
Field Total	188	6,888,590	0	0	0
Prairie Dog					
Hermosa	198	459,034	0	0	0
J Sand	0	0	0	0	0
Marmaton	0	353,066	0	0	0
Muddy (J)	0	29,882	0	0	0
Field Total	198	841,982	0	0	0
Prairie View					
D Sand	60,444	54,656	0	0	0
Field Total	60,444	54,656	0	0	0
Prewitt					
D Sand	29,968	2,280	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	81,709	12,040	0	0	0
Field Total	111,677	14,320	0	0	0
Price Gramps					
Dakota, Morrison	6,811,770	0	0	0	0
Field Total	6,811,770	0	0	0	0
Price Ranch					
Niobrara	0	45,945	0	0	79
Field Total	0	45,945	0	0	79
Prickly Pear					
J Sand	0	0	0	0	0
Muddy (J)	13,748	0	0	0	0
Field Total	13,748	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Prism					
J Sand	0	0	0	0	0
Muddy (J)	18,643	0	0	0	0
Field Total	18,643	0	0	0	0
Pronghorn					
J Sand	57,681	371,376	0	0	23,562
Muddy (J)	562,207	4,471,188	0	0	0
Field Total	619,888	4,842,564	0	0	23,562
Pronto					
D Sand	96,847	75,192	0	0	0
Field Total	96,847	75,192	0	0	0
Prospect					
D Sand	72,998	337,928	0	0	1,954
J Sand	0	0	0	0	0
Muddy (J)	8,907	324,796	0	0	0
Field Total	81,905	662,724	0	0	1,954
Prosperity					
D Sand	635	103,495	0	0	0
Field Total	635	103,495	0	0	0
Puma					
J Sand	560	78,074	0	0	82
J Sand	431	46,381	0	0	754
Muddy (J)	58,190	539,831	0	0	0
Niobrara, Codell Ss	2,658	60,900	0	0	0
Field Total	61,839	725,186	0	0	836
Purdy					
D Sand	6,446	54,373	0	0	0
D Sand	5,026	2,306	0	0	0
Field Total	11,472	56,679	0	0	0
Purgatoire					
Atoka	8,203	3	0	0	0
Vermajo Coal	0	25,399	0	0	8,792
Field Total	8,203	25,402	0	0	8,792
Purgatoire River					
Carlile, Greenhorn	0	1,504	0	0	0
Dakota	0	0	0	0	0
Dakota	0	0	0	0	0
Fort Hays	0	5,477	0	0	11,249
Graneros	0	0	0	0	0
Greenhorn Ls	0	143	0	0	0
Niobrara	0	8,092	0	0	35,723
Not Complete	0	0	0	0	221
Pierre Sh	0	6,508	0	0	1,547
Raton Coal	0	0	342	0	22,286
Raton Coal	0	894,478	4,318,346	0	8,432,102
Raton Sand	0	3,317	4,623	0	17,889
Raton Sand	0	1,026,674	549,578	0	1,977,556
Raton Ss, Vermejo	0	31,941	0	0	53,515
Raton, Vermejo Coal	0	0	0	0	13,438,837
Raton, Vermejo Coal	0	1,275,792	8,507,345	0	19,271,930
Vermejo Coal	0	30,288	91,273	0	92,061,390
Vermejo Coal	0	6,663,683	94,510,948	0	83,198,477
Williams Fork, Cameo	112	117,035	0	0	1,338
Field Total	112	10,064,932	107,982,455	0	218,524,060

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Pyramid					
D Sand	7,260	287,396	0	0	0
Field Total	7,260	287,396	0	0	0
Quail					
J Sand	56,978	753,763	0	0	18,789
Muddy (J)	558,451	8,740,108	0	0	0
Field Total	615,429	9,493,871	0	0	18,789
Quarry					
J Sand	9,584	157,802	0	0	1,689
Muddy (J)	43,863	954,681	0	0	0
Field Total	53,447	1,112,483	0	0	1,689
Quest					
J Sand	103,116	0	0	0	4,963,376
Muddy (J)	79,115	0	0	0	0
Field Total	182,231	0	0	0	4,963,376
Quill					
D Sand, Muddy (J)	2,067	0	0	0	0
J Sand	8,144	7,758	0	0	3,469
Muddy (J)	446,811	1,243,870	0	0	0
Field Total	457,022	1,251,628	0	0	3,469
Quirt					
J Sand	0	0	0	0	0
Muddy (J)	289	29,836	0	0	0
Field Total	289	29,836	0	0	0
Quiver					
Mississippian	42,220	8,200	0	0	0
Mississippian, Spergen	45,004	0	0	0	75,773
Spergen	502,737	0	0	0	530,342
Field Total	589,961	8,200	0	0	606,115
Raccoon					
D Sand	23,581	21,015	0	0	0
Field Total	23,581	21,015	0	0	0
Radar					
D Sand	364,836	2,156,868	0	0	3,060
D Sand, Muddy (J)	314,627	1,931,347	0	0	204
J Sand	76,000	462,354	0	0	5,352
Muddy (J)	603,826	3,577,267	0	0	0
Field Total	1,359,289	8,127,836	0	0	8,616
Ragged Mountain					
Corcoran	192	158,505	0	0	89
Cozette	212	214,222	0	0	240
Cozzette, Corcoran	174	166,040	0	0	0
Mesaverde	3,536	1,794,007	0	0	0
Field Total	4,114	2,332,774	0	0	329
Rago					
D Sand	330,256	114,518	0	0	2,085
J Sand	2,966	0	0	0	0
Muddy (J)	83,335	25,207	0	0	0
Field Total	416,557	139,725	0	0	2,085
Rago North					
D Sand	805,749	110,481	0	0	52,387
J Sand	268,141	43,234	0	0	11,203,660
Muddy (J)	2,067,919	372,059	0	0	0
Field Total	3,141,809	525,774	0	0	11,256,047

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Rain Dance					
D Sand	14,840	19,306	0	0	0
Field Total	14,840	19,306	0	0	0
Rainbow					
J Sand	52,550	34,484	0	0	1,053,736
Muddy (J)	433,782	273,705	0	0	0
Field Total	486,332	308,189	0	0	1,053,736
Raindrop					
J Sand	0	0	0	0	0
Muddy (J)	526	308,502	0	0	0
Field Total	526	308,502	0	0	0
Rake					
D Sand	458,295	1,417,574	0	0	0
Field Total	458,295	1,417,574	0	0	0
Ram					
J Sand	0	0	0	0	0
Muddy (J)	4,051	0	0	0	0
Field Total	4,051	0	0	0	0
Ramey					
J Sand	431	128,025	0	0	38,952
Muddy (J)	3,356	39,092	0	0	0
Field Total	3,787	167,117	0	0	38,952
Ramona					
Gallup Ss	1,392	0	0	0	0
Field Total	1,392	0	0	0	0
Ramp					
J Sand	79,024	0	0	0	129,469
Muddy (J)	1,061,856	72,836	0	0	0
Field Total	1,140,880	72,836	0	0	129,469
Ramrod					
J Sand	0	0	0	0	0
Muddy (J)	301,790	518,823	0	0	0
Field Total	301,790	518,823	0	0	0
Ranchero					
D Sand	60,219	643,622	0	0	72,425
J Sand	77,682	12,426	0	0	797,487
Muddy (J)	1,010,639	706,319	0	0	0
Field Total	1,148,540	1,362,367	0	0	869,912
Rangely					
Dakota	12	0	0	0	0
Dakota, Mancos Sh	60	3,150	0	0	0
Emery	45	0	0	0	0
Entrada Ss	0	52,293	0	0	0
Mancos B	0	0	0	0	0
Mancos Sh	14,278,115	640,083	0	0	4,906
Morrison	91,478	1,946,177	0	0	0
Navajo	0	0	0	0	0
Salt Wash	80,969	21,432	0	0	9,943
Shinarump	212,087	51,937	0	0	0
Weber Ss	857,844,447	770,582,934	0	0	484,843,143
Field Total	872,507,213	773,298,006	0	0	484,857,992

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Rangely Southwest					
Castlegate	0	119,163	0	0	645
Dakota	0	0	0	0	1
Mancos B	0	3,506,786	0	0	13,586
Mancos Sh	0	8,294,448	0	0	223
Mesaverde	0	789,334	0	0	0
Field Total	0	12,709,731	0	0	14,455
Rangely West					
Castlegate	0	407,268	0	0	3,819
Mesaverde	0	15,251	0	0	0
Field Total	0	422,519	0	0	3,819
Ranger					
J Sand	81,453	0	0	0	1,214,426
Muddy (J)	1,243,180	0	0	0	0
Field Total	1,324,633	0	0	0	1,214,426
Raton					
Raton Coal	0	569,820	2,177,195	0	2,905,212
Raton Sand	0	703,779	0	0	14,162
Raton Sand, Vermejo Coal	0	14,621	0	0	16,504
Raton, Vermejo Coal	0	1,493,197	17,221,970	0	22,751,410
Sangre de Cristo	0	0	0	0	116,627
Vermejo Coal	0	2,483,693	12,771,647	0	18,260,517
Field Total	0	5,265,110	32,170,812	0	44,064,432
Rattlesnake					
D Sand	2,300	14,446	0	0	0
D Sand, Muddy (J)	99,203	520,916	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	4,821	2,851	0	0	0
Field Total	106,324	538,213	0	0	0
Rattlesnake Buttes					
D Sand	394	4,376	0	0	0
Field Total	394	4,376	0	0	0
Rawhide					
D Sand	177,660	131,383	0	0	0
Field Total	177,660	131,383	0	0	0
Raymer Creek					
D Sand	209,152	439,274	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	55	68,452	0	0	0
Field Total	209,207	507,726	0	0	0
Razor					
J Sand	0	0	0	0	0
Muddy (J)	10,224	16,385	0	0	0
Field Total	10,224	16,385	0	0	0
Red Cloud					
D Sand	37,902	1,918	0	0	64,160
J Sand	9,402	0	0	0	241,731
Muddy (J)	279,462	51,048	0	0	0
Field Total	326,766	52,966	0	0	305,891
Red Giant					
Lansing	150,187	6,745	0	0	893,627
Mississippian	0	187,307	0	0	5,752
Morrow	0	42,882	0	0	0
Morrow V7	0	218,741	0	0	5,046
Field Total	150,187	455,675	0	0	904,425

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Red Lion					
D Sand	0	2,467,533	0	0	0
Field Total	0	2,467,533	0	0	0
Red Mesa					
Barker Creek	0	237,624	0	0	0
Carlile	9,794	0	0	0	0
Codell Ss	23,161	0	0	0	0
Dakota	1,333,327	1,590,124	0	0	7,338
Dakota, Morrison	25,947	19,058	0	0	0
Gallup Ss	668,893	345,940	0	0	4,463
Mancos Sh	112,586	156,223	0	0	17
Menefee	16	0	0	0	44
Menefee Coal	0	0	0	0	0
Mesaverde	6	1,036,880	0	0	10,271
Mesaverde Coal	0	0	28,364	0	0
Morrison	11,589	4,616	0	0	350
Point Lookout	0	10,243	0	0	1,405
unknown	0	0	0	0	0
Field Total	2,185,319	3,400,708	28,364	0	23,888
Red Willow					
Niobrara	0	49,314	0	0	1,240
Field Total	0	49,314	0	0	1,240
Redwing					
D Sand	1,572,491	2,654,978	0	0	1,152,386
Field Total	1,572,491	2,654,978	0	0	1,152,386
Reflex					
D Sand	33,548	581,318	0	0	0
Field Total	33,548	581,318	0	0	0
Regent					
D Sand	188,899	230,412	0	0	2,016
Field Total	188,899	230,412	0	0	2,016
Renegade					
D Sand	2,194	204,169	0	0	0
Field Total	2,194	204,169	0	0	0
Renfro Creek					
Mancos Sh	2,074	0	0	0	0
Field Total	2,074	0	0	0	0
Republican					
Lakota, Morrison	0	0	0	0	0
Niobrara	0	37,299,903	0	0	945,591
Field Total	0	37,299,903	0	0	945,591
Rerun					
J Sand	0	0	0	0	0
Muddy (J)	0	18,146	0	0	0
Field Total	0	18,146	0	0	0
Reward					
D Sand	329	0	0	0	0
D Sand	12,954	27,091	0	0	0
Field Total	13,283	27,091	0	0	0
Rhoades					
Morrow B	70,105	284,051	0	0	0
Field Total	70,105	284,051	0	0	0
Ridge					
D Sand	33,810	219,993	0	0	0
Field Total	33,810	219,993	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Rift					
D Sand	0	50,588	0	0	0
Field Total	0	50,588	0	0	0
Rill					
D Sand	134,846	10,965	0	0	0
J Sand	6,820	2,553	0	0	0
Field Total	141,666	13,518	0	0	0
Rimrock					
J Sand	1,098	367,580	0	0	0
Muddy (J)	14,325	2,114,617	0	0	0
Field Total	15,423	2,482,197	0	0	0
Ring					
J Sand	9,976	0	0	0	117,939
Muddy (J)	526,700	103,527	0	0	0
Field Total	536,676	103,527	0	0	117,939
Ringer					
D Sand	1,639	17	0	0	0
Field Total	1,639	17	0	0	0
Rio					
D Sand	36,710	36,710	0	0	0
Field Total	36,710	36,710	0	0	0
Ripple					
D Sand	2,777	0	0	0	0
Field Total	2,777	0	0	0	0
Rita					
Lansing	26,753	0	0	0	0
Lansing, Kansas City	151,259	0	0	0	216,404
Lyons Ss	0	0	0	0	21,577
Field Total	178,012	0	0	0	237,981
Riverside					
J Sand	474	0	0	0	0
Muddy (J)	0	3,891,613	0	0	0
Field Total	474	3,891,613	0	0	0
Roadrunner					
Ismay	2,110,627	4,238,706	0	0	400,346
Lower Ismay	45,239	188,337	0	0	666,722
Field Total	2,155,866	4,427,043	0	0	1,067,068
Roadside					
D Sand	989	0	0	0	0
J Sand	10,832	0	0	0	5,686
Muddy (J)	61,791	1,313	0	0	0
Field Total	73,612	1,313	0	0	5,686
Roberts Canyon					
Corcoran	0	127,983	0	0	1,514
Cozette	0	126,297	0	0	1,931
Dakota	0	816,146	0	0	547
Dakota, Mancos Sh	0	0	0	0	0
Mancos Sh	0	0	0	0	0
Field Total	0	1,070,426	0	0	3,992
Rock					
Dakota	628	0	0	0	0
Niobrara	0	25,657	0	0	1,973
Field Total	628	25,657	0	0	1,973

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Rock Canyon					
Dakota	0	1,954,039	0	0	175
Field Total	0	1,954,039	0	0	175
Rock Creek					
Niobrara	191	18,082,102	0	0	136,415
Field Total	191	18,082,102	0	0	136,415
Rockies					
D Sand	1,103	0	0	0	0
Field Total	1,103	0	0	0	0
Rocky Point					
Mancos B	5,601	0	0	0	82
Mancos Sh	24,785	7,686	0	0	0
Field Total	30,386	7,686	0	0	82
Rodeo Bullfighter					
J Sand	0	0	0	0	0
Muddy (J)	3,893	0	0	0	0
Field Total	3,893	0	0	0	0
Roderick					
J Sand	59,928	0	0	0	905,822
Muddy (J)	2,069,761	140,567	0	0	0
Field Total	2,129,689	140,567	0	0	905,822
Roggen					
D Sand	1,792,818	5,499,091	0	0	2,392
D Sand, Muddy (J)	10,246	176,516	0	0	0
J Sand	921	60,276	0	0	968
J Sand	37,853	2,047,234	18,240	0	98,243
Muddy (J)	996,229	17,885,488	0	0	0
Niobrara	1,403	1,456	0	0	0
Timpas	0	0	0	0	0
Field Total	2,839,470	25,670,061	18,240	0	101,603
Rolling Hills					
J Sand	0	0	0	0	0
Muddy (J)	16,908	1,197	0	0	0
Field Total	16,908	1,197	0	0	0
Roman Nose					
J Sand	94,180	3,036	0	0	289,782
J Sand	0	0	0	0	0
Muddy (J)	692,496	186,078	0	0	0
Muddy (J)	316,510	108,280	0	0	0
Field Total	1,103,186	297,394	0	0	289,782
Roman Nose North					
J Sand	0	0	0	0	0
Muddy (J)	83,710	75,347	0	0	0
Field Total	83,710	75,347	0	0	0
Rooster					
Lansing	1,219	0	0	0	0
Field Total	1,219	0	0	0	0
Rose Ranch					
Mississippian	795	386	0	0	0
Mississippian, St Louis	0	0	0	0	0
Field Total	795	386	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Rosener					
D Sand	73,384	66,753	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	250,009	1,242,574	0	0	0
Field Total	323,393	1,309,327	0	0	0
Roughneck					
J Sand	40,838	0	0	0	0
Muddy (J)	243,159	0	0	0	0
Field Total	283,997	0	0	0	0
Roulette					
D Sand	138,813	944,170	0	0	306
Field Total	138,813	944,170	0	0	306
Round Stone					
Morrow	2,419	1,233,074	0	0	1
Morrow V7	0	124,334	0	0	0
Field Total	2,419	1,357,408	0	0	1
Round Table					
Fort Union	954	0	0	0	0
Field Total	954	0	0	0	0
Roundup					
J Sand	0	0	0	0	0
Muddy (J)	182,801	6,668,293	0	0	0
Field Total	182,801	6,668,293	0	0	0
Rowel					
Dakota, Muddy (J)	135,136	0	0	0	0
J Sand	19,083	0	0	0	520,273
Field Total	154,219	0	0	0	520,273
Royal Flush					
Mississippian	894	0	0	0	0
Field Total	894	0	0	0	0
Rubicon					
J Sand	0	0	0	0	0
J Sand	76,368	0	0	0	358,449
Muddy (J)	23,559	3,587	0	0	0
Muddy (J)	619,080	0	0	0	0
Field Total	719,007	3,587	0	0	358,449
Ruby					
D Sand	584,887	3,664,160	0	0	0
Field Total	584,887	3,664,160	0	0	0
Rufus Run					
D Sand	96,658	2,857	0	0	6,396
Field Total	96,658	2,857	0	0	6,396

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Rulison					
Cameo	348	114,708	0	0	2,221
Cameo Coal	129	43,911	74,094	0	1,414
Cameo Coals, Mesaverde	1,099	152,210	0	0	19
Cameo Sd, Corcoran	105	52,020	0	0	368
Corcoran	0	1,118,158	0	0	3,028
Cozette	0	79,416	0	0	389
Cozzette, Corcoran, Mesaverde	10	34,859	0	0	0
Crcn, Cozz, Cameo Sd, Wmfk	1,301	781,691	0	0	1,566
Crcn, Cmeo, Wmfk	972	416,830	0	0	735
Mancos Sh	0	614,093	0	0	6,920
Mesaverde	167,778	49,874,998	0	0	10,883
Mesaverde Coal	0	0	1,530,917	0	0
Ohio Creek	2,866	0	0	0	361,722
Rollins	59	12,465	0	0	102
Rollins, Cozzette, Corcoran	0	32,900	0	0	0
Wasatch	32	20,862,546	0	0	796
Wasatch G	0	224,322	0	0	0
Williams Fork	135,641	37,707,454	110,302	0	323,136
Williams Fork, Cameo	443,688	156,702,159	1,160,160	0	1,656,471
Williams Fork, Cameo Coal	9,636	2,593,039	0	0	13,664
Williams Fork, Cameo Ss	1,090	316,108	0	0	1,938
Field Total	764,754	271,733,887	2,875,473	0	2,385,372
Run					
D Sand	80	14,979	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	89	44,384	0	0	0
Field Total	169	59,363	0	0	0
Running Bear					
D Sand	7,078	0	0	0	0
Field Total	7,078	0	0	0	0
Running Creek					
D Sand	14,931	23,942	0	0	0
Fort Hays	0	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	13,339	14,048	0	0	0
Niobrara	5,269	3	0	0	0
Field Total	33,539	37,993	0	0	0
Runnymede					
J Sand	0	0	0	0	0
Muddy (J)	345	0	0	0	0
Field Total	345	0	0	0	0
Rush Creek					
D Sand	38,081	4,966,191	0	0	0
Field Total	38,081	4,966,191	0	0	0
Rush Creek Draw					
St Louis	2,468	2,644	0	0	0
Field Total	2,468	2,644	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Rush Willadel					
D Sand	726,889	12,464	0	0	2,436,331
J Sand	434,833	37,939	0	0	11,967,439
Muddy (J)	5,870,284	0	0	0	0
Niobrara	0	947,267	0	0	0
Field Total	7,032,006	997,670	0	0	14,403,770
Saber					
D Sand	2,188,466	11,074,058	0	0	0
D Sand	466,333	2,632,149	0	0	0
Field Total	2,654,799	13,706,207	0	0	0
Sable					
D Sand	231	0	0	0	0
Niobrara	0	63,101	0	0	2,532
Field Total	231	63,101	0	0	2,532
Saddle					
J Sand	0	0	0	0	0
Muddy (J)	125,764	18,823	0	0	0
Field Total	125,764	18,823	0	0	0
Saddlebag					
Raton Coal	0	88,014	432,992	0	366,917
Raton Sand	0	40,946	0	0	149,839
Raton, Vermejo Coal	0	5,272	6,549,648	0	3,114,930
Vermejo Coal	0	0	932,178	0	1,805,090
Field Total	0	134,232	7,914,818	0	5,436,776
Sage					
Ismay	287,049	567,067	0	0	9,410
Field Total	287,049	567,067	0	0	9,410
Sage Brush Hills II					
Mancos A	0	13,482	0	0	447
Mancos B	355	24,748	0	0	596
Mancos Sh	539	395,837	0	0	0
Mesaverde	75	223,219	0	0	77
Williams Fork	201	19,118	0	0	408
Field Total	1,170	676,404	0	0	1,528
Sage Creek					
Niobrara	148,545	3,480	0	0	0
Field Total	148,545	3,480	0	0	0
Sage Creek North					
Niobrara	753,200	455,452	0	0	1
Field Total	753,200	455,452	0	0	1
Sagehen					
Ismay	45,170	59,592	0	0	0
Lower Ismay	180	0	0	0	0
Field Total	45,350	59,592	0	0	0
Salerno					
Mississippian	25,735	0	0	0	0
Mississippian, Spergen	15,473	0	0	0	652
Field Total	41,208	0	0	0	652
Salis					
Marmaton	121,253	0	0	0	90,741
Shawnee	195,413	0	0	0	275,346
Spergen	15,909	0	0	0	56,911
Topeka A	16,097	0	0	0	0
Topeka Ls	82,249	0	0	0	956,300
Field Total	430,921	0	0	0	1,379,298

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Salt Lake					
Morrow	761,244	845,100	0	0	104,333
Field Total	761,244	845,100	0	0	104,333
San Arroyo					
J Sand	0	0	0	0	0
Field Total	0	0	0	0	0
San Arroyo					
Muddy (J)	0	9,747	0	0	0
Field Total	0	9,747	0	0	0
San Arroyo Creek					
D Sand	17,279	4,324	0	0	0
Field Total	17,279	4,324	0	0	0
San Jacinto					
Cherokee	1,413	0	0	0	0
Field Total	1,413	0	0	0	0
Sanborn Draw					
Niobrara	1,163	12,695	0	0	0
Field Total	1,163	12,695	0	0	0
Sand Creek					
Marmaton	1,617	773	0	0	0
Marmaton, Morrow	1,962	0	0	0	0
Field Total	3,579	773	0	0	0
Sand River					
D Sand	4,126,272	3,665,335	0	0	2,330,324
Field Total	4,126,272	3,665,335	0	0	2,330,324
Sandia Peak					
Dakota, Muddy (J)	10,819	0	0	0	0
Field Total	10,819	0	0	0	0
Sandy					
J Sand	0	0	0	0	0
Muddy (J)	7,481	0	0	0	0
Field Total	7,481	0	0	0	0
Sandy Hill					
D Sand	119,241	40,149	0	0	0
Field Total	119,241	40,149	0	0	0
Sans Arc					
J Sand	926	0	0	0	0
Muddy (J)	28,234	34,558	0	0	0
Field Total	29,160	34,558	0	0	0
Santo					
Dakota, Muddy (J)	8,233	0	0	0	0
J Sand	536	0	0	0	2,207
Field Total	8,769	0	0	0	2,207
Sapphire					
J Sand	0	0	0	0	0
Muddy (J)	115,653	59,450	0	0	0
Field Total	115,653	59,450	0	0	0
Satanta					
D Sand	700	109,374	0	0	0
Field Total	700	109,374	0	0	0
Sawbuck					
D Sand	21,016	183,633	0	0	542
J Sand	0	0	0	0	0
Muddy (J)	5,613	114,003	0	0	0
Field Total	26,629	297,636	0	0	542

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Scabbard					
D Sand	23,587	93,268	0	0	0
J Sand	7,614	106,717	0	0	918
Muddy (J)	35,414	572,151	0	0	0
Field Total	66,615	772,136	0	0	918
Scarp					
D Sand, Muddy (J)	177,323	474,392	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	366,564	692,191	0	0	0
Field Total	543,887	1,166,583	0	0	0
Schneider Ditch					
D Sand	0	36,212	0	0	0
Field Total	0	36,212	0	0	0
Schramm					
Niobrara	0	8,202,566	0	0	166,196
Field Total	0	8,202,566	0	0	166,196
Scott Hill					
Dakota	103,067	0	0	0	191,163
Dakota, Weber Ss	87,528	0	0	0	0
Frontier	7,822	0	0	0	110,758
Weber Ss	308,532	0	0	0	772,701
Field Total	506,949	0	0	0	1,074,622
Scottie					
Niobrara	0	102,182	0	0	0
Field Total	0	102,182	0	0	0
Scout					
D Sand	32,314	0	0	0	0
Field Total	32,314	0	0	0	0
Seal					
J Sand	0	0	0	0	0
Muddy (J)	10,138	121,933	0	0	0
Field Total	10,138	121,933	0	0	0
Second Creek					
D Sand	72,106	27,098	0	0	0
D Sand, Muddy (J)	61,788	100,780	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	1,631	705	0	0	0
Field Total	135,525	128,583	0	0	0
Second Wind					
Morrow	3,097,097	3,636,369	0	0	35,776
Morrow V7	0	539,037	0	0	18,089
Field Total	3,097,097	4,175,406	0	0	53,865
Sentinel					
Kansas City	6,785	0	0	0	0
Keyes	6,385	16,165	0	0	0
Marmaton	4,861	0	0	0	0
Topeka Ls	1,524	0	0	0	0
Field Total	19,555	16,165	0	0	0
Sentry					
D Sand	89,404	29,563	0	0	0
Field Total	89,404	29,563	0	0	0
Serendipity					
D Sand	21,535	1,117,001	0	0	7,445
Field Total	21,535	1,117,001	0	0	7,445

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Settlement					
Niobrara	0	964	0	0	0
Field Total	0	964	0	0	0
Settler					
J Sand	0	0	0	0	0
Muddy (J)	4,126	173,094	0	0	0
Field Total	4,126	173,094	0	0	0
Seven Cross					
J Sand	0	0	0	0	0
Mancos Sh	0	0	0	0	0
Muddy (J)	13,466	29,948	0	0	0
Field Total	13,466	29,948	0	0	0
Severence					
Codell Ss	35,444	85,410	0	0	0
Niobrara	1,263	1,522	0	0	0
Niobrara, Codell Ss	188,474	614,648	0	0	3,790
Sussex	10,007	10,426	0	0	0
Field Total	235,188	712,006	0	0	3,790
Shamrock					
D Sand	10,413	0	0	0	0
Field Total	10,413	0	0	0	0
Shavano					
Lansing	7,021	0	0	0	0
Field Total	7,021	0	0	0	0
Shears Draw					
J Sand	54,325	0	0	0	68,897
Muddy (J)	398,811	14,940	0	0	0
Field Total	453,136	14,940	0	0	68,897
Sheehan					
D Sand	4,673	36,447	0	0	0
J Sand	293	25,888	0	0	70
Muddy (J)	5,880	213,561	0	0	0
Field Total	10,846	275,896	0	0	70
Sheep Creek					
Cozzette, Corcoran	0	6	0	0	0
Mesaverde	0	290,515	0	0	0
Morapos	0	0	0	0	0
Williams Fork	237	77,834	0	0	1,298
Field Total	237	368,355	0	0	1,298
Sheep Mountain					
Dakota	0	0	0	1,058,552,698	127,734
Entrada Ss	0	3,377,063	0	244,654,191	25,694
Field Total	0	3,377,063	0	1,303,206,889	153,428
Shell Creek					
Fort Union	5,540	1,158,290	0	0	0
Mancos Sh	0	239,716	0	0	0
Nugget Ss	110	4,051,993	0	0	0
Field Total	5,650	5,449,999	0	0	0
Sheridan Lake					
Marmaton	7,858	5,151	0	0	0
Field Total	7,858	5,151	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Shield					
D Sand	0	6,338	0	0	0
J Sand	25,081	5,030	0	0	759,139
Muddy (J)	1,137,918	1,583,904	0	0	0
Field Total	1,162,999	1,595,272	0	0	759,139
Shinnecock					
Mississippian	0	5,240	0	0	4,227
Morrow	0	23,810	0	0	6,060
Field Total	0	29,050	0	0	10,287
Shire Gulch					
Cameo	0	21,589	0	0	0
Corcoran	156	6,979,663	0	0	30,978
Cozette	107	384,846	0	0	5,683
Cozzette, Corcoran	325	1,702,520	0	0	90
Cozzette, Corcoran, Cameo C	0	22,859	0	0	0
Cozzette, Corcoran, Mesaverde	0	523,186	0	0	0
Dakota	10	11,308,850	0	0	18,051
Dakota, Cedar Mountain	0	1,669,242	0	0	0
Dakota, Cedar Mtn, Corcoran	0	43,566	0	0	0
Dakota, Mancos Sh	0	76,805	0	0	0
Dakota, Morrison	0	755,199	0	0	5
Frontier	0	4,744	0	0	8
Frontier, Dakota	0	250,511	0	0	0
Mancos Sh	0	14,322	0	0	0
Mesaverde	0	18,281,854	0	0	0
Morrison	0	39,305	0	0	185
Field Total	598	42,079,061	0	0	55,000
Shivaree					
J Sand	0	0	0	0	0
Muddy (J)	3,940	4,500	0	0	0
Field Total	3,940	4,500	0	0	0
Shoal					
D Sand	17,275	0	0	0	0
Field Total	17,275	0	0	0	0
Shoreline					
D Sand, Dakota	9,128	359,816	0	0	0
D Sand, O Sand	0	0	0	0	0
Field Total	9,128	359,816	0	0	0
Shout					
Niobrara	0	3,671,352	0	0	40,258
Field Total	0	3,671,352	0	0	40,258
Siaana (Mount Pearl)					
Morrow B	75,626	1,106,121	0	0	14,026
Field Total	75,626	1,106,121	0	0	14,026
Sidewinder					
D Sand	181,086	1,489,075	0	0	1,724
D Sand, Muddy (J)	132,252	318,790	0	0	0
J Sand	6,091	30,599	0	0	475
Muddy (J)	262,504	3,848,231	0	0	0
Field Total	581,933	5,686,695	0	0	2,199
Sierra					
Dakota	131,478	29,021	0	0	0
Field Total	131,478	29,021	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Signal Hill					
J Sand	0	0	0	0	0
Morrow	1,425	2,583,981	0	0	48
Muddy (J)	182	71,069	0	0	0
Field Total	1,607	2,655,050	0	0	48
Simpson					
J Sand	0	0	0	0	0
Muddy (J)	41,652	18,297	0	0	0
Field Total	41,652	18,297	0	0	0
Single					
J Sand	0	0	0	0	0
Muddy (J)	0	10,435	0	0	0
Field Total	0	10,435	0	0	0
Singletree (Spindle)					
Sussex	5,488	6,489	0	0	2,703
Field Total	5,488	6,489	0	0	2,703
Sioux					
D Sand	358,917	138,003	0	0	6,781
Field Total	358,917	138,003	0	0	6,781
Skinner Ridge					
Cameo	0	0	0	0	0
Cameo Coal	0	0	0	0	0
Mesaverde	0	0	0	0	0
Mesaverde Coal	0	0	99,925	0	0
Field Total	0	0	99,925	0	0
Skipping Stone					
Codell Ss	195	0	0	0	0
Field Total	195	0	0	0	0
Slater Dome					
Iles	0	1,827	577	0	148,034
Mesaverde	0	3,632	0	0	0
Field Total	0	5,459	577	0	148,034
Sleeper					
D Sand	474,659	893,820	0	0	0
D Sand, Muddy (J)	7,019	6,806	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	68,474	235,530	0	0	0
Field Total	550,152	1,136,156	0	0	0
Sleeping Ute					
Ismay	201,870	478,328	0	0	51,791
Field Total	201,870	478,328	0	0	51,791
Slick Rock					
Ismay	0	8,854	0	0	0
Lower Ismay	0	0	0	0	0
Field Total	0	8,854	0	0	0
Slippery Sides					
Niobrara	48,442	38,895	0	0	0
Field Total	48,442	38,895	0	0	0
Sloan					
D Sand	7,205	75,242	0	0	733
D Sand, Muddy (J)	89,759	476,294	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	4,671	26,993	0	0	0
Field Total	101,635	578,529	0	0	733

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Smiley					
D Sand	12,559	0	0	0	0
Field Total	12,559	0	0	0	0
Smoky Creek					
Fort Scott Ls	1,653	0	0	0	8,715
Keyes	645	737,185	0	0	1,212
Mississippian	1,624,101	1,746	0	0	0
Mississippian, Osage	0	0	0	0	0
Mississippian, Spergen	132,552	0	0	0	530,754
Morrow	2,552	69,486	0	0	13,485
Shawnee	1,104	0	0	0	7,097
Spergen	799,746	3,274	0	0	2,876,029
Warsaw	141,466	0	0	0	1,065,506
Field Total	2,703,819	811,691	0	0	4,502,798
Smoky Hill					
Fort Scott Ls	49,235	877	0	0	0
Keyes	108,393	785	0	0	0
Mississippian	67	15,869	0	0	0
Morrow	1,142,654	2,053,656	0	0	611,966
Morrow 3	268	78,573	0	0	60
Morrow A	3,441	944,547	0	0	941
Morrow V7	855	487,777	0	0	528
Field Total	1,304,913	3,582,084	0	0	613,495
Sniff Ranch					
Atoka	61,363	41,975	0	0	0
Field Total	61,363	41,975	0	0	0
Snowbird					
J Sand	0	0	0	0	0
Muddy (J)	16,928	0	0	0	0
Field Total	16,928	0	0	0	0
Snowdrift					
J Sand	0	0	0	0	0
Muddy (J)	11,587	67	0	0	0
Field Total	11,587	67	0	0	0
Snowflake					
J Sand	0	0	0	0	0
Muddy (J)	23,472	1,308,457	0	0	0
Field Total	23,472	1,308,457	0	0	0
Soda Lake					
Niobrara	15,275	3,820	0	0	0
Timpas	0	0	0	0	0
Field Total	15,275	3,820	0	0	0
Sodbuster					
J Sand	8,071	9,500	0	0	7,100
Muddy (J)	372,481	82,482	0	0	0
Field Total	380,552	91,982	0	0	7,100
Soldier Canyon					
Buckhorn	0	636	0	0	0
Dakota	0	114,822	0	0	0
Dakota	0	4,435,206	0	0	0
Mancos B	0	1,695	0	0	0
Mancos Sh	200	22,492	0	0	0
Mesaverde	0	0	0	0	0
Wasatch	0	0	0	0	0
Field Total	200	4,574,851	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Solitaire					
Niobrara	0	10,093	0	0	0
Field Total	0	10,093	0	0	0
Sombrero					
Niobrara	0	18,928	0	0	0
Field Total	0	18,928	0	0	0
Sonar					
D Sand	193,254	2,810,932	0	0	1,635
D Sand, Muddy (J)	43,467	1,089,400	0	0	0
Dakota, Muddy (J)	1,457	60,582	0	0	0
J Sand	4,560	78,579	0	0	340
Muddy (J)	4,226	103,756	0	0	0
Field Total	246,964	4,143,249	0	0	1,975
Songbird					
D Sand	271,417	569,068	0	0	2,045
J Sand	0	0	0	0	0
Muddy (J)	17,903	492,393	0	0	0
Field Total	289,320	1,061,461	0	0	2,045
Sooner					
D Sand	2,110,936	7,618,637	0	0	2,499,890
Dakota, Muddy (J)	0	22,918	0	0	0
J Sand	0	2,030	0	0	0
Muddy (J)	15,239	8,348	0	0	0
Field Total	2,126,175	7,651,933	0	0	2,499,890
Sorrento					
D Sand	1,750	0	0	0	102,969
J Sand	128	0	0	0	12,180
Keyes	159,683	335,204	0	0	2,791
Marmaton	46,154	1,101	0	0	4,333
Mississippian	34,025	125,951	0	0	0
Mississippian, Spergen	0	0	0	0	0
Morrow	14,483,861	13,189,870	0	0	1,362,723
Morrow B	0	0	0	0	0
St Louis	9,514	0	0	0	0
Field Total	14,735,115	13,652,126	0	0	1,484,996
Sorrento South					
Mississippian	4,471	0	0	0	0
Mississippian, Spergen	0	0	0	0	0
Field Total	4,471	0	0	0	0
South Canyon					
Buckhorn	0	543,513	0	0	0
Cedar Mountain	513	2,157,893	0	0	314
Dakota	23,908	43,384,580	0	0	34,340
Dakota	0	106,003	0	0	15
Dakota, Buckhorn	13	223,809	0	0	0
Dakota, Cedar Mountain	46	4,302,743	0	0	14
Dakota, Morrison	23,472	19,363,427	0	0	50
Morrison	1,163	2,486,306	0	0	1,222
Morrison	0	536,333	0	0	87
Field Total	49,115	73,104,607	0	0	36,042

