Utilization of Water Produced from Coal Bed Methane Operations at the North Antelope / Rochelle Complex Campbell County, Wyoming

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Biographical Sketch of Author
Philip A. Murphree is the hydrologist at Powder River Coal Company's North Antelope / Rochelle Complex. His work includes permitting and design of surface and ground water facilities; water supply management, and management of construction and maintenance activities. Mr. Murphree is a graduate of the Mackay School of Mines at the University of Nevada, Reno holding a Bachelor of Science in Geophysics and a Master of Science in Hydrology / Hydrogeology.

Abstract: Coal bed methane production has recently begun in the vicinity of the North Antelope / Rochelle Complex (NA/RC) in Campbell County, Wyoming, the world's largest coal mine. In order to supplement the mine's water supply and to reduce use of deep water supply wells placed in the Fort Union and Fox Hills Formations, provision has been made to utilize the mine's upstream flood control system to capture and temporarily hold water produced from coal bed methane operations. Water will then be pumped into the mine and held for dust suppression operations and facilities use. Water from coal bed methane operations will also aid in the establishment of wetlands and other reclamation features. Water discharged from the coal bed methane operations near to NA/RC is expected to be of very high quality. Water discharged from the mine has also been shown to be of high quality by monitoring of flow on downstream Porcupine Creek. This should continue when coal bed methane development reaches its full potential.

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Introduction

Powder River Coal Company's North Antelope / Rochelle Complex (NA/RC) is the world's largest coal mine, producing 74.8 million tons of sub-bituminous coal in 2001. The mine is located on the eastern flank of the Powder River Basin in Campbell County, approximately 65 miles south of Gillette, Wyoming (Figure 1). The topography is generally flat with most surface drainages flowing into ephemeral streams. Four landforms originally existed in the permit area. Well-developed soils exist on the gentle sloping upland tablelands in the northern part of the permit area, which covers approximately 27,000 acres. Highly erosive badlands, which have mostly been removed by mining, are characteristic of the central portion of the permit area. The most conspicuous landforms in the southern portion of the permit are erosion resistant clinker (porcelainite) hills. Lastly, sheetwash deposits, colluvium, and lesser amounts of alluvium exist along portions of the ephemeral drainages. Reclaimed portions of the permit area, as required by law, are characterized by well-vegetated gently sloping hills. A downstream section of the main drainage in the permit area, Porcupine Creek, was classified as intermittent. Two sections of lower Porcupine Creek were also classified as alluvial valley floors (AVF) not significant to farming. The mine has already reclaimed these sections of Porcupine Creek using specialized methods.

The climate of the North Antelope / Rochelle Complex is cool and semi-arid and is characterized by dry cold winters and short warm summers. Factors controlling the regional climate include elevation, abundant sunshine, with mountainous moisture barriers to the west and south. The generally open terrain of the region permits free movement of wind and weather systems through the area allowing rapid and extreme weather changes. The elevation of the permit area ranges from 4500 to 5000 feet a.m.s.l. Mean annual precipitation at NA/RC is approximately 11.5 inches per year with the major portion of precipitation occurring as scattered thunderstorms during the late spring or early summer. Predicted annual evapotranspiration at Douglas, Wyoming, approximately 65 miles south of NA/RC, is nearly 23 inches per year (U.S. Dep't Commerce, 1969).

Porcupine Creek is tributary to Antelope Creek, which is tributary to the Dry Fork of the Cheyenne River and the Cheyenne River. The North Antelope / Rochelle Complex maintains upstream and downstream gauging stations on Porcupine Creek. Generally, there has been very little flow recorded upstream of the mine. This is due to the large number of stock ponds on upper Porcupine Creek and the sandy surface soils of the upstream tributaries. Surface water quality is variable depending on flow, but is usually poor due to the amount of evapotranspiration taking place in the alluvium and pooled water, and the lack of flushing flows. Most recent flow downstream of the mine recorded has been due to discharge of pumped water from the North Antelope / Rochelle facilities area. This flow has been significantly reduced since 1999 due to the mine's use of water approaching the volume of available supply. Water quality downstream of the mine is generally very good due to the amount of pumped water from the coal, porcelainite, and lower Fort Union aquifers and the amount of vegetation in the final mine impoundment. Downstream of the mine, at the confluence of Porcupine and Antelope Creeks, is the 330 acre-foot Porcupine Reservoir. Flow to Antelope Creek has only been recorded once over the last ten

years. This occurred following a storm event of greater than 100-yr 24-hr frequency on the east side of the mine, directly upstream of the reservoir.

