Drawdown Calculation Narrative
Powder River Gas – Coal Creek POD

Introduction:
Methane (CH_4 or natural gas) is contained in coal seam aquifers where either biogenic or thermogenic methane production has occurred, and the hydrostatic pressure is sufficient to allow for the adsorption of the methane onto the coal surface. This adsorption allows methane concentrations to reach economic levels. CBNG is typically produced by reducing the hydrostatic pressure (head) within the coal seam to near the top of the coal seam by pumping groundwater out of the coal aquifer. This reduction in head causes the methane to desorb from the coal surface, and flow to the low pressure at the well head. The pumping of this groundwater causes a drawdown cone to develop around each well (BLM, 2003).

It has been shown that for a hypothetical well field, of 1,082 CBNG wells, the 20' drawdown contour may extend 4 to 5 miles from the edge of the well field while drawdown within the coal field is expected to be to near the top of the coal seams (Wheaton and Metesh, 2002). In the area of reduced head it would be anticipated that the yield of wells finished in the developed coal seams, and from springs which receive their water from the developed coal seams, would be reduced. It is not anticipated that wells or springs would go dry since the coal seam would continue to be saturated; however yields will be reduced as a result of decreasing the artesian pressure.

Hydro-Geologic Setting:
The Wall and Flowers-Goodale coal seams are proposed for testing under the PRG Coal Creek POD, which is the subject of this analysis. The Wall and Flowers-Goodale are contained within the Tertiary Tongue River Member of the Fort Union Formation. The clay rich units within this unit cause the vertical hydrologic conductivity to be extremely low (Wheaton and Donato, 2004). The coals are also typically bounded by clay rich units. As such the coals are considered to be confined aquifers. Faults in this area are also known to be aquitards (Van Voast and Reiten, 1988). A Geologic Map showing known faults in this area is provided in the Figures section of this report (Vuke et al., 2001). The nearest documented fault to the project area is approximately 3 miles away, however minor faults are known to exist throughout this area. Based upon the results of 370 aquifer tests Wheaton and Metesh (2002) have calculated that the geometric mean horizontal hydraulic conductivity value of the coal seam aquifers in the Fort Union Formation is 1.1 feet per day. The geometric mean horizontal hydrologic conductivity less one standards deviation is $9.8x10^{-2}$ feet per day, and the horizontal hydrologic conductivity plus one standards deviation is 13 feet per day. Mean storativity values of these coals are approximately $9x10^{-4}$ (storativity is unitless) (Wheaton and Metesh, 2002). The average thickness of the produced coal seams from the POD application are as follows: Wall = 55'; Flowers-Goodale = 20'.

Scenarios Analyzed:

The number of wells to be produced in each seam under each alternative, for both the direct and cumulative analysis, are as follows. For the cumulate analysis it is assumed that if these wells are productive they will eventually be produced, along with the other wells that could be drilled on the associated leases with an 80 acre well spacing.

Table C1: Number Of Direct And Cumulative CBNG Wells By Alternative

	Coal Seam	Alternative A No Action	Alternative B No Federal Action	Alternative C Proposed Action
Direct	Wall	0	5	9
	Flowers-Goodale	0	5	9
Cumulative	Wall	0	13	23
	Flowers-Goodale	0	13	23

20' of drawdown has been determined to be an appropriate magnitude of drawdown for evaluating the impacts from CBNG development (BLM, 2003). The distance that the 20 foot contour extends was determined for both of the produced coal seams after 6 months of pumping to evaluate direct impacts. 1 year, 5 years, 10 years, and 20 years of production were also calculated in order to consider potential cumulative future development. These cumulative calculations were conducted using the appropriate number of wells from Table 1.

Method:

The predicted drawdown in each coal seam is calculated using regional aquifer characteristics and the Theis equation. The Theis equation is:

$$dh = \frac{Q}{4\pi T} W(u)$$

Where

dh = change in head (feet)
Q = pumping rate (ft^3/day)
T = Transmisivity (ft^2/day)
W(u) is the Well Function

This can be rearranged to solve for W(u) as follows:

$$W(u) = \frac{4dh\pi T}{Q}$$

W(u) is defined as (Fetter, 1994):

$$W(u) = -0.5772 - \ln u + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} - \frac{u^4}{4 \cdot 4!} \cdots$$

Therefore once W(u) is known u can be calculated, or determined from tabulated data, such as that contained in Appendix 1 of Fetter (1994). u is defined as:

$$u = \frac{r^2 S}{4Tt}$$

Where

r = distance from the pumping well (feet)
S = Storativity, and (unitless)
t = Time (days)

This can then be rearranged to solve for r as follows:

$$r = \sqrt{\frac{4uTt}{S}}$$

Thus the distance that a drawdown (dh) of a particular magnitude (such as the 20' drawdown contour) will extend from the edge of a well (r=0) can be determined via the Theis equation.

This procedure can then be modified to address drawdown from a well field. The shape of the dh/r curve at any time (t), given an average pumping rate (Q) over that time period, is a function of the transmisivity (T; T=Kb where K=hydraulic conductivity and b= the aquifer thickness), and storativity (S) of the aquifer. Therefore if the drawdown (dh) at the edge of the well being analyzed or the edge of the well field (r=0) is known, the distance that a particular magnitude of drawdown will reach at that time can also be determined. This result is independent of the number of wells in the well field. These relationships are illustrated in Figures C1 and C2 below.

As such, the distance that the 20' drawdown contour would be expected to reach from a well field, on average, is determined by calculating the r value for a single well which is pumping water at a rate equal to the sum of the average pumping rates (q) for all the wells over the time period in the field (Q). This r value is then applied to the exterior of the well field (r=0). It should be noted that this result is subject to the assumptions of the Theis equation, and also subject to the additional restraint that the result is only valid at a distance from the well field where the drawdown cones from the individual wells have merged to form a single drawdown cone.

Figure C1

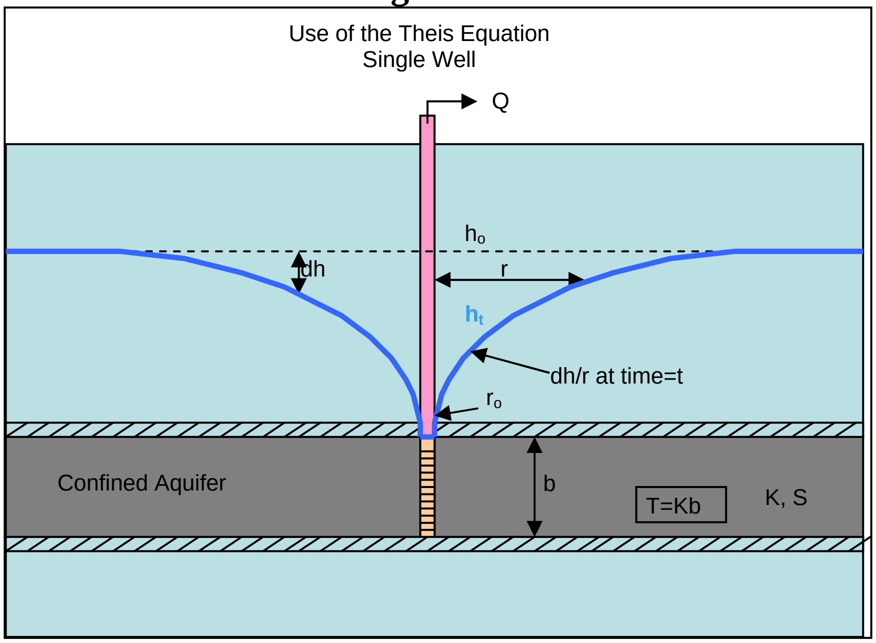

Figure C1: Drawdown from a single well calculated via the Theis method. Note that the change in head (dh) at a given distance from the well (r) (or conversely the distance that a given change in head will reach from the well) is a function of Q, K, b, S, and t.