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
South Shale Ridge					
Cameo Coal	0	0	45,861	0	8,623
Cameo Coal	0	0	346,339	0	19,749
Mesaverde Coal	0	0	62,261	0	0
Mesaverde Coal	0	0	692,914	0	0
Field Total	0	0	1,147,375	0	28,372
Space City					
D Sand	225,699	18,871,380	0	0	170
D Sand, Muddy (J)	14,841	348,200	0	0	0
J Sand	5,492	147,208	0	0	1,320
Muddy (J)	209,649	2,727,578	0	0	0
Field Total	455,681	22,094,366	0	0	1,490
Spanish Peaks					
Raton Coal	0	107,628	561,332	0	819,321
Raton, Vermejo Coal	0	30,515	3,865,274	0	6,820,833
Vermejo Coal	0	1,668,699	85,252,507	0	40,968,241
Field Total	0	1,806,842	89,679,113	0	48,608,395
Spar					
J Sand	53,582	13,771	0	0	1,748,502
Muddy (J)	850,480	72,337	0	0	0
Field Total	904,062	86,108	0	0	1,748,502
Speaker					
Morrow	2,820,224	2,390,672	0	0	213,699
Morrow	129,496	484,148	0	0	177,588
Morrow V7	183	613	0	0	0
Field Total	2,949,903	2,875,433	0	0	391,287
Speaker North					
Marmaton	160,739	19,806	0	0	8,781
Field Total	160,739	19,806	0	0	8,781
Spear					
Niobrara	744	6,556,752	0	0	1,438
Field Total	744	6,556,752	0	0	1,438
Spelunker					
Keyes	267	74,626	0	0	23,581
Red Cave	0	7,285,569	0	0	444,304
Wabaunsee	0	2,317	0	0	464
Field Total	267	7,362,512	0	0	468,349
Spenson					
D Sand	471,538	1,488,611	0	0	6,402
Field Total	471,538	1,488,611	0	0	6,402

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Spindle					
Codell Ss	32,274	162,254	0	0	21,155
Codell Ss	11,118	23,925	0	0	1,153
Dakota	11,239	420,061	0	0	3,016
J Sand	16,523	654,844	0	0	12,001
J Sand	27,339	3,639,399	0	0	37,222
Muddy (J)	2,998	140,663	0	0	0
Muddy (J), Niobrara, Codell Ss	9,879	273,178	0	0	540
Muddy (J.) Sussex	7,422	48,705	0	0	0
Muddy (J.) Sussex	3,187	126,036	0	0	0
Niob, Ft Hys, Codell, Sussex	611	13,596	0	0	0
Niobrara	4,188	10,083	0	0	1,089
Niobrara, Codell Ss	52,834	1,169,695	0	0	2,257
Niobrara, Codell Ss	17,636	238,575	0	0	3,377
Niobrara, Codell Ss, Sussex	1,044,351	2,611,826	0	0	0
Niobrara, Codell Ss, Sussex	35,363	236,926	0	0	0
Niobrara, Fort Hays, Codell Ss	9,638	76,984	0	0	0
Niobrara, Fort Hays, Codell Ss	319	10,743	0	0	157
Niobrara, Sussex	22,236	0	0	0	0
Niobrara, Timpas, Codell	44,364	180,763	0	0	8,485
Niobrara, Timpas, Codell, Sussex	33,993	112,442	0	0	0
Niobrara, TimpasNiobrara, Timpas, Sussex	0	0	0	0	0
Shannon	15,811	522,712	0	0	617
Shannon	643,041	4,935,892	0	0	32,224
Sussex	6,537,140	11,290,112	0	0	92,080
Sussex	2,290	20,505	0	0	291
Sussex	30,316,969	139,504,348	0	0	782,404
Sussex, Codell Ss	105,537	97,838	0	0	0
Sussex, Codell Ss	44,336	40,217	0	0	0
Sussex, Shannon	19,340,201	124,938,776	0	0	211,681
Sussex, Shannon, Niobrara, Codell Ss	149,822	1,884,258	0	0	1,094
Sussex, Timpas, Codell	7,932	16,179	0	0	0
Timpas	0	0	0	0	0
Timpas, Codell	5,316	9,858	0	0	1,557
Field Total	58,555,907	293,411,393	0	0	1,212,400
Spotted Dog					
J Sand	398,424	0	0	0	2,504,097
Niobrara	0	37,426	0	0	0
Smoky Hill	0	43,218	0	0	0
Field Total	398,424	80,644	0	0	2,504,097
Spring					
Mesaverde	29	21,322	0	0	106
Williams Fork	47	35,819	0	0	307
Field Total	76	57,141	0	0	413

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Spring Creek					
J Sand	0	0	0	0	0
Muddy (J)	61,187	21,880	0	0	0
Field Total	61,187	21,880	0	0	0
Springdale					
D Sand	164,231	59,387	0	0	259,830
J Sand	0	0	0	0	0
Muddy (J)	19,986	4,202,824	0	0	0
Field Total	184,217	4,262,211	0	0	259,830
Springdale South					
J Sand	5,995	0	0	0	193,050
Muddy (J)	763,022	434,753	0	0	0
Field Total	769,017	434,753	0	0	193,050
Spruce					
D Sand	2,310	48,694	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	24,175	322,917	0	0	0
Field Total	26,485	371,611	0	0	0
Spur					
Mississippian	396,492	0	0	0	1,616,670
Morrow	0	0	0	0	0
Shawnee	62,043	1,272	0	0	592,465
Warsaw	82,942	0	0	0	0
Field Total	541,477	1,272	0	0	2,209,135
Spurgin					
D Sand	14,824	9,588	0	0	0
Field Total	14,824	9,588	0	0	0
Spurgin North					
J Sand	0	0	0	0	0
Muddy (J)	4,918	826	0	0	0
Field Total	4,918	826	0	0	0
Squaw Creek					
Desert Creek	11,189	24,332	0	0	0
Field Total	11,189	24,332	0	0	0
Stage Stop					
Dakota	0	0	0	0	0
Dakota, J, Niobrara, Codell	178	13,242	0	0	0
J Sand	0	71,123	0	0	0
Muddy (J), Niobrara, Codell Ss	1,963	203,665	0	0	0
Niobrara, Codell Ss	23,683	162,891	0	0	1,905
Field Total	25,824	450,921	0	0	1,905
Stagecoach					
D Sand	125,182	29,749	0	0	0
Field Total	125,182	29,749	0	0	0
Stallion					
J Sand	51,931	0	0	0	441,448
Muddy (J)	152,968	0	0	0	0
Niobrara	0	23,921	0	0	0
Smoky Hill	0	0	0	0	0
Field Total	204,899	23,921	0	0	441,448
Stampede					
J Sand	0	0	0	0	0
Muddy (J)	19,609	1,224,277	0	0	0
Field Total	19,609	1,224,277	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Stanley Cup					
J Sand	93,935	0	0	0	1,627,268
Muddy (J)	34,418	0	0	0	0
Field Total	128,353	0	0	0	1,627,268
Star					
D Sand	904	570	0	0	0
Field Total	904	570	0	0	0
Stateline					
Fort Union	0	1,080	0	0	0
Lance	0	59,915	0	0	0
Lewis Sh,	0	99,050	0	0	0
Field Total	0	160,045	0	0	0
Stem					
D Sand	0	373,293	0	0	0
Field Total	0	373,293	0	0	0
Sterling					
J Sand	0	0	0	0	0
Muddy (J)	0	156,558	0	0	0
Field Total	0	156,558	0	0	0
Stirrup					
D Sand	514,307	0	0	0	106,601
Field Total	514,307	0	0	0	106,601
Stockade					
D Sand	56,545	249	0	0	197
Field Total	56,545	249	0	0	197
Stockholm					
Morrow	83,502	486	0	0	0
Field Total	83,502	486	0	0	0
Stone Corral					
D Sand	20,979	277,023	0	0	2,130
Field Total	20,979	277,023	0	0	2,130
Stone Pony					
Ismay	6,950	689,266	0	0	82
Ismay, Desert Creek	975	127,196	0	0	0
Field Total	7,925	816,462	0	0	82
Stoneham					
D Sand	25,599	726,720	0	0	0
J Sand	3,151	101,470	0	0	0
Muddy (J)	37,957	463,817	0	0	0
Field Total	66,707	1,292,007	0	0	0
Stoneham South					
D Sand	2,090	159,455	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	270,972	246,222	0	0	0
Field Total	273,062	405,677	0	0	0
Stones Throw					
Niobrara	0	118,609	0	0	24,973
Field Total	0	118,609	0	0	24,973
Stonington					
Topeka B, C	0	58,465	0	0	3,960
Topeka Ls	0	7,555,213	0	0	59,070
Field Total	0	7,613,678	0	0	63,030

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Stony Buttes					
D Sand	1,283	136,881	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	69,074	21,054	0	0	0
Field Total	70,357	157,935	0	0	0
Stony Point					
D Sand	10,006	9,270	0	0	0
Field Total	10,006	9,270	0	0	0
Strand					
J Sand	0	0	0	0	0
Muddy (J)	4,248	1,274	0	0	0
Field Total	4,248	1,274	0	0	0
Strasburg					
D Sand	93,283	453,378	0	0	0
J Sand	157	137	0	0	3,058
Muddy (J)	2,600	0	0	0	0
Field Total	96,040	453,515	0	0	3,058
Strike					
J Sand	0	0	0	0	0
Muddy (J)	4,537	100,221	0	0	0
Field Total	4,537	100,221	0	0	0
Stubble					
J Sand	0	0	0	0	0
Muddy (J)	2,985	641,970	0	0	0
Field Total	2,985	641,970	0	0	0
Stump					
J Sand	437	23,835	0	0	0
Field Total	437	23,835	0	0	0
Sugar Loaf					
Almond	1,569	375,377	0	0	173
Fort Union	40,808	674,727	0	0	1,112
Fort Union, Mesaverde	3,264	1,541,708	0	0	0
Lewis Sh	83	30,779	0	0	69
Mesaverde	311,440	80,801,423	0	0	9,570
Nugget Ss	0	0	0	0	0
Wasatch	350	87,694	0	0	300
Field Total	357,514	83,511,708	0	0	11,224
Sulphur Creek					
Douglas Creek	0	9,980	0	0	0
Fort Union, Wasatch	122	3,575	0	0	0
Green River	483	1,574	0	0	0
Mancos B	0	0	0	0	0
Mancos Sh	0	23,852	0	0	0
Mesaverde	4,348	1,582,587	0	0	0
Parachute Creek	100	0	0	0	0
Piceance Creek	0	0	0	0	0
Wasatch	2,660	7,058,167	0	0	0
Wasatch F	0	0	0	0	0
Wasatch G	0	286,557	0	0	0
Williams Fork	832	168,722	0	0	4,244
Field Total	8,545	9,135,014	0	0	4,244

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO₂ (Mscf)	Water (Barrels)
Sulphur Creek South					
Green River	0	6,551	0	0	0
Wasatch	18	430,555	0	0	0
Wasatch G	0	0	0	0	0
Field Total	18	437,106	0	0	0
Sun					
D Sand	591,849	3,126,110	0	0	2,775
D Sand, Muddy (J)	144,084	1,035,251	0	0	0
J Sand	28,802	287,997	0	0	2,158
Muddy (J)	87,306	1,256,568	0	0	0
Field Total	852,041	5,705,926	0	0	4,933
Sunbonnet					
J Sand	0	0	0	0	0
Muddy (J)	3,425	0	0	0	0
Field Total	3,425	0	0	0	0
Sundance					
Spergen	177,458	16,038	0	0	16,927
Field Total	177,458	16,038	0	0	16,927
Sundown					
D Sand	105,458	623,148	0	0	11,980
Field Total	105,458	623,148	0	0	11,980
Sunup					
J Sand	29,194	0	0	0	1,493,530
Muddy (J)	237,376	0	0	0	0
Field Total	266,570	0	0	0	1,493,530
Supaha					
J Sand	0	0	0	0	0
Muddy (J)	43,496	475,452	0	0	0
Field Total	43,496	475,452	0	0	0
Superior					
Codell Ss	14,182	64,528	0	0	0
D Sand, Codell SS, Niobrara	1,355	11,780	0	0	0
Dakota	7,340	519,615	0	0	0
Dakota, Muddy (J)	1,393	116,615	0	0	0
Muddy (J), Niobrara, Codell Ss	3,001	76,194	0	0	0
Niobrara, Codell Ss	14,352	78,122	0	0	0
Field Total	41,623	866,854	0	0	0
Surrey (Spindle)					
Sussex	1,296	4,404	0	0	751
Field Total	1,296	4,404	0	0	751
Surveyor Creek					
D Sand	680,757	4,133,975	0	0	157,880
Dakota	11,958	24,760	0	0	94,504
Mesaverde	0	2,879	0	0	0
Field Total	692,715	4,161,614	0	0	252,384
Swan					
D Sand	1,716,466	310,172	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	1,623,016	402,516	0	0	0
Field Total	3,339,482	712,688	0	0	0
Table Mountain					
Niobrara, Codell Ss	3,696	9,412	0	0	0
Field Total	3,696	9,412	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Tabletop					
Morrow	0	20,132	0	0	0
Morrow	51	1,539,182	0	0	0
Field Total	51	1,559,314	0	0	0
Taco					
D Sand	9,941	120,448	0	0	0
J Sand	1,958	38,199	0	0	0
Field Total	11,899	158,647	0	0	0
Taiga Mountain					
Castlegate	146,908	429,573	0	0	12,429
Dakota	3,316	273,560	0	0	0
Mancos B	8,767	16,935	0	0	28
Mancos Sh	47,210	52,932	0	0	0
Mesaverde	466,994	5,410,746	0	0	0
Field Total	673,195	6,183,746	0	0	12,457
Tampa					
D Sand	606,312	5,746,556	0	0	4,264
J Sand	0	0	0	0	0
Muddy (J)	47,876	504,922	0	0	0
Field Total	654,188	6,251,478	0	0	4,264
Tap					
D Sand	255,434	0	0	0	525,980
Field Total	255,434	0	0	0	525,980
Tapadero					
D Sand	1,812	24,400	0	0	0
Field Total	1,812	24,400	0	0	0
Tarn					
D Sand	12,273	18,150	0	0	0
Field Total	12,273	18,150	0	0	0
Teardrop					
Lewis Sh	30,690	7,882,186	0	0	17,339
Lewis Sh,	3,694	668,031	0	0	44
Field Total	34,384	8,550,217	0	0	17,383
Tempest					
J Sand	0	0	0	0	0
Muddy (J)	1,408	5,128	0	0	0
Field Total	1,408	5,128	0	0	0
Temple Canyon					
Dakota	783	140	0	0	0
Minturn	75,517	265,191	0	0	0
Moenkopi	447	0	0	0	0
Morrison	27,263	17,500	0	0	0
Phosphoria	33,942	1,557	0	0	0
Shinarump	194,908	19	0	0	0
Field Total	332,860	284,407	0	0	0
Tenderfoot					
D Sand	16,038	728,709	0	0	37,475
D Sand, Muddy (J)	0	0	0	0	0
Field Total	16,038	728,709	0	0	37,475
Tepee					
J Sand	0	0	0	0	0
Muddy (J)	2,723	0	0	0	0
Field Total	2,723	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Terrace					
D Sand	481,206	6,170,726	0	0	1,811
J Sand	349	2,091	0	0	0
Field Total	481,555	6,172,817	0	0	1,811
Terrace South					
D Sand	27,087	838,641	0	0	0
Field Total	27,087	838,641	0	0	0
Texas Mountain					
Castlegate	0	279,149	0	0	179
Dakota	0	6,728,977	0	0	854
Mancos A	421	23,994	0	0	517
Mancos B	474	225,645	0	0	1,012
Mancos Sh	73,627	1,855,370	0	0	0
Mesaverde	1,900	4,067,012	0	0	0
Morapos	0	0	0	0	0
Morrison	0	70,362	0	0	245
Field Total	76,422	13,250,509	0	0	2,807
Third Creek					
J Sand	118,954	1,908,814	0	0	10,055
J Sand	44,079	398,613	0	0	0
Muddy (J)	2,172,364	16,828,002	0	0	0
Muddy (J)	2,305,049	16,596,805	0	0	0
Field Total	4,640,446	35,732,234	0	0	10,055
Thistle					
J Sand	0	0	0	0	0
Muddy (J)	16,763	0	0	0	0
Field Total	16,763	0	0	0	0
Thornburg					
Dakota	0	4,298,658	0	0	0
Dakota	0	684,211	0	0	0
Entrada Ss	0	4,808,309	0	0	0
Entrada Ss	0	754,245	0	0	0
Shinarump	0	107,998	0	0	0
Weber Ss	211,986	365,961	0	0	0
Weber Ss	541,870	7,338,876	0	0	0
Field Total	753,856	18,358,258	0	0	0
Three Bridges					
Raton Coal	0	8,313	3,716	0	0
Trinidad	0	28,026	6,755	0	3,798
Field Total	0	36,339	10,471	0	3,798
Thunder					
Dakota	2,049	2,408,234	0	0	247
Mancos B	5	812,824	0	0	2,148
Mancos Sh	0	4,173,037	0	0	247
Field Total	2,054	7,394,095	0	0	2,642
Thunderbird					
J Sand	0	0	0	0	0
Muddy (J)	12,496	5,572	0	0	0
Field Total	12,496	5,572	0	0	0
Tierra Plano					
Niobrara	0	3,052,452	0	0	95,303
Field Total	0	3,052,452	0	0	95,303
Timber Creek					
Mississippian	39,690	0	0	0	0
Field Total	39,690	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Timberline					
Mesaverde	85	27,630	0	0	0
Williams Fork	55	23,429	0	0	76
Field Total	140	51,059	0	0	76
Timpe					
D Sand	187,816	99,124	0	0	1,987
Field Total	187,816	99,124	0	0	1,987
Titan					
D Sand	20,518	37,284	0	0	0
Field Total	20,518	37,284	0	0	0
Toad					
J Sand	0	0	0	0	0
Muddy (J)	3,453	8,517	0	0	0
Field Total	3,453	8,517	0	0	0
Tom Cat					
Codell Ss	6,642	8,484	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	4,271	201,042	0	0	0
Niobrara, Codell Ss	8,732	35,729	0	0	0
Field Total	19,645	245,255	0	0	0
Tomahawk					
J Sand	0	0	0	0	0
Muddy (J)	193,503	98,987	0	0	0
Field Total	193,503	98,987	0	0	0
Tom-Tom					
D Sand	12,331	292,793	0	0	0
Field Total	12,331	292,793	0	0	0
Tonto					
Mississippian	10,347	8	0	0	0
Mississippian, Spergen	0	0	0	0	0
Field Total	10,347	8	0	0	0
Tootsie					
J Sand	0	0	0	0	0
Muddy (J)	233	91,824	0	0	0
Field Total	233	91,824	0	0	0
Topaz					
J Sand	6,096	0	0	0	3,500
Muddy (J)	239,423	36,076	0	0	0
Field Total	245,519	36,076	0	0	3,500
Toque					
D Sand	67,232	427,715	0	0	5
D Sand, Muddy (J)	145,184	625,938	0	0	0
J Sand	763	15,432	0	0	0
Field Total	213,179	1,069,085	0	0	5
Tornado Butte					
D Sand, Muddy (J)	1,419	755	0	0	0
Niobrara, Codell Ss	31,890	10,282	0	0	0
Field Total	33,309	11,037	0	0	0
Totem					
D Sand	81,165	290,607	0	0	80
D Sand, Muddy (J)	141,430	863,824	0	0	0
J Sand	11,141	336,157	0	0	0
Muddy (J)	147,380	8,203,554	0	0	0
Field Total	381,116	9,694,142	0	0	80

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Tow Creek					
Niobrara	3,033,475	338,899	0	0	0
Field Total	3,033,475	338,899	0	0	0
Towaoc					
Ismay	322,650	783,933	0	0	97,459
Molas	475,561	379,555	0	0	0
Field Total	798,211	1,163,488	0	0	97,459
Tower					
J Sand	0	0	0	0	0
Muddy (J)	15,302	8,139	0	0	0
Field Total	15,302	8,139	0	0	0
Track					
D Sand	184,144	682,005	0	0	0
Field Total	184,144	682,005	0	0	0
Trader					
J Sand	136,251	0	0	0	6,882,650
Muddy (J)	722,915	7,739	0	0	0
Field Total	859,166	7,739	0	0	6,882,650
Trading Post					
St. Louis	21,307	8,231	0	0	0
Field Total	21,307	8,231	0	0	0
Trail					
D Sand	19,594	0	0	0	0
Field Total	19,594	0	0	0	0
Trail Canyon					
Buckhorn	0	20,879	0	0	0
Cedar Mountain	0	0	0	0	0
Dakota	95	764,644	0	0	4
Dakota	457	8,867,587	0	0	3,447
Mancos B	0	0	0	0	0
Mancos B	10	361,045	0	0	0
Mancos Sh	0	3,223	0	0	0
Mancos Sh	5,413	1,765,407	0	0	0
Field Total	5,975	11,782,785	0	0	3,451
Trail Ridge					
Mesaverde	320	716,149	0	0	3,627
Wasatch	525	2,324,394	0	0	0
Williams Fork	566	258,330	0	0	3,477
Williams Fork, Cameo	0	117,313	0	0	0
Field Total	1,411	3,416,186	0	0	7,104
Trail South					
J Sand	0	0	0	0	0
Muddy (J)	44,132	3,323	0	0	0
Field Total	44,132	3,323	0	0	0
Trapper					
D Sand	1,206,003	6,699,219	0	0	5,324
D Sand, Muddy (J)	167,039	1,664,777	0	0	0
J Sand	53,594	1,491,046	0	0	6,156
Muddy (D)	1,762	23,789	0	0	36
Muddy (J)	327,150	5,438,552	0	0	0
Field Total	1,755,548	15,317,383	0	0	11,516

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Trapper South					
D Sand	181,339	1,275,974	0	0	5,239
D Sand, Muddy (J)	400	296	0	0	0
J Sand	3,178	62,643	0	0	0
Muddy (J)	9,845	80,608	0	0	0
Field Total	194,762	1,419,521	0	0	5,239
Travois					
D Sand	192,068	354,757	0	0	7,333
Hygiene	0	0	0	0	0
Shannon	269	0	0	0	0
Field Total	192,337	354,757	0	0	7,333
Trend					
D Sand	384,923	3,505,020	0	0	0
Field Total	384,923	3,505,020	0	0	0
Trevarton					
Niobrara, Codell Ss	534	0	0	0	0
Field Total	534	0	0	0	0
Tribute					
Dakota	60	1,503	0	0	0
J Sand	151	88,047	0	0	19,862
Muddy (J)	1,170	45,350	0	0	0
Field Total	1,381	134,900	0	0	19,862
Trigger					
D Sand	288,215	969,741	0	0	1,933
D Sand, Muddy (J)	122,743	425,335	0	0	0
J Sand	5,736	62,817	0	0	40
Muddy (J)	30,198	75,679	0	0	0
Field Total	446,892	1,533,572	0	0	1,973
Trooper					
Lansing	315	0	0	0	0
Morrow	2,706	206,548	0	0	0
Field Total	3,021	206,548	0	0	0
Trout Creek					
Niobrara	425	0	0	0	0
Field Total	425	0	0	0	0
TRUJILLO					
Unknown					
Field Total					
Tumbleweed					
D Sand	32,146	5,864	0	0	0
D Sand, Muddy (J)	16,522	20,693	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	75,920	10,251	0	0	0
Field Total	124,588	36,808	0	0	0
Turner					
D Sand	454	0	0	0	0
Field Total	454	0	0	0	0
Turquoise					
D Sand	174,979	12	0	0	0
D Sand, Muddy (J)	16,409	0	0	0	0
J Sand	7,654	0	0	0	0
Field Total	199,042	12	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Twin Buttes					
Dakota	112	664,985	0	0	1,327
Dakota, Morrison	1,711	1,978,882	0	0	0
Mancos B	4	0	0	0	0
Morrison	431	3,576,948	0	0	1,768
Niobrara	3,478	6,260	0	0	0
Wasatch	120	120,362	0	0	131
Field Total	5,856	6,347,437	0	0	3,226
Twin Mills					
J Sand	60,015	8,891	0	0	1,458,651
Muddy (J)	294,626	2,215,701	0	0	0
Field Total	354,641	2,224,592	0	0	1,458,651
Two Mile					
D Sand	2,667	3,853	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	49,788	2,457,977	0	0	0
Field Total	52,455	2,461,830	0	0	0
Unicorn					
D Sand	5,871	8,063	0	0	0
Field Total	5,871	8,063	0	0	0
Union Reservoir					
Sussex	1,598	0	0	0	0
Field Total	1,598	0	0	0	0
Unknown					
Cameo Coal	0	0	66,237	0	1,411
Cameo Coal	0	0	172,872	0	21,248
Codell Ss	110	1,095	0	0	0
D Sand	3,920	260,050	0	0	0
Dakota	0	50,121	0	0	57
J Sand	508	8,920	0	0	915
Kansas City	0	3,169	0	0	0
Niobrara, Codell Ss	352	8,887	0	0	140
Niobrara, Codell Ss	2,142	14,326	0	0	725
Unkown					
Unkown					
Field Total	7,032	346,568	239,109	0	24,496
Unkown					
Mississippian, Osage	0	49,467	0	0	0
Mississippian, Spergen	0	1,889	0	0	0
Morrow	0	14,409	0	0	26
Unkown					
Williams Fork	187	84,178	0	0	342
Williams Fork, Cameo	0	234,947	0	0	1,874
Field Total	187	384,890	0	0	2,242

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Unnamed					
Carmel	0	0	0	0	0
Codell Ss	5,240	25,493	0	0	2,630
Cozette	0	5,014	0	0	0
D Sand	50	0	0	0	2,060
D Sand	5,343	67,446	0	0	0
Dakota	0	0	0	0	0
Dakota	90	89,634	0	0	5,670
Fruitland Coal	0	690,533	568,572	0	57,275
J Sand	1,546	31,407	0	0	129
J Sand	318	20,242	0	0	983
J Sand	2,533	105	0	0	42,425
J Sand	3,500	402,553	0	0	35,085
Mesaverde	0	907	0	0	15,180
Mesaverde Coal	0	0	0	0	0
Mesaverde Coal	0	193	0	0	19,154
Morrison	0	50,241	0	0	316
Niobrara	0	2,668	0	0	0
Niobrara	0	805,973	0	0	0
Niobrara, Codell Ss	4,458	8,923	0	0	1,020
Smoky Hill	0	300	0	0	0
Williams Fork, Cameo	0	782,222	0	0	10,766
Field Total	23,078	2,983,854	568,572	0	192,693
Uranus					
D Sand	443,220	181,933	0	0	1,493
J Sand	21,685	0	0	0	436,244
Field Total	464,905	181,933	0	0	437,737
Valentine					
Sussex	217	74,801	0	0	0
Field Total	217	74,801	0	0	0
Vallery					
D Sand	89,475	9,736,366	0	0	584
J Sand	0	0	0	0	0
Muddy (J)	113,462	1,342,491	0	0	0
Field Total	202,937	11,078,857	0	0	584
Valley					
J Sand	1,458	89,165	0	0	0
Muddy (J)	1,761	118,864	0	0	0
Field Total	3,219	208,029	0	0	0
Vaquero					
J Sand	0	0	0	0	0
Muddy (J)	0	826,245	0	0	0
Field Total	0	826,245	0	0	0
Vega					
Cozette	0	0	0	0	0
Mesaverde	203	118,084	0	0	0
Mesaverde Coal	24	0	80,804	0	0
Field Total	227	118,084	80,804	0	0
Velvet					
J Sand	0	0	0	0	0
Muddy (J)	27,467	22,047	0	0	0
Field Total	27,467	22,047	0	0	0
Venus					
D Sand	243	39,257	0	0	0
Field Total	243	39,257	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Verde					
Atoka	0	64,612	0	0	0
Keyes	118,993	1,412	0	0	0
Red Cave	0	4,555	0	0	0
Field Total	118,993	70,579	0	0	0
Vermejo Ranch					
Raton Coal	0	18,063	234,198	0	749,387
Raton, Vermejo Coal	0	198,395	8,912,678	0	16,055,519
Vermejo Coal	0	895,973	8,871,179	8,938	18,644,035
Field Total	0	1,112,431	18,018,055	8,938	35,448,941
Vernon					
Niobrara	0	6,985,902	0	0	62,645
Field Total	0	6,985,902	0	0	62,645
Vigor					
D Sand	2,214	3,644	0	0	0
J Sand	9,014	0	0	0	17,332
Muddy (J)	68,803	44,981	0	0	0
Field Total	80,031	48,625	0	0	17,332
Vilas					
Glorieta	0	0	0	0	5,972
Topeka Ls	0	34,307,621	0	0	78,034
Field Total	0	34,307,621	0	0	84,006
Vim					
D Sand	82,403	498,986	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	38,203	0	0	0	0
Field Total	120,606	498,986	0	0	0
Vimy Ridge					
J Sand	0	0	0	0	0
Muddy (J)	1,150	567	0	0	0
Field Total	1,150	567	0	0	0
Vista					
J Sand	773	35	0	0	1,103
Muddy (J)	148,409	76,037	0	0	0
Field Total	149,182	76,072	0	0	1,103
Voltage					
D Sand	73,252	43,769	0	0	0
J Sand	1,087	0	0	0	0
Muddy (J)	148,310	29,180	0	0	0
Field Total	222,649	72,949	0	0	0
Volten					
J Sand	5,723	120	0	0	21,916
Muddy (J)	12,087	0	0	0	0
Field Total	17,810	120	0	0	21,916
Vortex					
J Sand	3,995	0	0	0	146,069
Muddy (J)	1,225,320	0	0	0	0
Field Total	1,229,315	0	0	0	146,069
Waddle Creek					
Niobrara	735,944	93,277	0	0	15,960
Field Total	735,944	93,277	0	0	15,960
Wages					
Niobrara	0	3,976,344	0	0	50,420
Field Total	0	3,976,344	0	0	50,420

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Wagon Trail					
Codell Ss	6	16	0	0	0
Morrow	74,375	12,015,765	0	0	131
Morrow Upper	0	25,435	0	0	0
Niobrara	74	104	0	0	0
Field Total	74,455	12,041,320	0	0	131
Wahoo					
J Sand	1,726	0	0	0	0
Muddy (J)	243,717	27,801	0	0	0
Field Total	245,443	27,801	0	0	0
Waite Lake					
Codell Ss	3,101	172	0	0	0
D Sand	810,155	4,325,490	0	0	9,355
D Sand, Muddy (J)	85,662	1,342,726	0	0	65
Greenhorn Ls	3,493	34,931	0	0	0
J Sand	6,833	348,768	0	0	40,740
Muddy (J)	107,804	6,069,455	0	0	0
Niobrara	220	0	0	0	0
Field Total	1,017,268	12,121,542	0	0	50,160
Walker					
D Sand	570	198,019	0	0	0
Dakota	33,643	21,587	0	0	0
J Sand	11,801	2,904	0	0	336,405
Muddy (J)	1,980,321	4,372,701	0	0	0
O Sand	0	0	0	0	0
Field Total	2,026,335	4,595,211	0	0	336,405
Wallbanger					
D Sand	745,717	2,747,775	0	0	0
D Sand, Muddy (J)	96,961	277,746	0	0	0
J Sand	5,991	10,470	0	0	0
Muddy (J)	120,649	191,510	0	0	0
Field Total	969,318	3,227,501	0	0	0
Walsh					
Permian	0	16,633	0	0	0
Topeka A	0	8,046	0	0	0
Topeka Ls	19	29,988,368	0	0	161,506
Topeka Ls, Wabaunsee	0	293,278	0	0	0
Wabaunsee	0	1,348,052	0	0	22,621
Wolfcamp	0	173,968	0	0	0
Field Total	19	31,828,345	0	0	184,127
Wampum					
J Sand	16,841	0	0	0	1,221,432
Muddy (J)	224,431	0	0	0	0
Field Total	241,272	0	0	0	1,221,432
War Dance					
D Sand	5,461	9,882	0	0	0
Field Total	5,461	9,882	0	0	0
Ward					
J Sand	0	0	0	0	0
Muddy (J)	32,247	0	0	0	0
Field Total	32,247	0	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Warlock					
D Sand	8,814	189,013	0	0	278
D Sand, Muddy (J)	7,614	97,245	0	0	0
J Sand	18,795	321,232	0	0	0
Muddy (J)	225,440	2,439,029	0	0	0
Field Total	260,663	3,046,519	0	0	278
Warpaint					
D Sand	5	89,957	0	0	0
Field Total	5	89,957	0	0	0
Warrior					
D Sand	40,033	507,899	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	121,631	580,124	0	0	0
Field Total	161,664	1,088,023	0	0	0
Watkins					
J Sand	0	0	0	0	0
J Sand	1,872	58,695	0	0	1,493
Muddy (J)	756	18,757	0	0	0
Niobrara, Codell Ss	472	3,238	0	0	92
Niobrara, Codell Ss	983	45,875	0	0	0
Field Total	4,083	126,565	0	0	1,585
Wattenberg					
Codell Ss	151,949	1,402,820	0	0	5,506
Codell Ss	249,563	1,858,812	0	0	21,114
Codell Ss	54,832	409,511	0	0	6,222
Codell Ss	12,891	18,086	0	0	0
Codell Ss	33,726,358	379,502,118	0	0	2,411,294
Codell, Fort Hays	5,096	82,571	0	0	4,056
Codell, Fort Hays	29,789	315,963	0	0	1,812
D Sand	140,858	2,107,280	0	0	9,829
D Sand	327,864	2,319,499	0	0	3,946
D Sand, Muddy (J)	280,723	3,491,527	0	0	27
D Sand, Muddy (J)	22,036	536,736	0	0	0
Dakota	14,438	584,920	0	0	13,314
Dakota	9,404	485,647	0	0	7,631
Dakota	3,410	183,156	0	0	4,343
Dakota	408,833	32,500,655	0	0	564,694
Dakota, Greenhorn Ls, Codell Ss	8,071	289,685	0	0	0
Dakota, J, Codell	1,362	19,897	0	0	0
Dakota, J, Codell	1,453	43,278	0	0	0
Dakota, J, Codell	142,182	5,603,666	0	0	0
Dakota, Muddy (J)	22,165	1,928,303	0	0	5
Dakota, Muddy (J)	143,182	9,271,127	0	0	292
Dakota, Muddy (J), Niobrara, Codell Ss	14,343	405,164	0	0	0
Dakota, Muddy (J), Niobrara, Codell Ss	9,513	192,414	0	0	0
Dakota, Muddy (J), Niobrara, Codell Ss	92,023	2,759,315	0	0	0
Dakota, Muddy (J), Niobrara, Codell Ss, Sussex	14,934	512,759	0	0	0
Dakota, Muddy (J), Sussex	61,975	3,289,372	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Dkta, J, Nbr, Codl, Sussex	9,141	335,871	0	0	0
Fort Hays	15,517	202,312	0	0	3,024
Fruitland Coal	0	0	243,315	0	36,114
Graneros	232	3,343	0	0	419
Graneros	201	3,157	0	0	109
Greenhorn Ls	3,539	121,230	0	0	518
Greenhorn Ls	26	81,070	0	0	0
Greenhorn Ls	574	798	0	0	0
Greenhorn Ls	35,823	398,993	0	0	15,218
J Sand	563,914	26,376,180	0	0	330,073
J Sand	3,410	124,545	0	0	2,668
J Sand	245,579	9,046,054	0	0	75,874
J Sand	46,950	2,646,903	0	0	39,968
J Sand	0	0	0	0	0
J Sand	132,275	2,005,890	0	0	1,352
J Sand	4,473,146	391,644,836	26,177	0	7,029,778
J, Codell Ss	129	917	0	0	31
J, Codell, Sussex	14,192	589,852	0	0	0
J, Niobrara, Codell Ss	45	4,313	0	0	75
J, Niobrara, Ft Hays, Codell	60,372	1,980,868	0	0	0
J, Niobrara, Ft Hays, Codell	894	29,191	0	0	0
J, Niobrara, Ft Hays, Codell	9,261	332,977	0	0	0
J-2 Sand	1,300	22,486	0	0	0
Lakota	5	1,341	0	0	3
Lyons Ss	0	0	0	0	0
Muddy (J)	2,118,592	96,274,245	0	0	0
Muddy (J)	94,580	16,879,747	0	0	0
Muddy (J)	446,882	19,312,442	0	0	0
Muddy (J)	4,786,062	561,262,708	0	0	0
Muddy (J), Codell Ss	78,821	1,726,446	0	0	0
Muddy (J), Codell Ss	199,275	2,892,958	0	0	0
Muddy (J), Codell Ss	2,233,063	66,391,747	0	0	4,624
Muddy (J), Codell Ss, Niobrara, Sussex	311,203	7,311,098	0	0	41
Muddy (J), Codell Ss, Niobrara, Sussex, Shannon	27,729	337,228	0	0	0
Muddy (J), Niobrara	4,075	209,255	0	0	238
Muddy (J), Niobrara,	528,510	8,192,586	0	0	0
Muddy (J), Niobrara, Codell Ss	411,017	10,017,736	0	0	0
Muddy (J), Niobrara, Codell Ss	23,931,349	42,756,236	0	0	839
Muddy (J), Shannon	1,473	172,975	0	0	0
Muddy (J), Codell Ss, Niobrara, Shannon	1,864	46,873	0	0	0
Muddy (J), Sussex	0	0	0	0	0
Muddy (J), Sussex	178	7,103	0	0	0
Niob, Ft Hys, Codell, Sussex	4,719	308,659	0	0	0

