REPORT TO THE CHIEF ENGINEER
ON
WATER PERMIT APPLICATION NO. 2686-2
POWERTECH (USA) INC. Inyan Kara
NOVEMBER 2, 2012

Powertech (USA) proposes to recover uranium by a method known as in-situ recovery, or ISR, in which groundwater from the formation containing uranium (the Inyan Kara Group) is pumped to the surface from a field of wells, fortified with oxygen and carbon dioxide, and recirculated through the formation. The oxidized groundwater changes the uranium to a soluble form and is pumped to the surface, where uranium is removed from the solution. ISR circulates water through the uranium ore zone. Only a small fraction of the water is a net withdrawal because most water is recirculated back through the ore zone. A portion of the water extracted from the Inyan Kara Aquifer will be "bled off" to maintain a cone of depression so native groundwater continually flows toward the center of the production zone. Production bleed rates may vary in the range of 0.5 to 3 percent over the life of the project. If necessary, a bleed of up to 17 percent of 500 gpm will be used briefly during aquifer restoration. The ISR process is repeated until the economic reserves of uranium are fully removed from that particular well field. The process moves to another well field, and the uranium depleted well field is restored by continuing to circulate clean water through the wells until the water is similar in quality to the water that existed in the formation prior to the ISR operations. Most of the water removed from the Inyan Kara Aquifer during the ISR process is recirculated and re-injected through the well field, resulting in the net consumptive use of water being a small portion of the gross withdrawal rate. Most of the water used in the ISR operations will be obtained from the Inyan Kara Group. However, Powertech (USA) plans to use water from the Madison Aquifer to make up for water that is not provided from the ISR process. The amount of "make-up" from the Madison Aquifer will depend upon the water disposal method which is either deep disposal well or land application. The use of water from these two formations necessitates obtaining water permits from each source. The eastern portion of the project area is known as the Burdock area. It will include a series of ISR well fields and a central processing plant. The western portion of the project areas is the Dewey areas which will include ISR well fields and a satellite processing plant.

Water Permit Application No. 2686-2 proposes to appropriate up to 274.2 acre feet of water annually (ac-ft/yr) from wells completed into the Inyan Kara aquifer at depths between 200 – 800 feet. The wells will be located within a project area that encompasses approximately 10,580 acres located in portions of Sections 1-5, 10-12, and 14-15 in T7S-R1E and Section 20-21, and 27-35 in T6S-R1E, Black Hills Meridian. This application proposes a gross withdrawal (flow) rate of 18.938 cubic feet of water per second (cfs) which is equivalent to approximately 8,500 gallons per minute (gpm). A "net" or consumptive use of water will be a small portion of the gross withdrawal rate. Approximately two percent of the water is "bled off" during the process in order to maintain flow gradients toward the center of the well field. The remaining approximate ninety eight percent of the water is recirculated and continuously re-injected into the Inyan Kara aquifer as part of the In-Situ Recovery (ISR) process. Approval of this permit would authorize a maximum net (consumptive) withdrawal rate from the Inyan Kara aquifer

limited to 0.38 cfs (170 gpm) and limit the net (consumptive) withdrawal volume from the Inyan Kara aquifer to 274.2 acre feet of water annually.
Uranium recovery operations will continue for approximately 7 to 20 years. A typical well field grid of Inyan Kara wells consists of a 100 by 100 foot grid with one production well in the center and four surrounding wells for injection into the ore body. The well pattern may differ from well field to well field and be modified as needed to fit the characteristics of each ore body. Well fields will be completed along the various uranium zones. Current development plans include the construction of approximately 600 ISR production wells in the" Dewey" portion of the project area and approximately 900 ISR production wells in the "Burdock" portion of the project area. The maximum number of production wells in operation at any one time within the entire project area during production and restoration is 1,000 wells. Based on the project life and number of production wells scheduled as the well fields are developed, Powertech (USA) anticipates requesting a permit amendment in the future for an extension of the five year construction period pursuant to SDCL 46-2A-8. Powertech (USA) will provide an annual diversion report to DENR describing the number and location of pumping production wells. This report will include a request for change in the number and designated locations of pumping wells pursuant to SDCL 46-5-13.1. This statute allows for the location of point of diversion or additional points of diversion to be approved without application or publication if the wells are completed into the same source, no additional water is appropriated and the Chief Engineer makes a finding that the change does not increase the potential for interference with existing diversions.

**AQUIFER: INYAN KARA (INKR)**

**GEOLOGY AND AQUIFER CHARACTERISTICS:**
The Inyan Kara aquifer is composed of the portions of the Lower Cretaceous aged Inyan Kara Group that contain sufficient saturated permeable material to yield quantities of groundwater to wells. The Inyan Kara Group was deposited in shallow waters along the eastern shore of the Skull Creek Sea (Merewether, 1975) and in general, consists of a sequence of interbedded sandstones, siltstones, and mudstones of fluvial, lacustrine, and possibly eolian origin (Schnabel, 1963). The Inyan Kara Group is made up of two geologic formations: the Fall River formation and the underlying Lakota formation. The Fall River formation, which is about 150 feet thick in the Burdock quadrangle (Schnabel, 1963) and has an average thickness of 125 feet in the Dewey quadrangle (Brobst, 961), has been mapped as three units in this area: an upper unit composed of interlayed mudstones and fine to very fine-grained sandstones; a middle unit of interbedded sandstone and mudstone with massive, medium-grained sandstone; and a lower unit of siltstone and thin beds of sandstone (Brobst, 1961; and Schnabel, 1963)). The Lakota formation has been divided into three units that in descending order are: the Fuson member, which is a sequence of sandstone and mudstone; the Minnewaste member, which is a series of impure limestones; and the Chilson member, which consists of thick channel sandstone interbedded with sandstone and mudstone (see figure 1). The Lakota formation ranges in thickness from about 200 feet to about 350 feet in the Burdock quadrangle (Schnabel, 1963). In the Dewey quadrangle, the average thickness of the Lakota formation is estimated to be 225 feet (Brobst, 1961).

