# APPENDIX B

# METHODOLOGY AND ASSUMPTIONS FOR OIL AND GAS RFD PROJECTIONS

# 1.0 GENERAL INFORMATION

Primary Data Source: IHS (2004) data files were sorted by the BLM for use in this study. Two IHS data files were used to establish the existing level of oil and gas development in the Wyoming PRB: one for production and one for all wells. Both files covered all of Campbell, Johnson, and Sheridan counties. All of Converse County also was provided, but only wells identified as part of the PRB study area were considered in the analysis. Production data provided information on producing wells in the study area for the period of December 1, 2003, to December 1, 2004, according to permit number. The earliest information provided in the production file was from 1974. The other file ('*all well*') provided information on location (latitude/longitude), completion depth, and initial target product for all wells within the study area. In order to eliminate duplication between the two data files, location information (latitude/longitude) from the *all well* data was applied to wells in the production file, identical wells were identified by comparing American Petroleum Institute (API) numbers, and all wells were mapped and 4$^{th}$ level watersheds (subwatersheds) assigned through the GIS.

Secondary Information Source: The WOGCC (2005b) web site provided a current searchable CBNG database, which was used during this analysis for production comparisons. It also provided mineral rights ownership on a well-by-well basis, which was spot-checked against mapped mineral ownership information.

Tertiary Information Source: BLM and WOGCC. BLM information concerning projected federal APDs for CBNG, the rate of APDs that actually become wells, information on CBNG production lives, and mineral rights ownership was used in this study. The WOGCC provided information concerning potential numbers of inactive conventional wells that may be present in the study area.

The following sections describe the methodology and key assumptions used in developing the database of past, present, and reasonably foreseeable oil and gas development in the Wyoming PRB.

# 2.0 2003 PRODUCTION DATA DETERMINATION

The production file (IHS 2004) included well locations, well types, and initial production date as well as production data from 1990 to 2004. In order to normalize the data for 2003, allowing consistency with the timeline for the remainder of the PRB Coal Review Task 2 past and present data, only wells listed as first producing prior to 2004 were considered in the analyses. Wells were plotted and assigned subwatershed locations using GIS, then identified as conventional wells or CBNG wells based on well types and production information (only gas wells not producing oil within the IHS file time frame were considered to be CBNG; injection wells not producing any oil or gas were not included with either grouping). The number of active versus inactive wells was determined for each production type and subwatershed. Conventional wells designated as inactive were determined to be either shut-in (destined for plugging and abandonment) or seasonally active. Seasonally active wells were categorized separately (see Section 5.0 for further discussion). CBNG wells designated as inactive were determined to be drilled and ready to produce (Eggerman 2005), and were therefore lumped with active wells for current and future calculations.

Production (baseline and cumulative) information was developed for wells grouped by subwatershed and well type. Because information in the IHS data was limited to 1990 through 2004, wells within these groupings were then analyzed by BLM for cumulative and yearly production since 1974. Cumulative data included all production through 2003.

Assumptions;

1) Wells not showing a history of oil production in the IHS file and did not produce oil in the past, and are CBNG wells, with the following exception. There are a small number of conventional gas wells that produce from sandstones in the Fort Union Formation (Randall 1989). The number of these wells reported by Randall (1989) was 37, and the source of the gas was reportedly from coal seams. These wells were deemed insignificant when compared with the total number of CBNG wells in the study area.
2) Historic wells included in the IHS *all wells* file, but not included in the IHS production file, were assumed to be conventional wells.

# 3.0 ESTIMATE OF CONVENTIONAL OIL AND GAS WELLS DRILLED PER YEAR

Numbers of conventional wells drilled since 1990 were determined using the IHS *all wells* file. Only wells with a completion date between December 31, 1989, and the present (2003) were used in this analysis. Also, only wells that were located in T34N through T58N were used. Only wells deeper than 2,000 feet were considered to be conventional oil and gas wells. A breakdown according to the well classification provided in the IHS data file (e.g., plugged and abandoned [P&A], wildcat, injection, etc.) subsequently was performed. The final result was an estimate of 100 conventional oil and gas wells drilled in the PRB per year from 1990 through 2004.