Figure C1 shows an illustration of a drawdown cone around a single well completed in a confined aquifer with the different parameters associated with the Theis calculation (initial head, change in head, the curve of change in head vs. distance from the well, the aquifer thickness, the hydraulic conductivity of the aquifer, and the storativity of the aquifer) shown graphically.

Figure C2

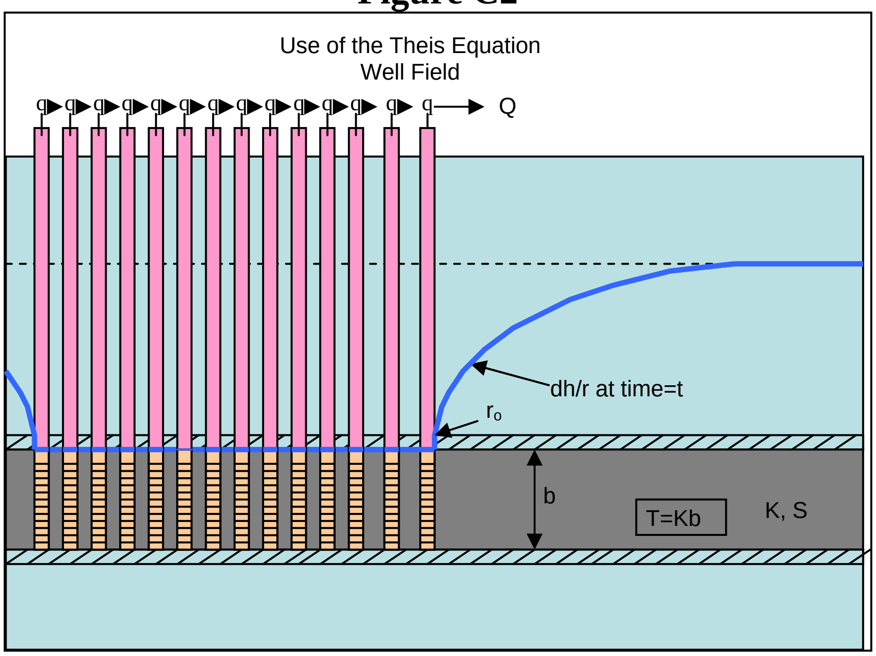

Figure C2: The shape of the dh/r curve is a function of Q, K, b, S, and t, therefore if dh at r=0 is constant, the distance that a particular magnitude of drawdown (i.e. 20') reaches from r=0 will also be constant at time = t regardless of the number of wells contributing their incremental discharge (q) to the overall discharge rate (Q).

Figure C2 shows an illustration similar to Figure C1, except that several wells in a well field combine to create the volume of discharge (Q) required to drawdown the hydrostatic pressure within the well field to near the top of the confined aquifer. The shape of the drawdown cone (dh/r) is the same; however within the well field the hydrostatic pressure is held to near the top of the confined aquifer..

Assumptions:
There are several assumptions required to use the Theis equation (Fetter, 1994). Those assumptions indicated with an asterisk (*) are discussed in more detail below. These include:

- The aquifer is confined top and bottom.*
- There is no source of recharge to the aquifer.*
- The aquifer is compressible and water is released instantaneously from the aquifer as the head is lowered.
- The well is pumping at a constant rate.*

There are also several assumptions required to use any analytical method to determine groundwater drawdown (Fetter, 1994). These include:

- All geologic formations are horizontal and of infinite extent.*
- The potentiomentric surface of the aquifer is horizontal prior to the start of pumping.
- The potentiomentric surface of the aquifer is not changing with time prior to the start of pumping.
- All changes in the position of the potentiomentric surface are due to the effect of the pumping being analyzed.
- The aquifer is homogeneous and isotropic.*
- All flow is radial towards the well.
- Groundwater flow is horizontal.
- Darcy's law is valid (flow is laminar rather than turbulent).
- Groundwater has a constant density and viscosity.
- The pumping wells and any observation wells are fully penetrating.
- The pumping well has an infinitesimal diameter and is 100% efficient.

The assumption of confinement is assumed to be valid as discussed above due to coals in this area being typically bounded by shale.

The assumption of no recharge is believed to be appropriate since the amount of recharge into these coal seams would be low when compared to the rate at which CBNG wells would remove it. Thus recharge can be assumed to be zero, particularly in the area near the well field. The use of this assumption will tend to overestimate the radius of the drawdown cone and the magnitude of drawdown.

It is anticipated that the rate of discharge from CBNG wells will decrease over time. In particular, for this project PRG has estimated that the wells will initially discharge at a rate of 25 gpm, and decrease at a rate of 20% per year. However the assumption of a constant pumping rate can be used if the average pumping rate over the time period being analyzed is used.

The assumption that the coal seams are horizontal is believed to be appropriate since the dip in this area is less than 1^{o} to the NNW (Lopez, in prep; Stoner and Lewis, 1980).

The assumption that the aquifer is of infinite extent would be appropriate, if there were no faults, since the distance to outcrop is much greater than the distance being modeled. The presence of faults, which function as flow barriers, will cause the drawdown cone to be truncated in the direction of the fault, and to extend asymmetrically away from the fault. As such, the calculation of the radius of the 20' drawdown contour provides an average distance that this drawdown would reach. This drawdown would not extend as far in the direction of the fault (since it would be cut off by the fault), and it would extend further in the direction away from the fault. In the instance where CBNG pumping occurs within a fault block (faults on all sides) the magnitude of the drawdown within the block would be greater than calculated, however it would be limited in extent to the fault block.

The assumptions of isotropy and homogeneity are rarely truly correct, however there is little data to provide an estimate of the actual degree of isotropy, or the distribution of the heterogeneities. When these assumptions are used the calculation of the radius of the 20' drawdown contour still provides an average distance that this drawdown would reach. If isotropy is present the drawdown cone would extend asymmetrically in the direction of greater transitivity. Heterogeneities will cause the shape of the drawdown cone to be less regular, however the overall average radius of drawdown would be the similar so long as the assumed aquifer characteristics are representative of the aquifer as a whole.