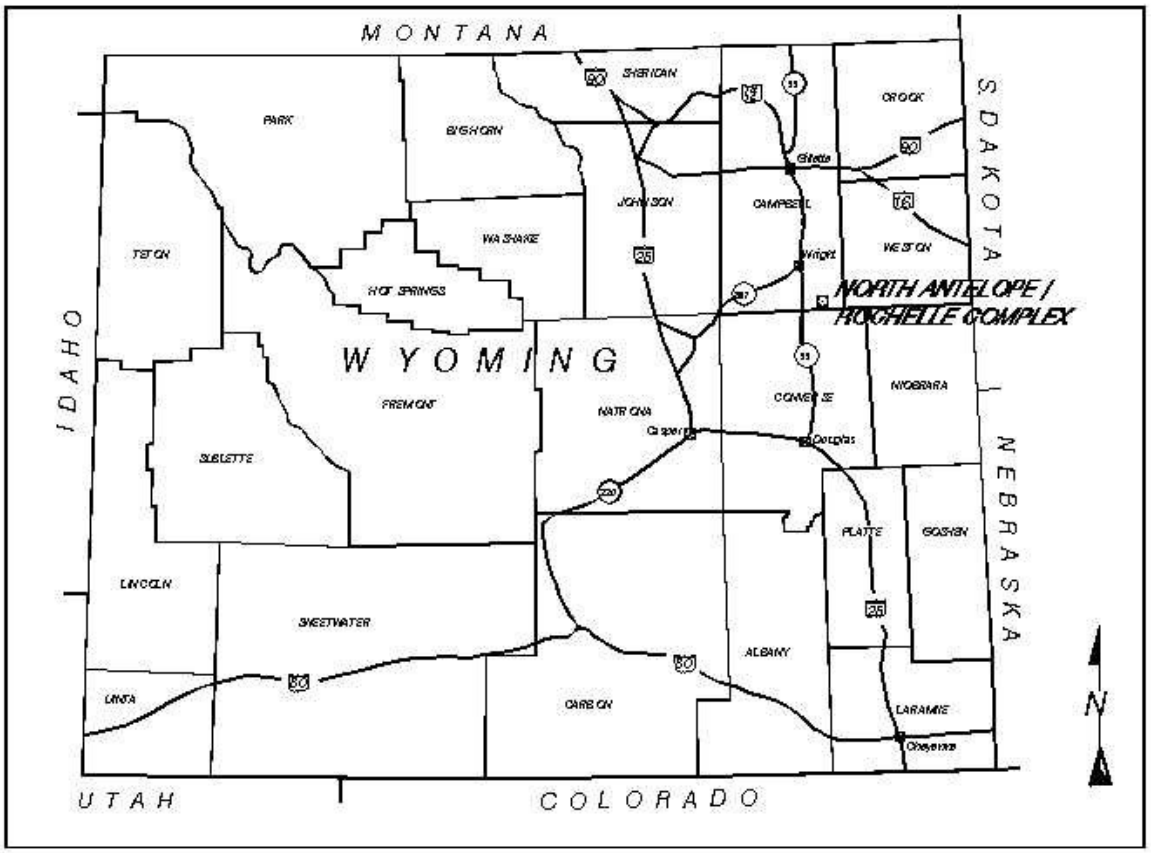

Figure 1: Location of North Antelope / Rochelle Complex; Campbell County, Wyoming.

Water used at NA/RC for dust suppression and facilities use currently originates from a variety of sources, including deep water supply wells, pit pumping of ground water, and surface runoff. The mine formerly operated ahead-of-mining dewatering wells placed in the overburden and coal, but has replaced the coal wells with coalbed methane wells as gas rights were acquired and gas pipelines developed in the vicinity of the mine. Haulroad dust suppression, which may account for up to three million gallons per day in summer, is the major use of water at NA/RC, followed by facilities washdown, with potable water use composing the remainder.