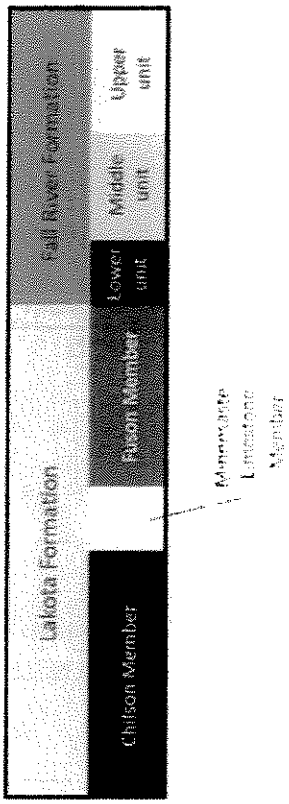


Figure 1. Generalized stratigraphic column for the Inyan Kara Group

The applicant contends that the Fuson member of the Lakota formation is an aquitard between a "Fall River aquifer" and a "Lakota aquifer" and data submitted with this permit application suggest distinct potentiometric surfaces with slightly different groundwater flow directions between the two "aquifers". However, the Fusion member consists of a sequence of sandstone and mudstone and "Locally, the sandstone beds reach varying degrees of prominence, and in some places form the whole Fuson member" (Schnabel, 1963). Although it is possible that the Fuson member of the Lakota formation is an aquitard in the vicinity of this project, on a regional scale the degree to which the Fall River and Lakota formations are hydraulically connected or separated is unclear and the two formations are typically considered parts of a single Inyan Kara aquifer (e.g. Driscoll and others, 2002; Galloway, 1999; and Strobel, et. al., 2000). For the purpose of appropriations, the DENR-Water Rights Program and the Water Management Board consider the Inyan Kara a single aquifer.

The Inyan Kara aquifer occurs at a regional scale, extending into Wyoming, North Dakota and Nebraska as well as a major portion of South Dakota (see figure 2). The Inyan Kara underlies over 36,000 square miles and contains over 324 million acre-feet of recoverable water in storage in western South Dakota alone (Allen and others, 1985). Although the Inyan Kara is areally extensive, only a portion of the water it contains is fresh. More than one-half of the water in the Inyan Kara is moderately saline, and the water is saline to brine in parts (Driscoll and others, 2002). The Inyan Kara Group outcrops in the eastern portion of the project area proposed by this application and the top of the Inyan Kara is approximately 600 feet below grade at the western edge of the project area (Carter and Redden, 1999). The potentiometric surface of the Inyan

Kara aquifer ranges from around 3,800 feet mean sea level elevation (msl) to 3,600 feet msl in this area (Strobel and others, 2000). The aquifer is under unconfined conditions in the eastern portion of the proposed project area and under confined conditions in the western portion of the area. Water levels of wells in the project area reportedly range from approximately 140 feet below grade to over 74 feet above ground surface (i.e. flowing wells with up to 32 psi shut-in pressure).

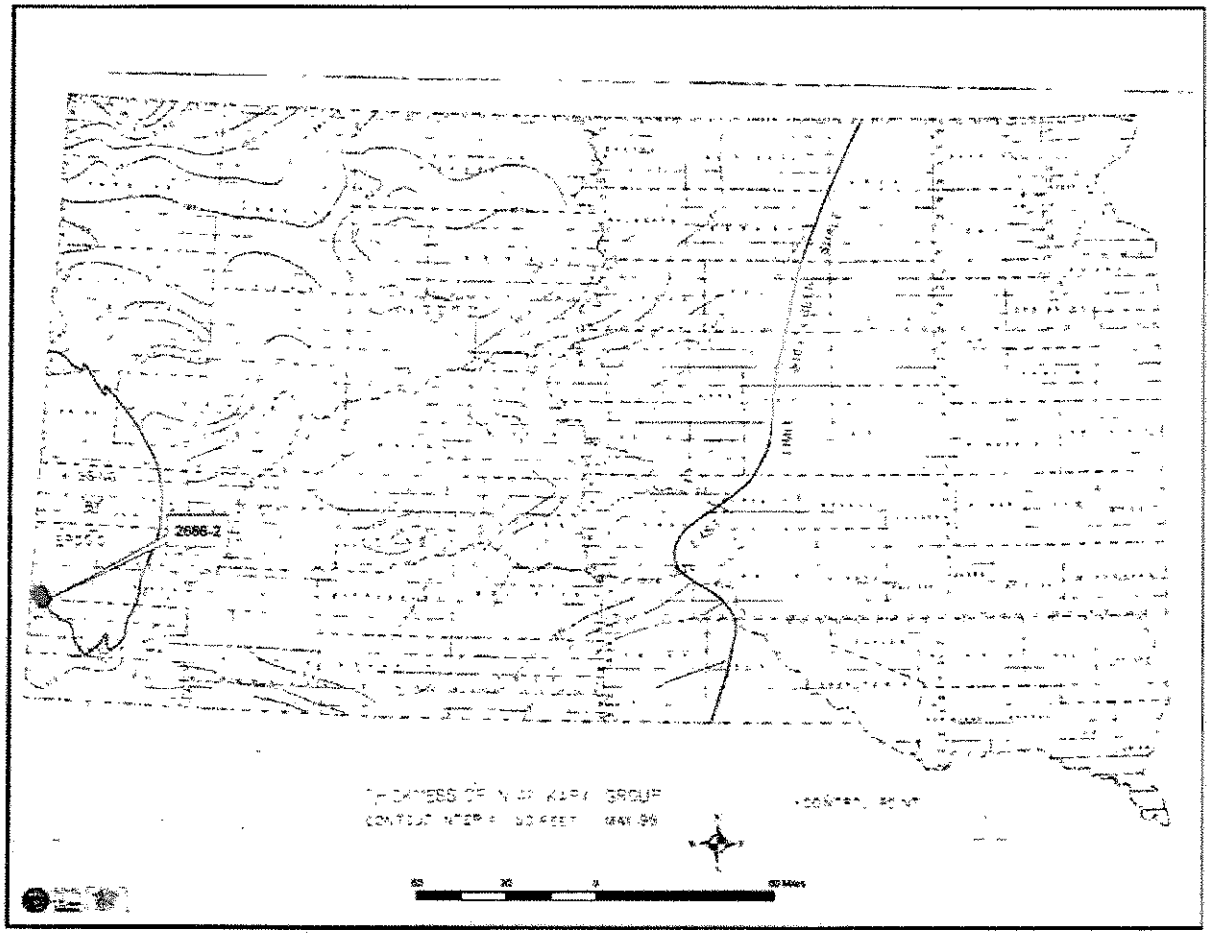


Figure 2. Areal extent of the Inyan Kara aquifer and the location of Water Permit Application No. 2686-2: (modified from Gries, 1981)