It is felt that the use of the Theis Equation to determine the average distance that drawdown will extend from the well field is an appropriate analysis for this project given the uncertainty associated with the variable nature of the hydrologic properties of the coal seams in this area.

Evaluation of Pumping Rates:

In order to determine the drawdown related impacts from CBNG development it is first necessary to determine the pumping rates that will be needed to drawdown the coal seam to "near the top of the coal seam". PRG has estimated that the initial rate will be 25 gpm, with a 20% per year reduction. This can be compared to the pumping rate that would be calculated to be needed to drawdown monitoring well MBMG MONITORING WELL * CBM02-4WC by 58 feet at 1 foot away from the well. This well is located approximately 1.4 miles from the POD area and is finished in the Wall coal. This well has a static water level 63 feet above the top of coal, so lowering it by 58 feet would bring it to within 5 feet of the top of the coal. If it is assumed that K=1.1 ft/day, then the initial pumping (at t=7days) would be approximately 16.5 gpm. Thus the initial rate of

25 gpm is greater than that expected for the Wall coal seam. If the required discharge rate is calculated for several more time steps it can be seen that for a single well the rate of water production would be expected to drop off faster than estimated by PRG, but to level off more quickly. Over time, as individual wells begin to interact within the well field, recharge to each well will be reduced in the direction of other wells, thus the average rate of pumping required for each well over time would be less than that calculated for a single well. In either case the rate of production estimated by PRG would be greater than calculated by the Theis equation over at least the first 3 years. As such the 20% decline in the pumping rate per year appears to be a reasonable, if somewhat conservative, estimate (See Figure C3).

Figure C3

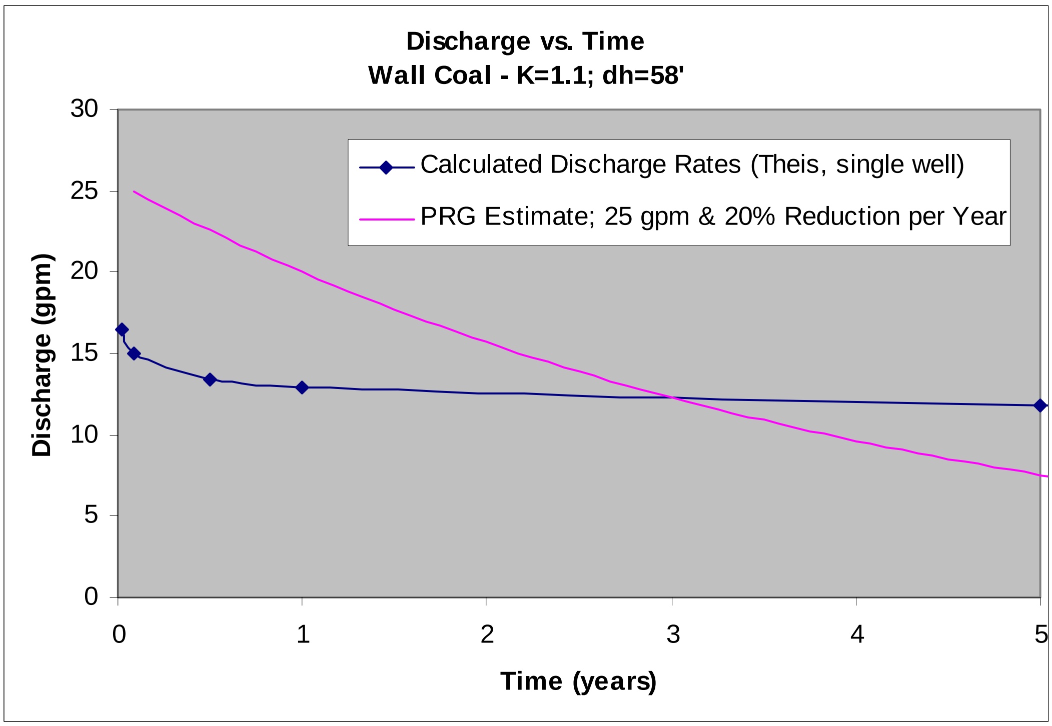

Figure C3: Comparison of PRG estimated discharge rate per well and the rate calculated from the Theis equation.

Figure C3 shows a graph with time on the x axis (range = 0-5 years) and discharge rate (gpm) on the y axis (range = 0-30 gpm). On this graph there are 2 curves of discharge vs. time for an individual well. One represents the discharge assumed by PRG (initial rate=25 gpm with a 20% reduction per year). The other is determined by the Theis equation for a single well reducing the hydrostatic pressure to near the top of the coal. The PRG curve is initially higher than the Theis curve (25 gpm vs. ~17 gpm); however the Theis curve levels off more rapidly than the PRG curve. After 1 year the Theis curve shows little change, holding near 13 gpm. The PRG curve continues to decline at 20% per year, and after 3 years the PRG curve drops below the Theis curve. At 5 years the PRG curve is at ~7gpm.

The nearest well that is known to be in the Flowers-Goodale coal seam is located approximately 18 miles from the POD area, near Birney. This is MBMG MONITORING WELL * CBM02-8FG. This well is located in the discharge zone, with an upward gradient, thus the head values from this well would not be applicable to the

POD area, however the statigraphic information may be applicable. The Flowers-Goodale coal seam is less thick than the Wall (20 vs. 55 feet) which would cause a lower pumping rate to be required; however it would also be expected to have a greater artesian pressure which would require a higher pumping rate. Thus these factors may offset, and since data on this coal seam is not available in this area, the 25 gpm initial production rate provides a reasonable rate for this analysis.

Results:
The results pumping rate the potential well field for the No Federal Action alternative, and the Proposed Action alternative are shown in Tables 2 and 3 below. These include analysis of the effects when $K=9.8x10^{-2}$, 1.1, and 13 ft/day. The geometric mean K is typically considered to give the most representation of hydrologic conductivity for an aquifer, therefore it is these results which are included in the EA. It should also be noted that for this analysis (using the 20'drawdown contour as the criteria for effects) the K=1.1 results consistently give the greatest drawdown radius. With No Action by any agency no drawdown would occur in the Wall or Flowers-Goodale coal seams in this area, so no calculations were conducted.

For each alternative charts of the calculated drawdown cones after 6 months for $K=9.8x10^{-2}$, 1.1, and 13 ft/day (geometric mean and ± 1standard deviation) are included. The drawdown map shown in the Figures section of this report uses the radius of drawdown calculated under each scenario using K=1.1 ft/day (the geometric mean). The changes in the shape of the drawdown cone over time using K=1.1 ft/day for the Wall coal (the shallowest unit proposed for testing) are also provided. The wells and springs which are located within the 20' drawdown contour for each scenario when K=1.1 ft/day are listed on Table 4.