Because estimating future activity in the region based on past activity did not account for recent increases in oil prices (which may cause an increased interest in oil in the region), or the potential for reactivating dormant wells, the future estimate was based on the predicted number of operating conventional wells in the region. Numbers of predicted operating wells were based on the expected numbers of operating wells per year taken from a graph provided by the BLM Reservoir Management Group (RMG) (2005), which accounts for the potential increase in oil and gas production in the region based on increasing oil price estimates (based on changing percent increases or decreases in wells) (see **Table B-1**). Unanticipated future price fluctuations could affect (increase or decrease) future well projection numbers. The previous year estimate of active wells was multiplied by the indicated factor to estimate the current year number of active wells. The numbers of historic wells used by the BLM RMG closely tracked with the number of wells from the IHS database designated as crude oil, but production information and well counts produced for this study also included the wells designated as gas, oil, or injection that had produced oil. The year the additional wells came on line was determined, and they were added to the historic numbers from the BLM RMG (2005) based on these dates. Therefore, the historic active well numbers were adjusted upward based on the number of those wells that came on line each year. All wells operating prior to 1974 were added to 1974. Future well numbers then were projected.

**Table B-1**
**Changes In Projected Number of Operating Conventional Wells**

| Years | Increase or Decrease | Percent |
|---|---|---|
| 2005 | Decrease | 1 |
| 2006-2009 | Increase | 5 |
| 2010-2012 | Decrease | 2 |
| 2013-2020 | Decrease | 3 |

The number of projected new wells each year was estimated based on the assumptions that the P&A rate of operating conventional wells is 10 percent, and the percent of new wells drilled that are unsuccessful (therefore P&A) is 40 percent (IHS 2004). Wells that are not P&A were assumed to be producing. This equation follows:

*New active wells = 0.6 x current year new wells – 0.9 x previous year active wells*

Assumptions:

1) Wells located in T34N through T58N are within the PRB study area.
2) All shallow wells (completion depth of less than 2,000 feet) are CBNG wells.
3) The PRB will see a short-term increase in the number of operating wells in the region, followed by a slow decline.
4) Forty percent of wells drilled will be nonproductive and P&A within that year, and an additional 10 percent of active wells will be P&A each year.

# 4.0 ESTIMATE OF FUTURE P&A CONVENTIONAL OIL AND GAS WELLS RELATIVE TO THE TOTAL NUMBER OF WELLS

For the last 15 years, the percent of new wells that have been drilled and P&A in the study area has been 40 percent (IHS 2004). This includes all classifications of wells: wildcats, development wells, and injection wells. The number of wells P&A in each subwatershed was determined by year from 1990 to 2004 using the IHS *all wells* file. Historically, the mean percent of P&A wells relative to the number of active wells was 1.6 percent (IHS 2004). This ratio was applied to yearly totals of conventional wells to estimate the number of P&A wells for the years 2004 to 2009. Because the predicted decline of active wells between 2010 and 2020 (BLM RMG 2005) required an increase in the number of P&A wells, the P&A rate was adjusted to equal the decline rate of those years plus 0.5 percent. The sum of the new P&A wells and the operating P&A wells was the total for each year.

Assumptions:

1) Forty percent of new wells are unproductive and P&A within the first year after drilling.
2) Decline rates were based on data provided by BLM RMG (2005).
3) The wells to be abandoned will not depend on geographic location.

