D. APPENDIX D

Sioux Ranger District Leasing EIS
Custer National Forest
Harding County, South Dakota

REASONABLY FORESEEABLE DEVELOPMENT SCENARIO FOR OIL AND GAS IN THE CAVE HILLS, SLIM BUTTES AND SHORT PINES AREAS

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CUSTER NATIONAL FOREST SIOUX RANGER DISTRICT – HARDING COUNTY, SOUTH DAKOTA REASONABLY FORESEEABLE DEVELOPMENT SCENARIO FOR OIL AND GAS

Introduction

This Reasonably Foreseeable Development Scenario (RFDS) describes the geology and the potential for petroleum occurrence in the Forest Service managed lands in Harding County, South Dakota. It also provides a forecast of petroluem exploration/development activities that could result from leasing of the federal mineral estate in a region where oil and gas production are already occurring. This information is required by regulation at 36 CFR 228.102, as part of the environmental analysis process for making a leasing decision, and by planning regulations (36 CFR 219.22) under which the Custer Forest Plan was developed.

The Custer National Forest's Sioux Ranger District is located in northwestern South Dakota. This area lies in the southern portion of the hydrocarbon-rich Williston Basin. This area is on trend and approximately 12 to 20 miles south east of the prolific Cedar Creek anticline. As of October 2001, there were five issued leases on Federal minerals in the Sioux that covered about 4,590 acres. All the leases are held by oil or gas production. The leases are located primarily in the North and South Cave Hills. There are 49 nominations of land for lease requesting over 45,000 acres (some of these requests overlap).

An RFDS has several parts. It predicts the potential for mineral occurrence based on the geologic information. It also predicts the potential for mineral development based on historical drilling trends, economic trends, and other factors that affect the rate of development. The assessment of development potential includes a drilling activity forecast which is an estimate of the type and amount of drilling and development activity which might take place should all legally available lands be allowed to be leased and developed. The drilling activity forecast is unconstrained in the sense that limiting factors such as lease stipulations, or the possibility that some areas may not be administratively available for leasing, are not taken into consideration at this stage of analysis. This RFDS also includes a prediction of possible well locations and a surface use forecast. The forecast of activity helps analyze the effect of the alternatives on the unconstrained RFDS. Various lease stipulations are applied which could preclude or alter the activity taking place in some areas. The RFDS also provides information for the analysis of effects of the Forest Plan and leasing decision on many resources such as wildlife, recreation, or air. It is a representation to the public and decision maker of the potential "on-the-ground" effects of a leasing decision.

Geology

Regional Synopsis

Harding County lies at the southern end of the Williston Basin, a large sedimentary & structural basin noted for its ample petroleum reserves. Inland marine seaways advanced into and retreated from the Williston Basin during the Paleozoic and Mesozoic Eras, beginning with Cambrian deposits (ca. 570 million years ago) and finishing late in the Cretaceous (ca. 66 million years ago). Tertiary sedimentary rocks are non-marine and consist predominately of mudstones and sandstones. This record of Earth history is contained in some 17,000 feet of sedimentary rock, made up of sandstone, shale, limestone, dolomite, and evaporites (halite and anhydrite). The stratigraphic column also includes unconformities (erosional or depositional breaks) and stratigraphic variations related to basin tilting, changes in sea level, and transgressive-regressive eposides. (Williston Basin location – RFDS–F1)

Petroleum exploration in the Williston Basin has generally targeted oil pools (some with associated gas). Gas fields are present in some areas. Hydrocarbon source beds accumulated during the Ordovician, Devonian, Mississippian, Pennsylvanian and Cretaceous Periods; reservoir rocks occur in many strata from the Cambrian Deadwood Formation through the Triassic Spearfish Formation. The Eagle and Judith River Formations (late Cretaceous) yield natural gas.

Historically, the most productive strata are those of the Madison Group (Mississippian) and Red River Formation (Ordovician). Other strata that have attracted interest include the Deadwood, Interlake, Duperow, Nisku, Bakken and Tyler Formations. (see stratigraphic column RFDS-F2)

Although coal beds occur in Sioux RD project areas, none are considered suitable targets for Coal Bed Methane (CBM) exploration (see stratigraphic column RFDS-F3). The coal beds are thin (less than ten feet thick), buried at depths less than 300'-500' (which is considered a minimum for economic methane exploration), and are exposed along the sides of North and South Cave Hills. The methane gas is liable to escape from coal beds that are exposed on or near the surface. Accordingly, CBM occurrence potential is judged as low to nonexistent.

