Environment

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Task 2 Report for the Powder River Basin Coal Review – Past and Present and Reasonably Foreseeable Development Activities

List of Acronyms

APD	Application for Permit to Drill
AQD	Air Quality Division
ARI	Advanced Resources International
BACT	Best Available Control Technology
bpd	barrels per day
BCB	Binderless Coal Briquetting
Bcf	billion cubic feet
BLM	Bureau of Land Management
BNSF	Burlington Northern and Santa Fe Railroad
CAMR	Clean Air Mercury Rule
CANDO	Converse Area New Development Organization
CBNG	coal bed natural gas
CCEDC	Campbell County Economic Development Corporation
CO_2	carbon dioxide
CPR	Canadian Pacific Railway
CTL	coal-to-liquid
DM&E	Dakota, Minnesota, & Eastern
EA	environmental assessment
EIS	environmental impact statement
EOR	enhanced oil recovery
FERC	Federal Energy Regulatory Commission
FS	U.S. Department of Agriculture, Forest Service
GDP	gross domestic product
GHG	greenhouse gas
GIS	Geographical Information System
GTL	gas-to-liquid
IGCC	integrated gasification combined cycle
I-90	Interstate 90
kV	kilovolt
kW	kilowatt
LBA	lease by application
LQD	Land Quality Division
Mcf	thousand cubic feet

MDEQ	Montana Department of Environmental Quality
MMBtu	million British thermal units
MMcfpd	million cubic feet per day
mmgpy	million gallons per year
mmtpy	million tons per year
MSHA	Mine Safety and Health Administration
MW	megawatts
MWH	Montgomery Watson Harza
NEPA	National Environmental Policy Act
NO_x	oxides of nitrogen
P&A	plugged and abandoned
P&M	Pittsburg and Midway Coal Mining Company
PM_{10}	particulate matter with an aerodynamic diameter of 10 microns or less
PRB	Powder River Basin
PSO	Public Service Company of Oklahoma
REX	Rockies Express Pipeline Project
RFD	reasonably foreseeable development
RMG	Reservoir Management Group
ROD	record of decision
ROW	right-of-way
SH	State Highway
SR	State Route
SO_2	sulfur dioxide
STB	Surface Transportation Board
STIP	State Transportation Improvement Program
Tcf	trillion cubic feet
tpy	tons per year
TRRC	Tongue River Rail Company
UCG	underground coal gasification
U.S.	United States
UP	Union Pacific
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USNRC	U.S. Nuclear Regulatory Commission
WDEQ	Wyoming Department of Environmental Quality

WECC	Western Electricity Coordinating Council
WIA	Wyoming Infrastructure Authority
WISE	World Information Service on Energy
WOGCC	Wyoming Oil and Gas Conservation Commission
WSFC	Wyoming School Facilities Commission
WYDOT	Wyoming Department of Transportation

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1.0 Introduction

The Powder River Basin (PRB) Coal Review is a regional technical study for assessing the existing conditions and the projected future cumulative impacts associated with past, present, and reasonably foreseeable development (RFD) activities in the PRB. This Task 2 report summarizes the past and present energy-related development activities that have occurred in the PRB through the end of base year 2008 and the projected RFD activities for future years 2020 and 2030. The Task 2 component of the study provides the basis for the analysis of cumulative impacts for air quality, water resources, social and economic values, and other environmental resources as a result of existing and ongoing energy-related development in the PRB; the base year conditions (Task 1) and projected cumulative effects (Task 3) for these resources are described in separate stand-alone documents. This study is being conducted by AECOM, Inc. dba AECOM Environment (AECOM) under the direction of the Bureau of Land Management (BLM) High Plains District Office and Wyoming State Office.

1.1 Study Background

The PRB of Wyoming and Montana is a major energy development area with diverse resource and environmental values. The PRB is the largest coal-producing region in the United States (U.S.); PRB coal is used to generate electricity both within and outside of the region. The PRB also has produced large amounts of oil and natural gas resources. Over the last decade, this region has experienced nationally significant development of natural gas from coal seams (coal bed natural gas [CBNG]).

During the 1970s and early 1980s, federal coal leasing in the PRB was a high profile activity as over 90 percent of the coal is federally owned. Between 1974 and 1982, the BLM issued three and started a fourth separate regional coal environmental impact statement (EIS), all addressing federal coal leasing and development, as well as other regional development.

In 1982, the BLM temporarily halted further coal leasing. However, mining continued on existing leases. When leasing resumed in 1990, the existing mines were mature operations, and there was no need for regional leasing to open new mines. However, many of the mines were depleting their original reserves, so there was a need for maintenance leasing to provide the reserves to enable existing mines to meet the expanding demand. At that time, the Powder River Regional Coal Team decertified the region, allowing BLM to use the lease by application (LBA) process to meet this need.

To date, the BLM continues to use the LBA process to meet the need for maintenance coal leasing. Each LBA requires preparation of an EIS or environmental assessment (EA), as appropriate, as part of the leasing process. As required under the National Environmental Policy Act (NEPA), each EIS and EA must include an evaluation of the cumulative impacts on the environment that result from the incremental impact of the action (e.g., an LBA) when added to other past, present, and reasonably foreseeable future actions.

Starting with the first LBAs, the BLM met the need for cumulative analysis in each EIS or EA with a discrete analysis that was updated for each subsequent EIS or EA. In the mid-1990s, the BLM conducted a study called the Coal Development Status Check (BLM 1996) to evaluate how actual development levels compared to the development levels predicted in the earlier regional EISs. In the late 1990s, annual coal production and associated impacts drew closer to the maximum projections in the regional EISs. Furthermore, the large scale oil and gas development associated with CBNG activity had not been foreseen in those EISs. To meet the need of the coal mine LBA EISs and EAs at that time, the BLM used the cumulative analysis from their Wyodak Final EIS (BLM 1999) and their PRB Oil and Gas Final EIS (BLM 2003), particularly for air and water resources. Both EISs projected regional development, including CBNG activity. They both also used market demand projections to estimate future levels of coal development.

In early 2003, Montgomery Watson Harza (MWH), in coordination with the BLM, completed a study of PRB coal demand through 2020 (MWH 2003). The study projected production to increase at a steady pace, with current mines able to meet the demand as long as the existing mines continued to have access to additional coal reserves. Therefore, the need for leasing using LBAs will continue into the foreseeable future. As part of processing these LBAs, BLM will need to maintain a current cumulative impact analysis. The PRB Coal Review study was developed to meet that need.

Initiated in 2003, Phase I of the PRB Coal Review included the identification of current conditions (Task 1 reports); identification of base year (2003 and subsequently 2007) and RFD energy-related activities (including future coal production scenarios) for 2010, 2015, and 2020 (Task 2 report); and predicted future cumulative impacts (Task 3 reports) in the PRB. Phase II of the PRB Coal Review was initiated in January 2010 to update the Phase I analyses. Under Phase II of the study, base year information and current conditions descriptions have been updated through the end of 2008. Also, new RFD projects have been developed, and projected cumulative impacts will be analyzed for 2020 and 2030.

The PRB Coal Review provides data, models, and projections to facilitate cumulative analyses for BLM's future land use planning efforts and for the cumulative impact sections of future coal mine LBA EISs and EAs in compliance with NEPA. It should be noted that the PRB Coal Review itself is not a NEPA document. It also is not a policy study, analysis of regulatory actions, or an analysis of the impacts of project-specific development.

For purposes of this study, the Wyoming PRB cumulative effects study area (**Figure 1-1**) comprises all of Campbell County, all of Sheridan and Johnson counties outside of the Bighorn National Forest lands to the west of the PRB, and the northern portion of Converse County. It includes all of the area administered by the BLM Buffalo Field Office, a portion of the area administered by the BLM Casper Field Office, and a portion of the Thunder Basin National Grasslands, which is administered by the U.S. Forest Service (FS) (**Figure 1-2).** The Montana portion of the PRB cumulative effects study area (**Figure 1-1**) comprises the area of relevant coal mines and the air quality cumulative effects study area, including portions of Rosebud, Custer, Powder River, Big Horn, and Treasure counties. It encompasses the area administered by the BLM Miles City Field Office and the Billings Field Office (**Figure 1-2**). State and privately owned lands also are included in the study area (**Figure 1-3**).

As shown in **Figure 1-3**, the majority of the surface ownership in the PRB cumulative effects study area is private. Conversely, the majority of the mineral ownership in the Wyoming PRB cumulative effects study area is federal (**Figure 1-4**). Federal mineral ownership may include all minerals in some locations and only specific minerals (e.g., coal or oil and gas) in other locations. As a result, split-estates (where the surface ownership is different than the mineral ownership) exist in a large portion of the PRB.

The Task 2 component of the PRB Coal Review defines the past and present development actions in the study area that have contributed to the existing environmental and socioeconomic conditions in the PRB cumulative effects study area, as well as the projected RFD scenarios for the Wyoming and Montana PRB cumulative effects study areas. For the Wyoming PRB, the past and present development and RFD scenarios include coal mine development as well as coal-related activities (e.g., railroads and coal-fired power plants) and non-coal-related activities (e.g., other minerals, CBNG, and conventional oil and gas). Past and present development and RFD scenarios for coal mine development and coal-related activities also are included for the Montana PRB.

1.1.1 Phase I of the Study

Phase I of the PRB Coal Review was developed as a regional technical study for assessing the existing environmental and socioeconomic conditions in the PRB study area as of the end of 2003 and the projected future cumulative impacts associated with ongoing energy-related development in the PRB for years 2010, 2015, and 2020. A subsequent update of both the existing conditions through the end of 2007 and the projected future cumulative impacts for years 2010, 2015, and 2020 also was completed

during Phase I. The past and present activities identified in the original Task 2 report (ENSR 2005) were based on the available data at the end of 2003 and provided the basis for the resource-specific descriptions of existing conditions presented in the PRB Coal Review Task 1 reports. The past and present activities described in the updated Task 2 report (AECOM 2009a) were based on the available data for energy-related development in the study area through base year 2007 and reflected updated information on the status of existing projects, as well as identification of newly constructed and operational projects since 2003.

The RFD scenarios presented in the original Task 2 report (ENSR 2005) were based on information available through the end of 2004 and provided the basis for the analysis of potential cumulative impacts in the Task 3 reports. The RFD scenarios presented in the updated Task 2 report (AECOM 2009a) reflected updated information available on previously identified foreseeable development, as well as information on newly identified foreseeable development projected to be operational or constructed by 2010, 2015, or 2020.

1.1.2 Phase II of the Study

Identical to Phase I, Phase II of the PRB Coal Review is a regional technical study to determine the base year (2008) conditions and assess potential future (2020 and 2030) cumulative effects of projected development-related activities in the PRB. Phase II of the study was initiated due to the ongoing energy-related development in the PRB, the elapsed time since initiation of Phase I of the study, and the BLM's need to maintain up-to-date development projections and related predicted future cumulative impact analyses for use in the agency LBA EISs and EAs. Under Phase II, the existing and projected future energy-related development activities have been updated (Task 2) based on updated information, and the air quality, water resources, socioeconomic, and environmental resources base year analyses (Task 1) and projected cumulative impact analyses (Task 3) subsequently will be updated.

1.1.3 Overview of Approach

The accuracy of any projected cumulative impact analysis is dependent on the adequacy and accuracy of information regarding potential future development activities in the affected area. While it is impossible to identify all potential future activities over the next 20 years, it is possible and desirable to identify RFDs based on current industry announcements, agency plans, economic trends, and technological advances affecting major industry sectors. Information regarding potential new development is constantly changing; therefore, to facilitate development of the information in this study, the RFDs identified in this report reflect information available through mid 2010.

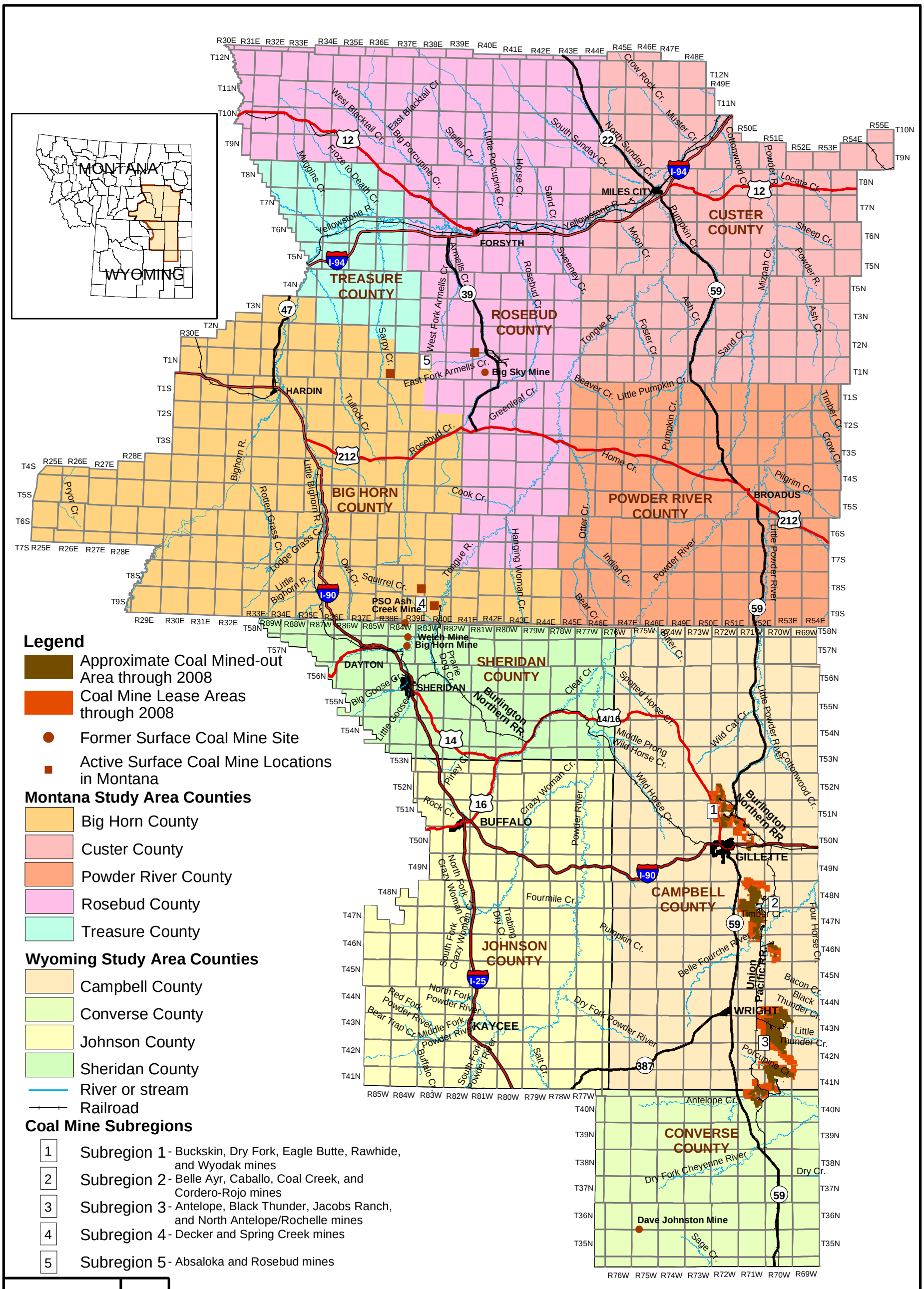
The past and present actions in this report were identified based on information in the updated Phase I PRB Coal Review Task 2 report (AECOM 2009a), existing NEPA documents on file with federal and state agencies, operating permits and annual reports on file with state agencies, and industry contacts. The RFD scenarios in this report were developed based on recent information that identifies proposed and anticipated development in the PRB, including NEPA documents; various other technical reports and studies; federal, state, and local (county) agency management plans; and permit applications. The specific development scenarios and development activities identified in these sources were assessed as to their current status prior to inclusion in the RFD scenarios for the PRB Coal Review. In addition, potential additional projects were identified through interviews with agency and industry representatives, review of published news articles and trade publications, and discussions with community leaders.

The identified RFD activities subsequently were evaluated as to their likelihood for occurrence. Due to the lack of detailed information for many developments beyond the next few years, the degree of uncertainty associated with the predicted developments and trends increases as the timeframe extends further into the future. In addition, the variables and uncertainties associated with potential future changes in regulations for air emissions, as well as the current attention focused on climate change and the role of coal in meeting future demand, also add to the degree of uncertainty associated with future projections as acknowledged in the applicable sections of this report.

For each of the past and present and RFD projects and activities, project-specific impact-causing parameters (e.g., disturbance acreage, groundwater pumping rates, employment levels, etc.) have been compiled from the sources identified above. Where specific information was unavailable, assumptions were developed and included based on typical industry-specific standards, permit criteria for similar existing industries, and professional judgment.

In order to account for the variables associated with future coal production, two detailed coal production scenarios (reflecting upper and lower production estimates) were projected for this study to bracket the most likely foreseeable regional coal production level and to provide a basis for quantification of related impact-causing parameters. These future production levels were derived from the analysis of historic production levels and current PRB coal market forecasts, public and private information sources, and input from individual PRB coal operators.

The methodology used to define the past and present and RFD activities is summarized in Chapter 2.0. Information specific to the past and present and RFD activities identified for this study is summarized in Chapter 3.0. The summary of the associated impact-causing parameters is provided in **Appendices A** through **C** of this report.



Note: Approximate coal mined-out areas were not available for the Montana mine sites.

Source: BLM 2003, 2010a.

Powder River Basin Coal Review

Figure 1-1

Montana and Wyoming Study Area

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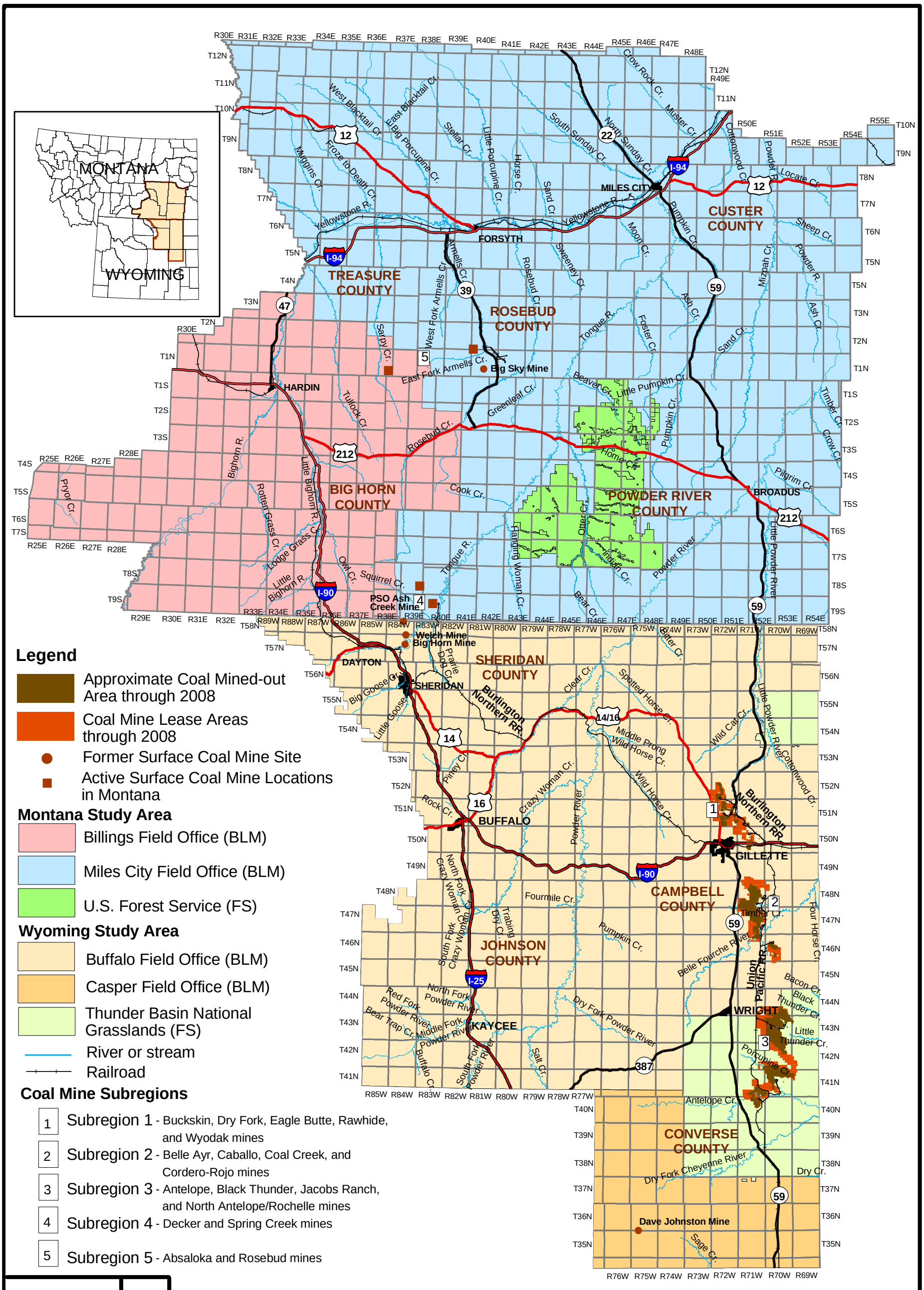

Note: Approximate coal mined-out areas were not available for the Montana mine sites.

Source: BLM 2003, 2010.

Powder River Basin Coal Review

Figure 1-2

Federal Land Management

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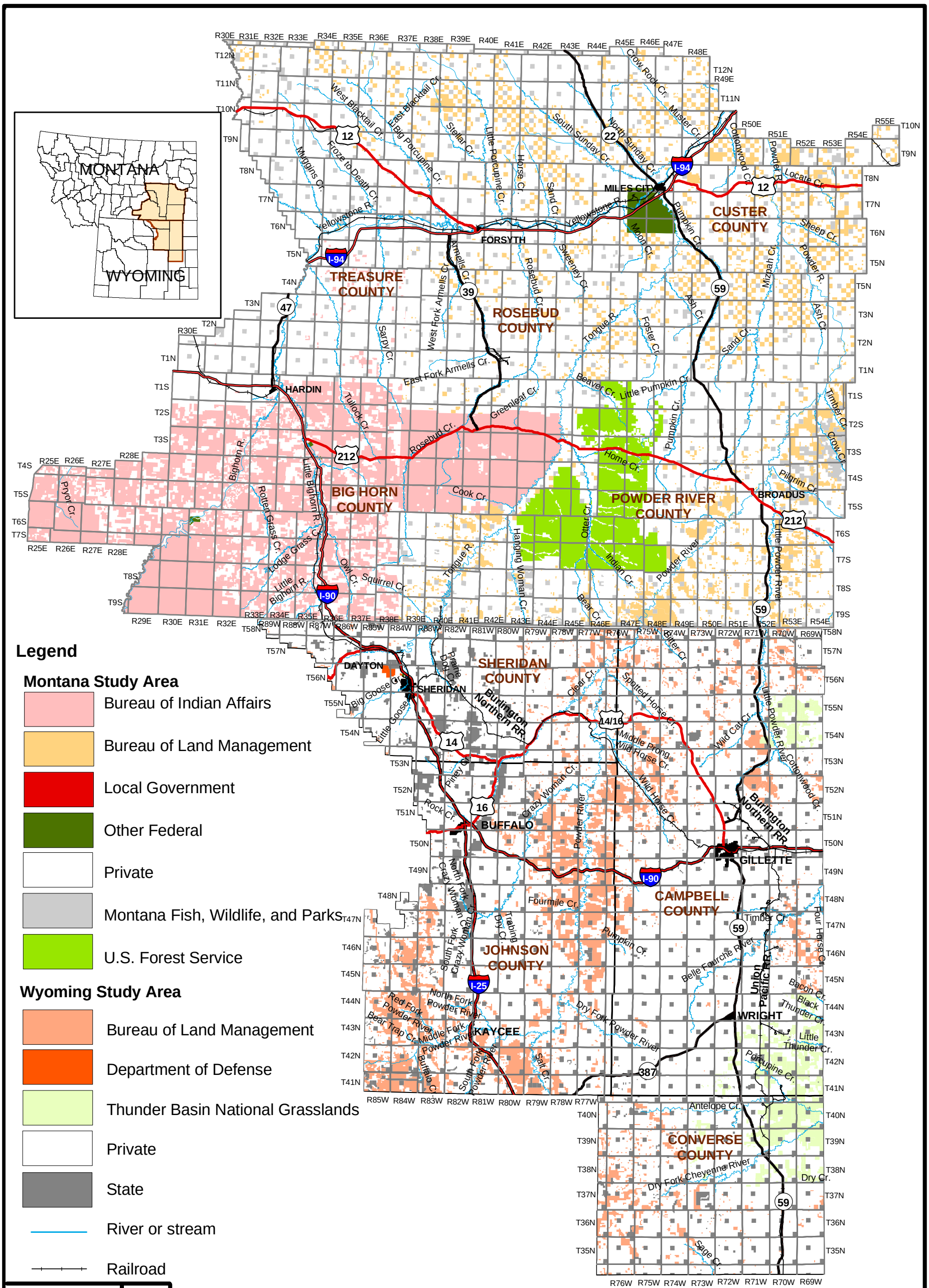

Source: BLM 2003.

Powder River Basin Coal Review

Figure 1-3

Surface Ownership

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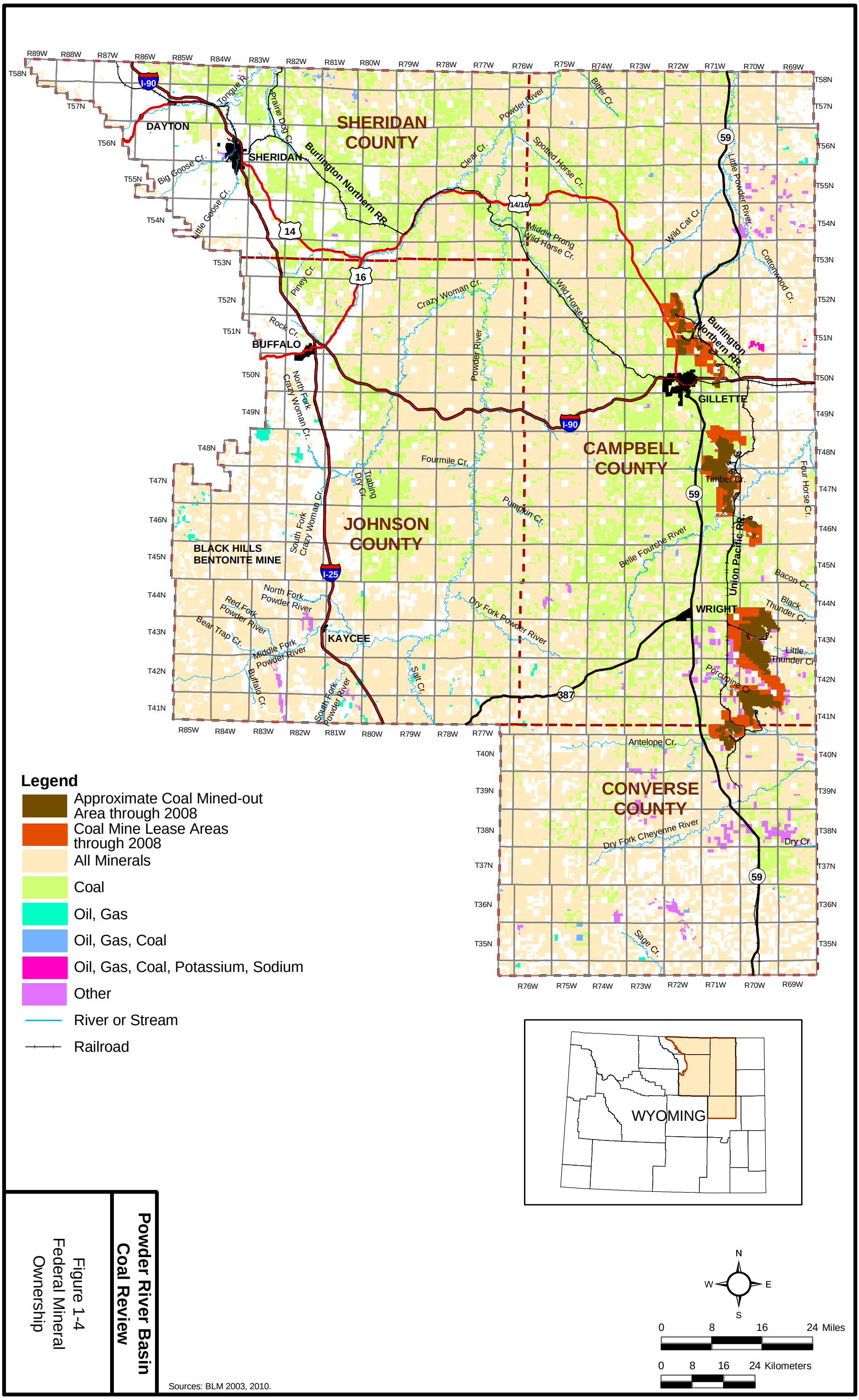

Sources: BLM 2003, 2010.

Powder River Basin Coal Review

Figure 1-4
Federal Mineral Ownership

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2.0 Methodology

To the extent possible, identification parameters (e.g., proponent/project name and/or location) and impact-causing parameters were identified for each of the past and present and RFD actions identified in this report. These parameters include factors that are common to all resources and resource-specific factors, as discussed below. This information was used to describe the past and present actions and RFD scenarios analyzed in this study and is summarized in the tables in **Appendices A** through **C**. These summaries have been revised for the Phase II effort and formatted to facilitate the development of Task 1 (current conditions) and Task 3 (impact analyses) information, which will be used for future land use planning efforts and for the cumulative impact sections of future coal mine LBA EISs in compliance with NEPA.

The existing disturbance acreages were based on the Phase II data spreadsheets compiled for this Task 2 report and, where resource-specific data were required, the associated Geographical Information System (GIS) data. Existing disturbance acreages generated through GIS vary from the disturbance acreages in the Task 2 data spreadsheets due to the following variables.

- The information in the data spreadsheets was compiled based on information obtained from the data sources and the applied assumptions identified in this Task 2 report. As a result, the data spreadsheets specify a discrete disturbance acreage for each of the development activities (e.g., coal mines, individual oil and gas wells, etc.) identified for the study. Conversely, the GIS analysis accounted for the spatial relationship of the various development activities, thereby avoiding double counting of disturbance acreages where mapped disturbance areas overlap.
- Slight variations between the GIS study area boundary and GIS resource-specific layers may result in some under-counting of disturbance acreages.

The existing disturbance acreages presented in the summary tables in **Appendices A** and **C** were generated using the Task 2 data spreadsheets; those presented in **Appendix B** were generated through GIS. Where disturbance acreages are presented elsewhere in this study, the appropriate source is noted.

Future disturbance and reclamation acreages for the RFD scenarios in this study were based on the data spreadsheets compiled for this report with the following variables and uncertainties of using GIS analysis for defining this information. The methodology and assumptions in **Appendix D** relative to oil and gas development provide a means of identifying the number of new wells to be developed and the number of wells to be plugged and abandoned (P&A) within each of the subwatersheds for the target years of this study (i.e., 2020 and 2030). However, discrete locations for new and P&A well sites for these future time periods are not available. For coal mines, the methodology and assumptions presented in Section 3.2 provide for calculation of future disturbance and reclamation acreages. However, although the general area of potential future coal mine-related disturbance can be identified based on projected reserves, the actual disturbance footprint associated with future mining and the actual locations of future reclaimed areas for the target years are not known. As a result, based on existing information, the spatial relationship between projected future disturbance and reclamation areas and the resource-specific information in the GIS layers for these industries cannot be determined. Conversely, the data spreadsheet information does provide for quantification of future disturbance and reclamation acreages on a subwatershed basis and, with other information (e.g., projected locations of future coal reserves), a means of qualitatively analyzing future resource-specific impacts for those resources that are site-specific (e.g., vegetation, soils, wildlife habitat). The disturbance acreages for the RFD scenarios (based on the Task 2 data spreadsheets) are presented in the tables in **Appendices A** and **C**.

2.1 Factors Common to All Resources

Proponent/Project Name. The proponent or operator and associated project name have been identified for tracking purposes in the data spreadsheets for all past, present, and RFD actions with the exception of oil and natural gas (conventional and CBNG) projects and facilities; the latter typically are geographically dispersed and, therefore, are more appropriately tracked on a general location basis.

Location. Based on the inclusion of project-specific locations in the data spreadsheets, and the structuring of the data spreadsheets using 4th level sub-basins (referred to as subwatersheds in this study for consistency with the Phase I reports) as a common denominator, the impact-causing parameters within specified areas have been summarized to facilitate cumulative impact evaluations. Mapped locations of the past, present, and RFD projects analyzed in this study are presented in Chapter 3.0 in association with the industry-specific discussions.

Timeframe. Past and present actions have been summarized based on base year 2008 data; parameters for RFD scenarios have been established for 2020 and 2030 based on available information through mid 2010.

Land Ownership. Surface ownership in the Wyoming PRB study area primarily is private, with federal and state lands comprising approximately 14 and 8 percent of the area, respectively (see **Figure 1-3**). In the Montana PRB study area, the majority of the land is privately owned, with federal and state lands comprising approximately 25 and 5 percent, respectively.

Acreage. Mining activity has been projected forward in 5-year increments based on available reserves and high and low projected production levels to facilitate a more accurate estimate of future coal mine disturbance and reclamation for 2020 and 2030. The projected mining activity was combined with industry input from the PRB coal producers, and public historical and permitted reclamation activity data, to forecast future disturbance and reclamation acreages.

Future disturbance and reclamation acreages related to coal railroad transportation infrastructure and coal technology projects were estimated from numerous information sources as listed in Sections 3.5 and 3.6, respectively.

Acreages for other past, present, and RFD actions were obtained from permit applications, EISs or EAs, or estimated based on typical facility sizes.

Schedule. The estimated schedule for the construction, operation, and closure/reclamation of proposed coal mines, non-coal mines, coal technology projects, and coal railroad transportation infrastructure was derived from public information on record with the Wyoming Department of Environmental Quality (WDEQ) and Montana Department of Environmental Quality (MDEQ), industry input (including information contained on corporate and agency websites) regarding mine-specific reserve sequencing projections, and press releases and other published articles. Given the projected high and low production rates, there are adequate economic reserves to sustain all proposed coal mining activity through the year 2030.

Schedules for other past, present, and RFD actions have been based on industry input, permitting documents, and assumptions related to trends for related industries (e.g., coal production forecasts in relation to rail capacity).

Production Estimate. Analysis of historic PRB coal production levels, and current reports forecasting future PRB coal market activity from sources including IHS Global Insight, U.S. Energy Information Administration, Wood McKenzie, and International Energy Agency, were combined with input from the PRB coal mine operators and regulatory agency input from specialists within the Wyoming and Montana BLM, WDEQ, and MDEQ to project the upper and lower total coal production scenarios for the

PRB. Individual mine production then was allocated based on historic market share performance, current air quality permit limitations, proposed expansion applications on file with the WDEQ and MDEQ Air Quality Divisions (AQDs), coal rail loadout capacities, and coal mine operator input.

Capital Investment. Capital investment information relative to RFD actions is presented in the text portion of this report, as available. Capital investment related to coal mine development was estimated based on requirements for site-specific mine infrastructure (e.g., rail loop and loadout facilities, major mobile equipment purchases, and highway relocations within permitted mine boundaries). Estimated costs are based on historic costs for similar facilities and equipment.

Likelihood. Following identification of the RFDs through year 2030 for the study area, each capital project was assigned a rating for the likelihood of development or occurrence. Both private and public sector activities have been considered. Likelihood ratings were assigned to the identified actions based on the numerical rating system presented below. The numerical rating for each action is identified in the Chapter 3.0 discussion, with the exception of oil and gas activities. Oil and gas activities differ from individual capital projects due to the dispersed nature of the facilities; therefore, the projection of these activities reflects their likelihood and timeframe.

- Certain/highly likely (1) – Inclusive of actions that have been fully funded, permitted, are under construction, or are necessitated to achieve expanded coal output. These actions have an identified proponent/sponsor, project location, and specific details regarding capacity, output, and/or costs.
- Moderately likely (2) – Inclusive of actions for which applications have been submitted to an agency, that are part of a defined capital improvement plan/program, involve an established technology or process, have an identified proponent/sponsor with a demonstrated track record in undertaking/completing similar or related projects, or for which an EIS or EA is in preparation.
- Low likelihood (3) – Inclusive of actions that are undergoing market or feasibility analyses, previously were proposed but failed to proceed and are now under reconsideration, or for which some descriptive information is available but for which no formal regulatory or administrative approval processes have been initiated.
- Speculative (4) – Projects for which insufficient information is available for analysis purposes, or to determine the likelihood of the project moving forward, have been assigned a likelihood of speculative. These actions are identified in text with an explanation for their elimination from consideration.

Included in this Task 2 report is information on potential future development for which specific projects have not been identified but for which the potential for development or expansion of a specific industry (e.g., carbon sequestration) has been identified. This potential for development or expansion was based on increased activity in an industry sector or new technologies, and the resources in the PRB conducive to their future development.

2.2 Resource-specific Factors

Air Emissions Estimates. Information relative to current conditions will be based on air emissions inventories obtained from a variety of sources as detailed in the Air Quality Assessment Protocol for this study (AECOM 2010a). Air emissions for RFDs will be based on average operations in base year 2008, as well as air emissions estimates published in air permits or EISs. For each group of sources, an average emissions profile will be developed for modeling purposes, based on production and design data. Air emissions data will be summarized in technical support documents prepared in support of the Task 1A and 3A reports.

Water Production/Disposal. During Phase I of the study, coal mine-related groundwater production data were obtained from individual mine operators and data as reported to the Wyoming State Engineer's

Office for permitted wells through 2002. Based on the ongoing groundwater pumpage associated with CBNG development in the eastern Wyoming PRB study area in advance of coal mine development, it is assumed that the Phase I coal mine-related groundwater production data provide a conservative estimate of ongoing coal mine-related groundwater production. Therefore, the data have been carried forward for use in Phase II. This data and the assumptions presented in Section 3.2 of this report were used to determine the future coal mine-related groundwater pumping rates.

Current water production and disposal volumes associated with conventional oil and gas and CBNG development have been based on data in the IHS Global Insight™ (HIS) (2010) and Wyoming Oil and Gas Conservation Commission databases, as well as discharge data provided by the WDEQ – Water Quality Division (WQD). Future CBNG water production and discharge was estimated by the BLM (2010b), based on actual permitted pumping rates and the scaling down of pumping rates over the 9-year life cycle of a pod of wells.

Water Consumption. Dust suppression practices at active coal mines are the single largest factor in water consumption, accounting for an estimated 85 percent of the total water used. Wyoming mine operators are required to submit an annual fugitive emissions control report to the WDEQ/AQD that summarizes the annual gallons of water consumed, dust suppression additives, and application techniques used to control dust emissions. For coal mines in the Wyoming PRB, the past several years of reports (which reflect water consumption levels in recent drought years) were reviewed and analyzed, and future water consumption was projected forward based on current practices and forecasted production levels. As a result, the projections for water consumption reflect potential higher use rates in the event dry conditions persist. Water consumption projections for Montana mines were based on the information for Wyoming mines and adjusted for annual production and mining method.

Current and future non-coal mine, coal technology projects, and coal railroad transportation-related water consumption is expected to be minimal. Power plant-related water consumption was estimated based on recent analyses at other facilities.

Workforce. Current and future PRB coal mine-related Wyoming employment was estimated by reviewing the past annual reports of the Wyoming State Mine Inspector and U.S. Mine Safety and Health Administration (MSHA) records, correlating productivity gains to changes in mine production, and forecasting total employment forward as a function of mine productivity and production. Montana employment information was based on information for Wyoming mines and adjusted for annual production and mining method.

Current and future non-coal mine employment is expected to increase only moderately above current levels and was estimated from existing data on file with the WDEQ and MDEQ, as available, or based on similar existing operations, as applicable.

Due to the lack of existing commercial-scale coal beneficiation facilities, current and future coal technology employment is based on information from company press releases, securities filings, and information relative to proposed projects, as available. These estimates are of necessity “order of magnitude” and subject to revision as any future projects move forward into the environmental permitting process.

Current and future Wyoming workforce requirements for the oil and gas industry are a function of the pace of drilling, number of producing wells, anticipated production life of the wells, and future reclamation activities. Employment assumptions for modeling of social and economic impacts are discussed in the Task 3C report.

Current and future Wyoming workforce requirements for power plants in the PRB are based on information obtained from the operators, project application filings, local economic development organizations, the Wyoming Department of Employment, and the WDEQ/Industrial Siting Division.

2.3 Assumptions

Industry-specific assumptions were developed to provide a basis for quantification of impact-causing parameters where actual data, or the basis for projected data, were lacking. The assumptions were developed, as needed, for past and present development and RFD activities as summarized at the end of each industry-specific section in Chapter 3.0. These assumptions were based on typical industry-specific standards, permit criteria for similar existing industries, and professional judgment.

3.0 Past, Present, and Reasonably Foreseeable Development

3.1 Relationship among Industries and Projects

Many of the past and present energy-related and industrial projects in the PRB study area are interdependent. In addition, many of the RFD activities in the PRB are interrelated or dependent on other types of industries to provide the necessary infrastructure to support their development and operation. For example, coal mines depend on rail lines with sufficient capacity to transport coal to power plants outside of the PRB, or on the presence of mine-mouth coal-fired power plants. Power plants in turn are dependent on the availability of sufficient transmission line capacity for the transport of electricity to markets. The oil and gas industry depends on the availability of sufficient transportation pipeline capacity for the transport of product to markets outside of the basin. Alternately, some of the identified projects are related from the standpoint of resource impacts, such as the potential cumulative effects of groundwater drawdown associated with the coal mine and CBNG industries. As a result, the PRB Coal Review includes the array of industries and projects identified above to define the development limitations that exist as a result of their interdependency (a factor in determining the likelihood for development of the RFDs) and to fully analyze the potential impacts in the study area.

3.2 Coal Mines

3.2.1 Past and Present Development

3.2.1.1 Wyoming

The first coal mine in the Wyoming PRB was developed near Glenrock, in Converse County, in 1883 (Foulke et al. 2002). During the 1970s and early 1980s, the PRB emerged as a major coal-producing region. As a result, federal coal leasing became a high profile activity since the PRB's coal is over 90 percent federally owned. In 1982, the BLM temporarily halted further coal leasing; however, the existing mines continued producing coal, which depleted their leased federal coal reserves. As a result, interest in leasing federal coal to extend mining operations at existing mines in the PRB increased in the late 1980s. However, there was little to no interest in opening new mines, and therefore, there was not enough interest in leasing to justify a regional coal sale. In early 1990, the Powder River Regional Coal Team decertified the Powder River Federal Coal Region, which allowed BLM to begin processing applications by existing mines to lease maintenance tracts of federal coal using the LBA process.

Applications for leases by several mines are continuing to be processed to replace their depleted coal reserves so that operations can continue into the future. As forecast during Phase I of the study, production from the Wyoming PRB increased steadily until 2009 when there was a decline in production (from approximately 444 million tons per year (mmtpy) to approximately 420 mmtpy resulting from the national economic adjustment in late 2008. Historically, there have been several annual production declines with an overall trend of year-on-year increases. Although difficult to accurately predict, existing mining operations continue with some increases in production from 2009 levels.

As of the end of base year 2008, there were 13 operating coal mines in the Wyoming PRB study area. These are grouped by subregion as shown in **Figure 3-1** and as described below. For purposes of this study, the mines in the Sheridan, Wyoming, area have been included in Subregion 4 (Sheridan/Decker), which is discussed in Section 3.2.1.2 of this report.

- Subregion 1 (North Gillette) – Buckskin, Dry Fork (which includes the old Fort Union), Eagle Butte, Rawhide, and Wyodak mines

- Subregion 2 (South Gillette) – Belle Ayr, Caballo, Coal Creek, and Cordero-Rojo mines
- Subregion 3 (Wright) – Antelope, Black Thunder, Jacobs Ranch (as part of Black Thunder), and North Antelope/Rochelle mines

Other coal mines or mining-related disturbance within the Wyoming PRB study area and their status are described below. Based on their status, these facilities are not analyzed further in this study.

- Clovis Point Mine – part of operating Wyodak and Dry Fork mines
- Izita – permitted dragline walkway from the Coal Creek Mine to the Black Thunder Mine
- KFx – haul road to supply coal from the Wyodak Mine to the adjacent KFx facilities located at the old Fort Union Mine (now part of Dry Fork) area

3.2.1.2 Montana

For purposes of this study, Subregion 4 encompasses the coal mining activity in the Sheridan, Wyoming, and Decker, Montana, areas. Subregion 5 encompasses mining activity in the Ashland/Colstrip, Montana area. The active coal mines in these subregions as of the end of base year 2008 are shown in **Figure 3-1** and are identified below. Production in 2008 was 43.8 million tons and dropped to 38.3 million tons in 2009 as a result of the national economic adjustment in late 2008.

- Subregion 4 (Sheridan/Decker) – Decker (east and west pits) and Spring Creek mines
- Subregion 5 (Ashland/Colstrip) – Absaloka and Rosebud mines

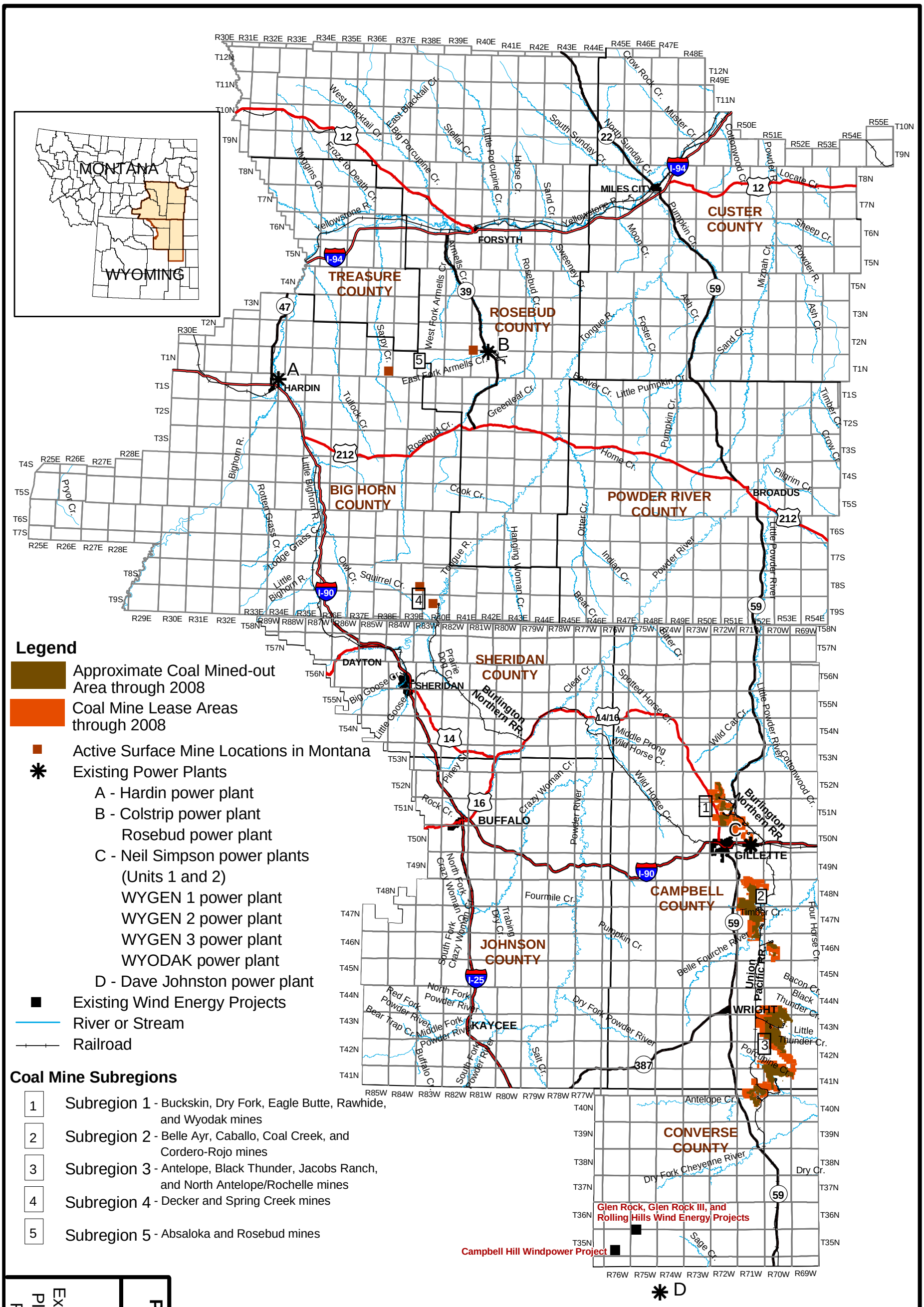
Other coal mines in Subregions 4 and 5 and their status are described below. These mines are shown in **Figure 1-1**; however, based on their status, these facilities are not analyzed further in this study.

- Big Horn Mine – in final reclamation and awaits final bond release
- Welch Mine – in final reclamation and awaits final bond release; part of an exchange with the Pittsburg & Midway Coal Mining Company (P&M)
- Public Service Company of Oklahoma's (PSO) Ash Creek Mine – has been reclaimed and awaits final bond release
- Big Sky Mine – in final reclamation and awaits final bond release
- Other historic underground mines – Many square miles of historic underground workings exist to the south-southwest of the historic Welch Mine. These mines were closed and sealed in 1953. Subsequent roof collapses over one of these mines (Acme Mine No. 42) led to the development of underground coal fires in the Monarch and possibly the Carney coal beds, which may have spread to other overlying coal beds (i.e., Dietz 2 and Dietz 3). These historic workings have been eliminated from further analysis in this study.

3.2.2 Reasonably Foreseeable Development

Due to the variables associated with future coal production, two coal production scenarios reflecting a lower and an upper production level were projected for the PRB Coal Review to bracket the most likely foreseeable regional coal production level and to provide a basis for quantification of associated impact-causing parameters. Production from 1990 through 2009 increased at an average rate of approximately 4.5 percent per year. For this study, the projected production scenarios begin with the 2010 production level. The resulting estimated range of production in 2030 is 529 to 752 million tons.

Figures A-1 through **A-4** in **Appendix A** show the projected coal development under the lower and upper production scenarios. **Figures A-5** and **A-6** graphically compare the production levels for



Note: Approximate coal mined-out areas were not available for the Montana mine sites.

Source: BLM 2010; CH2MHILL 2009.

Powder River Basin Coal Review

Figure 3-1

Existing Coal Mine, Power Plant, Wind Energy, and Railroad Development

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Wyoming and Montana, respectively. The basis for the projected production ranges included: 1) an analysis of historic PRB production levels in comparison to the gross domestic product (GDP) and national coal demand; 2) an analysis of current PRB coal market forecasts against other coal-producing regions in the United States (U.S.), and mining and transportation costs of PRB coal as compared with demand and other coal-producing regions; 3) the availability, projected production cost, and quality of future mine-specific coal reserves within the PRB region; and 4) the availability of adequate infrastructure for coal transportation. The projected lower and upper production scenarios have been allocated to coal mine subregions in the Wyoming and Montana PRB study areas and to individual mines based on past market shares and information from mine operators. Individual mine production levels were reviewed relative to potential future production constraints (e.g., loadout capacities, air quality permitted production levels, mining costs, coal quality, adjacent remaining coal reserves and existing infrastructure, and observed changes in production levels due to market conditions).

PRB coal production is influenced by a variety of factors including domestic and international electricity consumption, regulatory issues in Central Appalachia, exports of higher rank coals from Illinois basin and Central Appalachian producers, and the erosion of the U.S. dollar against foreign currencies. Various proposed regulatory limits on emissions (e.g., carbon dioxide [CO_2]) create uncertainties that may negatively affect coal consumption and, thus, reduce demand for coal as a source of fuel for the generation of electricity in the U.S. PRB coal provides a low cost fuel supply and replaces the higher rank coals where production in these areas is curtailed or redirected as exports. Growth of coal as a fuel source internationally creates a market demand that increases the export of U.S. coal, including PRB coal.

The methodology used to develop the future coal mine projections for both the lower and upper production scenarios is summarized below.

- The range of total PRB coal mine production was estimated based on information from the following sources:
  - IHS Global Insight (2010) – Electricity consumption is projected to grow 1 percent annually, with coal losing share to natural gas and other energy sources; PRB total annual production is projected to be approximately 460 million tons in 2030, or approximately the same as actual 2008 production.
  - Wood McKenzie (2010) (formerly Hill & Associates) – Total PRB annual production is projected to increase from 464 million tons in 2009 to 644 million tons in 2030.
  - International Energy Agency (2010) – Global electricity consumption is projected to grow 2.5 percent annually to 2030, with the largest demand of all energy sources being for coal. Demand for coal is projected to increase 3 to 4 percent internationally by 2030.
  - U.S. Energy Information Administration (2010) – Similar projection as IHS Global Insight for domestic production; similar projection as International Energy Agency for international production.
  - Information provided by PRB coal mine operators.
- Specific assumptions used to determine the distribution of the two projected production levels included the following:
  - Maximum production limits were based on air quality permits.
  - Production increases for Wyoming PRB study area coal mines were prioritized based on heat value, with the order of production increases being Wright, South Gillette, and North Gillette (Subregions 3, 2, and 1, respectively).

  - Opportunities in Montana for the Many Stars Project (coal mine and mine-mouth coal-to-liquids [CTL] plant) and Otter Creek Mine were based on recent activity with corresponding production start-up.
  - Mine production for future coal conversion project fuel supply in Wyoming was included; the source could be from existing and planned mines (e.g., School Creek Mine).
  - Production at the School Creek and Otter Creek mines would come on-line to fulfill lease terms for due diligence.
  - The Dry Fork, Wyodak, and Rosebud mines would maintain relatively constant production due to mine-mouth customers (i.e., power plants).

- Specific mine loadout capacities were estimated from Burlington Northern Santa Fe (BNSF) railroad reports, mine permit data, knowledge of operations and in-place infrastructure (e.g., storage tracks, number of loadouts, and coal handling facilities), and adjusted based on input from PRB coal mine operators.
- The South Gillette and Wright subregion mines (Subregions 2 and 3, respectively) are serviced by Wyoming State Route (SR) 59, and the North Gillette subregion (Subregion 1) is serviced by U.S. Highway 14/16. Numerous spur roads are tied to these main highways and serve as access roads into the mines in the Wyoming PRB study area.
- The existing road infrastructure provides access to all existing mines and proposed development projects in the Sheridan/Decker subregion (Subregion 4). It is assumed that only minor upgrades to portions of these routes would be required to address possible increases in traffic and capacity of the routes.
- The Ashland/Colstrip subregion (Subregion 5) would include the proposed Otter Creek Mine and Many Stars Project that would require development of infrastructure (e.g., upgrades to existing road networks, power transmission facilities, and other required transportation facilities).
- Two new operations would be developed in the Sheridan/Decker and Ashland/Colstrip subregions (Subregions 4 and 5, respectively) at locations yet to be determined.

3.2.2.1 Wyoming

Based on the analysis conducted for this study, it is projected that the base year (2008) production of 444 mmtpy of coal in the Wyoming PRB study area would grow under the lower production scenario (468 mmtpy) through 2030. Under the upper production scenario, coal production is projected to increase to 615 mmtpy by 2030. Production at currently operating mines is projected to continue throughout the study period (through 2030).

One new mine (School Creek Mine) recently was permitted in the Wright area (Subregion 3); operations are projected to begin in 2012 due to market demand. The WDEQ approved the School Creek Mine permit application on July 17, 2009, as well as an air quality permit for a production rate of 40 mmtpy. It is expected that this mine would supply coal with the other Subregion 3 coal mines for a portion of that subregion's projected production demand. The School Creek Mine would add to production from mines in the higher heat value portion of the Wyoming PRB study area near Wright.

Following the projection of individual mine production levels for the lower and upper production scenarios, likely reserve and mining sequence layouts were developed based on geologic information, 2008 mine pit progressions and projected mine reserve sequence maps on file with the WDEQ/Land Quality Division (LQD), and recovery information provided by PRB operators. The mapped areal extent of mine reserves subsequently was projected in increments beginning in 2009 through 2030 (**Figures A-1** and **A-2** in **Appendix A**). Future coal mining in the Wyoming PRB study area through 2030 is considered highly likely based on the projected production rates in relation to the available economic reserves.

Mine-related capital investment under both the projected lower and upper production scenarios is presented in **Table 3-1**. Other impact-causing parameters associated with Wyoming coal mine operations are summarized in **Tables A-1** and **A-2** in **Appendix A** of this report.

3.2.2.2 Montana

Based on the analysis conducted for this study, it is projected that the base year (2008) production of 44 mmtpy of coal in the Montana PRB study area would increase to 61 mmtpy under the lower production scenario and to 137 mmtpy under the upper production scenario by 2030. Production at currently operating mines is projected to continue throughout the study period (through 2030).

Table 3-1 Projected Coal Mine Total Capital Investment by Year (million dollars)

	Lower Production Scenario		Upper Production Scenario	
	2020	**2030**	**2020**	**2030**
Mobile Equipment[1]				
Subregion 1 – North Gillette	85	110	171	187
Subregion 2 – South Gillette	93	138	296	343
Subregion 3 – Wright	977	831	1,362	1,363
Subregion 4 – Sheridan/Decker	257	44	530	321
Subregion 5 – Ashland/Colstrip	269	286	585	549
Subtotal	**1,681**	**1,409**	**2,944**	**2,763**
Rail Loadout Facilities[2]				
Subregion 1 – North Gillette	0	0	20	0
Subregion 2 – South Gillette	0	0	50	0
Subregion 3 – Wright	0	0	20	50
Subregion 4 – Sheridan/Decker	140	5	280	5
Subregion 5 – Ashland/Colstrip	140	140	285	190
Subtotal	**280**	**145**	**655**	**245**
Highway Transportation[3]				
Subregion 1 – North Gillette	25	0	25	0
Subregion 2 – South Gillette	25	0	40	0
Subregion 3 – Wright	25	0	25	0
Subregion 4 – Sheridan/Decker	10	0	20	0
Subregion 5 – Ashland/Colstrip	10	10	20	10
Subtotal	**95**	**10**	**130**	**10**
Total	**2,056**	**1,564**	**3,729**	**3,018**

[1] Calculated in 2010 dollars at $2.53 per bank cubic yard annual capacity.

[2] Calculated in 2010 dollars based on estimated current facilities capacity and required upgrades. Additional estimated cost for addition of other facilities included where required.

[3] Calculated in 2010 dollars at $6.0 million per road mile relocated. Does not include costs for land acquisition or design and permitting of coal leases.

The proposed Youngs Creek Mine is in the Sheridan/Decker area (Subregion 4). The mine would be located in Wyoming just south of the Montana-Wyoming state line and would incorporate PSO's former Ash Creek Mine. Two other potential coal mines (i.e., Otter Creek and the Many Stars mines) also have been identified in the Montana PRB study area (Subregions 5). No permit applications have been submitted at this time; however, it is likely that these three mines would be developed due to the projected demand for coal and clean coal energy. Also, lower cost coal reserves in the PRB are being depleted, and there would be continued demand for production from within the region.

Based on overall demand for coal from the PRB as described by the mine operators, it is assumed that there would be two additional new mines developed in the Montana PRB. As these operations have not been announced, it is assumed that one would be in the Sheridan/Decker area (Subregion 4) and one would be in the Ashland/Colstrip area (Subregion 5). These assumptions include startup in 2020 with increasing production through 2030. Projected rates and volumes were estimated based on the projected new coal mines for which information is available (Youngs Creek and Otter Creek Mines); production scenarios for these mines are considered typical.

Under the lower production scenario, it is projected that production at the Youngs Creek Mine would be initiated by 2020, and the Otter Creek and Many Stars mines would be developed by 2020 and 2025, respectively. Under the upper production scenario, it is projected that production would be initiated at both the Youngs Creek and Otter Creek mines by 2020, with the Many Stars Mine initiated by 2025. Development of these mines would depend on the market for the coal. It is projected that the Youngs Creek Mine would ship coal by a new rail spur in Montana. In late 2009, the Ark Land Company leased the privately owned coal at the Otter Creek Mine area. The state reserves at Otter Creek also have been leased by the company. It is assumed that development of the Otter Creek Mine would require construction of some transportation infrastructure to connect to the existing BNSF mainline north of the project. It is assumed that the Many Stars Mine would be developed in conjunction with a mine-mouth CTL plant.

Following the development of individual mine production levels for the lower and upper production scenarios, individual mine reserves and mining sequence layouts were developed based on geologic information and 2009 mine pit progressions on file with the MDEQ. Reserves beyond the current mine permit boundaries and existing mine lease boundaries (e.g., potential developments including Otter Creek and Many Stars mines) were sequenced based on stripping ratios. The mapped areal extent of mine reserves subsequently was projected in increments beginning in 2009 through 2030 (**Figures A-3** and **A-4** in **Appendix A**). Future coal mining in the Montana PRB study area is considered highly likely based on the anticipated production rates in relation to the available economic reserves.

Mine-related capital investment under both the projected lower and upper production scenarios is presented in **Table 3-1**.

3.2.3 Assumptions

In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for coal mines.

<u>Past and Present Development Assumptions</u>

- Existing operations are not part of the abandoned mine lands programs.

<u>RFD Assumptions</u>

- All currently operating coal mines in the Wyoming and Montana PRB study areas would continue to operate through 2030 based on projected production rates in relation to available economic resources.

- The School Creek Mine would be operational by 2020 under both the lower and upper production scenarios. This mine is considered highly likely under both production scenarios.
- Youngs Creek Mine and the other Decker area mines would obtain new WDEQ- and MDEQ-approved air quality permits, as applicable, consistent with their forecasted production levels.
- The Otter Creek Mine would be developed by 2020 under the lower production scenario and would initiate production by 2020 under the upper production scenario based on due diligence requirements of the state lease area. The likelihood for this mine is considered moderate for 2020 under both the lower and upper development scenarios.
- The Youngs Creek Mine would initiate production by 2020 under both the lower and upper production scenarios. The likelihood for this mine is considered moderate to high for 2020 under both the lower and upper development scenarios.
- The Many Stars Mine would be operational by 2030 under both the lower and upper production scenarios. Development of this mine is dependent on development of a mine-mouth CTL plant. The likelihood for this mine is considered low to moderate for 2030 under both the lower and upper development scenarios.
- Two new Montana PRB coal mines would begin operations under the upper production scenario by 2020. The likelihood for these mines is considered low to moderate.
- Some transportation mode or combination of modes, potentially including rail, would be required to serve the proposed Youngs Creek and Otter Creek mines. However, these options would not include construction of the full 130 miles of new rail line between Miles City and Decker, Montana, previously proposed as the Tongue River Railroad (as identified during Phase I). It is projected that Youngs Creek Mine production would be transported by a new rail spur that would connect to the existing BNSF spur line south of the Decker Mine, which in turn connects to a BNSF main line near Sheridan, Wyoming. A rail line to support the Otter Creek Mine, which conceivably could incorporate a portion of the alignment identified for the Tongue River Railroad, likely would extend north from that proposed operation to connect with an existing BNSF main line across southern Montana.
- No major state or interstate highways would be impacted by future mining activities in the Montana PRB study area. (See Section 3.15.2.1 relative to mining-related highway relocation in the Wyoming PRB study area.)
- Continued capacity increases by Union Pacific (UP) and BNSF railroads would accommodate demand and resulting production increases in the Wyoming PRB study area.
- Groundwater pumpage would come from the Wasatch and Fort Union formations.

