Cumulative Hydrological Impact Assessment of Coal Mining in the Middle Powder River Basin, Wyoming

Wyoming Department of Environmental Quality
Land Quality Division

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Cover photos from top left to lower right: (1) Belle Fourche River at the Cordero Rojo Mine, facing upstream to the southern portion of the Maysdorf I Amendment area, (2) Dog Leg Pit at the Cordero Rojo Mine, (3) alluvial well in Gold Mine Draw headwaters at the Caballo Mine, (4) weir at the LBFR station on the Belle Fourche River at the Cordero Rojo Mine.
Photos by Matt Kunze, November 2010

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Prepared by the
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ABSTRACT

The action evaluated by this cumulative hydrologic impact assessment (CHIA) is the approval of the Maysdorf I Amendment at the Cordero Rojo Mine. The Maysdorf I Amendment will add 4,414 acres (ac) to the south and west portion of the Cordero Rojo Mine permit area. Approximately 84 percent of the acreage will be disturbed, with coal removal scheduled from 2012 to 2022. This CHIA analyzes the impact of the amendment, along with existing coal mining at the Caballo, Belle Ayr, Cordero Rojo, and Coal Creek mines to determine whether mining will result in material damage to the surface and groundwater resources of the area. The cumulative impact area (CIA) is located in the middle Powder River Basin (PRB), Wyoming. The surface water CIA includes two separate drainages in the upper Belle Fourche River Basin (**Plate 1**). The groundwater CIA extends from the outcrop of the coal in a rough semicircular shape eight to twelve miles to the west and extending about six miles north of the Caballo Mine and about four miles south of the Coal Creek Mine (**Plate 1**).

The Wyoming Environmental Quality Act requires that no surface mining be approved unless the operation is designed to prevent material damage to the hydrologic balance outside of the permit area and will not cause material damage to the quantity and quality of water in surface or groundwater systems that supply alluvial valley floors deemed significant to farming (Article 4, §35-11-406(n)(iii) and §35-11-406(n)(v)(B)). To determine whether a proposed operation has been designed to prevent material damage, the Land Quality Division (WDEQ/LQD) defines material damage to the hydrologic balance as a significant long-term or permanent adverse change to the hydrologic regime (WDEQ/LQD Coal Rules and Regulations, Chapter 1, Section 2(cd)). That definition is further expanded in the relation to the Wyoming State Constitution, or of statutes administered by the Wyoming State Engineer's Office (WSEO), or water quality standards administered by the Water Quality Division (WQD) by an agreement between the Director of the Wyoming Department of Environmental Quality and the Wyoming State Engineer, dated February 7, 1997.

Hydrologic concerns identified and analyzed include the potential for changes to surface water quality and quantity, impacts to surface water rights, changes in the groundwater potentiometric surface, comparability of the backfill aquifer physical characteristics to the pre-mining aquifer, and backfill aquifer water quality compared to the post mining land use. Data from the coal mine permits and from other sources, including United States Geological Survey (USGS) stream gage data, were used in the analysis.

The PRB presents a challenge in hydrologic analysis because the surface water drainage basins and the groundwater basins do not coincide. In the middle PRB, the geological beds dip to the west and the groundwater in the coal aquifer likewise flows to the west. However, the topographic relief results in surface water drainage to the east.

Two surface water drainage basins in the upper Belle Fourche River Basin are examined: Caballo Creek and a portion of the Belle Fourche River. The Caballo Creek CIA has a drainage area of 260 square miles and the Belle Fourche River CIA has a drainage area of 594 square miles. Both streams are intermittent and flow primarily in response to snowmelt in the spring and intense rainstorms in the summer.

There is low potential for coal mining to cause material damage to surface water quantity in the two CIAs. Analysis of streamflow data shows that the runoff response can be variable, highly dependent upon factors such as precipitation and antecedent moisture. The potential for mining to cause measurable change to surface water quantity is deemed low due to the high variability of the natural system, the extent of disturbance in relation to the CIA, and reclamation practices. Material damage to surface water rights is not expected. The additional mining proposed by the Maysdorf I Amendment at the Cordero Rojo Mine is not expected to change conditions such that material damage would occur to surface water quantity and surface water rights.

The potential for coal mining to cause material damage to surface water quality is also low. The available surface water quality data were analyzed for the baseline and during-mining periods in each of the major drainages of the CIAs. Summary statistics were compared between baseline and during-mining periods, as well as upstream and downstream of mining activity. The analysis showed that WDEQ/WQD surface water quality standards for Class 2ABww and Class 3B waters have been satisfied for the majority of constituents evaluated. Occasional exceedences of dissolved metals have occurred, but in most cases these were also observed in pre-mining sampling and at monitoring stations upstream from mining activity. The median concentrations of all constituents evaluated are within WDEQ/WQD standards for Class 2ABww and Class 3B waters. The overall results indicate that material damage has not occurred to surface water quality in the major drainages of the CIAs. The additional mining proposed by the Maysdorf I Amendment is not expected to change the potential for material damage to surface water quality.

Three aquifers and a leaky aquitard unit make up the shallow aquifer systems. The alluvial aquifer is present along major drainages. The water quality was generally calcium-sulfate type (Ca-SO_4) and a median TDS concentration of 3,345 mg/l was calculated from 1,190 samples. The clinker aquifer is the most permeable shallow aquifer. The water quality of the clinker aquifer is generally a calcium-sulfate (Ca-SO_4) type with a median TDS concentration 2,354 mg/l from 194 samples. Within the Wasatch Leaky Aquitard Unit, sand lenses are sometimes local aquifers. The Wasatch Leaky Aquitard Unit has the lowest hydraulic conductivity of the units. The water is a Ca-SO_4 type and the median TDS for 1,268 samples was 2,568 mg/l. The Wyodak Anderson coal aquifer is generally considered to be the most important aquifer in the CIA. The hydraulic conductivity of the Wyodak Anderson coal aquifer varies with the fracturing of the coal. The water quality is generally Na-HCO_3 with a median TDS concentration of 932 mg/l from 1,133 samples.

The potential for material damage to the groundwater system is also low. There will be some impacts due to mining, but they are not expected to be permanent. Since maximum impacts are predicted in the Wyodak Anderson coal aquifer with smaller impacts to the other aquifers, the following discussion focuses on the Wyodak Anderson coal aquifer. Based on worst case analysis, water levels are predicted to drop at least five-feet in the CIA during mining (**Plate 1**). Likewise, based on worst case analysis, the water levels are predicted to take from the tens to hundreds of years to fully recover in the Wyodak Anderson coal aquifer, with the backfill aquifer and parts of the Wasatch Leaky Aquitard Unit taking somewhat longer than the coal aquifer to recover. However, continued monitoring has shown these worst-case estimates to be significantly larger than the actual impacts. Monitoring data indicates that the actual drawdown area is approximately one third of the predicted worst case drawdown. Additionally, coal bed methane (CBM) development is occurring in the CIA and impacts from CBM are predicted to exceed the impacts of the coal mines. With CBM impacts, the aquifers are projected to recover to near pre-mining levels in several hundreds of years time frame, depending on the assumptions in the model used. Since the recovery is log-normal, most of the recovery will occur in the initial few years with the final recovery taking much longer.

The physical properties of the backfill aquifer, based on the comparison analysis completed for this CHIA, as well as literature research, appears sufficiently permeable to restore the essential hydrologic interconnection of the clinker recharge area to the remaining coal aquifer. In addition, the backfill aquifer will likely yield sufficient water to be a water source for the post mining land use of livestock grazing.

The water quality in the backfill aquifer is predicted to have increased dissolved salts. However, based on predictions in the permits, literature research, and monitoring data submitted by the mines, it appears the backfill aquifer will meet livestock class of use. The water quality of the backfill aquifer is a $Ca\text{-}SO_4$ type with a median TDS of 3,080 mg/l for 1,709 samples. After the initial flushing of the backfill and establishment of geochemical equilibrium, the concentrations of dissolved salts in the backfill aquifer are expected to drop.

Alluvial valley floors (AVFs) have been declared on several streams within the Caballo Creek CIA. No AVFs are present in the Belle Fourche River CIA. The Gold Mine Draw AVF at the Caballo Mine has been determined to be significant to farming and therefore cannot be mined under WDEQ/LQD Coal Rules and Regulations. The remaining AVFs in the Caballo Creek CIA are either not significant to farming or are grandfathered because the mine was active prior to the passage of Surface Mining Control and Reclamation Act (SMCRA) in 1977. The essential hydrologic functions of all AVFs have been identified and the mines have developed plans to ensure the functions are maintained and/or restored after mining. An analysis of surface water quantity, surface water quality, alluvial water levels, and alluvial water quality in the undisturbed AVFs indicates that the essential functions are being maintained. The analysis also indicates material damage has not occurred to the significant AVF on Gold Mine Draw. Additional monitoring will be needed to fully assess the restoration of essential hydrologic functions on AVFs that have been reconstructed.

Based on the information presented in the permits and analysis completed for this CHIA, no material damage to the hydrologic system is expected from approval of the Cordero Rojo Maysdorf I Amendment Area.

1. INTRODUCTION

The purpose of this report is to examine the cumulative hydrologic impact of the proposed Maysdorf I Amendment at the Cordero Rojo Mine along with existing surface coal mining at the Caballo, Belle Ayr, Cordero Rojo, and Coal Creek mines. The four mines are located in the middle Powder River Basin (PRB) of Wyoming (**Figure 1**). The Maysdorf I Amendment will add 4,414 acres (ac) to the western and southern portion of the Cordero Rojo Mine permit area. Approximately 84 percent of the new permit acreage will be disturbed. Mining in the amendment area will consist primarily of dragline and truck and shovel operations, with coal removal scheduled from 2012 to 2022.

A determination is made as to whether material damage will occur to the hydrologic system. To complete those tasks, it is necessary to define a cumulative impact area (CIA) where existing and proposed mining activities may cause measurable changes to the hydrologic environment. Baseline data are summarized to describe the pre-mining hydrologic conditions within the CIA. Hydrologic concerns are identified and their potential impacts are analyzed. The potential impacts are then evaluated against material damage criteria developed jointly by the Wyoming Department of Environmental Quality (WDEQ) and the Wyoming State Engineer's Office (WSEO). A finding is made regarding the potential for material damage.

A brief description of the middle PRB physical setting is included below. A general description of the mining in the PRB is also discussed. Other sections of this report deal directly with the items outlined in the previous paragraph.

1.1 TOPOGRAPHY, GEOMORPHOLOGY, AND GEOLOGY

The landscape of the PRB can be described as three general land types (Coates and Naeser, 1984). First, the land west of the clinker is gently rolling topography with only a few steep hills. Soils have sufficient permeability to result in little runoff and a loosely knit, poorly integrated drainage network. Wind deflation has created areas of closed drainage now occupied by playas. Second, the land dominated by clinker consists of nearly flat to gently rolling uplands. The clinker is highly fractured, permeable and quickly absorbs water resulting in little through drainage and minimal surface erosion. Third, the land east of the clinker is underlain entirely by the Fort Union Formation (Paleocene). The Fort Union Formation has a higher clay content and lower permeability than the Wasatch Formation (Eocene), resulting in greater surface water runoff. Most of the Fort Union Formation is poorly consolidated and weathers to a landscape of low relief. Surficial deposits in the region consist of alluvium, residuum, alluvial fans, bench, mesa, eolian, landslides, clinker and terrace deposits. Playa deposits are present in local areas. The Lightening, Moorcroft and Kaycee terraces are present regionally throughout the PRB and represent deposition periods at 2,500, 1,200, and 130 years, respectively, before the present (Leopold and Miller, 1954).

Structurally, the PRB is a large north-northwest to south-southeast trending asymmetric syncline in northeastern Wyoming and southeastern Montana. The basin is approximately 250 miles long by 90 miles wide and contains as much as 23,000 feet (ft) of sediment (Denson et al., 1989). The structural fold axis is located along the western part of the basin with the western limb characterized by steeply dipping bedrock and the eastern limb characterized by gently dipping bedrock (Wyoming Water Resources Center, 1997). The mines and CIA are located on the eastern limb of the PRB where the bedrock regionally dips about two degrees to the west-southwest (Black Thunder Mine Permit, 2011). Local folding and faulting may cause steeper dips in the coalbeds (Bureau of Land Management, 1994).

The following discussion is limited to the formations which will be affected by coal mining: the Fort Union Formation, Wasatch Formation, clinker and alluvium. Regional bedrock geology is presented on **Plate 1** and individual descriptions are included in **Table 1**. Most of the commercial coal production in the PRB is from the Wyodak Anderson coal seam in the Upper Tongue River Member of the Fort Union Formation. Local names, such as the Anderson, Canyon, Roland, Smith and Wyodak are used where the coal seams split. In this report, the Wyodak Anderson coal is used as an umbrella term to describe all of the mined seams and individual coal seams are not analyzed. The combined thickness of the coal seams is typically from 70 to 100 ft.

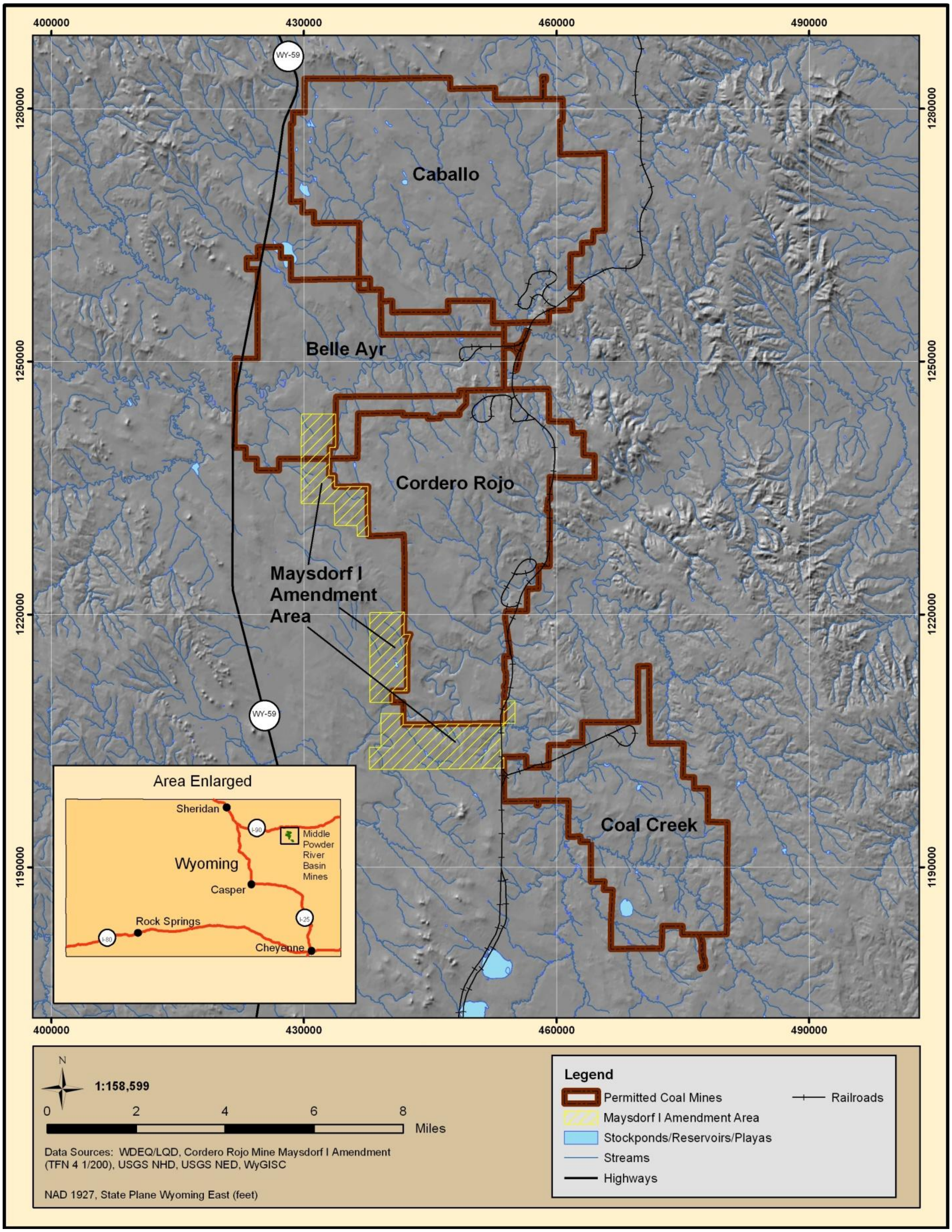


FIGURE 1. LOCATION OF THE COAL MINES AND THE MAYSDORF I AMENDMENT AREA AT THE CORDERO ROJO MINE, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

TABLE 1. GENERALIZED GEOLOGIC AND HYDROLOGIC CHARACTERISTICS OF THE ALLUVIUM, CLINKER, WASATCH FORMATION, AND FORT UNION FORMATION, POWDER RIVER BASIN, WYOMING.

Geologic Unit, *Age*		Thickness, *feet*	Geologic Description	Hydrologic Characteristics
Recent Alluvium *Holocene*		5-50 (common) 100 (local)	Unconsolidated silt, sand and gravel. Typically fine grained and poorly sorted in intermittent drainages. Occasionally very thin, clean inter bedded sand lenses.	Low yields and excessive dissolved solids sometimes make these aquifers unsuitable for domestic, agricultural, and livestock usage. Low infiltration capacity unless covered by sandy eolian blanket.
Clinker *Holocene to Pleistocene*		100 (common) 200 (local)	Baked and fused clays and sands resulting from burning of underlying coal seams which ignited on the outcrop. The reddish clinker varies greatly in the degree of alternation, from dense and glassy to vesicular and porous. Erosion resistant	An aquifer where saturated and permeable. Where fractured, high infiltrations rates. High transmissivity and well yields have been documented in local areas. Where underlain by clays, springs are observed. Water quality is generally suitable for livestock use.
Wasatch Formation *Eocene*		0-2000	Lenticular fine sands inter bedded in predominantly very fine grained siltstone and claystone. Discontinuous sands may yield low to moderate quantities of poor to good quality water. Low overall permeabilities and slow groundwater movement. Generally considered to be a regional aquitard although locally may be an aquifer. Water quality generally does not meet Wyoming drinking water standards due to the dissolved mineral content, although coarser grained deposits in the southern part of the basin may have better water quality. Coal seams are interspersed. Thin bedding and high shale and non-marine limestone content indicative of a more lake-dominated environment than the Fort Union Formation.	Discontinuous sands may yield low to moderate quantities of poor to good quality water. Low overall permeabilities and slow groundwater movement. Generally considered to be a regional aquitard although locally may be an aquifer. Water quality generally does not meet Wyoming drinking water standards due to the dissolved mineral content, although coarser grained deposits in the southern part of the basin may have better water quality.
Fort Union Formation *Paleocene*	**Tongue River Member**	600 (Gillette) 800 (Sheridan)	Argillaceous mudstones and sandstones, siltstones, and coal. Many laterally persistent coal seams. Largest coal seam, the Wyodak-Anderson ranges from 50-100 feet thick. Mean sand fraction is 54 percent.	The coal serves as a regional groundwater aquifer and exhibits highly variable aquifer properties with permeability and porosity associated with fractures. Water from coal wells is generally suitable for livestock and occasionally for domestic use. Transmissivity is typically less than 13 ft^2/d and commonly less than 1.3 ft^2/d.
	Lebo Member	150 to 400	Soft clay-like shale and thin beds of sandstone and siltstone. Locally contains ferruginous concretions and thin beds of coal	Also referred to as "The Lebo Confining Layer". Typically yields small quantities of poor quality groundwater. Where sand content is locally large, caused by channel or deltaic deposits, may yield as much as 10 gpm.
	Tullock Member	785 (mean) 1,100 southern part of basin, thins to north	Friable, light-colored sandstone; dark to light gray shale; and thin beds of coal. A mean sand content of 53 percent with a range of 21 percent to 88 percent.	Generally functions as a regional aquifer. Yields of 15-400 gpm. Transmissivities of 200-400 ft^2/d. Water quality often meets drinking standards. Extensive sandstone units are commonly developed for domestic and industrial uses. Gillette and Wright use wells completed in this unit for municipal water requirements. Coal mines often have facilities wells completed in the unit.

Information modified from Bureau of Land Management, 2003; Glass, 1980; Lewis and Hotchkiss, 1981; Mapel, 1958; Martin *el al*, 1988; Robinson and Foley, 1941; and Wyoming Water Resources Center, 1997

1.2 CLIMATE, SOILS, AND VEGETATION

The PRB is semiarid with cool, dry winters and warm, dry summers. Windy conditions exist year-round with prevailing winds from the west to northwest at 8 to 10 miles per hour. Isolated, but often intense, thunderstorms occur during the warmer months and light to moderate snow falls during the colder months. The middle PRB receives approximately 13 to 15 inches (in) of precipitation annually, with nearly 75 percent of the precipitation occurring during the growing season which extends from April to September (Western Regional Climate Center, 2010a). Annual precipitation generally increases from south to north in the basin. The potential evapotranspiration rate exceeds precipitation. Average annual pan evaporation for the Gillette 9 ESE (Station 483855) near Gillette, Wyoming is 50.67 in (Western Regional Climate Center, 2010b). National Weather Service Cooperative Network stations Gillette 9 ESE (Station 483855), Dillinger (Station 482580), and Wright 12 W (Station 489805) are located near the mines, and their climate summaries are provided in **Table 2** (Western Regional Climate Center, 2010a).

Soils in the basin are primarily residual and vary from 20 to 30 in thick on gentle slopes and swales to only a few inches thick on steeper slopes. Sandy soils tend to develop in areas underlain by sandstone and sandy shale. Fine-textured, clayey soils tend to develop in areas underlain by shales or claystones (Martin et al., 1988).

The flora of the eastern PRB area consists of species that are typical of the Northern Great Plains and Rocky Mountain regions. Native vegetation can be classified into dominant vegetation classes whose species composition reflects the amount of moisture available. Upland sagebrush/grassland communities occur on terraces and gently sloping hillsides are completely dependent upon direct precipitation. Upland communities include big sagebrush (*Artemisia tridentata),* blue gramma (*Bouteloua gracilis*), needle and thread grass (*Stipa comate*) and prairie june grass (*Kohleria micrantha*). Bottomland communities receive augmented moisture via surface and subsurface hydrologic convergence and thus demonstrate species with higher water requirements. Ephemeral drainage dominant species include western wheatgrass (*Agropyron smithii*), Kentucky bluegrass (*Poa pratensis*) and silver sagebrush (*Artemisia cana*). Immediately adjacent to stream courses, narrow primarily sub-irrigated mesic communities demonstrate prairie cordgrasss (*Spartina pectinata*), chair maker's rush (*Scirpus americanus*) and common spikerush (*Eleocharis macrostachya*). Lesser communities within the PRB include bunchgrass and cushion plant communities which are found upon steep highly eroded surfaces such as clinker buttes and Wasatch Formation outcrops. Reclaimed areas within the PRB demonstrate vegetation types, coverage, and production that is comparable to native communities (Belle Ayr Mine Permit, 2011; Coal Creek Mine Permit, 2011).

TABLE 2. CLIMATE DATA SUMMARIES FOR THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
GILLETTE 9 ESE, WYOMING (No. 483855) - 3/1/1902 to 12/31/2009													
Average Max. Temperature (F)	32.1	36.5	44.5	55.5	65.5	76.0	86.2	84.9	73.7	60.1	44.3	35.0	**57.9**
Average Min. Temperature (F)	11.0	15.0	21.4	30.3	39.9	48.5	55.5	54.0	44.1	33.8	22.4	14.3	**32.5**
Average Total Precipitation (in.)	0.58	0.54	1.00	1.81	2.65	2.60	1.56	1.20	1.27	1.15	0.67	0.64	**15.67**
Average Snow Depth (in.)	2	1	1	0	0	0	0	0	0	0	1	2	**1**
DILLINGER, WYOMING (No. 482580) - 7/1/1941 to 12/31/2009													
Average Max. Temperature (F)	33.3	38.1	45.1	56.3	66.7	77.5	87.6	86.2	74.6	60.6	45.1	35.4	**58.9**
Average Min. Temperature (F)	7.2	12.2	19.5	28.6	38.8	47.3	53.7	51.9	41.2	30.3	18.1	9.2	**29.8**
Average Total Precipitation (in.)	0.36	0.50	0.75	1.61	2.51	2.40	1.58	1.13	1.05	0.98	0.51	0.45	**13.84**
Average Snow Depth (in.)	2	2	1	0	0	0	0	0	0	0	1	2	**1**
WRIGHT 12 W, WYOMING (No. 489805) - 7/1/1991 to 12/31/2009													
Average Max. Temperature (F)	34.2	37.3	45.8	54.5	65.1	74.5	85.5	84.4	72.8	57.6	43.5	34.2	**57.4**
Average Min. Temperature (F)	12.5	15.2	21.5	29.1	38.2	46.3	54.0	52.6	43.0	31.1	21.3	13.0	**31.5**
Average Total Precipitation (in.)	0.40	0.48	1.01	1.55	2.23	1.96	1.55	0.84	1.12	1.48	0.52	0.37	**13.50**
Average Snow Depth (in.)	2	2	1	1	0	0	0	0	0	0	1	1	**1**
Data from Western Regional Climate Center (2010a)													

1.3 HYDROLOGY

The PRB presents a challenge in hydrologic analysis because the surface water drainage basins and the groundwater basins do not coincide. The aquifers outcrop at the edges of the geological structural basin (**Figure 2**) and dip toward the center of the basin. Groundwater flow in the coal aquifers is generally from the outcrop toward the center of the structural basin with a regional flow component to the north. However, surface water flows north in the Powder and Tongue Rivers drainage and east in the Belle Fourche River and Cheyenne River drainages. This difference in direction of groundwater and surface water flow results in the need to have different CIA areas for groundwater and surface water.

The Tongue and Powder Rivers have their headwaters in the Bighorn Mountains on the western side of the PRB and are generally perennial throughout their entire length even as they flow through the plains. The Belle Fourche and Cheyenne Rivers originate on the plains and are ephemeral in the upper reaches trending toward intermittent and eventually perennial in the downstream reaches. Most tributaries of the plains river system are ephemeral or intermittent, flowing in response to precipitation and snow melt. Infrequent points of groundwater expression may be observed providing small quantities of water in localized areas. Surface water in the PRB supports fish, wildlife, stock watering, and irrigation uses.

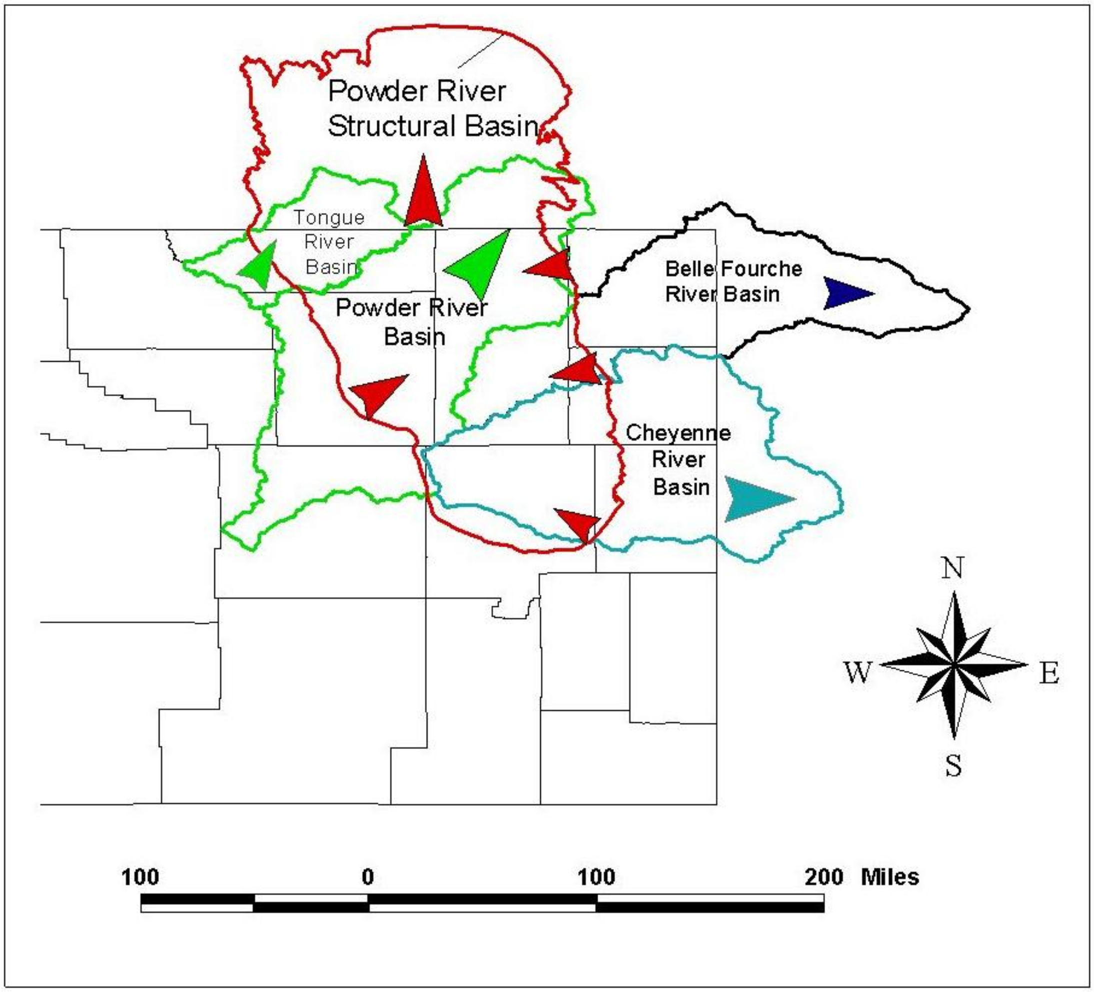


FIGURE 2. GENERAL DIRECTION OF SURFACE WATER DRAINAGE WITHIN THE BASINS (BLUE AND GREEN ARROWS) AND GROUNDWATER FLOW IN THE COAL AQUIFER (RED ARROWS) IN THE POWDER RIVER BASIN, WYOMING.

1.4 MINING

The coal mines in the middle PRB are open pit surface mines. Draglines, truck and shovel operations, or combinations are used to removed overburden, mine the coal, and replace overburden (**Table 3**). Cast blasting is used to move some of the overburden material directly from an overburden face to the bottom of the pit where the coal was previously removed. The influence of the mining method on the reclaimed spoils aquifer is discussed later in this report under *Hydrologic Concerns*. Depending on equipment availability, the coal to overburden strip ratio, and economics, one or several working faces are present at each mine. Coal from these faces is blended to meet customer specifications. Facilities at the mines include crushing, storage, loading, administrative, and equipment maintenance facilities. Coal is generally transported off-site by rail car with minor amounts of coal transported off-site by truck. More details of the specific mining process at each mine may be found in the mine plan section of the respective permits.

The middle PRB coal mines are large scale strip mines covering thousands of acres. Approval of the Maysdorf I Amendment to the Cordero Rojo Mine will bring the total permitted area at the four coal mines to nearly 63,000 ac (**Table 3**). However, this total also includes acreage that is covered by more than one mine permit. For example, the Belle Ayr Mine permit area includes over 2,000 ac that are also permitted at the Caballo Mine and Cordero Rojo Mine. In addition, some of the area of the proposed Maysdorf I Amendment overlaps permitted lands at the Belle Ayr Mine. Mining operations are expected to continue through 2020 to 2034 with reclamation to be completed approximately 15 years after the completion of coal removal (**Figure 3**). Using this estimate, reclamation activities are expected to continue until approximately 2050 at the Caballo Mine.

TABLE 3. SUMMARY OF COAL MINING METHODS AND PERMITTED ACRES FOR THE MINES IN THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Mine	Truck & Shovel	Dragline	Cast Blasting	Permitted Acres	Approved Acres to Affect
Caballo	Yes	No	No	19,974.70	11,982.40
Belle Ayr	Yes	No	No	11,935.63	11,621.10
Cordero Rojo	Yes	Yes	Yes	17,025.00	14,121.00
Coal Creek	Yes	Yes	Yes	9,696.21	8,328.41
Cordero Rojo - Maysdorf I Amendment	*Yes*	*Yes*	*Yes*	*4,414.00*	*3,696.00*
TOTAL				**63,045.54**	**49,748.91**

Acres compiled from Form 1 in permits. Note that since the Belle Ayr permit boundary overlaps with the Caballo and Cordero Rojo permit boundaries, the total acreage values in the last row are actually less than the amount shown.

With the approval of the Maysdorf I Amendment, nearly 50,000 ac will be approved to be affected by disturbance at the four mines. As of 2010, the life-of-mine disturbed acreage at the four mines was much less, totaling 29,201 ac. A breakdown of disturbance by WDEQ/LQD Coal Annual Report Format (CARF) land status category at the four mines is shown in **Figure 4**. The active coal pits account for 9,151 ac of disturbance, or 31 percent of the total. Permanently reclaimed areas account for 9,960 ac, or 34 percent of the total disturbed acreage (**Figure 4**). In 2009-2010, the Cordero Rojo Mine produced the most coal (40,223,766 short tons), followed by the Belle Ayr Mine (28,655,953 short tons), Caballo Mine (22,618,808 short tons), and Coal Creek Mine (9,766,852 short tons).

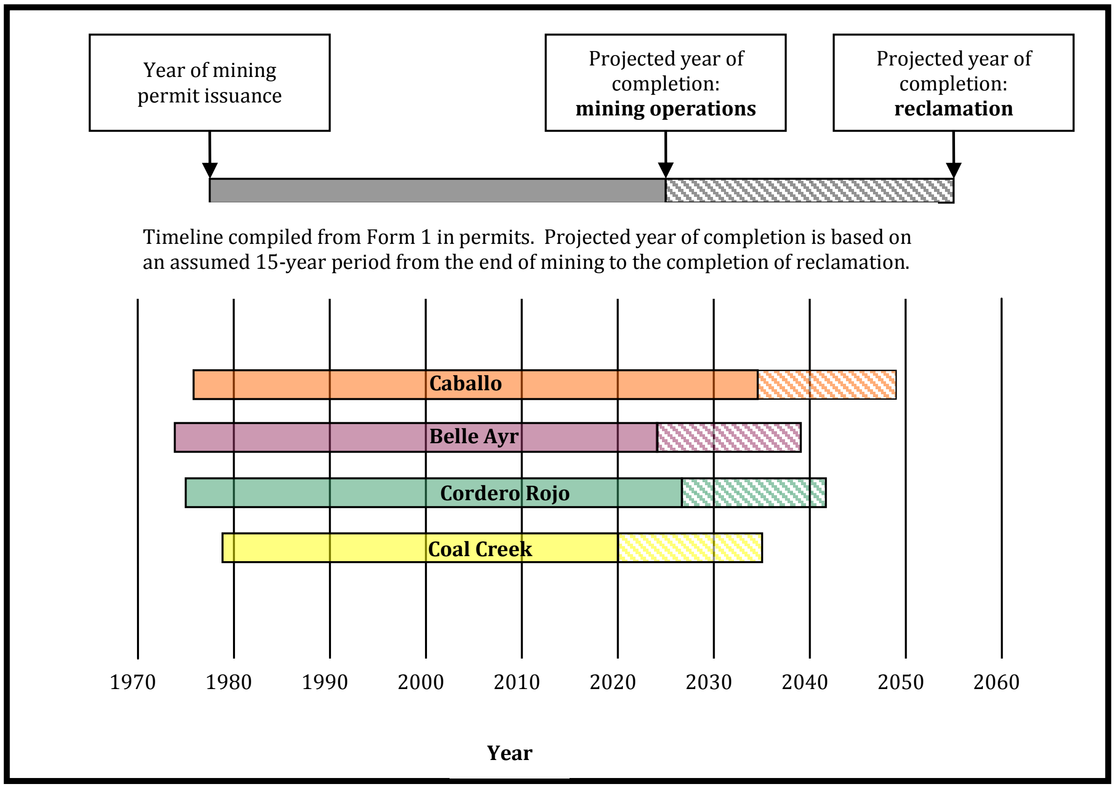


FIGURE 3. MINING AND RECLAMATION PROJECTIONS FOR THE MIDDLE POWDER RIVER BASIN COAL MINES, WYOMING, 2011.

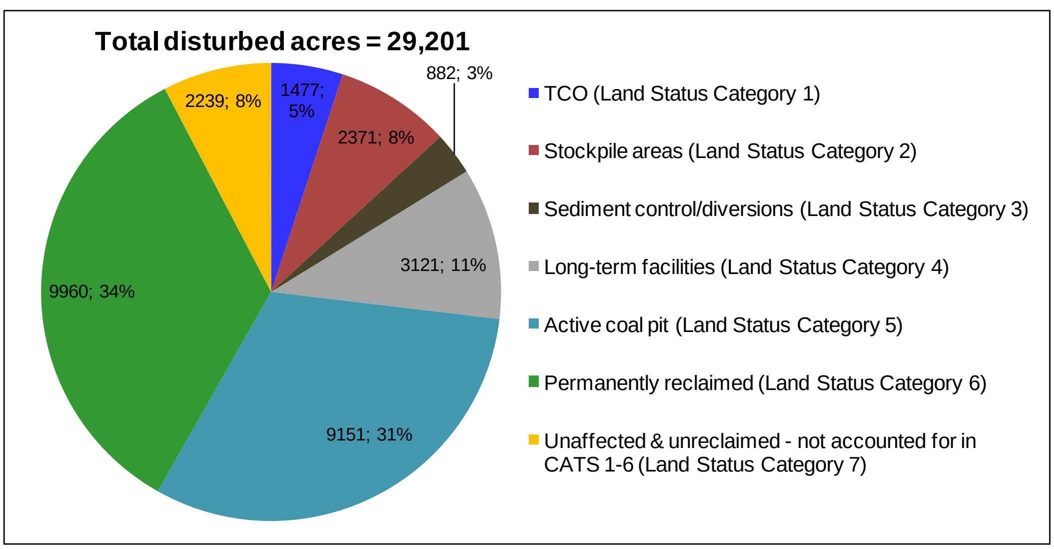


FIGURE 4. TOTAL LIFE-OF-MINE ACREAGE DISTURBED BY WDEQ/LQD LAND STATUS CATEGORY AT THE MIDDLE POWDER RIVER BASIN COAL MINES, WYOMING, 2011.

2. CUMULATIVE IMPACT AREA

The cumulative impact area (CIA) is the area where existing and proposed mining activities may cause measurable changes to the hydrologic environment and depends on the characteristics of the surface and groundwater systems. Surface and groundwater impact areas are defined separately in this CHIA because of the differences in flow systems and areas of impact. The final CIA encompasses both the surface and groundwater impact areas. The CIA lies within the middle part of the PRB and within the upper Belle Fourche River drainage basin, a tributary of the Missouri River.

2.1 SURFACE WATER

The surface water CIA includes the drainage area upstream from a point where mining impacts can be cumulated. Two separate surface water CIAs are delineated in this CHIA: (1) Caballo Creek upstream from United States Geological Survey (USGS) Station No. 06425900 – *Caballo Creek at Mouth Near Piney, Wyoming*, and (2) the Belle Fourche River (BFR) upstream from USGS Station No. 06425780 - *Belle Fourche River above Dry Creek near Piney, Wyoming*. **Table 4** and **Plate 1** show the location and period of record for all surface water stations used to evaluate baseline and during-mining hydrologic conditions in the two CIAs.

The Caballo Creek CIA covers a drainage area of 260 square miles (mi^2) upstream from USGS Station No. 06425900. The Caballo Creek CIA contains 98 percent of the Caballo Mine permit area, 100 percent of the Belle Ayr Mine permit area, and 38 percent of the Cordero Rojo Mine permit area (**Plate 1**). Major tributaries to Caballo Creek in the vicinity of the mines within the CIA include Tisdale Creek, Duck Nest Creek, and Bone Pile Draw. Hoe Creek is another major tributary to Caballo Creek but the drainage is entirely upstream from the mines (**Plate 1**).

Approximately two percent of the Caballo Mine permit area falls outside of the CIA and into the Dry Donkey Creek drainage. This area is located within the northeastern portion of the permit area. Dry Donkey Creek is a tributary to Donkey Creek, which flows into the BFR downstream of the CIAs. The Caballo Mine currently has no plans to mine within the Dry Donkey Creek drainage (Caballo Mine Permit, 2011). Therefore, the area draining to Dry Donkey Creek will not be considered as part of the CIA for this analysis.

The BFR CIA covers a drainage area of 594 mi^2 upstream from USGS Station No. 06425780. This station is currently known as station LBFR at the downstream (eastern) permit boundary of the Cordero Rojo Mine (**Plate 1**). Coal Creek is the major tributary to the BFR within the CIA.

Approximately 52 percent (8,849 ac) of the Cordero Rojo Mine permit area is contained within the BFR CIA (**Plate 1**). Approximately ten percent of the permit area or 1,650 ac fall outside the both the Caballo Creek and BFR CIAs. A majority of this total (approximately 1,600 ac) drains to

Kicken Draw, which flows into the BFR downstream of USGS Station No. 06425780. Some of this area has been disturbed by mining, but was not included in the CIA due to the lack of a close USGS gaging station. The next closest USGS gage on the BFR is approximately 25 miles downstream below Moorcroft, Wyoming. The station has a drainage area of 1,690 mi^2, making it too large to determine cumulative effects and material damage. Furthermore, the gage also receives flow from the Wyodak Mine in the northern part of the PRB near Gillette. Because of these reasons, the BFR CIA was not expanded to include the area of Kicken Draw at the Cordero Rojo Mine.

Approximately 15 percent (1,500 ac) of the Coal Creek Mine permit area lies in either the Dry Creek drainage or another unnamed tributary that flows into the BFR downstream of USGS Station No. 06425780. Although this portion of the mine contains the facilities area, rail loop, and some mining activity, this area was not considered as part of the CIA due to the lack of a close USGS gaging station.

TABLE 4. GAGING STATIONS USED TO EVALUATE BASELINE AND DURING-MINING HYDROLOGIC CONDITIONS IN THE CABALLO CREEK AND BELLE FOURCHE RIVER CIAS, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

CIA	Gaging Station	Location	Drainage Area (mi^2)	Baseline Period	During-Mining Period
Caballo Creek	UGM (Caballo Mine)	Gold Mine Draw – upstream	4.1	3/1978 to 12/1986	4/1987 to 3/2010
	LGM (Caballo Mine)	Gold Mine Draw – downstream	10.5	4/1977 to 12/1986	4/1987 to 3/2010
	Upper North Tisdale (Caballo Mine)	North Tisdale Creek	4.7	1/1979 to 10/1986	-
	Upper Tisdale (Caballo Mine)	Tisdale Creek – upstream	13.3	1/1979 to 11/1995	-
	Lower Tisdale (Caballo Mine)	Tisdale Creek - downstream	26.5	1/1978 to 10/1989	-
	Duck Nest Creek (Belle Ayr Mine)	Duck Nest Creek	4.8[1]	2/1990 to 3/2001	-
	Bone Pile Creek (Belle Ayr Mine)	Bone Pile Creek	44[1]	2/1990 to 11/2007	-
	BA-6 (Belle Ayr Mine)	Caballo Creek –Belle Ayr Mine west permit boundary	127	4/1980 to 9/1983	2/1984 to 9/2009
	BA-1 (Belle Ayr Mine)	Caballo Creek – below Caballo Reservoir	184	4/1978 to 9/1983	-
	BA-4 (Belle Ayr Mine)	Caballo Creek – Belle Ayr Mine east permit boundary	212	4/1978 to 9/1983	2/1984 to 9/2009
	USGS 06425900	Caballo Creek at mouth near Piney, WY	260	8/1977 to 9/1983	12/2000 to 7/2010
Belle Fourche River	CC-12	Coal Creek at downstream permit boundary – Coal Creek Mine	71[1]	-	3/1999 to 10/2009
	USGS 06425750	Coal Creek near Piney, WY	71.8	10/1980 to 9/1983	-
	USGS 06245720/UBFR[2]	Belle Fourche River below Rattlesnake Creek near Piney, WY	495	10/1975 to 4/1983	3/1994 to 7/2010
	USGS 06425780/LBFR[3]	Belle Fourche River above Dry Creek near Piney, WY	594	10/1975 to 9/1983	3/1994 to 6/2010

[1]Drainage area estimated.
[2]The Cordero Rojo Mine uses the station name UBFR to report data from this station; the USGS also currently collects data at the station.
[3]The Cordero Rojo Mine uses the station name LBFR to report data from this station; the USGS was responsible for data collection from 1975 to 1983.

2.2 GROUNDWATER

Conceptually, the groundwater CIA is defined as: (1) areas impacted by mine induced groundwater level drawdown; (2) the extent of any measurable impacts the groundwater drawdown may have on the surface water system; and (3) areas where plumes of degraded groundwater may develop and migrate. For assessing groundwater impacts, the CIA encompasses the area delineated by the maximum cumulative five-foot drawdown contour in the Wyodak Anderson coal aquifer for the Cordero Maysdorf I Amendment, Cordero Rojo Mine and the other three coal mines in the middle PRB: Caballo, Belle Ayr, and Coal Creek. The CIA for groundwater impacts includes parts of the Caballo Creek and Belle Fourche River drainage basins.

The groundwater CIA is defined by compilation of the impacts from individual mines to individual aquifers. The maximum extent of the predicted cumulative five-foot drawdown contour in the coal aquifer for these mines in the middle PRB is estimated by overlaying and cumulating the individual predicted drawdowns from each mine. The predicted maximum extent of the five-foot drawdown contours for each mine are considered in order to conservatively predict the maximum extent of the cumulative five-foot drawdown contour and define the groundwater CIA to the north, west and south. The groundwater CIA is extended approximately one-fourth mile to the east of the mined areas to encompass any projected impact the mines may have on the clinker aquifer. Generally, the impacts to the alluvial aquifer and Wasatch Leaky Aquitard Unit are less than the drawdown impacts to the Wyodak Anderson coal aquifer and lie within the area of the coal drawdown. The application for the Cordero Maysdorf I Amendment (TFN 4 1/200) did not include a five-foot drawdown projection. In place of that information, projection of the drawdown in the Cordero Maysdorf I Amendment was made using drawdown discussions in the main plan of the Cordero Maysdorf I Amendment application and the projected drawdown presented in the final EIS (Bureau of Land Management, 2007) for this coal lease.

Potential impacts to the groundwater system from mine facility water supply wells are considered insignificant and are not further evaluated for the following two reasons. First, potable water at the mines is produced from wells completed between 1,000 and 2,200 feet below the land surface and 600 plus feet below the deepest anticipated mining activities. The wells are typically completed in the Tullock aquifer of the Fort Union Formation. The strata located below the coal and above the Tullock aquifer consist of low to very low permeability sediments of the lower Tongue River Member of the Lebo shale, a confining unit, thus induced vertical leakage is not anticipated. Second, water level declines in sub-coal Fort Union wells generally occur within one mile of the pumped wells (Martin et al., 1988). Mine supply wells are separated by distances of one mile or more, therefore, little interference is expected between mine supply wells (Bureau of Land Management, 1994).

3. BASELINE HYDROLOGIC CONDITIONS

Baseline data are collected to characterize pre-mining hydrologic conditions. A generalized summary is presented here and additional information is available in individual permits.

Conceptually defining baseline seems relatively straightforward. The reality is more complex for a CIA analysis. For example, the baseline data from the CIAs are reflective of both temporal and spatial variability. Not all mines initiated mining at the same time. New lands have also been amended to existing permits. Data collected at new amendment areas have the potential to be influenced by previous mining. Underlying those temporal changes, both aquifers and watersheds have natural spatial variability. This natural variability can be reflected when new data, via the additions of new amendments, are collected to characterize the system. Furthermore, since 1997, coal bed methane (CBM) has been rapidly developing in the PRB. Although CBM production has decreased in recent years in the middle PRB, the activity still has the potential to affect the same aquifers and surface water drainages as the coal mines.

3.1 SURFACE WATER

The baseline water quantity and water quality of individual drainages in the Caballo Creek and BFR CIAs are described in the following sections.

3.1.1 BASELINE WATER QUANTITY AND WATER QUALITY OF INDIVIDUAL DRAINAGES IN THE CABALLO CREEK CIA

The primary drainages within the mines in the Caballo Creek CIA include Gold Mine Draw, North Tisdale Creek, Tisdale Creek, Bone Pile Draw, Duck Nest Creek, and Caballo Creek. In addition, the CIA includes thousands of acres of non-contributing drainage represented by closed basins containing playas **(Plate 1).**

3.1.1.1 GOLD MINE DRAW

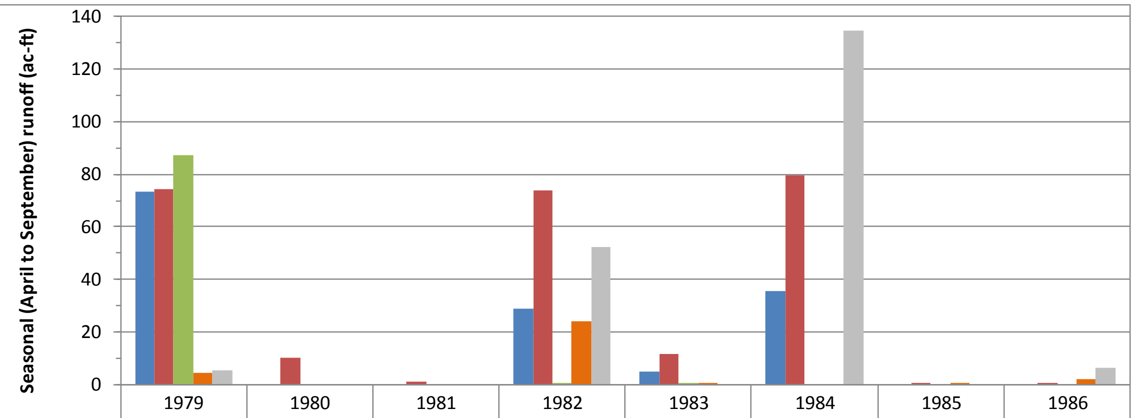
Gold Mine Draw is a tributary to Tisdale Creek with a drainage area of approximately 10.8 mi^2. The drainage lies in the east portion of the Caballo Mine permit area (**Plate 1**). The watershed has remained mostly undisturbed by mining due to the presence of an alluvial valley floor (AVF) significant to farming. AVFs significant to farming cannot be mined; more discussion of this AVF is found in Section 3.3 – *Alluvial Valley Floors*. Pre-mine stockponds influence the hydrology of the drainage, as 17 stock reservoirs exist in the watershed (Caballo Mine Permit, 2011). Surface water rights in the watershed are mostly associated with stock reservoirs and irrigation near the declared AVF (Wyoming State Engineer's Office, 2010).

The Caballo Mine installed gages on upper and lower Gold Mine Draw in 1979 and 1978, respectively (**Table 4**, **Plate 1**). Both stations are currently active. Water quality sampling initiated in 1977 at Lower Gold Mine Draw (LGM) and in 1978 at Upper Gold Mine Draw (UGM). The UGM station is located upstream of the declared AVF and has a drainage area of 4.1 mi^2. The LGM station is located upstream of the confluence with Tisdale Creek and has a drainage area of 10.5 mi^2. For the purposes of the CHIA, the 1977 to 1986 period will be evaluated for baseline conditions. Since little mining disturbance has occurred in Gold Mine Draw, the 1977 to 1986 period was selected somewhat arbitrarily to coincide with the period available at other Caballo Mine stations in the Tisdale Creek watershed. Section 6 will provide additional analysis of trends in surface water quantity and quality on Gold Mine Draw.

The seasonal (April through September) runoff volumes at the upper and lower stations on Gold Mine Draw from 1979 to 1986 are plotted in **Figure 5**. Total runoff volumes at the other Caballo Mine stations in the Tisdale Creek drainage are also shown for comparison. More runoff was recorded in each year at LGM compared to UGM. The annual differences ranged from 0.3 ac-ft in 1986 to 22.9 ac-ft in 1983. The pattern of streamflow was also different between stations, as UGM was more characteristic of an ephemeral regime while flows at LGM were intermittent. Flows at LGM were also very erratic during the fall and winter, suggesting water was released from upstream impoundments.

The maximum mean daily discharge at UGM was 11 cfs, recorded in January 1983. The maximum mean daily discharge on LGM was 144 cfs, recorded on May 18, 1978. This mean is between a 2.33 and 5-yr event, as predicted by USGS peak-flow regression equations for the central basins and northern plains region of Wyoming (Miller, 2003). Although the peak discharge for the storm is not available, it is likely that the peak flow was indicative of a more rare event. Approximately four to five inches of rain fall across northeastern Wyoming during May 16-19, 1978. Since antecedent moisture had resulted in saturated conditions and snowmelt runoff was already occurring, the storm caused widespread flooding throughout the region (Parrett et al., 1984). The May 18-19, 1978 flood stands as the highest peak discharge recorded at several of the long term USGS gaging stations in the PRB.

The WDEQ/WQD has classified Gold Mine Draw as Class 3B water (Wyoming Department of Environmental Quality, 2001). Class 3B waters are intermittent or ephemeral tributaries with uses for aquatic life other than fish (**Table 5**). Class 3B waters need to meet acute and chronic water quality standards for aquatic life other than fish. The WDEQ/WQD surface water numeric standards for Gold Mine Draw are presented in **Table 6**.



	1979	1980	1981	1982	1983	1984	1985	1986
Upper Gold Mine Draw	73.4	0.0	0.0	28.6	4.7	35.6	0.0	0.0
Lower Gold Mine Draw	74.4	10.1	1.0	73.9	11.5	79.6	0.8	0.6
Upper North Tisdale	87.4	0.0	0.0	0.3	0.1	0.0	0.0	0.0
Upper Tisdale	4.6	0.0	0.0	23.9	0.0	0.0	0.3	1.8
Lower Tisdale	5.4	0.0	0.0	52.1	0.0	134.7	0.0	6.3

FIGURE 5. COMPARISON OF SEASONAL (APRIL THROUGH SEPTEMBER) RUNOFF VOLUMES AT GAGING STATIONS IN THE TISDALE CREEK WATERSHED AT THE CABALLO MINE, 1979 TO 1986, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

TABLE 5. WYOMING SURFACE WATER USE CLASSIFICATIONS.

Class	Use	Sub-Class	Description
Class 1	Outstanding Waters		
Class 2	Fisheries and Drinking Water	Class 2A	Drinking Water
		Class 2AB	Game Fish and Drinking Water
		Class 2B	Game Fish (cold and warm water)
		Class 2C	Non-Game Fish (warm water)
Class 3	Aquatic Life Other Than Fish	Class 3A	Isolated waters
		Class 3B	Intermittent and ephemeral tributaries
		Class 3C	Perennial
Class 4	Agricultural, Industry, Recreation, and Wildlife	Class 4A	Canals and ditches
		Class 4B	Intermittent and ephemeral
		Class 4C	No aquatic life potential
From WDEQ/WQD (2001)			

The WDEQ/LQD Hydrology Database only contains water quality collected data on Gold Mine Draw since 1999. Because of this, a detailed statistical summary in relation to Class 3B standards is not possible for a large part of the period of record. The 1978 to 1986 water quality data from the Caballo Mine permit indicate that UGM had a mixed cation-sulfate type water (Caballo Mine Permit, 2011). TDS at 180 degrees C from 24 samples ranged from 124 to 2,380 mg/l, with a mean of 624 mg/l. Class 3B standards were exceeded for aluminum, cadmium, copper, lead, and selenium. At LGM, the 1977 to 1986 data indicate Ca-SO_4 water type. TDS at 180 degrees C from 67 samples ranged from 218 to 3,340 mg/l, with a mean of 1,410 mg/l. Class 3B standards were exceeded for pH, manganese, cadmium, chromium, copper, lead, and selenium (Caballo Mine Permit, 2011).

TABLE 6. NUMERIC SURFACE WATER STANDARDS BASED ON CLASS OF USE, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	Units	Class 2AB (ww)		Class 3B					
		CABALLO CREEK	BELLE FOURCHE RIVER	GOLD MINE DRAW	NORTH TISDALE CREEK	TISDALE CREEK	DUCK NEST CREEK	BONE PILE CREEK	COAL CREEK
Hardness as $CaCO_3$	mg/l	711[1]	1,026[2]	1,114[3]	NA[4]	NA[5]	411[6]	705[7]	319[8]
Ammonia(NH3 as N) (total)	mg/l	2.43[9]	2.43[9]	NA[10]	NA[10]	NA[10]	NA[10]	NA[10]	NA[10]
Turbidity	NTU	< 15[11]	< 15[11]	NA	NA	NA	NA	NA	NA
Temperature	°C	< 30	< 30	NA[12]	NA[12]	NA[12]	NA[12]	NA[12]	NA[12]
pH	SU	6.5 - 9.0	6.5 - 9.0	6.5 - 9.0	6.5 - 9.0	6.5 - 9.0	6.5 - 9.0	6.5 - 9.0	6.5 - 9.0
Aluminum (dissolved)	mg/l	0.75[13]	0.75[13]	0.75[13]	0.75[13]	0.75[13]	0.75[13]	0.75[13]	0.75[13]
Barium (total)	mg/l	2	2	NA	NA	NA	NA	NA	NA
Chloride (total)	mg/l	230	230	NA	NA	NA	NA	NA	NA
Dissolved oxygen	mg/l	> 3[14]	> 3[14]	NA[15]	NA[15]	NA[15]	NA[15]	NA[15]	NA[15]
Iron (dissolved)	mg/l	1[16]	1[16]	1	1	1	1	1	1
Nitrate+Nitrite as N (total)	mg/l	10	10	NA	NA	NA	NA	NA	NA
Manganese (dissolved)*	mg/l	3.105[16]	3.105[16]	3.105	3.105	3.105	3.105	3.105	2.746
Arsenic	mg/l	0.01[17]	0.01[17]	0.15[18]	0.15[18]	0.15[18]	0.15[18]	0.15[18]	0.15[18]
Cadmium (dissolved)*	mg/l	0.0006[19]	0.0006[19]	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005
Chromium(III)*	mg/l	0.1[17]	0.1[17]	0.231[18]	0.231[18]	0.231[18]	0.231[18]	0.231[18]	0.192[18]
Copper (dissolved)*	mg/l	0.029[19]	0.029[19]	0.029	0.029	0.029	0.029	0.029	0.024
Lead (dissolved)*	mg/l	0.011[19]	0.011[19]	0.011	0.011	0.011	0.011	0.011	0.009
Mercury	µg/L	0.05[17]	0.05[17]	0.77[18]	0.77[18]	0.77[18]	0.77[18]	0.77[18]	0.77[18]
Nickel*	mg/l	0.1[17]	0.1[17]	0.169[18]	0.169[18]	0.169[18]	0.169[18]	0.169[18]	0.139[18]
Selenium (dissolved)	mg/l	0.0046[19]	0.0046[19]	0.0046	0.0046	0.0046	0.0046	0.0046	0.0046
Zinc (dissolved)*	mg/l	0.388[19]	0.388[19]	0.388	0.388	0.388	0.388	0.388	0.320

Table developed from WDEQ/WQD Rules and Regulations, Chapter 1 (Adopted April 25, 2007). Criteria presented represent concentrations meant to protect both human health and aquatic life uses. Although the constituents in this table are evaluated in this CHIA, it is not an exhaustive list of all constituents with standards established by WDEQ/WQD.

* Hardness dependent criteria for aquatic life, calculated using 400 mg/l when hardness > 400 mg/l; hardness values <400 mg/l will result in more stringent criteria for metals; [1] Calculated mean from period of record at USGS Station No. 06425900; [2] Calculated mean from period of record at USGS Station No. 06425720; [3] Calculated mean from period of record at Caballo Mine LGM station; [4] Hardness data not collected at the Caballo Mine Upper North Tisdale Creek station; [5] Hardness data not collected at Caballo Mine Lower Tisdale Creek or Upper Tisdale Creek stations; [6] Calculated mean from period of record at Belle Ayr Mine Duck Nest Creek station; [7] Calculated mean from period of record at Belle Ayr Mine Bone Pile Creek station; [8] Calculated mean from period of record at USGS Station No. 06425750; [9] Chronic Criterion for fish early life stages present - calculated using mean pH and temperature from baseline period listed in Table 4 at USGS Station No. 06425900 and USGS Station No. 06425720; [10] Numeric criteria do not apply but concentrations of ammonia attributable to or influenced by human activities shall not be present in concentrations which could result in harmful acute or chronic effects to aquatic life, or which would not fully support existing and designated uses; [11] In all warm water or nongame fisheries, the discharge of substances attributable or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than 15 NTUs; [12] A maximum allowable temperature does not apply, but effluent attributable to or influenced by the activities of man shall not be discharged in amounts which change ambient water temperatures to levels which result in harmful acute or chronic effects to aquatic life, or which not fully support existing and designated uses; [13] Acute value which assumes pH ≥ 7.0 and hardness as $CaCO_3$ ≥ 50 mg/l; [14] 1-day minimum instantaneous concentration for other life stages; [15] Minimum concentrations do not apply but wastes attributable to or influenced by the activities of man shall not deplete dissolved oxygen amounts to a level which will result in harmful acute or chronic effects to aquatic life, or which would not fully support existing and designated uses; [16] The numeric human health criteria for iron and manganese do not apply to Class 2 waters in the Belle Fourche River drainage upstream from the confluence with Donkey Creek - the value listed is the aquatic life criterion; [17] Total value; [18] Dissolved value; [19] Value shown is the aquatic life criterion since the human health fish & drinking water value was less stringent or did not apply; NA (not applicable).

3.1.1.2 NORTH TISDALE CREEK

North Tisdale Creek is an ephemeral tributary to Tisdale Creek located in the central portion of the Caballo Mine permit area. The contributing drainage area is approximately 7.2 mi^2. Surface water rights in the drainage are held by the Caballo Mine for stock watering, wetlands, flood control, sediment control, and dust suppression. Ten pre-mine stock reservoirs were located in the drainage within the Caballo Mine permit boundary; three of these will be disturbed by mining (Caballo Mine Permit, 2011).

The Caballo Mine operated a flume on Upper North Tisdale Creek from 1979 to 1986 (**Table 4**, **Plate 1**). The station monitored a contributing area of 4.7 mi^2. The period of record flows illustrate the ephemeral nature of runoff in the watershed. Flow occurred only 2.6 percent of the time. The maximum mean daily flow was 12.6 cfs in June 1979. The seasonal runoff volumes from 1979 to 1986 are plotted in **Figure 5**. With the exception of 1979, runoff was very infrequent. The 1979 data indicate more runoff occurred in North Tisdale Creek compared to Lower Tisdale Creek and Lower Gold Mine Draw, despite these stations having larger contributing areas. These differences are presumably due to the spatial variability in rainfall across the Caballo Mine, although other factors may be involved such as water retention or releases from stock reservoirs.

The WDEQ/WQD has classified North Tisdale Creek as Class 3B water (Wyoming Department of Environmental Quality, 2001). The WDEQ/WQD surface water numeric standards for North Tisdale Creek are presented in **Table 6**. The WDEQ/LQD Hydrology Database currently does not contain any of the water quality data from North Tisdale Creek, so a detailed statistical summary in relation to Class 3B standards is not possible. The 1979 to 1986 water quality data presented in the Caballo Mine permit showed $Mg\text{-}SO_4$ type water (Caballo Mine Permit, 2011). TDS at 180 degrees C ranged from 147 to 13,050 mg/l, with a mean of 3,527 mg/l. The maximum concentrations of aluminum, cadmium, copper, lead, and selenium exceeded Class 3B standards. It appears that these exceedences were infrequent and are within the range of variability expected for ephemeral drainages in the PRB.

3.1.1.3 TISDALE CREEK

Tisdale Creek is the primary drainage at the Caballo Mine, and joins Caballo Creek about one mile south of the permit area. The drainage has a contributing area of approximately 40 mi^2. The majority of Tisdale Creek is ephemeral with the exception of the lower reaches which are intermittent. Runoff is sparse due to closed depressions, stockponds, and highly permeable eolian sands. Surface water rights in the drainage are mostly held by the Caballo Mine for stock watering, wetlands, flood control, sediment control, and dust suppression (Caballo Mine Permit, 2011).

The Caballo Mine operated two gaging stations on Tisdale Creek to establish baseline conditions. Upper Tisdale Creek monitored 13.3 mi^2 of the upper watershed and Lower Tisdale Creek had a contributing area of approximately 19.5 mi^2 (**Table 4**, **Plate 1**). The Lower Tisdale Creek station was located approximately two miles upstream from the confluence with Caballo Creek. The Upper Tisdale station was operational from 1979 to 1995, and Lower Tisdale was active from 1978 to 1989. Upper Tisdale was located upstream of mining activity during its period of record. The period of record at Lower Tisdale was included for baseline characterization, despite mining activity occurring upstream from the gage. A third site, Tisdale West, was constructed in 1991 on Tisdale Creek near the upstream permit boundary. This site was discontinued in 2009 due to lack of flow (Caballo Mine Permit, 2011). Since little data exist for this station, it will not be further discussed in the CHIA.

The period of record flow data at the Upper and Lower stations confirms the ephemeral flow regime of the majority of Tisdale Creek within the Caballo Mine. Flows at both gages were infrequent, occurring only about seven percent of the period of record. A comparison of runoff volumes between gages during the period when both stations were active showed that one to four times more runoff was measured at Lower Tisdale (**Figure 5**). The maximum mean daily discharge recorded at Upper Tisdale over 1979 to 1995 was 20.5 cfs, recorded in March 1979. At Lower Tisdale, the maximum mean daily discharge recorded between 1978 and 1989 was 225 cfs. This maximum occurred during the flood event of May 18, 1978. This mean daily flow corresponds to approximately a 5-yr flood event, as predicted by Miller (2003).

The WDEQ/WQD has classified Tisdale Creek as Class 3B water (Wyoming Department of Environmental Quality, 2001). The WDEQ/WQD surface water numeric standards for Tisdale Creek are presented in **Table 6**. The WDEQ/LQD Hydrology Database currently does not contain any of the water quality data from Tisdale Creek, so a detailed statistical summary in relation to Class 3B standards is not possible. The water quality data presented in the Caballo Mine permit indicate that Upper Tisdale Creek was Mg-SO_4 type water while Lower Tisdale was mixed cation-sulfate type water (Caballo Mine Permit, 2011). TDS at 180 degrees C at Upper Tisdale ranged from 115 to 3,090 mg/l, with a mean of 830 mg/l. At Lower Tisdale, TDS at 180 degrees C ranged from 63 to 5,170 mg/l, with a mean of 597 mg/l. At Upper Tisdale, Class 3B exceedences were noted for pH, aluminum, iron, cadmium, copper, lead, and selenium. With the exception of pH and iron, these same parameters showed exceedences on Lower Tisdale Creek (Caballo Mine Permit, 2011).

3.1.1.4 DUCK NEST CREEK

Duck Nest Creek is an ephemeral tributary to Caballo Creek in the northwest portion of the Belle Ayr Mine permit area. The drainage area is approximately 6.6 mi^2. Runoff is affected by numerous impoundments in the watershed. The lower reaches contained a groundwater discharge area where seeps created a few small, shallow pools and wet terrace surfaces (Belle Ayr Mine Permit, 2011). The lower portion of the drainage has been mined and mining will continue to advance into the upper drainage (Belle Ayr Mine Permit, 2011). CBM activity is also occurring in the upper watershed, potentially affecting streamflows and water quality. Surface water rights in the drainage are mostly held by the Belle Ayr Mine for flood control. Adjudicated water rights for irrigation also exist upstream of the mine (Wyoming State Engineer’s Office, 2010).

