CHAPTER 6

GEOLOGY
(R645-301-600)

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CRANDALL CANYON MINE, MINE AND RECLAMATION PLAN
CHAPTER 6
GEOLOGY

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Note: Bold number plates and appendices are included with this submittal.

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6.10 Introduction

This Chapter presents discussion of geologic conditions within and adjacent to the Genwal Mine Permit Area, which consists of Lease Areas SL062648 and U054762, State Lease ML-21569, State Lease ML-21568, Federal Lease UTU-68082 (including the lease modification), Federal Lease UTU-78953, the SITLA/PacifiCorp sublease and the Nielson Fee Lease. Conclusions herein are based on field reconnaissance, exploratory drilling and previous documentation. Report references are shown at the end of this chapter.

6.11 General Requirements

The geology within and adjacent to the permit area is discussed in Sections 6.21 through 6.27 of this chapter. Plans for casing and sealing of exploration holes and for subsidence monitoring are discussed in Sections 6.30 through 6.32.

6.12 Certification

All required maps, plans and cross-sections presented in this chapter have been certified by a registered professional engineer.

6.20 Environmental Description

This section presents a description of the geologic resources in, and adjacent to the permit area.

6.21 General Requirements

Regional Geology

The Wasatch Plateau consists of Tertiary and Cretaceous strata, mostly limestone, sandstone, and shale that differ in resistance to erosion (Davis and Doelling, 1977). Limestones and sandstones generally form cliffs, whereas the shales form recessive slopes.

Stratigraphic units present in the vicinity of the Crandall Canyon area include from youngest to oldest (1) the North Horn Formation (slope-forming mudstone and sandstone). (2) the Price River Formation which consists of the basal Castlegate Sandstone Member (cliff-forming sandstones, conglomerates and minor amounts of shale, of deltaic origin) and the Upper Price River Member (steep slope-forming sandstone with minor interbeds of pebble conglomerate and shale, of fluvial origin). (3) the Blackhawk Formation (cliff-forming sandstone underlain by slope-forming mudstone, shale and coal, of paludal origin). (4) the Star Point Sandstone (cliff-forming sandstones consisting of deltaic and beach deposits), and (5) the Masuk Shale Member of the Mancos Shale

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mudstone, shale and coal, of paludal origin). (4) the Star Point Sandstone (cliff-forming sandstones consisting of deltaic and beach deposits), and (5) the Masuk Shale Member of the Mancos Shale (slope-forming marine shales), refer to Appendix 6-3 and 6-4 and Plate 6-1. The Star Point Sandstone contains several shale tongues of the underlying Masuk Shale in the Wasatch Plateau region.

The stratigraphic record produced by these units indicates that deposition up through the Blackhawk Formation consisted mostly of fine-grained detritus under conditions of relatively quiet and uniform sedimentation (Davis and Doelling, 1977). An erosional disconformity exists at the top of the Blackhawk Formation, which is overlain by coarse clastics of the Castlegate Sandstone. These coarse continental sediments suggest tectonic movement to the west and probably mark the onset of the Laramide orogeny (Davis and Doelling, 1977).

The Wasatch Plateau lies in a transition zone between the relatively stable Colorado Plateau to the east and the relatively complex and unstable Basin and Range province to the west (Davis and Doelling, 1977). Strata of the western Wasatch Plateau dip into a complexly faulted monocline, whereas strata on the east side have predominantly gentle dips and faults are less numerous (Davis and Doelling, 1977).

Major faults present within the region of the coal fields are north-trending with maximum displacements of up to 2,300 feet (Davis and Doelling, 1977). Many north-trending faults with minor displacements are present and few east-trending faults, most of which have displacements of less than 100 feet, are also present locally.

Most of the strata in the coal field form broad anticlines and synclines that trend northeast or are roughly perpendicular to the principal fault zones (Davis and Doelling, 1977).

Geology of Project Vicinity

The drainage basins of Crandall Blind and Horse Canyons cover approximately 5.7, 2.0 and 7.0 square miles respectively and expose six geologic units which range in age from Cretaceous to Tertiary. Surface lands within the permit area consist entirely of outcrop exposures of sandstones, mudstones and coal of the Castlegate Sandstone, Blackhawk Formation, Star Point Sandstone, Price River Formation, and North Horn Formation and are shown on Plate 6-1.

