4.0 STREAM CHANNEL STABILITY EVALUATION

The PRB Coal Review includes an evaluation of cumulative impacts to stream channel stability in the PRB Wyoming study area. This evaluation was conducted by AEC (2009). In general, cumulative impacts to channel stability largely relate to changes in water quantity associated with discharges from existing or projected development activities as compared to the runoff characteristics of the receiving drainages. Of particular importance is the quantity of discharge water directly conveyed to the receiving drainages. For purposes of this evaluation, it was assumed that the water discharged directly to the receiving drainages would be limited to CBNG activities (ACE 2009), which are projected to be the primary source of discharge water in the study area through 2020.

Typically, runoff from tributary watersheds is considered the primary factor in channel development. For the subwatersheds in the semiarid study area, this runoff may be infrequent and occur only in response to precipitation events. With respect to the PRB, Martin et al. (1988) concluded that "the fluvial system currently (1987) is stable. Although some gullying and headcutting is occurring, the processes appear to be related to natural rejuvenation of the basins and generally are of a local nature." Therefore, it is likely that active erosion is occurring in some of the ephemeral drainages (ACE 2009).

To the extent possible, the impact to perennial drainages was addressed quantitatively at the subwatershed level using regression equations related to discharge and channel width (ACE 2009). Due to limited data, geomorphic relationships between mean annual discharge, channel gradient and geometry, bed material load, and median sediment size (Lane 1955; Schumm 1977) also were used to provide a qualitative assessment of potential cumulative impacts associated with the discharge of CBNG production water. These relationships provided a qualitative assessment of the response of the receiving drainages to an increase in discharge related to the introduction of CBNG production water.

A site-specific assessment also was performed to evaluate the impact of increased stream flows associated with discharge of CBNG production water in Caballo Creek on existing and reclaimed channels, as well as diversion channels and structures constructed in accordance with coal mine permit criteria. Data available for Caballo Creek in the vicinity of the Subregion 2 coal mines was obtained, reviewed, and utilized to complete the site-specific assessment of channel stability.

4.1 Perennial Stream Channel Evaluation

4.1.1 Methodology

USGS records for the Belle Fourche River below Moorcroft, Wyoming (USGS Gage 06426500), and the Little Powder River above Dry Creek, near Weston, Wyoming (USGS Gage 06324970), provided the basis for the evaluation of perennial stream channel stability (ACE 2009). The daily discharge data for the Little Powder River showed that days with zero discharge occurred less than 3 percent of the days of record, while the daily discharge data for the Belle Fourche River showed that days with zero discharge occurred approximately 23 percent of the days of record. Based on the projected CBNG discharge data (ACE 2009, Appendix A), the modeled annual stream flow in the Little Powder and Belle Fourche rivers is projected to increase by a maximum of 2.2 and 4.3 cfs, respectively, and essentially may eliminate records of zero stream flow (ACE 2009).

Channel-forming discharge was estimated using the peak annual discharge recurrence interval and the common range for channel-forming discharge of between the 1.5- and 2-year recurrence interval. The channel-forming discharge for both the Little Powder and Belle Fourche rivers is presented in **Table 4-1**.

Hydraulic geometry relationships for channel width were developed as a function of discharge for the Little Powder and Belle Fourche rivers from all USGS field measurements classified as “good” during data collection. Using the relationships developed, channel width in the range of the channel-forming discharge was computed by ACE (2009) for the existing condition and for the maximum CBNG production water discharge condition by adding the predicted CBNG discharge rate to the existing condition discharge (see **Table 4-1**).

4.1.2 Perennial Stream Channel Stability Effects

Based on the results of the evaluation as shown in **Table 4-1**, the calculated change in channel width for the Little Powder River is less than 0.3 percent. For the Belle Fourche River, it was calculated to be less than 0.2 percent (ACE 2009). These results suggest that for the larger perennial streams the effect of CBNG production water discharge would be minimal.

Table 4-1
Projected Impact of CBNG Production Water Discharge on Perennial Streams

Location	Channel-forming Discharge[1] (cfs)	CBNG Discharge		Estimated Width		Potential Impact (increased channel width)	
		(cfs)	(percent)	Existing Conditions (feet)	Combined Discharge (feet)	(feet)	(percent)
Little Powder River above Dry Creek near Weston, Wyoming (USGS Gage 06324970)	270 to 420	2.2	0.5 to 0.8	47.3 to 56.3	47.4 to 56.4	0.15 to 0.12	0.3
Belle Fourche River below Moorcroft, Wyoming (USGS Gage 06426500)	652 to 789	3.9	0.5 to 0.6	66.9 to 72.1	67.0 to 72.2	0.16 to 0.14	0.2

[1] Discharge associated with the 1.5- to 2-year recurrence interval.

Source: ACE 2009.

Geomorphic relationships were used to provide insight into the potential impacts of the CBNG production water discharge on the mean annual discharge events associated with the perennial drainages. Based on the projected relatively low increase in mean annual discharge in the perennial streams, the potential trends predicted by the geomorphic relationships (increases in channel width, depth, and meander wavelength) would be considered imperceptible.