Field	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO₂ (Mscf)	Water (Barrels)
Producing Formation					
Niobrara	5,318	91,629	0	0	219
Niobrara	46,154	217,053	0	0	2,696
Niobrara	1,415	19,461	0	0	700
Niobrara	792,150	9,184,221	0	0	61,018
Niobrara	0	208,183	0	0	0
Niobrara, Codell Ss	463,610	3,792,732	0	0	23,055
Niobrara, Codell Ss	1,272,961	9,090,621	0	0	76,627
Niobrara, Codell Ss	156,188	1,454,684	0	0	40,992
Niobrara, Codell Ss	47,085,232	682,905,931	6,012	0	2,670,388
Niobrara, Codell Ss, Dakota	2,353	17,704	0	0	0
Niobrara, Codell Ss, Shannon	290,319	6,603,937	0	0	0
Niobrara, Codell Ss, Sussex	40,259	248,397	0	0	0
Niobrara, Codell Ss, Sussex	4,379,662	71,389,335	0	0	967
Niobrara, Fort Hays, Codell Ss	14,246	208,505	0	0	0
Niobrara, Fort Hays, Codell Ss	1,385	17,926	0	0	0
Niobrara, Fort Hays, Codell Ss	130,237	3,263,655	0	0	3,387
Niobrara, Ft Hays	956	8,917	0	0	0
Niobrara, Ft Hays	1,485	13,702	0	0	0
Niobrara, Ft Hays	766	26,271	0	0	0
Niobrara, Ft Hays, Sussex	1,121	21,149	0	0	0
Niobrara, Sussex	24,694	494,339	0	0	0
Niobrara, Timpas, Codell	551	18,437	0	0	0
Parkman	51,648	9,843	0	0	43,046
Richards Ss	35,787	0	0	0	0
Shannon	6,487	212,586	0	0	476
Shannon	188,042	5,618,855	0	0	57,889
Shannon, Codell Ss	24,969	987,821	0	0	0
Sussex	13,466	107,107	0	0	3,923
Sussex	2,973,950	48,996,971	0	0	1,285,550
Sussex, Codell Ss	118,111	27,511	0	0	0
Sussex, Codell Ss	1,820,324	19,890,722	0	0	0
Sussex, Shannon	2,331	20,436	0	0	374
Sussex, Shannon	39,551	351,768	0	0	4,484
Sussex, Shannon, Niobrara, Codell Ss	7,671	67,003	0	0	0
Sussex, Shannon, Niobrara, Codell Ss	62,910	624,054	0	0	350
Timpas, Codell	0	0	0	0	0
Timpas, Codell	583	15,405	0	0	25
Field Total	136,802,056	2,586,394,321	275,504	0	14,871,217
Waverly					
J Sand	1,782	125,644	0	0	1,509
Niobrara	0	51,389,468	0	0	147,870
Field Total	1,782	51,515,112	0	0	149,379

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Weasel					
J Sand	1,558	32,819	0	0	996
Muddy (J)	4,234	138,328	0	0	0
Field Total	5,792	171,147	0	0	996
Weaver Ridge					
Castlegate	114	0	0	0	0
Mesaverde	2,972	654,304	0	0	0
Field Total	3,086	654,304	0	0	0
Weldona					
D Sand	1,937	1,576	0	0	0
Field Total	1,937	1,576	0	0	0
Wellington					
Muddy	130,387	65,456	0	0	5,450,217
Muddy (J)	8,140,250	18,969,931	0	0	0
Field Total	8,270,637	19,035,387	0	0	5,450,217
West Lightfoot					
J Sand	6,372	7,550	0	0	24,645
Unkown					
Field Total	6,372	7,550	0	0	24,645
West Side Canal					
Almond	20	18,191	0	0	4,022
Fort Union	0	4	0	0	0
Lance	0	2,421,046	0	0	0
Lewis Sh	59,851	21,772,578	0	0	61,480
Mesaverde	0	499,070	0	0	0
Field Total	59,871	24,710,889	0	0	65,502
Westfork					
J Sand	7,895	0	0	0	14,622
Muddy (J)	3,702,374	888,287	0	0	0
Field Total	3,710,269	888,287	0	0	14,622
Westplains					
D Sand	274,418	312,183	0	0	0
Dakota	10,622	0	0	0	0
O Sand	0	0	0	0	0
Field Total	285,040	312,183	0	0	0
Westplains North					
D Sand	11,890	1,419,339	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	13,691	0	0	0	0
Field Total	25,581	1,419,339	0	0	0
Wetzel Creek					
J Sand	0	0	0	0	0
Muddy (J)	399,313	88,185	0	0	0
Field Total	399,313	88,185	0	0	0
Wheeler Lake					
Shannon	8,820	335	0	0	779
Field Total	8,820	335	0	0	779
Whirlpool					
J Sand	0	0	0	0	0
Muddy (J)	15,994	0	0	0	0
Field Total	15,994	0	0	0	0
Whisper					
Niobrara	0	3,440,457	0	0	13,717
Field Total	0	3,440,457	0	0	13,717

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
White					
J Sand	0	0	0	0	0
Muddy (J)	5,727	250,465	0	0	0
Field Total	5,727	250,465	0	0	0
White Butte					
D Sand	3,477	665,315	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	143,402	29,023	0	0	0
Field Total	146,879	694,338	0	0	0
White Eagle					
Niobrara	132	7,535,518	0	0	42,094
Field Total	132	7,535,518	0	0	42,094
White Face Butte					
Dakota	2	79,644	0	0	1,540
Mesaverde	0	0	0	0	0
Unkown					
Field Total	2	79,644	0	0	1,540
White River					
Cameo	0	0	0	0	0
Cameo Coal	1,727	52,381	14,877	0	2,072
Cameo Coals, Mesaverde	8,569	441,965	275,800	0	11,437
Cameo Sands, Mesaverde	956	71,082	0	0	77
Corcoran	0	0	0	0	0
Cozette	93	5,592	0	0	338
Iles	0	0	0	0	0
Mesaverde	72,673	5,548,099	0	0	56,585
Mesaverde Coal	91,329	0	983,295	0	0
Rollins	0	0	0	0	0
Sego	0	0	0	0	0
Wasatch	11,261	17,860,334	0	0	9,262
Weber Ss	37,930	424,449	0	0	15,287
Williams Fork	239,225	22,426,658	133,519	0	1,765,975
Williams Fork Coal	14,500	0	3,466,334	0	325,453
Williams Fork, Cameo	6,968	507,590	0	0	64,925
Williams Fork, Cameo Coal	3,374	717,135	0	0	7,248
Field Total	488,605	48,055,285	4,873,825	0	2,258,659
White Woman Creek					
Unkown	0	0	0	0	0
Field Total	0	0	0	0	0
Whitetail					
D Sand	0	53,107	0	0	0
Field Total	0	53,107	0	0	0
Whitewater					
Dakota	1,636	11,637	0	0	0
Field Total	1,636	11,637	0	0	0
Wickiup					
D Sand	43,254	27,252	0	0	2,104
J Sand	692	36,335	0	0	3,455
Field Total	43,946	63,587	0	0	5,559
Wiggins					
J Sand	0	0	0	0	0
Muddy (J)	149	3,341	0	0	0
Field Total	149	3,341	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Wigwam					
D Sand	164,982	411,135	0	0	49,437
D Sand	336,865	239,391	0	0	0
J Sand	2,127	67,149	0	0	2,240
Muddy (J)	908	127,152	0	0	0
Field Total	504,882	844,827	0	0	51,677
Wild Card					
D Sand	342	0	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	9,623	14,709	0	0	0
Niobrara	0	358	0	0	0
Field Total	9,965	15,067	0	0	0
Wild Dove					
Unkown					
Field Total					
Wild Fox					
Mississippian, Morrow	0	40,892	0	0	0
Morrow	1,269	347,935	0	0	73
Unkown					
Field Total	1,269	388,827	0	0	73
Wild Horse					
Codell Ss	4,708	22,080	0	0	0
D Sand	679,793	3,673,947	0	0	1,072
Field Total	684,501	3,696,027	0	0	1,072
Wild Rose					
J Sand	0	0	0	0	0
Muddy (J)	2,830	0	0	0	0
Field Total	2,830	0	0	0	0
Wild Sage Brush					
Mississippian	9,160	0	0	0	0
Morrow	370	521,737	0	0	0
Morrow	0	44,050	0	0	0
St Louis	24,985	141,930	0	0	0
Field Total	34,515	707,717	0	0	0
WILDCAT					
Almond	368	5,847	0	0	1,157
Almond	0	0	0	0	142,022
Arbuckle	0	0	0	0	0
Atoka	0	0	0	0	0
Barker Creek	948	53,876	0	0	115
Blaine	0	0	0	0	0
Cameo Coal	0	0	0	0	0
Cameo Coal	0	598	0	0	1,926
Carlile, Greenhorn	0	0	0	0	0
Cherokee	0	94,838	0	0	0
Cherokee	14,133	0	0	0	9,286
Corcoran	0	5,428	0	0	0
Corcoran	130	109,356	0	0	3,863
Corcoran	0	0	0	0	0
Cozette	0	0	0	0	0
Cozzette	0	47,601	0	0	0
Cutler	85	0	264,300	0	774

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
D Sand	67,358	119,219	0	0	0
D Sand	0	0	0	0	0
D Sand	5,005	67,549	0	0	1,189
D Sand	41,170	126,589	0	0	0
Dakota	0	113,544	0	0	1,143
Dakota	0	0	0	0	0
Dakota	102	30,270	0	0	44
Dakota	0	0	0	0	0
Dakota	0	27,396	0	0	0
Dakota	130	89,110	0	0	628
Desert Creek	90,694	353,082	0	0	0
Entrada Ss	0	0	0	0	0
Entrada Ss	0	0	0	0	0
Fort Hays	0	0	0	0	0
Fort Union Coal	0	0	0	0	17,296
Greenhorn Ls	0	0	0	0	0
Honaker Trail	0	0	0	0	0
Honaker Trail	10,701	2,514,614	0	0	1,119
Igneous Sill, Intrusive	0	6,613	0	0	0
Iles	0	20	1,514	0	116,758
Ismay	125	24,527	0	0	58
Ismay	0	0	0	0	0
J Sand	0	0	0	0	0
J Sand	0	0	0	0	0
J Sand	28,570	99,055	0	0	32,353
J Sand	0	0	0	0	0
J Sand	4,660	0	0	0	365,825
J Sand	5,685	21,345	0	0	26,313
J-2 Sand	260	5,107	0	0	21,760
Lance	0	0	0	0	0
Leadville	190	0	0	0	0
Lewis Sh	80	47,354	0	0	239
Lyons Ss	74,473	0	0	0	24,586
Mancos B	0	0	0	0	0
Mancos B	400	94,178	0	0	0
Mancos Sh	2,145	17,084	0	0	527
Mancos Sh	0	0	0	0	0
Marmaton	0	0	0	0	0
Marmaton	2,140	0	0	0	3,347
Mesaverde	0	0	0	0	0
Mesaverde	0	0	0	0	0
Mesaverde	0	0	0	0	0
Mesaverde	0	0	0	0	0
Mesaverde	0	601	0	0	34,739
Mesaverde	551	164,383	0	0	20,965
Mississippian, Pennsylvanian	2,043	0	0	0	2,747
Morrison	0	10,390	0	0	0
Morrison	0	0	0	0	0
Morrow	0	0	0	0	0
Morrow	0	0	0	0	0
Morrow	0	0	0	0	0
Morrow	0	77,143	0	0	101

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Niobrara	0	1,952	0	0	9,980
Niobrara	0	4,238	0	0	3,044
Niobrara	0	2,802	0	0	0
Niobrara	91	320	0	0	216
Niobrara	0	641,757	0	0	9,538
Not Complete	0	8,179	0	0	19,179
Osage	0	0	0	0	0
Paradox	255	82,180	0	0	256
Paradox	0	1,537	0	0	0
Pierre Sh	0	6,055	0	0	0
Pierre Sh	0	0	0	0	0
Raton Coal	0	0	0	0	0
Raton Coal	0	0	10,534	0	224,707
Raton, Vermejo Coal	0	0	0	0	21,056,775
Raton, Vermejo Coal	0	0	0	0	0
Red Cave	0	0	0	0	0
Rollins	439	82,729	0	0	4,334
Rollins	0	0	0	0	0
Rollins	0	0	0	0	0
Rollins, Cameo	0	800	0	0	5,537
Sego	450	213,321	0	0	7,762
Sego	130	159,877	0	0	6,791
Spergen	0	0	0	0	0
Sundance	0	0	0	0	0
Topeka Ls	0	559	0	0	869
Unkown					
Vermejo Coal	0	1,015	11,978	0	6,197,166
Vermejo Coal	0	55,978	450,385	0	3,164,571
Warsaw	0	0	0	0	0
Wasatch	0	0	0	0	0
Wasatch	0	0	0	0	0
Williams Fork	950	228,182	0	0	8,366
Williams Fork	0	112,556	0	0	0
Williams Fork	0	2,226	0	0	9,800
Williams Fork	2,163	816,938	0	0	22,736
Williams Fork	0	0	151	0	1,278,324
Williams Fork Coal	0	0	63,250	0	2,300,831
Williams Fork Coal	0	0	0	0	1,693,228
Williams Fork, Cameo	0	0	31,072	0	437,076
Wolfcamp	0	174,974	0	0	0
Field Total	356,624	6,924,892	833,184	0	37,291,966
Wildcat Creek					
D Sand	91,450	2,854,487	0	0	0
Field Total	91,450	2,854,487	0	0	0
Wildflower					
D Sand	6,949	33,650	0	0	8,340
J Sand	3,258	556,955	0	0	1,323
Unkown					
Field Total	10,207	590,605	0	0	9,663
Wildwood					
J Sand	3,189	0	0	0	10,084
Muddy (J)	23,553	40	0	0	0
Field Total	26,742	40	0	0	10,084

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Willard					
D Sand	150,202	154,165	0	0	0
Field Total	150,202	154,165	0	0	0
Williams Fork					
Dakota	724,291	30,326	0	0	0
Frontier	0	29,456	0	0	0
Morrison	0	259,633	0	0	0
Ohio Creek	28	58,227	0	0	795
Shinarump	86,720	5,913	0	0	0
Weber Ss	7,366	0	0	0	0
Field Total	818,405	383,555	0	0	795
Willow Creek					
Ohio Creek	30	128,694	0	0	1,246
Ohio Creek	0	163,061	0	0	1,824
Wasatch	27	10,892	0	0	95
Williams Fork	440	184,247	0	0	5,758
Field Total	497	486,894	0	0	8,923
Wilson Creek					
Mancos Sh	0	0	0	0	105,003
Minturn	352,346	8,774,105	0	0	98,281
Morrison	60,242,888	59,545,041	0	0	21,963,986
Niobrara	88,208	111,241	0	0	0
Shinarump	187	123,930	0	0	0
Sundance	27,302,230	6,052,274	0	0	47,210,982
Weber Ss	0	0	0	0	0
Field Total	87,985,859	74,606,591	0	0	69,378,252
Winchester					
J Sand	0	0	0	0	0
Muddy (J)	121,407	162,394	0	0	0
Field Total	121,407	162,394	0	0	0
Wind Song					
D Sand	83,750	3,180	0	0	0
Field Total	83,750	3,180	0	0	0
Windmill					
Topeka C	0	245,764	0	0	6,421
Topeka Ls	13	2,631,904	0	0	899
Field Total	13	2,877,668	0	0	7,320
Windsock					
Lewis Sh	11,338	2,480,727	0	0	3,021
Unkown					
Field Total	11,338	2,480,727	0	0	3,021
Windy					
J Sand	0	0	0	0	0
Muddy (J)	1,708	230,891	0	0	0
Field Total	1,708	230,891	0	0	0
Windy Hill					
J Sand	0	0	0	0	0
Muddy (J)	497,999	124,453	0	0	0
Field Total	497,999	124,453	0	0	0
Winston					
J Sand	0	0	0	0	0
Muddy (J)	482,787	67,568	0	0	0
Field Total	482,787	67,568	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Winston North					
D Sand	10	0	0	0	0
J Sand	5,494	100	0	0	915
Muddy (J)	122,161	26,095	0	0	0
Field Total	127,665	26,195	0	0	915
Winter Valley					
Dakota	277,433	13,741,240	0	0	0
Mancos Sh	143,321	0	0	0	0
Minturn	40,608	1,217,650	0	0	0
Weber Ss	40,019	11,444	0	0	0
Field Total	501,381	14,970,334	0	0	0
Wishbone					
D Sand	205,800	65,977	0	0	0
Niobrara	0	5,263	0	0	540
Field Total	205,800	71,240	0	0	540
Wolf Creek					
Cozzette, Corcoran	0	0	0	0	0
Mesaverde	0	12,629,822	0	0	0
Field Total	0	12,629,822	0	0	0
Wolf Mountain					
Niobrara	895,835	87,322	0	0	0
Field Total	895,835	87,322	0	0	0
Woodchuck					
J Sand	0	0	0	0	0
Muddy (J)	16,115	64,982	0	0	0
Field Total	16,115	64,982	0	0	0
Woodlin					
J Sand	0	0	0	0	0
Muddy (J)	66,985	0	0	0	0
Field Total	66,985	0	0	0	0
Woodrow					
J Sand	30,511	0	0	0	19,201
Unkown					
Field Total	30,511	0	0	0	19,201
Woodrow East					
D Sand	207,915	45,519	0	0	27,546
J Sand	0	0	0	0	0
Muddy (J)	3,519	2,130,084	0	0	0
Field Total	211,434	2,175,603	0	0	27,546
Woodrow South					
D Sand	475,170	158,717	0	0	25,507
J Sand	103	782	0	0	0
Muddy (J)	73,127	46,088	0	0	0
Field Total	548,400	205,587	0	0	25,507
Woodrow West					
D Sand	767,992	432,399	0	0	67,210
Field Total	767,992	432,399	0	0	67,210
Wrangler					
D Sand	33,136	133,866	0	0	0
Field Total	33,136	133,866	0	0	0
Wringer					
Niobrara	963	862	0	0	0
Field Total	963	862	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Wyatt School					
Codell Ss	16,648	0	0	0	105
Lyons	50	0	0	0	0
Niobrara	1,132	0	0	0	0
Field Total	17,830	0	0	0	105
Xenia					
D Sand	0	72,659	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	90,413	147,197	0	0	0
Field Total	90,413	219,856	0	0	0
Xenia North					
D Sand	4,775	23,494	0	0	0
J Sand	20,471	0	0	0	32,807
Muddy (J)	843,681	656,722	0	0	0
Field Total	868,927	680,216	0	0	32,807
Xenia West					
D Sand	49,520	17,025	0	0	0
J Sand	57,669	0	0	0	2,622,677
Muddy (J)	2,616,170	1,318,394	0	0	0
Field Total	2,723,359	1,335,419	0	0	2,622,677
Yampa					
Mesaverde	0	3,109	0	0	0
Mesaverde Coal	0	0	32,326	0	0
Field Total	0	3,109	32,326	0	0
Yellow Creek					
Mancos B	0	0	0	0	0
Mancos Sh	0	398	0	0	0
Mesaverde	0	885	0	0	0
Field Total	0	1,283	0	0	0
Yellow Rose					
Marmaton	37,581	190	0	0	9,974
Field Total	37,581	190	0	0	9,974
Yenter					
J Sand	117,125	114,714	0	0	4,890,145
Muddy (J)	10,466,375	24,496,194	0	0	0
Field Total	10,583,500	24,610,908	0	0	4,890,145
Yodel					
Niobrara	0	2,679,683	0	0	37,153
Field Total	0	2,679,683	0	0	37,153
Yodel North					
Niobrara	0	1,100,677	0	0	28,971
Field Total	0	1,100,677	0	0	28,971
Young					
D Sand	0	0	0	0	0
D Sand	50,794	7,133,973	0	0	0
J Sand	0	0	0	0	0
Field Total	50,794	7,133,973	0	0	0
Yoyo					
D Sand	14,770	917	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	225,555	201,559	0	0	0
Field Total	240,325	202,476	0	0	0

Field Producing Formation	Oil (Barrels)	Gas (Mscf)	CBM (Mscf)	CO ₂ (Mscf)	Water (Barrels)
Yucca					
J Sand	0	0	0	0	0
Muddy (J)	1,245	460	0	0	0
Field Total	1,245	460	0	0	0
Yuk					
J Sand	278	0	0	0	0
Muddy (J)	40,065	0	0	0	0
Field Total	40,343	0	0	0	0
Zenith					
D Sand	564,397	3,255,141	0	0	3,057
D Sand, Muddy (J)	16,225	102,029	0	0	0
J Sand	34,396	289,427	0	0	27,526
Muddy (J)	238,551	1,678,738	0	0	0
Field Total	853,569	5,325,335	0	0	30,583
Zephyr					
D Sand	26,893	83,232	0	0	0
Field Total	26,893	83,232	0	0	0
Zodiac					
D Sand	1,406	710	0	0	0
Field Total	1,406	710	0	0	0
Zorichak					
D Sand	2,266,942	2,839,640	0	0	10,124
D Sand, Muddy (J)	8,564	128,263	0	0	0
J Sand	0	0	0	0	0
Muddy (J)	21,362	57,736	0	0	0
Field Total	2,296,868	3,025,639	0	0	10,124
State Total	3,920,010,118	22,233,798,222	8,835,489,078	13,396,942,196	3,226,691,578

Facility ID	Facility Name	Field Name	Formation	Type	Initial Injection	Injection Discontinued	Status	Cumulative Injection as of 12/31/98	Units
150146	Adena J Sand Unit	Adena	J Sand	Propane	07/01/61	01/30/63	CL	270,633 Bbl	
150146	Adena J Sand Unit	Adena	J Sand	Gas	11/01/62	11/30/65	CL	251,945 Mcf	
150146	Adena J Sand Unit	Adena	J Sand	Water	02/25/57	Active	AC	265,852,849 Bbl	
150295	Adena D Sand Unit	Adena	D Sand	Water	12/01/92	Active	AC	343,752 Bbl	
150214	Akron East North Unit	Akron East	D Sand	Water	03/16/71	09/01/96	CL	3,330,894 Bbl	
150147	Akron East Unit	Akron East	D Sand	Water	03/23/63	10/01/98	CL	1,907,482 Bbl	
150281	Arapahoe/Stateline Unit	Arapahoe	Morrow B	Gas	06/13/90	Active	AC	13,364,298 Mcf	
150281	Arapahoe/Stateline Unit	Arapahoe	Morrow B	Water	11/01/91	Active	AC	1,771,460 Bbl	
150327	Northwest Arapahoe Unit	Arapahoe	Morrow	Water	04/16/92	Active	AC	1,873,546 Bbl	
150327	Northwest Arapahoe Unit	Arapahoe	Morrow	Gas	04/16/92	Active	AC	8,460,060 Mcf	
150242	Steele B-1	Arapahoe East	Morrow	Gas	A/D	05/16/88	CL		
	Atwood East	Atwood East	D Sand	Water	03/01/62	05/30/69	CL	9,635,951 Bbl	
	Aztec Wash	Aztec Wash	Gallup Sand	Water	09/23/62	06/30/64	CL	255,528 Bbl	
	Aztec Wash	Aztec Wash	Gallup Sand	Air	N/A	N/A	N/A	77,834 Mcf	
	Azure	Azure	D Sand	Water	09/02/61	08/30/69	CL	1,153,271 Bbl	
	Azure East	Azure East	D Sand	Water	08/10/70	06/30/73	CL	178,883 Bbl	
150148	Badger Creek Waterflood	Badger Creek	D Sand	Water	09/18/58	01/01/89	CL	20,045,030 Bbl	
	Badger Creek West	Badger Creek West	J Sand	Water	11/28/70	03/30/74	CL	493,350 Bbl	
	Battle Canyon	Battle Canyon	J Sand	Water	06/16/61	12/31/67	CL	2,946,529 Bbl	
150150	Belle Unit	Belle	J Sand	Water	02/01/79	Active	AC	2,721,157 Bbl	
150297	Berthoud Dakota Unit	Berthoud	Dakota	Water	04/19/90	04/14/97	CL	586,584 Bbl	
150151	Big Sandy Unit	Big Sandy	J Sand	Water	01/15/80	03/26/85	CL		
	Bijou	Bijou	D Sand	Water	11/22/63	9/31/71	CL	6,245,874 Bbl	
	Bijou West	Bijou West	D Sand	Water	12/13/68	11/30/71	CL	3,941,038 Bbl	
150152	Black Hollow Unit	Black Hollow	Lyons	Water	08/16/58	Active	AC	34,465,588 Bbl	
150018	Black Jack Unit ¹	Black Jack	J Sand	Water	06/29/68	02/28/91	CL	5,769,252 Bbl	
150275	Bledsoe Ranch Unit	Bledsoe Ranch	Morrow	Gas	10/01/89	Active	AC	1,572,711 Mcf	
150275	Bledsoe Ranch Unit	Bledsoe Ranch	Morrow	Water	12/01/92	Active	AC	1,350,035 Bbl	
150229	Bluebird Unit	Bluebird	J Sand	Water	07/18/88	12/01/98	CL	1,944,726 Bbl	
150153	Bobcat D Sand Unit	Bobcat	D Sand	Water	04/12/68	Active	AC	22,138,985 Bbl	
150154	Boxer Unit	Boxer	D Sand	Water	02/18/72	2/29/86	CL	12,733,886 Bbl	
	Boxer North	Boxer North	D Sand	Water	06/29/72	04/30/75	CL	393,190 Bbl	
150155	Brandon Northwest Unit	Brandon	St Louis-Spergen	Water	10/10/72	07/30/78	CL	10,934,686 Bbl	
	Buckingham	Buckingham	D Sand	Water	03/05/67	04/30/69	CL	663,352 Bbl	
150156	Buckingham West Waterflood	Buckingham West	D Sand	Water	01/29/84	12/31/88	CL	424,538 Bbl	
	Busy Bee	Busy Bee	D Sand	Water	01/11/61	07/30/63	CL	309,739 Bbl	
150157	Busy Bee Unit	Busy Bee	D Sand	Water	10/18/60	07/11/95	CL		
159059	Busy Bee D Sand Unit	Busy Bee	D Sand	Water	08/08/01	Active	AC		
150158	Cache Unit	Cache	Ismay	Water	03/12/68	Active	AC	14,478,579 Bbl	

Facility ID	Facility Name	Field Name	Formation	Type	Initial Injection	Injection Discontinued	Status	Cumulative Injection as of 12/31/98	Units
150306	Tanner Unit	Campo	Lansing	Water	04/07/92	Active	AC	4,495,004 Bbl	
150356	S.E. Campo Unit	Campo	Lansing	Water	03/01/94	Active	AC	9,842,427 Bbl	
150420	Lansing D Sand Unit	Campo	Lansing D	Water	10/01/97	Active	AC	213,526 Bbl	
	Canadian River	Canadian River	Dakota-Lakota	Water	07/09/58	01/30/63	CL	829,158 Mcf	
150313	Caretaker D Sand Unit	Caretaker	D Sand	N/A	N/A	N/A	IJ		
150159	Clarks Lake Muddy Sand Unit	Clarks Lake	Muddy	Water	08/05/65	Active	AC	5,640,229 Bbl	
150206	South Clarks Lake Unit	Clarks Lake	Muddy	Water	01/31/86	Active	AC	2,076,493 Bbl	
150371	Cliff D Sand Unit	Cliff	D Sand	N/A	N/A	N/A	AC		
	Danforth Hills	Danforth Hills	Sundance	Water	06/13/63	02/28/81	CL	16,724,440 Bbl	
	Danforth Hills	Danforth Hills	Morrison	Water	03/16/62	07/30/85	CL	9,894,602 Bbl	
150199	Govt Treleaven 7	Danforth Hills	Sundance	Water	N/A	08/08/85	CL		
150160	Govt Treleaven 1	Danforth Hills	Morrison	Water	N/A	04/05/88	CL		
150217	Govt Treleaven 3	Danforth Hills	Morrison-Sundance	Water	N/A	09/08/94	CL		
150219	Darby Creek Pilot Flood	Darby Creek	D Sand	Water	12/31/86	01/31/89	CL	606,081 Bbl	
150161	Divide Unit	Divide	D Sand	Water	11/25/60	10/07/97	AC	31,069,519 Bbl	
	Dune Ridge	Dune Ridge	D Sand	Gas	07/19/55	02/04/59	CL	1,167,813 Mcf	
150162	Dune Ridge Unit	Dune Ridge	D Sand	Water	02/01/58	06/30/84	CL	10,633,533 Bbl	
150330	Emerald Unit	Emerald	J Sand	Water	06/20/92	Active	AC	2,640,029 Bbl	
150163	Fort Collins	Fort Collins	Muddy	Water	03/01/80	Active	AC	33,267,368 Bbl	
	Fort Morgar ²	Fort Morgan	D Sand	Gas	07/01/58				
150272	Frontera Unit	Frontera	Morrow B	Gas	09/01/89	Active	AC	4,217,886 Mcf	
150296	Frontera Upper Sand Unit	Frontera	Morrow A	Gas	10/11/90	Active	AC	756,023 Mcf	
	Gary North	Gary North	D Sand	Water	02/25/62	07/30/78	CL	1,791,704 Bbl	
	Luft	Graylin Northwest	D Sand	Water	01/23/59	02/28/67	CL	10,710,268 Bbl	
	Graylin NW	Graylin Northwest	J Sand	Water	11/19/69	11/01/72	CL	4,376,114 Bbl	
150215	Logan J Sand Unit	Graylin Northwest	J Sand	Water	N/A	06/08/06	AC		
150164	NW Graylin D Sand Unit	Graylin Northwest	D Sand	Water	08/26/60	Active	AC	84,232,774 Bbl	
150096	Luft 3-8	Graylin Northwest	J Sand	Water	11/18/75	Active	CL	546,457 Bbl	
	Greasewood	Greasewood	D Sand	Water	09/27/62	07/31/70	CL	1,826,743 Bbl	
150283	Parkman Sandstone Formation Unit	Greeley	Parkman	Water	12/19/89	Active	AC	839,728 Bbl	
150230	Hiawatha Mid Oil Sand Unit	Hiawatha	Wasatch	Water	10/17/88	02/01/93	AC	817,560 Bbl	
150273	Colomeadows Farms Uni ³	Hombre	J Sand	Water	11/01/84	10/30/89	CL	320,874 Bbl	
150305	Amoco Nitrogen Injection Project	Ignacio Blanco	Fruitland Coal	Gas	07/01/92	08/30/93	CL	361,096 Mcf	
150402	Tiffany Unit	Ignacio Blanco	Fruitland Coal	N ₂	01/31/98	Active	AC	5,213,238 Mcf	
	Jackpot	Jackpot	D Sand	Water	08/24/60	06/30/68	CL	3,567,761 Bbl	
	Kejr North	Kejr	D Sand	Water	01/15/59	12/31/72	CL	7,904,270 Bbl	
150071	Keota	Keota	J Sand	Water	11/11/63	05/30/85	CL	543,920 Bbl	
150165	Lanyard Field	Lanyard	D Sand	Water	N/A	09/06/90	CL		
150166	Lanyard Unit	Lanyard	D Sand	Water	06/14/78	Active	AC	14,151,627 Bbl	

Facility ID	Facility Name	Field Name	Formation	Type	Initial Injection	Injection Discontinued	Status	Cumulative Injection as of 12/31/98	Units
150189	Lanyard Extension	Lanyard	D Sand	Water	02/01/82	Active	AC	6,020,664 Bbl	
	Leader	Leader	J Sand	Gas	04/01/57	02/28/62	CL	1,166,762 Mcf	
	Leader	Leader	J Sand	Water	09/11/59	08/30/62	CL	551,364 Bbl	
150167	Lewis Creek J Sand Unit	Lewis Creek	J Sand	Water	05/13/59	Active	AC	44,437,655 Bbl	
	Liberty	Liberty	J Sand	Water	05/22/63	06/30/67	CL	3,288,491 Bbl	
159064	Liberty J Sand Unit	Liberty	J Sand	Water	08/20/01	Active	AC		
150290	Lilli Pilot Gas Injection Project	Lilli	D Sand	Gas	A/D	12/18/89	IJ		
150392	Lilli Field Unit	Lilli	D Sand	Gas	02/01/96	Active	AC	1,361,953 Mcf	
	Little Beaver D Sand Unit	Little Beaver	D Sand	Propane	07/01/62	11/30/62	CL	9,651 Bbl	
150168	Little Beaver D Sand Unit	Little Beaver	D Sand	Water	10/16/58	06/01/98	AC	107,113,891 Bbl	
150169	Little Beaver East Unit	Little Beaver East	D Sand	Water	09/19/58	06/01/94	CL	18,652,947 Bbl	
	Luster	Luster	J Sand	Water	10/28/60	10/30/69	CL	1,528,700 Bbl	
	Masters	Masters	D Sand	Water	12/20/60	08/30/69	CL	1,421,924 Bbl	
	McCallum Unit - Pierre B	McCallum	Pierre B	Gas	01/01/73	02/29/80	CL	1,653,721 Mcf	
	McCallum	McCallum	Dakota-Lakota	Gas	09/01/76	11/30/83	CL	1,801,845 Mcf	
	McCallum	McCallum	Dakota-Lakota	Water	09/20/64	07/30/86	CL	1,461,117 Bbl	
150141	McCallum Unit 10	McCallum	Dakota-Lakota	Water	N/A	09/22/86	CL		
150170	McCallum Unit - Pierre B	McCallum	Pierre B	Water	01/01/73	Active	AC	17,281,449 Bbl	
150208	Conoco State 16-1	McCallum South	Pierre B	Water	N/A	09/22/86	CL		
150171	Middlemist Field Unit	Middlemist	J Sand	Water	02/03/64	08/30/85	CL	8,180,246 Bbl	
150172	Minto	Minto	J Sand	Water	10/10/63	Active	AC	14,147,065 Bbl	
150240	North Minto J Sand Unit	Minto North	J Sand	Water	04/28/90	Active	AC	784,764 Bbl	
150173	Moccasin Unit	Moccasin	J Sand	Water	12/02/67	12/01/95	CL	7,641,160 Bbl	
150174	Knowlton 13/Moffat Field	Moffat	Dakota	Water	11/29/63	06/01/90	CL	5,591,868 Bbl	
150175	Mount Hope Unit	Mount Hope	D Sand	Water	03/15/63	Active	AC	85,789,751 Bbl	
150225	Mount Pearl Unit	Mount Pearl	Morrow B	Gas	10/30/87	Active	AC	23,044,543 Mcf	
150225	Mount Pearl Unit	Mount Pearl	Morrow B	Water	03/01/88	Active	AC	10,317,910 Bbl	
150176	New Windsor Unit	New Windsor	Sussex	Water	04/01/81	06/30/86	CL	100,784 Bbl	
150207	Nile D Sand Unit	Nile	D Sand	Water	02/10/88	Active	AC	8,882,439 Bbl	
150177	Nugget Unit	Nugget	D Sand	Water	04/14/61	03/01/96	AC	14,306,461 Bbl	
	Orchard - West Unit	Orchard	D Sand	Water	06/03/66	02/29/68	CL	259,643 Bbl	
	Orchard - East Unit	Orchard	D Sand	Water	06/15/66	12/31/68	CL	628,028 Bbl	
150178	Peoria J Sand Unit	Peoria	J Sand	Water	07/21/73	10/01/94	AC	71,937,468 Bbl	
	Phegley	Phegley	D Sand	Water	10/08/59	01/30/72	CL	11,878,428 Bbl	
	Phegley ⁴	Phegley	D Sand	Propane		Prior to '68	CL	152,432 Bbl	
	Phegley ⁴	Phegley	D Sand	Gas		Prior to '68	CL	442,874 Mcf	
150179	Pierce Lyons Sand Unit	Pierce	Lyons	Water	06/28/66	Active	AC	40,737,046 Bbl	
150180	Plum Bush Creek Unit	Plum Bush Creek	J Sand	Water	06/15/59	10/30/92	CL	122,486,642 Bbl	
150181	Poncho J Sand Unit	Poncho	J Sand	Water	04/18/81	11/01/95	CL	9,987,135 Bbl	