The Hiawatha and Blind Canyon coal seams, which will be of importance in the permit area are present at or near the base of the Blackhawk Formation (Campanian in age). Several other thin lenticular coal seams are present at the property, but none are of significant thickness or of probable lateral extent to be of economic interest. In much of the permit area, including the U-68082 lease mod area, only the Hiawatha seam is of sufficient thickness to be economically recoverable. However, in the South Crandall lease area both seams are mineable.

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The Hiawatha coal seam has been mined and is exposed at an approximate elevation of 7,900 feet amsl (Appendix 6-1). Mining overburden above the Hiawatha coal seam in the permit area consists of the Blackhawk Formation, Castlegate Sandstone, and the Upper Price River Member and

results in a maximum overburden of approximately 2,400 feet and an average overburden of approximately 1,100 feet. The entire area is underlain by the Star Point Sandstone.

The coal-bearing unit is the Upper Cretaceous Blackhawk Formation. The Blackhawk Formation is composed of grey sandstone, siltstone, shale, and coal; it is composed of about 50% fine-grained sandstone and is present in thicknesses of 650 to 1,000 feet at Crandall Canyon. The Hiawatha coal bed is the thickest coal bed present (10 feet at Crandall Canyon), and is found near the base of the Blackhawk (Lines, 1985).

The Upper Cretaceous Star Point Formation underlies the Blackhawk Formation. It is predominately composed of massive tan medium-grained sandstone with minor interbeds of shale and siltstone near its base. This formation outcrops east of the Crandall Canyon Mine and reaches a thickness of 350 to 450 feet. At the southeast end of Trail Mountain, where the Star Point is exposed, it is about 500 feet thick (Lines, 1985). This formation is of significance since it and the saturated portions of the Blackhawk Formation comprise a regional aquifer present at both mine sites.

The Upper Cretaceous Castlegate Formation overlies the Blackhawk Formation and is dominated by massive tan medium-grained massive sandstone. It has a thickness of about 170 to 200 feet at Trail Mountain, and is 250 feet thick at Crandall Canyon (Lines, 1985).

The Castlegate is overlain by the Upper Cretaceous Price River Formation, a grey medium - to coarse - grained sandstone interbedded with several thin shale beds at both mine sites. The Price River is about 700 feet thick at the Trail Mountain Mine (Lines, 1985), and is about 600 feet thick at the Crandall Canyon Mine.

Overlying the Castlegate is the North Horn Formation of Upper Cretaceous and Tertiary age. It is composed of interbedded shales, siltstone, sandstones, and limestones. At the Trail Mountain mine it reaches a thickness of about 1,000 feet, although thicknesses of only several hundred feet are present at Genwal, due to erosion. The North Horn Formation caps the mountain ridges in the area, and serves as a recharge unit to underlying formations and supplies water to springs within the formation.

The Joes Valley Fault breaks the continuity of these geologic units at both the Trail Mountain and Crandall Canyon Mines. The Joes Valley Fault lies along the west base of Trail Mountain, and along the west base of East Mountain at the Crandall Canyon Mine (Davis and Doelling, 1977). The Joes Valley Fault forms the eastern boundary of a graben about 3 miles wide which extends north and south of both mines (Davis and Doelling, 1977). Davis and Doelling (1977) estimate approximately 2300 feet of vertical displacement along the fault in this area. Stratigraphic dip at both mine sites is approximately 2 to 3 degrees to the southeast (Lines, 1985).

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As discussed in Section 5.25, mining-induced subsidence will not intersect the Joes Valley Fault. The maximum limit of subsidence in the permit area is depicted on Plates 5-2, 5-2B, and Figure 5-9, and subsidence-induced hydrologic effects are discussed in Section 7.0.

Geologic inspection of the property indicates that prior mining of the Hiawatha Seam did not encounter subsurface water. The maps submitted in Appendices 6-3 and 6-4 and Plate 6-1 are included to show the relative location of the geologic formations to the mine permit area.