Once the wells and springs located within the potential areas of drawdown were known, it needed to be determined if the produced coals were the sources of water for these features. Only those wells which are finished within the coal seams being developed, or springs which emit from these coal seams, would be anticipated to be impacted by CBNG related drawdown due to the low vertical hydrologic conductivity in these units (Wheaton and Donato, 2004).

In order to determine if wells may be receiving their water from the produced coal seams the elevation range over which the Wall and Flowers-Goodale coal seams would be expected in this area was calculated. This elevation varies depending on structure in this area, with the beds dipping to the SSE at $\sim 1^{o}$ (Lopez, in review). The Wall in this area would be expected to be located between 2560 and 3414 feet above mean sea level (ft-amsl). The Flowers-Goodale in this area would be expected to be located between 1771 and 2591 ft-amsl. If a well is determined to be finished within one of these ranges, a site specific analysis of the elevation of the coal seam at that well site is then conducted. If the elevation at which the well is finished is within 20' of the calculated coal seam elevation it is then considered to have the potential to be finished in the coal seam. Finally the well logs for each individual well that has the potential to be finished in the developed coal seams is examined to determine if the lithology logs disprove this conclusion.

Based upon recent geologic mapping of this area (Vuke et al., 2001) the nearest outcrop of the Wall coal, which is stratigraphically the highest seam being developed, is approximately 11 miles to the northeast, near Wall Creek. For this reason it is not believed that any of the springs which are located within the potential groundwater drawdown areas, under either the direct or cumulative scenarios, emit from the produced coal seams. Thus none of these springs would be anticipated to be affected by the groundwater drawdown resulting from this project.

Table C2: Summary of Predicted 20 Foot Drawdown from the PRG - Coal Creek CBNG Project - Alternative B - No Federal Action

Time Pumped	Average Pumping Rate per Well (gpm)	Number of Wells per Seam	Average Pumping Rate per Coal Seam (gpm)	Coal Seam	Hydrologic Conductivity (K)		
					$9.8x10^{-2}$ ft/day	1.1 ft/day	13 ft/day
6 Months	24	5	119	Wall	0.54	0.86	0.07
				Flowers-Goodale	0.19	0.37	0.24
1 Year	22	13	291	Wall	0.89	1.76	0.98
				Flowers-Goodale	0.62	1.39	1.82
5 Years	15		190	Wall	1.86	3.38	0.93
				Flowers-Goodale	1.30	2.81	2.75
10 Years	9		123	Wall	2.43	3.94	0.35
				Flowers-Goodale	1.74	3.51	2.34
20 Years	5		67	Wall	3.04	3.85	0.02
				Flowers-Goodale	2.23	4.02	1.04

Figure C4

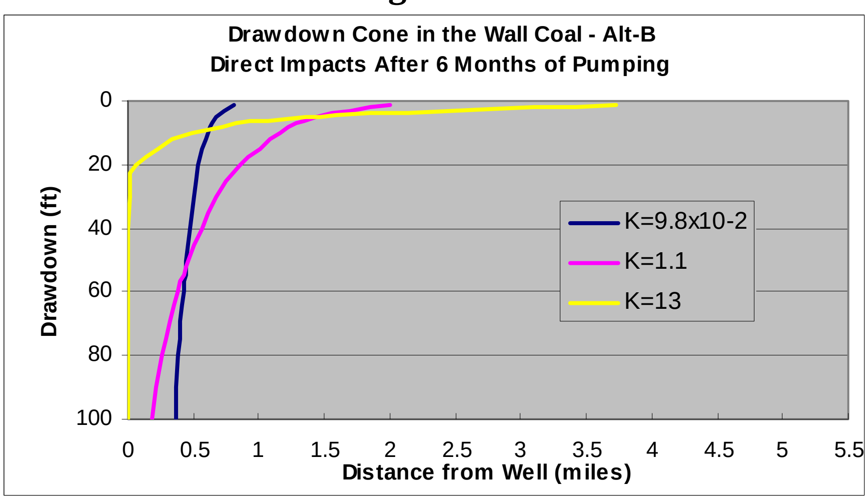

Figure C4 shows a graph with distance from the well on the x axis (range = 0-5.5 miles) and drawdown on the y axis (range = 0-100 feet). On this graph there are 3 curves of drawdown vs. distance (dh/r) which are all calculated after 6 months of pumping for the Wall coal under Alternative B. One curve represents the result if the hydraulic conductivity (K) is $9.8x10^{-2}$ ft/day, the next is for K=1.1 ft/day, and the third is for

K=13 ft/day. The K=13 curve is the most concave, with it hugging the y axis until ~22 feet and then curving sharply out. The K=1.1 curve is the next most curved, and the K=9.8x10^{-2} curve is the straightest. With 100 feet of drawdown the K=13 curve is at essentially 0 miles from the well, the K=1.1 curve is at 0.19 miles from the well, and the K=9.8x10^{-2} curve is at 0.36 miles from the well. With 20 feet of drawdown the K=13 curve is at 0.07 miles from the well, the K=1.1 curve is at 0.86 miles from the well, and the K=9.8x10^{-2} curve is at 0.54 miles from the well. With 1 foot of drawdown the K=13 curve is at 3.73miles from the well, the K=1.1 curve is at 2.00 miles from the well, and the K=9.8x10^{-2} curve is at 0.81 miles from the well.

Figure C5

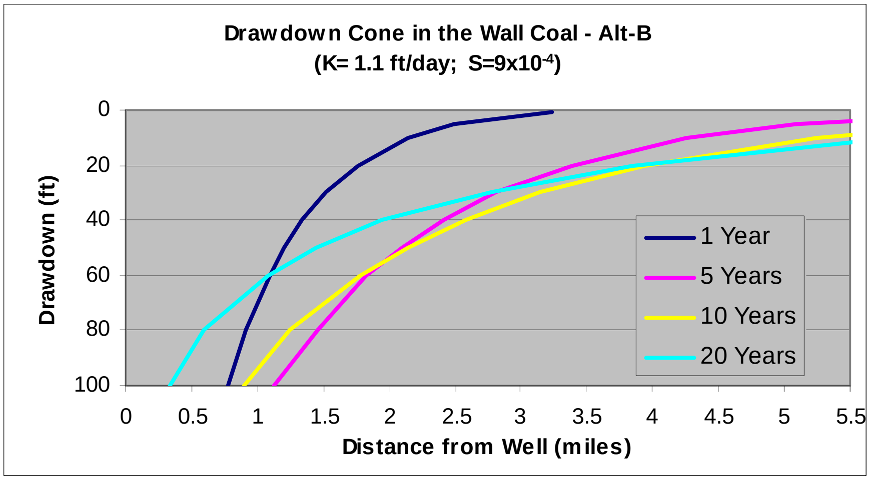

Figure C5 shows a graph with distance from the well on the x axis (range = 0-5.5 miles) and drawdown on the y axis (range = 0-100 feet). On this graph there are 4 curves of drawdown vs. distance (dh/r) which are all calculated using a hydraulic conductivity of 1.1 ft/day (the geometric mean) for the Wall coal under Alternative B. The 4 curves represent the calculated drawdown curves (dh/r) that result after 1, 5, 10, and 20 years of pumping. The curve for 1 year is the most sharply curved, while each successive curve is more "laidback". With 100 feet of drawdown the 1 year curve is at 0.77 miles from the well, the 5 year curve is at 1.12 miles from the well, the 10 year curve is at 0.90 miles from the well, and the 20 year curve is at 0.33 miles from the well. With 20 feet of drawdown the 1 year curve is at 1.76 miles from the well, the 5 year curve is at 3.38 miles from the well, the 10 year curve is at 3.94 miles from the well, and the 20 year curve is at 3.85 miles from the well.