Prior to 2001, North Antelope / Rochelle utilized a diversion system for flood control and to route most storm water through the mine. However, operational concerns, including the limited reclamation that could be performed with the diversion in place, dictated removal of the diversion. Large reservoirs on the upstream drainages have now replaced the diversion for the purpose of flood control. The four largest of these flood control structures have been designed to hold the 100-year 24-hour runoff event. Capacity to temporarily hold and pump water produced from nearby coalbed methane operations has also been designed into the structures. That water will be combined with flood control waters and pumped into the mine for use in dust suppression operations and for reclamation use. The use of coal bed methane water will allow NA/RC to reduce the use of water from deep water supply wells, while at the same time, continue to meet ever stricter air quality regulations and improve the quality of our reclamation efforts.

Current Water Supply and Use at the North Antelope / Rochelle Complex

The North Antelope / Rochelle Complex (NA/RC) uses a considerable amount of water for a variety of uses including haulroad dust suppression, facilities washdown, and potable water. Facilities washdown includes the frequent washing of all crusher and transfer facilities as well as the periodic washing of equipment and vehicles. All potable water and much of the facilities water is provided by deep water supply wells. However, only a portion of the haulroad water budget is provided by wells. There are currently three water supply wells placed in the Fort Union Formation. These wells are approximately 2,000 feet deep and produce approximately 200 gallons per minute (gpm) of high quality water (TDS ~250 mg/l). These wells are separated by approximately 1.5 miles to limit the influence of one well on another. A single 5,300 feet deep well placed in the Fox Hills Formation provides approximately 350 gallons per minute of lesser quality water (TDS ~750 mg/l). Facilities washdown water for the western portion of the mine is provided through a reservoir supplied by one of the Fort Union wells. Water recaptured from the mines primary downstream sedimentation pond and from the clinker adjacent to the facilities area and recycled back through the water supply pond has significantly reduced use of ground water for facilities use.

The maximum daily use for haulroad dust suppression in the summer months is approximately three million gallons per day (~2,100 gallons per minute (gpm)), while the minimum daily use in the winter is approximately 170,000 gallons per day. Prior to 1995, almost all of the water supply needs were provided by groundwater pumped to tanks or lined water supply reservoirs. Runoff water was discharged from the mine site following storm events. However, as the mine began to expand and increase production, the water use at the mine began to exceed the capacity of the wells at the mine. In order to provide a secondary source of water, sediment ponds were converted to facilities ponds to supply water trucks from runoff and mine pit pumpage. Today, most haulroad dust suppression water is provided from water supply ponds placed on the mine backfill. Total haulroad and ramp acreage is currently 212 acres. Annual water use for haul roads at NARC in 2000 was 338 million gallons. The water use at the mine is expected to increase over the next few years due to the lengthening of haul roads and continuing efforts to meet strict dust control standards.

Due to the scarcity of significant runoff events and pit pumping rates that average approximately 200 gallons per minute on the west side of the mine, it is essential that water be accumulated in reservoirs in the relatively wet and cold winter and spring for use in the summer months. Water from wells, pit pumping, and surface runoff is combined in these ponds. The water storage reservoirs, a subset of the facilities reservoirs, at the mine differ from sediment ponds in that they either do not provide final sediment control or are large enough to store water while still maintaining their sedimentation capacity. There is approximately 238 acre-feet (77.4 million gallons) of water storage available in these structures. However, it has been rare to have all of the water supply reservoirs full at the same time due to the limited runoff and ground water supply. During dry and windy periods, the available water supply can be quickly depleted by dust suppression activities.

Water loadouts for loading water trucks are located at five reservoirs at NA/RC. The conventional loadouts are designed to load the mine's five smaller water trucks, which carry between 12,000 and 20,000 gallon. Two fast fill loadouts are designed to load the single 44,000-gallon water truck (Figure 2). In 2001, a significant effort was made to connect the water supply reservoirs with each other to allow sharing of water between the pits. Water may now be moved from the eastern portion of the mine to the middle and north portions, where there is more need for the water. Water can also be returned from the middle portion of the mine to the western

portion of the mine. Sediment traps and small sediment ponds have also been constructed to protect the water supply reservoirs from excessive sedimentation in order to maintain capacity.