6.22 Cross Sections, Maps and Plans

Stratigraphic sections, best available BLM and Genwal data are shown in Appendices 6-1, 6-4 and 6-5. Drill hole results and cross sections are shown in Appendix 6-5. The Geologic map is on Plate 6-1. Coal seam isopachs for the Hiawatha, Blind Canyon and Bear Canyon Seams are shown on Plates (all applicable data) 6-3, 6-4 and 6-5, respectively. Overburden is shown on Plate 6-6. Structure is shown in Appendix 6-3. A structure contour map of the top of the Hiawatha seam is shown on Plate 6-7. Refer to Plates 5-2(H) and 5-2(BC) for information regarding the South Crandall lease area, and the U-68082 lease mod area including coal seam thickness, seam interval, overburden thickness, and drill hole locations. A generalized geologic cross-section is shown in Appendix 6-7.

6.22.1 Test Borings and Coal Sampling

Genwal has included two lithologic, depth correlated sections to show thicknesses of interburden and coal from the Star Point Sandstone to the surface. These geologic sections are provided in Appendix 6-1 and Appendix 6-5. The lithofacies of the Blackhawk Formation in the vicinity of the mine area are shown in stratigraphic section within Appendix 6-1 and Appendix 6-5. Two additional holes have been drilled, MW-3 and MW-4 in State Section ML-21569. MW-4 was drilled and cored and is a water monitoring source (Appendix 6-5). MW-3 was drilled down but not cored. These sections should provide sufficient technical information to determine the nature, depth and thickness of the coal seams, rider seams, overburden and interburden strata for the permit area. The thickness and extent of all formations in the area adjacent to the mine area are shown on Plates 6-1 through 6-6, with related discussion in Section 6.21. Borehole locations are shown on Plate 5-2. The known locations of proposed in-mine up-drilled borings and surface bore holes are shown on Plate 5-2.

The drilling results obtained during 1985 indicate the presence of the Blind Canyon seam although it is of unminable thickness in the vicinity of the Crandall Canyon No. 1 Mine (Appendices 6-1 and 6-5). The upper seam will be called the Blind Canyon Seam at the request of DOGM to simplify discussion. The same seam has been referred to as the "upper Hiawatha Seam" and the "lower Bear Canyon Seam" at various other locations.

Analysis of coal samples collected from the Hiawatha Seam indicate that it is a high volatile

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bituminous coal with a BTU content ranging from 12,500 to 13,000 BTU, ash content of 6% to 8%, moisture of 3% to 5%, volatile matter from 40% to 44%, fixed carbon from 43% to 46% and sulfur from 0.44% to 0.55%. Forms of Sulfur average 0.016% pyritic sulfur, 0.09% sulfate sulfur, and 0.30% organic sulfur, Appendix 6-2. Locations of samples are at 1st Right Main West, 9th left 1st East, and 1st North 1st Right.

Within the South Crandall lease there is only one drill hole of geologic data, HC-4. This hole was drilled in 1981 and encountered 6'9" of coal in the Blind Canyon, and 5.0' in the Hiawatha, which is marginally mineable with low coal equipment. The coal analysis from this hole is: Blind Canyon 13352 BTU, 0.61% sulfur, 5.46% ash - Hiawatha: 13126 BTU, 0.56% sulfur, 6.3% ash. The location HC-4 is shown on Plates 5-2 (BC) and 5-2 (H).

6.22.2 Coal Seams, Overburden, Stratum Coal Seams

Additional technical information has been submitted to determine the nature, depth and thickness of the coal seams, rider seams, overburden and interburden strata for the permitted mine area based upon drilling completed to date (Appendices 6-1 and 6-5 and Plates 5-2). There is insufficient evidence to support the presence of the Blind Canyon Seam in Crandall Canyon, but it thickens southward to the Mill Fork area, beyond which it again is of little value (Doelling, 1972, p. 189). The old workings can provide information on the lower seam (Hiawatha) and some ground water information but nothing about the other seams. Additional geologic information was submitted by Mr. Wollen, a former operator of the Genwal property, which contained specific lithologic characterizations of the interburden, and the strata immediately above and below the coal seams (Appendices 6-1 and 6-2). Additional geologic information about the South Crandall lease area is found in Appendix 6-6.