# 5.0 ESTIMATE OF THE NUMBER OF FUTURE ACTIVE, INACTIVE, P&A, AND TOTAL CONVENTIONAL OIL AND GAS WELLS

The estimated number of P&A wells was based on the number of new wells multiplied by a factor of 0.4 (which is the approximate rate of new wells closed within the first year of operation based on oil field data within the area), plus the previous year's cumulative total wells and the current number of inactive wells multiplied by a factor of 0.1. The following equation was used:

*P&A wells = (previous years cumulative wells x 0.100) + (new wells for year x 0.4) + (0.1 x inactive wells)*

The number of cumulative wells was determined based on the sum of the previous year's cumulative wells plus the new wells. The following equation was used:

*Cumulative wells = (previous year's cumulative wells) x (1-0.100) + new wells for year*

The number of inactive wells (over 3,000) for the baseline year was determined using the IHS production file. According to WOGCC (2005b), it is possible and reasonable that the number of shut-in wells in the region could be estimated at 2,000. The remaining wells could be considered to be seasonally active, but may not have been listed as active in the IHS production database, because the information was downloaded during winter months while these wells were inactive. Because locating individual shut-in or seasonally active wells was not realistic; wells reclassified as seasonally active (about 1,000 wells) were removed from the inactive category and distributed throughout subwatersheds proportionally to the number of active wells. Future rates of seasonally active wells were estimated to remain constant, while a yearly P&A rate of 10 percent was applied to the remaining inactive (shut-in) wells.

Assumptions:

1) Approximately 2,000 truly inactive (shut-in) wells exist within the PRB study area. Remaining wells designated as inactive in the IHS database are actually seasonally active. These wells were distributed proportionally to the active wells in the region.

# 6.0 ALLOCATION OF FUTURE CONVENTIONAL OIL AND GAS WELLS BY SUBWATERSHED

The number of wells drilled per subwatershed was determined by year from 1990 to 2004, using the IHS *all wells* file and GIS. The mean ratio of wells drilled per subwatershed relative to the basin-wide total number of wells was determined for this period, and the mean ratio was applied to the estimated future total number of wells to distribute them throughout the subwatersheds.

Assumptions:

1) The future distribution pattern of wells by subwatershed will be similar to past and present distribution patterns.

# 7.0 ESTIMATE OF THE RATE OF P&A CBNG WELLS PER SUBWATERSHED PER YEAR

Because CBNG in the PRB is a relatively new play, past P&A rates of CBNG wells in the region is not an accurate predictor for future rates. Also, due to changes in technology and drilling depths, previous estimates of well life at 7 years may be too low. Current rates of unsuccessful wells drilled in the region are 4.1 percent (BLM RMG 2005). Estimated rates for plugging and abandoning successful wells were based on well age, with the majority of wells ending their productive lives at 10 years (**Table B-2**).

**Table B-2**
**Expected Lifespan of CBNG Wells**

| Age of Well (year) | Percent of Active Wells for Year Expected to be P&A |
|---|---|
| 8 | 10 |
| 9 | 20 |
| 10 | 30 |
| 11 | 30 |
| 12 | 10 |
| **Total** | **100** |

P&A wells were distributed among the subwatersheds based on the proportion of active wells in the subwatershed. Wells were further subdivided by oil and gas mineral ownership proportionally to the ownership distribution of the previous years active wells.

Assumptions:

1) It is assumed that abandonment rates of new wells will be 4.1 percent (BLM RMG 2005).
2) Wells will be P&A between 8 and 12 years after they start producing, with the majority of wells abandoned after 10 years of operation (BLM RMG 2005).
3) The distribution pattern of abandoned wells between subwatersheds will be proportional to the numbers of active wells in the subwatersheds.