A detailed analysis of flow conditions on Duck Nest Creek is not possible because the Belle Ayr Mine has not established a continuous recording station. The mine estimated the peak discharges for 24-hr storms of varying recurrence intervals using the Soil Conservation Service

(SCS) Triangular Hydrograph Method (**Table 7**). For Duck Nest Creek, estimates were made at a point approximately one mile upstream from the confluence with Caballo Creek.

TABLE 7. ESTIMATES OF PEAK DISCHARGES FOR THE 24-HR STORMS OF VARYING RECURRENCE INTERVALS ON DUCK NEST CREEK AND BONE PILE CREEK, AS ESTIMATED BY THE BELLE AYR MINE, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Location and Contributing Area	2-yr, 24-hr Peak Discharge (cfs)	10-yr, 24-hr Peak Discharge (cfs)	100-yr, 24-hr Peak Discharge (cfs)
Duck Nest Creek (5.5 mi^2)	165	700	1,760
Bone Pile Creek at Mouth (44.2 mi^2)	280	1,250	3,380

The Belle Ayr Mine has also collected instantaneous discharge measurements and water quality samples from a site on Duck Nest Creek in the northwest portion of the permit area within the declared AVF (**Table 4**, **Plate 1**). The WDEQ/LQD Hydrology Database contains data from this station from 1990 to 2001. The entire record is applicable for baseline characterization since mining has not occurred upstream from the gage. The Belle Ayr Mine also periodically samples water quality in Duck Nest Reservoir, but these data will not be discussed in the CHIA.

The WDEQ/WQD has classified Duck Nest Creek as Class 3B water (Wyoming Department of Environmental Quality, 2001). The WDEQ/WQD surface water numeric standards for Duck Nest Creek are presented in **Table 6**. Approximately 20 samples collected from 1990 to 2001 are available for analysis (**Table 8**). AqQA software was used to determine water type (RockWare, Inc., 2006). The most common water type was $Mg\text{-}SO_4$, which was noted in 41 percent of the samples.

The summary statistics in **Table 8** for constituents with non-detect concentrations were calculated using methods recommended by Helsel (2005). For constituents with < 50 percent below-detects, the non-parametric Kaplan-Meier method was used. For constituents with 50-79 percent below-detects, the robust regression on order statistics (ROS) method was used. For constituents with ≥ 80 percent non-detects, summary statistics were not calculated but rather the proportion of data below the maximum detection limit was reported. An Excel spreadsheet available from www.practicalstats.com was used to calculate Kaplan-Meier estimates. Minitab software (Minitab, Inc., 2007) was used to calculate ROS estimates using macros available from www.practicalstats.com.

TDS @ 180 degrees C on Duck Nest Creek ranged from 30 to 4,100 mg/l, with a median of 268 mg/l (**Table 8**). TSS ranged from 2 to 41 mg/l, with a median of 20 mg/l. Dissolved metal concentrations were very low, with numerous values below laboratory detection limits. The samples collected during the 1990-2001 period show that water quality on Duck Nest Creek is quite high, and WDEQ/WQD standards were satisfied for Class 3B waters. The only exceedence occurred for the maximum concentration of aluminum (1.48 mg/l). The mean and median concentrations of each constituent evaluated showed no exceedences over the period (**Table 8**).

TABLE 8. BASELINE WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON DUCK NEST CREEK AND BONE PILE CREEK AT THE BELLE AYR MINE, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	USGS Parameter Code	Units	Duck Nest Creek (1990-2001)					Bone Pile Creek (1990-2007)				
			Count	Min	Max	Mean	Median	Count	Min	Max	Mean	Median
Temperature (field)	00010	°C	22	0.5	19.0	7.5	7.8	56	1.0	24.8	10.6	9.2
Turbidity	00076	NTU	22	2.3	300	50.6	27.3	53	<1.0	90	17.7	12.0
Dissolved oxygen (field)	00300	mg/l	5	0.1	8.7	3.1	2.2	34	0.1	10.2	5.1	4.9
pH (field)	00400	S.U.	20	6.00	8.70	7.59	7.60	53	7.0	9.7	8.3	8.4
Ammonia as N (dissolved)	00608	mg/l	22	<0.01	0.71	0.11	0.06	55	<0.05	2.00	0.20	0.07
Sodium (dissolved)	00930	mg/l	22	1	343	85	40	56	2	1,516	364	196
Chloride (dissolved)	00940	mg/l	22	1.0	16.0	4.8	3.5	56	2.0	47.0	11.8	11.0
Sulfate (dissolved)	00945	mg/l	22	1	2,993	466	154	56	<1	5,180	1,085	241
Fluoride (dissolved)	00950	mg/l	22	0.04	1.10	0.27	0.15	56	<0.05	6.45	0.86	0.78
Arsenic (dissolved)	01000	mg/l	13	<0.005	<0.005	100% <0.005		47	<0.005	0.005	96% <0.005	
Barium (dissolved)	01005	mg/l	13	<0.5	<0.5	100% <0.5		48	<0.5	0.5	98% <0.5	
Boron (dissolved)	01020	mg/l	22	<0.01	0.21	0.08	0.08	56	<0.01	0.39	0.10	0.07
Cadmium (dissolved)	01025	mg/l	13	<0.002	<0.002	100% <0.002		48	<0.002	0.002	98% <0.002	
Chromium (dissolved)	01030	mg/l	17	<0.02	<0.02	100% <0.02		52	<0.01	<0.02	100% <0.02	
Copper (dissolved)	01040	mg/l	13	<0.01	<0.01	100% <0.01		48	<0.01	<0.01	100% <0.01	
Iron (dissolved)	01046	mg/l	22	<0.05	0.64	0.16	0.11	56	<0.05	0.59	0.09	0.05
Lead (dissolved)	01049	mg/l	13	<0.02	<0.02	100% <0.02		48	<0.02	0.02	96% <0.02	
Manganese (dissolved)	01056	mg/l	15	<0.02	1.15	0.15	0.05	51	<0.02	2.54	0.23	0.06
Nickel (dissolved)	01065	mg/l	13	<0.01	<0.01	100% <0.01		48	<0.01	0.01	96% <0.01	
Zinc (dissolved)	01090	mg/l	13	<0.01	0.04	0.04	0.04	48	<0.01	0.12	0.009	0.001
Aluminum (dissolved)	01106	mg/l	13	<0.10	1.48	0.30	0.09	48	<0.10	1.05	85% <0.10	
Selenium (dissolved)	01145	mg/l	18	<0.005	<0.005	100% <0.005		53	<0.005	0.007	98% <0.005	
TDS dried at 180 °C	70300	mg/l	21	30	4,100	829	268	53	26	8,374	1,991	740
Mercury (dissolved)	71890	µg/l	22	<1	<1	100% <1		56	<1	<1	100% <1	
Total suspended solids	80154	mg/l	22	2	401	57	20	55	<1	360	22	12

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Means and medians were not calculated for constituents having ≥ 80% below-detect values. Concentrations shown in red exceed WDEQ/WQD Class 3B surface water quality standards.

3.1.1.5 BONE PILE CREEK

Bone Pile Creek is an ephemeral tributary to Caballo Creek in the west portion of the Belle Ayr Mine permit area. The drainage has a contributing area of approximately 44.2 mi^2. Runoff is affected by numerous impoundments. One impoundment near the confluence with Caballo Creek has resulted in 31 ac of naturally subirrigated land and 35 ac of naturally flood irrigated land (Belle Ayr Mine Permit, 2011). Groundwater discharge does not contribute to baseflows in lower Bone Pile Creek (Belle Ayr Mine Permit, 2011). The Belle Ayr Mine currently has no plans to mine in Bone Pile Creek, but some of the lower watershed will be affected by diversions for Caballo Creek. CBM activity is also occurring in the watershed, potentially affecting streamflows and water quality. No surface water rights exist on Bone Pile Creek within the boundary of the Belle Ayr Mine. Upstream of the mine, surface water rights are held for irrigation, stock, and domestic purposes (Wyoming State Engineer's Office, 2010).

A detailed analysis of flow conditions on Bone Pile Creek is not possible because the Belle Ayr Mine has not established a continuous recording station. The mine estimated the peak discharges for 24-hr storms of varying recurrence intervals using the SCS Triangular Hydrograph Method (**Table 7**).

The WDEQ/WQD has classified Bone Pile Creek as Class 3B water (Wyoming Department of Environmental Quality, 2001). The WDEQ/WQD surface water numeric standards for Bone Pile Creek are presented in **Table 6**. The Belle Ayr Mine has collected instantaneous discharge measurements and water quality samples from a site on Bone Pile Creek in the west portion of the permit area near the declared AVF (**Table 4, Plate 1**). The WDEQ/LQD Hydrology Database contains data from this station from 1990 to 2007, with approximately 50 available for analysis (**Table 8**). The entire record is applicable for baseline characterization since mining has not occurred upstream from the gage. The dominant water type in 75 percent of the samples was Na-SO_4 (RockWare, Inc., 2006). TDS @ 180 degrees C ranged from 26 to 8,374 mg/l, with a median of 740 mg/l. TSS ranged from <1 to 360 mg/l, with a median of 12 mg/l (**Table 8**). Dissolved metal concentrations were very low, with numerous values below detection limits. The samples collected during the 1990-2007 period show that water quality on Bone Pile Creek is quite high, and WDEQ/WQD standards were satisfied for Class 3B waters. The only exceedences occurred for the maximum pH, and the maximum concentrations of cadmium, lead, aluminum, and selenium. The mean and median concentrations of each constituent evaluated showed no exceedences over the period (**Table 8**).

3.1.1.6 CABALLO CREEK

Caballo Creek is an intermittent tributary of the Belle Fourche River that flows in an easterly direction through the Belle Ayr Mine permit area. Caballo Creek has a drainage area of 260.5 mi^2. The main channel has been diverted in several locations over the course of mining at Belle Ayr. The hydrology of Caballo Creek has also been affected by pre-mine in-channel impoundments such as Caballo Reservoir (aka Dunlap Lake) and numerous small stockponds. Mine dewatering and CBM activity have also affected flows. Water rights along the mainstem of Caballo Creek within the vicinity of the mines are held for industrial use, stock watering, wildlife, and fish culture (Wyoming State Engineer's Office, 2010). A majority of these water rights are held by the Belle Ayr Mine.

Several gaging stations have been used to monitor Caballo Creek (**Table 4**). The Belle Ayr Mine began monitoring streamflow and water quality in the mid 1970s at three stations across the permit area. Station BA-1 was located downstream of Caballo Reservoir, Station BA-2 was located in the central portion of the permit area, and station BA-4 is located at the downstream (eastern) permit boundary (**Plate 1**). Another station (BA-6) was installed in 1980 at the current upstream (western) permit boundary (**Plate 1**). The BA-4 and BA-6 stations are currently active. BA-2 was mined through in 1991. BA-1 was inundated following the construction of Caballo Creek Diversion No. 7 (Belle Ayr Mine Permit, 2011). For the purposes of baseline characterization, streamflow data from BA-1, BA-4, and BA-6 are analyzed in the CHIA. Streamflow and water quality data from stations BA-4 and BA-6 will also be analyzed in Section 6 to evaluate during-mining conditions.

Another source of data for Caballo Creek is USGS Station No. 06425900 – *Caballo Creek at Mouth Near Piney, Wyoming* (U.S. Geological Survey, 2010a). The station is located at the accumulation point for the CIA, approximately four miles downstream of the Belle Ayr and Caballo mines (**Plate 1**). The station has six years of daily streamflow data (September 1977 to September 1983), and water quality samples were collected monthly. The station was reactivated in December 2000 to collect monthly water quality samples and instantaneous discharge measurements as part of a regional effort to monitor CBM impacts in northeastern Wyoming (Clark et al., 2005).

Characterizing pre-mine hydrologic conditions on Caballo Creek is difficult since the Belle Ayr Mine was in operation prior to start up date for any of the monitoring stations. The Belle Ayr Mine is one of the oldest mines in the PRB, with overburden removal first occurring in 1972; coal was first removed in 1973 (Belle Ayr Mine Permit, 2011). The Caballo Creek channel near the facilities area was mined and diverted in the early stages of mining. The mine also began discharging pit water into Caballo Creek as early as 1975. From December 1975 until December 1983, pit discharge to Caballo Creek ranged from 0 to 97 ac-ft/month (Belle Ayr Mine Permit, 2011). For the purposes of this CHIA, the baseline period for Caballo Creek was assumed to occur until September 1983, when the USGS Station was first deactivated. Although mining, permitted discharges, and diversions were active during this period, the scale of operations was small compared to the present-day.

At USGS Station No. 06425900, the average daily flow from 1977 to 1983 was 2.6 cfs, resulting in an average annual runoff of 1,879 ac-ft, and a unit-area annual runoff of 7.3 ac-ft/mi^2/yr. On a monthly basis, the majority of streamflow occurred in May due to snowmelt. Convective thunderstorms also produced runoff in the summer months, while little to no runoff occurred in the winter months. Daily flows for the baseline period range from no flow for months at a time to a mean daily discharge of 1,500 cfs on May 19, 1978 (**Figure 6**). The same date had an instantaneous peak discharge of 2,170 cfs, corresponding to approximately a 25-year event as predicted by USGS peak-flow regression equations (Miller, 2003). On Caballo Creek within the Belle Ayr Mine permit area, the May 19, 1978 event resulted in a mean daily discharge of 520 cfs Creek at BA-1 and 640 cfs at BA-4 (Belle Ayr Mine Permit, 2011). A flow duration curve for the 1977-1983 period is shown in **Figure 7**. No flow occurred 58 percent of the time.

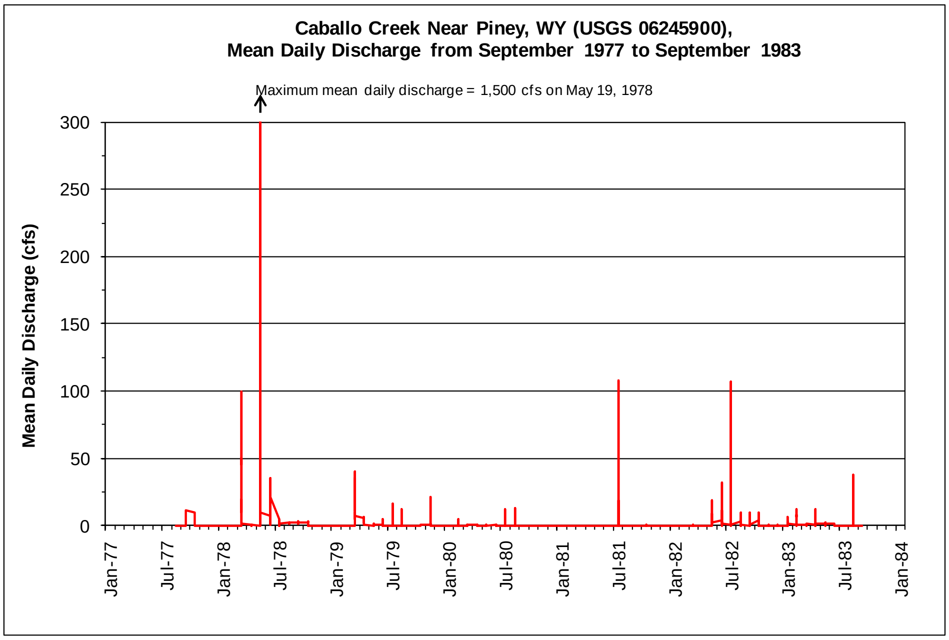


FIGURE 6. MEAN DAILY DISCHARGE FOR CABALLO CREEK NEAR PINEY, WY (USGS 06245900), SEPTEMBER 1977 TO SEPTEMBER 1983, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

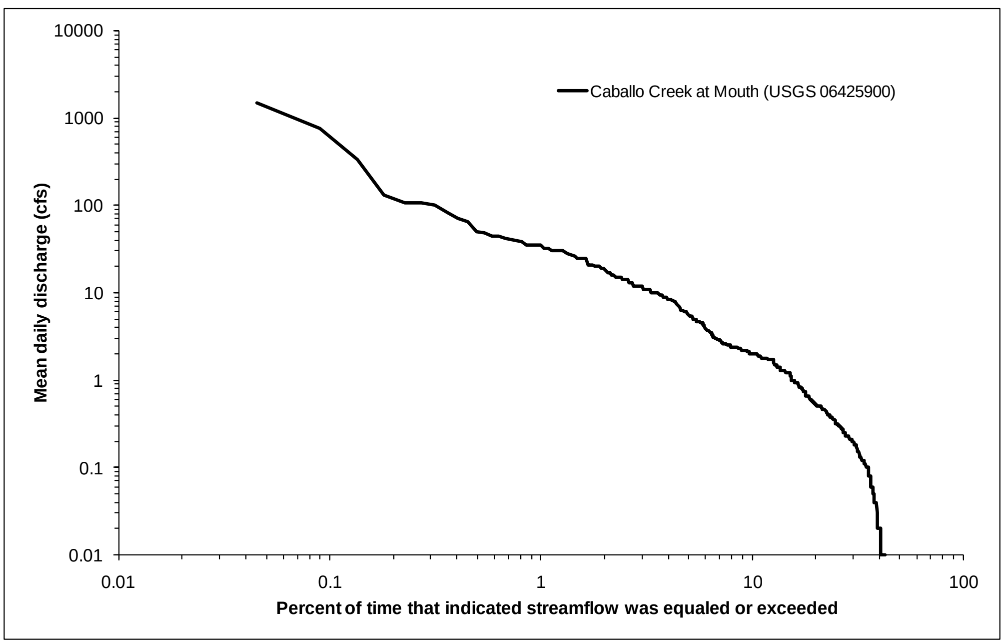
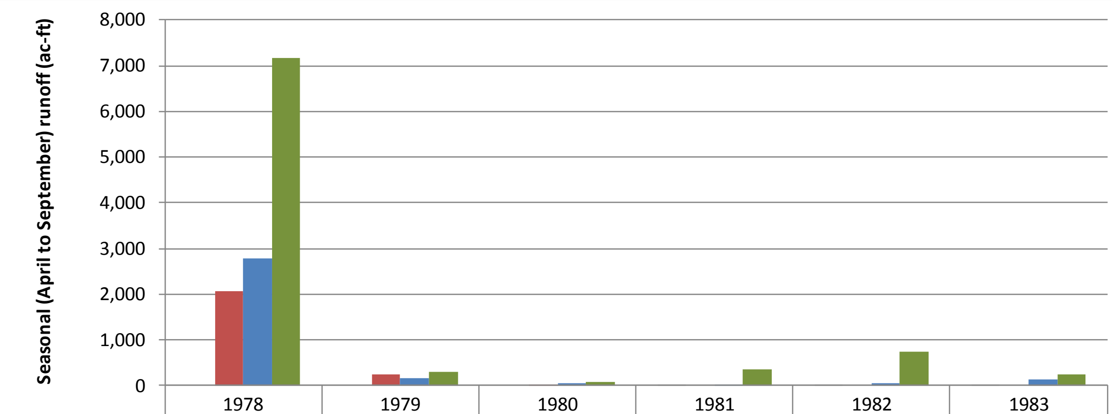


FIGURE 7. FLOW DURATION CURVE FOR CABALLO CREEK NEAR PINEY, WY (USGS 06245900), SEPTEMBER 1977 TO SEPTEMBER 1983, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

A comparison of seasonal (April through September) runoff volumes from 1978 to 1983 at the Belle Ayr Mine stations and the USGS station is shown in **Figure 8**. With the exception of 1978, seasonal runoff volumes were less than 1,000 ac-ft at each station. Due to damage from the May 1978 flooding, the Belle Ayr Mine and the WGFD breached the dam on Caballo Reservoir in summer

1978 (Belle Ayr Mine Permit, 2011). Removal of the dam most likely affected the flow regime on Caballo Creek at the Belle Ayr Mine. Caballo Reservoir was constructed in the early 1940s by the WGFD for fish culture and stock watering. After reclamation, Caballo Lake will be restored as a permanent post-mine feature (Belle Ayr Mine Permit, 2011). The data in **Figure 8** show that runoff volumes were highest in each year at the USGS station, which is to be expected given the larger drainage area. The Belle Ayr Mine also indicates that a minor baseflow component is maintained by recharge to the scoria and coal aquifer between the T-7 Road and the east permit boundary. This helps to explain the increase in flows from BA-6 to BA-4. Within the active disturbance area, there were small but insignificant areas of groundwater discharge to Caballo Creek (Belle Ayr Mine Permit, 2011).



	1978	1979	1980	1981	1982	1983
BA-6 (127 sq mi)	No data	No data	No data	2.4	8.6	3.3
BA-1 (184 sq mi)	2,053	234	11.7	0	0	0
BA-4 (212 sq mi)	2,782	151	62.1	3.3	52.1	123
USGS 06425900 (260 sq mi)	7,170	309	79.2	354	737	245

FIGURE 8. COMPARISON OF SEASONAL (APRIL TO SEPTEMBER) RUNOFF VOLUMES AT GAGING STATIONS ON CABALLO CREEK, 1978 TO 1983, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Precipitation data from meteorological stations near the middle PRB show that the six years used for baseline characterization had annual precipitation that varied from slightly below normal to well above the long-term average of 13 to 15 inches. For example, annual precipitation at the Dillinger station ranged from a low of 12.6 inches in 1983 to a high of 20.5 inches in 1982. The flooding in May 1978 also occurred in an above-average precipitation year (17.7 inches). It should be cautioned that the short periods of record at the USGS gages on Caballo Creek and the Belle Fourche River are probably not suitable for determining long-term average conditions. Lowham (1988) suggests that a minimum of 25 years of data are required to reasonably establish flow characteristics such as annual runoff, mean daily flows, and unit-area runoff on intermittent and ephemeral drainages in Wyoming.

The WDEQ/WQD originally classified Caballo Creek as Class 2 water, with designated uses for game fish and drinking water. In 2001, WDEQ/WQD changed the classification to 3B based on information in the WGFD inventory database, which indicated Caballo Creek did not contain any resident species of fish (Wyoming Department of Environmental Quality, 2001). WDEQ/WQD reviewed the classification in 2004 based on the results of fish inventories conducted by the Belle

Ayr Mine in the 1970s (Wyoming Department of Environmental Quality, 2004a). These baseline surveys found seven species of warm water fish in Caballo Creek. Rainbow trout were also found due to the stocking of Caballo Reservoir by WGFD. Fish were also observed during macroinvertebrate sampling by WDEQ/WQD in 2000. Based on this information, in 2004 WDEQ/WQD changed the classification to 2ABww since a game fishery is both an existing and naturally attainable use (Wyoming Department of Environmental Quality, 2004b). Class 2AB waters support game fish populations or spawning and nursery areas at least seasonally. Class 2AB waters are also presumed to have sufficient water quality and quantity to support drinking water supplies. The “ww” notation indicates a predominance of warm water species present (Wyoming Department of Environmental Quality, 2007). The WDEQ/WQD surface water numeric standards for Caballo Creek are presented in **Table 6**. It should be noted that the numeric human health criteria for dissolved iron and manganese do not apply to Caballo Creek according to site specific criteria established by WDEQ/WQD (Wyoming Department of Environmental Quality, 2007).

The baseline (1977 to 1983) water quality samples from USGS Station 06245900 on Caballo Creek indicate a mixed water type (RockWare, Inc., 2006). Calcium-sulfate type water was present in 44 percent of the samples, followed by Mg-SO_4 in 26 percent of the samples, Na-SO_4 in 26 percent of the samples, and Na-Cl in four percent of the samples. TDS @ 180 degrees C ranged from 147 to 4,600 mg/l, with a median of 1,610 mg/l. TSS ranged from 5 to 14,500, with a median of 37 mg/l (**Table 9**). TDS @ 180 degrees C generally decreased with increasing discharge, while TSS generally increased with flow. Dissolved metal concentrations were very low, with numerous values below detection limits. The water quality data collected during the baseline period show that water quality standards were satisfied for Class 2ABww waters. The only exceedences occurred for the minimum and maximum pH and the maximum concentration of mercury. With the exception of mercury, the mean and median concentrations of each constituent evaluated showed no exceedences over the baseline period (**Table 9**).

TABLE 9. BASELINE WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON CABALLO CREEK AT USGS STATION NO. 06425900, 1977 TO 1983, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	**USGS Parameter Code**	**Units**	**Caballo Creek at mouth near Piney, WY (USGS 06425900) (1977-1983)**				
			Count	**Min**	**Max**	**Mean**	**Median**
Temperature (field)	00010	°C	35	0	24.5	9.6	8.0
Dissolved oxygen (field)	00300	mg/l	27	5.0	12.2	9.3	9.7
pH (field)	00400	S.U.	27	6.1	9.1	8.0	8.1
Ammonia as N (total)	00610	mg/l	22	<0.01	0.23	0.10	0.10
Nitrite plus nitrate as N (total)	00630	mg/l	19	<0.1	1.6	0.1	NA[1]
Sodium (dissolved)	00930	mg/l	27	12	500	199	200
Chloride (dissolved)[2]	00940	mg/l	27	4.4	190.0	44.9	28.0
Sulfate (dissolved)	00945	mg/l	27	66	2,300	953	840
Fluoride (dissolved)	00950	mg/l	27	0.1	1.8	0.4	0.4
Arsenic (total)	01002	mg/l	9	<0.001	0.002	0.002	0.002
Barium (total)	01007	mg/l	8	<0.1	0.2	0.09	0.08
Boron (dissolved)	01020	mg/l	27	0.11	1.20	0.40	0.30
Cadmium (dissolved)	01025	mg/l	10	<0.001	<0.003	100% <0.003	
Chromium (total)	01034	mg/l	9	<0.01	0.02	0.02	0.01
Copper (dissolved)	01040	mg/l	10	<0.002	<0.01	100% <0.01	
Iron (dissolved)	01046	mg/l	27	<0.01	0.12	0.1	0.1
Lead (dissolved)	01049	mg/l	10	<0.001	<0.025	100% <0.025	
Manganese (dissolved)	01056	mg/l	15	<0.01	1.10	0.20	0.03
Nickel (total)	01067	mg/l	9	<0.03	<0.03	100% <0.03	
Zinc (dissolved)	01090	mg/l	10	<0.02	0.13	0.03	0.02
Aluminum (dissolved)	01106	mg/l	7	<0.1	0.05	0.02	0.01
Selenium (dissolved)	01145	mg/l	10	<0.001	0.002	80% <0.001	
TDS dried at 180 °C	70300	mg/l	27	147	4,600	1,816	1,610
Mercury (total)	71900	µg/l	9	<0.1	0.2	0.1	0.1
Total suspended solids	80154	mg/l	43	5	14,500	1,422	37

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Means and medians were not calculated for constituents having ≥ 80% below-detect values. Values shown in red exceed WDEQ/WQD Class 2ABww water quality standards. [1]Kaplan-Meier would not return a median for unknown reasons. [2]The WDEQ/WQD standard for chloride is expressed as a total concentration, but only dissolved data are reported for the station.

3.1.1.7 NON-CONTRIBUTING DRAINAGES

There are several closed basins containing playas located within or adjacent to the mines in the Caballo Creek CIA. These areas are considered non-contributing to the drainage network, but may have standing water present for periods of time following significant rainfall or snowmelt.

The Caballo Mine documented seven native playas with a total drainage area of 2,217 ac. The playas rarely hold surface water, and two of the playas have been used as hay meadows. CBM water has also been stored in one of the playas (Caballo Mine Permit, 2011).

The Belle Ayr Mine documented twelve pre-mine playa complexes within and adjacent to the permit area. A few of the playas overlap with the Caballo and Cordero Rojo mines. The playa acreage was estimated at 435 ac, and the total drainage area to the playas was approximately 3,226 ac (Belle Ayr Mine Permit, 2011). The soils, vegetation, geology, hydrology, and wildlife use of three of the playas have been extensively studied. The mine continues to monitor groundwater levels and quality in some of the playas. The playas have both a recharge and discharge function, although the overall hydrological significance of these functions was determined to be minor. Because of the limited groundwater interaction, the playas are best characterized as surface features that provide temporary water for livestock and habitat for wildlife. Human use is limited due to poor water quality (Belle Ayr Mine Permit, 2011).

At the Cordero Rojo Mine, including the area of the Maysdorf I Amendment, there are three closed basins containing playas within the Caballo Creek CIA. The total drainage area within the three closed basins is 355 ac, and the maximum playa capacity is 229 ac (Cordero Rojo Mine Permit, 2011). In summary, there is a total of approximately 9.1 mi^2 of closed basin area that contains playas within the Caballo, Belle Ayr, and Cordero Rojo mine permit boundaries in the Caballo Creek CIA.

3.1.2 BASELINE WATER QUANTITY AND WATER QUALITY OF INDIVIDUAL DRAINAGES IN THE BELLE FOURCHE RIVER CIA

3.1.2.1 COAL CREEK

Coal Creek is an ephemeral tributary of the Belle Fourche River with a drainage area of approximately 75 mi^2. Coal Creek is the primary drainage at the Coal Creek Mine, although the mainstem only flows through a small portion of the western permit area. Most of the Coal Creek Mine is drained by East Fork Coal Creek and the Section 18 Tributary. The West Fork and Middle Fork of Coal Creek are primary tributaries upstream of the Coal Creek Mine. The Cordero Rojo Mine permit area also occupies about 200 ac of the Coal Creek watershed, including the confluence of Coal Creek and the BFR. The Cordero Rojo Mine will only disturb a small tributary to Coal Creek (Cordero Rojo Mine Permit, 2011).

Runoff in the Coal Creek drainage is sparse, and is affected by several small stock reservoirs. Water rights in the Coal Creek drainage within the Coal Creek Mine are mostly for stock and industrial use. Upstream of the Coal Creek Mine, water rights are held for stock, domestic, and irrigation use (Wyoming State Engineer's Office, 2010).

Coal Creek and its tributaries have been monitored by the USGS, the Coal Creek Mine, and the Cordero Rojo Mine. The most reliable station for baseline characterization was established by the USGS in 1980 (U.S. Geological Survey, 2010a). USGS Station No. 06425750, *Coal Creek Near Piney, Wyoming,* was located approximately 2.5 miles upstream from the confluence with the BFR, monitoring 71.8 mi^2 of the drainage (**Table 4**, **Plate 1**). Streamflow was continuously monitored for three years (October 1980 to September 1983), but few water quality samples were collected due to the lack of flow. Suspended sediment was also continuously monitored at the gage (U.S. Geological Survey, 2010b). The Coal Creek Mine currently monitors a station (CC-12) on Coal Creek at the downstream permit boundary (**Table 4**, **Plate 1**). Data from this station will be discussed in Section 6. The Cordero Rojo Mine also samples selenium and TSS at two stations on pools on Coal Creek near the confluence with the BFR (Cordero Rojo Mine Permit, 2011).

The average daily flow from 1980 to 1983 at USGS Station No. 06425750 on Coal Creek was 1.09 cfs, resulting in an average annual runoff of 788 ac-ft, and a unit-area annual runoff of 11 ac-ft/mi^2/yr. Daily flows for the baseline period range from no flow for months at a time to a mean daily discharge of 251 cfs on May 27, 1981 (**Figure 9**). The peak flow for the event was 1,170 cfs (Rankl, 2004). The three year record demonstrates the ephemeral nature of Coal Creek, as flow was recorded only 39 percent of the time.

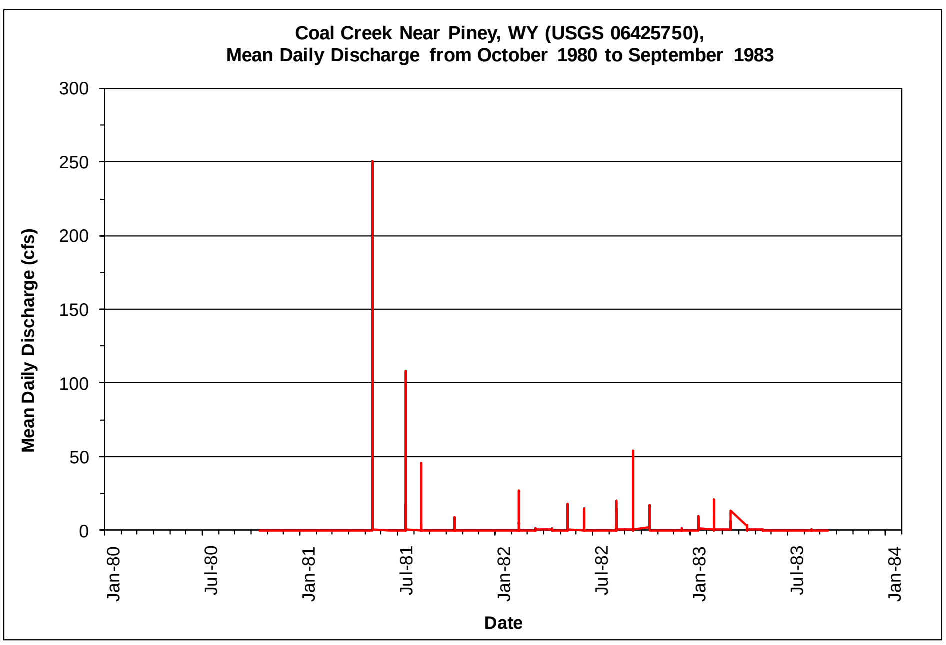


FIGURE 9. MEAN DAILY DISCHARGE FOR COAL CREEK NEAR PINEY, WY (USGS 06425750), OCTOBER 1980 TO SEPTEMBER 1983, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

The WDEQ/WQD has classified Coal Creek as Class 3B water (Wyoming Department of Environmental Quality, 2001). The WDEQ/WQD surface water numeric standards for Coal Creek are presented in **Table 6**. Since the mean hardness at USGS Station No. 06425750 is less than 400 mg/l, the criteria for hardness-dependent metals are more stringent than for other Class 3B waters evaluated in this CHIA. The samples collected from 1980 to 1983 indicate the water type was mostly Na-Cl and Na-SO_4 (RockWare, Inc., 2006). However, not all of the major ions were sampled, particularly bicarbonate. Samples were generally collected under low flow conditions, as the median instantaneous discharge was 0.4 cfs during sampling. TDS @ 180 degrees C ranged from 259 to 2,690 mg/l, with a median of 609 mg/l (**Table 10**). TSS ranged from 76 to 2,380, with a median of 1,183 mg/l. Dissolved metal concentrations were very low, with numerous values below detection limits. The water quality data collected during the 1980-1983 period show that water quality standards were satisfied for Class 3B waters. There were no exceedences for any of the constituents sampled (**Table 10**).

An analysis by the USGS indicated that the Coal Creek drainage may be a major source of sediment to the Belle Fourche River (Martin et al., 1988). The USGS evaluated sediment load data from the 1977 to 1983 water years at USGS stations on the BFR upstream and downstream of the Coal Creek confluence. These data are plotted in **Figure 11** in the next section. The downstream station on the BFR had a median annual sediment yield that was eight times higher, and the increase was attributed to inputs from Coal Creek (Martin et al., 1988). Rankl (2004) further analyzed sediment data from 14 storm events on Coal Creek from 1981 to 1982 and found a direct relationship between peak discharge and sediment load (R^2 = 0.96). The intercept for the regression equation was statistically higher than the intercept developed for the same relationship at the USGS station on the BFR downstream of the Coal Creek confluence. This indicates that the Coal Creek watershed has higher sediment availability, possibly due to differences in soil erodibility, vegetation, and slope (Rankl, 2004).

TABLE 10. BASELINE WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON COAL CREEK AT USGS STATION NO. 06425750, 1980 TO 1983, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	USGS Parameter Code	Units	Coal Creek near Piney, WY (USGS 06425750) (1980-1983)				
			Count	Min	Max	Mean	Median
Temperature (field)	00010	°C	11	0.5	19.0	7.2	6.0
Dissolved oxygen (field)	00300	mg/l	7	6.4	12.4	9.1	9.4
pH (field)	00400	S.U.	7	7.8	8.6	8.3	8.5
Ammonia as N (total)	00610	mg/l	4	0.12	1.80	0.60	0.20
Nitrite plus nitrate as N (total)	00630	mg/l	1	0.61	0.61	na	na
Sodium (dissolved)	00930	mg/l	7	50	420	197	170
Chloride (dissolved)	00940	mg/l	7	15	220	93	74
Sulfate (dissolved)	00945	mg/l	7	22	1,500	313	110
Fluoride (dissolved)	00950	mg/l	7	0.4	2.0	1.0	0.8
Arsenic (dissolved)	01000	mg/l	4	0.01	0.02	0.01	0.01
Barium (dissolved)	01005	mg/l	3	<0.1	0.1	0.08	0.08
Boron (dissolved)	01020	mg/l	7	0.15	1.40	0.60	0.40
Cadmium (dissolved)	01025	mg/l	4	<0.001	<0.003	100% <0.003	
Chromium (dissolved)	01030	mg/l	4	<0.01	0.01	0.01	0.01
Copper (dissolved)	01040	mg/l	4	<0.01	0.02	0.013	0.010
Iron (dissolved)	01046	mg/l	7	0.02	0.31	0.10	0.10
Lead (dissolved)	01049	mg/l	4	<0.001	<0.001	100% <0.001	
Manganese (dissolved)	01056	mg/l	7	<0.01	0.21	0.04	0.01
Nickel (dissolved)	01065	mg/l	4	<0.03	<0.03	100% <0.03	
Zinc (dissolved)	01090	mg/l	4	<0.02	0.03	0.02	0.01
Aluminum (dissolved)	01106	mg/l	0	na	na	na	na
Selenium (dissolved)	01145	mg/l	4	0.001	0.001	0.001	0.001
TDS dried at 180 °C	70300	mg/l	7	259	2,690	939	609
Mercury (dissolved)	71890	µg/l	5	<0.1	0.2	0.1	0.1
Total suspended solids	80154	mg/l	4	76	2,380	1,206	1,183

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Means and medians were not calculated for constituents having ≥ 80% below-detect values. na= not applicable.

3.1.2.2 BELLE FOURCHE RIVER

The Belle Fourche River (BFR) is a major drainage of northeastern Wyoming and a tributary of the Cheyenne River in western South Dakota. The BFR flows through the southeast portion of the Cordero Rojo Mine permit area, maintaining an ephemeral to intermittent flow regime. The BFR has been relocated and diverted over time to facilitate mining at the Cordero Rojo Mine (Cordero Rojo Mine Permit, 2011).

Two USGS gaging stations on the BFR are used to evaluate baseline hydrologic conditions and during-mining impacts (U.S. Geological Survey, 2010a). USGS Station No. 06425720, *Belle Fourche River Below Rattlesnake Creek*, is located near the southwest corner of the Cordero Rojo Mine permit boundary, and drains a total of 495 mi^2 (**Table 4**, **Plate 1**). The primary tributaries to the BFR upstream of the station include Hay Creek, Fourmile Creek, All Night Creek, Mud Spring Creek, Greasewood Creek, Wild Horse Creek, and Threemile Creek. No coal mining has occurred upstream of the station, although activities associated with the Maysdorf I Amendment may affect the site in the future. There are numerous small stockponds in the watershed, as well as ongoing CBM activity. The town of Wright is also located within the drainage. The USGS operated the station from October 1975 to April 1983. The station remained inactive until 1989 when the Cordero Rojo Mine resumed surface water quality sampling. Monitoring of daily streamflow was not resumed at the site until 1994. In March 2001, the USGS resumed monitoring at the station as part of a regional effort to monitor CBM impacts in northeastern Wyoming (Clark et al., 2005). The Cordero Rojo Mine also currently collects water quality samples at the station (Cordero Rojo Mine Permit, 2011). Data from the 1975 to 1983 period are used for baseline characterization.

The second gage on the BFR is located approximately five miles downstream at the eastern Cordero Rojo Mine permit boundary (**Table 4**, **Plate 1**). USGS Station No. 06425780, *Belle Fourche River above Dry Creek near Piney, Wyoming*, drains a total of 594 mi^2 and represents the accumulation point for the BFR CIA. The station was maintained by the USGS from October 1975 until September 1983. The station remained inactive until 1989 when the Cordero Rojo Mine resumed surface water quality sampling. Monitoring of daily streamflow was not resumed at the site until 1994. The mine currently operates the station under the name of "LBFR", collecting daily streamflow data and water quality samples (Cordero Rojo Mine Permit, 2011). Data from the 1975 to 1983 period are used for baseline characterization. Although this period overlaps with early mining at the Cordero Rojo Mine, the scale of operations was small compared to the present-day. The period also coincides with a permanent relocation of the BFR channel near the Cordero Rojo Mine facilities area that was constructed in 1975 (Cordero Rojo Mine Permit, 2011).

The average daily flow at USGS Station No. 06425720 from October 1975 to April 1983 was 2.43 cfs, resulting in an average annual runoff of 1,756 ac-ft, and a unit-area annual runoff of 3.5 ac-ft/mi^2/yr. For the same time period at the downstream station, the average daily flow was nearly two times higher at 4.59 cfs, resulting in an average annual runoff of 3,317 ac-ft, and a unit-area annual runoff of 5.6 ac-ft/mi^2/yr. The maximum mean daily flow at the upstream station was 1,060 cfs on May 19, 1978. The same date had an instantaneous peak discharge of 4,100 cfs (Parrett et al., 1984), corresponding to approximately a 25 to 50-year event as predicted by Miller (2003). At the downstream station, the maximum mean daily discharge was 2,150 cfs on May 18, 1978, with a peak discharge of 5,630 cfs. This peak is on the order of a 50 to 100-yr event (Miller, 2003). The USGS indicates that the peak discharge for the flood event of May 18-19, 1978 was influenced by dam failure in the upper BFR watershed (U.S. Geological Survey, 2010a).

The 1975 to 1983 period indicates that mean daily flows were higher at the downstream station 60 percent of the time, while flows were higher at the upstream station 16 percent of the time and flows were equal 24 percent of the record. A comparison of flow duration curves for the 1975 to 1983 period illustrates the differences in flow between stations (**Figure 10**). At the downstream station (06425780), flows equaled or exceeded 0.08 cfs 50 percent of the time, and no flow was recorded 22 percent of the time. In contrast, at the upstream station (06425720) flows equaled or exceeded 0.01 cfs 50 percent of the time and no flow was recorded 45 percent of the time (**Figure 10**). It is reasonable to expect the downstream station to have higher flows given the addition of 99 mi^2 of drainage area, mostly owing to the Coal Creek watershed. Data also suggest that the reach in between the stations is a gaining stream during periods of baseflow. For example, Druse et al. (1981) found flow to be 0.68 and 0.1 cfs higher during instantaneous discharge measurements taken at both stations in September and October 1978, respectively.

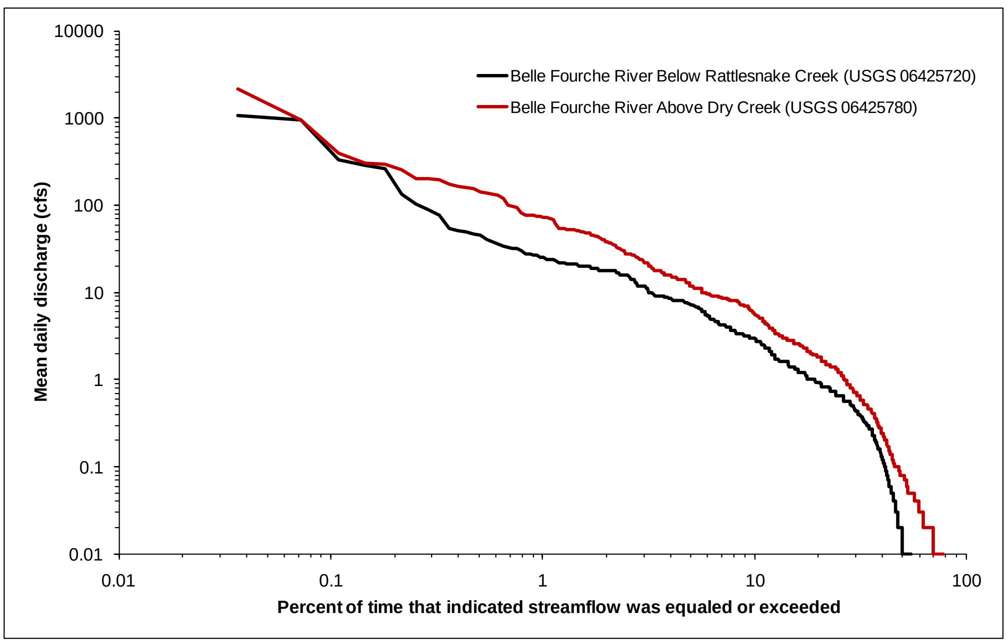


FIGURE 10. COMPARISON OF FLOW DURATION CURVES AT USGS STATIONS NO. 06425720 AND 06425780 ON THE BELLE FOURCHE RIVER, OCTOBER 1975 TO APRIL 1983, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

The WDEQ/WQD has classified the BFR as Class 2ABww water (Wyoming Department of Environmental Quality, 2001). The WDEQ/WQD surface water numeric standards for the BFR are presented in **Table 6**. The numeric human health criteria for dissolved iron and manganese do not apply to this section of the BFR according to site specific criteria established by WDEQ/WQD (Wyoming Department of Environmental Quality, 2007).

The dominant water type at USGS Station No. 06425720 on the upstream BFR over the 1975 to 1983 period was $Na\text{-}SO_4$, while a smaller proportion (31 percent) of the samples was a Ca-

SO_4 type (RockWare, Inc., 2006). The water type at USGS Station No. 06425780 on the downstream BFR was more mixed, with 54 percent of the samples as Ca-SO_4 and the remaining samples as Na-SO_4 (RockWare, Inc., 2006).

A comparison of water quality summary statistics between the two USGS stations over the 1975 to 1983 period is shown in **Table 11**. Field parameters, major ions, and iron were sampled much more frequently than metals, and the downstream station was sampled more often than the upstream station. TDS @ 180 degrees C at the upstream station ranged from 1,120 to 3,610 mg/l, with a median of 2,050 mg/l. TDS @ 180 degrees C was slighter higher at the downstream gage, ranging from 186 to 4,440 mg/l, with a median of 2,300 mg/l. TSS at the upstream station ranged from 8 to 927 mg/l, with a median of 58 mg/l. TSS concentrations at the downstream site were higher, ranging from 3 to 4,020 mg/l, with a median of 75 mg/l (**Table 11**).

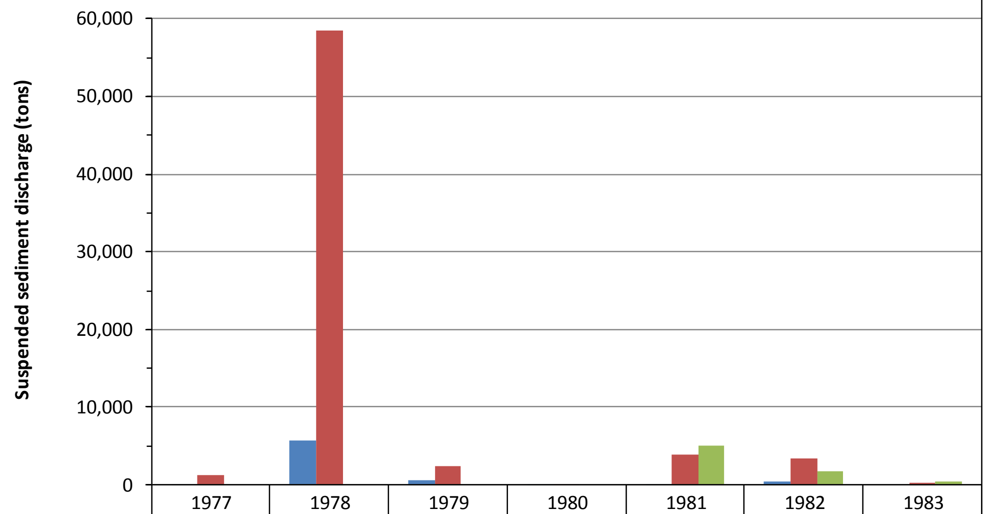
Additional TSS data were collected at each station as part of an intensive sediment yield monitoring program (U.S. Geological Survey, 2010b). Daily records of suspended sediment concentration and loads were compiled for the 1977 to 1983 water years. Sediment loads were highest at each station during the 1978 water year due to the May 18-19 flood (**Figure 11**). At the downstream station, the sediment load on May 18, 1978 alone was 40,100 tons, which accounted for 69 percent of the total sediment load in the 1978 water year. Sediment loads were generally several orders of magnitude higher at the downstream station in each year. As mentioned in the previous sub-section, the downstream station had a median annual sediment yield that was eight times higher due to sediment inputs from Coal Creek (Martin et al., 1988). In water years 1981 and 1982, sediment loads on Coal Creek were respectively 10,000 and 345 percent higher than loads measured on the upstream BFR gage (**Figure 11**), despite a drainage area that is 85 percent smaller.

Dissolved metal concentrations at both stations on the BFR were mostly very low, with numerous values below detection limits (**Table 11**). At the upstream station, exceedences of Class 2ABww standards were noted for cadmium (one sample) and mercury (five samples). Only the mean and median value for mercury exceeded standards. At the downstream station, Class 2ABww standards were exceeded for temperature (one sample), nitrate plus nitrite as nitrogen (four samples), cadmium (one sample), copper (one sample), selenium (two samples), and mercury (eleven samples). The mean and median mercury concentrations exceeded standards (**Table 11**). The WDEQ/WQD Class 2ABww standard for turbidity stipulates that the discharge of substances attributable to or influenced by human activities shall not occur such that turbidity increases by more than 15 NTU. Turbidity was 260 NTU in one sample at the downstream station, and this caused the mean turbidity value to also exceed 15 NTU. However, it is impossible to determine if the elevated value was caused by natural factors or human activities. The higher TSS and turbidity values at the downstream station are likely due to sediment inputs from Coal Creek, as previously discussed. The overall comparison of water quality between USGS stations on the BFR over the 1975-1983 period indicates that the upstream station shows slightly better water quality and fewer exceedences of Class 2ABww standards.

TABLE 11. BASELINE WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON THE BELLE FOURCHE RIVER AT USGS STATIONS NO. 06425720 AND 06425780, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	USGS Parameter Code	Units	Belle Fourche River below Rattlesnake Creek (upstream) (USGS Station No. 06425720) (1975-1983)					Belle Fourche River above Dry Creek (downstream) (USGS Station No. 06425780) (1975-1983)				
			Count	**Min**	**Max**	**Mean**	**Median**	**Count**	**Min**	**Max**	**Mean**	**Median**
Temperature (field)	00010	°C	59	0	28.5	12.3	13.5	92	0	32.0	11.1	11.0
Turbidity	00076	NTU	6	5	15	9	9	11	3	260	30	7
Dissolved oxygen (field)	00300	mg/l	40	6.3	13.8	9.8	9.9	65	4.3	19.0	10.4	10.0
pH (field)	00400	S.U.	38	7.2	8.5	7.9	7.9	64	7.3	8.7	8.0	8.0
Ammonia as N (total)	00610	mg/l	32	<0.01	0.32	0.07	0.06	50	<0.06	0.59	0.13	0.09
Nitrite plus nitrate as N (total)	00630	mg/l	28	<0.1	0.2	0.06	0.05	43	0.01	47.0	3.3	0.3
Sodium (dissolved)	00930	mg/l	36	100	1,200	400	385	61	13	700	272	270
Chloride (dissolved)[1]	00940	mg/l	36	4.1	55.0	20.3	19.0	61	2.0	43.0	15.2	14.0
Sulfate (dissolved)	00945	mg/l	36	510	5,400	1,957	2,000	61	77	3,400	1,442	1,500
Fluoride (dissolved)	00950	mg/l	36	0.2	0.9	0.4	0.4	61	0.2	0.8	0.4	0.4
Arsenic (total)	01002	mg/l	20	<0.001	0.004	0.002	0.001	29	<0.001	0.025	0.002	0.001
Barium (total)	01007	mg/l	4	<0.1	0.1	0.1	0.1	6	<0.1	0.1	0.1	0.1
Boron (dissolved)	01020	mg/l	36	0.05	0.90	0.21	0.14	61	0.06	1.70	0.40	0.30
Cadmium (dissolved)	01025	mg/l	10	<0.001	0.01	90% <0.002		13	<0.001	0.01	93% <0.002	
Chromium (total)	01034	mg/l	21	<0.01	0.02	0.010	0.009	30	<0.01	0.08	0.01	0.01
Copper (dissolved)	01040	mg/l	7	<0.001	<0.002	100% <0.002		18	<0.002	0.03	94% <0.002	
Iron (dissolved)	01046	mg/l	36	<0.01	0.41	0.08	0.05	61	<0.01	0.80	0.11	0.06
Lead (dissolved)	01049	mg/l	10	<0.001	<0.001	100% <0.001		17	<0.001	<0.002	100% <0.002	
Manganese (dissolved)	01056	mg/l	14	0.06	0.80	0.23	0.19	26	<0.02	2.00	0.30	0.22
Nickel (total)	01067	mg/l	21	<0.002	<0.2	100% <0.2		30	<0.05	<0.05	100% <0.05	
Zinc (dissolved)	01090	mg/l	10	<0.01	0.04	0.05	0.04	17	<0.02	0.03	0.03	0.03
Aluminum (dissolved)	01106	mg/l	6	<0.1	0.04	0.02	0.02	8	<0.1	0.03	0.02	0.02
Selenium (dissolved)	01145	mg/l	10	<0.001	0.002	0.001	0.001	17	<0.001	0.022	0.003	0.001
TDS dried at 180 °C	70300	mg/l	9	1,120	3,610	2,127	2,050	19	186	4,440	2,259	2,300
Mercury (total)	71900	µg/l	21	<0.1	0.2	0.07	0.05	30	<0.1	0.4	0.12	0.10
Total suspended solids	80154	mg/l	31	8	927	102	58	51	3	4,020	542	75

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Means and medians were not calculated for constituents having ≥ 80% below-detect values. Concentrations shown in red exceed WDEQ/WQD Class 2ABww surface water quality standards. [1]The WDEQ/WQD standard for chloride is expressed as a total concentration, but only dissolved data are reported for both USGS stations on the BFR.



	1977	1978	1979	1980	1981	1982	1983
BFR below Rattlesnake Creek (upstream)	80.4	5,736	522	9.3	49.4	409	No data
BFR above Dry Creek (downstream)	1,257	58,503	2,443	36.6	3,852	3,462	228
Coal Creek near Piney	No data	No data	No data	No data	5,032	1,819	472

FIGURE 11. COMPARISON OF SUSPENDED SEDIMENT DISCHARGE AT THE BELLE FOURCHE RIVER BELOW RATTLESNAKE CREEK, BELLE FOURCHE RIVER ABOVE DRY CREEK, AND COAL CREEK NEAR PINEY, 1977 TO 1983 WATER YEARS, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

3.1.2.3 NON-CONTRIBUTING DRAINAGES

There are approximately 6.4 mi^2 of non-contributing drainage within the Coal Creek drainage, and approximately 0.4 mi^2 of this is contained within the boundaries of the Coal Creek Mine. At the Cordero Rojo Mine, including the area of the Maysdorf I Amendment, there are 2,090 ac of closed basins containing playas. The playas have a combined maximum capacity of 1,393 ac-ft (Cordero Rojo Mine Permit, 2011). In total, 9.7 mi^2 of closed basins exist in the drainage area in between USGS stations No. 06425720 and 06425780 on the BFR.

3.2 GROUNDWATER

Baseline data for the groundwater flow systems, and aquifer quality and quantity are available from a variety of sources for the PRB. The coal mine permits for the mines in the middle PRB contain extensive information on the aquifers and leaky units within the permit areas. Covering a broader area, there are Environmental Assessments, Environmental Impact Statements, hydrologic and geologic studies completed by the USGS, University of Wyoming, Wyoming Water Resources Research Institute, Wyoming Water Development Commission (WWDC), Wyoming Geological Survey as well as many other entities.

3.2.1 FLOW SYSTEMS

The groundwater can be characterized by four flow systems – the alluvial aquifer, the clinker aquifer, the coal aquifer, and the Tullock aquifer. The first three systems are often interrelated. The first flow system consists primarily of the alluvial sediments where they are extensive enough to form an aquifer. The alluvial sediments receive recharge from precipitation, surface water flows, and in some cases discharge from the overburden, clinker, and coal. Flow is in the direction of the stream drainage. Discharge is by evapotranspiration, discharge to the surface water, or recharge to the coal or overburden.

The second flow system is the clinker aquifer. The clinker aquifer receives recharge from precipitation, and in some cases, from the coal, alluvial or overburden units. Flow is generally to the coal aquifer although in some cases the water may also discharge to permeable overburden units.

The third flow system is the coal aquifer. The coal aquifer flow system is recharged from the clinker aquifer, the coal outcrops, and by leakage from alluvial aquifer, and the overburden and underburden aquitards. Flow in the coal aquifer is locally to the west with a northwest regional component. The water quality of the coal aquifer naturally changes as the water flows to the west. This water quality evolution is due to the change from oxidizing to reducing conditions, the presence of sulfate reducing bacteria, and the process of ion exchange.

The Tullock aquifer is isolated from the overlying units by an extensive thickness of sediment and does not interact on the CIA scale with the overlying aquifers. No large scale faults or dikes are mapped in the general area.

3.2.2 GROUNDWATER QUANTITY AND QUALITY OF AQUIFERS AND LEAKY AQUITARDS

Within the groundwater CIA, there are four major aquifers and two aquitards. The alluvium, clinker, coal and Tullock, are considered aquifers. The overburden (Wasatch Leaky Aquitard Unit) and, in some cases, underburden are generally considered leaky aquitards although individual sand lenses within the units may serve as local water sources and at smaller scales than this analysis may be considered aquifers and viewed as such by the WQD (Don Fischer, WDEQ/WQD, personal communication, 2004).

Groundwater quality varies both between aquifers and within aquifers. The variation between aquifers is probably due to the differences in aquifer materials as well as geochemical and biochemical changes along the flow paths of the groundwater. Within aquifers the variability is partially due to the proximity of a given sampling location to recharge/discharge zones and structural features. Water quality is compared throughout this document to the WDEQ/WQD groundwater standards (**Table 12**).

TABLE 12. WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY, WATER QUALITY DIVISION, GROUNDWATER CLASS OF USE STANDARDS.

Underground Water Class Use Suitability			
Constituent	**Class I, Domestic Concentration**	**Class II, Agriculture Concentration**	**Class III, Livestock Concentration**
Aluminum (Al)	---	5.0	5.0
Ammonia (NH_3 as N)	0.5	---	---
Arsenic (As)	0.05	0.1	0.2
Barium (Ba)	2.0	---	---
Beryllium (Be)	---	0.1	---
Boron (B)	0.75	0.75	5.0
Cadmium (Cd)	0.005	0.01	0.05
Chloride (Cl)	250.0	100.0	2000.0
Chromium (Cr)	0.10	0.1	0.05
Cobalt (Co)	---	0.05	1.0
Copper (Cu)	1.0	0.2	0.5
Cyanide (CN)	0.2	---	---
Fluoride (F)	4.0	---	---
Hydrogen Sulfide (H_2S)	0.05	---	---
Iron (Fe)	0.3	5.0	---
Lead (Pb)	0.015	5.0	0.1
Lithium (Li)	---	2.5	---
Manganese (Mn)	0.05	0.2	---
Mercury (Hg)	0.002	---	0.00005
Nickel (Ni)	---	0.2	---
Nitrate (NO_3 as N)	10.0	---	---
Nitrite (NO_2as N)	1.0	---	10.0
Nitrate + Nitrite (NO_3 + NO_2 as N)	---	---	100.0
Oil and Grease	Virtually Free	10.0	10.0
Phenol	0.001	---	---
Selenium (Se)	0.05	0.02	0.05
Silver (Ag)	0.10	---	---
Sulfate (SO_4)	250.0	200.0	3000.0
Total Dissolved Solids (TDS)	500.0	2000.0	5000.0
Vanadium (V)	---	0.1	0.1
Zinc (Zn)	5.0	2.0	25.0
pH	6.5-8.5 s.u.	4.5-9.0 s.u.	6.5-8.5 s.u.
SAR	---	8	---
RSC Combined Total	---	1.25 meq/L	---
Radium 226 and Radium 228	5 pCi/L	5 pCi/L	5 pCi/L
Total Strontium 90	8 pCi/L	8 pCi/L	8 pCi/L
Gross alpha particle radioactivity (including Radium 226 but excluding Radon and Uranium)	15 pCi/L	15 pCi/L	15 pCi/L

From WDEQ/WQD Rules and Regulations, Chapter 8; values in milligrams per liter unless otherwise indicated; [1]total ammonia nitrogen. See Chapter 8 for more details on interpretation of this information.

3.2.2.1 ALLUVIAL AQUIFER

The alluvium deposit along Caballo Creek, Belle Fourche River and segments of the tributaries store and transmit water in sufficient quantities to be considered aquifers in some parts of the CIA. The characteristics of alluvial aquifers in the area were recently summarized by the WWDC (2002a) as part of a basin planning effort. Additional characteristics of the alluvial aquifer have been described by Hodson, et al., 1971, Davis et al., 1978, and Bureau of Land Management, 2001 as well as other authors. Detailed data exists from the mining permits, especially where the potential AVFs were investigated. Mines collected data in areas along the Caballo Creek, Belle Fourche River, Tisdale Creek and Gold Mine Draw, and tributaries associated to those drainages.

The alluvial materials are characterized by lenticular deposits of clay or silty sand with occasional lenses of more permeable sands or gravels. When in hydrologic connection, materials, classified as alluvium, colluviums, and terrace deposits are lumped together in the category of alluvial deposits. In some cases, all the saturated materials are interconnected as an alluvial aquifer. In other localities, down-cutting and incising of the drainage may isolate or drain some materials.

A total of 275 alluvial monitor wells are reported in the coal mine permits. For purposes of this examination, all monitor wells completed only in the alluvium were considered. The distribution of alluvial monitor wells by mine is given in **Table 13**. Belle Ayr has 35 percent of the alluvial wells, Caballo has 33 percent, Cordero Rojo has 18 percent, and Coal Creek has 14 percent.

TABLE 13. NUMBER AND PERCENT OF ALLUVIAL AQUIFER MONITOR WELLS BY MINE FOR THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Mine	Number of Alluvial Aquifer Monitor Wells	Percent of Alluvial Aquifer Monitor Wells
Caballo	90	33
Belle Ayr	96	35
Cordero Rojo	50	18
Coal Creek	39	14

The time period of well completion, type of casing used, and the current number of monitor wells was also examined. The timeframe during which the wells were completed is summarized in **Table 14**. Almost 50 percent of the alluvial aquifer monitor wells were completed during the 1970-1979 period, when coal development was initiated in the middle Powder River Basin. Based on the available data, most of the alluvial monitor wells were constructed with PVC casing but one of the wells has steel casing. Over time, monitoring has been discontinued at 232 alluvial aquifer monitor wells. However, 43 alluvial monitor wells are actively monitored.

TABLE 14. THE RANGE OF YEARS OVER WHICH THE ALLUVIAL AQUIFER MONITOR WELLS WERE COMPLETED, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Year Range	Number of Alluvial Aquifer Monitor Wells Completed
1970-1979	136
1980-1989	98
1990-1999	1
2000-2009	4
Completion date not in database	36

Well depth was listed for 274 of the alluvial monitor wells. The depth varied based on the well location from 3.5 ft to 140 ft with a median depth of 17.5 ft. Approximately 76 percent of the wells have a completion depth of 20 ft or less (**Figure 12**).

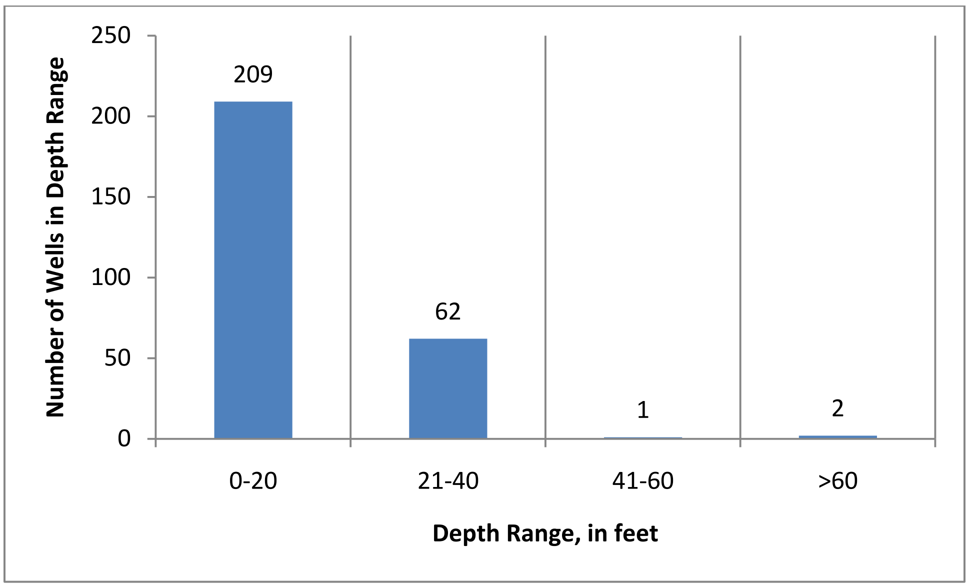


FIGURE 12. HISTOGRAM OF DEPTH OF ALLUVIAL AQUIFER MONITOR WELLS, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Hydraulic conductivities of the alluvial aquifer were tested by Belle Ayr Mine Permit (2011) for the sediment associated with Caballo Creek. A bailed, slug test resulted in an estimated hydraulic conductivity of 85 ft/d. Since the test was a slug test, no storage coefficient was calculated. The thickness of the alluvial deposits varied from 0 ft to 25 ft with thickness commonly in the 10-20 ft range at the Belle Ayr Mine. The Caballo Mine Permit (2011) estimates of hydraulic conductivity varied from 0.1 to 68 ft/d for the alluvial aquifer with saturated thickness in the 8 to 16 ft range. WWDC (2002a) in their basin planning study reported the alluvial aquifer system to have a thickness varying from 1 to 100 ft with the thickness generally less than 50 ft. Like the hydraulic conductivity, the thickness of the alluvial sediments in the CIA are lower than the range of values reported for the PRB, most likely reflecting the thinner deposits associated with the smaller streams in the CIA.

The generalized direction of groundwater flow in the alluvial aquifer is in the downstream or down valley directions with much of the discharge occurring by evapotranspiration. Recharge occurs primarily from runoff and snowmelt with some localized discharge from the underlying units. Water levels vary seasonally and between drainages.

Water quality in the alluvial aquifer varies from well to well and sometimes seasonally. The median TDS @ 180 degrees C was 3,345 mg/l (**Table 15**) for 1,190 samples. The water quality was dominated by the SO_4 anion with the median concentration of 1,704 mg/l (**Table 15**).

TABLE 15. MEDIAN CONCENTRATION AND NUMBER OF SAMPLES FOR MAJOR IONS AND TOTAL DISSOLVED SOLIDS FROM THE ALLUVIAL AQUIFER, CLINKER AQUIFER, WASATCH LEAKY AQUITARD UNIT, WYODAK ANDERSON COAL AQUIFER, AND UNDERBURDEN UNIT, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	**Alluvial Aquifer**		**Clinker Aquifer**		**Wasatch Leaky Aquitard Unit**		**Wyodak Anderson Coal Aquifer**		**Underburden Leaky Aquitard Unit**	
	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples
Cl	32	1405	9	195	16	1367	11	1364	13	157
HCO_3	503	1359	333	172	485	1131	795	1395	674	154
SO_4	1,704	1523	1,170	196	1,369	1379	54	1464	26	152
Na	292	1513	91	193	255	1368	248	1496	220	156
K	13	1513	32	192	13	1364	9	1489	9	156
Ca	361	1509	373	192	258	1362	62	1485	39	152
Mg	167	1512	99	192	98	1368	26	1489	18	155
TDS @180 C	3,345	1190	2,353	194	2,568	1268	932	1133	717	158
Concentrations shown in red exceed the WYDEQ/LQD Domestic Class I standard										

The median concentration of the major ions and TDS calculated from an average of about 1,440 samples from the alluvial aquifer is represented in **Figure 13**. In general, the water in the alluvial aquifer is suitable for livestock use, although at some locations, concentrations of individual parameters may exceed the livestock standards for a few samples had lower concentrations than the livestock standards (WDEQ/WQD, 1993). Based on AqQA (2004), the water is classified as a Ca-SO_4 type (**Figure 14**).