Coal Reserves Coal-seam data for lease area SL 062648 indicates that approximately 840,000 tons of coal are in place, of which 400,000 tons are recoverable. Lease area U 54762 contains approximately 2.5 million tons of coal in place, of which approximately 1.5 million tons are recoverable. Approximately 0.5 million tons will be left in place for final retreat, leaving approximately one million tons minable during advance.

In-place tonnage for State Leases ML-215688 and ML-21569 is estimated at 18,000,000 tons, of which 8,000,000 tons are considered recoverable. The Lease #UTU-68082 has an estimated in-place tonnage of 36,000,000 tons, of which 12,000,000 tons are considered recoverable. In the South Crandall lease area the estimated recoverable reserves are 7.63 million tons. Due to the speculative nature of the U-68082 lease mod area no recoverable reserves are estimated.

All mining within the Crandall Canyon #1 Mine is within the Hiawatha seam. The Blind Canyon seam is present above the Crandall Canyon #1 Mine but is not thick enough to mine. (Coal seam isopachs for this area are shown on Plates 6-4 and 6-5) in the area of the South Crandall Mine (i.e., within the South Crandall lease area) both the Hiawatha and the Blind Canyon seams reach minable thickness. The approved R2P2 for the South Crandall Mine include extraction from both seams. The coal seam thickness isoapchs for the seams in the South Crandall lease area are shown on Plates 5-2(H) and 5-2(BC).

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Drill hole and geological information for the area around the South Crandall lease area is shown on Plates 5-2(H) and 5-2(BC). There is only one drill hole on the South Crandall lease, HC-4. The driller's log for HC-4 is included in Appendix 6-6. The Bear Canyon seam in this hole is only 2' thick.

The information obtained from underground drill holes 1 and 2 show the Blind Canyon above the Crandall Canyon No. 1 Mine to be approximately 59 and 40 inches thick, respectively, which makes this seam unminable and of no economic value. Surface drill holes 3 and 4 indicate the Blind Canyon seam is 54 and 40 inches thick, respectively, in those areas. The Blind Canyon seam is located approximately 40 to 60 feet above the Hiawatha seam. Refer to Plate 5-2 for locations, DH-2 in Federal lease SL-062648 its location is shown on Plates 5-2(H) and 5-2(BC). There is approximately 60 acres of Blind Canyon coal at a thickness of 5 feet or more, equivalent to approximately 418,000 tons of coal in place. Although this seam remains fairly continuous across the property in the area above the Crandall Canyon No. 1 Mine , it is not mineable. In the area of the South Crandall mine the Blind Canyon seam is thicker and is considered mineable.

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Additional drilling information has been provided for the State Leases. This information is included in Appendix 6-1 and 6-5. The seam information has been translated to the isopach maps, Plates 6-3, 6-4 and 6-5. As shown on the isopach maps, the Hiawatha Seam is the only seam which is considered economically recoverable.

Five monitoring wells have also been drilled underground for ground water evaluation. Details on these wells are provided in Chapter 7, Section 7.31.21 and Appendices 7-46 and 7-47.

Reserve Classifications. A map is provided delineating coal outcrop lines from the Hiawatha and Blind Canyon seams with the strike and dip indicated at one point, refer to Plate 6-1.

Stratigraphy. The Blackhawk Formation is comprised of approximately 1,000 feet of gray carbonaceous shales, siltstones, coals and thin interbedded sandstones. The coal beds to be mined near the base of the formation are 6 to 11 feet thick and are generally classified as a high volatile bituminous coal. The Blackhawk Formation is underlain by the massive cliff-forming Star Point Sandstone, which is 200 to 400 feet thick.

Appendix 6-1 includes two stratigraphic sections which were obtained by traversing the stratigraphic column from Crandall Creek to the Castle Gate Sandstone. The entire stratigraphic column is shown in Appendix 6-1 for the permit area. A generalized stratigraphic section is provided in Appendix 6-4. This section has been confirmed by field analyses of distances between coal seams and the thickness of the overburden in the mine area, as described above. The stratigraphic section accompanies this chapter as part of Appendix 6-4.