Table C3: Summary of Predicted 20 Foot Drawdown from the PRG - Coal Creek CBNG Project – Alternative C - Proposed Action

Time Pumped	Average Pumping Rate per Well (gpm)	Number of Wells per Seam	Average Pumping Rate per Coal Seam (gpm)	Coal Seam	Hydrologic Conductivity (K)		
					9.8x10^{-2} ft/day	1.1 ft/day	13 ft/day
6 Months	24	9	214	Wall	0.60	1.11	0.39
				Flowers-Goodale	0.20	0.44	0.48
1 Year	22	23	516	Wall	0.97	2.07	2.04
				Flowers-Goodale	0.66	1.56	2.55
5 Years	15		336	Wall	2.03	4.11	2.72
				Flowers-Goodale	1.40	3.21	4.43
10 Years	9		218	Wall	2.69	5.03	1.80
				Flowers-Goodale	1.87	4.10	4.60
20 Years	5		118	Wall	3.42	5.44	0.42
				Flowers-Goodale	2.44	4.91	3.13

Figure C6

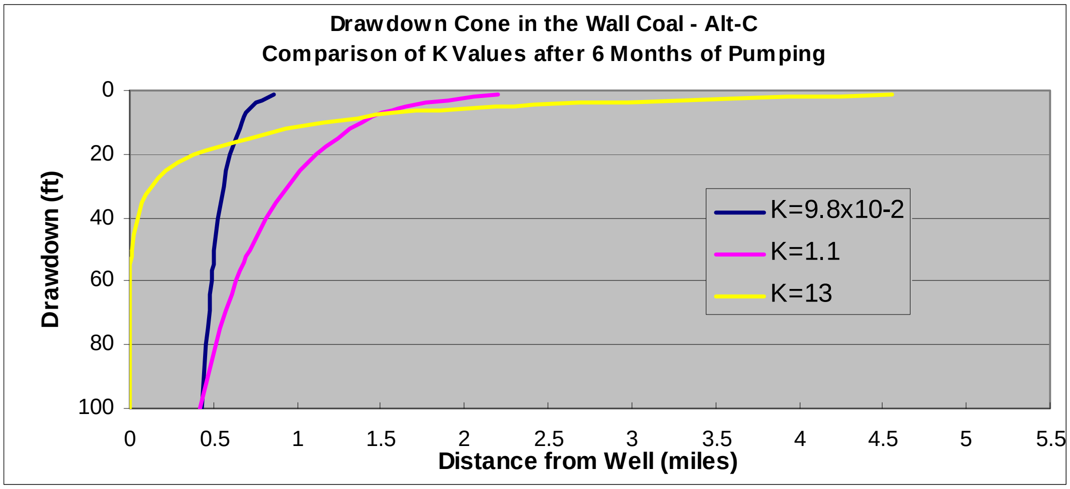

Figure C6 shows a graph with distance from the well on the x axis (range = 0-5.5 miles) and drawdown on the y axis (range = 0-100 feet). On this graph there are 3 curves of drawdown vs. distance (dh/r) which are all calculated after 6 months of pumping for the Wall coal under Alternative C. One curve represents the result if the hydraulic conductivity (K) is $9.8x10^{-2}$ ft/day, the next is for K=1.1 ft/day, and the third is for K=13 ft/day. The K=13 curve is the most concave, with it hugging the y axis until ~50 feet and then curving sharply out. The K=1.1 curve is the next most curved, and the $K=9.8x10^{-2}$ curve is the straightest. With 100 feet of drawdown the K=13 curve is at essentially 0 miles from the well, the K=1.1 curve is at 0.42 miles from the well, and the $K=9.8x10^{-2}$ curve is at 0.43 miles from the well. With 20 feet of drawdown the K=13 curve is at 0.39 miles from the well, the K=1.1 curve is at 1.11 miles from the well, and the $K=9.8x10^{-2}$ curve is at 0.60 miles from the well. With 1 foot of drawdown the K=13 curve is at 4.55 miles from the well, the K=1.1 curve is at 2.20 miles from the well, and the $K=9.8x10^{-2}$ curve is at 0.86 miles from the well.

Figure C7

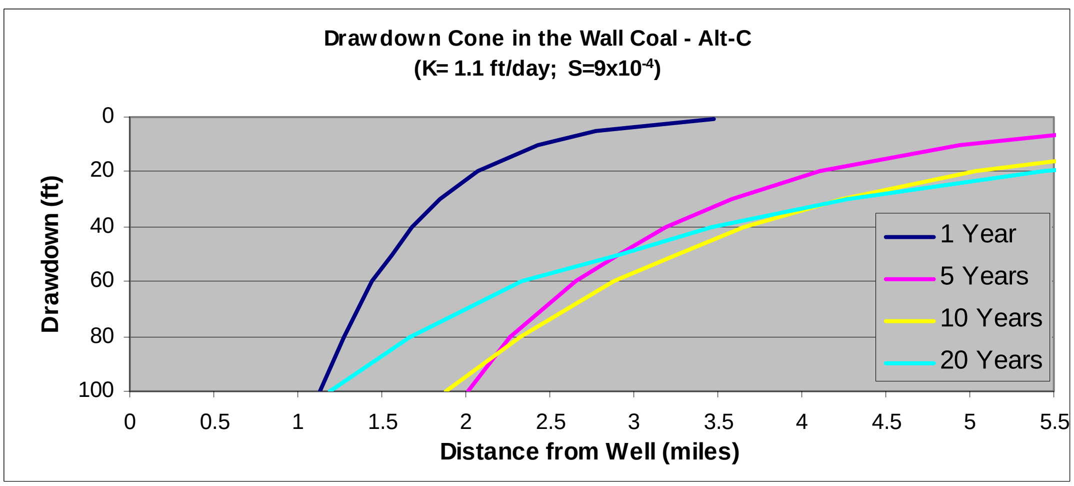

Figure C7 shows a graph with distance from the well on the x axis (range = 0-5.5 miles) and drawdown on the y axis (range = 0-100 feet). On this graph there are 4 curves of drawdown vs. distance (dh/r) which are all calculated using a hydraulic conductivity of 1.1 ft/day (the geometric mean) for the Wall coal under Alternative C. The 4 curves represent the calculated drawdown curves (dh/r) that result after 1, 5, 10, and 20 years of pumping. The curve for 1 year is the most sharply curved, while each successive curve is more "laidback". With 100 feet of drawdown the 1 year curve is at 1.13 miles from the well, the 5 year curve is at 2.01 miles from the well, the 10 year curve is at 1.88 miles from the well, and the 20 year curve is at 1.20 miles from the well. With 20 feet of drawdown the 1 year curve is at 2.07 miles from the well, the 5 year *curve is at 4.11 miles from the well, the 10 year curve is at 5.03 miles from the well, and the 20 year curve is at 5.44 miles from the well.*