3.2.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to coal mine development in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b).

Updated information relative to coal mine projects for Phase II of the study was obtained from publically available information, as well as proprietary reports and industry input from individual coal mine operators. Public information in the form of permit documents, annual reports, permit applications, LBAs, EISs, correspondence, and articles obtained from the WDEQ/LQD and AQD, MDEQ, BLM High Plains District Office and Wyoming State Office, BLM Montana State Office, Wyoming State Mine Inspector's Office, U.S. Department of Energy (USDOE), Federal Energy Regulatory Commission (FERC), and numerous trade and industry publications. Proprietary economic reports forecasting regional coal market activity were obtained from Wood McKenzie, IHS Global Insight, and proprietary industry input from the

individual coal mine operators in the Wyoming and Montana PRB study areas. Specific references used for the coal mine information in this report include the following:

Burlington Northern Santa Fe Railroad (BNSF). 2010. Internet website: http://www.bnsf.com. Accessed on February 2010.

Bureau of Land Management (BLM). 2010. Casper Field Office, Digital Files of PRB Area (Areas 1, 2, and 3). Accessed on March 2010.

Foulke, T., R. Coupal, and D. Taylor. 2002. Economic Trends in Wyoming's Mineral Sector: Coal. University of Wyoming Cooperative Extension Service. January 2002.

IHS Global Insight. 2010. Coal outlook information. Internet website: http://www.ihsglobalinsight.com/ ProductsServices/ProductDetail770.htm#US (BLM subscription of proprietary information). Accessed on February 2010.

International Energy Agency. 2010. Projected coal production information. Internet website: http://www.iea.org. Accessed on February 2010.

Many Stars Project. 2010. Project Website. Australian-American Energy Company LLC and Crow Nation. Internet website: www.manystarsctl.com. Accessed on April 28, 2010.

Mine Safety and Health Administration. 2010. Internet website: http://www.msha.gov/. Accessed on February-May-2010.

Montana Department of Environmental Quality (MDEQ). 2010. Air Quality Permits.

- Decker Coal Company, West, North, and East Decker Mining Areas, Permit #1435-05. May 9, 2008.
- Spring Creek LLC, Spring Creek Mine, Permit #1120-10. March 18, 2009.
- Western Energy Company, Areas A, B, D, and E, Rosebud Mine, Permit #1483-08. October 5, 2010.
- Western Energy Company, Area C, Rosebud Mine, Permit #1570-06. July 19, 2010.
- Westmoreland Resources, Inc. Absaloka Mine, Permit #1418-06. March 25, 2010.

Montana Department of Environmental Quality, Industrial and Energy Mineral Bureau. 2010. Annual Mining Reports.

- Big Sky Coal Company, Big Sky Mine, January 1, 2008 – December 31, 2008. March 30, 2009.
- Spring Creek Coal LLC, Spring Creek Mine, January 1, 2008 – December 31, 2008.
- Decker Coal Company, West & North Pits, January 1, 2008 – December 31, 2008. April 20, 2009.
- Decker Coal Company, East Pits, January 1, 2008 – December 31, 2008. April 20, 2009.
- Signal Peak Energy, LLC, Bull Mountains Mine No.1, 2008 Annual Report. April 10, 2009.
- Western Energy Company, Rosebud: Area A, October 1, 2007 to September 30, 2008. February 27, 2009.
- Western Energy Company, Rosebud: Area B, October 1, 2007 to September 30, 2008. February 27, 2009.
- Western Energy Company, Rosebud: Area C, October 1, 2007 to September 30, 2008. February 27, 2009.
- Western Energy Company, Rosebud: Area D, October 1, 2007 to September 30, 2008. February 27, 2009.
- Western Energy Company, Rosebud: Area E, October 1, 2007 to September 30, 2008. February 27, 2009.
- Westmoreland Resources, Inc., January 1, 2008 – December 31, 2008. March 20, 2009.

- Westmoreland Savage Corporation, Savage Mine, January 1, 2008 - December 31, 2008. February 27, 2009.

Montana Department of Natural Resources and Conservation, Land and Trust Management Division. 2010. Otter Creek Data – Version 2006.08.15 (link to Norwest study). Internet website: http://dnrc.mt.gov/trust/MMB/otter_creek/Default.asp. Accessed on February 2010.

Norwest Corporation. 2009. Montana Otter Creek State Coal Valuation. Submitted to Montana Department of Natural Resources & Conservation, Trust Land Management Division, Helena, Montana. January 30, 2009.

Union Pacific (UP) Railroad. 2010. Internet website: http://www.up.com/. Accessed on February 2010.

U.S. Energy Information Administration. 2010. Projected coal production information. Internet website: http://www.eia.doe.gov/fuelcoal.html. Accessed on February 2010.

Wood McKenzie. 2010. Projected coal production information. Internet website: http://www.woodmacresearch.com/cgibin/wmprod/portal/energy/productServices.jsp?region= ANY&sector= 09&project=ANY&hidden_region=ANY&hidden_sector=09&hidden_project=ANY (BLM subscription of proprietary information). Accessed on February 2010.

Wyoming Department of Environmental Quality/Air Quality Division (WDEQ/AQD). 2010. Air Quality Annual Reports.

- Alpha Coal West, Inc., Belle Ayr Mine, Annual Report Permit MD-1476A2, 2008.
- Alpha Coal West, Inc., Eagle Butte Mine, Annual Report Permit MD-1251A, 2008.
- Arch Coal, Inc., Jacobs Ranch Mine, Annual Report Permit MD-3851A, 2008.
- Arch Coal, Inc., Coal Creek Mine, Annual Report Permit MD-5393, 2008.
- Cloud Peak Energy, Antelope Mine, Annual Report Permit MD-1543, 2008.
- Cloud Peak Energy, Cordero Rojo Mine, Annual Report Permit MD-1058, 2009.
- Kiewit Mining Groups, Inc., Buckskin Mine, Annual Report Permit MD-1513, 2008.
- Powder River Coal Company, Caballo Mine, Annual Report Permit MD-1477, 2008.
- Powder River Coal Company, North Antelope Rochelle Mine, Annual Report Permit MD-6375, 2008.
- Powder River Coal Company, North Rochelle Mine, Annual Report Permit CT-6445, 2008.
- Powder River Coal Company, School Creek Mine, Annual Report Permit CT-6445, 2008.
- Powder River Coal Company, Rawhide Mine, Annual Report Permit MD-212, 2009.
- Western Fuels-Wyoming, Inc., Dry Fork Mine, Annual Report Permit MD-6913, 2008.
- Wyodak Resources Development Corp., Wyodak Mine, Annual Report Permit MD-1510, 2008.

Wyoming Department of Environmental Quality/Land Quality Division (WDEQ/LQD). 2010. Annual Reports for Operating Coal Mines, Permit and TFN Mine Plan Sections.

- Antelope Mine AR 2008/2009. March 2009.
- Ash Creek Mine 2009 Annual Report. February 2010.
- Belle Ayr Mine 2010 Annual Report. January 2010.
- Big Horn Coal Company 2008-2009 Annual Report. August 2009.
- Buckskin Mining Company 2009 Annual Report, January 1, 2009 – December 31, 2009, January 22, 2010.
- Caballo Mine 2009 Annual Report. Revised January 2010.
- Cordero Rojo Mine 2008-2009 Annual Report. October 2009.
- Dave Johnston Mine 2010 Annual Report. December 17, 2009.
- Dry Fork Mine, Annual Report, January 1, 2008 through December 31, 2008. April 2009.
- Eagle Butte Mine 2009 Annual Report. December 2009.
- Fort Union Mine 2009 Annual Report. March 2010.

- Jacobs Ranch Mine, January 1, 2008 – December 31, 2008. Revised July 19, 2009.
- North Antelope Rochelle Mine, 2009 Annual Report. December 2009.
- KFx Mine 2009 Annual Report. February 2010.
- Rawhide Mine 2009 Annual Report. December 2009.
- School Creek Mine, Mine Plan Section 764-T1 Permit. September 2007.
- Thunder Basin Coal Company, Black Thunder Mine 2009 Annual Report. December 2009.
- Thunder Basin Coal Company, Coal Creek Mine, 2009-2010 Annual Report. February 2010.
- Triton Coal Company, North Rochelle Mine 2009 Annual Report. December 2009.
- Welsh No. 1 North Mine 2009-2010 Annual Report. March 2010.
- Wyodak Mine, Wyodak Resources Development Corp., 2009 Annual Report. January 2010.
- Youngs Creek Mine, Mine Plan Section TFN 4 6/314. December 2009.

3.3 Power Plants

3.3.1 Past and Present Development

3.3.1.1 Wyoming

As of the end of base year 2008, five coal-fired power plants were in operation in the PRB study area and one was under construction (**Figure 3-1**). Black Hills Corporation owns and operates the Neil Simpson Units 1 and 2 (21.7 megawatts [MW] and 80 MW, respectively), WYGEN 1 (80 MW), WYGEN 2 (90 MW), and Wyodak (330 MW) power plants, all of which are located approximately 5 miles east of Gillette, Wyoming. Black Hills Corporation's 110-MW WYGEN 3 power plant located east of Gillette was under construction in base year 2008; construction was completed and operations initiated in 2010. Additionally, Pacific Power and Light's Dave Johnston Power Plant is located near Glenrock, Wyoming, outside of, but adjacent to, the study area.

Hartzog, Arvada, and Barber creeks are three separate interconnected gas-fired power plants located near Gillette, Wyoming. Each contains three separate 5-MW rated turbines to provide electric power to Basin Electric and its customers. In winter, the maximum capacity can reach 22.6 MW from each site. All units are in operating condition, although they do not operate at maximum capacity.

3.3.1.2 Montana

As of the end of base year 2008, three coal-fired power plants were in operation in the Montana PRB study area (**Figure 3-1**). The major existing coal-fired power plant (Colstrip Power Plant) is located in Rosebud County near Colstrip, Montana. The facility consists of four separate coal-fired units on the same plant site. Units 1 and 2 are estimated to have 450 MW of power generation capacity each, and units 3 and 4 have a design capacity of 778 MW each. The facility has a permit to burn up to 28 percent petroleum coke in Units 1 and 2, replacing coal as a fuel source.

A smaller coal-fired power plant (Colstrip Energy Limited's Rosebud Power Plant) is in operation at a site approximately 1.5 miles north of Colstrip, Montana (**Figure 3-1**). The facility generally burns waste coal and has operated below maximum capacity (approximately 120 MW) in recent years.

The Hardin Generation Project initiated operation in 2007 (Wheeler 2008) at a site approximately 1.2 miles northeast of Hardin, Montana (**Figure 3-1**). This coal-fired boiler unit has a capacity of 113 MW of electric generation.

3.3.2 Reasonably Foreseeable Development

Coal-fired power plants have been, and likely would continue to be, constructed in the PRB to avoid high shipping costs for coal. Currently, adequate transmission line capacity exists to deliver the existing generating capacity to market; however, that capacity would need to be increased in order to provide adequate markets for new power plants.

Construction of new coal-fired power plants may involve some of the largest capital investments undertaken by industry, and substantial time would be required for obtaining permits and constructing such facilities. Recent estimates for a major coal-fired power plant are that a project would require 2 to 4 years to obtain the required permits, with an additional 4 to 6 years for construction (Basin Electric 2008). An estimated development cost of over $1 billion would apply to most major coal-fired power plants (based on an estimated $3,200 per installed kilowatt [kW] [$3.2 million per installed MW] generating capacity) (U.S. Energy Information Administration 2010). A workforce of up to 1,500 personnel would be required at peak construction, with a likely operating workforce of 100 to 150 for each operating plant based on estimates from current operating facilities.

Air emissions from coal-fired power plants are undergoing intense scrutiny by regulatory agencies, environmental groups, and the general public. Recent proposed legislation in the U.S. Congress and proposed regulations by the U.S. Environmental Protection Agency (USEPA) may influence air emissions limits, including CO_2, which is now currently regulated.

The USEPA finalized its rule for the permitting of greenhouse gas (GHG) emissions from major industrial sources (75 Federal Register 31514, June 3, 2010), which targets GHGs for major source permitting actions under the Clean Air Act. This requirement includes analysis of “Best Available Control Technology” (BACT) for GHGs, if above 25,000 tons per year (tpy) of CO_2-equivalents for new sources. Although undefined, this requirement poses substantial uncertainty for the development of coal-fired power generation, and it is likely that current plans are on hold until these crucial issues are resolved.

The USEPA finalized its rule to regulate mercury emissions from coal-fired power plants as part of its New Source Review regulations (USEPA 2005). This so-called Clean Air Mercury Rule (CAMR) specified limits on new and existing sources, and generally required controls on mercury emissions from major coal-fired power plants. On February 8, 2008, the D.C. Circuit Court of Appeals vacated the CAMR, which has yet to be re-promulgated. The uncertain status of this regulation raises the uncertainty of construction planning for coal-fired power plants.

Even a well-regulated facility would have major emissions of criteria air pollutants. For example, for a 1,000-MW plant using the BACT for this industry, the estimated sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions would be approximately 2,500 tpy for each pollutant. Particulate matter emissions likely would be 600 to 700 tpy from the power plant stack, with additional fugitive emissions from the handling of coal and waste. The air permit for each facility would need to demonstrate BACT for each of the major criteria air pollutants, including lead.

Water requirements for each coal-fired power plant would involve both a determination of the control technologies (wet scrubber versus dry scrubber for SO_2) and the facility cooling operations (wet or dry cooling towers, or a potential hybrid). The estimated maximum water supply requirement for a wet scrubber and a wet cooling tower at a typical 1,000-MW coal-fired power plant is approximately 10,000 to 12,000 acre-feet per year, based on recent analyses at other facilities.

3.3.2.1 Wyoming

Two projects currently under construction (Basin Electric’s Dry Fork project and Black Hills Corporation’s WYGEN 3 project) are projected to be operational in 2020 and 2030. No additional coal-fired power plants currently are being planned for the Wyoming PRB study area, and given the uncertainty of current and potential air quality regulations, no additional plants are projected for operation by 2020. Any proposed coal-fired power plant that plans to initiate operation by 2020 currently would need to be undergoing air permit review in order to obtain the required construction permits and complete construction by 2020.

<u>WYGEN 3 Power Plant</u>. Black Hills Corporation obtained an air construction permit for the 110-MW coal-fired WYGEN 3 power plant, located east of Gillette, Wyoming (**Figure 3-1**). Construction was completed and operations initiated in 2010.

Dry Fork Power Plant. Basin Electric Power Cooperative obtained an air construction permit for a 422-MW (gross) coal-fired power plant (Dry Fork) near Gillette, Wyoming (**Figure 3-2**). As of June 2010, construction of the facility was estimated at approximately 85 percent complete, with a projected startup date of 2011. An estimated 1.2 million tons of coal per year would be required to fuel the facility. The control technology includes a state-of-the-art selective catalytic reduction system for the control on NO_x, and a dry scrubber. Cooling operations would be provided by an air-cooled condenser, thereby minimizing the water demand for this facility. Operation of this facility is included in the upper and lower production scenarios for 2020 and 2030.

Two-Elk Unit 1. North American Power Group obtained a permit for a 280-MW coal-fired power plant (Two-Elk Unit 1) at a 40-acre site located approximately 15 miles southeast of Reno Junction (near Wright), Wyoming. This unit would be dry-cooled, requiring very little water. As permitted, the project also would include installation of a 45-MW gas-fired turbine. Campbell County approved more than $123 million in industrial revenue bonds for application to the Two-Elk financing. The air permit originally was issued in August 2002; construction was initiated, with startup originally projected for 2011. However, the permit for the facility has lapsed (Potter 2010), and completion of construction is considered not likely for 2020 and speculative for 2030. Therefore, it has been eliminated from further consideration in this study.

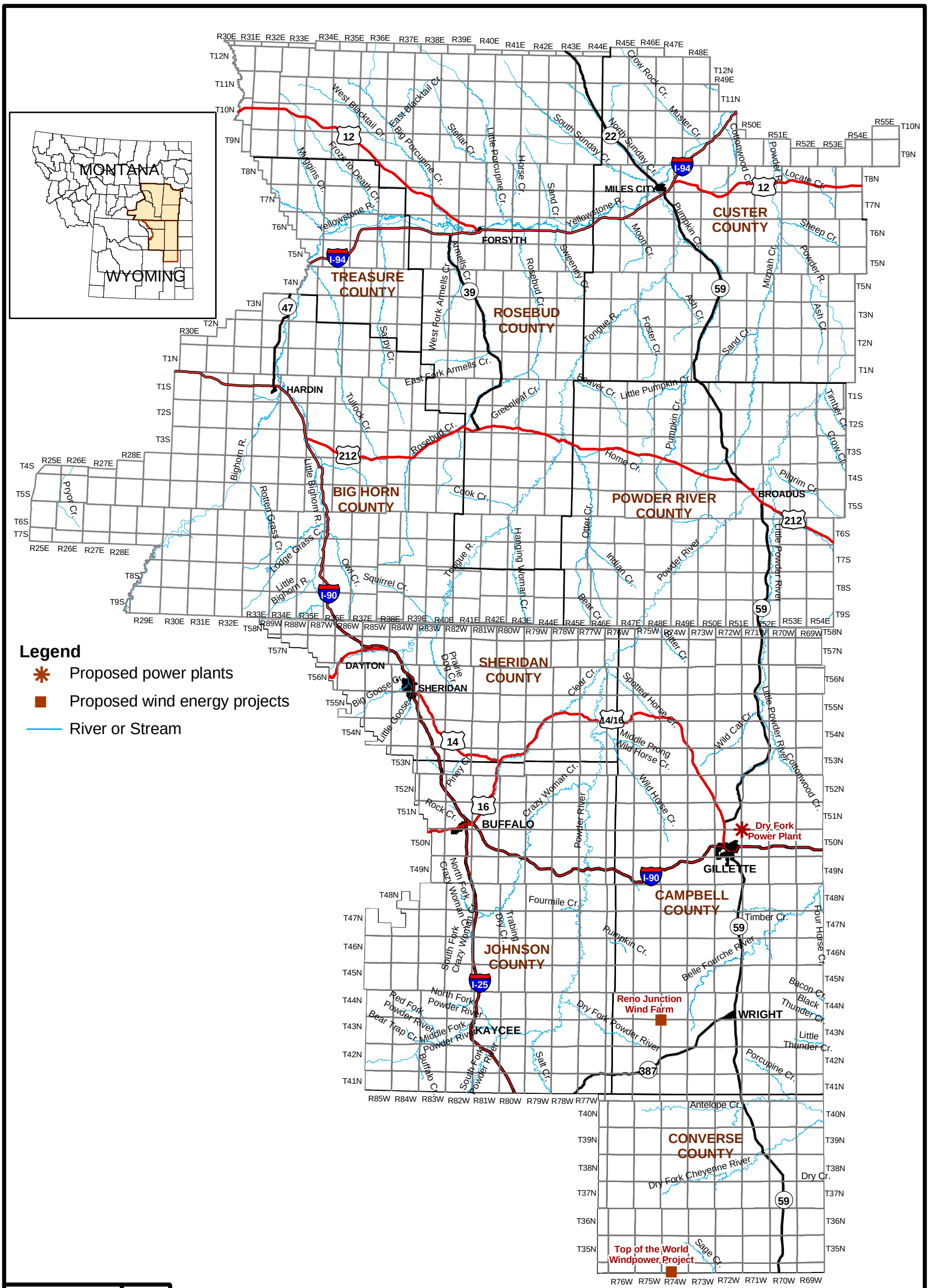
Two-Elk Unit 2. Wyoming Power Company (a subsidiary of North American Power Group) has submitted a permit application for Two-Elk Unit 2. This unit would be a 750-MW supercritical pulverized coal-fired electric generating unit that would burn coal from the nearby mines. The unit would be located on an approximately 60-acre site adjacent to Two-Elk Unit 1. However, the air quality permit for this facility has lapsed, and construction is not considered likely for 2020 and speculative for 2030. Therefore, it has been eliminated from further consideration in this study.

Oxy-fuel-fired Pulverized Coal Demonstration Plant. A consortium headed by Babcock & Wilcox, and including the Black Hills Corporation, Air Liquide, and Battelle Memorial Institute, submitted an application for a federal grant from the USDOE under the Clean Coal Power Initiative – Round 3 to develop a 100-MW oxy-fuel-fired pulverized coal demonstration power plant near Gillette, Wyoming, by 2016. The project was intended to establish the technical and economic viability of a near-zero emissions power plant. Achieving near-zero emissions would be accomplished in part through CO_2 capture (a target of 1 mmtpy) and either carbon sequestration or use of the CO_2 in enhanced oil recovery (EOR) operations. The application was unsuccessful (National Energy Technologies Laboratory 2010). Due to the uncertainty regarding the consortium's continued interest in developing a demonstration project or the availability of funding to do so, the project is considered speculative. Therefore, it has been eliminated from further consideration in this study.

Other Power Plants. It is estimated that under the upper production scenario a maximum of one additional 700-MW coal-fired power plant would be constructed through 2030. It is assumed the additional unit, if developed, would be constructed in the Gillette area or near operating coal mines. The main restriction appears to be the lack of electric power transmission capacity from the area to customers outside the state. All existing power plants in the PRB region are assumed to remain operational through 2030.

3.3.2.2 Montana

Otter Creek Energy Project. In the Phase I update of the Task 2 report (AECOM 2009a), the Otter Creek Energy Project (previously projected for potential construction near Ashland, Montana) was identified as having a low likelihood for development by 2020. However, there has been no evident regulatory activity in support of this project. Therefore, the likelihood for development of this facility currently is considered speculative throughout the timeframe of this study (through 2030), and it has been eliminated from further consideration.



Source: BLM 2010; CH2MHILL 2010.

Powder River Basin Coal Review

Figure 3-2

RFD Power Plants and Wind Energy Projects

11/03/10

Roundup Power Plant. Bull Mountain Development Company has permitted the Roundup Power Project, a coal-fired power plant that would operate two 390-MW pulverized coal-fired boilers. This mine-mouth power plant, if constructed, would be located adjacent to the Bull Mountains Mine, approximately 12 miles south-southeast of Roundup, Montana, and just east of U.S. Highway 87 in Musselshell County. As this power plant would be located greater than 30 miles west of the Montana PRB study area, the facility has been eliminated from further analysis in this study.

3.3.3 Assumptions

In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for power plants:

Past and Present Development Assumptions

- Surface disturbance associated with a typical power plant facility would be 60 to 200 acres, based on available acreage data from other power plants.
- Annual emissions for the Colstrip Power Plant would be 16,000 tpy of SO_2, 32,000 tpy of NO_x, and approximately 500 tpy of particulate matter with an aerodynamic diameter of 10 microns or less (PM_{10}) from the main stacks.
- Power plant construction would require a workforce of 750 to 1,000 construction workers employed over a 4-year period, with up to 1,500 workers employed during peak construction. The operating workforce is estimated at 100 to 150 workers.

RFD Assumptions

- All power plants operating in 2008 would continue operating through 2030.
- New power plants would have a construction workforce of 750 to 1,000 construction workers employed over a 4-year period (with up to 1,500 workers employed during peak construction) and an operations workforce of 100 to 150 workers.
- Operation of the WYGEN 3 power plant (located east of Gillette) would be initiated in 2010. As originally permitted, annual emissions for the power plant would be 2,028 tpy of NO_x, 3,381 tpy of SO_2, and 421 tpy of PM_{10}. Continued operation of this facility is considered highly likely under both the upper and lower production scenarios through 2030.
- The Basin Electric Power Cooperative's 250-MW Dry Fork power plant (located east of Gillette) would be operational by 2011. Operation of this facility is considered highly likely under both the upper and lower production scenarios for 2020, with continued operations through 2030.
- Under the upper production scenario, one additional 700-MW power plant also could be constructed in the Wyoming PRB study area (presumably near Gillette) by 2030.
- New power plants would result in minimal added rail shipping and associated emissions.
- Existing power plants would be required to apply additional controls for NO_x, SO_2, PM_{10}, and particulate matter with an aerodynamic diameter of 2.5 microns or less in response to the regional haze rule.
- New power plants would comply with BACT for maximum controls. These current factors would be used to estimate emissions. (For example, 0.06 pounds per million British thermal unit [lb/MMBtu] for NO_x and sulfur oxides, and 0.025 lb/MMBtu for PM_{10} emissions controls.)

3.3.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to power plant development in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for

the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). For Phase II of the study, updated information relative to existing power plants in the Wyoming PRB study area was obtained from construction and operating permits on file with the WDEQ and direct contact with power plant operators. Data for existing power plants in the Montana PRB study area were obtained from the facility permits available through the MDEQ website and from discussions with MDEQ staff. Information relative to reasonably foreseeable power plants through 2020 was obtained from existing permit applications either under review or extended for a start of construction and news releases. Data also were obtained from identified proponents (Black Hills Corporation and North American Power Group). Additional information was obtained from the following sources:

Basin Electric. 2008. PSD Permit Application for the NexGen Power Plant, South Dakota.

National Energy Technologies Laboratory. 2010. National Energy Technology Laboratory, Major Demonstration – Clean Coal Power Initiative (CCPI). Internet website: http://www.netl.doe.gov/ technologies/coalpower/cctc/ccpi/index.html. Accessed on January 11, 2011.

Potter, D. 2010. Wyoming Department of Environmental Quality. Personal communication with B. Macdonald, AECOM. March 31, 2010.

U.S. Energy Information Administration. 2010. Updated Capital Cost Estimates for Electric Generation Plants, Table 1. Internet website: http://www.eia.doe.gov/beck_plantcosts/index.html. Release date November 2010.

U.S. Environmental Protection Agency (USEPA). 2005. Utility Mercury Reductions Rule. Internet website: http://www.epa.gov/air/mercuryrule/.

Wheeler, C. 2008. Montana Department of Environmental Quality. Personal communication with B. Macdonald, AECOM, relative to Hardin Generation Project. May 28, 2008.

3.4 Wind Energy

3.4.1 Past and Present Development

Wyoming ranks among the top states in terms of wind energy potential. Although many Wyoming locations having the highest potential are in the southern portion of the state, areas within the Wyoming PRB study area (i.e., Converse and Campbell counties) also offer excellent potential to support commercial-scale wind generation projects.

As of the end of base year 2008, there was one operating wind power generation project and three others under construction in Converse County near Glenrock, Wyoming. Three of the projects are owned by PacifiCorp and are located on or near the site of the former Dave Johnson Mine, approximately 15 miles north of the existing Dave Johnson Power Plant (**Figure 3-1**).

The Glenrock Wind Energy Project, a 99-MW project with 66/1.5-MW turbines, began operations in December 2008. The Rolling Hills Wind Energy Project, a 99-MW project with 66/1.5-MW turbines, and the Glenrock III Wind Energy Project, a 39-MW project with 26/1.5-MW turbines, began operations in January 2009 (PacificCorp 2010). The fourth project (Campbell Hill Windpower Project) is owned by Three Buttes LLC, a subsidiary of Duke Energy. The Campbell Hill Windpower Project, a 99-MW project with 66/1.5-MW turbines, is located north of Glenrock, near the Natrona County line. This project began operations in December of 2009. Campbell Hill supplies wind energy to PacifiCorp under the terms of a 20-year power purchase agreement (Duke Energy 2009a).

Surface disturbance for wind energy projects is associated with development of access roads, a turbine assembly pad, and a foundation pad for each wind turbine tower. Additional surface disturbance results

from the installation of transformers and substations, underground electric and fiber optic cables, one or more operations and maintenance facilities, meteorological towers, and a transmission line connecting the project to the regional grid. Much of the disturbance area is reclaimed immediately following construction, with long-term disturbance associated with permanent facilities (i.e., access roads, support facilities, and tower foundations).

Wind generating projects have an expected life of approximately 25 years, which could be extended based on market conditions and the overall condition of the infrastructure. Some redisturbance would occur at the time of decommissioning, followed by final reclamation.

3.4.2 Reasonably Foreseeable Development

With increasing concerns over global climate change, there is strong interest from consumers, investor-owned utilities, and environmental and economic sustainability interests in renewable energy projects, including wind energy. The current interest in wind energy generation is driven in part by state mandates for utilities to increase the use of renewable energy sources in their overall energy portfolio, decisions by environmentally conscious firms to use renewable energy sources, and the development of a wind energy manufacturing infrastructure in the region. As an example of the above, Xcel Energy, an electric power and natural gas energy company with major operations in Colorado, plans to meet 20 percent of its energy sales in Colorado from renewable resources. Also, Vestas Americas has begun manufacturing blades for wind turbine generators at a new facility in Windsor, Colorado (Xcel Energy 2007).

Duke Energy's 200-MW Top of the World Windpower Project, located approximately 4 miles northeast of Glenrock, initiated construction in January 2010 and anticipates completion during the later part of the year (**Figure 3-2**). The company plans to install 66 General Electric 1.5-MW turbines and 44 Siemens Energy 2.3-MW turbines. PacifiCorp will buy all of the power generated by the Top of the World project (Duke Energy 2009b).

Third Planet Windpower's proposed Reno Junction Wind Project, a 150-MW project with 100/1.5-MW turbines, would straddle Wyoming State Highway (SH) 50 approximately 40 miles south of Gillette near Black Hills Corporation's recently-constructed substation (**Figure 3-2**). The company received a permit from the Wyoming Industrial Siting Council in July 2010 and plans to initiate construction in late 2010 on approximately 14,000 acres leased from landowners and the State of Wyoming. The project is anticipated to go online in 2011 (Gillette News Record 2010a,b).

No other currently proposed wind energy projects have been identified in the Wyoming PRB study area. However, the quality of wind resources in the Wyoming PRB suggests that additional wind energy development is likely to occur within the timeframe of this study. Therefore, for this analysis, it is projected that two additional 99-MW projects would be developed in Converse County by 2030.

3.4.3 Assumptions

In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for wind energy projects:

<u>Past and Present Development Assumptions</u>

- Disturbance acreage assumptions include:
  - Substations: 3 acres per 100-MW phase or project
  - Roads/power lines: 0.25 mile per tower, with a combined 50-foot-wide right-of-way (ROW)
  - Tower foundations: 0.5 acre per tower

RFD Assumptions

- Based on a project life of 25-years, the four wind energy projects operating or under construction in the study are as of end of base year 2008 still would be operational in 2020 and 2030.
- Third Planet Windpower's 150-MW Reno Junction Wind Project would be constructed and operational by 2012. Therefore, this project is considered highly likely for 2020, with assumed continued operation for 2030.
- Duke Energy's 200-MW Top of the World Windpower Project would be constructed and operational by the end of 2010. Therefore, this project is considered highly likely for 2020, with assumed continued operation for 2030.
- Two more wind energy projects, each with a rated capacity of 99 MW, would be completed by 2030. Both of these facilities would be located in Converse County.
- Disturbance acreage assumptions for RFD wind energy projects are the same as identified above for past and present development.

3.4.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to wind energy development in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). Updated information relative to wind energy projects for Phase II of the study was obtained from the following sources:

CH2MHILL. 2010. Final Report, Wyoming Industrial Development Information and Siting Act, Section 109 Permit Application, Reno Junction Wind Energy Project. Prepared for Third Planet Windpower, LLC. April 22, 2010.

_____. 2009. Wyoming Industrial Development Information and Siting Act, Section 109 Permit Application, Campbell Hill Windpower Project. Prepared for Duke Energy Corporation/Three Buttes Windpower, LLC. January 2009.

Duke Energy. 2009a. Duke Energy Brings Wyoming Wind Project Online. Internet website: http://www.duke-energy.com/news/releases/2009120101.asp. December 1, 2009. Accessed on March 24, 2010.

_____. 2009b. Duke Energy Brings Two Wind Power Projects On Line. Internet website: http://www.duke-energy.com/news/releases/2009100101.asp#. October 1, 2009. Accessed on March 24, 2010.

Gillette News Record. 2009. The New Wyoming Wind Rush. Internet website: http://www.gillettenewsrecord.com/ articles/2009/06/21/news/today/news03.txt. June 20, 2009. Accessed on March 24, 2010.

_____. 2010a. Area's First Wind Farm Could Face County, State Zoning Laws. Internet website: http://www.gillettenewsrecord.com/articles/2010/02/04/news/today/news04.txt. Accessed on July 24, 2010.

_____. 2010b. Wind Farm Gets Siting Council Okay. Internet website: http://www.gillettenewsrecord.com/articles/2010/07/14/news/today/news02.txt. Accessed on July 24, 2010.

PacifiCorp. 2010. Renewable Energy – Summary of Projects. Internet website: http://www.pacificorp.com/es/re.html. Accessed on July 2010.

Rural Utilities Service. 2007. Draft Environmental Impact Statement for the Basin Electric Power Cooperative Dry Fork Station and Hughes Transmission Line. August 2007.

The Glenrock Independent. 2009. Top of the World: 110 Turbines. Internet website: http://www.warms.com/documents/TopoftheWorld110Turbines.pdf. Accessed on July 28, 2010, October 1, 2009.

Xcel Energy. 2007. News Release: Xcel Energy Files Long-range Generation Resource Plan: Aligns Efforts to Meet Colorado Climate Action Plan. Internet website: http://www.xcelenergy.com/Colorado/Company/Newsroom/News%20Releases/Pages/Xcel_Energy_files_long_range_generation_resource_plan_aligns_efforts_to_meet_Colorado_Climate_ Action_Plan_goal.aspx. Accessed on July 2010.

3.5 Railroads

3.5.1 Past and Present Development

3.5.1.1 Wyoming

The Wright and South Gillette subregion coal mines located south of Interstate 90 (I-90) are serviced by a joint UP/BNSF rail line (**Figure 3-1**). In 2003, the shipping capacity of the joint line was estimated at approximately 350 mmtpy. The 2003 coal production from the same mines totaled 308 mmtpy, equating to an 88 percent utilization of the available rail capacity. By the end of 2007, the capacity of the line was estimated at over 400 mmtpy as the result of a series of capacity expansion projects. The 2007 coal production from the same mines totaled 359 mmtpy, equating to a 90 percent utilization of the existing rail capacity. In July 2008, additional expansion work was completed to increase rail capacity to approximately 450 mmtpy. The 2008 coal production from these mines was approximately 368 mmtpy, equating to an 82 percent utilization of the existing rail capacity.

In 2003, the capacity of the BNSF rail line servicing the Subregion 1 coal mines north of I-90 (**Figure 3-1**) was estimated at 250 mmtpy. The 2003 coal production from the Subregion 1 mines totaled 55 mmtpy, equating to an approximate 22 percent utilization of the available rail capacity. No major expansion projects had been constructed on this line by the end of base year 2008. The base year 2008 coal production from these same mines totaled approximately 76 mmtpy, equating to 30 percent utilization of the existing rail capacity. An unknown amount of coal shipped from the Subregion 1 mines on the BNSF line is transported farther south along the joint UP/BNSF line. This unknown amount was not included in the estimated utilization of the joint UP/BSNF line; therefore, current actual utilization of the joint line could be higher.

A BNSF mainline runs diagonally through the Wyoming PRB study area; the alignment generally runs from Sheridan to Gillette and then to Newcastle, Wyoming. North of Sheridan, the mainline provides service to the Pacific Northwest and upper Midwest. South and west of Newcastle, the mainline serves the Midwest. The existing Decker spur, located east of Sheridan, runs north from the mainline and serves the Decker and Spring Creek mines in Montana.

3.5.1.2 Montana

Existing BNSF rail lines are in place with adequate capacity for all existing mines. An existing BNSF rail spur extends from the mainline in Wyoming into Montana, serving both the Decker and Spring Creek mines. It is assumed that the existing railroad infrastructure has capacity for approximately 100 mmtpy from the region.

3.5.2 Reasonably Foreseeable Development

The current attention focused on climate change and the role of coal in meeting future energy demand casts a degree of uncertainty into the coal production forecasts and the associated forecasts for development of coal-related activities, including railroads.

3.5.2.1 Wyoming

UP/BNSF Joint Rail Line Expansion. The single largest capital and infrastructure cost related to projected future coal mining rates is rail expansion for the mines south of Gillette (Subregions 2 and 3). Plans are underway to improve sections of the existing joint UP/BNSF rail line and to increase capacity from the current 450 mmtyp to 500 mmtpy by 2012. However, neither railway has released detailed information regarding the timing of construction and capacity expansion. Under the lower production scenario, the current rail capacity of 450 mmtpy would be sufficient to accommodate the projected coal production from these mines through 2030, at which point production is projected to peak at approximately 393 mmtpy. However, expansion of the rail line would be required to accommodate production under the upper production scenario. Based on the projected upper production rate of approximately 448 mmtpy of coal from the southern coal mines by 2020, a rate of approximately 479 mmtpy by 2025, and a projected peak rate of approximately 515 mmtpy in 2030, it is anticipated that the rail expansion could occur by 2020. However, expansion of the rail line to 500 mmtpy would be insufficient to accommodate the projected upper production rate from the mines south of Gillette through 2030.

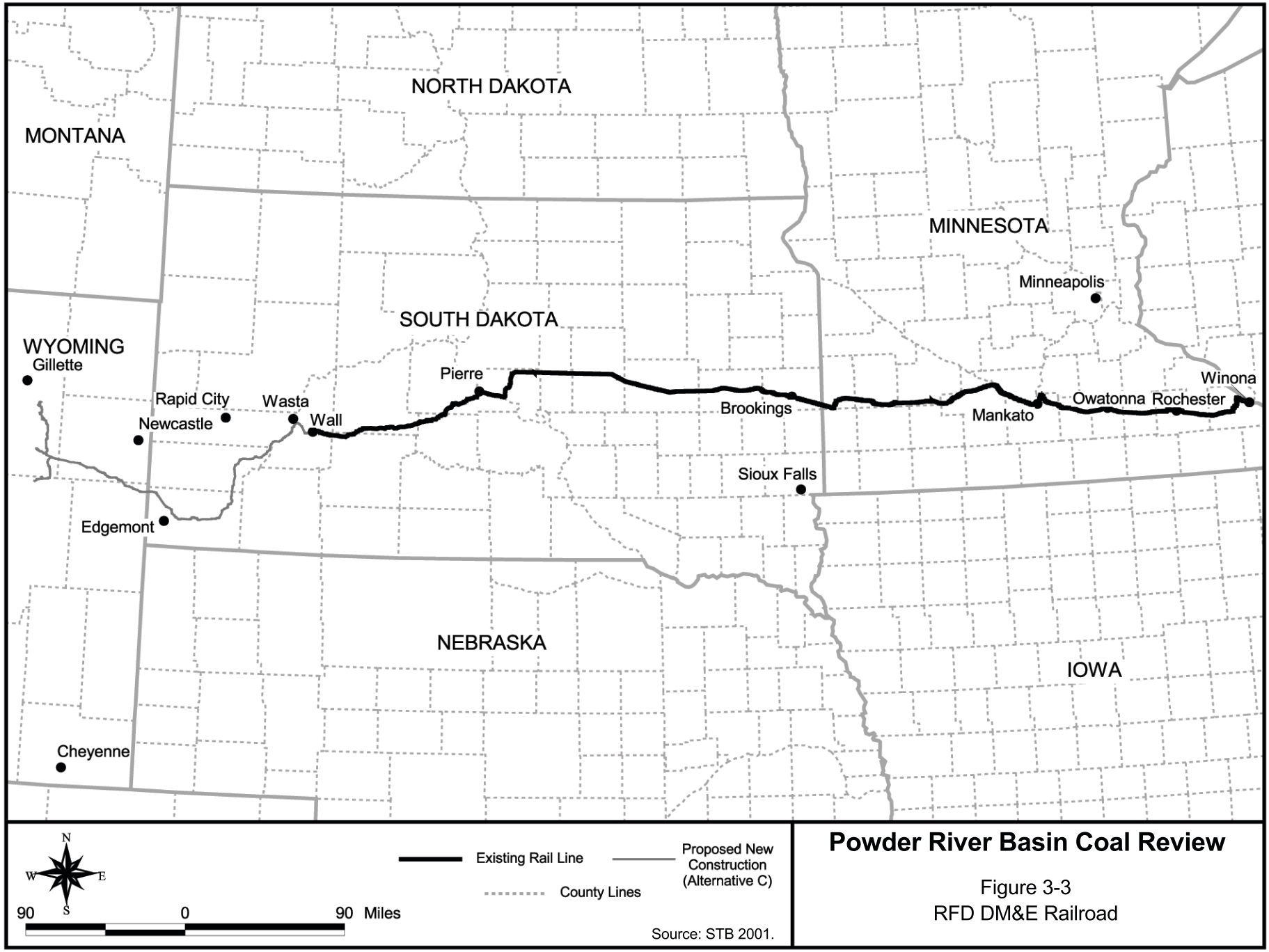
Dakota, Minnesota & Eastern/Canadian Pacific Rail Line. The proposed Dakota, Minnesota & Eastern (DM&E) rail line would include new rail construction in South Dakota and Wyoming (approximately 15 and 265 miles, respectively, inclusive of 78 miles in the Wyoming PRB [**Figure 3-3**]) and 600 miles of rail line rehabilitation in South Dakota and Minnesota. On January 28, 2002, the U.S. Surface Transportation Board (STB) issued a final written decision granting DM&E authority to construct and operate the line. The Record of Decision (ROD) was successfully appealed, and additional environmental analysis was required as a result. The additional environmental analysis was completed in 2005, and the STB granted approval to construct in 2006.

In 2007, Canadian Pacific Railway (CPR) acquired DM&E with plans to integrate DM&E's operations into their operations. CPR officially gained control of DM&E on October 30, 2008. To date, CPR has not decided to proceed with construction, citing weak economic conditions. However, CPR also has indicated that the project is not "dead" (DM&E 2010; Lincoln Journal Star 2009).

Detailed financial data regarding the annual volume of rail traffic necessary to support construction of the DM&E rail line are not available. However, given recent coal production volumes in the PRB and CPR's decision to defer construction, it is reasonable to conclude that a sustained annual rail haulage requirement of 450 to 500 mmtpy from the Wyoming PRB may be required before the DM&E rail line would be constructed. If completed, the project would provide approximately 100 mmtpy of additional new rail capacity for coal mines in the Wyoming PRB, primarily for the Jacobs Ranch, Black Thunder, Caballo-Rojo, Coal Creek, Cordero, and Belle Ayr mines in Subregions 2 and 3, and open new markets for this coal. As discussed above for the UP/BNSF Joint Rail Line Expansion, coal production from the Subregion 2 and 3 mines under the upper production scenario is expected to exceed 450 mmtpy in approximately 2020, and the planned expansion of the existing UP/BNSF rail line to 500 mmtpy would be insufficient to accommodate the upper coal production rate of approximately 515 mmtpy in 2030. Therefore, it is assumed that construction of the DM&E rail line in the Wyoming PRB study area could occur between 2025 and 2030.

3.5.2.2 Montana

BNSF Decker/Spring Creek Spur. The existing Decker spur has been considered as a possible rail option to transport coal from the Young's Creek Mine proposed by a Chevron/CONSOL joint venture (Chevron 2010). The mine would be located in the Wyoming portion of coal mine Subregion 4; however, a portion of the proposed rail alignment for a new branch line from the Decker spur would be located in Montana. That action requires approval of the Montana State Land Board. The board recently deferred action on that application on the grounds that the Youngs Creek Mine, in part, could compete for market share with coal from the proposed Otter Creek Mine in Montana (Montana State Land Board 2009).



Powder River Basin Coal Review

Figure 3-3
RFD DM&E Railroad

If built, construction of the new Youngs Creek spur and associated upgrades of the existing BNSF line potentially could occur over a 1- to 2-year period. The Montana State Land Board action increases the uncertainty regarding the completion of this spur line. It is unclear whether the Chevron/CONSOL joint venture is reviewing the feasibility of other rail alignments. Given the uncertainties resulting from the deferred action by the Montana State Land Board on the ROW application, the new spur line is not anticipated prior to 2015, with construction between 2015 and 2020 being more plausible. This timeframe would coincide with the projected start of production at the Youngs Creek Mine in 2020.

It is anticipated that future production rates from the currently operating and projected new mines in Subregion 4 would not exceed the capacity of the existing BNSF rail line (100 mmtpy) through 2030 (**Figure 3-1**). It also is anticipated that the existing capacity (100 mmtpy) of the currently operating BNSF rail line would be sufficient to accommodate additional production transported to Montana and the Pacific Northwest from Wyoming. As a result, any upgrades would be minor.

BNSF Mainline and Spur. The BNSF operates the two spur lines from its main line across Montana. One line runs south from Sarpy Junction to the existing Absaloka Mine; the other line runs from Nichols to serve the Rosebud/Colstrip mine and generating station.

It is anticipated that some transportation mode or combination of modes, including rail, would be required to serve the proposed Otter Creek Mine. A rail line to support the Otter Creek Mine, which conceivably could incorporate a portion of the alignment previously identified for the Tongue River Railroad, likely would extend north from that proposed mine to connect with an existing BNSF main line across southern Montana. That connection would provide access for production from the Otter Creek Mine to markets in the upper Midwest and Pacific Northwest, the latter including potential export markets. Construction of such a line likely would occur between 2015 and 2020 to coincide with the construction and operation of the Otter Creek Mine.

Tongue River Railroad. In a series of actions through 2006, the STB approved construction of the Tongue River Railroad. However, construction was not initiated due in part to financing and economic feasibility, the latter likely linked to the marketing of coal at that time from Otter Creek and other Montana mines. In 2007, the STB granted final approval to the Tongue River Railroad Company (TRRC) for construction of approximately 17 miles of new line in Montana. The approval was for the third segment of the proposed 130-mile route for the Tongue River Railroad which generally follows the Tongue River from the Decker Mine to Miles City, Montana. If constructed, the rail line could serve the proposed Otter Creek Mine, and also offer a potential connection to the existing Decker/Spring Creek spur line coming north from the BNSF main line near Sheridan, Wyoming. The project would provide 100 mmtpy of new rail capacity. However, the TRRC faces continued opposition from environmental groups, and financing to complete the project remains uncertain. Due to the uncertainties surrounding the TRRC, the Tongue River Railroad has been eliminated from further analysis in this study.

3.5.3 Assumptions

In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for railroads:

Past and Present Development Assumptions

- The existing ROW disturbance ROW for the UP/BNSF rail line is assumed to be 150 feet in width. Existing ROWs for the BNSF rail lines are assumed to be 100 feet in width.

RFD Assumptions

- ROWs for new rail lines are assumed to be 100 feet in width.

- The UP/BNSF rail capacity for the southern portion of the PRB would increase from 450 mmtpy in 2008 to 500 mmtpy by 2020; associated construction would include the addition of sidings and trackage parallel to existing facilities within the existing ROW. The expansion has an assumed likelihood rating of highly likely for 2020 under the upper production scenario.
- The Youngs Creek spur line and Decker spur upgrade would be constructed between 2015 and 2020 under the upper production scenario. It is assumed that the new spur would be 6 miles in length. Operation of the new and upgraded spur lines by 2020 is assumed to be low to moderately likely under the upper and lower production scenario based on projected production at the Youngs Creek Mine starting in 2020.
- It is assumed that a new rail line would be constructed from the proposed Otter Creek Mine northward to an existing BNSF mainline across southern Montana. Operation of the rail line by 2020 to coincide with the start of operation at the Otter Creek Mine is considered low to moderately likely.
- The DM&E rail line would include the construction of 78 miles of new rail line in the Wyoming PRB. The new rail line would provide approximately 100 mmtpy of additional rail capacity for the Subregion 2 and 3 coal mines. Project construction between 2025 and 2030 has an assumed likelihood rating of moderately likely to highly likely under the upper production scenario.

3.5.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to railroad development in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). Updated information relative to railroad projects for Phase II of the study was obtained from the following sources:

Chevron Corporation 2010. Chevron Corporation 10-K Filing to the SEC (2/25/2010). Internet website: http://investor.chevron.com/phoenix.zhtml?c=130102&p=IROL-secToc&TOC=aHR0cDovL2lyLmludC53ZXN0bGF3YnVzaW5lc3MuY29tL2RvY3VtZW50L3YxLzAwMDA5NTAxMjMtMTAtMDE2ODQ2L3RvYy9wYWdl&ListAll=1&sXBRL=1. Accessed on March 30, 2010.

DM&E. 2010. Dakota, Minnesota and Eastern Railroad Webpage - About Us: History. Internet website: http://www.dmerail.com/About_Us/History.html. Accessed on March 30, 2010.

Lincoln Journal Star. 2009. DM&E Railroad Suspends Effort to Carry Powder River Basin Coal. Internet website: http://journalstar.com/business/article_d2a79182-9344-11de-95e0-001cc4c002e0.html. Accessed on March 30, 2010.

Montana State Land Board. 2009. Land Board Minutes – August 2009, Youngs Creek Mine Railroad Spur Easement. Internet website: http://dnrc.mt.gov/commissions/land_board/2009/August/Minutes.pdf. Accessed on July 26, 2010.

Montana Trust Lands Division. 2010. Otter Tracts. Internet website: http://dnrc.mt.gov/trust/MMB/otter_creek/Default.asp. Accessed on July 24, 2010.

3.6 Coal Technology

3.6.1 Past and Present Development

3.6.1.1 Wyoming

As of the end of base year 2008, no commercial-scale coal technology projects were operating in the Wyoming PRB study area. Test facilities were constructed by AMAX (predecessor to Foundation Coal

West, Inc.) at the Belle Ayr Mine and by ENCOAL at the Buckskin Mine. These facilities have since been idled, dismantled, or are no longer in use. Therefore, they were eliminated from further analysis in this study.

Evergreen Energy, formerly operating as KFx, built a prototype commercial-scale coal upgrading plant near the old Fort Union Mine (now part of the Dry Fork Mine). The plant produced K-Fuel® (an enhanced coal product) and achieved limited-scale commercial production levels for a short period. The product was used for testing and demonstration purposes. Subsequently, the company sought to refine and optimize the production process, working with Bechtel Power Corporation; however, Evergreen Energy opted to idle the plant in May 2008, laying off all but a caretaker staff.

The Wyoming Infrastructure Authority (WIA) was created in 2004 by the Wyoming State legislature. It was tasked with promoting economic development in the state by assisting in the development of interstate electric transmission infrastructure. Limits on transmission capacity have been a constraint to the development of additional power generation in Wyoming, which also has implications on the coal mining industry in the state. In 2005, WIA's role was expanded to also promote advanced coal technologies related to electric generation.

In 2007, the WIA entered into a public-private partnership with PacifiCorp to assess the feasibility of developing an integrated gasification combined cycle (IGCC) power plant. PacifiCorp is a major energy supplier in the Rocky Mountain and Pacific coast regions. Following the conclusion of feasibility studies, the WIA and PacifiCorp began working together to secure federal funds to help develop such a plant in southwest Wyoming, opting for a demonstration facility at the Jim Bridger Power Plant in Sweetwater County (WIA 2008). The plans for that facility subsequently were cancelled.

3.6.1.2 Montana

A coal processing facility, used to reduce moisture content and remove sulfur, was associated with the Rosebud Mine. However, that facility has been dismantled and removed from the mine site. Therefore, it is not considered further in this study.

3.6.2 Reasonably Foreseeable Development

The PRB has long been a target of interest for coal enhancement technologies. In part, this interest has been driven by the vast reserves of sub-bituminous coal in the PRB, which represent an enormous energy resource supply. Coal enhancement technologies are viewed as a means to expand the market for PRB coal by addressing its distance from major markets, relative lower energy content, high transportation costs, and various environmental concerns.

Interest in coal enhancement in general, as well as other energy technologies, has been piqued by mounting concerns regarding the supply and price of crude oil, the possibility of "peak oil" (the concept that the global annual output of crude oil has or will soon peak), global climate change, and the potential for carbon sequestration. However, such facilities are costly, and competition for available capital is intense. Moreover, a number of international developments in coal enhancement technologies, including the successful completion of several demonstration/pilot projects, have shifted some of the focus away from the PRB. Nonetheless, the coal technology dimension of the PRB energy industry is very dynamic. The initiation of several commercial-scale facilities and infusions of private capital and joint development agreements, appear to have increased the overall likelihood of one or more coal technology facilities being developed within the PRB prior to 2030.

3.6.2.1 Wyoming

Evergreen Energy Coal Beneficiation Project. Long-term plans for Evergreen Energy's coal upgrading plant have not been announced, although reopening or dismantling of the plant and redeploying some of the equipment to another location are possibilities. However, in filings with the Security and Exchange

Commission, Evergreen Energy does not indicate an expectation of any significant production or revenue from the facility in the foreseeable future (Evergreen Energy 2010). Given the uncertainties regarding economics, markets, and transportation, the likelihood for reopening of, or commercial-scale production from, this facility is considered speculative. Therefore, it has been eliminated from further analysis in this study.

Rentech Inc. Coal Liquefaction Project. In 2004, Rentech Inc. (Rentech) completed a feasibility study for a coal liquefaction facility to produce low-sulfur diesel fuel from sub-bituminous coal. Based on those results, Rentech considered development of a commercial-scale facility in the PRB. Subsequently, Rentech undertook its first commercial-scale project near Natchez, Mississippi. The company also licensed its process to DKRW Energy LLC, which is moving forward with development of a commercial-scale project near Medicine Bow, Wyoming. Rentech had entered into a joint development agreement with Peabody Energy to develop two CTL plants on Peabody's extensive coal reserves, potentially including one in Montana. However, there have been no recent public news releases indicating that such a project is moving forward, and Rentech's various commercialization initiatives appear to have drawn attention away from the PRB (Rentech 2010). The likelihood for development of this facility is considered speculative. Therefore, it has been eliminated from further analysis in this study.

White Energy Coal North America. White Energy Coal North America (White Energy Coal), a subsidiary of Australian-based White Energy Company, is actively pursuing coal enhancement projects in the PRB. "White Energy is the exclusive worldwide licensee of the Binderless Coal Briquetting (BCB) technology, which is a low cost mechanical process that upgrades high moisture, low value sub-bituminous and lignite coals through a process of dehydration and compaction. The resultant product is a dense, physically and chemically stable briquette with higher energy content and value which can be handled like normal coal" (White Energy 2010a). White Energy Coal has entered into agreements with both the Kiewit Group (Buckskin Mining Company) and Peabody Energy (Caballo Mine) to facilitate development of coal upgrading facilities. The agreement with the Kiewit Group covers only a land lease to site the facility, while that with Peabody Energy creates a joint venture addressing both siting and coal supply. Plants having an initial capacity of 1.0 mmtpy are being planned at each mine. Potential sites have been selected for both projects. Eventual production targets for the two facilities are 8 mmtpy at the Buckskin location and 20 mmtpy at the Caballo location (White Energy Coal 2010a,b).

GreatPoint Energy and Peabody Energy. These two companies entered into an agreement in January 2008, under which Peabody Coal would become the preferred provider of coal to GreatPoint Energy for use in a commercial-scale coal-to-gas conversion plant in the PRB and for up to a dozen total projects. GreatPoint Energy is in the early stages of facility planning, which would use a proprietary catalytic conversion process to produce pipeline quality gas. According to GreatPoint Energy, its process also would capture CO_2, which then could be sequestered. GreatPoint Energy asserts that its product is as clean as natural gas and could be used in the same applications as natural gas (e.g., residential heating and power generation). A demonstration project for testing the process was completed at a facility in Illinois. GreatPoint Energy's push towards commercialization follows a successful capitalization effort that raised $150 million from various corporate investors (GreatPoint Energy 2010). The likelihood for development of this facility is considered speculative. Therefore, it has been eliminated from further analysis in this study.

Peabody Energy. Peabody Energy is among the global leaders with respect to coal reserves; coal production; and in advancing clean coal technology, as demonstrated by its development agreements with GreatPoint Energy and White Energy Coal (see above) as well as Rentech (see Section 3.6.2.2). Peabody's interest in clean coal technologies was underscored by its recent $2 million grant to the Clean Coal Technology Laboratory at the University of Wyoming Energy Resource Center (Peabody 2010a,b).

Linc Energy (Underground Coal Gasification). Australian-based Linc Energy Ltd's wholly owned subsidiaries, Linc Energy (Wyoming), Inc. and Linc Energy (Montana), Inc. (Linc Energy), have signed agreements with Wyoming-based GasTech, Inc. (GasTech) and Wold Oil Properties, Inc. (Wold Oil), to

acquire 81,268 acres of additional coal lease areas in Wyoming, Montana, and North Dakota. These lease areas would add to the 92,059 acres of coal leases in the PRB that already are held by Linc Energy. According to Linc Energy, this land position "…puts Linc Energy into a very strong position to undertake commercial UCG operations in Wyoming and move quickly to the construction of a commercial Gas to Liquids facility in the USA….using UCG. That gas flow will feed a GTL plant, but it will also provide additional opportunities such as the sale of CO_2 for use in stranded oil recovery in the Wyoming region, and the ability to produce cost effective power... the utilization of UCG in Wyoming will transform the State and Linc Energy over the next 24 months." The company is reportedly conducting site selection and permitting for a pilot project. According to Linc Energy, it proposes to use proven underground coal gasification (UCG) and gas-to-liquid (GTL) processes in its project. The company presently operates a demonstration and technology development facility in Australia. If the pilot project is successful, Linc Energy indicates that its resource base could support multiple commercial scale facilities (Casper Star 2009; Linc Energy 2010). The combination of an identified project proponent, local (Wyoming) partner, established land position, and intent to deploy established technologies, is considered to increase the potential for development of this facility.

Luca Technologies (Active Biogenesis of Methane). Luca Technologies is an energy production company focused on developing environmentally clean and sustainable production of natural gas via the microbial cultivation and harvesting of methane from underground hydrocarbon resources. In 2008 through 2010, the company received six patents on processes to stimulate and actively manage the natural biologic conversion of coal, kerogenin shales, and residual crude oil into cleaner-burning natural gas (DeBruyn 2010). The gas then could be produced and transported using the conventional energy infrastructure. Luca Technologies has established a field office in Gillette, Wyoming, to support its process development and potential commercialization. According to Luca Technologies, the sheer size of the PRB coal bed resource as a substrate for biogenic methane creation is the primary incentive. The PRB coal beds contain approximately 580 billion tons of coal in contiguous seams at least 20 feet thick, and only a small portion of this coal is accessible via conventional mining. The conversion of only 1 percent of the known PRB coal resource would generate approximately 86 trillion cubic feet (Tcf) of natural gas (Luca Technologies 2010a,b). At present, the company has not announced plans or timetables for a future demonstration or commercialization venture in the PRB. Therefore, development of a commercial-scale project is considered speculative and has been eliminated from further analysis in this study.

Wyoming Infrastructure Authority. The WIA's mission was expanded to promote advanced coal technologies as they might relate to electrical generation. The WIA has not announced an active role in any reasonably foreseeable coal technology plants. Due to the lack of defined plans, the likelihood for development of such a facility with WIA participation is considered speculative at this time, and it has been eliminated from further analysis in this study.

3.6.2.2 Montana

Rentech Inc. Coal Liquefaction Project. Rentech has a commercially viable process for converting coal to synthetic ultra clean diesel and aviation fuels. Rentech had entered into a joint development agreement with Peabody Energy to develop a CTL plant intended to use Peabody's extensive coal reserves near Colstrip, Montana. Peabody Coal continues to actively pursue coal technology projects in the PRB (see Section 3.6.2.1). However, the status of this project is uncertain as it has not been the subject of any recent news releases regarding location, permitting status, or development timetable (Peabody 2010; Rentech 2010). Therefore, development of a project is considered speculative and has been eliminated from further analysis in this study.

The Crow Tribe and Australian-American Energy Company, LLC. The two parties announced an agreement to pursue the Many Stars Project, a multi-billion dollar project involving construction of a new coal mine and mine-mouth CTL conversion plant on the Crow Reservation. The anticipated initial production capacity of the Many Stars CTL plant is up to 24,000 barrels per day (bpd) of fuels and naptha, doubling over the first decade and ultimately expanding to as much as 125,000 bpd.

Australian-American Energy is engaged in ongoing evaluation of the coal resources, facility design, and site location studies. Current project planning efforts indicate a construction workforce of up to 4,000, with a permanent workforce of 900 during production. Australian-American Energy is a privately held company that has initiated other coal conversion projects in Australia. The partnership received approval of the partnership agreement in June 2010. That approval paves the way to pursue environmental permitting, with target dates for initiation of construction and operation reportedly being 2012 and 2016, respectively (Many Stars CTL 2010; News from Indian Country 2009). However, operation of the mine-mouth CTL plant is dependent on development of the Many Stars Mine. As discussed in Section 3.2.2.2, it is projected that the Many Stars Mine would be developed by 2025 under the lower production scenario and operational by 2025 under the upper production scenario. Given the in-place agreement between the parties, access to coal resources, and apparent access to both the technology and capital associated with such facilities, the project is considered moderately likely. Based on the projected timeframe for the Many Stars Mine, it is projected that the start of construction and operation of the CTL plant would more likely occur in approximately 2021 and 2025, respectively.

3.6.3 Assumptions

Past and Present Development Assumptions

- There are no assumptions regarding past and present coal technology projects.

RFD Assumptions

- White Energy and Kiewit would initiate construction of a commercial-scale coal beneficiation project at the Buckskin Mine in 2015, with operations initiated prior to 2020. The facility would employ an assumed 350 construction workers for 3 years and 125 operations workers. Potential for project development and operation by 2020 is considered to be moderately likely under both the upper and lower development scenarios.
- White Energy and Peabody Energy would initiate construction of a commercial-scale coal beneficiation project at the Caballo Mine in 2015, with operations initiated prior to 2020. The facility would employ an assumed 350 construction workers for 3 years and 125 operations workers. Potential for project development and operation by 2020 is considered to be moderately likely under both the upper and lower development scenarios.
- Linc Energy would begin construction of a demonstration-scale/pilot UCG/GTL project between 2015 and 2020, with operations initiated by 2020. Future commercial-scale development is not assumed for this study. Potential for development and operation of a demonstration-scale/pilot facility by 2020 is considered to be moderately likely under both the upper and lower development scenarios.
- The Many Stars CTL project would initiate construction and operations in 2021 and 2025, respectively. Therefore, operation of the facility by 2030 under both the upper and lower production scenarios is considered to be moderately likely. Associated surface disturbance is assumed to be 160 acres. The project is assumed to have a peak work force of 1,500 workers during construction and employ 400 workers during initial operations.