4.2 Ephemeral Stream Channel Evaluation

4.2.1 Methodology

Limited data on stream flows are available for the smaller, ephemeral drainage channels in the study area that may receive CBNG production water discharge (ACE 2009). In addition, projected future CBNG production water discharge rates for the PRB Coal Review were developed on a subwatershed basis. Therefore, for purposes of this study it was assumed that CBNG production water would represent a much higher percentage of the mean annual discharges in some of the ephemeral drainages within the study area. As a result, impacts to channel stability may include increases in channel erosion, headcutting, and incision (ACE 2009).

Geomorphologic studies using data developed from different locations to infer landform development through time commonly use a technique termed location-for-time substitution. This technique was used to develop a Channel Evolution Model (CEM) for Oaklimeter Creek, an incised stream in northern Mississippi (Schumm et al. 1984, 1981). Simon and Hupp (1987) later developed a similar model of channel evolution based on Schumm et al. (1984, 1981). The CEM consists of five channel-reach types that describe the evolutionary phases typically encountered in an incised channel. The model is based on the assumption that moving downstream through the system is equivalent to remaining in place and monitoring changes due to the passage of time (ACE 2009). Therefore, the response at any given location in the channel can be estimated from the morphology of downstream channel locations. As noted above, some of the ephemeral channels that are projected to receive CBNG production water discharge currently are actively eroding.

Fundamentally, the cause for channel incision (gully formation) is an imbalance between the sediment transport capacity and the sediment supply. The primary value of the CEM sequence is that it supports the identification of the evolutionary state of the channel based on field reconnaissance (ACE 2009). The physical characteristics of the channel reach types also can be correlated with hydraulic, geotechnical, and sediment transport parameters (Harvey and Watson 1986; Watson et al. 1988). The evolution sequence provides an understanding that while reaches of a stream may differ markedly in appearance, the channel form in one reach is associated with that in adjacent and remote reaches by an evolutionary process.

4.2.2 Ephemeral Stream Channel Stability Effects

The projected discharge of CBNG production water into the ephemeral drainages in the study area may initiate or increase erosion within ephemeral stream channels. Should erosion be initiated, it is anticipated that a small incision may occur, given the relatively minor flow compared to the typical gully section in the typical ephemeral drainage channel. In addition, the sustained nature of the projected CBNG production water discharge also may generate and support an increase in diversity and density of the vegetation along the channel. An increase in vegetation may prevent channel erosion, or partially stabilize existing erosion, within the ephemeral drainage channels.

Similar to the perennial stream channels, the geomorphic relationships were used to provide insight into the potential impacts of CBNG production water discharge on the mean annual discharge events associated with the ephemeral drainages. Given that the incremental increase in mean annual discharge would be more substantial in the ephemeral drainage channels, and that the increases attributable to CBNG production water would be sustained, it is likely that potential increases in channel width and depth would occur along with local reductions in channel gradient.

4.3 Caballo Creek Channel Stability Evaluation

4.3.1 Methodology

For purposes of this evaluation, stream flow data were collected in Caballo Creek from above and below the Subregion 2 coal mines, and annual mine reports that contained information regarding CBNG production water discharges in the area were obtained. In addition, precipitation data were analyzed to evaluate the impact of potential drought conditions on the hydrologic period of record selected for this evaluation. Data available from a precipitation gage near Gillette, Wyoming, were used for this analysis. Further evaluation of the impact of potential drought conditions was conducted through evaluation of the Palmer Drought Index on the Belle Fourche drainage basin in Wyoming. The Palmer Drought Index, typically used as a measure of dryness, is based on a supply and demand model of soil moisture and has proven most effective in determining long-term drought. In addition, field reconnaissance was performed to document the condition of stream banks, channels, and stream flows within the study area.

A USGS water quality sampling site (USGS 06425800 - Caballo Creek near Gillette, Wyoming) is located near the crossing of Caballo Creek and SR 59, upstream and on the western side of the Subregion 2 mine permit boundary. Near the USGS sampling site is the first of two Caballo Creek stream gages (Gage BA-6). This USGS sampling site includes a drainage area of 122 square miles. A second gage (Gage BA-4) is located at the downstream or eastern Subregion 2 mine permit boundary. Mine permit documents indicate that Caballo Creek is an intermittent stream with a drainage area from the eastern mine permit boundary of 200 square miles (Western Water Consultants, Inc. 1997). The 2-year peak flow recurrence interval storm was estimated to range from 400 to 441 cfs for this drainage area (Western Water Consultants, Inc. 1997). Included in this drainage area (and tributary to Caballo Creek) are Bone Pile Creek and Duck Nest Creek, both located north of Caballo Creek and flowing across the western Subregion 2 mine permit boundary. As documented in annual mine reports, the majority of the CBNG production water discharge has been contributed from the Bone Pile Creek and Duck Nest Creek watersheds.