# 8.0 ESTIMATE OF THE FUTURE RATE OF CBNG WELLS DRILLED PER SUBWATERSHED PER YEAR

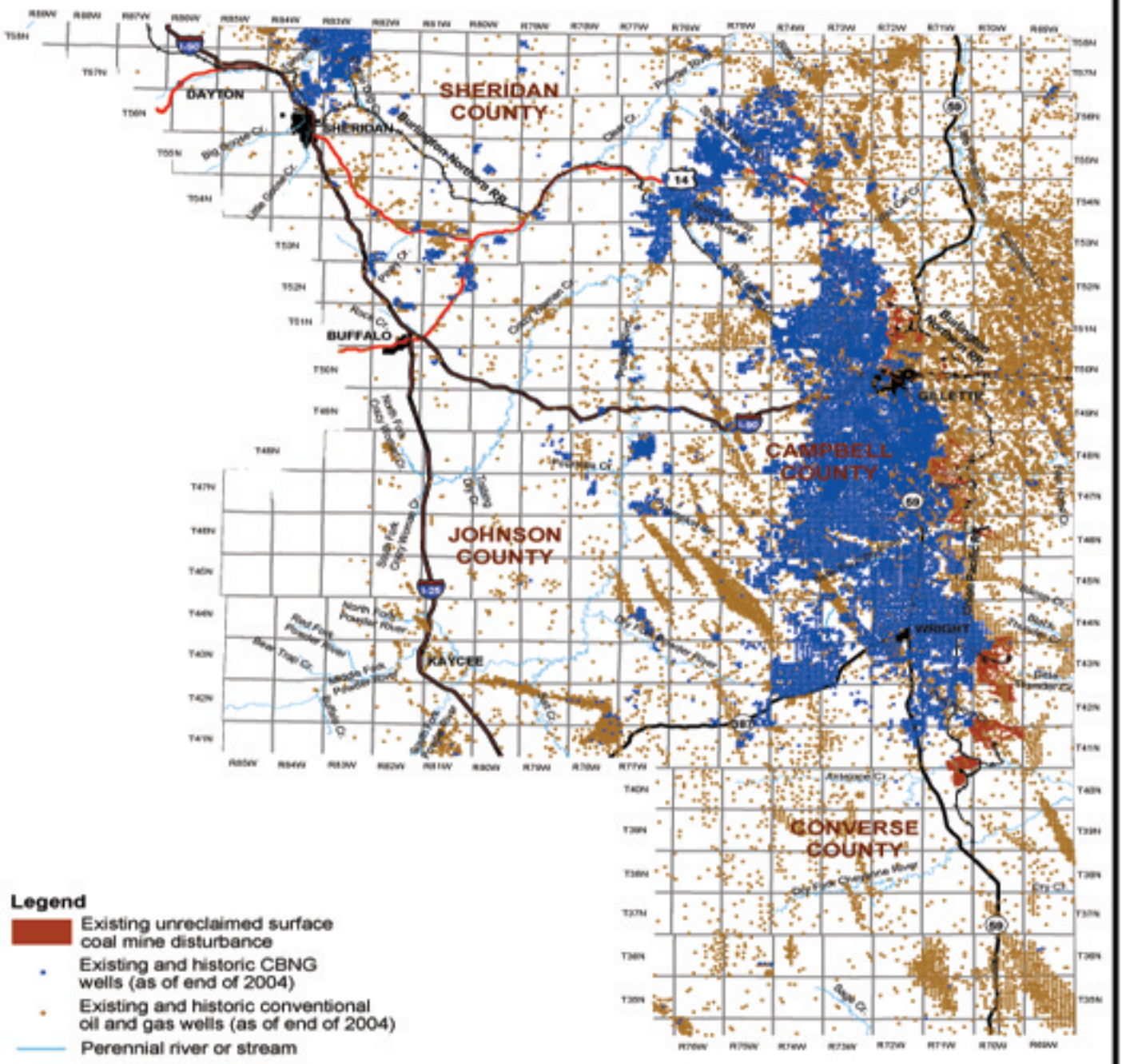
The number of CBNG wells drilled per subwatershed between 1990 and 2004 was determined from the IHS *all wells* file, based on the dates the wells went on line and the dates the wells were completed (the numbers were within 0.1 percent of each other). The total number of wells drilled from 2002 to 2004 was compared to future estimates presented in Table 2-1 in the PRB Oil and Gas Final EIS (BLM 2003). The (then) future estimates from the Final EIS were higher than the actual data from the IHS file. Because mineral rights in the region are primarily federal, future wells drilled would be largely dependent on the projected number of APDs to be issued by the BLM Field Offices in the region.