Figure 2: 44,000 Gallon Water Truck in Operation in Coal Hopper Area During Windy Day.

Flood Control and the North Antelope / Rochelle Water Distribution System
Due to removal of the upstream Porcupine Creek Diversion in 2001, five flood control reservoirs were constructed on upstream drainages. These are connected to the rest of the mine's upstream flood control system by surface HDPE pipelines. Discharging water from large flood control reservoirs usually involves pumping around the active mine due to the difficulty of finding a pipeline route from the reservoir across the active pit and through to the completed reclamation. Although Porcupine Creek has provided very little water to the mine historically due to the large number of stock ponds on its upstream reaches, the onset of CBM production is expected to fill the large amount of pool storage available on Porcupine Creek and allow floodwaters to reach the mine.

At North Antelope / Rochelle, flood waters and coal bed methane discharge water will be pumped into water supply reservoirs using four large flood control reservoirs in the northwest of the permit area. Three of these reservoirs have a large amount of capacity reserved for water storage. Water from smaller upstream flood control reservoirs is pumped to these large reservoirs, but coal bed methane water will not be pumped to these smaller reservoirs. Generally, capacity is maintained for the 100-year, 24-hour storm event in the larger flood control reservoirs, while the smaller flood control reservoirs are designed for the 10-year, 24-hour storm event.

Water collected in the northwest portion of the permit area can be released through a slidegate to flow approximately one mile to a large stockpond within the current primary coal bed methane production area. From this stockpond, water is pumped approximately one mile north to mine's largest flood control structure, which has a total capacity of 275 acre-feet (200 acre-feet flood control, 75 acre-feet temporary storage). Water may then be pumped another mile east to a

smaller flood control structure (61 acre-feet flood control, 20 acre-feet storage), and then two miles east to another flood control structure (100 acre-feet flood control, 75 acre-feet storage) (Figure 3). A total of 170 acre-feet of water storage are provided in the upstream flood control reservoirs. From the last upstream flood control structure, water is pumped nearly three miles across an abandoned mine highwall to a water supply reservoir in the backfill. Water can then be distributed using the mine's water distribution system. More than twenty-five miles of 6, 8, and 14-inch diameter HDPE pipe were added in 2001 to construct the new flood control system and upgrade the mine's water supply capacity. These pipelines can be moved and extended as flood control reservoirs are replaced by new structures and new water supply reservoirs are constructed.