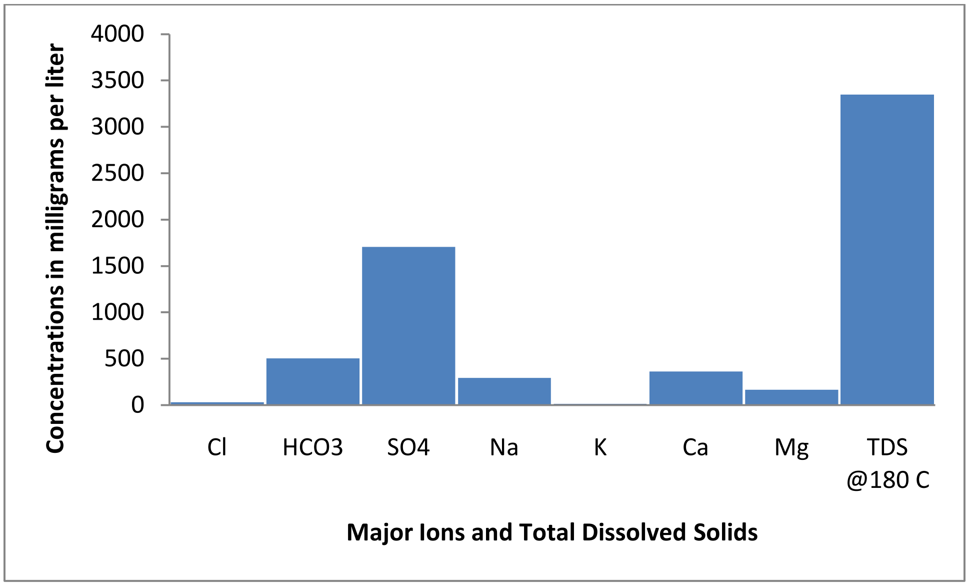


FIGURE 13. MEDIAN CONCENTRATION OF ALLUVIAL AQUIFER WATER SAMPLES, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

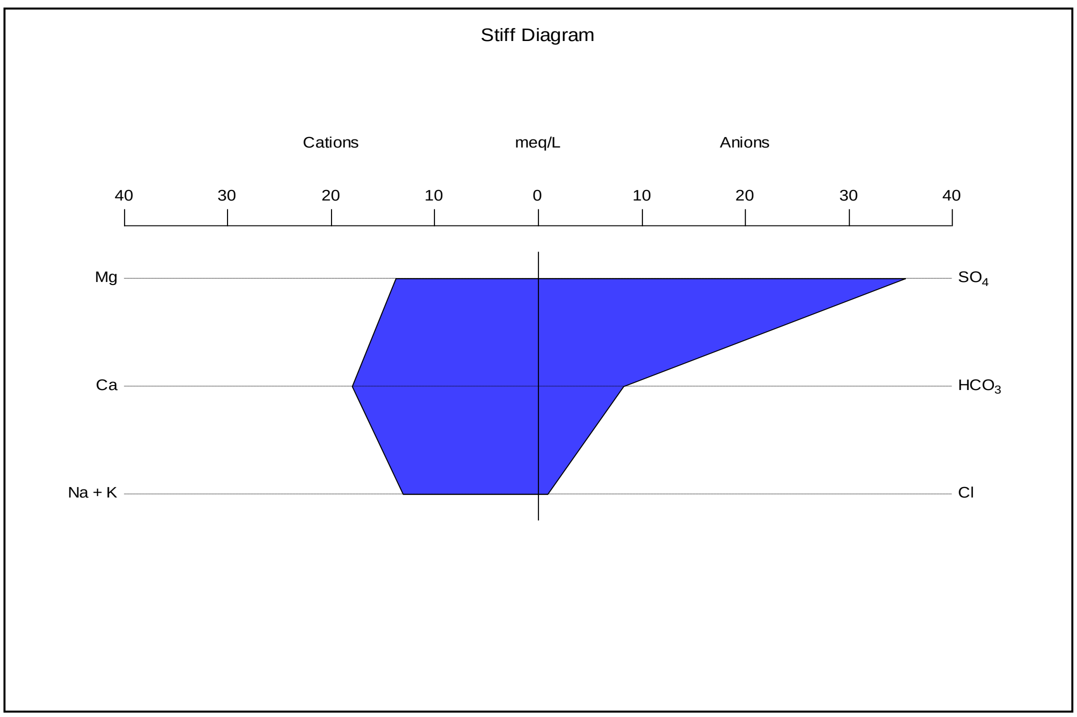


FIGURE 14. STIFF DIAGRAM OF MEDIAN CONCENTRATIONS OF WATER SAMPLES FROM THE ALLUVIAL AQUIFER, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

3.2.2.2 CLINKER AQUIFER

Clinker deposits associated with the Wyodak Anderson coal are present along the edge of the mines east of the coal crop line and are locally called scoria. Natural burning of the coal seams over the past 3 million years (Heffern and Coats, 1996) created extreme heat and produced pyrometamorphic rocks, named clinker, from the overlying claystones, siltstones, and sandstones. The characteristic red color which has resulted in the nickname "red dog" arises from oxidizing the iron in the sediments. Additional clinker deposits to the west are associated with the Wasatch coals, but those deposits are not included in this CHIA analysis due to the lack of interactions with the projected coal mine impacts. Where saturated and interconnected, the clinker is a good aquifer with high hydraulic conductivity. Characteristics of the clinker as an aquifer have been summarized by Heffern and Coats 1999, and Heffern et al., 1996, as well as by other authors. Some physically continuous clinker may not be continuous hydrologically.

A total of 45 clinker monitor wells are reported in the coal mine permits. For purposes of this examination, all monitor wells completed only in the clinker were considered. The distribution of clinker monitor wells by mine is given in **Table 16**. Caballo has 56 percent of the clinker wells, Belle Ayr has 16 percent of the clinker wells, and Cordero Rojo has 29 percent of the clinker wells. No clinker wells are located in the Coal Creek mine.

TABLE 16. NUMBER AND PERCENT OF CLINKER AQUIFER MONITOR WELLS BY MINE FOR THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Mine	Number of Clinker Aquifer Monitor Wells	Percent of Clinker Aquifer Monitor Wells
Caballo	25	56
Belle Ayr	7	16
Cordero Rojo	13	29
Coal Creek	0	0

The time period of well completion, type of casing used, and the current number of monitor wells was also examined. The timeframe during which the wells were completed is summarized in **Table 17**. Approximately 40 percent of the clinker aquifer monitor wells were completed during the 1970-1979 period and approximately 47 percent of the clinker monitor wells were completed during the 1980-1989 period. Based on the available data, most of the alluvial monitor wells were constructed with PVC casing but nine of the wells had steel casing and six were completed with blackline pipe. Over time, monitoring has been discontinued at 34 clinker aquifer monitor wells. However, 11 clinker monitor wells are actively monitored.

TABLE 17. THE RANGE OF YEARS OVER WHICH THE CLINKER AQUIFER MONITOR WELLS WERE COMPLETED, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Year Range	Number of Clinker Monitor Wells Completed
1970-1979	18
1980-1989	21
1990-1999	6
2000-2009	0
Completion date not in database	0

Well depth was listed for all 45 of the clinker monitor wells. The depth varied based on the well location from 50 ft to 220 ft with a median depth of 95 ft. Over 51 percent of the wells have a completion depth of between 80 and 110 ft (**Figure 15**).

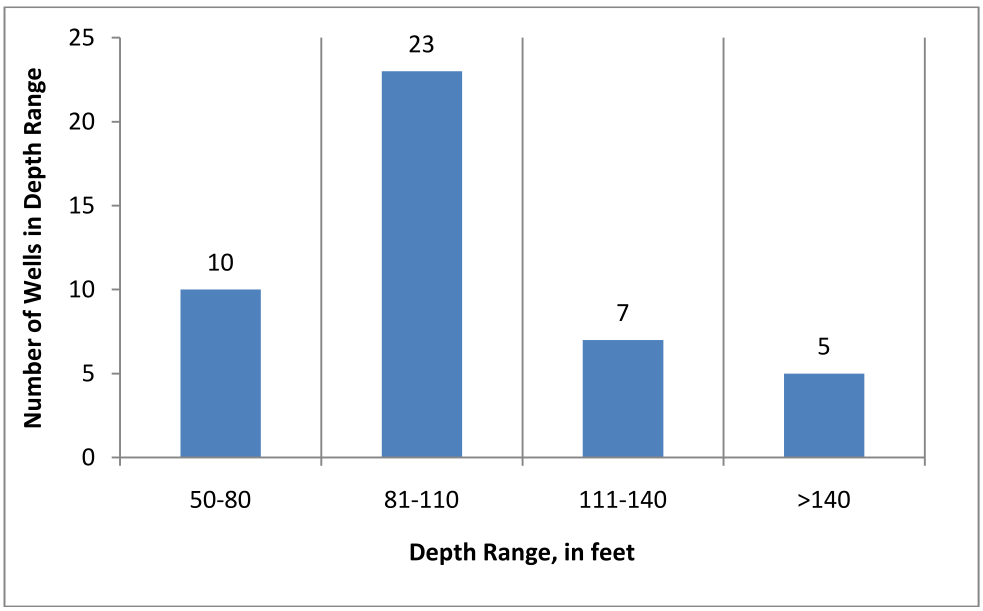


FIGURE 15. HISTOGRAM OF DEPTH OF CLINKER AQUIFER MONITOR WELLS, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Well yields and hydraulic conductivity for the clinker aquifer in the CIA are highly variable. Eleven aquifer tests in clinker wells at Caballo Mine Permit (2011) reported saturated thickness from 8 to 40 feet and hydraulic conductivity from 0.1 to 230,000 ft/d. The large hydraulic conductivities of clinker are comparable to gravel, karstic limestone and permeable basalt (Freeze and Cherry, 1979). The permeability of outcrops of clinker was observed by Rahn (1976) to be several times that of overburden or coal aquifers. These high hydraulic conductivities for the clinker may have considerable uncertainties due to the difficulty of calculating hydraulic conductivities from the small amount of drawdowns measured in the observation wells. The range of saturated thickness reported at the Caballo Mine is slightly thinner than the 60 ft assumed by Heffern and Coats (1999) in their basin wide analysis of clinker.

Where the clinker is highly fractured and permeable, precipitation infiltrates rapidly which results in the clinker having an important role in the storage and flow of water in the PRB. Clinker is able to store large amounts of rainfall and snow melt, protect it from evaporation, and discharge the water to springs, streams, and aquifers (Heffern et. al., 1996). Shallow soils, coupled with the high porosity and hydraulic conductivity, often result in high recharge. The clinker generally recharges the coal aquifer, but in limited areas it may locally recharge the alluvial aquifer, Wasatch Formation sands or discharge to the surface. The recharge rate of the clinker may exceed the flow rate into the coal. Under those conditions, water within the clinker at some localities may also discharge as springs and seeps through units adjacent to the clinker. Tritium samples collected from two clinker springs in the PRB indicated that water was recharged since 1952 (Bartos and Ogle, 2002).

The median concentration of TDS at 180 degrees C from 194 samples from the clinker aquifer was 2,354 mg/l (**Table 15**). The dominate anion was SO_4 with a median concentration of 1,170 mg/l from 196 samples and Ca is the dominate cation with a median concentration of 373 mg/l from 192 samples (**Figure 16**). The median concentration of the major ions and TDS calculated from an average of about 190 samples from the alluvial aquifer is represented in **Figure 16**. In general, the water in the clinker aquifer is suitable for livestock use, although at some locations, concentrations of individual parameters may exceed the livestock standards for a few samples had lower concentrations than the livestock standards (WDEQ/WQD, 1993). Based on AqQA (2004), the water is classified as a Ca-SO_4 type (**Figure 17**).

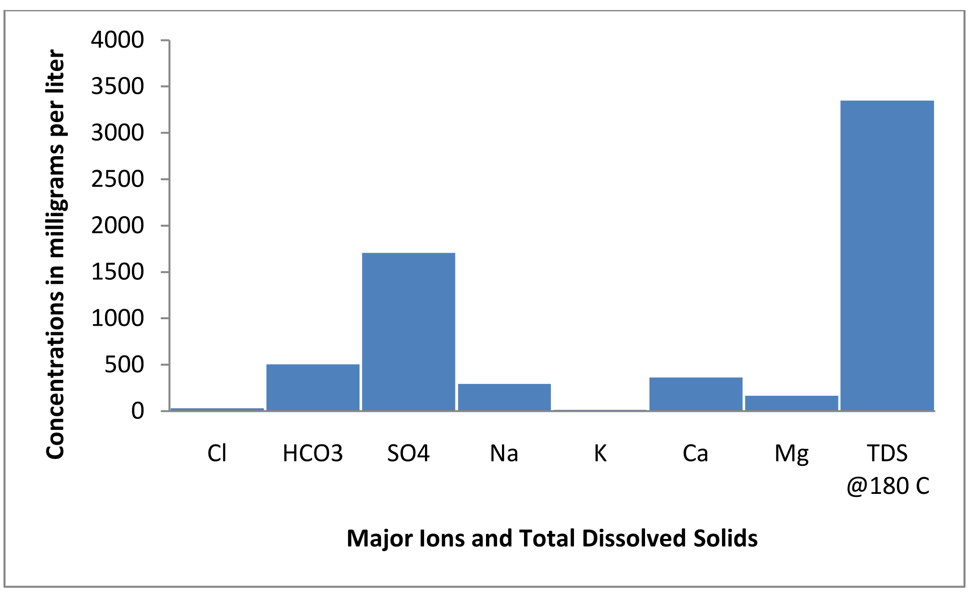


FIGURE 16. MEDIAN CONCENTRATION OF CLINKER AQUIFER WATER SAMPLES, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

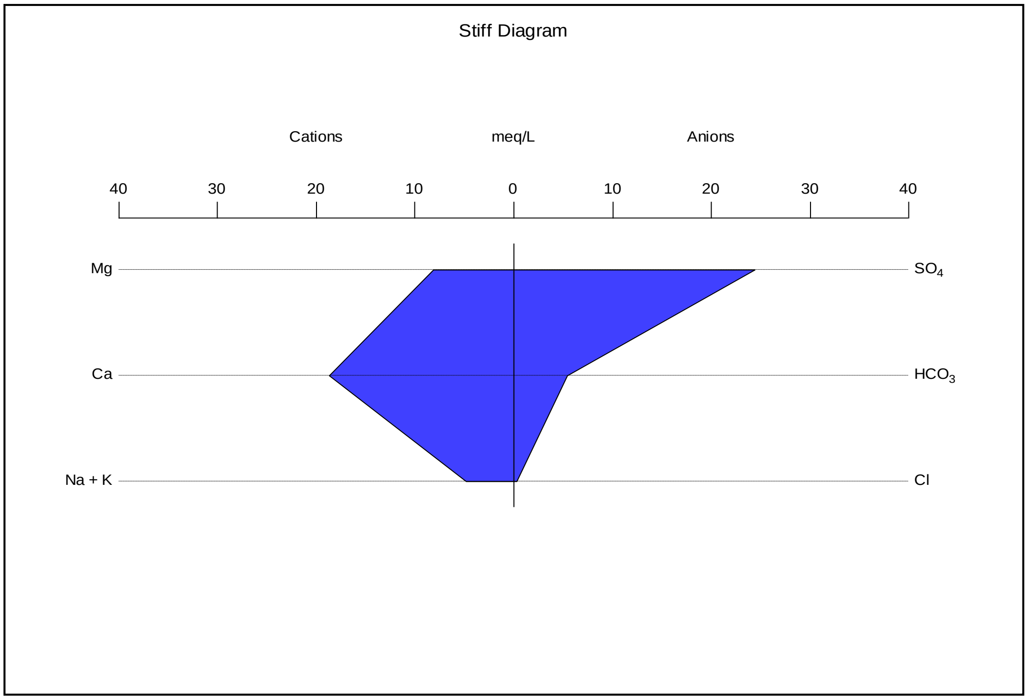


FIGURE 17. STIFF DIAGRAM OF MEDIAN CONCENTRATIONS OF WATER SAMPLES FROM THE CLINKER AQUIFER, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

3.2.2.3 WASATCH LEAKY AQUITARD UNIT

The Wasatch Leaky Aquitard Unit is a hydrologic unit that includes both the Wasatch Formation and any deposits of the Fort Union Formation lying above the Wyodak Anderson coal. Regionally the Wasatch Formation dips gently two to three degrees to the west, slightly less than the Fort Union Formation; however that different is often not discernable on a local level. The Wasatch Leaky Aquitard Unit is considered overburden at the coal mines and varies in thickness from none at the coal outcrop up to 300 ft at the western edge of the mines. The materials comprising the unit are primarily clay, siltstones and shale layers with isolated sandstones.

Groundwater encountered in the Wasatch Leaky Aquitard Unit is usually considered unconfined or perched. Groundwater movement in the Wasatch Leaky Aquitard Unit varies because of the discontinuous nature of the sand deposits but a shallow system is thought to follow the topography. A deeper component of the Wasatch Leaky Aquitard Unit may be influenced by the regional geology and the flow pattern may parallel the Wyodak Anderson Coal aquifer. In the areas of the mines, the Wasatch Leaky Aquitard Unit is generally considered a recharge source to the underlying coal aquifer in the Fort Union Formation.

A total of 211 Wasatch Leaky Aquitard Unit monitor wells are reported in the coal mine permits. For purposes of this examination, all monitor wells completed only in the Wasatch Leaky Aquitard Unit were considered. The distribution of Wasatch Leaky Aquitard Unit monitor wells by mine is given in **Table 18**. Caballo has 42 percent of the Wasatch Leaky Aquitard Unit wells, Cordero Rojo has 33 percent of the Wasatch Leaky Aquitard Unit wells, and Belle Ayr has 23 percent of the Wasatch Leaky Aquitard Unit wells. The Coal Creek mine only has 3 percent of the Wasatch Leaky Aquitard Unit wells.

TABLE 18. NUMBER AND PERCENT OF WASATCH LEAKY AQUITARD UNIT MONITOR WELLS BY MINE FOR THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Mine	Number of Wasatch Leaky Aquitard Unit Monitor Wells	Percent of Wasatch Leaky Aquitard Unit Monitor Wells
Caballo	88	42
Belle Ayr	48	23
Cordero Rojo	69	33
Coal Creek	6	3

The time period of well completion, type of casing used, and the current number of monitor wells was also examined. The timeframe during which the wells were completed is summarized in **Table 19**. Approximately 27 percent of the Wasatch Leaky Aquitard Unit monitor wells were completed during the 1970-1979 period and approximately 46 percent of the Wasatch Leaky Aquitard Unit monitor wells were completed during the 1980-1989 period. Based on the available data, most of the Wasatch Leaky Aquitard Unit monitor wells were constructed with PVC casing but eleven of the wells had steel casing, five were completed with blackline pipe, and four were completed with fiberglass. Over time, monitoring has been discontinued at 169 Wasatch Leaky Aquitard Unit monitor wells. However, 42 Wasatch Leaky Aquitard Unit monitor wells are actively monitored.

TABLE 19. THE RANGE OF YEARS OVER WHICH THE WASATCH LEAKY AQUITARD UNIT MONITOR WELLS WERE COMPLETED, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Year Range	Number of Clinker Monitor Wells Completed
1970-1979	57
1980-1989	98
1990-1999	41
2000-2009	6
Completion date not in database	9

Well depth was listed for all 211 of the Wasatch Leaky Aquitard Unit monitor wells. The depth varied based on the well location from 5 ft to 490 ft with a median depth of 125 ft. Almost 50 percent of the wells have a completion depth of between 100 and 200 ft (**Figure 18**).

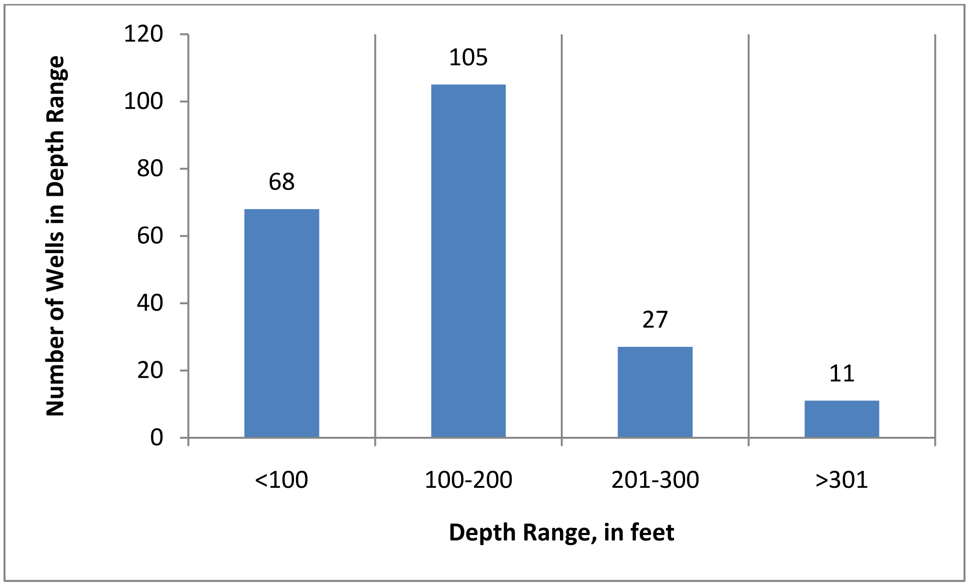


FIGURE 18. HISTOGRAM OF DEPTH OF WASATCH LEAKY AQUITARD MONITOR WELLS, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Hydraulic conductivity for the Wasatch Leaky Aquitard Unit varies but is generally low. The hydraulic conductivities of the Wasatch Leaky Aquitard Unit have a range comparable to silty sand or to silt. The hydraulic conductivity of the Wasatch Leaky Aquitard Unit varied from 0.004 to 78 ft/d in the testing completed at Caballo Mine Permit (2011). The variability is most likely due to the discontinuous nature of the sediments and the difficulty in testing wells that are low yielding. WWDC (2002a) in their basin planning study reported hydraulic conductivities ranged from 0.001 ft/d to 8.8 ft/d for the Wasatch Formation in the northeast Wyoming river basins plan which includes the CIA. The values reported for the CIA slightly exceed that range, most likely because the mines have concentrated some testing specifically on the more permeable sand lenses in the Wasatch Leaky Aquitard Unit. Saturated thickness varied from 30 feet to over 200 feet. Testing of the saturated thickness of the Wasatch Leaky Aquitard Unit in the CIA is limited by factors affecting coal strip mining. Under current operating plans, mines generally do not strip more than 200 to 300 feet of overburden, thus that is usually the limit of testing.

Generally, water quality in the Wasatch Leaky Aquitard Unit is suitable for livestock use although at some locations, concentrations of individual constituents may exceed the livestock standards and a few samples had parameters with lower concentrations than the livestock standards (WDEQ, 1993). Median TDS at 180 degrees C concentration in 1,268 samples from Wasatch Leaky Aquitard Unit wells in the CIA was 2,568 mg/l (**Table 15**). Water in the Wasatch Leaky Aquitard Unit generally is dominated by the SO_4 anion with a median concentration of 1,369 mg/l from 1,379 samples and bicarbonate (HCO_3) at a median concentration of 485 mg/l for 1,131 samples. Both Na and Ca are present in nearly equal quantities (**Figure 19**). **Table 15** presents the median concentration of the major ions calculated from an average of about 1,300 samples. Based on AqQA (2004), the water is classified as a Ca-SO_4 type (**Figure 20**).

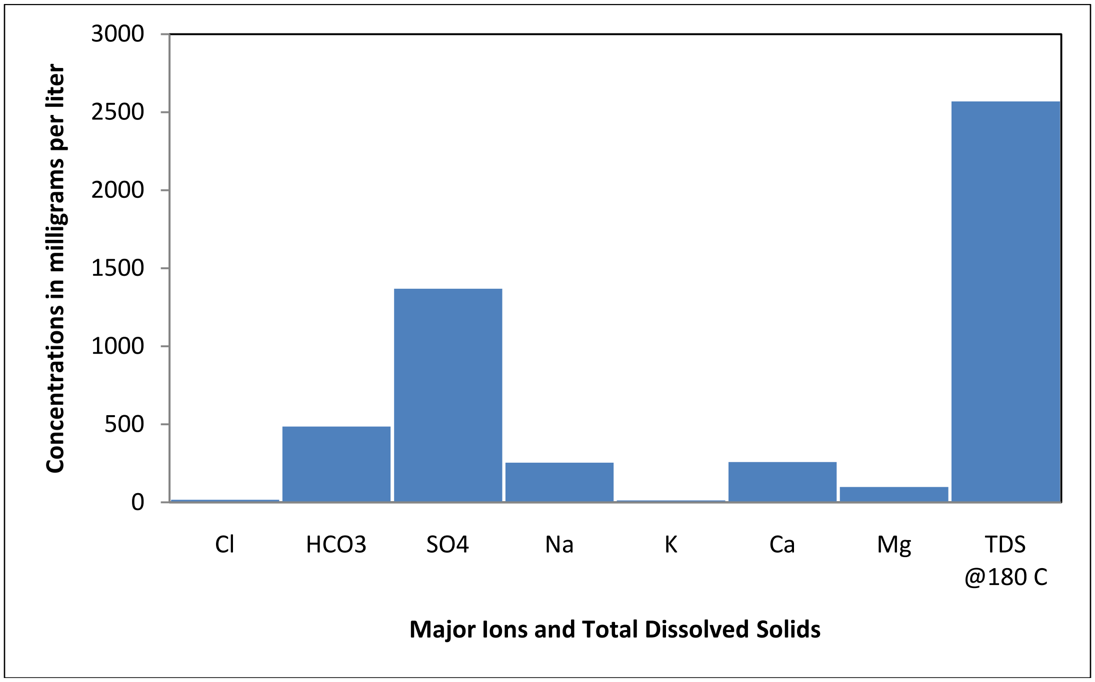


FIGURE 19. MEDIAN CONCENTRATION OF WASATCH LEAKY AQUITARD UNIT WATER SAMPLES, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

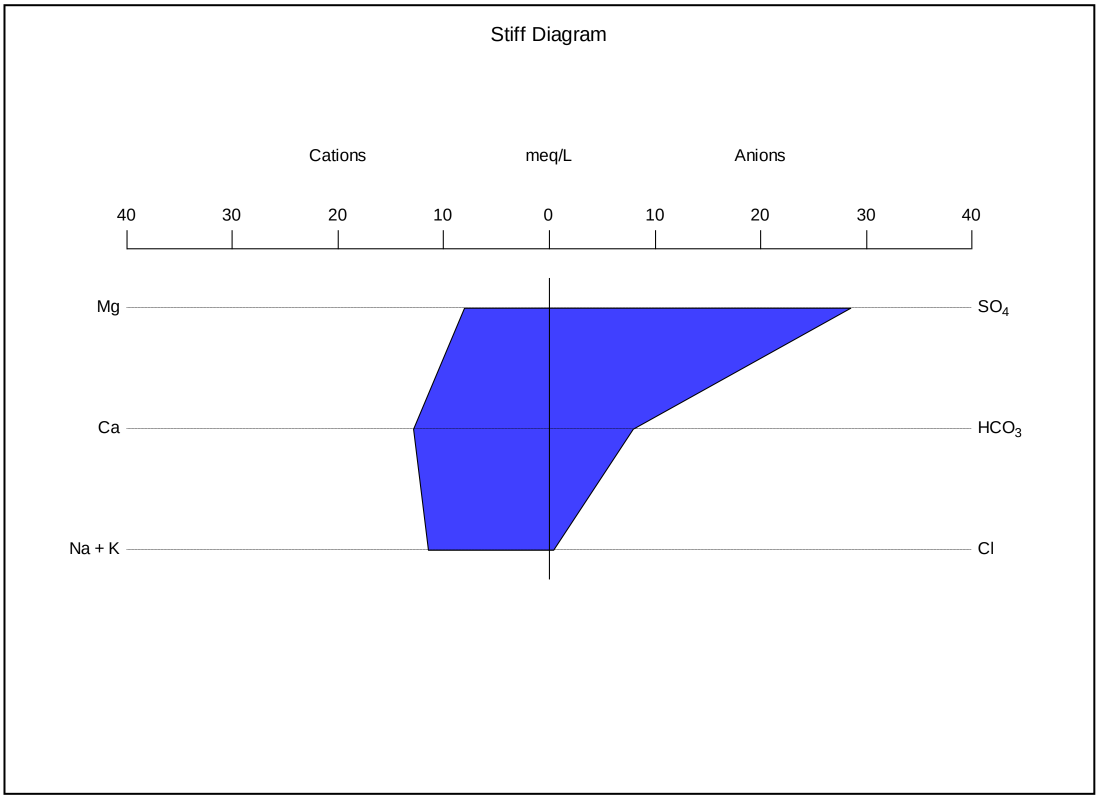


FIGURE 20. STIFF DIAGRAM OF MEDIAN CONCENTRATIONS OF WATER SAMPLES FROM THE WASATCH LEAKY AQUITARD UNIT, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

3.2.2.4 WYODAK ANDERSON COAL AQUIFER

The Wyodak Anderson coal seam within the Fort Union Formation in the PRB is one of the world's largest known coal deposits (Denson and Keefer, 1974). Except for a few areas near the outcrop where the coal seam is dry or partially saturated, the Wyodak Anderson coal seam is also an aquifer. The Wyodak Anderson coal is either a single bed or a group of closely spaced beds separated by thin partings. For clarity of discussion, the coal seams will be lumped into the general term of Wyodak Anderson coal and analyzed as a unit. Groundwater is stored and flows through fractures and cleats in the coal. The saturated thickness of the coal seams increases to the west as the seams dip below the water table and the coal aquifer changes from an unconfined aquifer to a confined aquifer. The three-dimensional groundwater model developed by the Caballo Mine Permit (2011) used an approximately 75 feet thickness for the Wyodak Anderson coal aquifer in their modeling.

A total of 244 Wyodak Anderson Coal Aquifer monitor wells are reported in the coal mine permits. For purposes of this examination, all monitor wells completed only in the Wyodak Anderson Coal Aquifer were considered. The distribution of Wyodak Anderson Coal Aquifer monitor wells by mine is given in **Table 20**. Caballo and Cordero Rojo each have approximately 30 percent of the Wyodak Anderson Coal Aquifer wells and Belle Ayr and Coal Creek each have approximately 20 percent of the Wyodak Anderson Coal Aquifer wells.

TABLE 20. NUMBER AND PERCENT OF WYODAK ANDERSON COAL AQUIFER MONITOR WELLS BY MINE FOR THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Mine	Number of Wyodak Anderson Coal Aquifer Monitor Wells	Percent of Wyodak Anderson Coal Aquifer Monitor Wells
Caballo	80	33
Belle Ayr	45	18
Cordero Rojo	70	29
Coal Creek	49	20

The time period of well completion, type of casing used, and the current number of monitor wells was also examined. The timeframe during which the wells were completed is summarized in **Table 21**. Approximately 53 percent of the Wyodak Anderson Coal Aquifer monitor wells were completed during the 1970-1979 period and approximately 32 percent of the Wyodak Anderson Coal Aquifer monitor wells were completed during the 1980-1989 period. Based on the available data, most of the Wyodak Anderson Coal Aquifer monitor wells were constructed with PVC casing but eleven of the wells had steel casing, sixteen were completed with blackline pipe, fifteen were completed with steel, and three were completed with fiberglass. Over time, monitoring has been discontinued at 195 Wyodak Anderson Coal Aquifer monitor wells. However, 49 Wyodak Anderson Coal Aquifer monitor wells are actively monitored.

TABLE 21. THE RANGE OF YEARS OVER WHICH THE WYODAK ANDERSON COAL AQUIFER MONITOR WELLS WERE COMPLETED, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Year Range	Number of Wyodak Anderson Coal Aquifer Monitor Wells Completed
1970-1979	129
1980-1989	78
1990-1999	21
2000-2009	2
Completion date not in database	14

Well depth was listed for all 244 of the Wyodak Anderson Coal Aquifer monitor wells. The depth varied based on the well location from 36 ft to 484 ft with a median depth of 220 ft. Approximately 63 percent of the wells have a completion depth of between 100 and 300 ft (**Figure 21**).

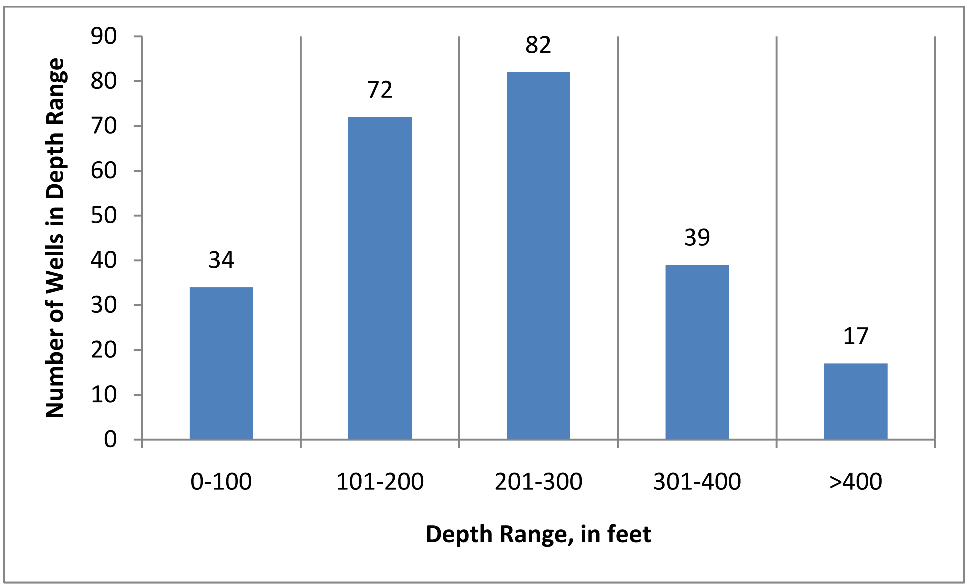


FIGURE 21. HISTOGRAM OF DEPTH OF WYODAK ANDERSON COAL AQUIFER MONITOR WELLS, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Aquifer tests from selected wells in the groundwater CIA area were compiled and hydraulic conductivity and storativity of the coal aquifer were examined. Freeze and Cherry (1979) noted that little was known about the hydraulic properties of coal. The permeability of coal is characterized by cleat permeability and secondary permeability due to folding and faulting. Coal permeabilities found in the CIA range more than six orders of magnitude, indicating extreme variations in coal fracture densities.

The hydraulic conductivities of the coal aquifer range from 0.1 ft/d to 197 ft/d in the Caballo Mine Permit (2011) a range, comparable to a range covering silt to clean sand. The variability is most likely due to fractured nature of the coal. Many of the aquifer tests were single well or slug tests and storage coefficients could not be calculated. When a storage coefficient was reported, it was usually in the confined range of expected values. The saturated thickness of the tested coal aquifer varied from 10 ft to 80 ft. The Caballo Mine Permit (2011) model used hydraulic conductivities of 0.001 to 0.1 ft/d near the outcrop to 1 to 8 ft/d as the permeability of the coal increases away from the outcrop.

The generalized direction of groundwater flow in the coal aquifer is to the west with a regional north, northwest component. Water levels are generally confined and rise above the top of the coal bed away from the outcrop area. Water levels in the areas of the coal mine permit areas are generally from a few feet to over a hundred feet below land surface.

Median TDS at 180 degrees C concentration in 1,133 samples from Wyodak Anderson Coal Aquifer wells in the CIA was 932 mg/l (**Table 15**). Water in the Wyodak Anderson Coal Aquifer generally is dominated by the HCO3 anion with a median concentration of 795 mg/l from 1,395 samples. Na is the predominate cation with a median concentration of 248 mg/l from 1,496 samples. **Table 15** presents the median concentration of the major ions calculated from an average of about 1,300 samples.

The median concentration of the major ions and TDS from about 1,400 samples was calculated for the Wyodak Anderson Coal Aquifer and is shown in **Figure 22**. In general, the water in the Wyodak Anderson Coal Aquifer is suitable for livestock use, although a few locations, concentrations of individual parameters may exceed the livestock standards and a few samples had parameters at lower concentrations than the livestock standards (WDEQ, 2005). Based on AqQA (2004), the water is classified as a Na-HCO_3 type (**Figure 23**).

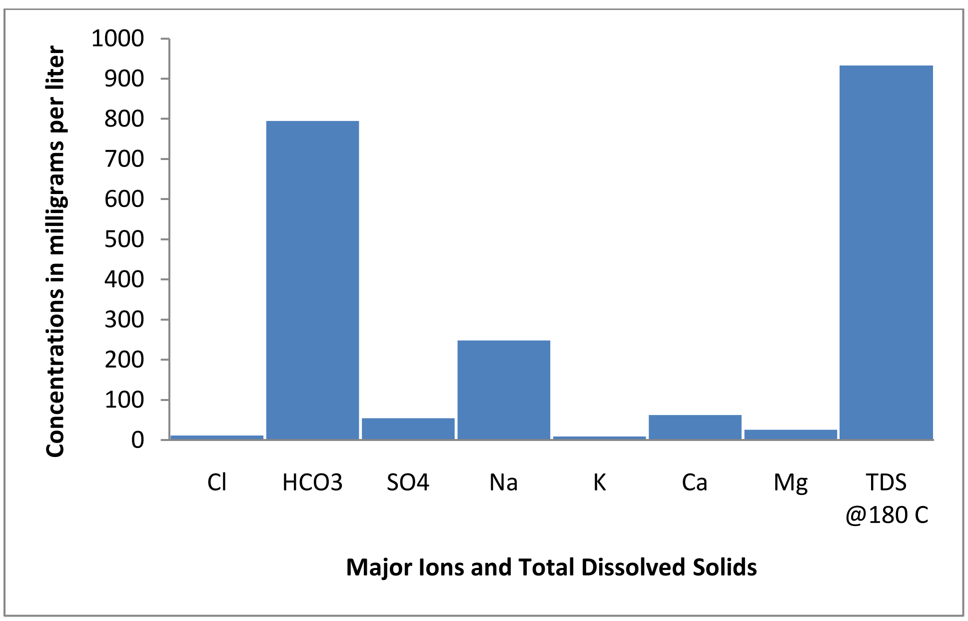


FIGURE 22. MEDIAN CONCENTRATION OF WYODAK ANDERSON COAL AQUIFER WATER SAMPLES, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

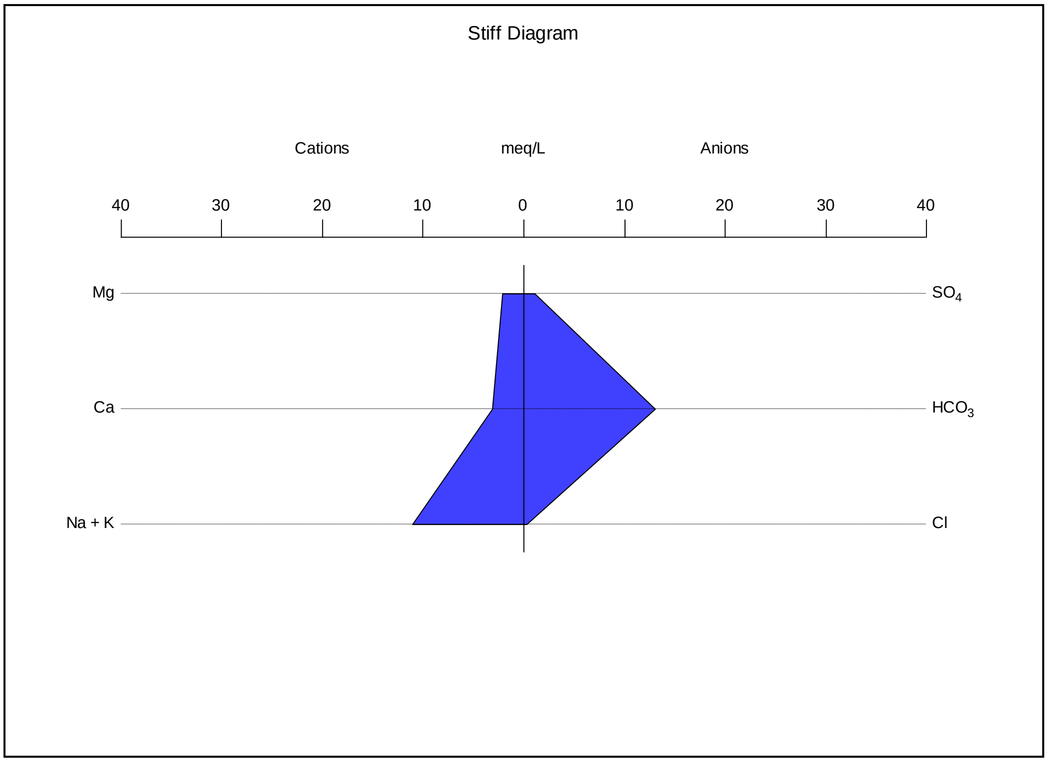


FIGURE 23. STIFF DIAGRAM OF MEDIAN CONCENTRATIONS OF WATER SAMPLES FROM THE WYODAK ANDERSON COAL AQUIFER, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Water quality in the Wyodak Anderson coal aquifer varies along the flow path due to microbial activity of sulfate reducing bacteria, ion exchange, and precipitation. The transition of the water, from higher to lower TDS and from sulfate to bicarbonate as the dominant anion is attributed to: (a) dissolution of minerals from clinker ash, coal, and soil by oxygenated water infiltrating from the surface through coal and clinker outcrops along the eastern portions of these three mines; and (b) precipitation of calcium sulfate in the coal as groundwater moves west from the recharge areas (Heffern & Coates, 1996). In the PRB in Montana, Lee (1981) identified mixing and bacterially promoted reduction of sulfate as mechanisms to explain the lower sulfate concentrations along the flow path. Dockins, et al., 1980, identified sulfate-reducing bacteria (*Desulfovibrio desulfuricans*) in the same groundwater of southeastern Montana and fractionation of the 32S and 34S isotopes reflective of that bacterial process.

3.2.2.5 UNDERBURDEN LEAKY AQUITARD UNITS

Underburden consists of thin discontinuous sandstone lenses inter-bedded with siltstone and claystone. The underburden has low permeability. However, where sand lenses are present, the underburden is semi-confined or perched and may be under artesian conditions away from the outcrop. In this analysis interburden units are lumped with the Wyodak Anderson Coal Aquifer Unit, however at the scale of analysis for the individual mine permits, it may be treated as a separate unit.

At the Caballo Mine, one well (CA-349-SC) was sampled in the underburden immediately under the coal. The water type was a mixed Ca, Na, and SO_4 type, with SO_4 concentration of 1,500 mg/l. The Lebo Shale is locally approximately 1,700 feet thick (Brown 1979) and consists of predominantly shale and concretionary sandstone with siltstone, and thin coal beds. The Lebo Shale is considered a confining unit due to the predominance of shale (Wyoming Water Resources Center, 1997).

A total of 19 underburden monitor wells are reported in the coal mine permits. For purposes of this examination, all monitor wells completed only in the underburden were considered. The distribution of underburden monitor wells by mine is given in **Table 22**. Cordero Rojo has approximately 58 percent of the underburden wells and Belle Ayr has approximately 32 percent of the underburden wells. Caballo has approximately 11 percent of the underburden wells and there are no recorded underburden wells in the Coal Creek mine.

TABLE 22. NUMBER AND PERCENT OF UNDERBURDEN MONITOR WELLS BY MINE FOR THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Mine	Number of Underburden Monitor Wells	Percent of Underburden Monitor Wells
Caballo	2	11
Belle Ayr	6	32
Cordero Rojo	11	58
Coal Creek	0	0

The time period of well completion, type of casing used, and the current number of monitor wells was also examined. The timeframe during which the wells were completed is summarized in **Table 23**. Approximately 53 percent of the underburden monitor wells were completed during the 1980-1989 period. Based on the available data, most of the underburden monitor wells were constructed with PVC casing but three of the wells had iron/steel casing. Over time, monitoring has been discontinued at 16 underburden monitor wells. However, three underburden monitor wells are actively monitored.

TABLE 23. THE RANGE OF YEARS OVER WHICH THE UNDERBURDEN MONITOR WELLS WERE COMPLETED, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Year Range	Number of Underburden Monitor Wells Completed
1970-1979	8
1980-1989	10
1990-1999	1
2000-2009	0
Completion date not in database	0

Well depth was listed for all 19 of the underburden monitor wells. The depth varied based on the well location from 118 ft to 1,840 ft with a median depth of 300 ft. Approximately 53 percent of the wells have a completion depth of between 100 and 300 ft (**Figure 24**).

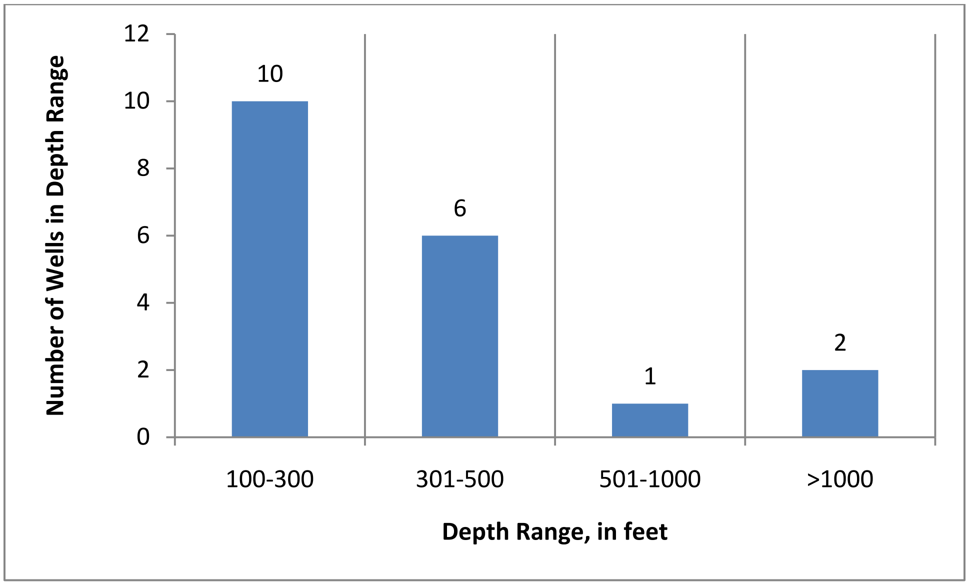


FIGURE 24. HISTOGRAM OF DEPTH OF UNDERBURDEN MONITOR WELLS, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Median TDS at 180 degrees C concentration in 157 samples from underburden wells in the CIA was 717 mg/l (**Table 15**). Water in the underburden generally is dominated by the HCO_3 anion with a median concentration of 674 mg/l from 154 samples. Na is the predominate cation with a median concentration of 220 mg/l from 156 samples. **Table 15** presents the median concentration of the major ions calculated from an average of about 155 samples.

The median concentration of the major ions and TDS from about 155 samples was calculated for the underburden and is shown in **Figure 25**. In general, the water in the underburden is suitable for livestock use, although in a few locations, concentrations of individual parameters may exceed the livestock standards and a few samples had parameters at lower concentrations than the livestock standards (WDEQ, 2005). Based on AqQA (2004), the water is classified as a Na-HCO_3 type (**Figure 26**).

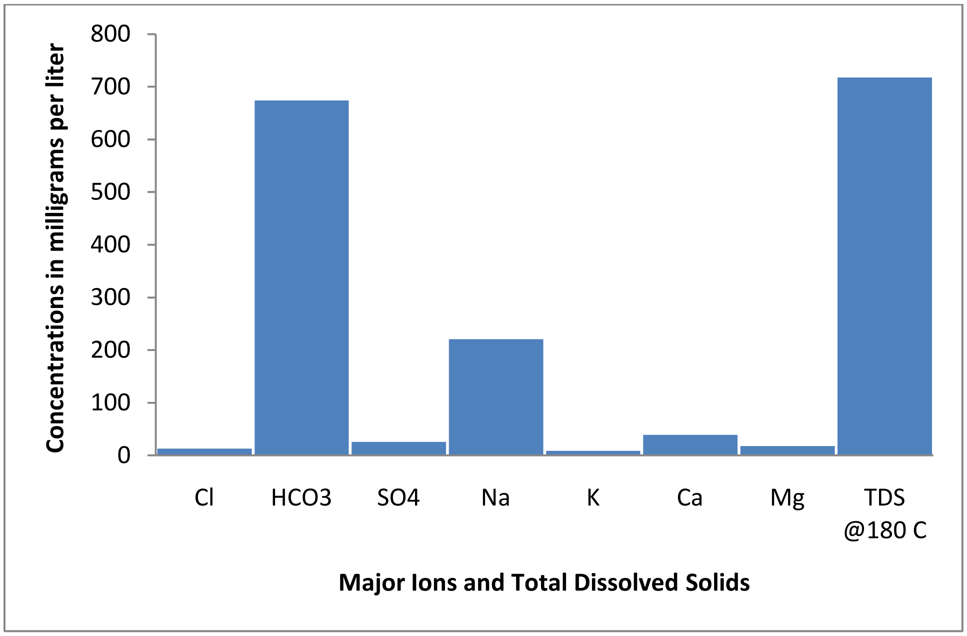


FIGURE 25. MEDIAN CONCENTRATION OF UNDERBURDEN WATER SAMPLES, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

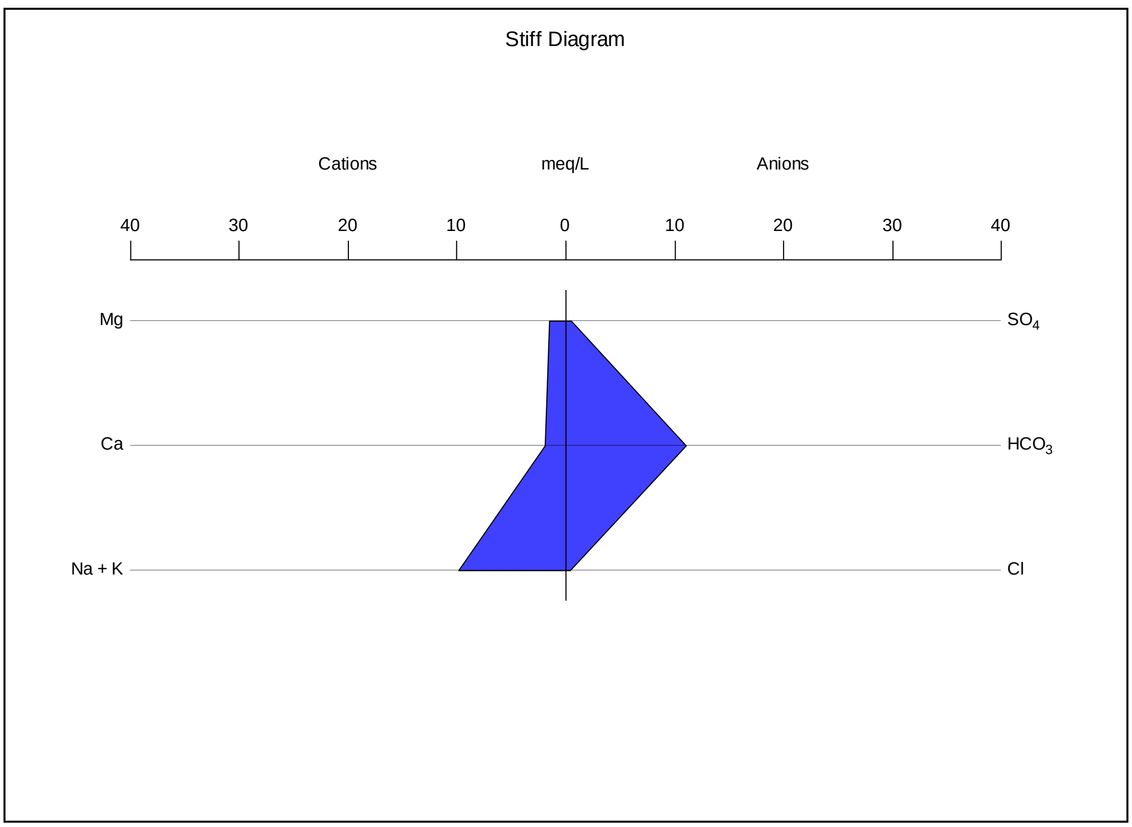


FIGURE 26. STIFF DIAGRAM OF MEDIAN CONCENTRATIONS OF WATER SAMPLES FROM THE WYODAK ANDERSON COAL AQUIFER, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

3.2.2.6 TULLOCK AQUIFER

The Tullock aquifer consists of shale, fine-grained sandstone, and thin coals within the Tullock Member of the Fort Union Formation and is considered an aquifer. Most coal mine facility wells are completed in the Tullock aquifer, but often within different sands in the aquifer. Caballo Mine Permit (2011) has four wells (DW-1, Fort Union #2, CA-1357-WW and CA-1541-U) that are completed at depths from 405 to 1,605 feet below land surface. Likewise, Belle Ayr and Coal Creek have wells completed in the deeper Fort Union formation to supply facilities water. The water quality of the Tullock aquifer is generally suitable for domestic water source. Belle Ayr Mine also has two deeper wells completed in the Fox Hills Sandstone. The deepest of the Fox Hills Sandstone wells was drilled to a depth of 10,200 ft, but perforated from 2,967 ft to 3,980 ft.

The water quality in the various mine water supply wells, completed in the deeper portions of the Fort Union Formation, generally meets the standards for domestic use as well as agricultural and livestock use.

3.2.3 RECHARGE

Clinker deposits are highly permeable and groundwater is usually present in unconfined conditions. Confined conditions, however, may occur where overlain by alluvium or colluvium. Depending on local conditions, clinker may be a zone of groundwater recharge to the underlying units, or a zone of groundwater discharge. In general, clinker is considered a significant source of groundwater recharge to the coal aquifer (Heffern et al., 1996). The potentiometric surface of the coal aquifer indicates recharge to the coal from the clinker to the east (GAGMO, 2000). There are also indications that some recharge occurs in the overburden, which then flows through the clinker to the coal.

Recharge to the water bearing strata throughout CIA occurs primarily along upland areas where bedrock outcrops are located. Other important sources of groundwater recharge are considered to be from periodic infiltration along ephemeral drainages and playas or from precipitation on other outcrop areas. Additional recharge and discharge occurs along many local streams and creeks.

3.3 ALLUVIAL VALLEY FLOORS

The Wyoming Environmental Quality Act defines alluvial valley floors (AVFs) as "the unconsolidated stream laid deposits holding streams where water availability is sufficient for subirrigation or flood agricultural activities but does not include upland areas which are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion, deposits by unconcentrated runoff or slope wash, together with talus, other mass movement accumulation and windblown deposits" (W.S. § 35-11-103(e)(xviii) (Wyoming Department of Environmental Quality, 2010a). Coal mining operations may not interrupt, discontinue, or preclude farming on AVFs that are irrigated or naturally subirrigated, provided that the AVF is significant to a farm's agricultural production (W.S. § 35-11-406(n)(v)(A) (Wyoming Department of Environmental Quality, 2010a). Significance to farming is determined by calculating the percent farm production loss as a result of mining the AVF. Any loss greater than 10 percent is considered to exceed a negligible impact to both small and large Wyoming farming operations, and thus mining of the AVF is prohibited (Wyoming Department of Environmental Quality, 2000). Coal mining also must not materially damage the quantity or quality of water in surface or underground systems that supply AVFs deemed significant to farming (W.S. § 35-11-406(n)(v)(B) (Wyoming Department of Environmental Quality, 2010a). This includes AVFs adjacent to or downstream of the permit area.

AVFs in Wyoming can be mined provided that either: (1) the AVF is not significant to farming or is on undeveloped rangeland, or (2) the mine produced coal in commercial quantities prior to the effective date of SMCRA (August 3, 1977). However, in each of these cases the mine must restore the essential hydrologic functions of the AVF after mining. Essential hydrologic functions are defined as "those conditions of surface and groundwater hydrology that support or enhance subirrigation or flood irrigation agricultural activities" (WDEQ/LQD Coal Rules and Regulations, Chapter 1, Section 2(ar)). If the AVFs are located off-site and will not be mined, the essential hydrologic functions still must be preserved.

WDEQ/LQD has made numerous AVF determinations at the coal mines in the middle PRB. The determinations were made using baseline studies conducted by the mines, and in some cases have been modified over time as new information is evaluated. AVF investigations are typically interdisciplinary, involving an analysis of surface water quantity and quality, alluvial aquifer water levels and quality, vegetation, soils, geomorphology, and geology. Some of these baseline data have been previously discussed in Section 3.1. Categories of WDEQ/LQD AVF determinations include:

- **AVF – Significant to Farming**: The AVF is significant to farming and cannot be mined. Mining must not materially damage the quantity or quality of water in surface or underground systems that supply the AVF.

- **AVF – Not Significant to Farming**: The AVF is not significant to farming and can be mined provided that the essential hydrologic functions are restored after mining. If the AVF is not mined, the essential hydrologic functions still must be preserved.

- **AVF – Grandfathered**: The area is an AVF, but significance to farming test is not required since the mine produced coal in commercial quantities prior to the effective date of SMCRA (August 3, 1977). The AVF can be mined provided that the essential hydrologic functions are restored after mining. If the AVF is not mined, the essential hydrologic functions still must be preserved.

- **Not an AVF**: The area does not meet the definition of an AVF. The area can be mined.

A description of the AVF determinations in the Caballo Creek and BFR CIAs is presented below.

3.3.1 CABALLO CREEK CIA

WDEQ/LQD issued AVF determinations for the Caballo Mine in 1983 in the T-1 of the State Decision Document (SDD). Gold Mine Draw was declared an AVF from the confluence with Tisdale Creek upstream to the Section 12/13 boundary. Most of Gold Mine Draw within Section 13 was declared an AVF significant to farming (approximately 144 ac), while the remainder downstream to the confluence was declared a grandfathered AVF (**Figure 27**). Upstream from Section 13, Gold Mine Draw was declared not to be an AVF. The Gold Mine Draw AVF is located in the historical Czapla Farm, which constructed and permitted several spreader dykes and impoundments in 1969 to facilitate irrigated agriculture. The AVF supports artificially flood irrigated and natural subirrigated crops. WDEQ/LQD determined that the AVF was significant to the Czapla Farm unit and mining of the AVF would exceed a negligible impact. The essential hydrologic functions of the Gold Mine Draw AVF include: (1) stabilization of the geometric characteristics of the valley floor during flood events, (2) use of surface water for irrigation, (3) subirrigation of cultivated land, (4) recharge to the alluvium from surface water, (5) dynamic hydraulic equilibrium between water in the alluvium and that in abutting rock formations, and (6) preservation of the quality of the surface and groundwater (Caballo Mine Permit, 2011).

The Gold Mine Draw AVF is the only AVF declared significant to farming within an active coal mine in the PRB of Wyoming. Since the coal underlying the AVF could not be mined, the Bureau of Land Management (BLM) and Powder River Coal Company completed a lease exchange in 2006 (Bureau of Land Management, 2006; Bureau of Land Management, 2007). The BLM acquired the lease rights for 921.6 ac of federal coal underlying the Gold Mine Draw AVF in exchange for 47,700,000 minable tons of coal on 623 ac at the North Antelope Rochelle Mine in the southern PRB (Bureau of Land Management, 2006; Bureau of Land Management, 2007).

WDEQ/LQD also declared the Tisdale Creek/Gold Mine Draw “confluence area” a grandfathered AVF in the T-1 SDD for the Caballo Mine. The definition of the “confluence area” is somewhat ambiguous in the Caballo Mine SDD. The Caballo Mine has interpreted the confluence area to include about one mile of Tisdale Creek upstream from the confluence with Gold Mine Draw **(Figure 27).** Negative AVF determinations were given to North Tisdale Creek and on Tisdale Creek upstream from the confluence area (**Figure 27**).

Several streams were also given negative AVF determinations after the North Caballo AVF studies in 2004 (Caballo Mine Permit, 2011). These include the Tisdale Creek Depression, the West Branch of North Tisdale Creek, North Tisdale Creek, Gold Mine Draw headwaters, and Dry Donkey Creek (**Figure 27**). In April 2008, WDEQ/LQD also declared that there were no AVFs in the Caballo Mine West LBA area in T48N, R71W Sections 7, 17, 18, 19, and 20. This area included unnamed ephemeral tributaries to Tisdale Creek and Duck Nest Creek (**Figure 27**).

At the Belle Ayr Mine, two reaches of Caballo Creek were declared grandfathered AVFs by WDEQ/LQD in the T-1 SDD in 1983 (**Figure 27**). The "western AVF" comprised 69.9 ac (60 ac subirrigated and 3.9 flood irrigated) and the "eastern AVF" comprised 134 ac. The eastern AVF will not be physically disturbed. The western AVF had the following essential hydrologic functions: (1) availability and quality of alluvial groundwater beneath the lower terraces to facilitate subirrigation of agriculturally useful plants, (2) availability and quality of surface runoff to support subirrigation activities of the upper terraces through the use of spreader dams, and where possible, flood irrigation activities, and (3) availability of large, relatively flat terrace deposits adjacent to the active stream which are conducive to agricultural development through irrigation or preferential grazing activities (Belle Ayr Mine Permit, 2011). Other sections of Caballo Creek within the T-1 permit area were declared not to be AVFs. The reach near the original mine site had no declaration, presumably due to historic pre-law disturbance. Other streams implicitly declared as not AVFs in the T-1 permit area included Draw No. 1, Draw No. 2, Royal Draw, Clabaugh Draw, and Demott Draw (**Figure 27**).

Additional AVF studies were completed at the Belle Ayr Mine for the Duck Nest Tracts. In 1996, WDEQ/LQD declared AVFs on sections of Caballo Creek (33.2 ac), Bone Pile Creek (16 ac), and Duck Nest Creek (24.3 ac) (**Figure 27**). All of the AVF acreage was determined to be not significant to farming. The essential hydrologic functions of these AVFs are: (1) the ability to convey runoff, (2) the presence of an alluvial aquifer that stores water during periods of high runoff for use later in the growing season, and (3) the provision of habitat for wildlife by supporting streamside vegetation and maintaining pools of water (Belle Ayr Mine Permit, 2011).

The current Cordero Rojo Mine was created from the consolidation of the Cordero Mine (Permit 237) and the Caballo Rojo Mine (Permit 211). The northern portion of the Caballo Rojo Mine contained drainage to Caballo Creek. In the T-1 SDD (signed in 1985), WDEQ/LQD declared several tributaries of Caballo Creek not to be AVFs (Cordero Rojo Mine Permit, 2011). These included Les Draw, Demott Draw, Clabaugh Draw, Windmill Draw, and Draw No. 3 (**Figure 27**). Draw No. 3 is also known as Royal Draw at the Belle Ayr Mine.

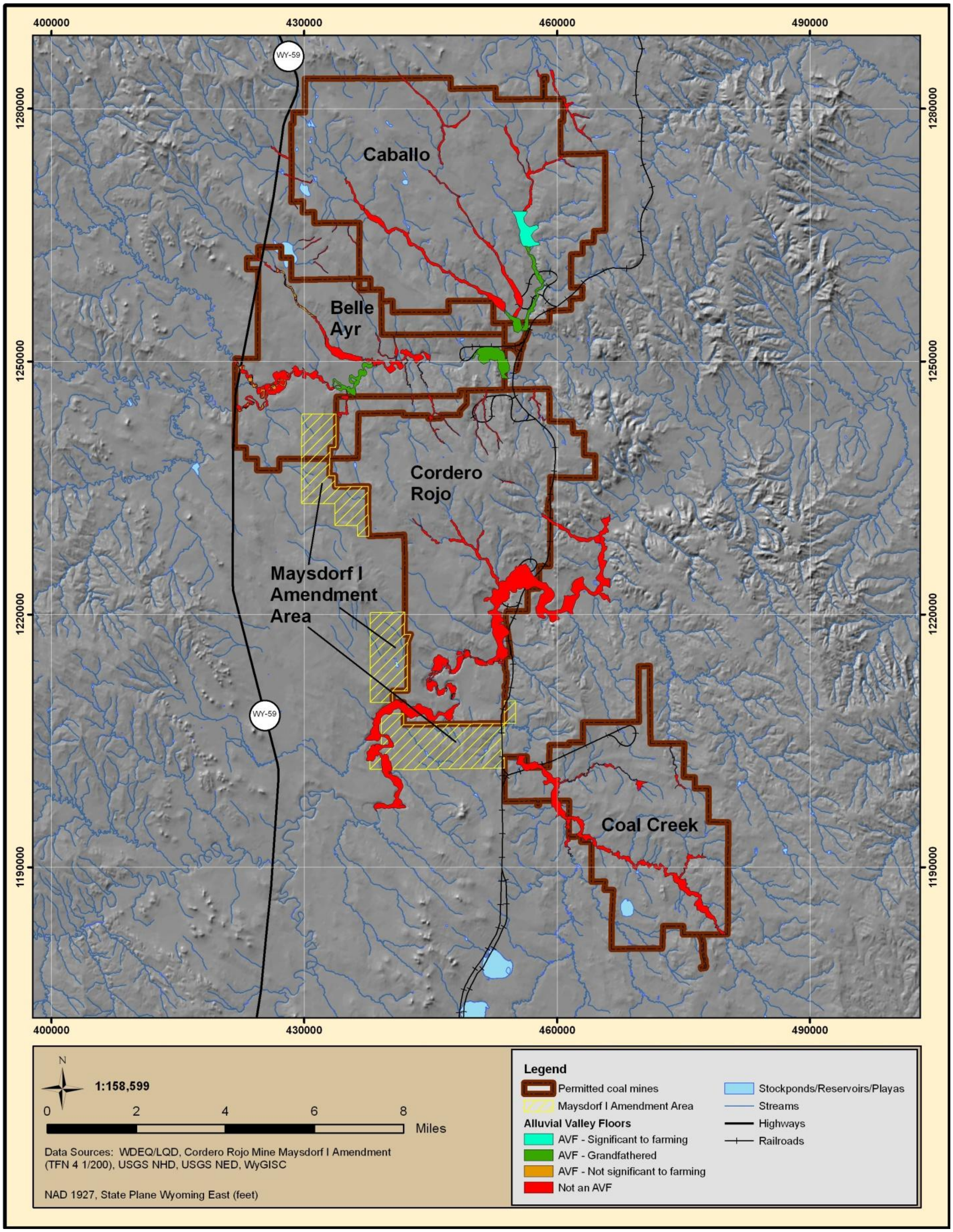


FIGURE 27. CURRENT EXTENT OF ALLUVIAL VALLEY FLOORS (AVFS) AT COAL MINES IN THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

3.3.2 BELLE FOURCHE RIVER CIA

There are no AVFs in the BFR CIA. The T-1 SDD for the Cordero Mine was signed in 1984, declaring the BFR not to be an AVF within and downstream of the T-1 permit boundary (**Figure 27**) (Cordero Rojo Mine Permit, 2011). Although the geomorphic AVF criteria were met, it was determined that the BFR in the vicinity of the mine was not capable of supporting flood irrigation or subirrigation agricultural activities. The T-1 AVF findings for the Cordero Mine also found Coal Creek near the confluence with the BFR not to be an AVF. Kicken Draw and Bengal Draw were also given negative determinations (Cordero Rojo Mine Permit, 2011). Approximately six additional miles of the BFR were evaluated for AVF status for the Maysdorf I Amendment application. In October 2007, WDEQ/LQD declared this reach of the BFR not to be an AVF due to: (1) the limited extent of streamlaid deposits, (2) lack of historic agricultural development, and (3) poor water quality unsuitable to support agricultural development (Cordero Rojo Mine Permit, 2011).

