activities. As other primary resources (e.g., coal and oil and gas) are developed, aggregate would need to be produced to support these ongoing activities. New quarries and increased production from existing operations are expected. It is anticipated that these operations would vary in size based on the immediate need from the primary industries. However, based on the lack of specific information relative to related impact-causing parameters, these activities are not analyzed further in this analysis.

Based on current commodity forecasts as of June 2004, no specific uranium mine development is anticipated in the Wyoming PRB study area. Although some claims have been staked since that time, they are primarily land position plays with no specifically defined projects. As a result, RFD uranium mining has been eliminated from further consideration in this study.

It is assumed that bentonite mining would continue throughout the study period. It is anticipated that production would continue from existing active mines, with no new mines developed through 2020.

3.6.3 Data Sources

The information for past, present, and RFD sand, gravel, scoria, and uranium operations was obtained from public information available through WDEQ. Where operations are large enough to file annual reports, acreages of disturbance and reclamation were tabulated. Information relative to bentonite mines was based on WDEQ/LQD permit information and annual reports.

3.6.4 Assumptions

In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for sand, gravel, scoria, and uranium mines:

Past and Present Development: No assumptions relative to past and present sand, gravel, scoria, or uranium mines have been identified.

RFD:

- It is assumed that growth in demand for aggregates for use as construction materials would occur, while growth in demand for uranium may not occur.

3.7 Oil and Gas

3.7.1 Past and Present Development

3.7.1.1 Conventional Oil and Gas

Early oil exploration in the PRB was based on direct evidence of surface seeps or drilling anticlinal structures that were exposed on the surface. Oil was first produced from the PRB in 1887 from the Newcastle Formation on the east side of the basin near Moorcroft, Wyoming (MacGregor 1972). In 1889, oil seeps led to the discovery of oil production at Shannon Field on the north end of the Salt

Creek anticline. In 1908, the crest of the anticline was drilled resulting in the discovery of the Salt Creek Oil Field. Salt Creek had produced over 669 million barrels (bbls) of oil to the end of 2002 and is still in production. The discovery of Salt Creek led to the drilling of other large anticlines located on the southern periphery of the basin. Big Muddy was discovered in 1916, and Lance Creek was discovered in 1918 (WOGCC 2004).

During the 1930s, low prices depressed exploration in the basin. After World War II, a new round of exploration began with extensive use of seismic surveys to look for structural traps that could not be readily verified from surface mapping (McGregor 1972). Also in the early 1950s, stratigraphic trapping of oil was discovered in the Newcastle Sandstone on the east side of the basin. A number of other Cretaceous reservoirs formed by stratigraphic trapping were discovered in the 1950s, but with a few exceptions, drilling generally was confined to relatively shallow targets. In the late 1950s, oil production was found in sandstones of the Minnelusa Formation. Minnelusa production has been prolific over the years with the main production fairway being in the northeast part of the basin. However, the Minnelusa equivalents ("Leo" Sands) also produce on the southeast side of the basin. Pennsylvanian rocks also produce along the basin axis in the western part of the basin.

In the 1960s and 1970s, drilling moved into deeper parts of the basin that resulted in the discovery of some prolific oil fields in stratigraphic traps in upper and lower Cretaceous rocks (McGregor 1972). The discovery of giant Bell Creek in 1967 (reserves greater than 150 million barrels of oil from the Muddy Sandstone) on the Montana side of the basin set off a wave of exploration that resulted in a number of discoveries in Wyoming in the Muddy Sandstone (Drew 1990). Such Muddy fields included Recluse, Kitty, and Highlight. Drilling continued for deeper targets and resulted in the discovery of upper Cretaceous fields such as House Creek, Hartzog Draw, Holler Draw, and Jepson Draw, all characterized by long narrow reservoirs that were deposited as marine bars. Stratigraphic traps in upper Cretaceous rocks remained as prime targets for drillers in the late 1970s into the early 1980s with discoveries such as Well Draw and Scott Field, located in southern Converse County. The Minnelusa also provided a mainstay for wildcat drillers during that time period.

Very little conventional oil and gas activity has occurred in the last 15 years in the study area, and only approximately 1,500 wells were drilled from 1990 to 2003. The 1,500 wells include producing, injection, and wildcat (exploration) wells. The only significant discovery has been the African Swallow Field, discovered in 2000, which produced over a million barrels of oil and 14 billion cubic feet (BCF) of gas from two wells by the end of 2003 (WOGCC 2004).