Facility ID	Facility Name	Field Name	Formation	Type	Initial Injection	Injection Discontinued	Status	Cumulative Injection as of 12/31/98	Units
150282	Pow-Wow Unit	Pow Wow	J Sand	Water	09/17/92	Active	AC	2,135,777 Bbl	
150182	Powder Wash	Powder Wash	Wasatch	Water	05/29/68	Active	CL	1,692,034 Bbl	
150370	Burro Canyon Gas Unit 4	Purgatoire River	Raton Coal	N ₂	09/01/95	08/01/96	AC	212,061 Mcf	
150369	Horn Springs Gas Com 1 ⁵	Purgatoire River	Raton-Vermejo Coals	N ₂			CL		
	Rake	Rake	D Sand	Water	12/24/66	11/30/69	CL	1,087,197 Bbl	
	Rangely	Rangely	Weber	Gas	11/26/50	08/30/70	CL	401,875,550 Mcf	
150200	Rangely Weber Sand Unit	Rangely	Weber	Water	12/25/57	Active	AC	4,383,431,961 Bbl	
150183	Rangely NE Weber Sand Unit	Rangely	Weber	Water	02/06/77	Active	AC	5,801,214 Bbl	
150200	Rangely Weber Sand Unit	Rangely	Weber	CO ₂	10/12/86	Active	AC	816,090,556 Mcf	
150252	Rhoades Unit	Rhoades	Morrow B	Water	12/14/88	Active	AC	1,258,723 Bbl	
150252	Rhoades Unit	Rhoades	Morrow B	Gas	01/15/89	Active	AC	3,496,985 Mcf	
	Roggen SW	Roggen	D Sand	Water	11/14/57	05/30/62	CL	873,650 Bbl	
	Roggen SW	Roggen	D Sand	Water	04/26/66	05/30/70	CL	1,938,179 Bbl	
	Saber	Saber	D Sand	Gas	11/23/64	12/30/73	CL	9,115,875 Mcf	
	Saber	Saber	D Sand	Water	08/13/69	09/30/76	CL	9,396,952 Bbl	
150131	Salt Lake Unit	Salt Lake	Morrow	Gas	08/21/85	10/01/90	CL	1,046,411 Mcf	
150131	Salt Lake Unit	Salt Lake	Morrow	Water	01/12/87	Active	AC	1,255,178 Bbl	
150184	Sand River	Sand River	D Sand	Water	09/15/66	Active	AC	11,313,749 Bbl	
150337	Second Wind Unit	Second Wind	Morrow	Gas	12/03/92	Active	AC	1,768,002 Mcf	
150256	Sooner D Sand Unit	Sooner	D Sand	Gas	10/24/90	04/01/95	CL	820,020 Mcf	
150256	Sooner D Sand Unit	Sooner	D Sand	Water	09/23/89	Active	AC	6,891,761 Bbl	
150126	Mull Unit	Sorrento	Morrow	Gas	04/01/85	Active	AC	7,012,607 Mcf	
150377	Speaker Unit	Speaker	Morrow	Gas	09/01/95	Active	AC	1,064,473 Mcf	
150310	Sussex-Shannon Gas Pilot	Spindle	Sussex-Shannon	Gas	N/A	02/18/86	CL		
150185	Suckla Brown Unit	Spindle	Sussex	Water	04/14/75	12/30/87	CL	1,893,341 Bbl	
150186	Spindle/Nesssu	Spindle	Sussex	Water	11/10/81	12/30/87	CL	831,590 Bbl	
150347	Stockholm Unit	Stockholm	Morrow	Water	N/A	Active	AC		
	Swan/Kejr South	Swan/Kejr South	D Sand	Water	09/18/58	01/30/68	CL	5,896,515 Bbl	
150393	Terrace D Sand Gas Injection	Terrace	D Sand	N/A	N/A	N/A	IJ		
150433	Third Creek J Sand Waterflood	Third Creek	J Sand	Water	N/A	N/A	CL		
150220	Trend D Sand Unit	Trend	D Sand	Water	N/A	N/A	CL		
150187	Vortex Unit	Vortex	J Sand	Water	12/12/84	07/23/97	CL	4,998,596 Bbl	
150136	Wellington Muddy Unit	Wellington	Muddy	Water	09/12/76	Active	AC	18,876,453 Bbl	
150188	Westfork Unit	Westfork	J Sand	Water	02/19/66	10/30/89	CL	15,424,919 Bbl	
	Willard	Willard	D Sand	Water	09/18/56	01/01/56	CL	320,783 Bbl	
	Wilson Creek Morrison Unit	Wilson Creek	Morrison	Gas	05/14/46	08/30/75	CL	31,310,330 Mcf	
	Wilson Creek	Wilson Creek	Sundance	Gas	03/20/76	05/01/89	CL	2,144,390 Mcf	
150143	Wilson Creek Morrison Unit	Wilson Creek	Morrison	Water	01/20/59	Active	AC	180,253,459 Bbl	
150139	Wilson Creek Sundance Unit	Wilson Creek	Sundance	Water	03/07/61	Active	AC	180,780,487 Bbl	

Facility ID	Facility Name	Field Name	Formation	Type	Initial Injection	Injection Discontinued	Status	Cumulative Injection as of 12/31/98	Units
	Winston	Winston	J Sand	Water	12/12/64	02/28/67	CL	497,004 Bbl	
	Xenia West	Xenia West	J Sand	Water	11/06/59	05/30/65	CL	3,489,588 Bbl	
159095	Xenia West J Sand Unit	Xenia West	J Sand	Water	07/23/03	Active	AC		
159092	Duplicatet	Xenia West	J Sand	Water	10/20/59	N/A	CL		
	Zorichak	Zorichak	D Sand	Water	07/01/64	05/30/70	CL	3,970,463 Bbl	

A/D = Application Denied, A/D; Not Available, N/A

¹ Approved as enhanced recovery project 11/21/87

² Originally enhanced recovery project; currently active gas storage project

³ Previously disposal facility number 62; enhanced recovery started August 1989

⁴ No reported injection August 1964 through January 1968

⁵ Never injected

Operating Company	Xcel Energy	El Paso/CIG	El Paso/CIG
Storage Facility Name	Asbury	Flank ¹	Fort Morgan
Facility Status	Active	Active	Active
County	Mesa	Baca	Morgan
Year Activated/Deactivated	1,965	1,979	1,966
Discovery/Development Year	1,949	1,961	1,954
Reservoir Description			
Type of Storage	Depleted Reservoir	Depleted Reservoir	Depleted Reservoir
Original Contents	Gas	Oil-Gas	Oil-Gas
Discovery Pressure (psig)	870	1,139	1,371
Original In-Place Gas Reserves (MMcf)	3,163	16,270	9,946
Original In-Place Oil Reserves (bbls)			
Storage Formation Name	Dakota	Cherokee & Morrow B	Dakota D
Storage Lithology	Sandstone	Sandstone	Sandstone
Gross Thickness (ft)	25	18	21
Type of Geologic Trap	Stratigraphic	Structural/Stratigraphic	Stratigraphic
Geologic Age	Cretaceous	Pennsylvanian	Cretaceous
Maximum Depth to Formation (ft)	2,873	4,800	5,544
Minimum Depth to Formation (ft)	2,833	4,542	5,473
Areal Extent of Reservoir (acres)		3,678	1,091
Facility Data			
Injection/Withdrawal Wells - Total	8	38	26
Injection/Withdrawal Wells - Horizontal		0	0
Pressure Control/Observation Wells	3	24	6
Total Horsepower	650	7,250	6,551
Horsepower Shared	Yes	No	No
Gathering Lines - Total (miles)	6	23	7
Gathering Lines - Maximum Pipe Size (in)		16	16
Design Values			
Base Gas (MMcf)	1,224	11,437	6,362
Working Gas Capacity (MMcf)	2,797	7,183	8,496
Maximum Storage Pressure (psi)	1,200	1,335	2,000
Maximum Design Deliverability (Mcf/d)	16,000	164,000	450,000
Late Season/Last Day Delivery (Mcf/d)	4,775		
Annual Cycling Capability	1	1	1
Data Updated in 2004?	Yes	Yes	Yes

¹ Formation thickness and discovery pressure are for the Morrow B formation.

Source: American Gas Association, 2004

Operating Company	Xcel Energy	El Paso/CIG	Xcel Energy
Storage Facility Name	Fruita ²	Latigo	Leyden Mine
Facility Status	Active	Active	Active
County	Mesa	Arapahoe	Jefferson
Year Activated/Deactivated	1,971	1,975	1,959
Discovery/Development Year	1,958	1,971	
Reservoir Description			
Type of Storage	Depleted Reservoir	Depleted Reservoir	Abandoned Mine
Original Contents	Gas	Oil-Gas	Coal
Discovery Pressure (psig)	895	1,505	
Original In-Place Gas Reserves (MMcf)	600	16,011	
Original In-Place Oil Reserves (bbls)			
Storage Formation Name	Buckhorn	Dakota J	Lower Laramie
Storage Lithology	Sandstone	Sandstone	Coal
Gross Thickness (ft)	30	19	8
Type of Geologic Trap	Stratigraphic	Stratigraphic	Structural
Geologic Age	Cretaceous	Cretaceous	Cretaceous
Maximum Depth to Formation (ft)	2,606	6,820	1,100
Minimum Depth to Formation (ft)	2,580	6,641	678
Areal Extent of Reservoir (acres)		2,314	
Facility Data			
Injection/Withdrawal Wells - Total	1	31	16
Injection/Withdrawal Wells - Horizontal		2	
Pressure Control/Observation Wells	1	12	16
Total Horsepower	0	4,400	16,958
Horsepower Shared	Yes	No	Yes
Gathering Lines - Total (miles)		15	
Gathering Lines - Maximum Pipe Size (in)	3	16	24
Design Values			
Base Gas (MMcf)	38	13,228	790
Working Gas Capacity (MMcf)	226	9,050	2,002
Maximum Storage Pressure (psi)	1,050	2,435	250
Maximum Design Deliverability (Mcf/d)	2,000	139,000	185,000
Late Season/Last Day Delivery (Mcf/d)	363		2,824
Annual Cycling Capability	1	1	2
Data Updated in 2004?	Yes	Yes	Yes

² Compression listed under Asbury also serves Fruita.

Source: American Gas Association, 2004

Operating Company	Xcel Energy	Rocky Mountain Natural Gas Company	Young Gas Storage, Ltd.
Storage Facility Name	Roundup	Wolf Creek	Young Storage Field ³
Facility Status	Active	Active	Active
County	Morgan	Mesa/Pitkin	Morgan
Year Activated/Deactivated	1,978	1,972	1,995
Discovery/Development Year	1,968	1,961	1,957
Reservoir Description			
Type of Storage	Depleted Reservoir	Depleted Reservoir	Depleted Reservoir
Original Contents	Gas	Gas	Gas
Discovery Pressure (psig)	1,800	1,514	1,430
Original In-Place Gas Reserves (MMcf)	14,200	12,000	8,498
Original In-Place Oil Reserves (bbls)			
Storage Formation Name	Dakota J	Cozzette	Dakota D
Storage Lithology	Sandstone	Sandstone	Sandstone
Gross Thickness (ft)	10	20	26
Type of Geologic Trap	Stratigraphic	Structural	Structural/Stratigraphic
Geologic Age	Cretaceous	Cretaceous	Cretaceous
Maximum Depth to Formation (ft)	6,545	4,710	5,952
Minimum Depth to Formation (ft)	6,399	4,680	5,700
Areal Extent of Reservoir (acres)			1,410
Facility Data			
Injection/Withdrawal Wells - Total	27	7	21
Injection/Withdrawal Wells - Horizontal			0
Pressure Control/Observation Wells	6	3	13
Total Horsepower	2,853	1,825	6,000
Horsepower Shared	No	Yes	No
Gathering Lines - Total (miles)			9
Gathering Lines - Maximum Pipe Size (in)	6	10	12
Design Values			
Base Gas (MMcf)	3,000	7,436	4,156
Working Gas Capacity (MMcf)	5,174	4,564	5,790
Maximum Storage Pressure (psi)	1,800	1,514	2,000
Maximum Design Deliverability (Mcf/d)	50,000	22,000	199,000
Late Season/Last Day Delivery (Mcf/d)	15,946	N/A	
Annual Cycling Capability	1	1	1
Data Updated in 2004?	Yes	Yes	Yes

³ In 2003, Young Gas Storage, Ltd. filed amendment to Certificate to drill 3 horizontal wells. Amendment approval is pending as of Feb. 18, 2004.

Source: American Gas Association, 2004

Appendix 7

Data Recording Forms and Data Dictionary for the CO₂ Sequestration Information System (CO₂S/S)

Data Recording Forms for CO₂SIS

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Main Switchboard

CO₂ Sequestration Information System

ARIZONA GEOLOGICAL SURVEY

COLORADO GEOLOGICAL SURVEY

KANSAS GEOLOGICAL SURVEY

NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES

OKLAHOMA GEOLOGICAL SURVEY

TEXAS BUREAU OF ECONOMIC GEOLOGY

UTAH GEOLOGICAL SURVEY

WYOMING STATE GEOLOGICAL SURVEY



**For explanation and description of fields,
see DataDictionary on CD**

- ☐ Reservoir Data System
- ☐ Add New Data Form (To Add New Data Only)
- ☐ Data Source Directory
- ☐ Geologic Libraries
- ☐ Core and Sample Repository
- ☐ Search Database
- ☐ EXIT

Form View

FLTR NUM

CO₂ Sequestration Information System - [Frm Reservoir Data System : Form]

File Edit View Insert Format Records Tools Window Help Adobe PDF Type a question for help

Close Previous Record Next Record

RESERVOIR DATA SYSTEM

UNIQUE STATE ID#: EO-000001

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

Field/Reservoir Identification

EIA Field Code: 004194 TOTL "Dwights" Code:
Reservoir Source: RS TOTL "Unique" Code:
Play name: D SAND/MUDDY (J) SAND
Play Code: RMD8-4/RMD8-5
Subplay Name:
Subplay Code:
USGS Province and Play Code: 39 0 Play Code Source flag:

Field/Reservoir Location

Postal Code: CO API State Code: 05
Primary County: MORGAN Primary County Code: 087
Other Counties:
District: LATITUDE: 40.0626 LONGITUDE: -103.8023
Basin Name: DENVER BASIN Basin Code: 540
Gas Atlas Region: RM View Basin Maps

- Reservoir Type
- Field Information Status
- Geology
- Reservoir Status and Completion Counts
- Reservoir Area and Spacing
- Reservoir Parameters
- Gas and Fluid Properties
- Drilling and Evaluation
- Stimulation and Completion
- Geologic Type Well
- Median Recovery Well
- Completion Recovery Statistics
- Volumetric Data
- Gas Composition
- Coal Composition
- Oil Analysis
- Produced Water Composition
- Advanced PVT Properties
- Advanced PVT CO₂ Properties

Record: 1 of 180
unique identifier used to link tables

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Frm Res Type & Field Info Status : Form

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

Return

Reservoir Type

State Designation: OG
Tight Gas:
Coalbed Methane:
Shale Gas:
Cycled Gas:
GOR-based Reservoir Type: O
Atlas Prod Type:
Prorated:
Unitized:
Co-mingled Prod: N

Field Information Status

Status: P
Discovery Year: 1953
Field Type:
USGS Size Class: 15
Elevation (ft): 4524
Elevation Type: KB
Water Depth (ft):

Main Switchboard Frm Re...

Form View

FLTR. NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF Type a question for help

Form Geology : Form

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

Return

GEOLOGY

Formation Name: DAKOTA
Zone or Member: DAKOTA
Geologic Era: MESOZOIC
Geologic System: CRETACEOUS
Geologic Series: LOWER CRETACEOUS

Geologic Age Code: 217
General Lithology: SC
General Lithology Source: RS
Specific Lithology: SH, SAND
Specific Lithology Source: RS
General Trap Type: STRAT
General Trap Source: RS
Specific Trap Type: SR
Specific Trap Source: RS
Reservoir Seal:
Depositional Environment:
Depositional Environment Source:
Vertical Heterogeneity: DEPO; DIAG
Vertical Heterogeneity Source: R
Vertical Heterogeneity Level: HIGH
Vertical Heterogeneity Level Source: R
Lateral Heterogeneity:
Lateral Heterogeneity Source:
Lateral Heterogeneity Level:
Lateral Heterogeneity Level Source:
Atlas Biozone:
PlayLevel Depositional Environment: FLUV
Dykstra-Parsons Coefficient:

Main Switchboard Fm Re...

Form View FLTR NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF Type a question for help

Frm Reservoir Status & Completion and Area & Spacing : Form

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

Return

RESERVOIR STATUS AND COMPLETION COUNTS

Discovery Year:	1953	Historical Oil Wells:	292
Status:	P	Historical Oil/Gas Leases:	
Producing Gas Wells:	16	Producing Oil Wells:	222
Historical Gas Wells:	22	Inactive Oil Wells:	70
Inactive Gas Wells:	6	Enhanced Recovery Method:	
Enhanced Recovery Rate:		Number of Gas or Water Injection Wells:	26
Enhanced Recovery Data Source:			

RESERVOIR AREA AND SPACING (acres)

Published Productive Area:	12974	Allowable Spacing Source:	RS
Calculated Productive Area:	16022.62	Maximum Allowable Spacing:	160
Published Productive Area Source:	RS	Minimum Allowable Spacing:	40
Calculated Average Spacing:	728.3011	Total Oil Gas Area:	16022.62
Allowable Spacing (acres):	40		

Main Switchboard Frm Re...

Form View FLTR NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Return

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

RESERVOIR PARAMETERS

Depth (ft): MIN: 5344 AVG: 5561 MAX: 5908 Depth Source: D
Net pay (ft): MIN: AVG: 32 MAX: 72 Net Pay Source: RS
Gross pay (ft): MIN: AVG: MAX: Gross Pay Source:
Gas/Oil Saturated Intvl (ft): 72.4 Gas/Oil Saturated Source: R
Initial Oil Saturation(%): Initial Gas Saturation(%):
Initial Water (Sw) (%): MIN: 25 AVG: 32.1 MAX: 81 Water Saturation Source: R
Current Oil Saturation(%): Current Gas Saturation(%):
Current Water Saturation(%):
Current Saturation Measurement Date (mm/dd/year):
Porosity (%): MIN: 13.5 AVG: 20.4 MAX: 23 Porosity Sources: RS
Permeability Gas (md): MIN: AVG: 471 MAX: Permeability Source: RS
Permeability Oil (md): MIN: AVG: MAX: Permeability Source:
Reservoir Temp (F): 150 Reservoir Temp Source: R
Publ Initial Press (psi): Publ Initial Press Type: SI
Initial Pressure Type: Initial Pressure Source: R
Initial Pressure (psi): MIN: 972 AVG: 2600 MAX: 1540 IP Date:
Pressure Msmt1 (psi) WHSIP: BHP1: Msmt1 Date:
Pressure Msmt2 (psi) WHSIP: BHP2: Msmt2 Date:
Initial Press Gradient (psi/ft): 0.465

Main Switchboard Form

Form View FLTR NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF Type a question for help

Frm Gas Properties, Drilling, Stimulation, Completion : Form

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

GAS AND FLUID PROPERTIES

Gas Gravity: 0.735 Gas Gravity Source: RS
Liquid Gravity (API): 41 Liquid Gravity Source: RS
Resistivity (ohm-m): 1.3 Resistivity Source: RS
Resistivity Temp (F): 78 Resistivity Temp Source: RS
Salinity (ppm): 27000 Salinity Source: R

DRILLING AND EVALUATION

Drilling Fluid: MUD
Intermediate Casing:
Horizontal or Slant Well:

STIMULATION AND COMPLETION

Stimulated: Stimulated Source:
Stimulation Type: Stimulation Type Source:
Fracture Stimulation Size:
Typical Completion Type: PER, OH Typical Completion Type Source: R

Main Switchboard Frm

Form View FLTR NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Form Geologic Type & Median Recovery : Form

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

Return

GEOLOGIC TYPE WELL

API Number:
Unit Name:
Unit Name at Total Depth:
Type Well Operator: FALCON SEABOARD DRILLING CO., SNODGRASS #2
Well No; Well Name:
Section: 20 Township: 1N Range: 57W Quarter Section:
Interval: Top (ft): Bottom (ft): Completion Year: 1953

MEDIAN RECOVERY WELL

API Number: 050870672500
Unit Name:
Name of Unit at Total Depth:
Dwights ID: 40888
Operator: RAYMOND OIL CO INC
Well Name: STATE GRAY 1 SENWNE

Main Switchboard

Form View

FLTR. NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF Type a question for help

Frm Completion Recovery & Volumetric Data : Form

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

COMPLETION RECOVERY STATISTICS

GAS DATA:

No. Completions Evaluated: 1
Mean EURG/Compl (mmcf): 1842
Median EURG/Comp (mmcf): 1842
Min EURG/Comp (mmcf): 1842
Max EURG/Comp (mmcf): 1842

OIL DATA:

No. Completions Evaluated:
Mean EURO/Compl (bbl):
Median EURO/Comp (bbl):
Min EURO/Comp (bbl):
Max EURO/Comp (bbl):

VOLUMETRIC DATA

Annual Gas Prod (mmcf): 19983
Published OGIP (mmcf):
Published OGIP Source:
Non-assoc. gas EUR (mmcf): 128
Non-assoc. gas RUR (mmcf): 11691
Annual Gas Recycled (mmcf):

Annual Oil Prod (bbl): 49156
Published OOIP (bbl): 25855000
Published OOIP Source: RS
Oil EUR (bbl):
Oil RUR (bbl):
Date RUR (mm/dd/year):

Date Cum/Annual Prod. (mm/dd/year): 6/25/1905
Cummulative Gas Production (mmcf): 89682.013
Cummulative Liquids Production (bbl): 62835066
Cummulative Water Production (bbl): 14442824

Form View FLTR. NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Frm Gas, Coal, Oil : Form

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

Return

GAS COMPOSITION		COAL COMPOSITION	
Methane (mole %):	75	Carbon (weight %):	
Ethane (mole %):	6.5	Hydrogen (weight %):	
Propane (mole %):	5.9	Nitrogen (weight %):	
Butanes (mole %):	3.2	Oxygen (weight %):	
Pentanes (mole %):	1.7	Vitrinite (volume %):	
Hexanes (mole %):	0.4	Exinite (volume %):	
Hydrogen Sulfide (mole %):		Inertinite (volume %):	
Carbon Dioxide (mole %):	0.9	Coal Density:	
Nitrogen (mole %):	6.1	Coal Rank:	
Helium (mole %):	0.07	Moisture (weight %):	
Other (mole %):	0.3	Ash (weight %):	
Heating Value (btu/scf):	1228	Sulfur (weight %):	
Gas Sample Well:		Heat Content (Btu/lb):	
API Number:		Volatiles Matter (weight %):	
		Fixed Carbon (weight %):	
		Vitrinite Reflectance (%):	

CRUDE OIL ANALYSIS	
Specific Oil Gravity:	0.82029
Liquid Oil Gravity (API):	41
Pour Point of Oil:	
Color of Oil:	
Viscosity of Oil:	1
Temperature of Viscosity Measurement:	

Main Switchboard

Form View

FLTR

NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Frm Produced Water Composition : Form

State: COLORADO
Field Name: ADENA
Reservoir Name: DAKOTA

Return

Produced Water Composition

Average Na (mg/l):		Resistivity:	1.3
Average K (mg/l):		Resistivity Temperature:	25.555556
Average Ca (mg/l):		pH:	
Average Mg (mg/l):			
Average Cl (mg/l):			
Average SO ₄ (mg/l):			
Average HCO ₃ (mg/l):			
Average CO ₃ (mg/l):			
Average calc. TDS (mg/l):	15000		

Main Switchboard

Frm Re...

Form View

FLTR

NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

State: COLORADO UNIQUE STATE ID#: CO-000001

Field Name: ADENA

Reservoir Name: DAKOTA

Return

ADVANCED PVT PROPERTIES

PVT_Well_ID	P_pvt	Bo_pvt	Rs	Rsw
*				

Record: 1 of 1

Main Switchboard

Frm Re...

API number for well from which PVT measurements were made

FLTR.

NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

State: COLORADO UNIQUE STATE ID#: CO-000001

Field Name: ADENA

Reservoir Name: DAKOTA

Return

ADVANCED PVT_{CO2} PROPERTIES

PVTCO ₂ _Well_ID	P_pvtco2	Bo_pvtco2	Rs_co2	Rsw_co2

Record: 1 of 1

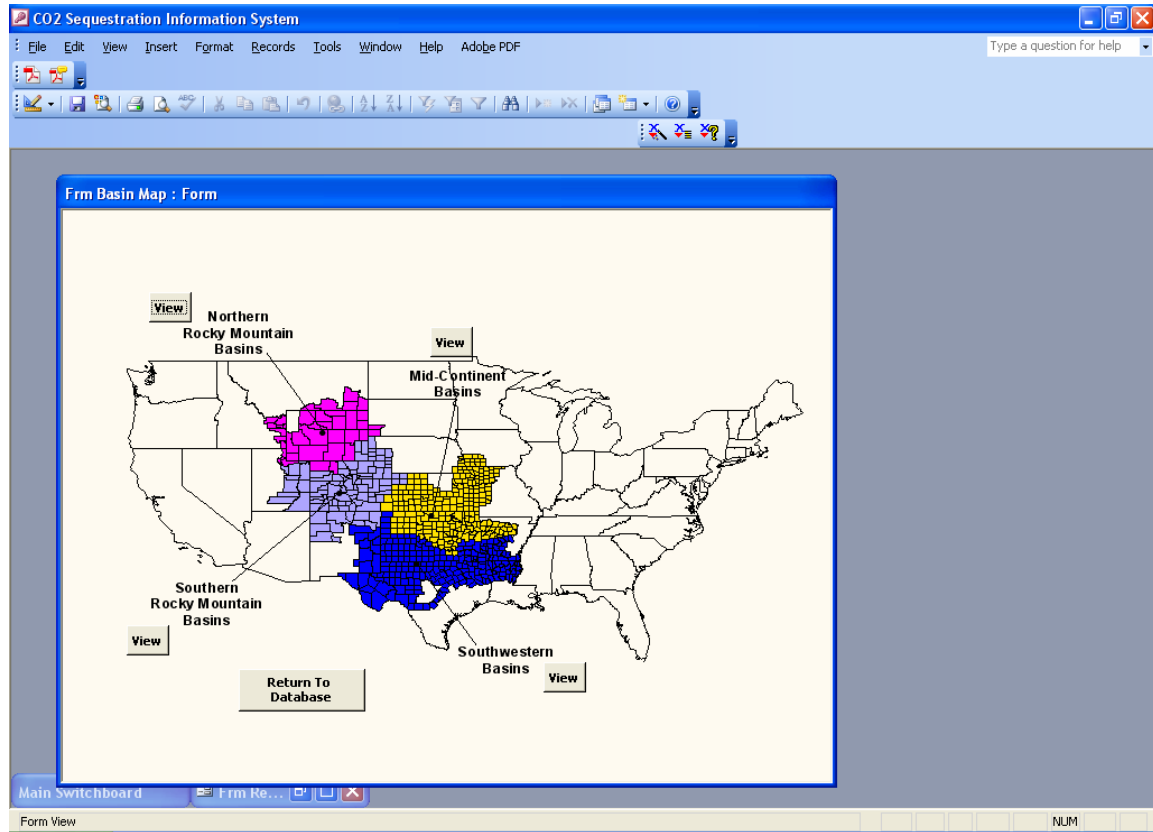
Main Switchboard

Frm Re...

Form View

FLTR.

NUM



CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Frm Northern Rocky Mountain Basins : Form

Northern Rocky Mountain Basins

520 Big Horn Basin

530 Wind River Basin

507 Central Western Overthrust

515 Powder River Basin

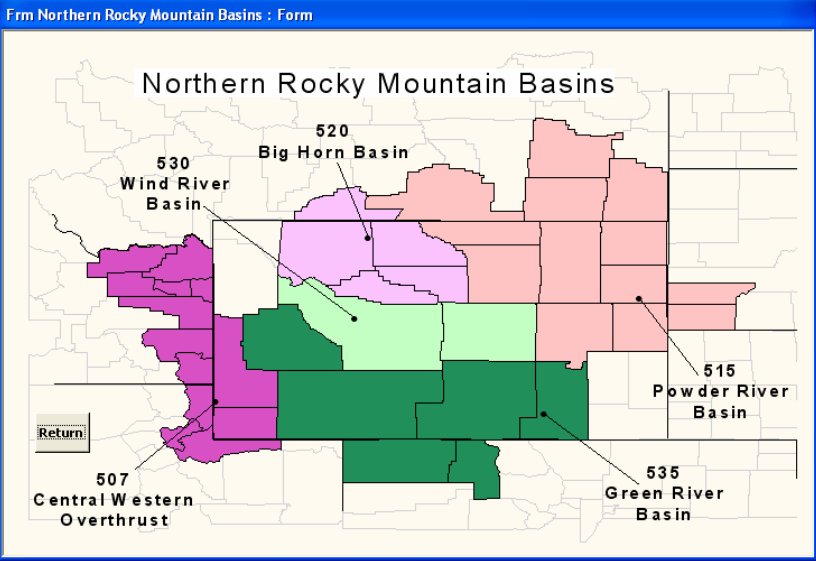
535 Green River Basin

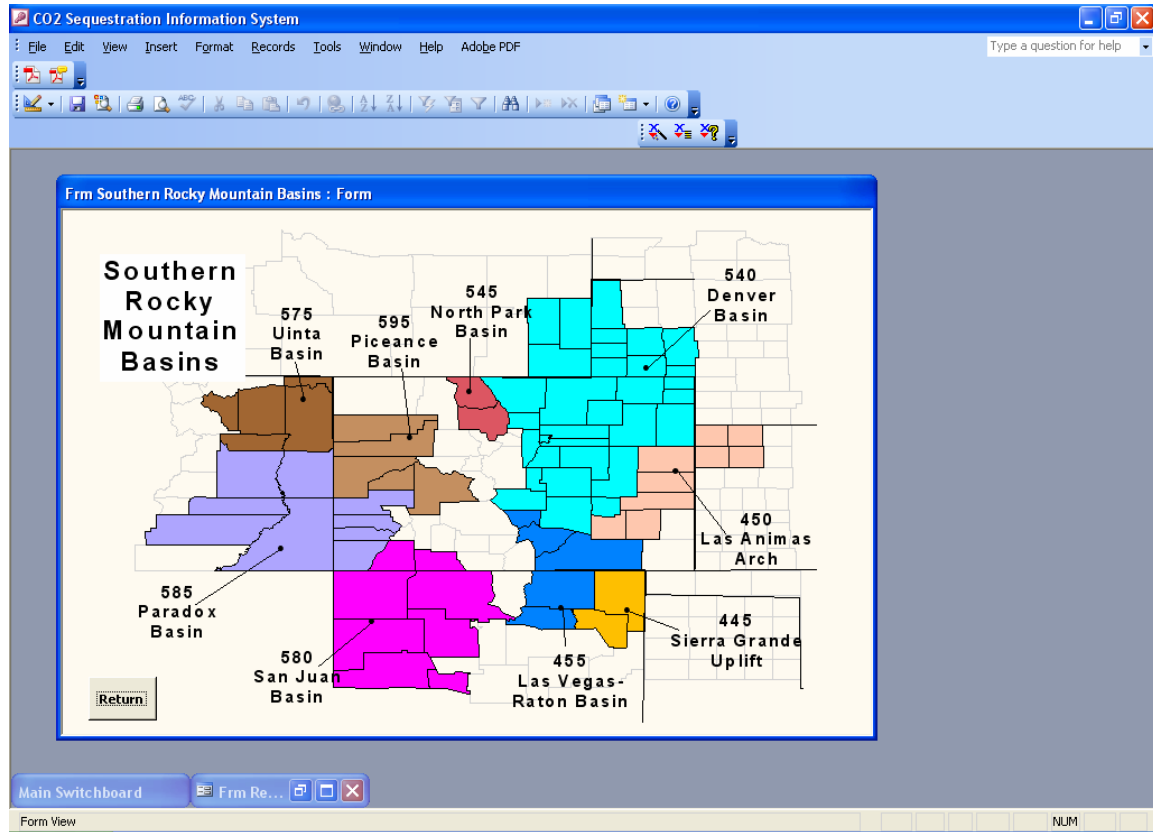
Return

Main Switchboard Frm Re...

Form View

NUM





CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Form Database Directory : Form

DATA SOURCE DIRECTORY

Close

Unique ID: 298

Title: 1995 NATIONAL ASSESSMENT OF U.S. OIL AND GAS RESOURCES-RESULTS, METHODOLOGY, AND SUPPORTING DATA. (DDS-30)

Type: PETROLEUM GEOLOGY, INDUSTRY ACTIVITY AND STATISTICS

Subjects: FIELD IDENTIFICATION/LOCATION, STRATIGRAPHY

Coverage: United States

Format: AUTOMATED

Level: REGION, BASIN, PLAY

Developer: U.S. GEOLOGICAL SURVEY

PO, Div, MS Address: NATIONAL CENTER, MAILSTOP 950

Street Address: 12201 SUNRISE VALLEY DRIVE

City: RESTON State: VA ZIP: 22092-9998

Telephone: (703) 648-4000 FAX:

Contact:

Supplier:

Time Span:

Updating:

No. Records: No. Elements:

MEDIA: CD-ROM Cost:

Hardcopy: Cost:

Online Info: THE UNITED STATES GEOLOGICAL SURVEY'S WEB SITE IS AT: <http://www.usgs.gov> OR AT <http://info.er.usgs.gov>

ABSTRACT: THIS REPORT (USGS DIGITAL DATA SERIES 30) SUMMARIZES THE RESULTS OF A 3-YR STUDY OF THE OIL AND GAS RESOURCES OF THE ONSHORE AND STATE WATERS OF THE UNITED STATES BY THE USGS.

ESTIMATES OF PROVED RESERVES, FUTURE ADDITIONS, AND UNDISCOVERED RESOURCES IN BOTH CONVENTIONAL AND CONTINUOUS-TYPE (LARGELY UNCONVENTIONAL) ACCUMULATIONS ARE PRESENTED.

Record: 14 of 283

Form View

NUM

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Form Geologic Libraries : Form

GEOLOGIC LIBRARIES

Close

Unique ID: 301

Library Name: TUSCON EARTH SCIENCE INFORMATION CENTER

Center:

Address: 340 NORTH 6TH AVENUE

City, State, Zip: TUSCON, AZ 85705-8325

Telephone: (602) 670-5584 FAX: (602) 670-5591

Contact: DIANE MURRAY

Address: (If Different)

Hours: 8:00-4:00

Days: MONDAY-FRIDAY

Appointments:

Coverage: AVAILABLE DATA:
US GEOLOGICAL SURVEY INFORMATION AND MATERIALS INCLUDING PROFESSIONAL PAPERS, BULLETINS, SPECIAL SERIES, INVESTIGATIONS, AND FIELD STUDIES. THE CENTER ALSO HAS

Miscellaneous Information: THE CENTER HAS ALL CD-ROM-DATABASES PUBLISHED BY THE US GEOLOGICAL SURVEY. THE CENTER ALSO HAS ACCESS TO THE USGS AERIAL PHOTOGRAPHY DATABASE. TEACHER PACKETS ARE ALSO AVAILABLE.

Publications: THE FACILITY IS A JOINT EFFORT OF THE US GEOLOGICAL SURVEY AND THE ARIZONA GEOLOGICAL SURVEY. ITS PURPOSE IS TO PROVIDE PUBLIC ACCESS TO USGS INFORMATION AND MATERIALS.

Facilities: THE STAFF AIDS IN LOCATING MATERIALS AND REFERRING PATRONS TO ENTITIES OUTSIDE THE CENTER IF ADDITIONAL INFORMATION IS REQUIRED.

Services: THE STAFF AIDS IN LOCATING MATERIALS AND REFERRING PATRONS TO ENTITIES OUTSIDE THE CENTER IF ADDITIONAL INFORMATION IS REQUIRED.

Dues:

Record: 1 of 24

Main Switchboard

Form View

Appendix 7 Data Recording Forms and Data Dictionary for CO₂SIS.doc - Microsoft

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF Type a question for help

Form Core and Sample Repositories : Form

CORE AND SAMPLE REPOSITORIES

Close

Unique ID: 300

Center Name: GEOLOGICAL SURVEY OF ALABAMA

Address: SAMPLE AND CORE LIBRARY

P.O. BOX 0

City, State, Zip: UNIVERSITY, AL 35486

Telephone: (205) 349-2852 FAX:

Contact:

Address: SCIENTIFIC COLLECTIONS BUILDING

500 HACKBERRY LANE, TUSCALOOSA, ALABAMA

Hours: 8:00-12:00; 1:00-5:00

Days: MONDAY-FRIDAY

Appointment: APPOINTMENT IS NECESSARY

Oil Gas Holding: 85% Coal Holding: 2%

Oil Shale Holding: 0% Other Holding: 3%

Water Well Holding: 10%

Coverage:

STATE	PERCENTAGE
ALABAMA:	95%
FLORIDA:	5%

Cores by State:

Core: 750 LOCATIONS

Core Chips: 1,000 LOCATIONS

Cuttings: 9,000 OIL OR GAS WELLS

Core Footage:

Information: INFORMATION IS MAINTAINED ON INDEX CARDS AND LISTS. DATA INCLUDE LOCATION, FORMATION NAME, TYPE OF SAMPLE, AND DEPTH.

Services:

Facility: THE FACILITY OCCUPIES 12,300 SQUARE FEET IN A MASONRY BUILDING EQUIPPED WITH CLIMATE CONTROL. THE BUILDING HAS FOUR EXAMINATION ROOMS.

Fees: NO Sampling: YES Loan: NO

Remarks: FACILITY IS ACCEPTING NEW MATERIAL. MATERIALS CAN BE KEPT CONFIDENTIAL FOR SIX MONTHS UPON WRITTEN REQUEST.