A coal isopach (Plate 6-3) and overburden isopach map showing the depth to the minable Hiawatha Seam is included as Plate 6-6 to support extrapolation of ground water hydrology projections from nearby mines to the Crandall Canyon Mine and to support projections of subsidence.

Structure. Formations in the central Wasatch Plateau generally dip 1-3 degrees to the west. This regional structural attitude is broken by several north-south trending, high angle normal faults which offset the rocks from less than 10 feet to approximately 250 feet or more. As mapped, there are no major faults (other than the Joe's Valley Fault) present within the boundaries of the permit area. Springs are present in the upper reaches of the canyon near the Castlegate Sandstone-Blackhawk Formation contact. Several seeps have been noted in the Crandall permit area issuing from the Star Point Sandstone. A complete discussion of the springs and seeps encountered within the permit area is in Chapter 7.

6.22.3 Coal Outcrop / Strike and Dip

Coal outcrops are shown on the isopach maps (Plates 6-3, 6-4 and 6-5) and on all mine plans and progress maps (Chapter 5). Plate 6-7 is a structure contour map of the top of the Hiawatha seam.

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Plates 5-2 and 6-1 show strike and dip providing an average strike over the entire area where the coal outcrop data have been obtained. An average strike designation was necessary due to the severe erosional and geographic conditions of the area, which would make anything but an average direction highly inaccurate. This dip is to the southeast, and varies slightly from the regional dip due to local geologic conditions.

6.22.4 Gas and Oil Wells

There are no gas or oil wells known to exist within, or adjacent to, the permit area.

6.23 Geologic Determinations

The acid- or toxic-forming characteristics of the strata are discussed in Sections 6.24.32 and 6.24.33 and in Appendix 6-2.

The subsidence control and monitoring plans are discussed in Section 5.25 and in Chapter 5.

6.24 Geologic Information

(1) Information presented in Section 7 indicates that the water table in the Star Point Sandstone is below the coal seams of the lower Blackhawk Formation. The flow of ground water in the formation is toward Huntington Creek.

(2) The Star Point Sandstone, which underlies the Hiawatha seam, is predominantly a light-gray massive sandstone with minor interbedded layers of shale and siltstone near its base (Doelling, 1972). In the vicinity of the mine, the Star Point Sandstone is 200-400 feet thick. The Star Point Sandstone serves as a regional aquifer (Danielson et al., 1981) yielding water to several minor and some major springs where fractured and jointed.

(3) The Blackhawk Formation (at the base of the Hiawatha seam) could contain perched aquifers in lenticular sandstones interbedded within the shales. The shales of the Blackhawk Formation are not very permeable; consequently, ground water within the formation is perched. The shales of the Blackhawk Formation are bentonitic and swell when wet; therefore, faults and fractures in the Blackhawk tend to seal, limiting secondary permeability, refer to the exceptions itemized in Section 7.

Detailed Columns of Interest and Cross Sections. See Appendix 6-1 included with this chapter. Stratigraphic section A was taken at the portal area and stratigraphic section B was taken 500 feet east of the portal area.

Additional information on the regional and permit area geology is presented in Section 6.21, and on maps, cross-sections and plans presented in this chapter and in Chapters 5 and 7.

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Geologic literature and practices are discussed throughout this chapter and in the list of references at the end of the chapter.

Geologic Information Pertaining to Little Bear Spring

The Little Bear Spring is located close to the southern boundary of the South Crandall lease area. This spring is an important source of culinary water for many residents of Emery County. In order to ensure that the spring would be protected from the effects of mining in the South Crandall lease area the Forest Service and the BLM required a number of detailed hydrology studies to ascertain the source of the spring. Based on the result of these studies the federal government has concluded that the potential for mining this lease to alter the flow of Little Bear Spring is low and has issued a Finding of No Significant Impact (FONSI) regarding the proposal to conduct mining operations within the lease. The following studies were required by the Forest Service and BLM prior to leasing action and are included in this MRP as appendices in Chapter 7. Each report includes an extensive discussion of the geology of the South Crandall tract as relates to the occurrence of ground-water, aquifers, and recharge sources of the Little Bear Spring.