Productive Strata

Two stratigraphic intervals yield hydrocarbons in northwestern South Dakota: Ordovician Red River Formation and Cretaceous Shannon Sandstone (member of the Eagle Formation).

Red River—These strata are dolomite and dolomitic limestones that originated as bioclastic mounds and tidal flat deposits. They include cyclic deposits of carbonate, evaporite, and organic-rich shale, and as such make up the critical association of reservoir, source and seal rocks. Major Red River oil accumulations are found on regional anticlines (e.g., Cedar Creek and Nesson) while smaller fields occur on local structures.

Shannon Sandstone—Upper Cretaceous sandstones yield biogenic gas from localized reservoirs; sub- or suprajacent, organic-rich shales are likely source rocks.

Existing Fields

The following fields account for the bulk of oil and gas production in Harding County. They are adjacent to leased and unleased federal minerals of the Cave Hills and Short Pines areas. (see figures RFDS – F4 & F5, source, South Dakota DENR)

Buffalo Field—Oil is produced from the Red River Formation at depths around 8,500 feet. Red River strata make up some 140 feet of the stratigraphic section at Buffalo Field. Three stratigraphic subdivisions (regionally named A, B, and C) are based on wireline log patterns. The productive B interval (36 feet thick) consists of light gray to dark brown, porous dolomite. Dolomite is sucrosic, fragmental, slightly argillaceous and anhydritic; B zone is strongly fractured. An overlying impermeable zone of massive limestone and dolomite averages 22 feet thick. The trapping mechanism is primarily stratigraphic, fostered by horizontal and vertical changes in porosity. The porosity averages 20%.

Production from the Red River has been improved in the past several years by horizontal drilling, waterflooding and fireflooding. Waterfloods inject water to increase reservoir presssure and sweep oil to producing wells. Firefloods enhance recovery by injecting air into the reservoir. The air sustains a combustion front which heats the reservoir and increases pressure which moves the oil toward the producing wells.

Development by horizontal drilling is forecast for Red River reservoirs. Water/fire flooding should enhance recovery.

West Short Pine Hills Field—Natural gas comes from the Shannon Sandstone Member of the Eagle Formation. The Eagle Sandstone is recognized by the Ardmore bentonite at its top and occurs at the eastern (or seaward) edge of shelf sandstone development as it grades into the Gammon shale. The limits of the gas reservoir are determined (1) stratigraphically by the amount of sand (compared to silt and shale), and (2) structurally by position of the gas/water contact (George Long, 1985).

The discovery well for West Short Pine Hills Field was completed in November 1977. Natural gas comes from untreated Shannon sandstone at 1,405-11 feet. Gas accumulated in porous/permeable strata draped over a structural high. Since its discovery, nine additional producing wells have been completed. The average depth to the producing zone is 1,465 feet and net pay thickness is 35-40 feet. The reservoir porosity averages 30%, with permeability at 35-40 millidarcies. The gas is composed of 95% methane; with the remainder ethane and carbon monoxide. The BTU content is between 956 and 960 (Petroleum Information Corporation, 1980).

The Shannon test wells will probably be drilled vertically.

Petroleum Occurrence Potential

The potential for petroleum occurrence in Harding County is a qualitative forecast based on the following categories from the BLM's handbook:

High Potential: The demonstrated presence of a mature source bed, suitable reservoir strata (containing adequate porosity and permeability) and traps into which petroleum has migrated.

Moderate Potential: The inferred presence of a mature source bed, suitable reservoir strata, migration pathways and traps with a hydrocarbon charge.

Low Potential: The inference that a mature source bed, suitable reservoir strata, migration pathways and charged traps may not be present.

All of Harding County is classified as having *high* potential for the *occurrence* of oil and natural gas. The High Potential ranking is based on the demonstrated presence of oil and natural gas in pooled accumulations, located at Buffalo, Yellow Hair, and West Short Pines Fields.

Geological Assessment of Individual Project Areas

North Cave Hills—A northwest-trending anticline holds oil at Yellow Hair Field. Other testable structures are not apparent. Off-structure, horizontal drilling may locate additional Red River stratigraphic reserves.