The BLM Casper Field Office expects to issue 35 federal APDs each year between 2005 and 2020. The BLM Buffalo Field Office expects to issue 2,500 APDs per year from 2005 to 2020. The number of wells drilled in 2003 and 2004 were obtained from the IHS production database. Approximately 89.8 percent of federally issued APDs would result in drilled wells (BLM RMG 2005).

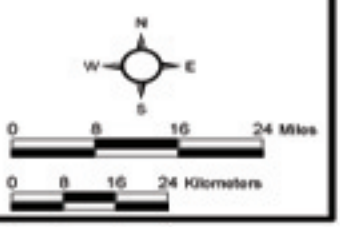
The number of state/fee permits anticipated per year in the PRB study area was calculated in several steps. Estimates of available pads were determined using GIS, as follows. 1) The area of consideration in each subwatershed was defined as that area overlying the major coal-bearing strata of the Fort Union Formation. 2) Currently active conventional wells and all CBNG wells were plotted (see **Figure B-1**), and an 80-acre buffer around each existing well was removed from consideration for future development. 3) The areas remaining were quantified in acres according to oil and gas mineral ownership. Although areas that contain thin multiple coal seams or low gas content could not be economically drilled, they have not been defined for or excluded from this study which looked at the averages. 4) Available acreages were divided into 80-acre parcels to estimate the number of available well pads. Each year, the number of available pads was reduced by the estimated number of APDs issued for each ownership divided by 1.45, which is the overall number of CBNG wells per pad (BLM 2003). First, the ratio of available state/fee 80-acre pads available for development relative to federal mineral ownership lands was estimated. This proportion was applied to the number of federal APDs issued to calculate the anticipated number of state/fee APDs issued. An estimated 72.4 percent of state/fee APDs are drilled (BLM RMG 2005). The estimated number of wells drilled was calculated by the following equation:

*BLM Casper Field Office APDs for 2005 – 2020 = 35/year*

*BLM Buffalo Field Office APDs for 2005 – 2020 = 2,500/year*








Source: BLM 2003, IHS 2005, WOGCC 2005.

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Figure B-1

Producing Oil and Gas Wells and Completed Wells Ready to Produce



07/18/06

*Federal APDs = BLM Buffalo Field Office APDs + BLM Casper Field Office APDs*

*Federal wells drilled = Federal APDs x 0.898*

and

$$\textit{State/Fee APDs} = \frac{\textit{State/Fee Available Pads}}{\textit{Federal Available Pads}} \times \textit{Federal APDs}$$

*State/Fee wells drilled = State/Fee APDs x 0.724*

and

*Current year Federal pads = Previous year Federal Pads – Previous year Federal APDs/1.45*

*Current year State/Fee pads = Previous year State/Fee Pads – Previous year State/Fee APDs/1.45*

and

*Wells drilled for year = Federal Wells Drilled + State/Fee Wells Drilled*

Distribution of new wells into subwatersheds was based on the proportion of available pads.

Assumptions:

1) The BLM Buffalo Field Office will issue 2,500 APDs/year from 2005 to 2020. The BLM Casper Field Office will issue 35 APDs per year between 2005 and 2020. Of all federal APDs issued, 89.8 percent will be drilled (BLM RMG 2005).
2) The number of state/fee APDs that the WOGCC will issue will be proportional to the number of federal APDs issued, as well as to the amount of remaining available spacing for state/fee pads. Of the state APDs issued, 72.4 percent will be drilled.
3) An average of 1.45 wells will be drilled per pad (BLM 2003a).
4) Distribution of new wells in the PRB subwatersheds will be proportional to remaining available pads.
5) No significant CBNG development will occur outside of the Wasatch/Fort Union coal outcrop.
6) Technology used to extract CBNG will not change significantly during the time frame of this study.
7) Future wells will be drilled based on 80-acre pad spacing.