Table C4: Domestic and Stock Wells and Springs within the Calculated 20' Drawdown Contour

Powder River Gas - Coal Creek POD

Site Name	Township	Range	Section	Type	Total Depth	Ground Surface Elevation	Finish Elevation	Top of Wall less Well Elevation	Top of Lebo	Wall Under-burnden	Base of Wall	Top of Wall
Wells and Springs in Drawdown Area under Direct Alt B												
MUSGRAVE BILL	08S	41E	7	WELL	146	3700	3554	140.00				
Developed Spring (ID by PRG)	08S	41E	6	SPRING	---	---	---					
Wells and Springs Added to Drawdown Area under Direct Alt C												
ASPEN SPRINGS	08S	40E	1	SPRING	---	---	---					
TRUSSLER BILL	08S	40E	13	WELL	200	3420	3220	-194.00	1680	1360	3040	3095
FOREST DUNNING	08S	40E	1	WELL	296	3790	3494	80.20				
Wells and Springs Added to Drawdown Area Cumulative Alt B												
RUZRIKE JOE * 4.2 M NW TONGUE RIVER DAM	07S	40E	35	SPRING	---	---	---					
LEE * 2.2 MI NW GAGING ST. TONGUE R. RES.	08S	40E	2	SPRING	---	---	---					
MONTAYLOR	08S	40E	15	SPRING	---	---	---					
SPRING GULCH SPRING	08S	41E	2	SPRING	---	---	---					
HORSESHOE SPRING	08S	41E	10	SPRING	---	---	---					
HILLSIDE SPRING	08S	41E	15	SPRING	---	---	---					
LOWER DUGOUT	08S	41E	16	SPRING	---	---	---					
MIDDLE DUGOUT	08S	41E	15	SPRING	---	---	---					
UPPER DUGOUT	08S	41E	15	SPRING	---	---	---					
UPPER ANDERSON CREEK SPRING	08S	41E	14	SPRING	---	---	---					
THREE MILE SPRINGS	08S	40E	35	SPRING	---	---	---					
INDIAN SPRING	08S	40E	11	SPRING	---	---	---					
POST CREEK SPRING	07S	40E	35	SPRING	---	---	---					
RUZRIKE JOE * 5 M NW TONGUE RIVER DAM	07S	40E	27	WELL	10	3745	3735	320.60				
LEE R. * 13.5 M NW DECKER MT	08S	40E	11	WELL	14	3490	3476	62.00				
RUZICKA JOSEPH	07S	40E	28	WELL	21	3925	3904	490.00				

Table C4: Domestic and Stock Wells and Springs within the Calculated 20' Drawdown Contour

Powder River Gas - Coal Creek POD

Site Name	Township	Range	Section	Type	Total Depth	Ground Surface Elevation	Finish Elevation	Top of Wall less Well Elevation	Top of Lebo	Wall Under-burnden	Base of Wall	Top of Wall
Wells and Springs Added to Drawdown Area Cumulative Alt B (cont.)												
RANCH HOLME CATTLE CO *MORELAND MARK	08S	41E	9	WELL	35	3780	3745	331.00				
STATE WATER CONSERVATION BOARD	08S	41E	18	WELL	42	3450	3408	-6.00	1670	1360	3030	3085
BOUSQUET MAURICE E & LILLIAN	08S	40E	13	WELL	50	3424	3374	-40.00	1680	1360	3040	3095
CADY RICK	08S	40E	13	WELL	100	3424	3324	-90.00	1680	1360	3040	3095
PENSON CHAS. & GREG	08S	41E	21	WELL	125	3725	3600	186.00				
TONGUE RIVER - PEE WEE POINT	08S	40E	26	WELL	127	3520	3393	-21.00	1590	1360	2950	3005
CARLAT ROBERT * 12 M NE DECKER MT *	08S	41E	21	WELL	99	3733	3634	220.00				
MONTAYLOR *TOWNSITE	08S	40E	22	WELL	162	3600	3438	23.80				
MONTAYLOR *SEWER SITE	08S	40E	23	WELL	176	3465	3289	-125.10	1610	1360	2970	3025
PENSON CHARLES AND GREGG	08S	41E	32	WELL	199	3635	3436	22.00				
DECKER COMMUNITY CENTER	08S	40E	27	WELL	200	3560	3360	-54.00	1600	1360	2960	3015
KINNISON TOM	08S	40E	13	WELL	200	3424	3224	-190.00	1670	1360	3030	3085
LEGGE KELLY & ROBIN	08S	40E	14	WELL	300	3500	3200	-214.00	1675	1360	3035	3090
HOSFORD R.S. * 16.3 M W BIRNEY MONTANA	07S	41E	19	WELL	NR	---	---					
LEAF ROCK SPRINGS	08S	40E	10	WELL	NR	---	---					
Wells and Springs Added to Drawdown Area Cumulative Alt C												
MONTAYLOR *LEAF ROCK SPRING TURNOUT PASTURE	07S	40E	32	SPRING	---	---	---					
MONTAYLOR *LEAF ROCK SPRING	08S	40E	32	SPRING	---	---	---					
MONTAYLOR *POST CREEK ORCHARD	07S	40E	29	SPRING	---	---	---					
MONTAYLOR *LEAF ROCK HOUSE ORCHARD PASTURE	08S	40E	32	SPRING	---	---	---					

Table C4: Domestic and Stock Wells and Springs within the Calculated 20' Drawdown Contour