South Cave Hills—Contiguous with Buffalo Field (to SW). A major syncline trends NW-SE across the northeastern portion of area. Potential recoverable reserves may be located in southwestern portion of area, structurally above a predicted oil/water contact.

Slim Buttes—Regional homocline dips northeast: no obvious structural features to exploit. Horizontal drilling may discover a stratigraphic Red River accumulation.

West Short Pine Hills—Adjacent to West Short Pine Hills Field. A potential recoverable-gas reservoir may be located along the east side of area, above a gas/water contact.

East Short Pine Hills—Syncline (N-S) crosses the eastern area. To the west, a homocline dips east. Promising structural features have not been identified. There are possibilities of stratigraphic traps in Shannon Sandstone.

Factors Affecting RFDS Projections

Future oil and gas development in the Williston Basin will be influenced by a number of interrelated factors. First, there are economic trends such as oil and gas prices, national economic growth, and supply and demand. Second, there are technology and equipment trends such as technological advances and equipment supply. Third, past drilling trends can be used to predict future activity. Finally, past Forest Service, Bureau of Land Management, and State decisions such as land access and past leasing decisions can affect the rate and location of petroleum development. Events of the last 25 years indicate that some important aspects of the petroleum and natural gas industries are inherently difficult or impossible to predict. Despite uncertainties, the purpose of the following discussion is to identify and interpret those factors based upon the best available information.

Economic Trends

A primary source for the economic analysis is projections developed by the U.S. Department of Energy (DOE) in the Annual Energy Outlook 2002, published in December, 2001. The DOE's projections are not intended as prophecies. Instead, the projections provide scenarios of how energy prices might be with current energy policies and various assumptions for world and national oil prices, and supply and demand.

Oil Prices—Crude oil pricing is critical to future oil and gas development. The level of activity in the South Dakota portion of the Williston Basin varies with the price of crude oil as shown by Figure RFDS- F6. Uncertainty exists as to the future trend of crude oil prices but the Department of Energy (DOE) compiles a well-documented forecast annually. The most recent long-range projections published by the DOE forecast that world crude oil prices will gradually increase at 0.6 per cent per year as measured in 2000 dollars until the year 2020. Table RFDS-T1 shows base, low, and high world oil price scenarios, United States lower 48 oil price predictions, and lower 48 natural gas price predictions.

Regional price variations cause the actual prices received for oil and gas in Harding County to vary from the national average and the DOE price predictions for the lower 48 states. Also, oil prices may vary based on the type of contract. Portions of the Harding County oil are sold based on a NYMEX average price.

Table RFDS-T1. Price Predictions as of December 2001

Year	2000	2005	2010	2015	2020
	World Crude Energy Prices (2000 dollars per barrel)				
Base	27.72	22.73	23.36	24.00	24.68
Low Economic Growth Price	17.35		22.75	23.09	23.45
High Economic Growth Price	17.35		23.87	24.82	25.81
	United States Lower 48 Oil Prices (2000 dollars per barrel)				
Base	27.59	22.28	20.70	23.15	23.79
	Gas Wellhead Prices (2000 dollars per MCF)				
Base	3.60	2.66	2.85	3.07	3.26
Low Economic Growth Price	2.08		2.66	2.88	2.94
High Economic Growth Price	2.08		3.31	3.36	3.65
Source: Dept. of Energy, Annual Energy Outlook 2002 Lower 48 Oil – Table A15, Pg.145			World Oil Prices – Table A12, Pg. 142, Table B12, Page 170 Gas – Table A14, Pg. 144		

Other Economic Trends—Several other economic trends affect the path of future prices and thus the rate of oil development in the Williston Basin. These include the U.S. economy's rate of growth as measured by changes in the gross domestic product. In general, the greater the increase in the gross domestic product, the higher the demand will be for all energy. The 2002 DOE base case economic growth projections assume an annual growth rate of 3.0 percent per year between 2000 and 2020. Second, demand is another important economic trend that influences prices and petroleum development. It is linked to economic growth, but other factors such as price and environmental and national security issues will also affect demand. The 2002 DOE, Annual Energy Outlook forecast that petroleum demand would increase 1.4% annually through 2020. Other signals from economic trends affecting oil prices are mixed.