# 9.0 DETERMINATION OF FUTURE YEARLY TOTAL PRODUCTION OF NATURAL GAS AND WATER FROM CBNG WELLS AND OIL, GAS, AND WATER FROM CONVENTIONAL WELLS

The mean current (2003) well production (oil, natural gas, and water) was determined by subwatershed on a per operating well basis for 2003. The mean current production was estimated on a per operating well basis. The mean production rate was applied on a per well basis for future estimates. Where no historical production information was available to develop future subwatershed-based estimates, basin-wide mean per-well production was used. Because production levels varied greatly between and within subwatershed data, and because current means were not available for some subwatersheds (i.e., no wells were producing within the subwatershed), means of the production of each product or water across all subwatersheds for each production type (conventional oil and gas and CBNG) were used. These means were multiplied by the estimated number of producing wells in each future time period analyzed for this study. It should be noted that estimates of future production rates could be affected by unanticipated oil and gas price fluctuations, potential lower production rate per well, or the tapping of thinner coal seams that proportionally would produce less gas.

Assumption:

1) While production from individual wells can vary greatly, because the number of wells is fairly large, the overall mean is representative of regional production.
2) The average rate of production per well will not change greatly over the period of this study.
3) Average annual production is 30,000 MCF/year based on the average number of wells for 2002, 2003, and 2004 divided into the total production each year, then averaged over the 3-year period.

# 10.0 DETERMINATION OF FUTURE CUMULATIVE VALUES FOR PRODUCTION OF OIL, NATURAL GAS, AND WATER

Future cumulative production values were identified by determining the estimated yearly production (products and water) for the yearly estimated number of wells and adding these to the previous dataset's cumulative estimate. The equation for this is:

*Estimated cumulative production for given year = previous year estimated cumulative + current year estimated production*

# 11.0 DETERMINATION OF WATER PRODUCTION, CONSUMPTION, INJECTION, AND DISCHARGE AMOUNTS

The number of injection wells and volumes of injection water for 2003 were determined from the IHS production file for wells identified as injection. The number of injection wells in relation to the overall number of wells in the basin was negligible.

Assumptions:

1) Water reported in the IHS database for wells identified as injection was assumed to be the volume of water injected.
2) Water produced within a subwatershed either would be injected or discharged within the same subwatershed.

# 12.0 ESTIMATE OF DISTURBED AND RECLAIMED ACREAGE RELATED TO CONVENTIONAL OIL AND GAS AND CBNG ACTIVITIES

The overall rates of disturbance due to CBNG well development were estimated in the PRB Oil and Gas Final EIS (BLM 2003a); the following information was developed from **Tables 2-1**, **2-23**, and **2-24**, which summarized alternative 2A. Total short- and long-term per-well disturbance was estimated by dividing the estimated total acreages disturbed (inclusive of pads, roads, pipelines, etc.) (**Tables 2-23** and **2-24**) by the estimated number of new wells drilled during the period (**Table 2-1**). Estimated disturbance was 5.2 acres per well for short-term disturbance, and 2.4 acres per well for long-term disturbance. As a result, each per pad disturbance acreage also accounts for a portion of the well field-related road, pipeline, water handling facilities, and other associated facilities disturbance. Drilling multiple wells per pad was factored in the EIS calculations. The short-term disturbance area was calculated based on the number of new wells during the year. Long-term disturbance was calculated based on the cumulative number of wells excluding new wells for the year. Reclamation each year was based on the addition of the number of new P&A wells multiplied by the long-term disturbance (5.2 acres), old P&A wells multiplied by short-term disturbance (2.4 acres), and the partial reclamation of new well pads for operating wells for the year (2.8 acres).