3.6.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to coal technology projects in the Wyoming and Montana PRB study areas are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). Updated information on the status of coal enhancement projects was derived from the corporate websites of Evergreen Energy, Rentech, White Energy, GreatPoint Energy, Peabody Energy, and WIA. Information also was obtained from published news articles. The specific sources cited above include:

Casper Star Tribune. 2009. GasTech on Cutting Edge of Coal Energy. Internet website: http://www.casperjournal.com/articles/2009/10/14/news/news50.txt.

DeBruyn, R. 2010. Personal communication between R. DeBruyn, Luca Technologies, and T. Johnson, BLM, regarding recent company activities.

Evergreen Energy. 2010. 2009 Annual Report on Form 10-K. Internet website: http://edg1.vcall.com/irwebsites/evergreen/10-03-31%20EEE%2010-K.pdf. Accessed on May 16, 2010.

GreatPoint Energy. 2010. Corporate Website. Internet website: http://www.greatpointenergy.com/about.php. Accessed on May 2010.

Linc Energy. 2010. Linc Energy Increases Its Coal Lease Holdings in Wyoming, Montana, and North Dakota, USA, to 173,327 Acres. Internet website: http://www.lincenergy.com.au/pdf/asx-201.pdf. December 24, 2009. Accessed on May 2010.

Luca Technologies. 2010a. Corporate website: Technology. Internet website: http://www.luca technologies.com/technology.php. Accessed on July 2010.

_____. 2010b. Corporate website: Technology_White Papers. Internet website: http://www.luca technologies.com/technology_whitepapers.php. Accessed on July 2010.

Many Stars CTL. 2010. Many Stars CTL – Facts and Figures. Internet website: http://www.many starsctl.com/faq.html. Accessed on June 9, 2010.

News from Indian Country. 2009. Feds Give Initial Approval to Crow Coal Plant (03-2009). Internet website: http://indiancountrynews.net/index.php?option=com_content&task=view&id=5974&Itemid=5. Accessed on May 2010.

Peabody Energy. 2010a. Peabody Energy Grants $2 Million to Develop Clean Coal Technology Lab at the University of Wyoming. Internet website: http://phx.corporate-ir.net/phoenix.zhtml?c=129849&p=irol-newsArticle&ID=1429441&highlight=#splash. Accessed on May 16, 2010.

_____. 2010b. News Release (2/18/2010): Peabody Energy and GreatPoint Energy Announce Agreement to Pursue Development of Coal-to-Gas and Coal-to-Hydrogen Facilities with Carbon Capture and Storage. Internet website: http://phx.corporate-ir.net/phoenix.zhtml?c=129849&p=irol-newsArticle&ID= 1392644&highlight=. Accessed on May 16, 2010.

_____. 2010c. News Release (5/13/2010) White Energy and Peabody Energy Enter Into Clean Coal Development Agreement Covering North America and China. Internet website: http://phx.corporate-ir.net/ phoenix.zhtml?c=129849&p=irol-newsArticle&ID=1288174&highlight. Accessed on May 16, 2010.

Rentech. 2010. Facilities and Processing, Information Regarding Licensing of the Rentech Process. Internet website: http://www.rentechinc.com/licensing.php. Accessed on May 16, 2010.

White Energy Company. 2010a. North America – Peabody Project. Internet website: http://www.whiteenergyco.com/projects/north-america/peabody-project/index.php. Accessed on May 16, 2010.

_____. 2010b. North America – Buckskin Project. Internet website: http://www.whiteenergyco.com/projects/north-america/buckskin-project/index.php. Accessed on May 16, 2010.

Wyoming Infrastructure Authority (WIA). 2008. First Stage Feasibility Report, High Plains Express (Power Point Presentation). Internet website: http://www.rmao.com/wtpp/HPX HighPlainsExpress%20 First% 20Stage%20Feasiblity%20Powerpoint%2006_08.pdf. Accessed on June 10, 2008.

3.7 Transmission Lines

3.7.1 Past and Present Development

Major transmission lines in the Wyoming PRB study area that support the regional distribution system are associated with PacifiCorp's Dave Johnston Power Plant located near Glenrock, Wyoming; the power plants operated by Black Hills Corporation, located east of Gillette (see **Figure 3-1**); and Basin Electric's Dry Fork Station north of Gillette (see **Figure 3-2** for power plant location). Most of these 230-kilovolt (kV) transmission lines (**Figure 3-4**) have been in place for several years, and their associated permanent disturbance is minimal.

As of the end of base year 2008, one new transmission line (Hughes Transmission Line) was under construction in the PRB study area (**Figure 3-4**). Basin Electric completed and charged the Hughes Transmission Line at the end of 2009. The 136-mile, 230-kV line connects a substation near Rozet, Wyoming, with a substation near Gillette and another one north of Sheridan.

A series of relatively short high-voltage transmission lines connect each of the existing wind energy projects in the Wyoming PRB study area to nearby substations. These interconnections are dedicated lines feeding power generated by the projects to the regional power grid. For purposes of this study, these power lines have been factored in proportionally on a per wind tower basis, as discussed in Section 3.4.

Distribution power lines associated with CBNG and conventional oil and gas well development also occur within the study area. For purposes of this study, these power lines have been factored in proportionally on a per well basis, as discussed in **Appendix D**.

3.7.2 Reasonably Foreseeable Development

Transmission lines are a necessary supporting infrastructure for power generating facilities, including power plants and wind energy projects, to provide interconnections to the national grid (Western Electricity Coordinating Council [WECC] 2010; WIA 2010a,b). As a result, it is assumed that transmission line capacity expansion would be required as part of the overall system development for the RFD power plants identified in Section 3.3, wind energy projects identified in Section 3.4, and other industrial development identified in Section 3.14.

The following two new transmission line projects are under consideration in the Wyoming PRB study area.

- Wyodak South – approximately 110-mile-long, 230-kV transmission line that would run from near Gillette, to Pumpkin Buttes, and on to a point near the existing Dave Johnston Power Plant; proposed by Black Hills Corporation (WECC 2010); and
- Northern Lights Inland Express - transmission line is being considered from near Gillette to Nevada and Arizona; proposed by TransCanada.

Three additional new transmission line projects are under consideration near, but outside of, the Wyoming PRB study area. These projects would have a common terminus at the proposed Windstar substation that would be located north of the existing Dave Johnston Power Plant near Glenrock, Wyoming. In addition to providing a terminus for several transmission lines, the substation would provide access into the national energy grid for energy produced by a number of current and proposed wind energy projects in the Wyoming PRB study area. However, due to their location outside of the study

area, the transmission lines identified below have been eliminated from further consideration in this study.

- Wyoming-Colorado Intertie - from the proposed Windstar substation to the Colorado Front Range; multiple sponsors including the Wyoming Infrastructure Authority;
- High Plains Express - from the proposed Windstar substation through Colorado to New Mexico and Arizona; proposed by Tri-State Generation and Transmission Association, Inc.; and
- Gateway West - from the proposed Windstar substation to Idaho; proposed by PacifiCorp and Idaho Power.

The driving forces behind the multiple transmission line proposals in the region are long-term projected growth in energy demand in the far west and the need for additional transmission capacity to improve reliability. Several of the projects listed above, as well as several others being considered for development outside of the PRB study area, are competing to serve markets in Arizona, California, Nevada, and the Pacific Northwest. Consequently, the potential exists that an affirmative decision to proceed by one project could delay or preclude one or more of the other projects. At the same time, the current economic recession has tempered demand for electricity and increased uncertainty regarding future growth in demand, slowing the momentum behind these projects. In late 2009, a decision by Xcel Energy to pursue less wind energy power from Wyoming sources dealt a potential setback to the Wyoming-Colorado Intertie project.

Markets will dictate the size and timing of such facilities, although several of the projects have progressed beyond the basic feasibility analysis. For example, an open-season for the Wyoming-Colorado Intertie project, which essentially allows power companies to bid for capacity on the transmission line and ultimately determines its fate, was held in early 2008 and resulted in bids for approximately 75 percent of the line's capacity. It is unclear whether those subscriptions are sufficient for the project to proceed (WIA 2010).

3.7.3 Assumptions

In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for transmission lines.

<u>Past and Present Development Assumptions</u>

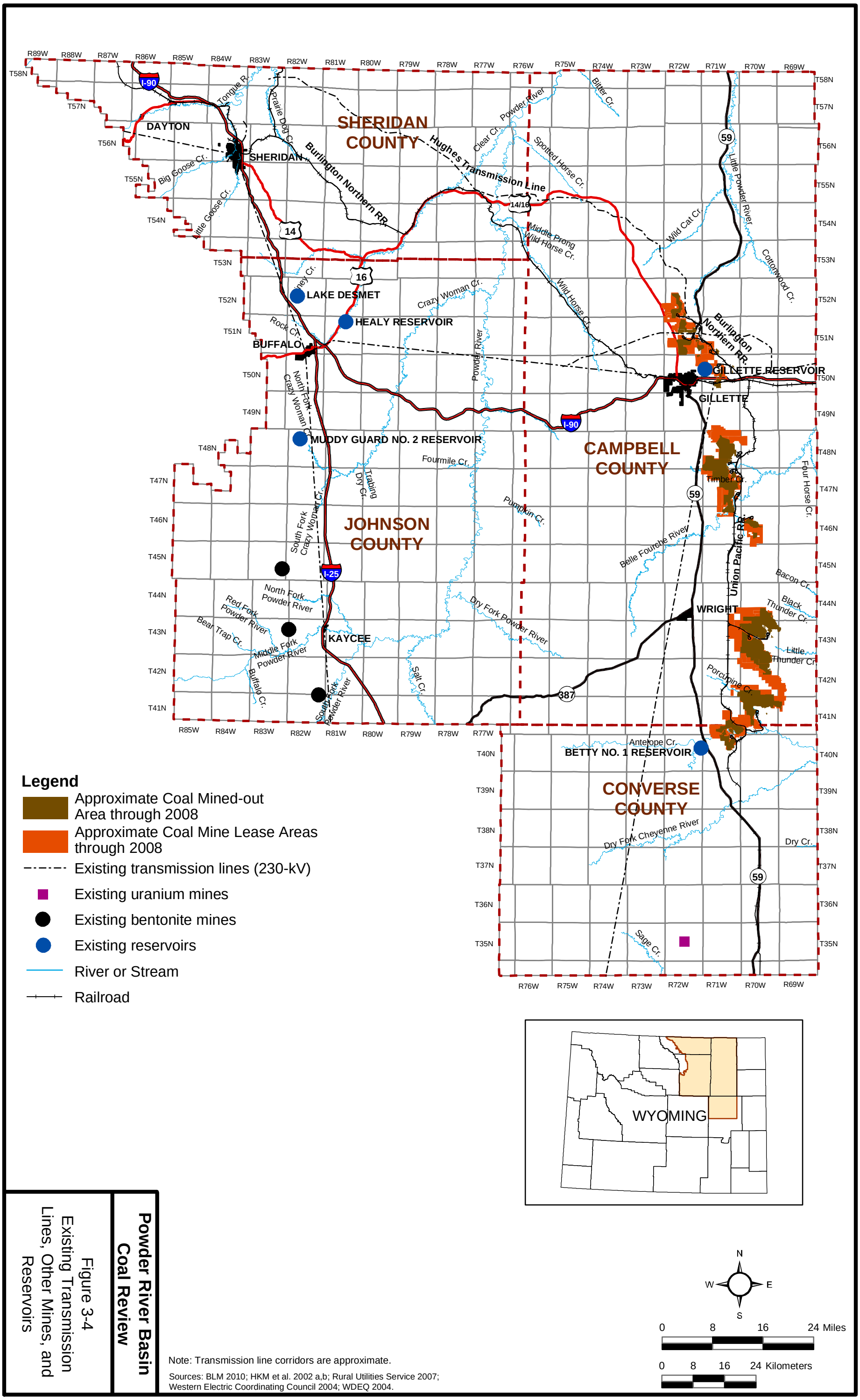
- Surface disturbance associated with previously existing transmission lines is minimal; therefore, it is not accounted for in this study.
- Newly constructed transmission lines would have a temporary surface disturbance of approximately 35 percent of the total permitted ROW acreage. Approximately 98 percent of disturbance would be reclaimed within the year of construction.

<u>RFD Assumptions</u>

- Black Hills Corporation's 230-kV line (Wyodak South) would be completed by 2015. Therefore, it is considered highly likely that this transmission line would be in service by 2020, with continued operation through 2030.
- One additional transmission line (Northern Lights Inland Express) could be built in the Wyoming PRB study area during the timeframe of this study (through 2030).

3.7.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to transmission lines in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the



Note: Transmission line corridors are approximate.

Sources: BLM 2010; HKM et al. 2002 a,b; Rural Utilities Service 2007; Western Electric Coordinating Council 2004; WDEQ 2004.

Powder River Basin Coal Review

Figure 3-4
Existing Transmission Lines, Other Mines, and Reservoirs

11/29/2011

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Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). Updated information relative to RFD transmission line projects for Phase II of the study was based on information provided by the Wyoming Infrastructure Authority and posted on various government and industry websites. Specific sources used in developing the above summary included the following:

PacifiCorp. 2008. Transmission Line Facts and Projects – Energy Gateway. Internet website: http://www.pacificorp.com/Navigation/Navigation584.html. Accessed on June 9, 2008.

Wyoming Infrastructure Authority (WIA). 2010a. Introduction to the WIA. Internet website: http://wyia.org/about-us/. Accessed on March 2010.

_____. 2010b. Introduction to Transmission Line Projects. Internet website: http://wyia.org/projects/. Accessed on March 2010.

Western Electricity Coordinating Council (WECC). 2010. Transmission Expansion Planning – Summary Listing of Projects under Consideration. Internet website: http://www.wecc.biz/Planning/Transmission Expansion/Transmission/Pages/default.aspx. Accessed on July 2010.

3.8 Carbon Sequestration

Carbon sequestration, the process of carbon capture, separation, and storage or reuse, is being researched as a means to stabilize and reduce concentrations of CO_2 (a GHG). Direct options for carbon sequestration would involve means to capture CO_2 at a source (e.g., power plant) before it enters the atmosphere coupled with “value-added” sequestration (e.g., use of captured CO_2 in enhanced oil recovery operations). Indirect sequestration would involve means of integrating fossil fuel production and use with terrestrial sequestration and enhanced ocean storage of carbon.

3.8.1 Past and Present Development

There are no existing commercial carbon sequestration projects operating in the Wyoming PRB study area. However, CO_2 injection for EOR does occur in the study area (see Section 3.10).

3.8.2 Reasonably Foreseeable Development

The 59th Session of the Wyoming Legislature passed, and Governor Dave Freudenthal signed into law, legislation that could affect long-term energy-related development in the PRB. Now part of Wyoming Statute 34-1, the legislation specified the ownership of subsurface “pore” space, established the rights to use such space for carbon sequestration, and maintained the primacy of the mineral estate and the owners of such estate to reasonable use of the surface for the purpose of mineral exploration and production.

The legislation also vested regulatory control over carbon sequestration with the WDEQ and directed the department to promulgate rules, regulations (including permitting processes), and standards for such use. The legislation also specified that applications for a carbon sequestration project must describe the geology of the area, aquifers above and below the intended injection zone, drill holes and operating wells in the area, potential impacts to other fluid resources, and indentify a program for detecting migration and excursion of any injected CO_2. Finally, the legislation established that it did not impede or impair the rights of oil and gas operators to inject CO_2 through an approved EOR project and to establish, verify, register, and sell emission reduction credits.

The WDEQ subsequently created a working group to implement the directives of the legislation, issuing a report and recommendations in September 2009. The report addressed a series of liability, financial assurance, and regulatory topics and included a draft statute for legislative consideration. A version of

that statute was introduced in the 2010 legislative session, amended, and subsequently was passed and enacted in March of 2010.

The 2009 legislative session resulted in the enactment of two bills addressing carbon sequestration. The provisions of these bills were as follows:

- Confirmed the dominance of the mineral estate when determining the priority of subsurface uses between a severed mineral estate and pore space;
- Established that the party injecting CO_2 into a sequestration site is presumed to be the owner of the CO_2 and liable for the consequences of injection, but also that this presumption of ownership can be overcome by a preponderance of evidence in an action to establish ownership; and
- Established that no person is liable for the consequences of injecting CO_2 simply because they own the pore space, have the ability to control the pore space, or have given consent to the injection.

The legislative framework outlined above establishes definitions and the regulatory environment in which carbon sequestration can occur. That framework can be critical in promoting the future development of carbon sequestration in the region (Wyoming Legislature 2010).

Although no commercial carbon sequestration projects presently are operating in the study area, a consortium headed by Babcock & Wilcox is proposing an oxy-fuel-fired power plant near Gillette, Wyoming. The plant would be fueled by pulverized coal and also would implement CO_2 capture for sequestration or use in EOR (see Section 3.3.2.1).

Because of its vast energy resources and electrical generating potential, the PRB is pivotal to ongoing research into carbon sequestration. The USDOE is a major sponsor of such research, funding seven regional partnerships to investigate potential safe and efficient carbon sequestration technologies. The PRB is included in both the Big Sky Carbon Sequestration Partnership and the Plains CO_2 Reduction Partnership. Research activities sponsored by these partnerships are likely to support future research and demonstration projects within the PRB.

3.8.3 Assumptions

In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for transmission lines.

<u>Past and Present Development Assumptions</u>

- There are no assumptions relative to past and present carbon sequestration.

<u>RFD Assumptions</u>

- One or two carbon sequestration demonstration projects would be developed in the PRB study area by 2020, and one or more commercial-scale carbon sequestration projects would be developed by 2030. However, the timing, location, and characteristics of these projects are unknown at this time. Therefore, such projects are considered speculative and have been eliminated from further analysis in this study.

3.8.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to carbon sequestration in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present Reasonably Foreseeable Development Activities

(AECOM 2009b). Updated information pertaining to carbon sequestration in Wyoming was collected from internet postings by various sources, including the sources identified below.

Babcock & Wilcox Company. 2010. Babcock & Wilcox and Black Hills Corporation: Oxy-Fuel Demonstration Project. Internet website: http://www.babcock.com/services/research_and_development/oxy_fuel_demonstration/presentation/bhc_project.pdf. Accessed on June 1, 2010.

Wyoming Legislature, Legislative Services Office. 2010. 2010 Budget Session, 60th Legislature – House Bills Index/Senate Files Index, Original House Bill No. 0017, Carbon sequestration-financial assurances and regulation. Enrolled Act No. 26, House of Representatives. Signed March 2010. Internet website: http://legisweb.state.wy.us/2010/Enroll/HB0017.pdf.

3.9 Other Mines

3.9.1 Past and Present Development

Past and present uranium, bentonite, and aggregate (sand, gravel, clinker, and scoria) mines exist in the Wyoming PRB study area. Detailed information on past development and current conditions for mineral resources in the PRB is presented in the BLM's mineral occurrence and development potential reports (BLM 2009a, 2004). Leonardite (a special form of lignite) also is mined in the Wyoming PRB study area.

3.9.1.1 Uranium

Uranium was discovered in the Wyoming PRB study area in 1952 (Love 1952). There are three defined uranium districts in the PRB, including Pumpkin Buttes, Southern Powder River, and Kaycee (BLM 2003). Numerous uranium mining sites occur in these districts; however, they have been mined out or were not considered economically viable. Uranium currently is produced via the in situ leach method in the Southern Powder River district at Smith Ranch and Highland/Morton Ranch (BLM 2009a) (**Figure 3-4).** Between 1977 and 2008, approximately 45 million pounds of uranium was mined in the study area (**Figure 3-5**). In base year 2008, uranium production in the Wyoming PRB was 1.2 million pounds, all from the Smith Ranch-Highland uranium in situ recovery facility in Converse County (Wyoming Department of Revenue 2010).

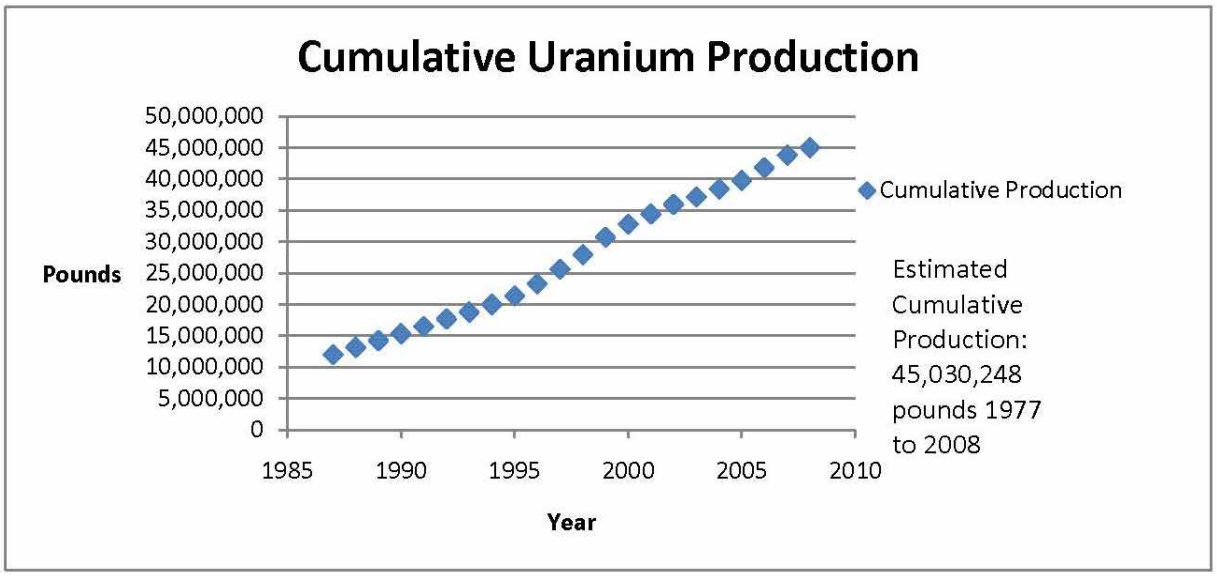
Due to the rapid change in price, resource recovery estimates based on recent economics are not readily available. However, a resource assessment published in 1976 indicated there was a recoverable uranium reserve of 107,200 tons (214 million pounds), based on $30 per pound of uranium oxide in the PRB (Curry 1976). Because $30 per pound in 1976 dollars translates to $110 in 2010 dollars, and because the 1976 resource assessment did not distinguish between surface mining and in situ recovery, the reported reserve estimate may not be applicable to present day conditions. However, the reported reserve estimate is evidence of an important uranium resource.

3.9.1.2 Bentonite

In the Wyoming PRB study area, bentonite is mined in the Kaycee Mining District located in Johnson and Natrona counties. Bentonite beds occur in the upper Cretaceous Frontier and Mowry formations in an area west and southwest of Kaycee, Wyoming (BLM 2009a). In 1976, the mineable bentonite resource in the Kaycee District was estimated to be 15 million tons (Thorson 1976). Prior to 1964, production from the Kaycee District was described as insignificant; however, production increased greatly in 1964 with the installation of a processing plant.

As of 1975, the Kaycee District cumulatively produced over 2.5 million tons of bentonite, with an average annual production of approximately 250,000 tons (Thorson 1976). As of end of base year 2008, cumulative production from the district was estimated at 12.0 to 14.0 million tons (**Figure 3-6**). Bentonite production from the Kaycee District mines has averaged approximately 354,000 tpy from 1988 to 2008, for a total of approximately 7.4 million tons. The Johnson County portion of the district within the

Wyoming PRB study area has produced over 6.0 million tons during the same time period (Wyoming Department of Revenue 2010). Bentonite is a primary component in drilling mud; it also is used as an absorbent in cat litter or sealing material in a variety of applications (e.g., metal castings, animal feed) (Black Hills Bentonite LLC 2009). Currently, Black Hills Bentonite has two operating open pit bentonite mines in the Wyoming PRB study area, the Mayoworth Mine and the Willow Creek Mine (BLM 2009a) (**Figure 3-4**).



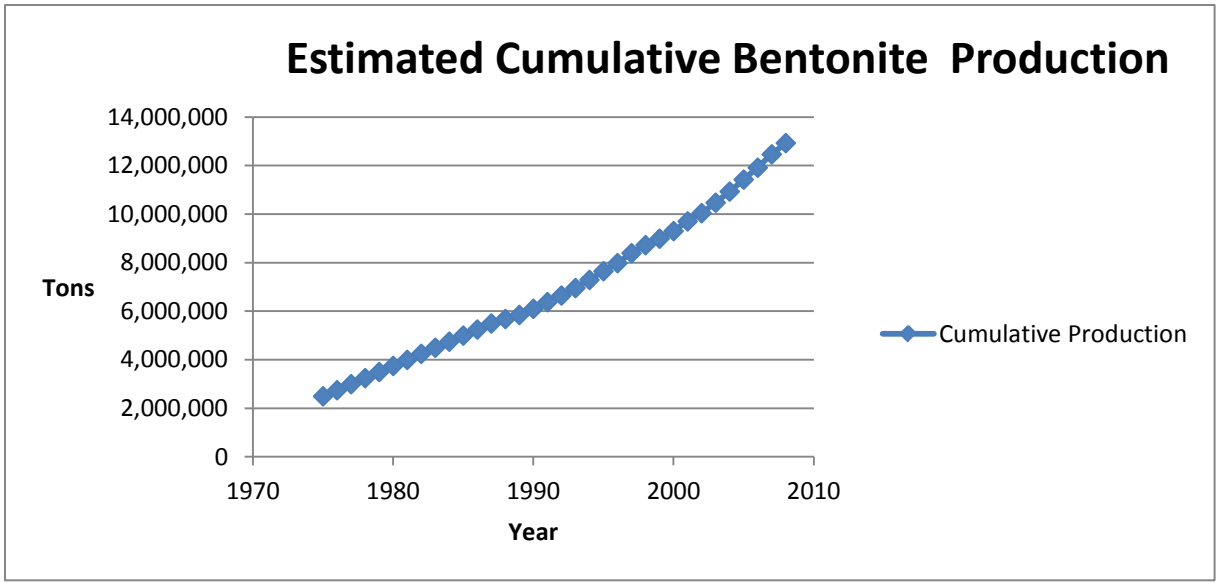
Sources: BLM 2004; ENSR 2005; Wyoming Department of Revenue 2010.

Figure 3-5 Estimated Cumulative Uranium Production in the Wyoming PRB Study Area

3.9.1.3 Aggregates

Based on total tonnage mined, the more important aggregate mining localities are in Campbell County (Wyoming Department of Revenue 2010). Johnson and Sheridan counties have much lower aggregate production. Although gravel is produced in Converse County, no production was assigned to gravel pits within the Wyoming PRB study area (Wyoming Department of Employment 2010). Campbell County is the leading producer of sand and gravel in the study area, and production has increased from approximately 2.9 million tons in 1998 to 5.7 million tons in base year 2008 (Wyoming Department of Revenue 2010). Similarly, production in Johnson County has increased from 106,736 to 1,034,365 tons, and production in Sheridan County increased from 215,590 to 503,307 tons in the same time period. Scoria or clinker, which is formed when coal beds burn and the adjacent rocks become baked, is used as aggregate where alluvial gravel is not available. Scoria generally is mined in Campbell County.

Locations of sand and gravel operations and associated impact-causing parameters (e.g., production) have not been assigned to subwatersheds for this study, because many of the quarries listed by WDEQ (2010) and the Wyoming Department of Employment (2010) are mobile operations and have no specific location reference. As a result, surface disturbance associated with sand, gravel, clinker, and scoria operations is not considered further in this study due to the lack of information relative to their specific locations and the low overall associated disturbance acreage (approximately 100 acres), which per subwatershed would be minimal. However, aggregate production numbers by county (as presented above) were obtained for the study from the Wyoming Department of Revenue (2010).



Sources: Thorson 1976; Wyoming Department of Revenue 2010.

Figure 3-6 Estimated Cumulative Bentonite Production in the Kaycee Mining District

3.9.1.4 Leonardite

Leonardite is a form of lignite (low rank coal) that is high in humic acid (Black Hills Bentonite LLC 2002). It is used primarily as a drilling fluid additive, although it also is used as a fertilizer. From 1988 to 2008, 872,941 tons of leonardite were mined from pits located north of Glenrock, Wyoming (Wyoming Department of Revenue 2010; Wyoming Department of Employment 2010). Production for base year 2008 was 54,162 tons, an increase of approximately 3,000 tons over the previous year's production. Black Hills Bentonite LLC has permits to mine leonardite in various sections in Townships 35, 36, and 37 North and Ranges 74 and 75 West in Converse County, within the Dry Fork Cheyenne River and the Middle North Platte River subwatersheds (WDEQ 2010).

3.9.2 Reasonably Foreseeable Development

Increasing world-wide demand for uranium has increased prices and drawn attention to uranium deposits in the Wyoming PRB study area, resulting in numerous applications for uranium recovery licenses. Demand for drilling mud has buoyed bentonite mining in the study area. Increased sand, gravel, and scoria production and associated surface disturbance also are anticipated in the study area in the future. As long as demand for drilling fluid remains strong, mining of leonardite should continue.

3.9.2.1 Uranium

In the original Task 2 report (ENSR 2005b), reasonably foreseeable uranium development was eliminated from further consideration because there were no specific projects with pending applications and no development was projected, based on market conditions. Due to the subsequent increased overall demand for energy, spot prices for uranium increased from $30.10 per pound in 2005 to over $136 a pound in 2007 (Cameco 2010). As of June 2010, the spot price fell to $41.75 per pound. The projected long-term price as of June 2010 was $59.00 per pound (World Information Service on Energy [WISE] 2010).

In response to the increased price of uranium, several uranium mines currently are proposed in the Wyoming PRB study area (**Table 3-2**). Locations of RFD mining activities are shown in **Figure 3-7**. Since the last update of the Task 2 report with the base year of 2007 (AECOM 2009a), one application to the U.S. Nuclear Regulatory Commission (USNRC) has resulted in the issuance of a draft license (Moore Ranch), two projects have merged (Reno Southwest with Reno), and the North Butte project was classified as a "satellite" to the Smith Ranch project (USNRC 2010b; WISE 2010). A new site, Jane Dough, was added to the application for Nichols Ranch. The status of the other previously identified projects has changed primarily in the filing of new applications; however, review still is pending and approvals may be years away, not including environmental analysis and permitting by the State. Therefore, development of most of these projects by 2020 is assumed to be moderately likely. The proposed developments are primarily in the Pumpkin Buttes District in southwestern Campbell County; however, one is in Johnson County and two are in Converse County. The actual number of projected uranium mines that would become operational would depend on several factors, including market price of uranium and approval of permits.

Uranium production to 2020 is estimated to be 15.9 million pounds from those projects assigned a high likelihood (Moore Ranch, Christensen-Irigaray, and Nichols Ranch). Assuming these projects initiate production by 2015 as discussed above, reserves essentially would be exhausted by 2020. As a result, there would be no uranium production by 2030, unless some of the projects with a moderate to low likelihood were to come on line between 2020 and 2025.

Table 3-2 USNRC Applications for In Situ Recovery Uranium Projects in the Wyoming PRB

Project/Company	Location	Type Application	Subwatershed/ Mining District	Likelihood/ Rationale
Moore Ranch/Uranium One USA (formerly Energy Metals Corporation)	T41-42N, R74-75W; Campbell and Converse counties	New	Antelope Creek, Upper Powder River/Pumpkin Buttes District	High for 2020/USNRC issued draft license June 2010.
Nichols Ranch-Hank Unit/Uranerz	Nichols Ranch: T43N, R76W; Campbell and Johnson counties Hank Unit: T43-44N, R75W; Campbell County	New	Upper Powder River/Pumpkin Buttes District	High for 2020/USNRC applications filed, draft generic EIS of December 2009 still under review as of August 2010, air quality permit issued by WDEQ October 2009.
Jane Dough Unit/Uranerz	T43N, R76W; Campbell County	New	Upper Powder River/Pumpkin Buttes District	High for 2020/Added as an amendment to the Nichols Ranch-Hank application.
Christensen-Irigaray Ranch/Uranium One USA	T44N, R76W; Johnson County	Restart	Upper Powder River/Pumpkin Buttes District	Moderate for 2020/USNRC application submitted September 2008, still under review as of June 2010.

Table 3-2 USNRC Applications for In Situ Recovery Uranium Projects in the Wyoming PRB

Project/Company	Location	Type Application	Subwatershed/ Mining District	Likelihood/ Rationale
Smith Ranch/Power Resources	T36N, R74W; Converse County	Expansion	Middle North Platte River/South Powder River Basin District	Moderate for 2020/expansion of existing facility, letter of intent to USNRC January 2010, application expected 2011.
North Butte Ruth/ Power Resources	T44N, R76W; Campbell County	Expansion under Smith Ranch	Upper Powder River/Pumpkin Buttes District	Moderate for 2020/to be licensed as satellite to Smith Ranch.
Collins Draw/ Uranerz	T42N, R76W and T43N, R76W; Campbell County	New	Upper Powder River/Pumpkin Buttes District	Moderate for 2020/letter of intent to USNRC March 2008, application expected 2009.
Allemand-Ross/ Uranium One	Converse County	Expansion	Antelope Creek/South Powder River Basin District	Moderate for 2020/letter of intent to USNRC February 2009, application expected September 2010.
Ludeman/Uranium One	Converse County	Expansion	Antelope Creek/ Pumpkin Butte District	Moderate for 2020/ USNRC application submitted January 2010.
Ruby Ranch/ Cameco	T43N, R75W; Campbell County	New	Upper Belle Fouche River/Pumpkin Buttes District	Low for 2020/letter of intent to USNRC January 2010, application expected 2013.
Reno Creek/ Bayswater Uranium Corporation	Sec 27-30, 33-35; T43N, R73; Campbell County	New	Upper Belle Fourche River, Antelope Creek/Pumpkin Buttes District	Low for 2020/letter of intent to USNRC April 2010, application expected December 2011.
Southwest Reno Creek/Bayswater Uranium Corporation	Sec 31, T42N, R73W; Sec 36, T43N,74W; Sec 6, T42N, R73W; Sec 1 & 2, T42N, R74W	New under Reno Creek	Antelope Creek/ Pumpkin Buttes District	Low for 2020/included with Reno Creek.

Sources: USNRC 2010b; WISE 2010.

3.9.2.2 Bentonite

The mineable bentonite reserve estimate in 1976 was 15 million tons, and the Kaycee Bentonite District in Johnson County had produced an estimated 12 to 14 million tons by 2008. However, there was no readily available information on current bentonite resources or reserves. Although reserve data are not provided, according to the BLM's Final Mineral Occurrence and Development Potential Report (BLM 2009a), "given the estimated quantities of reserves, a sustainable level of bentonite clay resources appears to be available to meet demand."

3.9.2.3 Aggregates

The likelihood of continuing production of aggregate materials is considered high, as aggregate would be required for road maintenance and new construction activities in support of increased development of other primary resources (e.g., oil and gas, coal, and uranium). 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, a decline in aggregate production would be anticipated as CBNG development is projected to reach low levels of drilling from 2013 to 2015 (Stilwell et al. 2009). After 2020, CBNG development is projected to revive somewhat, with levels of projected new wells drilled exceeding 1,000 wells per year from 2021 to 2026. As a result, sand and gravel production in the Wyoming PRB study area is projected to be approximately 4.5 million tons in 2020 and 3.1 million tons in 2030, compared to approximately 5.7 million tons in base year 2008.

3.9.2.4 Leonardite

No readily available information concerning potential leonardite reserves was identified. However, based on its use as a drilling fluid additive and the projected ongoing oil and gas development in the Wyoming PRB study area, production of leonardite is projected to continue at a constant rate consistent with the 20-year average production from 1988 to 2008, or approximately 41,500 tpy.

3.9.3 Assumptions

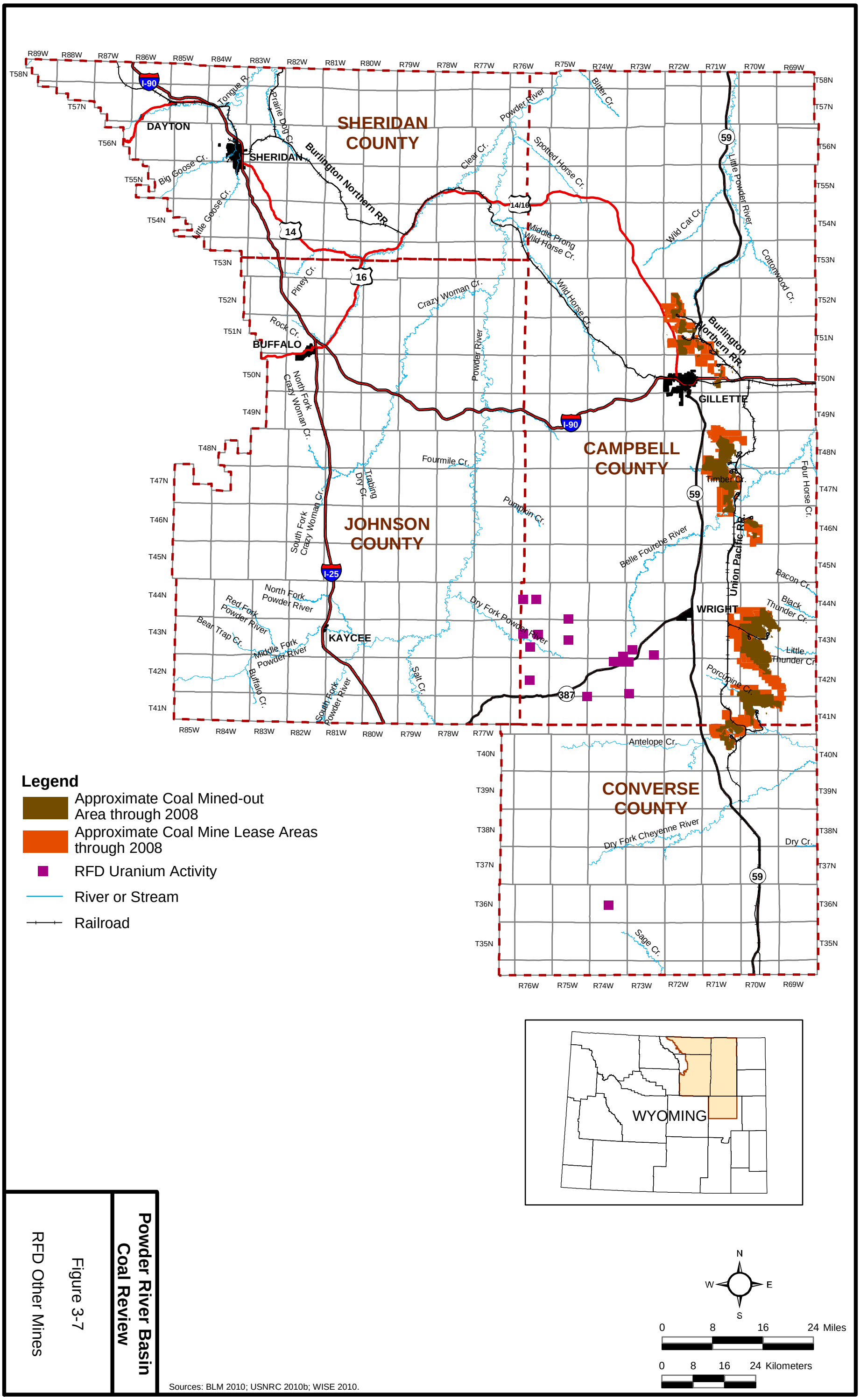
In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for uranium, bentonite, aggregate, and leonardite mines:

<u>Past and Present Development Assumptions</u>

- Surface disturbance by bentonite mining would occur at a ratio of 7,000 tons per acre, including direct and related disturbance (BLM 2009b), and would represent less than 0.2 percent of the disturbance in the Wyoming PRB. Disturbance areas sequentially would be reclaimed starting an assumed 5 years after disturbance.

<u>RFD Assumptions</u>

- Any new uranium mining would be conducted by in situ leach method recovery, not surface or underground mining.
- The demand for uranium would encourage the development of in situ leach method recovery facilities.
- Three new uranium projects would be developed by 2015, and they would be near the end of their reserves by 2020. Uranium production by 2030 would be dependent on one or more of the low to moderately likely projects initiating production between 2020 and 2030.
- Long-term disturbance for each uranium in situ recovery project would be a nominal 120 acres (Energy Information Agency 1995; Power Resources Inc. 2008). The disturbance would be reclaimed following the life of each project.



Sources: BLM 2010; USNRC 2010b; WISE 2010.

Powder River Basin Coal Review

Figure 3-7

RFD Other Mines

11/29/2011

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- Bentonite reserves should be adequate to meet demand through 2030. Associated surface disturbance would be 60 acres per year based on the average 2003 through 2008 production rates and a disturbance ratio of 7,000 tons per acre. Disturbance areas sequentially would be reclaimed.
- Aggregate production would fluctuate primarily in relation to varying levels of CBNG development, with a projected annual production of 4.5 million tons by 2020 and 3.1 million tons by 2030.
- Leonardite production would average 41,500 tpy through 2030.

3.9.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to other mines in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). Updated information relative to other mines for Phase II of the study was obtained from public information available through the BLM, Wyoming Department of Revenue, USNRC, Energy Information Agency, WISE, Wyoming Department of Employment, and publically available industry-related information. Specific resources are identified below.

AECOM. 2009. Update of the Task 2 Report for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities. Prepared for the Bureau of Land Management, High Plains District Office and Wyoming State Office. December 2009.

Black Hills Bentonite LLC. 2010. Bentonite Uses. Internet website: http://www.bhbentonite.com/ uses.html. Accessed on September 15, 2010.

____. 2002. Wyoming Lignite: Leonardite. Internet website: http://www.bhbentonite.com/lignite.html. Accessed on August 30, 2010.

Bureau of Land Management (BLM). 2009a. Final Mineral Occurrence and Development Potential Report. Buffalo Resource Management Plan Revision. Buffalo Field Office, Wyoming. June 19, 2009.

____. 2009b. Environmental Assessment -WY-010-EA10-08 Bentonite Mine Plan of Operation WYW142434Black Hills Bentonite, L.L.C. Internet website: http://www.blm.gov/wy/st/en/info/NEPA /wfodocs/blackhills-bentonite.html. Accessed on August 11, 2010.

_____. 2008. Analysis of the Management Situation. Buffalo Field Office Management Area. Buffalo Field Office, Buffalo, Wyoming.

____. 2004. Mineral Occurrence and Development Potential Report. Casper Field Office Planning Area. Casper Field Office, Wyoming. January 2004.

____. 2003. Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project. Wyoming State Office and Buffalo Field Office. Cheyenne and Buffalo, Wyoming. January 2003.

Cameco. 2010. Uranium Prices. Internet website: http://www.cameco.com/marketing/uranium_prices_ and_ spot_price/longterm_5yr_history/. Accessed on July 15, 2010.

Curry, D. L. 1976. Evaluation of Uranium Resources in the Powder River Basin. In: R. B. Laudon, Editor. Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook. Casper, Wyoming, p. 235-242. September 1976,

ENSR. 2005. Task 2 Report for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities. Prepared for the Bureau of Land Management, Casper Field Office and Wyoming State Office. Revised October 2005 (with errata).

Energy Information Agency. 1995. Decommissioning of U.S. Uranium Production Facilities. DOE/EIA-0592 Distribution Category UC-950, 71 p.

Love, J. D. 1952. Preliminary Report on the Uranium Deposits in the Pumpkin Buttes Area Powder River Basin, Wyoming. U.S. Geological Survey Circular 176.

Power Resources, Inc. 2008. Plan of Operations Gas Hills Uranium ISL Project. Power Resources, Inc., dba Cameco Resources 400 East 1st Street Casper, Wyoming. Prepared by Lidstone and Associates, Inc., Fort Collins, Colorado. August 2008.

Stilwell, D. P., S. W. Davis-Lawrence, A. M. Elser, and F. J. Crockett. 2009. Draft Reasonably Foreseeable Development Scenario for Oil and Gas, Buffalo Field Office Planning Area, Wyoming. Bureau of Land Management, Wyoming State Office, Reservoir Management Group. June 12, 2009.

Thorson, T. 1976. Bentonite Mining Near Kaycee, Wyoming, In: Laudon, R.B. (editor), Geology and Energy Resources of the Powder River. Wyoming Geological Association 28th Annual Field Conference Guidebook, Casper, Wyoming, p.277-281.September 1976,

U.S. Geological Survey (USGS). 2002. Assessment of Undiscovered Oil and Gas Resources of the Powder River Basin Province of Wyoming and Montana, 2002. USGS National Oil and Gas Assessment Fact Sheet FS-146-02.

U.S. Nuclear Regulatory Commission (USNRC). 2010a. Bear Creek Uranium. Internet website: http://www.nrc.gov/info-finder/decommissioning/uranium/bear-creek.html. Accessed on July 28, 2010.

_____. 2010b. Expected Uranium Recovery Facility Applications. Internet website: http://www.nrc.gov/info-finder/materials/uranium/. Accessed on July 28, 2010.

World Information Service on Energy (WISE). 2010. Uranium Project. Internet website: http://www.wise-uranium.org/index.html. Accessed on July 15, 2010.

Wyoming Department of Employment. 2010. Wyoming Inspector of Mines Annual Reports. Internet website: http://doe.wyo.gov/employers/MiningInformation/pages/default.aspx. Accessed on July 26, 2010.

Wyoming Department of Environmental Quality (WDEQ). 2010. Wyoming Storm Water Program, Authorizations Under the Mineral Mining General Permit. Updated September 30, 2010. Internet website: http://deq.state.wy.us/wqd/wypdes_permitting/wypdes_storm_water/stormwater.asp#Non-storm%20water%20permits. Accessed on October 7, 2020.

Wyoming Department of Revenue. 2010. Annual Reports 1989 to 2009. Internet website: http://revenue.state.wy.us/PortalVBVS/DesktopDefault.aspx?tabindex=3&tabid=10. Accessed on July 27, 2010.

Wyoming Oil and Gas Conservation Commission (WOGCC). 2010. Internet website: http://wogcc.state.wy.us/FieldReport.CFM. Accessed on August 12, 2010.

3.10 Oil and Gas

3.10.1 Past and Present Development

3.10.1.1 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 of oil to the end of 2002. Based on IHS (2010) data, cumulative production from the Salt Creek Oil Field through 2009 was 717.7 million barrels. 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 (Wyoming Oil and Gas Conservation Commission [WOGCC] 2010).

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; however, 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 portion 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, resulting 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), including fields such as 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 Formation also provided a mainstay for wildcat drillers during that time period.

Compared to CBNG, very little conventional oil and gas activity has occurred in the PRB study area in the last 20 years, and approximately 2,145 wells have been drilled from 1990 to 2008. The wells include 1,105 development oil wells, 693 wildcat (exploration) wells, and 347 service wells of various types (injection, disposal, source water, and observation wells). The only significant discovery has been the African Swallow Field, discovered in 2000, which produced over a million barrels of oil and nearly 17.5 billion cubic feet (Bcf) of gas from two wells by the end of 2008 (WOGCC 2010).

As of the end of base year 2008, there were approximately 3,060 productive conventional oil and gas wells in the Wyoming PRB study area and 784 inactive wells (WOGCC 2010). **Table 3-3** lists the annual production in the Wyoming PRB for the original (2003) and updated (2007 and 2008) base years. The numbers reflect a slow decline in annual production. **Figure 3-8** shows the location of all wells (producing, non-producing, and P&A).

Table 3-3 Annual Conventional Oil and Gas Production for Original and Updated Base Years

Base Year	Annual Oil Production (million barrels)	Annual Gas Production (Bcf)
2003	13.0	41.0
2007	11.4	22.0
2008	10.5	21.2

Sources: AECOM 2009; WOGCC 2010.

3.10.1.2 CBNG

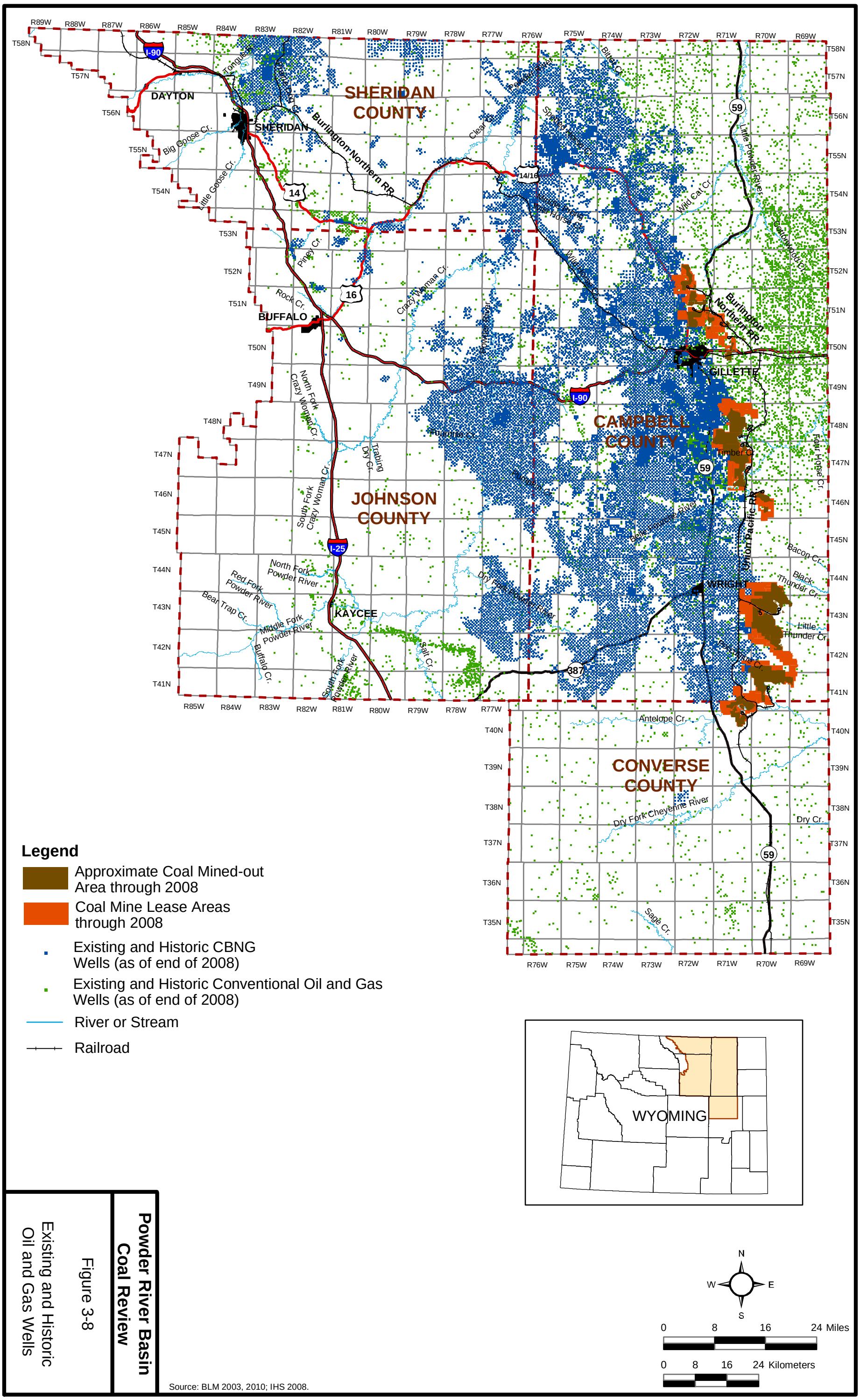
CBNG activity in the Wyoming PRB began in the 1980s; however, it took a number of years before commercially viable production was established. A total of three Applications for Permit to Drill (APDs) were issued in 1986 for CBNG wells in Campbell County (WOGCC 2010). The first commercial gas production 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 2010). 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 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 PRB study area, and total production for 2003 was 346 Bcf, or 88 percent of the total gas production from the basin (AECOM 2009a). From 1987 to 2003, the total cumulative gas production from PRB coals was over 1.2 Tcf. The total water production for the same time period was approximately 2.3 billion barrels (approximately 297,000 acre-feet). Annual CBNG production has increased rapidly since 1999, and by 2003 appeared to have started to level off or even decrease. Water production 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). CBNG production appeared to have peaked from a high of 977 MMcfpd in October 2003 to 899 MMcfpd in March 2004 (AECOM 2009a). By the end of base year 2008, CBNG gas production had rebounded to 1.5 MMcfpd, and cumulative production was 3.2 Tcf (WOGCC 2010). The status of the CBNG activity in the Wyoming PRB study area at the end of base year 2008 is summarized in **Table 3-4**.

Table 3-4 Summary of CBNG Activity in the Wyoming PRB Study Area as of the End of 2008

Category	Number of Wells
Wells drilled, completed, and with reported production	24,597
Wells drilled, completed, but no reported production	1,563
Dry holes	556
Wells spudded (drilling commenced) but suspended	731
Well locations (APDs approved)	3,788
Abandoned locations	3
Total	31,238

Sources: IHS Energy 2010; Crockett 2010.



Source: BLM 2003, 2010; IHS 2008.

Powder River Basin Coal Review

Figure 3-8

Existing and Historic Oil and Gas Wells

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3.10.2 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 timeframe 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.

The likelihood of new oil and gas activities (including CO_2 EOR and associated pipelines) occurring in the future is a certainty; however, 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 D**.

3.10.2.1 Conventional Oil and Gas

Table 3-5 summarizes the projected production and number of wells associated with conventional oil and gas development. The projections were based on Stilwell et al. (2009) and Stilwell and Crockett (2005) as incorporated into the oil and gas methodology in **Appendix D**. The projected well numbers would include a certain number of service wells; however, the related disturbance assumptions would not change. By the end of base year 2008, the number of existing conventional oil and gas wells was estimated to be approximately 3,844 active and inactive wells (WOGCC 2010). As shown in **Table 3-5**, annual oil and gas production is projected to decline through 2030.

Table 3-5 Projected Conventional Oil and Gas Activity

Wells and Production	Current Base Year	Projection Years	
	2008	**2020**	**2030**
Annual Gas Production (Bcf)	20.1	17.1	9.7
Annual Oil Production (million barrels)	10.7	4.8	1.8
Active Wells	3,107	2,783	1,976

It is certain that conventional oil and gas exploration and development would continue in the Wyoming PRB study area, but at a rate below previous historic levels. 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. However, technological innovation coupled with a recent market-driven push for oil could revive drilling in the basin. Of note is potential production of oil and gas from formations composed primarily of shale through the use of horizontal drilling and staged hydraulic fracturing. Activity in the Bakken Formation in the Williston Basin of Montana and North Dakota has accelerated in recent years. It remains to be seen whether formations like the Niobrara and Mowry and other resource plays can revive

non-coal bed production in the PRB study area. The primary method for accessing the resource plays would be through horizontal drilling and hydraulic fracturing methods. It is expected that at least 25 percent of the new wells drilled would be horizontal. Horizontal drilling is being used to access oil and gas resources from the Parkman Formation in the Savageton Field in southwestern Campbell County in order to maximize recovery of oil and gas and to minimize water production (Wheeler 2009). As of 2009, El Paso Exploration & Production Company had drilled 51 horizontal wells in the field and expected a primary recovery of 7.5 million barrels of oil and a secondary recovery of 5.5 million barrels of oil (Wheeler 2009).

The U.S. Geological Survey (USGS 2002) estimated that the mean undiscovered non-coal bed hydrocarbon resource in the PRB (including Montana) is 1.8 billion barrels of oil equivalent. This number indicates that the PRB has a potentially important non-coal bed hydrocarbon resource base. Whether that resource is exploited is dependent upon a number of factors. Because of lackluster gas prices and an overabundance of supply nationally, the economics favor oil rather than the gas resource. Since the rise of oil prices to record levels in 2008, the price has stabilized to between $70 and $80 per barrel, providing incentive for investing in oil resources.

In 2003, Petro Source built a 125-mile, 16-inch pipeline from Bairoil, Wyoming, to the Salt Creek oil field in Natrona County to conduct an EOR project (Bailey 2010). Soon thereafter, Anadarko Petroleum Corporation (Anadarko) bought the pipeline and the Salt Creek oil field. Although the Salt Creek oil field is not in the Wyoming PRB study area, Anadarko is conducting a CO_2 EOR project there that is highly relevant to PRB oil and gas development. Anadarko's EOR project began in 2004 and, as of the end of 2009, had injected 181 million cubic feet of CO_2. Oil production increased from 4,000 bpd in 2002 to approximately 9,000 bpd in 2008 (Bailey 2010). When all planned phases of the project have been initiated, Anadarko expects production to be approximately 12,000 bpd, an incremental increase of 8,000 bpd.

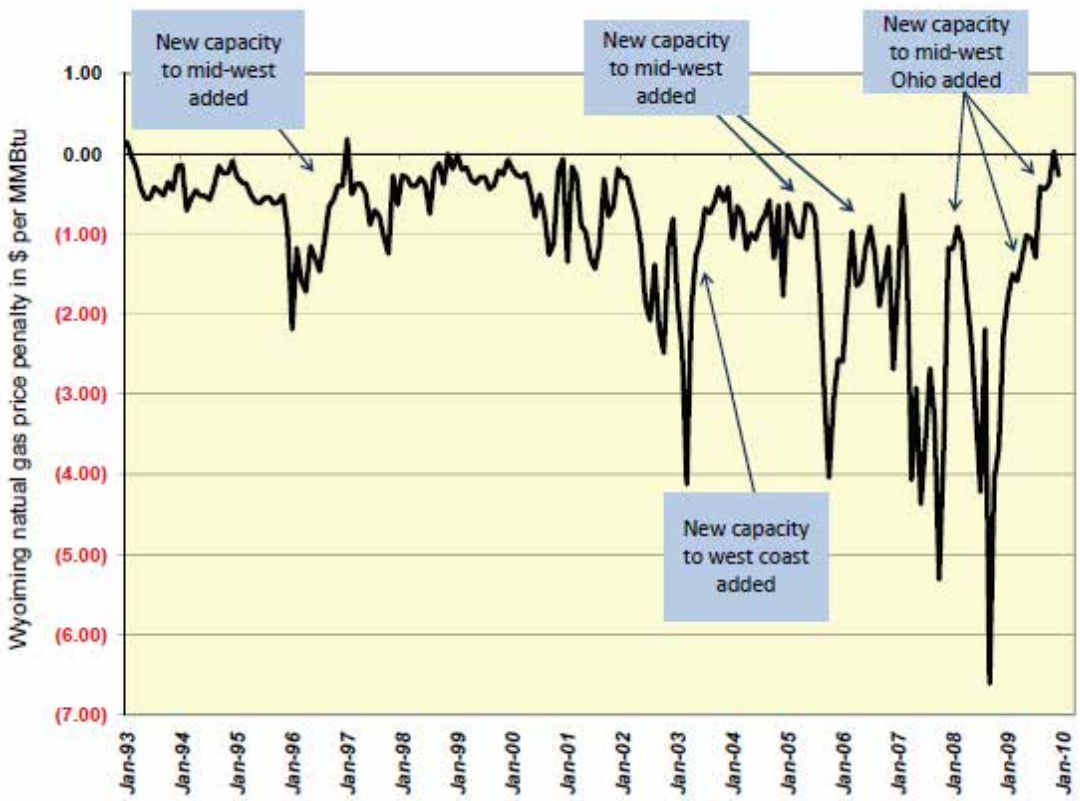
There is potential for EOR activity in the Wyoming PRB study area. Projects that have been conducted to date are pilot scale and involve hauling the gas to individual injection wells by tanker truck. Possible EOR candidates in the PRB include Harzog Draw, House Creek, Hilight, Raven Creek, Rozet, Kitty, 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 LaBarge Anticline in the Green River Basin, and there 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 3.11, Pipelines). To encourage producers to take advantage of the CO_2 resource and to encourage oil production, the State of Wyoming provides a severance tax break of 2 percent on oil produced from WOGCC-approved CO_2 EOR projects. 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). Since the CO_2 pipeline at Salt Creek originally was proposed to end at Hartzog Draw (DeBruin 2001), the likelihood rating of any such CO_2 EOR project is considered speculative.

A proposal to build a CO_2 pipeline from Lost Cabin to Bell Creek, Montana, was submitted to the BLM in 2009 by Encore (now Denbury Resources). This pipeline would cross some of the highly prospective areas for EOR in the PRB. See Section 3.11 for a discussion of this proposed pipeline and implications for PRB non-coal bed production.

3.10.2.2 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 price differential between 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 resulted due to inadequate pipeline capacity to move Rocky Mountain region gas to markets outside of the area. Historically, the differential has been as high as $2.4 MMBtu (Holcomb 2003), or roughly 1 thousand cubic feet [Mcf]. This disparity in price has resulted in an estimated loss of more than $2 billion 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 MMBtu to $0.60 per MMBtu (Holcomb 2004). However, the addition of the Kern River system capacity did not completely solve the differential problem. **Figure 3-9** shows the variation in the price differential from January 1993 to January 2010. The additional pipeline capacity caused the differential to narrow; however, it subsequently widened again. The new capacity of the Rockies Express (REX) Pipeline Project in early 2008 reduced the differential to near zero by January 2010 (Wyoming Pipeline Authority 2010). The expectations for REX to lower the differential were not realized until the REX project was extended into Ohio and markets beyond the Mississippi River in 2009.



Source: Wyoming Pipeline Authority 2010.

Figure 3-9 Historic Wyoming Natural Gas Price Differential Compared to Gulf Coast Price

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

- Under a status quo price scenario, where the basin price differential is $1.80 per Mcf, the economically recoverable CBNG resource would be 1.5 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 does not 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 goes 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 EIS and Proposed Plan Amendment for the PRB Oil and Gas Project (BLM 2003), 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). 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 EIS and Proposed Plan Amendment for the PRB Oil and Gas Project (BLM 2003). New CBNG well numbers fell from a high of slightly more than 4,600 in 2001 to approximately 2,000 in 2004, an annual rate that generally continued through 2008. It is projected that the number of new wells would decrease so that between 2010 and 2020 the number of new wells drilled per year basin-wide would range between 304 and 859. Between 2020 and 2030, the projected number of new wells drilled per year basin-wide would range between 434 and 1,156, with the peak occurring in 2024. (Refer to Appendix D for assumptions used in the analysis of CBNG activity.) There would be 13,534 active CBNG wells by 2010, much lower than the over 40,000 wells predicted for the same time period in the Final EIS and Proposed Plan Amendment for the PRB Oil and Gas Project (BLM 2003). Previously it was projected that production in the cumulative effects study area would increase from the 430 Bcf observed in 2007 to approximately 1,026 Bcf annual production in 2020. As shown in **Table 3-6**, the estimated production for 2020 is approximately 160 Bcf, with a rebound to approximately 283 Bcf for 2030. Overall, estimated recoverable gas by 2030 is expected to be less than 9 Tcf (Stilwell et al. 2009); lower than any of the previous predictive scenarios described above.