Natural Gas—Nationally, natural gas use and production are on upward trends that are expected to continue. The most recent long-range projections published by the DOE project gas wellhead prices will be gradually declining at -0.5 per cent per year as measured in 2000 dollars until the year 2020. Table RFDS-T1 shows base, low, and high gas wellhead price scenarios. As a note, other forecasts predict price increases due to a tightening of supplies.

Price Forecast—The above forecasts and trends do not take into account the potential for major disruptions in the world's oil supply, possible gas shortages, and the subsequent price changes. Because the price forecasts are mixed, this RFD is based on the expectations that prices will fluctuate as they have during the last fifteen years.

Technology and Equipment Trends

Advances in petroleum exploration, drilling and production technology have resulted in additional drilling in the Williston Basin. Advances in technology that have reduced the risk and cost of horizontal drilling have made wells to the Red River and other formations economical. Vertical wells could not effectively drain these reservoirs but horizontal wells can. Exploration techniques, such as 3-D seismic, have helped pinpoint additional drilling opportunities around

existing fields. Technology will continue to advance, causing new opportunities in the Williston Basin.

In the South Dakota portion of the Williston Basin, the advances in horizontal drilling have lead to advances in secondary recovery. Continental Resources Inc. has successfully initiated a fireflood to increase recovery in the Buffalo Field. "Fireflooding" involves injecting air into the Red River Formation to maintian an ***in-situ*** zone of combustion. The combustion front burns residual oil to maintain/increase reservoir pressure by generating "flu gas" and heat. The generation of flue gas, which is composed primarily of nitrogen, carbon dioxide, and steam, causes a pressure increase which helps the free oil in the reservoir flow to the producing wells. The gas and the heat also improve the mobility of the oil which increases overall oil recovery (Russ Atkins, Continental Resources, personal communication, 2002). The horizontal drilling has also increased production from more traditional waterflood operations.

The availability of conventional and directional (i.e. horizontal) exploration and development well-drilling personnel, equipment, and supplies, are a factor that influences the rate of oil and gas development. Availability of pipelines and transportation infrastructure also influences the rate of oil and gas development. The boom-bust cycles of petroleum development in the Williston Basin can cause local shortages of personnel and equipment associated with oil and gas exploration and development. The shortages are reflected in the delay between oil price increases and increased numbers of wells drilled.

Past Drilling, Production and Revenues

Over 14,000 wells have been drilled in the in the North Dakota portion of the Williston Basin from the discovery of oil in 1951 through 2000. Approximately 300 wells have been drilled in the South Dakota portion of the Basin.

The Federal government owns most surface lands and subsurface minerals within the boundary of the Harding County portion of the Sioux Ranger District. Thirteen wells have been drilled on the project area as shown in Table RFDS T-2. Three are currently productive. One well located adjacent to the boundary of the South Cave Hills unit drains federal minerals.

Table RFDS-T2. Wells Drilled in Sioux Project Area

Buffalo Field Wells located in South Cave Hills (or within spacing unit)

Koch # 34-26	26-21N-4E	SWSE	OIL	9/89 active producer
CRI # 24-36H	36-21N-4E	SESW	OIL	unknown – active producer that drains Fed. Minerals, surface location adjacent to FS
Meridian #14-30	30-21N-5E	SWSW	D/A	5/89

Yellow Hair Field Wells located in North Cave Hills

Mosbacher 1-1 Federal	1-21N-5E	NWSW	D/A	1/85
Luff # M-20-H Stearns	20-22N-5E	SWSW	D/A	82 or 83
Total 1-9 Fuller Canyon Fed	9-22N-5E	NENE	OIL	4/84 - active producer
Federal 1-10	10-22N-5E	NESW	SWD	Salt water disposal
Luff # 1-15 Sawmill Canyon	15-22N-5E	NWSW	OIL-P&A	11/81
Total # 1-16 Custer Federal	16-22N-5E	NENE	D/A	12/85
Sun Gregg # 1 Govt.	21-22N-5E	NWSE	D/A	2/56
Occidental # 1 Govt. Norreg	27-22N-5E	NENW	D/A	11/69
Journey Operating # 1-827	27-22N-5E	SENE	OIL	3/84 active producer
Journey Operating # 42-27	27-22N-5E	SENE	SWD	Salt water disposal on same pad as 1-827

West Short Pine Hills

Amerada #1 USA Ellis Tract	24-17N-1E	SESE	D/A	7/56

Annual production, revenues and royalties for the last five years are shown in Table RFDS – T3. Royalties ranged from a high of $105,000 in fiscal year 2000 to a low $61,000 in FY1999. Because the vast majority of land in the Sioux project area is Public Domain land, fifty percent of the federal royalties are shared with the State of South Dakota. The Forest Service manages approximately 74,000 acres of public domain land and nine acres of acquired land in Harding County, South Dakota. If the acquired lands were leased, royalties from those lands would be shared with Harding County. BLM manages 165 acres of split estate land in the project area.