In 1978, WDEQ/LQD declared AVFs on several stream segments at the Coal Creek Mine. These AVFs included: (1) Coal Creek in Sections 19 and 13, (2) Section 16 Tributary to Dry Creek, (3) Middle/West Fork Coal Creek in Section 19 and the north half of Section 30, and (4) East Fork Coal Creek from Section 33 to Section 19. The Section 18 Tributary to Coal Creek and the Section 27 Tributary to East Fork Coal Creek were declared not to be AVFs (Coal Creek Mine Permit, 2011).

The AVF status at the Coal Creek Mine was reevaluated by WDEQ/LQD in August 1981. AVFs were then declared on: (1) the Section 16 Tributary to Dry Creek, (2) Coal Creek from the confluence of the East and West Forks downstream to the permit boundary, and (3) East Fork Coal Creek upstream from an unnamed tributary in Section 33 to the upstream permit boundary. In January 1985, WDEQ/LQD again revised the AVF determination for the mine. The positive AVF status was removed on the Section 16 Tributary and East Fork Coal Creek. In February 1986, WDEQ/LQD issued the AVF findings for the Coal Creek Mine in the T-1 SDD. Coal Creek was declared an AVF not significant to farming from the confluence with the East and West Forks to the downstream permit boundary (Coal Creek Mine Permit, 2011). The reasons for the positive determination included the natural subirrigation and flood irrigation that had occurred upstream and downstream of Thrush Dam, and the past history of artificial flood irrigation of the area.

In September 2004, the AVF designation on Coal Creek was removed by WDEQ/LQD following a site visit to the area (Coal Creek Mine Permit, 2011). The determination was changed because: (1) the site visit showed that a majority of the channel was deeply incised with little evidence of subirrigation, (2) the small area adjacent to the channel showing evidence of subirrigation was too small for special management under common regional practices, (3) the narrow band of active floodplain was too small and isolated for managed natural flood irrigation, and (4) artificial flood irrigation was historically attempted but failed. In summary, there are no declared AVFs within the Coal Creek Mine permit area (**Figure 27**).

4 HYDROLOGIC CONCERNS

The objective of this assessment is to determine the probable cumulative hydrologic impacts of the existing and anticipated mine operations within the delineated CIAs. Impacts to the quantity and quality of surface and groundwater are addressed. The following discussion in this section and the next section identify the general hydrologic concerns that are addressed in this evaluation.

4.1 SURFACE WATER

4.1.1 WATER QUANTITY

4.1.1.1 DURING MINING

Surface water runoff is affected by climate, geomorphology, topography, soil characteristics, vegetation, and land use. Mining has the potential to affect all of these factors except climate.

Increased Runoff: Runoff can increase during mining if mines are dewatering aquifers and discharging the water into ponds or stream channels. However, the potential for increased runoff is probably somewhat limited in the PRB since a large portion of the water intercepted by the mine pits is used for dust suppression. There are some instances when water may be discharged downstream, temporarily changing the flow regime. Runoff can also increase during mining due to an increase in impervious surfaces that decrease infiltration rates. These include the presence of unpaved access or haul roads and infrastructure associated with mine facilities. Since the mines progress with contemporaneous reclamation, the entire permit area is not completely disturbed at any one time. This practice serves to lessen the impact of mining on runoff.

Decreased Runoff: Runoff from areas upstream of a mine is either captured by ponds or the mine pit or routed around the active mining and reclaimed areas. This capture or diversion effectively isolates the mine area from contributing flow downstream. Sediment control is required for all areas disturbed by mining and associated activities. Runoff from disturbed areas is required to pass through some type of treatment structure. These can range from simple rock check dams to large settling ponds. All impoundments greater than 2 ac-ft are required to be permitted with the WSEO. Impoundments less than 2 ac-ft can be permitted under one mine permit providing the cumulative capacity is less than 19.8 ac-ft.

Water collected by sediment ponds is often used for dust control, equipment wash down, or livestock and wildlife use, rather than being released once Wyoming Pollutant Discharge Elimination System (WYPDES) standards are met. Evaporation and seepage may result in additional surface water losses. Subsurface contributions to streamflow may also be temporarily disconnected as a result of disruptions to the local aquifer during overburden and coal excavation. The cumulative effect of these activities may cause a reduction in runoff volumes and peak flows, which may temporarily impact downstream water rights. However, these actions are usually necessary to protect downstream water quality.

4.1.1.2 POST MINING

Increased Runoff: Surface mine reclamation has the potential to change runoff volumes and peak flows. In most instances, topsoil that has been salvaged for site reclamation is often stockpiled for long periods of time. When the topsoil is reapplied over the reclaimed surface, it can lack structure. Soils with diminished structure have lower infiltration rates when compared to native soils, which may result in increased runoff.

Several studies have shown that after reclamation, infiltration rates increase over time as root and soil structure develops. Hutten and Gifford (1984) performed a series of rainfall simulator tests to compare changes in infiltration rates over time on native and reclaimed soils in the PRB of Wyoming. The study found that infiltration rates on reclaimed soils approached those of native soils over time. Infiltration studies conducted at the Rosebud Mine near Hanna, Wyoming produced similar results. During the early stages of reclamation, the infiltration rates of reclaimed soils were less than native soils but approached native rates over time (Rosebud Mine Permit, 2011). Similar results were found during rainfall simulation experiments at the Belle Ayr Mine from 1979-1983. These experiments found that over time, reclaimed areas develop an infiltration-runoff response that closely reflects that of undisturbed areas (Belle Ayr Mine Permit, 2011). Schafer et al., (1979) examined soil genesis on mine spoils that ranged in age from 1 to 50 years at a surface coal mine near Colstrip, Montana. The results showed that between four and six years were required for root systems in mine spoil to become similar to native plant communities. The study found no difference between infiltration rates on mine spoil and undisturbed soils. However, there have been some studies that refute these findings. For example, a coal mine in western North Dakota, Gilley et al., (1977) found spoil infiltration rates to be less than undisturbed soils. Plots on both cultivated and non-cultivated spoil generated several times more runoff than plots in undisturbed rangeland.

Vegetation plays an important role in runoff generation. Changes in plant species could reduce the amount of precipitation captured by interception. Early in the reclamation phase there is the potential for increased runoff due to reduced interception losses and limited root structure. Additionally, the thickness and extent of litter during the early stages of reclamation is less than pre-mine conditions, which may result in increased runoff.

Decreased Runoff: The Belle Ayr Mine has thin overburden conditions (Belle Ayr Mine Permit, 2011), while the other three mines are classified as approximate original contour (AOC). Thin overburden conditions means that there is insufficient material available to restore the landscape to AOC. This often results in a decrease in runoff due to decreases in average slope, increases in surface water travel time, and increases in infiltration. Changes in slope aspect may affect the overall runoff response due to changes in precipitation storage and antecedent moisture conditions.

Mine pits are backfilled with un-compacted material. Coincidentally, there is the potential for some differential settling to occur, resulting in the creation of small depressions. However, because of their small size, any decrease in drainage area is generally considered negligible. This may not be the case if larger features such as sediment ponds are not reclaimed but rather left as permanent post-mine impoundments. Justification to leave these features is associated with maintaining or enhancing the post-mining land use or replacement of a pre-mine feature. If there is an increase in the number of post-mine features compared to what existed pre-mine, there could be a reduction in runoff volume due to a net increase in storage capacity. All features that have the potential to capture and detain runoff generally require WSEO approval of appropriated water rights.

After reclamation, most reconstructed drainage basins have comparable drainage areas to the pre-mining drainage area although individual sub-basins may vary somewhat from the pre-mining configuration. A change in contributing drainage area at the sub-basin scale may result in a change in runoff volumes for individual sub-basins. However, changes in sub-basin contributing areas should be compensated for at a larger watershed scale, resulting in little or no change in total contributing drainage area. This implies that runoff volumes after mining should be similar to pre-mining since the total contributing drainage area has not changed.

Runoff may also decrease in the reclamation period due to increased infiltration and reduced overland flow resulting from an increase in vegetative cover. Anecdotal evidence from coal mines in the PRB suggests that groundcover, particularly litter, tends to be much higher post-mine than pre-mine (L. Barbula, WDEQ/LQD, personal communication, August 2007). This increase is due in part to a reduction in grazing. In addition, exotics and annuals such as cheat grass can rapidly invade a reclamation site and result in an increase in cover. Higher ground cover generally results in increased interception, increased infiltration, and slowed overland flow velocities, which translates to less runoff. The implication is that the resumption of grazing practices to pre-mine levels would help offset any decrease in runoff following reclamation.

Wetlands are replaced on a one-to-one area basis as regulatory statutes require, and in most cases, playas will also be replaced. Isolated wetlands associated with playas are no longer considered jurisdictional wetlands by the Army Corps of Engineers (ACOE) and are excluded from regulatory commitments. While the final placement of wetlands and playas may not always reflect the locations of the original features, they are designed to function as hydrologic features that will preserve the hydrologic balance and support the post-mining land use.

Based on the discussion above, runoff at the end of the bond release period, or shortly thereafter, is expected to be equal to or slightly less than pre-mining runoff. Due to the subdued post-mining topography, post-mining peak flows are expected to be slightly lower than pre-mining peak flows.

4.1.2 WATER QUALITY

4.1.2.1 DURING MINING

Degraded Quality: The removal of vegetation and topsoil exposes overburden and can result in increased erosion potential. Runoff from disturbed areas may contain increased concentrations of sediments or other constituents which may increase turbidity and degrade water quality. Erosion can also increase during mining due to an increase in impervious surfaces that decrease infiltration rates. These include the presence of unpaved access or haul roads and infrastructure associated with mine facilities. All surface water runoff from disturbed areas is required to pass through a sediment pond or alternate sediment control measure (ASCM) and meet specific water quality criteria prior to discharge. The proper design of diversion ditches and culvert crossings help ensure that downstream water quality impacts are minimized.

Water generated from dewatering operations also has the potential to degrade surface water quality in two ways. The first is the potential to accelerate erosion with the change in flow regime. This can result in gullying and downcutting, increasing the transport capacity of channels. Secondly, the water quality of several aquifers may be poorer compared to surface water. If this is the case, if groundwater is discharged into a stream channel rather than being used for industrial purposes, there is potential to degrade surface water quality.

Improved Quality: All surface water leaving areas affected by mining is treated and released after WYPDES regulations are met. Two sets of standards are outlined in WDEQ/WQD Rules and Regulations, Chapter 10, allowing for the mine to permit either under TSS or total settleable solids criteria. Water which has passed through these treatment facilities typically has a much lower TSS concentration than water in native/undisturbed drainages.

4.1.2.2 POST-MINING

Changes in various landscape characteristics, such as vegetation, hillslope profile, channel morphology, and soils, have the potential to affect surface water quality.

Degraded Quality: A decrease in vegetation density and/or infiltration rates can result in increased runoff and ultimately the transport of additional sediment to reclaimed channels. Increased erosion and sedimentation can develop if stream channels are designed improperly. For example, if the reclaimed gradient is too steep, incision or other forms of channel adjustment may occur, resulting in erosion of the channel bed and/or banks. Conversely, if the gradient is not sufficiently steep to transport the sediment load through the system, sediment is deposited, which increases channel gradient and ultimately results in channel incision as the channel attempts to find a slope that balances sediment load and discharge. These adjustments in channel morphology have the potential to result in temporary increases in sediment load.

Improved Quality: Surface water quality has the potential to be improved because of permit commitments by the mining companies to cover all unsuitable material with a minimum of four feet of material. The burial depth is generally increased to eight feet under major drainages. Therefore, the potential to expose any problematic material is reduced.

Reclaimed hillslope profiles are generally concave up, similar to what can be expected of a mature landscape. This profile shape tends to reduce the sediment loading of stream channels because a substantial portion of the sediment is deposited at the toe of the slope.

Prior to the release of bond for any mined area, WDEQ/LQD requires the operator to demonstrate that the reclaimed land exhibits sufficient surficial stability and development of post-mining vegetation to show that runoff does not need to pass through a sediment pond or an ASCM. Final bond release requires that the post-mining vegetation cover meets or exceed pre-mining conditions. If post-mining total vegetation and vegetation cover meet the requirements, it is assumed that interception losses and protection of the soil surface closely resembles pre-mining conditions. An increase in vegetative cover following reclamation will increase infiltration and slow overland flow velocities. This will help trap and filter sediment before entering stream channels, helping to improve water quality.

Toy (1989) preformed a study at the Dave Johnston Mine near Glenrock, Wyoming on the sheetwash erosion of natural and reclaimed slopes. The study concluded that the difference in sheetwash erosion between native and reclaimed slopes was virtually non-detectible. The Big Horn Mine near Sheridan, Wyoming performed a series of plot studies on reclaimed and native lands between 1982 and 1996. The mine concluded that sediment yield from reclaimed lands was less than that from native lands (Big Horn Mine Permit, 2011).

4.2 GROUNDWATER

While there are numerous groundwater impacts from coal mining in the PRB, three concerns are identified as cumulative in nature.

4.2.1 CUMULATIVE POTENTIOMETRIC SURFACE CHANGES

Activities at coal mines will lower groundwater levels in the Wasatch Leaky Aquitard Unit and the Wyodak Anderson coal aquifer in the vicinity of the mine. A small amount of drawdown may also occur in the alluvial aquifer, but the cumulative effect will be minimal if any. Groundwater levels will be lowered by de-watering activities and pit inflow. Pumping of the facility wells will also create a cone of depression in the underlying Tullock aquifer. The amount of decrease in the water level is generally a log-normal function of distance, thus the amount of drawdown of the water levels decreases rapidly with distance from the mine.

However, the water level drawdowns are additive where they intersect, which commonly happens when mines are in close proximity. These same water levels are also being affected by activities of CBM development, municipal and sub-division development, and private wells for households and livestock use. Lowering groundwater elevations could potentially decrease groundwater available to wells.

In some areas of the PRB, groundwater from coal seams and overburden contribute to base flow by discharging to alluvium or directly to streams. Lowering groundwater potentiometric surface will decrease the amount of groundwater available to discharge into those areas. If the quantity is large enough, there is the potential to affect downstream water rights.

4.2.2 BACKFILL AQUIFER PHYSICAL CHARACTERISTICS

Removal of the overburden and coal results in a large open pit. That pit is then backfilled with a mixture of overburden and interburden material resulting in a reconstructed backfill aquifer with different physical properties than the pre-mine aquifers – coal and overburden. Rahn (1976) and Van Voast et al., (1976) performed studies that indicate the horizontal permeability of dragline-replaced backfill is greater than that for pre-mine coal or overburden. Studies by Van Voast et al., (1978) and data from the Big Horn Mine in northern Wyoming (Big Horn Mine Permit, 2011) and the Jacobs Ranch Mine Permit (2011) also indicate that the backfill aquifer may actually consist of a rubble zone at the base of the backfill or at the base of each lift, overlain by finer-grained material that may act as a confining layer. Permeability of the backfill may initially be greater than that for pre-mine strata; however, with time, the backfill may settle and the permeability decrease. These differences between the reclaimed and pre-mine aquifer characteristics may alter the groundwater flow regime and may locally alter the location and amount of groundwater discharging to the surface.

4.2.3 BACKFILL AQUIFER GROUNDWATER QUALITY

Groundwater flowing through the backfill aquifer may have larger concentrations of dissolved constituents because more fresh mineral surfaces are exposed for chemical reaction in the backfill than in the undisturbed sediments. Also, initial conditions in the backfill are a more oxidized environment as compared to the undisturbed conditions. This increase in exposed mineral surfaces and difference in oxidation state may cause an increase in TDS and other constituents in groundwater.

Studies in the PRB indicate that the backfill water quality is similar to pre-mine overburden water quality (Van Voast and Hedges, 1975; Davis, et. al., 1978). Van Voast, et al., (1976) found that the first groundwater to enter a backfill aquifer dissolves a high percentage of the available salts.

However, subsequent groundwater is less mineralized. This subsequent, less mineralized water probably results from the clay content of the backfill causing reduction and cation exchange.

4.3 ALLUVIAL VALLEY FLOORS

WDEQ/LQD Coal Rules and Regulations require that all potential AVFs be identified prior to mining. WDEQ/LQD makes final determinations on the extent of AVFs and farming significance using information submitted by the coal mines. The mines are required to submit information on the essential hydrologic functions of all AVFs and conduct a material damage assessment for AVFs that are deemed significant to farming. Operators are required to submit detailed monitoring plans to ensure that: (1) no material damage occurs to AVFs significant to farming, (2) the essential hydrologic functions of all AVFs are maintained, and (3) the essential hydrologic functions of AVFs approved to be mined are successfully reestablished after mining (Wyoming Department of Environmental Quality, 2009).

Several of the surface water and groundwater hydrologic concerns previously identified in this section also apply to AVFs. These concerns have the potential to affect the essential hydrologic functions of the AVF, which in turn can reduce the capability of the AVF to support subirrigation or flood irrigation activities. With respect to AVFs, these hydrologic concerns are primarily related to changes in surface water quantity, degraded surface water quality, water level changes in the alluvial aquifer, degraded alluvial water quality, and overall water balance.

4.3.1 CHANGES IN SURFACE WATER QUANTITY

With respect to surface water quantity, the primary concern in a semi-arid environment is decreased surface water flow to AVFs, although increased water quantity may also be a concern. Decreased runoff may reduce natural flood irrigation of vegetation in AVFs, as well as the capability for artificial flood irrigation. This may result in a reduction in the amount of flood irrigable land in AVFs. An increase in water quantity may change vegetation composition in AVFs.

4.3.2 DEGRADED SURFACE WATER QUALITY

Degradation of surface water quality may affect soils and vegetation in AVFs. In particular, increases in TDS may increase salinity which can affect soils and growth of certain plant species.

4.3.3 WATER LEVEL CHANGES IN THE ALLUVIAL AQUIFER

Water level changes in the alluvial aquifer may be caused by: (1) disturbance or removal of the alluvium or other aquifers that show hydrologic connection to the alluvial aquifer, (2) mine dewatering, or (3) activities that reduce surface water flow to the alluvium such as stream diversions and impoundments. Decreases in alluvial water levels may potentially reduce the amount of subirrigated land in AVFs. The loss of diurnal fluctuations in alluvial water levels may also affect subirrigated vegetation in AVFs. Mining activities may also increase water levels in some cases, and this may affect vegetation composition in AVFs.

4.3.4 DEGRADED ALLUVIAL WATER QUALITY

The water quality of the alluvial aquifer in the middle PRB is poorer compared to deeper aquifers. The alluvial aquifer has the highest median TDS concentration of the baseline aquifer units evaluated in this CHIA. Despite the poorer water quality in the alluvial aquifer, any increases in TDS concentrations over pre-mine conditions may have the potential to increase salinity and affect soils and vegetation in AVFs.

5. MATERIAL DAMAGE CRITERIA

The objective of this section is to develop appropriate material damage criteria for surface water, groundwater, and alluvial valley floors.

The Wyoming Environmental Quality Act requires that no surface mining be approved unless the operation is designed to prevent material damage to the hydrologic balance outside of the permit area (Article 4, §35-11-406(n)(iii)). To determine whether a proposed operation has been designed to prevent material damage, the WDEQ/LQD defines material damage to the hydrologic balance as a significant long-term or permanent adverse change to the hydrologic regime (WDEQ/LQD, 2009, Coal Rules and Regulations, Chapter 1, Section 2(cd)). A significant long-term or permanent adverse change is defined as changes to the surface or groundwater hydrology that are inalterable conditions contrary to the Wyoming State Constitution, or of statutes administered by the WSEO, or water quality standards administered by the WDEQ/WQD (Director of the Wyoming WDEQ, Dennis Hemmer, and the Wyoming State Engineer, Gordon Fassett, February 7, 1997 Memorandum). A detailed evaluation of the available monitoring data and information in the mining permits is used to indicate when material damage to the hydrologic balance may have occurred as a result of coal mining impacts. The criteria for surface and groundwater are described in more detail below.

Except where authorized by permit, it is prohibited to cause, threaten, or allow discharge of any pollution into waters of the state (W.S. §35-11-301). Pollution is defined as contamination or other alteration of the physical, chemical, or biological properties of any waters of the State which creates a nuisance or renders any waters harmful, detrimental or injurious to public health, safety or welfare, to domestic commercial, industrial agricultural, recreational, or other legitimate beneficial uses, or to livestock, wildlife or aquatic life, or degrades the water for its intended use, or adversely affects the environment (W.S. §35-11-103(b)(i)).

A groundwater appropriation permit does not include the right of the appropriators to have the water level or artesian pressure maintained at any level or pressure higher than that required for maximum beneficial use of the water in the source of the supply (W.S. §41-3-933). Additionally, the State of Wyoming has agreed to several river compacts that address the allocation of surface water flows out of Wyoming (W.S. §41-12-101, -201, -301, -401, -501, -601, and -701).

5.1 SURFACE WATER

The material damage criteria for surface water are examined for water quantity and water quality.

5.1.1 WATER QUANTITY

Surface water quantity is evaluated to determine if coal mining will cause cumulative impacts to downstream surface water rights. The available surface water quantity data are evaluated for the baseline and during-mining periods in each of the major drainages within the CIA. Specific data elements evaluated include mean daily flows, peak flows, flow duration, and seasonal and annual runoff volumes. In addition to this analysis, the assessment considers factors such as the proximity of downstream water rights, extent of dewatering, extent of surface disturbance, extent and capacity of water retention features, and changes to post-mine drainage basins. Material damage to surface water quantity occurs if the analysis demonstrates that coal mining has caused or will cause a decrease in surface water quantity such that downstream surface water rights will be materially affected.

5.1.2 WATER QUALITY

Cumulative effects on surface water quality are evaluated using available sample data and applicable WDEQ/WQD Rules and Regulations. WDEQ/WQD has classified surface waters according to their use or potential use. Each surface water classification has a set of numeric criteria established to meet the defined use. The available surface water quality data are analyzed for the baseline and during-mining periods in each of the major drainages within the CIA. Summary statistics, including the minimum, maximum, mean, and median concentrations are compiled. Discussion of changes between baseline and during-mining periods, as well as upstream and downstream of mining activity are included. The frequency of water quality standard exceedences is also examined. Material damage is presumed to occur when the median concentrations of a given constituent exceed WDEQ/WQD surface water standards, and the available evidence suggests the cause of exceedence is due to coal mining activity and will contribute to permanent or long-term change of use suitability. The median concentration of a given constituent is assumed to be most indicative of the long-term condition of surface water quality.

5.2 GROUNDWATER

The material damage criteria for groundwater are examined for water quantity and water quality. Within those two categories, specific areas of concern are changes to the potentiometric surface and the physical and chemical characteristics of the backfill aquifer.

5.2.1 GROUNDWATER POTENTIOMETRIC SURFACE CHANGES

Coal mine operations will lower groundwater elevations. Groundwater elevations in private wells located within and adjacent to a permit boundary may be lowered by de-watering, pit inflow, and mine facility wells completed into the deeper aquifers. Lowering groundwater elevations may decrease groundwater availability to some existing private wells.

In some areas of the PRB, groundwater from coal seams and overburden may contribute to baseflow by discharging to alluvium or to streams. Lowering groundwater elevations may decrease the amount of groundwater available to discharge to streams in some areas. This potentially could affect downstream water rights.

5.2.2 BACKFILL AQUIFER PHYSICAL CHARACTERISTICS

To assess how physical characteristics of the backfill aquifer will affect groundwater availability within the permit area and flow through the backfill aquifer to natural aquifers, it is necessary to review local and regional conditions. The ability of the backfill aquifer to store and transmit water will determine how productive the backfill aquifer will be to support the post-mining land use. The physical characteristics of the backfill aquifer are compared to the pre-mining baseline conditions of the aquifers to determine what alteration to flow regimes might occur. Hydrologic conductivities in backfill aquifers are examined to determine if changes in flow in the reclaimed aquifers will affect the availability of water in the aquifers. Material damage is assessed by comparing the physical characteristics of the backfill aquifer to the pre-mining baseline conditions.

5.2.3 BACKFILL AQUIFER WATER QUALITY

Groundwater which initially saturates backfill aquifer may have a higher concentration of dissolved constituents than groundwater in the undisturbed systems. Potentially the groundwater in the backfill aquifer could impact groundwater quality in adjacent aquifers or affect the quality of baseflow in streams if its chemical quality differs significantly from those water resources. Changes in water quality may be affected and if severe, prohibit the use of the water. Cumulative effects of backfill aquifer quality in the CIA will be assessed and the identification of material damage will be based on comparison to baseline data, pre-mining class of use and post-mining land use.

5.3 ALLUVIAL VALLEY FLOORS

The Wyoming Environmental Quality Act requires that no surface mining be approved unless the operation will not materially damage the quantity and quality of water in surface or groundwater systems that supply alluvial valley floors deemed significant to farming (§35-11-406(n)(v)(B)). Material damage with respect to AVFs is defined by WDEQ/LQD Coal Rules and Regulations as "changes in the quality or quantity of the water supply to any portion of an alluvial valley floor where such changes are caused by coal mining and reclamation operations and result in changes that significantly decrease the capability of the alluvial valley floor to support subirrigation or flood irrigation activities" (Wyoming Department of Environmental Quality, 2009, Ch. 1, Sec. 2(ce)). Only AVFs on developed lands that have been determined to be significant to farming necessitate material damage findings by the regulatory authority (W.S. § 35-11-406(n)(v)).

The only AVF determined to be significant to farming in the middle PRB is on Gold Mine Draw at the Caballo Mine. A material damage assessment is conducted for this AVF. The remaining AVFs in the CIAs are either not significant to farming or occur in areas at mines that produced coal in commercial quantities prior to the effective date of SMCRA (August 3, 1977). For these AVFs, the essential hydrologic functions must be maintained and/or restored if the AVF is approved to be mined. The maintenance of essential hydrologic functions will be evaluated on these AVFs. These assessments will be conducted using data on surface water quantity, surface water quality, alluvial water levels, and alluvial water quality.

5.3.1 SURFACE WATER QUANTITY

Surface water quantity on drainages with AVFs will be evaluated. Decreases in surface water flows may reduce natural flood irrigation of vegetation in AVFs, as well as the capability for artificial flood irrigation. This may result in a reduction in the amount of flood irrigable land in AVFs. Increased flows may affect vegetation composition in AVFs.

5.3.2 SURFACE WATER QUALITY

Surface water quality on drainages with AVFs will be evaluated. Degradation of surface water quality may affect soils and vegetation in AVFs. Water quality will be evaluated to determine trends over time in relation to pre-mining conditions.

5.3.3 ALLUVIAL WATER LEVELS

Alluvial water levels on drainages with AVFs will be evaluated. Decreases in water levels may potentially reduce the amount of subirrigated land in AVFs. The loss of diurnal fluctuations in water levels may also affect subirrigated vegetation in AVFs. Increased water levels may affect vegetation in AVFs.

5.3.4 ALLUVIAL WATER QUALITY

Alluvial water quality on drainages with AVFs will be evaluated. Increases in TDS concentrations may increase salinity and affect soils and vegetation in AVFs. TDS concentrations will be evaluated to determine trends over time in relation to pre-mining conditions. TDS concentration will also be evaluated in reclaimed AVFs to assess water quality in relation to pre-mining conditions.

6. ANALYSIS OF CUMULATIVE HYDROLOGIC IMPACTS

6.1 SURFACE WATER

The following section discusses during-mining impacts to surface water quantity and quality in the Caballo Creek and Belle Fourche River CIAs. Predicted cumulative hydrologic impacts are also discussed. Post-mining impacts are qualitatively discussed since none of the larger watersheds at the three mines have been fully reclaimed.

6.1.1 DURING-MINING WATER QUANTITY AND WATER QUALITY OF INDIVIDUAL DRAINAGES IN THE CABALLO CREEK CIA

6.1.1.1 GOLD MINE DRAW

As discussed in Section 3.1.1.1, very little mining disturbance has occurred in the Gold Mine Draw drainage at the Caballo Mine due to the presence of an AVF determined to be significant to farming. Some limited disturbance has occurred in the lower drainage due to the facilities area and rail loop (Caballo Mine Permit, 2011). During-mining hydrologic conditions on Gold Mine Draw were assessed using data from the stations on upper Gold Mine Draw (UGM) and lower Gold Mine Draw (LGM). Mean daily flow data from 1987 to 2009 and water quality data from 1999 to 2010 were analyzed for the during-mining period. The distinction between baseline and during-mining periods in Gold Mine Draw is somewhat arbitrary since little mining has occurred in the drainage. The during-mining analysis will be used to evaluate material damage and the maintenance of essential hydrologic functions on the AVF in Section 6.3.

A comparison of seasonal (April through September) runoff volumes between UGM and LGM over the 1979 to 2009 period is shown in **Figure 28**. Annual precipitation at the nearby Dillinger station is also plotted. The plot in **Figure 28** does not include years when one or both of the surface water stations had missing or invalidated data (1990, 1993 to 1996, and 2007). With the exception of 2006, more runoff was recorded in each year at LGM compared to UGM. The annual differences ranged from 0.8 ac-ft in 1989 to 206.5 ac-ft in 2009. Similar to the baseline period, UGM was more characteristic of an ephemeral stream while flows at LGM were more intermittent. There is no clear trend in changes in runoff at either station over time, and annual precipitation appears to have a mixed effect on seasonal runoff. Flows at LGM may also be influenced by the release of water from upstream impoundments. The Caballo Mine also reports that CBM producers north and west of the mine agreed to pump discharge water around the mine and into Gold Mine Draw from 1999 to 2001 (Caballo Mine Permit, 2011). Most of the water was used by a local landowner for irrigation. CBM produced flows at and near the mine have been substantially reduced since 2003 (Caballo Mine Permit, 2011).

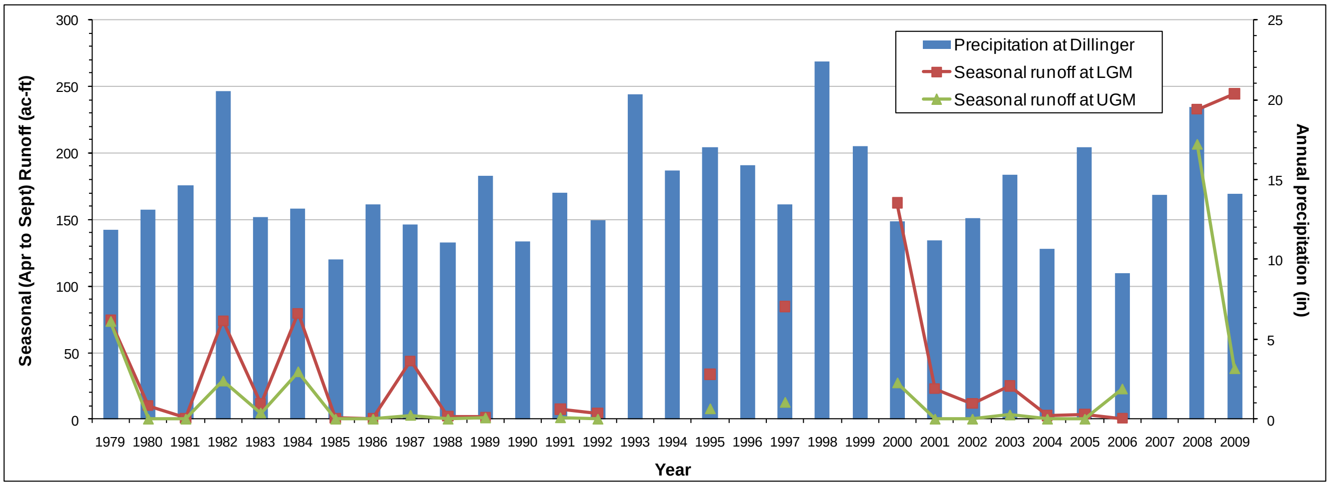


FIGURE 28. COMPARISON OF ANNUAL PRECIPITATION AT DILLINGER AND SEASONAL (APRIL TO SEPTEMBER) RUNOFF AT UPPER GOLD MINE DRAW (UGM) AND LOWER GOLD MINE DRAW (UGM), 1979 TO 2009, MIDDLE POWDER RIVER BASIN, WYOMING, 2011. [MISSING DATA POINTS INDICATE THE STATION WAS NOT ACTIVE OR DATA ARE INVALIDATED].

The WDEQ/LQD Hydrology Database contains water quality collected data on Gold Mine Draw from 1999 to 2010. Over this period, 16 samples were collected at UGM and 39 samples were collected at LGM. A statistical summary of the data collected at both stations is provided in **Table 24**. Similar to the 1978 to 1986 data discussed in Section 3.1.1.1, the water type at UGM was a mixed cation-sulfate type. At LGM, $Ca-SO_4$ was the water type noted in 97 percent of the samples (RockWare, Inc., 2006). It is also noted that the 2007-2009 sample data from the Gold Mine Draw stations do not explicitly state whether TDS was measured at 180 degrees C.

TDS at UGM ranged from 152 to 2,680 mg/l, with a median of 610 mg/l (**Table 24**). At LGM, TDS was higher, ranging from 370 to 3,654 mg/l, with a median of 2,560 mg/l. The median TSS concentrations were low (≤ 9 mg/l) at each station. Dissolved metal concentrations were very low at both stations, with numerous values below detection limits. At UGM, WDEQ/WQD Class 3B standards were satisfied with the exception of exceedences of copper (one sample), iron (two samples), aluminum (two samples), and selenium (one sample). At LGM, Class 3B standards were exceeded for the minimum and maximum pH, and the maximum concentrations of lead, aluminum, and selenium. Selenium was the only constituent to show multiple exceedences, as three out of the 39 samples exceeded the standard of 0.0046 mg/l. At both stations, the mean and median concentrations of each constituent evaluated showed no exceedences over the 1999 to 2010 period (**Table 24**). These findings indicate that water quality on Gold Mine Draw has remained quite high, and that there have been no obvious changes in water quality conditions over the period of record. The occasional exceedences of Class 3B standards appear related to natural factors and are not attributable to mining. Section 6.3 will further discuss hydrologic conditions on Gold Mine Draw with respect to material damage and essential hydrologic functions on the declared AVF.

TABLE 24. DURING-MINING WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON UPPER GOLD MINE DRAW AND LOWER GOLD MINE DRAW AT THE CABALLO MINE, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	USGS Parameter Code	Units	Upper Gold Mine Draw (UGM) (1999-2010)					Lower Gold Mine Draw (LGM) (1999-2010)				
			Count	Min	Max	Mean	Median	Count	Min	Max	Mean	Median
Temperature (field)	00010	°C	14	9	64	43	42	32	1	67	30	30
Turbidity	00076	NTU	16	3	927	80	11	37	1	68	7	3
Dissolved oxygen (field)	00300	mg/l	0	na	na	na	na	0	na	na	na	na
pH (field)	00400	S.U.	14	6.63	8.58	7.49	7.35	33	6.30	9.50	7.92	7.81
Ammonia as N (dissolved)	00608	mg/l	16	<0.05	0.78	0.16	0.11	39	<0.05	1.23	0.20	0.08
Sodium (dissolved)	00930	mg/l	16	4	254	84	52	39	9	270	164	174
Chloride (dissolved)	00940	mg/l	16	1.8	56.0	18.9	15.0	39	3	188	99	105
Sulfate (dissolved)	00945	mg/l	16	31	1,510	501	255	39	79	2,188	1,303	1,340
Fluoride (dissolved)	00950	mg/l	15	<0.1	1.7	0.4	0.2	37	<0.1	4.1	0.9	0.8
Arsenic (dissolved)	01000	mg/l	16	<0.005	<0.005	100% <0.005		38	<0.005	<0.005	100% <0.005	
Barium (dissolved)	01005	mg/l	16	<0.5	<0.5	100% <0.5		38	<0.5	0.56	97% <0.5	
Boron (dissolved)	01020	mg/l	16	<0.01	0.21	0.06	0.04	38	<0.01	1.03	0.45	0.49
Cadmium (dissolved)	01025	mg/l	16	<0.002	<0.002	100% <0.002		39	<0.002	<0.002	100% <0.002	
Chromium (dissolved)	01030	mg/l	16	<0.01	<0.02	100% <0.02		39	<0.01	<0.02	100% <0.02	
Copper (dissolved)	01040	mg/l	16	<0.01	0.11	88% <0.01		39	<0.01	0.02	95% <0.01	
Iron (dissolved)	01046	mg/l	16	<0.05	1.50	0.33	0.10	39	<0.05	0.44	0.08	0.05
Lead (dissolved)	01049	mg/l	16	<0.02	<0.02	100% <0.02		39	<0.02	0.02	97% <0.02	
Manganese (dissolved)	01056	mg/l	16	0.03	0.71	0.22	0.13	39	<0.02	2.94	0.49	0.36
Nickel (dissolved)	01065	mg/l	16	<0.01	0.02	81% <0.01		39	<0.01	0.01	92% <0.01	
Zinc (dissolved)	01090	mg/l	16	<0.01	0.09	0.01	0.001	39	<0.01	0.02	92% <0.01	
Aluminum (dissolved)	01106	mg/l	16	<0.1	3.60	81% <0.1		38	<0.1	0.90	89% <0.1	
Selenium (dissolved)	01145	mg/l	16	<0.005	0.007	94% <0.005		38	<0.005	0.009	89% <0.005	
TDS dried at 180 °C[1]	70300	mg/l	16	152	2,680	959	610	39	370	3,654	2,454	2,560
Mercury (dissolved)	71890	µg/l	16	<1	<1	100% <1		38	<1	<1	100% <1	
Total suspended solids	80154	mg/l	16	<1	488	48	9	37	<5	41	8	3

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Means and medians were not calculated for constituents having ≥ 80% below-detect values. Concentrations shown in red exceed WDEQ/WQD Class 3B surface water quality standards. [1]The 2007-2009 sample data did not explicitly state whether TDS was measured at 180 degrees C.

6.1.1.2 NORTH TISDALE CREEK

As discussed in Section 3.1.1.2, the Upper North Tisdale Creek station was discontinued in 1986 due the advancement of the pit at the Caballo Mine. Because of this, during-mining water quantity and water quality in the North Tisdale Creek drainage cannot be evaluated. The cumulative effects of mining in the North Tisdale Creek drainage are considered in Section 6.1.1.6 for Caballo Creek.

6.1.1.3 TISDALE CREEK

As discussed in Section 3.1.1.3, the Lower Tisdale Creek station was discontinued in 1989 due the advancement of the pit at the Caballo Mine. The Upper Tisdale Creek station operated until 1995, but no mining occurred upstream of the station prior to it being deactivated. Because of this, during-mining water quantity and water quality in the Tisdale Creek drainage cannot be evaluated. The cumulative effects of mining in the Tisdale Creek drainage are considered in Section 6.1.1.6 for Caballo Creek.

6.1.1.4 DUCK NEST CREEK

As discussed in Section 3.1.1.4, the Belle Ayr Mine is currently mining in the Duck Nest Creek drainage. The mine has not established a monitoring station downstream of mining activity. Because of this, during-mining water quantity and water quality in the Duck Nest Creek drainage cannot be evaluated. The cumulative effects of mining in the Duck Nest Creek drainage are considered in Section 6.1.1.6 for Caballo Creek. Section 6.3 also provides as assessment of conditions on Duck Nest Creek with respect to the declared AVF and essential hydrologic functions.

6.1.1.5 BONE PILE CREEK

As discussed in Section 3.1.1.5, the Belle Ayr Mine has no plans to mine within the Bone Pile Creek drainage. The lower portion of the drainage near the confluence with Caballo Creek has been affected by a diversion for Caballo Creek, but the mine's monitoring station is upstream of this activity. Because of these factors, an evaluation of during-mining water quantity and water quality in the Bone Pile Creek drainage is not applicable. Section 6.3 provides as assessment of conditions on Bone Pile Creek with respect to the declared AVF and essential hydrologic functions.

6.1.1.6 CABALLO CREEK

During-mining hydrologic conditions on Caballo Creek were assessed using data from the two gaging stations upstream (BA-6) and downstream (BA-4) of the Belle Ayr Mine. Daily flow data from 1984 to 2009 were analyzed. A review of the mean daily flow data available in the WDEQ/LQD Hydrology Database shows numerous days with no data available at both the BA-6 and BA-4 stations over the 1984 to 2009 period. The stations were also not typically operated during the winter months. Therefore, only the days with data available from both stations were used in this analysis.

The average daily flow at BA-6 over the 1984 to 2009 period was 0.08 cfs, resulting in an average annual runoff of 58 ac-ft, and a unit-area annual runoff of 0.5 ac-ft/mi^2/yr. At BA-4 downstream of the mine, the average daily flow was nearly 13 times higher at 1.03 cfs, resulting in an average annual runoff of 744 ac-ft, and a unit-area annual runoff of 3.5 ac-ft/mi^2/yr. For comparison, the mean daily flow over the 1977 to 1983 period on the USGS station on Caballo Creek was 2.6 cfs. The maximum mean daily flow at BA-6 was 24.11 cfs on February 19, 1997, and the maximum peak daily discharge of 38.32 cfs occurred on February 18, 1997. At BA-4, the maximum mean daily discharge was 26.14 cfs on April 6, 1997, and the maximum peak daily discharge was 49.83 cfs on March 4, 1987.

The mean daily discharge by year over the 1984 to 2009 period at both stations is plotted in **Figure 29**. Annual precipitation at the Dillinger station is also plotted. With the exception of 1992, mean daily flows were higher at the downstream station in each year. The increase in runoff at the downstream station is to be expected given the larger drainage area and increased baseflow due to groundwater contributions. The Belle Ayr Mine predicts that the scoria aquifer, which is a groundwater discharge source for lower Caballo Creek, will not be disturbed throughout the mining operation (Belle Ayr Mine Permit, 2011). Permitted discharges at the Belle Ayr Mine may also result in increased flows at the downstream station, although this source would be variable and inconsistent over time. The higher mean at BA-4 for year 2007 (**Figure 29**) was computed from very few days, so the value may not be representative of actual flows during that year.

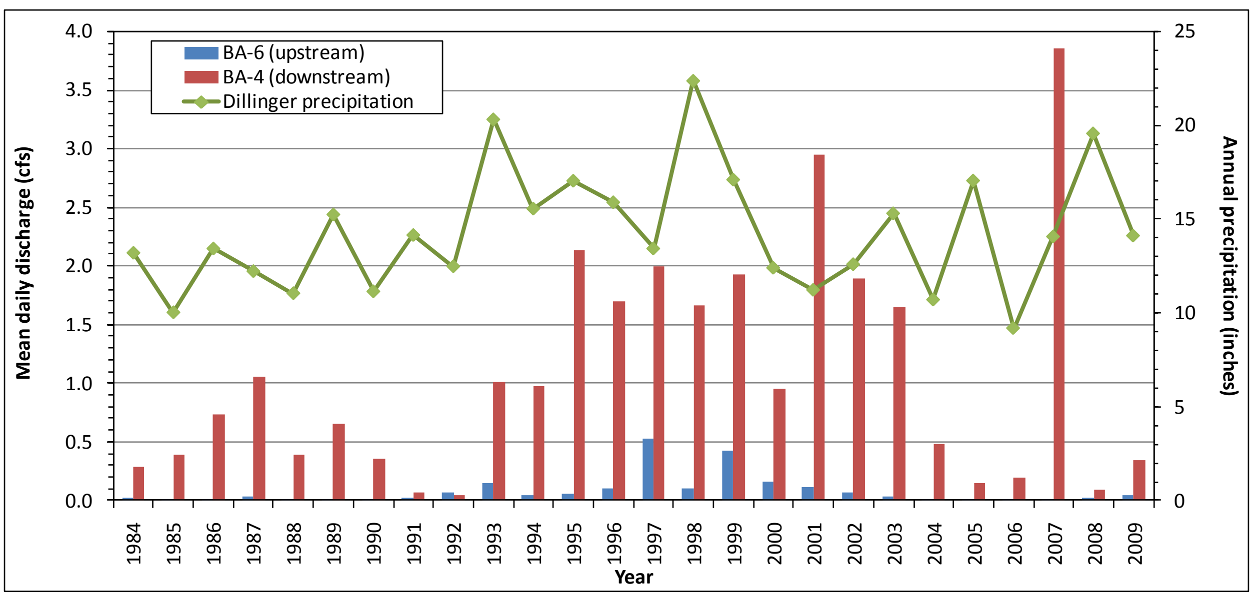


FIGURE 29. COMPARISON OF ANNUAL PRECIPITATION AT DILLINGER AND MEAN ANNUAL DAILY DISCHARGE ON CABALLO CREEK AT BELLE AYR MINE STATIONS BA-6 AND BA-4, 1984 TO 2009, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

The 25-year flow record shows an increase in flows at both stations beginning in the early to mid 1990s until the early 2000s (**Figure 29**). There are two possible reasons for this increase.

First, precipitation was above normal from 1993 to 1999. Anderson Consulting Engineers, Inc., (2009) performed an analysis of the Palmer Drought Index in the Gillette area and found that drought conditions were present from 1984 to 1992. Starting in 1993, the Palmer Drought Index suggested that moisture conditions improved, which also corresponded to an increase in streamflow in the Belle Fourche River drainage basin (Anderson Consulting Engineers, Inc., 2009).

The second reason for the streamflow increase at the stations is due to CBM discharge in the upper Caballo Creek watershed (Anderson Consulting Engineers, Inc., 2009). The increase is most apparent at the downstream station (BA-4) due to inputs from Bone Pile Creek and Duck Nest Creek. CBM in the Caballo Creek drainage has been continuously active since 1993 (Wyoming Oil and Gas Conservation Commission, 2010). The watershed has 2,925 CBM wells, although only about 68 percent of the wells currently have some level of activity. There are currently 411 CBM discharge outfalls with active WDEQ/WQD WYPDES permits in the drainage (Wyoming Department of Environmental Quality, 2010b). Water production in the drainage peaked in 2000 at nearly 96 million barrels, and gas production peaked in 2001 at nearly 71 million MCF (**Figure 30**). Water and gas production has been declining ever since, and the 2009 levels were the lowest recorded since 1994 (Wyoming Oil and Gas Conservation Commission, 2010). Pumping rates in the drainage are expected to continue to decline over the next ten years (AECOM, Inc., 2009a). This trend indicates that CBM should continue to have a diminishing effect on surface water quantity in the drainage.

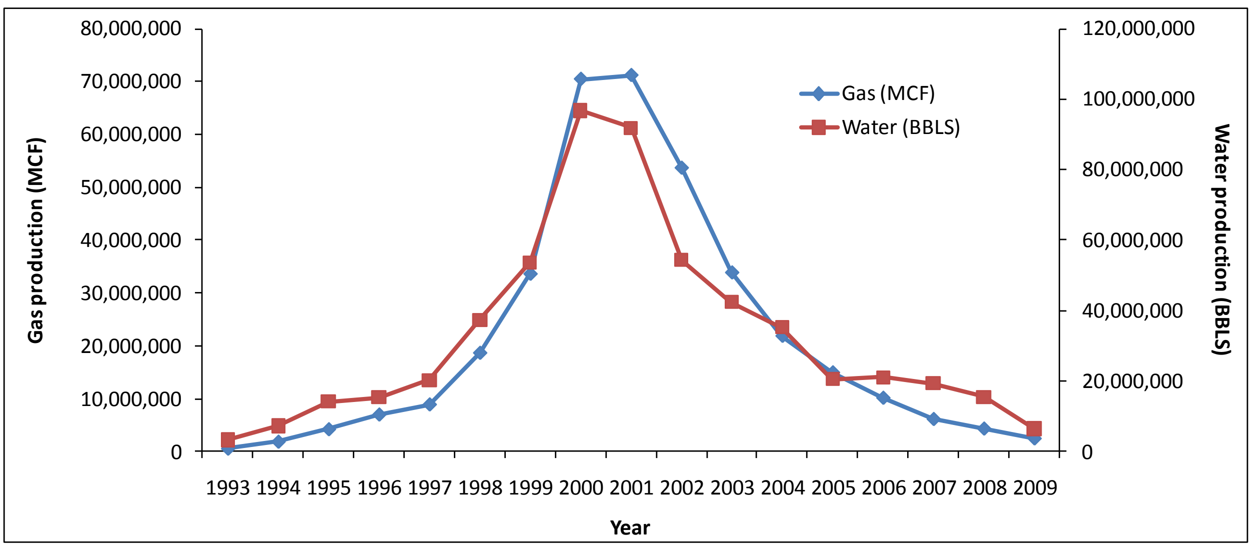


FIGURE 30. COAL BED METHANE GAS AND WATER PRODUCTION IN THE CABALLO CREEK WATERSHED, 1993 TO 2009, MIDDLE POWDER RIVER BASIN, WYOMING, 2011. [DATA FROM WYOMING OIL AND GAS CONSERVATION COMMISSION, 2010].

Overall, the 25-year discharge record at the stations on Caballo Creek indicates flows continue to be higher at the downstream station, suggesting that the Belle Ayr Mine has not materially affected water quantity. Several diversions have been used over the course of the mining operation to route flows around the mine. Caballo Creek Diversion No. 10 is the current diversion used to route flows from the native channel north onto backfill and into the reconstructed Caballo Creek channel (Belle Ayr Mine Permit, 2011). Phase II of the diversion will route flows parallel to Highway 59 and then intersect Bone Pile Creek. The diversion will have a maximum design life of seven years and will require the relocation of the BA-4 gaging station into the diversion, slightly downstream from its current location (Belle Ayr Mine Permit, 2011).

Two non-AVF reaches of Caballo Creek have been reconstructed at the Belle Ayr Mine and are receiving upstream streamflow inputs. The first reach was completed in the early 1980s near the facilities area. A second reach of nearly 7,500 ft was completed in the late 1990s. This reach was constructed with a total of seven pool-run series (Belle Ayr Mine Permit, 2011). Further information on the reconstruction plans for the AVF-declared reaches of Caballo Creek are provided in Section 6.3.1.

A comparison of water quality summary statistics between the upper and lower stations on Caballo Creek over the 1984 to 2009 period is shown in **Table 25**. The dominant water type at BA-6 was Mg-SO_4 (RockWare, Inc., 2006). The water type at BA-4 on lower Caballo Creek was slightly more variable; Na-SO_4 was noted in 75 percent of the samples. In the early 2000s, the water type at BA-4 showed a stronger Na-HCO_3 signature, indicating the influence of CBM discharge.

TDS @ 180 degrees C at the upstream station ranged from 508 to 18,520 mg/l, with a median of 6,256 mg/l (**Table 25**). TDS @ 180 degrees C was much lower at the downstream gage, ranging from 332 to 9,360 mg/l, with a median of 2,040 mg/l. The high TDS at BA-6 relative to BA-4 is suspected to be related to the differences in flow between sites; TDS typically increases with decreasing flow. The TSS at the upstream station was very low, ranging from <5 to 108 mg/l, with a median of 10 mg/l. TSS at the downstream site was also low, ranging from <1 to 360 mg/l, with a median of 6 mg/l (**Table 25**).

Dissolved metal concentrations at both stations were mostly very low, with numerous values below detection limits (**Table 25**). At the upstream station, exceedences of Class 2ABww standards were noted for dissolved oxygen (eight samples), pH (one sample), ammonia as nitrogen (three samples), chloride (three samples), arsenic (one sample), cadmium (two samples), copper (four samples), iron (two samples), lead (one sample), manganese (four samples), nickel (one sample), zinc (one sample), aluminum (two samples), selenium (14 samples), and mercury (one sample). The mean and median of each constituent sampled at the upstream station showed no exceedences of standards. At the downstream station, Class 2ABww standards were exceeded for temperature (three samples), dissolved oxygen (11 samples), ammonia as nitrogen (one sample), cadmium (two samples), copper (three samples), iron (one sample), lead (one sample), manganese (two samples), zinc (one sample), selenium (four samples), and mercury (one sample). The mean and median of each constituent sampled at the downstream station showed no exceedences of standards (**Table 25**). The overall comparison indicates that the downstream station on Caballo Creek has slightly better water quality over the during-mining period evaluated. This is likely due to the diluting effect of increased flow. Although class of use standards are occasionally exceeded at the downstream station, the exceedences are not persistent and do not appear related to mining.

TABLE 25. DURING-MINING WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON CABALLO CREEK AT BELLE AYR MINE STATIONS BA-6 AND BA-4, 1984 TO 2009, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	USGS Parameter Code	Units	Caballo Creek at west Belle Ayr Mine permit boundary (upstream) (BA-6) (1984-2009)					Caballo Creek at east Belle Ayr Mine permit boundary (downstream) (BA-4) (1984-2009)				
			Count	Min	Max	Mean	Median	Count	Min	Max	Mean	Median
Temperature (field)	00010	°C	109	0	28.0	9.4	8.2	124	0	36.0	11.5	10.5
Turbidity	00076	NTU	91	1	50	12	8	100	<1	1,406	25	3
Dissolved oxygen (field)	00300	mg/l	40	1.5	12.2	5.7	4.8	43	0.2	12.3	5.6	5.2
pH (field)	00400	S.U.	104	6.50	9.10	7.89	7.90	124	6.30	9.00	7.80	7.80
Ammonia as N (dissolved)*	00608	mg/l	106	<0.1	151.68	2.25	0.16	122	<0.01	21.88	0.35	0.08
Nitrite plus nitrate as N (dissolved)*	00631	mg/l	99	<0.05	4.43	0.35	0.01	115	<0.01	3.21	0.19	0.01
Sodium (dissolved)	00930	mg/l	110	51	2,550	667	570	128	28	1,160	328	294
Chloride (dissolved)*	00940	mg/l	110	4	2,072	78	38	127	5	94	23	18
Sulfate (dissolved)	00945	mg/l	110	224	11,200	4,027	3,870	128	156	5,380	1,351	1,176
Fluoride (dissolved)	00950	mg/l	110	<0.05	5.73	0.73	0.42	128	<0.05	4.11	0.79	0.66
Arsenic (dissolved)*	01000	mg/l	69	<0.005	0.011	88% <0.005		82	<0.005	0.006	99% <0.005	
Barium (dissolved)*	01005	mg/l	70	<0.5	<0.5	100% <0.5		81	<0.5	<0.5	100% <0.5	
Boron (dissolved)	01020	mg/l	110	<0.01	1.48	0.25	0.19	128	<0.01	1.97	0.46	0.41
Cadmium (dissolved)	01025	mg/l	70	<0.002	0.004	97% <0.002		80	<0.002	0.07	98% <0.002	
Chromium (dissolved)*	01030	mg/l	72	<0.01	<0.02	100% <0.02		81	<0.01	0.03	99% <0.02	
Copper (dissolved)	01040	mg/l	70	<0.01	0.03	81% <0.01		81	<0.01	0.04	88% <0.01	
Iron (dissolved)	01046	mg/l	110	<0.05	12.62	0.25	0.06	127	<0.05	1.05	0.07	0.04
Lead (dissolved)	01049	mg/l	70	<0.02	0.04	97% <0.02		81	<0.02	0.03	99% <0.02	
Manganese (dissolved)	01056	mg/l	65	<0.02	12.00	1.18	0.60	75	<0.02	7.08	0.43	0.12
Nickel (dissolved)*	01065	mg/l	70	<0.01	0.11	0.01	0.005	81	<0.01	0.07	0.01	0.004
Zinc (dissolved)	01090	mg/l	70	<0.01	3.53	0.06	0.001	81	<0.01	3.14	0.05	0.003
Aluminum (dissolved)	01106	mg/l	70	<0.1	1.1	90% <0.1		81	<0.1	0.5	90% <0.1	
Selenium (dissolved)	01145	mg/l	82	<0.005	0.03	83% <0.005		96	<0.005	0.007	96% <0.005	
TDS dried at 180 °C	70300	mg/l	109	508	18,520	6,497	6,256	128	332	9,360	2,428	2,040
Mercury (dissolved)*	71890	µg/l	109	<1	1	99% <1		127	<1	1	99% <1	
Total suspended solids	80154	mg/l	108	<5	108	16	10	126	<1	360	14	6

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Means and medians were not calculated for constituents having ≥ 80% below-detect values. Concentrations shown in red exceed WDEQ/WQD Class 2ABww surface water quality standards. *The WDEQ/WQD standard is expressed as a total concentration, but only dissolved data were available.

Selenium has been identified as a potential issue on Caballo Creek at the Belle Ayr Mine due to elevated levels of selenium in areas of backfill (Belle Ayr Mine Permit, 2011). Because of this, the mine samples selenium in six pools along the reconstructed Caballo Creek channel. A review of the 2007-2009 data from these pools indicates no problems with selenium, as all samples except for one have had concentrations been below detection. The selenium data from BA-4 and BA-6 indicate selenium is slightly higher and shows higher frequency of Class 2ABww exceedences at the upstream station. The results to date indicate the reclaimed channel has not been a significant source of selenium to downstream areas on Caballo Creek.

A mentioned in Section 3.1.1.6, USGS Station No. 06425900 at the mouth of Caballo Creek was reactivated in December 2000 to collect monthly water quality samples. Continuous flow has not been monitored at the station since 1983, so an assessment of flow statistics in the during-mining period is not possible. The number of constituents sampled at the station since 2000 is reduced compared to what was sampled in the 1977-1983 period. The only metals that were consistently sampled were barium, beryllium, aluminum, selenium, iron, manganese, and arsenic (U.S. Geological Survey, 2010a).

The water quality summary statistics over the 2000 to 2010 period at the USGS station on Caballo Creek is shown in **Table 26**. TDS @ 180 degrees C ranged from 511 to 5,380 mg/l, with a median of 1,395 mg/l. The maximum TDS @ 180 degrees C concentration is higher than any value measured during the baseline period, but during-mining median concentration is slightly lower than the baseline concentration. The total aluminum concentration exceeded 0.75 mg/l in five samples (nine percent of total). However, the values greater than 0.75 mg/l cannot easily be interpreted as exceedences since the WDEQ/WQD aquatic life standard is expressed as dissolved aluminum. The only other constituent to exceed WDEQ/WQD Class 2ABww standards was selenium (**Table 26**). However, this occurred in only one sample and the median selenium concentration of 0.001 mg/l is well below standards.

TABLE 26. DURING-MINING WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON CABALLO CREEK AT USGS STATION NO. 06425900, 2000 TO 2010, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	USGS Parameter Code	Units	Caballo Creek at mouth near Piney, WY (USGS 06425900) (2000-2010)				
			Count	Min	Max	Mean	Median
Temperature (field)	00010	°C	76	0	24.0	8.2	8.0
Dissolved oxygen (field)	00300	mg/l	70	3.2	13.8	9.2	9.7
pH (field)	00400	S.U.	76	7.4	8.8	8.2	8.2
Ammonia as N (dissolved)[1]	00608	mg/l	25	<0.02	0.11	0.03	0.02
Nitrite plus nitrate as N (dissolved)[1]	00631	mg/l	25	<0.04	0.37	0.06	0.03
Sodium (dissolved)	00930	mg/l	72	79	640	271	248
Chloride (dissolved)[1]	00940	mg/l	72	10.9	121.0	33.5	23.6
Sulfate (dissolved)	00945	mg/l	72	234	3,210	886	667
Fluoride (dissolved)	00950	mg/l	72	0.21	1.84	0.90	0.88
Arsenic (total)	01002	mg/l	23	0.0006	0.0027	0.0013	0.0012
Barium (total)	01007	mg/l	74	0.02	0.26	0.07	0.06
Iron (dissolved)	01046	mg/l	72	<0.01	0.13	0.02	0.01
Manganese (dissolved)	01056	mg/l	72	0.06	0.68	0.12	0.08
Aluminum (total)[2]	01105	mg/l	53	0.03	7.69[3]	0.50	0.22
Selenium (total)	01147	mg/l	53	0.0004	0.0116	0.0015	0.0010
TDS dried at 180 °C	70300	mg/l	72	511	5,380	1,743	1,395

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Concentrations shown in red exceed WDEQ/WQD Class 2ABww surface water quality standards. [1]The WDEQ/WQD standard is expressed as a total concentration, but only dissolved data were available. [2]The WDEQ/WQD aquatic life standard for aluminum is expressed as a dissolved concentration, but only total data were available. [3]Note this value is expressed as a total, but the aquatic life standard is expressed as 0.75 mg/l dissolved aluminum.

Overall, the 2000 to 2010 water quality data from the mouth of Caballo Creek indicate that class of use criteria are met and mining has not caused material damage to surface water quality. This indicates that mining in the upstream drainages of Tisdale Creek and Duck Nest Creek has not caused downstream cumulative impacts. It is notable that the water type at the USGS station on Caballo Creek since 2000 is different from the water type noted during the baseline period. Since 2000, the dominant water type is $Na\text{-}SO_4$, which was noted in 88 percent of the samples (RockWare, Inc., 2006). From 1977-1983, $Ca\text{-}SO_4$ was the dominant water type and $Na\text{-}SO_4$ was represented by only 26 percent of the samples. One possible reason for the change in water type is due to CBM discharges in the upper watershed. As shown in **Figure 30**, CBM water and gas production in the Caballo Creek drainage peaked in 2000 but has been steadily declining over time. Pumping rates are expected to continue to decline over the next ten years (AECOM, Inc., 2009a). This trend indicates that CBM should continue to have a diminishing effect on surface water quality.

Although CBM has been active in the drainage for 17 years, the impact to surface water quality at the mouth of Caballo Creek may be somewhat mitigated for several reasons. First, the mines have used CBM water for other purposes such as dust control, facilities water, livestock watering, or wetland establishment (Caballo Mine Permit, 2011). Second, CBM producers are required to meet the requirements of their WYPDES permits prior to discharging to surface waters. Sediment and flood control reservoirs at the mines also capture and retain CBM flows above and within the mines. In addition, CBM impacts are generally limited to within a few miles of a discharge outfall due to infiltration and evaporative losses, which may total approximately 70-90 percent, depending of the time of year (AECOM, Inc., 2009a). Nearly all of the 411 active CBM WYPDES discharge outfalls in the watershed are located approximately 9 to 22 miles upstream from the mouth of the CIA (Wyoming Department of Environmental Quality, 2010b). Despite these factors, an analysis by the USGS indicated changes in SAR and specific conductance at the USGS station on Caballo Creek may be related to upstream CBM activity (Clark and Mason, 2007). Given the sharp decline in CBM production in the watershed, the ability to detect CBM impacts will likely become more difficult. Continued monitoring will be needed to assess how water quantity and water quality changes over time as a result of CBM activity (Bureau of Land Management, 2003).

6.1.1.7 NON-CONTRIBUTING DRAINAGES

Mining has the potential to change the geomorphic parameters of non-contributing drainages, such as slope, drainage area, and channel characteristics. During-mining surface water quantity and quality monitoring is usually not conducted in non-contributing drainages due to the lack of surface water. Further details on the characteristics of post-mining non-contributing drainages and playas at the mines in the Caballo Creek CIA are provided in Section 6.1.3.

6.1.2 DURING-MINING WATER QUANTITY AND WATER QUALITY OF INDIVIDUAL DRAINAGES IN THE BELLE FOURCHE RIVER CIA

6.1.2.1 COAL CREEK

Hydrologic conditions in during-mining period on Coal Creek were evaluated using data from the CC-12 gage at the downstream boundary of the Coal Creek Mine (**Plate 1**). Mean daily flows and water quality samples from 1999 to 2009 were available in the WDEQ/LQD Hydrology Database for analysis.

The hydrograph of mean daily flows on Coal Creek for the 1999 to 2009 period is presented in **Figure 31**. Similar to the baseline period (1980-1983), flows at CC-12 were ephemeral, punctuated by short-lived runoff events in the spring due to snowmelt or in the summer due to intense rainstorms. No flow was recorded approximately 60 percent of the period that the gage was active. This percentage is nearly identical to what was observed during the 1980 to 1983 period at the USGS station. The maximum mean daily flow from 1999 to 2009 was 440 cfs, recorded on July 13, 2004 (**Figure 31**). The Coal Creek Mine meteorological station recorded 5.9 inches of rain during the July 13, 2004 storm, which was estimated to be a 1,000-yr precipitation event (Coal Creek Mine Permit, 2011). The storm resulted in a peak discharge of 1,327 cfs at CC-12, which is estimated to be nearly a 25-yr event as defined by the regression equations of Miller (2003). The July 2004 peak discharge was probably one of the largest events to occur on Coal Creek since mining began. However, this event is still nearly half the size of the estimated peak of 2,500 cfs that occurred during the May 1978 flood event on Coal Creek (Coal Creek Mine Permit, 2011).

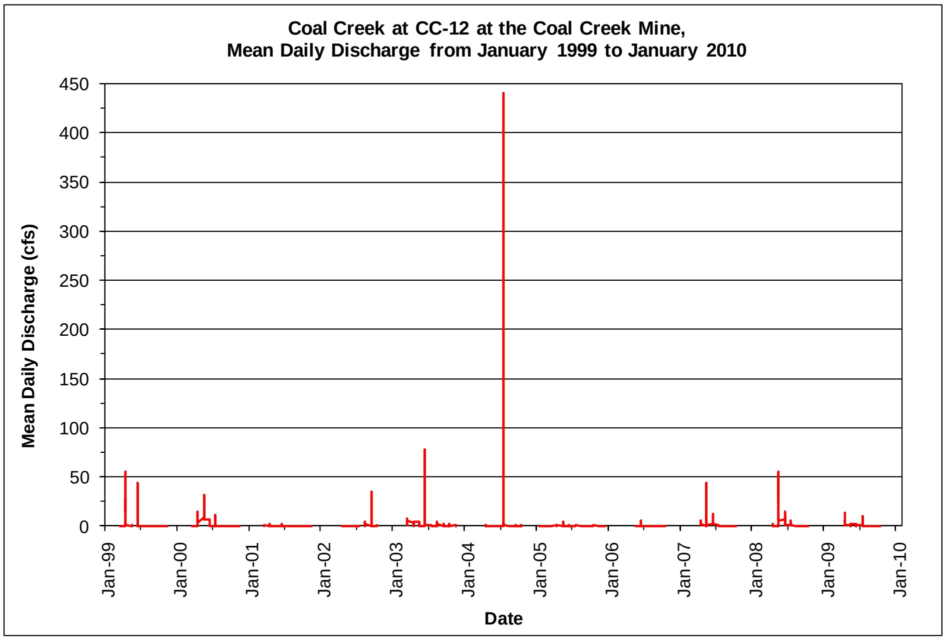


FIGURE 31. MEAN DAILY DISCHARGE FOR COAL CREEK AT CC-12 AT THE COAL CREEK MINE, 1999 TO 2010, MIDDLE POWDER RIVER BASIN, WYOMING, 2011. [GAPS INDICATE PERIODS OF MISSING DATA OR WHEN THE GAGE WAS NOT ACTIVE].

The water quality dataset for the 1999 to 2009 period at CC-12 yields 26 samples (**Table 27**). The water type found in 73 percent of the samples was Na-HCO_3 (RockWare, Inc., 2006). TDS @ 180 degrees C ranged from 280 to 2,350 mg/l, with a median of 1,005 mg/l. This range is comparable to what was measured during the baseline period at the USGS station, although the baseline median was 39 percent lower. Dissolved metal concentrations were very low, with numerous values below detection limits. Class 3B standards were exceeded for cadmium (one sample), iron (one sample), lead (one sample), aluminum (five samples), selenium (11 samples), and mercury (one sample). The mean selenium concentration of 0.009 mg/l also exceeded standards, although the median met the standard (**Table 27**). The reasons for the high frequency of exceedences for selenium are not known, and it is not clear if mining is a factor. Exceedences were not noted in the baseline data from the USGS gage, although only four samples were available for analysis. One contributing factor for the exceedences may be due to the low streamflows under which the samples were collected. During the period when the CC-12 gage was active and measuring flows, all of the exceedences occurred when the mean daily flow was less than one cfs.