Table 3-6 Projected CBNG Activity

Wells and Production	Current Base Year Data		Projected Data
	2008	2020	2030
Annual Production (Bcf)	546.7	159.9	282.9
Active Wells	19,509	8,646	9,127

3.10.3 Assumptions

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

3.10.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to oil and gas development in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). Updated information relative to oil and gas development for Phase II of the study was obtained from WOGCC on-line well files, BLM public documents, IHS well data, Wyoming Geological Survey publications, BLM Wyoming State Office RMG, ARI, and other sources as indicated below:

Advanced Resources International (ARI). 2002. Powder River Basin Coal Bed Methane Development and Produced Water Management Study. Internet website: http://www.netl.doe.gov/KMD/Forms/Search.aspx?st=1&pubtitle=produced%20water%20powder%20river%20basin&selAndOr=0&sortDir=0. Accessed on August 25, 2010.

AECOM. 2009. Update of the Task 2 Report for the Powder River Basin Coal Review, Past and Present and Reasonably Foreseeable Future Development Activities. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. December 2009.

Bailey, A. 2010. CO_2 Triple Win at Salt Creek Oil Field. Internet website: http://www.greeningofoil.com/post/CO2-triple-win-at-Salt-Creek-oil-field.aspx. Accessed on August 24, 2010.

Bureau of Land Management (BLM). 2003. Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project. Wyoming State Office and Buffalo Field Office, Cheyenne and Buffalo, Wyoming. Internet website: http://www.blm.gov/wy/st/en/info/NEPA/bfodocs/prb_eis.html. January 2003.

Crockett, F. 2010. Petroleum Geologist, Bureau of Land Management, Wyoming Reservoir Management Group. Personal communication with AECOM. August 13, 2010.

DeBruin, R. 2001. Carbon Dioxide in Wyoming. Wyoming State Geological Survey, Laramie, Wyoming. Information Pamphlet No. 8.

DeBruin, R. H. and R. W. Jones, 1989. Coalbed Methane in Wyoming. In: J. L. Eisert, Editor. Gas Resources of Wyoming; Wyoming Geological Association of Geologists 40th Field Conference Guidebook, Casper, Wyoming. pp. 97-103. September 10-14, 1989.

Drew, L. J. 1990. Oil and Gas Forecasting: Reflections of a Petroleum Geologist. Oxford University Press, New York, New York. 252 pp.

Flores, R. M., G. D., Stricker, J. F. Meyer, T. E. Doll, P. H. Norton, Jr., R. J. Livingston, and M. C. Jennings. 2001. A Field Conference on Impacts of Coalbed Methane Development in the Powder River Basin. U.S. Geological Survey Open-file Report 01-126.

Holcomb, J. 2004. Rocky Mountain Pipeline Infrastructure: The Need for More Capacity. Rocky Mountain Gas Symposium, Denver, Colorado. February 11, 2004.

IHS Energy Services™ (IHS). 2010. PI/DWIGHTS Rocky Mountain Oil and Gas Production and Well History Database.

McGregor, A. A. 1972. The Powder River Basin. In: W. W. Mallory, Editor. Geologic Atlas of the Rocky Mountain Region: Denver, Colorado. Rocky Mountain Association of Geologists. pp. 269-270.

U.S. Geological Survey (USGS). 2002. Assessment of Undiscovered Oil and Gas Resources of the Powder River Basin Province of Wyoming and Montana, 2002. USGS National Oil and Gas Assessment Fact Sheet FS-146-02.

Wheeler, D. M. 2009. Discovery and Horizontal Development of Savageton Field, Powder River Basin, Wyoming: Geosteering in Thin Parkman Sandstone to Minimize Water Production and Enhance Ultimate Recovery. In: *Outcrop* (newsletter of the Rocky Mountain Association of Geologists), July 2009, p. 20-21.

Wyoming Oil and Gas Conservation Commission. 2010. Statistics. Internet website: http://wogcc.state.wy.us/online_stats_bk/main_menu.cfm. Accessed on September 16, 2010.

Wyoming Pipeline Authority. 2010. Internet website: http://www.wyopipeline.com/. Accessed on September 16, 2010.

3.11 Pipelines

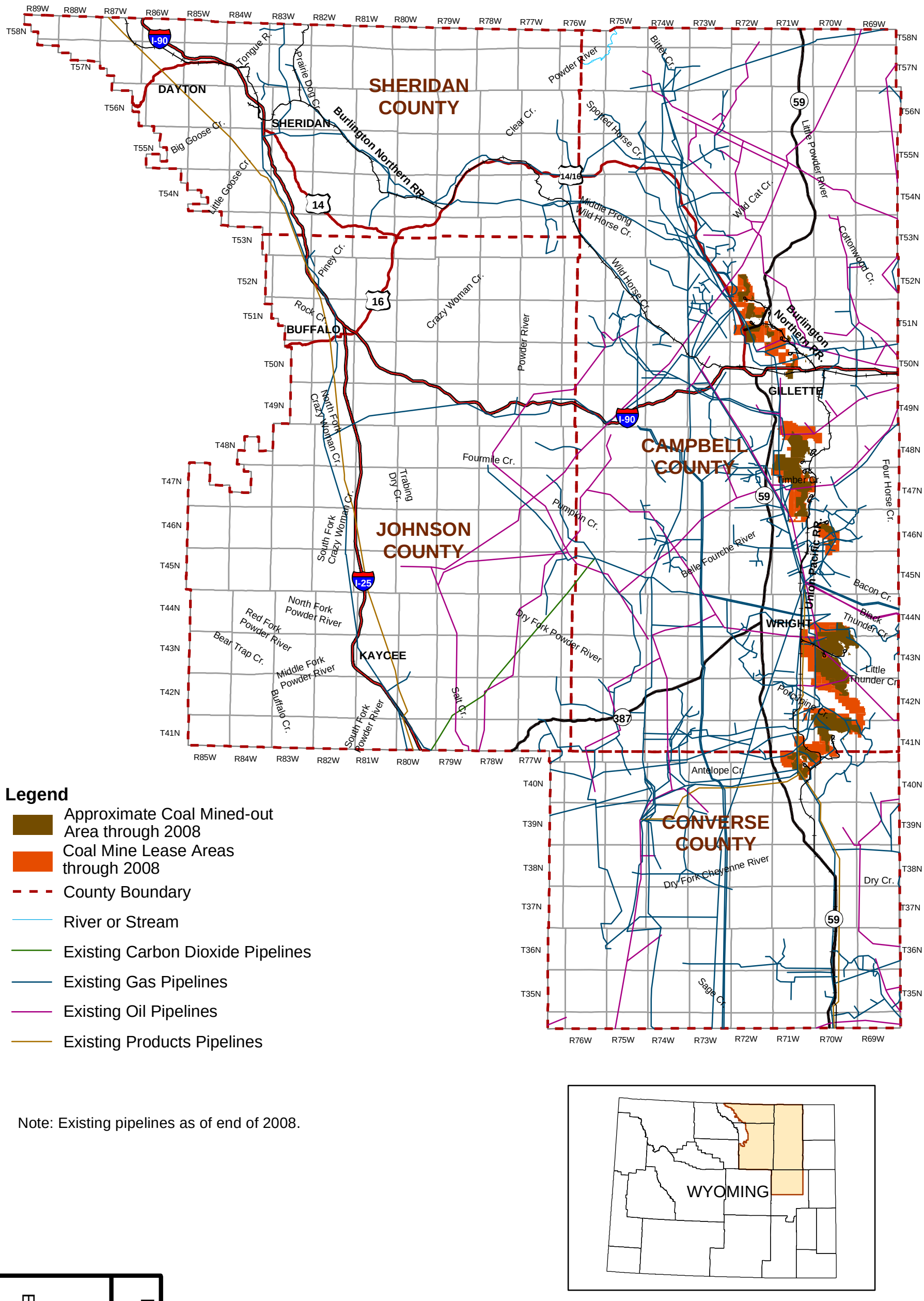
3.11.1 Past and Present Development

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. Since preparation of the original Task 2 report (ENSR 2005), no major natural gas transportation lines have been constructed in the Wyoming PRB study area. In base year 2008, there were over 13 major transportation pipeline systems in the PRB that transported gas resources to markets outside of the PRB (AECOM 2009a; Flores et al. 2001). The current capacity of these pipeline systems is approximately 2.1 Bcf per day (Wyoming Pipeline Authority 2010). As of base year 2008, the combined natural gas production (CBNG and conventional gas) in the Wyoming PRB study area was approximately 1.55 Bcf per day. As shown in **Figure 3-10**, there also are numerous oil, gas, and products pipelines in the PRB study area. Gathering lines associated with conventional oil and gas and CBNG development also occur within the PRB study area; for purposes of this study, these gathering lines have been factored in proportionally on a per well basis, as discussed in **Appendix D**.

3.11.2 Reasonably Foreseeable Development

The availability of major transportation pipeline capacity is a key factor in the future development of CBNG and conventional gas resources in the Wyoming PRB study area. Increased recovery of crude oil also may depend somewhat on the availability of CO_2 for EOR projects. Currently, there are two proposed transportation pipeline projects that would cross the PRB study area: the Bison Pipeline Project would transport natural gas, and the Greencore Pipeline would transport CO_2 (**Table 3-7** and **Figure 3-11**). Northern Border Pipeline (50 percent owner of the Bison Pipeline Project) was actively seeking shippers through an open season that began in 2008 (TransCanada PipeLines Limited [TransCanada] 2010). The Bison Pipeline would originate in the Wyoming PRB study area and transport gas from the PRB to outside markets. The previously proposed Pathfinder Pipeline (AECOM 2009a) would have crossed the Wyoming PRB study area, although the main supply of gas would have been from the Green River Basin where it would have originated. However, the Pathfinder Pipeline was cancelled in favor of the Bison Pipeline Project, which began construction in 2010.

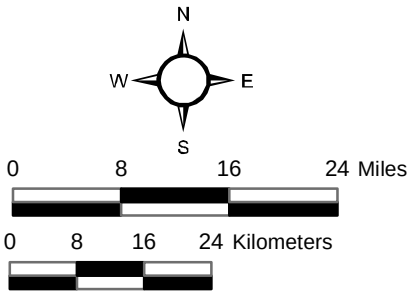
In the original Task 2 report (ENSR 2005), reported estimates of the growth of Wyoming PRB CBNG production ranged from a 2003 level of 900 MMcfpd to 3 to 4 Bcf per day in 2007, and it was anticipated that production would remain at or above those levels until 2015 (Holcomb 2003). However, production rates of 3 to 4 Bcf per day were not realized by 2008, and the average daily production for all gas (conventional and CBNG) was approximately 1.55 Bcf per day (WOGCC 2010). The addition of the



Legend

- Approximate Coal Mined-out Area through 2008
- Coal Mine Lease Areas through 2008
- County Boundary
- River or Stream
- Existing Carbon Dioxide Pipelines
- Existing Gas Pipelines
- Existing Oil Pipelines
- Existing Products Pipelines

Note: Existing pipelines as of end of 2008.



Source: BLM 2010; Debruin 2002.

Powder River Basin Coal Review

Figure 3-10

Existing Major Pipelines

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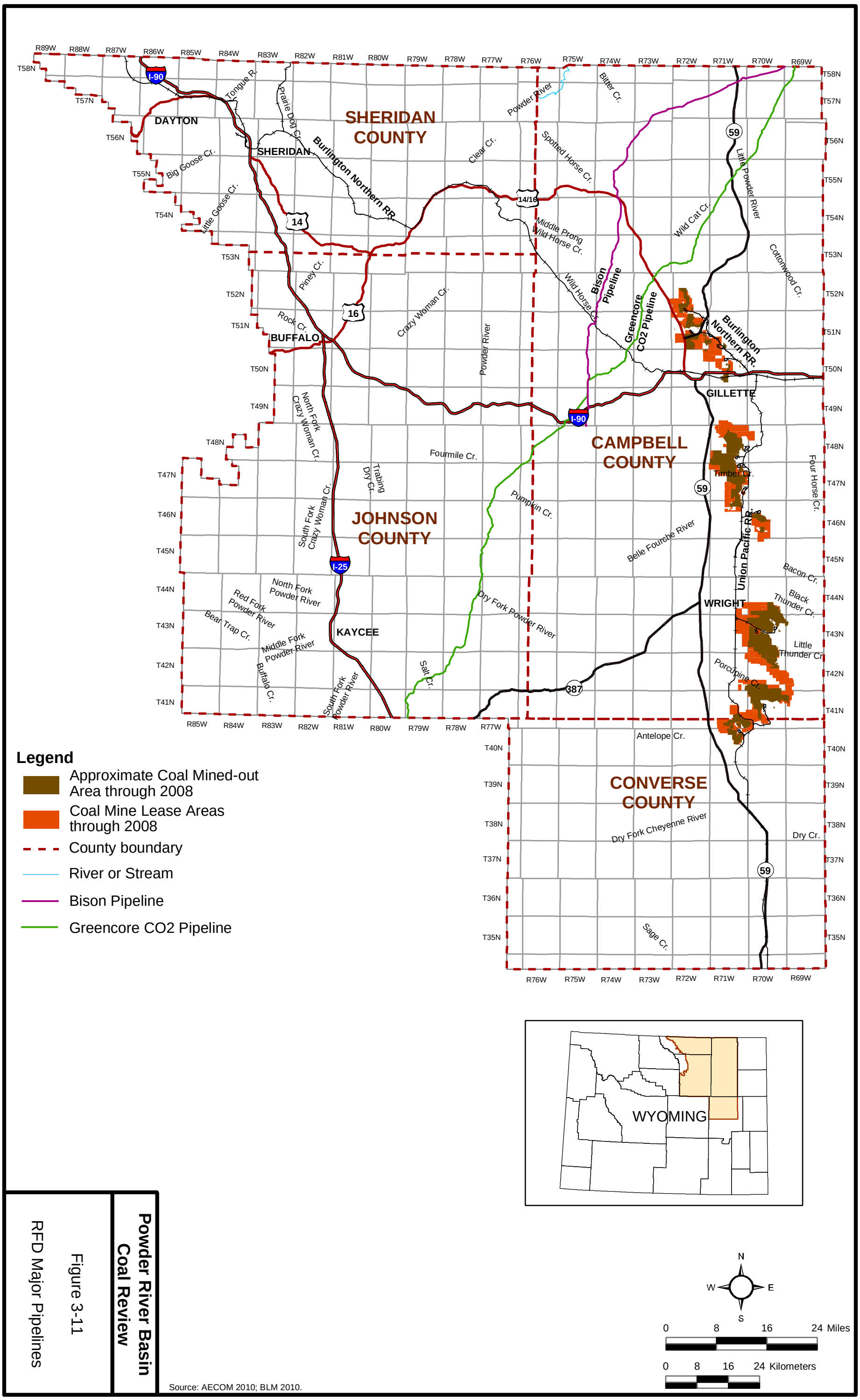

Source: AECOM 2010; BLM 2010.

Powder River Basin Coal Review

Figure 3-11

RFD Major Pipelines

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Bison Pipeline Project would increase the take-away capacity from the PRB to approximately 2.5 Bcf per day (Wyoming Pipeline Authority 2010), more than adequate to handle the CBNG production from the PRB. Other than the Bison Pipeline Project, it is not likely that additional natural gas transportation pipelines would be constructed in the foreseeable future given existing conditions.

Table 3-7 Proposed Pipeline Projects in the Wyoming PRB Study Area

Project/ Company	Location	Product	Description	Mileage within Wyoming PRB Study Area Subwatersheds	Likelihood
Bison/ TransCanada Corporation	Campbell County	Natural gas	30-inch, 308-mile pipeline, approximately 447 MMcfpd, from Dead Horse Creek, Wyoming to Morton County, North Dakota	Upper Powder River (28.9 miles), Middle Powder River (14.4 miles), Little Powder River (33.5 miles)	High. Project under construction in summer 2010; projected in-service date of November 15, 2010.
Greencore/ Denbury Resources	Campbell and Johnson counties	CO_2	Combined 8- and 10-inch, 230-mile pipeline; estimated to increase oil production from existing wells from 1,200 bpd to a peak response of 7,000 bpd; from Lost Cabin Plant in Wyoming to wells throughout the 21,000-acre Bell Creek Field in southeastern Montana	Little Powder River (55.7 miles), Salt Creek (14.4 miles), Upper Powder River (64.4 miles)	High. Permitting and surveys being conducted in 2010. Estimated in-service in 2011.

Sources: Greencore Pipeline Company LLC 2010; TransCanada 2010.

In the original Task 2 report (ENSR 2005), it was indicated that Anadarko Petroleum Corporation was planning to extend its CO_2 pipeline that runs between Bairoil, Wyoming, and Salt Creek, Wyoming, to the Sussex Field located in the southern Johnson County portion of the Wyoming PRB study area. However, more recent information indicates that this has not occurred (Anadarko Petroleum Corporation 2008). According to the Wyoming Enhanced Oil Recovery Institute, fields in the Wyoming PRB study area that would be good candidates for EOR using CO_2 include Hartzog Draw, Hilight, and House Creek (Boyles and vant Veld 2006). The Greencore Pipeline by Denbury Resources is undergoing permitting and environmental field surveys as of the summer of 2010 and would carry CO_2 to the Bell Creek field in Montana. Laterals from the Greencore Pipeline may be constructed in the future to carry CO_2 to potential EOR projects in the Wyoming portion of the Powder River Basin; however, no projects are currently planned.

3.11.3 Assumptions

In addition to the information obtained in the identified data sources, the following assumptions were used to define specific impact-causing parameters for pipelines.

Past and Present Development Assumptions

- The 2008 pipeline capacity out of the PRB was slightly less than 2.1 Bcf per day, and daily production in the Wyoming PRB study area was 1.55 Bcf.
- Existing pipeline ROWs have a disturbance width of 50 feet, which conservatively accounts for access roads, ground-disturbing maintenance activities, and permanent facilities (e.g., compressor stations, valves, etc.) located at intervals along the ROWs.
- In the Wyoming PRB study area, there are 2,672 miles of natural gas transportation pipelines, 906 miles of crude oil pipelines, 210 miles of petroleum product pipelines, and 37 miles of CO_2 pipeline.

RFD Assumptions

- Any new major transportation pipelines would incur a disturbance area based on an average construction ROW width of 100 feet during the year of construction. It is assumed that in subsequent years there would be a ROW disturbance width of 50 feet, which conservatively accounts for access roads, ground-disturbing maintenance activities, and permanent facilities (e.g., compressor stations, valves, etc.) located at intervals along the ROWs.
- Construction of the Bison Pipeline Project would be completed in 2010, with a projected in-service date of November 15, 2010. Operation of the pipeline through 2030 is considered highly likely. The pipeline would add approximately 76.8 miles of natural gas transportation pipeline infrastructure to the study area. It also would increase pipeline capacity in the study area to slightly more than 2.5 Bcf per day.
- The Greencore CO_2 Pipeline would be constructed and in-service in 2011. Operation of the pipeline through 2030 is considered highly likely. The pipeline would add approximately 134.5 miles of CO_2 pipeline infrastructure to the study area.

3.11.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to pipelines in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). Updated information relative to pipeline projects for Phase II of the study was obtained from the Wyoming Pipeline Authority website, applicant websites, and published sources as documented below:

AECOM. 2009a. Update of the Task 2 Report for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. Submitted by AECOM, Inc. Fort Collins. Colorado, December 2009.

Anadarko Petroleum Corporation. 2008. Operations: Enhanced Oil Recovery. Internet website: http://www.anadarko.com/opreations_by_region/u.s._rockies/enhanced_oil_recovery.asp. Accessed on May 22, 2008.

Boyles, J. M. and K. vant Veld. 2006. Preliminary CO_2 Demand Analysis for the Powder River Basin. Wyoming Enhanced Oil Recovery Institute presentation to the Wyoming Pipeline Authority, January 24, 2006. Internet website: http://www.wyopipeline.com/presentations.asp. Accessed on September 15, 2010.

Casper Star Tribune. 2010. Gas Pipeline Projects are Great New for Wyoming. Internet website: http://trib.com/news/opinion/editorial/article_fca2531c-f2c2-590a-8f9a-cc9095dc372d.html. April 29, 2010. Accessed on September 15, 2010.

ENSR. 2005. Task 1C Report for the Powder River Basin Coal Review Current Social and Economic Conditions. Prepared for BLM Casper Field Office and Wyoming State Office. Prepared by ENSR Corporation, Fort Collins, Colorado. March 2005.

Flores, R. M., G. D., Stricker, J. F. Meyer, T. E. Doll, P. H. Norton, Jr., R. J. Livingston, and M. C. Jennings. 2001. A Field Conference on Impacts of Coalbed Methane Development in the Powder River Basin. U.S. Geological Survey Open-file Report 01-126.

Greencore Pipeline Company LLC. 2010. Greencore CO_2 Pipeline Project; Project Number: 394019 Draft Plan of Development. Prepared by CH2MHill.

Holcomb, J. 2003. Rocky Mountain Pipeline Assessment. Prepared for Pace Global Energy Services. February 7, 2003. Presented at the Rocky Mountain Association of Geologists and Petroleum Technology Transfer Council Coalbed Methane Symposium. Denver, Colorado. June 10, 2003.

Jefferies, B. 2010. Rockies Historical Development of Natural Gas Pipelines. Internet website: http://www.wyopipeline.com/presentations.asp. April 2010. Accessed on September 15, 2010.

TransCanada PipeLines Limited (TransCanada). 2010. Bison Pipeline Project; Status and Timelines. Internet website: http://www.transcanada.com/bisonpipelineproject.html. Site updated September 16, 2010. Accessed on October 1, 2010.

Wyoming Oil and Gas Conservation Commission. 2010. Statistics. Internet website: http://wogcc.state.wy.us/online_stats_bk/main_menu.cfm. Accessed on September 16, 2010.

Wyoming Pipeline Authority. 2010. Internet website: http://www.wyopipeline.com/. Accessed on September 16, 2010.

3.12 Refineries

3.12.1 Past and Present Development

As of end of base year 2008, there were no operating petroleum refineries in the Wyoming PRB study area. The closest existing refinery is the Wyoming Refining Company's refinery in Newcastle (Weston County), Wyoming, approximately 76 highway miles southeast of Gillette. Due to the lack of refining capacity within the PRB, much of the oil produced in the PRB is transported out-of-state to be refined.

Initial construction of a new refinery in the Wyoming PRB study area was completed by Interline Resources in 2008. The facility, known as the NorthCut Refinery, is located in Converse County approximately 20 miles north of Douglas, Wyoming. The refinery is adjacent to and east of SH 59, with the joint UP/BNSF rail line located just to the west of the highway. The site previously had been the location of the Well Draw Gas Plant (approximately 20 acres), which shut down in 2002 following a fire. Interline Resources acquired an additional 12 acres bordering the original site for various administrative, maintenance, and transportation functions (Interline Resources 2008).

The refinery is a crude oil topping plant specifically engineered to process approximately 5,000 bpd of sweet crude produced in the PRB and delivered to the facility via a company-owned pipeline and third-party tanker trucks. The refinery is designed to produce naptha, off-road diesel, and reduced crude oil. The markets for the products include ethanol manufacturers, mines, and other refineries. Plans are for finished products from the facility to be transported via tanker trucks (Interline Resources 2008).

Following initial project construction, Interline Resources experienced financial difficulties, thereafter seeking and apparently securing additional financial participation by an outside party. Although a company news release reported the completion of construction, the project did not become operational,

failing to secure all of its environmental compliance and regulatory permits. In late 2009, the company filed notice with the Securities and Exchange Commission to terminate its registration under the Security and Exchange Act of 1934 and suspension of duty to file reports with the Securities and Exchange Commission. At about the same time, control of the refinery property assets was assumed by Utah-based Garco LLC. According to the WDEQ, the firm is working toward achieving environmental compliance so the plant can become operational, with initial operations reasonably foreseen beginning in 2011 (Clark 2010; Security and Exchange Commission 2010).

3.12.2 Reasonably Foreseeable Development

Assuming Garco LLC is successful in achieving environmental compliance at the previously constructed NorthCut Refinery, it is anticipated that operations would begin in 2011. No reasonably foreseeable plans have been identified for construction and operation of any additional petroleum refineries in the Wyoming PRB study area.

3.12.3 Assumptions

In addition to the information obtained from the identified data sources, the following assumptions were used to define specific impact-causing parameters for refineries.

Past and Present Development Assumptions

- There are no assumptions relative to past and present refineries.

RFD Assumptions

- The NorthCut Refinery would become operational in 2011 and continue operating throughout the timeframe of this study (through 2030). Therefore, the project is assumed to be highly likely.
- No major expansions in refining capacity would occur, and no additional new refineries would be constructed in the study area during the timeframe of this study (through 2030).

3.12.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to refineries in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). General data sources reviewed for potential information relative to refineries in the Wyoming PRB study area for Phase II of the study included the petroleum databases maintained by the USDOE, Energy Information Administration (http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html), WDEQ, input from the Campbell County Economic Development Corporation (CCEDC) and Wyoming Business Council, and online internet data searches (e.g., EDGAR, the Security and Exchange Commission's online electronic filing database [http://www.sec.gov/edgar.shtml]). Historical information for the NorthCut Refinery was obtained from Interline Resources. Specific sources of information used in developing this summary included:

Clark, D. 2010. Ombudsman, Wyoming Department of Environmental Quality. Personal communication with R. Dutton, Sammons/Dutton LLC. March 2010.

Interline Resources. 2008. Crude Oil Refining – NorthCut Refining LLC. Internet website: http://www.interlineresources.com/Crude%20Oil%20Refining. Accessed on June 3, 2008.

Securities and Exchange Commission. 2010. EDGAR Online database. Listing of filings by Interline Resources (IRCE). Internet website: http://www.sec.gov/cgi-bin/browse-edgar?company=&match=&CIK= IRCE&filenum= &State=&Country=&SIC=&owner=exclude&Find=Find+Companies&action=getcompany. Accessed on March 2010.

3.13 Reservoirs and Other Water Developments

Reservoirs in the Wyoming PRB study area were identified based on the Powder/Tongue River Basin Water Plan (HKM Engineering et al. 2002a) and Northeast Wyoming River Basins Water Plan (HKM et al. 2002b). These plans, which encompass the PRB study area, were prepared for the Wyoming Water Development Commission for their Basin Planning Program. The plans identified the key water supply reservoirs (generally 1,000 acre-feet or greater) in these basins; industrial ponds and impoundments were not addressed in the plans.

Industrial ponds or impoundments associated with mining and CBNG development occur within the Wyoming PRB study area. For purposes of this study, impoundments associated with coal mining activity have been accounted for in the mine-related disturbance areas. The disturbance area associated with CBNG-related impoundments has been factored in on a per well basis as discussed in **Appendix D**. As of 2000, there were a total of 1,976 stock water ponds in the study area (BLM 2003). Although additional stock water ponds may have been constructed since 2000, the incremental increase is assumed to be low. Therefore, based on the assumed low overall associated acreage per subwatershed, stock ponds have been eliminated from further analysis in this study.

3.13.1 Past and Present Development

Currently, there are 14 key water storage reservoirs in the Powder/Tongue River Basin and 5 key water storage reservoirs in the Northeast Wyoming River Basins (HKM Engineering et al. 2002a,b). Three of the key water storage reservoirs located in the Powder/Tongue River Basin planning area (Healy, Lake DeSmet, and Muddy Guard No. 2) and two of the key water storage reservoirs in the Northeast Wyoming River Basins planning area (Gillette and Betty No. 1) occur in the Wyoming PRB study area (**Figure 3-3)**. These reservoirs provide for irrigation water and recreational activities.

3.13.2 Reasonably Foreseeable Development

Based on the Powder/Tongue River Basin Water Plan (HKM Engineering et al. 2002a) and the Northeast Wyoming River Basins Water Plan (HKM Engineering et al. 2002b) that were prepared for the Wyoming Water Development Commission for its Basin Planning Program, there are long-range projections for development of additional reservoirs in the Wyoming PRB study area. There are two new water-storage projects on the western side of the PRB study area that currently are being studied for feasibility. One is in the Big and Little Goose creek drainages and the other is in the headwaters of Rock Creek, Clear Creek, and French Creek drainages (Besson 2010; States West Water Resources Corporation 2008). However, no new reservoirs currently are proposed for construction (Besson 2010); therefore, their likelihood is considered speculative. As a result, they have been eliminated from further analysis.

3.13.3 Assumptions

No assumptions were required for this study to define specific impact-causing parameters for reservoirs and water developments.

3.13.4 Data Sources

Information presented in the Powder/Tongue River Basin Water Plan (HKM Engineering et al. 2002a) and the Northeast Wyoming River Basins Water Plan (HKM Engineering et al. 2002b) was used to develop the reservoirs and other water developments section of this report. These plans were developed for the Wyoming Water Development Commission for their Basin Planning Program. Information also was obtained directly from the Wyoming Water Development Commission. Specific sources are provided below.

Besson, L. 2010. Deputy Director for Dam and Reservoir Planning, Wyoming Water Development Commission. Personal communication with D. Fetter, AECOM. February 2010.

Bureau of Land Management (BLM). 2003. Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project. Wyoming State Office and Buffalo Field Office, Cheyenne and Buffalo, Wyoming. January 2003.

HKM Engineering, Inc., Lord Consulting, and Watts and Associates. 2002a. Powder/Tongue River Basin Plan. Prepared for Wyoming Water Development Commission Basin Planning Program. February 2002. Internet website: http://waterplan.state.wy.us/plan/newy/newy-plan.html. Accessed on January 14, 2010.

_____. 2002b. Northeast Wyoming River Basins Plan. Prepared for Wyoming Water Development Commission Basin Planning Program. February 2002. Internet website: http://waterplan.state.wy.us/ plan/powder/powder-plan.html. Accessed on January 14, 2010.

States West Water Resources Corporation. 2008. Hopkins Producers Irrigation District Watershed/Water Storage Project Level I, Final Report. October 2008. Internet website: http://library.wrds.uwyo.edu/wwdcrept/ Hopkins_Producers_Irrigation_District/Hopkins_Producers_ID-Watershed_Water_Storage_Level_I-Final_ Report-2008.html. Accessed on March 30, 2010.

Wyoming Water Development Commission (WWDC). 2007a. NE Wyoming River Basin, Wyoming: Summary of Potential Dam and Reservoir Project Literature. Internet website: http://wwdc.state.wy.us/dam_reservoir/ NEWY_DamRes_Survey07.pdf. Accessed on February 1, 2010.

_____. 2007b. Powder Tongue River Basin, Wyoming: Summary of Potential Dam and Reservoir Project Literature. Internet website: http://wwdc.state.wy.us/dam_reservoir/Powder_DamRes_Survey10.pdf. Accessed on February 1, 2010.

3.14 Other Industrial Manufacturing

3.14.1 Past and Present Development

There are many existing industrial manufacturing and service establishments in the Wyoming PRB study area. Most are relatively small in terms of employment, serving primarily local and regional markets linked directly or indirectly to energy resource development and production. Hettinger LLC and L&H Industrial, both with major facilities in Gillette, Wyoming, are among the largest industrial manufacturing firms in the region, specializing in repairs, rebuilding, and fabrication for the region's mining industry. Although classified as wholesalers and repair establishments, Wyoming Machinery and P&H Mining Equipment also serve the mining and oil and gas industries. Other industrial manufacturing and service establishments in the region provide metal fabrication, metal plating, custom and precast concrete products, and specialized chemical products and services. Many of these firms, particularly those specializing in construction equipment and services, also serve the oil and gas and wind energy industries.

Over the years, some of these establishments have grown in size and capabilities and now support activities and markets outside the region. However, they remain dependent upon the local markets to sustain their existing operations.

3.14.2 Reasonably Foreseeable Development

Local economic development organizations, including the Campbell County Economic Development Corporation and Converse Area New Development Organization (CANDO), continually are engaged in efforts to recruit new business formation in the Wyoming PRB and to retain existing businesses and help them grow. These organizations also engage in work force recruiting and training. The current economic recession has provided additional challenges to what was already a challenging task. As a result, no new

major industrial manufacturing prospects have been identified for consideration in the Wyoming PRB study area.

3.14.3 Assumptions

No assumptions were required for this study to define specific impact-causing parameters for other industrial manufacturing.

3.14.4 Data Sources

Other local industrial manufacturing serves a critical role in supporting the region's energy industry. Because much of the market is local, other industrial manufacturing is not a major recruitment target for local economic development efforts. Therefore, future expansion is likely to occur in response to, or as an adjunct to, development in one of the other industries addressed in this study. As a result, update of the information in this section involves review of multiple sources that eventually may or may not identify any new prospects. Alternately, new sources of information may become available for future updates that would be identified based on future internet searches.

Data sources reviewed in an effort to locate data regarding past and present development and RFD for other industrial manufacturing activity included the following local and regional print media, development highlights for local communities, the websites of the Wyoming Business Council and local economic development organizations, and contacts with state and local economic development representatives for northeastern Wyoming.

Azzam, R. Converse Area New Development Organization. Personal Correspondence: razzam@candowyoming.com.

Campbell County Economic Development Corporation. Leading Employers Menu Option. Internet website: http://www.ccedc.net.

Casper Star-Tribune. Internet website: http://trib.com.

Chino, P. Executive Director, Campbell County Economic Development Corporation. Personal Correspondence: Phillipe@CCEDC.Net.

City of Gillette, 2010. Developing Gillette – The 2009 Annual Development Summary. Internet website: http://www.ci.gillette.wy.us/Modules/ShowDocument.aspx?documentid=1277. March 2010.

Gillette News Record. Internet website: http://www.gillettenewsrecord.com.

Spencer, D. Northeast Regional Director, Wyoming Business Council. Personal Correspondence: Dave.Spencer@wybusiness.org.

Wyoming Business Council. "News" Internet website: http://www.wyomingbusiness.org.

Wyoming Department of Employment, Research and Planning Division. Labor Market Information. Internet website: http://doe.state.wy.us/lmi/default.htm.

3.15 Other Development

3.15.1 Past and Present Development

In addition to the specific projects and developments described above, the Wyoming PRB hosts a vast network of public and private physical infrastructure, private businesses, and public activities that have developed over time. Examples of infrastructure include highway and road networks, airports,

government offices, hospitals, schools, municipal water and wastewater systems, and extensive residential and commercial real estate development. Private enterprises include local retail and service establishments, newspaper publishing, and transportation and distribution firms.

The construction, maintenance, and continuing operations associated with this network of development represent extensive public and private investment, as well as changes in land use, surface disturbances, water consumption, and factors influencing and characterizing local air quality. Those investments and changes have occurred over a period of time. Some of the larger projects completed prior to the end of base year 2008 are identified below.

- A new $10 million headquarters for the Campbell County Fire Department that provides administrative, training, and storage space in addition to multiple parking bays for firefighting apparatus was completed in 2007.
- Campbell County's new public health building was completed in 2007.
- Construction of the 177,000-square-foot expansion of the CAM-PLEX conference and multi-event center in Gillette, Wyoming, named the Wyoming Center, was completed in 2008. The expansion includes more exhibit space, conference and indoor athletic facilities with seating for up to 9,000, an indoor ice rink, and various concession and support spaces.

3.15.2 Reasonably Foreseeable Development

There are numerous current and anticipated plans for future investment in public and private infrastructure in the Wyoming PRB study area. Such investments would include state and local investment in transportation, administrative, and educational facilities. Given the timing, scale, year-to-year variability, relatively short construction timetables associated with such public and private investments, the existence of a relatively large and diversified construction industry in the region and nearby areas, and the limited potential for these projects to alter long-term conditions in the Wyoming PRB study area, they are not included in the RFD database. However, one or more of these and similar projects could warrant consideration in a cumulative analysis for a site-specific project due to proximity or coincidental project schedules and timetables.

3.15.2.1 Highways and Airports

Public highways and airports are important components of the public infrastructure in the PRB. The Wyoming Department of Transportation (WYDOT) prepares an annual State Transportation Improvement Program (STIP) based on an ongoing process of needs assessment, priority rating, fiscal analysis, and manpower analysis. In general, Wyoming transportation projects scheduled through 2015 include maintenance, reconstruction, and improvement projects. Airport improvement plans consist primarily of pavement rehabilitation and overlays, with some minor expansion of taxiways, aprons, and parking. No construction of new highways is scheduled, and no new airports are proposed.

In addition to highway projects included in the 2008 STIP, three of the coal mines in the eastern portion of the Wyoming PRB study area are proposing road relocations to facilitate ongoing mining. The Eagle Butte Mine is proposing the relocation of U.S. Highway 14/16 in the vicinity of the Gillette/Campbell County Airport, north of the City of Gillette, Wyoming. The relocation is proposed to facilitate the recovery of approximately 40 million tons of additional coal acquired by the mine through a LBA coal sale. Three alternative alignments, involving construction of up to 6.8 miles of new roadway, have been identified. Assuming an affirmative decision to proceed with relocation, construction of the new highway segment is anticipated in 2011/2012 (WYDOT and Foundation Coal Company 2008). Highway relocation also would be required for both the Caballo and Belle Ayr mines to access unleased federal coal west of SR 59. Depending on the advance of mining, the Belle Ayr Mine would need to relocate an approximately 5-mile segment of SR 59. It is anticipated that the road would be relocated to the east onto reclaimed lands or to the west around the advance of mining in the 2021 to 2025 time period. The Caballo Mine would need to relocate an approximately 4-mile segment of SR 59 under the

upper production scenario only. Under this scenario, it is anticipated that the road would be relocated to the west around the advance of mining in the 2021 to 2025 time period.

3.15.2.2 Other Public Facilities

Local governments, school districts, and other special service districts and public entities continually engage in long-term planning. A vital element of such planning assesses the condition of existing facilities and infrastructure and outlines a capital improvement plan to ensure adequate capacity to meet future needs and extend services to new residents and businesses. Capital improvement plans reflect a balance between needs and available funding resources.

Constrained fiscal times tend to focus spending on maintenance of core administrative, utility, and transportation facilities. Increases in anticipated revenues generally allow more consideration to service expansion, community development, parks and recreation, and other more “discretionary” projects. The cumulative level of capital spending over time can be substantial; however, individual projects are seldom sufficiently extensive enough to warrant analysis in the RFD scenarios of this study. Such is the case at present. Some of the larger public projects recently completed (since 2008), ongoing, or anticipated in the near future are listed below:

- Campbell County completed expansion and remodeling of the county’s detention center and sheriff’s office in 2009.
- A new 186,000-square-foot, $55 million recreation center, developed as a joint project between Campbell County, the City of Gillette, and the Campbell County School District was constructed in April 2009.
- The Gillette Regional Water Supply Project would involve approximately 42 miles of new pipeline, generally paralleling I-90 from the vicinity of Moorcroft (east of Gillette) to approximately U.S. Highway 14, and generally paralleling U.S. Highway 14 to the northeast.
- Multiple transportation and drainage system improvements by the City of Gillette, including the Burma Street Overpass and Extension.
- Completion of a wastewater treatment facility upgrade and water system improvements.
- The county, city, and Gillette College partnered in the development of a Campus Housing Complex and Industrial Technical Education Center.
- Campbell County Memorial Hospital completed a 6,000-square-foot expansion of the Emergency Department and an extensive clinical laboratory in 2009. A $68 million expansion project began in June 2009 with construction of a 3.5 level, 294 space parking structure adjacent to the main entrance. A three-level hospital addition capable of supporting three additional levels is scheduled to begin construction in 2010.
- The Wyoming School Facilities Commission (WSFC) approved and funded the recent completion of two new elementary schools in Campbell County; a third is under construction, and plans have been approved for an alternative high school (WSFC 2009a,b).

3.15.2.3 General Industrial and Commercial Development

Additional private sector industrial and commercial development is expected to occur within the context of normal community and economic development. With the strong economic base provided by the coal mines, oil and gas companies, and power plant construction, major goals for local economic development currently include work force recruitment and training, diversification of the economic base, expansion of retail trade and personal services to serve the growth in consumer demand, and development of affordable housing. Gillette’s location on I-90 and the strong demand for lodging by energy workers, travelers, and visitors associated with events at the CAM-PLEX also have spurred construction of several new motels (CCEDC 2008; City of Gillette 2008). Housing needs associated with

the recently completed Dry Fork Station prompted construction of a substantial quantity of new multifamily dwelling units.

3.15.3 Assumptions

Past and Present Development Assumptions

- There are no assumptions relative to other past and present development.

RFD Assumptions

- A portion of U.S. Highways 14 and 16 would be relocated to accommodate coal mining activities at the Eagle Butte Mine, with construction occurring in 2011-2012. The selected alternative for the relocation would involve approximately 2.7 miles of new construction, with a ROW width of 100 feet. Likelihood for this relocation is considered moderate under both the upper and lower production scenarios for 2020.
- A 5-mile segment of SR 59 would be relocated to accommodate coal mining activities at the Belle Ayr Mine, with construction occurring between 2021 and 2025. The ROW width would be 100 feet. Likelihood for this relocation is considered moderate under both the upper and lower production scenarios for 2030.
- A 4-mile segment of SR 59 would be relocated to accommodate coal mining activities at the Caballo Mine, with construction occurring between 2021 and 2025. The ROW width would be 100 feet. Likelihood for this relocation is considered moderate under the upper production scenario for 2030. The road would not be relocated under the lower development scenario.
- A new water transmission pipeline will be completed by 2015 as part of the Gillette Regional Water Supply Project. Likelihood for this project is considered moderate under both the upper and lower production scenarios for 2020.
- Any new surface disturbance associated with highway and airport maintenance projects (e.g., resurfacing) would be minimal or would involve previously disturbed lands that have since been revegetated.
- New surface disturbance associated with future public infrastructure and private commercial and industrial development would be limited and occur primarily within or adjacent to the presently urbanized areas in the study area.

3.15.4 Data Sources

Data sources used during Phase I of the PRB Coal Review to obtain information relative to other development in the Wyoming PRB study area are documented in the Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities (AECOM 2009b). Updated information for Phase II of the study was obtained from the sources identified below.

Campbell County Economic Development Corporation (CCEDC). 2008. A Five-Year $2,000,000 Economic Development and Diversification Strategy for Campbell County, Wyoming. Internet website: http://www.ccedc.net/images/POWER%20campaign$20brochure.pdf. Accessed on May 13, 2008.

Campbell County Memorial Hospital. 2010. Campbell County Memorial Hospital – Facilities. Internet website: http://www.ccmh.net/About_Us/Our_Facilities.aspx. Accessed on July 2010.

City of Gillette, 2010a. Developing Gillette – The 2009 Annual Development Summary. Internet website: http://www.ci.gillette.wy.us/Modules/ShowDocument.aspx?documentid=1277. Accessed on March 2010.

_____. 2010b. Gillette Regional Water Supply Project. Internet website: http://www.ci.gillette.wy.us/ index.aspx?page=454. Accessed on June 2010.

_____. 2008. A Five-Year $2,000,000 Economic Development and Diversification Strategy for Campbell County, Wyoming. Internet website: http://www.ccedc.net/images/POWER%20campaign% 20brochure.pdf. Accessed on May 13, 2008.

Wyoming Department of Transportation (WYDOT) and Foundation Coal Company. 2008. Background information and other materials presented at a public open house and information meeting on the proposed location of U.S. Highway 14/16 north of Gillette. Internet website: http://www.eaglebuttehighway1416.com/ 2007_Dec12thOpenHouse/boards%201-3.pdf. Accessed on May 31, 2008.

Wyoming School Facilities Commission (WSFC). 2009a. 2009 Annual Report and 2011-2012 Budget Presentation to the Governor and Select Committee on School Facilities. Internet website: http://www.wyoming.gov/loc/03302010_1/SiteCollectionDocuments/2009%20Annual%20Report%20and %202011-12%20budget%20Prfesentation%209-1-09.pdf.

_____. 2009b. Campbell County School District #1 Facility Vision Plan. May 7, 2009. Internet website: http://www.wyoming.gov/loc/03302010_1/resources/Documents/facility%20plansCAM01% 20Facility%20Plan.pdf.

4.0 List of Preparers

Bureau of Land Management PRB Coal Review - Task 2 Team		
Responsibility	**Name**	**BLM Office Location**
Project Manager	Mike Brogan	High Plains District Office
Task 2 Manager, Coal	Mike Karbs	High Plains District Office
Oil and Gas	Fred Crockett	Wyoming State Office, Reservoir Management Group
Oil and Gas Actual Data	Andrea Meeks	High Plains District Office
Coal Mine Actual Data	Ginger Vickers	High Plains District Office

AECOM PRB Coal Review – Task 2 Team	
Responsibility	**Name**
Project Manager	Molly Giere – AECOM
Assistant Project Manager, Task 2 Manager	Dolora Koontz – AECOM
Technical Advisor	Valerie Randall – AECOM
Coal Mines	Eldon Strid – MEI
Oil and Gas, Pipelines, Other Mines	William Berg – AECOM
Power Plants	Bruce Macdonald – AECOM
Reservoirs	David Fetter – AECOM
Transportation, Coal Technology, Transmission Lines, Wind Energy, Carbon Sequestration, Refineries, Other Industrial Manufacturing, Other Development	Ron Dutton – Sammons/Dutton LLC
Database Team	Dolora Koontz – AECOM Sue Milcan – AECOM Jason Thoene – AECOM
GIS	Merlyn Paulson – AECOM Jason Thoene – AECOM Brent Read – AECOM

5.0 References

The general references for this report and figures are presented below. Industry-specific references used for update of the base year (2008) and RFD (2020 and 2030) projections are presented in the industry-specific sections of Chapter 3.0 to facilitate BLM's future updates.

AECOM. 2010a. Powder River Basin Coal Review Air Quality Assessment Protocol, Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. September 2010.

_____. 2010b. Alignments for Reasonably Foreseeable Major Pipeline Projects. September 2010.

_____. 2009a. Update of the Task 2 Report for the Powder River Basin Coal Review, Past and Present and Reasonably Foreseeable Future Development Activities. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. December 2009.

_____. 2009b. Task 2 Report Update Manual for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activity. Prepared for the Bureau of Land Management, High Plains District Office and Wyoming State Office. December 2009.

Bureau of Land Management (BLM). 2011. Actual 2003-2010 CBNG and conventional oil and gas data, well location files, and associated assumptions provided by A. Meeks, BLM, to M. Giere, AECOM. October 13, 2011.

_____. 2010a. Coal mine shapefiles provided by A. Meeks, BLM High Plains District Office, to D. Koontz, AECOM. June 22, 2010.

_____. 2010b. Estimation of Pumpage Rates for Drainage Basins in the Powder River Basin, Wyoming - Final. Prepared by F. Crockett, BLM Wyoming State Office, Reservoir Management Group, Cheyenne, Wyoming. October 29, 2010.

_____. 2009. Final Mineral Occurrence and Development Potential Report. Buffalo Resource Management Plan Revision. Buffalo Field Office, Wyoming. June 19, 2009.

_____. 2004. Mineral Occurrence and Development Potential Report. Casper Field Office Planning Area. Casper Field Office, Wyoming. January 2004.

_____. 2003. Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project. Wyoming State Office and Buffalo Field Office, Cheyenne and Buffalo, Wyoming. January 2003.

_____. 1999. Wyodak Coal Bed Natural Gas Project Final Environmental Impact Statement. Buffalo Field Office. May 1999.

_____. 1996. Coal Development Status Check Powder River Federal Coal Region Montana and Wyoming Data Tables. Data Compiled by: Wyoming Bureau of Land Management Buffalo Resource Area, Casper District, and State Offices, and Montana Bureau of Land Management Powder River Resource Area, Miles City District and State Offices.

CH2MHILL. 2010. Final Report, Wyoming Industrial Development Information and Siting Act, Section 109 Permit Application, Reno Junction Wind Energy Project. Prepared for Third Planet Windpower, LLC. April 22, 2010.

_____. 2009. Wyoming Industrial Development Information and Siting Act, Section 109 Permit Application, Campbell Hill Windpower Project. Prepared for Duke Energy Corporation/Three Buttes Windpower, LLC. January 2009.

DeBrain, R. 2002. Oil and Gas Field Maps of the Powder River Basin, Wyoming. Map Series 57. Wyoming Geological Survey, Laramie, Wyoming.

ENSR. 2005. Task 2 Report for the Powder River Basin Coal Review, Past and Present and Reasonably Foreseeable Future Development Activities. Prepared for the Bureau of Land Management Casper Field Office and Wyoming State Office. Revised October 2005 (with errata).

HKM Engineering, Inc., Lord Consulting, and Watts and Associates. 2002a. Powder/Tongue River Basin Plan. Prepared for Wyoming Water Development Commission Basin Planning Program. February 2002. Internet website: http://waterplan.state.wy.us/plan/newy/newy-plan.html. Accessed on January 14, 2010.

_____. 2002b. Northeast Wyoming River Basins Plan. Prepared for Wyoming Water Development Commission Basin Planning Program. February 2002. Internet website: http://waterplan. state.wy.us/plan/powder/powder-plan.html. Accessed on January 14, 2010.

IHS Global Insight™ (IHS). 2010. PI/DWIGHTS Rocky Mountain Oil and Gas Production and Well History Database.

Mine Engineers Inc. (MEI). 2011. Shapefiles of projected coal reserve blocks forwarded by E. Strid, MEI, to D. Koontz and M. Paulson, AECOM. August 2011.

Montgomery Watson Harza (MWH). 2003. Coal Planning Estimates Report. Prepared for the Bureau of Land Management Wyoming State Office. March 2003.

Rural Utilities Service. 2007. Draft Environmental Impact Statement for the Basin Electric Power Cooperative Dry Fork Station and Hughes Transmission Line. August 2007.

The Glenrock Independent. 2009. Top of the World: 110 Turbines. Internet website: http://www.warms.com/documents/TopoftheWorld110Turbines.pdf. Accessed on July 28, 2010. October 1, 2009.

U.S. Nuclear Regulatory Commission. 2010. Expected Uranium Recovery Facility Applications. Internet website: http://www.nrc.gov/info-finder/materials/uranium/. Accessed on July 28, 2010.

Western Electricity Coordinating Council (WECC). 2010. Transmission Expansion Planning – Summary Listing of Projects under Consideration. Internet website: http://www.wecc.biz/ PlanningTransmissionExpansion/Transmission/Pages/default.aspx. Accessed on July 2010.

World Information Service on Energy (WISE). 2010. Uranium Project. Internet website: http://www.wise-uranium.org/index.html. Accessed on July 15, 2010.

Appendix A

Supporting Tables and Figures – Coal Mine Subregions

Table A-1 Wyoming PRB Coal Development by Subregion Impact-causing Parameters under the Lower Production Scenario

Subregion	Annual Production for Most Recent Report Year (million tons)	Cumulative Disturbed Area for Year (acres)	Cumulative Permanently Reclaimed Areas through Most Recent Report Year (acres)	Cumulative Unreclaimed Areas Available for Reclamation through Most Recent Report Year (acres)	Cumulative Unreclaimed Areas Unavailable for Reclamation through Most Recent Report Year (acres)	Total Employment for Report Year	Annual Water Consumption (mmgpy)	Annual Water Production[1] (acre-feet)
Base Year (Actual 2008)								
Subregion 1	76	14,860	3,692	5,496	5,672	1,012	533	781
Subregion 2	104	26,913	8,885	9,654	8,374	1,523	392	2,133
Subregion 3	264	49,455	17,070	19,774	12,610	3,236	954	4,661
Total for 2008 Actual	**444**	**91,228**	**29,648**	**34,924**	**26,656**	**5,771**	**1,879**	**7,575**
Reasonably Foreseeable Development (2020)								
Subregion 1	75	20,212	7,383	6,767	6,062	1,033	550	781
Subregion 2	95	38,652	16,880	12,342	9,430	1,467	397	2,133
Subregion 3	286	71,737	34,983	24,315	12,439	3,251	1,577	4,661
Total for 2020	**456**	**130,601**	**59,245**	**43,425**	**27,931**	**5,751**	**2,524**	**7,575**
Reasonably Foreseeable Development (2030)								
Subregion 1	75	25,380	11,246	7,607	6,527	1,063	566	781
Subregion 2	94	48,479	24,432	13,732	10,315	1,582	448	2,133
Subregion 3	299	95,807	53,395	27,806	14,605	3,652	1,987	4,661
Total for 2030	**468**	**169,666**	**89,074**	**49,146**	**31,447**	**6,297**	**3,001**	**7,575**

[1] Based on Phase I data.

Note: Slight differences are due to rounding.

Table A-2 Wyoming PRB Coal Development by Subregion Impact-causing Parameters under the Upper Production Scenario

Subregion	Annual Production for Most Recent Report Year (million tons)	Cumulative Disturbed Area for Year (acres)	Cumulative Permanently Reclaimed Areas through Most Recent Report Year (acres)	Cumulative Unreclaimed Areas Available for Reclamation through Most Recent Report Year (acres)	Cumulative Unreclaimed Areas Unavailable for Reclamation through Most Recent Report Year (acres)	Total Employment for Report Year	Annual Water Consumption (mmgpy)	Annual Water Production[1] (acre-feet)
Base Year (Actual 2008)								
Subregion 1	76	14,860	3,692	5,496	5,672	1,012	533	781
Subregion 2	104	26,913	8,885	9,654	8,374	1,523	392	2,133
Subregion 3	264	49,455	17,070	19,774	12,610	3,236	954	4,661
Total for 2008 Actual	**444**	**91,228**	**29,648**	**34,924**	**26,656**	**5,771**	**1,879**	**7,575**
Reasonably Foreseeable Development (2020)								
Subregion 1	90	20,973	7,882	6,961	6,130	1,137	659	781
Subregion 2	117	39,954	17,644	12,762	9,547	1,645	508	2,133
Subregion 3	331	73,126	35,815	24,747	12,564	3,521	1,846	4,661
Total for 2020	**538**	**134,052**	**61,341**	**44,469**	**28,242**	**6,303**	**3,013**	**7,575**
Reasonably Foreseeable Development (2030)								
Subregion 1	100	27,988	12,964	8,263	6,761	1,263	799	781
Subregion 2	134	53,441	27,841	14,839	10,761	1,874	658	2,133
Subregion 3	381	101,147	57,183	28,878	15,086	4,120	2,504	4,661
Total for 2030	**615**	**182,577**	**97,988**	**51,980**	**32,609**	**7,257**	**3,961**	**7,575**

[1] Based on Phase I data.

Note: Slight differences are due to rounding.

Table A-3 Montana PRB Coal Development by Subregion Impact-causing Parameters under the Lower Production Scenario

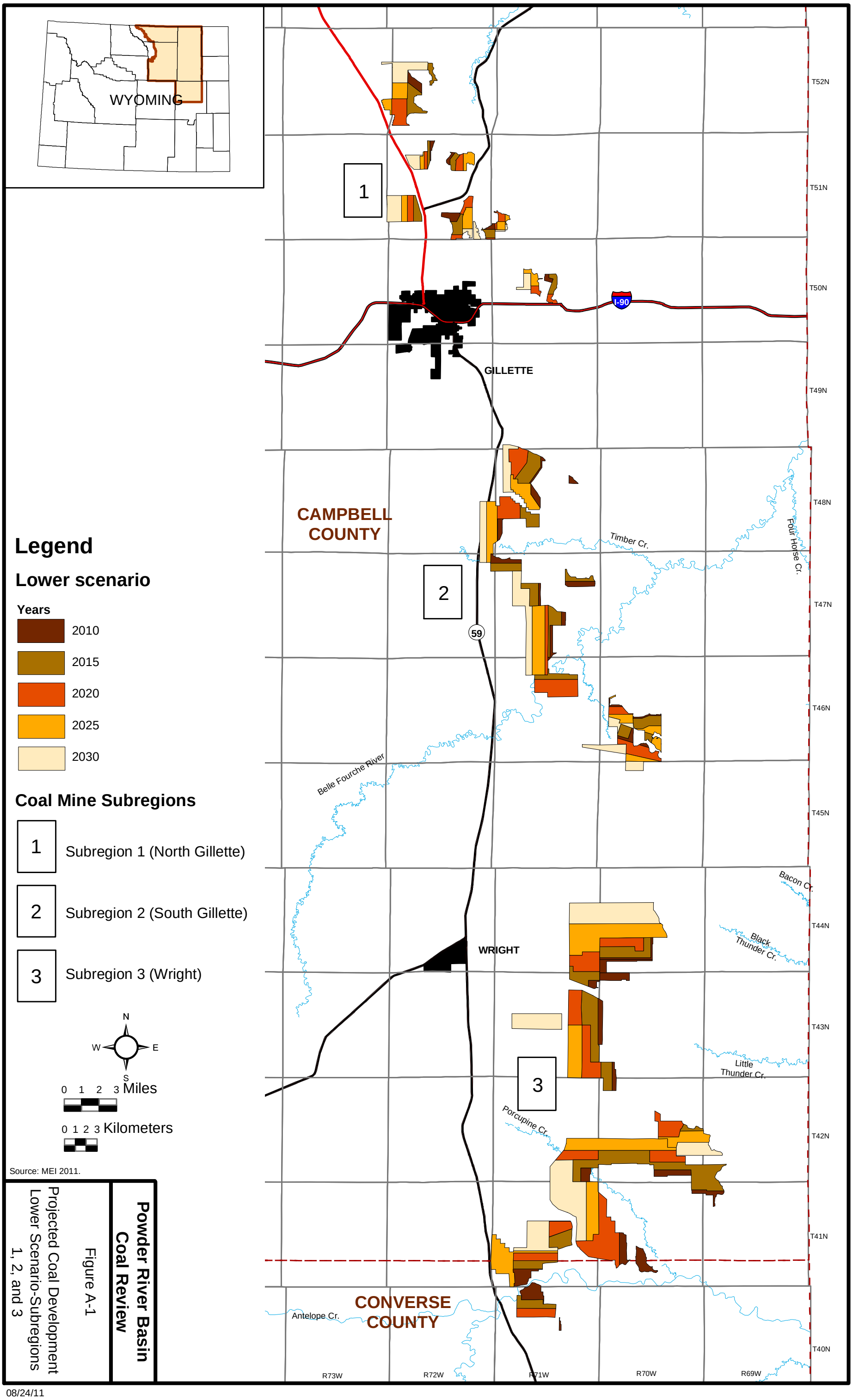
Subregion	Annual Production for Most Recent Report Year (million tons)	Cumulative Disturbed Area for Year (acres)	Cumulative Permanently Reclaimed Areas through Most Recent Report Year (acres)	Cumulative Unreclaimed Areas Available for Reclamation through Most Recent Report Year (acres)	Cumulative Unreclaimed Areas Unavailable for Reclamation through Most Recent Report Year (acres)	Total Employment for Report Year	Annual Water Consumption (mmgpy)
Base Year (Actual 2008)							
Subregion 4	24	13,587	2,817	7,490	3,279	381	122
Subregion 5	19	39,048	14,023	22,323	2,702	611	141
Total for 2008 Actual	**44**	**52,635**	**16,841**	**29,813**	**5,981**	**992**	**263**
Reasonably Foreseeable Development (2020)							
Subregion 4	26	15,834	4,346	8,006	3,481	381	153
Subregion 5	25	44,338	21,505	19,725	3,108	785	158
Total for 2020	**51**	**60,172**	**25,851**	**27,731**	**6,589**	**1,166**	**311**
Reasonably Foreseeable Development (2030)							
Subregion 4	26	18,192	6,103	8,395	3,693	381	153
Subregion 5	35	50,228	25,817	20,773	3,638	1,111	234
Total for 2030	**61**	**68,420**	**31,920**	**29,169**	**7,332**	**1,492**	**387**

Note: Slight differences are due to rounding.

Table A-4 Montana PRB Coal Development by Subregion Impact-causing Parameters under the Upper Production Scenario

Subregion	Annual Production for Most Recent Report Year (million tons)	Cumulative Disturbed Area for Year (acres)	Cumulative Permanently Reclaimed Areas through Most Recent Report Year (acres)	Cumulative Unreclaimed Areas Available for Reclamation through Most Recent Report Year (acres)	Cumulative Unreclaimed Areas Unavailable for Reclamation through Most Recent Report Year (acres)	Total Employment for Report Year	Annual Water Consumption (mmgpy)
Base Year (Actual 2008)							
Subregion 4	24	13,587	2,817	7,490	3,279	381	122
Subregion 5	19	39,048	14,023	22,323	2,702	611	141
Total for 2008 Actual	**44**	**52,635**	**16,841**	**29,813**	**5,981**	**992**	**263**
Reasonably Foreseeable Development (2020)							
Subregion 4	34	15,965	4,421	8,051	3,493	453	198
Subregion 5	48	45,225	22,022	20,015	3,187	1,215	268
Total for 2020	**82**	**61,190**	**26,443**	**28,066**	**6,681**	**1,668**	**466**
Reasonably Foreseeable Development (2030)							
Subregion 4	59	20,279	7,422	8,975	3,882	698	340
Subregion 5	78	55,059	29,042	21,944	4,073	1,754	441
Total for 2030	**137**	**75,338**	**36,464**	**30,919**	**7,955**	**2,452**	**781**

Note: Slight differences are due to rounding.