As of the end of 2003, there were approximately 3,500 productive conventional oil and gas wells in the Wyoming PRB study area plus 1,386 seasonally active wells (IHS 2004). **Figure 3-5** shows the location of all wells (producing, non-producing, and plugged and abandoned). Approximately 13 million barrels of oil and 41 BCF of conventional gas (20.24 million barrels of oil equivalent [BOE]) were produced from these wells in 2003 based on WOGCC (2004) data; IHS (2004) data report approximately 13 million barrels of oil and approximately 40 BCF of conventional gas. The USGS (2002) estimated that the mean undiscovered non-coal bed hydrocarbon resource in the PRB (including Montana) is 1.8 BOE.

3.7.1.2 CBNG

CBNG activity began in the 1980s, however it took a number of years before commercially viable production was established. A total of three Applications for Permit to Drill (APDs) were issued in 1986 for CBNG wells in Campbell County (WOGCC 2004). The first commercial gas production directly from coal seams occurred in 1989 at Rawhide Butte north of Gillette (Debruin and Jones 1989). Annual submission of APDs did not exceed 100 until 1992 when 110 APDs were filed. By the late 1990s, after commercially viable production was proven, the number of APDs submitted began to soar: 561 in 1996, 808 in 1997, 1,494 in 1998, and 5,101 in 1999 (WOGCC 2004). In the 1-year period from June 2003 to May 2004, over 6,700 APDs were received statewide by the WOGCC.

The initial coal bed development in the early 1990s was concentrated in the area between Gillette and Wright, Wyoming, and State Routes (SRs) 59 and 50 in the Marquiss and Lighthouse project areas (Flores et al. 2001). The development soon moved out of that area and spread to the west and northwest. At the end of 2003, there were 14,758 producing CBNG wells in the study area (IHS 2004), and total production for 2003 was 346 BCF, or 88 percent of the total gas production from the basin (WOGCC 2004). From 1987 to 2003, the total cumulative gas production from PRB coals was over 1.2 trillion cubic feet. The total water production for the same time period was approximately 2.3 billion barrels. Annual methane production has increased rapidly since 1999 and appears to have started to level off or even decrease. Water production has decreased slightly; however, it still was more than 500 million barrels during 2003. In 2003, the average CBNG production was 900 million cubic feet per day (MMcfpd) (Holcomb 2003). CBNG production appears to have peaked from a high of 977 MMcfpd in October 2003 to 899 MMcfpd in March 2004 (Oil and Gas Journal 2004). CBNG wells in the Wyoming PRB study area as of the end of 2003 are shown in **Figure 3-5**.

3.7.2 Reasonably Foreseeable Development

Conventional oil and gas and CBNG development does not fit in the capital project likelihood of occurrence classifications as discussed in Section 2.1. Oil and gas exploration and development have inherent characteristics that set it apart from other capital projects. These characteristics include the following:

- The activities are conducted by multiple companies or entities;
- The activities cover broad geographic areas;
- Generally, permitting can take place in a relatively short time frame compared to other capital projects;
- The activities are extremely price sensitive and, therefore, hard to predict over long periods of time; and
- Technological advancements can be rapidly implemented resulting in sudden increases of activity in a relatively short period of time.