Facility Size: 12,300 SQUARE FEET

Examination Room: 1,200 SQUARE FEET

Equipment: BINOCULAR AND PETROGRAPHIC MICROSCOPES AND TESTING CHEMICALS

Main Record: 1 of 29

Form View

CO₂ Sequestration Information System

File Edit View Insert Format Records Tools Window Help Adobe PDF

Type a question for help

Frm Search menu : Form

SEARCH MENU

Return to Main Menu

Search [Text Field] Search by State

Search [Text Field] Search by Basin Name

Search [Text Field] Search by Field Name

Search [Text Field] Search by Play Name

Record: 14 1 of 1

Main Switchboard

Form View NUM

Data Dictionary for CO₂SIS

FIELD/RESERVOIR IDENTIFICATION

label: Unique state ID #
field name: UCOP_DB_#
type: alpha-numeric (starts with state postal abbreviation followed by
unique six digit number)
format: 8
units:
definition: unique identifier used to link database tables

label: field name
field name: FLDNAME
type: character
format: 35
units:
definition: field name

label: EIA field code
field name: DOEFLD
type: character
format: 6
units:
definition: EIA field code

label: reservoir name
field name: RESNAME
type: character
format: 45
units:
definition: reservoir name

label: reservoir source
field name: R_STUDY
type: character
format: 2
units:
definition: reservoir data source
codes: GA Gas Atlas
PM PUMP studies
TL TOTL
TO TORIS database
RS Reservoir Studies

label: atlas play name
field name: PLAYNAME
type: character
format: 140
units:
definition: gas atlas or PUMP study geologic play name

label: play code
field name: PLAYCOD
type: character
format: 11
units:
definition: gas atlas or PUMP study geologic play code

label: subplay name
field name: SUBPLAYN
type: character
format: 60
units:
definition: gas atlas or PUMP study subplay name

label: subplay code
field name: SUBPLAY
type: character
format: 10
units:
definition: gas atlas or PUMP study subplay code

label: USGS province code
field name: USGSPROV
type: character
format: 2
units:
definition: Geologic Province code from USGS's 1995 Assessment of
U.S. Oil and Gas Resources

codes: 20 - Uinta - Piceance Basin
21 - Paradox Basin
22 - San Juan Basin
24 - Northern Arizona
33 - Powder River Basin
34 - Big Horn Basin
35 - Wind River Basin
36 - Wyoming Thrust Belt
37 - Southwestern Wyoming
38 - Park Basins
39 - Denver Basin

40 - Las Animas Arch
41 - Raton Basin-Sierra Grande Uplift
43 - Palo Duro Basin
44 - Permian Basin
45 - Bend Arch - Fort Worth Basin
53 - Cambridge Arch - Central Kansas Uplift
55 - Nemaha Uplift
58 - Anadarko Basin
59 - Sedgwick Basin
60 - Cherokee Platform
61 - Southern Oklahoma
62 - Arkoma Basin

label: USGS play code

field name: USGSPLAY

type: character

format: 4

units:

definition: Play code from USGS's 1995 Assessment of U.S. Oil and Gas Resources

codes: 2001 - Piceance Tertiary Conventional
2002 - Uinta Tertiary Oil and Gas
2003 - Upper Cretaceous Conventional
2004 - Cretaceous Dakota to Jurassic
2005 - Permian-Pennsylvanian Sandstones and Carbonates
2010 - Tight Gas Piceance Mesaverde lles
2015 - Tight Gas Uinta Tertiary East

2101 - Buried Fault Blocks, Older Paleozoic
2102 - Porous Carbonate Buildup
2105 - Salt Anticline Flank
2107 - Cretaceous Sandstone

2201 - Porous Carbonate Buildup
2205 - Dakota Central Basin Gas
2206 - Basin Margin Dakota Oil
2207 - Tociito/Gallup Sandstone Oil
2208 - Mancos Fractured Shale
2209 - Central Basin Mesaverde Gas
2211 - Pictured Cliffs Gas
2212 - Fruitland-Kirtland Fluvial Sandstone Gas
2250 - San Juan Basin - Overpressured

3302 - Basin Margin Anticline
3305 - Lakota Sandstone
3306 - Fall River Sandstone
3307 - Muddy Sandstone
3309 - Deep Frontier Sandstone
3310 - Turner Sandstone
3312 - Sussex-Shannon Sandstone
3313 - Mesaverde-Lewis

3402 - Basin Margin Anticline
3406 - Phosphoria Stratigraphic

3501 - Basin Margin Subthrust
3502 - Basin Margin Anticline
3503 - Deep Basin Structure
3504 - Muddy Sandstone Stratigraphic

3604 - Absaroka Thrust

3701 - Rock Springs Uplift
3702 - Cherokee Arch
3703 - Axial Uplift
3704 - Moxa Arch-Labarge
3705 - Basin Margin Anticline
3707 - Platform
3709 - Deep Basin
3740 - Greater Green River Basin - Cloverly-Frontier
3741 - Greater Green River Basin - Mesaverde
3742 - Greater Green River Basin - Lewis

3801 - Cretaceous - Upper Jurassic Structural
3901 - Pierre Shale Sandstones
3903 - Niobrara Chalk - Shallow Biogenic Gas
3904 - Greater Wattenberg Codell/Niobrara Oil and Gas
3905 - Dakota Group (Combined J and D Sandstones)
3906 - J Sandstone Deep Gas (Wattenberg)

4001 - Middle and Upper Pennsylvanian Carbonates Oil
4004 - Lower Pennsylvanian (Morrowan) Sandstone Oil, Gas, and
Natural Gas Liquids

4301 - Upper Paleozoic

- 4401 - Pre-Pennsylvanian, Delaware - Val Verde Basins
- 4402 - Pre-Pennsylvanian, Central Basin Platform
- 4403 - Pre-Pennsylvanian, Northwestern and Eastern Shelves
- 4404 - Lower Pennsylvanian (Bend) Sandstone
- 4405 - Horseshoe Atoll, Upper Pennsylvanian - Wolfcampian
- 4406 - Upper Pennsylvanian, Northwestern and Eastern Shelves, Northern Delaware and Midland Basins and Northern Central Basin Platform
- 4407 - Upper Pennsylvanian and Lower Permian Shelf, Slope and Basin Sandstones
- 4408 - Wolfcampian Carbonate, Eastern and Southern Margins of the Central Basin Platform
- 4409 - Spraberry-Dean
- 4410 - San Andres-Clearfork, Central Basin Platform and Ozona Arch
- 4411 - San Andres-Clearfork, Northwestern and Eastern Shelves
- 4412 - Delaware Sandstones

- 4501 - Pre-Mississippian Carbonate
- 4502 - Mississippian Carbonate
- 4504 - Lower Pennsylvanian (Bend) Sandstone and Conglomerate
- 4505 - Strawn (Desmoinesian)
- 4506 - Post-Desmoinesian

- 5304 - Mississippian and Devonian
- 5305 - Pennsylvanian Cyclical Carbonates and Sandstones
- 5309 - Early Ordovician/Cambrian Arbuckle

- 5501 - Pre-Woodford Paleozoic
- 5503 - Mississippian
- 5504 - Pennsylvanian-Permian Structural
- 5505 - Pennsylvanian Stratigraphic

- 5801 - Deep Structural Gas
- 5802 - Uppermost Arbuckle
- 5804 - Wichita Mountains Uplift
- 5807 - Viola Oil and Gas
- 5809 - Hunton Stratigraphic-Unconformity Gas and Oil
- 5812 - Deep Stratigraphic Gas
- 5813 - Lower Mississippian Stratigraphic Oil and Gas
- 5814 - Upper Mississippian Stratigraphic Gas and Oil
- 5815 - Springer Stratigraphic Gas and Oil
- 5816 - Morrow Sandstone Gas and Oil Stratigraphic
- 5817 - Atokan Sandstone Stratigraphic Gas
- 5818 - Atokan Limestone Stratigraphic Gas and Oil
- 5819 - Lower Desmoinesian Stratigraphic Gas and Oil

5820 - Upper Desmoinesian Oil and Gas
5821 - Lower Missourian Stratigraphic Oil and Gas
5822 - Upper Missourian Oil and Gas
5823 - Lower Virgilian Sandstone Gas and Oil
5824 - Upper Virgilian Stratigraphic Oil and Gas
5825 - Permian Carbonate Stratigraphic Gas
5827 - Washes
5828 - Permian Sandstone Oil and Gas

5902 - Mississippian Combination Traps
5903 - Pennsylvanian Combination Traps

6004 - Pennsylvanian Structural

6101 - Deep Gas
6103 - Simpson Structural Oil
6104 - Viola Oil and Gas
6105 - Hunton Oil
6107 - Misener-Woodford-Sycamore Gas and Oil
6108 - Springer Sandstone Oil and Gas
6110 - Desmoinesian Sandstone Oil
6111 - Missourian Sandstone Oil and Gas
6112 - Virgilian Sandstone Oil and Gas

6202 - Atoka-Desmoinesian Fluvial-Deltaic and Shelf Sandstone Gas
6203 - Atoka Deep-Water Sandstone Gas
6204 - Morrowan Shallow Marine Sandstone and Limestone Gas
6205 - Arbuckle Through Misener Basement Fault and Shelf Gas
6206 - Cromwell-Spiro-Wapanucka Sub-Choctaw Thrust Gas

label: USGS play code source flag

field name: S_USGSPL

type: character

format: 1

units:

definition: Flag identifying source of USGS play code assignment

codes: O = play code assigned by comparison with USGS OFR 97-28
reservoir database.

E = analysis by EEA using play descriptions, play maps, and
stratigraphic columns.

label: TOTL "dwights" code
field name: DWIGHTS
type: numeric
format: 9.0
units:
definition: Dwights TOTL, DOGR field and reservoir code (from GASIS)

label: TOTL "uniqid" code
field name: UNIQID
type: character
format: 9
units:
definition: Dwights TOTL database unique key (form GASIS)

FIELD/RESERVOIR LOCATION

label: state name
field name: STATE
type: character
format: 15
units:
definition: state name

label: state postal code
field name: STPOST
type: character
format: 2
units:
definition: two character state postal code

label: API state code
field name: STCODE
type: character
format: 2
units:
definition: two digit API state code

label: county
field name: COUNTY
type: character
format: 25
units:
definition: primary county or parish name

label: county code
field name: COCODE
type: character
format: 3
units:
definition: API primary county code

label: Other Counties
field name: OTHER COUNTIES
type: character
format: 50
units:
definition: secondary county or parish name(s)

label: district
field name: DISTRICT
type: character
format: 8
units:
definition: state regulatory district

label: AAPG basin name
field name: BASINNM
type: character
format: 26
units:
definition: AAPG basin (geologic province) name

label: AAPG basin code
field name: BASCODE
type: character
format: 3
units:
definition: AAPG basin (geologic province) code

label: Gas Atlas Region
field name: ATLASREG
type: character
format: 2
units:
definition: code for gas atlas region.
DOES NOT DENOTE DATA SOURCE.
codes: AP Appalachian
MC Mid-Continent
RM Rocky Mountain
TX Texas.

label: latitude (degrees)
field name: LATITUDE
type: numeric
format: 9.5
units: degrees
definition: latitude of median recovery well

label: longitude (degrees)
field name: LONGITUD
type: numeric
format: 9.5
units: degrees
definition: longitude of median recovery well

RESERVOIR TYPE

label: state reservoir designation
field name: RESTYPE
type: character
format: 4
units:
definition: reservoir designation (state agency)
codes: O oil
G gas
OG oil and gas
A associated gas (primarily Texas)
S saline aquifer

label: GOR-based reservoir type
field name: RTYPEGOR
type: character
format: 1
units:
definition: reservoir designation based on gas/oil ratio.
Reservoirs with GOR > 20,000 scf/bbl classified as Gas,
Other reservoirs classified as oil.
codes: O oil
G gas

label: tight gas
field name: TIGHT
type: character
format: 1
units: Y/N
definition: tight gas reservoir flag (GRI database; Rocky Mt. Atlas)

label: coalbed methane
field name: CBMETH
type: character
format: 1
units: Y/N
definition: coalbed methane reservoir flag

label: shale gas
field name: SHGAS
type: character
format: 1
units: Y/N
definition: shale reservoir flag

label: gas cycling/injection
field name: CYCLED
type: character
format: 1
units: Y/N
definition: cycled/injected gas reservoir flag

label: atlas production type
field name: GASTYPE
type: character
format: 3
units:
definition: gas production type
codes: N non-associated
K casinghead
A associated
G gas well

label: prorated
field name: PRORATED
type: character
format: 1
units: Y/N
definition: prorated reservoir flag

label: unitized
field name: UNIT
type: character
format: 1
units: Y/N
definition: unitized reservoir flag

label: commingled
field name: CMGLPROD
type: character
format: 1
units: Y/N
definition: commingled production flag

FIELD INFORMATION AND STATUS

label: field status
field name: FLDSTAT
type: character
format: 1
units:
definition: field status
codes: P producing
A abandoned
I inactive
C combined

label: field discovery year
field name: FYRDISC
type: numeric
format: 4.0
units: year
definition: field discovery year

label: field type
field name: FLDTYPE
type: character
format: 3
units:
definition: field type designation (state agency)
codes: O oil
G gas
OG oil and gas

label: USGS field size class
field name: I_CLAS
type: numeric
format: 2.0
units: 1-20
definition: USGS field size class including growth

codes:class	mmboe		bcf	
	min	max	min	max
1	0	0.006	0.015	0.031
2	0.006	0.012	0.031	0.062
3	0.012	0.024	0.062	0.125
4	0.024	0.047	0.125	0.25
5	0.047	0.095	0.25	0.5
6	0.095	0.19	0.5	1
7	0.19	0.38	1	2
8	0.38	0.76	2	4
9	0.76	1.52	4	8
10	1.52	3.04	8	16
11	3.04	6.07	16	32
12	6.07	12.14	32	64
13	12.14	24.3	64	128
14	24.3	48.6	128	256
15	48.6	97.2	256	512
16	97.2	194.3	512	1024
17	194.3	388.6	1024	2048
18	388.6	777.2	2048	4096
19	777.2	1554.5	4096	8192
20	1554.5	3109	8192	16380

label: field elevation (ft)
field name: FELEV
type: numeric
format: 5.0
units: feet
definition: field elevation (sea level datum)

label: elevation type
field name: ELEVTYPE
type: character
format: 2
units:
definition: elevation reference point
codes:KB kelly bushing
GR ground
DF derrick floor

label: water depth (ft)
field name: H2ODEPTH
type: numeric
format: 5.0
units: feet
definition: static water depth in type well

GEOLOGY

label: formation name
field name: PRODFOR
type: character
format: 45
units:
definition: producing formation name

label: zone or member
field name: ZONE
type: character
format: 35
units:
definition: producing zone or member name

label: geologic era
field name: ERANM
type: character
format: 9
units:
definition: geologic era name

label: geologic system
field name: SYSNM
type: character
format: 20
units:
definition: geologic system name

label: geologic series
field name: SERNM
type: character
format: 20
units:
definition: geologic series name

label: geologic age code
field name: GEOLAGE
type: character
format: 3
units:
definition: three digit USGS geologic age code

label: general lithology
 field name: GENLITH
 type: character
 format: 2
 units:
 definition: general lithology
 codes: SC siliciclastic
 CB carbonate
 COAL coal
 BO both SC and CB

label: gen lith source
 field name: S_GENLIT
 type: character
 format: 2
 units:
 definition: general lithology source
 codes: GA Gas Atlas
 TL TOTL
 TO TORIS database
 RS Reservoir Studies

label: specific lithology
 field name: SPECLITH
 type: character
 format: 4
 units:
 definition: specific lithology of reservoir (codes)
 codes: CONG conglomerate
 COAL coal
 SAND sandstone
 SILT siltstone
 SH shale
 CHER chert
 ARK arkose
 DOLO dolostone
 CHLK chalk
 LS limestone undifferentiated
 CARB carbonate undifferentiated

label: spec lith source
field name: S_SPECLI
type: character
format: 2
units:
definition: specific lithology source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: general trap type
field name: GENTRAP
type: character
format: 5
units:
definition: general reservoir trap type
codes:STRUC structural
STRAT stratigraphic
COMB combination

label: gentrap source
field name: S_GENTRA
type: character
format: 2
units:
definition: general reservoir trap type source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: specific trap type
field name: SPECTRAP
type: character
format: 14
units:
definition: specific trap type (14 codes)
codes:

structural trap types:

AN	anticline/dome
FT	fault
NO	nose
FA	faulted anticline
FN	faulted nose
SD	salt dome
FR	fracture
SC	structural undesignated

stratigraphic trap types:

FC	facies change
UN	unconformity
RF	reef
LP	lateral porosity change
CA	chemical alteration
SR	stratigraphic undesignated
CB	coal bed

label: spec trap source
field name: S_SPECTR
type: character
format: 2
units:
definition: specific trap type source
codes: GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: reservoir seal
field name: SEAL
type: character
format: 5
units:
definition: reservoir seal type
codes: SALT salt
SHALE shale
ANHYD anhydrite

label: depo. environment
field name: DEPEND
type: character
format: 10
units:
definition: depositional environment of reservoir
codes: LACUS lacustrine
PERIT peritidal
SHSHF shallow shelf
SHMAR shelf margin
REEF reef
SLBAS slope/basin
BASIN basinal
EOL eolian
FLUV fluvial
ALLUV alluvial fan
DELTA delta
STRAN strandplain
SHELF shelf

label: depo env source
field name: S_DEPEND
type: character
format: 2
units:
definition: depositional environment source
codes: GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: vertical heterogeneity
 field name: VERHET
 type: character
 format: 10
 units:
 definition: vertical heterogeneity type
 codes: DEPO general depositional heterogeneity
 DIAG diagenetic porosity variation
 EROS erosional discontinuities
 FACIES reservoir facies change
 FAULT faults
 FRAC fractures
 NONE no vertical heterogeneity
 STRUC general structural heterogeneity
 UNKN vertical heterogeneity unknown

label: ver het source
 field name: S_VERHET
 type: character
 format: 2
 units:
 definition: vertical heterogeneity type source
 codes: GA Gas Atlas
 TL TOTL
 TO TORIS database
 RS Reservoir Studies

label: vertical het. level
 field name: VHETLVL
 type: character
 format: 8
 units:
 definition: vertical heterogeneity level (low,mod,high)
 codes: LOW low level of vertical heterogeneity
 MODERATE moderate level of vertical heterogeneity
 HIGH high level of vertical heterogeneity

label: vertical het. level source
field name: S_VHETLV
type: character
format: 2
units:
definition: vertical heterogeneity level source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: lateral heterogeneity
field name: HORHET
type: character
format: 20
units:
definition: lateral heterogeneity type
codes:DEPO general depositional heterogeneity
DIAG diagenetic porosity variation
EROS erosional discontinuities
FACIES reservoir facies change
FAULT faults
FRAC fractures
NONE no vertical heterogeneity
STRUC general structural heterogeneity
UNKN vertical heterogeneity unknown

label: lat het source
field name: S_HORHET
type: character
format: 2
units:
definition: lateral heterogeneity type source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: lateral het. level
field name: HHETLVL
type: character
format: 8
units:
definition: lateral heterogeneity level
codes: LOW low level of horizontal heterogeneity
MODERATE moderate level of horizontal heterogeneity
HIGH high level of horizontal heterogeneity

label: lateral het. level source
field name: S_HHETLV
type: character
format: 2
units:
definition: lateral heterogeneity level source
codes: GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: Dykstra-Parsons coeff.
field name: DP_coeff
type: numeric
format: 6.6
units:
definition: a measure of vertical reservoir heterogeneity expressed as a fractional number between 0 and 1

label: biozone
field name: BIOZONE
type: character
format: 6
units:
definition: Gulf Coast gas atlas biozone
label: Play-level depositional environment code
field name: PLAYDEPO
type: character
format: 5
units:
definition: depositional environment of the play containing this
reservoir
codes: AFAN alluvial fan
BASIN basinal
DELTA deltaic
EOLN eolian
FLUV fluvial
LACUS lacustrine
PERIT peritidal
REEF reef
SHELF shelf
SHMAR shelf margin
SHSHF shelf margin
SLBAS slope/basin
STRAN strandplain

RESERVOIR STATUS AND COMPLETION COUNTS

label: reservoir discovery year
field name: YRDISC
type: numeric
format: 4.0
units: year
definition: reservoir discovery year

label: reservoir status
field name: STATUS
type: character
format: 1
units:
definition: reservoir status
codes: A abandoned
C combined
I inactive
P producing
U unknown

label: no. of producing gas wells
field name: PRODCGW
type: numeric
format: 6.0
units:
definition: number of gas completions producing in 2003

label: no. of historical gas completions
field name: HISTCGW
type: numeric
format: 6.0
units:
definition: total historical gas completions through 2003

label: no. of inactive gas completions
field name: INACTCGW
type: numeric
format: 6.0
units:
definition: number of inactive gas completions in 2003

label: no. of historical oil wells
field name: HISTOW
type: numeric
format: 6.0
units:
definition: number of historical oil wells through 2003

label: historical oil leases
field name: HISTOL
type: numeric
format: 6.0
units:
definition: historical oil leases through 2003

label: no. of producing oil wells
field name: PRODOW
type: numeric
format: 6.0
units:
definition: number of producing oil wells in 2003

label: no. of inactive oil wells
field name: INACT OW
type: numeric
format: 6.0
units:
definition: number of inactive oil wells in 2003

label: Enhanced Recovery Method
field name: ERECMTD
type: character
format: 5
units:
definition: enhanced recovery method
codes:CO2 carbon dioxide flood
GR gas reinjection
NR nitrogen reinjection
WF water flood

label: no. of injection wells
field name: INJWELLS
type: numeric
format: 6.0
units:
definition: number of injection wells in 2003

label: Enhanced Recovery Rate
field name: ERECMT
type: character
format: 12
units:
definition: rate of gas or water injection (in mcf/d, gpm)

label: Enhanced Recovery Data Source
field name: S_ERECD
type: character
format: 2
units:
definition: source of enhanced recovery data
codes: GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

RESERVOIR AREA AND SPACING

label: calc productive area (acres)
field name: PRODAREA
type: numeric
format: 7.0
units: acres
definition: calculated historic area with production

label: publ productive area (acres)
field name: ACRES
type: numeric
format: 7.0
units: acres
definition: published productive area of reservoir

label: publ prod area source
field name: S_ACRES
type: character
format: 2
units:
definition: published productive area source (ACRES)
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: calc avg spacing (acres)
field name: CALCSPAC
type: numeric
format: 4.0
units: acres/well
definition: calculated average well spacing

label: allowable spacing (acres)
field name: AVGSPAC
type: numeric
format: 4.0
units: acres/well
definition: predominant allowable well spacing

label: allowable spacing source
field name: S_AVGSPA
type: character
format: 2
units:
definition: allowable well spacing source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: max allowable spacing (acres)
field name: MAXSPAC
type: numeric
format: 4.0
units: acres/well
definition: maximum allowable well spacing for reservoir

label: min spacing (acres)
field name: MINSPAC
type: numeric
format: 4.0
units: acres/well
definition: minimum allowable well spacing for reservoir

label: total reservoir area
field name: TOTAREA
type: numeric
format: 7.0
units: acres
definition: total productive area of reservoir

RESERVOIR PARAMETERS

label: Depth (ft) AVG
field name: DEPTHTOP_AV
type: numeric
format: 5.0
units: feet
definition: average reported reservoir depth

label: Depth (ft) MIN
field name: DEPTHTOP_MN
type: numeric
format: 5.0
units: feet
definition: minimum reservoir depth

label: Depth (ft) MAX
field name: DEPTHTOP_MX
type: numeric
format: 5.0
units: feet
definition: maximum reservoir depth

label: depth source
field name: S_DEPTH
type: character
format: 2
units:
definition: average reservoir depth source
codes:GA Gas Atlas
DW Dwights DOGR
TL Dwights TOTL
TO TORIS database
RS Reservoir Studies

label: Net pay (ft) AVG
field name: AVTHICK
type: numeric
format: 6.1
units: feet
definition: average or reported net pay thickness

label: Net pay (ft) MIN
field name: MNTHICK
type: numeric
format: 6.1
units: feet
definition: net pay range minimum

label: Net pay (ft) MAX
field name: MXTHICK
type: numeric
format: 6.1
units: feet
definition: net pay range maximum

label: Net Pay Source
field name: S_THICK
type: character
format: 2
units:
definition: data source for net pay
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: Gross pay (ft) AVG
field name: AVGRPY
type: numeric
format: 6.1
units: feet
definition: average or reported gross pay thickness

label: Gross pay (ft) MIN
field name: MNGRPY
type: numeric
format: 6.1
units: feet
definition: gross pay range minimum

label: Gross pay (ft) MAX
field name: MXGRPY
type: numeric
format: 6.1
units: feet
definition: gross pay range maximum

label: Gross Pay Source
field name: S_GRPY
type: character
format: 2
units:
definition: data source for gross pay
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: Gas/Oil Saturated Intvl (ft)
field name: SIAVTHK
type: numeric
format: 6.1
units: feet
definition: average thickness of gas/oil saturated interval

label: Gas/Oil Saturated Source
field name: S_SIAVTH
type: character
format: 2
units:
definition: gas/oil saturated thickness source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: Initial Oil Saturation (%)
field name: I_OIL_SAT
type: numeric
format: 2
units: percent
definition: initial reservoir oil saturation, expressed as a percentage

label: Initial Gas Saturation (%)
field name: I_GAS_SAT
type: numeric
format: 2
units: percent
definition: initial reservoir gas saturation, expressed as a percentage

label: Current Oil Saturation (%)
field name: CUR_OIL_SAT
type: numeric
format: 2
units: percent
definition: current reservoir oil saturation, expressed as a percentage

label: Current Gas Saturation (%)
field name: CUR_GAS_SAT
type: numeric
format: 2
units: percent
definition: current reservoir gas saturation, expressed as a percentage

label: Current Water Saturation (%)
field name: CUR_WATER_SAT
type: numeric
format: 2
units: percent
definition: current reservoir water saturation, expressed as a
percentage

label: Current Saturation Measurement Date (mm/dd/year)
field name: CUR_DATE
type: numeric
format: 8
units: (mm/dd/year)
definition: date of the current reservoir saturation measurements

label: avg porosity (%)
field name: AVPOR
type: numeric
format: 6.2
units: %
definition: average or reported porosity of pay interval

label: min porosity (%)
field name: LOPOR
type: numeric
format: 6.2
units: %
definition: porosity range minimum of pay interval

label: max porosity (%)
field name: HIPOR
type: numeric
format: 6.2
units: %
definition: porosity range maximum of pay interval

label: porosity source
field name: S_POR
type: character
format: 2
units:
definition: data source for porosity
codes: GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: Gas Permeability (md) AVG
field name: AVPERM
type: numeric
format: 10.4
units: millidarcies
definition: average gas permeability of pay interval

label: Gas Permeability (md) MIN
field name: LOPERM
type: numeric
format: 10.4
units: millidarcies
definition: gas permeability range minimum

label: Gas Permeability (md) MAX
field name: HIPERM
type: numeric
format: 10.4
units: millidarcies
definition: gas permeability range maximum

label: Permeability Gas Source
field name: S_PERM
type: character
format: 2
units:
definition: data source for gas permeability
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: Oil Permeability (md) AVG
field name: AVPERM_OIL
type: numeric
format: 10.4
units: millidarcies
definition: average oil permeability of pay interval

label: Oil Permeability (md) MIN
field name: LOPERM_OIL
type: numeric
format: 10.4
units: millidarcies
definition: oil permeability range minimum

label: Oil Permeability (md) MAX
field name: HIPERM_OIL
type: numeric
format: 10.4
units: millidarcies
definition: oil permeability range maximum

label: Permeability Oil Source
field name: S_PERM_OIL
type: character
format: 2
units:
definition: data source for gas permeability
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: reservoir temp (F)
field name: RESTEMP
type: numeric
format: 3.0
units: degree F
definition: average reservoir temperature

label: reservoir temp. source
field name: S_RESTEM
type: character
format: 2
units:
definition: average reservoir temp data source
codes: GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: publ initial press
field name: PUBPRES
type: numeric
format: 5.0
units: psi
definition: gas atlas published initial reservoir pressure

label: publ init press type
field name: PRESTYP
type: character
format: 5
units:
definition: gas atlas published initial reservoir pressure type
codes: WHSIP calc. from wellhead SIP
DST drillstem test
BHPG bottom hole gauge SIP
UN unknown

label: initial pressure type
field name: IPRESTYP
type: character
format: 2
units:
definition: initial reservoir pressure type (GASIS)
codes: FL well head flowing pressure
SI well head shut-in pressure
BH shut-in bottom hole pressure
L Langmuir

label: initial pressure source
field name: S_IPRES
type: character
format: 2
units:
definition: initial reservoir pressure source
codes: TL TOTL
TO TORIS database
RS Reservoir Studies

label: initial pressure (psi)
field name: IPRES
type: numeric
format: 5.0
units: psi
definition: average initial reservoir pressure (GASIS estimate)

label: low initial pressure (psi)
field name: IPRESLO
type: numeric
format: 5.0
units: psi
definition: lowest observed initial reservoir pressure

label: high initial pressure (psi)
field name: IPRESHI
type: numeric
format: 5.0
units: psi
definition: highest observed initial reservoir pressure

label: IP Date
field name: IP_DATE
type: numeric
format: 8
units:
definition: date of initial reservoir pressure measurement

label: BHP1
field name: BHP
type: numeric
format: 5.0
units: psi
definition: bottom hole pressure measurement 1

label: Pressure Msmt1 (psi) WHSIP
field name: WHSIP
type: numeric
format: 5.0
units: psi
definition: well head shut-in pressure measurement 1

label: Msmt1 Date
field name: MSMT1_DATE
type: numeric
format: 12
units: (MO/ DY/YEAR)
definition: date of reservoir pressure measurement 1

label: BHP2
field name: MSMT_BHP2
type: numeric
format: 5.0
units: psi
definition: bottom hole pressure measurement 2

label: Pressure Msmt2 (psi) WHSIP
field name: MSMT2_WHSIP
type: numeric
format: 5.0
units: psi
definition: well head shut-in pressure measurement 2

label: Msmt2 Date
field name: MSMT2_DATE
type: numeric
format: 12
units: (MO/DY/YEAR)
definition: date of reservoir pressure measurement 2

label: init press gradient (psi/ft)
field name: GRADIENT
type: numeric
format: 6.4
units: psi/ft
definition: calculated initial reservoir pressure gradient

label: Gradient > Hydrostatic
field name: HIGEOPRESS
type: character
format: 1
units: Y/N
definition: calculated pressure gradient greater than hydrostatic (0.465 psi/ft)

label: Gradient < Hydrostatic
field name: LOGEOPRESS
type: character
format: 1
units: Y/N
definition: calculated pressure gradient less than hydrostatic (0.465 psi/ft)

label: initial water saturation (Sw) (%)
field name: WATSAT
type: numeric
format: 7.3
units: %
definition: calculated or reported initial water saturation (Sw)

label: low initial water saturation (Sw) (%)
field name: WATSATLO
type: numeric
format: 7.3
units: %
definition: lowest observed initial water saturation (Sw)

label: high initial water saturation (Sw) (%)
field name: WATSATHI
type: numeric
format: 7.3
units: %
definition: highest observed initial water saturation (Sw)

label: water saturation source
field name: S_WATSAT
type: character
format: 2
units:
definition: water saturation data source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: drive mechanism
field name: DRIVE
type: character
format: 11
units:
definition: reservoir drive mechanism (6 codes)
codes:GC gas cap
GS gravity segregation
SG solution gas
PD pressure depletion
WD water drive
CO combination
GD gas depletion

label: drive source
field name: S_DRIVE
type: character
format: 2
units:
definition: drive mechanism source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: Face Cleat Orientation (°)
field name: CLEATDIR
type: numeric
format: 8
units: 0 to 360 degrees
definition: face cleat direction (0-360°)

label: Face Cleat Spacing
field name: CLEATSPAC
type: numeric
format: 8.2
units: inches
definition: distance between cleats

label: Coal Gas Content
field name: GASCONT
type: numeric
format: 8
units: scf/ton
definition: coal gas content in scf/ton

label: Coal Gas Content Basis
field name: GASCONT BASIS
type: character
format: 3
units:
definition: coal gas content measurement basis
codes:AR as received
DAF dry, ash free

label: Coal Sorption Capacity CH₄
field name: CH4SORP
type: numeric
format: 8
units: scf/ton
definition: methane sorption capacity in scf/ton

label: Coal Sorption Capacity Basis
field name: CH4SORP BASIS
type: character
format: 2
units:
definition: coal gas content measurement basis
codes:BM USBM estimate (Kim)
M measured

label: Coal Sorption Capacity CO₂
field name: CO2SORP
type: numeric
format: 8
units: scf/ton
definition: carbon dioxide sorption capacity in scf/ton

label: Coal Sample Type
field name: COAL_SAMTYP
type: character
format: 3
units:
definition: type of coal sample measured for gas content
codes: WHC whole core
SIC sidewall core
PRC pressure core
CTG cuttings

GAS AND FLUID PROPERTIES

label: gas gravity
field name: GRAVITY
type: numeric
format: 8.4
units: API units
definition: specific gas gravity

label: gravity source
field name: S_GRAV
type: character
format: 2
units:
definition: gas gravity source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: liquid gravity (API)
field name: LIQGRAV
type: numeric
format: 7.2
units: API gravity
definition: liquid hydrocarbon gravity

label: liq grav source
field name: S_LIQGRA
type: character
format: 2
units:
definition: liquid hydrocarbon gravity source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: resistivity (ohm-m)
field name: OHM
type: numeric
format: 10.4
units: ohm-meter
definition: measured resistivity of produced water

label: resist source
field name: S_OHM
type: character
format: 2
units:
definition: measured resistivity source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: resistivity temp. (F)
field name: TRES
type: numeric
format: 3.0
units: degree F
definition: temperature of water at measured/reported resistivity

label: resist temp. source
field name: S_TRES
type: character
format: 2
units:
definition: temp. of water resistivity source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: salinity (ppm)
field name: SALIN
type: numeric
format: 9.2
units: ppm
definition: salinity of produced water

label: salinity source
field name: S_SALIN
type: character
format: 2
units:
definition: salinity of produced water source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

DRILLING AND EVALUATION

label: drilling fluid
field name: DRILLFL
type: character
format: 3
units:
definition: predominant drilling fluid used (air,mud,om)
codes: AIR air
MUD mud
OM oil based mud

label: intermediate csng
field name: INTCASE
type: character
format: 1
units: Y/N
definition: intermediate casing typically run

label: horiz/slant well
field name: HORZNTL
type: character
format: 1
units: Y/N
definition: horizontal or slant wells in reservoir

STIMULATION DATA

label: stimulated
field name: STIM
type: character
format: 1
units: Y/N
definition: stimulated reservoir flag

label: stimul source
field name: S_STIM
type: character
format: 1
units:
definition: stimulated reservoir flag source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: stimulation type
field name: STIMTYP
type: character
format: 5
units:
definition: usual stimulation type
codes:AC acidized
HF hydraulic fracture
SH shot
CA cavitation
UR under reaming

label: stimul type source
field name: S_STIMTY
type: character
format: 1
units:
definition: usual stimulation type source
codes:GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

label: stimulation type
field name: FRACS2
type: character
format: 40
units:
definition: amount of propanant used in fracture stimulation
codes: SM < 50,000 # propanant
MD 50,000 – 250,000 # propanant
LG > 250,000 # propanant

COMPLETION DATA

label: typical completion
field name: CMPTYP
type: character
format: 6
units:
definition: typical completion type (OH,PER,AJ,SL,CAS)
codes: OH open hole
PER cased hole/perforated
AJ cased hole/abrasi jet
SL slotted liner
CAS cased hole, completion details unknown

label: compl type source
field name: S_CMPTYP
type: character
format: 1
units:
definition: typical well completion type source
codes: GA Gas Atlas
TL TOTL
TO TORIS database
RS Reservoir Studies

TYPE WELL DATA (RESERVOIR STUDIES)

label: type well operator, no., well name
field name: TWOPWL
type: character
format: 65
units:
definition: geologic type well operator name, well name and number

label: type well API number
field name: TWAPI
type: character
format: 12
units:
definition: geologic type well API number

label: type well township
field name: TWTWP
type: character
format: 4
units:
definition: geologic type well township number

label: type well range
field name: TWRNG
type: character
format: 5
units:
definition: geologic type well range number

label: type well section
field name: TWSEC
type: character
format: 2
units: 1-36
definition: geologic type well section number

label: type well location
field name: TWQQ
type: character
format: 15
units:
definition: geologic type well location within section

label: type well top of formation intvl (ft)
field name: INTVTOP
type: numeric
format: 5.0
units: feet
definition: geologic type well top of formation interval

label: type well bottom of formation intvl (ft)
field name: INTVBOT
type: numeric
format: 5.0
units: feet
definition: geologic type well bottom of formation interval

label: type well producing unit name
field name: TWUNITNM
type: character
format: 45
units:
definition: name of producing unit in type well

label: type well unit at TD name
field name: TWTDUNIT
type: character
format: 45
units:
definition: name of unit at total depth in type well

label: type well completion year
field name: TWCMPYR
type: numeric
format: 8.0
units:
definition: year the type well was completed

MEDIAN RECOVERY WELL DATA (RESERVOIR STUDIES)

label: median well Dwights id
field name: MSERCODE
type: character
format: 13
units:
definition: median recovery well Dwights identifier

label: median well operator
field name: MWOPER
type: character
format: 24
units:
definition: median recovery well operator name

label: median well name
field name: MEDWELL
type: character
format: 36
units:
definition: median recovery well name

label: median well API number
field name: MWAPI
type: character
format: 12
units:
definition: median recovery well API number

label: median well township
field name: MWTWN
type: character
format: 4
units:
definition: median recovery well township number

label: median well range
field name: MWRNG
type: character
format: 5
units:
definition: median recovery well range number

label: median well section
field name: MWSEC
type: character
format: 2
units: 1-36
definition: median recovery well section number

label: median well location
field name: MWQQ
type: character
format: 6
units:
definition: median recovery well location within section

label: median well top of interval (ft)
field name: MWTOP
type: numeric
format: 5.0
units: feet
definition: median recovery well top of completion interval

label: median well bottom of interval (ft)
field name: MWBOT
type: numeric
format: 5.0
units: feet
definition: median recovery well bottom of completion interval

label: median well completion year
field name: MWCMPYR
type: numeric
format: 4.0
units: year
definition: median recovery well completion year

label: median recovery well producing unit name
field name: MWUNITNM
type: character
format: 45
units:
definition: median recovery well producing unit name

label: median recovery well unit at TD name
field name: MWTDUNIT
type: character
format: 45
units:
definition: median recovery well unit at TD name

COMPLETION RECOVERY STATISTICS

label: no. of comp. evaluated
field name: GASCMP
type: numeric
format: 6.0
units:
definition: number of gas completions evaluated for recovery statistics

label: no. of comp. evaluated
field name: OILCMP
type: numeric
format: 6.0
units:
definition: number of oil completions evaluated for recovery statistics

label: mean gas eur/comp (mmcf)
field name: MN_EURG
type: numeric
format: 10.0
units: mmcf
definition: mean ultimate recovery gas per completion (estimate)

label: mean oil eur/comp (bbl)
field name: MN_EURO
type: numeric
format: 10.0
units: bbl
definition: mean ultimate recovery oil per completion (estimate)

label: median gas eur/comp (mmcf)
field name: MED_EURG
type: numeric
format: 10.0
units: mmcf
definition: median ultimate recovery gas per completion (estimate)

label: median oil eur/comp (bbl)
field name: MED_EURO
type: numeric
format: 10.0
units: bbl
definition: median ultimate recovery oil per completion (estimate)

label: min gas eur/comp (mmcf)
field name: MIN_EURG
type: numeric
format: 10.0
units: mmcf
definition: minimum ultimate recovery gas per completion (estimate)

label: min oil eur/comp (bbl)
field name: MIN_EURO
type: numeric
format: 10.0
units: bbl
definition: minimum ultimate recovery oil per completion (estimate)

label: max gas eur/comp (mmcf)
field name: MAX_EURG
type: numeric
format: 10.0
units: mmcf
definition: maximum ultimate recovery gas per completion (estimate)

label: max oil eur/comp (bbl)
field name: MAX_EURO
type: numeric
format: 10.0
units: bbl
definition: maximum ultimate recovery oil per completion (estimate)

Notes-

1) EEA used Dwights production data to prepare individual completion recovery estimates. In some reservoirs, the sum of the completion level cumulative production exceeded the GASIS reservoir level cumulative production. In such cases, the product of the number of completions (mwncmp) times the mean recovery per completion (mean_eurg) may be larger than the reported reservoir ultimate recovery (eurg). The differences in volumes are artifacts of the way data are tracked and reported by the state agencies and Dwights.