Powder River Gas - Coal Creek POD

Site Name	Township	Range	Section	Type	Total Depth	Ground Surface Elevation	Finish Elevation	Top of Wall less Well Elevation	Top of Lebo	Wall Under-burnden	Base of Wall	Top of Wall
Wells and Springs Added to Drawdown Area Cumulative Alt C (cont.)												
MONTAYLOR *LEAF ROCK HOUSE	08S	40E	32	SPRING	---	---	---					
MOUTH OF HARRIS CREEK	07S	41E	23	SPRING	---	---	---					
WEBSTER RANCH	08S	41E	12	SPRING	---	---	---					
FLOREY SPRING	08S	41E	13	SPRING	---	---	---					
MONTAYLOR *CROSSROADS	07S	40E	28	SPRING	---	---	---					
WILSON LEWIS C AND BEULAH A	08S	41E	35	WELL	12	3985	3973	559.00				
PETERSON RACINE * 13.75 M S BIRNEY MT	07S	41E	27	WELL	20	3370	3350	-64.00	1750	1360	3110	3165
PETERSON RACINE * 5.8 M NE TONGUE R.DAM	07S	41E	27	WELL	20	3370	3350	-64.00	1750	1360	3110	3165
HOSFORD R.S. * 8.3 M NW TONGUE RIVER D	07S	40E	15	WELL	29	3790	3761	347.00				
KUKUCHKA	08S	40E	34	WELL	40	3440	3400	-14.00	1460	1360	2820	2875
PETRE PRESTON	07S	41E	22	WELL	43	3255	3212	-202.00	1810	1360	3170	3225
PRESTON PETE * 10 MI SW BIRNEY MONTANA	07S	41E	22	WELL	44	3260	3216	-198.00	1810	1360	3170	3225
DEPT OF FISH-WILDLIFE AND PARKS	08S	40E	35	WELL	46	3445	3399	-15.00	1400	1360	2760	2815
KUKUCHKA WILLIAM	08S	40E	34	WELL	98	3540	3442	28.00				
KUCHKUKA	08S	40E	34	WELL	98	3435	3337	-77.00	1460	1360	2820	2875
MONTAYLOR *LEAF ROCK HOUSE	07S	40E	32	WELL	119	3770	3651	237.40				
HOLMES RANCH CO * 1.8 MI N HOLMES RANCH.	08S	41E	34	WELL	181	3655	3474	60.00				
KUKUCHKA * 1.25 MI NE TONGUE RIVER MINE.	08S	40E	34	WELL	553	3450	2897	-517.00	1460	1360	2820	2875
KUKUCHKA WM * 6.5 M NE DECKER MT	08S	40E	33	WELL	NR	---	---					

Comparison of Theis type analysis to 2D MODFLOW Model:
In order to assess the adequacy of the Theis type drawdown calculation approach taken in this analysis a 2D MODFLOW model was prepared by MBMG to address the drawdown that would be anticipated from the proposed action in the Wall coal seam. It is felt that a 2D model will adequately address this drawdown since coal seams are confined aquifers. The Wall was modeled as being 55 feet thick with K=1.1 ft/day and S=$9x10^{-4}$. The aquifer was assumed to be homogeneous and isotropic, with no flow barriers. As discussed previously flow barriers will have a strong effect on the actual distribution and magnitude of drawdown. This model used 45 time steps with the period length varying from 1 to 42 days. The transient simulation with pumping extended for a total of 252 days. The grid spacing varies from 100 feet in the well field to about 1300 feet at edges of model grid; the model has 267 rows and 311 columns. The CBNG wells were modeled as constant head cells set at 60 feet above the bottom of the coal seam (5 feet above the top).

This model was used to simulate pumping for up to 252 days, and also used to simulate recovery after 180 days of pumping. The results of the pumping analysis are shown in Table 5 below.

Table C5: 2D MODFLOW Model
Proposed Action
Drawdown in the Wall Coal Seam
(9 wells pumping to within 5' of the top of coal)
(initial head = 60' above top of coal per CBM02-4WC)

Time (days)	Radius of 20' Drawdown Contour from the edge of the Well Field (ft)		Theis 20' Contour (PRG pumping rate)
	(feet)	(miles)	(miles)
0	0	0	0
42	990	0.19	0.54
84	1530	0.29	0.76
126	2000	0.38	0.93
168	2250	0.43	1.07
180	2490	0.47	1.11
252	2900	0.55	1.30

Note: Radius depends on what is taken as the edge of the well field.
These values were determined from the easternmost well

These results are less then, but not inconsistent with the Theis approach. It is believed that the major reason for this difference is that the MODFLOW model used constant head cells to represent the wells. Thus water is removed at the rate needed to drawdown the head in the coal seam to the elevation of these constant head cells. The Theis approach used the PRG projected pumping rate of 25 gpm with a reduction of 20% per year. As discussed above, this 25 gpm estimate is initially consistent with the rates anticipated to be needed, however the Theis approach to calculating the pumping rate needed to drawdown the coal seams indicates that the rate would drop off faster than predicted, then level off rather than continuing to decline (see Figure C5). Over the time period of the

MODFLOW model the effect of this is to predict higher pumping rates for the Theis calculations, and so drawdown is calculated to extend further than in the MODFLOW model. As such it is believed that the Theis approach is appropriate for this analysis; however it should be recognized that it may somewhat over predict the drawdown radius over the short term due to the pumping rate analyzed.

This MODFLOW model was also used to evaluate the time required for head levels within the well field to recovery to within 20 feet of pre-testing levels. For this analysis the heads which resulted after 180 days of pumping were used in the model after removing the constant head "wells". This analysis showed that within the well field head levels would recover to within 20' of pre-testing levels approximately after 160 days.

Discussion of Results:

Direct Impacts:

No Action:

Under the No Action Alternative there would be no impacts to groundwater levels, and no wells or springs would be affected.

No Federal Action:

Under the No Federal Action Alternative it is calculated that after 6 months of pumping from 5 wells per coal seam the 20 foot drawdown contour would extend on average approximately 0.86 miles from the well field in the Wall coal seam, and approximately 0.37 miles in the Flowers-Goodale coal seam.

As shown on Table 4, according to MBMG's GWIC database (http://mbmggwic.mtech.edu/), 1 well, and no springs exist within this potential drawdown area. As shown on Table 4 this is the Musgrave well in T8S, R41E, Section 7. Based upon the reported well depth (146 feet), and the elevation of this site (3,700 ft-amsl based upon the 1:24,000 USGS topographic map; Tongue River Dam), this well is finished at an elevation of approximately 3,554 ft-amsl. This is not within the overall elevation range of the Wall coal within this area (2560-3414 ft-amsl), and so would not be anticipated to the be effected by CBNG related drawdown.

Proposed Action:

Under the Proposed Action Alternative it is calculated that after 6 months of pumping from 5 wells per coal seam the 20 foot drawdown contour would extend on average approximately 1.11 miles from the well field in the Wall coal seam, and approximately 0.44 miles in the Flowers-Goodale coal seam.

As shown on Table 4, according to MBMG's GWIC database (http://mbmggwic.mtech.edu/), two more wells and one more spring are located within this potential drawdown area verses the No Federal Action direct impacts. Of these the Trussler well is finished at an elevation of approximately 3,220 ft-amsl. This is within the overall range of the Wall coal in this area (2,560-3,414 ft). The site specific analysis of the elevation of the Wall coal for this well site shows that the Wall would be expected to occur from 3040 – 3095 ft-amsl. As such this well is not anticipated to be finished in the Wall coal, and would not be affected by CBNG related drawdown.