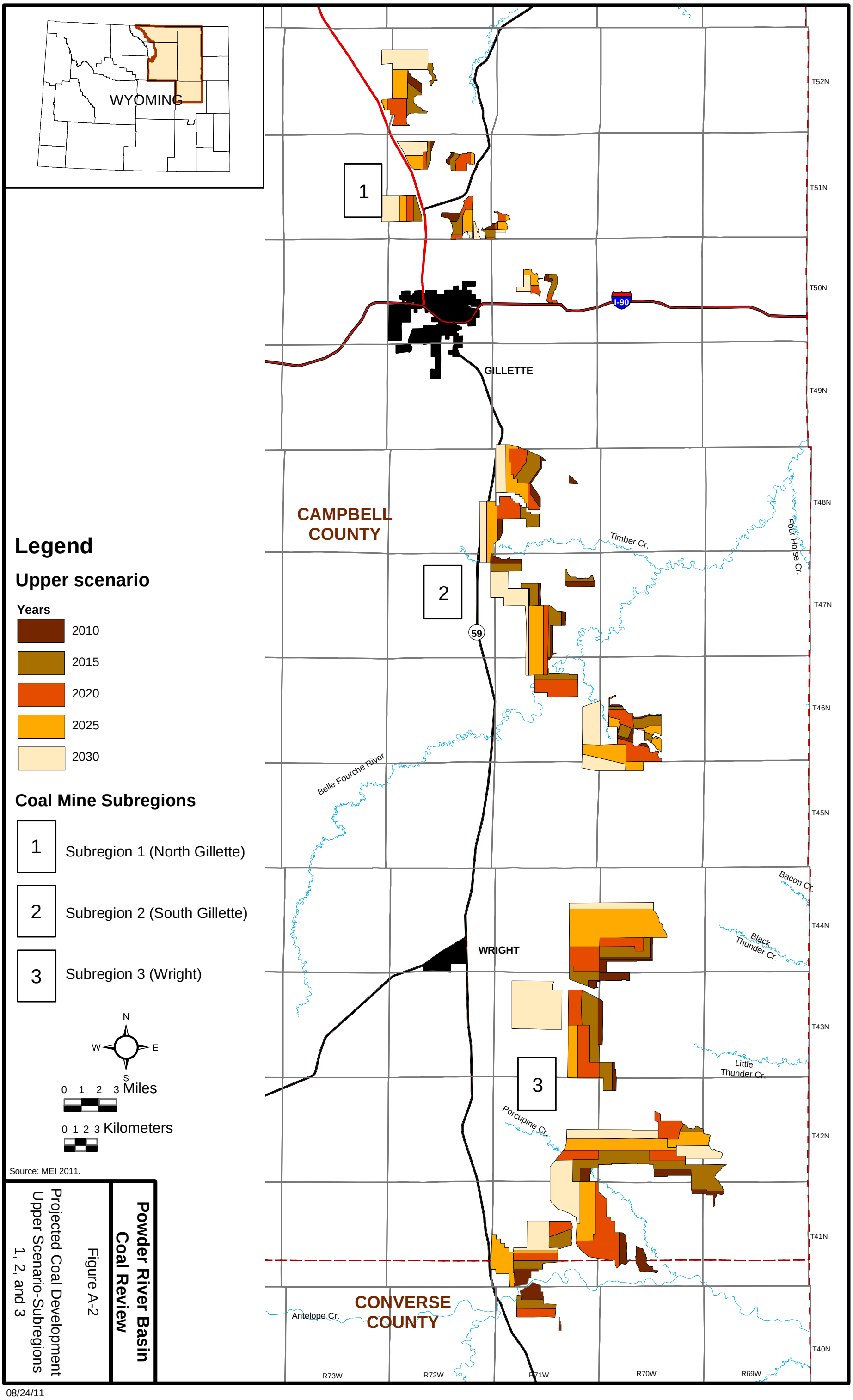
Source: MEI 2011.

Powder River Basin Coal Review

Figure A-1

Projected Coal Development
Lower Scenario-Subregions
1, 2, and 3

08/24/11



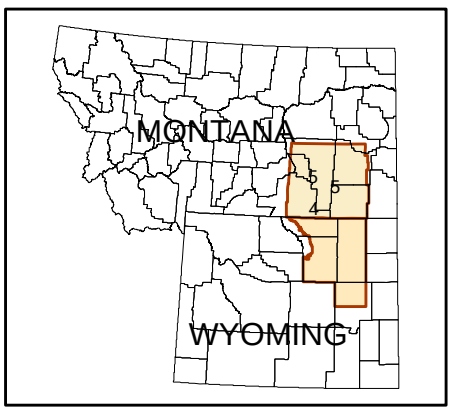
Source: MEI 2011.

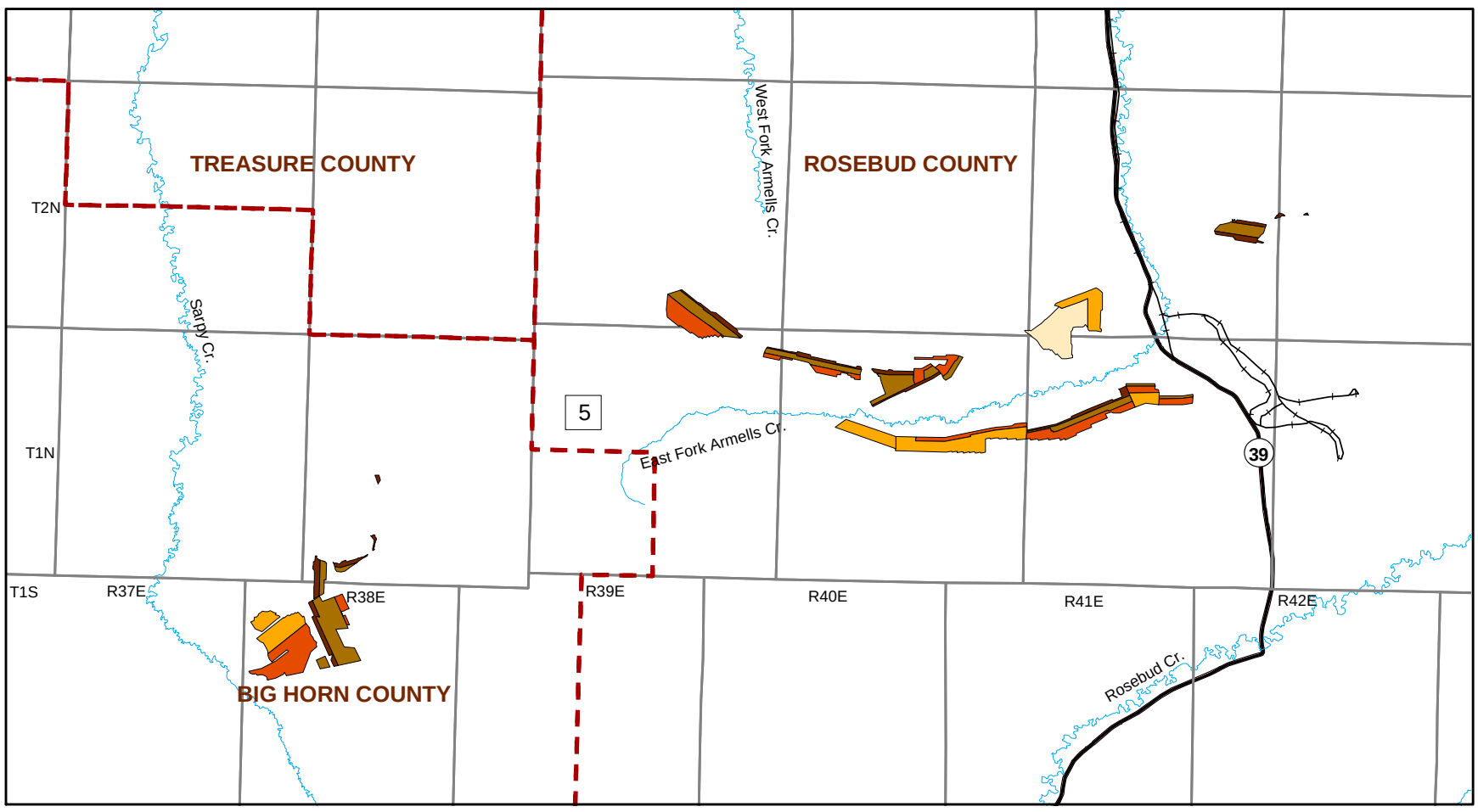
Powder River Basin Coal Review

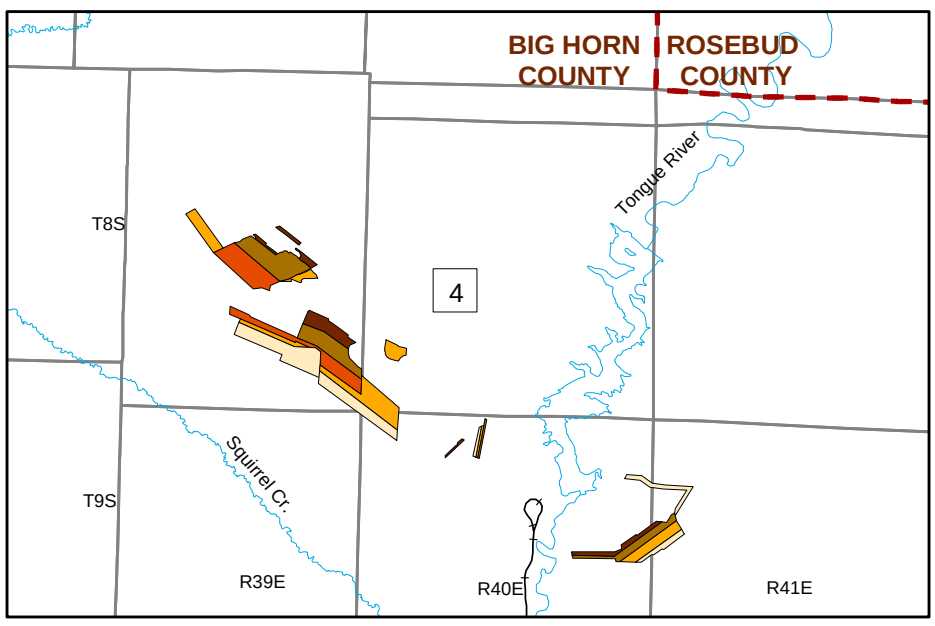
Figure A-2

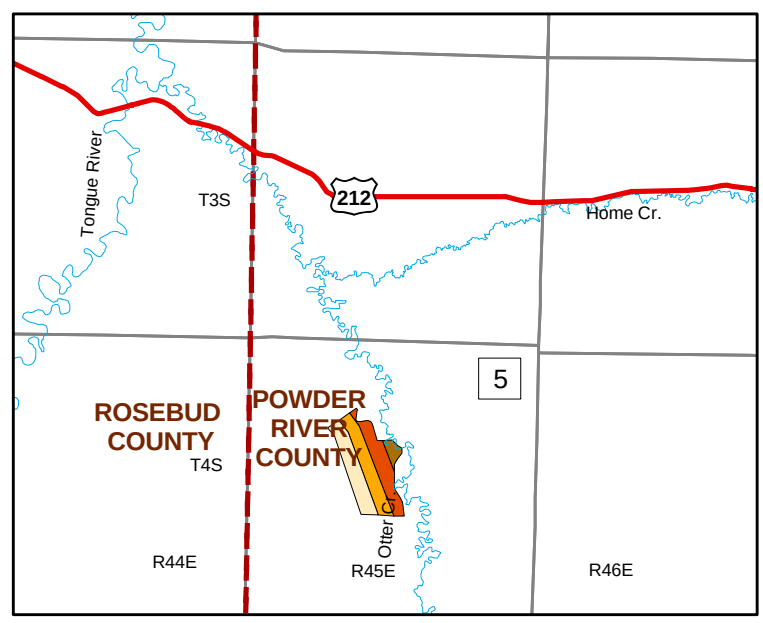
Projected Coal Development Upper Scenario-Subregions 1, 2, and 3

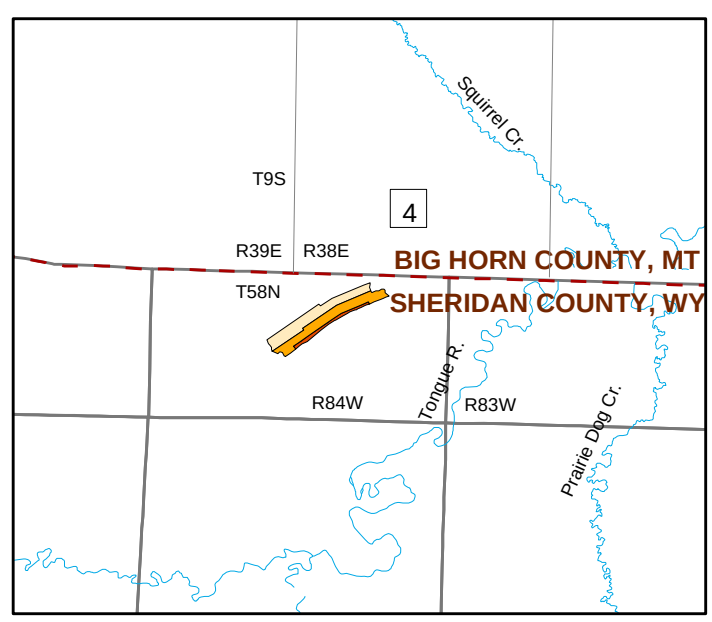
08/24/11











Legend

Lower Scenario

Years

- 2010
- 2015
- 2020
- 2025
- 2030

Coal Mine Subregions

- 4 Subregion 4 (Sheridan/Decker)
- 5 Subregion 5 (Ashland/Colstrip)

N W E S

0 2 4 6 Miles

0 2 4 6 Kilometers

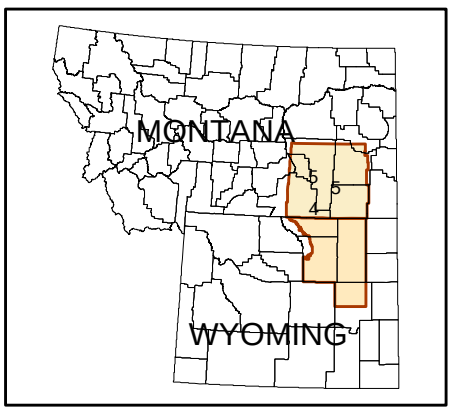
Source: MEI 2011.

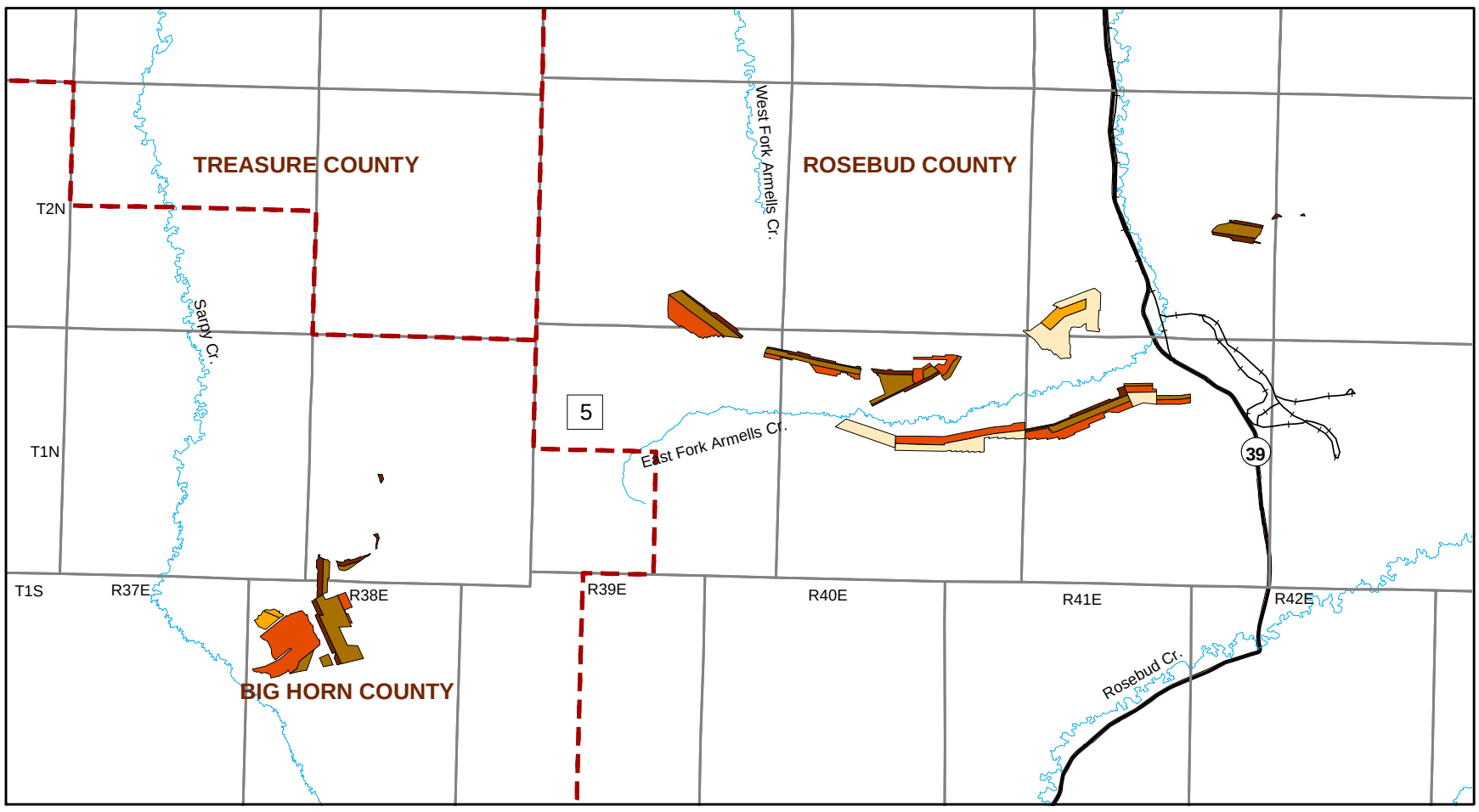
Powder River Basin Coal Review

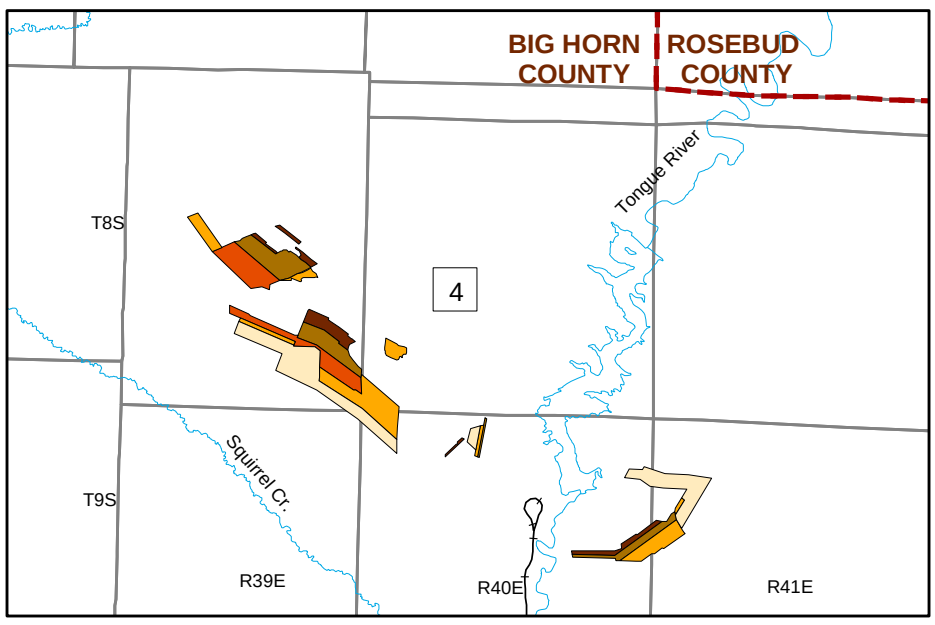
Figure A-3

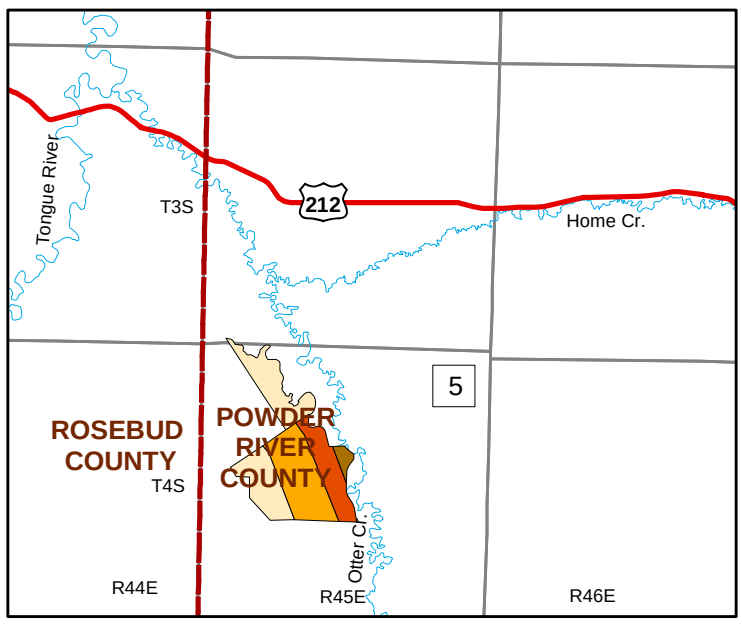
Projected Coal Development
Lower Scenario-Subregions
4 and 5

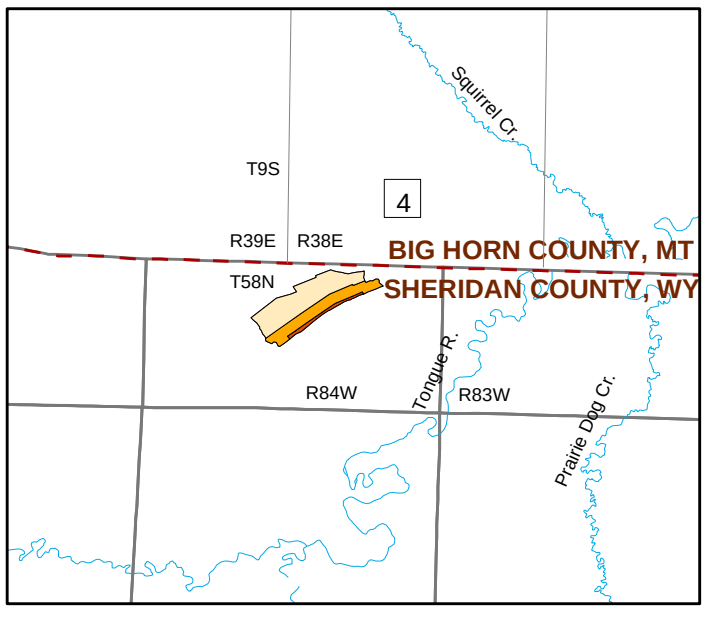
08/24/11











Legend

Upper Scenario

Years

- 2010
- 2015
- 2020
- 2025
- 2030

Coal Mine Subregions

- 4 Subregion 4 (Sheridan/Decker)
- 5 Subregion 5 (Ashland/Colstrip)

N
W E
S

0 2 4 6 Miles

0 2 4 6 Kilometers

Source: MEI 2011.

Powder River Basin Coal Review

Figure A-4

Projected Coal Development
Upper Scenario-Subregions
4 and 5

08/24/11

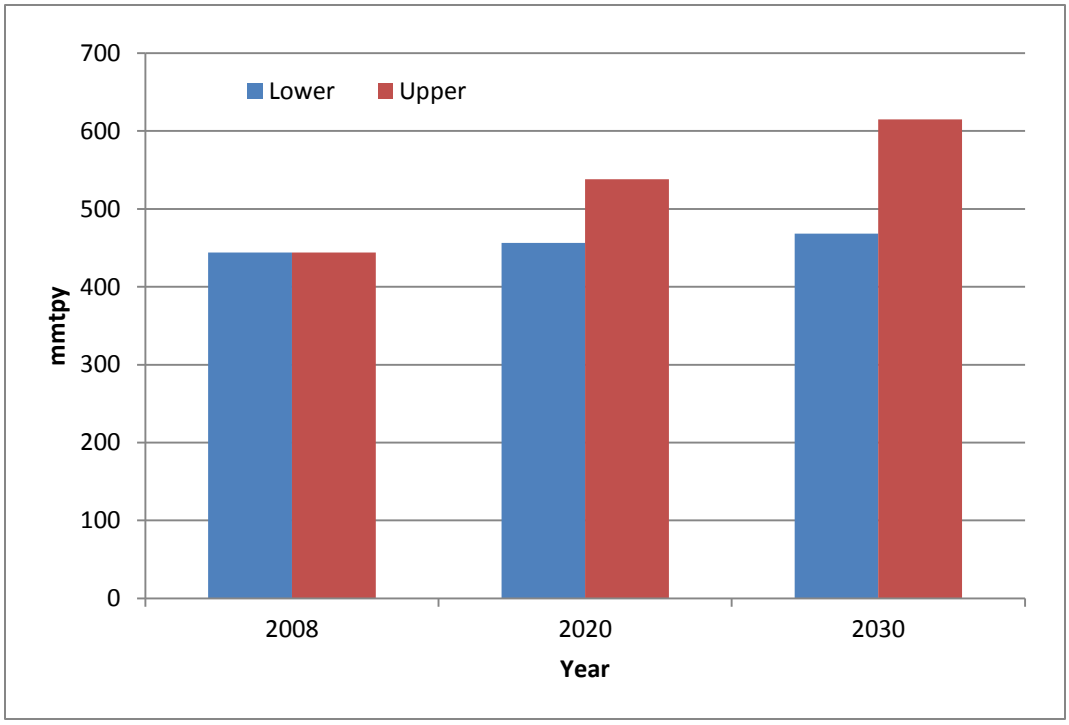


Figure A-5 Total Coal Production for Mines in Subregions 1, 2, and 3 – Lower and Upper Production Scenarios

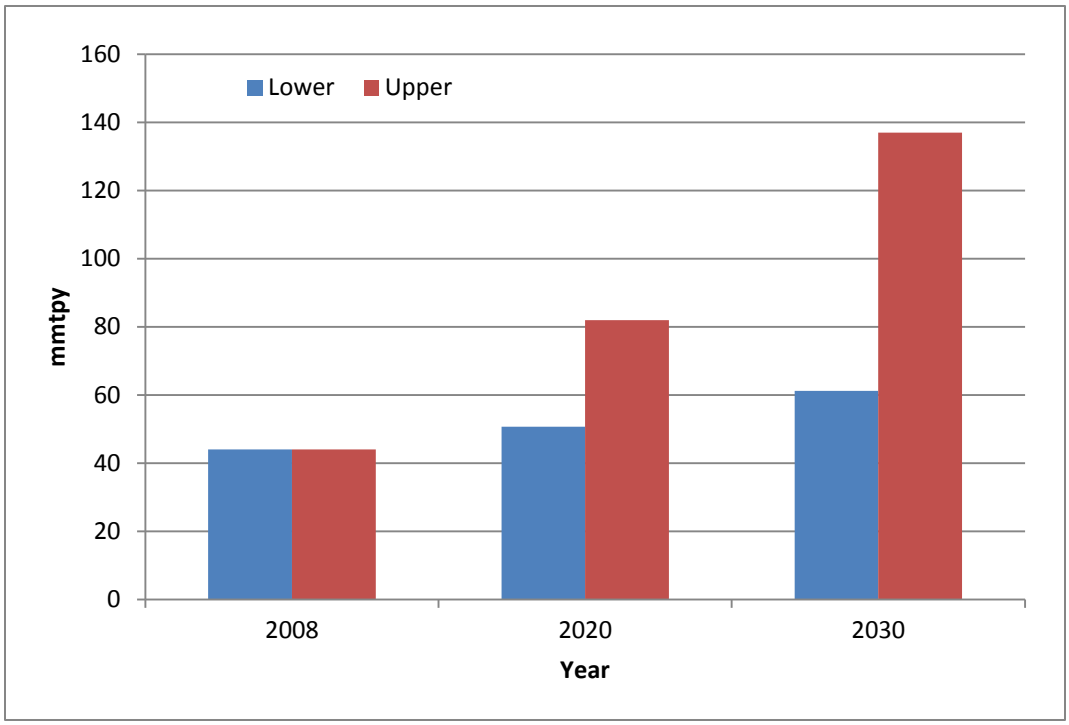


Figure A-6 Total Coal Production for Mines in Subregions 4 and 5 – Lower and Upper Production Scenarios

Appendix B

GIS Data for Actual 2008 Base Year Disturbance

Table B-1 Disturbance Acreages Associated with Coal Mined-out Areas in the Eastern Wyoming PRB Study Area (based on GIS)

Area	Disturbance (acreage as of end 2008)
Disturbance by Subregion	
Subregion 1	9,124
Subregion 2	20,453
Subregion 3	37,665
Total	**67,242**
Disturbance by Subwatershed	
Little Powder River	7,874
Antelope Creek	16,295
Upper Cheyenne River	21,371
Upper Belle Fourche River	21,702
Total	**67,242**

Table B-2 Total Past and Present Development-related Cumulative Disturbance in the Wyoming PRB Study Area by Subwatershed (based on GIS)

Subwatershed	Total Disturbance (acres as of end of 2008)
Antelope Creek	30,753
Clear Creek	7,189
Crazy Woman Creek	1,706
Dry Fork Cheyenne River	2,719
Lightning Creek	3,371
Little Bighorn River	103
Little Missouri River	452
Little Powder River	30,361
Middle Fork Powder River	617
Middle North Platte River	1,340
Middle Powder River	7,323
North Fork Powder River	0
Salt Creek	1,610
South Fork Powder River	662
Upper Belle Fourche River	62,790
Upper Cheyenne River	26,769
Upper Powder River	44,446
Upper Tongue River	10,134
Total Disturbance Acreage	**232,345**

Appendix C

Supporting Tables and Figures for Wyoming PRB Study Area

Table C-1 Wyoming PRB Coal-related Development Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower and Upper Production Scenarios		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year (acres)	Cumulative Unreclaimed Through Most Recent Report Year (acres)
Base Year (Actual 2008)			
Antelope Creek	564	0	564
Clear Creek	622	75	547
Crazy Woman Creek	0	0	0
Dry Fork Cheyenne River	218	0	218
Lightning Creek	600	0	600
Little Bighorn River	55	0	55
Little Missouri River	0	0	0
Little Powder River	801	286	515
Middle North Platte River	0	0	0
Middle Powder River	0	0	0
Middle Fork Powder River	0	0	0
North Fork Powder River	0	0	0
Salt Creek	0	0	0
South Fork Powder River	0	0	0
Upper Belle Fourche River	2,015	14	2,001
Upper Cheyenne River	436	0	436
Upper Powder River	945	160	785
Upper Tongue River	1,794	137	1,657
Total for 2008 Actual	**8,051**	**672**	**7,378**
Reasonably Foreseeable Development (2020)			
Antelope Creek	564	0	564
Clear Creek	622	75	547
Crazy Woman Creek	0	0	0
Dry Fork Cheyenne River	218	0	218

Table C-1 Wyoming PRB Coal-related Development Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower and Upper Production Scenarios		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year (acres)	Cumulative Unreclaimed Through Most Recent Report Year (acres)
Lightning Creek	600	0	600
Little Bighorn River	55	0	55
Little Missouri River	0	0	0
Little Powder River	894	286	608
Middle North Platte River	0	0	0
Middle Powder River	0	0	0
Middle Fork Powder River	0	0	0
North Fork Powder River	0	0	0
Salt Creek	0	0	0
South Fork Powder River	0	0	0
Upper Belle Fourche River	2,015	14	2,001
Upper Cheyenne River	436	0	436
Upper Powder River	945	160	785
Upper Tongue River	1,794	137	1,657
Total for 2020	**8,144**	**672**	**7,471**
Reasonably Foreseeable Development (2030)[2]			
Antelope Creek	564/782	0	564/782
Clear Creek	622	75	547
Crazy Woman Creek	0	0	0
Dry Fork Cheyenne River	218	0	218
Lightning Creek	600	0	600
Little Bighorn River	55	0	55
Little Missouri River	0	0	0
Little Powder River	894	286	608
Middle North Platte River	0	0	0

Table C-1 Wyoming PRB Coal-related Development Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower and Upper Production Scenarios		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year (acres)	Cumulative Unreclaimed Through Most Recent Report Year (acres)
Middle Powder River	0	0	0
Middle Fork Powder River	0	0	0
North Fork Powder River	0	0	0
Salt Creek	0	0	0
South Fork Powder River	0	0	0
Upper Belle Fourche River	2,075/2,379	14	2,061/2,365
Upper Cheyenne River	436/909	0	436/909
Upper Powder River	945	160	785
Upper Tongue River	1,794	137	1,657
Total for 2030	**8,204/9,198**	**672**	**7,531/8,526**

[1] Coal-related activities as defined for this study include coal-fired power plants, railroads, major (230-kV) transmission lines, and coal technology projects. The Wyoming PRB study area and associated subwatersheds are presented in **Figure C-1**.

[2] Acreages apply to both the upper and lower production scenarios except where indicated (e.g., 2030 Antelope Creek = 564 lower/782 upper).

Note: Minor discrepancies in total acreages are the result of rounding.

Table C-2 Wyoming PRB Oil and Gas and Related Development Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower and Upper Production Scenarios		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year (acres)	Cumulative Unreclaimed Through Most Recent Report Year (acres)
Base Year (Actual 2008)			
Antelope Creek	14,171	6,631	7,540
Clear Creek	3,320	1,723	1,597
Crazy Woman Creek	2,278	1,102	1,176
Dry Fork Cheyenne River	2,625	1,240	1,385
Lightning Creek	3,558	1,600	2,000
Little Bighorn River	48	24	24
Little Missouri River	269	133	137
Little Powder River	19,856	9,412	10,444
Middle Fork Powder River	420	200	226
Middle North Platte River	691	370	359
Middle Powder River	7,833	3,605	4,227
North Fork Powder River	0	0	0
Salt Creek	824	420	435
South Fork Powder River	411	191	228
Upper Belle Fourche River	35,395	16,827	18,568
Upper Cheyenne River	5,099	2,545	2,554
Upper Powder River	47,055	20,898	26,157
Upper Tongue River	13,400	6,043	7,357
Total for 2008 Actual	**157,255**	**72,965[2]**	**84,415[3]**
Reasonably Foreseeable Development (2020)			
Antelope Creek	17,944	11,211	6,733
Clear Creek	3,838	2,353	1,485
Crazy Woman Creek	3,089	1,722	1,368
Dry Fork Cheyenne River	2,750	1,419	1,337

Table C-2 Wyoming PRB Oil and Gas and Related Development Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower and Upper Production Scenarios		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year (acres)	Cumulative Unreclaimed Through Most Recent Report Year (acres)
Lightning Creek	3,847	2,051	1,857
Little Bighorn River	48	24	24
Little Missouri River	291	148	145
Little Powder River	21,876	14,962	6,915
Middle Fork Powder River	445	233	217
Middle North Platte River	691	382	347
Middle Powder River	10,399	7,365	3,034
North Fork Powder River	0	0	0
Salt Creek	1,191	733	555
South Fork Powder River	431	229	210
Upper Belle Fourche River	37,060	25,964	11,096
Upper Cheyenne River	5,293	3,429	1,863
Upper Powder River	63,065	43,901	19,164
Upper Tongue River	14,425	11,178	3,247
Total for 2020	**186,683**	**127,303[2]**	**59,597[3]**
Reasonably Foreseeable Development (2030)			
Antelope Creek	19,718	13,372	6,347
Clear Creek	10,336	5,667	4,669
Crazy Woman Creek	7,839	4,415	3,424
Dry Fork Cheyenne River	3,273	1,807	1,466
Lightning Creek	4,003	2,417	1,586
Little Bighorn River	48	24	24
Little Missouri River	291	172	121
Little Powder River	22,859	16,755	6,104
Middle Fork Powder River	445	248	202

Table C-2 Wyoming PRB Oil and Gas and Related Development Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower and Upper Production Scenarios		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year (acres)	Cumulative Unreclaimed Through Most Recent Report Year (acres)
Middle North Platte River	691	393	336
Middle Powder River	11,559	9,114	2,445
North Fork Powder River	0	0	0
Salt Creek	1,257	879	476
South Fork Powder River	444	262	191
Upper Belle Fourche River	39,120	29,632	9,487
Upper Cheyenne River	5,425	3,729	1,696
Upper Powder River	75,766	57,343	18,422
Upper Tongue River	20,554	14,686	5,868
Total for 2030	**223,629**	**160,915[2]**	**62,865[3]**

[1] Inclusive of conventional oil and gas and CBNG activities and major transportation pipelines. Disturbance associated with ancillary facilities (including gather lines and distribution power lines) has been factored in on a per well basis as discussed in **Appendix D** of this report. The Wyoming PRB study area and associated subwatersheds are presented in **Figure C-1**.

[2] CBNG-related disturbance acreages retained for non-CBNG purposes equal 936 for 2008, 11,016 for 2020, and 14,907 for 2030 and are no longer attributed to CBNG activity (see Oil and Gas Assumptions and Methodology in **Appendix D**). Therefore, the cumulative reclamation acreages above reflect total reclamation of CBNG P&A wells. The cumulative acreage retained for non-CBNG activity is reflected in **Table C-3** (Total Development-related Disturbance).

[3] For the cumulative unreclaimed acreages, differences result from inconsistent reporting of well numbers in the IHS 2003-2008 dataset.

Note: Minor discrepancies in total acreages are the result of rounding.

Table C-3 Wyoming PRB Total Development-related Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower Production Scenario			Upper Production Scenario		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year[2] (acres)	Cumulative Unreclaimed through Most Recent Report Year[2] (acres)	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed through Most Recent Report Year[2] (acres)	Cumulative Unreclaimed Through Most Recent Report Year[2] (acres)
Base Year (Actual 2008)						
Antelope Creek	36,931	12,549	24,382	36,931	12,549	24,382
Clear Creek	6,841	1,746	5,096	6,841	1,746	5,096
Crazy Woman Creek	2,326	1,085	1,241	2,326	1,085	1,241
Dry Fork Cheyenne River	2,843	1,234	1,609	2,843	1,234	1,609
Lightning Creek	4,158	1,584	2,574	4,158	1,584	2,574
Little Bighorn River	103	24	79	103	24	79
Little Missouri River	269	133	136	269	133	136
Little Powder River	33,342	12,713	20,629	33,342	12,713	20,629
Middle Fork Powder River	851	425	426	851	425	426
Middle North Platte River	1,181	359	821	1,181	359	821
Middle Powder River	7,833	3,553	4,279	7,833	3,553	4,279
North Fork Powder River	0	0	0	0	0	0
Salt Creek	824	411	414	824	411	414
South Fork Powder River	843	467	376	843	467	376
Upper Belle Fourche River	66,644	25,954	40,690	66,644	25,954	40,690
Upper Cheyenne River	32,964	13,595	19,369	32,964	13,595	19,369

Table C-3 Wyoming PRB Total Development-related Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower Production Scenario			Upper Production Scenario		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year[2] (acres)	Cumulative Unreclaimed through Most Recent Report Year[2] (acres)	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed through Most Recent Report Year[2] (acres)	Cumulative Unreclaimed Through Most Recent Report Year[2] (acres)
Upper Powder River	48,000	20,908	27,092	48,000	20,908	27,092
Upper Tongue River	15,194	6,113	9,082	15,194	6,113	9,082
Total for 2008 Actual	**261,150**	**102,855**	**158,296**	**261,150**	**102,855**	**158,296**
Reasonably Foreseeable Development (2020)						
Antelope Creek	55,309	27,309	27,999	55,659	27,524	28,135
Clear Creek	7,360	2,274	5,086	7,360	2,274	5,086
Crazy Woman Creek	3,137	1,644	1,493	3,137	1,644	1,493
Dry Fork Cheyenne River	2,969	1,405	1,564	2,969	1,405	1,564
Lightning Creek	4,447	2,030	2,417	4,447	2,030	2,417
Little Bighorn River	103	24	79	103	24	79
Little Missouri River	291	148	143	291	148	143
Little Powder River	40,361	20,555	19,806	41,113	21,049	20,064
Middle Fork Powder River	1,229	866	363	1,229	866	363
Middle North Platte River	1,529	371	1,157	1,529	371	1,157
Middle Powder River	10,399	6,657	3,742	10,399	6,657	3,742
North Fork Powder River	0	0	0	0	0	0
Salt Creek	1,191	707	484	1,191	707	484

Table C-3 Wyoming PRB Total Development-related Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower Production Scenario			Upper Production Scenario		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year[2] (acres)	Cumulative Unreclaimed through Most Recent Report Year[2] (acres)	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed through Most Recent Report Year[2] (acres)	Cumulative Unreclaimed Through Most Recent Report Year[2] (acres)
South Fork Powder River	1,216	862	354	1,216	862	354
Upper Belle Fourche River	80,921	41,627	39,293	82,231	42,397	39,834
Upper Cheyenne River	40,896	21,330	19,566	41,935	21,947	19,987
Upper Powder River	64,550	39,870	24,680	64,550	39,870	24,680
Upper Tongue River	16,283	10,085	6,198	16,283	10,085	6,198
Total for 2020	**332,189**	**177,763**	**154,425**	**335,640**	**179,859**	**155,781**
Reasonably Foreseeable Development (2030)						
Antelope Creek	68,275	38,010	30,265	70,256	39,184	31,072
Clear Creek	13,858	5,439	8,419	13,858	5,439	8,419
Crazy Woman Creek	7,887	4,159	3,728	7,887	4,159	3,728
Dry Fork Cheyenne River	3,491	1,792	1,699	3,491	1,792	1,699
Lightning Creek	4,603	2,396	2,207	4,603	2,396	2,207
Little Bighorn River	103	24	79	103	24	79
Little Missouri River	291	171	120	291	171	120
Little Powder River	45,967	25,555	20,411	48,517	27,237	21,280
Middle Fork Powder River	1,229	881	348	1,229	881	348
Middle North Platte River	1,529	502	1,027	1,529	502	1,027

Table C-3 Wyoming PRB Total Development-related Disturbance Acreages in the Wyoming PRB Study Area[1]

Subwatershed	Lower Production Scenario			Upper Production Scenario		
	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed Through Most Recent Report Year[2] (acres)	Cumulative Unreclaimed through Most Recent Report Year[2] (acres)	Cumulative Disturbance Through Most Recent Year (acres)	Cumulative Permanently Reclaimed through Most Recent Report Year[2] (acres)	Cumulative Unreclaimed Through Most Recent Report Year[2] (acres)
Middle Powder River	11,559	8,095	3,464	11,559	8,095	3,464
North Fork Powder River	0	0	0	0	0	0
Salt Creek	1,257	853	405	1,257	853	405
South Fork Powder River	1,229	895	335	1,229	895	335
Upper Belle Fourche River	93,774	52,691	41,082	99,097	56,136	42,960
Upper Cheyenne River	53,906	31,202	22,704	57,956	33,816	24,141
Upper Powder River	77,371	51,951	25,420	77,371	51,951	25,420
Upper Tongue River	23,049	13,791	9,259	23,483	14,044	9,439
Total for 2030	**409,377**	**238,408**	**170,970**	**423,716**	**247,575**	**176,141**

[1] Inclusive of disturbance associated with coal mining, coal-related activities, oil and gas and related development, and other development activities identified for this study. Other quantifiable activities include disturbance associated with major water storage reservoirs, wind energy development, highway relocations, and other mines. The Wyoming PRB study area and associated subwatersheds are presented in **Figure C-1**.

[2] CBNG-related disturbance acreages retained for non-CBNG purposes equal 936 for 2008, 11,016 for 2020, and 14,907 for 2030 and are no longer attributed to CBNG activity (see Oil and Gas Assumptions and Methodology in **Appendix D**). These acreages are reflected in this table as a reduction in the cumulative reclaimed acreages and an addition in the cumulative unreclaimed acreages.

Note: Minor discrepancies in total acreages are the result of rounding.

Table C-4 Wyoming PRB Coal Mine and Coal-related Production, Employment, and Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Lower Production Scenario				Upper Production Scenario			
	Annual Coal Production for Report Year (million tons)	Total Employment for Report Year[2]	Annual Water Consumption (mmgpy)	Annual Water Production[3] (acre-feet)	Annual Coal Production for Report Year (million tons)	Total Employment for Report Year[2]	Annual Water Consumption (mmgpy)	Annual Water Production[3] (acre-feet)
Base Year (Actual 2008)								
Antelope Creek	133	1,510	266	2,758	133	1,510	266	2,758
Clear Creek	0	0	0	0	0	0	0	0
Crazy Woman Creek	0	0	0	0	0	0	0	0
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0
Lightning Creek	0	0	0	0	0	0	0	0
Little Bighorn River	0	0	0	0	0	0	0	0
Little Missouri River	0	0	0	0	0	0	0	0
Little Powder River	70	896	502	781	70	896	502	781
Middle North Platte River	0	0	0	0	0	0	0	0
Middle Powder River	0	0	0	0	0	0	0	0
Middle Fork Powder River	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0
Salt Creek	0	0	0	0	0	0	0	0
South Fork Powder River	0	0	0	0	0	0	0	0
Upper Belle Fourche River	110	3,014	511	2,133	110	3,014	511	2,133
Upper Cheyenne River	131	1,726	688	1,903	131	1,726	688	1,903

Table C-4 Wyoming PRB Coal Mine and Coal-related Production, Employment, and Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Lower Production Scenario				Upper Production Scenario			
	Annual Coal Production for Report Year (million tons)	Total Employment for Report Year[2]	Annual Water Consumption (mmgpy)	Annual Water Production[3] (acre-feet)	Annual Coal Production for Report Year (million tons)	Total Employment for Report Year[2]	Annual Water Consumption (mmgpy)	Annual Water Production[3] (acre-feet)
Upper Powder River	0	0	0	0	0	0	0	0
Upper Tongue River	0	0	0	0	0	0	0	0
Total for Actual 2008	**444**	**7,146**	**1,967**	**7,575**	**444**	**7,146**	**1,967**	**7,575**
Reasonably Foreseeable Development (2020)								
Antelope Creek	141	1,666	607	2,758	154	1,744	646	2,758
Clear Creek	0	0	0	0	0	0	0	0
Crazy Woman Creek	0	0	0	0	0	0	0	0
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0
Lightning Creek	0	0	0	0	0	0	0	0
Little Bighorn River	0	0	0	0	0	0	0	0
Little Missouri River	0	0	0	0	0	0	0	0
Little Powder River	69	1,792	519	781	84	1,892	626	781
Middle North Platte River	0	0	0	0	0	0	0	0
Middle Powder River	0	0	0	0	0	0	0	0
Middle Fork Powder River	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0
Salt Creek	0	0	0	0	0	0	0	0

Table C-4 Wyoming PRB Coal Mine and Coal-related Production, Employment, and Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Lower Production Scenario				Upper Production Scenario			
	Annual Coal Production for Report Year (million tons)	Total Employment for Report Year[2]	Annual Water Consumption (mmgpy)	Annual Water Production[3] (acre-feet)	Annual Coal Production for Report Year (million tons)	Total Employment for Report Year[2]	Annual Water Consumption (mmgpy)	Annual Water Production[3] (acre-feet)
South Fork Powder River	0	0	0	0	0	0	0	0
Upper Belle Fourche River	101	2,333	516	2,133	123	2,515	629	2,133
Upper Cheyenne River	145	1,585	970	1,903	177	1,777	1,200	1,903
Upper Powder River	0	0	0	0	0	0	0	0
Upper Tongue River	5	53	25	0	5	53	25	0
Total for 2020	**461**	**7,429**	**2,637**	**7,575**	**543**	**7,981**	**3,126**	**7,575**
Reasonably Foreseeable Development (2030)								
Antelope Creek	141	1,867	745	2,758	166	2,034	839	2,758
Clear Creek	0	0	0	0	0	0	0	0
Crazy Woman Creek	0	0	0	0	0	0	0	0
Dry Fork Cheyenne River	0	0	0	0	0	0	0	0
Lightning Creek	0	0	0	0	0	0	0	0
Little Bighorn River	0	0	0	0	0	0	0	0
Little Missouri River	0	0	0	0	0	0	0	0
Little Powder River	69	1,807	527	781	94	1,997	754	781
Middle North Platte River	0	0	0	0	0	0	0	0
Middle Powder River	0	0	0	0	0	0	0	0

Table C-4 Wyoming PRB Coal Mine and Coal-related Production, Employment, and Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Lower Production Scenario				Upper Production Scenario			
	Annual Coal Production for Report Year (million tons)	Total Employment for Report Year[2]	Annual Water Consumption (mmgpy)	Annual Water Production[3] (acre-feet)	Annual Coal Production for Report Year (million tons)	Total Employment for Report Year[2]	Annual Water Consumption (mmgpy)	Annual Water Production[3] (acre-feet)
Middle Fork Powder River	0	0	0	0	0	0	0	0
North Fork Powder River	0	0	0	0	0	0	0	0
Salt Creek	0	0	0	0	0	0	0	0
South Fork Powder River	0	0	0	0	0	0	0	0
Upper Belle Fourche River	100	2,463	575	2,133	141	2,765	791	2,133
Upper Cheyenne River	158	1,785	1,242	1,903	215	2,086	1,665	1,903
Upper Powder River	0	0	0	0	0	0	0	0
Upper Tongue River	5	53	25	0	15	99	74	0
Total for 2030	**473**	**7,975**	**3,114**	**7,575**	**631**	**8,981**	**4,123**	**7,575**

[1] The Wyoming PRB study area and associated subwatersheds are shown in **Figure C-1**.

[2] Based on coal mine information, with the exception of power plant-related employees identified in the Little Powder River, Upper Belle Fourche River, and Upper Cheyenne River subwatersheds.

[3] For purposes of this study, the annual coal mine-related water production is assumed to be the same under both the lower and upper production scenarios.

Note: Minor discrepancies in total acreages are the result of rounding.

Table C-5 Wyoming PRB Oil and Gas Production and Conventional Oil and Gas Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Annual Oil Production for Report Year (bbls)	Annual Gas Production for Report Year[2] (MMcf)	Annual Conventional Oil- and Gas-related Water Production (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Headwater Reservoir or Unlined Off-channel Containment) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Unlined On-channel Containment or Direct Discharge to Drainage) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Playa Lake Containment) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Injection) (mmgpy)
Base Year (Actual 2008)							
Antelope Creek	668,404	25,170	45	0	45	0	0
Clear Creek	0	545	0	0	0	0	0
Crazy Woman Creek	0	2	0	0	0	0	0
Dry Fork Cheyenne River	390,570	1,658	2	0	2	0	0
Lightning Creek	496,329	723	18	0	18	0	0
Little Bighorn River	0	0	0	0	0	0	0
Little Missouri River	171,505	1	395	228	56	0	111
Little Powder River	2,283,527	18,214	1,938	62	1,836	6	35
Middle Fork Powder River	143,670	0	378	218	54	0	106
Middle North Platte River	69,669	654	21	12	3	0	6
Middle Powder River	197,271	19,982	38	0	38	0	0
North Fork Powder River	0	0	0	0	0	0	0
Salt Creek	234,571	27	27	0	0	0	27
South Fork Powder River	94,156	0	102	59	15	0	29
Upper Belle Fourche River	3,731,727	44,578	1,425	1	1,424	0	0

Table C-5 Wyoming PRB Oil and Gas Production and Conventional Oil and Gas Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Annual Oil Production for Report Year (bbls)	Annual Gas Production for Report Year[2] (MMcf)	Annual Conventional Oil- and Gas-related Water Production (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Headwater Reservoir or Unlined Off-channel Containment) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Unlined On-channel Containment or Direct Discharge to Drainage) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Playa Lake Containment) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Injection) (mmgpy)
Upper Cheyenne River	92,415	4,028	10	0	4	6	0
Upper Powder River	2,127,375	373,690	190	3	184	0	3
Upper Tongue River	14,193	61,508	32	25	5	1	1
Total for 2008	**10,715,382**	**550,782**	**4,622**	**608**	**3,684**	**13**	**317**
Reasonably Foreseeable Development (2020)							
Antelope Creek	380,151	24,795	32	0	32	0	0
Clear Creek	0	4,100	0	0	0	0	0
Crazy Woman Creek	0	6,014	0	0	0	0	0
Dry Fork Cheyenne River	190,191	3,382	2	0	2	0	0
Lightning Creek	222,871	534	14	0	14	0	0
Little Bighorn River	0	0	0	0	0	0	0
Little Missouri River	113,238	0	527	303	75	0	148
Little Powder River	1,021,989	2,307	1,349	43	1,278	4	24
Middle Fork Powder River	56,282	0	268	154	38	0	75
Middle North Platte River	0	0	22	12	3	0	6
Middle Powder River	118,293	18,867	30	0	30	0	0

Table C-5 Wyoming PRB Oil and Gas Production and Conventional Oil and Gas Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Annual Oil Production for Report Year (bbls)	Annual Gas Production for Report Year[2] (MMcf)	Annual Conventional Oil- and Gas-related Water Production (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Headwater Reservoir or Unlined Off-channel Containment) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Unlined On-channel Containment or Direct Discharge to Drainage) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Playa Lake Containment) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Injection) (mmgpy)
North Fork Powder River	0	0	0	0	0	0	0
Salt Creek	138,321	17	194	0	2	0	193
South Fork Powder River	39,083	0	94	54	13	0	26
Upper Belle Fourche River	1,626,400	6,293	1,247	1	1,246	0	0
Upper Cheyenne River	48,075	1,522	11	0	5	6	0
Upper Powder River	861,434	100,966	170	3	164	0	3
Upper Tongue River	5,371	8,182	23	19	4	0	0
Total for 2020	**4,821,701**	**176,982**	**3,983**	**590**	**2,907**	**11**	**476**
Reasonably Foreseeable Development (2030)							
Antelope Creek	173,606	15,462	27	0	27	0	0
Clear Creek	0	53,010	0	0	0	0	0
Crazy Woman Creek	0	38,750	0	0	0	0	0
Dry Fork Cheyenne River	75,298	4,802	2	0	2	0	0
Lightning Creek	67,768	1,489	8	0	8	0	0
Little Bighorn River	0	0	0	0	0	0	0
Little Missouri River	21,785	0	192	111	27	0	54

Table C-5 Wyoming PRB Oil and Gas Production and Conventional Oil and Gas Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Annual Oil Production for Report Year (bbls)	Annual Gas Production for Report Year[2] (MMcf)	Annual Conventional Oil- and Gas-related Water Production (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Headwater Reservoir or Unlined Off-channel Containment) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Unlined On-channel Containment or Direct Discharge to Drainage) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Playa Lake Containment) (mmgpy)	Annual Conventional Oil- and Gas-related Water Disposal (Injection) (mmgpy)
Little Powder River	356,498	5,528	893	29	845	3	16
Middle Fork Powder River	16,774	0	151	87	22	0	43
Middle North Platte River	0	0	14	8	2	0	4
Middle Powder River	39,002	9,389	19	0	19	0	0
North Fork Powder River	0	0	0	0	0	0	0
Salt Creek	41,897	7	112	0	1	0	111
South Fork Powder River	13,655	0	62	36	9	0	18
Upper Belle Fourche River	748,273	12,423	1,088	1	1,087	0	0
Upper Cheyenne River	20,779	603	9	0	4	5	0
Upper Powder River	270,486	101,229	101	2	98	0	2
Upper Tongue River	1,804	50,008	15	12	2	0	0
Total for 2030	**1,847,626**	**292,699**	**2,692**	**285**	**2,153**	**8**	**246**

[1] The Wyoming PRB study area and associated subwatersheds are shown in **Figure C-1**.

[2] Reflects total natural gas production by conventional and CBNG wells.

Note: Minor discrepancies in total acreages are the result of rounding.

Table C-6 Wyoming PRB CBNG Water-related Information for the Wyoming PRB Study Area[1]

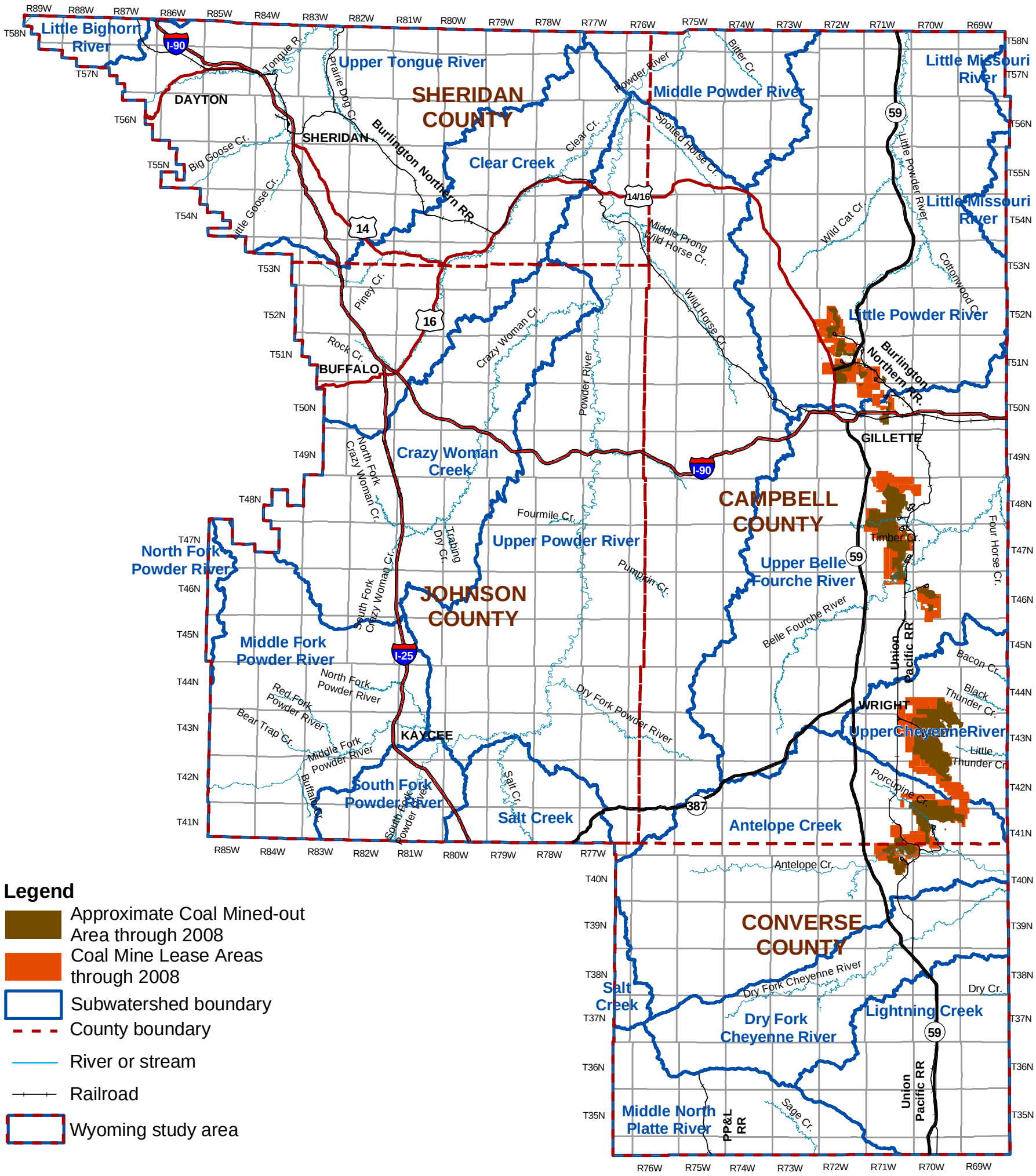
Subwatershed	Annual CBNG-related Water Production (mmgpy)	Annual CBNG-related Water Disposal (Headwater Reservoir or Unlined Off-channel Containment) (mmgpy)	Annual CBNG-related Water Disposal (Unlined On-channel Containment or Direct Discharge to Drainage) (mmgpy)	Annual CBNG-related Water Disposal (Playa Lake Containment) (mmgpy)	Annual CBNG-related Water Disposal (Injection) (mmgpy)
Base Year (Actual 2008)					
Antelope Creek	594	0	594	0	0
Clear Creek	509	463	0	0	46
Crazy Woman Creek	212	122	30	0	59
Dry Fork Cheyenne River	100	0	100	0	0
Lightning Creek	0	0	0	0	0
Little Bighorn River	0	0	0	0	0
Little Missouri River	0	0	0	0	0
Little Powder River	2,404	77	2,276	7	43
Middle Fork Powder River	0	0	0	0	0
Middle North Platte River	0	0	0	0	0
Middle Powder River	2,341	0	2,341	0	0
North Fork Powder River	0	0	0	0	0
Salt Creek	1	0	0	0	1
South Fork Powder River	0	0	0	0	0
Upper Belle Fourche River	2,355	2	2,352	0	0
Upper Cheyenne River	244	0	103	141	0
Upper Powder River	14,694	220	14,223	29	220
Upper Tongue River	4,222	3,378	692	68	84
Total for 2008 Actual	**27,675**	**4,263**	**22,713**	**245**	**454**
Reasonably Foreseeable Development (2020)					
Antelope Creek	1,679	0	1,679	0	0
Clear Creek	777	707	0	0	70
Crazy Woman Creek	998	575	143	0	280
Dry Fork Cheyenne River	0	0	0	0	0
Lightning Creek	0	0	0	0	0
Little Bighorn River	0	0	0	0	0
Little Missouri River	0	0	0	0	0
Little Powder River	558	18	528	2	10
Middle Fork Powder River	0	0	0	0	0
Middle North Platte River	0	0	0	0	0

Table C-6 Wyoming PRB CBNG Water-related Information for the Wyoming PRB Study Area[1]

Subwatershed	Annual CBNG-related Water Production (mmgpy)	Annual CBNG-related Water Disposal (Headwater Reservoir or Unlined Off-channel Containment) (mmgpy)	Annual CBNG-related Water Disposal (Unlined On-channel Containment or Direct Discharge to Drainage) (mmgpy)	Annual CBNG-related Water Disposal (Playa Lake Containment) (mmgpy)	Annual CBNG-related Water Disposal (Injection) (mmgpy)
Middle Powder River	757	0	757	0	0
North Fork Powder River	0	0	0	0	0
Salt Creek	0	0	0	0	0
South Fork Powder River	0	0	0	0	0
Upper Belle Fourche River	944	1	943	0	0
Upper Cheyenne River	199	0	84	115	0
Upper Powder River	8,361	125	8,093	17	125
Upper Tongue River	1,053	842	173	17	21
Total for 2020	**15,325**	**2,268**	**12,400**	**150**	**507**
Reasonably Foreseeable Development (2030)					
Antelope Creek	584	0	584	0	0
Clear Creek	4,351	3,959	0	0	392
Crazy Woman Creek	3,315	1,909	474	0	932
Dry Fork Cheyenne River	349	0	349	0	0
Lightning Creek	204	0	204	0	0
Little Bighorn River	0	0	0	0	0
Little Missouri River	0	0	0	0	0
Little Powder River	227	7	215	1	4
Middle Fork Powder River	0	0	0	0	0
Middle North Platte River	0	0	0	0	0
Middle Powder River	177	0	177	0	0
North Fork Powder River	0	0	0	0	0
Salt Creek	0	0	0	0	0
South Fork Powder River	0	0	0	0	0
Upper Belle Fourche River	186	0	186	0	0
Upper Cheyenne River	2	0	1	1	0
Upper Powder River	3,604	54	3,489	7	54
Upper Tongue River	3,221	2,577	528	52	64
Total for 2030	**16,220**	**8,507**	**6,207**	**60**	**1,446**

[1] The Wyoming PRB study area and associated subwatersheds are shown in **Figure C-1**.

Note: Minor discrepancies in total acreages are the result of rounding.