Table RFDS-T3. Federal Production, Value and Royalties

Year	Oil Production Barrels	Minimum Royalty	Sales Value	Royalty Value
FY2001	27,684	$1,878	$788,804	$100,479
FY2000	33,039	-$241	$846,500	$105,812
FY1999	37,907	na	$491,157	$61,394
FY1998	37,667	-$2,235	$583,173	$72,896
FY1997	na	$2,014	$750,971	$93,870

FY = Fiscal Year, Federal fiscal year includes October through September

Agency Land Management Decisions

Oil and gas leasing decisions made by the Forest Service and Bureau of Land Management affect only a small portion of Harding County. The State of South Dakota requires a state drilling permit for all wells drilled in the state. Wells on private surface and private minerals are permitted and inspected by the state. Wells on private surface with federal minerals are permitted and inspected by the BLM in addition to the state. On Forest Service managed federal surface/federal minerals, Forest Service approval of the surface use portion of the federal permit is required. The Forest Service also establishes reasonable terms and conditions for the surface use portion of wells drilled to private or state minerals that lie under Forest Service managed surface.

Past agency land management decisions can affect the rate and the location of mineral development. Portions of the Sioux District were leased and drilled in the 1980's. The Federal Onshore Oil and

Gas Leasing Reform Act was passed in 1987 that said "The Secretary of Interior may not issue any lease on National Forest System Lands reserved from the public domain over the objection of the Secretary of Agriculture." These gave the responsibility for determining the leasing conditions to the Forest Service. No leases could be issued until NEPA analysis and a leasing decision was made. The Forest Service developed their regulations concerning oil and gas in the late 1980's and issued them in 1990. In the early 1990's Region One prioritized the areas for leasing decisions and made decisions for other higher priority areas. No leases have been issued since the 1980's.

Industry submitted nominations for lease for Sioux lands in the mid 1990's. Because of the nominations an EIS was started for the Sioux in 1996.

Reasonably Foreseeable Development Scenario

Site-specific reasonably foreseeable development (RFDS) scenarios are used to estimate effects of exploration, development, and production activity. The hypothetical well locations were projected based on historical oil and gas development information from the South Dakota Department of Environment and Natural Resources – Oil & Gas Section, other known geologic information, interpretation of the information by BLM and Forest Service geologists and engineers, economic trends, and technology trends.

A purpose of the RFDS is to provide a basis for analyzing and estimating environmental effects. Wells have been predicted in different biophysical settings throughout the Sioux. To the extent that the biophysical settings are the same or similar throughout the analysis area, the effects of the action(s) will be the same, or similar, if the development occurs at locations different than forecast in the RFDS. Therefore, the site-specific RFDS forecast can serve as the basis for leasing decisions for "specific lands" throughout the area of analyzed effect, regardless of whether a specific area was, or was not, forecast to be affected in the RFDS. It must be recognized that future exploration and development may not occur where predicted in the RFDS. The RFDS also provides a basis for analyzing and estimating social, and economic effects.

The steps required to formulate a reasonably foreseeable oil and gas development scenario (RFDS) for the Sioux include application of the assumptions described below in order to identify possible locations where oil and gas exploration and development could occur. This is only one of many possible scenarios. The probability of divergence between the RFD scenario and actual development increases the further into the future the projections are extended. Regardless of where development actually occurs, the effects of drilling and field development within any given biophysical area (or other grouping of lands with similar biophysical characteristics) are highly similar. Therefore, the effects of development in Sioux are known with sufficient precision to make the leasing decision.

The primary components of the RFDS are: (1) leasing forecast; (2) the drilling and development activity forecast; and (3) the surface use forecast.

Leasing Forecast

The following assumptions and background information were used for the unconstrained leasing forecast.