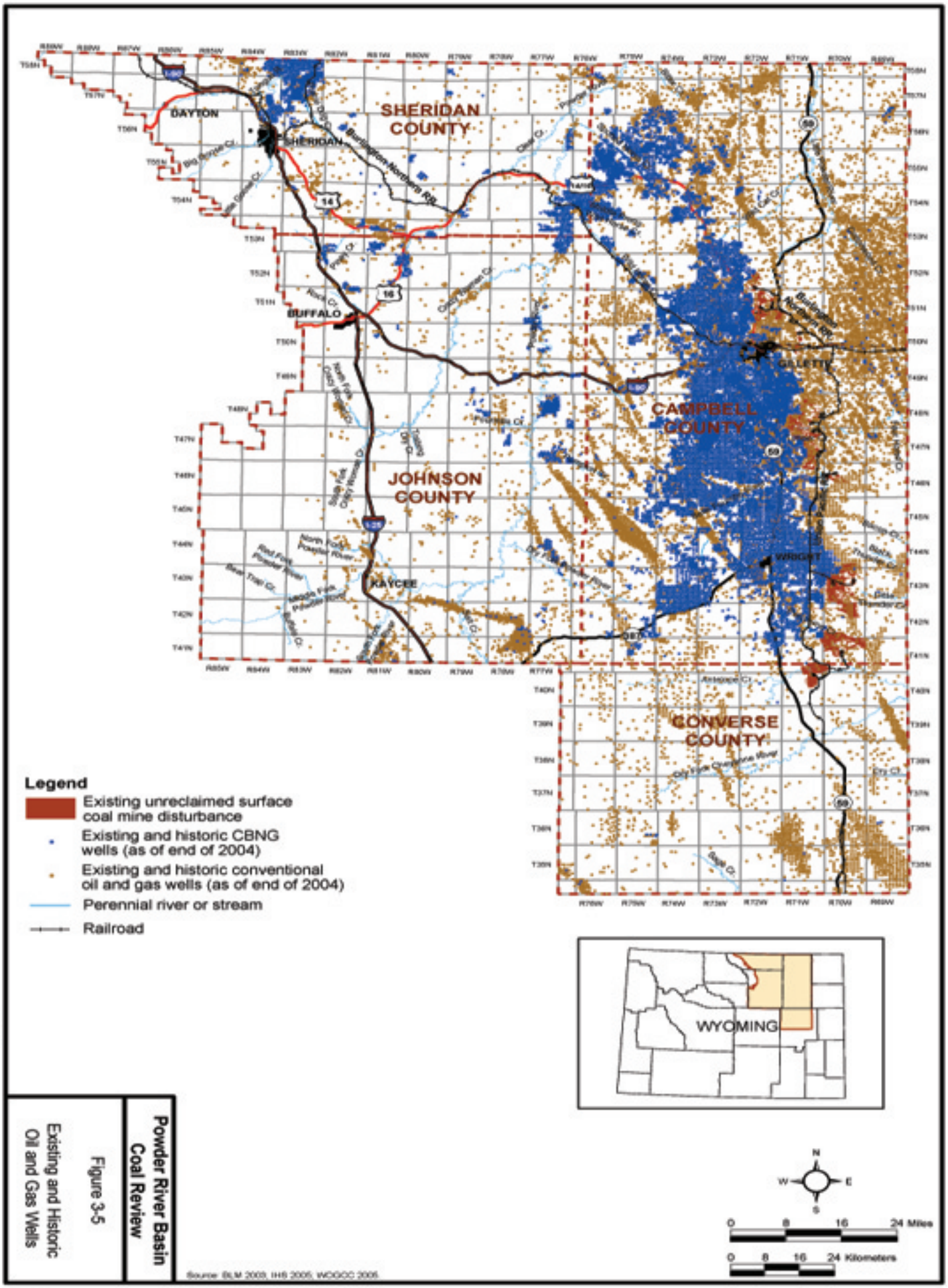

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Figure 3-5
Existing and Historic Oil and Gas Wells

Source: BLM 2003, IHS 2005, WOGCC 2005.

07/19/06

It can be said that the probability of new oil and gas activities (including CO_2 enhanced oil recovery [EOR] and associated pipelines) to occur in the future is a certainty, but the level of activity is uncertain. The following discussions of reasonably foreseeable activity for conventional oil and gas and CBNG are estimates of the level of activity that could be expected to occur, based on recent trends analyzed for this study and the methodology and assumptions presented in Appendix B.

3.7.2.1 Conventional Oil and Gas

Table 3-2 summarizes the projected production, number of wells, and long-term disturbance associated with conventional oil and gas development through 2020. From 1990 to 2004, a total of approximately 1,500 wells were drilled in the study area (IHS 2004). Of those, 60 percent were development wells drilled in established producing areas. The other 40 percent of wells were classified as wildcat wells or wells drilled outside of producing areas or wells drilled to test non-producing prospective zones in producing areas. Of the wildcat wells, about 75 percent were plugged and abandoned. From 1990 through 2003, new field wildcat wells resulted in the discovery of 61 new fields that provided 719,000 barrels of oil and 1.45 BCF of non-CBNG in 2003 (WOGCC 2004).

In a departure from the trend of the last 15 years, it is expected that the recent increase in oil prices would reverse the decline in oil production, with production increasing and peaking around 2010 at approximately 18.5 million barrels (BLM RMG 2005) (**Table 3-2**). (Refer to Appendix B for assumptions used in well number, production, and disturbance projections.)

The active wells identified in **Table 3-2** include wells that produce year-round, seasonally producing wells, and service wells (mainly injection wells). It is estimated that there are approximately 2,000 idle conventional oil and gas wells in the PRB study area (WOGCC 2005a); however, these wells gradually would be reduced in the future through aggressive plugging programs, and the idle well locations (once the wells are abandoned) would be reclaimed and no longer represent a disturbance.