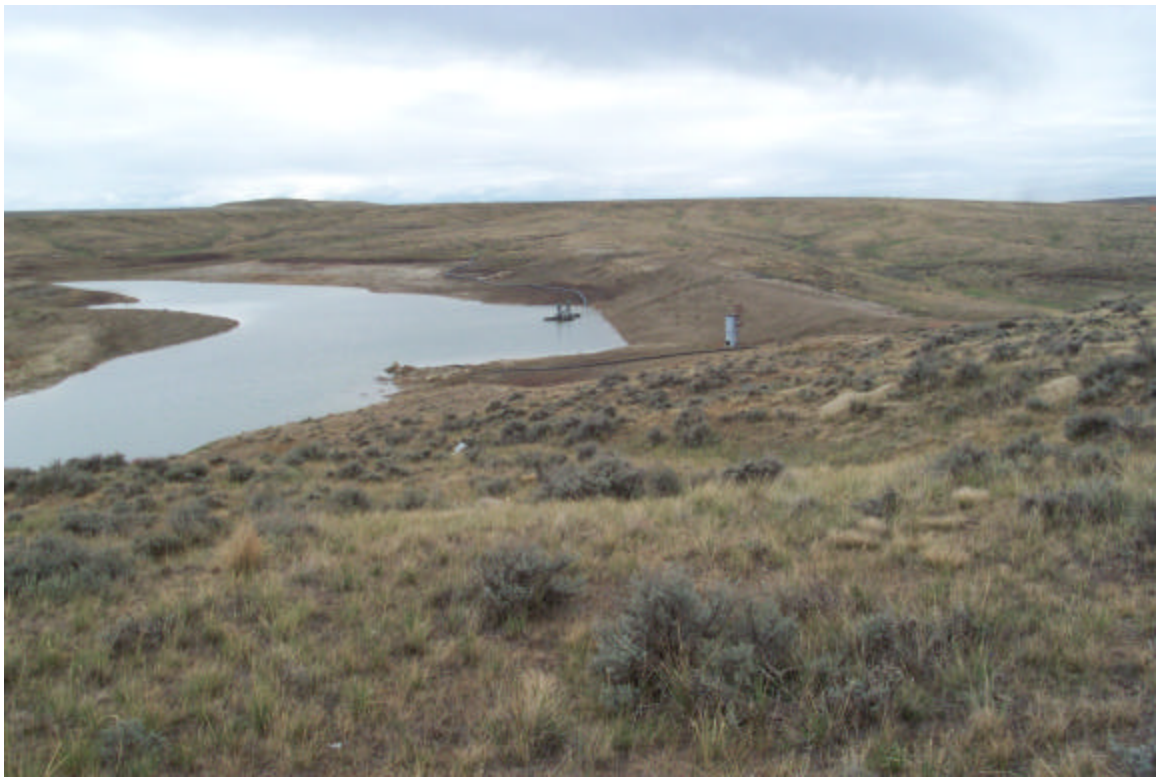

Figure 3: Coal Bed Methane Produced Water Stored in Flood Control Reservoir at North Antelope / Rochelle Complex, September 2002.

Coal Bed Methane in the Vicinity of the North Antelope / Rochelle Complex

Although coal bed methane production and development have been intensive in recent years in Campbell County, Wyoming, the first twenty-eight CBM wells drilled in the immediate contributing drainage of Porcupine Creek upstream of NA/RC were drilled in late-2001 and early-2002. Sixteen of these wells are now producing water, with combined production at approximately 500,000 gallons per day. The remaining twelve wells are expected to be online this year. Permitting delays involving the U.S. Forest Service (much of the mine and vicinity is within the Thunder Basin National Grasslands) and the Bureau of Land Management have slowed development of the large coal bed project areas to the north and west of NA/RC. Eventually it is expected that nearly 500 coal bed methane wells will be drilled in the Porcupine Creek drainage. It is difficult to estimate the amount of water that these new CBM wells will produce. Water production from CBM wells will quickly decline from peak levels and few of the wells will enter

production at the same time. Upstream storage for livestock use and/or irrigation may also consume some water as will seepage into alluvial and overburden aquifers. The water quality in the coal within the CBM production area is very good. The TDS is typically 435 mg/l and the SAR is about 6.4.

North Antelope / Rochelle has made agreements with coal bed methane producers upstream of the mine to handle produced water within the mine permit area. While concern has been raised that more CBM water will enter the mine than can be efficiently handled and that the mine will not be able to discharge the excess water within effluent limitations, the CBM producers will not be allowed to discharge more water to the mine than can be efficiently handled. Water produced from CBM operations must be discharged under all applicable state and federal permits. If more water is being produced from coal bed methane wells than the mine can process, other options for water discharge, including construction of upstream storage reservoirs, re-injection, or pumping around the mine, will have to be utilized by the CBM producers. Points of discharge are specified in the agreements between PRCC and CBM producers. Wherever possible, discharges will be directly to major drainages to limit uptake of salts from soils.

Use of Produced Water for Reclamation and Aquifer Recharge

In addition to improving the dust suppression capability at North Antelope / Rochelle and the reduction of deep water supply well use, the CBM-derived water will be used to improve reclamation at the mine. Water pumped held in storage during the colder and wetter winter and spring months, will be pumped out in the summer for use in dust suppression. Much of this water will flow through the reclaimed Porcupine Creek channel. As required by the mine's permit from the Wyoming Department of Environmental Quality / Land Quality Division (WDEQ/LQD), the reclaimed Porcupine Creek channel (feet) is underlain by an 80 feet wide by 20 feet deep reconstructed fill of material containing at least 70 percent sand. Water discharged from coal bed methane wells and used for dust control may also allow the mine to discharge water directly to the reclaimed stream channel. This has occurred frequently in 2002.