- Federal oil and gas mineral acres are 74,200 acres.
- As of October 2001, there were 4,590 leased Federal acres held by production (HBP). The assumption is made that these acres held by production will remain basically constant over the planning horizon.

The unconstrained leasing forecast is that lands in North and South Cave Hills and West Short Pine will be leased soon after the decision because of the proximity to existing production.

Lands in the Slim Buttes and East Short Pines Hills will be leased approximately half way through the analysis period of fifteen years. Once leases are issued, the lands will remain leased for 10 years. If oil or gas is discovered, the lease remains in effect as long as production in paying quantities continues.

Drilling, Development and Reclamation Activity Forecast

Predicted Amount of Drilling, Development and Reclamation - The estimate of drilling and development activity in the Sioux over the next fifteen years is based on:

- Projected economic factors as discussed above in Section "Economic Trends"
- Advances in technology
- Historical and current drilling activity in the Sioux project area

As discussed in the "Economic Factors" section of this report, it is impossible to definitely gauge future consumption patterns and oil prices that will affect drilling activity.

Petroleum Development Potential

Townships with active petroleum production are mapped as having *high potential* for oil and gas *development*. The remainder of Harding County is classified as *moderate development potential*. (See map RFDS-F7.)

There have been 210 wells drilled in South Dakota over the last 15 years, 1987 – 2001 (McGillivray, SD DENR, RFDS-F8). The majority has been in Harding County (SD DENR RFDS-F9). Advances in horizontal drilling technology have allowed industry to use fewer wells to develop reserves. Larger spacing units used during Red River Formation development in Harding County suggests that the overall number of wells drilled will drop. Spacing unit size has increased to one or two wells per section for the Red River compared to historical four wells per section (160 acres/well spacing). Development of gas reserves is predicted to remain at 160 acres/well. Based on these technology advances and historical drilling rate, 50 to 100 oil and gas wells are forecast to be drilled in Harding County over the planning period. There are 28 wells predicted to be drilled on Forest Service managed units in South Dakota.

Placement of Hypothetical Wells

Hypothetical locations for the 28 wells projected inside the Forest Service units were assigned using the following steps. At this stage of prediction, no consideration was given to ownership of minerals, past leasing decisions, or constraints imposed by the alternatives in the EIS. The assumption is that the majority of future drilling will be in the vicinity of proven production. These locations are forecast for analysis purposes only and may not reflect actual future development.

Hypothetical well locations were positioned within the North and South Cave Hills areas by the following assumptions:

- Hydrocarbons will be sought for and recovered from the Red River Formation at depths of approximately 8,000 - 9,000 feet.
- Production will come predominately from horizontal wells—wells drilled to follow productive intervals with the Red River.
- Spacing units along a synclinal axis in the South Cave Hills will not be attractive drilling targets. (See RFDS-F10 Contour Map.)
- Full field development includes producing wells and injection wells for waterflood or fireflood. Alternatively, selected production wells may be converted to injection wells at the end of their productive lives.
- Forecast development in the Red River Formation in South Cave Hills will emulate the fireflood field devlopment with spacing approximately one well per section.
- Forecast development for the Red River Formation in North Cave Hills will emulate waterflood field with spacing approximately two wells per section.
- Wells will be located in order to maximize the length of the horizontal leg; this means that most wells will be located in corner of a section and drilled on the diagonal toward the far section corner.
- Once production and reservoir characteristics have been confirmed, operators will follow a consistent pattern of development, i.e. spudding wells in a common section corner and drilling in consistent direction toward the oppossite section corner.
- Well locations have been adjusted for topography and accessibility. Accessibility is defined as to whether a road could reasonably be built to the location, not whether an access road already exists.

Vertical wells have been predicted for the other FS managed lands. Most vertical wells in South Dakota are drilled on 160 acre spacing units.

Hypothetical wells, including dry holes, producing wells and injectors, have been forecast for project areas based on trends of existing production technology and the present understanding of the petroleum accumulations. Locations are shown on maps, RFDS Figures 11 – 15. Wells were distributed according to the following Table RFDS-T4. The forecasted field development in the North Cave Hills is positioned on a possible structural high. Two dry holes were drilled in this area in the 1950's and 1960's. An economic well was drilled in 1984 but new horizontal drilling has not been done. While this is a "reasonable" location study the effects of possible field development, Figure RFDS-F16 shows alternate locations for the possible field development in the North Cave Hills.