2) Recovery data are not reported for reservoirs known to have undergone gas cycling, or for reservoirs where production from multiple completions is reported in a single "unit" record.

VOLUMETRIC DATA

label: year of ann/cum prod
field name: ANCMYR
type: numeric
format: 8
units: (MO/DY/YEAR)
definition: date for which annual and cumulative production is reported

label: annual gas prod (mmcf)
field name: GASAN
type: numeric
format: 9.0
units: mmcf
definition: annual total gas production for year given (non-associated plus associated/dissolved gas)

label: annual gas prod recycled (mmcf)
field name: GASANR
type: numeric
format: 9.0
units: mmcf
definition: annual total gas production recycled for year given

label: cumulative gas prod (mmcf)
field name: GASCM
type: numeric
format: 10.0
units: mmcf
definition: cumulative total gas production through year given (non-associated plus associated/dissolved gas)

label: cumulative liquids (bbl)
field name: LIQCM
type: numeric
format: 10.0
units: bbl
definition: cumulative liquids production through year given

label: cumulative water (bbl)
field name: WATCM
type: numeric
format: 9.0
units: bbl
definition: cumulative water production through year given

label: published ogip (mmcf)
field name: PUBOGIP
type: numeric
format: 9.0
units: mmcf
definition: published original gas-in-place

label: ogip source
field name: S_PUBOGI
type: character
format: 2
units:
definition: data source for published original gas-in-place
codes:GA Gas Atlas

label: published ooip (mmcf)
field name: PUBOOIP
type: numeric
format: 12.0
units: bbls
definition: published original oil-in-place

label: ooip source
field name: S_PUBOOI
type: character
format: 2
units:
definition: data source for published original oil-in-place
codes:GA Gas Atlas
TO TORIS

label: non-assoc rur (mmcf)
field name: RURG
type: numeric
format: 9.0
units: mmcf
definition: Estimated remaining non-associated gas reserves.
Primarily for gas reservoirs, data are also reported for some
combination reservoirs having gas wells.

label: remaining ultimate oil reserves (bbls)
field name: RURO
type: numeric
format: 12.0
units: bbls
definition: Estimated remaining oil reserves.

label: date of oil rur (bbls)
field name: RUR_DATE
type: numeric
format: 9.0
units: (MO/DY/YR)
definition: Date of estimation of remaining gas/oil reserves.

label: non-assoc gas eur (mmcf)
field name: EURG
type: numeric
format: 9.0
units: mmcf
definition: Approximate ultimate recovery non-associated gas. Primarily for gas reservoirs, data are also reported for some combination reservoirs having gas wells. In some cases, the reservoir ultimate recovery (eurg) may be less than the product of the number of completions (mwncmp) times the mean recovery per completion (mean_eur). The differences in volumes are artifacts of the way data are tracked and reported by the state agencies and Dwigths. Recovery data are not reported for reservoirs known to have undergone gas cycling.

label: oil eur (bbls)
field name: EURO
type: numeric
format: 12.0
units: bbls
definition: Approximate ultimate recovery oil.

label: cum. producing gas/oil ratio (scf/bbl)
field name: PRDGOR
type: numeric
format: 14.0
units: scf/bbl
definition: cumulative producing gas/oil ratio

label: initial gor (scf/bbl)
field name: INITGOR
type: numeric
format: 14.0
units: scf/bbl
definition: initial producing gas/oil ratio (GOR)

Notes on volumetric data:

- All gas volumes wet, after lease separation.
- Gas volumes are not adjusted for non-hydrocarbon gases or re-injection.
- Production volumes in KS, TX, and WY are from Dwights Energy data and are current through 1996.
- Production data in AZ, CO, NM, OK, and UT have been updated to various years, as given by the individual states.

GAS COMPOSITION

label: methane (mole %)
field name: METHANE
type: numeric
format: 8.4
units: mole %
definition: methane (C1) content of gas

label: ethane (mole %)
field name: ETHANE
type: numeric
format: 8.4
units: mole %
definition: ethane (C2) content of gas

label: propane (mole %)
field name: PROPANE
type: numeric
format: 8.4
units: mole %
definition: propane (C3) content of gas

label: butanes (mole %)
field name: BUTANE
type: numeric
format: 8.4
units: mole %
definition: butanes (C4) content of gas

label: pentanes (mole %)
field name: PENTANE
type: numeric
format: 8.4
units: mole %
definition: pentanes (C5) content of gas

label: hexanes+ (mole %)
field name: HEXANE
type: numeric
format: 8.4
units: mole %
definition: hexanes-plus (C6+) content of gas

label: H₂S (mole %)
field name: HSULFID
type: numeric
format: 8.4
units: mole %
definition: H₂S

label: CO₂ (mole %)
field name: GAS_CARBON
type: numeric
format: 8.4
units: mole %
definition: CO₂

label: nitrogen (mole %)
field name: NITROGN
type: numeric
format: 8.4
units: mole %
definition: nitrogen (N₂) content of gas

label: helium (mole %)
field name: HELIUM
type: numeric
format: 8.4
units: mole %
definition: helium (He) content of gas

label: other (mole %)
field name: OTHER
type: numeric
format: 8.4
units: mole %
definition: other components of gas

label: heating value (btu/scf)
field name: HEAT
type: numeric
format: 4.0
units: btu/scf
definition: heating value of gas

label: gas sample well API number
field name: API_GSAM
type: numeric
format: 12
units:
definition: API number of well for gas sample

label: gas sample well name
field name: GSAMNAME
type: numeric
format: 24
units:
definition: name of well for gas sample

COAL COMPOSITION

label: moisture (weight %)
field name: MOIST
type: numeric
format: 6.2
units: weight %
definition: moisture content of coal
codes:AR as-received
AD air dried
EQ equilibrium

label: ash (weight %)
field name: ASH
type: numeric
format: 6.2
units: weight %
definition: ash content of coal
codes:AR as-received
AD air dried
DRY dry

label: sulfur (weight %)
field name: COAL_SULFUR
type: numeric
format: 6.2
units: weight %
definition: sulfur content of coal

label: basis (sulfur analysis)
field name: COAL_SULFUR BASIS
type: character
format: 3
units:
definition: basis of sulfur analysis reported
codes:AR as-received
AD air dried
DRY dry

label: heat content (Btu/lb)
field name: HEATCNT
type: numeric
format: 6.0
units: Btu/lb
definition: heat content of coal

label: basis (heat content, Btu/lb)
field name: HEATCNT BASIS
type: character
format: 3
units:
definition: basis of heat content of coal analysis reported
codes:AR as-received
AD air dried
DRY dry
MMF moist mineral matter free

label: volatile matter (weight %)
field name: VOLMAT
type: numeric
format: 6.2
units: weight %
definition: volatile matter content of coal

label: basis (volatile matter)
field name: VOLMAT BASIS
type: character
format: 3
units:
definition: basis of volatile matter content of coal reported
codes:AR as-received
AD air dried
DRY dry
MMF moist mineral matter free

label: fixed carbon (weight %)
field name: FIXEDC
type: numeric
format: 6.2
units: weight %
definition: fixed carbon content of coal

label: basis (fixed carbon)
field name: FIXEDC BASIS
type: character
format: 3
units:
definition: basis of fixed carbon content of coal reported
codes:AR as-received
AD air dried
DRY dry
MMF moist mineral matter free

label: carbon (weight %)
field name: COAL_CARBON
type: numeric
format: 6.2
units: weight %
definition: carbon content of coal

label: hydrogen (weight %)
field name: COAL_HYDROGEN
type: numeric
format: 6.2
units: weight %
definition: hydrogen content of coal

label: nitrogen (weight %)
field name: COAL_NITROGEN
type: numeric
format: 6.2
units: weight %
definition: nitrogen content of coal

label: oxygen (weight %)
field name: COAL_OXYGEN
type: numeric
format: 6.2
units: weight %
definition: oxygen content of coal

label: vitrinite (volume %)
field name: VITRINITE
type: numeric
format: 6.2
units: volume %
definition: vitrinite content of mineral-free coal

label: exinite (volume %)
field name: EXINITE
type: numeric
format: 6.2
units: volume %
definition: exinite content of mineral-free coal

label: inertinite (volume %)
field name: INERTINITE
type: numeric
format: 6.2
units: volume %
definition: inertinite content of mineral-free coal

label: vitrinite reflectance (%)
field name: Ro
type: numeric
format: 3.1
units: %
definition: vitrinite reflectance value

label: basis (vitrinite reflectance)
field name: Ro BASIS
type: character
format: 3
units:
definition: basis of vitrinite reflectance value reported
codes:MMX mean maximum
RDM random

label: Coal Rank
field name: COAL RANK
type: character
format: 3
units:
definition: ASTM rank of the coal
codes:LIG lignite
SUB subbituminous
HVB high volatile bituminous
MVB medium volatile bituminous
LVB low volatile bituminous
ANT anthracite

label: coal density
field name: COAL DENSITY
type: numeric
format: 4.2
units: g/ccweight %
definition: coal density in grams per cubic centimeter (g/cc)

CRUDE OIL ANALYSIS

label: specific gravity
field name: SPGRAV
type: numeric
format: 6.4
units:
definition: specific gravity of oil

label: liquid gravity (API)
field name: OIL_LIQGRAV
type: numeric
format: 7.2
units: API gravity
definition: API liquid hydrocarbon gravity

label: pour point of oil
field name: POURPT
type: numeric
format: 4.0
units: ° F
definition: pour point temperature of oil

label: sulfur content of oil
field name: OIL_SULFUR
type: numeric
format: 6.2
units: weight %
definition: sulfur content of oil

label: nitrogen content of oil
field name: OIL_NITROGEN
type: numeric
format: 6.2
units: weight %
definition: nitrogen content of oil

label: color of oil
field name: COLOR
type: character
format: 12
units:
definition: color of oil

label: viscosity of oil
field name: VISC
type: numeric
format: 7.2
units: centistokes
definition: viscosity of oil

label: temperature of viscosity measurement
field name: T_VISC
type: numeric
format: 5.1
units: ° F
definition: temperature of viscosity measurement

label: oil sample well API number
field name: API_OSAM
type: numeric
format: 12
units:
definition: API number of well for oil sample

label: source of oil analysis data
field name: S_OSAMP
type: character
format: 30
units:
definition: source of oil analysis data

PRODUCED WATER COMPOSITION

label: Average Na
field name: PW_avg_Na
type: numeric
format: 8.0
units: mg/l
definition: average sodium content of produced water in milligrams per
liter

label: Average K
field name: PW_avg_K
type: numeric
format: 4.0
units: mg/l
definition: average potassium content of produced water in milligrams
per liter

label: Average Ca
field name: PW_avg_Ca
type: numeric
format: 4.0
units: mg/l
definition: average calcium content of produced water in milligrams per
liter

label: Average Mg
field name: PW_avg_Mg
type: numeric
format: 4.0
units: mg/l
definition: average magnesium content of produced water in milligrams
per liter

label: Average Cl
field name: PW_avg_Cl
type: numeric
format: 4.0
units: mg/l
definition: average chlorine content of produced water in milligrams per
liter

	label: Average SO ₄
	field name: PW_avg_SO ₄
	type: numeric
	format: 8.0
	units: mg/l
liter	definition: average sulfate content of produced water in milligrams per
	label: Average HCO ₃
	field name: PW_avg_HCO ₃
	type: numeric
	format: 4.0
	units: mg/l
	definition: average bicarbonate content of produced water in milligrams
	per liter
	label: Average CO ₃
	field name: PW_avg_CO ₃
	type: numeric
	format: 4.0
	units: mg/l
	definition: average carbonate content of produced water in milligrams
	per liter
	label: Average calc. TDS
	field name: PW_avg_TDS
	type: numeric
	format: 4.0
	units: mg/l
	definition: average calculated total dissolved solids content of produced
	water in milligrams per liter
	label: Resistivity
	field name: PW_Resistivity
	type: numeric
	format: 4.2
	units: ohms
	definition: measured resistivity of produced water in ohms
	label: Resistivity Temperature
	field name: PW_Res_temp
	type: numeric
	format: 4.1
	units: degrees Celsius
	definition: temperature of produced water in degrees Celsius when
	resistivity was measured

label: pH
field name: PW_pH
type: numeric
format: 4.2
units:
definition: pH of produced water

ADVANCED PVT PROPERTIES

label: PVT Well ID (API no.)

field name: PVT_API

type: numeric

format: 14.0

units:

definition: API number for well from which PVT measurements were made

label: P_pvt

field name: P_pvt

type: numeric

format: 7.0

units: psi

definition: reservoir pressure at which solution gas/oil and gas/water ratios were measured

label: Bo_pvt

field name: Bo_pvt

type: numeric

format: 8.4

units: Dimensionless (reservoir volume/stock tank volume – usually rb/stb)

definition: oil formation volume factor at the given pressure

label: Rs

field name: Rs

type: numeric

format: 7.0

units: SCF/stb

definition: solution gas/oil ratio, the amount of gas that comes out of solution in the oil at the given pressure

label: Rsw

field name: Rsw

type: numeric

format: 7.0

units: SCF/stb

definition: solution gas/water ratio, the amount of gas that comes out of solution in the water at the given pressure

ADVANCED PVT CO₂ PROPERTIES

label: PVTCO₂ Well ID (API no.)

field name: PVTCO₂_API

type: numeric

format: 14.0

units:

definition: API number for well from which CO₂ PVT measurements were made

label: P_pvtco₂

field name: P_pvtco₂

type: numeric

format: 7.0

units: psi

definition: reservoir pressure at which solution CO₂/oil and CO₂/water ratios were measured

label: Bo_pvtco₂

field name: Bo_pvtco₂

type: numeric

format: 8.4

units: Dimensionless (rb/stb usually)

definition: oil formation volume factor at the given pressure

label: Rs_co₂

field name: Rs_co₂

type: numeric

format: 7.0

units: SCF/stb

definition: solution CO₂/oil ratio, the amount of CO₂ that comes out of solution in the oil at the given pressure

label: Rsw_co₂

field name: Rsw_co₂

type: numeric

format: 7.0

units: SCF/stb

definition: solution CO₂/water ratio, the amount of CO₂ that comes out of solution in the water at the given pressure

Pilot Study Region	County	Basin	Field Name	Reservoir Name	Avg Depth Feet	Temp °F	Pres psi	°API	Cumulative Production			Total CO ₂ Capacity		
									Bcf	MMBO	MMBW	MMt	MT	Bcf
Craig	Moffat	Piceance	DANFORTH HILLS	DAKOTA, MORRISON	5659	140.9	2,646	35.0	0.24	1.39	0.27	0.83	0.92	15.75
Craig	Moffat	Piceance	DANFORTH HILLS	ENTRADA (SUNDANCE)	6525	153.3	3,049	35.0	0.04	1.74	0.00	0.96	1.05	18.07
Craig	Moffat	Piceance	DANFORTH HILLS	SHINARUMP, MOENKOPI, MINTURN, WEBER	7175	162.6	3,351	34.0	0.67	1.37	0.16	0.84	0.93	15.96
Craig	Moffat	Piceance	MAUDLIN GULCH	DAKOTA, MORRISON, ENTRADA (SUNDANCE)	6012	146.0	2,810	36.3	1.33	7.86	10.22	6.17	6.80	116.52
Craig	Moffat	Piceance	MAUDLIN GULCH	SHINARUMP, MOENKOPI, PHOSPHORIA, WEBER, MINTURN	7476	166.9	3,491	37.7	0.54	4.59	3.97	3.25	3.59	61.48
Craig	Rio Blanco	Piceance	NINE MILE	DAKOTA	7215	163.2	3,370		0.00	1.17	0.00	0.64	0.70	12.08
Craig	Rio Blanco	Piceance	WILSON CREEK	NIOBRARA	4163	119.5	1,950		0.10	0.08	0.00	0.06	0.06	1.10
Craig	Rio Blanco	Piceance	WILSON CREEK	MORRISON	6486	152.7	3,031	50.0	59.47	60.17	17.10	41.91	46.19	791.95
Craig	Rio Blanco	Piceance	WILSON CREEK	ENTRADA (SUNDANCE)	6731	156.3	3,145	50.0	6.02	27.04	36.49	21.59	23.80	408.04
Craig	Rio Blanco	Piceance	WILSON CREEK	SHINARUMP, MINTURN	8025	174.8	3,746		8.51	0.34	0.07	0.97	1.07	18.41
Craig	Routt	Sand Wash	BEAR RIVER	NIOBRARA	4302	112.1	2,015		1.61	1.25	0.00	0.93	1.02	17.51
Craig	Moffat	Sand Wash	BUCK PEAK	MANCOS SH	3288	99.8	1,544	39.0	1.11	1.24	0.00	0.88	0.97	16.65
Craig	Moffat	Sand Wash	BUCK PEAK	NIOBRARA	6822	142.5	3,187		6.46	3.43	0.13	2.61	2.87	49.26
Craig	Moffat	Sand Wash	BUCK PEAK	SHINARUMP	9402	173.8	4,387		0.00	0.01	0.00	0.01	0.01	0.10
Craig	Moffat	Sand Wash	CRAIG NORTH	LEWIS SH, MESAVERDE	2821	94.1	1,326		23.53	0.04	0.00	3.00	3.31	56.74
Craig	Routt	Sand Wash	GRASSY CREEK	NIOBRARA	5134	122.1	2,402		0.32	1.15	0.00	0.68	0.75	12.84
Craig	Moffat	Sand Wash	ILES	MORRISON	2953	95.7	1,388		0.06	1.34	0.00	0.69	0.76	13.07
Craig	Moffat	Sand Wash	ILES	ENTRADA (SUNDANCE)	3243	99.2	1,523		1.99	17.94	39.25	16.96	18.69	320.43
Craig	Moffat	Sand Wash	ILES	CURTIS	3310	100.1	1,554		0.00	0.07	0.00	0.04	0.04	0.73
Craig	Moffat	Sand Wash	THORNBURG	DAKOTA	2301	87.8	1,085		4.98	0.00	0.00	0.58	0.63	10.88
Craig	Moffat	Sand Wash	THORNBURG	ENTRADA SS	2902	95.1	1,364		5.56	0.00	0.00	0.73	0.81	13.85
Craig	Moffat	Sand Wash	THORNBURG	SHINARUMP, WEBER	3485	102.2	1,635	25.5	7.81	0.75	0.00	1.75	1.93	33.03
Craig	Routt	Sand Wash	TOW CREEK	NIOBRARA	3201	98.7	1,503	38.0	0.34	3.03	0.00	1.73	1.90	32.63
Craig	Moffat	Sand Wash	WEST SIDE CANAL	LANCE	2709	92.8	1,274		2.42	0.00	0.00	0.30	0.33	5.62
Craig	Moffat	Sand Wash	WEST SIDE CANAL	LEWIS SH	3769	105.6	1,767		20.98	0.06	0.05	3.40	3.75	64.31

Pilot Study Region	County	Basin	Field Name	Reservoir Name	Avg Depth Feet	Temp °F	Pres psi	°API	Cumulative Production			Total CO ₂ Capacity		
									Bcf	MMBO	MMBW	MMt	MT	Bcf
Craig	Moffat	Sand Wash	WEST SIDE CANAL	MESAVERDE	5830	130.5	2,726		0.52	0.00	0.00	0.06	0.07	1.14
Denver	Weld	Denver	ARISTOCRAT	NIOBRARA, CODELL SS, SUSSEX, SHANNON, DAKOTA GROUP	4436	131.4	2,077	48.7	24.60	0.88	0.08	3.23	3.56	60.99
Denver	Adams	Denver	BANNER LAKES	DAKOTA	7666	183.4	3,579		11.61	1.00	0.01	1.46	1.61	27.59
Denver	Adams	Denver	BASE LINE	CODELL SS	7026	173.1	3,282		0.00	0.00	0.00	0.00	0.00	0.01
Denver	Adams	Denver	BASE LINE	DAKOTA	7429	179.6	3,469	41.8	6.16	1.05	0.01	1.00	1.10	18.85
Denver	Weld	Denver	BLACK HOLLOW	LYONS SS	8965	204.3	4,183	36.0	0.33	11.15	5.93	7.05	7.77	133.17
Denver	Weld	Denver	BRACEWELL	SUSSEX, SHANNON	4344	129.9	2,035		0.26	0.01	0.00	0.04	0.04	0.69
Denver	Weld	Denver	BRACEWELL	NIOBRARA, CODELL SS, DAKOTA GROUP	6845	170.2	3,198		21.14	2.88	0.05	3.57	3.93	67.40
Denver	Adams	Denver	CHIEFTAIN	DAKOTA	7492	180.6	3,498	56.9	17.32	1.18	0.01	2.21	2.44	41.82
Denver	Larimer	Denver	CLARKS LAKE	DAKOTA	6162	159.2	2,880	38.4	0.99	2.18	1.77	1.56	1.72	29.44
Denver	Weld	Denver	EATON	NIOBRARA, CODELL SS	6910	171.3	3,228	46.8	11.56	2.61	0.03	2.50	2.76	47.27
Denver	Larimer	Denver	FORT COLLINS	NIOBRARA	3892	122.7	1,824		0.00	0.02	0.01	0.01	0.01	0.25
Denver	Larimer	Denver	FORT COLLINS	DAKOTA	4969	140.0	2,325	36.0	0.46	5.69	10.22	4.68	5.15	88.37
Denver	Larimer	Denver	FORT COLLINS	LYONS SS	6190	159.7	2,893	36.0	0.02	0.35	0.08	0.20	0.22	3.77
Denver	Morgan	Denver	GREASEWOOD	DAKOTA	6714	168.1	3,137		2.22	1.10	0.00	0.80	0.89	15.19
Denver	Weld	Denver	GREELEY	PARKMAN	3607	168.3	1,692		0.01	0.12	0.47	0.11	0.12	2.11
Denver	Weld	Denver	GREELEY	NIOBRARA, FORT HAYS, CODELL SS	6728	191.0	3,143	50.0	16.23	2.10	0.07	2.53	2.78	47.72
Denver	Weld	Denver	HAMBERT	SUSSEX	4389	130.7	2,056	51.0	47.02	1.07	0.06	6.04	6.66	114.09
Denver	Weld	Denver	HAMBERT	NIOBRARA, CODELL SS	6822	169.8	3,187		1.78	0.05	0.01	0.20	0.22	3.79
Denver	Adams	Denver	IRONDALE	DAKOTA	7045	173.4	3,291	45.0	7.66	1.83	0.00	1.70	1.88	32.16
Denver	Adams	Denver	JAMBOREE	DAKOTA	7781	185.3	3,633	47.5	24.15	1.33	0.01	2.87	3.16	54.26
Denver	Weld	Denver	KERSEY	NIOBRARA, FORT HAYS, CODELL SS	6512	164.8	3,043	52.1	17.91	2.28	0.06	2.98	3.29	56.36
Denver	Weld	Denver	LANYARD	CODELL SS	6467	164.1	3,022		0.00	0.00	0.00	0.00	0.00	0.02
Denver	Weld	Denver	LANYARD	DAKOTA	6920	171.4	3,233	39.8	4.93	3.44	1.92	2.63	2.90	49.67
Denver	Adams	Denver	LONGBRANCH	DAKOTA	7043	173.4	3,290	58.0	26.39	0.97	0.00	3.00	3.30	56.60
Denver	Weld	Denver	LOST CREEK	NIOBRARA	6093	158.1	2,848		0.00	0.00	0.00	0.00	0.00	0.00
Denver	Weld	Denver	LOST CREEK	DAKOTA	6778	169.1	3,166	47.3	13.74	1.36	0.04	2.05	2.26	38.73
Denver	Larimer	Denver	LOVELAND	SUSSEX AND SHANNON	1804	89.0	854		0.23	0.01	0.00	0.03	0.03	0.54

Pilot Study Region	County	Basin	Field Name	Reservoir Name	Avg Depth Feet	Temp °F	Pres psi	°API	Cumulative Production			Total CO ₂ Capacity		
									Bcf	MMBO	MMBW	MMt	MT	Bcf
Denver	Larimer	Denver	LOVELAND	NIOBRARA, CODELL SS, TIMPAS, DAKOTA GROUP, LAKOTA	4734	136.2	2,216	40.0	13.50	3.26	0.00	3.26	3.60	61.65
Denver	Larimer	Denver	LOVELAND	LYONS SS	6896	171.0	3,221		0.00	0.01	0.00	0.00	0.00	0.06
Denver	Arapahoe	Denver	LOWRY	NIOBRARA	7794	185.5	3,639		0.00	0.01	0.00	0.01	0.01	0.15
Denver	Arapahoe	Denver	LOWRY	DAKOTA	8493	196.7	3,964	39.1	4.24	1.72	0.05	1.30	1.44	24.61
Denver	Weld	Denver	NEW WINDSOR	SUSSEX	4254	128.5	1,993	41.9	0.02	0.30	0.00	0.16	0.18	3.00
Denver	Weld	Denver	NEW WINDSOR	CODELL SS	6877	170.7	3,213		0.00	0.00	0.00	0.00	0.00	0.00
Denver	Weld	Denver	NEW WINDSOR	LYONS SS	8993	204.8	4,196	41.1	0.03	0.91	0.00	0.50	0.55	9.38
Denver	Weld	Denver	PIERCE	LYONS SS	9221	208.5	4,302	36.0	0.49	12.03	4.58	7.31	8.06	138.16
Denver	Adams	Denver	RADAR	DAKOTA	7850	186.4	3,665	42.0	7.95	1.34	0.01	1.43	1.58	27.03
Denver	Weld	Denver	ROGGEN	NIOBRARA	6260	160.8	2,926	46.0	0.00	0.00	0.00	0.00	0.00	0.02
Denver	Weld	Denver	ROGGEN	DAKOTA	6970	172.2	3,256		25.40	2.83	0.08	3.93	4.33	74.25
Denver	Weld	Denver	SPACE CITY	DAKOTA	7907	187.3	3,691		22.09	0.45	0.00	2.20	2.42	41.56
Denver	Adams	Denver	SPINDLE	SUSSEX, SHANNON, NIOBRARA, FT HAYS, CODELL SS, TIMPAS, DAKOTA GROUP	4695	135.6	2,198	51.0	290.68	58.16	0.95	64.05	70.61	1,210.47
Denver	Adams	Denver	THIRD CREEK	DAKOTA	8303	193.7	3,876	47.8	35.35	4.61	0.01	5.55	6.12	104.88
Denver	Adams	Denver	TRAPPER	DAKOTA	7890	187.0	3,684	40.0	15.11	1.74	0.01	2.28	2.51	43.11
Denver	Weld	Denver	WAITE LAKE	NIOBRARA	5865	154.4	2,742		0.00	0.00	0.00	0.00	0.00	0.00
Denver	Weld	Denver	WAITE LAKE	CODELL SS	6152	159.0	2,875		0.00	0.00	0.00	0.00	0.00	0.03
Denver	Weld	Denver	WAITE LAKE	GREENHORN LS	6179	159.5	2,888		0.03	0.00	0.00	0.01	0.01	0.10
Denver	Weld	Denver	WAITE LAKE	DAKOTA	6525	165.1	3,049	47.3	11.99	1.00	0.04	1.71	1.89	32.35
Denver	Weld	Denver	WATTENBERG	PARKMAN	3651	118.8	1,712		0.01	0.04	0.01	0.02	0.03	0.44
Denver	Weld	Denver	WATTENBERG	SUSSEX, SHANNON, NIOBRARA, FT HAYS, CODELL SS, GREENHORN, GRANEROS, DAKOTA GROUP, LAKOTA, TIMPAS	4367	130.3	2,045		2,429.83	128.37	11.96	351.96	387.97	6,651.24
Denver	Larimer	Denver	WELLINGTON	MUDDY (J) SAND	4494	132.4	2,104	36.0	19.03	8.26	5.16	7.32	8.07	138.35
Ft Morgan	Morgan	Denver	ADENA	DAKOTA	5561	149.5	2,601	41.0	89.68	62.84	14.44	36.47	40.20	689.17
Ft Morgan	Washington	Denver	AKRON EAST	D SAND	4580	133.7	2,144	33.0	1.86	3.30	0.20	1.60	1.76	30.22
Ft Morgan	Adams	Denver	ARROYO	DAKOTA	5977	156.2	2,794	41.0	2.42	1.46	0.00	0.86	0.94	16.16
Ft Morgan	Logan	Denver	ATWOOD EAST	DAKOTA	4412	131.0	2,066	36.0	6.96	2.49	0.05	1.85	2.04	34.95

Pilot Study Region	County	Basin	Field Name	Reservoir Name	Avg Depth Feet	Temp °F	Pres psi	°API	Cumulative Production			Total CO ₂ Capacity		
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Ft Morgan	Adams	Denver	BADGER CREEK	DAKOTA	5296	145.3	2,477	38.0	2.57	6.48	0.41	3.00	3.30	56.66
Ft Morgan	Adams	Denver	BEACON	DAKOTA	5767	152.8	2,696	39.5	4.55	1.39	0.12	1.24	1.36	23.38
Ft Morgan	Washington	Denver	BELLE	DAKOTA	4841	137.9	2,266		0.25	1.09	0.28	0.65	0.72	12.26
Ft Morgan	Washington	Denver	BIG BEAVER	MUDDY (J) SAND	5015	140.7	2,347	38.0	1.71	13.08	4.78	7.89	8.70	149.08
Ft Morgan	Morgan	Denver	BIJOU	GREENHORN LS	5819	153.7	2,721	36.0	0.00	0.00	0.00	0.00	0.00	0.01
Ft Morgan	Morgan	Denver	BIJOU	D SAND	6095	158.1	2,849	40.0	6.81	1.60	0.00	1.54	1.70	29.17
Ft Morgan	Morgan	Denver	BIJOU WEST	D SAND	6158	159.1	2,878	37.0	3.12	1.21	0.00	0.96	1.06	18.20
Ft Morgan	Washington	Denver	BOBCAT	DAKOTA	5142	142.8	2,406	40.0	5.66	7.47	2.28	4.95	5.46	93.61
Ft Morgan	Morgan	Denver	BOXER	DAKOTA	5839	154.0	2,730	39.5	10.63	4.16	0.45	3.40	3.74	64.16
Ft Morgan	Adams	Denver	DEER TRAIL	DAKOTA	6220	160.1	2,907	39.5	10.48	0.39	0.00	1.26	1.39	23.75
Ft Morgan	Logan	Denver	DUNE RIDGE	DAKOTA	4443	131.5	2,081		2.05	1.77	0.06	1.17	1.29	22.19
Ft Morgan	Logan	Denver	ELM GROVE	DAKOTA	4604	134.1	2,156	35.0	4.21	1.41	2.75	1.65	1.81	31.09
Ft Morgan	Logan	Denver	FRASCO	DAKOTA	5410	147.1	2,530	40.0	0.82	1.42	0.85	0.98	1.08	18.52
Ft Morgan	Logan	Denver	GRAYLIN NORTHWEST	DAKOTA	4910	139.1	2,298	39.0	11.83	13.44	0.51	8.53	9.41	161.24
Ft Morgan	Washington	Denver	HARDWAY	D SAND	4438	131.5	2,078	38.0	0.54	1.04	0.24	0.64	0.71	12.18
Ft Morgan	Morgan	Denver	JACKPOT	D SAND	6461	164.0	3,019	39.0	2.53	1.57	0.00	1.09	1.20	20.65
Ft Morgan	Washington	Denver	KEJR	DAKOTA	4986	140.3	2,333	37.0	0.75	3.06	1.05	1.87	2.06	35.37
Ft Morgan	Weld	Denver	LILLI	CODELL SS	5930	155.5	2,772		0.21	0.03	0.00	0.04	0.04	0.70
Ft Morgan	Weld	Denver	LILLI	D SAND	6381	162.7	2,982	43.4	30.36	3.35	0.03	4.80	5.29	90.63
Ft Morgan	Washington	Denver	LITTLE BEAVER	DAKOTA	5201	143.7	2,433	40.5	20.76	17.55	3.00	12.08	13.32	228.35
Ft Morgan	Washington	Denver	LITTLE BEAVER EAST	DAKOTA	5064	141.5	2,369		2.59	4.27	0.00	2.56	2.82	48.31
Ft Morgan	Logan	Denver	LUFT	DAKOTA	4868	138.4	2,278	38.0	3.08	2.81	0.00	1.83	2.02	34.64
Ft Morgan	Morgan	Denver	MCREA	MUDDY (J) SAND	4933	139.4	2,309		0.67	1.41	0.00	0.82	0.91	15.59
Ft Morgan	Logan	Denver	MERINO	MUDDY (J) SAND	4980	140.2	2,330	39.0	1.51	4.42	2.23	2.86	3.15	54.08
Ft Morgan	Adams	Denver	MIDDLEMIST	MUDDY (J) SAND	5508	148.7	2,576		1.25	2.16	0.00	1.29	1.42	24.33
Ft Morgan	Adams	Denver	MOCCASIN	MUDDY (J) SAND	5417	147.2	2,534	53.0	1.13	1.15	0.00	0.74	0.81	13.91
Ft Morgan	Adams	Denver	NILE	DAKOTA	6360	162.4	2,972		3.61	3.42	1.28	2.40	2.65	45.35
Ft Morgan	Washington	Denver	NUGGET	D SAND	5216	144.0	2,440	39.0	1.21	2.49	0.03	1.46	1.61	27.65
Ft Morgan	Morgan	Denver	PARK	NIOBRARA	5232	144.2	2,448	38.5	0.00	0.01	0.00	0.00	0.00	0.08
Ft Morgan	Morgan	Denver	PARK	DAKOTA	6098	158.2	2,850		1.98	1.23	0.06	0.87	0.96	16.39
Ft Morgan	Logan	Denver	PAWNEE CREEK	MUDDY (J) SAND	5035	141.1	2,356	39.0	1.57	2.24	0.06	1.38	1.52	26.01
Ft Morgan	Morgan	Denver	PETERSON	D SAND	5173	143.3	2,420	40.0	0.39	1.17	1.13	0.84	0.93	15.96
Ft Morgan	Washington	Denver	PHEGLEY	D SAND	4856	138.2	2,273	38.0	0.46	2.58	0.00	1.42	1.56	26.77
Ft Morgan	Washington	Denver	PLUMB BUSH CREEK	MUDDY (J) SAND	4969	140.0	2,325	40.0	2.17	18.86	0.00	10.25	11.30	193.72
Ft Morgan	Washington	Denver	RAGO NORTH	DAKOTA	4876	138.5	2,282	43.5	0.52	3.09	8.82	3.07	3.39	58.11
Ft Morgan	Washington	Denver	RAMP	MUDDY (J) SAND	4915	139.1	2,300		0.07	1.13	0.10	0.62	0.69	11.80
Ft Morgan	Washington	Denver	RANCHERO	DAKOTA	4746	136.4	2,222		1.36	1.14	0.76	0.87	0.96	16.53
Ft Morgan	Washington	Denver	REDWING	D SAND	4555	133.3	2,133	29.0	2.65	1.56	1.01	1.28	1.41	24.24
Ft Morgan	Morgan	Denver	SAND RIVER	D SAND	5124	142.5	2,397	39.0	3.66	4.12	2.18	2.94	3.24	55.51