**SDCL 46-2A-9**

Pursuant to SDCL 46-2A-9, a permit to appropriate water may be issued only if there is reasonable probability that there is unappropriated water available for the applicant's proposed use, that the proposed diversion can be developed without unlawful impairment of existing rights and that the proposed use is a beneficial use and in the public interest.

**WATER AVAILABILITY:**

The probability of unappropriated water available for appropriation can be evaluated by considering SDCL 46-6-3.1 which requires that:

"No application to appropriate groundwater may be approved if, according to the best information reasonably available, it is probable that the quantity of water withdrawn annually from a groundwater source will exceed the quantity of the average estimated annual recharge of water to the groundwater source."

**Water Balance:**

Recharge:

Recharge to the Inyan Kara aquifer is through infiltration of precipitation at the outcrop and the aquifer also appears to be receiving water from the underlying Paleozoic aquifers (Schoon, 1971; Gott and others, 1974; Lobmeyer, 1985). An average annual recharge rate has not been quantified for the Inyan Kara aquifer. However, annual recharge to the portion of the Inyan Kara aquifer that outcrops in South Dakota alone, from the precipitation component only, was estimated for 1950-1998 to be 11,600 acre-feet per year (Driscoll and Carter, 2001).

Withdrawals:

There are a total of 185 Water Rights/Permits appropriating water from the Inyan Kara aquifer in South Dakota. In addition, Future Use Permit 1780-2, Town of New Underwood, reserves 142 ac-ft/yr from the Inyan Kara aquifer for future use. The estimated average annual withdrawal of appropriations is 10,700 ac-ft/yr. This estimate is based on: 1) annual water use reported in the latest public water system survey for municipal, suburban housing development and rural water system appropriations where applicable (DENR-Drinking Water Program, 2009-2012); 2) calculated annual use based permitted animals and rates of 20 gallons per day for beef cattle, 5 gallons per day for swine, 15 gallons per 100 turkeys, and 9 gallons per 100 chickens for large confinement operations permitted by DENR (Roth); 3) irrigation questionnaire reporting for irrigation permits when available (DENR-Water Rights Program, 2012a); 4) the most current water use reported for non-irrigation appropriations that are required to report (DENR-Water Rights Program, 2012b); 4) assuming unreported water rights/permits limited to an annual volume will be used to the maximum and water rights/permits limited by diversion rate will be used 60% of continuous pumping at the maximum diversion rate for their annual use period.

The estimated average annual withdrawal from the Inyan Kara (10,700 ac-ft/yr) is less than the precipitation recharge component alone for the aquifer (11,600 ac-ft/yr). Therefore, there is a reasonable probability that there is 274.2 acre-feet of unappropriated water available annually to supply this proposed appropriation. The quantities of both the average annual recharge and the average annual use for the Inyan Kara aquifer are both small percentages of the amount of water stored in the Inyan Kara aquifer so the aquifer can actually withstand several years of drought conditions with only minimal impact to wells.

The simple water budget comparing the estimated average annual recharge and the potential withdrawal by existing wells and current appropriations is not intended to suggest that all of the water that is in storage in the Inyan Kara aquifer or that all of the recharge to the aquifer is available for this appropriation, merely to demonstrate that in general the Inyan Kara aquifer is an immense resource that is relatively untapped.

**Localized Hydrologic Budget:**
A separate hydrologic budget was developed for a subarea of the Inyan Kara aquifer that includes the project area proposed by this application. The subarea was identified based on the structural geology of the area with the Dewey Fault and Structural Zone considered the northern boundary, and the Cottonwood Anticline and/or the Sheep Canyon Monocline considered the southern boundary (see Figure 3). (Note: the Cottonwood Anticline is just southeast of the area shown in figure 3).