Table RFDS-T4. Proposed Well Locations

Project Area	Dry Holes	Development/ Producing Wells	Injection Wells
North Cave Hills	0	6	6
South Cave Hills	0	7	2
Slim Buttes	4	0	0
West Short Pines	1	1*	0
East Short Pines	1	0	0
Totals	6	14	8

* gas

Production from Forecasted Fields

For the oil wells, the hypothetical rate of oil production was calculated based on a weighted average of typical decline curves from the common producing horizon. Representative decline curves were built for primary production from the Red River Formation. A typical Red River well is expected to produce some 200,000 barrels (more or less) of oil over its lifetime. This estimated volume assumes that the well is part of a secondary recovery unit, which may involve water or high-pressure air injection ("fireflood"). Both methods have been successfully used in Red River fields in this area (Harding County, South Dakota and Bowman County, North Dakota). A "possible" decline curve is included in Figure RFDS – F17. (Decline curve informaton compiled by Mike Nash, Bureau of Land Management, Dickinson ND)

Production of associated natural gas would be variable, depending upon the secondary recovery method employed. "Fire flooding" involves the ***in-situ*** combustion of residual oil to maintain/increase reservoir pressure and thus results in the generation of "flue gas." Flue gas, primarily nitrogen, has no known economic value. Otherwise, these wells may produce at a gas-oil ratio on the order of 500 cubic feet per barrel. Gas may be used on-lease to run production equipment, with any excess gas flared. If gas volumes are sufficient to make it economically feasible to connect to a gathering system, the gas may be sold. In either case, the oil production will provide the primary revenue stream.

Water may be produced at a rate of 1 to 2 barrels per barrel of oil. In the case of a fireflood (or in the absence of secondary recovery) this water will likely be disposed of into wells approved by the South Dakota Department of Environment and Natural Resources under the Underground Injection Control (UIC) program for saltwater disposal wells (SWD). If water injection is selected as the appropriate secondary recover method, all produced water will likely be reinjected into the producing formation to provide pressure maintenance.

Wells producing from the Shannon Sandstone (West Short Pine Hills) may average total production of approximately 400,000 thousand cubic feet (mcf). The volume of water produced with this gas is negligible. Any produced water would likely be disposed of by allowing it to evaporate in either lined or unlined pits.

Predicted Result of Drilling: Success Ratio - Over the last 15 years, 1987 – 2001, fewer than half of wells have found oil or gas in South Dakota. Approximately 42% percent of the wells drilled were/are producing or injection wells. Uneconomic producing wells may be converted to water or air injectors. (Personal conversation; John Bown, BLM Billings MT) The forecast ratio of producing or injection wells versus dry holes for the Sioux leasing analysis is higher than the state average in order to analyze the effects of potential field development.

Predicted Rate of Drilling – The rate of drilling is primarily determined by the price of oil and gas. Discoveries of new fields can also cause a the number of wells drilled in a year to increase while the field is being developed. For analysis purposes, we made the assumption that drilling would be relatively constant throughout the 15 year analysis period with one to two wells drilled per year on the Forest Service units.

Surface Use Forecast

Typically, producing wells/water injection wells on federal lands in the Williston Basin (Little Missouri National Grassland examples) disturb slightly less than 5 acres during the time the well is actively operating. (Norm Bishop, personal communication) The disturbance includes well pads and access roads. Pipelines and utility lines such as electricity or phone are usually buried in the road corridor. Production facilities are normally built on the well pads. Injection facilities such as pumping stations would probably be built off of federal lands. Once a well is plugged all disturbance is reclaimed with a year or two. Dry holes disturb approximately 5.7 acres and that is reclaimed within a year or two.

Factors that contribute to the total ground disturbance per producing well include:

- +2.40 acres for roads;
- +3.25 acres for well pad during drilling
- -0.75 acres of well pad is reclaimed between drilling and the production/injection phase
- 4.90 acres average ground disturbance per active well.

Hydrogen Sulfide gas has not been found to be a problem in wells drilled in Harding County, South Dakota. The State of South Dakota does not require monitoring or reports during or after drilling. (Personal communication: Gerald “Mack” McGillivray, 1996)

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