Cumulative Impacts:

Under the cumulative analysis it is assumed that if these wells prove to be productive the leases will be fully developed. This would require a total of 13 wells to be installed under the No Federal Action alternative, and 23 total wells to be installed under the Proposed Action. Under both of these alternatives it is assumed that the wells would be produced for up to 20 years.

No Action:

Under the No Action Alternative there would be no impacts to groundwater levels, and so no wells or springs would be affected.

No Federal Action:

Under the No Federal Action Alternative it is calculated that after 20 years of pumping from 13 wells per coal seam the 20 foot drawdown contour would extend on average approximately 3.94 miles from the well field in the Wall coal seam, and approximately 4.02 miles in the Flowers-Goodale coal seam.

As shown on Table 4, according to MBMG's GWIC database (http://mbmggwic.mtech.edu/), 18 more wells and 13 more spring are located within this potential drawdown area verses the Proposed Action direct impacts. Of these eight wells are finished at an elevations within the overall range of the Wall coal in this area (2,560-3,414 ft). As shown on Table 4 the site specific calculation of the elevation of the Wall coal at each of these well sites indicates that none of these wells is anticipated to be completed in the Wall coal. As such none of these well are anticipated to be affected by CBNG related drawdown.

Proposed Action:

Under the Proposed Action Alternative it is calculated that after 20 years of pumping from 23 wells per coal seam the 20 foot drawdown contour would extend on average approximately 5.44 miles from the well field in the Wall coal seam, and approximately 4.91 miles in the Flowers-Goodale coal seam.

As shown on Table 4, according to MBMG's GWIC database (http://mbmggwic.mtech.edu/), 14 more wells and 9 more spring are located within this potential drawdown area verses the No Federal Action cumulative impacts. Of these eight wells are finished at an elevations within the overall range of the Wall coal in this area (2,560-3,414 ft). As shown on Table 4 the site specific calculation of the elevation of the Wall coal at each of these well sites indicates that 2 of these wells are anticipated to be completed at an elevation consistent with the Wall coal. These are the Preston wells located in T7S, R41E, Section 22. The well logs for these wells indicate that both of these wells are finished in the alluvium adjacent to the Tongue River at depths of 43 and 44 feet below ground surface. As such none of the wells are anticipated to be affected by CBNG related drawdown.

Summary:

Based upon the elevations of the wells in this area and the elevation of the coal seams, the Wall coal is the only coal proposed for testing that could contain water wells. The direct drawdown from testing the proposed wells for 6 months would cause the 20' drawdown contour to extend, on average, approximately 0.86 miles from the well field in the Wall coal for the No Federal Action alterative, and 1.11 miles from the well field for the Proposed Action. No wells or springs would be anticipated to be effected by this direct drawdown under either alternative. Cumulative drawdown could result from this project, if the wells are tested and found to be productive. Under the No Federal Action alternative this cumulative drawdown would extend, on average, approximately 3.94 miles from the well field, while it would extend, on average, approximately 5.44 miles from the well field under the Proposed Action alterative. No wells or springs would be anticipated to be effected by this drawdown under either alternative.

Montana Bureau of Mines and Geology
Ground-Water Information Center Site Report
PETRE PRESTON

Location Information

GWIC Id:	104990	Source of Data:	
Location (TRS):	07S 41E 22 ACDC	Latitude (dd):	45.2154
County (MT):	ROSEBUD	Longitude (dd):	-106.6939
DNRC Water Right:		Geomethod:	TRS-TWN
PWS Id:		Datum:	NAD27
Block:		Altitude (feet):	3260.00
Lot:		Certificate of Survey:	
Addition:		Type of Site:	WELL

Well Construction and Performance Data

Total Depth (ft):	43.00	How Drilled:	CABLE TOOL
Static Water Level (ft):	18.00	Driller's Name:	RITOLA
Pumping Water Level (ft):	35.00	Driller License:	WWC133
Yield (gpm):	5.00	Completion Date (m/d/y):	4/24/1967
Test Type:	BAILER	Special Conditions:	
Test Duration:	2.00	Is Well Flowing?:	
Drill Stem Setting (ft):		Shut-In Pressure:	
Recovery Water Level (ft):		Geology/Aquifer:	110ALVM
Recovery Time (hrs):		Well/Water Use:	DOMESTIC
Well Notes:			

Hole Diameter Information

From	To	Diameter
0.0	43.0	6.0

Casing Information[1]

From	To	Dia	Wall Thickness	Pressure Rating	Joint	Type
0.0	43.0	6.0				18 LB. CASING

Annular Seal Information

No Seal Records currently in GWIC.

Completion Information[1]

From	To	Dia	# of Openings	Size of Openings	Description
28.0	43.0	6.0		1/4X6	SLOTS

Lithology Information

From	To	Description
0.0	20.0	GRAVEL WATER BEARING
20.0	23.0	BLUE SHALE

[1] - All diameters reported are **inside** diameter of the casing.

These data represent the contents of the GWIC databases at the Montana Bureau of Mines and Geology at the time and date of the retrieval. The information is considered unpublished and is subject to correction and review on a daily basis. The Bureau warrants the accurate transmission of the data to the original end user. Retransmission of the data to other users is discouraged and the Bureau claims no responsibility if the material is retransmitted. Note: non-reported casing, completion, and lithologic records may exist in paper files at GWIC.

Montana Bureau of Mines and Geology
Ground-Water Information Center Site Report
PRESTON PETE * 10 MI SW BIRNEY MONTANA

Location Information

GWIC Id:	7999	Source of Data:	
Location (TRS):	07S 41E 22 ACDC	Latitude (dd):	45.2147
County (MT):	ROSEBUD	Longitude (dd):	-106.6941
DNRC Water Right:		Geomethod:	MAP
PWS Id:		Datum:	NAD27
Block:		Altitude (feet):	3260.00
Lot:		Certificate of Survey:	
Addition:		Type of Site:	WELL

Well Construction and Performance Data

Total Depth (ft):	44.00	How Drilled:	
Static Water Level (ft):	18.00	Driller's Name:	
Pumping Water Level (ft):		Driller License:	
Yield (gpm):	5.00	Completion Date (m/d/y):	
Test Type:		Special Conditions:	
Test Duration:		Is Well Flowing?:	
Drill Stem Setting (ft):		Shut-In Pressure:	
Recovery Water Level (ft):		Geology/Aquifer:	110ALVM
Recovery Time (hrs):		Well/Water Use:	DOMESTIC
Well Notes:			

Hole Diameter Information

No Hole Diameter Records currently in GWIC.

Casing Information[1]

From	To	Dia	Wall Thickness	Pressure Rating	Joint	Type
0.0	0.0	6.0				STEEL

Annular Seal Information

No Seal Records currently in GWIC.

Completion Information[1]

From	To	Dia	# of Openings	Size of Openings	Description
28.0	43.0	0.0			PERFORATED CASING

Lithology Information

No Lithology Records currently in GWIC.

[1] - All diameters reported are **inside** diameter of the casing.

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