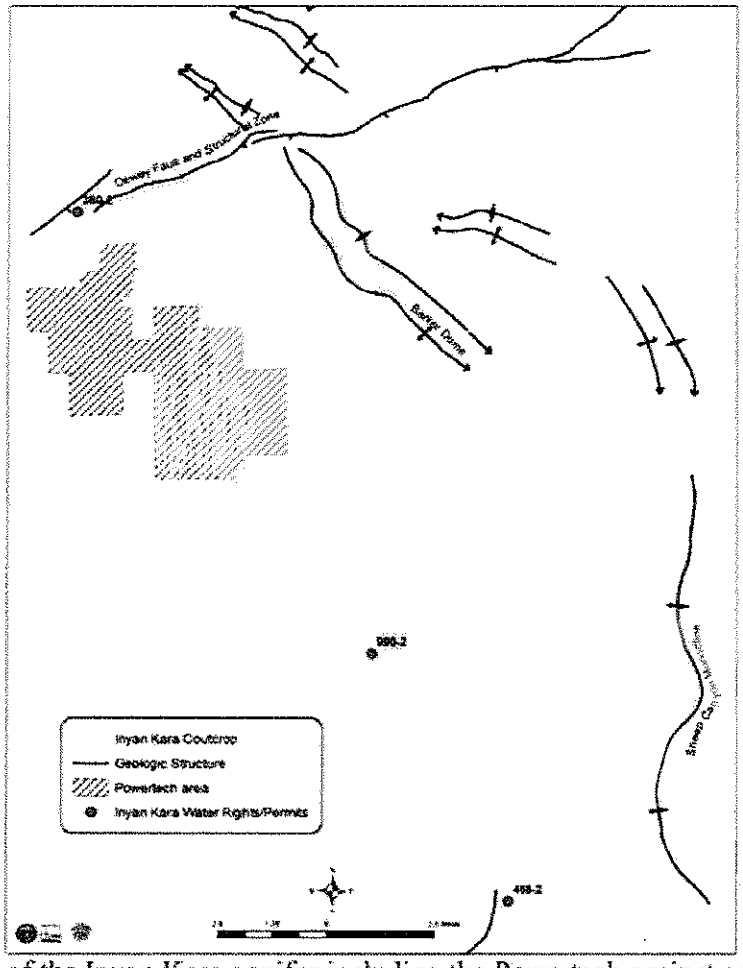


Figure 3. Subarea of the Inyan Kara aquifer including the Powertech project area and major structural features.

"The Dewey Fault begins in the Elk Mountains, about 2 ½ miles northeast of Dewey. The fault appears to be continuous for at least 6 ½ miles. Measurable vertical displacement on the fault is about 60 feet on the dip slope of the mountain but is at least 200 feet in Secs. 21, 22, and 28, T. 41 N., R. 60 W." (Brobst, 1961). Although the entire thickness of the Inyan Kara aquifer is not offset by the displacement of the fault, assuming the fault is a hydrologic barrier produces a more restrictive area and consequently produces a more conservative subarea.

Likewise, assuming the Cottonwood Anticline and/or the Sheep Canyon Monocline, the first major structural feature southeast of this project area, as a southern hydrologic barrier produces a conservative subarea.

The Inyan Kara Group outcrops over approximately 41,800 acres of the subarea shown in Figure 2. Precipitation recharge to the subarea estimated using the yield-efficiency algorithm developed by Driscoll and Crater (2001) is approximately 1,400 acre-feet per year. There are three existing water rights appropriating water from the Inyan Kara in this area (see table 1).

| PERMIT NO | NAME | STATUS | USE | CFS | ACRES | APPROPRIATION (AC-FT/YR) |
|---|---|---|---|---|---|---|
| 380-2 | HENRY C HOLLENBECK | LC | IRR | 0.85 | 60 | 180 |
| 468-2 | CITY OF EDGEMONT | LC | MUN | 0.2 | 0 | 86.88 |
| 990-2 | EFFIE M GOW | LC | IRR | 0.13 | 20 | 60 |
| LC= Water Right, IRR= Irrigation, Appropriation based on three acre-feet/acre per year for irrigation and 60% of full time pumping for municipal use | | | | | | |

Table 1. Water Rights within the subarea of the Inyan Kara aquifer that includes the project proposed by Application No. 2686-2

The estimated annual withdrawal from the subarea of Inyan Kara aquifer (<326.88 ac-ft/yr ) is less than the precipitation recharge estimated for subarea (1,400 ac-ft/yr) and there is a reasonable probability that there is 274.2 acre-feet of unappropriated water available annually to supply this proposed appropriation. (Incidentally, even if only the portion of the Inyan Kara outcrop that is directly up dip of the project area is considered, the precipitation recharge to the area can be expected to be at least 564 acre-feet per year using the yield-efficiency algorithm.)

**OBSERVATION WELL DATA:**

Administrative Rule of South Dakota Section 74:02:05:07 requires that "the Water Management Board shall rely upon the record of observation well measurements to determine that the quantity of water withdrawn annually from the aquifer does not exceed the estimated average annual recharge to the aquifer."

The DENR-Water Rights Program monitors nine observation wells completed into the Inyan Kara aquifer statewide. Eight of these wells are located near the perimeter of the Black Hills (see Figure 4). Hydrographs for the observation wells are shown in Figures 5-12.

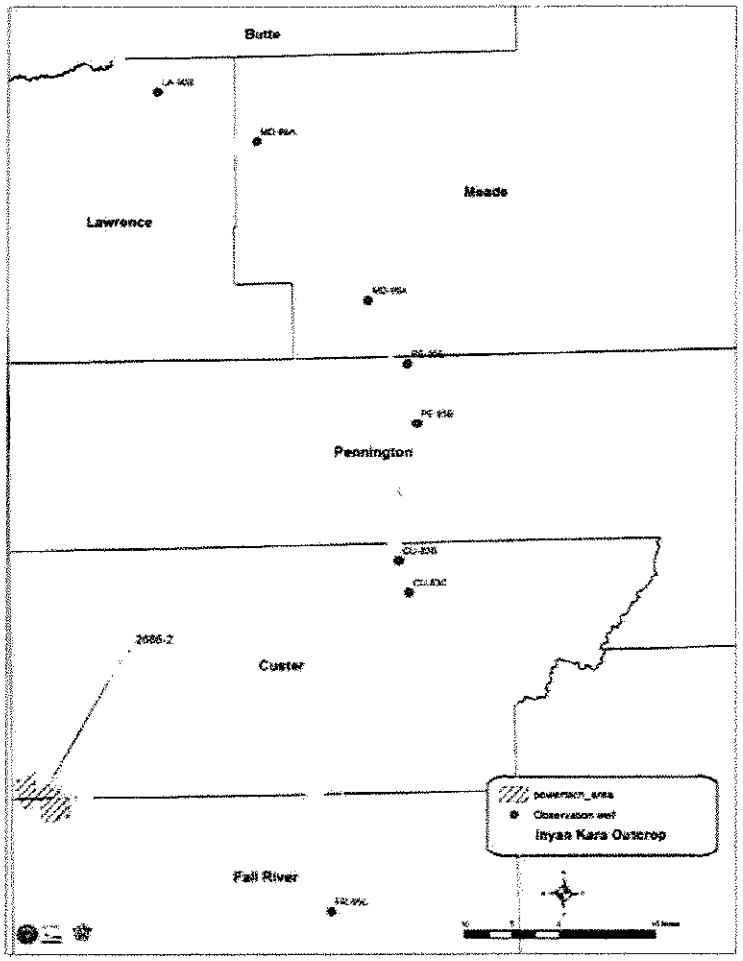


Figure 4. Location map of DENR-Water Rights' observation wells completed into the Inyan Kara aquifer