TABLE 27. DURING-MINING WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON COAL CREEK AT COAL CREEK MINE STATION CC-12, 1999 TO 2009, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	USGS Parameter Code	Units	Coal Creek at CC-12 (1999-2009)				
			Count	Min	Max	Mean	Median
Temperature (field)	00010	°C	25	2.0	22.0	10.8	10.3
Turbidity	00076	NTU	26	11	4,100	796	410
Dissolved oxygen (field)	00300	mg/l	19	4.0	15.2	9.1	9.2
pH (field)	00400	S.U.	25	6.9	8.9	8.1	8.2
Ammonia as N (dissolved)	00608	mg/l	26	<0.05	0.80	0.18	0.10
Nitrite plus nitrate as N (dissolved)	00631	mg/l	15	<0.01	0.57	0.15	0.14
Sodium (dissolved)	00930	mg/l	26	22	734	298	241
Chloride (dissolved)	00940	mg/l	26	5.2	338	131	96
Sulfate (dissolved)	00945	mg/l	26	15	916	188	91
Fluoride (dissolved)	00950	mg/l	26	0.11	4.33	1.67	1.38
Arsenic (dissolved)	01000	mg/l	26	<0.005	0.01	88% <0.005	
Barium (dissolved)	01005	mg/l	26	<0.5	2.0	88% <0.5	
Boron (dissolved)	01020	mg/l	26	0.07	1.70	0.71	0.61
Cadmium (dissolved)	01025	mg/l	26	<0.002	0.002	96% <0.002	
Chromium (dissolved)	01030	mg/l	26	<0.01	0.01	96% <0.02	
Copper (dissolved)	01040	mg/l	26	<0.01	0.01	96% <0.01	
Iron (dissolved)	01046	mg/l	26	<0.05	1.04	0.24	0.09
Lead (dissolved)	01049	mg/l	26	<0.02	0.02	96% <0.02	
Manganese (dissolved)	01056	mg/l	26	<0.02	0.32	0.03	0.02
Nickel (dissolved)	01065	mg/l	26	<0.01	0.03	92% <0.01	
Zinc (dissolved)	01090	mg/l	26	<0.01	0.16	81% <0.01	
Aluminum (dissolved)	01106	mg/l	26	<0.1	4.1	0.5	0.2
Selenium (dissolved)	01145	mg/l	26	<0.005	0.043	0.009	0.004
TDS dried at 180 °C	70300	mg/l	26	280	2,350	1,172	1,005
Mercury (dissolved)	71890	µg/l	26	<1	1	96% <1	
Total suspended solids	80154	mg/l	26	8	1,480	311	109

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Means and medians were not calculated for constituents having ≥ 80% below-detect values. na= not applicable. Concentrations shown in red exceed WDEQ/WQD Class 3B surface water quality standards.

6.1.2.2 BELLE FOURCHE RIVER

During-mining hydrologic conditions on the BFR were assessed using data from the two gaging stations on the BFR upstream and downstream of the Cordero Rojo Mine. The upstream station, USGS Station No. 06425720 - *Belle Fourche River Below Rattlesnake Creek*, was discontinued in 1983, but the Cordero Rojo Mine resumed water quality sampling at the site in 1989. Monitoring of daily streamflow was not resumed until 1994. In March 2001, the USGS resumed monitoring at the station; the Cordero Rojo Mine independently collects quarterly water quality samples. The USGS discontinued the downstream gage on the BFR, USGS Station No. 06425780 - *Belle Fourche River above Dry Creek near Piney, Wyoming*, in 1983. The Cordero Rojo Mine currently operates the station under the name "LBFR". The mine began collecting water quality samples at the gage in 1989 and daily streamflow monitoring was resumed in 1994. Daily flow data from 1994 to 2009 at both stations were used for during-mining analysis.

The average daily flow at USGS Station No. 06425720 on the upstream BFR from April 1994 to June 2010 was 2.79 cfs, resulting in an average annual runoff of 2,016 ac-ft, and a unit-area annual runoff of 4.1 ac-ft/mi^2/yr. At the downstream station, the average daily flow was 1.5 times higher at 4.09 cfs, resulting in an average annual runoff of 2,956 ac-ft, and a unit-area annual runoff of 5.0 ac-ft/mi^2/yr. In comparison to the 1975 to 1983 period, the average daily flow over the 1994 to 2010 period was 15 percent higher at the upstream station and 11 percent lower at the downstream station. The maximum mean daily flow at the upstream station was estimated at 500 cfs on July 14, 2004. The maximum peak discharge of 1,130 cfs occurred during the same storm, but is reported as occurring on July 13, 2004 (U.S. Geological Survey, 2010a). At the downstream station, the maximum mean daily discharge was 482 cfs on July 14, 2004, with a peak daily discharge of 886 cfs. The July 13-14, 2004 event at the BFR stations are both estimated to be less than five year events (Miller, 2003).

The mean daily discharge by year over the 1994 to 2009 period at both stations is plotted in **Figure 32**. Averages were computed for only days when both stations were active to ensure an accurate comparison. Annual precipitation at the Dillinger station is also plotted. With the exception of 1996, 1997, 1999, and 2000, mean daily flows were higher at the downstream station, which is similar to the results of the baseline monitoring. The Cordero Rojo Mine suspects that the reason flows were higher at the upstream station during the late 1990s is due to the 1996 Diversion, which may have caused losses due to infiltration into the channel (Cordero Rojo Mine Permit, 2011). The 1996 Diversion was constructed to allow mining of the native BFR channel; the diversion will be in place until 2011 (Cordero Rojo Mine Permit, 2011). In 2011, the mine will construct the Phase I Diversion to allow mining of the coal beneath the 1996 Diversion. The Phase I Diversion will be in place until 2019 and will divert flows into a portion of the reconstructed BFR channel. In 2019, the Phase II Diversion will be constructed further upstream and will be in place until 2029, or at least two years after the BFR has been fully reconstructed (Cordero Rojo Mine Permit, 2011). These diversions are expected to have a minimal effect on flows in the BFR. As the majority of the BFR discharge record over the last 15 years indicates, flows continue to be slightly higher at the downstream station (**Figure 32**). This indicates that mining has not materially affected water quantity on the BFR.

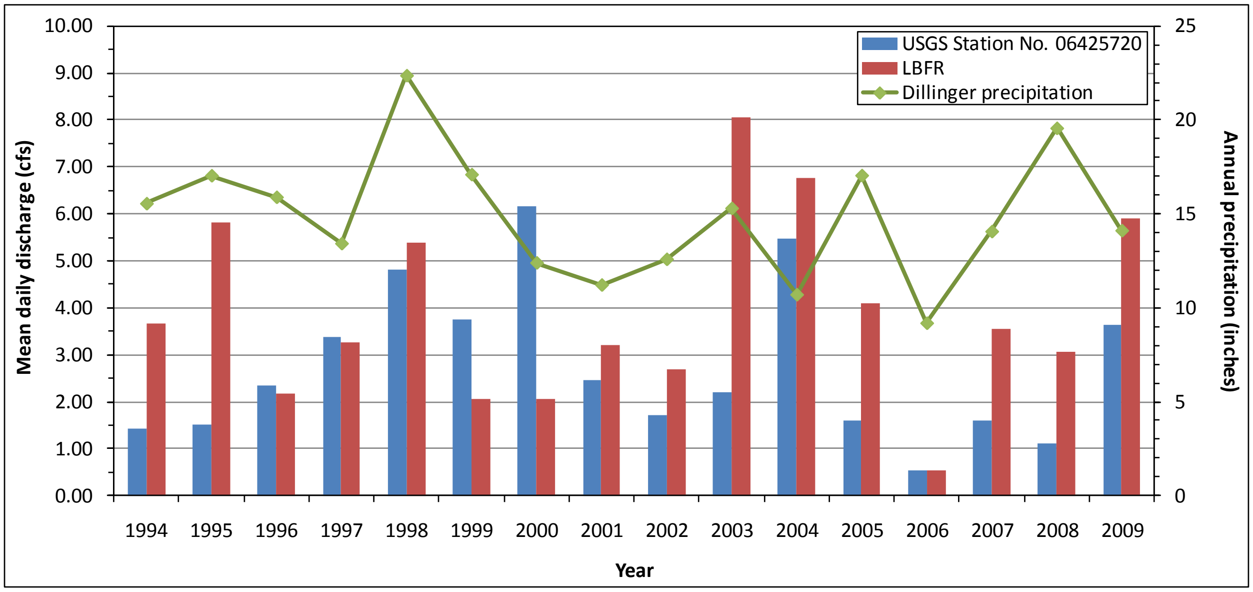


FIGURE 32. COMPARISON OF ANNUAL PRECIPITATION AT DILLINGER AND MEAN ANNUAL DAILY DISCHARGE ON THE BELLE FOURCHE RIVER AT USGS STATION NO. 06425720 AND CORDERO ROJO STATION LBFR, 1994 TO 2009, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

As just mentioned, the Cordero Rojo Mine has reconstructed a portion of the BFR channel, but the reach is not yet functional. Upstream flows will not be directed into a portion of the reach until after the Phase I Diversion is constructed in approximately 2011 (Cordero Rojo Mine Permit, 2011). Although the BFR was not declared an AVF, the mine has designed the channel to restore the pre-mine hydrologic functions. Channel form and alignment will be very similar to the pre-mine dimensions. Pool and run sequences will be recreated using a minimum of 17 channel pools constructed using vortex rock weirs. Alluvial material salvaged from terraces will be used to line the runs and create storage areas adjacent to the restored pools. The success of the restored channel will be evaluated using four geomorphic monitoring stations (Cordero Rojo Mine Permit, 2011). Continued monitoring at the LBFR station will assess how the restored channel functions with respect to water quantity and water quality.

A comparison of water quality summary statistics between the upper and lower stations on the BFR over a portion of the during-mining period is shown in **Table 28**. Data were available from 2001 to 2010 at USGS Station No. 06425720 and from 2003 to 2010 at LBFR. More samples of some constituents are available from the upstream station since the USGS collects samples monthly.

The dominant water type at USGS Station No. 06425720 on the upstream BFR over the 2001 to 2010 period was Na-SO_4 (RockWare, Inc., 2006), which was similar to what was found in the 1975 to 1983 period. All of the samples collected at the downstream station were of a Na-SO_4 type. This is a slight shift from what was noted in the 1975 to 1983 period, as only 46 percent of the samples were Na-SO_4 while the remaining samples were Ca-SO_4.

TABLE 28. DURING-MINING WATER QUALITY STATISTICS FOR SELECTED CONSTITUENTS ON THE BELLE FOURCHE RIVER AT USGS STATION NO. 06425720 AND CORDERO ROJO MINE STATION LBFR, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	USGS Parameter Code	Units	Belle Fourche River below Rattlesnake Creek (upstream) (USGS Station No. 06425720) (2001-2010)					Belle Fourche River above Dry Creek (downstream) (Cordero Rojo Mine Station LBFR) (2003-2010)				
			Count	Min	Max	Mean	Median	Count	Min	Max	Mean	Median
Temperature (field)	00010	°C	109	<0.1	29.8	9.1	9.0	24	2.0	26.7	12.6	13.0
Turbidity	00076	NTU	18	1	29	8	7	23	9	1,050	87	43
Dissolved oxygen (field)	00300	mg/l	102	0.7	17.9	8.0	8.3	20	5.3	17.3	9.7	9.5
pH (field)	00400	S.U.	109	6.8	9.2	8.0	8.0	24	7.3	8.8	8.1	8.2
Ammonia as N (dissolved)*	00608	mg/l	18	<0.1	0.40	0.20	0.17	23	<0.1	1.60	0.27	0.20
Nitrite plus nitrate as N (dissolved)*	00631	mg/l	17	<0.05	<0.05	100% <0.05		22	<0.05	0.91	0.24	0.16
Sodium (dissolved)	00930	mg/l	100	173	825	379	372	23	118	545	371	388
Chloride (dissolved)*	00940	mg/l	94	6.0	62.0	21.0	19.2	23	9.0	65.0	29.7	28.0
Sulfate (dissolved)	00945	mg/l	95	648	3,180	1,340	1,320	23	402	2,370	1,268	1,250
Fluoride (dissolved)	00950	mg/l	94	0.4	1.2	0.8	0.8	23	0.4	0.9	0.7	0.6
Arsenic (dissolved)*	01000	mg/l	85	<0.005	0.004	0.001	0.001	23	<0.005	0.005	96% <0.005	
Barium (dissolved)*	01005	mg/l	17	<0.5	<0.5	100% <0.5		23	<0.5	<0.5	100% <0.5	
Boron (dissolved)	01020	mg/l	17	0.07	0.21	0.15	0.15	23	0.12	1.34	0.32	0.22
Cadmium (dissolved)	01025	mg/l	17	<0.002	<0.002	100% <0.002		23	<0.002	<0.002	100% <0.002	
Chromium (dissolved)*	01030	mg/l	17	<0.01	<0.01	100% <0.01		23	<0.01	<0.01	100% <0.02	
Copper (dissolved)	01040	mg/l	17	<0.01	<0.01	100% <0.01		23	<0.01	<0.01	100% <0.01	
Iron (dissolved)	01046	mg/l	94	<0.05	1.69	0.06	0.03	23	<0.05	0.10	96% <0.05	
Lead (dissolved)	01049	mg/l	18	<0.02	<0.02	100% <0.02		23	<0.02	<0.02	100% <0.02	
Manganese (dissolved)	01056	mg/l	94	<0.02	4.09	0.27	0.11	23	<0.02	0.40	0.13	0.08
Nickel (dissolved)*	01065	mg/l	18	<0.01	0.02	83% <0.01		23	<0.01	0.02	83% <0.01	
Zinc (dissolved)	01090	mg/l	18	<0.01	<0.01	100% <0.01		23	<0.01	0.02	91% <0.01	
Aluminum (dissolved)	01106	mg/l	17	<0.1	0.1	88% <0.1		23	<0.1	0.3	91% <0.1	
Selenium (dissolved)	01145	mg/l	19	<0.005	0.0005	95% <0.005		23	<0.005	0.007	91% <0.005	
TDS dried at 180 °C	70300	mg/l	101	1,150	5,720	2,378	2,330	23	900	3,940	2,340	2,340
Mercury (dissolved)*	71890	µg/l	17	<1	<1	100% <1		23	<1	<1	100% <1	
Total suspended solids	80154	mg/l	18	<5	34	10	8	23	10	480	60	38

Summary statistics for constituents with below-detect values were calculated using methods recommended by Helsel (2005). Means and medians were not calculated for constituents having ≥80% below-detect values. Concentrations shown in red exceed WDEQ/WQD Class 2ABww surface water quality standards. *The WDEQ/WQD standard is expressed as a total concentration, but only dissolved data were available at both stations.

TDS @ 180 degrees C at the upstream station ranged from 1,150 to 5,720 mg/l, with a median of 2,330 mg/l (**Table 28**). TDS @ 180 degrees C was similar at the downstream gage, ranging from 900 to 3,940 mg/l, with a median of 2,340 mg/l. TSS at the upstream station was very low, ranging from <5 to 34 mg/l, with a median of 8 mg/l. TSS concentrations at the downstream site were higher, ranging from 10 to 480 mg/l, with a median of 38 mg/l. Dissolved metal concentrations at both stations were very low, with numerous values below detection limits (**Table 28**). At the upstream station, exceedences of Class 2ABww standards were noted for dissolved oxygen (five samples), pH (one sample), iron (one sample), and manganese (one sample). The mean and median of each constituent sampled at the upstream station showed no exceedences of standards. At the downstream station, Class 2ABww standards for selenium were exceeded on two samples, yet 91 percent of samples showed selenium less than the detection limit of 0.005 mg/l (**Table 28**). This indicates that the higher selenium values observed in the upstream tributary of Coal Creek (see **Table 27**) have not been routed to the mouth of the CIA. Selenium has been identified as a potential issue on the lower reaches of Coal Creek and the BFR at the Cordero Rojo Mine due to elevated levels of selenium in areas of backfill. Because of this, the mine has sampled selenium in two pools on the BFR and two pools on lower Coal Creek since the 1990s (Cordero Rojo Mine Permit, 2011). To date, the samples collected from the pools indicate no problems with selenium, as all concentrations have been below detection limits.

The summary statistics in **Table 28** show that the median turbidity value at the downstream station is over six times higher than the value at the upstream station. Because of this, additional analysis of turbidity was conducted to help identify the causes for the increase and whether or not mining may be a factor. To evaluate trends over time, additional turbidity data from 1989 to 2002 were obtained from Cordero Rojo Mine annual reports. No data were found in the annual reports for the 1982 to 1988 period. The entire turbidity dataset at both the upstream and downstream stations on the BFR are plotted in **Figure 33**. Turbidity data from 1999 to 2009 at Coal Creek Mine station CC-12 on Coal Creek are also plotted.

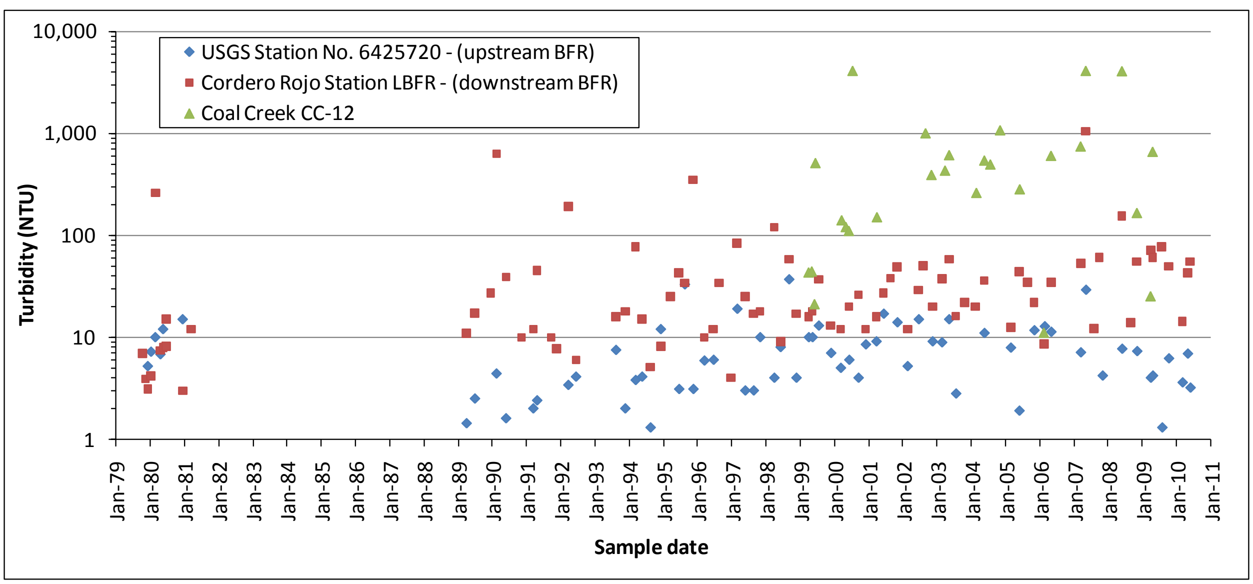


FIGURE 33. COMPARISON OF TURBIDITY OVER TIME AT USGS STATION NO. 6425720 AND CORDERO ROJO MINE STATION LBFR ON THE BELLE FOURCHE RIVER, AND COAL CREEK MINE STATION CC-12 ON COAL CREEK, 1979 TO 2010, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

The data in **Figure 33** show that turbidity was variable at each station over time, but comparisons between stations can be made. Turbidity was clearly higher over time at the downstream BFR station compared to the upstream BFR station. The median turbidity at the upstream station over the 1989 to 2010 period was 6 NTU, while a median of 25 NTU occurred at the downstream station. Turbidity was highest on Coal Creek, at least over the 1999 to 2009 period that had data available. This pattern suggests that the difference in turbidity between stations on the BFR may be due to sediment inputs from Coal Creek. This is also supported by the findings of the early suspended sediment monitoring conducted by the USGS from 1977 to 1983 (Martin et al., 1988).

The relationship between discharge and turbidity at the two stations on the BFR and the Coal Creek station were further examined to help evaluate differences in turbidity between stations (**Figure 34**). All non-zero mean daily discharge and turbidity values were plotted for the during-mining period with data available (1994-2010). The relationships show that turbidity is variable with discharge, particularly at the BFR stations, but there is a clear difference in the relationship between stations. For similar flows, turbidity is higher at the downstream BFR station compared to the upstream BFR station. On Coal Creek, turbidity is much higher than both BFR stations across a range of similar discharges (**Figure 34**). This implies that the differences in turbidity are not due to differences in discharge at the individual stations. The Coal Creek drainage appears to have higher sediment availability, which is likely resulting in increased TSS and turbidity levels at the downstream BFR station relative to the upstream BFR station.

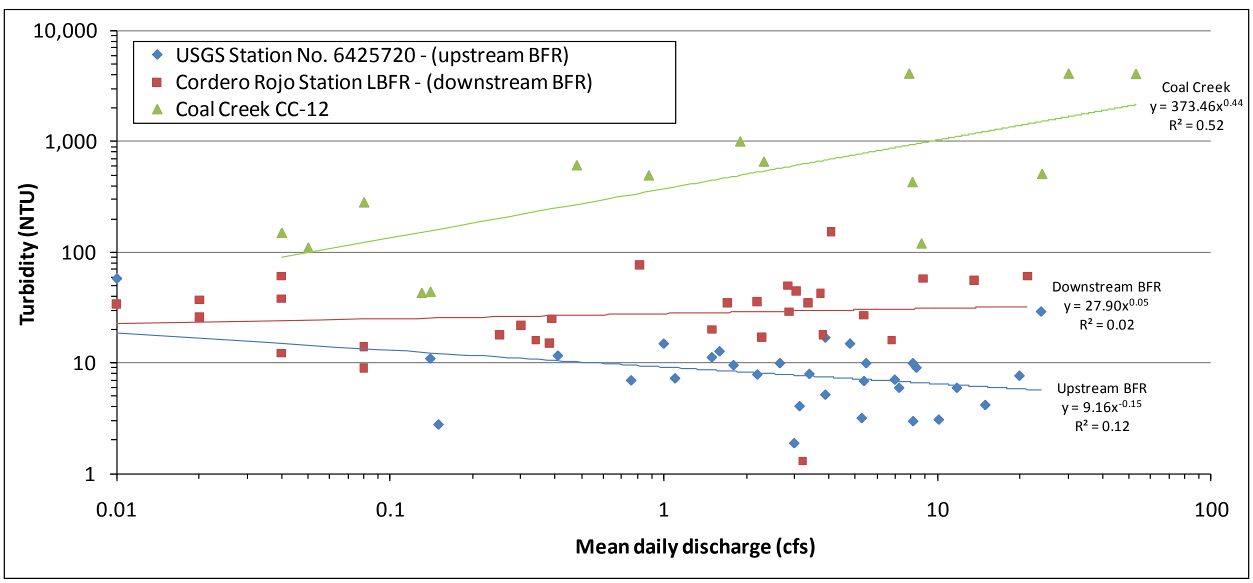


FIGURE 34. COMPARISON OF MEAN DAILY DISCHARGE VERSUS TURBIDITY AT USGS STATION NO. 6425720 AND CORDERO ROJO MINE STATION LBFR ON THE BELLE FOURCHE RIVER, AND COAL CREEK MINE STATION CC-12 ON COAL CREEK, 1994 TO 2010, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

A review was also conducted of the recent discharge monitoring reports (DMRs) submitted by the Cordero Rojo Mine as part of the mine's WYPDES permit with WDEQ/WQD (Wyoming Department of Environmental Quality, 2010c). The mine has 11 permitted outfalls that potentially discharge to the BFR in between the two gaging stations. The 2007-2009 DMRs showed that only three of the outfalls discharged to the river. Outfall 016 (South Pit Reservoir) discharged most frequently, with three discharges in 2007, four in 2008, and two in 2009. The other two outfalls only discharged once each in 2009. In all reported discharges, TSS concentrations were less than 25 mg/l and were well within the limits set by the WYPDES permit. The low frequency of discharges and low TSS concentrations suggest that permitted discharges at the Cordero Rojo Mine probably have very little effect on turbidity levels on the LBFR gage on the BFR. The DMR data also indicate that the sediment control structures at the mine are adequately capturing and retaining sediment from disturbed areas. This, combined with the historical and recent monitoring data that indicate Coal Creek is a natural source of sediment to the BFR, suggest that the increased TSS and turbidity at the downstream BFR station are not related to mining activities. Overall, the comparison of water quality between the BFR stations indicates that mining has not degraded water quality on the BFR and WDEQ/WQD class of use standards are being met.

Although this CHIA explicitly evaluates the effects of coal mining, CBM production has the potential to affect surface water quantity and quality. CBM development in the BFR watershed upstream of the coal mines has been continuously active since 1995 (Wyoming Oil and Gas Conservation Commission, 2010). The watershed has 4,074 CBM wells, although only about 74 percent of the wells currently have some level of activity. There 807 active CBM WYPDES outfalls in the BFR CIA (Wyoming Department of Environmental Quality, 2010b). Water production peaked in 2002 at nearly 110 million barrels, and gas production peaked in 2004 at nearly 64 million MCF (**Figure 35**). Water and gas production has been declining ever since, and the 2009 rates are the lowest recorded since 1999-2000 (Wyoming Oil and Gas Conservation Commission, 2010). Pumping rates in the upper Belle Fourche drainage are expected to continue to decline over the next ten years (AECOM, Inc., 2009a). This trend indicates that CBM should continue to have a diminishing effect on surface water quantity and quality in the upper Belle Fourche River drainage.

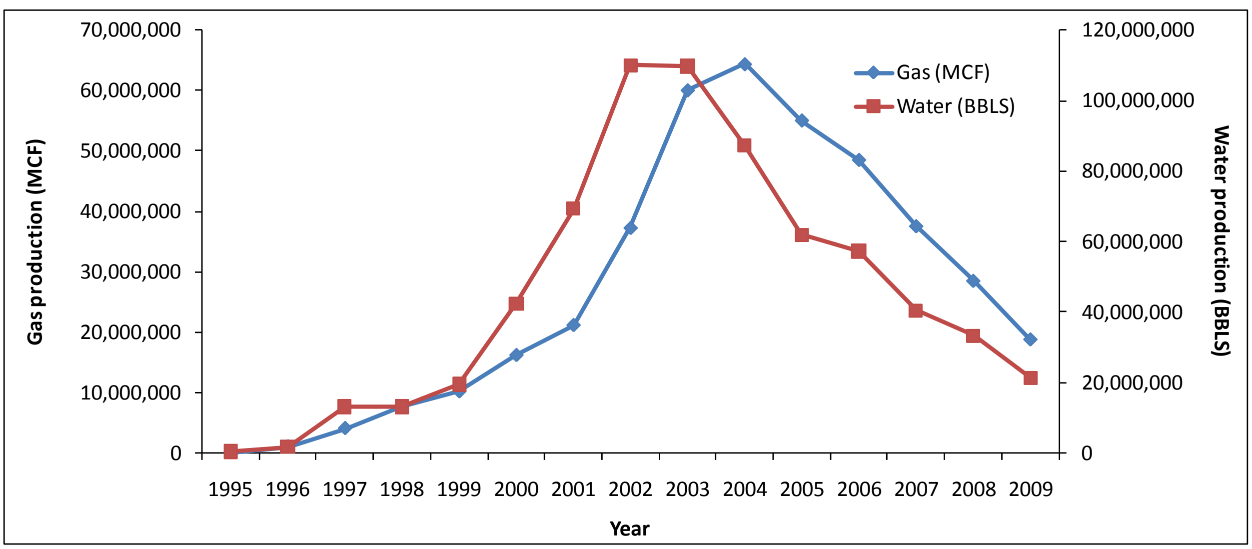


FIGURE 35. COAL BED METHANE GAS AND WATER PRODUCTION IN THE UPPER BELLE FOURCHE RIVER WATERSHED, 1995 TO 2009, MIDDLE POWDER RIVER BASIN, WYOMING, 2011. [DATA FROM WYOMING OIL AND GAS CONSERVATION COMMISSION, 2010].

As part of the 2009 update to the BLM's Powder River Basin Coal Review, an assessment of current and future CBM impacts on surface water quality was conducted for the upper BFR drainage (AECOM, Inc., 2009b; Anderson Consulting Engineers, Inc., 2009). The analysis evaluated electrical conductivity (EC) and sodium adsorption ratio (SAR) with respect to the Most Restrictive Proposed Limit (MRPL) and Least Restrictive Proposed Limit (LRPL). The MRPL and LRPL represent the desired concentrations of EC and SAR for irrigated agricultural, as compiled from the WDEQ, Montana Department of Environmental Quality, and South Dakota Legislative Council. For the BFR, the MRPL is 6 for SAR and 2,000 µS/cm for EC; the LRPL is 10 for SAR and 2,500 µS/cm for EC (Anderson Consulting Engineers, Inc., 2009).

CBM impacts to EC and SAR in the BFR were predicted under normal and dry-year scenarios in 2003, 2010, 2015, and 2020. Under normal-year conditions from 2003 to 2015, EC is projected to decline due to mixing of CBM production water and natural waters, while SAR is projected to slightly increase (AECOM, Inc., 2009b). EC and SAR are expected to return to base year (2003) levels by 2020 when discharge of CBM water to the drainage ceases. EC would not exceed the MRPL, expect for October 2010 and January through October 2015. EC would never exceed the LRPL. SAR would exceed the MRPL from January to August in 2010 and from January to September 2015, and would not exceed the LRPL for all months and years. Overall, the analysis predicts that surface water would be suitable for irrigation in the BFR through 2020 (AECOM, Inc., 2009b). Continued monitoring on drainages affected by CBM development in the BFR CIA will be needed to assess how water quantity and water quality changes over time (Bureau of Land Management, 2003).

6.1.1.3 NON-CONTRIBUTING DRAINAGES

Mining has the potential to change the geomorphic parameters of non-contributing drainages, such as slope, drainage area, and channel characteristics. During-mining surface water quantity and quality monitoring is usually not conducted in non-contributing drainages due to the lack of surface water. Further details on the characteristics of post-mining non-contributing drainages and playas at the mines in the BFR CIA are provided in Section 6.1.4.

6.1.3 POST-MINING WATER QUANTITY AND WATER QUALITY IN THE CABALLO CREEK CIA

The overall reclamation objective at the coal mines in the middle PRB is to restore the land to the pre-mining land use, which is mainly livestock grazing and wildlife habitat. With respect to surface water quantity and quality, the goal is to have post-mine conditions fall within the range of variability observed during the pre-mine period. It is assumed that proper reclamation will ensure that no material damage occurs to surface water quantity and quality as a result of mining.

At present, none of the mines in either CIA have reclaimed an entire drainage basin upstream of a surface water monitoring station. This means there are no surface water quantity or quality data available to compare against pre-mining and during-mining data. Thus, a prediction concerning post-mining water quantity and quality is based on a qualitative analysis. The reader is also referred to Section 4.1, which provided a theoretical discussion of the expected post-mining surface water hydrologic conditions.

The Caballo, Cordero Rojo, and Coal Creek mines are classified as AOC, which means that there is sufficient spoil available to construct a post-mine topography (PMT) that is similar to pre-mine conditions, conceding that there may be some overall reduction in elevation. The Belle Ayr Mine is designated as thin overburden, meaning that there is insufficient material available to restore the landscape to AOC. A significant amount of pre-mine geomorphic data have been collected each mine to design PMT that reflects the pre-mine topography. Pre-mine basin characteristics such as relief, valley and channel profiles, drainage density, and slope histograms are used to develop post-mining reclamation design. Post-mining geomorphic parameters such as slope distribution, drainage area, drainage density, non-contributing drainage acreage, and stream sinuosity are designed to be similar to the pre-mining condition.

Pre-mine stream morphology measurements have been used to design and evaluate reconstructed stream channels. Runoff modeling is used to evaluate hydraulic suitability and predict post-mine discharges in reconstructed channels for varied recurrence intervals. The reclaimed topography includes the reconstruction of portions of several of the main channels within the Caballo Creek CIA, including the main stem of Caballo Creek, Tisdale Creek, North Tisdale Creek, and Duck Nest Creek. WDEQ/LQD requires that each stream channel design demonstrates that significant erosion will not occur during the design peak discharge event. Some bed and bank erosion is likely to occur, but the channel slope and cross-sectional dimensions should not substantially change. Post-mine channels are generally wider and often flow at shallower gradients than corresponding pre-mine channels. This design results in greater cross-sectional area providing flow resistance and lower velocities while enhancing erosional stability.

At the Caballo Mine, the average post-mine slope will increase slightly from 3.82 to 4.10 percent (Caballo Mine Permit, 2011). The PMT will be flatter and more rolling than pre-mine, although the proportion of slopes less than five percent will be approximately the same. The Tisdale Creek drainage area will be increased by 2.8 mi^2 or 14 percent, mostly owing to the opening of closed basins and an encroachment into the North Tisdale Creek drainage. The North Tisdale Creek drainage area will decrease by 1.6 mi^2 or 23 percent. Because of these drainage area changes, runoff peaks and volumes are expected to slightly increase in Tisdale Creek and slightly decrease in North Tisdale Creek. The combined post-mining sediment yields from the Tisdale Creek, North Tisdale Creek, and Gold Mine Draw drainages are expected to increase six percent due to changes in drainage area configuration (Caballo Mine Permit, 2011).

At the Belle Ayr Mine, pre-mine and post-mine drainage densities are projected to be similar, while average post-mining slopes will be flatter (4.22 percent post-mine vs. 4.41 percent pre-mine) (Belle Ayr Mine Permit, 2011). This is predicted to result in a slight decrease in sediment production and sediment yield. Caballo Creek and Duck Nest Creek are the primary channels that will be reconstructed. The drainage of Caballo Creek in the vicinity of the mine is expected to increase by 516 ac (0.4 percent) due to reconstruction activities at adjacent mines. Since the Belle

Ayr Mine has overlapping permit boundaries with the Caballo and Cordero Rojo mines, PMT will be blended across the adjacent topography (Belle Ayr Mine Permit, 2011).

At the Cordero Rojo Mine, the PMT will result in slight changes to the contributing drainage area to Caballo Creek (Cordero Rojo Mine Permit, 2011). Within the permit area, the area draining to Caballo Creek will increase three percent. This is expected to result in a 17 percent increase in mean annual runoff and an 11 percent decrease in sediment yield to Caballo Creek (Cordero Rojo Mine Permit, 2011).

At the Caballo Mine, mining will disturb seven closed basins containing playas that had a total drainage area of 2,217 ac (Caballo Mine Permit, 2011). Three replacement closed basins, having a total of four playa pools, will be created to replace those disturbed by mining. The three post-mining playas will have a drainage area of 1,335 ac, which represents about a 40 percent decrease compared to pre-mining. The post-mining playas are expected to help recharge the backfill aquifer. The mine will use surface water sampling and backfill wells to monitor post-mining playas (Caballo Mine Permit, 2011). At the Belle Ayr Mine, seven playas will exist post-mining (Belle Ayr Mine Permit, 2011). One playa will be created to replace three playas removed by mining. The total post-mine playa capacity will be 1,121 ac-ft, which represents a 30 percent decrease over pre-mine conditions. All post-mining playas will be located in similar locations and will be designed to have similar hydrologic functions (Belle Ayr Mine Permit, 2011). At the Cordero Rojo Mine, including the area of the Maysdorf I Amendment, five post-mine closed basins will exist with a drainage area of 1,489 ac and maximum playa capacity of 1,270 ac-ft (Cordero Rojo Mine Permit, 2011). This represents a 39 percent decrease in drainage area and a 22 percent decrease in playa capacity. Two of the closed basins will reside in the area of the pre-mine Caballo Creek CIA.

Permanent post-mining impoundments fall into two categories: small impoundments that are generally used as stockponds and major impoundments. Stockponds are defined by WDEQ/LQD as impoundments that have a capacity of less than 20 ac-ft and a dam height of less than 20 ft. A major impoundment provides a storage capacity of greater than 20 ac-ft and/or has an embankment height greater than 20 ft (Wyoming Department of Environmental Quality, 1996). Both small and major impoundments must have a designed spillway to provide through drainage, and WSEO approval must be obtained for a water right. The WSEO requires structures whose capacity exceeds 20 ac-ft and whose embankment exceeds 20 ft in height to have safety of dam inspections. Depending on the size and number of impoundments that remain after reclamation, there may be some decrease in water yield due to increased evaporative losses. However, permanent post-mining impoundments are beneficial in that they support the post-mine land use of livestock and wildlife. In many cases these permanent impoundments replace pre-mining impoundments.

At the Caballo Mine, 19 permanent impoundments are planned to replace the stockponds and wetland features disturbed by mining (Caballo Mine Permit, 2011). The total post-mining capacity of the impoundments will be 439.25 ac-ft, which represents a six percent decrease compared to pre-mining. The impoundment capacity in Tisdale and North Tisdale Creek will decrease while the capacity in Gold Mine Draw will remain the same (Caballo Mine Permit, 2011).

At the Belle Ayr Mine, a total of seven permanent impoundments will be created (Belle Ayr Mine Permit, 2011). The largest impoundment is Caballo Lake Reservoir, which will replace its pre-mining counterpart (aka Dunlap Lake). Caballo Lake Reservoir will have a permitted capacity of 1,867 ac-ft, while the old reservoir had a capacity of 868 ac-ft. The increase in storage is compensated by a transfer of water rights from the Temporary North Pit Reservoir (617.8 ac-ft) and water rights obtained with the enlargement of the Temporary North Pit Reservoir (381.41 ac-ft). Water balance calculations indicate there will be enough surface water to compensate for losses due to seepage. The six other permanent impoundments will be constructed on reclaimed channels and will have a total capacity of 32.8 ac-ft, which is a decrease of 51 percent over pre-mine conditions. Impoundments will be designed to periodically flush, helping to maintain water quality (Belle Ayr Mine Permit, 2011).

At the Cordero Rojo Mine, including the area of the Maysdorf I Amendment, a total of 17 permanent impoundments will exist after mining, with a total capacity of 197.6 ac-ft (Cordero Rojo Mine Permit, 2011). This is a reduction of 17 percent compared to pre-mine capacity. Five of the impoundments will reside in the Caballo Creek CIA, with a combined capacity of 68 ac-ft (Cordero Rojo Mine Permit, 2011).

All disturbed wetlands in the CIAs are required to be replaced on a one-to-one area basis per regulatory statutes. At the Caballo Mine, 12.65 ac of riverine wetlands and 31.45 ac of stockpond wetlands will be disturbed (Caballo Mine Permit, 2011). The wetland mitigation plan will result in more post-mining wetlands than were delineated pre-mine. For example, 29.7 ac of riverine wetlands and 48.3 ac of stockpond wetlands will be created. Since the post-mining wetlands are small in volume and mostly replace existing features, they are not expected to significantly affect the water balance of any of the reclaimed drainages (Caballo Mine Permit, 2011). At the Belle Ayr Mine, 46.6 ac of wetlands will be restored for life-of-mine disturbances through 2007. Most of the wetlands are riverine wetlands associated with Caballo Creek and Duck Nest Creek (Belle Ayr Mine Permit, 2011).

Prior to replacing topsoil and contouring, the mines have committed to cover unsuitable spoil with a minimum of four feet of suitable material. In the vicinity of major reclaimed channels, this commitment is generally increased to eight feet. These commitments should provide an adequate rooting zone and minimize any impairment concerning vegetation reestablishment. The increased burial depth within major drainages should assist in reducing the amount of unwanted salts or trace elements being wicked to the surface during dry periods and into surface water during runoff events.

Vegetative cover will be lower during the early stages of reclamation when compared to the pre-mine environment. To obtain final bond release, vegetative cover for each community type must be equal to or exceed pre-mine conditions. If post-mining vegetation cover meets these requirements, it is assumed that the level of soil surface protection closely resemble pre-mining conditions. Prior to bond release, WDEQ/LQD requires that the unit of permanently reclaimed land exhibit sufficient surficial stability and sufficient vegetation establishment. Operators must demonstrate that drainage from the reclaimed unit does not need to pass through a sediment pond or ASCM structure. Thus, regulatory bond release requirements help ensure that sediment yield will be less than or equal to pre-mine levels. This helps maintain post-mine surface water quality so that surface water quality class of use standards are met.

The above discussion indicates that the differences between pre-mine and post-mine topography, drainage patterns, infiltration rates, interception rates, and vegetation cover will be minimal following reclamation at the mines in the Caballo Creek CIA. This suggests that runoff at the end of the bond release period is expected to be equal to or slightly less than pre-mining runoff. Post-mine sediment yield is expected to be similar or lower than pre-mine yields, and this would be consistent with results from other Wyoming coal mines that have shown that sediment yield from reclaimed lands is usually less than yields from adjacent native lands. Monitoring of water quantity and water quality will continue up until bond release. Approximately 18 percent of the Caballo Creek drainage is approved to be disturbed from mining activities at the Caballo, Belle Ayr, and Cordero Rojo mines. To date, only about 11 percent of the drainage has been affected by mining disturbance, and this also includes areas that have been permanently reclaimed. Based on the limited amount of acreage affected relative to the size of the watershed, the ability to detect changes in surface water quantity and quality due to mining is low. Dilution from water upstream of the mines also helps negate impacts.

6.1.4 POST-MINING WATER QUANTITY AND WATER QUALITY IN THE BELLE FOURCHE RIVER CIA

At the Cordero Rojo and Coal Creek mines, post-mining geomorphic parameters such as slope distribution, drainage area, drainage density, non-contributing drainage acreage, and stream sinuosity are designed to be similar to the pre-mine condition. At the Coal Creek Mine, the average post-mine slope of 3.8 percent is less than the average pre-mine slope of 5.0 percent (Coal Creek Mine Permit, 2011). At the Cordero Rojo Mine, post-mine average (5.0 percent) and maximum (60.3 percent) slopes are predicted to be lower than pre-mine values (5.8 percent average and 57.1 percent maximum) (Cordero Rojo Mine Permit, 2011). Flatter, less steep slopes will increase flow travel times, reduce peak flow magnitudes, and reduce sediment production.

At the Cordero Rojo Mine, the PMT will result in slight changes to the contributing drainage area to the BFR (Cordero Rojo Mine Permit, 2011). Within the permit area, the area draining to the BFR will increase 14 percent. Modeling by the mine indicates this will result in a 29 percent increase in mean annual runoff and a 14 percent increase in sediment yield to the BFR (Cordero Rojo Mine Permit, 2011).

Pre-mine stream morphology measurements have been used to design and evaluate the suitability of all reconstructed stream channels. The major channels to be reconstructed at the Coal Creek Mine include portions of the Section 18 Tributary, the Section 27 Tributary, East Fork Coal Creek, and Middle Fork Coal Creek (Coal Creek Mine Permit, 2011). The PMT will result in minor changes in the contributing areas to these drainages, and the predicted peak flows for the 2-yr, 10-yr, and 100-yr events are predicted to be lower post-mine compared to pre-mine. At the Cordero

Rojo Mine, channel reconstruction will take place on the BFR and several of its named and unnamed ephemeral tributaries (Cordero Rojo Mine Permit, 2011). The BFR will have an alignment very similar to its pre-mining alignment. The channel will have a minimum of 17 pools constructed from vortex rock weirs. Alluvial material salvaged from terraces will be used to line the runs and create storage areas adjacent to the restored pools. Smooth transitions will be used to blend reconstructed reaches with native upstream and downstream reaches (Cordero Rojo Mine Permit, 2011).

At the Coal Creek Mine, a total of 12 post-mining permanent impoundments will be created to replace those removed by mining (Coal Creek Mine Permit, 2011). The impoundments will provide a total of 60.2 ac-ft of storage, which is ten percent greater than the pre-mine storage of 54.7 ac-ft. The additional storage will be permitted with the WSEO (Coal Creek Mine Permit, 2011). At the Cordero Rojo Mine, including the area of the Maysdorf I Amendment, a total of 17 permanent impoundments will exist after mining, with a total capacity of 197.6 ac-ft (Cordero Rojo Mine Permit, 2011). This is a reduction of 17 percent compared to pre-mine capacity. Eleven of the impoundments will reside in the BFR CIA, with a combined capacity of 113.1 ac-ft. All impoundments will be designed to flush regularly to help maintain water quality (Cordero Rojo Mine Permit, 2011).

No closed depressions will be created in the PMT at the Coal Creek Mine (Coal Creek Mine Permit, 2011). At the Cordero Rojo Mine, including the area of the Maysdorf I Amendment, five post-mine closed basins will exist with a drainage area of 1,489 ac and maximum playa capacity of 1,270 ac-ft (Cordero Rojo Mine Permit, 2011). This represents a 39 percent decrease in drainage area and a 22 percent decrease in playa capacity. Three of the closed basins will reside entirely within the BFR CIA, while two of the basins have area within both the Caballo Creek and BFR CIAs (Cordero Rojo Mine Permit, 2011).

All disturbed wetlands in the CIA are required to be replaced on a one-to-one area basis per regulatory statutes. At the Coal Creek Mine, 19.62 ac of riverine wetlands will be mitigated, along with 3.81 ac of stockpond wetlands and 8.29 ac of Other Waters of the United States (OWUS) (Coal Creek Mine Permit, 2011). This total is slightly greater than the wetland acreage that existed pre-mine. The Cordero Rojo Mine contained a total of 86.21 ac of jurisdictional wetlands, 23.05 ac of open water, and 8.21 ac of OWUS (Cordero Rojo Mine Permit, 2011). As of May 2002, the mine had disturbed 76.09 ac of wetlands, with an additional 2.14 ac approved to be disturbed at a later date. The mine will mitigate 80.86 of wetlands, with the majority of these within the BFR CIA along the reconstructed BFR channel. The Maysdorf I Amendment Area has a total of 7.12 ac of wetlands and open water (Cordero Rojo Mine Permit, 2011).

Assuming the post-mine hydrologic and geomorphic conditions approximate pre-mine conditions following reclamation, the post-mining water quantity and quality in the BFR CIA should be similar to pre-mine conditions. Approximately four percent of the BFR CIA is approved to be disturbed from mining activities at the Coal Creek and Cordero Rojo mines. To date, only about three percent of the CIA has been affected by mining disturbance, and this also includes areas that have been permanently reclaimed. Based on the limited amount of acreage affected relative to the size of the watershed, the ability to detect changes in surface water quantity and quality due to mining is low. Dilution from the 495 mi^2 watershed upstream of the CIA also helps negate impacts at the LBFR station on the BFR.

6.2 GROUNDWATER

Analysis of the cumulative impacts on groundwater as a result of mining at the Caballo, Belle Ayr, Cordero Rojo, and Coal Creek mines, with the addition of the Maysdorf I Amendment Area, was performed by qualitatively assessing the additive impacts of the mines. Considered in this analysis are the cumulative aquifer head drawdown, the physical properties of the backfill aquifer and the water quality of the backfill aquifer. The mines generally have conservation practices in place to minimize water use by re-using water from any de-watering activities for industrial purposes such as dust suppression.

6.2.1 CUMULATIVE POTENTIOMETRIC SURFACE DRAWDOWNS

Pit inflows and dewatering in advance of the pit cause drawdown to the aquifers intersected by the mining pit. Water use by the mines results in drawdown to the aquifer tapped by the mine's facilities wells. The predicted drawdown in individual aquifers is analyzed below. The largest extent of drawdown, based on a predicted five foot of drawdown over the life of the individual mines, is in the Wyodak Anderson coal aquifer and is used as the basis for the CIA for groundwater impacts since the other impacts lie within that delineated area.

Impacts to local aquifers will occur as groundwater levels are drawn down, temporarily decreasing the quantity of groundwater available. Each mine evaluated the impacts based on site-specific characteristics such as hydraulic conductivity, mining sequence, and local geology. Mines usually model groundwater drawdown using the conservative, worst-case scenario. Therefore, it is unlikely that the actual drawdown will extend as far from the mine permit boundaries as predicted by the models. It is difficult to place precise numbers on the predicted time for groundwater recovery since each mine uses different predictive tools, modeling techniques, assumptions, and reports different recovery time periods. In general, drawdown in groundwater levels in both the coal and overburden will be greatest adjacent to the pit area and decrease with distance away from the mine.

6.2.1.1 ALLUVIAL AQUIFER

During mining, sections of the alluvial aquifer in the vicinity of the mines will be affected in various ways, such as by removal and replacement, drawdown due to the influences of the pit, dewatering due to temporary diversion of the stream, or increased water levels due to the infiltration of pit and pond discharges. In general, those effects are local and do not extend large distances beyond the permit area. Caballo Mine has alluvial sediments along Tisdale Creek and other tributaries to Caballo Creek, Belle Ayr Mine contains a segment of the alluvial aquifer along Caballo Creek and Cordero Rojo Mine has Belle Fourche River alluvial sediments within its permit area. All of the mines also contain alluvial sediments along smaller tributaries to Caballo Creek or the Belle Fourche River.

Cumulative effects to the alluvial aquifer are mitigated by the distribution of the alluvial sediments and the spatial distribution of the mines. The alluvial aquifer is continuous only along drainages. These sediments tend to form linear fingers trending in a west to east direction along the major drainages. The mines lie in a north to south distribution along the coal outcrop area. Thus, few of the impacts to the alluvial aquifer are cumulative in nature since the mines each tend to impact different sections of discrete alluvial sediments. In addition, most of the impacts are temporary in nature and will be mitigated upon reclamation of the mines. The changes of water levels and TDS concentrations over time were examined in three alluvial monitor wells (WRRI9, MA-35-1-P, and BAS 17 E). These wells were selected because each had records over approximately 20 years (from the early 1980's) to the early 2000's). Although water level fluctuations over time were noted, no systematic trends were apparent in the data.

Any discharge of backfill aquifer water in the alluvial aquifer, based on available data, should have approximately the same water quality as the baseline water quality pre-mining in the alluvial aquifer.

6.2.1.2 CLINKER AQUIFER

Disturbance of the clinker aquifer will be avoided at the mines, although some of the mines do use clinker deposits in unsaturated areas as construction material. Economic deposits of coal are usually located west of the clinker since the clinker's formation resulted from burning of the underlying coal. In some areas the clinker is dry and in other areas it is saturated. In some locations the clinker aquifer has very high hydraulic conductivity and, if disturbed, could result in significant water problems to a mine. Because of those potential problems, no significant impact to the clinker aquifer is projected.

There are three groundwater rights associated with the clinker aquifer in the CIA. Two of those water rights are for springs and will not be impacted by mining operations. The other water right is for a well which will be destroyed by mining at the Caballo Mine (Caballo Mine Permit, 2011).

The clinker aquifer is generally a recharge area for the coal and, after mining, for the backfill aquifer. Minimal water quality impacts due to mining are anticipated since groundwater flow is generally out of the clinker aquifer rather than into it. However, there may be local areas where the flow direction may be different and flow may be from the other aquifers into the clinker aquifer.

6.2.1.3 WASATCH LEAKY AQUITARD UNIT

Geological data collected by these mines document that the Wasatch Formation consists of a complex system of discrete lenticular sandstone units, interbedded with siltstones, claystones, conglomerates and localized lignite seams. When the Cordero Rojo Mine (Cordero Rojo Mine Permit, 2011) has encountered saturated sandstone lenses, groundwater flow decreases significantly over time, generally within a few days to weeks. This is a characteristic often associated with small perched aquifer systems. Cordero Rojo Mine (Cordero Rojo Permit, 2011, 2002-2004 Annual Report) de-waters the overburden with a combination of pumping wells, passive drains, and monitoring wells with the resulting water used for dust suppression.

Cumulative effects of mining on the Wasatch Leaky Aquitard Unit appear limited. Sandstone units are thin, discontinuous and interbedded with claystone and siltstone. The aquifer conditions are usually unconfined. All of those conditions limit the extent of groundwater impacts. The drawdowns predicted for individual mines are much smaller than the drawdowns predicted for the Wyodak Anderson coal aquifer. Predicted drawdowns in the Wasatch Leaky Aquitard Unit often lie within the permit areas, but in a few areas extend one-half mile to one and one-half miles to the east.

Mining and backfilling of the pit will cause the Wasatch Leaky Aquitard Unit to be in hydraulically connection with the backfill aquifer. This will allow groundwater to flow from one unit to the other depending on the hydraulic gradient. As a result, the overburden will lose groundwater to the backfill aquifer while the backfill aquifer saturates. When the backfill aquifer saturates, the natural gradient will re-establish. The Wasatch Leaky Aquitard Unit is predicted to recover asymptotically with 25 percent recovery occurring in the first 25 years, 75 percent recovery in 200 years and 100 percent recovery in 1,500 years (Caballo Mine Permit, 2011).

Generally the Wasatch Leaky Aquitard Unit has water quality that is suitable for livestock quality of use and any interaction between this unit and the backfill aquifer, based on available data and predictions should be also suitable for livestock quality of use.

6.2.1.4 WYODAK ANDERSON COAL AQUIFER

The most extensive impact is expected to the Wyodak Anderson coal aquifer. Cumulative groundwater impacts on the Wyodak Anderson coal aquifer were examined both spatially and temporally. The cumulative groundwater drawdown is not evaluated to the east because the Wyodak Anderson coal aquifer is truncated eastward due to natural erosion. Spatially, the potentiometric surface of the coal aquifer is examined using the worst-case cumulative drawdown developed from the mine permit predictions (outlined as the groundwater CIA on **Plate 1**) and EIS prediction (Bureau of Land Management, 2007). The predicted change in potentiometric surface due to drawdown from the CBM development as well as the coal mines on a basin scale from a BLM source is also included as a point of comparison (**Figure 36**). In that figure, Meyer (2000) compared the worst-case 5-foot drawdown for the coal mines (identified as the 1988 CHIA line) compared to the Wyodak EIS cumulative drawdown due to the CBM development alone and CBM and coal mining together. It can be seen on **Figure 36** that the effects of CBM are predicted to have a much larger magnitude basin-wide than the effects of coal mining.

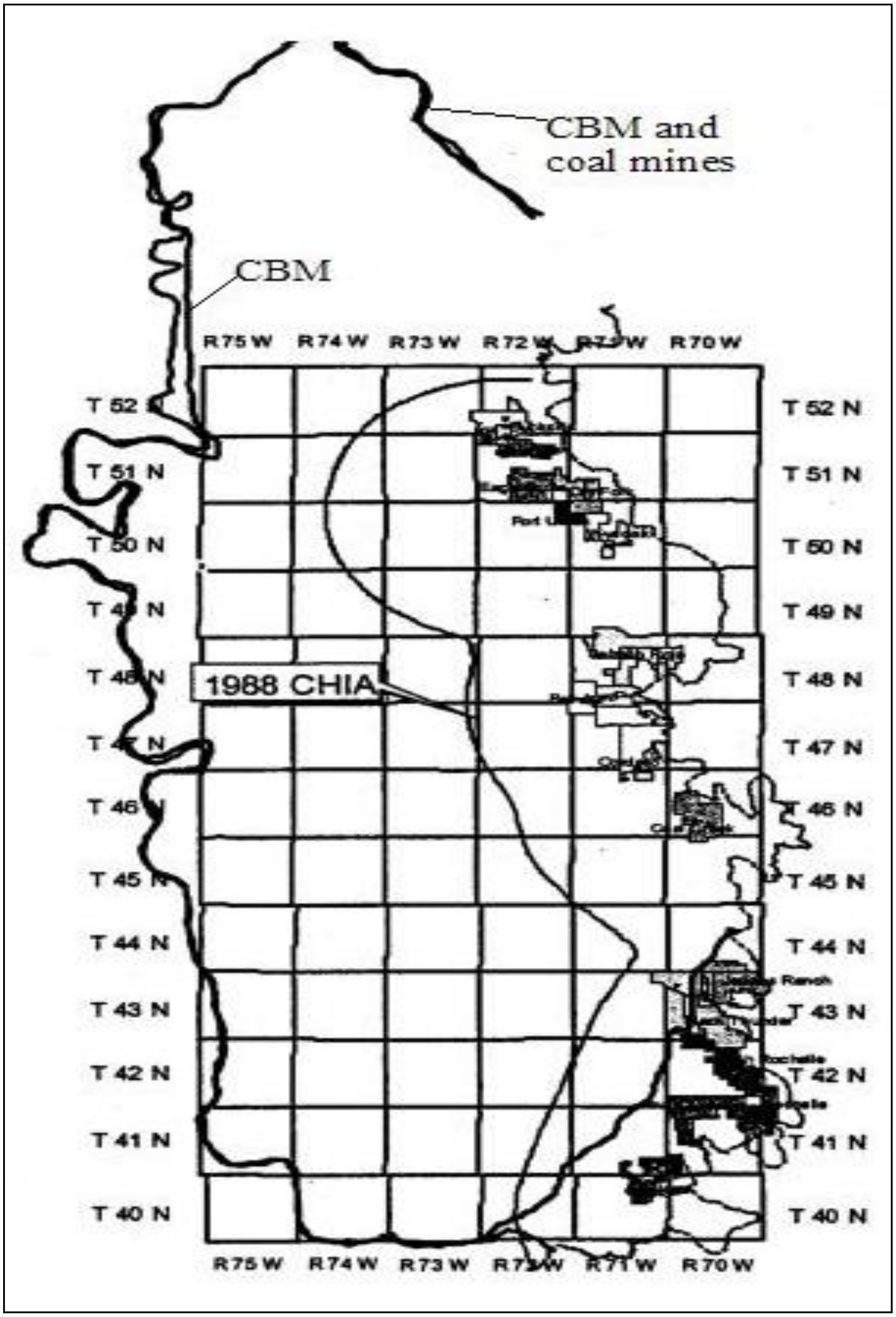


FIGURE 36. COMPARISON OF PREDICTED FIVE-FOOT DRAWDOWN CONTOURS IN THE COAL AQUIFER DUE TO COAL MINING AND TO COALBED METHANE DEVELOPMENT, POWDER RIVER BASIN, WYOMING (FROM MEYER, 2000).

For the purposes of predicting maximum worst-case cumulative drawdown, the Wyodak Anderson coal seam, with its rider and hanger seams, are considered to be a single unit. The predicted maximum five-foot drawdown contour from all five mines was superimposed and used to generate the CIA five-foot cumulative estimate (**Plate 1**). The drawdown extends eight to twelve miles to the west of the group of mines, about six miles to the north of the Caballo Mine and four miles south of the Coal Creek Mine.

Predictions of worse case drawdown are influenced by the modeling assumption as well as the time over which the pits are open. It is recognized that worse case analysis over-predicts the impacts. Predictions are compared to actual drawdown in the coal aquifer for the Cordero Rojo Mine in 1986 (**Figure 37**). The worse case prediction over-estimated the actual drawdown by about three times, with the predicted drawdown of the five foot contour extending over five miles to the east of the mine while the actual drawdown for the same time frame was under two miles. This difference is probably a result of several assumptions that are part of the predictive modeling process, with the most significant being the assumption of no leakage to the coal aquifer from the overlying and underlying units.

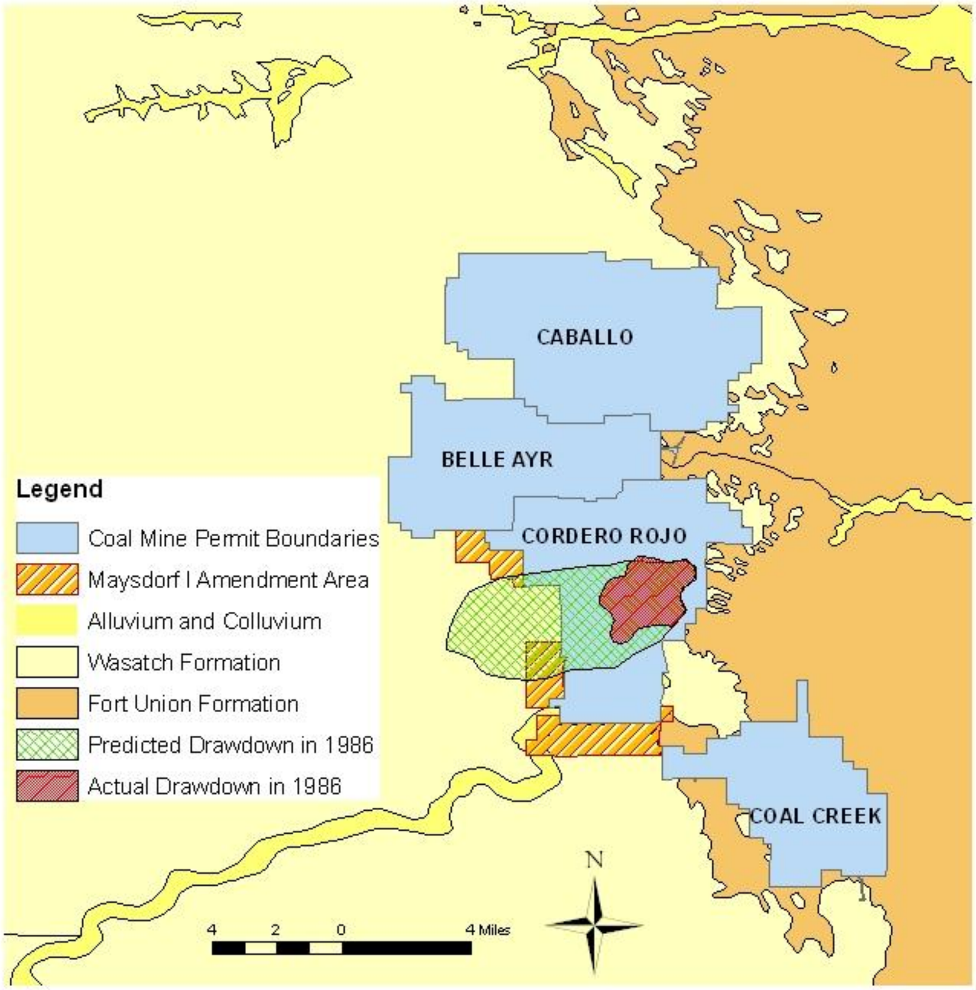


FIGURE 37. LOCATION OF THE COAL MINES AND THE MAYSDORF I AMENDMENT AREA AT THE CORDERO ROJO MINE, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Drawdown in individual wells varies by their proximity to the mine and to CBM development. In the Coal Creek Mine Permit (2011) the maximum drawdown experienced by 2000 was 45 ft in close proximity to the mine. As is noted by many other mines in the PRB, Coal Creek Mine is no longer able to obtain reliable data from monitor well CCR-35 in the southwest area of the mine due to gassy conditions which are usually attributed to the CBM development. Well MW-89-13-2C, a Cordero Rojo Mine coal monitor well, experienced an increased rate of drawdown in the last five years and had to be plugged due to gassy conditions (**Figure 38**).

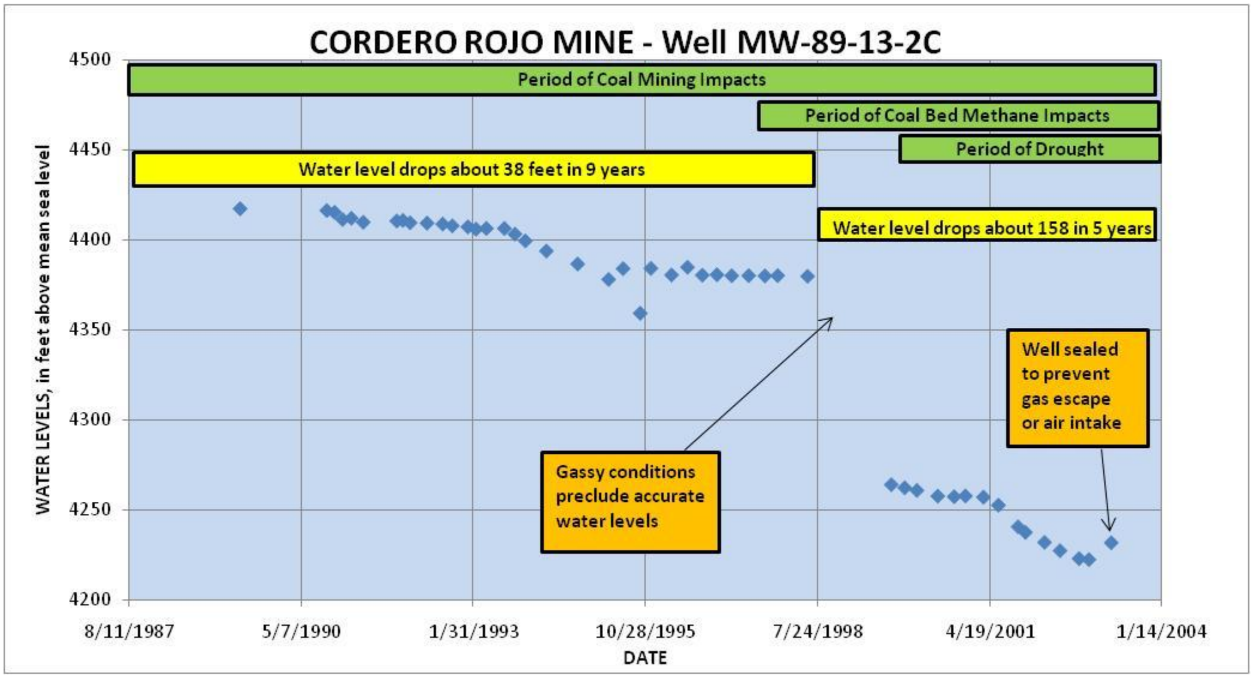


FIGURE 38. CHANGES IN WATER LEVELS OVER TIME AT A WYODAK ANDERSON COAL AQUIFER MONITOR WELL, CORDERO ROJO MINE, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Where the coal is mined, the excavation will be backfilled with spoils creating a backfill aquifer. With time, the backfill aquifer will begin to saturate. As part of that process the water levels will also begin to recover in the affected aquifers. The time frame predicted for recovery is very dependent on the assumed hydrologic conditions. Since recovery of the water levels is a log-normal relation with both time and space, only the center part of the backfill aquifer will take the full length of time to recover. After the initial rise in groundwater level, there will be small changes in water level until the system fully stabilizes. Cordero Rojo Mine Permit (2011) indicates that the time for complete recovery in both the bedrock aquifers and the backfill aquifer will be in 250 to 640 years. Caballo Mine permit (2011) estimated that 25 percent recovery of the Wyodak Anderson coal aquifer occurs in the first 5 years, 75 percent in 75 years and a 100 percent in 300 years.

6.2.1.5 INTERBURDEN AND UNDERBURDEN UNITS

Cumulative impacts on the interburden are insignificant. The interburden is thin and is comprised of discontinuous, interbedded claystone, siltstone, and sandstone. Therefore, any impacts are expected to be minimal within the mine permit boundaries. Underburden is a minor source of recharge to the overlying coal aquifer in some areas. Coal dewatering operations at the mines could cause an increase in groundwater flow from the underburden to the coal aquifer. However, the underburden consists of discontinuous, lenticular deposits of sandstone, siltstone, and claystone. Therefore, any impacts to the underburden are expected to be slight to non-existent.