Observations made during a field reconnaissance showed no evidence of active erosion within the natural channels of Caballo Creek, Bone Pile Creek, or Duck Nest Creek. Also, there was no evidence of active erosion within the diversion channels or adjacent to the structures within the diversion channels. Increases in vegetation diversity and density were noted within all drainage channels receiving CBNG production water discharge.

4.3.2 Hydrologic and Meterologic Data Results

Hydrologic data from Caballo Creek gages BA-4 and BA-6 for the time period from 1984 to 2004 indicate that discharges recorded at both gages started increasing in approximately 1992. The noted increases in flow were consistent with CBNG production water discharges from wells located within the Caballo Creek, Bone Pile Creek, and Duck Nest Creek watersheds. Based on a review of the Caballo Creek stream flow data:

- Both gages may have received CBNG production water discharge for approximately 10 years.
- The average annual discharge for the BA-4 gage (downstream gage) increased from 0.5 cfs (from 1984 to 1992) to 1.6 cfs (from 1993 to 2004). This represents an increase of 1.1 cfs that potentially is attributable to the contribution of CBNG production water.
- The average annual discharge for the BA-6 gage (upstream gage) increased from 0.02 cfs (from 1984 to 1992) to 0.21 cfs (from 1993 to 2004). This represents an increase of 0.19 cfs that potentially is attributable to the contribution of CBNG production water.

It should be noted that the BA-6 gage is located upstream of the CBNG wells within the Bone Pile Creek and Duck Nest Creek watersheds. Therefore, the impact of the CBNG-related discharge is more evident on the flow data reflected for the BA-4 gage.

The precipitation data reflect the same general trend as the gage data. A general increase in average annual precipitation from 14.36 inches (for the time period from 1984 to 1992) to 18.14 inches (for the time period form 1993 to 2004) was recorded. This represents an increase of 3.78 inches (or 19 percent) in average annual precipitation. Based on a comparative evaluation of the gage data at BA-4, the increase in annual precipitation tends to minimize the impact of the CBNG production water discharge on the increase in stream flow observed at the gage.

Evaluation of the Palmer Drought Index resulted in the following observations:

- Drought conditions were present during the time period from 1984 to 1992, with noticeable improvement or absence of drought conditions beginning in 1993. Minor drought conditions were evident in 2000, the last year of the available data.
- As expected, a correlation between the index values and precipitation data was observed. The increase in annual precipitation beginning in 1993 was refelected in an increase in the Palmer Drought Index and an absence of drought conditions from 1993 to 1999.
- The increase in the Palmer Drought Index beginning in 1993 supports a corresponding increase in stream flow within the Belle Fourche drainage basin.
- With the addition of CBNG production water discharge into Caballo Creek in 1992, the data for the Palmer Drought Index tend to minimize the impact of the CBNG-related discharge on the increase in stream flow observed at the BA-4 gage.

4.3.3 Caballo Creek Channel Stability Effects

A dominant or channel-forming discharge implies that the natural channel morphology (width, depth, slope, and plan form) adjusts to a discharge that is largely responsible for the channel geometry. Dominant discharge generally is considered to be in the range of the 1.5- to 2-year recurrence interval. The 2-year peak discharge for Caballo Creek at the eastern (downstream) Subregion 2 coal mine boundary was estimated to be approximately 400 cfs. The estimated contribution of CBNG production water discharge of 1.1 cfs represents less than 1 percent of the 2-year peak discharge. Based on the relative magnitude of the flow contribution from CBNG production water discharge, geomorphic relationships confirm the conclusion that the minor contribution from CBNG production water discharge to the flow in Caballo Creek likely would not result in active erosion to the channel. Furthermore, given the relatively flat channel gradient and the highly sinuous channel, a sustained discharge of this magnitude likely would promote an increase in diversity and density of the vegetation along the channel. These results were confirmed by observations of the existing channels during the field reconnaissance.

A threshold may exist where the contribution of CBNG production water discharge may create erosion within the receiving drainage channel. Based on the channel slope, channel sinuosity, and watershed area, drainages such as Caballo Creek may not realize an increase in channel erosion but would more likely realize an increase in vegetation diversity and density along the channel. Smaller drainages, such as Bone Pile Creek or Duck Nest Creek, may be more likely to exhibit channel erosion depending on the magnitude of the flow contribution from CBNG water production compared to the channel-forming discharge. However, field observations in these watersheds found similar increases in vegetation along the channels.

4.4 Summary

To have an impact on channel stability that is manifested in active channel erosion, CBNG production water discharge likely would have to represent a substantial portion of the channel-forming discharge in watersheds where the channel slope is steep enough and the width, depth, and sinuosity low enough to impact channel morphology. Based on the magnitude of the projected CBNG production water discharges compared to the channel forming discharge (1.5- to 2-year recurrence interval), the impact more likely would be evident in small ephemeral drainages that are characterized by steep channel gradients, lower sinuosity, and smaller widths and depths. Overall, as the drainage area increases, the channel slope typically decreases along with an increase in sinuosity, thereby reducing the impact of CBNG production water discharge on channel stability.