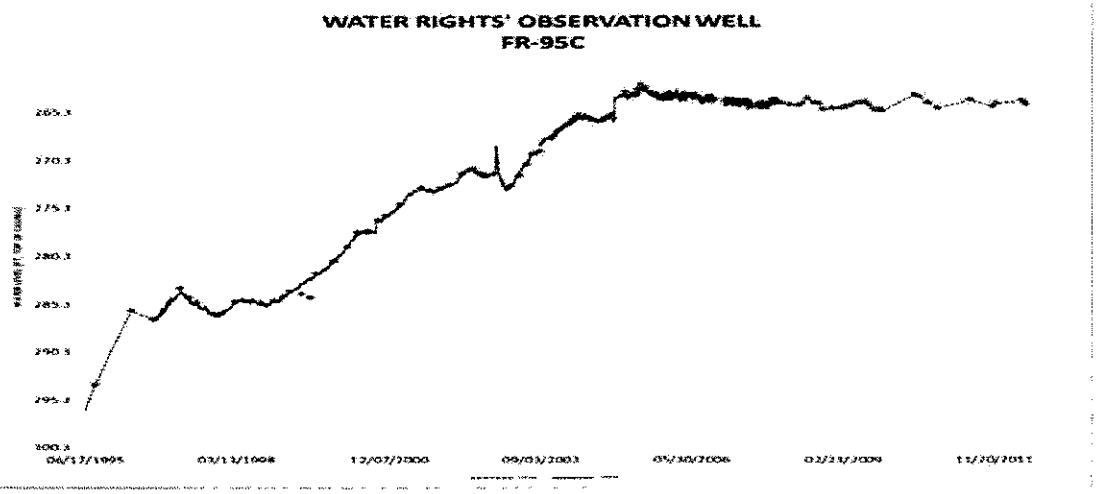


Figure 5. Hydrograph of Inyan Kara aquifer observation well, see figure 4 for location.

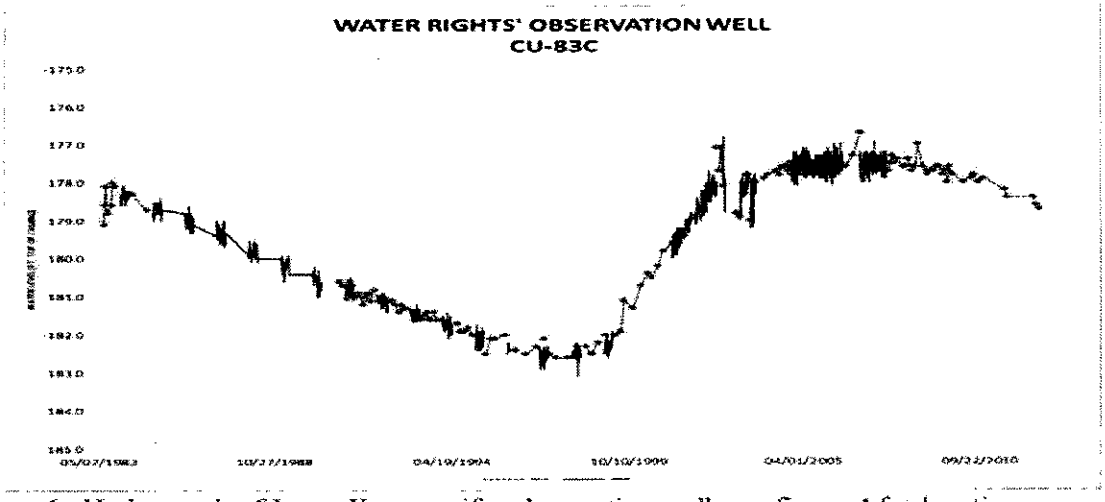


Figure 6. Hydrograph of Inyan Kara aquifer observation well, see figure 4 for location.

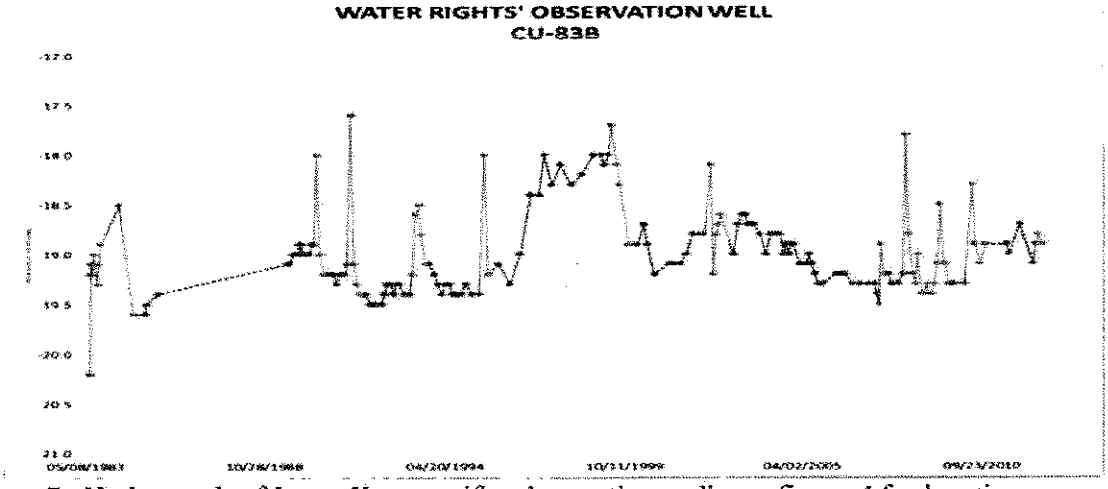


Figure 7. Hydrograph of Inyan Kara aquifer observation well, see figure 4 for location.