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Ft Morgan	Logan	Denver	SHIELD	DAKOTA	4845	138.0	2,268		1.59	1.16	0.70	0.90	1.00	17.06
Ft Morgan	Weld	Denver	SOONER	DAKOTA	6279	161.1	2,934	48.0	7.58	2.09	2.07	2.21	2.43	41.71
Ft Morgan	Washington	Denver	SWAN	DAKOTA	5036	141.1	2,356		0.71	3.34	0.00	1.85	2.04	35.02
Ft Morgan	Morgan	Denver	VALLERY	DAKOTA	5904	155.1	2,760	42.0	11.04	0.20	0.00	1.24	1.37	23.46
Ft Morgan	Washington	Denver	VORTEX	MUDDY (J) SAND	4936	139.5	2,310		0.00	1.23	0.22	0.69	0.76	12.99
Ft Morgan	Washington	Denver	WESTFORK	MUDDY (J) SAND	4924	139.3	2,304	43.0	0.89	3.71	0.00	2.07	2.28	39.07
Ft Morgan	Washington	Denver	XENIA WEST	DAKOTA	4710	135.8	2,205	45.0	1.34	2.72	2.19	1.93	2.12	36.39
Ft Morgan	Morgan	Denver	ZORICHAK	DAKOTA	4945	139.6	2,314	42.0	3.03	2.30	0.01	1.56	1.72	29.46
Ignacio	La Plata	Paradox	ALKALI GULCH	DAKOTA	3074	120.3	1,444		0.00	0.00	0.00	0.00	0.00	0.00
Ignacio	La Plata	Paradox	ALKALI GULCH	HERMOSA GROUP	8192	220.6	3,824		25.22	0.00	0.00	2.04	2.25	38.55
Ignacio	La Plata	Paradox	ALKALI GULCH	MOLAS	9752	251.1	4,549		7.45	0.00	0.00	0.56	0.62	10.67
Ignacio	La Plata	Paradox	BARKER DOME	DAKOTA	3178	122.3	1,492		0.31	0.00	0.00	0.03	0.03	0.58
Ignacio	La Plata	Paradox	BARKER DOME	HERMOSA GROUP	7683	210.6	3,587	60.0	118.71	0.12	0.04	9.89	10.90	186.93
Ignacio	La Plata	Paradox	RED MESA	DAKOTA, MORRISON	3396	126.6	1,594	34.3	3.24	2.14	0.02	1.37	1.51	25.86
Ignacio	La Plata	San Juan	IGNACIO BLANCO	MESAVERDE GROUP, DAKOTA, MORRISON	4963	157.3	2,322		1,430.63	0.13	122.41	154.59	170.40	2,921.33
Palisade	Mesa	Piceance	BAR X	DAKOTA, MORRISON	2496	95.7	1,175	35.4	6.97	0.07	0.00	0.81	0.89	15.26
Palisade	Mesa	Piceance	BAR X	ENTRADA SS	3035	103.4	1,426		6.78	0.00	0.00	0.80	0.88	15.03
Palisade	Garfield	Piceance	BRIDLE	DAKOTA, MORRISON	3118	104.6	1,465		19.95	0.00	0.00	2.37	2.62	44.86
Palisade	Garfield	Piceance	BRIDLE	ENTRADA SS	3700	112.9	1,735		0.01	0.01	0.00	0.01	0.01	0.15
Palisade	Mesa	Piceance	BUZZARD CREEK	WASATCH	396	65.7	199		0.13	0.00	0.00	0.01	0.01	0.15
Palisade	Mesa	Piceance	BUZZARD CREEK	MESAVERDE GROUP	4503	124.4	2,109		11.45	0.00	0.04	1.48	1.63	27.95
Palisade	Garfield	Piceance	DIVIDE CREEK	MESAVERDE GROUP	3009	103.0	1,414		62.74	0.00	0.00	7.34	8.09	138.63
Palisade	Garfield	Piceance	GRAND VALLEY	MESAVERDE GROUP	3619	111.8	1,698		174.21	0.06	1.97	24.18	26.66	456.99
Palisade	Mesa	Piceance	HUNTERS CANYON	DAKOTA, MORRISON	6161	148.1	2,880		4.24	0.00	0.00	0.45	0.49	8.48
Palisade	Garfield	Piceance	MAM CREEK	MESAVERDE GROUP	3845	115.0	1,803		163.82	1.10	2.62	23.68	26.10	447.52
Palisade	Garfield	Piceance	PARACHUTE	MESAVERDE GROUP	3810	114.5	1,786		68.73	0.02	0.64	9.64	10.62	182.09
Palisade	Mesa	Piceance	PLATEAU	MESAVERDE GROUP	3734	113.4	1,751		5.22	0.00	0.12	0.74	0.82	14.07
Palisade	Mesa	Piceance	PLATEAU	DAKOTA, MORRISON	7360	165.2	3,437		1.69	0.00	0.01	0.16	0.18	3.06
Palisade	Garfield	Piceance	RULISON	MESAVERDE GROUP	4153	119.4	1,946	50.5	212.31	0.67	1.85	29.23	32.22	552.33
Palisade	Garfield	Piceance	RULISON	MANCOS SH	8004	174.5	3,737		0.29	0.00	0.01	0.03	0.03	0.53

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Palisade	Mesa	Piceance	SHIRE GULCH	Mesaverde Group, Dakota, Frontier, Cedar Mtn, Mancos, Morrison	775	71.1	375	39.0	40.25	0.00	0.04	2.92	3.22	55.20
Palisade	Pitkin	Piceance	WOLF CREEK	MESAVERDE	1643	83.5	779		12.63	0.00	0.00	1.29	1.43	24.43
Rangely	Garfield	Piceance	BAXTER PASS	MANCOS	3000	102.9	1,410		0.53	0.00	0.00	0.06	0.07	1.18
Rangely	Garfield	Piceance	BAXTER PASS	DAKOTA, CEDAR MOUNTAIN, BUCKHORN, MORRISON	6303	150.1	2,946	40.0	16.23	0.03	0.03	1.71	1.88	32.23
Rangely	Rio Blanco	Piceance	DOUGLAS CREEK	DAKOTA	4719	127.5	2,209	40.0	14.09	0.00	0.38	1.83	2.01	34.50
Rangely	Garfield	Piceance	GASAWAY	MESAVERDE GROUP	3721	113.2	1,745		0.88	0.00	0.01	0.13	0.14	2.36
Rangely	Garfield	Piceance	GASAWAY	MANCOS	4435	123.4	2,077		3.76	0.01	0.01	0.49	0.54	9.31
Rangely	Garfield	Piceance	GASAWAY	DAKOTA	8370	179.7	3,907		10.41	0.00	0.02	0.93	1.03	17.59
Rangely	Rio Blanco	Piceance	HELLS HOLE CANYON	MANCOS	3317	159.5	1,557		0.86	0.10	0.01	0.12	0.14	2.31
Rangely	Rio Blanco	Piceance	HELLS HOLE CANYON	DAKOTA, CEDAR MOUNTAIN, BUCKHORN, MORRISON	6956	85.0	3,249	51.3	29.72	0.08	0.04	3.23	3.56	60.97
Rangely	Rio Blanco	Piceance	PARK MOUNTAIN	MANCOS B	3726	113.3	1,747		0.02	0.00	0.00	0.00	0.00	0.08
Rangely	Rio Blanco	Piceance	PARK MOUNTAIN	DAKOTA, CEDAR MOUNTAIN, BUCKHORN, MORRISON	7196	162.9	3,361	60.5	25.67	0.09	0.05	2.53	2.79	47.88
Rangely	Rio Blanco	Piceance	PICEANCE CREEK	DOUGLAS CREEK	2741	99.2	1,289		56.49	0.00	0.00	6.41	7.07	121.21
Rangely	Rio Blanco	Piceance	PICEANCE CREEK	WASATCH	2886	101.3	1,357		193.40	0.13	0.90	22.45	24.74	424.16
Rangely	Rio Blanco	Piceance	PICEANCE CREEK	MESAVERDE GROUP, OHIO CREEK	7053	160.9	3,294		8.67	0.03	0.64	0.98	1.08	18.44
Rangely	Rio Blanco	Piceance	PICEANCE CREEK	MANCOS B	14370	265.5	6,697		0.02	0.00	0.00	0.00	0.00	0.03
Rangely	Rio Blanco	Piceance	RANGELY	MORRISON FM	3542	110.7	1,662	35.0	1.97	0.17	0.01	0.35	0.39	6.67
Rangely	Rio Blanco	Piceance	RANGELY	ENTRADA SS	4298	121.5	2,013		0.05	0.00	0.00	0.01	0.01	0.13
Rangely	Rio Blanco	Piceance	RANGELY	SHINARUMP	5287	135.6	2,473		0.05	0.21	0.00	0.12	0.13	2.30
Rangely	Rio Blanco	Piceance	RANGELY	WEBER SS	5973	145.4	2,792	35.0	770.72	852.48	396.29	616.08	679.11	11,642.40
Rangely	Garfield	Piceance	SOUTH CANYON	DAKOTA, CEDAR MOUNTAIN, BUCKHORN, MORRISON	4669	126.8	2,186		71.56	0.05	0.03	9.03	9.96	170.71
Rangely	Garfield	Piceance	TRAIL CANYON	MANCOS	2389	94.2	1,126		2.07	0.01	0.00	0.23	0.26	4.38

Pilot Study Region	County	Basin	Field Name	Reservoir Name	Avg Depth Feet	Temp °F	Pres psi	°API	Cumulative Production			Total CO ₂ Capacity		
									Bcf	MMBO	MMBW	MMt	MT	Bcf
Rangely	Garfield	Piceance	TRAIL CANYON	DAKOTA, BUCKHORN	6414	151.7	2,997	40.0	9.40	0.00	0.00	0.97	1.07	18.34
Rangely	Rio Blanco	Piceance	WHITE RIVER	MESAVERDE GROUP	3370	108.2	1,582		24.65	0.41	1.91	3.59	3.96	67.81
Rangely	Rio Blanco	Piceance	WHITE RIVER	WEBER SS	14194	263.0	6,615		0.44	0.04	0.02	0.06	0.06	1.06

Temperature in degrees Fahrenheit (°F); Pressure in pounds per square inch (psi); Oil gravity in degrees API (°API); Gas production in billion cubic feet (Bcf); Oil production in million barrels (MMBO); Water production in million barrels (MMBW); CO₂ capacity in million metric tonnes (MMt), million short tons (MT), and billion cubic feet (Bcf)

Appendix 9

Methodology for Calculating Carbon Storage Capacity for Oil and Gas Reservoirs

A five-step process was utilized to calculate carbon storage capacity for oil and gas reservoirs within the SWP region. The methodology used minimum inputs of cumulative oil, gas, and water production as well as reservoir temperature, pressure, and salinity. Where temperature and pressure were not available, proxies were calculated from average depth to the mid-point of the reservoir, a temperature gradient of 1.96 °F per 100 feet, and a pressure gradient of 0.433 psi per foot. The details of the calculation process follow with a complete nomenclature table at the conclusion of this Appendix.

Step 1: Calculate the surface volume of CO₂ sequestered in the reservoir volume that is voided due to oil and water production.

Calculate the *in situ* reservoir volume for both the cumulative oil and water production in terms of reservoir barrels (RB):

$$V_{R,Np} = B_o \times N_p \quad (9.1)$$

and

$$V_{R,Wp} = B_w \times W_p \quad (9.2)$$

assuming $B_o = 1.2 \text{ RB/STB}$ and $B_w = \rho_{S,H2O} \div \rho_{R,H2O}$ where $\rho_{S,H2O} = 62.367 \text{ lbm/cf}$. Brine density ($\rho_{R,H2O}$) was determined by equation-of-state (EOS) as outlined by Batzel and Wang (1992) using reservoir temperature, pressure, and salinity. This density calculation is valid for reservoir temperatures in the range of 68 – 662 °F and reservoir pressures of 14.5 – 14,503 psi.

Total *in situ* reservoir volume of the cumulative oil and water production in terms of reservoir cubic feet is calculated from the sum of Equations (9.1) and (9.2) and the conversion factor 5.6146 cf/bbl:

$$V_{R,Np+Wp} = (V_{R,Np} + V_{R,Wp}) \times 5.6146 \quad (9.3)$$

The mass of CO₂ that may be sequestered in the *in situ* reservoir volume voided by the cumulative production of oil and water is calculated from Equation (9.3) and the density of CO₂ at reservoir conditions:

$$m_{R,CO_2 \rightarrow Np+Wp} = V_{R,Np+Wp} \times \rho_{R,CO_2} \times 2,000 \quad (9.4)$$

where ρ_{R,CO_2} is calculated using a Modified Redlich-Kwong EOS and standard thermodynamic equations. This formulation is based on the work of Kerrick and Jacobs (1981) and Weir and others (1996); Weir and others (1996) extended the work of Kerrick and Jacobs (1981) to lower temperatures (Weonshik Han, NMT, written communication, 2005). This density calculation is valid for reservoir temperatures in the range of 59 – 662 °F and reservoir pressures of 14.5 – 14,503 psi. The mass of CO₂ is converted to short tons using 2,000 lb/ton.

The surface volume of the CO₂ sequestered in the reservoir volume that is voided due the cumulative production of oil and water is calculated from Equation (9.4) and the density of CO₂ at surface conditions; that is, 60 °F and 14.7 psi. In terms of million cubic feet (MMcf), this volume is:

$$V_{S,CO_2 \rightarrow Np+Wp} = \frac{m_{R,CO_2 \rightarrow Np+Wp}}{\rho_{S,CO_2}} \times 10^{-6} \quad (9.5)$$

where the CO₂ density at surface conditions (ρ_{S,CO_2}) is 0.11666 lbm/cf.

Step 2: Calculate the surface volume of CO₂ sequestered in the reservoir volume that is voided due to gas production.

Calculate the pounds-mass of cumulative gas production at surface conditions:

$$m_{S,Gp} = G_p \times \rho_{S,CH_4} \times 10^{-9} \quad (9.6)$$

where the density of the produced gas (ρ_{S,CH_4}) is assumed to be that of pure methane (CH₄), which is 0.04237 lbm/cf at surface conditions. This simplification was considered necessary due to the absence of gas composition for many of the reservoirs in the SWP region.

The *in situ* reservoir volume of the cumulative gas production in terms of cubic feet was calculated from Equation (9.6) and the density of CH₄ at reservoir temperature and pressure:

$$V_{R,Gp} = \frac{m_{S,Gp}}{\rho_{R,CH_4}} \quad (9.7)$$

where ρ_{R,CH_4} was determined from the Redlich-Kwong EOS and standard thermodynamic equations (Redlich and Kwong, 1949). This density calculation is valid for reservoir temperatures in the range of 59 – 392 °F and reservoir pressures of 14.5 – 12,327 psi.

The mass of CO₂ that may be sequestered in the reservoir volume voided by the cumulative production of gas in terms of short tons is calculated from Equation (9.7) and the density of CO₂ at reservoir conditions:

$$m_{R,CO_2 \rightarrow Gp} = V_{R,Gp} \times \rho_{R,CO_2} \times 2,000 \quad (9.8)$$

The surface volume of the CO₂ sequestered in the reservoir volume that is voided due the cumulative production of gas is calculated from Equation (9.8) and the density of CO₂ at surface conditions. This volume is (MMcf):

$$V_{S,CO_2 \rightarrow Gp} = \frac{m_{R,CO_2 \rightarrow Gp}}{\rho_{S,CO_2}} \times 10^{-6} \quad (9.9).$$

Step 3: Calculate the surface volume of CO₂ sequestered due to solubility in water that is remaining in the reservoir.

Calculate the *in situ* barrels of water remaining in the reservoir based on cumulative water production:

$$V_{R,IWIP-Wp} = W_p \times \left[\frac{100}{R_{fw}} - 1 \right] \quad (9.10)$$

where the water recovery factor (R_{fw}) is assumed to be 20 percent.

The mass of water remaining in the reservoir is:

$$m_{R,IWIP-Wp} = V_{R,IWIP-Wp} \times \rho_{R,H_2O} \times 5.6146 \quad (9.11)$$

The mass of CO₂ that may be sequestered in the water mass calculated in Equation (9.11) is:

$$m_{R,CO_2 \Rightarrow R_{sw}} = m_{R,IWIP-Wp} \times \frac{MW_{CO_2}}{MW_{H_2O}} \times \frac{R_{s,CO_2 \Rightarrow H_2O}}{100 - R_{s,CO_2 \Rightarrow H_2O}} \quad (9.12)$$

where the molecular weights for CO₂ and H₂O are 44 and 18, respectively, and the solubility of CO₂ in water ($R_{s,CO_2 \Rightarrow H_2O}$) is assumed to be 3 mole percent.

The surface volume of CO₂ sequestered due to solubility in water is calculated from Equation (9.12) and the density of CO₂ at surface conditions. This volume is (MMcf):

$$V_{S,CO_2 \rightarrow IWIP-Wp} = \frac{m_{R,CO_2 \Rightarrow R_{sw}}}{\rho_{S,CO_2}} \times 10^{-6} \quad (9.13).$$

Step 4: Calculate the surface volume of CO₂ sequestered due to solubility in oil that is remaining in the reservoir.

Calculate the *in situ* barrels of oil remaining in the reservoir based on cumulative oil production:

$$V_{R,OOIP-Np} = N_p \times \left(\frac{100}{R_{fo}} - 1 \right) \quad (9.14)$$

where the oil recovery factor (R_{fo}) is assumed to be 20 percent.

The mass of oil remaining in the reservoir is:

$$m_{R,OOIP-Np} = V_{R,OOIP-Np} \times \rho_{R,oil} \times 5.6146 \quad (9.15)$$

where the density of oil is assumed to be 80 percent of water; that is, $\rho_{R,oil} = 0.8 \times 62.4$ lbm/cf. The mass of CO₂ that may be sequestered in the oil mass calculated in Equation (9.15) is:

$$m_{R,CO_2 \Rightarrow Rso} = m_{R,OOIP-Np} \times \frac{MW_{CO_2}}{MW_{Oil}} \times \frac{R_{s,CO_2 \Rightarrow Oil}}{100 - R_{s,CO_2 \Rightarrow Oil}} \quad (9.16)$$

where the average molecular weight for oil is assumed to be 150 and the solubility of CO₂ in oil ($R_{s,CO_2 \Rightarrow Oil}$) is assumed to be 65 mole percent.

The surface volume of CO₂ sequestered due to solubility in oil is calculated from Equation (9.16) and the density of CO₂ at surface conditions. This volume is (MMcf):

$$V_{S,CO_2 \Rightarrow OOIP-Np} = \frac{m_{R,CO_2 \Rightarrow Rso}}{\rho_{S,CO_2}} \times 10^{-6} \quad (9.17).$$

Step 5: Calculate the total surface volume of CO₂ sequestered in the reservoir.

From Equations (9.5), (9.9), (9.13), and (9.17), the total volume of CO₂ sequestered in the reservoir due to both fluid production and solubility in the fluids remaining in the reservoir can be calculated at surface conditions. In terms of billion cubic feet (Bcf), this volume is:

$$V_{S,CO_2Seq} = (V_{S,CO_2 \rightarrow Np+Wp} + V_{S,CO_2 \rightarrow Gp} + V_{S,CO_2 \Rightarrow IWIP-Wp} + V_{S,CO_2 \Rightarrow OOIP-Np}) \times 10^{-3}$$

or in terms of million short tons (MT):

$$V_{S,CO_2Seq} \times \rho_{S,CO_2} \times \frac{10^{+3}}{2,000}$$

or in terms of million metric tonnes (MMt):

$$V_{S,CO_2Seq} \times \rho_{S,CO_2} \times \frac{10^{+3}}{2,204.6}$$

Appendix I Nomenclature

Abbreviation	Explanation	Units
B_o	Oil formation volume factor	Reservoir barrels/stock tank barrels (RB/STB)
B_w	Water formation volume factor	Reservoir barrels/stock tank barrels (RB/STB)
G_p	Cumulative gas produced	10^{+9} cubic feet (Bcf)
$m_{R,CO_2 \rightarrow Gp}$	Mass of CO ₂ in volume voided by gas production at reservoir conditions	Short tons (2,000 lbs/ton)
$m_{R,CO_2 \rightarrow Np+Wp}$	Mass of CO ₂ in volume voided by oil and water production at reservoir conditions	Short tons (2,000 lbs/ton)
$m_{R,CO_2 \Rightarrow Rso}$	Mass of CO ₂ sequestered in remaining reservoir oil due to solubility	Pounds-mass (lbm)
$m_{R,CO_2 \Rightarrow Rsw}$	Mass of CO ₂ sequestered in remaining reservoir water due to solubility	Pounds-mass (lbm)
$m_{R,IWIP-Wp}$	Mass of water remaining in reservoir	Pounds-mass (lbm)
$m_{R,OOIP-Np}$	Mass of oil remaining in reservoir	Pounds-mass (lbm)
$m_{S,Gp}$	Mass of produced gas at surface conditions	Pounds-mass (lbm)
MW_{CO_2}	Molecular weight of CO ₂	Unitless
MW_{H_2O}	Molecular weight of water	Unitless
MW_{Oil}	Molecular weight of oil	Unitless
N_p	Cumulative oil produced	Stock tank barrels (STB)
R_{fo}	Oil recovery factor	Percent (%)
R_{fw}	Water recovery factor	Percent (%)
$R_{s,CO_2 \Rightarrow H_2O}$	Solubility of CO ₂ in water	Mole percent (mole %)
$R_{s,CO_2 \Rightarrow Oil}$	Solubility of CO ₂ in oil	Mole percent (mole %)
$V_{R,Gp}$	Reservoir volume of produced gas	Cubic feet (cf)
$V_{R,IWIP-Wp}$	Reservoir volume of remaining water	Reservoir barrels (RB)
$V_{R,Np}$	Reservoir volume of produced oil	Reservoir barrels (RB)
$V_{R,Np+Wp}$	Reservoir volume of produced oil and water	Cubic feet (cf)
$V_{R,OOIP-Np}$	Reservoir volume of remaining oil	Reservoir barrels (RB)
$V_{R,Wp}$	Reservoir volume of produced water	Reservoir barrels (RB)
$V_{S,CO_2 \rightarrow Gp}$	Surface volume of CO ₂ sequestered in volume voided by gas production	10^{+6} cubic feet (MMcf)

Abbreviation	Explanation	Units
$V_{S,CO_2 \rightarrow IWIP-Wp}$	Surface volume of CO ₂ sequestered in remaining water due to solubility	10 ⁺⁶ cubic feet (MMcf)
$V_{S,CO_2 \rightarrow Np+Wp}$	Surface volume of CO ₂ sequestered in volume voided by oil and water production	10 ⁺⁶ cubic feet (MMcf)
$V_{S,CO_2 \rightarrow OOIP-Np}$	Surface volume of CO ₂ sequestered in remaining oil due to solubility	10 ⁺⁶ cubic feet (MMcf)
V_{S,CO_2Seq}	Surface volume of CO ₂ sequestered in reservoir due to production and solubility	10 ⁺⁹ cubic feet (Bcf)
W_p	Cumulative water produced	Stock tank barrels (STB)

ρ_{R,CH_4}	Methane density at reservoir conditions	Pounds-mass/cubic foot (lbm/cf)
ρ_{R,CO_2}	CO ₂ density at reservoir conditions	Pounds-mass/cubic foot (lbm/cf)
ρ_{R,H_2O}	Water density at reservoir conditions	Pounds-mass/cubic foot (lbm/cf)
$\rho_{R,oil}$	Oil density at reservoir conditions	Pounds-mass/cubic foot (lbm/cf)
ρ_{S,CH_4}	Methane density at surface conditions	Pounds-mass/cubic foot (lbm/cf)
ρ_{S,CO_2}	CO ₂ density at surface conditions	Pounds-mass/cubic foot (lbm/cf)
ρ_{S,H_2O}	Water density at surface conditions	Pounds-mass/cubic foot (lbm/cf)

DENVER BASIN EAST

AGE		STRATIGRAPHIC UNIT
Quaternary		Eolian Deposits
Pliocene		Ogallala Group
Miocene		Arikaree Group
Oligocene		White River Group
Upper Cretaceous		Pierre Shale
		Niobrara Formation
		Smoky Hill Chalk Member
		Fort Hays Member
		Colorado (Benton) Group
		Carlile Shale
		Codell Sandstone Member
		Greenhorn Limestone
		Graneros Shale
		D Sandstone
Huntsman Shale		
Lower Cretaceous		Dakota Group
		Muddy (J) Sandstone
		Kiowa (Skull Creek) Shale
		Fall River (Cheyenne) Sandstone
Jurassic		Morrison Formation
Triassic		Undifferentiated
Permian		Dry Creek Dolo (Lykins Formation)
		Blaine Gyp (Lykins Formation)
		Nippewalla Group (Lyons Formation)
		Cedar Hills Sandstone
		Stone Corral Sandstone
		Sumner (Wellington) Group
		Chase Group (Ingleside Formation)
	Wolfcampain	Council Grove Group
	Upper Pennsylvanian	Virgilian
Wabaunsee Group		
Shawnee Group		
Topeka Member		
Douglas Group		
Lansing Group		
Missourian		Kansas City Group
		Pleasanton Group
Middle Pennsylvanian	Des Moinesian	Marmaton Group
		Cherokee Group
		Atoka Group
Lower Pennsylvanian		Morrow Group
Mississippian		Undifferentiated
Lower Ordovician		Arbuckle Group
Upper Cambrian		Reagan Sandstone
Precambrian		Precambrian Rocks

DENVER BASIN WEST

AGE	STRATIGRAPHIC UNIT
Quaternary	Eolian Deposits & Alluvial deposits
Pliocene	Ogallala Group
Miocene	
Oligocene	White River Group
Paleocene	Denver Formation
Upper Cretaceous	Arapahoe Formation
	Laramie Formation
	Fox Hills Sandstone
	Pierre Shale
	Parkman (Richards) Sandstone Member
	Terry (Sussex) Sandstone Member
	Hygiene (Shannon) Sandstone Member
	Niobrara Family
	Smoky Hill Chalk Member
	Fort Hays (Timpas) Member
	Benton (Colorado) Group
	Carlile Shale
	Codell Sandstone Member
	Greenhorn Limestone
	Graneros Shale
	D Sandstone
	Mowry (Huntsman) Shale
	Dakota Group
Lower Cretaceous	Muddy (J) Sandstone
	Skull Creek Shale
	Plainview (Dakota) Formation
	Lytle Formation (Lakota)
Jurassic	Morrison Formation
	Ralston Creek Formation
	Entrada (Sundance) Sandstone
Upper Triassic	Jelm (Chugwater Group)
Lower Triassic	Lykins Formation
Upper Permian	Forelle Limestone Member
Lower Permian	Upper Santanka Shale
	Lyons Sandstone
	Lower Santanka Shale
	Ingleside Formation
	Fountain Formation
Pennsylvanian	
Precambrian	Precambrian Rocks

LAS ANIMAS ARCH

AGE		STRATIGRAPHIC UNIT	
Quaternary		Eolian Deposits	
Pliocene		Ogallala Group	
Miocene			
Upper Cretaceous		Pierre Shale	
		Niobrara Formation	
		Smoky Hill Chalk Member	
		Fort Hays Member	
		Carlile Shale	
		Codell Sandstone Member	
		Greenhorn Limestone	
		Dakota Group	
		Graneros Shale	
Lower Cretaceous		Dakota (Cockrum) Sandstone	
		Purgatoire Formation	
		Kiowa Shale Member	
Jurassic		Cheyenne Sandstone Member	
		Morrison Formation	
Triassic		Ralston Creek Formation	
		Dockum Group	
Permian		Taloga Formation	
		Day Creek Dolo	
		Whitehorse Group	
		Blaine Gypsum	
		Nippewalla Group	
		Cedar Hills Sandstone	
		Stone Corral (Lyons) Sandstone	
		Sumner Group	
		Red Cave Formation	
		Wolfcampian	
	Council Grove Group		
	Neva Limestone		
	Pennsylvanian	Virgilian	
Wabaunsee Formation			
Shawnee Group			
Topeka Member			
Heebner Member			
Douglas Group			
Missourian			Lansing Group
			Kansas City Group
			Pleasanton Group
			Marmaton Formation
Desmonian			Cherokee Group
			Atoka Group
	Morrow Group		
Upper Mississippian		Chester Group	
		St. Genevieve Limestone	
		St. Louis Limestone	
Lower Mississippian		Spergen (Salem) Formation	
		Warsaw Family	
		Osage Limestone	
		Kinderhook Limestone	
Middle Ordovician		Viola Limestone	
Lower Ordovician		Simpson Group	
Upper Cambrian		Arbuckle Group	
Precambrian		Reagan Sandstone	
		Precambrian Rocks	

HUGOTON EMBAYMENT

AGE		STRATIGRAPHIC UNIT	
Quaternary		Eolian Deposits	
Pliocene		Ogallala Group	
Miocene			
Lower Cretaceous		Dakota Group	
Jurassic		Morrison Formation	
Triassic		Dockum Group	
Upper Permian		Taloga Formation	
		Day Creek Dolo	
		Whitehorse Group	
		Blaine Gypsum Member (Lykins)	
		Nippewalla Group	
		Cedar Hills Sandstone (Lyons)	
Lower Permian		Stone Corral Sandstone	
		Sumner Group	
		Red Cave Formation	
		Wolfcampian	Chase Group
			Council Grove Group
Neva Limestone			
Pennsylvanian	Virgilian	Admire Group	
		Wabaunsee Formation	
		Shawnee Group	
		Topeka Member	
		Heebner Member	
		Douglas Group	
	Pleasanton	Lansing Group	
		Kansas City Group	
		Pleasanton Group	
	Des Moinesian	Marmaton Group	
		Cherokee Group	
	Atoka Group		
	Morrow Group		
	Upper Mississippian	Chester Group	
St. Genevieve Limestone			
St. Louis Limestone			
Spergen Limestone			
Warsaw Limestone			
Lower Mississippian	Osage Limestone		
	Kinderhook Limestone		
	Misener Sandstone		
Middle Ordovician		Viola Limestone	
		Simpson Group	
Lower Ordovician		Arbuckle Group	
Upper Cambrian		Reagan Sandstone	
Precambrian		Precambrian Rocks	

RATON BASIN

AGE	STRATIGRAPHIC UNIT
Miocene	Devils Hole Formation
Oligocene	Farisita Formation
Eocene	Huerfano Formation
	Cuchara Formation
Paleocene	Poison Canyon Formation
	Raton Formation
Upper Cretaceous	Vermejo Formation
	Trinidad Sandstone
	Pierre Shale
	Niobrara Formation
	Smoky Hill (Apishapa) Member
	Fort Hays (Timpas) Limestone Member
	Benton Group
	Carlile Shale
	Codell Sandstone Member
	Greenhorn Limestone
	Graneros Shale
Lower Cretaceous	Dakota Sandstone
	Purgatoire (Lakota) Formation
Jurassic	Morrison Formation
	Ralston Creek (Wanakah) Formation
	Entrada Sandstone
Triassic	Dockum Group
	Chinle Formation
	Santa Rosa Formation
Permian	Glorietta Formation (Lyons)
	Yeso Formation (Lyons)
	Sangre De Cristo (Fountain) Formation
Pennsylvanian	Madera Formation
Precambrian	Precambrian Rocks

CAÑON CITY EMBAYMENT

AGE	STRATIGRAPHIC UNIT
Paleocene	Poison Canyon
Upper Cretaceous	Raton Formation
	Vermejo Formation
	Trinidad Sandstone
	Pierre Shale
	Niobrara Formation
	Smoky Hill (Apishapa) Member
	Fort Hays (Timpas) Limestone Member
	Carlile Shale
	Codell Sandstone Member
	Greenhorn Limestone
Lower Cretaceous	Graneros Shale
	Dakota Sandstone
Upper Jurassic	Purgatoire Formation
	Morrison Formation
Upper Permian	Ralston Creek Formation
	Lykins Formation
	Lyons Formation
Lower Permian	Fountain Formation
Pennsylvanian	
Mississippian	Glen Eyrie Member
	Beulah Limestone
	Hardscrabble Limestone
	Williams Canyon Limestone
Ordovician	Fremont Dolo
	Harding Sandstone
	Manitou Limestone
Precambrian	Precambrian Rocks

NORTH PARK BASIN

AGE	STRATIGRAPHIC UNIT
Eocene	Coalmont Formation
Paleocene	
Upper Cretaceous	Pierre Shale
	Niobrara Formation
	Carlile Shale
	Frontier Formation
	Graneros Shale
	Mowry Shale
	Muddy Sandstone
Lower Cretaceous	Dakota Group
	Dakota Sandstone
	Fuson Shale
	Lakota Sandstone
Upper Jurassic	Morrison Formation
	Sundance (Entrada) Formation
Triassic	Jelm Formation
	Chugwater Formation
Precambrian	Precambrian rocks

SAND WASH BASIN

AGE	STRATIGRAPHIC UNIT
Miocene	Browns Park Formation
Eocene	Green River Formation
	Wasatch Formation
Paleocene	Fort Union Formation
Upper Cretaceous	Lance Formation
	Fox Hills Formation
	Mesaverde Group
	Williams Fork Formation (Almond, Ericson)
	Iles (Rock Springs) Formation
	Mancos Shale
	Morapos Sandstone Member
	Niobrara Member
	Carlile (Benton) Member
	Frontier Sandstone
Lower Cretaceous	Mowry Shale
	Dakota Group
Jurassic	Morrison Formation
	Curtis Formation
	Entrada Sandstone
	Carmel Sandstone
	Nugget Sandstone
Triassic	Chinle Formation
	Shinarump Sandstone Member
	Moenkopi Formation
Upper Permian	Phosphoria (Park City) Formation
Lower Permian	Weber Sandstone
Pennsylvanian	Morgan (Belden) Formation
Mississippian	Madison or Leadville Limestone
Devonian	Chaffee Group
	Dyer Formation
	Parting Sandstone
Upper Cambrian	Lodore Formation
Precambrian	Precambrian Rocks

AXIAL BASIN UPLIFT

AGE	STRATIGRAPHIC UNIT
Eocene	Wasatch Formation
Paleocene	Fort Union Formation
Upper Cretaceous	Lance Formation
	Lewis Shale
	Mesaverde Group
	Williams Fork Formation
	Iles Formation
	Trout Creek Sandstone Member
	Tow Creek Sandstone Member
	Mancos Shale
	Morapos Sandstone Member
	Meeker Sandstone
	Niobrara Formation
Lower Cretaceous	Frontier Sandstone
	Mowry Shale
	Dakota Group
Jurassic	Morrison Formation
	Brushy Basin Member
	Salt Wash Member
	Curtis Formation
	Entrada (Sundance) Sandstone
Triassic	Chinle Formation
	Shinarump Sandstone Member
	Moenkopi Formation
Upper Permian	Phosphoria (State Bridge) Formation
Lower Permian	Weber Sandstone
Pennsylvanian	Morgan (Minturn) Formation
	Morgan (Belden) Formation
	Molas Formation
Mississippian	Madison (Leadville) Limestone
Upper Devonian	Chaffee Group
Ordovician	Manitou Formation
Upper Cambrian	Dotsero Formation
Lower Cambrian	Lodore (Sawatch) Formation
Precambrian	Precambrian Rocks

DOUGLAS CREEK ARCH

AGE	STRATIGRAPHIC UNIT
Eocene	Uinta Formation
	Green River Formation
	Wasatch Formation
Paleocene	Fort Union Formation
Upper Cretaceous	Mesaverde Group
	Upper Mesaverde
	Lower Mesaverde
	Sego Sandstone
	Castlegate Sandstone
	Mancos Group
	Morapos (Mancos A) Sandstone
	Emery (Mancos B) Sandstone
	Niobrara Formation
	Frontier Formation
Lower Cretaceous	Mowry Shale
	Dakota Group
	Dakota Sandstone
	Cedar Mountain (Buckhorn) Formation
Jurassic	Morrison Formation
	Brushy Basin Member
	Salt Wash Member
	Curtis (Summerville) Formation
	Entrada Sandstone
	Carmel Formation
	Glen Canyon Group
	Navajo Sandstone Member
Triassic	Chinle Formation
	Shinarump Sandstone Member
	Moenkopi Formation
Permian	Weber (Maroon) Sandstone
Pennsylvanian	Minturn (Morgan) Formation
	Belden (Madison) Limestone
	Molas Formation
Mississippian	Leadville (Madison) Limestone
Devonian	Chaffee Formation
Cambrian	Sawatch Sandstone
Precambrian	Precambrian Rocks

PICEANCE BASIN

AGE	STRATIGRAPHIC UNIT
Eocene	Uinta Formation
	Green River Formation
	Parachute Creek Member Douglas Creek Member
	Wasatch Formation
Paleocene	Fort Union Group
Upper Cretaceous	Mesaverde Group
	Ohio Creek Member
	Williams Fork Formation
	Cameo Zone
	Iles Formation
	Rollins Sandstone
	Cozzette Sandstone Member
	Corcoran Sandstone Member
	Sego Sandstone
	Castlegate Sandstone
	Mancos Shale
	Morapos (Mancos A) Sandstone
	Emery (Mancos B) Sandstone
	Meeker Sandstone
	Niobrara Formation
Lower Cretaceous	Frontier Formation
	Mowry Shale (Benton Shale)
	Dakota Group
Upper Jurassic	Cedar Mountain Formation
	Morrison Formation
	Brushy Basin Member Salt Wash Member
Middle Jurassic	Curtis Formation
Lower Jurassic	Entrada (Sundance) Sandstone
	Navajo (Nugget) Sandstone
Upper Triassic	Chinle Formation
	Shinarump Sandstone Member
	Moenkopi Formation
Upper Permian	Phosphoria Formation
Lower Permian	Weber (Maroon) Sandstone
Pennsylvanian	
	Minturn (Morgan) Formation
	Belden Shale
	Molas Formation
Mississippian	Leadville (Madison) Limestone
Devonian	Chaffee Group
Ordovician	Manitou Formation
Cambrian	Dotsero Formation
	Sawatch Sandstone
Precambrian	Precambrian Rocks

SAN JUAN BASIN

AGE	STRATIGRAPHIC UNIT
Eocene	San Jose Formation
Paleocene	Nacimiento Formation
	Animas Formation
Upper Cretaceous	Kirtland Shale
	Farmington Sandstone Member
	Fruitland Formation
	Pictured Cliffs Sandstone
	Lewis Shale
	Mesaverde Group
	Cliffhouse Formation
	Menefee Formation
	Point Lookout Sandstone
	Mancos Shale
	Niobrara Member
	Tocito Sandstone
	Gallup Sandstone
	Juana Lopez (Sanastee) Member
Lower Cretaceous	Carlile Member
	Greenhorn Limestone Member
	Graneros Shale Member
	Dakota Sandstone
	Burro Canyon Formation
Upper Jurassic	Morrison Formation
	San Rafael Group
	Summerville (Wanakah) Formation
Middle Jurassic	Entrada Sandstone
Upper Triassic	Glen Canyon Group
	Chinle Formation
	Shinarump Conglomerate Member
Lower Triassic	Moenkopi Formation
Lower Permian	Cutler Formation
Pennsylvanian	Hermosa Group
	Honaker Trail Formation
	Paradox Formation
	Ismay Zone
	Desert Creek Zone
	Akah Zone
	Barker Creek Zone
	Pinkerton Trail Formation
	Molas Formation
Lower Mississippian	Leadville Limestone
	Ouray Formation
Upper Devonian	Elbert Formation
	McCracken Sandstone Member
Upper Cambrian	Ignacio Formation
Precambrian	Precambrian Rocks

PARADOX BASIN

AGE	STRATIGRAPHIC UNIT
Upper Cretaceous	Mesaverde Group
	Mancos Shale
Lower Cretaceous	Dakota Sandstone
	Burro Canyon Formation
Jurassic	Morrison Formation
	San Rafael Group
	Summerville (Wanakah) Formation
	Entrada Sandstone
	Carmel Formation
	Glen Canyon Group
	Navajo Sandstone
Upper Triassic	Kayenta Formation
	Wingate Sandstone
	Chinle Formation
	Shinarump Conglomerate Member
Lower Permian	Cutler Group
Pennsylvanian	Hermosa Group
	Honaker Trail Formation
	Paradox Formation
	Ismay Member
	Desert Creek Member
	Akah Member
	Barker Creek Member
	Pinkerton Trail Formation
Mississippian	Molas Formation
Devonian	Leadville Limestone
	Ouray Formation
	Elbert Formation
	Upper Elbert Member
	McCracken Sandstone Member
Cambrian	Aneth Formation
Precambrian	Ignacio Quartz
	Precambrian Rocks

Basin	Seam	Coal Rank	Area acres	Avg Thick ft	Avg Depth ft	Density tons/ac-ft	Gas Content scf/t	Methane-in-Place Bcf	CO ₂ /CH ₄ Replacement Ratio	Net CO ₂ Capacity			Estimated Recovery Tcf
										Bcf	MT	MMt	
Denver	Laramie	Sub	504,891	10	1,703	1,800	293	2,666	10.0	17,330	1,002	909	1.5
Piceance	Cameo-Fairfield	MV	1,035,673	54	4,057	1,850	269	27,814	1.5	27,118	1,568	1,422	2.4
Piceance	Cameo-Fairfield	HVA	255,596	51	3,777	1,800	214	5,028	6.0	19,608	1,133	1,028	1.7
Piceance	Cameo-Fairfield	HV	77,565	55	3,090	1,800	155	1,191	3.0	2,322	134	122	0.2
Raton	Raton - Vermejo	MV	530,695	30	1,767	1,850	412	12,138	1.5	11,835	684	621	1.1
Raton	Raton - Vermejo	HV	47,595	30	2,339	1,800	205	526	3.0	1,026	59	54	0.1
San Juan	Fruitland	MV	300,698	59	2,845	1,850	396	12,975	1.5	12,651	731	663	1.1
San Juan	Fruitland	HVA	174,779	61	2,676	1,800	327	6,294	6.0	24,548	1,419	1,287	2.2
San Juan	Fruitland	HV	68,116	61	2,246	1,800	144	1,081	3.0	2,108	122	111	0.2
San Juan	Menefee	HVA	543,593	10	5,495	1,800	243	2,381	6.0	9,286	537	487	0.8
Sand Wash	Fort Union	HVA	367,033	33	3,828	1,800	260	5,668	6.0	22,107	1,278	1,159	2.0
Sand Wash	Fort Union	HV	335,411	23	4,545	1,800	330	4,582	3.0	8,936	517	469	0.8
Sand Wash	Williams Fork	HVA	315,312	84	5,453	1,800	460	21,931	6.0	85,529	4,944	4,485	7.6
Sand Wash	Williams Fork	HV	434,448	89	2,863	1,800	220	15,312	3.0	29,858	1,726	1,566	2.7
Sand Wash	Iles	HVA	163,452	65	6,134	1,800	450	8,606	6.0	33,562	1,940	1,760	3.0
Sand Wash	Iles	HV	349,401	33	3,839	1,800	280	5,811	3.0	11,332	655	594	1.0

Coal density in tons per acre-feet (tons/ac-ft) and gas content in standard cubic feet per ton (scf/t) are calculated from published correlations; see appendix 12 for further details. Net CO₂ capacity assumes 65 percent efficiency factor and is provided in billion cubic feet (Bcf), million short tons (MT), and million metric tonnes (MMt).