Approximately two miles of Porcupine Creek have been reconstructed. The upper section of the reclaimed Porcupine Creek was reconstructed using replacement alluvial material in 1999. Pools and counter-weirs were constructed on the channel in 1999 as well. Due to direct flow of water from the native Porcupine Creek through the Porcupine Creek Diversion, this area already shows good development of wetland characteristics only a few years following reclamation. Alluvial water levels are still rising in the upper Porcupine reclamation, but the reclaimed alluvial water quality is generally good and is similar to the water quality in the overburden (TDS of 1200 to 2200 mg/l, from which the replacement alluvium originated, and adjacent backfill. Surface water quality is also good, with TDS concentrations at approximately 1,100 mg/l. This is much better than the water quality in the native Porcupine Creek, where TDS often exceeded 3,000 mg/l. Trace metal concentrations have not been a concern in this section.

Although a lower one-mile section of Porcupine Creek was constructed in 1985 and 1986, a diversion bypassed the section until early-2001. Flow in this section was limited to infrequent discharges from a sediment reservoir upstream of this channel. In addition, the lower creek was reconstructed using an old channel design criteria that required channelization and limited the amount of pooled water. In early-2002, the adjacent diversion was removed and pools and counter-weirs were constructed on the lower reclaimed Porcupine Creek (Figure 4). Water has now been pumped from facilities area dewatering wells into this section of creek to fill the pools and maintain flow. Trees have been planted on the reclaimed channels and riparian vegetation along the channel is expected to improve, as more water is available. If water is discharged from the mine to the native Porcupine Creek, it will flow through this reclaimed channel.

Figure 4: Pool and Counter-Weir Sequence on Lower Section of Reclaimed Porcupine Creek Channel with Caged Coyote Willow (Salix exigua) Plantings

The lower reclaimed Porcupine Creek was constructed from native alluvium as required by the WDEQ/LQD at the time. Water quality in the four reclaimed alluvial wells in the lower channel has been poor. Premining alluvial wells located in the general vicinity of the above wells showed generally poor quality with TDS levels ranging from approximately 750 mg/l to 5,770 mg/l. However, alluvial wells in the Powder River Basin often show native water quality much worse than that reported above. One alluvial well on upstream Porcupine Creek has a TDS level of about 37,000 mg/l. When mixing and oxidation of the highly mineralized alluvial material occurred during mining and then the material was placed in the reclaimed alluvial valley floor, the water quality reflected the new mobility of the constituents. Although one shallow reclaimed alluvial well, showing seasonal variations in water level, has a range in TDS concentrations of between 1,230 and 2,652 mg/l, TDS concentrations in the three other reclaimed alluvial wells ranged from 5,500 to 12,250 mg/l. Trace metal concentrations in the reclaimed alluvium of the lower Porcupine Creek have fluctuated. Selenium concentrations have reached as high as 932 mg/l, but generally have ranged from 0 to 200 mg/l. As water recycled from facilities at the mine has been placed on the lower section of reclaimed channel, selenium concentrations have been lower and conditions appear to be more reducing.

Following construction of the pools and counter-weirs in January 2002, reclaimed alluvial water levels have risen approximately 3 feet. Boron concentrations are elevated as water is flushed through the unsaturated zone, but selenium and arsenic concentrations are much lower. As water was pumped out of the adjacent clinker in 2002, selenium and arsenic concentrations increased again, but decreased when pumping declined. It is expected that with water available to the lower reclaimed Porcupine Creek channel, ground water conditions can be kept consistently reducing

and the fluctuations in alluvial water levels will decrease. It is also hoped that sulfate-reducing bacteria will proliferate in the new wetter environment, thereby reducing concentrations of many of the constituents of concern. Sulfate-reducing bacteria exist in the deeper backfill wells adjacent to the reclaimed channel section. A compacted clay liner separates the standard backfill aquifer from the reclaimed alluvium, however, water levels in the reclaimed alluvium and the backfill are similar.