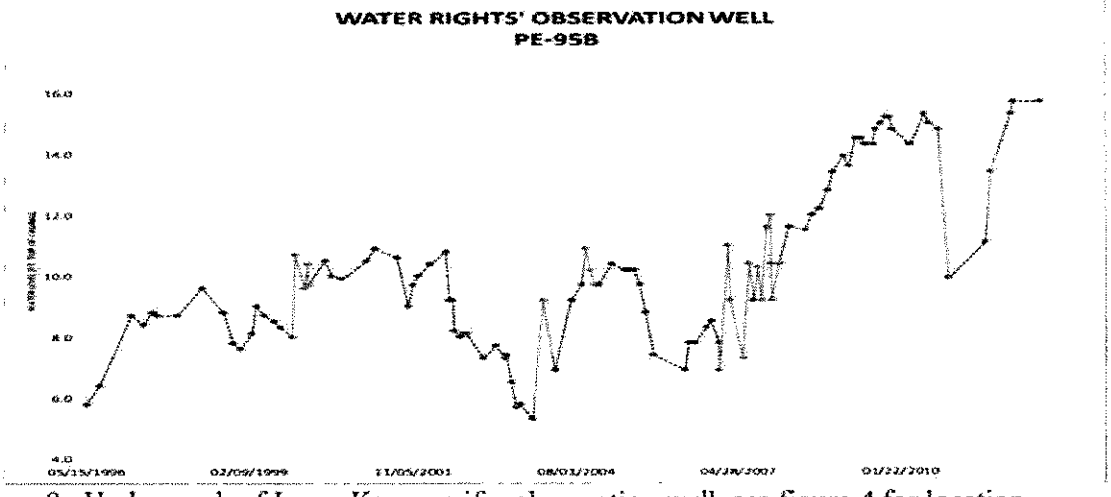


Figure 8. Hydrograph of Inyan Kara aquifer observation well, see figure 4 for location.

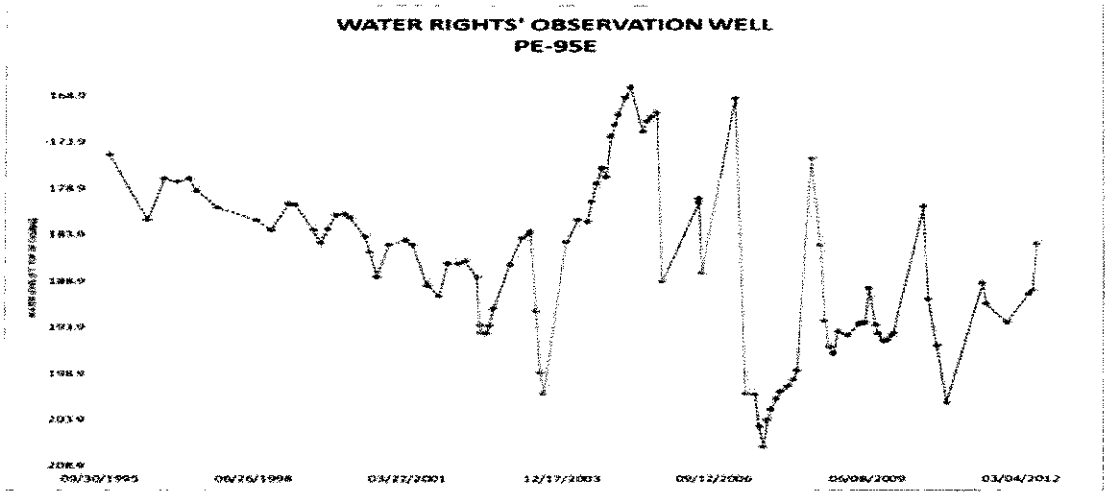


Figure 9. Hydrograph of Inyan Kara aquifer observation well, see figure 4 for location.

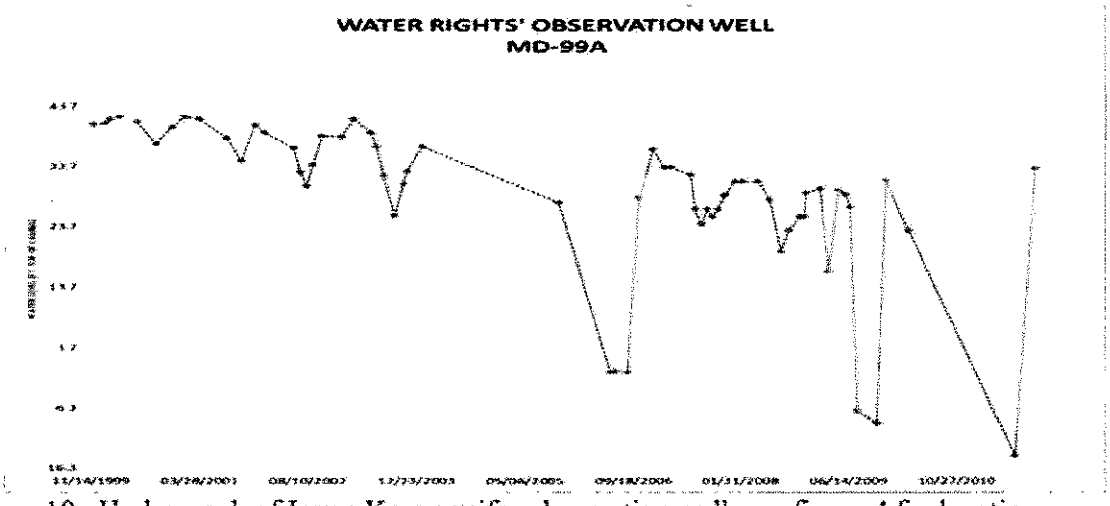


Figure 10. Hydrograph of Inyan Kara aquifer observation well, see figure 4 for location.