The rates of disturbance due to conventional oil and gas wells were estimated in the PRB Oil and Gas Final EIS (BLM 2003) at 2.75 acres for wells during construction, and as 2.0 acres during production. The per-well disturbance of 2.75 acres was applied to wells developed within the last year, and the per-well disturbance of 2.0 acres was applied to all other active and inactive wells for the period. Each per pad disturbance acreage also accounts for a portion of the associated ancillary facilities. Reclamation each year was based on the addition of the number of new P&A wells multiplied by the short-term disturbance (2.75 acres), old P&A wells multiplied by long-term disturbance (2.0 acres), and the partial reclamation of new operating wells for the year (0.75 acres).

Assumptions:

1) The estimated per-well disturbance acreages will not change during the study (initial disturbance of 2.75 acres for conventional oil and gas wells and 5.2 acres for CBNG wells).
2) Overall disturbance will be distributed evenly among wells.
3) A portion of the short-term disturbance will be reclaimed within the year after the well is drilled (0.75 acre for each conventional oil and gas well and 2.8 acres for each CBNG well).
4) Long-term disturbance due to conventional oil and gas and CBNG wells will be reclaimed within the year wells are listed as abandoned (2.0 acres for each conventional oil and gas wells and 2.4 acres for each CBNG well). This accounts for reclamation of associated roads, pipelines, water handling facilities, etc., as proportionally included in the disturbance acreage for each pad.

# 13.0 ESTIMATE OF THE VOLUME OF WATER DISPOSED OF BY VARIOUS DISPOSAL METHODS

It is assumed that the volume of water to be disposed of through each disposal method would vary between subwatersheds, according to the following table from the PRB Oil and Gas Final EIS (BLM 2003a).

**Percent of Total Water Production per Discharge Method**

| Subwatershed | Untreated Discharge | Passive Treatment | Active Treatment | Infiltration Impoundment | Containment Impoundment | LAD | Injection |
|---|---|---|---|---|---|---|---|
| Upper Tongue River | 0 | 25 | 5 | 45 | 10 | 5 | 10 |
| Upper Powder River | 35 | 0 | 10 | 40 | 5 | 5 | 5 |
| Salt Creek | 55 | 0 | 0 | 35 | 5 | 0 | 5 |
| Crazy Woman Creek | 35 | 0 | 10 | 30 | 5 | 15 | 5 |
| Clear Creek | 25 | 10 | 10 | 35 | 5 | 15 | 10 |
| Middle Powder River | 35 | 5 | 5 | 30 | 10 | 10 | 5 |
| Little Powder River | 45 | 0 | 0 | 30 | 10 | 10 | 5 |
| Antelope Creek | 55 | 0 | 0 | 35 | 5 | 0 | 5 |
| Upper Cheyenne River | 55 | 0 | 0 | 35 | 5 | 0 | 5 |
| Upper Belle Fouche River | 45 | 0 | 0 | 40 | 5 | 0 | 10 |

Sources: Beels 2005; BLM 2003b.

Where possible, estimated produced water volumes within subwatersheds were allocated among disposal methods according to this table. Water disposal in subwatersheds without an indicated preferred allocation for disposal methods (Dry Fork Cheyenne River, Lightning Creek, Little Bighorn River, Little Missouri River, Middle Fork Powder River, Middle North Platte River, North Fork Powder River, Salt Creek, and South Fork Powder River) was assumed to be allocated in the same way as Clear Creek, since Clear Creek offered the most widely distributed disposal methods.

Assumptions:

1) It is assumed that the percent of total produced water discharged to impoundments, outfalls, or through injection in each subwatershed will be allocated per the PRB Oil and Gas Final EIS (BLM 2003) estimates.
2) It is assumed that water disposal in subwatersheds without an indicated allocation in the PRB Oil and Gas Final EIS (BLM 2003) will be the same as identified in that document for the Clear Creek subwatershed.