Table 3-2
Projection of Conventional Oil and Gas Activity

Wells and Production	Existing	Projected		
	2003	2010	2015	2020
Annual Gas Production (BCF)	39.9	42.5	38.6	34.7
Annual Oil Production (million barrels)	12.9	15.9	14.4	12.9
Active Wells	4,852	5,392	4,904	4,414
Inactive Wells	1,994	954	563	332

A typical drilling location, including access road, is assumed to disturb approximately 2.75 acres. Long-term disturbance at existing well sites is assumed to be 2.0 acres following partial reclamation (BLM 2003a). If a well is abandoned, the entire disturbance area is reclaimed. If a well is productive, a portion of the disturbance area is reclaimed initially, with final reclamation occurring at the end of production. Based on these assumptions, **Table 3-2** shows the long-term disturbance at each of the benchmark years.

It is certain that conventional oil and gas exploration and development would continue, but at a rate far below previous levels in the basin's history. If the trends of the last 10 to 15 years are indicative of future activity, conventional oil and gas would continue to be produced but at ever decreasing rates.

The USGS (2002) estimated that the mean undiscovered non-coal bed hydrocarbon resource in the PRB (including Montana) is 1.8 billion BOE. This number indicates that the PRB, as well as the study area, has a potentially important non-coal bed hydrocarbon resource base. Whether that resource is exploited is dependent upon a number of factors. At present, the economics favor the shallow and easier exploitable CBNG resource. The low oil prices and preferential investment in CBNG resources probably has resulted in the investment into other plays in the basin, with an associated decline of oil and non-CBNG activity over the past 15 years. If the non-coal bed resource is to be exploited to any great degree in the future, industry would have to invest in those plays. As the CBNG play moves into maturity, and if oil prices stabilize over $45 per barrel, then oil and non-CBNG resources potentially could become attractive exploration targets. However, it is not likely that the PRB ever would reach a producing rate of 30 million barrels of oil per year again (BLM 2001).

As of the end of 2004, there were no readily available data concerning incremental production data from CO_2 flooding (WOGCC 2004). There is a potential for additional EOR activity in the study area, but so far the projects that have been conducted are pilot scale and involve the "huff and puff" process whereby the gas is brought to individual injection wells by tanker truck. Possible EOR candidates in the PRB include Harzog Draw, House Creek, Hilight, Raven Creek, Rozet, Kitty, Gas Draw, and Recluse Fields (DeBruin 2001). These fields could qualify for EOR because they had 50 million barrels or more of original oil in place; however, many smaller fields also could qualify. The potential for additional EOR activity would be dependent upon the availability of a CO_2 source. Wyoming has a large resource of CO_2 produced from the La Barge Anticline in the Green River Basin. There also are abundant CO_2 resources at the Madden Unit in the Wind River Basin. In total, Wyoming has a CO_2 production capacity in excess of 500 MMcfpd (DeBruin 2001). Pipelines would need to be constructed to transport this available CO_2 into the PRB (see Section 3.8, Pipelines). The State of Wyoming has a severance tax break of 2 percent on oil produced from WOGCC-approved CO_2 EOR projects to encourage producers to take advantage of the CO_2 resource and to encourage oil production. However, there are no proposals to extend the CO_2 pipeline that ends at Salt Creek and Sussex Fields in the near term (the next 5 years). The likelihood rating of any such CO_2 EOR project would be low, since the CO_2 pipeline at Salt Creek originally was proposed to end at Hartzog draw (DeBruin 2002).

3.7.2.2 CBNG

The future of CBNG development is highly sensitive to the price of gas. For a number of years, Wyoming natural gas production has been affected by the so-called price differential. The price differential is the difference in the gas price at the Opal and Cheyenne hubs in Wyoming and the national benchmark price recorded at the Henry Hub in Louisiana. The differential results when there is inadequate pipeline capacity to move Rocky Mountain region gas to markets outside of the area. Historically, the differential has been as high as $2.40 per million British thermal units (MMbtus) (Holcomb 2003) (1 Mcf is roughly equivalent to 1 MMBtus). This disparity in price has resulted in an estimated loss of more than $2 billion dollars to producers and attendant fiscal impacts for state and federal governments (Holcomb 2004). The lack of interstate pipeline

transmission capacity in Wyoming is cited as the major reason for the price differential. The differential was somewhat eased in 2003 with the opening of the Kern River Pipeline expansion that moves gas from southwestern Wyoming, northwestern Colorado, and northeastern Utah. At that time, the differential went from $1.86 per MMbtus to $0.60 per MMbtus (Holcomb 2004). However, the addition of the Kern River system capacity did not completely solve the differential problem.