6.2.1.6 TULLOCK AQUIFER

Mine facility wells will cause local drawdown in the deep Tullock Aquifer. Underburden consists of discontinuous sandstone layers interbedded with claystone and siltstone. Based on a U.S. Geological Survey study, impacts to the Tullock aquifer may only extend to one mile from the mine permit boundaries (Martin et al., 1988). For example, the Cordero Rojo Mine has two deep Fort Union Formation wells that are used to supply mine facilities. These two wells (Rojo No. 1 and Rojo 2A) are completed at 2,010 and 2,036 ft. Transmissivities of these two wells varied from 1,200 to 1,850 gpd/ft and averaged 300 gpm in yield. However, average annual pumping for the wells is considerably less than the yield. In 1989 the pumping rates varied from 34 to 84 gpm annually. Information and logs from these two wells indicated both wells are completed in the lower Tullock Member and produce the majority of their water from two lower sands in the 1,695 ft to 1,954 ft interval below land surface. The lithology at these wells indicated an aquitard separating the mine coal from the upper-most sandstone in the Fort Union Formation (Lower Tongue Member), below that sand layer is the Lebo Shale which was about 550 ft thick at well Rojo 2A. Most of the mine production wells in the middle PRB appear to be completed in the Upper Tullock Member, but some may be screened across other intervals. Because of various depths of completion in the Tullock Aquifer, cumulative effects are not anticipated.

6.2.1.7 BACKFILL AQUIFER

Plots of groundwater elevations versus time for wells listed on **Table 32** are provided in an Addendum to this report and show an overall positive trend of either increasing groundwater levels or groundwater levels that are steady, but still above the base year water level. Due to the progression of mining, the wells shown on the plots are typically located closer to the recharge area and so their recovery is likely faster than wells located in the backfill aquifer further to the west. As shown on the plots, fourteen of the wells have a groundwater elevation that is above the base year water level (GAGMO, 2010). Of these fourteen wells, nine show an overall increasing trend in groundwater elevation, i.e. groundwater levels are continuing to rise: two wells (BF-MW-90-2-1 and MB-26-3-P) are currently approximately 5-10 feet above baseline, four wells (RW2706, RW3407, CA-1539-B, and CCB-3) are approximately 15 feet above baseline, two wells (RW3304-1 and RW3401) are approximately 20-25 feet above baseline, and one well (CA-824-B) is over 40 feet above baseline. The remaining five wells where groundwater level elevations are above baseline show steady elevation levels over time. There are four wells where groundwater elevations are below base year levels but where water levels are showing an increasing trend (RW2902, RW3408, CA-1540-B, and CCB-1A). Groundwater elevations in these wells currently range from 20 to 60 feet below the base year water level. One well (RW2705) shows a steady groundwater elevation over time below the base year water level and three wells (RW2701, RW2804, and CA-969-) have sporadic groundwater levels that are routinely below the base year water level. Only one well (MB-26-1-P) shows a decreasing groundwater elevation trend that is also below the base year water level (currently approximately 7 feet below the base year level). Base year water level information was not available for six wells: four of these wells (RW3201, RW3405, RW3404, and MB-2-1-P) show an increasing groundwater elevation level and the remaining two wells without base year level information showed either a steady elevation or a sporadic level.

6.2.2 BACKFILL AQUIFER PHYSICAL CHARACTERISTICS

Where the coal is mined, the resulting excavation will be backfilled with spoils creating a backfill aquifer. This backfill aquifer will spatially lie between the clinker recharge area and the remaining coal that is too deep to be mined. The backfill aquifer will need to be sufficiently permeable to allow water to pass through it and recharge the remaining Wyodak Anderson coal aquifer and to yield water for post-mining land use. The backfill aquifers will likely have hydraulic conductivities at least that of the overburden and possibly even greater than the fractured coal, particularly at the base of the backfill or between the lifts of backfill material (Rahn (1976), Van Voast et al., (1976), and Van Voast et al., (1978).

In the model developed for Caballo Mine, a hydraulic conductivity for the backfill of 0.20 ft/d was used. This value is comparable to the low end of the range of values for the Wyodak Anderson coal aquifer and the Wasatch Leaky Aquitard Unit. Based on available data in the coal mine permits, it appears that the backfill aquifer will have sufficient permeability to allow interconnection between the clinker recharge area and the remaining coal aquifer. It also appears that the backfill aquifer will have sufficient permeability to yield quantities of water needed to meet the post-mining land use of livestock. Initial results in the southern part of the PRB indicate that the backfill aquifer is almost an order of magnitude more permeable than the pre-mining aquifers with the exception of the clinker. It is expected that there will be some loss of permeability with time as the clays swell within the backfill, compaction occurs and other physicochemical changes occur.

6.2.3 BACKFILL AQUIFER GROUNDWATER QUALITY

Groundwater flowing through a reclaimed backfill aquifer may become more mineralized because fresh mineral surfaces are exposed for chemical reaction in the backfill than in the undisturbed pre-mine strata. In addition, initial conditions in the backfill are probably more oxidized in comparison with the pre-mine conditions or with the conditions once the backfill is saturated. This increase in mineralization and difference in oxidation may affect the geochemical equilibrium and cause an increase in TDS and other constituents in groundwater.

Studies in the PRB indicate that the backfill water quality is similar to pre-mine overburden water quality (Van Voast and Hedges, 1975; Davis, et al., 1978). Van Voast (1974) indicated that the first groundwater to enter a backfill aquifer should dissolve a high percentage of the available salts.

However, subsequent groundwater would be less mineralized. This subsequent, less mineralized water probably results from the clay content of the backfill causing reduction and cation exchange. Davis, et al., (1978) found that chemical equilibrium was reached very quickly.

A total of 66 backfill aquifer monitor wells are reported in the coal mine permits. Of that total, 25 are discontinued and 41 are actively monitored. The distribution of backfill monitor wells by mine is given in **Table 29**. The Belle Ayr Mine has 45 percent of the backfill aquifer monitor wells. Caballo has 32 percent and Cordero Rojo has 20 percent. Only 3 percent of the backfill aquifer wells are in the Coal Creek Mine.

TABLE 29. NUMBER AND PERCENT OF BACKFILL AQUIFER MONITOR WELLS BY MINE FOR THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Mine	Number of Backfill Aquifer Monitor Wells	Percent of Backfill Aquifer Monitor Wells
Caballo	21	32
Belle Ayr	30	45
Cordero Rojo	13	20
Coal Creek	2	3

The time period of well completion, type of casing used, and the current number of monitor wells was also examined. The timeframe during which the wells were completed is summarized in **Table 30**. Approximately 14 percent of the backfill aquifer monitor wells were completed during the 1970-1979 period and approximately 52 percent of the backfill aquifer monitor wells were completed during the 1980-1989 period. Based on the available data, most of the backfill aquifer monitor wells were constructed with PVC casing but fourteen of the wells had steel casing. Over time, monitoring has been discontinued at 25 backfill aquifer monitor wells. However, 41 backfill aquifer monitor wells are actively monitored.

TABLE 30. THE RANGE OF YEARS OVER WHICH THE BACKFILL AQUIFER MONITOR WELLS WERE COMPLETED, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Year Range	Number of Clinker Monitor Wells Completed
1970-1979	9
1980-1989	34
1990-1999	14
2000-2009	5
Completion date not in database	4

Well depth was listed for all 66 of the backfill aquifer monitor wells. The depth varied based on the well location from 16 ft to 255 ft with a median depth of 125 ft. Approximately 42 percent of the wells have a completion depth of between 76 and 150 ft (**Figure 39**).

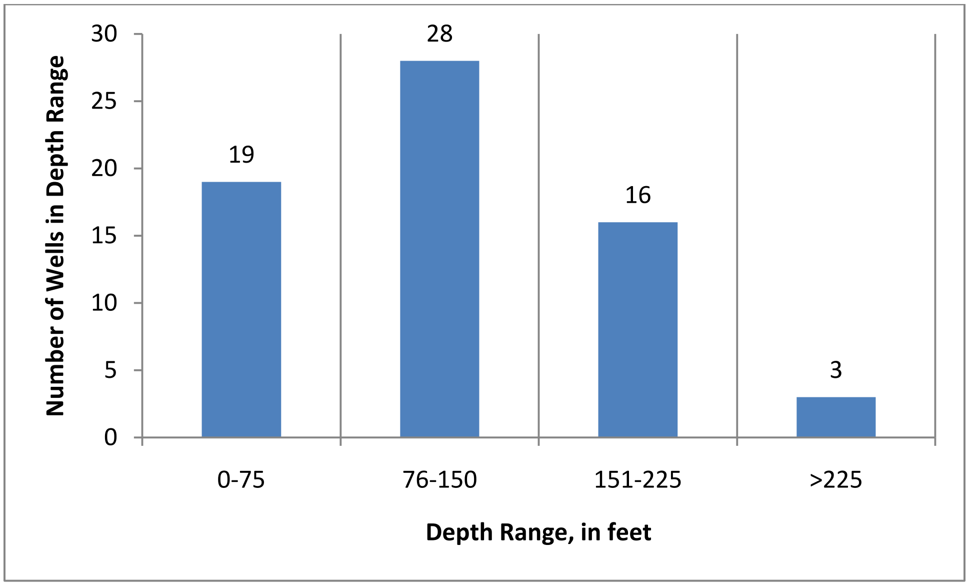


FIGURE 39. HISTOGRAM OF DEPTH OF BACKFILL AQUIFER MONITOR WELLS, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Data were compiled and analyzed for backfill aquifer based on information submitted by the middle PRB coal mines in their permits and annual reports for the period from 1977 to 2011. **Figure 40** shows the median concentration of the major ions and TDS in those samples. The median SO_4 and TDS concentrations are below the WQD livestock water standards of 3,000 mg/l for SO_4 and 5,000 mg/l for TDS.

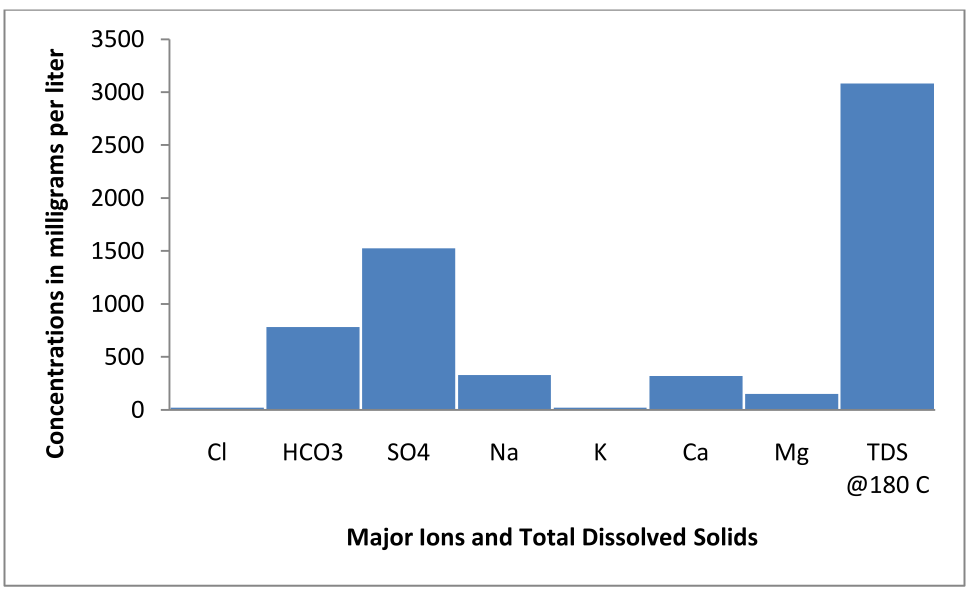


FIGURE 40. MEDIAN CONCENTRATION OF BACKFILL AQUIFER WATER SAMPLES, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

A comparison of the median concentrations of the major ions in the backfill aquifer to the other shallow aquifers in the area (**Table 31**) shows the water quality in the backfill aquifer is similar to the water quality in the Alluvial Aquifer, Clinker Aquifer, and the Wasatch Leaky Aquitard Unit.

TABLE 31. MEDIAN CONCENTRATION AND NUMBER OF SAMPLES FOR MAJOR IONS AND TOTAL DISSOLVED SOLIDS FROM THE ALLUVIAL AQUIFER, CLINKER AQUIFER, WASATCH LEAKY AQUITARD UNIT, WYODAK ANDERSON COAL AQUIFER, UNDERBURDEN UNIT, AND BACKFILL AQUIFER, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Constituent	Alluvial Aquifer		Clinker Aquifer		Wasatch Leaky Aquitard Unit		Wyodak Anderson Coal Aquifer		Underburden Leaky Aquitard Unit		Backfill Aquifer	
	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples	Median Concentration in mg/l	Number of Samples
Cl	32	1,405	9	195	16	1,367	11	1,364	13	157	20	1,786
HCO_3	503	1,359	333	172	485	1,131	795	1,395	674	154	782	1,248
SO_4	1,704	1,523	1,170	196	1,369	1,379	54	1,464	26	152	1,525	1,788
Na	292	1,513	91	193	255	1,368	248	1,496	220	156	329	1,772
K	13	1,513	32.2	192	13	1,364	9	1,489	9	156	20	1,773
Ca	361	1,509	373	192	258	1,362	62	1,485	39	152	320	1,769
Mg	167	1,512	99	192	98	1,368	26	1,489	18	155	151	1,773
TDS @180 C	3,345	1,190	2,353	194	2,568	1,268	932	1,133	717	158	3,080	1,709
Concentrations shown in red exceed the WYDEQ/LQD Domestic Class I standard												

Concentrations of TDS for individual wells in the middle PRB vary both in time and in space. **Table 32** lists the latest reported TDS values for backfill monitoring wells in the middle PRB mines. The concentrations vary from 700 mg/l to 6,305 mg/l TDS demonstrating the spatial variability of the backfill aquifer water quality. (Note that the lowest TDS concentration shown on **Table 32** is actually 570 mg/l for Well MB-26-3-P. However, this concentration is suspect because the previous TDS concentration from this well, collected on 8/1/2008, was 5,680 mg/l). This variability mirrors what was observed in the southern and northern areas of the PRB (Hoy, et al., 2003). Ogle (2004) found that higher TDS concentrations in the backfill aquifer were associated with proximity to drainage channels and clinker outcrops. The water type of the backfill aquifer, based on Aqua Chem (2004) analysis is Ca-SO_4, type (**Figure 41**). That is the same water type as the Wasatch Leaky Aquitard Unit which is the source of the backfill material.

TABLE 32. RECENT TOTAL DISSOLVED CONCENTRATIONS FOR INDIVIDUAL BACKFILL MONITOR WELLS IN THE MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Mine	Backfill Well	Date of Sample	Total Dissolved Solids at 180 C, in mg/L
BELLE AYR	RW2701	3/8/2007	2,272
BELLE AYR	RW2705	2/2/2005	1,450
BELLE AYR	RW2706	9/9/2009	3,660
BELLE AYR	RW2707	9/8/2009	4,580
BELLE AYR	RW2804	9/9/2009	1,320
BELLE AYR	RW2902	9/9/2008	3,440
BELLE AYR	RW3201	9/15/2009	4,100
BELLE AYR	RW3304-1	9/10/2009	4,970
BELLE AYR	RW3401	9/9/2009	4,400
BELLE AYR	RW3403	9/8/2009	2,000
BELLE AYR	RW3404	9/9/2009	1,870
BELLE AYR	RW3405	9/9/2009	4,970
BELLE AYR	RW3407	9/10/2009	980
BELLE AYR	RW3408	9/9/2009	1,150
BELLE AYR	RW3409	9/10/2009	2,890
CABALLO	CA-1449-B	1/30/2007	700
CABALLO	CA-1539-B	1/30/2007	1,210
CABALLO	CA-1540-B	1/30/2007	1,420
CABALLO	CA-724-B	8/17/2006	6,305
CABALLO	CA-824-B	11/9/2006	1,014
CABALLO	CA-969-B	8/17/2006	2,329
COAL CREEK	CCB-1A	12/22/2009	2,300
COAL CREEK	CCB-3	12/22/2009	3,240
CORDERO ROJO	BF-MW-90-2-1	9/21/2009	3,480
CORDERO ROJO	MB-13-1-P	9/17/2009	3,510
CORDERO ROJO	MB-2-1-P	9/17/2009	2,020
CORDERO ROJO	MB-26-1-P	9/21/2009	5,860
CORDERO ROJO	MB-26-2-P	9/21/2009	570
CORDERO ROJO	MB-26-3-P	9/21/2009	6,010

Note: The TDS concentration of 570 mg/l for Well MB-26-2-P is suspect. The previous TDS concentration collected on 8/1/2008 was 5,680 mg/l.

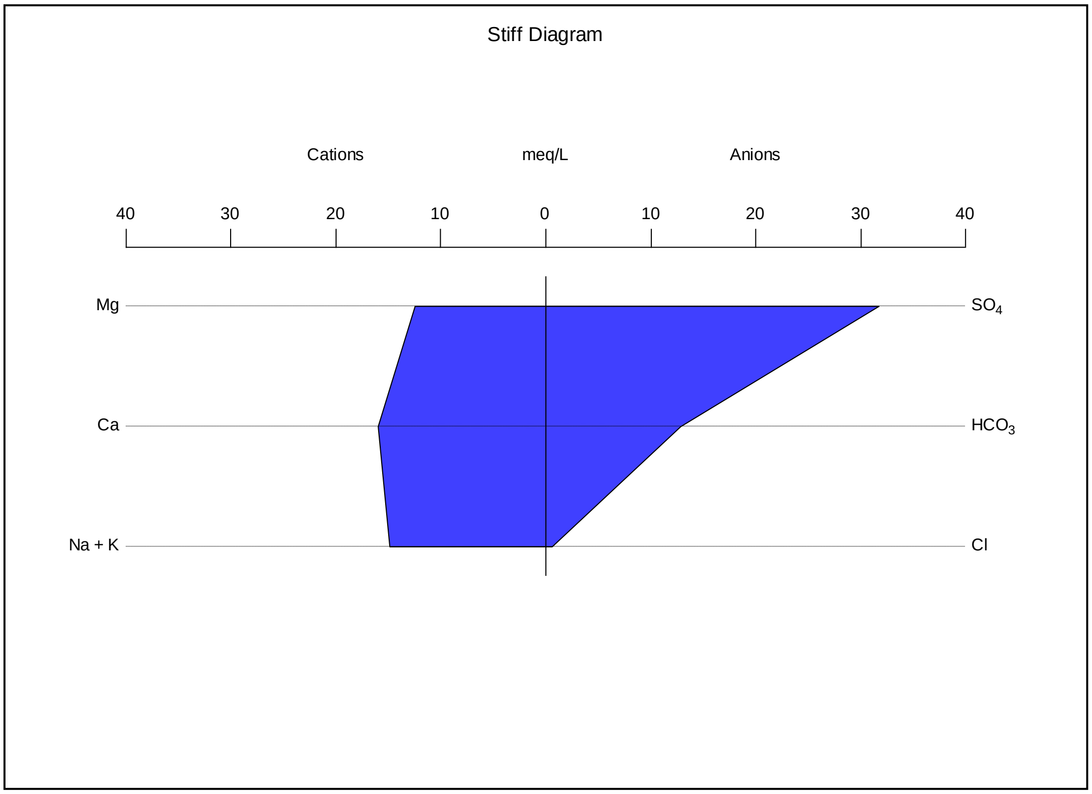


FIGURE 41. STIFF DIAGRAM OF MEDIAN CONCENTRATIONS OF WATER SAMPLES FROM THE BACKFILL AQUIFER, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Data in **Table 32** indicate that two wells at Cordero Rojo, and one well at Caballo have TDS concentrations in excess of 5,000 TDS. Most permits also include as discussion of the prediction that the groundwater quality in the backfill aquifer will improve with time due to flushing of the aquifer. Therefore, it is anticipated that the concentrations will not exceed pre-mine conditions, and the water will be suitable for the post-mine land use after reclamation and recovery are complete.

6.3 ALLUVIAL VALLEY FLOORS

The following section discusses during-mining and predicted post-mining impacts to AVFs in the Caballo Creek CIA. As discussed in Section 3.3, there are no declared AVFs in the BFR CIA. The analysis will focus on impacts to surface water quantity, surface water quality, alluvial water levels, and alluvial water quality. A material damage assessment is conducted for the Gold Mine Draw AVF that is significant to farming. The analysis will also be used to evaluate the maintenance and/or restoration of essential hydrologic functions on AVFs that are either grandfathered or not significant to farming.

6.3.1 CABALLO CREEK CIA

As discussed in Section 3.3.1, AVFs in the Caballo Creek CIA exist on Gold Mine Draw, the Gold Mine Draw/Tisdale Creek "confluence area", Caballo Creek, Bone Pile Creek, and Duck Nest Creek.

6.3.1.1 SURFACE WATER QUANTITY

As previously discussed, most of the AVF on Gold Mine Draw at the Caballo Mine cannot be mined because it has been declared an AVF significant to farming. In order to protect the area, the Caballo Mine placed a 200-ft buffer around the AVF. This buffer zone was enlarged to 1,200 feet in 1998 to prevent drawdown in the overburden underlying the alluvium in the buffer zone (Caballo Mine Permit, 2011). The buffer will help maintain the geometric characteristics of the Gold Mine Draw valley, which is one of the stated essential functions of the AVF. The Caballo Mine will also not disturb the existing impoundments in the valley, which provides up to 25 percent of the water used for irrigation in the AVF (Caballo Mine Permit, 2011).

As presented in Section 6.1.1.1, a comparison of seasonal runoff volumes between the upper and lower gaging stations on Gold Mine Draw was shown for the 1979 to 2009 period (**Figure 28**). With the exception of 2006, more runoff was recorded in each year at the lower station. There was no clear trend in changes in runoff at either station over time, and flows in the drainage appear to be affected by pre-mine impoundments. These results indicate that mining has not materially affected surface water quantity in the AVF and that essential hydrologic functions are being maintained.

Downstream of the significant AVF, Gold Mine Draw is a grandfathered AVF downstream to the confluence with Tisdale Creek. The mine also contains a grandfathered AVF on the Gold Mine Draw/Tisdale Creek "confluence area." The Caballo Mine predicts that the only disturbance to these AVFs may be caused by rail loop, which may interrupt subsurface flow to the alluvium. Long-term effects are predicted to be negligible since flows in Gold Mine Draw and Tisdale Creek are maintained by culverts and the facilities area and rail loop will be reclaimed after mining (Caballo Mine Permit, 2011).

At the Belle Ayr Mine, two reaches of Caballo Creek were declared to be grandfathered AVFs in the initial approval of the permit (**Figure 27**). The 134 ac "eastern AVF" has not been physically disturbed and continues to support subirrigated hayland. The 69.9 ac "western AVF" has been entirely mined through but not yet reconstructed.

An additional 33.2 ac AVF on Caballo Creek in the west portion of the mine was declared not significant to farming during the Duck Nest Tract determination in 1996. Around 68 percent of this AVF will be mined through. The construction of Phase II of the Caballo Creek Diversion No. 10 will also intercept flows to the AVF (Belle Ayr Mine Permit, 2011). The mine currently does not plan to mine this area, but has committed to monitoring and mitigating potential impacts of the diversion to the AVFs. Color infrared (CIR) photography will be analyzed from July in every other year. If the photography indicates a 20 percent reduction in the area of enhanced vegetation relative to the baseline conditions, flood irrigation or sprinkling of the AVF will be conducted. The mine also maintains alluvial monitoring wells to evaluate water levels in this portion of the AVF (Belle Ayr Mine Permit, 2011).

To date, the Belle Ayr Mine has only completed channel reconstruction on non-AVF portions of Caballo Creek. The mine plans to construct a single, contiguous 92.5 ac AVF on Caballo Creek in the west portion of the permit area upstream of Caballo Lake Reservoir (Belle Ayr Mine Permit, 2011). This single AVF will replace the "western AVF" and the portion of disturbed AVF declared in the Duck Nest Tract. The AVF reaches will be reconstructed to restore the pre-mine hydrologic functions. Pool/run sequences consisting of 18 pools will be constructed subgrade to the low-flow channel with a bottom width of 25 ft (Belle Ayr Mine Permit, 2011). A clay liner at least two feet thick will be used beneath and along the sides of the pool/run sequences. A 50-ft wide floodplain will be constructed on either side of the low flow channel. Materials for alluvial aquifer reconstruction will be derived from overburden sands or native alluvium provided that suitability requirements are met. The AVF will initially function solely on surface water flows until the potentiometric surface recovers. Approximately 50 days of flow will be needed to meet consumptive requirements, and this is expected to be similar to pre-mine conditions since AVF acreage is being replaced on a one-to-one basis. The AVF will not be fully functional until after mining when Caballo Lake Reservoir is completed. The reconstructed AVF will be monitored through alluvial wells, geomorphic stations, and channel surveys (Belle Ayr Mine Permit, 2011).

As presented in Section 6.1.1.4, an analysis of mean daily discharge by year over the 1984 to 2009 period was conducted for monitoring stations on Caballo Creek upstream and downstream of the Belle Ayr Mine (**Figure 29**). With the exception of one year, mean daily flows were higher at the downstream station in each year, indicating the Belle Ayr Mine has not materially affected surface water quantity. This also indicates that essential hydrologic functions are being maintained in the eastern AVF that has remained in agriculture production. Once the Caballo Creek AVF has been fully reconstructed, additional monitoring of surface water quantity will be needed to demonstrate the successful restoration of hydrologic functions.

The AVF on Duck Nest Creek at the Belle Ayr Mine comprises 24.3 ac and is not significant to farming (Belle Ayr Mine Permit, 2011). Approximately 65 percent of the AVF will be disturbed. Mining is currently occurring in the Duck Nest Creek drainage and AVF reconstruction has not taken place yet. The AVF will be reconstructed in the lower reaches of Duck Nest Creek to restore the pre-mine functions, which included an alluvial aquifer capable of providing 27 ac of subirrigation along the channel. This function will be replaced by four stockponds and alluvial aquifer reconstruction. The stockponds are expected to retain water and promote infiltration to the alluvium. An additional 11.2 ac of subirrigation will be created by constructing 4,300 ft of subirrigated channel to a width of 112 ft. Recovery of the AVF will initially rely on surface water until the potentiometric surface has recovered (Belle Ayr Mine Permit, 2011).

The AVF on Bone Pile Creek at the Belle Ayr Mine comprises 16 ac and is not significant to farming (Belle Ayr Mine Permit, 2011). None of the AVF acreage on Bone Pile Creek will be physically disturbed, although Phase II of the Caballo Creek Diversion No. 10 will intercept flows to a portion of the AVF between Highway 59 and the confluence with Caballo Creek. The Belle Ayr Mine will monitor the vegetation in the AVF using CIR photography and has developed a mitigation plan for potential impacts. Since the mine does not currently maintain a monitoring station on Bone Pile Creek, surface water quantity in the AVF cannot be directly assessed.

6.3.1.2 SURFACE WATER QUALITY

A statistical summary of surface water quality data at the stations on upper and lower Gold Mine Draw over the 1999 to 2010 period was presented in Section 6.1.1.1 in **Table 24**. The data indicate no change in water type or water quality conditions at either station over time. Although periodic exceedences of WDEQ/WQD surface water quality standards do occur, the mean and median concentrations of each constituent evaluated showed no exceedences over the 1999 to 2010 period. These findings indicate that material damage to surface water quality has not occurred and the essential functions of the Gold Mine Draw AVF are being supported.

Surface water quality in the Caballo Creek AVFs can be inferred using data from the BA-6 and BA-4 stations above and below the Belle Ayr Mine. A statistical summary of surface water quality data from these stations over the 1984 to 2009 period was presented in Section 6.1.1.6 in **Table 25**. Although periodic exceedences of WDEQ/WQD surface water quality standards do occur at both stations, the mean and median concentrations of each constituent evaluated showed no exceedences over the 1984 to 2009 period. The downstream station on Caballo Creek shows slightly better water quality, presumably due to the diluting effect of increased streamflow. These findings indicate that mining has not degraded surface water quality on Caballo Creek and the essential functions of the AVFs will be supported once reconstruction is complete.

Surface water quality in the Duck Nest Creek and Bone Pile Creek AVFs at the Belle Ayr Mine cannot be directly assessed since the mine does not maintain a monitoring station in either drainage. Surface water quality in these drainages is expected to be similar to Caballo Creek.

6.3.1.3 ALLUVIAL WATER LEVELS

The Caballo Mine maintains several alluvial wells within the Gold Mine Draw and Tisdale Creek/Gold Mine Draw "confluence area" AVFs. Three of these wells were selected to evaluate water levels over time: well CA-791-A in the portion of the Gold Mine Draw AVF significant to farming, well CA-674-A in the Gold Mine Draw grandfathered AVF, and well CA-657-A in the Tisdale Creek/Gold Mine Draw "confluence area" AVF. Well CA-791-A has 25 years of water level data available, while the other two wells have nearly 30 years of data. The period of record water levels at the three wells is presented in **Figure 42**. Water levels in wells CA-674-A and CA-657-A have been stable over time, indicating the Caballo Mine has not impacted the AVFs on lower Gold Mine Draw and the Tisdale Creek/Gold Mine Draw confluence area (**Figure 42b,c**).

At well CA-791-A within the significant AVF, water levels have shown upward and downward trends over time (**Figure 42a**). From 1984 to 1992, levels generally decreased approximately seven feet. Water levels then increased until 1995, and then decreased until 2006. From 2006 to 2009, water levels have increased again and remain at levels similar to initial measurements in 1984 (**Figure 42a**). These changes appear to be related to changes in precipitation, as precipitation accounts for a major source of recharge to the alluvial groundwater in the AVF (Caballo Mine Permit, 2011). The data suggest the alluvial water levels in the Gold Mine Draw AVF have not been materially impacted by mining, and that the potential for flood irrigation and subirrigation has been maintained. The establishment of the 1,200 ft buffer zone helps maintain water levels in the alluvium in the AVF. In the event that water levels in the AVF decline significantly below historic levels, and CIR photography indicates a greater than 20 percent reduction in enhanced vegetation, the Caballo Mine will provide supplemental water to the AVF in order to facilitate irrigated agriculture and recharge of the alluvium (Caballo Mine Permit, 2011).

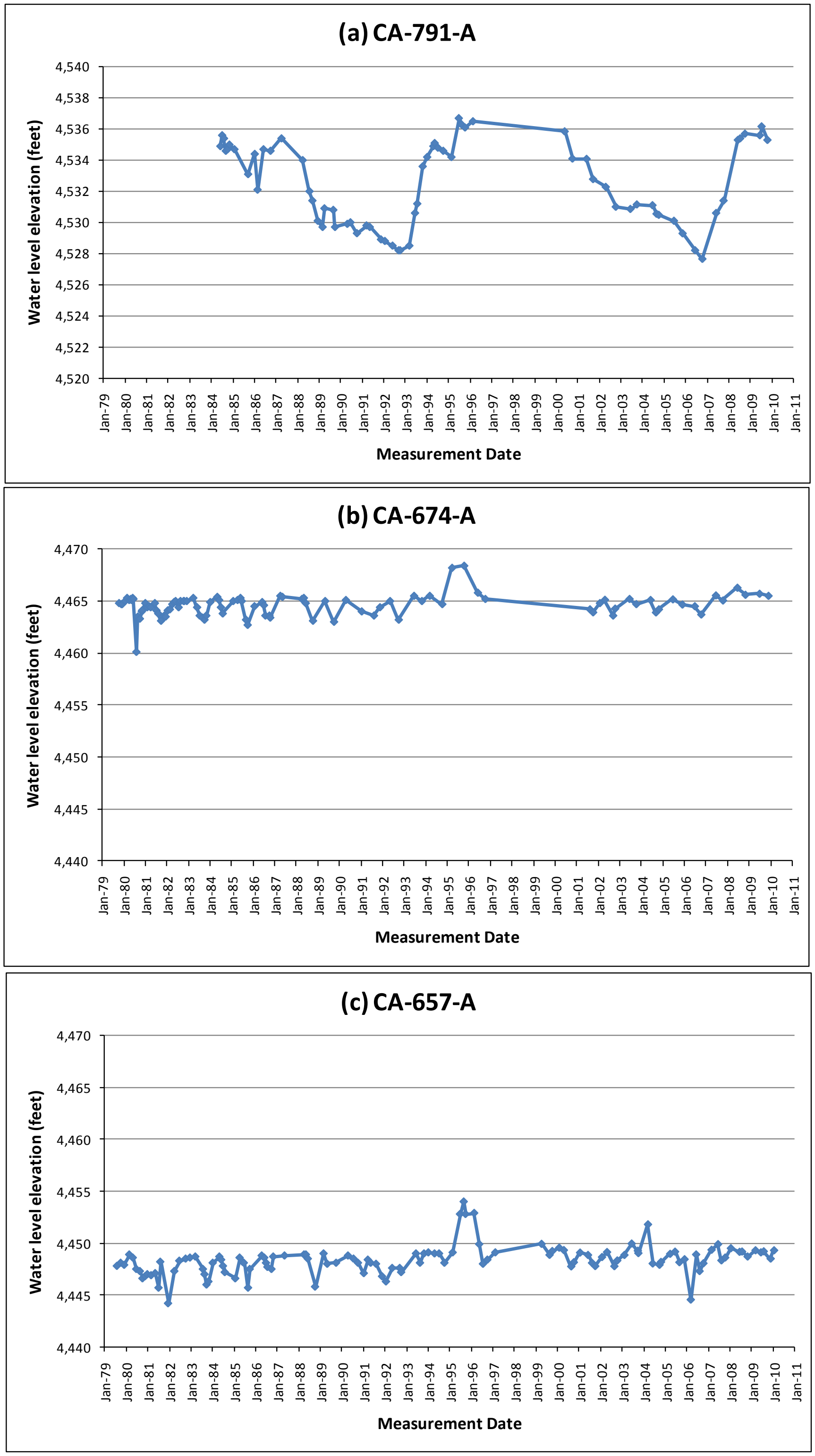


FIGURE 42. WATER LEVEL ELEVATIONS OVER TIME IN SELECTED ALLUVIAL WELLS AT THE CABALLO MINE: (A) CA-791-A IN THE GOLD MINE DRAW AVF SIGNIFICANT TO FARMING, (B) CA-674-A IN THE GOLD MINE DRAW GRANDFATHERED AVF, AND (C) CA-657-A IN THE GOLD MINE DRAW/TISDALE CREEK CONFLUENCE AREA GRANDFATHERED AVF, MIDDLE POWDER RIVER BASIN, WYOMING, 2011. [NOTE Y-AXIS SCALE IS DIFFERENT FOR (A)].

Two alluvial wells in the Caballo Creek AVF were selected to evaluate water levels and water quality over time: well WRRI9 in the undisturbed "eastern AVF" and well AV1-2 in the upper Caballo Creek AVF near Highway 59. WRRI9 has been active since 1975, and has several years of daily water level data available. AV1-2 was installed in 1986, but only ten years of data (1999-2009) are available in the WDEQ/LQD Hydrology Database for analysis. Water levels at both wells are plotted in **Figure 43**. Water levels at both wells have been relatively stable over time. At WRRI9, water levels have shown seasonal variation in response to periods of higher runoff, and annual variation in response to changes in precipitation inputs (**Figure 43a**). During most of the period of record, fluctuations have been less than a few feet. The data suggest the alluvial water levels in the AVF have not been impacted by mining, and that the potential for subirrigation has been maintained. At AV1-2, water levels have shown little variation over the past ten years, with the exception of a December 2001 drop of ten feet that may be a result of a measurement error (**Figure 43b**).

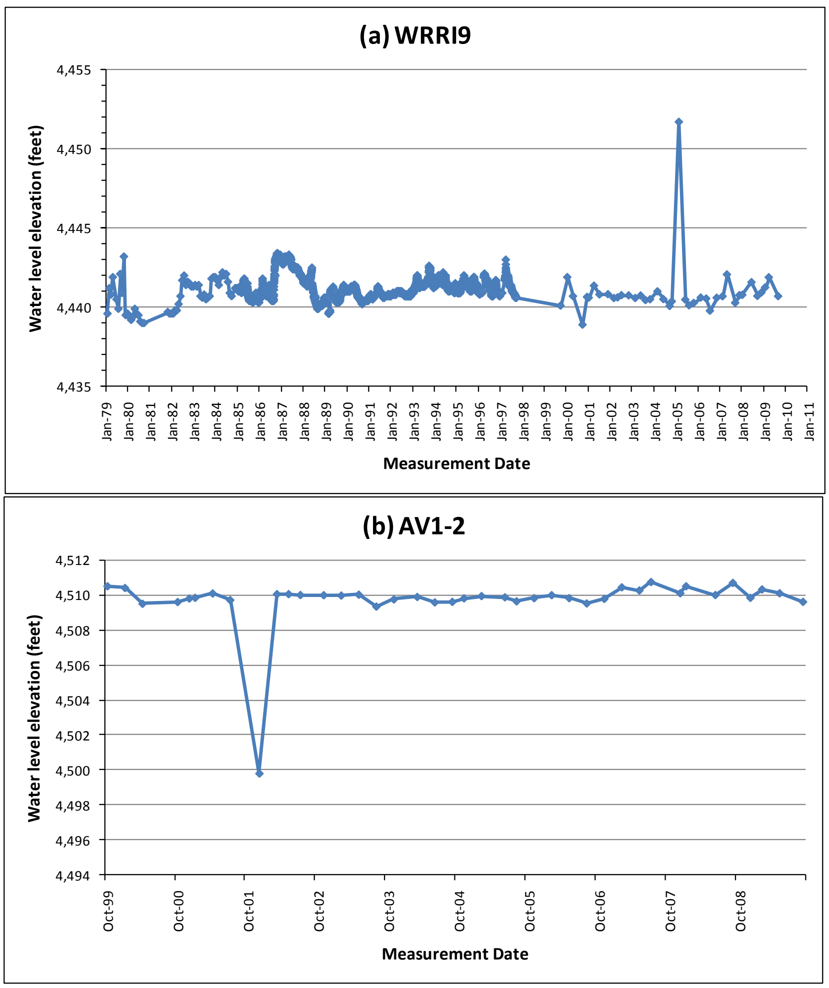


FIGURE 43. WATER LEVEL ELEVATIONS OVER TIME IN SELECTED ALLUVIAL WELLS IN THE CABALLO CREEK AVFS AT THE BELLE AYR MINE: (A) WRRI9 IN THE EASTERN AVF AND (B) AV1-2 IN THE UPPER AVF, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

The Belle Ayr Mine does not currently maintain any alluvial monitoring wells in the Duck Nest Creek and Bone Pile Creek AVFs. Therefore, an analysis of alluvial water levels in these AVFs cannot be conducted.

6.3.1.4 ALLUVIAL WATER QUALITY

Alluvial water quality data for the AVFs at the Caballo Mine was assessed using the same wells evaluated in Section 6.3.1.3 for alluvial water levels. However, water quality data for the three wells was much more limited in the WDEQ/LQD Hydrology Database. It is also noted that the 2007-2009 sample data from wells at the Caballo Mine do not explicitly state that TDS was measured at 180 degrees C. TDS concentrations from 26 samples collected from 1984 to 2009 at well CA-791-A in the significant AVF on Gold Mine Draw ranged from 315 to 2,960 mg/l, with a median of 1,135 mg/l (**Figure 44**). There were some short-lived increases and decreases in concentrations over time, but overall the data show that WDEQ/WQD Class III groundwater quality standards were met for livestock use. This indicates that the Caballo Mine has not caused material damage to alluvial water quality in the AVF and that essential hydrologic functions are being maintained.

TDS concentrations have been higher at the other two wells in the downstream AVFs at the Caballo Mine. At well CA-674-A in the grandfathered AVF on Gold Mine Draw, TDS concentrations have been mostly stable, ranging from 2,550 to 3,475 mg/l, with a median of 2,822 mg/l (**Figure 44**). At well CA-657-A in the Gold Mine Draw/Tisdale Creek "confluence area" AVF, the median TDS concentration is 3,356 mg/l, and there has been a slight decrease in concentrations over time (**Figure 44**). This indicates that mining has not degraded alluvial water quality in the AVF.

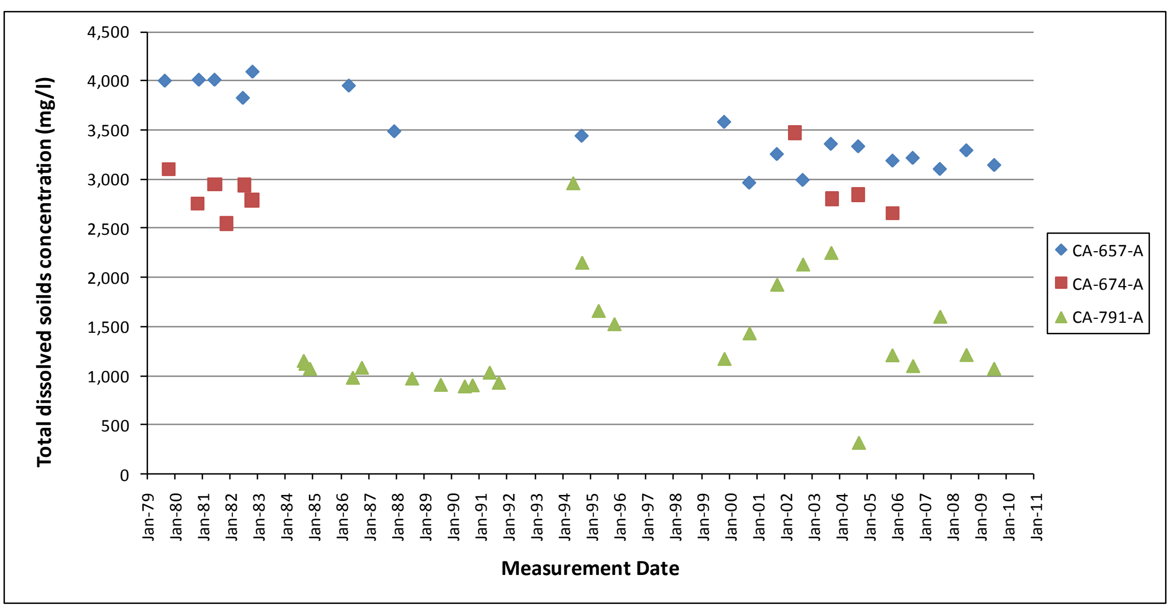


FIGURE 44. TOTAL DISSOLVED SOLIDS CONCENTRATIONS IN SELECTED ALLUVIAL WELLS AT THE CABALLO MINE: CA-791-A IN THE GOLD MINE DRAW AVF SIGNIFICANT TO FARMING, CA-674-A IN THE GOLD MINE DRAW GRANDFATHERED AVF, AND CA-657-A IN THE GOLD MINE DRAW/TISDALE CREEK CONFLUENCE AREA GRANDFATHERED AVF, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

Alluvial water quality in the Caballo Creek AVFs at the Belle Ayr Mine was assessed using the same wells evaluated in Section 6.3.1.3 for alluvial water levels. TDS @ 180 degrees C concentrations from 45 samples collected from 1986 to 2009 at well WRRI9 in the eastern AVF ranged from 1,360 to 3,886 mg/l, with a median of 2,238 mg/l (**Figure 45**). There were some short-lived increases and decreases in concentrations over time, but overall the data show that WDEQ/WQD Class III groundwater quality standards were met for livestock use. This indicates that mining has not degraded alluvial water quality in the AVF and essential hydrologic functions are being maintained. TDS @ 180 degrees C concentrations were higher at well AV1-2 in the upstream AVF, ranging from 3,611 to 4,300 mg/l, with a median of 3,908 mg/l (**Figure 45**). The surface water quality data above and below the Belle Ayr Mine also showed a decrease in TDS @ 180 degrees C concentrations in the downstream direction, presumably due to the diluting effect of higher streamflows.

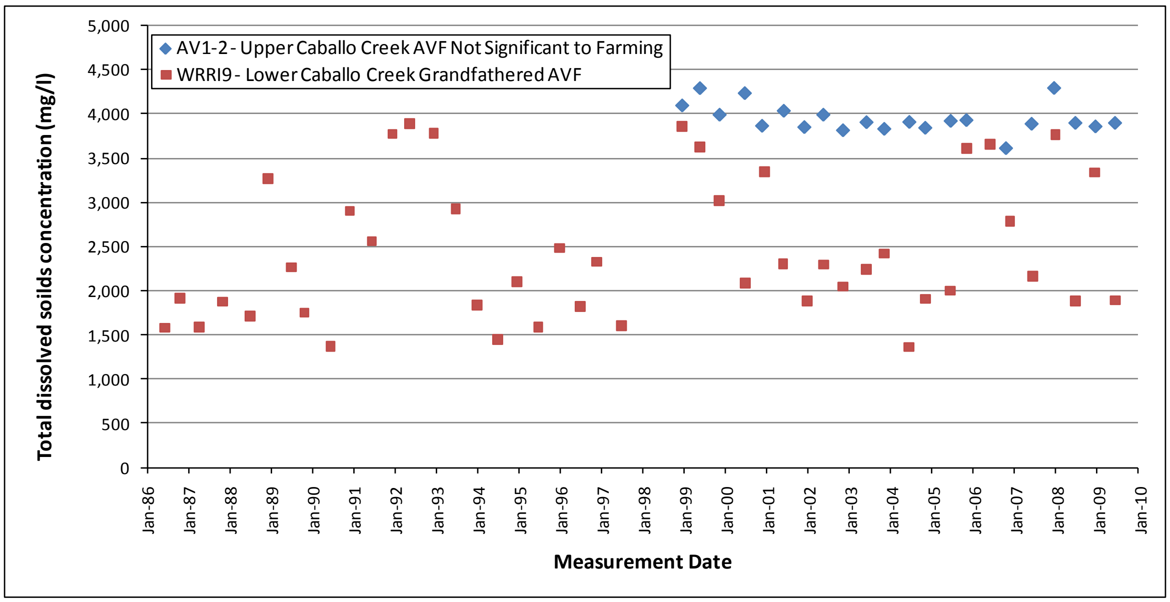


FIGURE 45. TOTAL DISSOLVED SOLIDS @ 180 DEGREES C CONCENTRATIONS IN SELECTED ALLUVIAL WELLS IN THE CABALLO CREEK AVFS AT THE BELLE AYR MINE: WRRI9 IN THE EASTERN AVF AND AV1-2 IN THE UPPER CABALLO CREEK AVF, MIDDLE POWDER RIVER BASIN, WYOMING, 2011.

As previously mentioned, the Belle Ayr Mine does not currently maintain any alluvial monitoring wells in the Duck Nest Creek and Bone Pile Creek AVFs. A review of baseline water quality from one well in each AVF indicated poor alluvial water quality with TDS @ 180 degrees C concentrations often exceeding 10,000 mg/l. Once the Duck Nest Creek AVF has been reconstructed, alluvial wells will be installed to monitor water levels and water quality, which will be used to assess the restoration of essential hydrologic functions (Belle Ayr Mine Permit, 2011).

7. MATERIAL DAMAGE POTENTIAL

The potential for material damage from coal mining was evaluated for the CIAs.

7.1 SURFACE WATER

The potential for the proposed and existing coal mining to cause material damage to surface water quantity and quality in the Caballo Creek and BFR CIAs was evaluated.

7.1.1 WATER QUANTITY

Surface water quantity has been evaluated to determine if coal mining will cause cumulative impacts to downstream surface water rights. The available surface water quantity data have been evaluated for the baseline and during-mining periods in each of the major drainages within the two CIAs. Specific data elements evaluated included mean daily flows, peak flows, flow duration, and monthly, seasonal, and annual runoff volumes. In addition to this analysis, the assessment considered factors such as the proximity of downstream water rights, extent of dewatering, extent of surface disturbance, extent and capacity of water retention features, and changes to post-mine drainage basins. Material damage to surface water quantity is presumed to occur if the analysis demonstrates that coal mining has caused or will cause a decrease in surface water quantity such that downstream surface water rights will be materially affected.

7.1.1.1 CABALLO CREEK CIA

The baseline flow data for Caballo Creek at USGS Station No. 06425900 spans a relatively short time period, making it difficult to completely characterize the pre-mine hydrology of the CIA. Nonetheless, the available data suggest a reasonable understanding of flow characteristics under normal or average conditions. Runoff is driven by snowmelt and short-duration, high intensity rainfall events. Streamflow records from USGS Station No. 06425900 as well as the mine stations indicate that precipitation and antecedent moisture conditions have a large control on runoff response. The variability in precipitation inputs over space and time makes it difficult to detect changes in runoff that can be attributed to mining activities alone. Gaining and losing reaches, along with losses and inputs due to impoundments or permitted discharges, further hamper the ability to detect changes in runoff due to mining.

Two of the mines in the Caballo Creek CIA are classified as AOC, which means that there is sufficient spoil available to construct a PMT that is similar to pre-mine conditions, conceding that there may be some overall reduction in elevation. The Belle Ayr Mine is designated as thin overburden, meaning that there is insufficient material available to restore the landscape to AOC. In either case, the mines have documented pre-mine geomorphic characteristics to ensure appropriate reconstruction and function in the PMT. As a result of material removed, the topography will be lowered and hillslope gradients will be reduced, resulting in a potential reduction in peak flows. A comparison of pre-mine and post-mine drainage basin characteristics at the mines indicate the two are mostly similar, suggesting little change in runoff potential. Each mine permit contains modeled runoff simulations for storms of varying intensity and duration; these models show minor changes in water quantity under the projected reclaimed conditions.

Although the mines in the Caballo Creek CIA have the capacity to divert water around the mining operations, it is reasonable to expect a short-term reduction in water yield due to water retention in the diversion structures, mining pits, sediment basins, and flood control reservoirs. Many of these structures are necessary to protect downstream water quality. Some of this water is used for other purposes such as dust suppression, and this amount may increase in dry years. Permitted discharges from CBM activity have also affected streamflows in Caballo Creek, although this source of water is expected to continue to decline as CBM production decreases in the watershed.

All surface water rights within the mine permit areas and within one half-mile radius have been identified and the probable impacts evaluated. There are no surface water rights on Caballo Creek downstream of the Belle Ayr Mine permit boundary. Water rights have been obtained for Caballo Lake Reservoir, which is the largest permanent post-mining impoundment in the CIA. Analysis by the Belle Ayr Mine indicates there should be no impacts to downstream water right holders on the Belle Fourche River. A bypass will be constructed on Caballo Lake Reservoir in the event a water call is made. The bypass will be capable of routing 20 cfs, which is greater than the appropriated amount for downstream water rights. The other proposed permanent post-mining impoundments at the mines in the CIA will have a storage capacity and contributing drainage area similar to or less than pre-mine conditions. All impoundments will be permitted with the WSEO. Therefore, the impoundments are not expected to impact post-mining streamflows, and no material damage to surface water rights is expected. In the event that a non-mine water right is impacted by mining activities, the law and permits require water supply to be replaced by a source suitable in quantity and quality. The potential for material damage to water rights downstream of the mines is therefore minimal.

Continuous streamflow monitoring has not been conducted on Caballo Creek at the mouth of the CIA since 1983, so a direct assessment of during-mining water quantity at the CIA scale is not possible. However, an analysis of 25 years of mean daily streamflow data on Caballo Creek upstream and downstream of the Belle Ayr Mine showed that flows are consistently higher downstream of the mine. This indicates surface water quantity on Caballo Creek has not been materially affected.

Only approximately 11 percent of the Caballo Creek CIA has been disturbed by life-of-mine impacts at the Caballo, Belle Ayr, and Cordero Rojo mines. The 11 percent also includes lands that are in some stage of reclamation, so the amount of land that is physically disturbed at any given point in time would be much lower. The Maysdorf I Amendment will add approximately 1,300 ac to the Cordero Rojo Mine permit within the Caballo Creek CIA. Assuming all of this acreage is disturbed at once, which is not proposed by the mine plan, the portion of mining related disturbance in the CIA increases to only 12 percent. The practice of contemporaneous reclamation helps limit the amount of cumulative disturbance present at the mines. Considering the size of CIA (260 mi^2), the likelihood of measuring water quantity changes that would be persistent and detectable at USGS Station No. 06425900 is small. Therefore, the potential for material damage to water quantity downstream of the mines is minimal.

7.1.1.2 BELLE FOURCHE RIVER CIA

Similar to the USGS gage on Caballo Creek, the baseline flow data for the two USGS stations on the Belle Fourche River spans a short time period, making it difficult to characterize the pre-mine hydrology of the CIA. Runoff is driven by snowmelt and short-duration, high intensity rainfall events. Streamflow records from the USGS stations as well as the mine stations indicate that precipitation and antecedent moisture conditions have a large control on runoff response. This variability in precipitation inputs over space and time makes it difficult to detect changes in runoff that can be attributed to mining activities alone.

Following coal removal, drainages at the Cordero Rojo and Coal Creek mines will be reconstructed to the approximate original contour. As a result of material removed, the topography will be lowered and hillslope gradients will be reduced, resulting in a potential reduction in peak flows. Watershed and stream morphology has been characterized in detail to ensure appropriate reconstruction and function in the PMT. A comparison of pre-mine and post-mine drainage basin characteristics indicate the two are mostly similar, suggesting little change in runoff potential. Each mine permit contains modeled runoff simulations for storms of varying intensity and duration; these models show minor changes in water quantity under the projected reclaimed conditions.

It is reasonable to expect some amount of short-term reduction in water yield in the BFR CIA due to retention in mining pits, sediment basins, diversion structures, and flood control reservoirs. Many of these structures are necessary to protect downstream water quality. The proposed permanent impoundments will have a storage capacity and contributing drainage area similar to or less than pre-mine conditions. All impoundments will be permitted with the WSEO. Therefore, post-mining impoundments are not expected to impact post-mining streamflows, and no material damage to surface water rights is expected.

All surface water rights within the mine permit areas and within one half-mile radius have been identified and the probable impacts evaluated. The Cordero Rojo Mine uses diversions to route the BFR around the active mining area to support maintenance of streamflows for downstream water rights. In the event that a non-mine water right is impacted by mining activities, the law and permits require water supply to be replaced by a source suitable in quantity and quality. The potential for material damage to water rights downstream of the mines is therefore minimal.

Analysis of 15 years of streamflow data on the BFR above and below the Cordero Rojo Mine showed that flows are typically higher downstream of the mine. A diversion of the main channel may have decreased streamflow at the downstream station, but this impact appears short-term, having only occurred during a few years of the record. The overall record shows that streamflows are higher downstream of the mine, indicating that surface water quantity on the BFR has not been materially affected by the mining operations.

Only approximately three percent of the BFR CIA has been disturbed by life-of-mine impacts at the Cordero Rojo and Coal Creek mines. This total also includes lands that are in some stage of reclamation, so the amount of land that is physically disturbed at any given point in time would be much lower. The Maysdorf I Amendment will add approximately 3,114 ac to the Cordero Rojo Mine permit within the BFR CIA. Assuming all of this acreage is disturbed at once, which is not proposed by the mine plan, the portion of mining related disturbance in the CIA increases to approximately four percent. The practice of contemporaneous reclamation helps limit the amount of cumulative disturbance present at the mines. Considering the size of CIA (594 mi^2), the likelihood of measuring water quantity changes that would be persistent and detectable at the mouth of the CIA on the BFR is small. Therefore, the potential for material damage to water quantity downstream of the mines is minimal.

7.1.2 WATER QUALITY

Material damage to surface water quality was assessed by determining if mining has caused or will cause a significant long-term or permanent adverse change such that WDEQ/WQD surface water quality standards and classes of use are no longer met. The available sample data have been analyzed for the baseline and during-mining periods in each of the major drainages of the two CIAs. Summary statistics have been compiled, and water quality has been compared between baseline and during-mining periods, as well as upstream and downstream of mining activity. The frequency of water quality standard exceedences has been examined. Material damage is presumed to occur when the median concentrations of a given constituent exceed WDEQ/WQD surface water standards for class of use, the available evidence suggests that the cause of exceedences is due to coal mining activity, and the change is permanent or long-term.

7.1.2.1 CABALLO CREEK CIA

Water quality data collected during the baseline period at the USGS station on Caballo Creek showed that water quality standards were satisfied for Class 2ABww waters. With the exception of mercury, the median concentrations of all constituents evaluated were within Class 2ABww standards. Baseline water quality data from mine stations on Gold Mine Draw, North Tisdale Creek, Tisdale Creek, Duck Nest Creek, and Bone Pile Creek were more limited in the WDEQ/LQD Hydrology Database for analysis. However, the available data showed that Class 3B water quality standards were generally met with the exception of occasional exceedences of dissolved metals.

The during-mining water quality data analyzed from the Belle Ayr Mine stations on Caballo Creek and the USGS station at the mouth of Caballo Creek indicate few changes with respect to the number and type of water quality exceedences. A comparison of 25 years of water quality data on Caballo Creek above and below the Belle Ayr Mine indicated the downstream station has slightly better water quality, presumably due to the diluting effect of increased streamflows. Occasional exceedences of Class 2ABww standards were noted at both stations, but the median concentrations of all constituents evaluated were within class of use standards. At the USGS station at the mouth of Caballo Creek, Class 2ABww standards were also typically met, although there were occasional exceedences noted for selenium. The median concentrations of all constituents evaluated were within class of use standards. Ten years of water quality data were also evaluated on the Gold Mine Draw tributary to Tisdale Creek. Occasional exceedences of Class 3B standards were noted, but appear related to natural factors and not mining. The overall results from the water quality data from the Caballo Creek CIA show that mining operations have not caused material damage to surface water quality.

Reclamation practices at each mine will help ensure that the post-mine surface water quality is similar to the pre-mine water quality. Some of the relevant reclamation practices include: (1) salvaging and replacing topsoil in a manner that prevents compaction, protects erosion, and conserves soil moisture, (2) covering all unsuitable spoils with a minimum of four feet of suitable material prior to replacing topsoil, with the thickness of suitable material increasing to eight feet in areas underlying major drainages, and (3) designing reconstructed landscapes to be erosionally stable, which will help minimize soil loss. The increase in sediment yield during mining is being mitigated through detailed sediment control plans, and point source discharges are monitored by the WYPDES program. All permanent impoundments are designed to meet the water quality criteria associated with the designated land use.

The limited amount of disturbance relative to the size of the Caballo Creek CIA makes it unlikely that water quality changes would be detectable at the point of accumulation at USGS Station No. 06425900. Dilution from water outside the permit areas also would help negate impacts to water quality. Therefore, the cumulative impact of the mines on water quality in the Caballo Creek CIA appears to be negligible. No material damage to water quality is expected. The addition of the Maysdorf I Amendment to the Cordero Rojo Mine is not expected to significantly change hydrologic conditions such that material damage to water quality would occur.

7.1.2.2 BELLE FOURCHE RIVER CIA

Water quality data collected during the baseline period at the USGS station on Coal Creek showed that water quality standards were satisfied for Class 3B waters, although very few samples were collected. The median concentrations of all constituents evaluated were within Class 3B standards. Baseline water quality data from the USGS stations on the BFR showed very few exceedences of Class 2ABww standards, although the downstream station showed slightly higher frequency of exceedence. With the exception of mercury at both stations, the median concentrations of all constituents examined met Class 2ABww standards.

The during-mining water quality data analyzed from the Coal Creek Mine station on Coal Creek showed higher frequency of water quality exceedences compared to the baseline period. The Class 3B standard for selenium was exceeded in 11 samples, although the median concentration was below the standard. The reasons for the high frequency of exceedences for selenium are not known, and it is not clear if mining is a factor. One contributing factor for the exceedences may be due to the low streamflows under which the samples were collected.

At the stations on the BFR above and below the Cordero Rojo Mine, the during-mining dataset showed no constituents where the median concentration exceeded Class 2ABww standards. The data indicate a slight improvement in water quality at the downstream station, which indicates the mining operations have not caused material damage to surface water quality. Selenium concentrations in 91 percent of samples at the downstream station were less than detection limits, indicating that the higher selenium values observed in the upstream tributary of Coal Creek have not been routed to the mouth of the CIA.

The median turbidity value at the downstream station on the BFR is over six times higher than the value at the upstream station. Additional analysis of turbidity, TSS, and streamflow showed that natural sediment inputs from Coal Creek are the likely causes for the increase in turbidity between BFR stations. These findings are supported by the baseline suspended sediment monitoring conducted by the USGS from 1977 to 1983 on Coal Creek and the BFR. The results indicate that the increased TSS and turbidity at the downstream station on the BFR are not due to mining activities. Overall, the comparison of water quality between the BFR stations indicates that mining has not degraded water quality on the BFR and WDEQ/WQD class of use standards are being met.

Reclamation practices at the Cordero Rojo and Coal Creek mines will help ensure that the post-mine surface water quality is similar to the pre-mine water quality. Some of the relevant reclamation practices include: (1) salvaging and replacing topsoil in a manner that prevents compaction, protects erosion, and conserves soil moisture, (2) covering all unsuitable spoils with a minimum of four feet of suitable material prior to replacing topsoil, with the thickness of suitable material increasing to eight feet in areas underlying major drainages, and (3) designing reconstructed landscapes to be erosionally stable, which will help minimize soil loss. The increase in sediment yield during mining is being mitigated through detailed sediment control plans, and point source discharges are monitored by the WYPDES program. All permanent impoundments are designed to meet the water quality criteria associated with the designated land use.

The limited amount of disturbance relative to the size of the BFR CIA makes it unlikely that water quality changes would be detectable at the point of accumulation at the Lower Belle Fourche River monitoring station at the Cordero Rojo Mine. Therefore, the cumulative impact of the mines on water quality in the BFR CIA appears to be negligible. No material damage to water quality is expected.

7.2 GROUNDWATER

Each mine quantitatively predicts the maximum extent of groundwater drawdown in the impacted aquifers, and evaluates potential effects of the backfill aquifer's physical characteristics and the backfill aquifer's water quality. These predicted effects were compiled, cumulated, and evaluated in CIA for groundwater. Although coal mining will have impacts, based on current data and analysis, the potential for material damage appears limited.

7.2.1 CUMULATIVE POTENTIOMETRIC SURFACE DRAWDOWNS

There are two concerns related to cumulative aquifer-head drawdowns on material damage. The first concern is the loss of the use of individual water wells due to drop in hydraulic head. The second concern is the amount of time that it will take for the aquifer potentiometric surface to recover.

The predicted maximum worst-case extent of the five-foot drawdown contour in the coal aquifer, based on cumulation of groundwater modeling results, will occur approximately eight to twelve miles west from the mine boundaries and about six miles south of Coal Creek Mine and four miles north of the Caballo Mine. At that distance, a loss of five feet of hydraulic head is predicted. The Wyodak Anderson coal aquifer is not present east of the mines due to natural, pre-historic erosion, so the coal outcrop becomes a natural boundary to the east. Actual data (Cordero Rojo Mine Permit, 2011) indicates the five-foot drawdown contour predicted using worse case analysis over estimates the extent of the drawdown by about three times based on a comparison of Cordero Rojo Mine's predicted and actual drawdowns for 1986. Predictions (Bureau of Land Management, 2003) of the drawdown of hydraulic head due to CBM are larger than the coal mining effects and may mask these predicted drawdowns.

Impacts to water supplies are addressed on an individual basis either by the WSEO interference process or by Wyoming Statute 35-11-415(b)(xiii) and 35-11-416 (b) which requires, within the constraints of the law, replacement of a water supply that has been affected by surface coal mine operations. The individual mine permits generally discuss the methods they would implement to assure that this requirement can be met, if needed. Some common methods are lowering the pumps, extending the depth of the well in the current aquifer, or replacing the well with a new well completed in a deeper aquifer. The mine permits evaluate wells within three miles of their permit area as required by the LQD permitting process.

Based on groundwater modeling results, groundwater elevations in the coal aquifer will recover 25 percent within the first 5 years after mining ceases, 75 percent within 75 years, and 100 percent within 300 years (Caballo Mine Permit, 2011). Some other mines predict a longer period of time. Most of the model area recovers much faster than 300 years, and only the most interior backfill locations require this long recovery period. The recovery of the water levels appears to be primarily predicated on the assumption of sufficient storage in the Wyodak Anderson coal aquifer to allow the recovery. These predictions do not include the effects of CBM dewatering.

Few wells, except monitoring and CBM wells, are completed in the coal seams west of the mines in the CIA because as the coal dips to the west, the depth to coal increases. As a result, many of the wells west of the mines are completed in the overlying Wasatch Leaky Aquitard Unit. The cumulative drawdown in the Wasatch Leaky Aquitard Unit is predicted to extend from one-half mile to one and one-half mile from the mine-permit boundaries. Because of the limited extent, fewer groundwater wells in the Wasatch Leaky Aquitard Unit will be affected by cumulative aquifer head drawdown. The Wasatch Leaky Aquitard Unit and the backfill aquifer follow a similar log normal recovery pattern as the Wyodak Anderson coal aquifer, but are predicted to take from 250 to 1,500 years to completely recover, with 25 percent of the recovery occurring in 25 years. Impacts are not expected to be permanent and material damage is not expected.

7.2.2 BACKFILL AQUIFER PHYSICAL CHARACTERISTICS

The backfill aquifer will be a groundwater sink until it saturates. Once the backfill saturates and the hydraulic head in the other aquifers recover, groundwater flow will approximate pre-mine groundwater flow conditions. With time, soil and root structure will develop and the infiltration rate into backfill may increase, thereby decreasing runoff and possibly decreasing surface flow to streams. However, if post-mine infiltration into the backfill is greater than pre-mine conditions, the backfill aquifer will likely saturate more quickly and any groundwater discharge to the streams will occur earlier than predicted.

If the backfill aquifer developed a very low hydraulic conductivity, it would interrupt the recharge to the Wyodak Anderson coal aquifer from the clinker aquifer and not yield sufficient water to meet post-mine land use. Initial aquifer tests performed in the reclaimed backfill has provided information on the hydraulic conductivity of the backfill shortly after reclamation. The hydraulic conductivity of the backfill was comparable to the range of hydraulic conductivity calculated for coal, overburden, and alluvial aquifers. With time, it is predicted that the backfill will settle and consolidate and the hydraulic conductivity will decrease somewhat but should remain comparable to pre-mine conditions.

7.2.3 BACKFILL AQUIFER WATER QUALITY

The predicted backfill aquifer groundwater quality was examined to determine if it will be of suitable quality to meet post-mining land use and its impact on surrounding aquifer quality. Initially, TDS concentrations are predicted to increase in the backfill aquifer. With time, the TDS concentrations are predicted to decrease and approach pre-mine groundwater quality or pre-mining quality of use. A comparison of the water quality in the backfill aquifer to the water quality in the alluvial, clinker, Wasatch Leaky Aquitard Unit and the Wyodak Anderson coal aquifer demonstrate that the backfill aquifer has elevated constituents as compared to those aquifers. However, even with the changes in TDS and other constituents, groundwater quality in the backfill aquifer in most instances would meet the same use classification of livestock as the pre-mine groundwater in the mined area. The median concentrations of major ions in the backfill aquifer generally meet the livestock water quality standards.

As water saturates the backfill aquifer and moves from the backfill into the undisturbed aquifers, the water quality of the undisturbed aquifers may increase in TDS and other constituents. It is predicted, based on coal mine permit information and published literature, after one to three pore volumes of backfill water move from the backfill into the undisturbed aquifer, a decrease in water quality is expected. The change will depend on the amount of mixing and geochemical precipitation, and ion exchange that occur. It is not expected that the water quality in the unaffected aquifers will increase over their pre-mining class of use, since the backfill aquifer will be suitable for livestock use as are the adjacent aquifers. The potential for the mines in the CIA to have a cumulative impact on groundwater quality is present, but based on current information and predictions the impact is not predicted to cause material damage.

7.3 ALLUVIAL VALLEY FLOORS

AVFs in the Caballo Creek CIA exist on Gold Mine Draw, the Gold Mine Draw/Tisdale Creek "confluence area", Caballo Creek, Bone Pile Creek, and Duck Nest Creek. The potential for material damage is only assessed for the Gold Mine Draw AVF since it has been determined to be significant to farming. The other AVFs are either not significant to farming or are grandfathered with respect to farming significance because the mine produced coal prior to the passage of SMCRA in 1977.