7-51	Little Bear Spring Water Replacement Agreement
7-52	Supplemental Hydrogeologic Information for LBA 11
7-53	Summary of New Isotopic Information for LBA 11
7-54	Results of In-Mine Slug Tests
7-55	Investigation of Alluvial Ground Water System in Mill Fork Canyon
7-56	Investigation of Potential for Little Bear Spring Recharge
7-57	Determination of Recharge Location of Little Bear Spring (Dye Tracing)
7-58	Summary of Hydro logic Baseline Information, South Crandall Lease
7-59	Little Bear Spring Study (Initial study, 1998) AquaTrack
7-60	Little Bear Spring Study (Expanded Study, 1999) AquaTrack
7-61	Mill Fork Resistivity Study, 2001 AquaTrack
7-62	Little Bear Spring (2nd Expanded Study, 2001) AquaTrack

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6.24.2 Chemical Analyses of Overburden

N/A - Strata above the coal seam will not be removed by underground mining.

6.24.3 Chemical Analyses / Lithology

Strata above and below the coal seam will not be mined or removed. Samples have been collected and analyzed as required.

6.24.31 Drill Hole Logs

Drilling results and details are summarized in Appendix 6-5. Additional information on lithology and potential impacts of mining on ground water is provided in Section 6.24 and in Chapter 7.

6.24.32 Chemical Analyses - Strata

Alkalinity. The pyrite, alkalinity and clay content information is from samples taken by applicant and submitted to Standard Laboratories, Huntington, Utah for chemical analysis. The lab reports are included with this document as Appendix 6-2.

The pyrite content and alkalinity content of the stratum immediately above the coal seams are as follows:

	Hiawatha	Blind Canyon
Pyrite	0.03%	0.09%
Paste pH	7.6	7.25
Alkalinity	63.3 mg/1	87.4 mg/1

The pyrite content, alkalinity and clay content of the stratum immediately below the coal seams are as follows:

	Hiawatha	Blind Canyon
Pyrite	0.06%	0.07%
Paste pH	3.95	3.90
Alkalinity	4.0 mg/1	0.0 mg/1
Clay Content	9.5%	10.5%

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As discussed in Section 5.28.30, waste rock is not produced during mining operations. When incidental quantities of rock are encountered, the rock is left in the mine and will not be removed at any time in the future; thus, no negative effects are expected from the acid-forming potential of strata which overlie and underlie the Hiawatha seam. However, to further characterize the acid-forming

potential of strata immediately above and below the Hiawatha seam, the applicant collected additional roof- and floor-rock samples from three equally spaced locations within the current mine workings (including the state leases and right-of-way areas). Analytical results from these three sets of samples are provided in Appendix 6-2 and are used to further characterize the acid-forming potential of the strata. The laboratory data indicate that neither the underburden or overburden are acid or toxic forming materials.

The characterization of the strata above and below the Blind Canyon Seam can not be done at this time due to no access to unweathered material. In approximately 6 months access to the Blind Canyon seam via the rock tunnel will be available. Samples and analysis will be done then.

6.24.33 Chemical Analysis - Coal

The total sulfur content of the Hiawatha coal has been analyzed at 0.58%, and the acid-base potential determined for the coal is +10.2 tons $CaCO_3$/1000 tons (Appendix 6-2). Under the current operation plan only a small quantity of coal is temporarily stockpiled on-site. The amount of coal remaining at the time of reclamation is likely to be insignificant. Plus, the data show that the coal is non-acid forming and non-toxic.

The characterization of the Blind Canyon Seam can not be done at this time due to no access to unweathered material. In approximately 6 months the rock tunnels from the Hiawatha seam will be completed. Samples and analysis will be done at that time.

6.24.34 Properties of Strata Above and Below Coal

This mine employs standard room and pillar mining operations and longwall technology; however, the stratigraphic sections (Appendix 6-1) and drilling results (Appendix 6-5) do not show any clays or soft rock immediately above or below the coal seam to be mined.