Current modeled estimates of water level recovery at North Antelope / Rochelle show that it may take over 1000 years for complete recovery to premining water levels in the coal. Fifty percent of the water level recovery will take place in the first 200 years following mining. With the development of coal bed methane, these estimates will increase significantly due to the large area of coal bed methane development and the great depth of coal bed methane wells towards the center of the Powder River Basin. Around the facilities areas, estimates of recovery to premining water levels are in the hundreds of years. However, seepage from water supply and sediment reservoirs on the mine backfill and water seeping into the backfill from the reclaimed alluvial aquifers has raised backfill water levels at NA/RC much faster than predicted by mine and area ground water models. Water levels near the facilities area near Porcupine Creek are near premining water levels approximately 15 years following mining. It is expected that water from coal bed methane operations being pumped through the mine for discharge or use in operations and reclamation use will similarly seep into the backfill aquifers and allow for more rapid than predicted recharge.

The postmining land use at NA/RC will be rangeland grazing and wildlife habitat. Water stored in sediment and water supply reservoirs as well as in reclaimed stream channels already supplies water to abundant populations of deer and antelope as well as numerous bird species. The reclaimed Porcupine Creek supports three species of non-game fish, one frog species, and numerous insects and invertebrates (Hansen and Murphree, 2002). During the next few years, it is expected that cattle will be introduced to the reclaimed lands at NA/RC, water from CBM operations is expected to supplement ground water from the shallow Fort Union Formation as a water source for livestock. Tree farming, using water from streams and wells, will also be practiced to help establish upland tree species.

Release of Water from the North Antelope / Rochelle Complex

As stated in the introduction and shown by flow records for the mine, most flow downstream of the mine as been due to discharge of pumped water from the mine's facilities area. This flow has been significantly reduced since 1999 due to the mine's use of water approaching the volume of available supply and more efficient recapture of water by the mine. Water quality downstream of the mine is generally very good due to the amount of water pumped from the coal, clinker, and lower Fort Union aquifers and the amount of vegetation in the final mine impoundment. The mean TDS concentration is 1644 mg/l and the mean SAR is 3.23. Trace metal concentrations are not a concern. Downstream of the mine, at the confluence of Porcupine and Antelope Creeks, is the 330 acre-foot Porcupine Reservoir. Flow to Antelope Creek has only been recorded once over the last ten years. This occurred following a storm event of greater than 100-yr 24-hr frequency on the east side of the mine.

Eventually, it is expected that some water will be discharged from Porcupine Reservoir into Antelope Creek due to mine discharges and the associated CBM produced water. However, agreements between Powder River Coal Company and the CBM producers will limit the volume of these discharges. Water quality at Porcupine Reservoir is monitored monthly by NA/RC. TDS concentrations at Porcupine Reservoir average 1088 mg/l with the mean SAR being 3.0. Water quality in the Porcupine Creek alluvium downstream of North Antelope / Rochelle has

actually improved since the opening of the mine due to dilution by mine discharges and vegetative uptake of solutes. In general, as long as discharges of water from the mine or CBM production are directly to major drainages, water quality in those drainages should not be detrimentally affected in the NA/RC area.

Conclusion

Coal bed methane production has recently begun in the vicinity of the North Antelope / Rochelle Complex (NA/RC) in Campbell County, Wyoming, the world's largest coal mine. In order to supplement the mine's water supply and to reduce use of deep water supply wells placed in the Fort Union and Fox Hills Formations, provision has been made to utilize the mine's upstream flood control system to capture and temporarily hold water produced from coal bed methane operations. Water will then be pumped into the mine and held for use in dust suppression operations and facilities use. Water from coal bed methane operations will also aid in the establishment of wetlands and other reclamation features. Water discharged from the coal bed methane operations near to NA/RC is expected to be of high quality. Water discharged from the mine has been shown to be of high quality by monitoring of flow on downstream Porcupine Creek. If discharges from Porcupine Creek to Antelope Creek occur due to coal bed methane production, water quality should not be detrimentally affected. If more water is being produced from coal bed methane wells than the mine can process, other options for water discharge, including construction of upstream storage reservoirs, re-injection, or pumping around the mine, will have to be utilized by the CBM producers.

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