Source: BLM 2010.

Powder River Basin Coal Review

Figure C-1

Wyoming Study Area and Subwatersheds

08/08/10

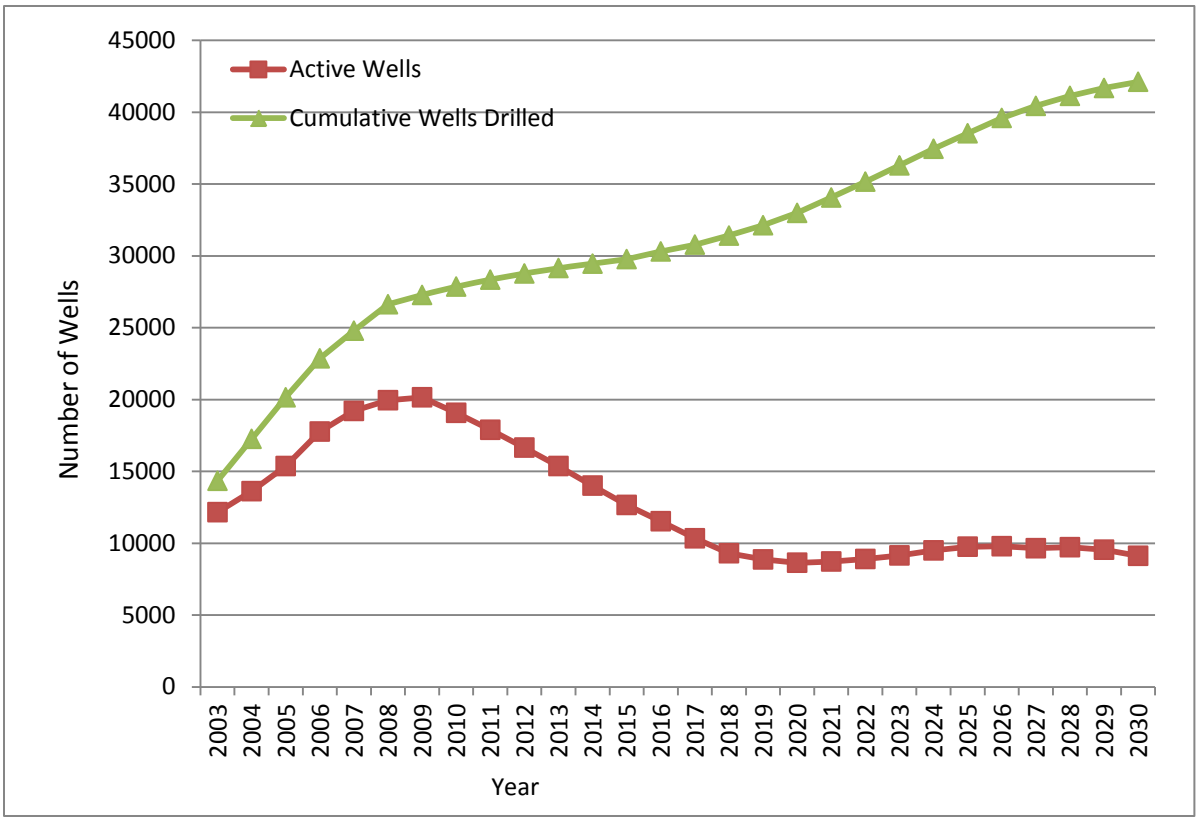


Figure C-2 Actual and Projected Numbers of Active and Cumulative CBNG Wells in the Wyoming PRB Study Area

Notes: Data through 2008 is based on actual information obtained from IHS (BLM 2011).
See **Appendix D** for methodology and assumptions used in developing CBNG well projections.

Appendix D

Oil and Gas Methodology and Assumptions

1.0 Introduction

The following summarizes the basis and rationale for the assumptions used to analyze past, present, and reasonably foreseeable development (RFD) coal bed natural gas (CBNG) and conventional oil and gas activity in the Wyoming Powder River Basin (PRB) and the associated impact-causing parameters. The assumptions address segregation of past and present CBNG and conventional oil and gas wells from the IHS Inc. (IHS) data set, projection of RFD well numbers, lateral (east to west) migration of CBNG and conventional oil and gas wells over time, vertical allocation of CBNG wells within the three defined coal layers for the study (shallow, Wyodak, and deep), quantification of wells by subwatershed, production (hydrocarbon and water), groundwater discharge volumes by discharge method, and associated disturbance acreages.

Recently, the Wyoming Bureau of Land Management (BLM) State Office Reservoir Management Group (RMG) prepared updated oil and gas RFD projections for the Buffalo Field Office (FO) area (Stilwell et al. 2009) in support of the Buffalo Resource Management Plan (RMP) revision. The Stilwell et al. (2009) RFD projections contain more detail than earlier projections and include almost 10 additional years for CBNG activity in the Wyoming PRB. In addition, the number of CBNG and conventional oil and gas wells projected to be drilled in the Wyoming PRB was revised substantially. The Stilwell et al. (2009) data provide more accurate numbers of total conventional oil and gas wells drilled in the Buffalo FO portion of the PRB study area as well as better classification of currently active wells as summarized below.

- 13,250 total cumulative conventional oil and gas wells have been drilled as of March 2009;
- 4,146 active wells and wells that have not been classified as plugged and abandoned (P&A), including shut-in and idle wells. This category consists of wells of all types including producing wells and service wells (e.g., injectors, disposal wells, source water wells). Thirteen wells had an undetermined status due to confidentiality of reporting, so the number of wells not P&A but whose status could be defined is 4,133; and
- 9,104 P&A wells.

The Stilwell et al. (2009) data also provide the following numbers for CBNG development.

- 29,716 CBNG wells were drilled through 2008; and
- 26,064 “existing” CBNG wells as of January 2009.

Although not explicitly stated in the Stilwell et al. (2009) RFD projections, it can be deduced that 3,652 wells have been abandoned up to the end of 2008. Also, out of the “existing” well category, there is no breakdown of the number of producing wells, completed not yet producing wells, or wells that are shut-in and ready to be abandoned.

The assumptions and RFD well numbers developed by Stilwell et al. (2009) have been adopted for the PRB Coal Review, with minor modifications. The Stilwell et al. (2009) RFD projections used a planning period from 2009 to 2028. Since the time frame for the PRB Coal Review is to 2030, well numbers were adjusted to fit the time frame for this study. Because the difference is only 2 years, the incremental adjustments were minimal. Information from Crockett and Stilwell (2005) for the BLM Casper FO portion of the study area (northern Converse County) also has been used. (It should be noted that approximately 95 percent of the projected CBNG wells would be in the Buffalo FO area where the land use plan is not yet finalized. When finalized, the BLM anticipates the total projected number of CBNG wells would be lower than the current projections [BLM 2010c].)

Unconventional hydrocarbon resources are those oil and gas resources in accumulations "that historically have not been produced using traditional development practices including 'tight' sandstones, gas shales, and CBNG" (USGS National Resource Assessment Team 1995). A reasonable interpretation of this definition also would include oil and gas production from the Mowry, Niobrara, and other formations through the use of horizontal drilling techniques, plays that may constitute substantial conventional oil and gas exploration and production over the next 20 years in the Wyoming PRB. Unconventional hydrocarbon accumulations were included under "conventional" oil and gas in the Stilwell et al. (2009) RFD projections. For purposes of this study, the term "conventional" oil and gas has been used to refer to hydrocarbon resources that do not involve natural gas from coal seams.

The following sections summarize the assumptions used during Phase I of the study as documented in Appendix E of the Phase I update of the Task 2 report (AECOM 2009), the basis and rationale for development of new assumptions for Phase II of the study, and the Phase II assumptions.

2.0 Actual Active, New, and P&A Wells and Production Data Determination

The following assumption was used by the BLM for segregation of CBNG and conventional oil and gas wells in the IHS dataset during the Phase I update of the Task 2 report. This assumption has been retained for Phase II.

Assumptions in the Phase I Task 2 Report

1. Wells were categorized as CBNG or conventional based on their listed tax credit type. Those wells listed with a CBNG tax credit were categorized as such; remaining wells were categorized as conventional wells.

Phase II Assumptions and Methodology

For Phase II, the BLM used the following assumptions for sorting and categorizing the actual well data obtained from IHS and the WOGCC for years 2003 through 2009 (BLM 2011b). Assumptions relative to actual production and well locations also are included.

1. Wells were categorized as CBNG or conventional based on their listed tax credit type. Those wells listed with a CBNG tax credit were categorized as such; remaining wells were categorized as conventional wells.
2. Each well has only one type of status for the year, as follows:
   - If a well was reported as "Active" and "New" in the same year, it was counted as new only and the production deleted.
   - If a well was reported as "Active" and "P&A" in the same year, it was counted as P&A only and the production deleted.
   - If a well was reported as "Spud" and "P&A" in the same year, or "New" and "Inactive" and "P&A" in the same year, it was not included. (Note: Very few wells fell into these categories.)
   - If a well was reported as "New" and "Inactive" in the same year, it was counted as new only.
   - If a well was reported as "Inactive" and "P&A" in the same year, it was counted as P&A only.
3. If a well has a reported spud date for the year = new well.
4. If a well has any reported production (oil, gas, or water) for the year = active well.

5. If a well has a reported status of P&A for the year = P&A well.
6. If the WOGCC Land Type Code is: 10, 11, 12, 13, 14, 91, 93, 94 = federal well.
7. If the WOGCC Land Type Code is: 40, 41, 43, 46 = state well.
8. If the WOGCC Land Type Code is: 20, 23, 30, 31, 34, 36, 81, 83, 84 = fee well.
9. Production totals are as reported in IHS.
10. Reported well locations (latitudes and longitudes) are in NAD 27.

In addition, the following methodology and assumptions were used to determine the cumulative number of wells drilled, the cumulative number of wells P&A, and the number of inactive CBNG wells.

11. CBNG and conventional wells drilled prior to 2003 are reflected in the 2003 actual well numbers in the active or P&A categories or are assumed to have been P&A and successfully reclaimed prior to 2003.
12. Cumulative wells drilled and cumulative wells P&A were calculated as follow:
    - 2003 cumulative P&A = P&A for 2003
    - 2003 cumulative wells drilled = active + new + P&A for 2003
    - Cumulative P&A for subsequent years = previous year's cumulative P&A + P&A wells for year
    - Cumulative wells for subsequent years = previous year's cumulative wells drilled + new wells for year.
13. Inactive CBNG wells for year = calculated cumulative CBNG wells drilled for year – calculated cumulative CBNG wells P&A for year – CBNG wells reported as active for year – CBNG wells reported as new for year

3.0 Estimate of Future Conventional Oil and Gas Wells Drilled per Year

Assumptions in the Phase I Task 2 Report

The following assumptions were used during Phase I; they have been replaced with updated assumptions for Phase II.

1. Wells located in T34N through T58N are within the PRB study area.
2. The PRB would see a short-term increase in the number of operating wells in the region, followed by a slow decline.
3. Forty percent of wells drilled would be nonproductive and P&A within that year, and an additional 10 percent of active wells would be P&A each year.

Basis and Rationale for New Assumptions

The Stilwell et al. (2009) RFD projections provide an estimate of the number of conventional oil and gas wells that would be drilled over the period of 2009 to 2028, and imply P&A rates, as summarized below.

- 1,359 new wells would be drilled from 2009 through 2028, an average of 68 new wells per year.
- Twenty-five percent of the 1,359 new wells would be P&A from 2009 to the end of 2028, resulting in 340 P&A wells and 1,019 new wells for the planning period.

- Existing wells at the beginning of the RMP RFD planning period consisted of 4,146 currently active and non-active wells that have not been classified as P&A.
- The 4,146 existing wells include conventional oil and gas producers and service wells associated with conventional oil and gas production (injection, disposal, and source water wells).
- The existing 4,146 conventional oil and gas producers and service wells would decline to 2,524 wells by the end of 2028; a decline of approximately 40 percent or approximately 81 wells per year.
- There would be a total of 3,543 conventional oil and gas and associated service wells by the end of 2028.

Phase II Assumptions and Methodology

The following new assumptions are based on Stilwell et al. (2009) as discussed above and incrementally expanded to cover the PRB Coal Review's RFD time period (2009 through 2030) and to account for conventional oil and gas activity in the Casper FO portion of the study area. A new assumption also has been developed to provide a more precise description of the PRB study area.

1. All RFD wells would be located in the Wyoming PRB study area (see **Figure C-1** in **Appendix C** of this report). This area includes portions of Campbell, Converse, Johnson, and Sheridan counties.
2. An assumed 68 wells per year would be drilled in the Buffalo FO portion of the study area for a total of 1,496 new wells. The projection is assumed to be constant, with 68 new wells drilled each year.
3. In the Casper FO portion of the PRB study area, an assumed 313 conventional oil and gas wells would be drilled to 2030, and 25 percent of those wells would be directionally or horizontally drilled (see assumption Number 5 below). (The number of wells per year was based on the well density in Figure 22, Stilwell and Crockett [2005].)
4. The relative proportions of conventional oil and gas wells drilled on federal and state/fee acreage would be consistent throughout the study period.
5. Based on potential for shale gas development, continuous resource oil plays, and recovery of by-passed gas, assumed 25 percent of future conventional oil and gas wells would be directional or horizontal wells, and producers would have a nominal spacing of 320 acres (two wells per section).

4.0 Estimates of Future Active and P&A Conventional Oil and Gas Wells

Assumptions in the Phase 1 Task 2 Report

Based on the discussion above in Sections 2.0 and 3.0, the following Phase I assumptions have been replaced for Phase II.

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

4. Approximately 2,000 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.

Basis and Rationale for New Assumptions

See Section 3.0 relative to the active versus P&A allocation of newly drilled wells.

Phase II Assumptions and Methodology

1. Future active well numbers reflect actual 2009 conventional oil and gas wells with continuing production in future years in addition to new RFD wells. Actual 2009 wells with continuing production in future years include reported active wells as of 2009 (see Section 2.0).
2. Of the actual wells within the study area projected to have continuing production in future years, 81 wells per year would be assigned as P&A.
3. Twenty-five percent of newly drilled conventional oil and gas wells would be P&A the same year as drilled (17 wells per year in Buffalo FO portion of the study area and 4 wells per year in the Casper FO portion of the study area).
4. Assuming a constant P&A reduction of 25 percent per year for new wells, through 2030 there would be a total of 1,122 new active wells in the Buffalo FO area and approximately 235 new active wells in the Casper FO area. New active wells subsequently would be P&A based on an average well life of 9 years.

5.0 Estimate of the Number of Future Cumulative Conventional Oil and Gas Wells

Phase II Assumptions and Methodology

The following assumptions were used to calculate cumulative conventional oil and gas well numbers.

1. Cumulative wells drilled and cumulative wells P&A were calculated as follow:
   - Cumulative P&A wells for year = previous year's cumulative P&A + P&A wells for year
   - Cumulative wells for year = previous year's cumulative wells + new RFD wells for year

6.0 Allocation of Future Conventional Oil and Gas Wells by Subwatershed

Assumption in the Phase I Task 2 Report

The following assumption used during Phase I has been replaced with updated assumptions for Phase II.

1. The future distribution pattern of wells by subwatershed would be similar to distribution patterns through 2003.

Basis and Rationale for New Assumptions

Figure 58 in Stilwell et al. (2009) depicts the projected allocation of RFD conventional oil and gas well drilling activity. The well drilling density was broken down into categories ranging from very high (more than 30 wells from 2009 to 2028) to none.

The most recent RFD projections for the Casper FO portion of the study area are from Crockett and Stilwell (2005). The Casper FO portion of the PRB study area was predicted to have a conventional well drilling density characterized as low (2 to 20 additional wells per township) over the planning period of 2001 to 2020.

Phase II Assumptions and Methodology

1. The future distribution pattern of conventional oil and gas wells would reflect the drilling densities depicted in Figure 58 from Stilwell et al. (2009) and the drilling densities depicted in Figure 22 from Crockett and Stilwell (2005). Wells would be proportionately allocated into undrilled spacing units (e.g., 40, 80, or 160 acres depending on Wyoming Oil and Gas Conservation Commission [WOGCC] order) within the subwatersheds in the study area.
2. Projected conventional oil and gas wells proportionately would be distributed through 2030 based on available well locations, with 68 wells allocated per year in the Buffalo FO portion of the study area and 14 wells allocated per year in the Casper FO portion of the study area.
3. Abandonment would be allocated proportionately among the subwatersheds based on the number of active wells.
4. The density of projected new wells in the Buffalo FO portion of the study area was based on the projections shown in Figure 58 in Stilwell et al. (2009). The density of projected new wells in the Casper FO portion of the study area was based on the projections shown in Figure 22 in Crockett and Stilwell (2005).

7.0 Estimate of the Future Rate of CBNG Wells Drilled Per Subwatershed per Year

Assumptions in the Phase I Task 2 Report

The following assumptions were used during Phase I. Assumptions 1 and 2 have been replaced with updated assumptions, and assumptions 4 and 5 have been modified. Assumptions 3, 6, and 7 have been retained for Phase II.

1. The BLM Buffalo FO would issue 2,500 applications for permits to drill (APDs) per year through 2015. Starting in 2016, the number of federal permits issued per year would decline at a rate of 200 per year until 2020 to account for a tapering off of activity that is expected to occur after 25 years of activity in the play. The BLM Casper FO would issue 35 APDs per year through 2020. Of all federal APDs issued, 89.8 percent would be drilled (BLM RMG 2005).
2. The number of state/fee APDs that the WOGCC would issue would be proportional to the number of federal APDs issued by each BLM office, as well as to the amount of remaining available spacing for state/fee pads within the BLM field office boundaries. Of the state APDs issued, 72.4 percent would be drilled.
3. An average of 1.45 wells would be drilled per pad (BLM 2003).
4. Distribution of new wells in the PRB subwatersheds would be proportional to remaining available pads within the jurisdiction of each BLM office.

5. No significant CBNG development would occur outside of the Wasatch/Fort Union coal outcrop.
6. Technology used to extract CBNG would not change significantly during the time frame of this study.
7. Future wells will be drilled based on 80-acre spacing.

Basis and Rationale for New Assumptions

The well drilling and abandonment rates as depicted in Figure A1-8 in Stilwell et al. (2009) have been used for Phase II. Therefore, assumptions 1 and 2 above have been eliminated for Phase II. The CBNG development in the Casper FO portion of the study area is minor in comparison to the Buffalo FO, and the Casper FO RFD projections (Crockett and Stilwell 2005) show only a small area where CBNG drilling density could exceed 100 wells per township.

The potential for production in the Casper FO portion of the study area is mainly from Wyodak zone coals in the northernmost townships of Converse County. These coals pinch out to the south, and deep coals do not appear to have the potential for significant gas production in this area based on limited development in the Dry Fork Cheyenne River subwatershed. Therefore, it is estimated that approximately 700 conceptual wells through 2030 would be more likely in the Casper FO portion of the study area (BLM 2010c) than the approximately 900 conceptual wells previously projected in Crockett and Stilwell (2005).

The Buffalo FO RFD projections (Stilwell et al. 2009) estimate that 13,803 CBNG wells would be drilled from 2009 to 2028. Figure A1-9 in Stilwell et al. (2009) shows the development potential by township, ranging from very high (greater than 220 wells per township) to very low (less than 5 wells per township).

Recent WOGCC data provided by the BLM RMG indicate that the observed failure rate, or wells classified as “dry holes,” is approximately 0.9 percent. Incorporation of such a low failure rate would have little if any effect on projected well numbers; therefore, a failure rate has not been tracked in this study.

Retention of Phase I assumption 3 (1.45 wells per pad) is subject to revision if it is not reflective of current conditions. According to Stilwell et al. (2009), 9.18 percent of wells drilled before 2009 were on a pad with another well, and 18.96 percent of wells drilled after 2008 (between 2009 and 2028) would be on a well pad with another well (a ratio of 1.2 wells per pad for future wells). However, the PRB Coal Review differs slightly from Stilwell et al. (2009) in that: 1) the PRB Coal Review extends through 2030 (2 years longer); and 2) RFD wells are allocated vertically based on stratigraphy. Therefore, to ensure sufficient spacing for well allocations over time, the ratio of 1.45 wells per pad has been retained for this study.

Assumptions 4 and 5 have been retained with additional final densities as shown in Figure A1-9 in Stilwell et al. (2009).

Phase II Assumptions and Methodology

1. Future CBNG drilling rates per subwatershed would reflect the future drilling rates presented in Figure A1-8 in Stilwell et al. (2009) and in the maps and data provided by the BLM RMG (2010).
2. In the Casper FO portion of the study area, an assumed 32 wells would be drilled per year through 2030 (a total of approximately 700).
3. An average of 1.45 wells would be drilled per pad.
4. Distribution of new wells by subwatershed would be proportional to remaining available pad spacing within the jurisdiction of each BLM office. (Final densities shown in Figure A1-9 in Stilwell et al. [2009] would be incorporated.)

5. No significant CBNG development would occur outside of the Wasatch/Fort Union coal outcrop. (Final densities shown in Figure A1-9 in Stilwell et al. [2009] would be incorporated.)
6. Technology used to extract CBNG would not change significantly during the time frame of this study.
7. Future wells would be drilled based on an 80-acre spacing.
8. Based on the low observed failure rate (approximately 0.9 percent), a failure rate was not tracked.

8.0 Estimate of the Rate of P&A CBNG Wells per Subwatershed per Year

Assumptions in the Phase I Task 2 Report

The following assumptions were used during Phase I. Assumptions 1, 2, and 3 have been replaced, and assumption 4 has been retained for Phase II.

1. It is assumed that abandonment rates of new wells would be 4.1 percent (BLM RMG 2005).
2. Wells would 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). Wells with a first production year of 2003 or later were closed based on age according to Table E-2 (in Phase I Task 2 report update).
3. Rates of abandonment for wells active prior to 2003 with an untracked first production year would be similar to the average closure rate in each subwatershed between 2003 and 2008.
4. The distribution pattern of abandoned wells between subwatersheds would be proportional to the numbers of active wells in the subwatersheds.

Basis and Rationale for New Assumptions

Figure A1-8 in Stilwell et al. (2009) presents the annual historical and projected drilling and abandonment rates for CBNG wells. The projection of plugged wells goes to 2030.

Phase II Assumptions and Methodology

1. Future CBNG P&A rates per subwatershed reflect the future abandonment rates presented in Figure A1-8 in Stilwell et al. (2009).
2. The distribution pattern of abandoned wells between subwatersheds would be proportional to the number of active wells in the subwatersheds.
3. Approximately 11 percent of the actual 2009 inactive wells in each subwatershed would re-initiate production each year from 2010 through 2018 and, based on an average well life of 9 years, subsequently would be P&A from 2019 through 2027. (See Section 2.0 relative to actual 2009 P&A wells.)
4. Approximately 11 percent of the actual 2009 producing wells in each subwatershed would be P&A each year from 2010 through 2018, based on an average well life of 9 years.

9.0 Determination of Future Yearly Total Production of Oil, Natural Gas, and Water

Assumptions in the Phase I Task 2 Report

The following assumptions were used during Phase I. Assumption 1 has been retained for Phase II, and assumptions 2 and 3 have been modified. New assumptions also have been incorporated to reflect updated RFD projections from the BLM RMG.

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 would not change greatly over the period of this study.
3. Average annual production per subwatershed was based on the number of wells for each year divided into the total production each year, then averaged.

Basis and Rationale for New Assumptions

Two new assumptions have been added for Phase II to incorporate recent BLM information including: 1) production estimates in Crockett and Stilwell (2005) and Stilwell et al. (2009), and 2) projected CBNG groundwater production rates (Crockett 2011) based on the BLM RMG's CBNG groundwater production report (BLM 2011d, 2010e). The BLM RMG report was developed using historical information to determine the gas-to-water ratio and the application of the ratio to the RFD CBNG groundwater production projections. The report and the associated projected CBNG groundwater production rates are presented in **Appendix E** of this report.

CBNG production in the Buffalo FO portion of the study area was estimated based on the projected gas production in Figure A1-15 of Stilwell et al. (2009) and prorated among active wells in the respective subwatersheds. The Casper FO RFD (Crockett and Stillwell 2005) does not break out the estimated future CBNG production separate from overall future gas production. Therefore, CBNG production in the Casper FO portion of the study area also was based on the prorated annual production calculated from the Stilwell et al. (2009) estimates. Conventional oil and gas production for the study area was based on the average historic gas to oil ratio per subwatershed/well as calculated from IHS data, the projected oil and gas production rates per Stillwell et al. (2009), and the projected oil production rates per Crockett and Stillwell (2005). Conventional gas production in the Casper FO portion of the study area was estimated based on the projected oil production (Crockett and Stillwell 2005) and the average historic gas to oil ratios.

Phase II Assumptions and Methodology

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 water production per CBNG well would not change greatly over the period of this study; however, gas production may vary.
3. Annual RFD conventional oil and gas production in the Buffalo FO portion of the study area was allocated on a subwatershed basis based on the projected number of active wells per subwatershed per year (see Section 3.0 above), the historic gas to oil ratio, and the projected annual oil and gas production provided in Table 5 from Stilwell et al. (2009). For the Casper FO portion of the study area, oil production rates was allocated on a subwatershed basis based on the projected number of active wells per subwatershed per year, the historic gas to oil ratio, and the projected annual oil production provided in Table 16 (Alternative E) from Crockett and

Stilwell (2005); gas production was estimated based on the per well oil production and the average historic gas to oil ratios.

4. Annual RFD CBNG production for the study area was allocated on a subwatershed basis based on the sum of: 1) the number of actual wells (active and idle wells) with production in the near-term RFD years (per Section 8.0) and the production decline rate provided in Stilwell et al. (2009), plus 2) the number of projected active wells per subwatershed per year (see Section 7.0 above) and the projected annual gas production provided in Stilwell et al. (2009).
5. Annual RFD CBNG groundwater production was allocated on a subwatershed basis (Crockett 2011) based on the projected number of active CBNG wells per subwatershed per year and the BLM RMG's CBNG groundwater production report (BLM 2011d, 2010e) (see **Appendix E**).
6. Annual RFD conventional groundwater production rates per Figure 32 in Stilwell et al. (2009) will be used. Produced groundwater will be allocated similarly to CBNG based on active wells per subwatershed per year.

10.0 Determination of Future Cumulative Values for Production of Oil, Natural Gas, and Water

Assumption in the Phase I Task 2 Report

Future cumulative production values were identified during Phase I by determining the estimated yearly production (products and water) for the yearly estimated number of wells and adding these to the previous year's cumulative estimate. The equation used is as follows:

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

Basis and Rationale for New Assumptions

Conventional Production – Oil, Gas, and Water:

Table 5 from Stilwell et al. (2009) provides cumulative production estimates for conventional oil and gas wells. From 2009, oil is assumed to decline at a rate of 6.2 percent per year, for a total estimated cumulative production of 95,528,744 barrels by 2028. Conventional gas production is assumed to decline at a rate of 2.8 percent per year, for a total cumulative production of 183,837,588 thousand cubic feet (MCF) of gas by 2028. Using these decline rates, it is possible to extrapolate cumulative conventional oil and gas production to 2030 (99,929,832 barrels of oil and 197,105,606 Mcf gas).

Figure 32 in Stilwell et al. (2009) shows the actual cumulative water production to the end of 2008 of 3.5 billion barrels of water (BW). This figure shows cumulative and yearly conventional water production. The cumulative curve builds at a rate of approximately 100,000,000 BW per year over 35 years. Therefore, assuming water would be produced at a steady volume of 100,000,000 BW per year, cumulative water production would be 5.7 billion BW (approximately 735,000 acre-feet) by 2030.

CBNG Production – Gas and Water

Stilwell et al. (2009) estimated that cumulative CBNG production would be 8,671 billion cubic feet (Bcf) by 2028. Figure A1-15 in Stilwell et al. (2009) shows a production history with a peak in 2003-2004, a slight decline, and then another peak in 2009-2010; projected annual production then decreases steeply

to 2018, with another peak in 2026 to 2027 and a decline in 2028. The projected peak in 2026-2027 is slightly less than 300 Bcf per year.

The RFD projections in Stilwell et al. (2009) do not provide an estimated water production value with which to extrapolate cumulative water production from CBNG. Annual and cumulative water production was estimated by Bank and Kuuskraa (2006) based on water production data on historically-matched type wells from a variety of PRB CBNG developments. Cumulative gas production ranged from 0.08 to 0.66 Bcf and averaged 0.233 Bcf. Water production ranged from 75,000 to 1,400,000 barrels, with the average being approximately 370,000 barrels. The average gas production is remarkably close to the 0.223 Bcf of a "typical" well presented in the Stilwell et al. (2009) RFD projections; however, the water from a typical well in the RFD projections was 3.48 million barrels. This is much higher than what would be expected. As discussed in Section 9.0, the BLM RMG's CBNG groundwater production report (BLM 2011d, 2010e) (see **Appendix E**) provided the basis for calculation of the annual groundwater production values for this study. The calculated annual rates then provided the basis for calculation of the cumulative CBNG groundwater production.

Phase II Assumptions and Methodology

1. Cumulative conventional oil and gas production was calculated from 2003 forward based on cumulative 2003 production data from Phase I, the IHS actual data through 2008 (BLM 2011b), and the projected yearly production as discussed in Section 9.0.
2. Cumulative CBNG production was calculated from 2003 forward based on cumulative 2003 production data from Phase I, the IHS actual data through 2008 (BLM 2011b), the projected annual production presented in Stilwell et al. (2009) and Crockett and Stilwell (2005), and the township by township well projections provided by the BLM RMG (2010).
3. Cumulative conventional water production was calculated from 2003 forward based on cumulative 2003 water production data from Phase I, the IHS actual data through 2008 (BLM 2011b), and the projected annual data (see Section 9.0).
4. Cumulative CBNG water production was calculated from 2003 forward based on cumulative 2003 water production data from Phase I, the IHS actual data through 2008 (BLM 2011b), and the projected annual data (see Section 9.0).
5. Cumulative oil, conventional natural gas, CBNG, and associated water production were allocated on a subwatershed basis.

11.0 Determination of Water Injection and Discharge

Assumptions in the Phase I Task 2 Report

The following assumptions were used during Phase I. Assumption 2 has been retained for Phase II; assumption 1 has been eliminated.

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

Phase II Assumptions and Methodology

1. Water produced within a subwatershed either would be injected or discharged within the same subwatershed. (Note: Percent of water discharged by method is discussed in Section 13.0.)

12.0 Estimate of Disturbed and Reclaimed Acreage Related to Conventional Oil and Gas and CBNG Activities

Assumptions in the Phase I Task 2 Report

The following assumptions were used during Phase I. Assumptions 1, 3, and 4 have been modified for Phase II; Assumption 2 has been eliminated.

1. The estimated per-well disturbance acreages would not change during the study (initial disturbance of 2.75 acres for conventional oil and gas wells and 5.2 acres for CBNG wells). Each per-pad disturbance acreage also accounts for a portion of the associated ancillary facilities (i.e., roads, gathering lines, power lines, and water handling facilities, as applicable).
2. Overall disturbance would be distributed evenly among wells.
3. A portion of the short-term disturbance would 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 CBNG and conventional oil and gas wells would 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."

Basis and Rationale for New Assumptions

Stillwell et al. (2009) provides the following lists of disturbance assumptions for CNBG wells:

- Reclamation would not be completed until 2 years after well abandonment.
- Ten percent of the CBNG wells that reach their economic limit would be converted to water wells. BLM-managed wells would be released via a signed agreement. Surface disturbance would no longer be credited to CBNG activity.
- Only 50 percent of the roads would be reclaimed after well abandonment, this applies to both federal and non-federal surface. Unreclaimed roads would not be used for CBNG operations.
- Constructed well pads are 0.9 acre, with initial reclamation to 0.5 acre in 2 years (constructed well pads are built using earth moving equipment).
- Non-constructed well pads are 0.9 acre, with initial reclamation to 0.3 acre in 2 years (non constructed well pads are established by driving on top of the natural surface).
- Federal wells include both public domain and split estate.
- Flow lines follow roads and would not add additional long-term (over 2 years) surface disturbance.
- The area in acres disturbed initially by roads and flow lines for an undrilled location would be 2.07 acres; after initial reclamation it would be 0.92 acre.
- Approximately 25 percent of the wells drilled before 2008 had constructed pads, and approximately 70 percent of the wells drilled after 2008 would have constructed pads.
- At the end of 2028, there would be an estimated 10,460 active CBNG wells in the Buffalo FO area, based on calculated abandonment rates.
- During 1990-2008, 24.13 percent of all the wells drilled were on federal surface (public domain.).

- During 2009-2028, 59.55 percent of the wells drilled would be on federal minerals, and 27.89 percent would be on federal surface.

The CBNG-related disturbance acreages used during Phase I have been updated for Phase II to reflect the more recent assumptions summarized above from Stilwell et al. (2009). For purposes of the PRB Coal Review, one short-term (initial 2-year) disturbance acreage and one long-term (operational well life) disturbance acreage has been applied on a per well basis throughout the Wyoming PRB study area and throughout the time frame of the study (through 2030). Based on the Stilwell et al. (2009) assumptions, the most conservative short-term and long-term disturbance acreages would be 3.0 and 1.4 acres per well, respectively. These acreages include the disturbance acreage for the pad and the associated proportional disturbance acreage for the road and flow line (i.e., pipelines). While not explicitly stated in Stilwell et al. (2009), a disturbance factor for CBNG-related water impoundments can be calculated based on information present therein and other information provided by the BLM RMG. Stilwell et al. (2009) states that at the beginning of 2008, “total estimated disturbance due to water impoundments was approximately 19,548 acres in the Buffalo FO area.” Assuming 25,762 existing wells at the beginning of 2008, the long-term disturbance would have been 0.80 acres per well. For purposes of this study, this per well acreage also has been applied to future wells, and the disturbance factor for water handling facilities (impoundments) has been considered to apply for the lifetime of the well. Therefore, the short-term and long-term per well disturbance acreages are assumed to be 3.8 and 2.2 acres, respectively. It is assumed that long-term disturbance (less 50 percent of the related per well road disturbance as discussed below) would be reclaimed within the year a well is abandoned.

Per the Stilwell et al. (2009) assumptions identified above, 10 percent of the CBNG wells that reach their economic life would be converted to water wells, and only 50 percent of the roads would be reclaimed. With a long-term per well pad disturbance of 0.5 acre, it is probable that most if not all of the pad disturbance area would be reclaimed following well conversion. Therefore, for purposes of this study, it is assumed that the well pads associated with converted wells would be reclaimed in the year that the wells reach the end of their productive lives. Retention of 50 percent of the roads for non-CBNG purposes (per Stilwell et al. [2009]) would result in a permanent disturbance. Based on a long-term per well road disturbance of 0.9 acre, permanent disturbance would be allocated on a subwatershed basis based on a per well permanent disturbance of 0.45 acre.

For CBNG wells, it is anticipated that a greater portion of future wells would be drilled on federal minerals than occurred up to 2008. Since much of the available state and fee acreage has been drilled, most of the remainder would be drilled on federal minerals. However, the available space to drill wells dictates final distribution.

Conventional oil and gas disturbance assumptions in Stilwell et al. (2009) are the same as used for Phase I of the PRB Coal Review (new short-term disturbance of 2.75 acres and long-term disturbance of 2.0 acres), and have been carried forward for Phase II. Different disturbance assumptions were used for the Casper FO RFD projections (Crockett and Stilwell 2005), probably based on depth and size of well locations needed. However, it has been assumed for the PRB Coal Review that conventional wells in the Casper FO portion of the study area are comparable in depth range to those in the Buffalo FO area, and that the disturbance assumptions used by Stilwell et al. (2009) as listed above are reasonable estimates for disturbance in the Casper FO portion of the study area.

<u>Phase II Assumptions and Methodology</u>

1. The estimated per-well disturbance acreages for conventional oil and gas wells would not change during the study (short-term [initial 2-year] disturbance of 2.75 acres and long-term [operational well life] of 2.0 acres). The disturbance assumptions apply to the entire study area, including the Casper FO portion. Each per-pad disturbance acreage also accounts for a portion of the associated ancillary facilities (i.e., roads, gathering lines, power lines, and water handling facilities, as applicable).

2. The estimated per-well disturbance acreages for CBNG wells would not change during the study (short-term [initial 2-year] disturbance of 3.8 acres and long-term [operational well life] of 2.2 acres). The disturbance assumptions apply to the entire study area, including the Casper FO portion. Each per-pad disturbance acreage also accounts for a portion of the associated ancillary facilities (i.e., roads, gathering lines, power lines, and water handling facilities).
3. Long-term disturbance due to conventional oil and gas wells (2.0 acres per well) would be reclaimed within the year the wells are identified as abandoned.
4. Ten percent of the CBNG wells that reach their economic life would be converted to water wells, with the pads reclaimed following conversion.
5. Of the 2.2 total acres of long-term disturbance per CBNG well, 1.75 acres would be reclaimed within the year the wells are indentified as abandoned. Fifty percent of the associated roads would be retained for purposes other than CBNG activity: therefore, the remaining 0.45-acre per well would represent permanent disturbance. The permanent disturbance would be allocated on a subwatershed basis.
6. Cumulative disturbance and reclamation acreages reflect 2003 CBNG and conventional oil and gas activity forward. (See assumption 11 in Section 2.0 relative to wells drilled prior to 2003.)

13.0 Estimate of the Volume of Water Disposed by Various Disposal Methods

Assumptions in the Phase I Task 2 Report

The following assumptions were used in Phase I. They have been replaced with an updated assumption for Phase II.

1. It is assumed that the percent of total produced water discharged to impoundments, outfalls, or through injection in each subwatershed would 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) would be the same as identified in that document for the Clear Creek subwatershed.

Basis and Rationale for New Assumptions

Water disposal by disposal method was not addressed in the BLMs updated RFD projections (Stilwell et al. 2009; Crockett and Stilwell 2005). Alternately, reported CBNG discharge water volumes by discharge method were obtained from the WDEQ – Water Quality Division (WQD) for the period of January 1, 2008, through August 1, 2010. Discharge locations were assigned to subwatersheds using GIS, and the percent of water discharge by discharge method for each subwatershed subsequently was calculated as discussed below.

Phase II Assumptions and Methodology

1. The percent of total produced water discharged to impoundments, outfalls, or through injection in each subwatershed were allocated per **Table D-1**.

Table D-1 Percent of Total CBNG Water Production per Discharge Method[1,2,3]

Subwatershed (Receiving Water)	Headwater Reservoir or Unlined Off-channel Containment[4]	Unlined On-channel Containment or Direct Discharge to Drainage[5]	Playa Lake Containment[6]	Injection
Antelope Creek	NA	100	NA	NA
Clear Creek	91	NA	NA	9.0
Crazy Woman Creek	57.6	14.3	NA	28.1
Dry Fork Cheyenne River	NA	100	NA	NA
Lightning Creek	NA	100	NA	NA
Little Powder River	3.2	94.7	0.3	1.8
Middle Powder River	0.0	100	0.0	0.0
Salt Creek	NA	0.8	NA	99.2
Upper Belle Fourche River	0.1	99.9	0.0	NA
Upper Cheyenne River	NA	42.2	57.8	NA
Upper Powder River	1.5	96.8	0.2	1.5
Upper Tongue River	80	16.4	1.6	2.0

[1] Based on WDEQ (2010a,c) CBNG discharge monitoring reports for the period of January 1, 2008, through August 1, 2010. Does not include discharge to off-channel impoundments permitted by WOGCC.

[2] The percentages shown are not upper thresholds that can or would be enforced. They are merely a disclosure of effects of one of many various ways water may be handled to meet Wyoming's water quality standards and agreements with bordering states.

[3] The percentages shown represent the distribution of water handling methods assumed for the analysis, not the amount of water that actually reaches the river.

[4] Discharge to a headwater reservoir has requirements mandating containment of all effluent in addition to storm water runoff from a 50-year/24-hour storm event. Headwater reservoirs typically are not lined (WDEQ 2010b) and have less than 40 acres of contributing area (BLM 2011a).

[5] Direct discharges to drainages in the Powder River and Tongue River drainages typically are treated for sodium adsorption ratio and/or electrical conductivity.

[6] Discharge to a topographically and hydrologically isolated playa lake.

Notes:

NA = not applicable; no produced water discharge by identified category.

Percentages of 0.0 indicate total water production of less than 0.1 percent.

Percentages apply to CBNG and conventional oil and gas wells for this study. Conventional well water disposal (in the Little Missouri River, Middle Fork Powder River, Middle North Platte River, and South Fork Powder River subwatersheds are assumed to be allocated per Crazy Woman Creek, for which allocation is distributed to the primary disposal methods.

14.0 Migration of CBNG Wells Over Time

During Phase I, BLM developed the projected migration pattern of CBNG wells over time for use in the air and groundwater models. The assumptions and methodology used for Phase II are presented below.

Basis and Rationale for New Assumptions

Although Plan of Development (POD) approval is not a definitive indicator of imminent CBNG development, it can indicate areas that may have a higher likelihood of development in the near-term (3 to 5 years). Therefore, recent PODs and data provided by the Buffalo FO were used to determine the near-term CBNG development patterns.

Well migration patterns over time were developed based on the BLM RMG's (2010) maps of projected well numbers by township in the Wyoming PRB, the projected number of wells drilled per year in the Buffalo FO as provided in Figure A1-8 in Stilwell et al. (2009) (see Section 7.0 above), and recent PODs. Using the BLM RMG's maps, groups of townships were selected for well migration for each future year, with the sum of the projected wells similar to each year's well development projection as provided in Figure A1-8 (Stilwell et al. 2009). Initial townships chosen for well migration were based on recently approved PODs. It is recognized that the number of locations in the PODs may not equal the number of wells projected by the BLM RMG in a given township.

Stilwell et al. (2009) assumed that well life begins on the date of first production, and the average well life is 9 years. Depleted wells could be shut-in for long periods before abandonment actually occurs. However, it is assumed that the abandonment rates presented by Stilwell et al. (2009) are consistent with the stated 9-year well life indicated above.

Phase II Assumptions and Methodology

1. The migration of new CBNG wells and abandonment of CBNG wells over time generally would be from east to west across the study area, with infilling, as appropriate, based on the known extent of the coals and other factors as described below.
2. Based on the BLM RMG map of projected CBNG well numbers by township in the Wyoming PRB, the number of wells drilled per year in the Buffalo FO portion of the study area would approximate the projection provided in Figure A1-8 in Stilwell et al. (2009).
3. For the Buffalo FO portion of the study area, townships identified for near-term (3 to 5 years) CBNG well development would be based on Buffalo FO data and PODs that were approved from 2008 to June 2010 (BLM 2010b). Beyond that timeframe, townships would be selected based on each year's new CBNG well development projection as provided in Figure A1-8 (Stilwell et al. 2009) and the BLM RMG's maps of future well distribution by township.
4. For the Casper FO portion of the study area, wells were migrated in accordance with the BLM RMG's maps of projected CBNG wells per township and a rate of approximately 32 wells per year.
5. Wells in the Buffalo FO portion of the study area would be abandoned at rates shown in Figure A1-8 in Stilwell et al. (2009). Wells in the Casper FO portion of the study area would be abandoned based on an average well life of 9 years.

15.0 Producing Zone Allocation of CBNG Wells

For Phase II, CBNG wells were allocated by production zone, based on stratigraphy, for use in the groundwater model as discussed below.

Basis and Rationale for New Assumptions

The percent allocation of CBNG wells by subwatershed and production zone was based on information provided by the BLM RMG as discussed below.

Much of the early CBNG development in the Wyoming PRB study area occurred in subwatersheds where the primary target was the Wyodak coals. Based on the remaining available well locations, some of these subwatersheds are approaching full development. Historical data from IHS through 2009 for CBNG wells in the Wyoming PRB study area indicate a basin-wide average completion ratio of 81 percent Wyodak coals and 19 percent deep coals; the shallow coals (above the Wyodak) comprise less than 1 percent of the development. No defined upward or downward trends in these ratios were observed in the historical data through 2009. Ratios of Wyodak coals to deep coals in individual subwatersheds vary greatly. The Clear Creek, Crazy Woman Creek, and Middle Powder River subwatersheds have a high level of remaining development potential (based on the number of undrilled well locations) and historically have had the deep coals as a primary target. These conditions indicate that an overall larger percentage of the future wells in the PRB study area would be to deeper coals. Historically, there has been no drilling in the Lightning Creek subwatershed; however, it was assumed that all projected future drilling would be to the deeper coals (based on coal stratigraphy) (BLM 2010a).

Considering the coal stratigraphy of each subwatershed and applying the historic drilling ratio of each subwatershed to the number of wells projected to be drilled resulted in an overall basin-wide average percentages as follows: 3 percent shallow coals, 68 percent Wyodak coals, and 29 percent deep coals (see **Table D-2**). This ratio also takes into account the projections made on the Antelope Creek subwatershed to consider the transition from drilling mostly to the Wyodak coals in the north to drilling to the deep coals in the south.

Phase II Assumption and Methodology

1. A coal nomenclature was used that divides the coals into the following zones: shallow coals, Wyodak Zone, and deep coals as shown in **Table D-3**.
2. Shallow coals (coals above the Wyodak Zone) currently comprise less than 1 percent, and are projected to comprise approximately 3 percent, of all completions and do not significantly contribute to water or gas production.
3. The vertical allocation of actual wells to production zone for each subwatershed was based on the percent distribution by coal zone for each subwatershed as provided by the BLM (2011c, 2010a) (see **Table D-2**).
4. The vertical allocation of RFD CBNG wells was based on the lateral migration (temporal and spatial) of CBNG wells described above in Section 14. 0 and the percent distribution by coal zone for each subwatershed as provided by the BLM (2011c) (see **Table D-2**).

Table D-2 Predicted Vertical CBNG Well Allocation per Subwatershed

Subwatershed[1]	Percent Allocated per Coal Zone		
	Shallow	Wyodak	Deep
Antelope Creek[2]	0	73	27
Clear Creek	23	26	51
Crazy Woman Creek	2	39	59
Dry Fork Cheyenne River	0	0	100
Lightning Creek	0	0	100
Little Powder River	0	67	33
Middle Powder River	0	31	69
Salt Creek	0	100	0
Upper Belle Fourche River	0	98	2
Upper Cheyenne River	0	100	0
Upper Powder River	1	82	17
Upper Tongue River	0	87	13
Total Wells	**3**	**68**	**29**

[1] Only subwatersheds in the study area for which CBNG activity currently exists or is projected to occur are included.

[2] Projected future allocation for Antelope Creek subwatershed reflects overall percentages based on different allocations to Wyodak coals and deep coals for three sections of the subwatershed: 1) 90 percent Wyodak coals and 10 percent deep coals north of T40N; 2) 50 percent Wyodak coals and 50 percent deep coals within T40N (transition zone); and 3) 100 percent deep coals south of T40N.

Source: BLM 2011c, 2010a.

16.0 Other Assumptions

The following additional assumptions apply to Phase II.

1. Methanogenesis is an unproven and not as yet approved technology. Therefore, it was not included in the RFD scenario. (The RFD projections by Stilwell et al. [2009] provide no guidance relative numbers of wells that might be engaged in such activity.)
2. Oil mining activity was not considered in this study since oil mining activities do not occur within the study area.

Table D-3 Historic Coal Bed Names as Related to the Coal Bed Categories for the PRB Coal Review

Coal Bed Categories/ Geologic Units	Original Coal Bed Names		Previous Coal Bed Names		USGS[1]		WSGS	Goolsby and Finley
	Taff 1909	Mapel 1973	Montana	Wyoming	Montana	Wyoming	Wyoming	Wyoming
Shallow Coals: Wasatch Formation and Alluvium						Ulm 1 Ulm 2 (Healy) Ucross Wyamo Felix	Buffalo Cameron Murray Ucross Felix Arvada	
Wyodak Coals: Fort Union Formation, Upper Tongue River Member Wyodak-Anderson Coal Zone	Dietz 1 Dietz 2 Dietz 3	Upper Wyodak Lower Wyodak	Roland Smith Anderson Dietz 1 Dietz 2	Roland Smith/Swartz Anderson (Wyodak) Canyon (Big George)	Roland/Smith Dietz 1 Dietz 2 Dietz 3	Roland, Smith, Swartz Upper Wyodak (lower/upper, middle/upper, and upper/upper) Lower Wyodak (lower/lower, middle/lower, and upper/lower)	Roland Smith Anderson Canyon Big George	Smith Swartz Anderson Canyon Cook Wall Wyodak
Deep Coals: Fort Union Formation Lower Tongue River Member Deep Coals			Canyon Cook Otter Wall Pawnee Cache Sawyer Knobloch Flowers/Goodale Terret	Carney Werner Gates Kennedy Carson Broadus Roberts Kendrick	Canyon Cook Otter Wall Pawnee Cache Sawyer Knobloch Flowers/Goodale Terret	Carney Werner Gates Kennedy Carson Broadus Roberts Kendrick	Cook Wall Pawnee Moyer	Pawnee Cache

[1] The USGS Wyodak coal zone includes the following coals: Roland, Smith, Swartz, Anderson, Canyon, Big George, Sussex Coal (Hardie and van Gosen 1986), Badger, School, and Wyodak.

Sources: Flores et al. 2010; Goolsby and Finley 2000; Jones and Rodgers 2007.

17.0 References

AECOM. 2009. Update of the Task 2 Report for the Powder River Basin Coal Review Past and Present and Reasonably Foreseeable Development Activities. Prepared for the Bureau of Land Management, High Plains District Office and Wyoming State Office. December 2009.

Bank, G. C. and V. A. Kuuskraa. 2006. The Economics of Powder River Basin Coalbed Methane Development. U.S. Department of Energy. Prepared by Advanced Resources International, Inc. 98 p. January 2006.

Bureau of Land Management (BLM). 2011a. Clarification Regarding Headwater Reservoirs Provided by M. Brogan, BLM, to M. Giere, AECOM. January 14, 2011.

_____. 2011b.Revised actual 2003-2010 CBNG and conventional oil and gas data, well location files, and associated assumptions provided by A. Meeks, BLM, to M. Giere, AECOM. October 13, 2011.

_____. 2011c. Percent allocation of CBNG wells per coal zone for the Salt Creek Subwatershed provided by M. Brogan, BLM, to M. Giere, AECOM. October 5, 2011.

_____. 2011d. Summary of 2011 Update to [CBNG Water] Pumpage Rate Estimates. December 22, 2011.

_____. 2010a. Information and table provided by M. Brogan, and F. Crockett, BLM, to M. Giere, AECOM, regarding CBNG drilling by production zone and subwatershed. September 23, 2010.

_____. 2010b. PODs Approved Under PRB EIS. Internet website: http://www.blm/gov/wy/st/en/field_offices/Buffalo/minerals.html. Accessed on July 2, 2010.

_____. 2010c. Information provided by F. Crockett, BLM, to W. Berg, AECOM, relative to project CBNG well numbers for Converse County. Meeting July 21, 2010.

_____. 2010d. Information provided by M. Brogan, BLM, to M. Giere, AECOM, relative to projected CBNG well numbers for the Buffalo Field Office area. September 22, 2010.

_____. 2010e. Estimation of CBNG Groundwater Pumpage Rates for Drainage Basins in the Powder River Basin, Wyoming – Final. Prepared by F. Crockett, BLM Wyoming State Office, Reservoir Management Group, Cheyenne, Wyoming. December 2010.

_____. 2003. Final Environmental Impact Statement and Proposed Plan Amendment for the Powder River Basin Oil and Gas Project. Wyoming State Office and Buffalo Field Office, Cheyenne and Casper, Wyoming. January 2003.

_____. 2001. Reasonably Foreseeable Development Scenario for Oil and Gas Development in the Buffalo Field Office Area, Wyoming. Internet website: http://www.blm.gov/wy/st/en/info/NEPA/bfodocs/prb_eis.html. Accessed on April 12, 2010.

Bureau of Land Management (BLM) Reservoir Management Group (RMG). 2010. Maps provided by F. Crockett, BLM RMG, to W. Berg, AECOM, providing RFD CBNG well numbers per township in the Wyoming PRB study area. April 28, 2010.

_____. 2005. Wyoming State Office. Personal communications with W. Berg and D. Dufresne, ENSR. March and April 2005.

Crockett, F. 2011. Projected CBNG water production data through 2030 provided by F. Crockett, Bureau of Land Management Reservoir Management Group, to M. Giere, AECOM. December 2011

Crockett, F. and D. Stilwell. 2005. Reasonable Foreseeable Development Scenario for Oil and Gas, Casper Field Office, Wyoming. Internet website: http://www.blm.gov/wy/st/en/programs/Planning/rmps/casper.html. Accessed on April 15, 2010.

Flores, R. M., B. D. Spear, S. A. Kinney, P. A. Purchase, and C. M. Gallagher. 2010. After a Century - Revised Paleogene Coal Stratigraphy, Correlation, and Deposition, Powder River Basin, Wyoming and Montana. U.S. Geological Professional Paper 1777. 97 p. September 2010.

Goolsby, J. E. and A. K. Finley. 2000. Correlation of Fort Union Coals in the Powder River Basin, Wyoming: A Proposed New Concept. In: Classical Wyoming Geology in the New Millennium; 51st Field Conference Guide Book, 2000. Wyoming Geological Association. Casper, Wyoming. pages 51-74.

Jones, N. R. and J. R. Rodgers. 2007. Coal Correlation and Coal Zones in the Powder River Basin Wyoming. Wyoming State Geological Survey Open File Report 07-3F.

Stilwell, D., S. W. Davis, A. M. Elser, and F. Crockett. 2009. Reasonable Foreseeable Development Scenario for Oil and Gas Buffalo Field Office Planning Area, Wyoming. Internet website: http://www.blm.gov/wy/st/en/programs/Planning/rmps/buffalo/docs.html. Accessed on April 12, 2010.

U.S. Geological Survey National Resource Assessment Team. 1995. 1995 Assessment of United States Oil and Gas Resources. U.S. Geological Survey Circular 1118, 30 p. Internet website: http://energy.cr.usgs.gov/oilgas/noga/1995.html. Accessed on April 12, 2010.

Wyoming Department of Environmental Quality - Water Quality Division (WDEQ-WQD). 2010a. CBNG discharge water volumes by discharge method for the period of January 1, 2008, through August 1, 2010, provided by K. Shreve, Environmental Program Principal, WDEQ-WQD, to D. Fetter, AECOM. August 3, 2010.

_____. 2010b. Information relative to headwater reservoirs provided by K. Shreve, Environmental Program Principal, WDEQ-WQD, to D. Fetter, AECOM. August 5, 2010.

_____. 2010c. CBNG discharge water injection volumes provided by A. Nunn, WDEQ-WQD, to D. Fetter, AECOM. September 13, 2010.

Appendix E

Estimation of CBNG Groundwater Pumpage Rates for Drainage Basins in the Powder River Basin, Wyoming (BLM 2010e) and Summary of 2011 Update to Pumpage Rate Estimates (BLM 2011d)

Revised Estimates of Water Pumpage Rates by Coal Horizon and Year for Eleven Watersheds in Northeast Wyoming

Introduction, Purpose, and Summary

This report is part of the "Task Two" project for BLM's coal leasing group in the High Plains District Office, Casper, Wyoming. This report is summarized by Table 1 which lists average estimated water pumpage rates for eleven northeast Wyoming watersheds with productive coalbed natural gas (CBNG) wells or projected future productive coalbed gas wells. Estimated annual pumpage rates from 2009 through 2030 range from less than one gallon per minute (gpm) to as much as 15 gpm. Through August 2010, a total of 843 thousand acre feet of water had been produced in the ten watersheds with productive CBNG wells (Figure 1). During the first eight months of 2010 an average of 0.39 acre feet of water per month (2.9 gpm) was produced by each producing CBNG well in the ten productive watersheds (Wyoming Oil and Gas Conservation Commission website, November 18, 2010).

Northeast Wyoming is one of the largest energy producing areas in the nation. It contains significant amounts of oil, natural gas, uranium, and especially low sulfur coal. Twenty percent of our nation's electricity is generated by low sulfur coal mined in northeast Wyoming. Figure 2 is a map of the northeast Wyoming watersheds included in this analysis. Large coal mines are present from 12 miles north of the city of Gillette to 20 miles south of the town of Wright, a total distance of 72 miles (Figure 2).

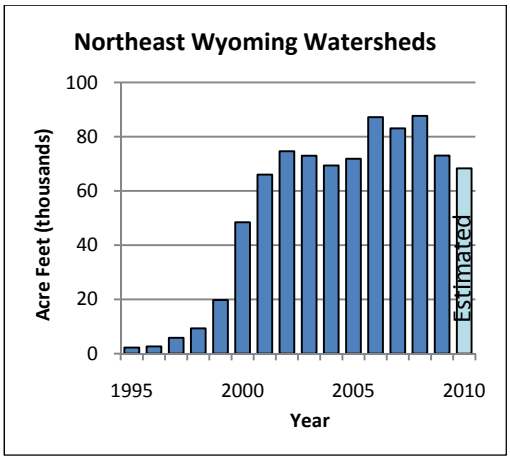


Figure 1. Annual water production from coalbed gas wells in ten northeast Wyoming watersheds. Data are from the WOGCC website.

Watershed and Coal Zone	2009	2010	2015	2020	2025	2030
Antelope Creek -- Wyodak	2.2	1.7	1.0	3.1	1.4	0.6
Antelope Creek -- Deep	15.0	13.1	10.4	10.9	9.7	7.9
Clear Creek -- Shallow	0.0	0.0	0.0	3.7	3.6	2.9
Clear Creek -- Wyodak	0.9	0.9	0.9	5.5	5.3	4.0
Clear Creek -- Deep	9.0	7.0	7.0	7.5	7.3	6.1
Crazy Woman Creek -- Shallow	0.0	0.0	4.7	2.4	3.7	3.0
Crazy Woman Creek -- Wyodak	3.6	3.8	7.3	3.1	6.1	4.4
Crazy Woman Creek -- Deep	9.2	9.3	9.5	4.1	7.3	5.5
Dry Fork Cheyenne River -- Deep	6.9	6.9	6.9	0.0	11.5	8.6
Lightening Creek -- Deep	0.0	0.0	0.0	0.0	13.0	9.5
Little Powder River -- Wyodak	1.5	1.6	1.5	4.3	2.3	2.4
Little Powder River -- Deep	2.1	2.1	2.1	4.0	2.6	2.7
Middle Powder River -- Wyodak	1.1	1.1	1.6	1.4	1.3	1.3
Middle Powder River -- Deep	3.6	3.6	3.9	2.9	2.6	2.7
Upper Belle Fourche River -- Shallow	1.6	1.6	1.6	0.0	0.0	0.0
Upper Belle Fourche River -- Wyodak	1.2	1.0	0.9	5.1	2.0	1.0
Upper Belle Fourche River -- Deep	4.3	3.6	2.4	12.7	6.6	3.2
Upper Cheyenne River -- Wyodak	1.5	1.5	1.5	13.5	2.6	0.7
Upper Powder River -- Shallow	2.0	2.3	2.4	3.2	3.0	2.2
Upper Powder River -- Wyodak	3.5	3.8	3.3	3.9	3.6	2.0
Upper Powder River -- Deep	6.4	6.6	5.5	5.2	4.8	2.7
Upper Tongue River -- Wyodak	3.7	3.7	4.1	4.7	4.4	3.5
Upper Tongue River -- Deep	2.2	2.2	2.7	6.5	6.3	5.8

Table 1 Summary of average annual estimated pumpage rates per well in gallons per minute for selected years from 2009 through 2030. Estimates for years 2010 and following were calculated using existing and projected wells. Where data allowed, regression lines through normalized historical production data for each watershed were calculated and used to predict average well performance. Data were compiled and modeled from WOGCC well data and IHS Inc. well and production data.

A draft report estimating future pumpage rates for six drainage basins (watersheds) in Northeast Wyoming was completed in 2007 (Crockett, 2007). Pumpage rates were estimated through the year 2020 based on production history. The 2007 report included information on coalbed gas production and well economics. This report does not. However, this report is more rigorous in its estimate of future water pumpage rates. It updates, revises, and adds detail to the previous study. This report estimates average pumpage rates based on well type curves and well number estimates for each producing coal horizon by year through 2030.