Estimated recovery in trillion cubic feet (Tcf) is calculated assuming 1.7 Tcf produced methane (CH₄) per billion tons of stored CO₂.

Appendix 12

Methodology for Calculating Carbon Storage Capacity for Coalbed Reservoirs

A four-step process was utilized to calculate carbon storage capacity for coalbed reservoirs within the SWP region. The methodology used minimum inputs of coal rank, volume, average depth, and a CO₂/CH₄ replacement ratio. The methodology was developed by Advanced Resources and provided to the SWP to provide a consistent basis for calculating carbon storage capacity throughout the region. The methodology is particularly beneficial for the “broad-brush” approach required of Phase I in that it relies on published correlations to calculate proxies for data not publicly available. The details of the calculation process follow with a complete nomenclature table at the conclusion of this Appendix.

Step 1: Estimate coal density based on rank if measured data is not available.

Coal density (ρ_{COAL}) is estimated from its rank for instances where measured data is not available (Table 12.1). Coal rank is generally publicly available, particularly from the wealth of Gas Research Institute publications dealing with coalbed methane development.

Table 12.1: Coal Density Versus Rank

Coal Rank	Coal Density	
	g/cc ¹	t/ac-ft ²
High Volatile B & C Bituminous	1.324	1800
High Volatile A Bituminous	1.324	1800
Medium Volatile Bituminous	1.361	1850
Low Volatile Bituminous	1.398	1900
Semi-Anthracite	1.435	1950

Source: Advanced Resources, written communication, 2005

¹ g/cc = grams per cubic centimeter; ² t/ac-ft = short tons per acre-feet

Step 2: Calculate the theoretical gas storage capacity based on average depth of the coalbed reservoir.

Gas storage capacity (G_C) is the maximum amount of gas or mixture of gases (normalized to the relevant basis) which can be adsorbed by the coal at a specific reservoir pressure, temperature, and moisture content. This capacity may be calculated directly from the adsorption isotherm where available for a specific coal or location. Alternatively, the gas storage capacity may be estimated from generalized correlations developed for this purpose by simply knowing the coal rank and an average reservoir depth (D). Table 12.2 summarizes the correlations utilized to calculate gas storage capacity for coalbed reservoirs in the SWP region. The units for this calculated gas content is standard cubic feet gas per ton of coal (scf/ton).

Table 12.2: Gas Storage Capacity Versus Coal Rank and Location

Coal Rank	San Juan Basin Fruitland	San Juan Basin Menefee
High Volatile B & C Bituminous	$G_C = 67.1 \times \ln D - 359.0$	$G_C = 67.1 \times \ln D - 451.0$
High Volatile A Bituminous	$G_C = 150.2 \times \ln D - 799.2$	$G_C = 150.2 \times \ln D - 882.5$
Medium Volatile Bituminous	$G_C = 150.2 \times \ln D - 734.0$	$G_C = 150.2 \times \ln D - 812.5$
Low Volatile Bituminous	$G_C = 150.2 \times \ln D - 723.8$	$G_C = 150.2 \times \ln D - 797.5$

Coal Rank	Piceance/Sand Wash	Raton
High Volatile B & C Bituminous	$G_C = 42.5 \times \ln D - 163.5$	$G_C = 0.35 \times D^{0.85}$
High Volatile A Bituminous	$G_C = 51 \times \ln D - 168$	
Medium Volatile Bituminous	$G_C = 36 \times \ln D - 2$	$G_C = 10.3 \times D^{0.49}$
Low Volatile Bituminous	$G_C = 37 \times \ln D - 3$	
Semi-Anthracite	$G_C = 31 \times \ln D + 61$	

Source: Advanced Resources, written communication, 2005

Step 3: Calculate the gas-in-place based on the volume of coal of a specific rank.

The total gas-in-place (GIP) for a given coal rank is calculated from the gas content (G_C), coal thickness (h), area (A), and density (ρ_{COAL}):

$$GIP = G_C \times h \times A \times \rho_{COAL} \times 10^{-6} \quad (12.1)$$

where the gas-in-place is in terms of billion cubic feet (Bcf).

Step 4: Calculate the CO₂ storage capacity of the coal as a function of rank and gas storage capacity.

The number of CO₂ molecules that are required to displace a methane molecule is referred to as the CO₂/CH₄ replacement ratio and is a function of coal rank (Bustin, 2002) (Table 12.3).

Table 12.3: CO₂/CH₄ Replacement Ratio Versus Coal Rank

Coal Rank	CO ₂ /CH ₄ Replacement Ratio
Low Volatile Bituminous	1:1
Medium Volatile Bituminous	1.5:1
High Volatile A Bituminous	3:1
High Volatile B & C Bituminous	6:1
Subbituminous	10:1

(Source: Reeves, 2003)

This replacement ratio is used to estimate the potential CO₂ sorption capacity of the coalbed reservoir from Equation (12.1). As this calculation assumes 100 percent efficiency in the replacement process, a downward adjustment is made to the volume by applying an efficiency factor (F_{eff}). In terms of billion cubic feet (Bcf), this volume is:

$$V_{S,CO_2/CH_4} = GIP \times (CO_2 / CH_4) \times F_{eff}$$

or in terms of million short tons (MT):

$$V_{S,CO_2/CH_4} \times \rho_{S,CO_2} \times \frac{10^{+3}}{2,000}$$

or in terms of million metric tonnes (MMt):

$$V_{S,CO_2/CH_4} \times \rho_{S,CO_2} \times \frac{10^{+3}}{2,204.6}$$

where the CO₂ density at surface conditions of 60 °F and 14.7 psi (ρ_{S,CO_2}) is 0.11666 lbm/cf. The efficiency factor (F_{eff}) is assumed to be 65 percent throughout the project area; that is, the process of displacing coalbed methane by sequestering carbon dioxide is assumed to be 65 percent efficient for the purposes of this study (Advanced Resources, written communication, 2005). In reality, this efficiency factor would need to be determined by detailed study on site-specific areas.

Appendix L Nomenclature

Abbreviation	Explanation	Units
A	Area	Acres (ac)
CO ₂ /CH ₄	CO ₂ /CH ₄ replacement ratio	Unitless
D	Depth	Feet (ft)
F _{eff}	Efficiency factor	Fraction
G _c	Gas storage capacity	Standard cubic feet gas per ton of coal (scf/ton)
GIP	Gas-in-place	Billion cubic feet (Bcf)
h	Thickness	Feet (ft)
V _{S,CO2/CH4}	Surface volume of CO ₂ storage capacity	Billion cubic feet (Bcf)
ρ _{S,CO2}	CO ₂ density at surface conditions	Pounds-mass/cubic foot (lbm/cf)
ρ _{COAL}	Coal density	Short tons per acre-feet (t/ac-ft)

Appendix 13

Aquifer Characteristics Used to Calculate Carbon Storage Capacity in Colorado

Twenty-five formations were identified in the seven pilot study regions where significant carbon-emitting power plants are located. The Denver and Fort Morgan regions of the Denver Basin contain four candidates each, the Palisade and Rangely regions of the Piceance Basin contain three each, the Craig region of the Sand Wash Basin contains two, the Ignacio region in the San Juan Basin contains six, and the Cañon City region contains three. The aquifer characteristics for each formation are summarized in the following tables.

Canon City Jurassic Morrison Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	2,884	IHS Energy, 2004
Average thickness	feet	320	DERL, 2004
Porosity	percent	15.7 ¹	Mark, 1961
Permeability	millidarcies	31 ¹	Mark, 1961
Salinity	ppm	56,500 ²	COGCC, 2004b
Reservoir temperature	°F	144 ³	Dixon, 2004
Reservoir pressure	psig	2,691	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	1,300	Calculated
Sequestration capacity	Gt CO ₂	2.15	Calculated

¹ Data are from the Morrison Formation in North McCallum field in Jackson County.

² Data are from a well in Entrada Sandstone in Huerfano County.

³ Average of 3 wells completed in the Morrison Formation in Fremont County

Canon City Permian Lyons Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	2,922	IHS Energy, 2004
Average thickness	feet	240	DERL, 2004
Porosity	percent	4.4 ¹	Lysinger, 1961
Permeability	millidarcies	0.9 ¹	Lysinger, 1961
Salinity	ppm	6,293 ²	COGCC, 2004b
Reservoir temperature	°F	123 ³	Dixon, 2004
Reservoir pressure	psig	2,644	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	1,600	Calculated
Sequestration capacity	Gt CO ₂	0.654	Calculated

¹ Data are from Loveland field in Larimer County

² Below minimum concentration of sequestration calculator, so salinity of 10,000 ppm assumed

³ No data found; value is interpolated between adjacent formations

Canon City Permian-Pennsylvanian Fountain Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	3,068	IHS Energy, 2004
Average thickness	feet	3,460	DERL, 2004
Porosity	percent	7	Robson and Banta, 1987
Permeability	millidarcies	2	Daniels, 1982
Salinity	ppm	22,000	Stoddard, 1982
Reservoir temperature	°F	102 ¹	Dixon, 2004
Reservoir pressure	psig	3,984	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	1,600	Calculated
Sequestration capacity	Gt CO ₂	17.4	Calculated

¹ Average of two wells completed in the Fountain Formation in Fremont County**Craig Jurassic Entrada Sandstone Formation Characteristics**

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	2,560	IHS Energy, 2004
Average thickness	feet	170	DERL, 2004
Porosity	percent	20	Gibbs, 1982
Permeability	millidarcies	400	Grace, 1961
Salinity	ppm	13,277	Gibbs, 1982
Reservoir temperature	°F	133 ¹	Dixon, 2004
Reservoir pressure	psig	2,362	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	2,900	Calculated
Sequestration capacity	Gt CO ₂	3.95	Calculated

¹ Average of 26 wells completed in the Entrada Sandstone in the Sand Wash Basin.**Craig Pennsylvanian Weber Formation Characteristics**

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	2,512	IHS Energy, 2004
Average thickness	feet	330	DERL, 2004
Porosity	percent	11	Severy, 1961
Permeability	millidarcies	2	Severy, 1961
Salinity	ppm	29,430	Severy, 1961
Reservoir temperature	°F	139 ¹	Dixon, 2004
Reservoir pressure	psig	2,844	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	3,400	Calculated
Sequestration capacity	Gt CO ₂	4.4	Calculated

¹ Average of 68 wells completed in the Weber Formation in the Sand Wash Basin.

Denver-Fort Morgan Jurassic Morrison Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	2,353	IHS Energy, 2004
Average thickness	feet	250	DERL, 2004
Porosity	percent	15.7 ¹	Mark, 1961
Permeability	millidarcies	31 ¹	Mark, 1961
Salinity	ppm	2,300-96,000 ²	COGCC, 2004b
Reservoir temperature	°F	199 ³	Dixon, 2002
Reservoir pressure	psig	3,156	IHS Energy, 2004; DERL, 2004
Reservoir area – Denver	sq. mi	5,400	Calculated
Reservoir area – Fort Morgan	sq. mi	3,300	Calculated
Sequestration capacity – Denver	Gt CO ₂	6.5	Calculated
Sequestration capacity – Fort Morgan	Gt CO ₂	3.9	Calculated

¹ Data are from North McCallum field in Jackson County.² Salinity concentration of 90,000 ppm assumed for sequestration capacity calculations.³ Average of 8 wells completed in the Morrison Formation in Adams County.**Denver – Fort Morgan Jurassic Entrada-Dockum Group Formation Characteristics**

Parameter	Units	Value	Reference
Minimum depth to top of formation	Feet	2,290	IHS Energy, 2004
Average thickness	Feet	60	DERL, 2004
Porosity	Percent	15.7 ¹	Mark, 1961
Permeability	Millidarcies	31 ¹	Mark, 1961
Salinity	Ppm	4,800-18,000 ²	COGCC, 2004 b
Reservoir temperature	°F	199 ³	Dixon, 2002
Reservoir pressure	Psig	3,039	IHS Energy, 2004; DERL, 2004
Reservoir area – Denver	sq. mi	5,445	Calculated
Reservoir area – Fort Morgan	sq. mi	3,269	Calculated
Sequestration capacity – Denver	Gt CO ₂	2.0	Calculated
Sequestration capacity – Fort Morgan	Gt CO ₂	1.2	Calculated

¹ Data are from Morrison Formation in North McCallum field in Jackson County.² Salinity concentration of 10,000 ppm assumed for sequestration capacity calculations.³ No data found; value is from overlying Morrison Formation.

Denver-Fort Morgan Permian Lyons Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	Feet	3,106	IHS Energy, 2004
Average thickness	Feet	100	DERL, 2004
Porosity	percent	12	Clark and Rold, 1961b
Permeability	millidarcies	88	Clark and Rold, 1961b
Salinity	Ppm	32,000	Clark and Rold, 1961b
Reservoir temperature	°F	187 ¹	Dixon, 2002
Reservoir pressure	Psig	3,525	IHS Energy, 2004; DERL, 2004
Reservoir area – Denver	sq. mi	5,500	Calculated
Reservoir area – Fort Morgan	sq. mi	3,300	Calculated
Sequestration capacity – Denver	Gt CO ₂	2.3	Calculated
Sequestration capacity – feet Morgan	Gt CO ₂	1.4	Calculated

¹ Average of 19 wells completed in the Lyons Formation in Weld County.

Denver-Fort Morgan Pennsylvanian Fountain Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	4,083	IHS Energy, 2004
Average thickness	feet	1,220	DERL, 2004
Porosity	percent	7	Robson and Banta, 1987
Permeability	millidarcies	1-1.5	Levings and others, 1996
Salinity	ppm	180,000	Levings and others, 1996
Reservoir temperature	°F	241 ¹	Dixon, 2002
Reservoir pressure	psig	4,130	IHS Energy, 2004; DERL, 2004
Reservoir area – Denver	sq. mi	5,200	Calculated
Reservoir area – Fort Morgan	sq. mi	757	Calculated
Sequestration capacity – Denver	Gt CO ₂	9.7	Calculated
Sequestration capacity – feet Morgan	Gt CO ₂	1.4	Calculated

¹ Average of 3 wells in Weld County; value is outside the range of temperatures in sequestration calculator, so temperature of 210° F assumed.

Ignacio Cretaceous Mesaverde Group Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	Feet	2,866	IHS Energy, 2004
Average thickness	Feet	560	DERL, 2004
Porosity	Percent	11-13	Gandera, 1982
Permeability	Millidarcies	0.02-0.5	Bowman, 1978
Salinity	Ppm	26,000	Gandera, 1982
Reservoir temperature	°F	116 ¹	Dixon, 2002
Reservoir pressure	Psig	2,286	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	755	Calculated
Sequestration capacity – feet Morgan	Gt CO ₂	1.8	Calculated

¹ Average of 7 wells completed in the Mesaverde Group in La Plata County.

Ignacio Cretaceous Dakota Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	Feet	2,700	IHS Energy, 2004
Average thickness	feet	190	DERL, 2004
Porosity	percent	7.5	Bowman, 1961
Permeability	millidarcies	0.02-0.7	Bowman, 1961
Salinity	ppm	1,170-24,616 ¹	COGCC, 2004 b
Reservoir temperature	°F	203 ²	Dixon, 2002
Reservoir pressure	psig	2,769	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	1,300	Calculated
Sequestration capacity – feet Morgan	Gt CO ₂	0.7	Calculated

¹ Salinity of 20,000 ppm assumed for calculation of sequestration capacity.

² Average of 154 wells completed in Dakota Sandstone in La Plata County.

Ignacio Jurassic Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	3,016	IHS Energy, 2004
Average thickness	feet	660	DERL, 2004
Porosity	percent	13.5	Freethy, 1987
Permeability	millidarcies	10-20	Levings and others, 1996
Salinity	ppm	0-4,000 ¹	Levings and others, 1996; Treviño, 2003; Lyford, 1979
Reservoir temperature	°F	195 ²	Dixon, 2002
Reservoir pressure	psig	2,750	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	1,400	Calculated
Sequestration capacity – feet	Gt CO ₂	4.9	Calculated

¹ Below minimum concentration of sequestration calculator, so salinity of 10,000 ppm assumed.

² No data found; value is interpolated from adjacent formations.

Ignacio Jurassic Entrada Sandstone Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	2,737	IHS Energy, 2004
Average thickness	feet	150	DERL, 2004
Porosity	percent	22-26 ¹	Campbell, 1979
Permeability	millidarcies	150-450	Campbell, 1979
Salinity	ppm	>10,000 ²	Stone and others, 1983; Lyford, 1979
Reservoir temperature	°F	186 ³	Dixon, 2002
Reservoir pressure	psig	2,423	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	1,500	Calculated
Sequestration capacity – feet Morgan	Gt CO ₂	0.19	Calculated

¹ Porosity of 24 percent assumed for sequestration capacity calculation.

² Salinity of 10,000 ppm assumed for sequestration capacity calculation.

³ No data found; value is interpolated from adjacent formations.

Ignacio Pennsylvanian Hermosa Group Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	3,866	IHS Energy, 2004
Average thickness	feet	1,880	DERL, 2004
Porosity	percent	8	Mobil Oil Co., 1961
Permeability	millidarcies	10	Mobil Oil Co., 1961
Salinity	ppm	76,000-149,000 ¹	COGCC, 2004b
Reservoir temperature	°F	178 ²	Dixon, 2002
Reservoir pressure	psig	3,475	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	1,600	Calculated
Sequestration capacity – feet Morgan	Gt CO ₂	5.9	Calculated

¹ Salinity concentration of 150,000 ppm assumed for sequestration capacity calculation.² Average of 9 wells completed in the Hermosa Group in the Paradox Basin.***Ignacio Mississippian Leadville Limestone Formation Characteristics***

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	6,756	IHS Energy, 2004
Average thickness	feet	180	DERL, 2004
Porosity	percent	8	Mark, 1961; Cargile, 1978
Permeability	millidarcies	10	Cargile, 1978
Salinity	ppm	72,000	COGCC, 2004b
Reservoir temperature	°F	159	Dixon, 2002
Reservoir pressure	psig	3,996	IHS Energy, 2004; DERL, 2004
Reservoir area	sq. mi	1,600	Calculated
Sequestration capacity – feet Morgan	Gt CO ₂	0.771	Calculated

Palisade and Rangely Cretaceous Dakota Sandstone Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	Feet	2,530	IHS Energy, 2004
Average thickness	Feet	130	DERL, 2004
Porosity	Percent	14	Parker, 1961
Permeability	millidarcies	0-1,500	Parker, 1961
Salinity	Ppm	35,000	Parker, 1961
Reservoir temperature	°F	158 ¹	Dixon, 2004
Reservoir pressure - Palisade	Psig	2,216	IHS Energy, 2004; DERL, 2004
Reservoir pressure - Rangely	Psig	1,987	IHS Energy, 2004; DERL, 2004
Reservoir area - Palisade	sq. mi	2,900	Calculated
Reservoir area - Rangely	sq. mi	2,600	Calculated
Sequestration capacity - Palisade	tonnes CO ₂	1.6 billion	Calculated
Sequestration capacity – Rangely	tonnes CO ₂	1.4 billion	Calculated

¹ Average of 97 wells completed in the Dakota Sandstone in the Piceance Basin.

Palisade and Rangely Jurassic Morrison Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	2,483	IHS Energy, 2004
Average thickness	feet	680	DERL, 2004
Porosity	percent	16	American Metal Climax, 1961
Permeability	millidarcies	21	Amerada Petroleum, 1961
Salinity	ppm	2,300-96,000 ¹	COGCC, 2004b
Reservoir temperature	°F	156 ²	Dixon, 2004
Reservoir pressure - Palisade	psig	2,360	IHS Energy, 2004; DERL, 2004
Reservoir pressure - Rangely	psig	2,204	IHS Energy, 2004; DERL, 2004
Reservoir area - Palisade	sq. mi	3,200	Calculated
Reservoir area - Rangely	sq. mi	2,600	Calculated
Sequestration capacity - Palisade	Gt CO ₂	9.6	Calculated
Sequestration capacity – Rangely	Gt CO ₂	7.6	Calculated

¹ Salinity concentration of 100,000 ppm assumed for sequestration capacity calculation.

² Average of 335 wells completed in the Morrison Formation in the Piceance Basin.

Palisade and Rangely Pennsylvanian Weber Formation Characteristics

Parameter	Units	Value	Reference
Minimum depth to top of formation	feet	3,008	IHS Energy, 2004
Average thickness	feet	880	DERL, 2004
Porosity	percent	12.5	Hembree, 1961
Permeability	millidarcies	10	Hembree, 1961
Salinity	ppm	109,000	Hembree, 1961
Reservoir temperature	°F	152 ¹	Dixon, 2004
Reservoir pressure – Palisade	psig	4,311	IHS Energy, 2004; DERL, 2004
Reservoir pressure – Rangely	psig	2,919	IHS Energy, 2004; DERL, 2004
Reservoir area - Palisade	sq. mi	2,700	Calculated
Reservoir area - Rangely	sq. mi	2,600	Calculated
Sequestration capacity – Palisade	Gt CO ₂	9.5	Calculated
Sequestration capacity – Rangely	Gt CO ₂	8.5	Calculated

¹ Average of 147 wells completed in the Weber Formation in the Piceance Basin.

Appendix 14

Calculations for Silicate Mineralization Resources and Sequestration Potential

Resources

Ore resources were calculated from the areal extent of map units falling within a 40-mile radius of CO₂ point sources. Map units and area were extracted digitally from 1:250,000-scale geologic maps using ArcMap 8.3™. Rock units were grouped on the basis of rock type and average geochemistry. The basalt category includes all basaltic flows, plugs, and dikes. The mafic category represents all mafic and ultramafic bodies and includes gabbro (most extensive), diabase, pyroxenite, diorite, dunite, and the various high-Mg relatives of these rocks. Syenite is the predominant rock type in the alkalic igneous category. Most basalt outcrops are flows of only a few hundred feet, thus the estimated mining depth is about 200 feet. Mafic and alkalic igneous rocks are nearly all intrusive and are assumed to extend to a much greater depth. A mining depth of 500 feet may be somewhat conservative.

Region	Ore type	Areal extent (ft ²)	Assumed mining depth (ft)	Volume (ft ³)	Specific gravity (g/cm ³)	Tonnage factor (ft ³ /ton) ¹	Ore available (tons) ²
Cañon City	Basalt	94,689,624	200	18,937,924,723	3.0	10.67	1,775,430,443
	Mafic*	754,576,202	500	377,288,101,029	3.0	10.67	35,359,709,562
	Alkalic ign.	706,646,368	500	353,323,183,800	2.8	11.43	30,911,914,593
Craig	Basalt	77,828,145,926	200	15,565,629,185,224	3.0	10.67	1,458,821,854,285
	Mafic	1,299,310,887	500	649,655,443,667	3.0	10.67	60,886,170,915
Palisade	Basalt	521,533,303	200	104,306,660,642	3.0	10.67	9,775,694,531

¹Tonnage factor = 2000/(specific gravity*62.5)

²Ore available = volume/tonnage factor

Geochemistry

Rock geochemistry was extracted from the U.S. Geological Survey's national PLUTO database. Samples falling within potential pilot study regions were assigned to one of the three rock type categories described above and average geochemistry was calculated per category. There were no samples found in the Palisade region; geochemistry of the basalt there was assumed to be similar in composition to basalt in the nearby Craig region.

Region	Ore type	Si	Mg	Ca	Na	K	Fe2	Fe	Number of samples
Cañon City	Basalt	23.59	3.54	5.81	2.37	1.87	3.99	3.27	4
	Mafic	21.94	5.83	8.28	1.66	0.59	2.26	5.75	14
	Alkalic ign.	28.29	0.91	1.54	4.15	4.22	1.34	2.51	12
Craig	Basalt	22.86	3.85	6.12	2.16	2.23	3.34	3.66	31
	Mafic	21.53	7.61	5.94	1.51	0.46	5.24	5.12	5
Palisade	Basalt	22.86	3.85	6.12	2.16	2.23	3.34	3.66	0*

All values listed in weight percent

*assumed to be similar to basalt in Craig region

Equations

In order to determine sequestration potential it is necessary to know the total mass of each cation in the ore and the number of moles available for carbonation. Using the molecular weights listed below, the number of available moles can be calculated using equation 1. The carbonation reactions are equimolar, so multiplying the total moles available by the molecular weight of CO₂ gives the total theoretical mass of CO₂ that can be sequestered (Equation 2). Research has shown that available resources in Colorado are not as efficient as an experimental feedstock of pure olivine, which has an efficiency rating of 60 to 80 percent. Since olivine is only one of many constituents in a potential whole rock feedstock, such as gabbro or basalt, the efficiency rating of these rocks is accordingly lower. Herein, mafic and alkalic igneous rocks are assumed to have an efficiency of about 20 percent; basalt is assumed to be 15 percent efficient. Additionally, the volume of CO₂ emitted during the carbonation process has been shown to be roughly 25 percent of the theoretical mass of CO₂ sequestered. Equation 3 provides a refined estimate of CO₂ sequestration potential by taking into account reaction efficiency of the feedstock and CO₂ emitted as a result of energy consumed.

Molecular weights:

element	atomic (molecular) weight
Ca	40.078
Fe ²⁺	55.847
Mg	24.305
Na	22.990
K	39.102
CO ₂	44.010

1. **Cation mass and moles available for carbonation:**

Moles available lb·mole = [(ion concentration/100)(ore available lb)]/(molecular weight of the ion lb/lb·mole)

$$\text{Ex: } [(5.83/100)(100 \text{ lb})]/24.305 \text{ lb/lb·mol} = 0.24 \text{ lb·mole}$$

where Mg concentration = 5.83 and ore available = 100 lb

2. **Theoretical mass of CO₂ that can be sequestered:**

Theoretical Mass CO₂ lb = (sum of moles available for each ion lb·mole)(molecular weight of CO₂ lb/lb·mol)

$$\text{Ex: } (0.48 \text{ lb·mole})(44 \text{ lb/lb·mol}) = 21.19 \text{ lb CO}_2 \text{ sequestered}$$

(Ca + Mg + Fe)

3. Actual sequestration potential:

$$\text{Actual Mass CO}_2 = (\text{Theoretical Mass CO}_2)(\text{Rx})(75\%)$$

where Rx is the reaction efficiency of the ore material (roughly 15% for basalt; 20% for gabbro) and 75% represents CO₂ avoided (CO₂ sequestered minus CO₂ emitted during the sequestration process).

$$\text{Ex: } (21.19)(0.20)(0.75) = 3.2 \text{ lb CO}_2 \text{ avoided}$$

Appendix 15

Calculations and Water Quality for Produced Water Mineralization Resources and Sequestration Potential

Resources

Production figures for water were compiled from reports provided by the Colorado Oil and Gas Commission.

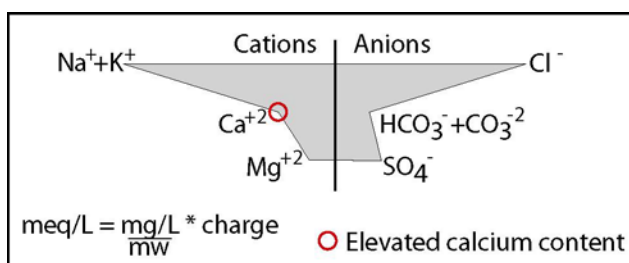
Region	Water production 1999-2003 (bbls) ¹	average annual production (bbls)	average annual production (liters) ²
Craig	111,207,488	22,241,498	2,652,009,449
Rangely	400,872,062	80,174,412	9,559,756,411
Palisade	7,427,088	1,485,418	177,116,738
Ignacio	122,468,468	24,493,694	2,920,554,544
Denver	44,205,985	8,841,197	1,054,197,807
Ft Morgan	70,236,515	14,047,303	1,674,958,268

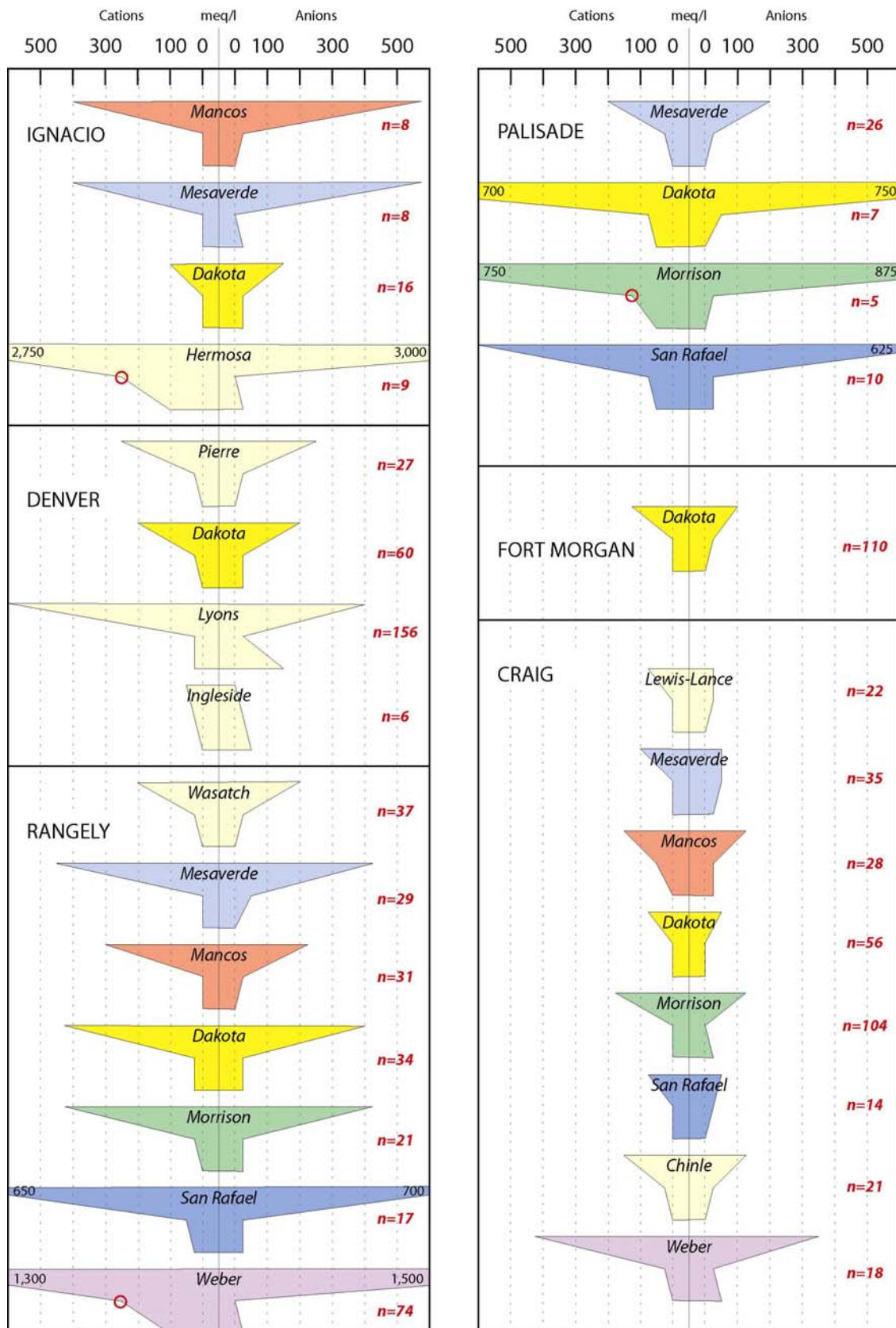
¹bbls = barrels

²1 barrel water = 119.237 liters

Water chemistry

Water chemistry for produced waters in potential pilot study regions was extracted from the U.S. Geological Survey National Produced Waters Database. Samples were first averaged according to the formation from whence they were produced. These averages are listed in the main body of this report and are also depicted on Stiff diagrams below. The cations appear on the left side of the diagram and the anions are shown to the right. Average values are in milliequivalents per liter (meq/L).





For the purposes of this report, it was deemed most practical to further average the samples according to pilot study region. This assumes that all produced water from the region will be commingled at a hypothetical carbonation plant and eliminates the need to keep waters produced from different horizons separate.

Region	Avg. Ca (mg/L)	Avg. Mg (mg/L)	Number of samples
Craig	246	41	298
Rangely	979	199	243
Palisade	1,295	352	48
Ignacio	1,752	488	41
Denver	264	70	249
Ft Morgan	36	13	110

Equations

In order to determine sequestration potential it is necessary to know the total mass of each cation in the water and the number of moles available for carbonation. Using the molecular weights listed below, the number of available moles can be calculated using equation 1. The carbonation reactions are equimolar, so multiplying the total moles available by the molecular weight of CO₂ gives the total theoretical mass of CO₂ that can be sequestered (Equation 2) assuming 100 percent efficiency. To date, there have been no estimates made of the energy requirements needed to complete this process; therefore, theoretical sequestration potential cannot be refined as has been done for the silicate mineralization process.

Molecular weights:

element	atomic (molecular) weight
Ca	40.078
Fe ²⁺	55.847
Mg	24.305
Na	22.990
K	39.102
CO ₂	44.010

1. Cation mass and moles available for carbonation:

Moles available g·mole = [(ion concentration mg/L)(water available L)]/(molecular weight of the ion lb/lb·mole)

Ex: Ca = [(246 mg/L)(1,000,000 L)] = 245,73400mg = 542 lb

$$(542 \text{ lb}) / (40.078 \text{ lb/lb}\cdot\text{mol}) = 13.52 \text{ lb}\cdot\text{mole}$$

where Ca concentration = 246 mg/L and water available = 1million L

2. Theoretical mass of CO₂ that can be sequestered:

*Theoretical Mass CO₂ lb = (sum of moles available for each ion
lb·mole)(molecular weight of CO₂ lb/lb·mol)*

$$\text{Ex: } (17.23 \text{ lb}\cdot\text{mole}) (44 \text{ lb/lb}\cdot\text{mol}) = 758 \text{ lb CO}_2 \text{ sequestered}$$

(Ca + Mg)