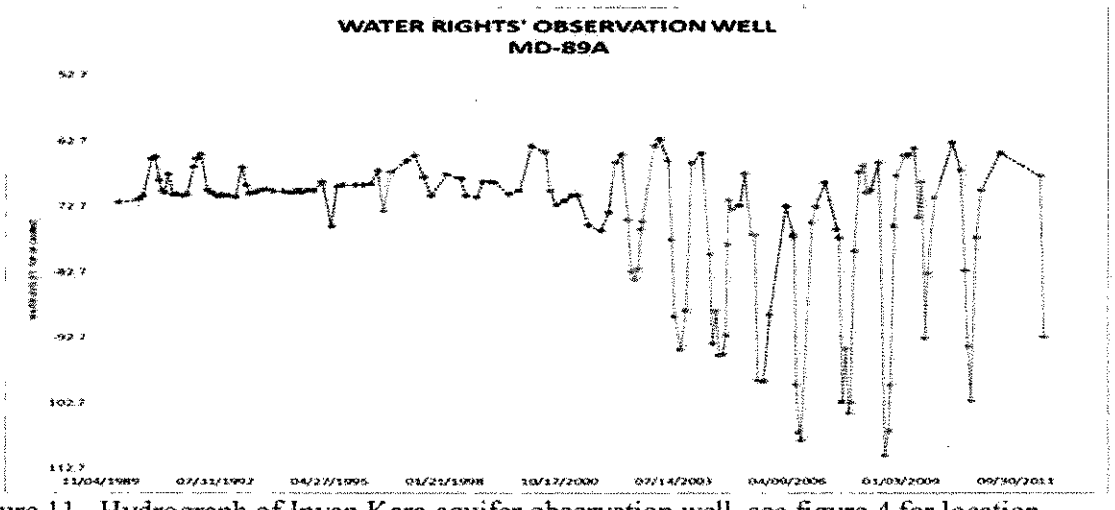


Figure 11. Hydrograph of Inyan Kara aquifer observation well, see figure 4 for location.

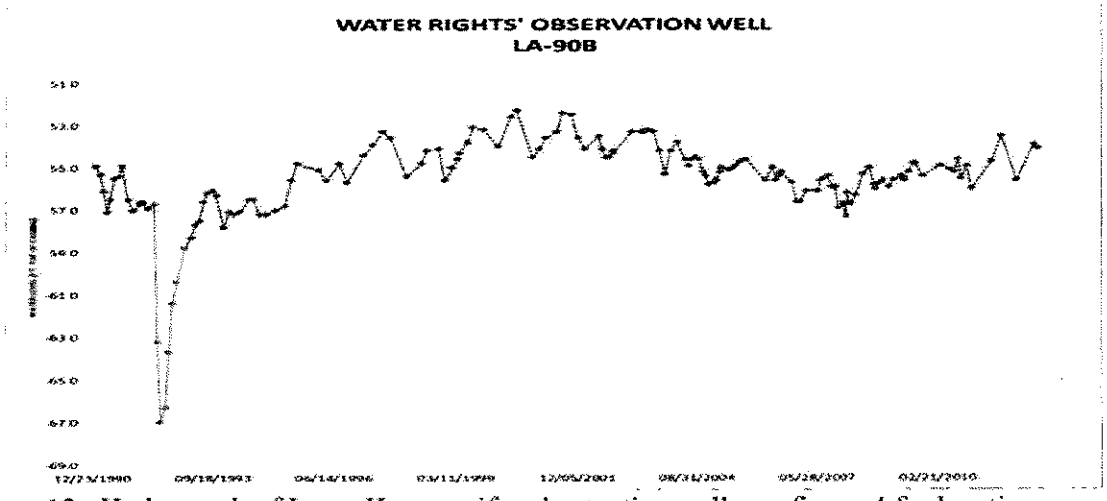


Figure 12. Hydrograph of Inyan Kara aquifer observation well, see figure 4 for location.

The observation well data for the Inyan Kara aquifer documents: 1) upward trending water levels; 2) that at the current level of development, climatic conditions greatly mask any temporal effects of well withdrawals thus the combined recharge to and natural discharge from the Inyan Kara aquifer significantly exceeds long term well withdrawals; and 3) the potentiometric surface of the aquifer has been relatively unchanged over time. Therefore, the observation well data shows that unappropriated water is available from the Inyan Kara aquifer.

**AFFECTS ON EXISTING WATER RIGHTS:**

Water rights/permits supplied by sources other than the Inyan Kara aquifer are not expected to be affected by Inyan Kara aquifer withdrawals since the aquifer is confined by the overlying Skull Creek shale and the underlying Morrison formation separates the aquifer from lower aquifers in this area.

The nearest water right to the project area proposed by this application that appropriates water from the Inyan Kara aquifer is Water Right No. 380-2 for Henry C. Hollenbeck. The water right authorizes the irrigation of 60 acres using a free flowing well located in the approximate center of the NW¼ of Section 17, T6S-R1E (i.e. approximately 0.6 miles north of the project area proposed by this application). Based on the Brobst (1961) delineation of the Dewey Fault and location of the well, the well that supplies Water Right No. 380-2 appears to be on the opposite side of the Dewey Fault from the Powertech project area. The displacement of this fault between the Hollenbeck well and the Powertech area is approximately 120 feet (Brobst, 1961). Since the fault does not completely offset the Inyan Kara Group in this area, the extent that the fault serves as a flow boundary is not clear. Earlier in this report, for the purpose of evaluating the availability of unappropriated water, the Dewey Fault was considered the northern extent of a subarea. Considering the fault as a flow barrier for the purpose of assessing water availability provided a "most conservative" analysis. For the purpose of considering the impairment of existing rights however, the most conservative analysis involves assuming the fault is not a flow boundary. Even by assuming the fault is not a flow boundary, and the entire 170 gallons per minute were withdrawn at the nearest possible point in the project area from the Hollenbeck well (an approach that over-predicts the maximum anticipated drawdown and produces a worst case scenario), drawdown at the Hollenbeck well is not expected to be significant based on the aquifer

characteristics for the Inyan Kara aquifer that were obtained from pump tests conducted in the Burdock area (Boggs and Jenkins, 1980). Since the pumping proposed by this application is to be spread over numerous wells, the maximum drawdown will be significantly less than for a single well. Any drawdown that would be measurable at the well that supplies Water Right No. 380-2 is not expected to be adverse. This is particularly true since the data on file with Water Right No. 380-2 indicates there is at least 40 feet of artesian pressure at the well and SDCL 46-6-6.1 does not require the protection of artesian head pressure as a means of diversion. The next closest South Dakota water right from the Inyan Kara aquifer is Water Right No. 990-2 for Effie M. Gow. Water Right No. 990-2 uses a free flowing well located approximately five miles southeast of this project area to flood irrigate 20 acres. Given the distance between Water Right No. 990-2 and the Powertech project area, adverse impacts are not likely.