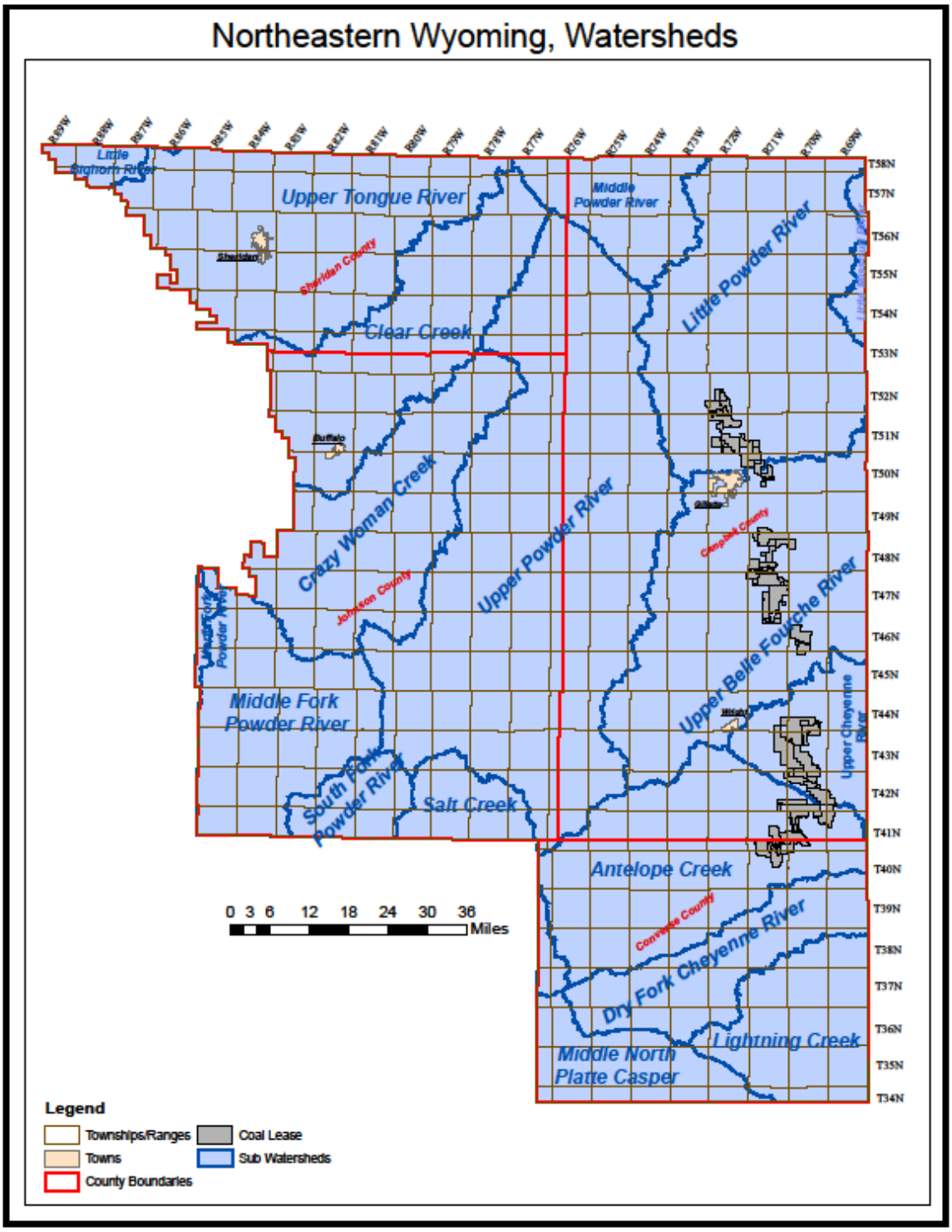


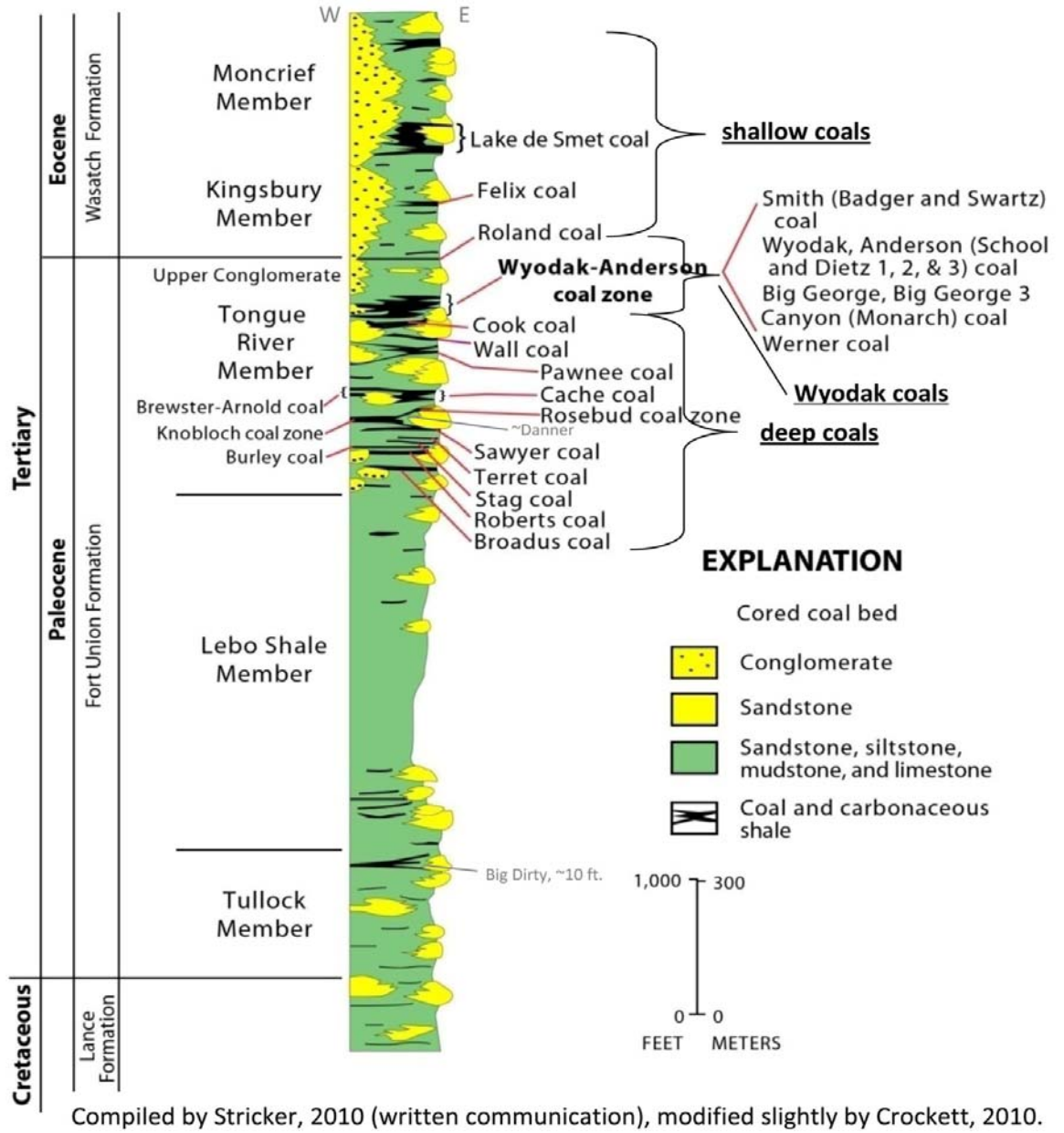
Figure 2. Map of the northeastern Wyoming watershed boundaries as used in this report. Major towns, county boundaries, and a township and range grid are shown for reference. Seventeen watersheds are shown. Federal Coal leases are also shown. Productive coalbed gas wells are present in ten watersheds. Map was compiled from BLM files.

In order to model ground water depletion as the projected development of CBNG continues through 2030, it is necessary to develop estimates of average pumpage rates for separate coal horizons. Previous estimates (Crockett, 2007) did not attempt to determine pumpage rates for separate horizons. Based on the work by Flores and others (2010a and 2010b) Tertiary age coals in northeast Wyoming were subdivided into deep, Wyodak, and shallow coal zones (Figure 3). It is the purpose of this report to provide average pumpage rates by year for each horizon. In this analysis water production from approximately 24,500 wells was separated by coal horizon. Further subdivision was not feasible due to time and budget constraints.

Coal Stratigraphy

Coal stratigraphy, gas content, and coal chemistry have been studied by Flores and others (1999, 2010a, and 2010b) and Stricker and others (2006, 2007). Water chemistry has been studied by Rice and others (2000). Longstanding coal correlation problems have recently been resolved by Flores and others (2010a and 2010b). This recent work allows coals (which were in some cases given inconsistent names by various coalbed gas well operators) to be correlated and identified within an overall coal stratigraphic framework. Details are given in U.S. Geological Survey Professional Paper 1777 (Flores and others, 2010b).

For this study coals were subdivided into zones groups, shallow, Wyodak, and deep (see Figure 3). Each zone contains several individual coal beds. The Wyodak coal zone is the primary water producing zone. It has produced nearly five times as much water as the shallow and deep zones combined. The Big George coal is included in Wyodak-Anderson zone. The name “Big George” as applied to coals by various coalbed gas operators and recorded in the IHS Inc. databases is not very useful because of inconsistent use (Flores, personal communication, 2010). It was not feasible to further subdivide the Wyodak-Anderson coal zone without a great deal more effort and cost. Shallow and deep coals are simply coals above and below the Wyodak zone as shown in Figure 3. Shallow coals are mostly Eocene age. Wyodak and deep coals are almost entirely Paleocene age. Continuity of coals varies greatly. Generally coals are more continuous north to south than east to west. General continuity and extent of individual



Compiled by Stricker, 2010 (written communication), modified slightly by Crockett, 2010.

Figure 3. Stratigraphic column of the coal bearing strata in the northeast Powder River Basin, Wyoming and Montana. The shallow, Wyodak, and deep coal intervals are identified. Completion intervals identified in well records were correlated into one of the three general coal zones shown in this stratigraphic section. Multiple completion intervals often covered more than one coal zone. The stratigraphic section was provided by Stricker (2010) with some modification by this author.

beds can be determined from the cross-sections in Flores and others (2010a and 2010b). Data are most abundant for Wyodak coals. The upper Wyodak coal can be traced in the subsurface for as much as 140 miles north to south and 50 miles east to west (2010b). Although the Lake de Smet coal (shallow coal) is over 200 feet thick locally, shallow coals are generally less thick and less continuous than deep coals. Deep coals are less thick and less continuous than

Wyodak coals. Flores and others (2010b) contains a great deal of information about coal thickness, continuity, and correlations across the Powder River Basin.

Previous Work

A previous compilation of pumpage rates was documented in a draft report dated January 5, 2007 (Crockett, 2007). Only six watersheds were reviewed. Water production data through October 2006 was used. Future pumpage rates were estimated by plotting water production data on a time-rate graph and observing the decline in the average gallons per minute per well for each of the six watersheds. Initially pumpage rates generally were high and erratic, then declined to a relatively stable rate of two to five gallons per minute per well. There was no attempt to construct type curves. For most watersheds it is unlikely that there was enough water production history to construct reliable type curves. Additionally, there was no attempt to separate coals into specific zones. Stratigraphic correlations which allow coals to be reliably segregated into zones were not completed until late 2009 (Flores and others, 2010a).

Procedure

A list of CBNG wells in northeast Wyoming (the Powder River Basin) were downloaded from the Wyoming Oil and Gas Conservation Commission (WOGCC) website and digitally plotted on the map shown in Figure 2. Then through the use of Geographic Information System analysis the CBNG wells were assigned to the appropriate watersheds. Only ten watersheds contained wells. American Petroleum Institute numbers for wells in each of the ten watersheds were then extracted and used to query the IHS Inc. well and production databases. Data from the IHS well and production databases were used for most of the analysis presented in this report. The same data are available from the WOGCC but is much more difficult to access in massive quantities than from IHS databases.

1.00	gallon/minute
34.3	barrels/day
5.45	cu m/day
1,044	barrels/month
0.135	acre feet/month
0.00223	cu ft/second
0.000631	cu m/second

Table 2. Commonly used water flow rates. Each value in the left column is equivalent (assumes 30.44 days per month).

In this report, water pumpage rates are listed in gallons per minute. Other rates and volumes are frequently used (Table 2). Produced water volumes from CBNG wells are reported in barrels (42 gallons) per month to the Wyoming Oil and Gas Conservation Commission.

Estimates of future pumpage rates were calculated using type curves based on normalized historic water production. A regression line was used to smooth the data. Type curves were used to calculate per well annual pumpage rates over a nine year well life (Table 1 and Appendix A). A nine year well life was used based on analysis of slightly over 7,000 wells (Appendix A). These annual per well pumpage rates were then combined with historical water production data and projected well numbers to calculate average annual per well pumpage rates and total annual pumpage rates for specific coal horizons and watersheds. Total pumpage rates for individual coal zones and watersheds were calculated by simply multiplying the per well pumpage rate by the number of producing wells for each year. Graphs of all the type curves and smoothing algorithms are listed in Appendix A. Coal zones with inadequate data to construct a reliable type curve are identified, and substitute type curves are listed.

Producing well numbers were determined by AECOM (2010). The total number of new wells to be drilled through 2030 was determined from the Buffalo and Casper Resource Management plans. A total of 15,223 new wells are projected to be drilled from 2009 through 2030. In addition, AECOM (2010) identified a total of 1,829 now idle wells which it projected to be started or restarted. Each idle well was treated as though it was a newly drilled well. Each well was given a well life of nine years. Including the idle wells adds about ten percent more water withdrawal wells and could result in a slight overestimate of the amount of coalbed gas well water withdrawn from watersheds in the Powder River Basin. However, this procedure avoids an underestimate of water withdrawal and therefore impacts. An underestimate of impacts could occur if a significant number of idle wells started producing water and were not included in the subsurface hydrologic modeling. BLM and AECOM scientists decided it was safer to err on the side of caution, and a slight overestimate of impacts would be more palpable than even a relatively small underestimate.

Data accuracy: The accuracy of produced water data is almost impossible to determine after the fact. Because of questions about the accuracy of produced water data, the Wyoming Oil and Gas Conservation Commission asked that water production from specific wells be measured and recorded for a 24 hour interval (Marvel, 2001). Water rates for 28 wells were measured by a flow meter. Based on the 24 hour volume, a monthly production total was estimated, then compared to reported water production. Estimated monthly water production was 83 percent of reported production. The subject wells are located in Ranges 71 through 73 West, and Townships 43, 44, 47, and 48 North. All wells were reported as producing from the Wyodak Coal.

Results of Current Analysis and Comparison with Previous Work

Pumpage rates calculated for this report are more rigorous and inclusive than the rates documented in the 2007 report (Table 3). The 2007 report simply projected historical rates into the future. Crockett (2007, figures 2 through 7 and Table 2) clearly shows that future water production was not modeled and was estimated to remain similar to 2006 or decline slightly, even though the total number of wells was estimated to eventually about double. Additional production data, better stratigraphic correlations, and revised future drilling estimates allow us to now calculate a more detailed, and more accurate estimate of reasonably foreseeable future actions. Table 4 allows the reader to

	<--- this report ---->			<--- 2007 report --->		
watershed	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**
Antelope Creek	2.1	2.3	5.6	2	2	2
Clear Creek	4.1	5.9	5.1	no analysis		
Crazy Woman Creek	5.4	7.3	3.2	no analysis		
Dry Fork Cheyenne River	6.9	7.2	7.5	5	3	2
Lightning Creek	NA	NA	NA	no analysis		
Little Powder River	2.2	2.2	3.5	2	1	1
Middle Powder River	3.1	3.4	2.5	no analysis		
Upper Belle Fourche River	1.1	1.1	6.2	5	3	1
Upper Cheyenne River	1.5	3.3	13.1	2	2	1
Upper Powder River	4.2	3.8	3.8	5	4	2
Upper Tongue River	3.2	4.1	4.5	no analysis		

Table 3. Comparison of average pumpage rates between 2007 report and this report for all coal zones, in gallons per minute for key years. Note the substantial differences. These are due to the current modeling approach on a year by year basis instead of a simple projection of pumpage rates from historical declines.

compare estimated future water production rates suggested in this report with those listed in the 2007 report.

Tables 4, 5, and 6 show projected average annual pumpage rates in gallons per minute for all the watersheds. Percentages are listed at the bottom of the tables, and may not add to 100 percent due to rounding. Projected average annual pumpage rates by coal horizon for an entire watershed help set a limit for water withdrawal rates during the subsurface hydrology modeling process. Total rates for entire watersheds were calculated by simply multiplying the average annual per well pumpage rates by the projected number of active wells. Total pumpage rates for all shallow coal zones in the entire watershed are listed in Table 5. Shallow coals have a relatively small proportion of the overall water production. Total water pumpage rates from Wyodak coals are shown in Table 6. The Wyodak coal zone was the first productive interval developed in the Powder River Basin. Many wells which produced from this interval are depleted and will

Shallow Coals Zone -- Total Pumpage Rate in GPM for Key Years					
Watershed	**2010**	**2015**	**2020**	**2025**	**2030**
Clear Creek	0	602	434	597	1,142
Crazy Woman	0	43	24	26	77
Upper Belle Fourche	118	117	394	245	116
Upper Powder River	35	62	114	151	67
Upper Tongue River	0	85	43	0	0
Totals for all watersheds	154	911	1,008	1,018	1,402
Percent of annual water from all watersheds	0.3%	2.3%	3.8%	2.8%	4.6%

Table 4. Total water pumpage rates in gallons per minute for all watersheds with projected production from shallow coal zones.

Wyodak coals zone -- Total Pumpage Rate in GPM for Key Years					
Watershed	**2010**	**2015**	**2020**	**2025**	**2030**
Antelope Creek	2,076	755	1,053	573	140
Clear Creek	116	380	350	998	1,779
Crazy Woman Creek	328	1,335	466	844	2,157
Little Powder River	666	388	358	313	294
Middle Powder River	187	309	267	162	124
Upper Belle Fourche River	2,225	515	831	867	325
Upper Cheyenne River	130	43	562	97	6
Upper Powder River	23,290	20,379	11,352	15,128	5,334
Upper Tongue River	1,543	1,491	1,197	2,702	4,910
Totals for all watersheds	30,561	25,595	16,437	21,685	15,068
Percent of all annual water from all watersheds	69.0%	63.5%	62.0%	60.5%	49.6%

Table 5. Total water pumpage rates in gallons per minute for all watersheds with projected production from Wyodak coal zones. Note the relative decrease in water from Wyodak coals over time.

be plugged and abandoned during the next few years.

Table 7 lists total water production from deep coals. There are sizeable areas in the Powder River Basin where deep coals have not been adequately tested. Deep coals are projected to produce proportionately more water than stratigraphically shallower coals. Note that water from deep coals is projected to increase from 30 percent to 45 percent of total water production as additional wells are drilled in areas where there relatively little development of deep coals.

Deep coals zone -- Total Pumpage Rate in GPM for Key Years					
Watershed	**2010**	**2015**	**2020**	**2025**	**2030**
Antelope Creek	542	1,149	2,279	2,569	972
Clear Creek	1,476	1,414	786	2,700	5,357
Crazy Woman Creek	433	1,917	747	1,523	4,073
Dry Fork Cheyenne River	152	80	8	854	836
Lightning Creek	0	0	0	221	388
Little Powder River	1,008	485	204	148	134
Middle Powder River	2,265	2,223	1,283	753	569
Upper Belle Fourche River	118	117	394	245	116
Upper Cheyenne River	0	0	0	0	0
Upper Powder River	7,553	6,408	3,359	4,145	1,473
Upper Tongue River	3	4	5	5	4
Totals for all watersheds	13,551	13,797	9,064	13,162	13,921
Percent of all annual water	30.6%	34.2%	34.2%	36.7%	45.8%

Table 6. Total water pumpage rates in gallons per minute for all watersheds with projected production from deep coal zones. Note the relative increase in water from deep coals over time.

Appendices

Appendix A contains a graph of the normalized data and regression line used for each type well. Coal zones with insufficient data to reliably construct a type well curve are identified. General water volumes and rates for each watershed and coal zone are listed. Appendix B contains graphs of historical and projected water withdrawals by watershed and coal zone. Discontinuities between historical and projected data are briefly explained.

Frederick J. Crockett 12-1-2010
Petroleum Geologist
Reservoir Management Group
Wyoming State Office, BLM

References

AECOM, (2010), written communication, BLM Contractor for Task II report, Fort Collins, Colorado.

Crockett, Fred (2007), Estimated Pumpage Rates for Six Drainage Basins in the Powder River Basin, Wyoming, 15 pp., internal BLM draft report dated January 5, 2007.

Flores, Romeo M., Brianne D. Spear, Scott A. Kinner, Peter A. Purchase, and Craig M. Gallagher, (2010), After a Century – Revised Subsurface Stratigraphic Framework of the Fort Union and Wasatch Formations, Powder River Basin, Wyoming and Montana, Open-File Report 2010–1061.

Flores, Romeo M., Brianne D. Spear, Scott A. Kinner, and Craig M. Gallager, (2010), After a Century – Revised Paleogene Coal Stratigraphy, Correlation, and Deposition, Powder River Basin, Wyoming and Montana, U.S. Geological Survey Professional Paper 1777, 97 pp.

IHS Inc., (2010) Well and Production databases.

Marvel, Rick, (2001), personal communication.

Rice, C.A., Ellis, M.S.1, and Bullock, J.H., Jr., (2000), Water co-produced with coalbed methane in the Powder River Basin, Wyoming: preliminary compositional data, Open-File Report 00-372.

Stilwell, Dean P. and Fred Crockett, (2005),Final - Reasonable Foreseeable Development Scenario for Oil and Gas, Casper Field Office, Wyoming, February 3, 2005, 160 pp., BLM Casper Field Office, available online at: http://www.blm.gov/style/medialib/blm/wy/programs/planning/rmps/casper/docs.Par.27322.File.dat/03_rfd.pdf .

Stilwell, Dean P., Stan W. Davis-Lawrence, Alfred M. Elser, and Frederick J. Crockett, (2009), Draft - Reasonable Foreseeable Development Scenario for Oil and Gas, Buffalo Field Office Planning Area, Wyoming, June 12, 2009, 98 pp., available online at: http://www.blm.gov/style/medialib/blm/wy/programs/planning/rmps/buffalo/docs/rfd.Par.69667.File.dat/01_text.pdf .

Stricker, Gary D., Romeo M. Flores, Dwain E. McGarry, Dean P. Stillwell, Daniel J. Hoppe, Cathy R. Stillwell, [sic] Alan M. Ochs, Margaret S. Ellis, Karl S. Osvald, Sharon L. Taylor, Marjorie C. Thorvaldson, Michael H. Trippi, Sherry D. Grose, Fred J. Crockett, and Asghar J. Shariff, (2006), Gas Desorption and Adsorption Isotherm Studies of Coals in the Powder River Basin, Wyoming and Adjacent Basins in Wyoming and North Dakota, U.S. Geological Survey Open-File report 2006-1174, 21 pp.

Stricker, Gary D. , Romeo M. Flores, Michael H. Trippi, Margaret S. Ellis, Carol M. Olson, Jonah E.

Sullivan, and Kenneth I. Takahashi, (2007), Coal Quality and Major, Minor, and Trace Elements in the Powder River, Green River, and Williston Basins, Wyoming and North Dakota, Open-File Report 2007–1116, 31 pp.

Wyoming Oil and Gas Conservation Commission website (2010).

Appendix A

Type Curves for Water Production from Coal Zones for

Ten Watersheds in Northeast Wyoming

Regression curves drawn through type well production data were used to predict future water pumpage rates from coalbed gas wells. A total of 18 type curves were constructed, one for each watershed and each horizon where there were sufficient data. A smoothing function (regression line) was then applied using Microsoft Excel. Equations for the regression lines by watershed are listed in Table A-1. Where reliable water production data were insufficient to construct a type curve and regression line, a type curve from an adjacent watershed was used.

An average well life of nine years was calculated for type wells based on the average economic life of slightly over 7,000 coalbed gas wells. The previous pumpage report (Crockett, 2007) used a seven year well life. As the play progressed westward, deeper wells were drilled. Those deeper wells have a slightly longer well life. Wells drilled earlier, on the east side of the play, are shallower and have a shorter well life. The longer well life is reflected in the available data.

Normalized produced water data were used to construct type curves. Productive coalbed gas wells were separated by producing coal interval (shallow, Wyodak, and deep) and by watershed. Monthly produced water data were normalized using Power Tools software. Normalization was done by adjusting monthly production data for each well to a common starting time (month and year). Months with zero production were not deleted. The monthly data were then converted from barrels per year to gallons per minute and an average annual rate was calculated. The average annual data were then plotted sequentially. A trendline through annual production data was then drawn using Microsoft's Excel software. A regression equation and r^2 value were calculated by Excel. Regression equations are listed in Table A-1 and the generalized forms are listed in Table A-2.

A parametric regression was used. The type curve should show declining rates of water production. Exponential, linear, logarithmic, and power regression equations were attempted in almost every case. The r^2 value was used to determine how closely the trend line corresponds to the normalized data. Logarithmic equations generally provided the highest r^2 values and matched the data as well or better than the other equations. In cases where the logarithmic equation did not provide the best correlation, it was often because the logarithmic algorithm predicted a pumpage rate decline to

$y = m \ln(x) + b$	Logarithmic
$y = b\, x^m$	Power function
$y = b\, e^{mx}$	Exponential

Table A-2. Regression equations used to smooth type curve data. In these equations "y" is the pumpage rate, "x" is the year (1, 2, 3, . . . 9), m and b are constants, and e = 2.71828183 .

near or below zero in the ninth year. This logically could not be the case. Logarithmic equations or power function equations usually produced the highest r^2 value.

After the appropriate equation was determined, that equation was used to calculate pumpage rates over the nine year life of each type well. Equations and the r^2 factors are listed in Table A-1. This procedure helped smooth the data and provide reasonable forward looking pumpage rates. Three watersheds contained too little data, or no data, for coal intervals which are predicted to be productive. In these instances a type curve from an adjacent watershed was used. A total of 18 type curves are listed for the shallow, Wyodak and deep coal zones. In every case but three the r^2 value is greater than 0.900. Before the projected water pumpage rates were calculated the data points from the type wells were reviewed to determine whether or not they were reliable.

In the normalized data the maximum number of data points is always first. In subsequent years (years two through nine) the number of data points generally decreased. The most reliable data were in year one with fewer data points and generally less reliable data in subsequent years. As a quality control measure, the percent of the maximum number of productive wells (wells in year one) for each coal zone in each watershed was calculated and displayed on the graphs. Portions of the type curve which used less than about 10 percent of the maximum number of productive wells was often times suspect. If the water production rate seemed erratic and there were relatively few wells used to calculate the data point, that data point was not used. This frequently happened where most of the wells had been producing only a few years. In six watersheds no additional wells are predicted. No type curves were calculated for these watersheds.

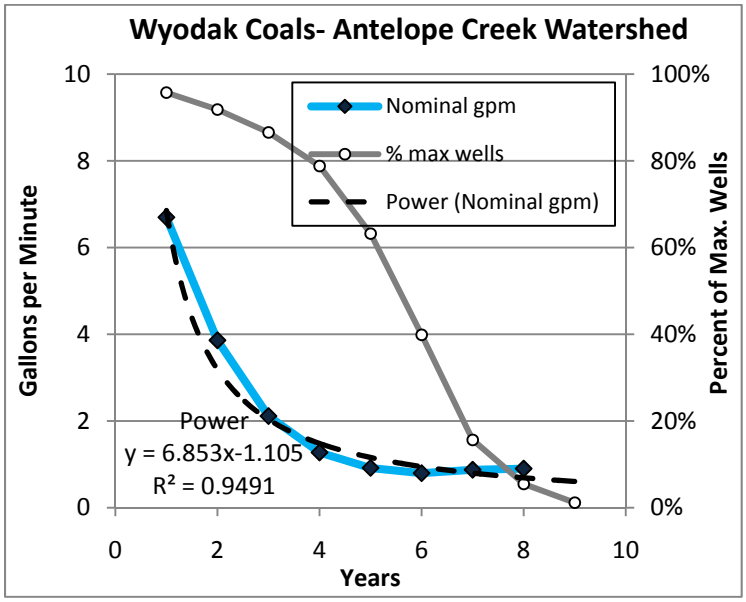


Figure A-1. Antelope Creek Watershed, Wyodak Coal. Maximum producing wells for normalization is 1192. Data were compiled from the IHS Inc. production database.

<u>Antelope Creek Watershed:</u> The Antelope Creek Watershed includes parts of Converse and Campbell counties. Although most of the acreage is in Converse county, most of the wells are in Campbell County. Most wells produce from Wyodak coals. No wells have produced from shallow coals and

only five wells have been completed in deep coals.

A total of 1,342 productive wells have been completed in Wyodak coals. Average depth is 782 feet. A total of 29,095 acre feet of water (22 acre feet per well) has been produced from the Wyodak coals interval. Figure A-1 shows eight years of normalized water production data for the Wyodak Coal producing zone. A graph of the relative number of wells by year used to calculate the normalized data is also shown. A dashed regression line (power equation) is displayed and extended to year nine. The equation of the regression line is displayed in the lower left hand corner of the graph.

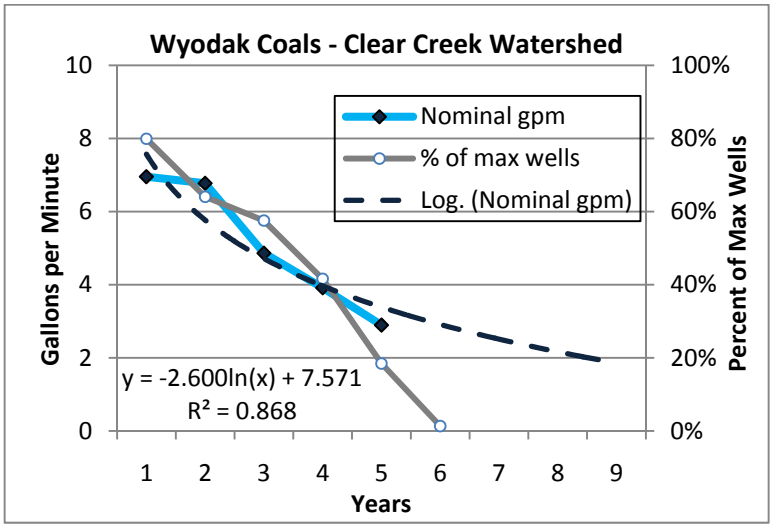


Figure A-2. Clear Creek watershed, Wyodak coals. Although there are only five reliable data points a logarithmic regression line was used as a type curve. Data were compiled from IHS Inc. production database.

Limited data are available for deep coals in the Antelope Creek watershed. Only five wells have been drilled. Their average depth is 1,756 feet. Total water production is 104 acre feet (21 acre feet per well). Data are insufficient to calculate a reliable type curve. The modeled type curve for the Dry Fork Cheyenne River watershed was used to predict pumpage rates for additional wells drilled to deep coal zones in the Antelope Creek watershed. The Dry Fork Cheyenne River watershed is south and adjacent to the Antelope Creek watershed.

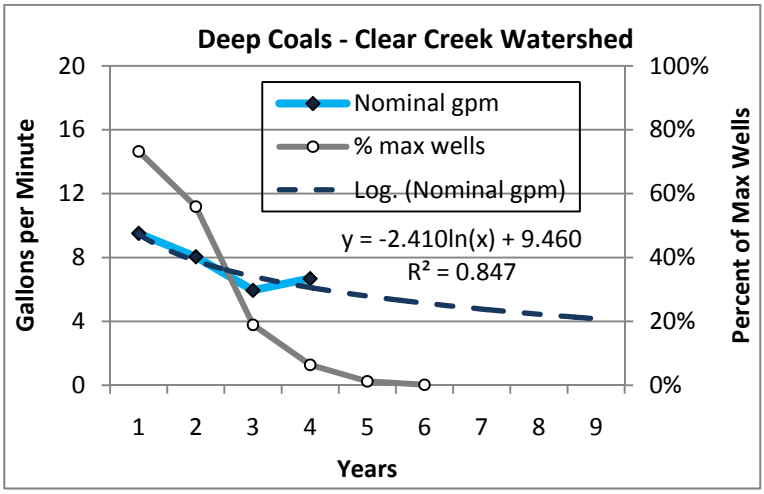


Figure A-3. Clear Creek watershed, deep coals. A logarithmic regression line was used even though only three reliable data points were available. The r^2 value seems to be acceptable. Data were compiled from IHS Inc. production database.

<u>Clear Creek Watershed:</u> The

Clear Creek watershed produces from all three coal horizons (shallow, Wyodak, and deep). It has a larger proportion of shallow wells (23 percent) than any other watershed.

Average well depth for wells completed in the shallow coals is 793 feet. Through 2009, 129 wells had been drilled. Additionally, nine wells produced from shallow coals commingled with Wyodak coals. Water production from shallow coals totaled 1,119 acre feet (nine acre feet per well). Unfortunately, coal dewatering has not been sufficient to establish a type curve. Shallow coal wells produced sporadically from 2002 through 2007. For years where reliable data appear to be available (2002 and 2005), wells produced an average of fewer than ten days per month in most cases. Water production did not appear to decline significantly. Shallow coal production from the Clear Creek watershed ended in September 2007.

It does not appear that the coalbed gas potential in shallow coals has been adequately tested in the Clear Creek watershed. The shallow coals type curve from the Upper Powder River watershed was used as a model to estimate future average pumpage rates for shallow coals in the Clear Creek watershed.

Average total depth of wells completed in the Wyodak coals is 1,488 feet. Through 2009 there were 159 productive wells drilled in the Wyodak coals. Total water recovery through 2009 is 3,181 acre feet (20 acre feet per well). Water production from Wyodak coals was modeled using a logarithmic equation (Figure A-2). Five reliable data points were available for the Wyodak coals. The regression line is similar to the Crazy Woman Creek, Upper Tongue River, and Upper Powder River watersheds

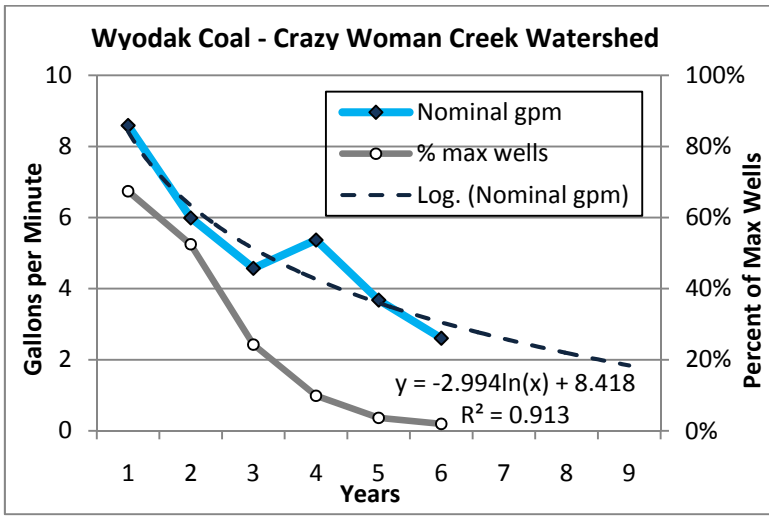


Figure A-4. Crazy Woman Creek Watershed, Wyodak coals. A maximum of 114 wells were used to determine normalized production, as many as 10 may have been commingled with deep coals. A maximum of three wells were used to calculate the data point for year six. The year six data point seems to follow the trend therefore it was not removed and was used to calculate the regression line. Data were compiled from IHS Inc. production database.

Two-hundred eighty six wells were productive from deep coals. Only four data points are available however. The yearly values of the regression line are similar to deep coal regression lines for both the Crazy Woman Creek and Upper Tongue River watersheds, and only moderately higher than the regression line for deep coals in

the Upper Powder River watershed. The average depth for wells productive from deep coals is 1,772 feet. Deep coal wells produced 5,372 acre feet of water (28.1 acre feet per well) through December 2009. Twenty two wells in the Clear Creek Watershed were completed in both the Wyodak and deep coals. Figures A-2 and A-3 show annual normalized water production and regression lines for the Clear Creek watershed.

Crazy Woman Creek Watershed: Productive wells were completed in all three coal horizons in the Crazy Woman Creek watershed. Five wells were completed in shallow coals, but produced only five months. A total of 1.3 acre feet of water (0.3 acre feet per well) was produced from shallow coals. Projected water production from shallow coals was calculated using the type curve for shallow coals in the Upper Powder River watershed.

Pumpage rates and projections for Wyodak coals in the Crazy Woman Creek watershed are shown in Figure A-4. Six reliable data points were used as the basis of a logarithmic regression line. Data points for years five and six were calculated from a maximum of only eight wells. Total water production from the Wyodak coals interval is 1,510 acre feet (14 acre feet per well). The average total depth for Wyodak wells in the Crazy Woman Watershed is 2,079 feet.

A total of 49 wells (10 commingled with the Wyodak interval) were completed in deep coals in the Crazy Woman watershed. Average depth of the wells is 2,116 feet. Total water production from deep coals is 981 acre feet (20 acre feet per well). Water production has not declined significantly, therefore, a type curve could not be determined. During November 2009, there were 12 wells producing from deep coals in the Crazy Woman Creek watershed. The type curve for deep coals in the Clear Creek watershed was used to calculate pumpage rates for projected wells completed in deep coals in the Crazy Woman Creek watershed.

Dry Fork Cheyenne River watershed: The Dry Fork Cheyenne River watershed is located in the southeast corner of the coalbed gas play area. Only 24 wells have been drilled in this watershed. All were completed in deep coals.

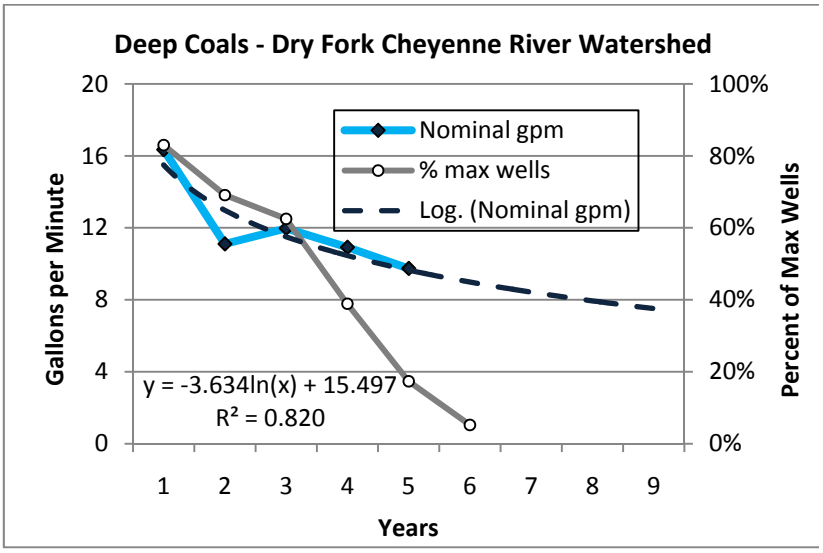


Figure A-5. Type curve for the Dry Fork Cheyenne River watershed. Normalized production data from 24 wells were used to construct the type curve. Data were compiled from IHS Inc. production database.

Future development will probably not occur until areas which now have existing infrastructure are more fully developed. Average well depth is 1,776 feet. Water production data provide five reliable data points, enough to support a logarithmic regression line (Figure A-5). Water production data from all 24 wells were used to construct the type curve. Total water production from the watershed is 1,349 acre feet (61 acre feet per well). During November 2009, 11 wells were producing from the watershed.

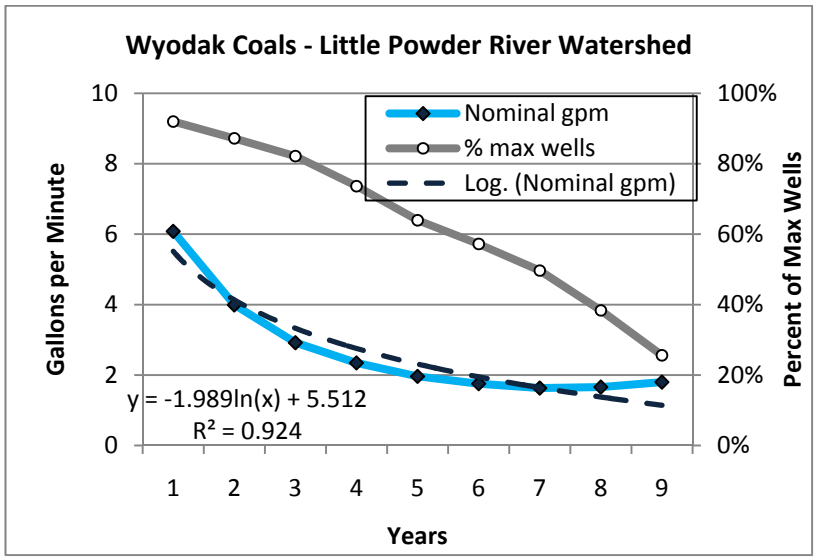


Figure A-6. Wyodak coals in the Little Powder River watershed. Nominal data show a slight increase in the pumpage rate for year nine. Maximum productive wells was 1,113. Data were compiled from IHS Inc. production database.

Lightening Creek Watershed: No wells have been drilled in the Lightening Creek watershed and none are projected until 2024. Only deep coals are considered prospective. The deep coals type well from Antelope Creek watershed was used to project pumpage rates for the Lightening Creek watershed. Average depths will probably be slightly less than those in the adjacent Dry Fork Cheyenne River watershed.

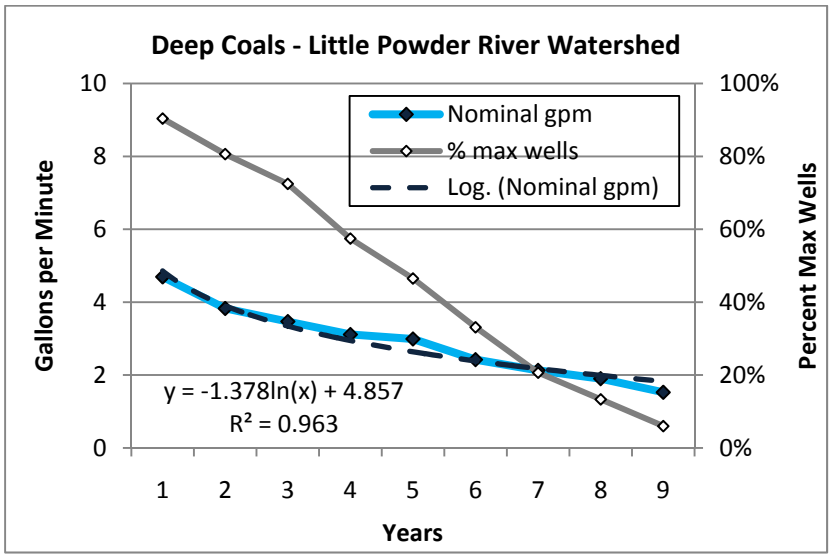


Figure A-7. Type curve for wells completed in deep coals in the Little Powder River Watershed. Maximum wells is 1,113. Data were compiled from IHS Inc. production database.

Little Powder River Watershed: Over 3,300 productive wells have been drilled in the Little Powder River watershed. The wells are distributed

one-third in deep coals and two-thirds in Wyodak coals.

Wells completed in Wyodak coals average 612 feet deep. The wells are concentrated in the western fourth of the watershed. Figure A-6 shows the data for the Wyodak coals type well. Water production through December 2009 for Wyodak coals totaled 62,433 acre feet (36.1 acre feet per well). A logarithmic equation was used to model the type well. Nine data points were used to calculate the regression line(r^2=0.924).

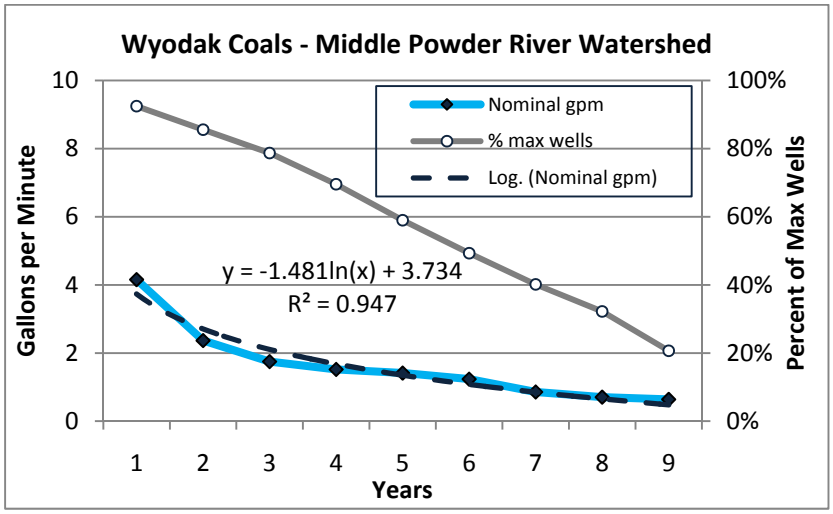


Figure A-8. Type curve for wells completed in the Wyodak coals in the Middle Powder River Watershed. Normalized production data from 556 wells were used to construct the type curve. Data were compiled from IHS Inc. production database.

Eleven-hundred thirteen wells have been completed in deep coals. The wells average 826 feet deep. A total of 25,113 acre feet of water (29.4 acre feet per well) were produced from deep coals through December 2009. Nine data points were used to calculate the regression equation Figure A-7). The logarithmic equation models the data closely (r^2=0.963).

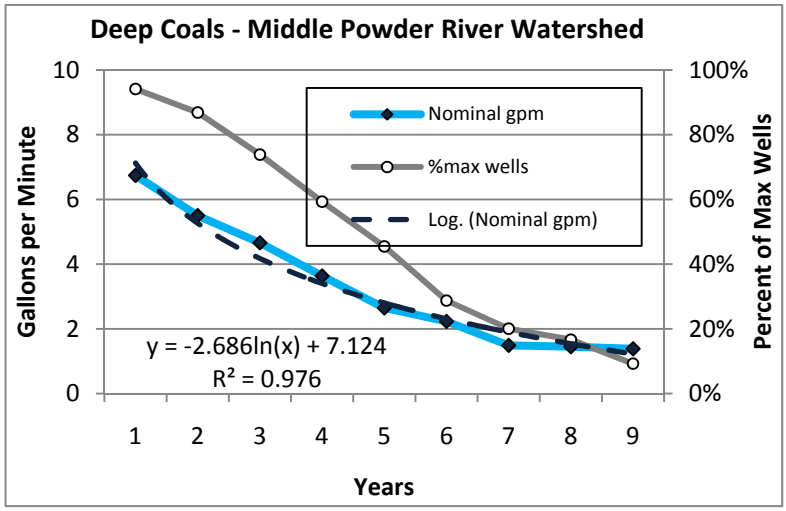


Figure A-9. Type curve for wells completed in the deep coals in the Middle Powder River Watershed. Normalized production data from 1,226 wells were used to construct the type curve. A logarithmic function was used to model the data. Data were compiled from IHS Inc. production database.

<u>Middle Powder River Watershed:</u> There have been 1,782 wells drilled in the Middle Powder River watershed. The wells are divided approximately 30 percent completed in Wyodak coals and 70 percent in deep coals.

Wyodak coals produced a total of 8,758 acre feet (22.8

acre feet per well) of water through December 2009. There were 301 producing wells in November 2009. Average TD for wells productive from the Wyodak coals is 602 feet. Figure A-8 shows the logarithmic equation used to model water production from deep coals in the Middle Powder River watershed.

Water production from deep coals totaled 35,626 acre feet (36.2 acre feet per well) through December 2009. There were 839 productive wells in November 2009. The average TD for wells productive from deep coals is 762 feet. A logarithmic equation was used to model water production from deep coals in the Middle Powder River watershed (Figure A-9).

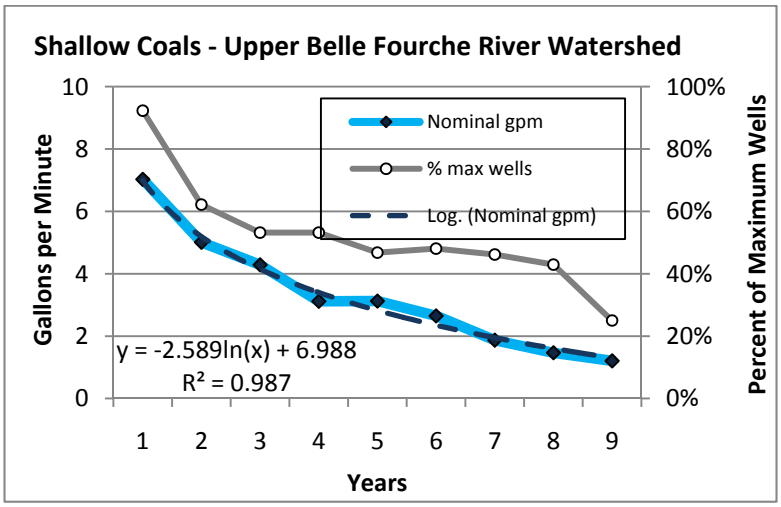


Figure A-10. Type curve for shallow coals in the Upper Belle Fourche watershed. Normalized production data from 13 wells were used to construct the type curve. A logarithmic function was used to model the data. Data were compiled from IHS Inc. production database.

<u>Upper Belle Fourche River Watershed:</u> A total of 6,736 productive wells have been drilled in the Upper Belle Fourche River watershed. Slightly over 98 percent of the wells were completed in the Wyodak coals.

Thirteen wells were completed in shallow coals. Their average depth is 634 feet, although the average depth of the nine shallowest wells is only 296 feet. The nine shallowest wells are all within T. 48 N., R. 73 W. The shallow wells have produced 316 acre feet (24 acre feet per well) of water through

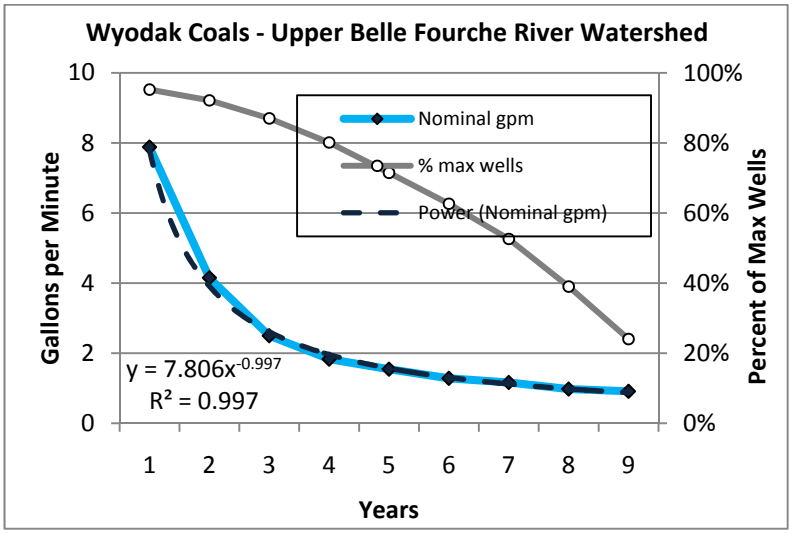


Figure A-11. Type curve for wells completed in the Wyodak coals in the Upper Belle Fourche River Watershed. Normalized production data from 6,655 wells were used to construct the type curve. A power function was used to model the data. Data were compiled from IHS Inc. production database.

December 2009. Three wells were still producing from shallow coals in November 2009. Although no shallow coals wells are predicted for the Upper Belle Fourche watershed, a type curve was constructed (Figure A-10). Wells completed in shallow coals have very poor coalbed gas recovery.

During November 2009 there were 2,577 wells producing from the Wyodak coals interval. Their average total depth is 932 feet. A total of 195,000 acre feet of water (38 acre feet per well) had been produced from the Wyodak coals interval through December 2009. Figure A-11 shows the type curve and regression line for Wyodak coals in the Upper Belle Fourche River watershed.

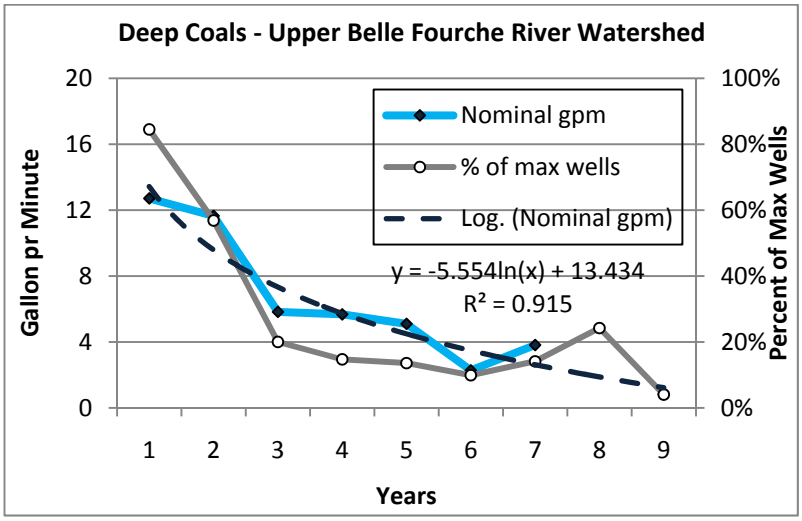


Figure A-12. Type curve for wells completed in the deep coals in the Upper Belle Fourche River Watershed. Normalized production data from 109 wells were used to construct the type curve. A logarithmic function was used to model the data. Data were compiled from IHS Inc. production database.

Only about 100 wells have been completed in the deep coals. Their average total depth is 1,073 feet, and they have cumulative production of 4,000 acre feet of water, which is an average of 59 acre feet per well. Figure A-12 shows the type curve and regression line.

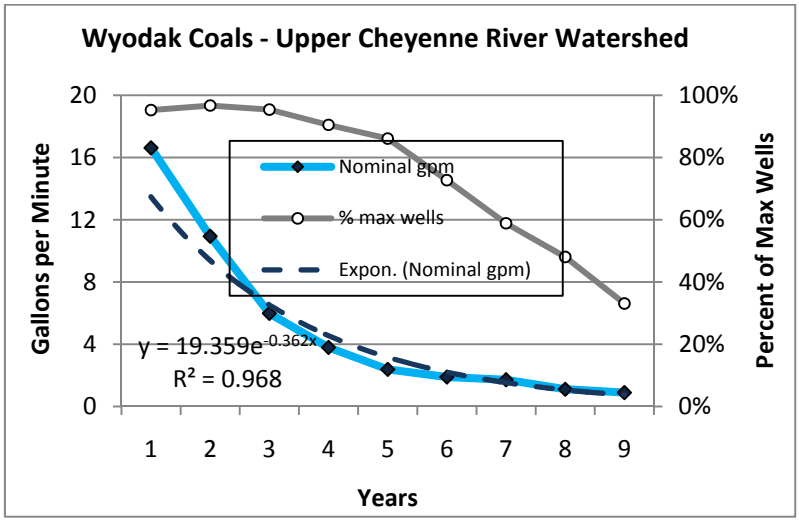


Figure A-13. Type curve for wells completed in Wyodak coals in the Upper Cheyenne River watershed. Normalized production data from 407 wells were used to construct the type curve. A power function was used to model the data. Data were compiled from IHS Inc. production database.

<u>Upper Cheyenne River Watershed:</u> Approximately 400 productive wells have been drilled in the Upper Cheyenne River watershed. All produce from Wyodak coals. Average depth for the

wells is 562 feet. Cumulative water production is 27,000 acre feet (71 acre feet per well). There were 160 producing wells in the Upper Cheyenne River watershed in November 2009. Figure A-13 shows the regression line used to model annual water production.

Upper Powder River Watershed: There have been 9,711 productive wells drilled in the Upper Powder River watershed, more wells than in any other northeast Wyoming watershed.

Sixty-one productive wells were completed in shallow coals. Figure A-14 shows the type well and regression line. Additionally 18 wells were completed in all three coal zones (shallow Wyodak and deep). Four wells were completed in only shallow and Wyodak coals. In no case was half or more of the net completion interval in shallow coals. Only the Clear Creek watershed has a greater number of coalbed gas wells completed in shallow coals than the Upper Powder River watershed. The average depth of wells completed entirely in shallow coals is 443 feet. Total water recovery from shallow coals through December 2009 was 1,860 acre feet (25 acre feet per well). During November 2009, there were 20 coalbed gas wells producing from shallow coals. Between February 2009 and October 2009, IHS Inc. records indicate

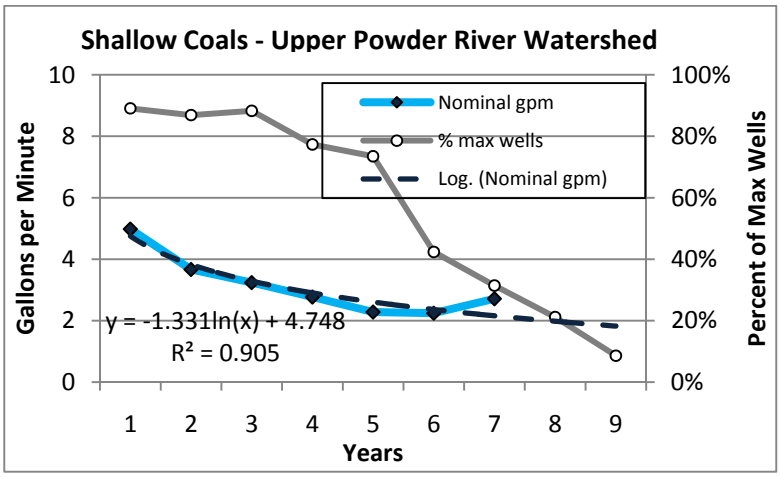


Figure A-14. Type curve for shallow coals. Normalized production data from 61 wells were used to construct the type curve. A logarithmic function was used to model the data. Data were compiled from IHS Inc. production database.

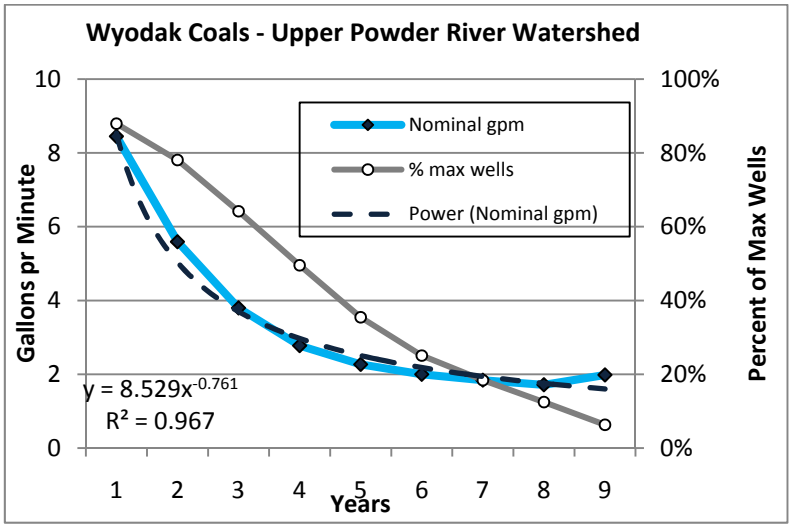


Figure A-15. Type curve for Wyodak coals. Normalized production data from 8,033 wells were used to construct this type curve. These wells include 149 wells which also produced from shallow and/or deep coals. A power function was used to model annual production data. Data were compiled from IHS Inc. production database.

51 productive wells were shut-in. Cumulative coalbed gas production from shallow coals in the Upper Powder River watershed is 17 million cubic feet per well, which is very marginal economically.

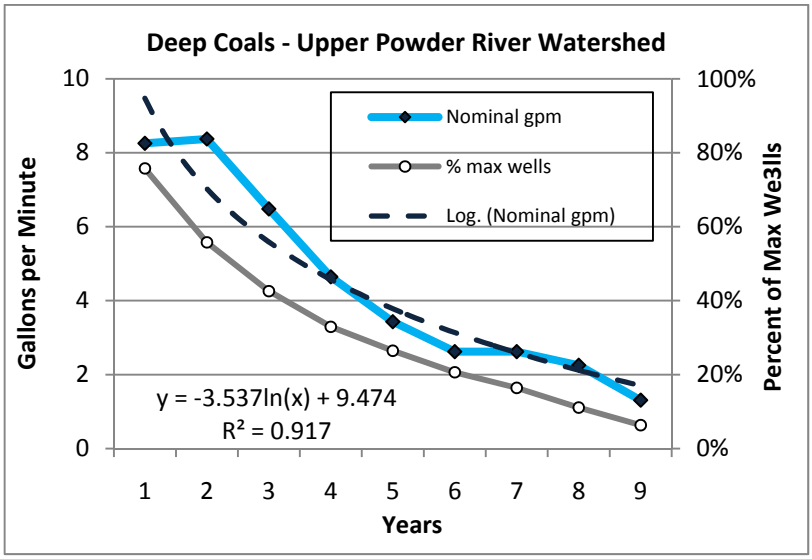


Figure A-16. Type curve for deep coals. Normalized production data from 1,669 wells were used to construct this type curve. These wells include approximately 246 wells which also produced from shallower coals. A logarithmic function was used to model annual production data. Data were compiled from IHS Inc. production database.

Wyodak coals in the Upper Powder River watershed have cumulatively produced 219,000 acre feet or water (34 acre feet per well) through December 2009. Average well depth for the Wyodak coals is 1,358 feet. During November 2009 there were 5,953 wells producing from the Wyodak coals in the Upper Powder River watershed. More wells produce from the Wyodak coals interval in the Upper Powder River watershed than from the Wyodak coals interval in any other watershed. Figure A-15 shows the type curve and regression line.

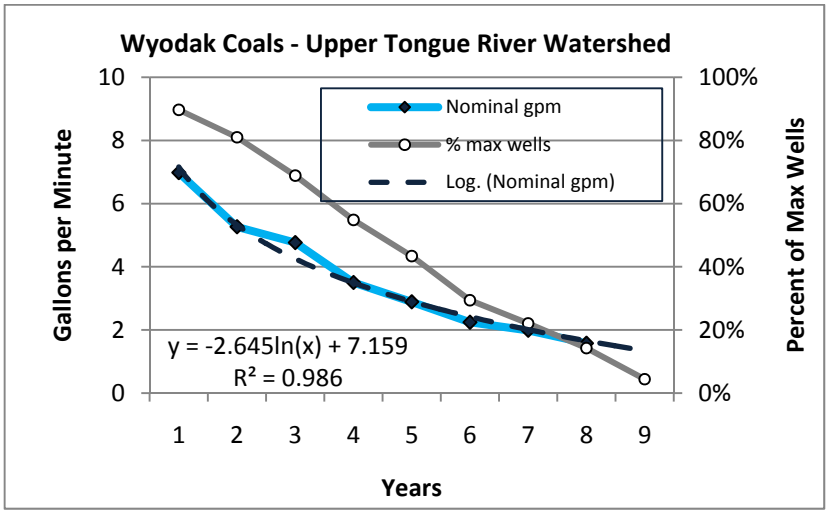


Figure A-17. Type curve for Wyodak coals in the Upper Tongue River watershed. Normalized production data from 615 wells were used to construct the type curve, including 151 wells which were also completed in deeper coals. A logarithmic function was used to model annual production data. Data were compiled from IHS Inc. production database.

Deep coals in the Upper Powder River watershed have cumulatively produced 45,000 acre feet of water (44 acre feet per well) through December 2009. Average well depth for the deep coals is 1,548. During November 2009 there were 861 wells producing

from deep coals. More wells produce from deep coals in the Upper Powder River watershed than in any other watershed. Figure A-16 shows the type curve and regression line.

Upper Tongue River Watershed: A total of 686 coalbed gas wells have been drilled in the Upper Tongue River watershed. Ninety were completed in deep coals, the remainder in Wyodak coals.

Wells completed in Wyodak coals have produced 16,000 acre feet of water (32 acre feet per well) through December 2009. The average well depth is 1,257 feet. During November 2009 there were 411 active wells producing from the Wyodak coals. Figure A-17 shows the type curve and regression line for water produced from Wyodak coals.

Wells completed in the deep coals have produced 3,000 acre feet of water (15.2 acre feet per well) through December 2009. Average well depth is 2,043 feet. During November 2009 there were 152 active wells producing from deep coals in the Upper Tongue river watershed. Figure A-18 shows the type curve and regression line for water production from deep coal in the Upper Tongue River watershed.