In the South Crandall lease area, where the Blind Canyon seam will be mined, the thickness of the clays and soft rock above and below the coal seam are shown on drill hole HC-4, Appendix 6-6. The engineering properties of these materials will be determined once the rock tunnels are constructed and access is gained to the Blind Canyon seam. Samples and analysis will be done at that time.

6.25 Additional Information

Additional information will be provided if determined necessary by the Division.

6.26 Waiver of Requirements

Not applicable.

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6.27 Overburden Thickness and Lithology

Provided in Appendix 6-1 and Plate 6-6.

6.30 Operation Plan

6.31 Casing and Sealing of Exploration Holes and Boreholes

Exploration holes, boreholes, or other holes will not remain open for use as water supply wells or ground water monitoring wells and will normally not be completed with casing. These holes will be plugged, capped, sealed, backfilled or otherwise managed to protect water resources without the use or installation of casing, but casing will be used if it is needed to maintain boring wall integrity.

The measures to be used to close the holes will include filling the hole or opening with cuttings or inert material until it is level with the surface. Those holes which flow or might flow as a result of artesian conditions will be cemented, and any holes which penetrate two or more aquifers with significantly different ground water quality will be cased or cemented.

Installation and abandonment of monitoring wells (and other wells) will be done by a licensed driller following Division of Water Rights rules and procedures.

6.31.1 Temporary Casing and Sealing of Drilled Holes

Those holes which remain open for use as water supply wells or for use as ground water monitoring well will be completed with casing or piezometers at a sufficient height above the land surface to prevent drainage of surface water or entrance of other material into the well. In addition, they will be fitted with caps to prevent introduction of foreign objects, other than monitoring and sampling equipment, into the well. When ground water monitoring wells are no longer needed or required for any purpose, each well will be sealed in accordance with the measures described above by a licensed driller following Division of Water Rights rules and procedures.

6.31.2 Permanent Casing and Sealing of Exploration Holes and Boreholes

When no longer needed for monitoring or other use approved by the Division upon a finding of no adverse environmental or health and safety effect, or unless approved for transfer as a water will under R645-301-731.400, each exploration hole or borehole will be plugged, capped, sealed, backfilled or otherwise properly managed under R645-301-631 and consistent with 30 CFR 75.1711. Permanent closure methods will be designed to prevent access to the mine workings by people, livestock, fish and wildlife, and machinery and to keep acid or other toxic drainage from entering water resources.

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6.32 Subsidence Monitoring

Subsidence monitoring is carried out on an annual basis and includes aerial surveys and visual surveys of the mine permit area. As required by R-645-301-525, a complete subsidence control plan addressing the regulations can be found in section 5.25 of this document. Projected subsidence from mining is shown on Plates 5-2(BC) and 5-2(H).

6.40 Performance Standards

6.41 All Exploration Holes and Boreholes

All exploration holes and boreholes will be permanently cased and sealed according to the requirements of R645-301-631 and R645-301-631-200.

6.42 Monuments and Surface Markers

All monuments and surface markers used as subsidence monitoring points and identified under R645-301-200 will be reclaimed in accordance with R645-301-521-210.

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References

Danielson, T.W., M.W. ReMillard. and R.H. Fuller. 1981. Hydrology of the Coal Resource Areas in the Upper Drainages of Huntington and Cottonwood Creeks, Central Utah. U.S. Geological Survey Water-Resources Investigations Open-File Report 81-539. Salt Lake City, Utah

Davis, F.D. and H.H. Doelling. 1977. Coal Drilling at Trail Mountain, North Horn Mountain, Johns Peak Areas, Wasatch Plateau, Utah Geological and Mineral Survey Bulletin 112. Salt Lake City, Utah.

Doelling, H.H. 1972. Central Utah Coal Fields: Sevier-Sanpete, Wasatch Plateau, Book Cliffs, and Emery. Utah Geological and Mineral Survey Monograph Series No. 3. Salt Lake City, Utah.