The potential for material damage to the significant AVF on Gold Mine Draw at the Caballo Mine is low. An analysis of surface water quantity, surface water quality, alluvial water levels, and alluvial water quality was completed to evaluate material damage potential and the maintenance of essential hydrologic functions. The available data show that mining has not caused impacts to the AVF and essential hydrologic functions are being maintained. Protection measures by the Caballo Mine, including a 1,200 ft buffer zone, will ensure that the functions of the AVF are supported throughout the mining operation.

The essential hydrologic functions have been identified on the non-significant AVFs on Caballo Creek, Duck Nest Creek, and Bone Pile Creek at the Belle Ayr Mine. AVFs that will not be disturbed will be monitored to ensure that the essential hydrologic functions are maintained during mining. An analysis of surface water quantity, surface water quality, alluvial water levels, and alluvial water quality was completed to evaluate the maintenance of essential hydrologic functions. The available data suggest that the essential functions are being maintained on the undisturbed AVFs on Caballo Creek and Bone Pile Creek. The Belle Ayr Mine has developed reconstruction plans for the Duck Nest Creek AVF and the portion of the disturbed Caballo Creek AVF to ensure the essential hydrologic functions are restored after mining. Future monitoring will be necessary to assess restoration of functions on AVFs that have been disturbed and reconstructed.

8. MATERIAL DAMAGE STATEMENTS OF FINDINGS

An affirmative finding is made that the approval of the Maysdorf I Amendment at the Cordero Rojo Mine, in conjunction with the already approved coal mining at Caballo, Belle Ayr, Cordero Rojo, and Coal Creek mines, will not result in material damage to the hydrologic balance outside the permit area and will not materially damage the Gold Mine Draw AVF.

8.1 SURFACE WATER

8.1.1 WATER QUANTITY

8.1.1.1 CABALLO CREEK CIA

Current mining at the Caballo, Belle Ayr, and Cordero Rojo mines is not expected to cause long-term or permanent damage to surface water quantity in the Caballo Creek CIA. The additional mining proposed by the Maysdorf I Amendment at the Cordero Rojo Mine is also not expected to cause material damage to surface water quantity.

Although approximately 11 percent of the Caballo Creek CIA is scheduled for mining-related disturbance through the life of mining, the actual amount of disturbance at a given point in time is much less. This makes it unlikely that water quantity changes would be persistent and detectable at the point of accumulation at USGS Station No. 06425900 on Caballo Creek. Therefore, the potential for material damage to water quantity downstream of the mines is minimal.

Due to the limited impact area, there should be no impact to water rights downstream of the Caballo Creek CIA. There are no water rights on Caballo Creek downstream of the mines. Water rights have been identified on the Belle Fourche River downstream of the mines, although the Belle Ayr Mine indicates that official water calls have never been made. There will be a net increase in storage capacity on Caballo Creek due to Caballo Lake Reservoir, and seepage losses may result in minor decreases in water yield downstream. Impacts to downstream water rights are not expected, and a diversion will be constructed on the reservoir to bypass flows in the event a water call is made. The potential for material damage to water rights downstream of the mines is therefore minimal.

8.1.1.2 BELLE FOURCHE RIVER CIA

Current mining at the Cordero Rojo and Coal Creek mines is not expected to cause long-term or permanent damage to surface water quality in the BFR CIA. The additional mining proposed by the Maysdorf I Amendment at the Cordero Rojo Mine is also not expected to cause material damage to surface water quantity.

Only approximately three percent of the BFR CIA is scheduled for mining-related disturbance through the life of mining, and the actual amount of disturbance at a given point in time is much less. This makes it unlikely that water quantity changes would be persistent and detectable at the point of accumulation at the Lower Belle Fourche River monitoring station at the Cordero Rojo Mine. Therefore, the potential for material damage to water quantity downstream of the mines is minimal.

Surface water rights exist on the BFR downstream of the mines, but impacts are not expected. The Cordero Rojo Mine uses diversions to route flows in the BFR around the mining operation, and monitoring data from above and below the mine indicate that flows have not been affected. The proposed permanent impoundments at the mines will have a storage capacity and contributing drainage area similar to or less than pre-mine conditions. Post-mining impoundments are not expected to impact post-mining streamflows. Therefore, no material damage to surface water rights is expected.

8.1.2 WATER QUALITY

8.1.2.1 CABALLO CREEK CIA

Current mining at the Caballo, Belle Ayr, and Cordero Rojo mines is not expected to cause long-term or permanent damage to surface water quality in the Caballo Creek CIA. The additional mining proposed by the Maysdorf I Amendment at the Cordero Rojo Mine is also not expected to cause material damage to surface water quality.

A comparison of the baseline vs. during-mining and upstream vs. downstream water quality data indicates that impacts from coal mining have been minimal. Data from stations on Caballo Creek above and below the Belle Ayr Mine indicate an improvement in water quality downstream of the mines, presumably due to the diluting effects of increased streamflow. WDEQ/WQD surface water quality standards for Class 2ABww and Class 3B waters have been satisfied for the majority of constituents evaluated. Occasional exceedences of dissolved metals and physical constituents have occurred, but in most cases these were also observed in pre-mining sampling and at monitoring stations upstream from mining activity. The during-mining median concentrations of all constituents evaluated are within WDEQ/WQD standards for Class 2ABww and Class 3B waters. WDEQ/WQD surface water quality standards in the Caballo Creek CIA should continue to be satisfied during and after mining.

The limited amount of disturbance relative to the size of the Caballo Creek CIA makes it unlikely that water quality changes would be detectable at the point of accumulation at USGS Station No. 06425900. Therefore, the cumulative impact of the mines on water quality in the Caballo Creek CIA appears to be negligible. No material damage to water quality is expected.

8.1.2.2 BELLE FOURCHE RIVER CIA

Current mining at the Cordero Rojo and Coal Creek mines is not expected to cause long-term or permanent damage to surface water quality in the BFR CIA. The additional mining proposed by the Maysdorf I Amendment at the Cordero Rojo Mine is also not expected to cause material damage to surface water quality.

A comparison of the baseline vs. during-mining and upstream vs. downstream water quality data indicates that impacts from coal mining have been minimal. Data from stations on the BFR above and below the Cordero Rojo Mine indicate a slight improvement in water quality downstream of the mines. WDEQ/WQD surface water quality standards for Class 2ABww waters have been satisfied for the majority of constituents evaluated. Occasional exceedences of dissolved metals and physical constituents have occurred, but in most cases these were also observed in pre-mining sampling and at monitoring stations upstream from mining activity. The during-mining median concentrations of all constituents evaluated are within WDEQ/WQD standards for Class 2ABww waters. WDEQ/WQD surface water quality standards in the BFR CIA should continue to be satisfied during and after mining.

The limited amount of disturbance relative to the size of the BFR CIA makes it unlikely that water quality changes would be detectable at the point of accumulation at the Lower Belle Fourche River monitoring station at the Cordero Rojo Mine. Therefore, the cumulative impact of the mines on water quality in the BFR CIA appears to be negligible. No material damage to water quality is expected.

8.2 GROUNDWATER

The potential for material damage to the hydrologic system in relation to groundwater is greatest for drawdown of the water levels in the aquifers, physical changes to the reclaimed backfill aquifer and changes in water quality related to the backfill aquifer. Each of those issues is addressed individually.

8.2.1 CUMULATIVE POTENTIOMETRIC SURFACE DRAWDOWNS

Groundwater drawdown was modeled by the mines and cumulated together for evaluation. The maximum worse-case extent of the five-foot groundwater drawdown contour in the Wyodak Anderson coal aquifer is expected to occur approximately eight to twelve miles from the mine permit western boundaries. Groundwater monitoring data has shown the five-foot drawdown estimated by worst case analysis over-estimates the extent of the drawdown by about three times (Cordero Rojo Mine Permit, 2011). Under the worse case analysis, the groundwater in the coal aquifer is predicted to recover 25 percent within the first 5 years after mining ceases, 75 percent within 75 years, and 100 percent within 300 years (Caballo Mine Permit, 2011). LQD Coal Rules and Regulations require coal mines to mitigate impacts to individual wells.

CBM production is an active industry in the PRB proximate to the coal mines. CBM production generally consists of pumping groundwater from the coal aquifer to lower the potentiometric head. This reduces the confining pressure on the methane in the coal allowing the methane to flow and be collected at recovery wells. During the process large quantities of groundwater are removed from the coal aquifer structurally down dip from the coal mines. At the time of this report, CBM development has occurred throughout the eastern portions of the PRB. Groundwater drawdown caused by CBM projects might impact the coal mines in the next several years and is predicted to generally exceed the impacts from the surface coal mines.

Pre- and post-mine potentiometric surfaces for the Wasatch Leaky Aquitard Unit will be similar. The maximum extent of the five-foot groundwater drawdown contours is expected to occur within one-half mile to one and one-half mile from the mine permit boundaries. Mining and subsequent backfilling will hydraulically connect the overburden, interburden, and underburden with the backfill aquifer. As a result, recovery of the potentiometric surfaces for these units depends on saturation of the backfill aquifer. As the backfill aquifer saturates, the Wasatch Leaky Aquitard Unit will likewise re-saturate. The Wasatch Leaky Aquitard Unit and the backfill aquifer follow a similar log normal pattern, but are predicted to take from 250 to 1,500 years to completely recover, with 25 percent of the recovery occurring in 25 years. Impacts are not expected to be permanent and material damage is not expected.

In addition, the mines are required to mitigate water rights impacted by surface coal mining.

8.2.2 BACKFILL AQUIFER PHYSICAL CHARACTERISTICS

Reclaiming pits with backfill results in a reconstructed aquifer with physical properties different from the pre-mine aquifer. The hydraulic conductivity of the backfill aquifer will be transient. Initial tests indicate that the median hydraulic conductivity is larger or comparable to the median hydraulic conductivity for the alluvial aquifer Wasatch Leaky Aquitard Unit and Wyodak Anderson coal aquifer. It is projected that the backfill aquifer will settle and consolidate with time. As a result, it is anticipated that the hydraulic conductivity of the backfill will decrease somewhat and may approach the hydraulic conductivity of the surrounding undisturbed materials. However, the backfill aquifer characteristics will be sufficiently permeable to restore the hydrologic balance.

Until the backfill aquifers saturate, the backfill will be a groundwater sink. Post-mine groundwater flow patterns are expected to approximate pre-mine flow patterns after the backfill aquifer saturates. In some areas, groundwater/surface water interactions may have the backfill aquifer as a water source instead of the original coal aquifer. Physical changes to the aquifers by backfill placement are expected to be insignificant and material damage is not anticipated.

8.2.3 BACKFILL AQUIFER GROUNDWATER QUALITY

Studies on reclaimed backfill aquifers in the PRB indicate that post-mine groundwater quality in backfill aquifers will approximate pre-mine groundwater quality (Van Voast and Hedges, 1975; Davis, et al., 1978) and this was confirmed by examination of the preliminary backfill water quality data in the CIA. Pre-mine groundwater quality in all aquifers varied but in most instances was suitable for livestock watering or lower quality. Available information indicates post-mine groundwater quality will also vary but will likely meet livestock or lower quality criteria similar to pre-mine groundwater quality. Transient impacts to groundwater quality in the backfill aquifer are expected, such as an initial increase in TDS and SO_4 followed by decreased concentrations. Permanent adverse impacts to groundwater quality are expected to be minimal and water quality is expected to meet livestock use. Material damage is not anticipated.

8.3 ALLUVIAL VALLEY FLOORS

AVFs are present in the Caballo Creek CIA but not the BFR CIA. There is low potential for material damage to the Gold Mine Draw AVF at the Caballo Mine that is significant to farming. Establishment of a buffer zone and other protection measures will help ensure that material damage does not occur and the essential hydrologic functions of the AVF are maintained. An analysis of surface water quantity, surface water quality, alluvial water levels, and alluvial water quality data support this finding. Similar analyses indicate that the essential hydrologic functions of the other undisturbed AVFs in the Caballo Creek CIA are being supported. Disturbed AVFs in the CIA on Caballo Creek and Duck Nest Creek have not been reconstructed. Future monitoring will be necessary to evaluate the restoration of essential hydrologic functions on these AVFs as reclamation proceeds.

8.4 DETERMINATION OF MATERIAL DAMAGE

Based on existing information, the WDEQ/LQD has determined that the additional mining impact of the Maysdorf I Amendment at the Cordero Rojo Mine to the surface coal mine operations in the middle PRB CIA, including the Caballo, Belle Ayr, Cordero Rojo, and Coal Creek mines, will not cause permanent adverse impacts to the hydrologic system.

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Date

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ABBREVIATIONS

ac	Acres
ac-ft	Acre-feet
ac-ft/yr	Acre feet per year
ac-ft/mi^2/yr	Acre feet per square mile per year
ACOE	Army Corps of Engineers
Ag	Silver
Aka	Also known as
Al	Aluminum
AOC	Approximate original contour
As	Arsenic
ASCM	Alternate sediment control measures
AVF	Alluvial valley floor
B	Boron
Ba	Barium
Be	Beryllium
BFR	Belle Fourche River
BLM	Bureau of Land Management
C	Celsius
Ca	Calcium
CARF	Coal annual report format
CBM	Coalbed methane
Cd	Cadmium
cfs	Cubic feet per second
CHIA	Cumulative hydrologic impact assessment
CIA	Cumulative impact area
CIR	Color infrared
Cn	Cyanide
Co	Cobalt
CO_3	Carbonate
Cr	Chromium
Cu	Copper
d	Day
DMR	Discharge monitoring report
EC	Electrical conductivity
EIS	Environmental impact statement
F	Fluoride
ºF	Fahrenheit
Fe	Iron
ft	Feet
ft/d	Feet per day
ft^2/d	Square feet per day
GAGMO	Gillette Area Groundwater Monitoring Organization
gpd/ft	Gallons per day per foot
gpm	Gallons per minute
H_2S	Hydrogen sulfide
HCO_3	Bicarbonate
Hg	Mercury
hr	Hour

in	Inches
in/yr	Inches per year
LBA	Lease by application
Li	Lithium
LQD	Land Quality Division
LRPL	Least restrictive proposed limit
MCF	1000 cubic feet
MEQ/l	Milliequivalents per liter
Mg	Magnesium
mg/l	Milligrams per liter
mi^2	Square miles
MRPL	Most restrictive proposed limit
N	Nitrogen
N/A	Not available
Na	Sodium
NH_3	Ammonia
Ni	Nickel
No.	Number
NO_2	Nitrite
NO_3	Nitrate
NTU	Nephelometric turbidity units
OSMRE	Office of Surface Mining Reclamation and Enforcement
OWUS	Other waters of the United States
pCi/l	Picocuries per liter
PMT	Post mine topography
PRB	Structural Powder River Basin
PVC	Polyvinyl chloride
ROS	Regression on order statistics
SAR	Sodium adsorption ratio
SDD	State decision document
Se	Selenium
SMCRA	Surface Mining Control and Reclamation Act
SO_4	Sulfate
SU	Standard units
TCO	Temporary cessation of operations
TDS	Total dissolved solids
TFN	Temporary filing number
TSS	Total suspended solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WDEQ	Wyoming Department of Environmental Quality
WDEQ/LQD	Wyoming Department of Environmental Quality/Land Quality Division
WDEQ/WQD	Wyoming Department of Environmental Quality/Water Quality Division
WRDS	Water Resources Data System
WRRI	Wyoming Water Resources Research Institute
WS	Wyoming Statute
WSEO	Wyoming State Engineer's Office
WWDC	Wyoming Water Development Commission
WYPDES	Wyoming Pollutant Discharge Elimination System
yr	Year

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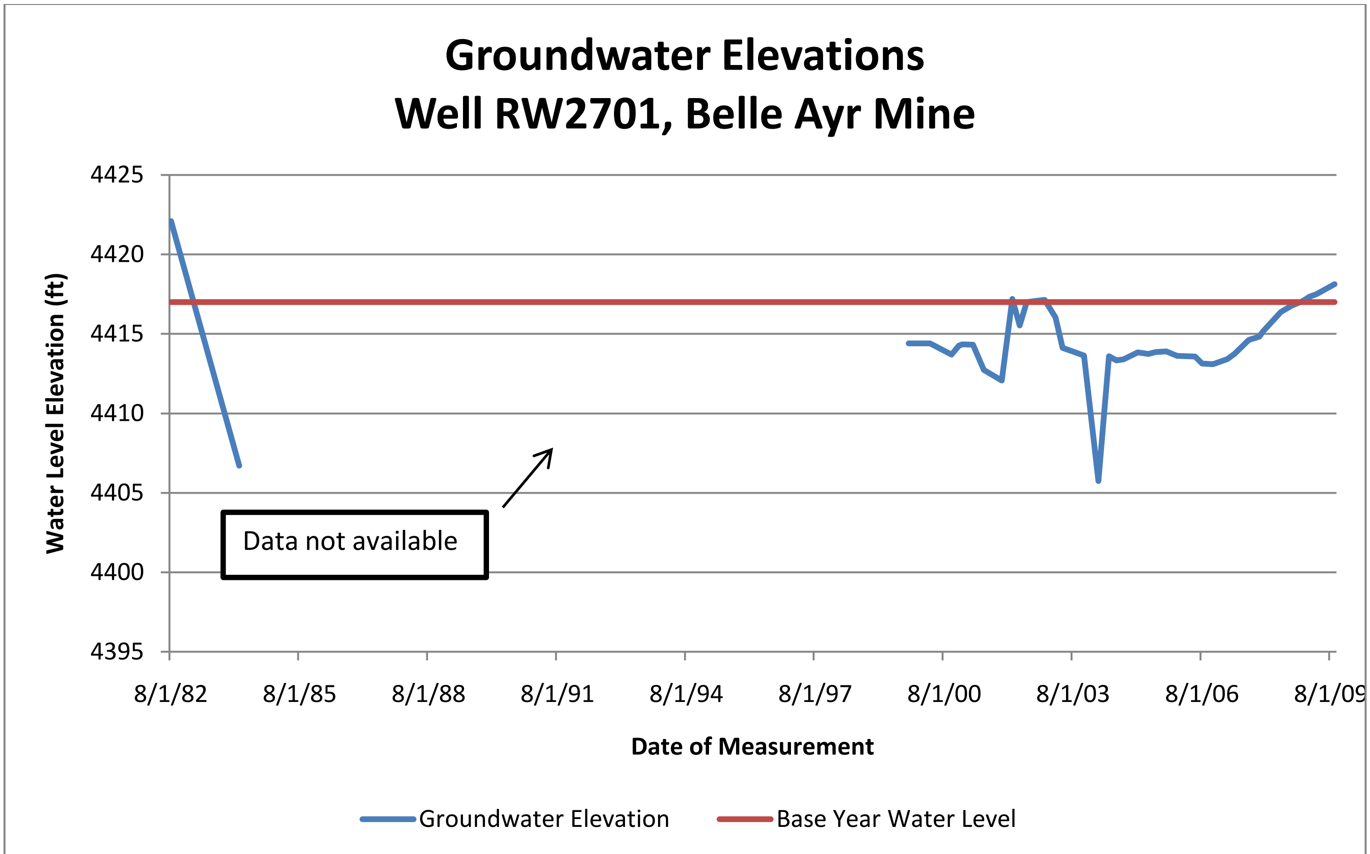
ADDENDUM: GROUNDWATER ELEVATION GRAPHS


Groundwater Elevations
Well RW2701, Belle Ayr Mine
Water Level Elevation (ft)
4425
4420
4415
4410
4405
4400
4395
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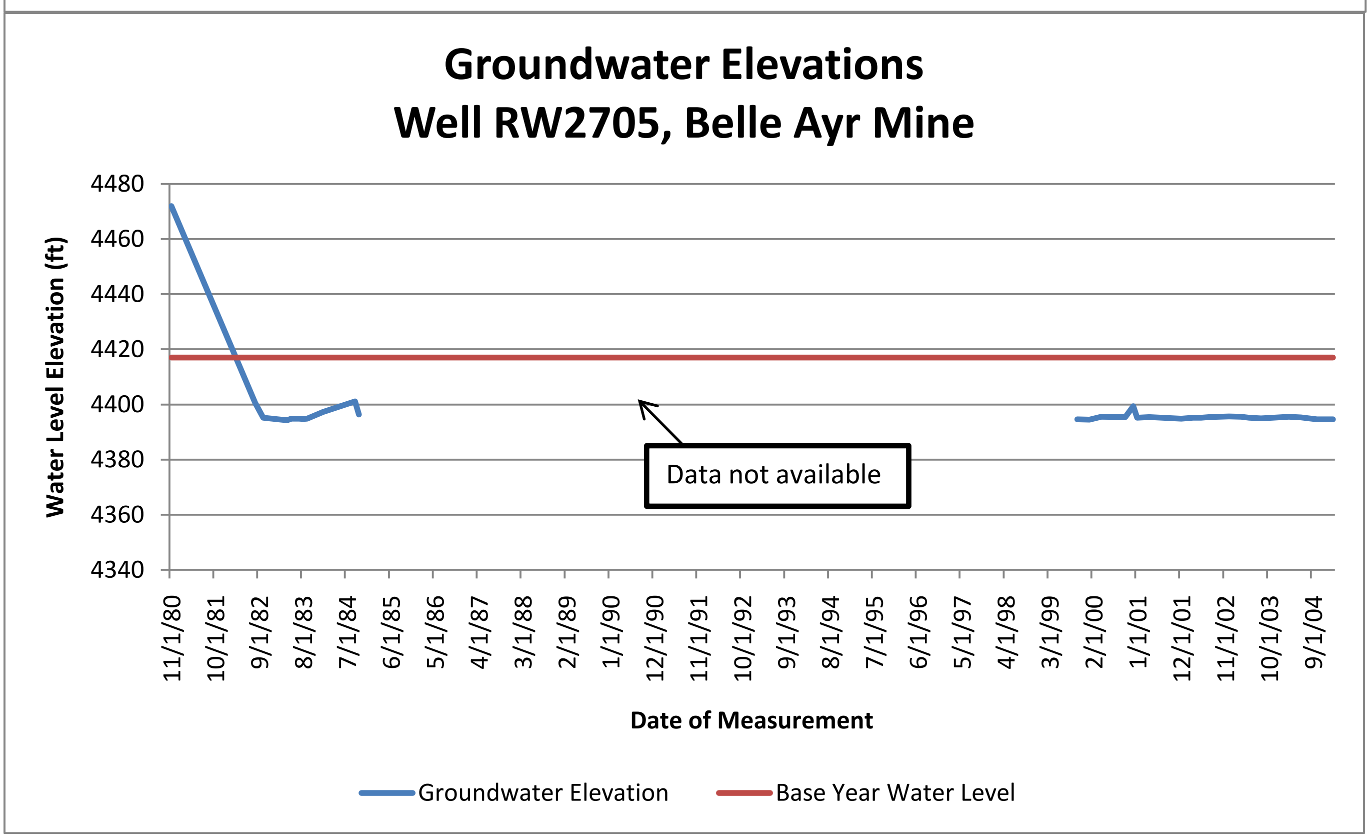
8/1/82
8/1/85
8/1/88
8/1/91
8/1/94
8/1/97
8/1/00
8/1/03
8/1/06
8/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level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Water Level Elevation (ft)
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4460
4440
4420
4400
4380
4360
4340
Data not available
11/1/80
10/1/81
9/1/82
8/1/83
7/1/84
6/1/85
5/1/86
4/1/87
3/1/88
2/1/89
1/1/90
12/1/90
11/1/91
10/1/92
9/1/93
8/1/94
7/1/95
6/1/96
5/1/97
4/1/98
3/1/99
2/1/00
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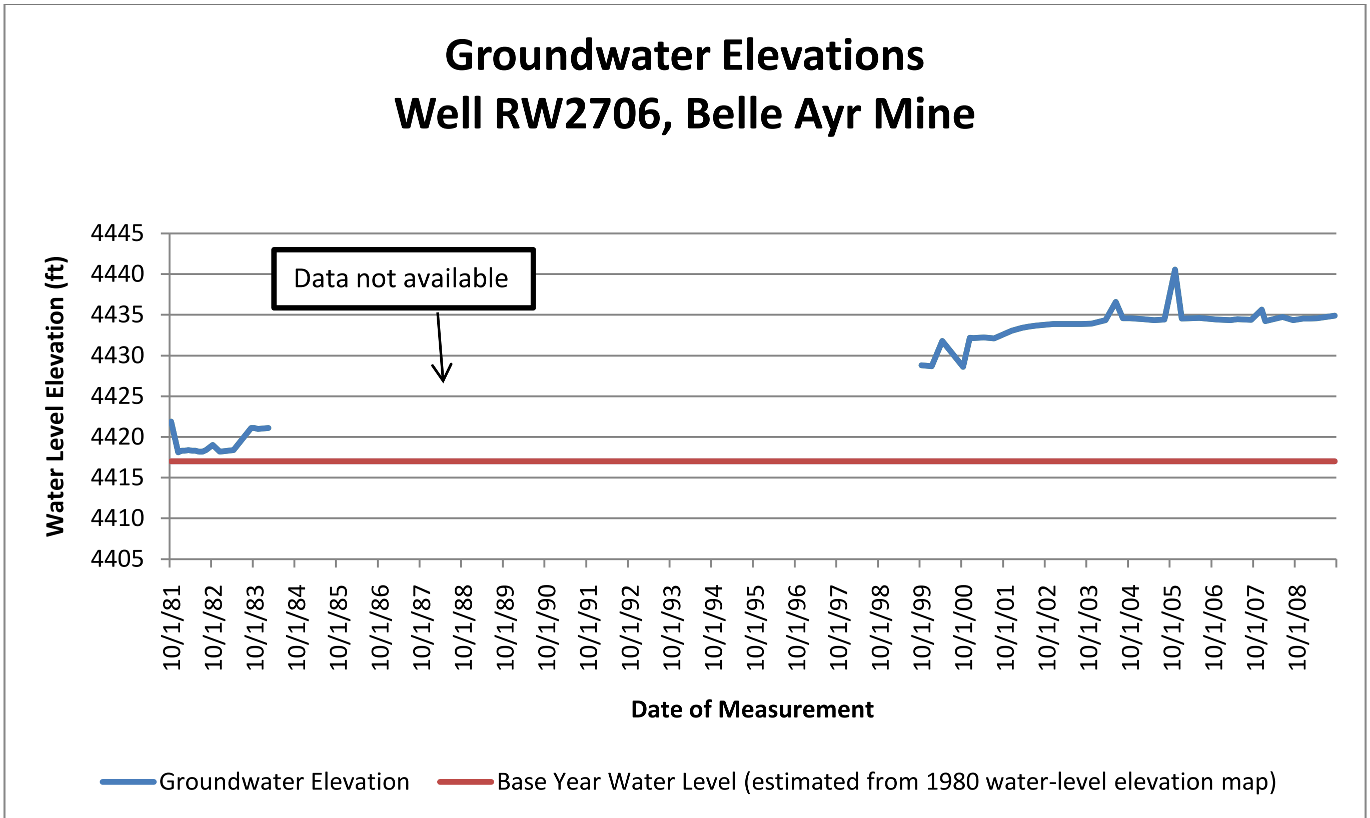
12/1/01
11/1/02
10/1/03
9/1/04
Date of Measurement
Groundwater Elevation
Base Year Water Level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Water Level Elevation (ft)
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4440
4435
4430
4425
4420
4415
4410
4405
10/1/81
10/1/82
10/1/83
10/1/84
10/1/85
10/1/86
10/1/87
10/1/88
10/1/89
10/1/90
10/1/91
10/1/92
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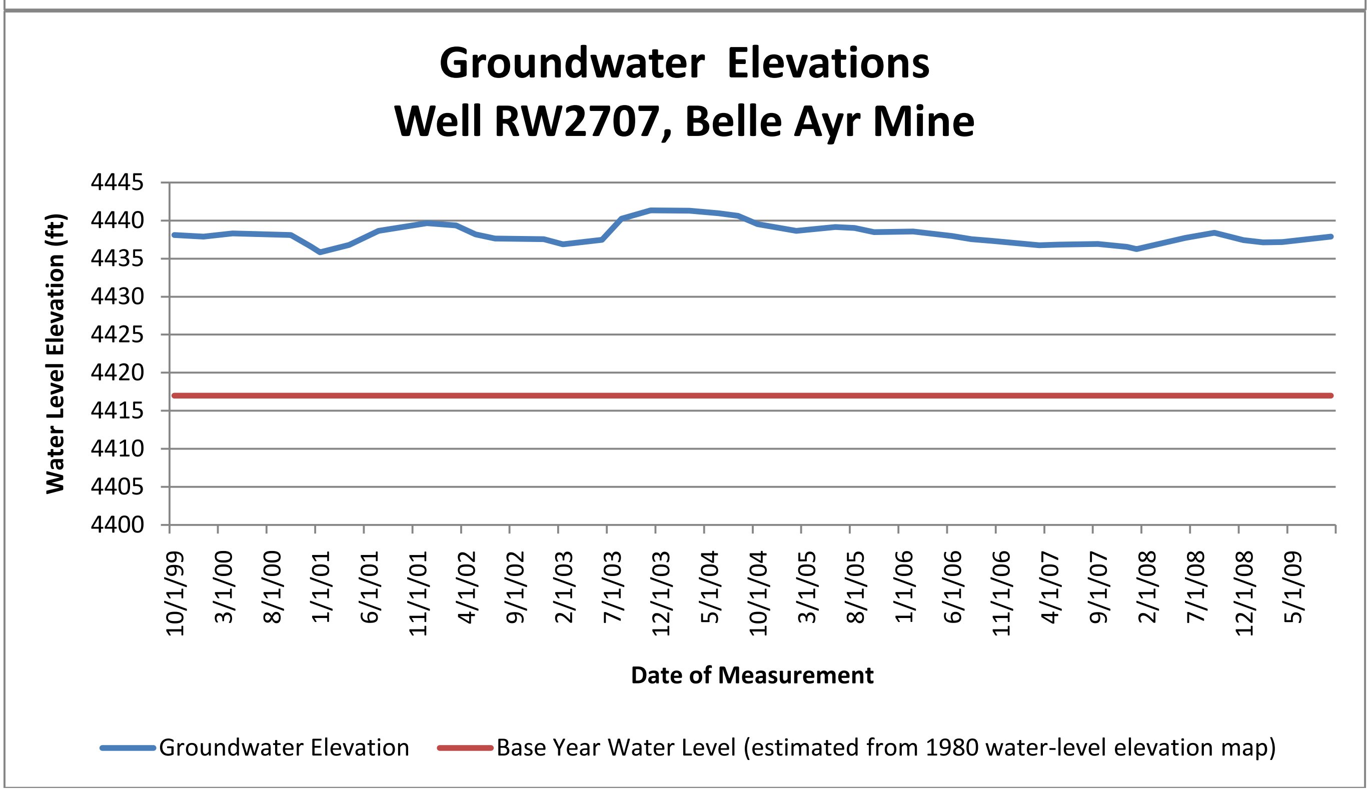
10/1/00
10/1/01
10/1/02
10/1/03
10/1/04
10/1/05
10/1/06
10/1/07
10/1/08
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)


Groundwater Elevations
Well RW2707, Belle Ayr Mine
Water Level Elevation (ft)
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4440
4435
4430
4425
4420
4415
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4400
10/1/99
3/1/00
8/1/00
1/1/01
6/1/01
11/1/01
4/1/02
9/1/02
2/1/03
7/1/03
12/1/03
5/1/04
10/1/04
3/1/05
8/1/05
1/1/06
6/1/06
11/1/06
4/1/07
9/1/07
2/1/08
7/1/08
12/1/08
5/1/09
Date of Measurement
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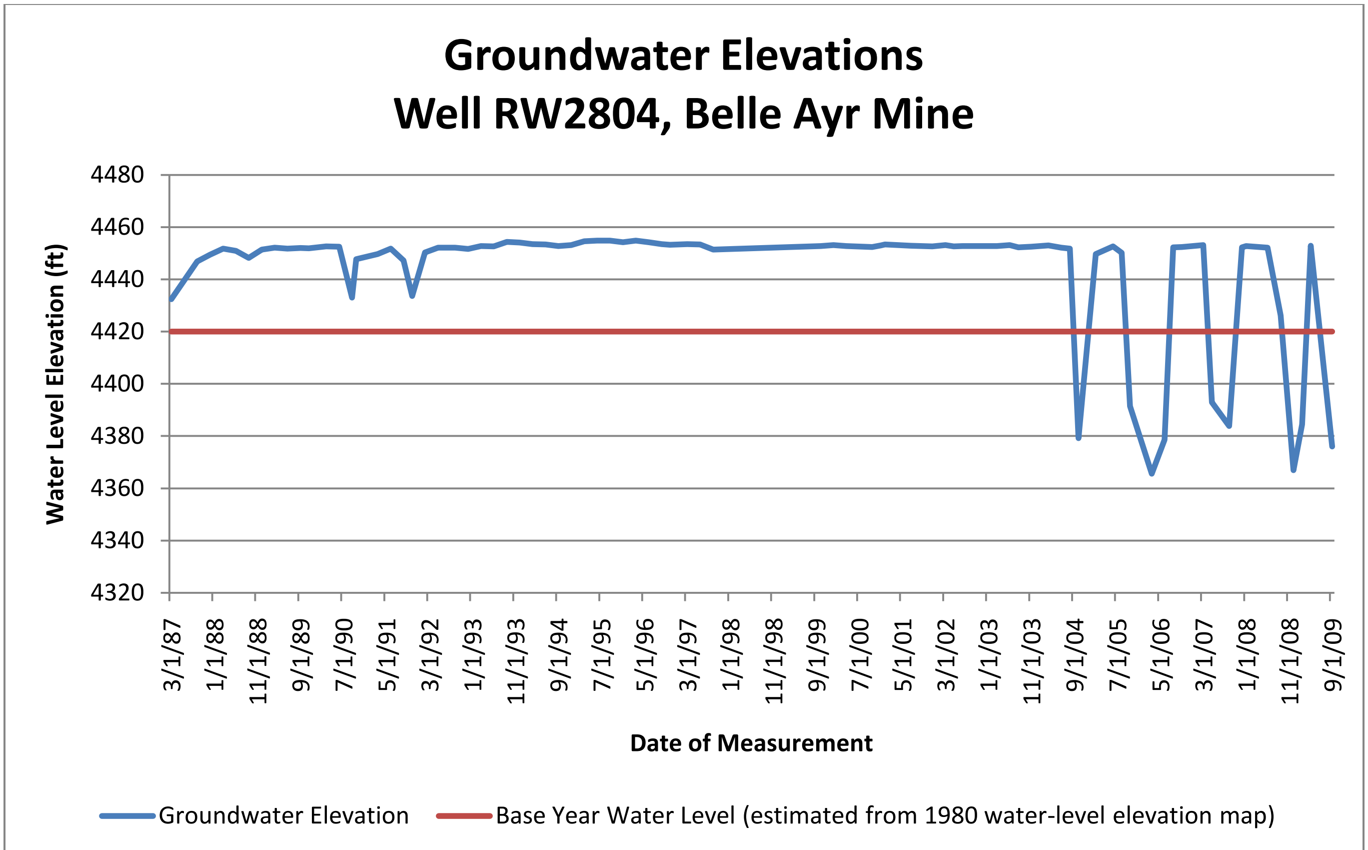
Base Year Water Level (estimated from 1980 water-level elevation map)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Water Level Elevation (ft)
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4460
4440
4420
4400
4380
4360
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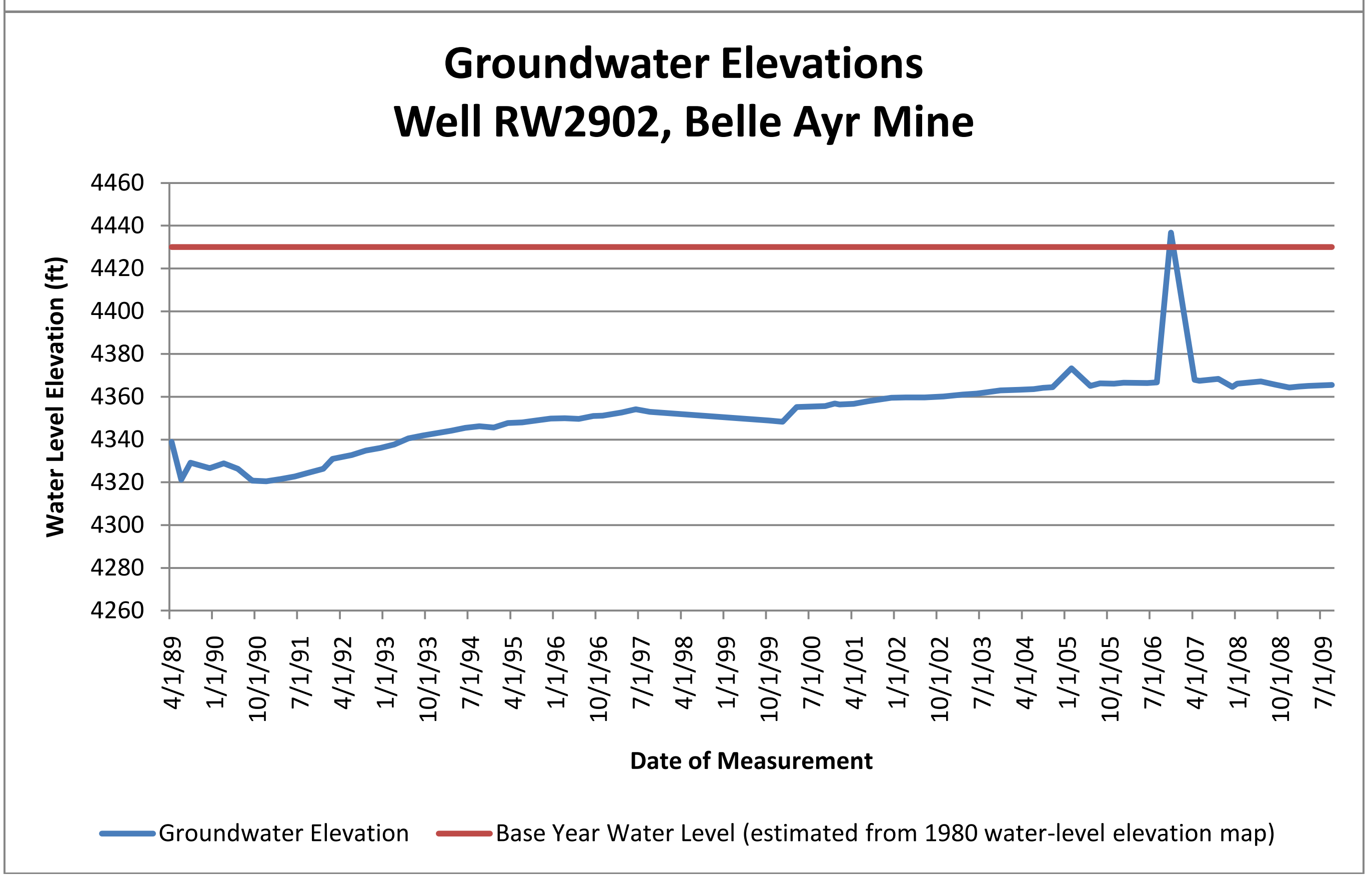
3/1/87
1/1/88
11/1/88
9/1/89
7/1/90
5/1/91
3/1/92
1/1/93
11/1/93
9/1/94
7/1/95
5/1/96
3/1/97
1/1/98
11/1/98
9/1/99
7/1/00
5/1/01
3/1/02
1/1/03
11/1/03
9/1/04
7/1/05
5/1/06
3/1/07
1/1/08
11/1/08
9/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)


Groundwater Elevations
Well RW2902, Belle Ayr Mine
Water Level Elevation (ft)
4460
4440
4420
4400
4380
4360
4340
4320
4300
4280
4260
4/1/89
1/1/90
10/1/90
7/1/91
4/1/92
1/1/93
10/1/93
7/1/94
4/1/95
1/1/96
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7/1/97
4/1/98
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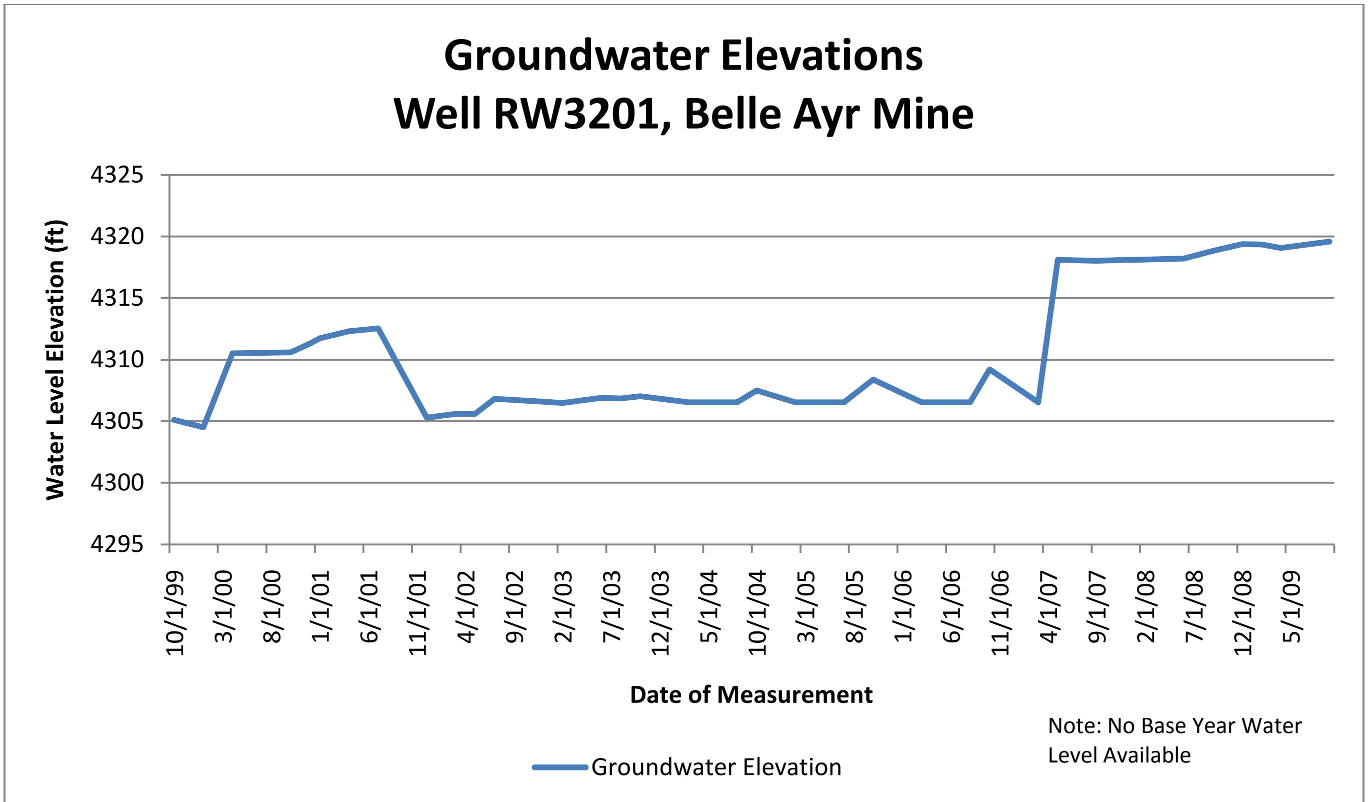
1/1/02
10/1/02
7/1/03
4/1/04
1/1/05
10/1/05
7/1/06
4/1/07
1/1/08
10/1/08
7/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)


Groundwater Elevations
Well RW3201, Belle Ayr Mine
Water Level Elevation (ft)
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4320
4315
4310
4305
4300
4295
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3/1/00
8/1/00
1/1/01
6/1/01
11/1/01
4/1/02
9/1/02
2/1/03
7/1/03
12/1/03
5/1/04
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3/1/05
8/1/05
1/1/06
6/1/06
11/1/06
4/1/07
9/1/07
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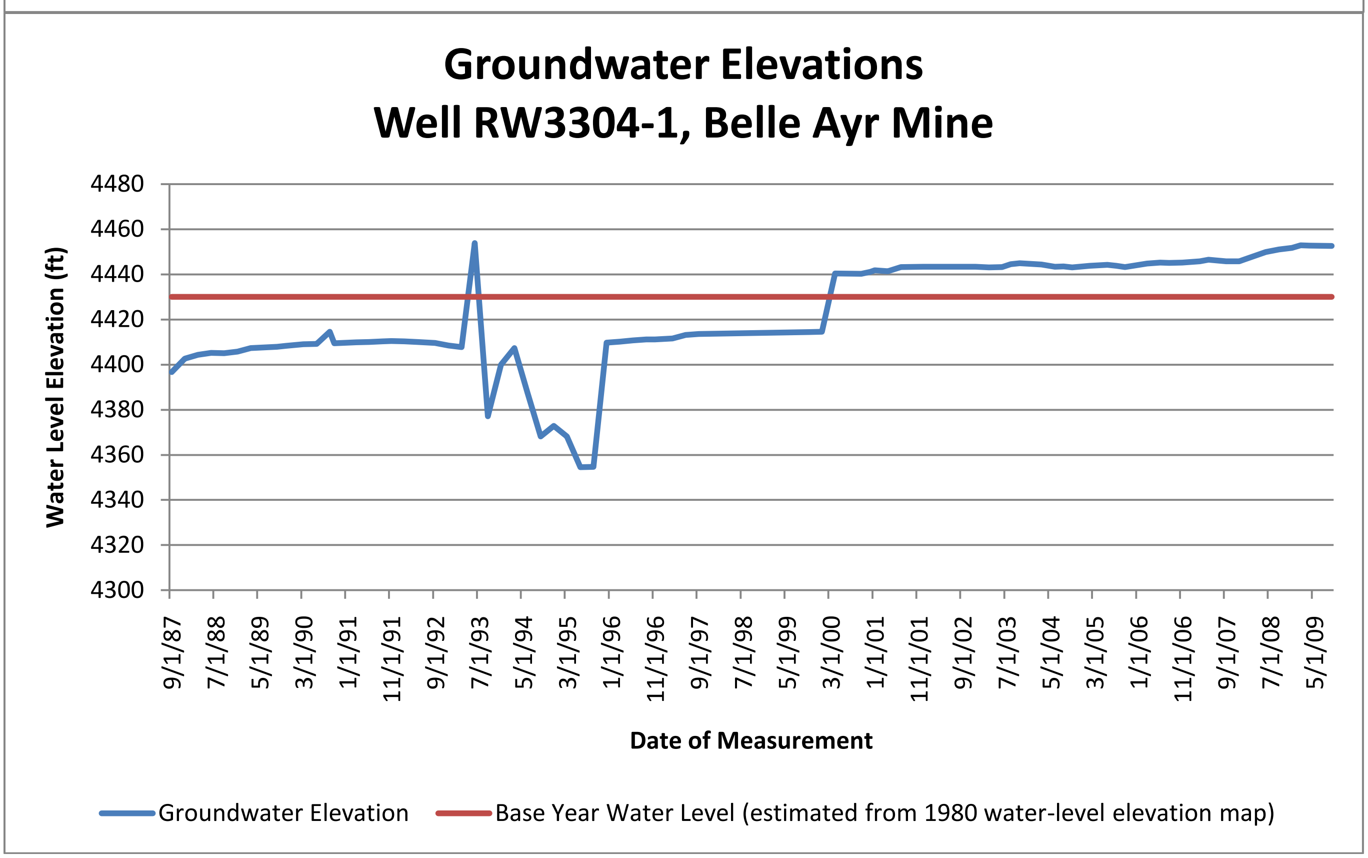
7/1/08
12/1/08
5/1/09
Date of Measurement
Groundwater Elevation
Note: No Base Year Water Level Available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Well RW3304-1, Belle Ayr Mine
Water Level Elevation (ft)
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4460
4440
4420
4400
4380
4360
4340
4320
4300
9/1/87
7/1/88
5/1/89
3/1/90
1/1/91
11/1/91
9/1/92
7/1/93
5/1/94
3/1/95
1/1/96
11/1/96
9/1/97
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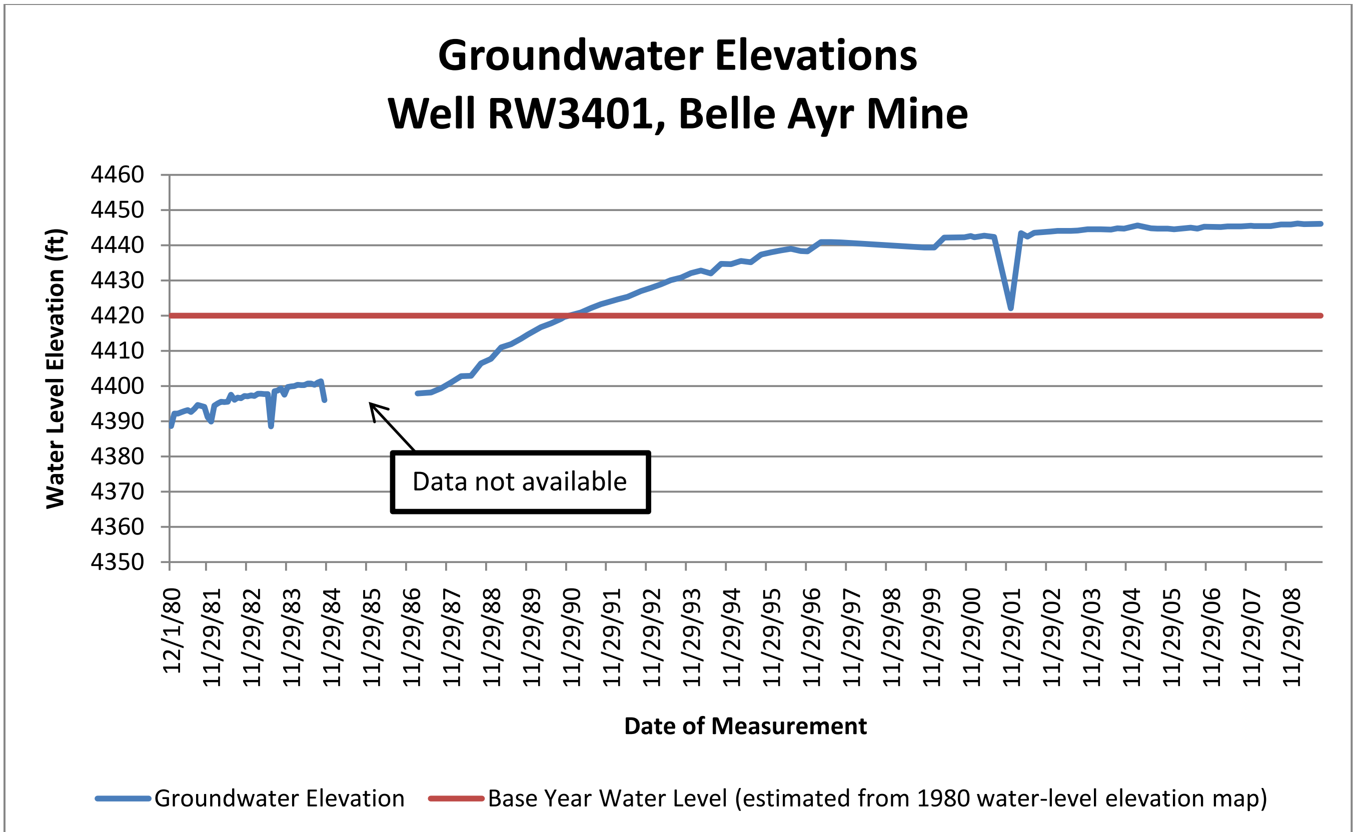
9/1/02
7/1/03
5/1/04
3/1/05
1/1/06
11/1/06
9/1/07
7/1/08
5/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)


Groundwater Elevations
Well RW3401, Belle Ayr Mine
Water Level Elevation (ft)
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4450
4440
4430
4420
4410
4400
4390
4380
4370
4360
4350
Data not available
12/1/80
11/29/81
11/29/82
11/29/83
11/29/84
11/29/85
11/29/86
11/29/87
11/29/88
11/29/89
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11/29/01
11/29/02
11/29/03
11/29/04
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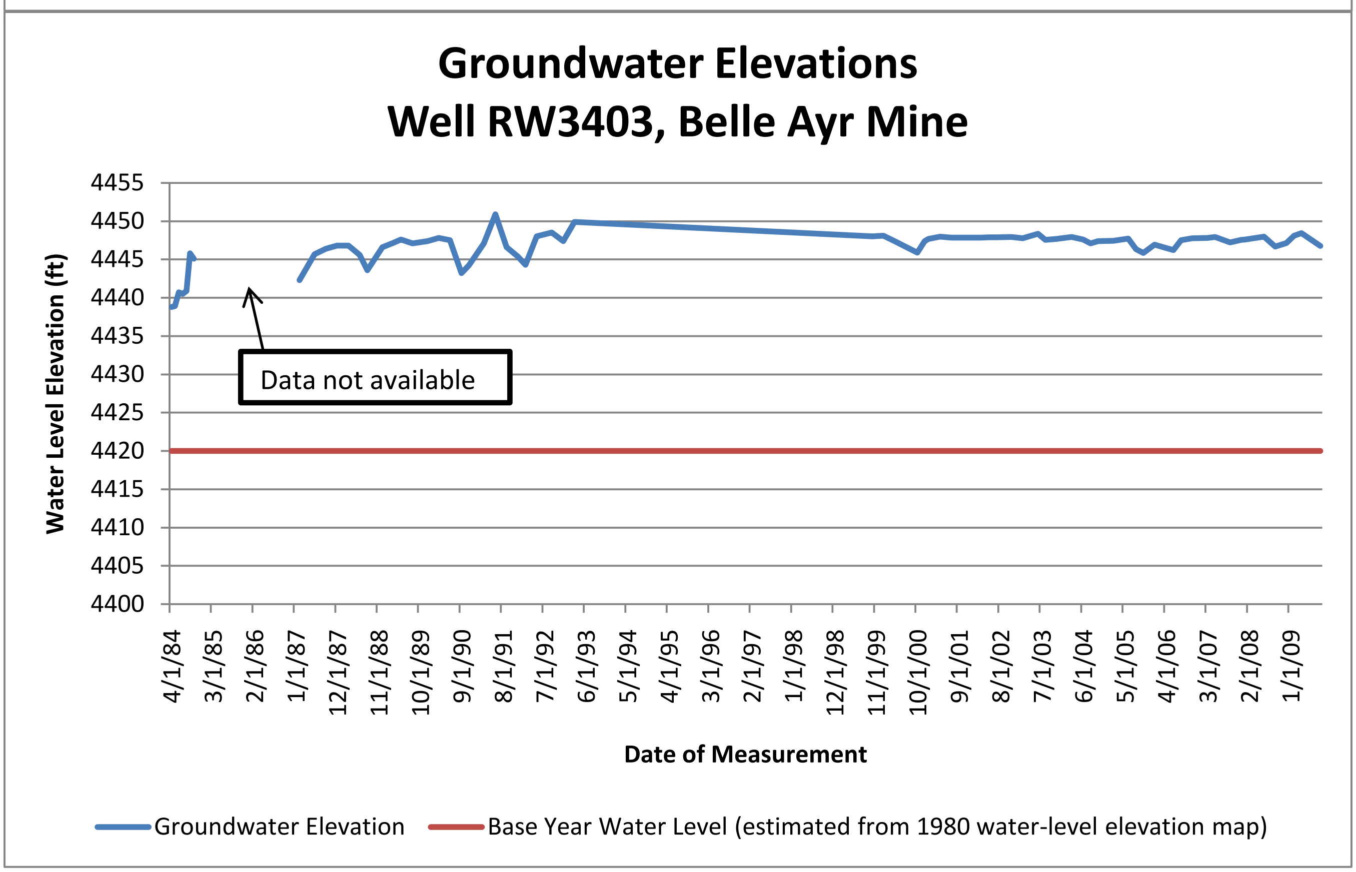
11/29/07
11/29/08
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)


Groundwater Elevations
Well RW3403, Belle Ayr Mine
Water Level Elevation (ft)
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4450
4445
4440
4435
4430
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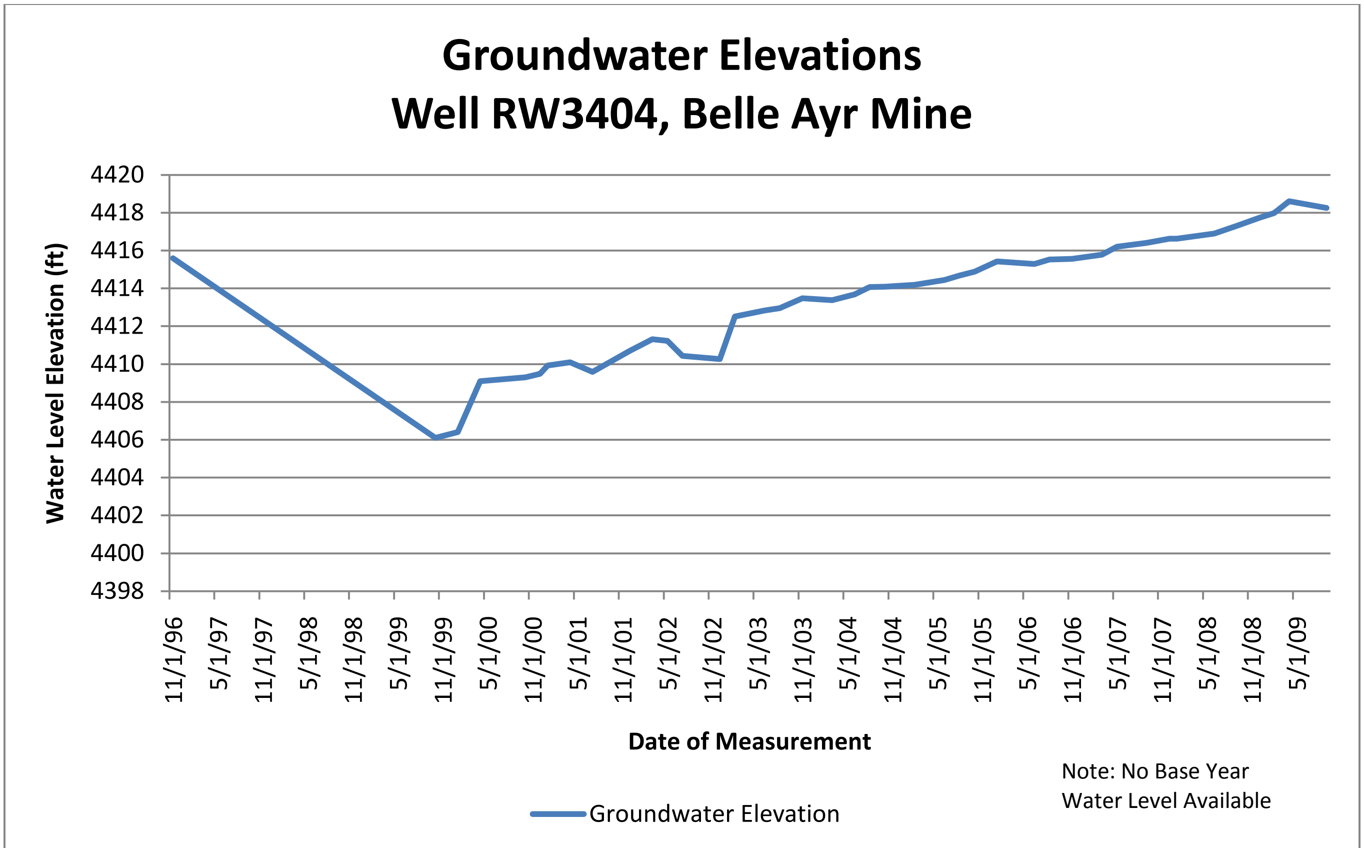
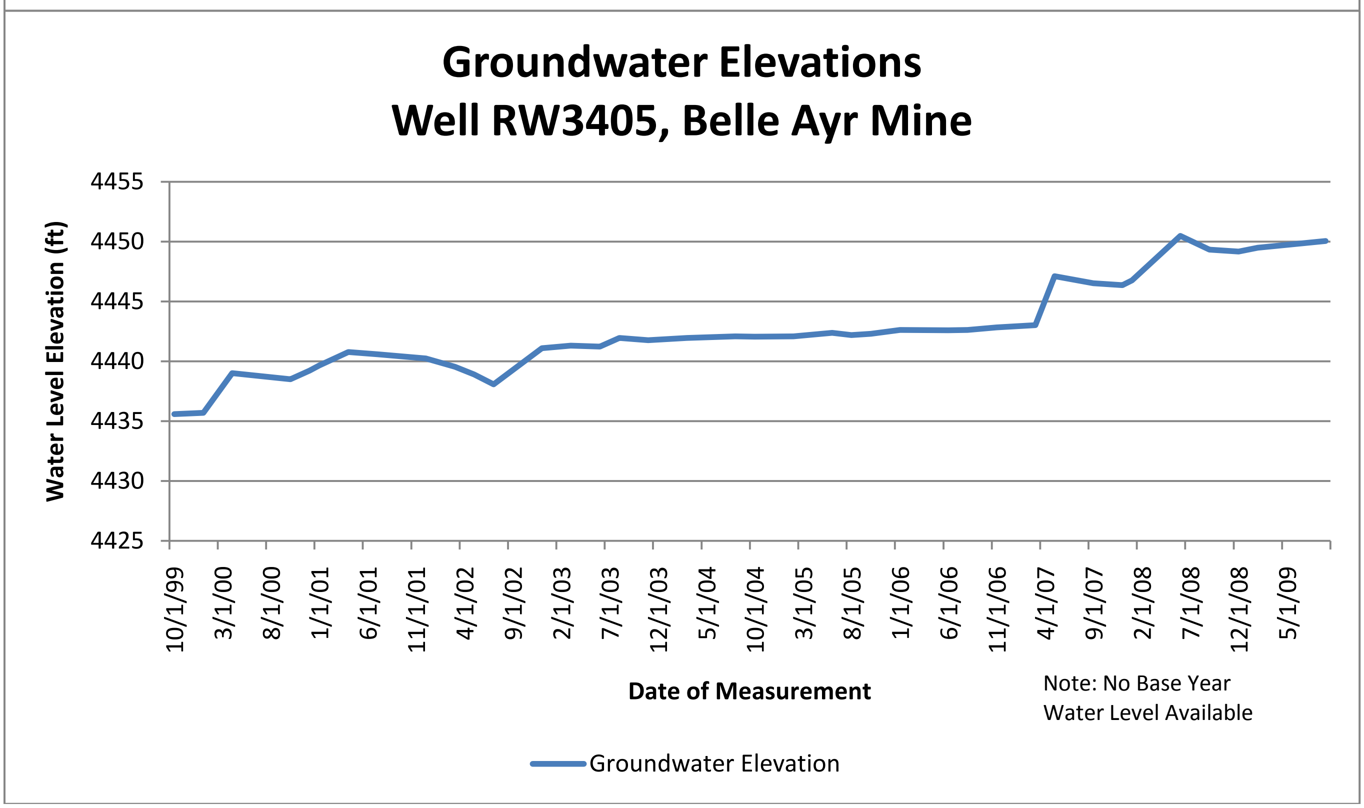
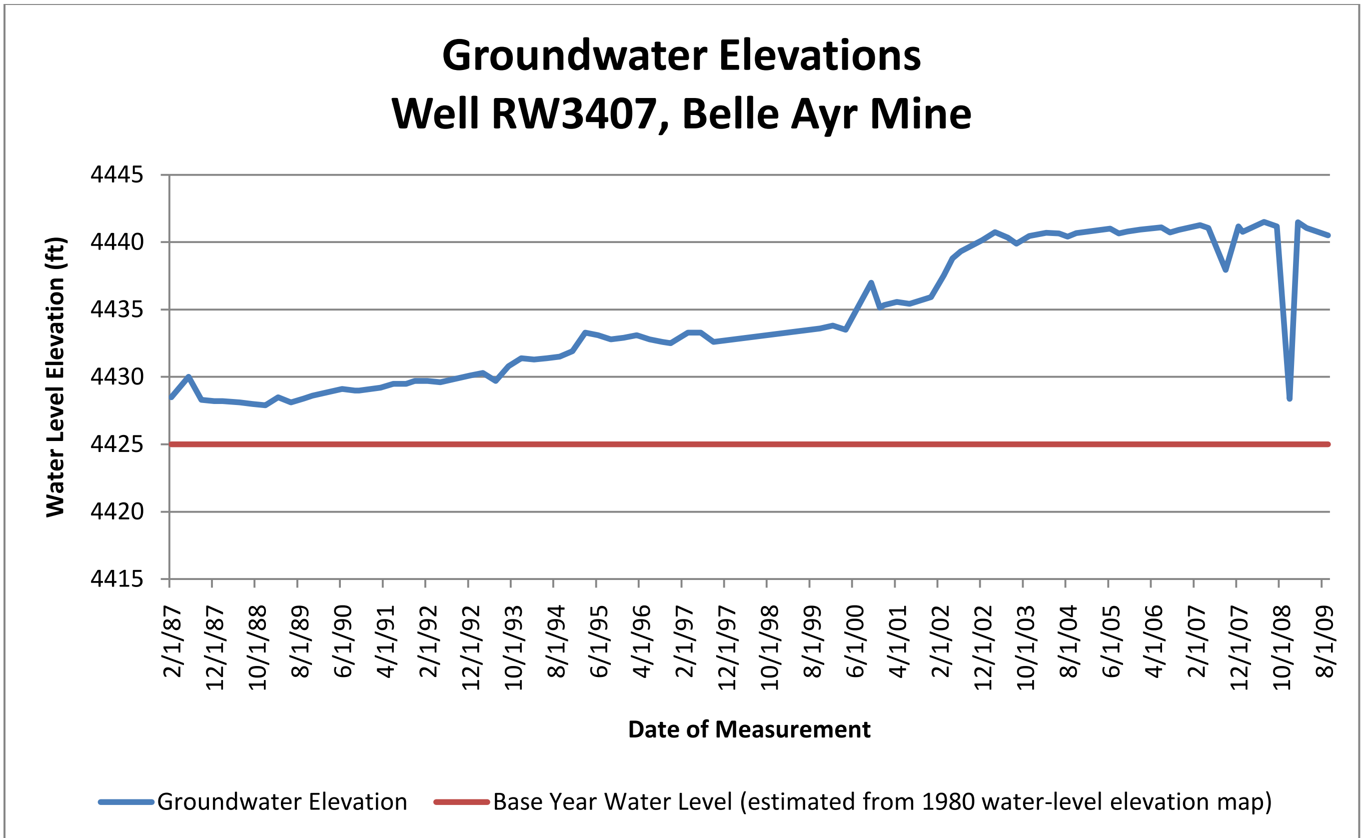
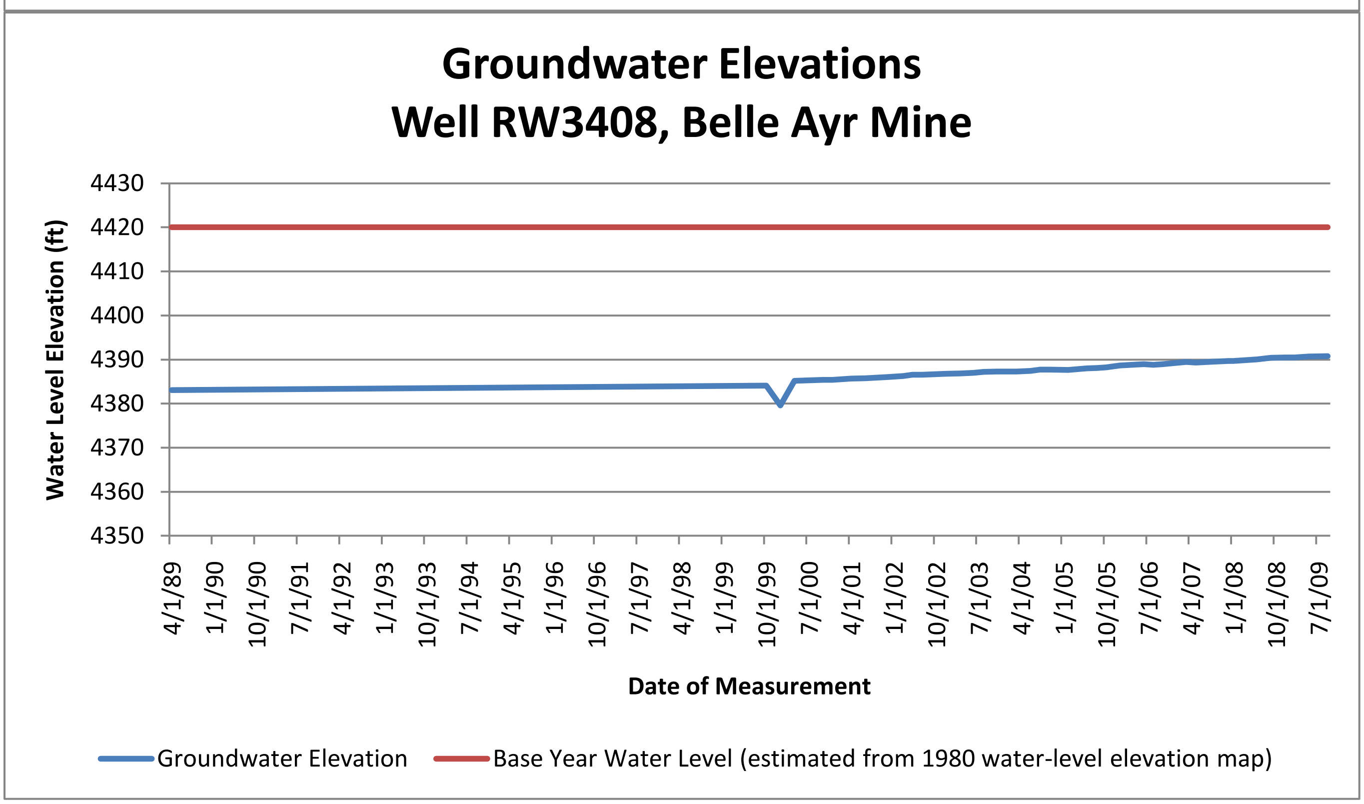
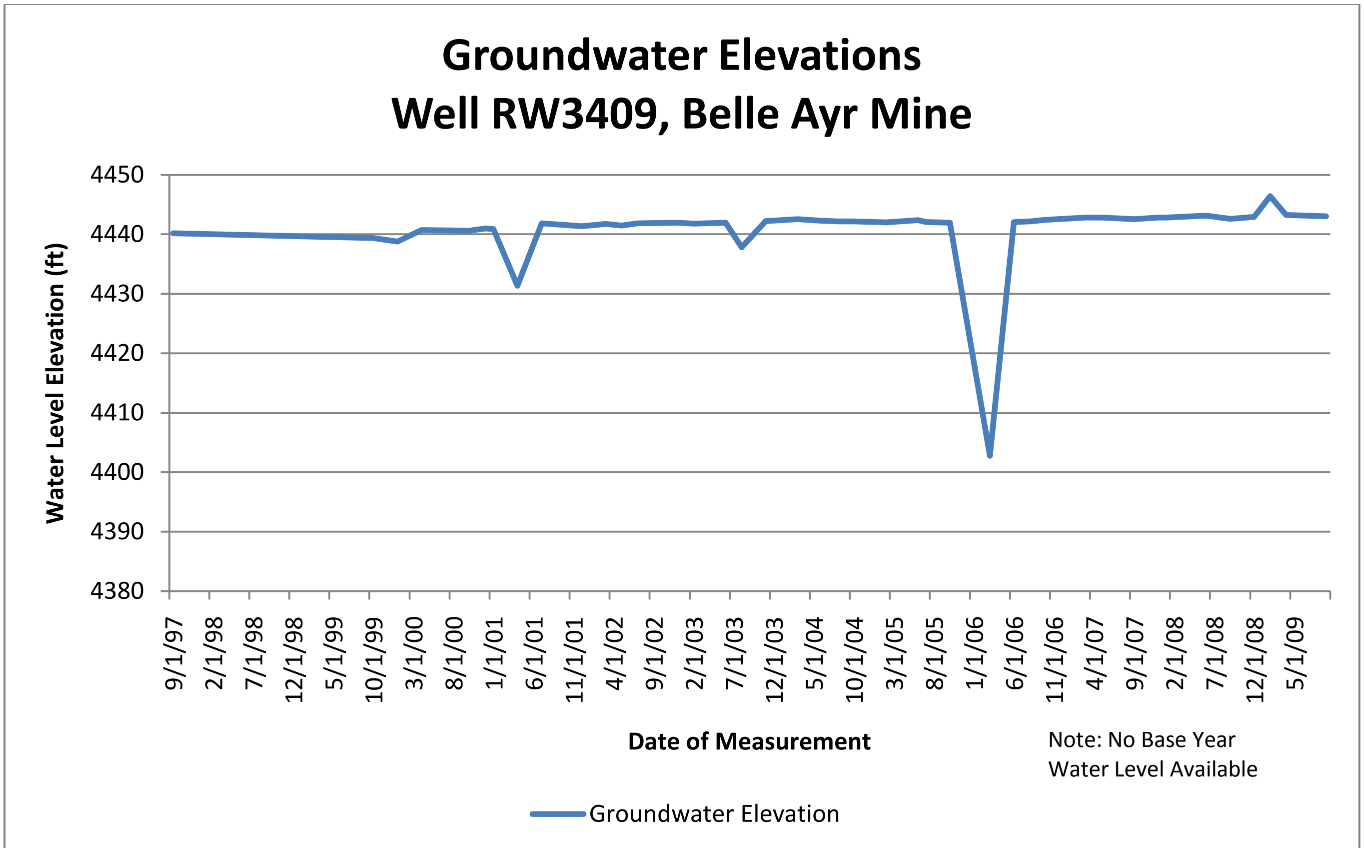
4420
4415
4410
4405
4400
Data not available
4/1/84
3/1/85
2/1/86
1/1/87
12/1/87
11/1/88
10/1/89
9/1/90
8/1/91
7/1/92
6/1/93
5/1/94
4/1/95
3/1/96
2/1/97
1/1/98
12/1/98
11/1/99
10/1/00
9/1/01
8/1/02
7/1/03
6/1/04
5/1/05
4/1/06
3/1/07
2/1/08
1/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