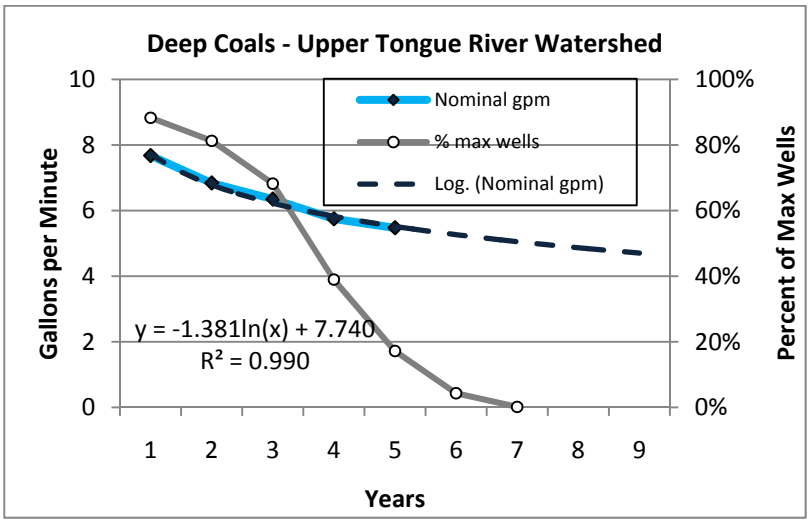


Figure A-18. Type curve for deep coals in the Upper Tongue River watershed. Normalized production from 242wells was used to construct the type curve. There were 19 wells which were also completed in Wyodak coals. A logarithmic function was used to model annual production data. Data were compiled from IHS Inc. production database.

Watersheds	Shallow Coals		Wyodak Coals		Deep Coals		Remarks
Antelope Creek	no data	no data	$y = 6.853x^{-1.105}$	$R^2 = 0.9491$	insufficient data		Dry Fork Cheyenne River watershed used for deep coals.
Clear Creek	insufficient data		$y = -2.600\ln(x) + 7.571$	$R^2 = 0.868$	$y = -2.410\ln(x) + 9.460$	$R^2 = 0.847$	Upper Powder River type curve used for shallow coals.
Crazy Woman Creek	insufficient data		$y = -2.994\ln(x) + 8.418$	$R^2 = 0.913$	insufficient data		Clear Creek used for deep coals and Upper Powder River used for shallow coals.
Dry Fork Cheyenne River	no data	no data	no data	no data	$y = -3.634\ln(x) + 15.497$	$R^2 = 0.820$	
Lightening Creek	no data	no data	no data	no data	no data	no data	Antelope Creek used for Wyodak coals, Dry Fork Cheyenne River used for deep coals.
Little Bighorn River	no data	no data	no data	no data	no data	no data	No wells are predicted for this watershed.
Little Powder River	no data	no data	$y = -1.989\ln(x) + 5.512$	$R^2 = 0.924$	$y = -1.378\ln(x) + 4.857$	$R^2 = 0.963$	
Middle Fork Powder River	no data	no data	no data	no data	no data	no data	No wells are predicted for this watershed.
Middle North Platte Casper	no data	no data	no data	no data	no data	no data	No wells are predicted for this watershed.
Middle Powder River	no data	no data	$y = -1.481\ln(x) + 3.734$	$R^2 = 0.947$	$y = -2.686\ln(x) + 7.124$	$R^2 = 0.976$	
North Fork Powder River	no data	no data	no data	no data	no data	no data	No wells are predicted for this watershed.
Salt Creek	no data	no data	no data	no data	no data	no data	No wells are predicted for this watershed.
South Fork Powder River	no data	no data	no data	no data	no data	no data	No wells are predicted for this watershed.
Upper Belle Fourche River	$y = -2.589\ln(x) + 6.988$	$R^2 = 0.987$	$y = 7.806x^{-0.997}$	$R^2 = 0.997$	$y = -5.554\ln(x) + 13.434$	$R^2 = 0.915$	
Upper Cheyenne River	no data	no data	$y = 19.359e^{-0.362x}$	$R^2 = 0.968$	no data	no data	Upper Belle Fourche type curve used for deep coals.
Upper Powder River	$y = -1.331\ln(x) + 4.748$	$R^2 = 0.905$	$y = 8.529x^{-0.761}$	$R^2 = 0.967$	$y = -3.537\ln(x) + 9.474$	$R^2 = 0.917$	
Upper Tongue River	no data	no data	$y = -2.645\ln(x) + 7.159$	$R^2 = 0.986$	$y = -1.381\ln(x) + 7.740$	$R^2 = 0.990$	Upper Powder River type curve used for shallow coals.

Table A-1. Summary of type well equations and r^2 values. These equations were used to model average annual pumpage rates for future production from northeast Wyoming watersheds. y = pumpage rate, x = incremental year (1,2,3,…, 9). Logarithmic equations seem to provide the best overall fit to the data as measured by the r^2 value.

Appendix B

Graphs of Historical and Projected Water Withdrawals by Watershed and Producing Horizon for Eleven Watersheds in Northeast Wyoming

Historical and projected pumpage rates are shown for each watershed and productive coal horizon. Cumulative totals for historical water production as well as projected figures for new and restarted wells and projected water production are listed in Table B-1. Projected future wells and projected idle well restarts were provided by AECOM (2010) and are within the projected well numbers given in BLM land use plans for the Buffalo and Casper field offices (Stillwell and Crockett, 2005, and Stilwell and others, 2009).

For the year 2009 there are both historical and projected pumpage rates. In most cases there is little difference between the two. Some graphs show a rather large difference however. The differences are due to projections which did not materialize. This should be expected when there are several forward looking estimates.

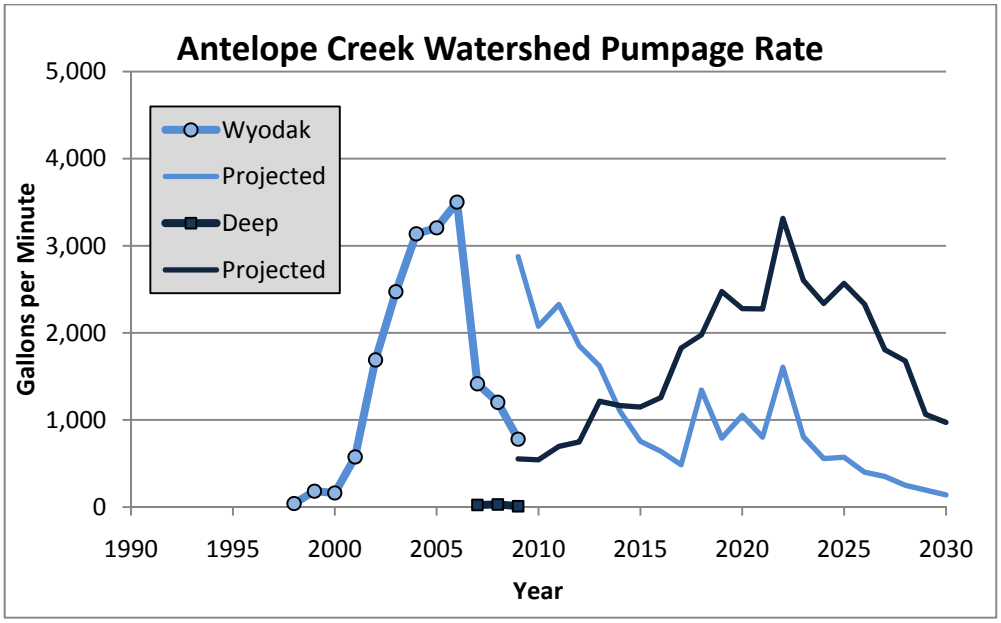


Figure B-1. A total of 29,745 acre feet of water have been produced, almost all of it from Wyodak coals. A total of 1,276 new wells (913 Wyodak and 363 deep) and 49 idle well restarts (39 Wyodak, 10 deep) are predicted. Future withdrawals are estimated to total 36,470 acre feet from the Wyodak zone and 59,415 from deep coals by the end of 2030.

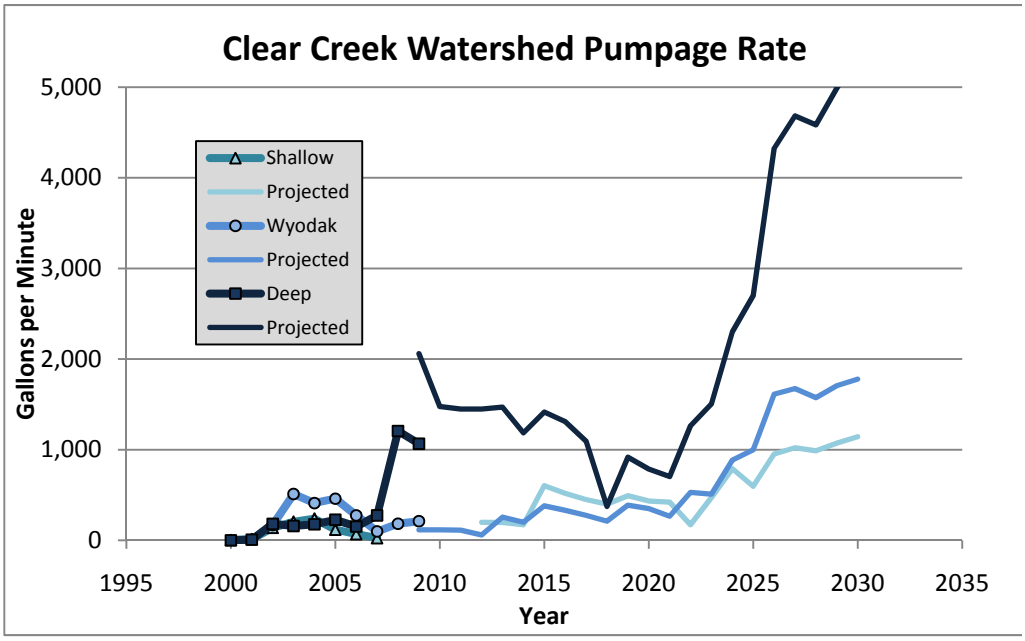


Figure B-2 A total of 9,672 acre feet of water have been recovered from this watershed and future withdrawals are estimate to total 117,481 acre feet by the end of 2030. A total of 1,842 new wells and 257 idle well restarts are predicted. See Table B-1 for details.

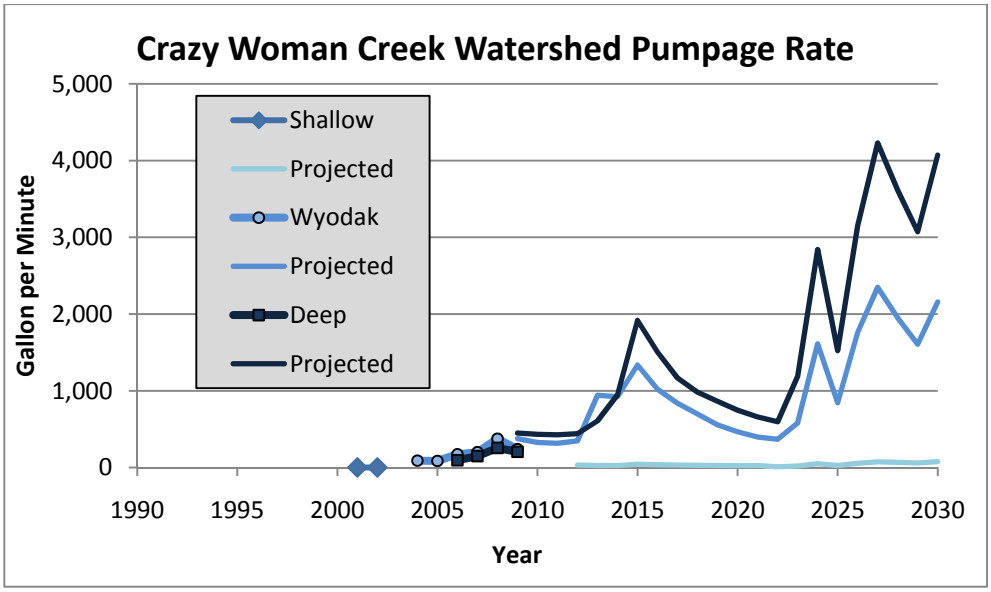


Figure B-3. A total of 2,492 acre feet of water have been recovered from this watershed and future withdrawals are estimated to total 93,514 acre feet through 2030. A total of 1,450 new wells and 192 idle well restarts are predicted. See Table B-1 for details.

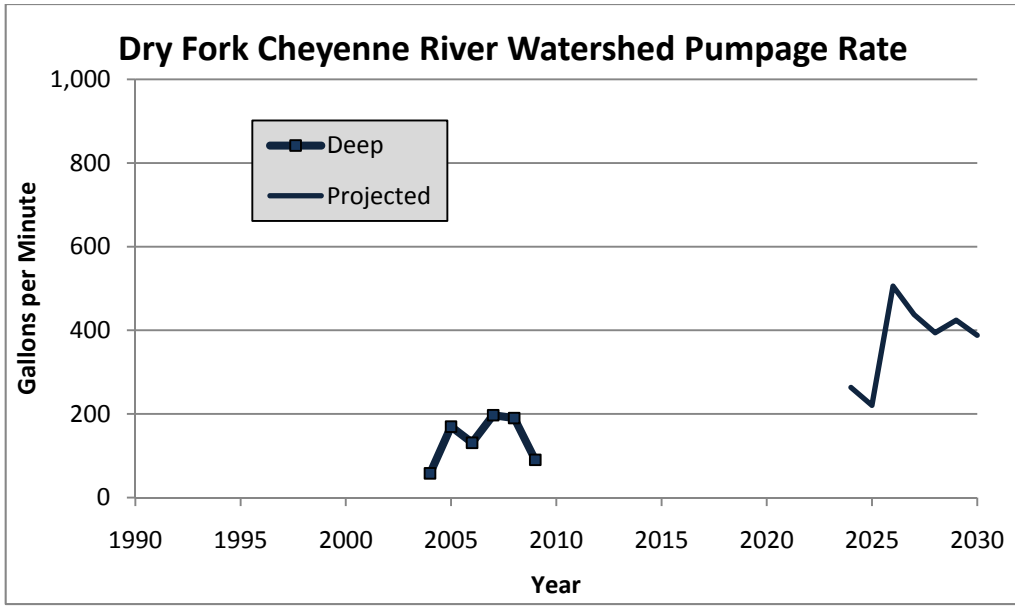


Figure B-4. A total of only 1,349 acre feet of water have been recovered from this watershed. Future withdrawals are expected to total 14, 342 acre feet by the end of year 2030. A total of 97 new wells and one idle well restart are predicted.

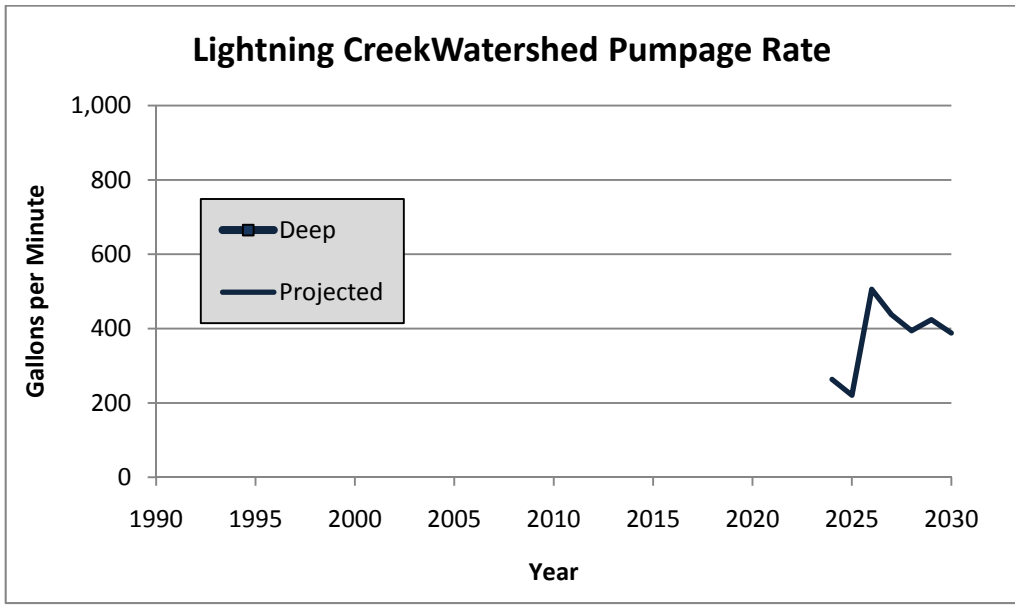


Figure B-5.No wells have been drilled in the Lightning Creek watershed. Total estimated withdrawal is 4,248 acre feet through year 2030. Only 41 wells are projected by 2030.

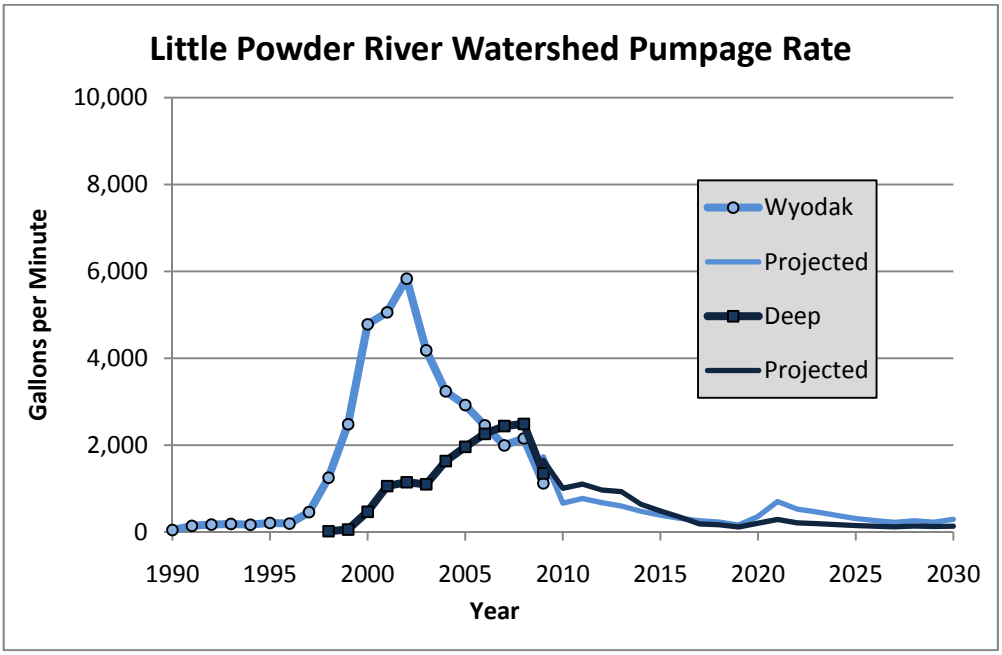


Figure B-6. A total of 87,546 acre feet of water has been produced and future withdrawals are expected to total 26,437 acre feet through 2030. A total of 346 new wells are expected, and 103 idle well restarts are predicted. See Table B-1 for details.

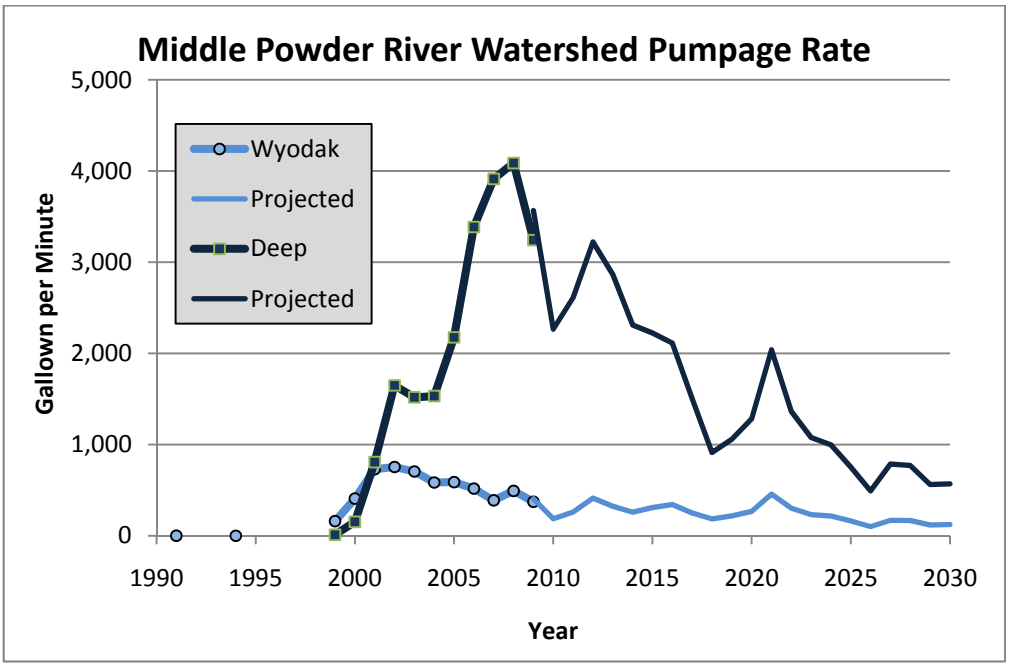


Figure B-7. A total of 44,384 acre feet of water has been withdrawn, and future water withdrawals is expected to total 59,438 acre feet by the end of year 2030. A total of 906 new wells is expected, and 28 new well restarts are expected. See Table B-1 for details.

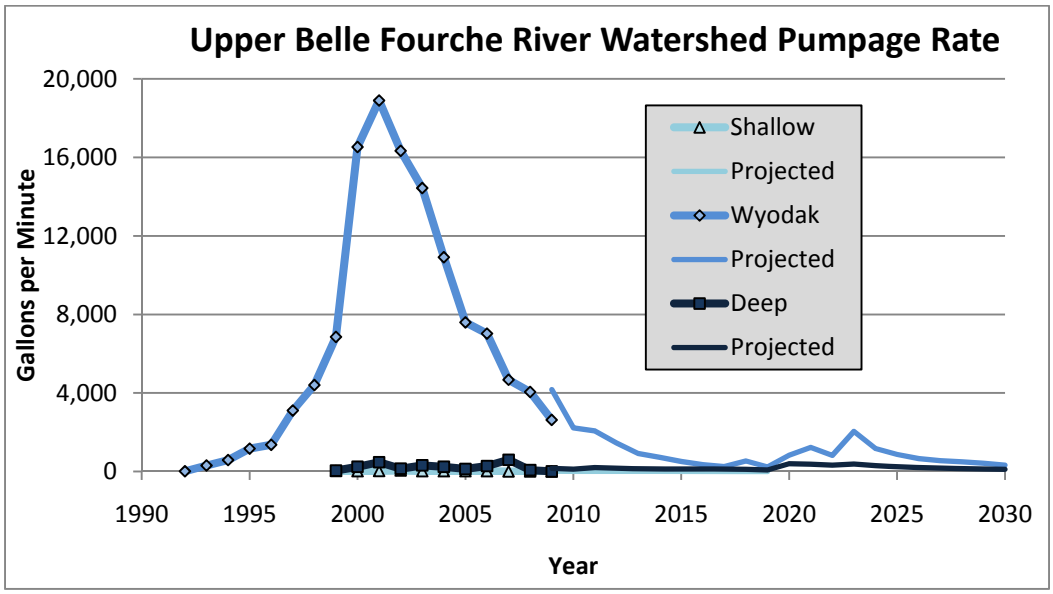


Figure B-8. A total of 199,524 acre feet of water has been withdrawn from the watershed, and future water withdrawal is estimated to be 36,846 acre feet by the end of year 2030. A total of 653 new wells and 66 idle well restarts are expected. See Table B-1 for details.

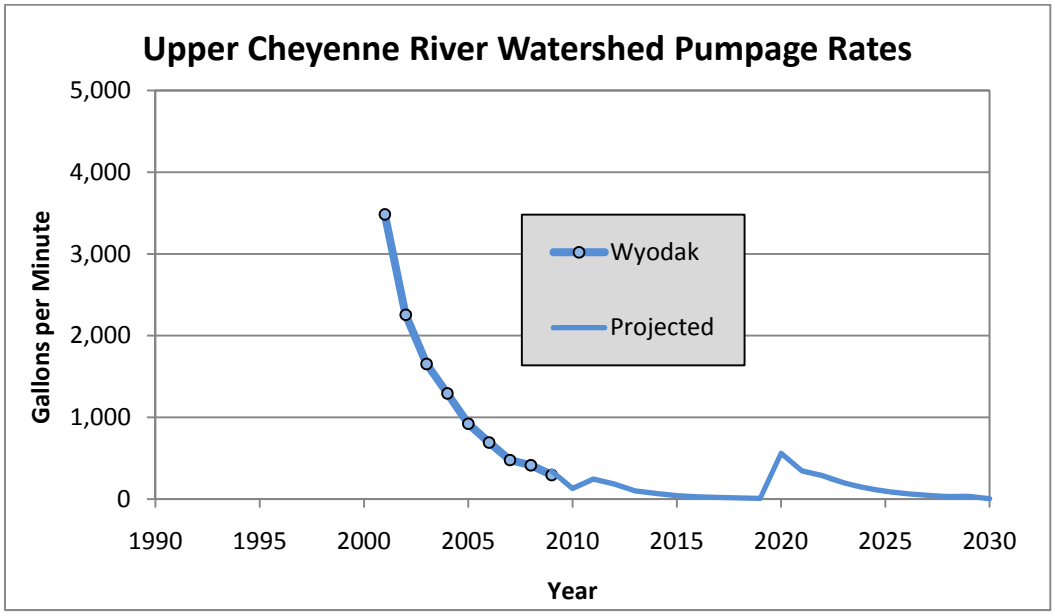


Figure B-9. A total of 26,790 acre feet of water has been withdrawn from the watershed, and future water withdrawal is estimated to be 4,308 acre feet by the end of year 2030. All from the Wyodak zone. A total of 38 new wells and 13 idle well restarts are projected.

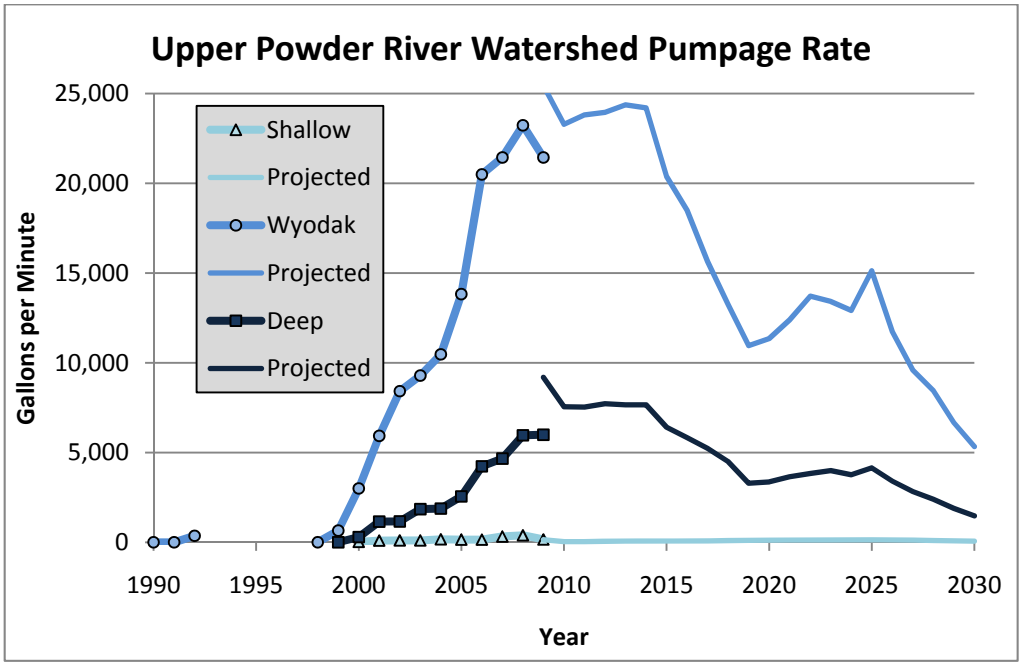


Figure B-10. A total of 266,506 acre feet of water has been withdrawn from the watershed, and future water withdrawals is estimated to be 676,278 acre feet by the end of year 2030. A total of 6,965 new productive wells and 773 idle well restarts are predicted.

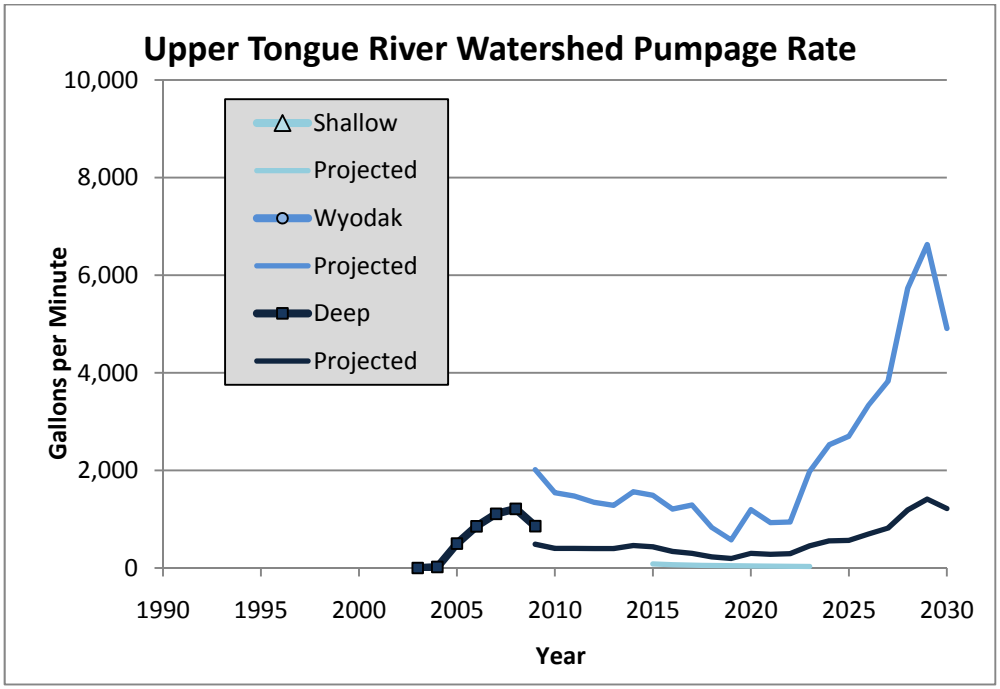


Figure B-11. A total of 18,690 acre feet of water has been withdrawn from the watershed, and future water withdrawals is estimated to be 95,433 acre feet by the end of year 2030. A total of 1,650 new productive wells and 306 idle well restarts are predicted.

Watershed and Coal Zone	<---------- Acre Feet ----------> Cumulative	Additional through 2030	Productive New Wells	Idle Well Restarts
Antelope Creek	29,745	95,885	1,276	49
Wyodak	29,641	36,470	913	39
deep	104	59,415	363	10
Clear Creek	9,672	117,481	1,842	257
shallow	1,119	17,901	423	140
Wyodak	5,372	23,121	480	71
deep	3,181	76,458	939	46
Crazy Woman Creek	2,492	93,514	1,450	192
shallow	1	1,202	30	7
Wyodak	1,510	35,130	566	124
deep	981	57,182	854	61
Dry Fork Cheyenne River	1,349	14,342	97	1
deep	1,349	14,342	97	1
Lightning Creek	0	4,248	41	0
deep	0	4,248	41	0
Little Powder River	87,546	26,437	346	103
Wyodak	62,433	13,814	232	69
deep	25,113	12,623	114	34
Middle Powder River	44,384	59,438	906	28
Wyodak	8,758	8,172	281	17
deep	35,626	51,266	625	11
Upper Belle Fourche River	199,524	36,846	653	66
shallow	316	56	0	1
Wyodak	195,091	30,147	642	59
deep	4,118	6,643	11	6
Upper Cheyenne River	26,790	4,308	38	13
Wyodak	26,790	4,308	38	12
deep	0	0	0	1
Upper Powder River	266,506	676,278	6,965	773
shallow	1,860	3,196	68	5
Wyodak	219,440	514,753	5,713	539
deep	45,206	157,329	1,184	229
Upper Tongue River	18,690	95,433	1,650	306
shallow	15	746	0	18
Wyodak	15,781	76,351	1,631	45
deep	2,894	18,336	19	243
Totals	686,698	1,224,210	15,264	1,788

Table B-1. Summary table showing cumulative water production through 2009, and estimated future water production through the year 2030. Figures are in acre feet. The estimated number of new productive wells and idle well restarts is also shown. Projected new productive wells are based on figures given in Reasonably Foreseeable Development Scenarios for BLMs Buffalo and Casper field offices resource management plans (2009 and 2005).

Summary of 2011 Update to Pumpage Rate Estimates

Introduction

Estimated well numbers and pumpage rates for watersheds in northeast Wyoming provided in this report are an annual update to the 2010 estimates initially provided to AECOM in October 2010. The watersheds are identical to those described in the initial 2010 report and are shown in Figure 1.

Procedure

Updated estimates of future drilling activity were determined by AECOM and provided to the BLM by Dolora Koontz (November, 2011). Additionally, the Excel spreadsheet used to calculate the initial pumpage rates, the 2010 estimates, was also provided. After slight modifications it was used to calculate updated pumpage rates based on the 2011 well estimates.

The term "existing wells" is defined as those wells existing in 2009, including wells which had never produced significant amounts of water, and in 2009 were in a nonproducing status. The term "restarted

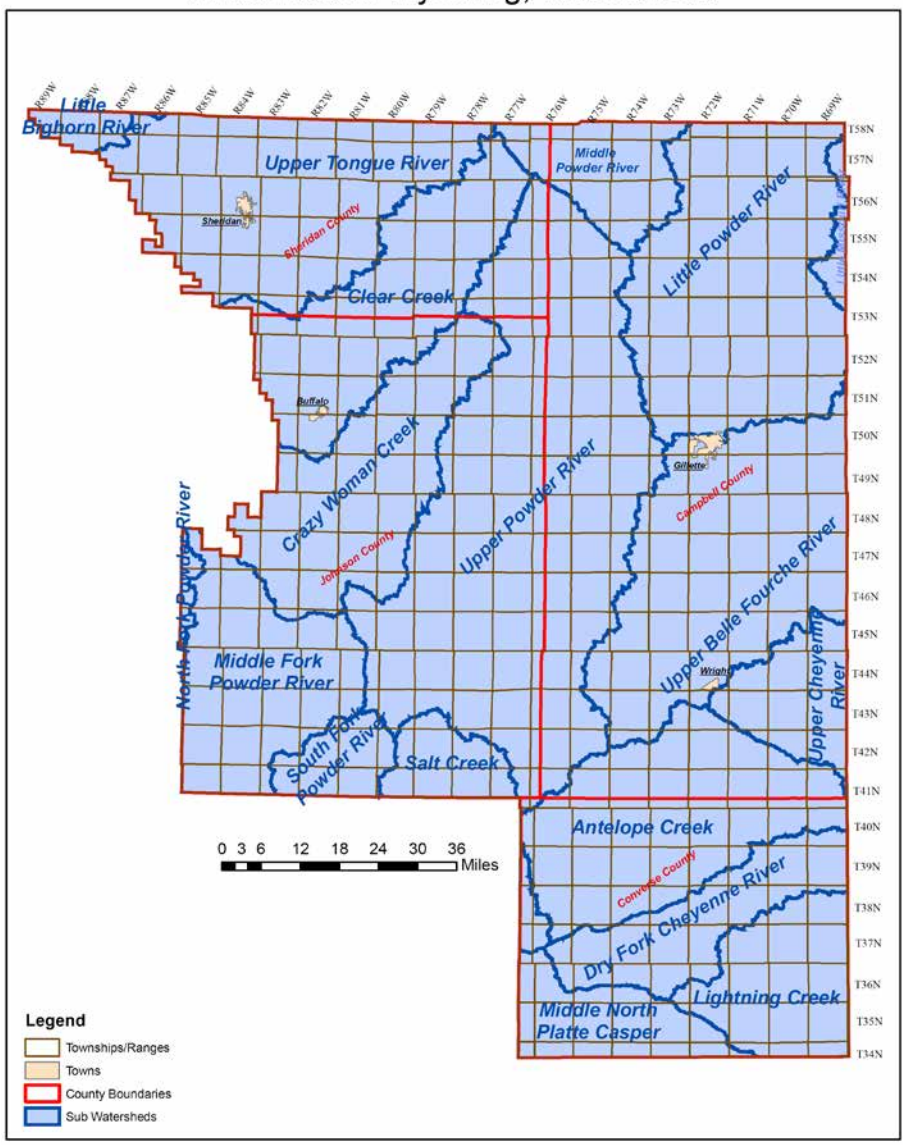


Figure 1. Map of Northeast Wyoming watersheds. These watersheds include all coalbed gas wells in the Powder River Basin, Wyoming. Several watersheds have no coalbed gas development.

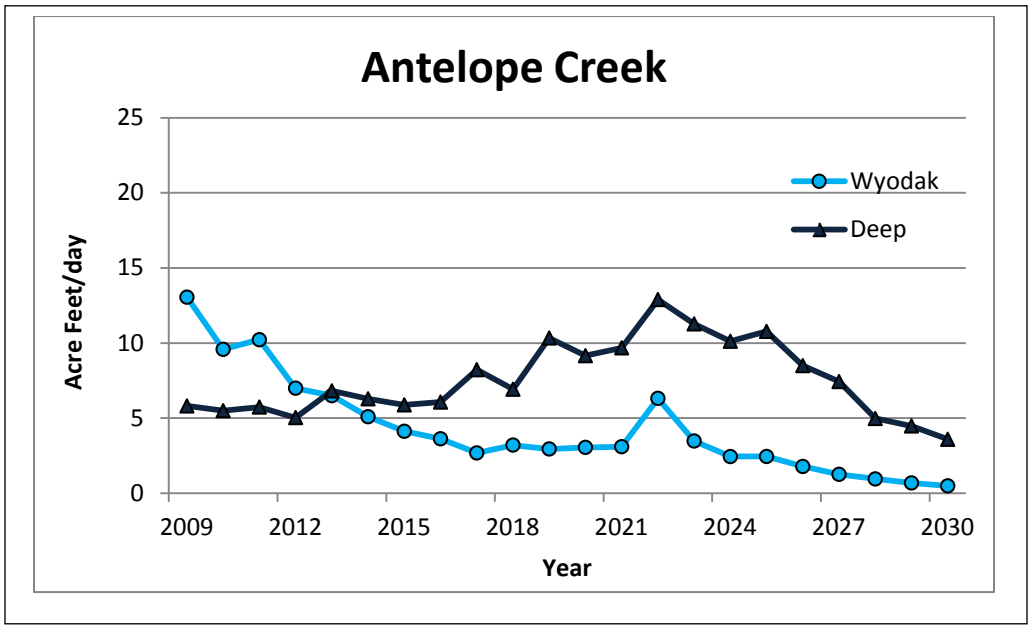
wells" is defined as those wells which, through 2009, had not produced significant amounts of water or gas and were in a nonproducing status in 2009. These wells were projected to restart during the project life (2010-2030) with estimated water production predicted to be the same as for newly drilled wells. Estimated initial production dates for these wells are as late as 2018. Newly drilled wells and restarted wells are both given nine year well lives. The last restart wells are predicted to begin producing in 2018 and stop producing in 2026.

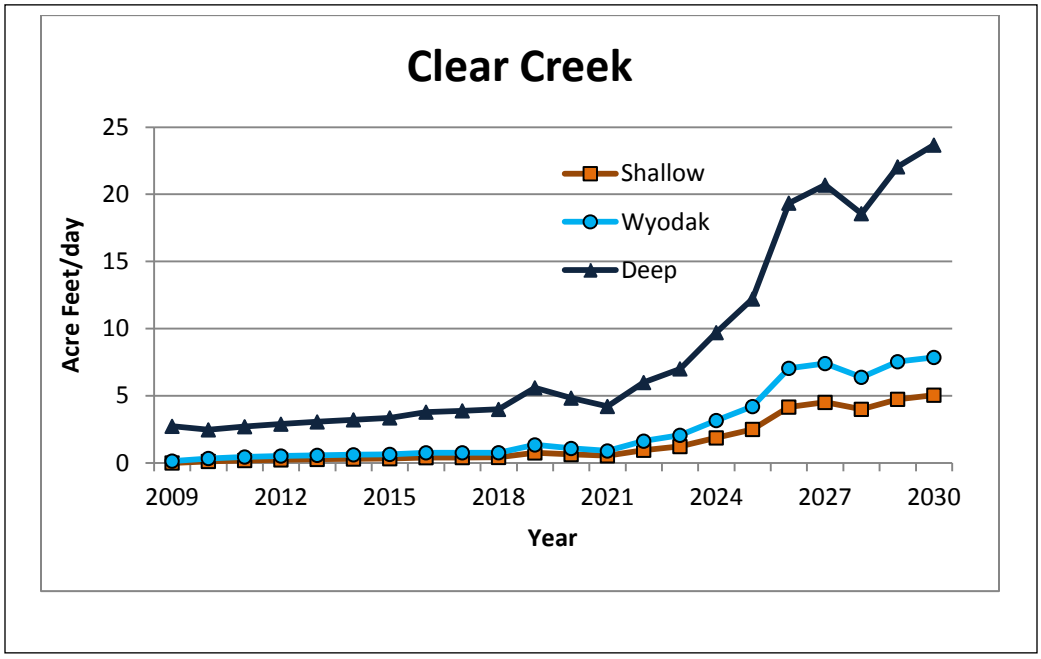
In order to not double count the restarted wells when calculating the average estimated per well pumpage rate, the number of restarted wells was subtracted from the existing well numbers before the average pumpage rate was calculated. Wells existing and producing in 2009 were given a flat pumpage rate. The restarted shut-in wells were given the same variable pumpage rate as newly drilled wells. Also, care was taken to not mix newly drilled wells and restarted wells with existing wells. As a check of AECOM's existing well projections the number of restart wells was subtracted from the existing well numbers. After the subtraction the number of existing wells should be zero after 2017 and this was found to be the case.

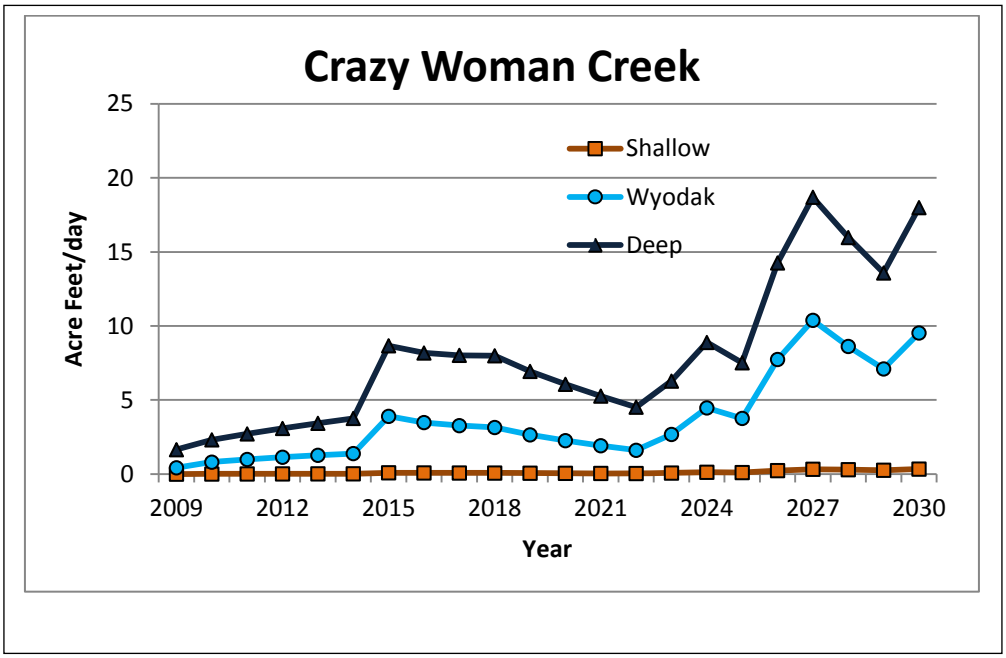
In the spreadsheet which was used to calculate average pumpage rates the total number of producing wells for each year was determined by adding the number of existing producing wells to the number of new wells drilled plus the number of restarted wells. The 2010 pumpage report numbers were selected from a different spreadsheet instead of calculating the number internally.

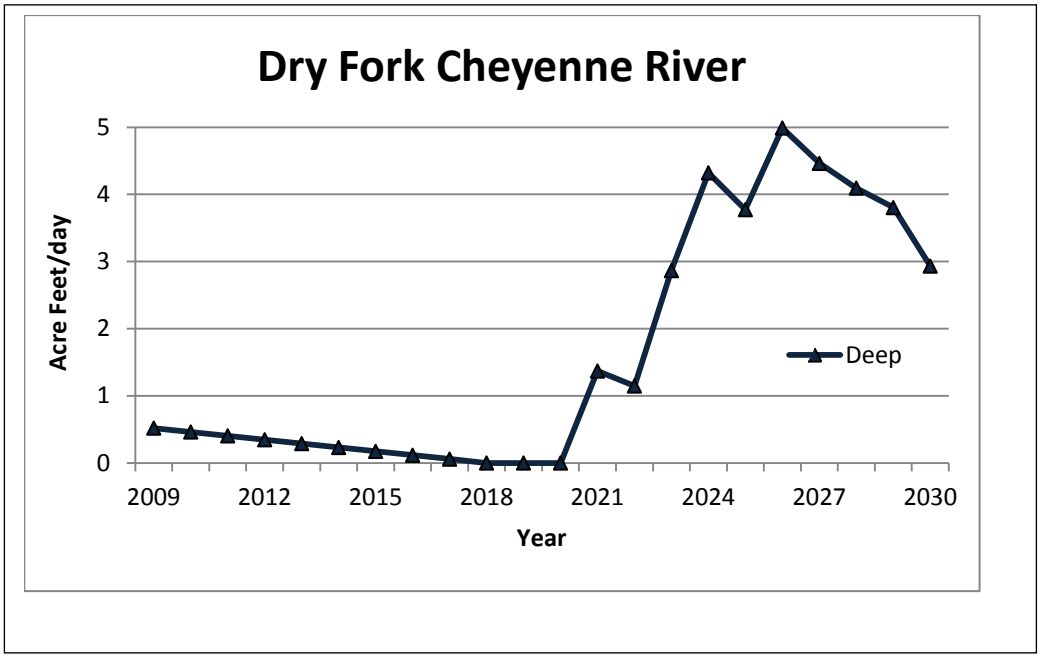
Graphs of each producing coal in each watershed area and the spreadsheet data are shown below. If there are any questions please contact Fred Crockett with the Bureau of Land Management, Wyoming Reservoir Management Group at (307) 261-7633.

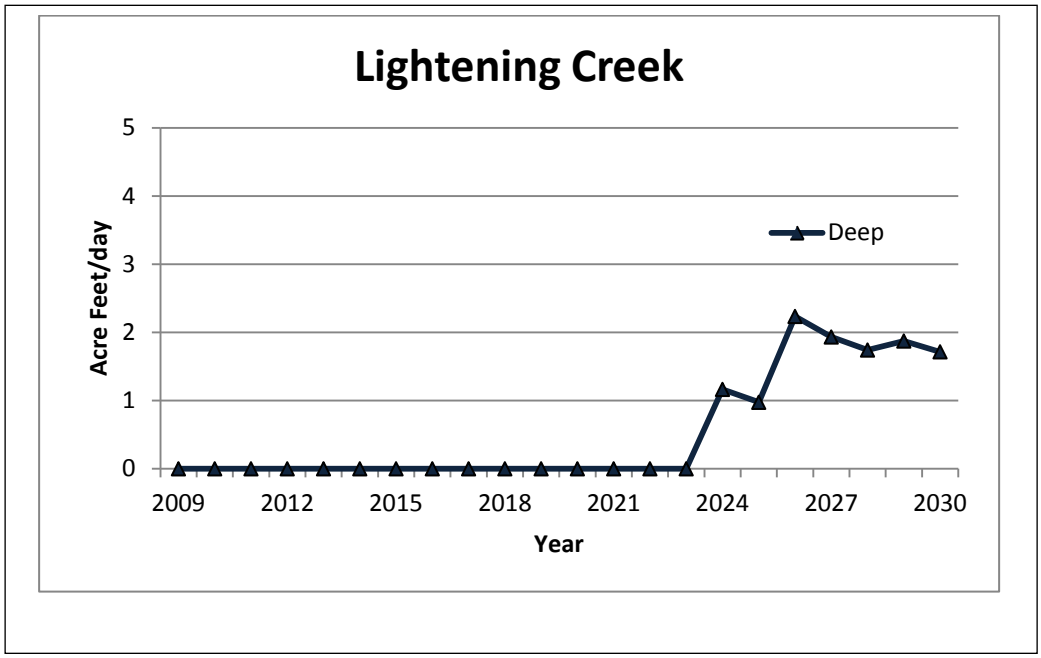
Fred Crockett 12-22-2011
Wyoming Reservoir Management Group
Casper, Wyoming

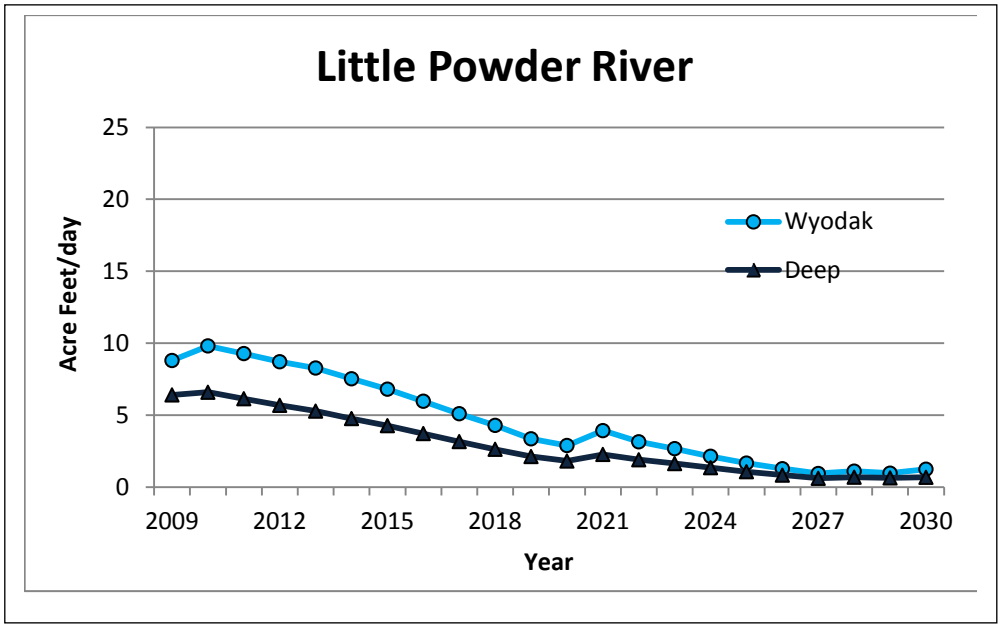

Antelope Creek
Acre Feet/day
25
20
15
10
5
0
2009
2012
2015
2018
2021
2024
2027
2030
Year
Wyodak
Deep

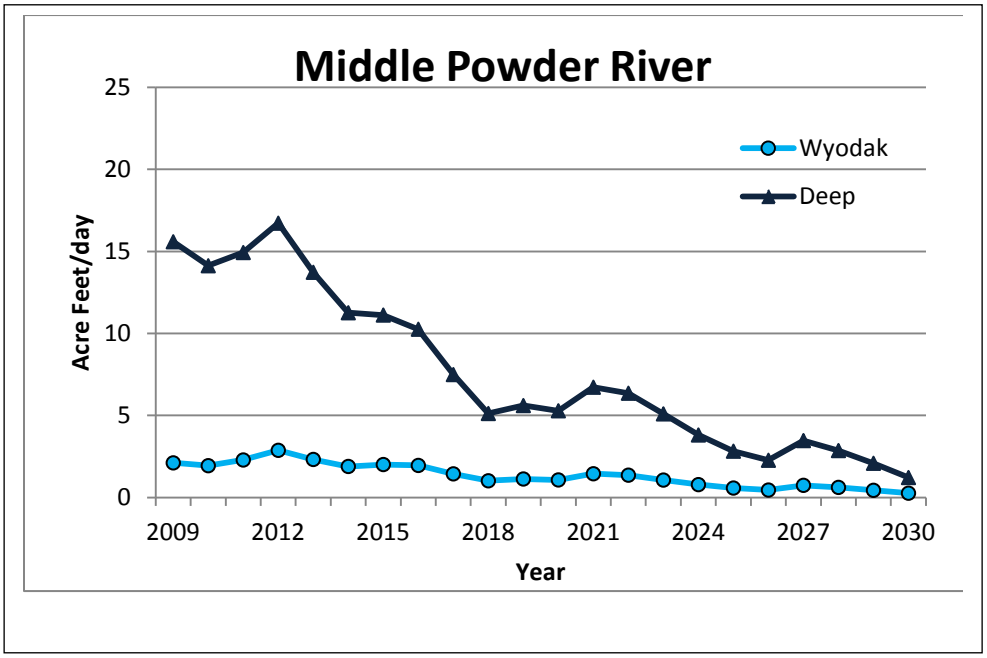

Clear Creek
Acre Feet/day
25
20
15
10
5
0
2009
2012
2015
2018
2021
2024
2027
2030
Year
Shallow
Wyodak
Deep

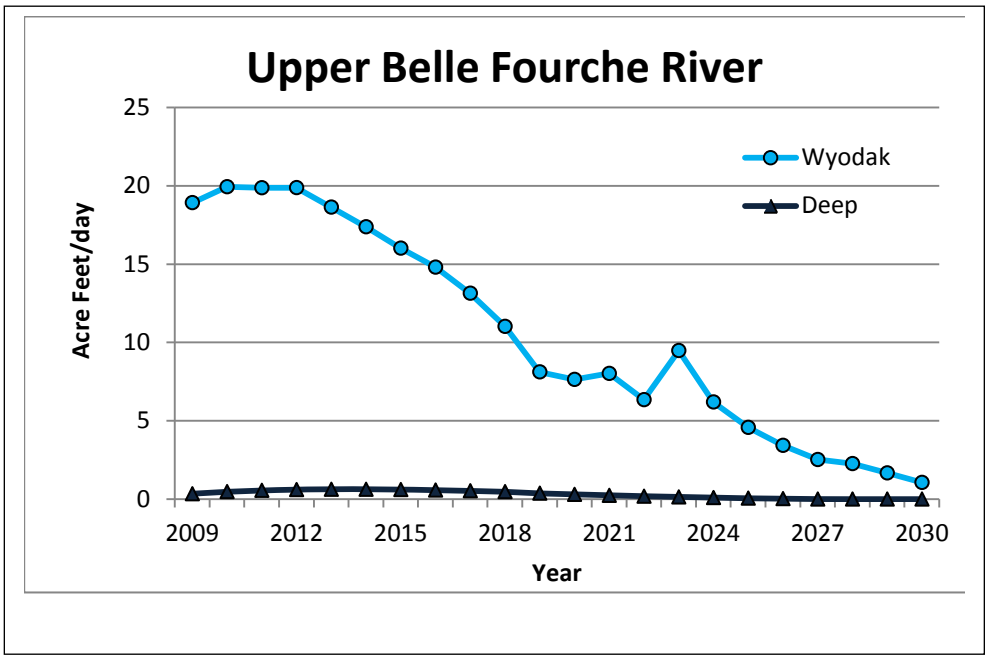

Crazy Woman Creek
Acre Feet/day
25
20
15
10
5
0
2009
2012
2015
2018
2021
2024
2027
2030
Year
Shallow
Wyodak
Deep

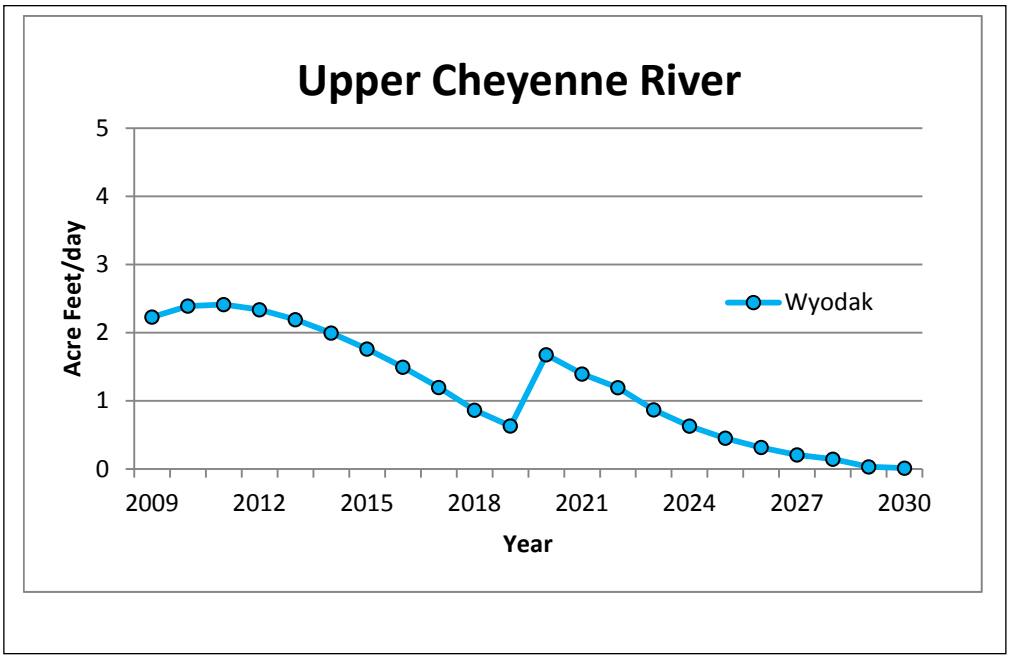

Dry Fork Cheyenne River
Acre Feet/day
5
4
3
2
1
0
2009
2012
2015
2018
2021
2024
2027
2030
Year
Deep

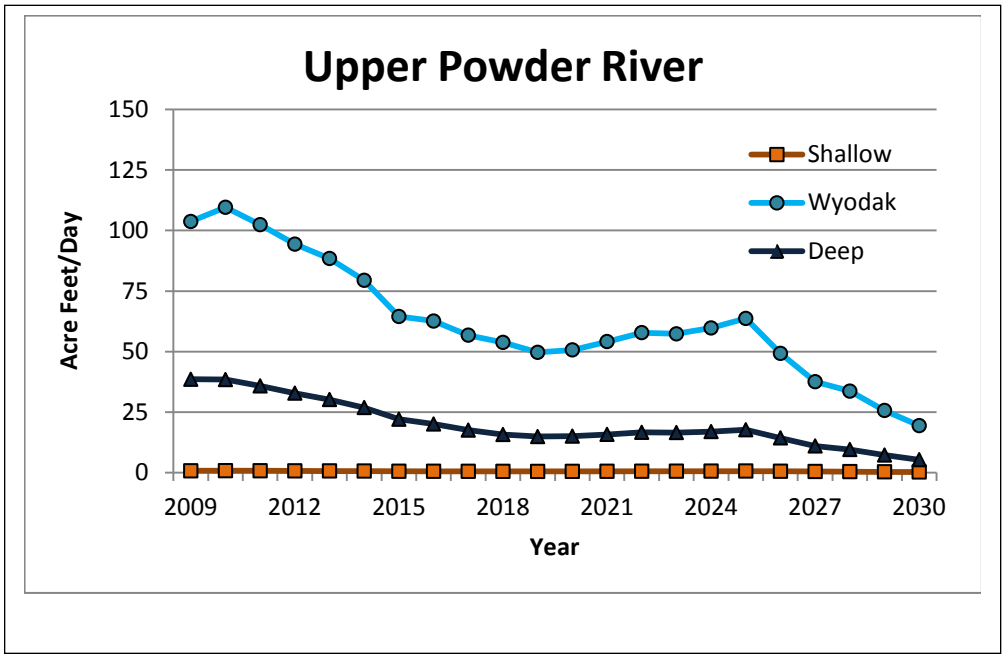

Lightening Creek
Acre Feet/day
5
4
3
2
1
0
Deep
2009
2012
2015
2018
2021
2024
2027
2030
Year

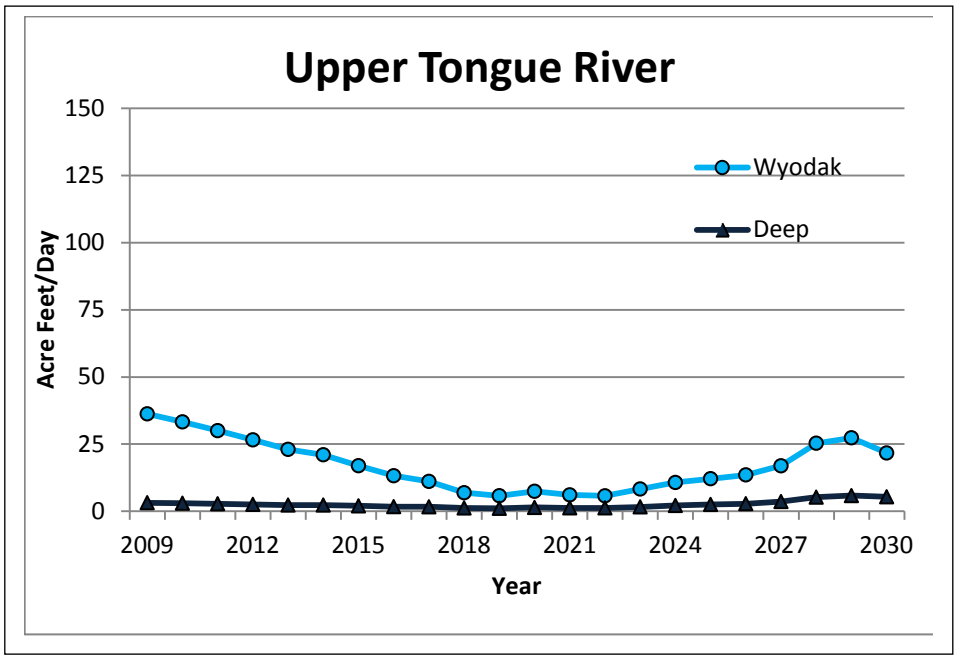

Little Powder River
Acre Feet/day
25
20
15
10
5
0
Wyodak
Deep
2009
2012
2015
2018
2021
2024
2027
2030
Year


Middle Powder River
Acre Feet/day
25
20
15
10
5
0
2009
2012
2015
2018
2021
2024
2027
2030
Year
Wyodak
Deep


Upper Belle Fourche River
Acre Feet/day
25
20
15
10
5
0
2009
2012
2015
2018
2021
2024
2027
2030
Year
Wyodak
Deep


Upper Cheyenne River
Acre Feet/day
5
4
3
2
1
0
2009
2012
2015
2018
2021
2024
2027
2030
Year
Wyodak


Upper Powder River
Acre Feet/Day
150
125
100
75
50
25
0
2009
2012
2015
2018
2021
2024
2027
2030
Year
Shallow
Wyodak
Deep


Upper Tongue River
150
125
100
75
50
25
0
Acre Feet/Day
2009
2012
2015
2018
2021
2024
2027
2030
Year
Wyodak
Deep