The consequences of the price differential were researched by Advanced Resources, International (ARI) (2002). ARI evaluated the impacts to the CBNG resource associated with various water disposal methods. ARI (2002) also evaluated the effects of three price scenarios on the CBNG resource as follow:

- Under a status quo price scenario (basin price differential of $1.80 per Mcf), the economically recoverable CBNG resource only would be 1.5 trillion cubic feet (Tcf), with the primary water disposal option being surface discharge. No other disposal options were economical under this price scenario. ARI (2002) states that much of this development already has occurred, and if the differential doesn't change, not much increase in development would be expected.

- In a transitional price scenario, where the basin differential narrows to $0.80 per Mcf after a number of years and beyond, variable amounts of the resource would be economical for a number of disposal options. Under this scenario, the economically recoverable resource ranges were projected to be 22.4 Tcf with surface discharge, 20.0 Tcf with impoundment infiltration, 18.8 Tcf with shallow re-injection, and 7.1 to 10.2 Tcf with active treatment.

- In the third scenario, the basin differential immediately would go to $0.80 per Mcf. Under this scenario, the economically recoverable resource ranges would be 29.1 Tcf with surface discharge, 27.8 Tcf with impoundment infiltration, 27.1 Tcf with shallow re-injection, and 17.8 to 2.6 Tcf with active treatment.

In the Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project (BLM 2003a), the preferred alternative favored the disposal of produced CBNG water in infiltration impoundments to be accompanied by groundwater and surface water monitoring, except in the Belle Fourche and Cheyenne River drainages where direct discharge to ephemeral streams was allowed. The disposal of produced coal bed water in infiltration impoundments would fit with the second or third ARI scenarios described above. The recoverable CBNG resource would be in the range of 20 to 29 Tcf if the price differential remains at $0.80 per Mcf or less, and gas prices in general remain at reasonable long-term levels ($3.56 per Mcf or equivalent to crude oil at $25 per barrel). In spite of recent record highs for crude oil, the long-term forecast (10 years or more) for crude oil prices is expected to be around $25 per barrel (Winnecke 2003). The size of the differential would be dependent upon the magnitude of production capacity in the Wyoming PRB and available pipeline capacity to deliver the gas to external markets. As a comparison to the ARI estimate, the USGS (2002) estimated that the undiscovered CBNG resource in the PRB is 14.3 Tcf.

The amount of CBNG activity appears to be at a lower rate than was forecast by earlier projections in the Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project (BLM 2003a). New CBNG well numbers fell from a high of slightly more than 4,600 in 2001 to approximately 2,000 in 2004. It is anticipated that the number of new wells would increase so that between 2005 and 2020 the number of new wells drilled per year would

range between 2,700 to 2,800. (Refer to Appendix B for assumptions used in the analysis of CBNG activity.) As shown in **Table 3-3**, there would be 24,874 CBNG wells by 2010, much lower than the over 40,000 wells predicted for the same time period in the Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project (BLM 2003a). It is anticipated that production would increase from the 338 BCF per year observed in 2003 to approximately 554 BCF per year in 2010.

Table 3-3
Projection of CBNG Activity

Wells and Production	Existing	Projections		
	2003	2010	2015	2020
Annual Production (BCF)	338	554	530	521
Active Wells	14,758	24,874	24,063	23,821

3.7.3 Data Sources

The data and information for conventional oil and gas and CBNG resource development projections were derived from several sources including: WOGCC on-line well files, BLM public documents, IHS well data, Wyoming Geological Survey publications, and the BLM Wyoming State Office Reservoir Management Group (RMG).

3.7.4 Assumptions

Assumptions relative to past and present and reasonably foreseeable oil and gas activity are presented in Appendix B.

3.8 Pipelines

3.8.1 Past and Present Development

Major transportation pipelines for the transport of product to outside markets are a key factor in the development of CBNG and conventional oil and gas resources in the Wyoming PRB study area. Major transportation pipelines also provide for transport of CO_2 to crude oil well fields, which depend somewhat on the availability of CO_2 for EOR. Currently, there are 13 major transportation pipeline systems in the PRB that transport gas resources to markets outside of the basin (Flores et al. 2001). The current capacity of these pipeline systems is 1.9 BCF per year. Currently, the combined natural gas production (CBNG and conventional gas) in the Wyoming PRB study area is approximately 1.06 BCF. As shown in **Figure 3-6**, there also are numerous oil, gas, and products pipelines in the study area. Gathering lines associated with conventional oil and gas and CBNG development also occur within the study area. For purposes of this study, these gathering lines have been factored in proportionally on a per well basis as discussed in Appendix B.