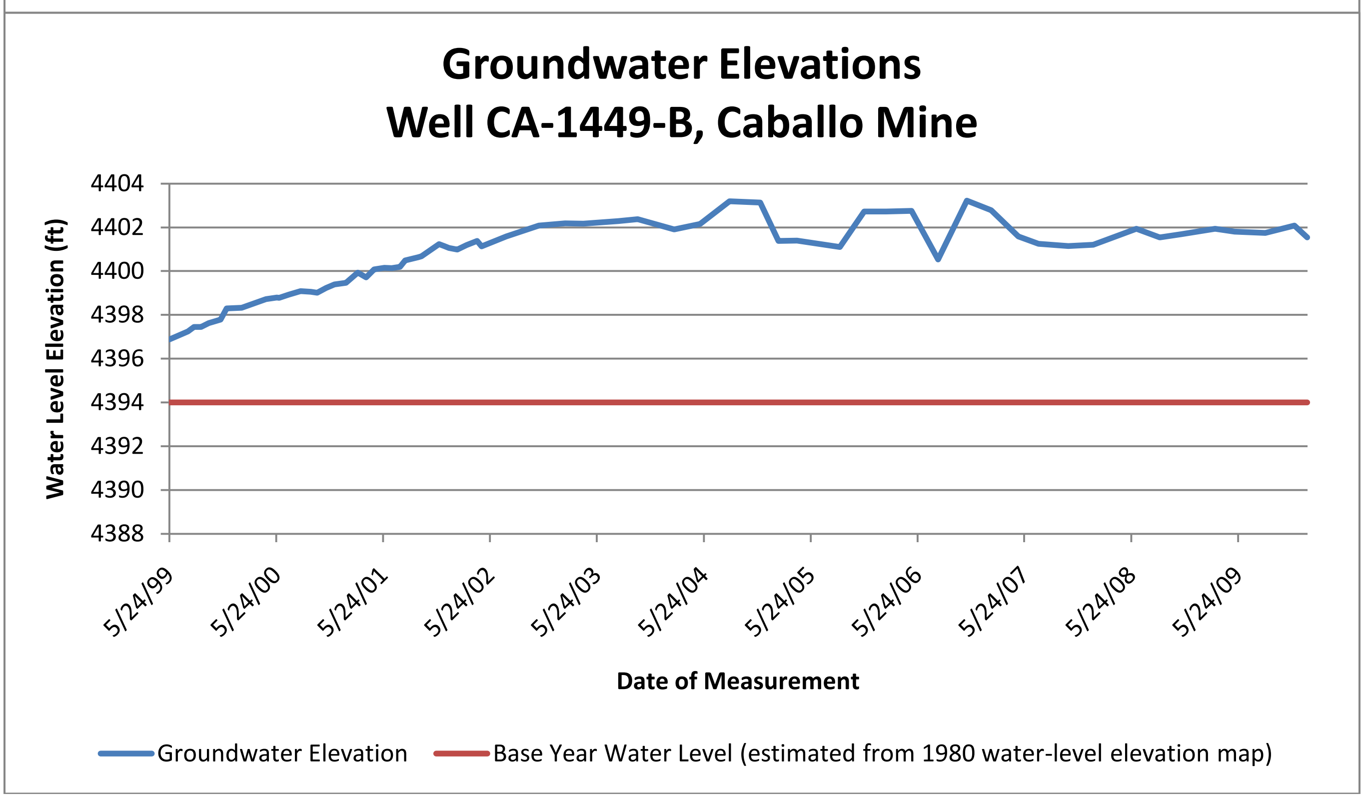

Groundwater Elevations
Well RW3404, Belle Ayr Mine
Water Level Elevation (ft)
4420
4418
4416
4414
4412
4410
4408
4406
4404
4402
4400
4398
11/1/96
5/1/97
11/1/97
5/1/98
11/1/98
5/1/99
11/1/99
5/1/00
11/1/00
5/1/01
11/1/01
5/1/02
11/1/02
5/1/03
11/1/03
5/1/04
11/1/04
5/1/05
11/1/05
5/1/06
11/1/06
5/1/07
11/1/07
5/1/08
11/1/08
5/1/09
Date of Measurement
Note: No Base Year
Water Level Available
Groundwater Elevation

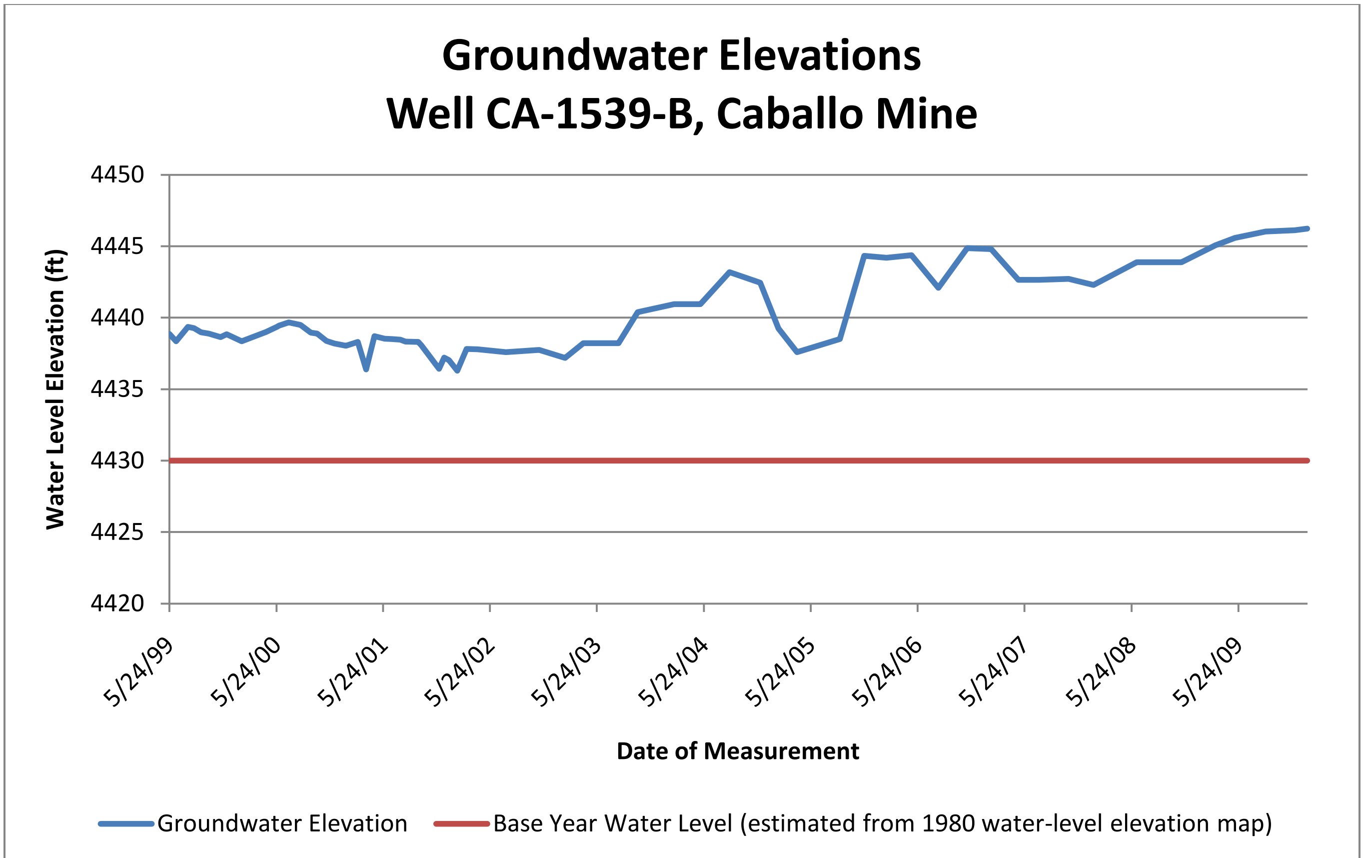

Groundwater Elevations
Well RW3405, Belle Ayr Mine
Water Level Elevation (ft)
4455
4450
4445
4440
4435
4430
4425
10/1/99
3/1/00
8/1/00
1/1/01
6/1/01
11/1/01
4/1/02
9/1/02
2/1/03
7/1/03
12/1/03
5/1/04
10/1/04
3/1/05
8/1/05
1/1/06
6/1/06
11/1/06
4/1/07
9/1/07
2/1/08
7/1/08
12/1/08
5/1/09
Date of Measurement
Note: No Base Year
Water Level Available
Groundwater Elevation

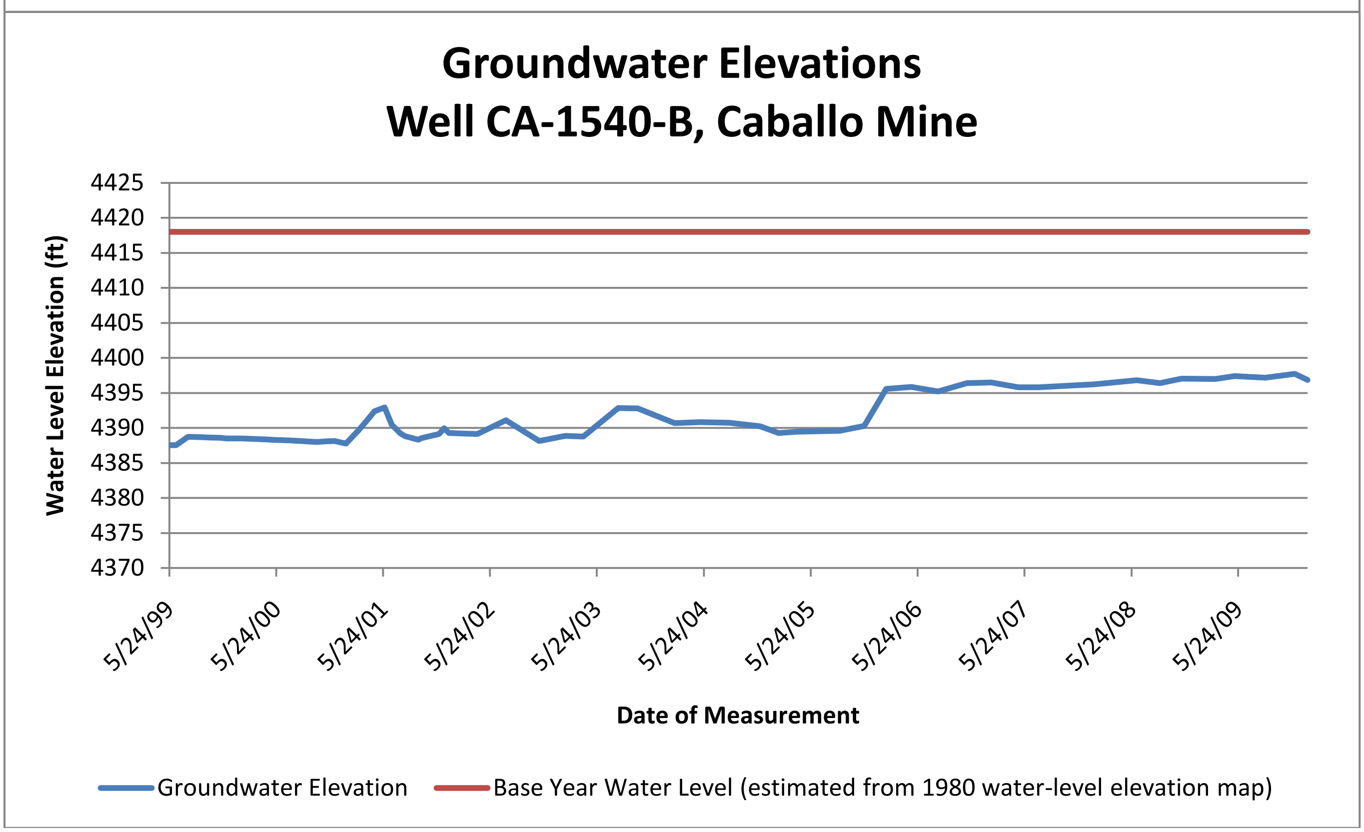

Groundwater Elevations
Well RW3407, Belle Ayr Mine
Water Level Elevation (ft)
4445
4440
4435
4430
4425
4420
4415
2/1/87
12/1/87
10/1/88
8/1/89
6/1/90
4/1/91
2/1/92
12/1/92
10/1/93
8/1/94
6/1/95
4/1/96
2/1/97
12/1/97
10/1/98
8/1/99
6/1/00
4/1/01
2/1/02
12/1/02
10/1/03
8/1/04
6/1/05
4/1/06
2/1/07
12/1/07
10/1/08
8/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

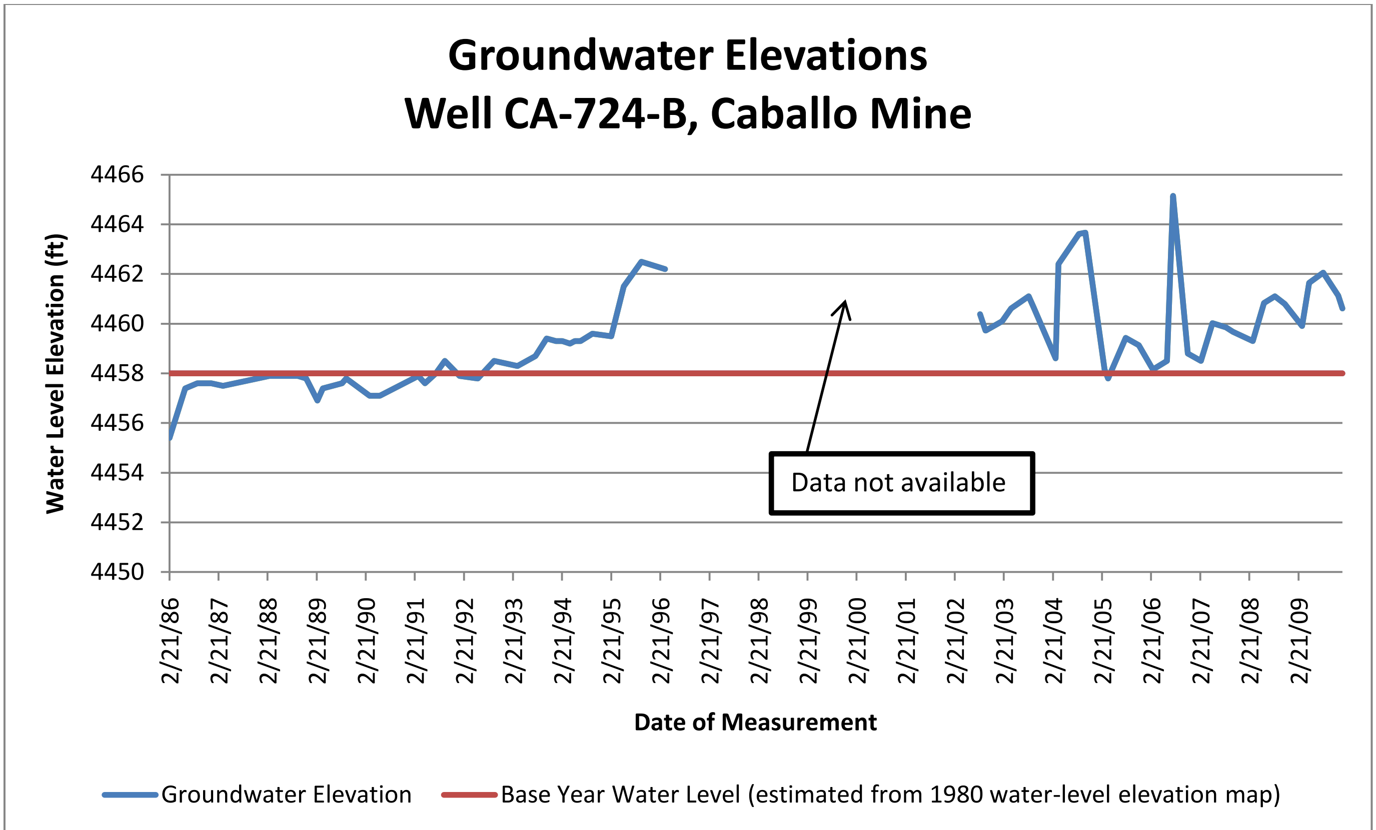

Groundwater Elevations
Well RW3408, Belle Ayr Mine
Water Level Elevation (ft)
4430
4420
4410
4400
4390
4380
4370
4360
4350
4/1/89
1/1/90
10/1/90
7/1/91
4/1/92
1/1/93
10/1/93
7/1/94
4/1/95
1/1/96
10/1/96
7/1/97
4/1/98
1/1/99
10/1/99
7/1/00
4/1/01
1/1/02
10/1/02
7/1/03
4/1/04
1/1/05
10/1/05
7/1/06
4/1/07
1/1/08
10/1/08
7/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

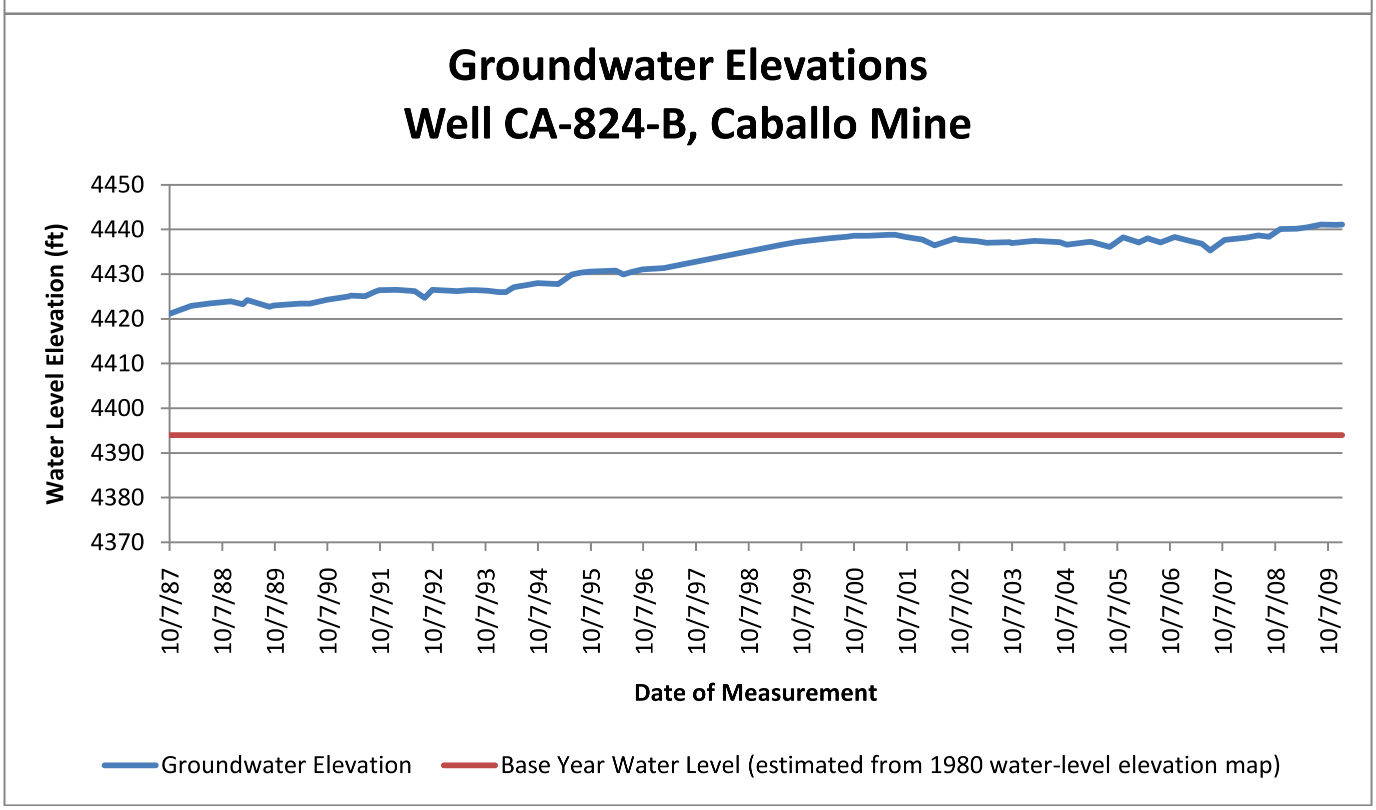

Groundwater Elevations
Well RW3409, Belle Ayr Mine
Water Level Elevation (ft)
4450
4440
4430
4420
4410
4400
4390
4380
9/1/97
2/1/98
7/1/98
12/1/98
5/1/99
10/1/99
3/1/00
8/1/00
1/1/01
6/1/01
11/1/01
4/1/02
9/1/02
2/1/03
7/1/03
12/1/03
5/1/04
10/1/04
3/1/05
8/1/05
1/1/06
6/1/06
11/1/06
4/1/07
9/1/07
2/1/08
7/1/08
12/1/08
5/1/09
Date of Measurement
Note: No Base Year Water Level Available
Groundwater Elevation

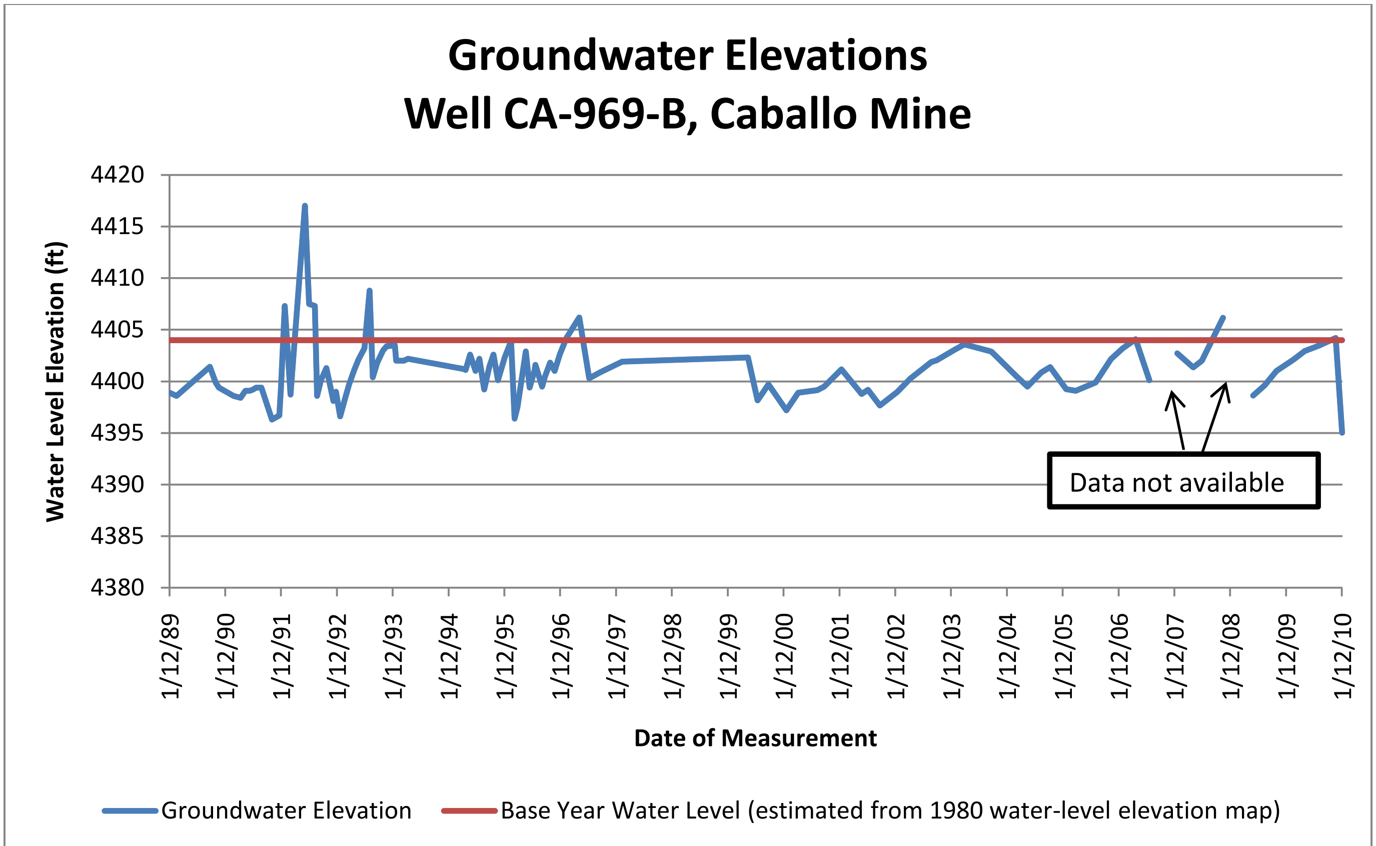

Groundwater Elevations
Well CA-1449-B, Caballo Mine
Water Level Elevation (ft)
4404
4402
4400
4398
4396
4394
4392
4390
4388
5/24/99
5/24/00
5/24/01
5/24/02
5/24/03
5/24/04
5/24/05
5/24/06
5/24/07
5/24/08
5/24/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

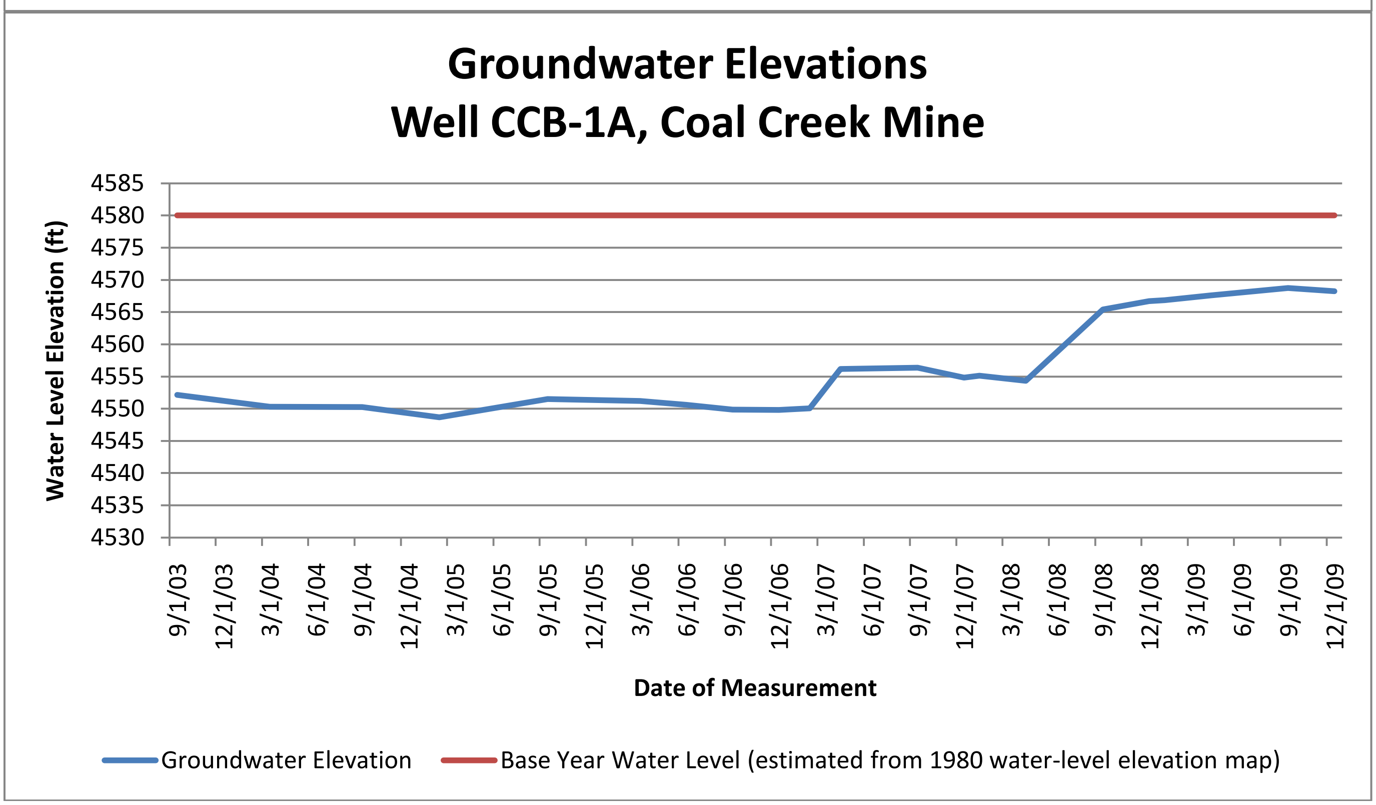

Groundwater Elevations
Well CA-1539-B, Caballo Mine
Water Level Elevation (ft)
4450
4445
4440
4435
4430
4425
4420
5/24/99
5/24/00
5/24/01
5/24/02
5/24/03
5/24/04
5/24/05
5/24/06
5/24/07
5/24/08
5/24/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

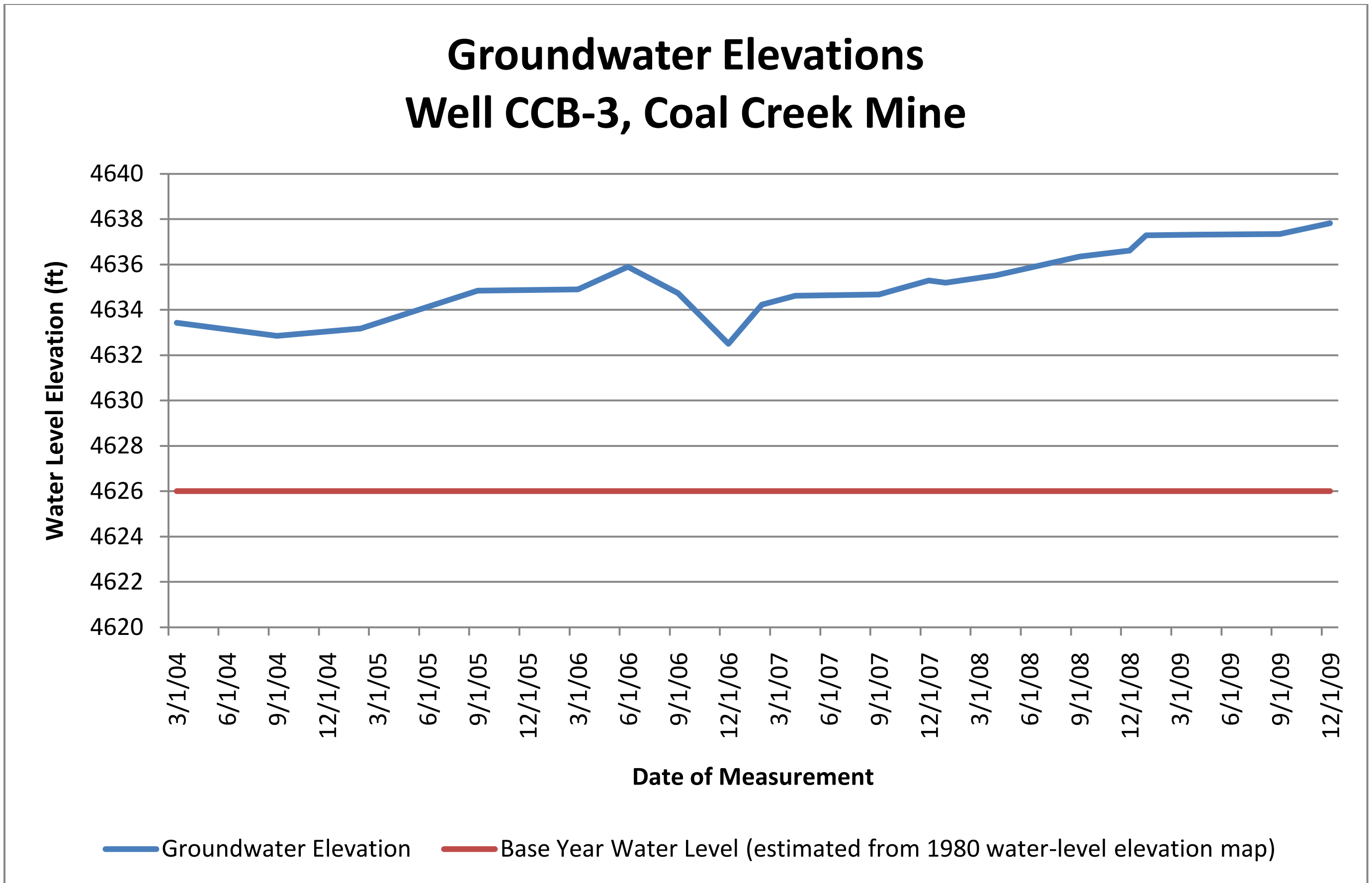

Groundwater Elevations
Well CA-1540-B, Caballo Mine
Water Level Elevation (ft)
4425
4420
4415
4410
4405
4400
4395
4390
4385
4380
4375
4370
5/24/99
5/24/00
5/24/01
5/24/02
5/24/03
5/24/04
5/24/05
5/24/06
5/24/07
5/24/08
5/24/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

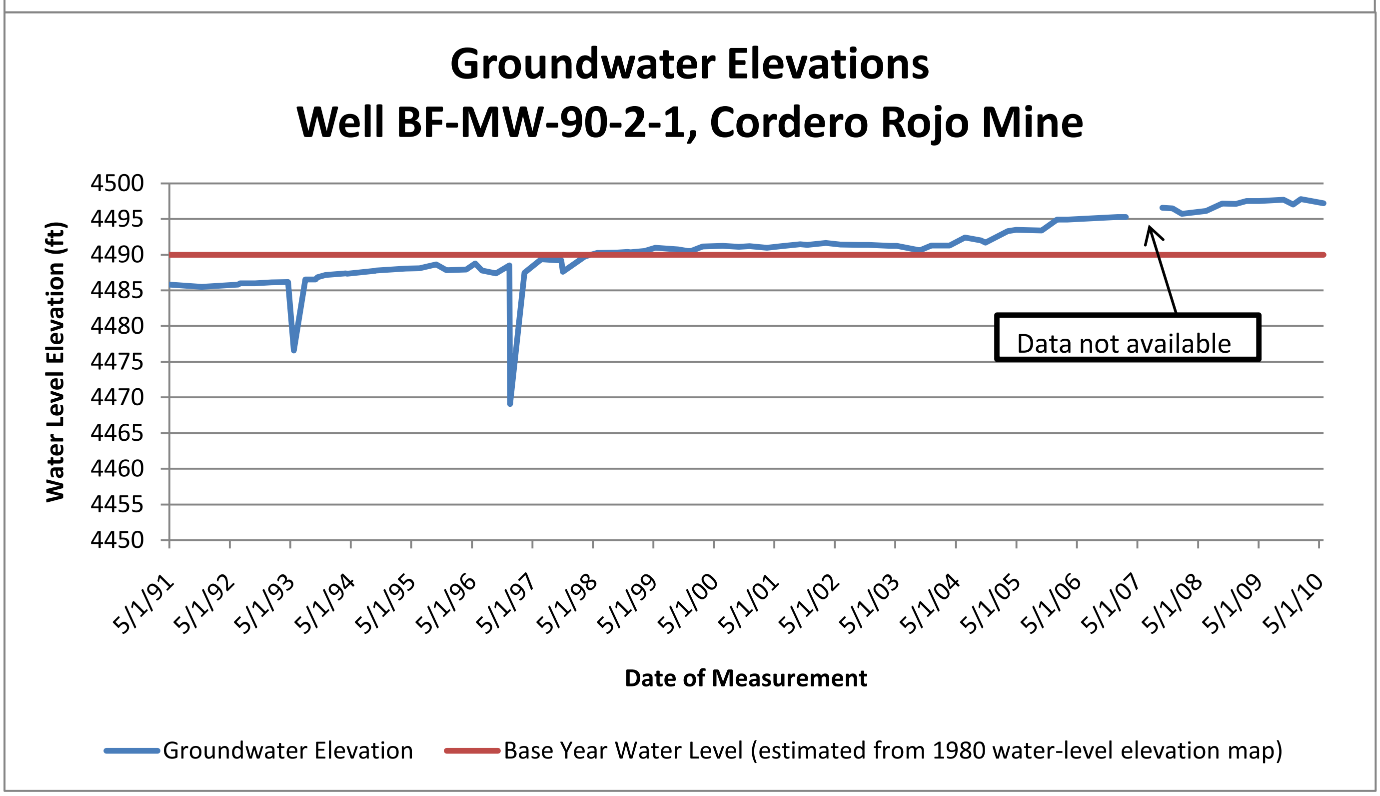

Groundwater Elevations
Well CA-724-B, Caballo Mine
Water Level Elevation (ft)
4466
4464
4462
4460
4458
4456
4454
4452
4450
Data not available
2/21/86
2/21/87
2/21/88
2/21/89
2/21/90
2/21/91
2/21/92
2/21/93
2/21/94
2/21/95
2/21/96
2/21/97
2/21/98
2/21/99
2/21/00
2/21/01
2/21/02
2/21/03
2/21/04
2/21/05
2/21/06
2/21/07
2/21/08
2/21/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

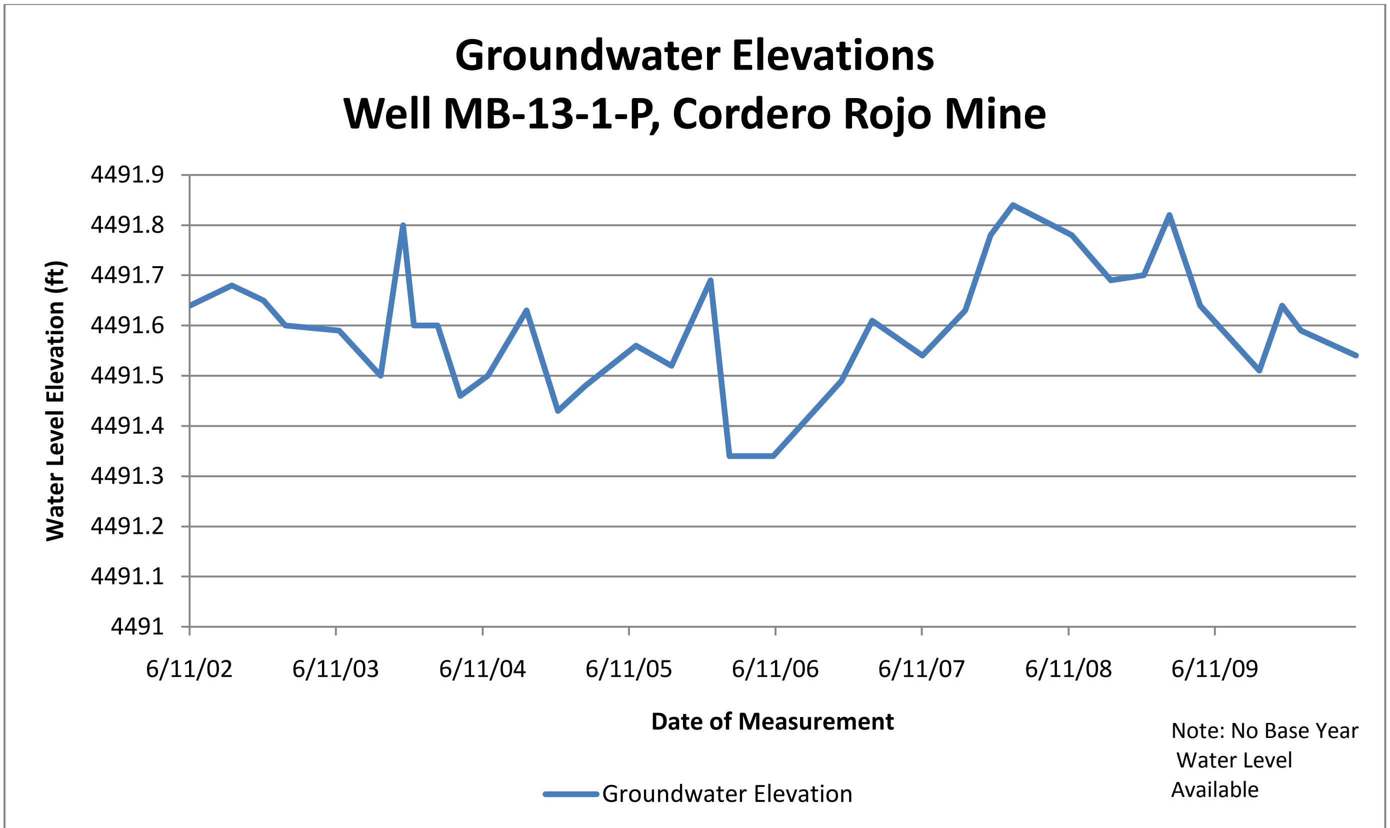

Groundwater Elevations
Well CA-824-B, Caballo Mine
Water Level Elevation (ft)
4450
4440
4430
4420
4410
4400
4390
4380
4370
10/7/87
10/7/88
10/7/89
10/7/90
10/7/91
10/7/92
10/7/93
10/7/94
10/7/95
10/7/96
10/7/97
10/7/98
10/7/99
10/7/00
10/7/01
10/7/02
10/7/03
10/7/04
10/7/05
10/7/06
10/7/07
10/7/08
10/7/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

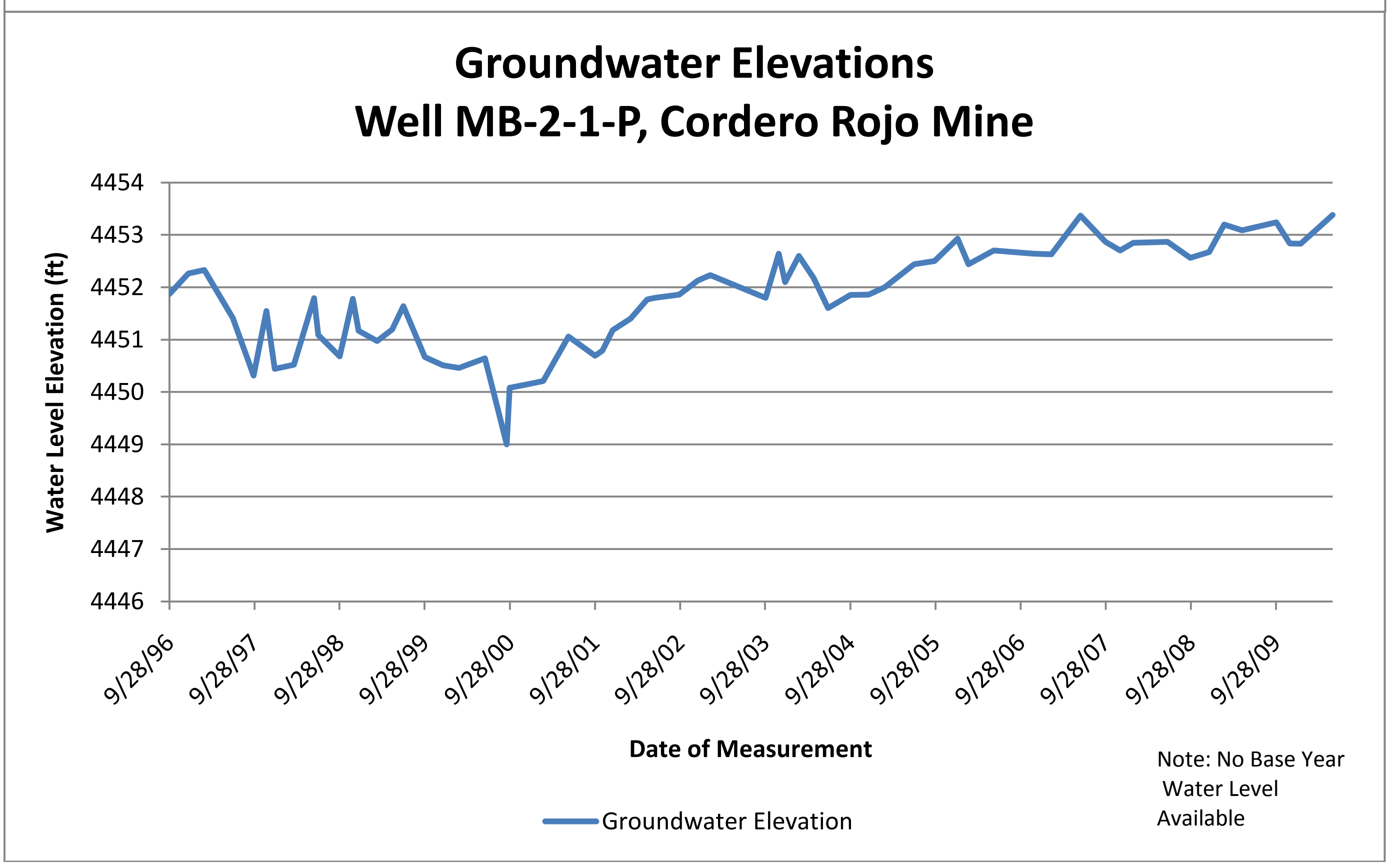

Groundwater Elevations
Well CA-969-B, Caballo Mine
Water Level Elevation (ft)
4420
4415
4410
4405
4400
4395
4390
4385
4380
Data not available
1/12/89
1/12/90
1/12/91
1/12/92
1/12/93
1/12/94
1/12/95
1/12/96
1/12/97
1/12/98
1/12/99
1/12/00
1/12/01
1/12/02
1/12/03
1/12/04
1/12/05
1/12/06
1/12/07
1/12/08
1/12/09
1/12/10
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

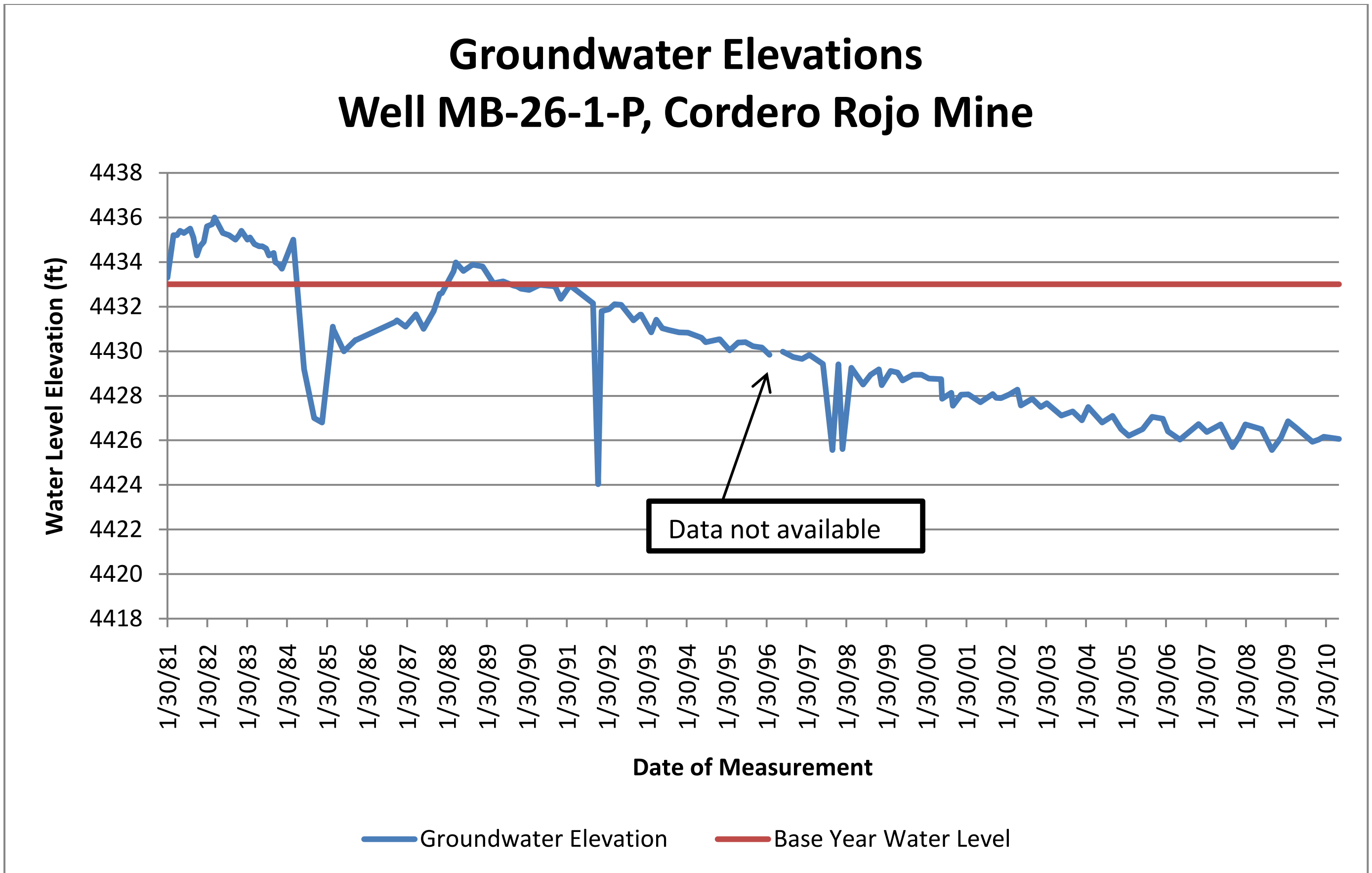

Groundwater Elevations
Well CCB-1A, Coal Creek Mine
Water Level Elevation (ft)
4585
4580
4575
4570
4565
4560
4555
4550
4545
4540
4535
4530
9/1/03
12/1/03
3/1/04
6/1/04
9/1/04
12/1/04
3/1/05
6/1/05
9/1/05
12/1/05
3/1/06
6/1/06
9/1/06
12/1/06
3/1/07
6/1/07
9/1/07
12/1/07
3/1/08
6/1/08
9/1/08
12/1/08
3/1/09
6/1/09
9/1/09
12/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

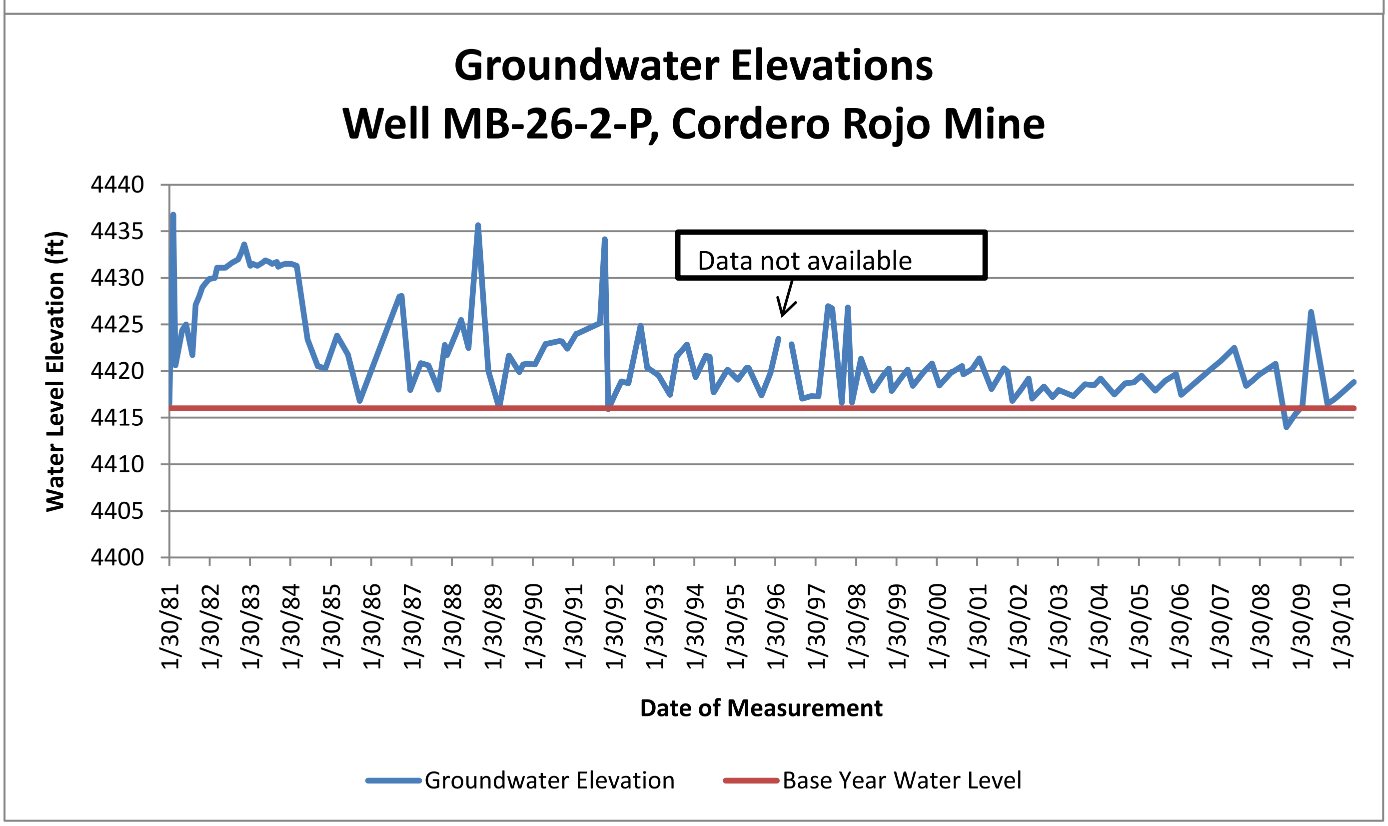

Groundwater Elevations
Well CCB-3, Coal Creek Mine
Water Level Elevation (ft)
4640
4638
4636
4634
4632
4630
4628
4626
4624
4622
4620
3/1/04
6/1/04
9/1/04
12/1/04
3/1/05
6/1/05
9/1/05
12/1/05
3/1/06
6/1/06
9/1/06
12/1/06
3/1/07
6/1/07
9/1/07
12/1/07
3/1/08
6/1/08
9/1/08
12/1/08
3/1/09
6/1/09
9/1/09
12/1/09
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)

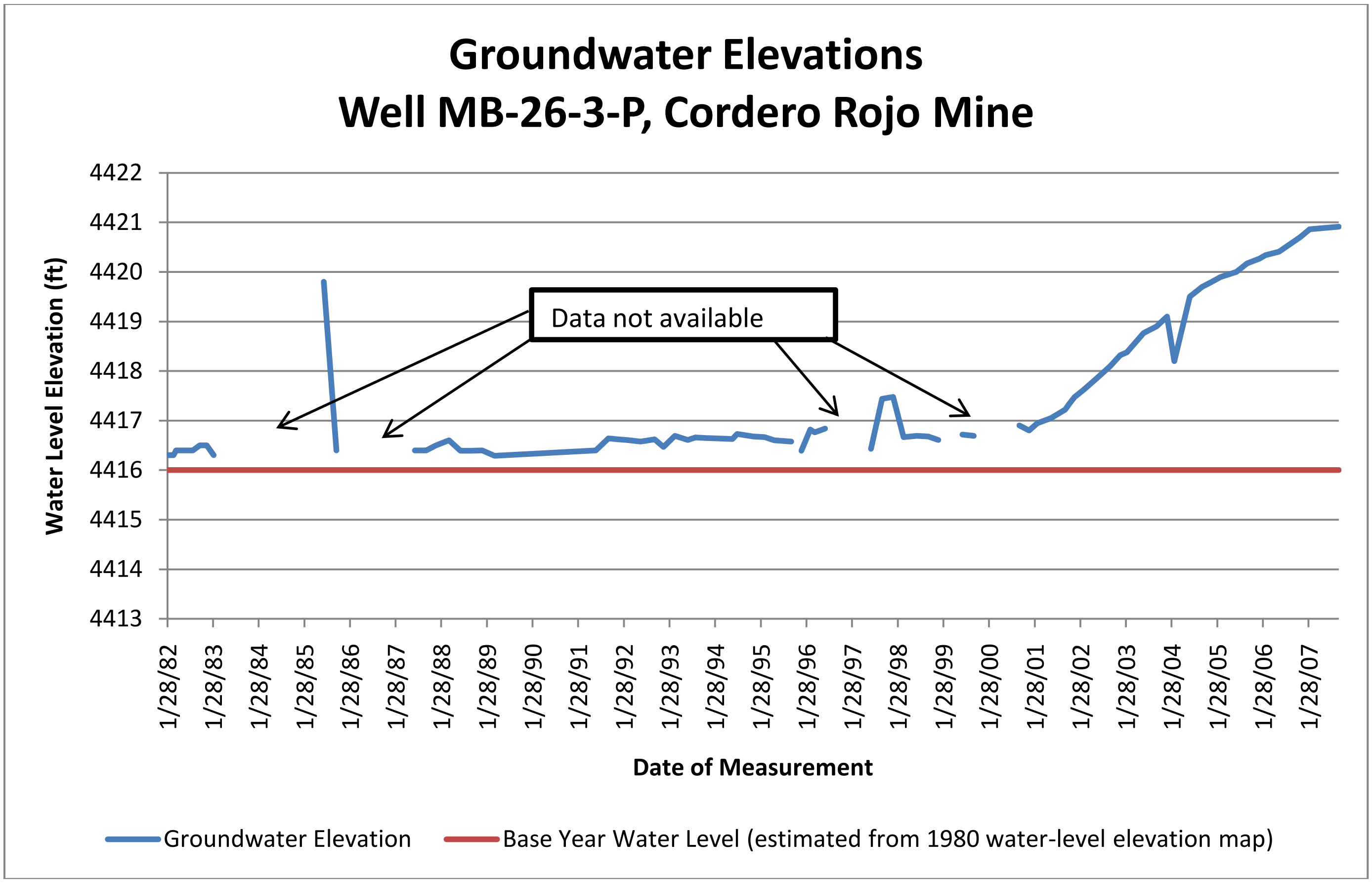

Groundwater Elevations
Well BF-MW-90-2-1, Cordero Rojo Mine
Water Level Elevation (ft)
4500
4495
4490
4485
4480
4475
4470
4465
4460
4455
4450
Data not available
5/1/91
5/1/92
5/1/93
5/1/94
5/1/95
5/1/96
5/1/97
5/1/98
5/1/99
5/1/00
5/1/01
5/1/02
5/1/03
5/1/04
5/1/05
5/1/06
5/1/07
5/1/08
5/1/09
5/1/10
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)


Groundwater Elevations
Well MB-13-1-P, Cordero Rojo Mine
4491.9
4491.8
4491.7
4491.6
4491.5
4491.4
4491.3
4491.2
4491.1
4491
Water Level Elevation (ft)
6/11/02
6/11/03
6/11/04
6/11/05
6/11/06
6/11/07
6/11/08
6/11/09
Date of Measurement
Groundwater Elevation
Note: No Base Year Water Level Available


Groundwater Elevations
Well MB-2-1-P, Cordero Rojo Mine
4454
4453
4452
4451
4450
4449
4448
4447
4446
Water Level Elevation (ft)
9/28/96
9/28/97
9/28/98
9/28/99
9/28/00
9/28/01
9/28/02
9/28/03
9/28/04
9/28/05
9/28/06
9/28/07
9/28/08
9/28/09
Date of Measurement
Groundwater Elevation
Note: No Base Year Water Level Available


Groundwater Elevations
Well MB-26-1-P, Cordero Rojo Mine
Water Level Elevation (ft)
4438
4436
4434
4432
4430
4428
4426
4424
4422
4420
4418
Data not available
1/30/81
1/30/82
1/30/83
1/30/84
1/30/85
1/30/86
1/30/87
1/30/88
1/30/89
1/30/90
1/30/91
1/30/92
1/30/93
1/30/94
1/30/95
1/30/96
1/30/97
1/30/98
1/30/99
1/30/00
1/30/01
1/30/02
1/30/03
1/30/04
1/30/05
1/30/06
1/30/07
1/30/08
1/30/09
1/30/10
Date of Measurement
Groundwater Elevation
Base Year Water Level


Groundwater Elevations
Well MB-26-2-P, Cordero Rojo Mine
Water Level Elevation (ft)
4440
4435
4430
4425
4420
4415
4410
4405
4400
Data not available
1/30/81
1/30/82
1/30/83
1/30/84
1/30/85
1/30/86
1/30/87
1/30/88
1/30/89
1/30/90
1/30/91
1/30/92
1/30/93
1/30/94
1/30/95
1/30/96
1/30/97
1/30/98
1/30/99
1/30/00
1/30/01
1/30/02
1/30/03
1/30/04
1/30/05
1/30/06
1/30/07
1/30/08
1/30/09
1/30/10
Date of Measurement
Groundwater Elevation
Base Year Water Level


Groundwater Elevations
Well MB-26-3-P, Cordero Rojo Mine
Water Level Elevation (ft)
4422
4421
4420
4419
4418
4417
4416
4415
4414
4413
Data not available
1/28/82
1/28/83
1/28/84
1/28/85
1/28/86
1/28/87
1/28/88
1/28/89
1/28/90
1/28/91
1/28/92
1/28/93
1/28/94
1/28/95
1/28/96
1/28/97
1/28/98
1/28/99
1/28/00
1/28/01
1/28/02
1/28/03
1/28/04
1/28/05
1/28/06
1/28/07
Date of Measurement
Groundwater Elevation
Base Year Water Level (estimated from 1980 water-level elevation map)