The applicant has identified a water right (No. P183561W) located approximately 1.2 miles west of the project area in Wyoming. Since the drawdown caused by this proposed operation is not expected to be substantial, it is unlikely that the water right would be adversely impacted (at least by South Dakota standards).

The DENR-Water Rights Program has several completion reports on file for domestic wells in the vicinity of the proposed Powertech project area. Again, with the drawdown spread over a number of wells, the maximum drawdown at any point should not be significant. However, pursuant SDCL 46-6-24,

> "The failure of a well to meet standards established pursuant to § 46-6-6.1 is not a defense in any action or proceeding regarding damage, loss of water production or quality, replacement cost, or increased operating expenses incurred by a municipal or domestic use well located in a formation older than or stratigraphically lower than the greenhorn formation caused by any person using or withdrawing groundwater for mine dewatering in a formation older than or stratigraphically lower than the greenhorn formation."

This statute may provide protection to artesian pressure in domestic and municipal wells and to domestic or municipal wells that are not "adequate wells" pursuant to ARSD 74:02:04:20(6). Powertech has submitted a water permit application to appropriate water from the Madison aquifer for purposes including "for domestic and livestock use for area landowners inside and near the project area". A mitigating action such as supplying water from an alternative source as proposed, could resolve impairment of domestic well issues.

**BENEFICIAL USE OF WATER AND PUBLIC INTEREST:**

In the past, the Water Management Board has determined that the use of water for mining purposes is a beneficial use of water. The Water Management Board has not yet considered if in situ recovery is a beneficial use of water.

**CONCLUSIONS:**

1. Water Permit Application No. 2686-2 proposes to appropriate 274.2 acre-feet per year from the Inyan Kara aquifer.

2. Water Permit Application No. 2686-2 proposes to divert water from as many as 1,000 wells at one time and re-inject all of the water back to the Inyan Kara aquifer except for a maximum of 170 gallons per minute.
3. The location of the wells that are to be used will change over the life of this project and construction will not be completed within the five year period provided by law.
4. An extension of the five year construction period may be necessary to completely build-out this project.
5. Approval of this application will not result in average annual withdrawals from the Inyan Kara aquifer to exceed the average annual recharge to the aquifer.
6. The Inyan Kara aquifer is an extensive aquifer and there is a reasonable probability that there is at least 274.2 acre-feet per year of unappropriated water is available from the aquifer.
7. SD DENR-Water Rights Program observation well data indicates that unappropriated water is available from the Inyan Kara aquifer.
8. There is a reasonable probability that the diversion proposed by this appropriation can be made without unlawful impairment of existing appropriative rights or domestic wells.

Ken Buhler
SD DENR-Water Rights Program

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**DEPARTMENT of ENVIRONMENT and NATURAL RESOURCES**
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**RECOMMENDATION OF CHIEF ENGINEER FOR WATER PERMIT APPLICATION NO. 2686-2, Powertech (USA) Inc.**

Pursuant to SDCL 46-2A-2, the following is the recommendation of the Chief Engineer, Water Rights Program, Department of Environment and Natural Resources concerning Water Permit Application No. 2686-2, Powertech (USA) Inc., c/o Richard Blubaugh, 5575 DTC Parkway, Suite #140, Greenwood Village CO 80111.

The Chief Engineer is recommending APPROVAL of Application No. 2686-2 because 1) there is reasonable probability that there is unappropriated water available for the applicant's proposed use, 2) the proposed diversion can be developed without unlawful impairment of existing rights, 3) the proposed use is a beneficial use and 4) it is in the public interest with the following qualifications:

1. Water Permit No. 2686-2 appropriates and places to beneficial use up to 18.938 cfs with an annual consumptive use volume of 274.2 acre feet of water (equal to 0.38 cfs) from the Inyan Kara Aquifer for the specific purpose of the production of uranium through the insitu mining process at the legal location listed in the permit.

2. The wells authorized by Permit No. 2686-2 shall be constructed by a licensed well driller and construction shall comply with Water Management Board Well Construction Rules, Chapter 74:02:04 with the well casing pressure grouted (bottom to top) pursuant to Section 74:02:04:28. Well completions report shall be submitted within one month of completing each production and/or injection well.

3. The Permit holder shall report to the Chief Engineer annually the amount of water withdrawn from the Inyan Kara Aquifer. This annual reporting shall report both the gross and net withdrawal from the Inyan Kara Aquifer.

4. The wells approved under this permit will be located near domestic wells and other wells which may obtain water from the same aquifer. The Well owner under this permit shall control his withdrawals so there is not a reduction of needed water supplies in adequate domestic wells or in adequate wells having prior water rights.

5. The Permit holder shall submit a planned diversion report annually setting forth the number anticipated and location of pumping wells to be constructed and/or operated during the next upcoming year.

See report on application for additional information.

Garland Erbele, Chief Engineer
November 6, 2012

NOTE: DENR recognizes that the number and location of production and injection wells completed into the Inyan Kara Aquifer will vary as well fields are constructed, insitu mining is conducted, restoration is conducted and decommissioning is completed. The application states that amendments for additional wells and changes in well locations as the project progresses will be requested subject to provisions of SDCL 46-5-13.1. As Chief Engineer, all requests for changes in well location and additional wells will be reviewed as set forth in SDCL 46-5-13.1.

In addition to obtaining water right permits, Powertech (USA) will be subject to compliance with all other state of South Dakota and federal government regulations relating to water use and insitu mining.