APPENDIX 6-6

DRILL HOLE HC-4 DRILLING LOG

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ARCO COAL COMPANY
BEAVER CREEK OPERATIONS -HUNTINGTON
LITHOLOGY LOG

PROJECT HUNTINGTON CANYON UT
LOCATION

SPUDDING DATE: 28JUN81
COMPLETION DATE: 21JUL81

COLLAR
COORDINATE TYPE: SPC
EASTING: 2096450.95000
NORTHING: 407268.40000
ELEVATION: 9374.74000

MISCELLANEOUS
TOTAL DEPTH: 1848.00
SURFACE OWNER: US FOREST SERVICE
COAL LEASE NO: U-45007
GEOLOGISTS: BLANCHARD GREGORY

DRILLING COMPANY: BEEMAN/ROBILOW
DRILLERS: CUNNINGHAM-CORE
BIT SIZE: 6.25"
CORE SIZE: 2.5" NC
DRILLING MEDIUM: AIR-FOAM&WATER SOAP
CASING DEPTH: 1393
BEDROCK DEPTH: SURFACE
WATER ENCOUNTERED: 520

WELL SURVEY COMPANY: ARCO OIL&GAS/DIGILOG
OPERATORS: J.SMITH/R.BOUFFARD
LOGS: GAMMA,SP,RES,DENS,CAL
CEMENTED INTERVALS: 1562-1340, SURFACE PLUG

*** COAL SUMMARY ***

COAL SEAM	TOP	BOTTOM	THICK -NESS	INCR BCY/TON	CUM BCY/TON
TKNH	0.00	15.00	15.00		
KPV	15.00	71.00	56.00		
KC	354.00	646.80	292.80		
KB	646.80	1274.80	628.00		
UNN	1274.80	1275.80	1.00		
UNN	1295.40	1296.50	1.10		
UNN	1371.00	1373.00	2.00		
BLDCYN	1404.20	1406.20	2.00		
BLDCYN	1407.20	1409.10	1.90		
UNN	1458.60	1460.30	1.70		
HIA	1510.00	1515.00	5.00		
UNN	1515.50	1515.60	0.10		
KSP	1515.60	1520.00	4.40		

*** CORE RETRIEVAL ***

CORE NO.	TOP	BOT	CUT	REC	CORE NO.	TOP	BOT	CUT	REC
D	0.00	1391.60	0.00	0.00					
1	1391.60	1392.80	1.20	1.20					
2	1392.80	1403.50	10.70	10.00					
3	1403.50	1413.80	10.30	10.00					
13	1404.60	1515.00	10.00	10.40					
4	1413.80	1423.80	10.00	10.00					
5	1423.80	1434.00	10.00	10.20					
6	1434.00	1444.40	10.00	10.40					
7	1444.40	1454.50	10.00	10.10					
8	1454.50	1465.10	10.00	10.60					
9	1465.10	1475.30	10.00	10.20					
10	1475.30	1484.30	10.00	9.00					
11	1484.30	1494.50	10.00	10.20					
12	1494.50	1504.60	10.00	10.10					
14	1515.00	1525.00	10.00	10.00					
D	1525.00	1564.50	0.00	0.00					

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TOP	BOTTOM	THICK	FORM-ATION	SEAM	ROCK CODE	ROCK TYPE	DESCRIPTION
0.00	15.00	15.00	TKNH	TKNH	300	SHALE	WITH SANDSTONE INTERBEDS: .
15.00	71.00	56.00	KPV	KPV	600	SANDSTONE	: TOP UNIT OF 'GREAT WHITE SS
71.00	91.50	20.50			320	SHALE	WITH SANDSTONE INTERBEDS, 25 - 50% SS: .
91.50	159.00	67.50			600	SANDSTONE	: LOWER UNIT OF GREAT WHITE SS
159.00	354.00	195.00			320	SHALE	WITH SANDSTONE INTERBEDS, 25 - 50% SS: BASE OF PRICE RIVER
354.00	520.00	166.00	KC	KC	630	SANDSTONE	LIGHT, VERY FINE-FINE GRAINED: .
520.00	541.00	21.00	KC	KC	320	SHALE	WITH SANDSTONE INTERBEDS, 25 - 50% SS: SHALE UNIT OF CASTLEGATE SS
541.00	646.80	105.80	KC	KC	630	SANDSTONE	LIGHT, VERY FINE-FINE GRAINED: LOWER UNIT OF CASTLEGATE
646.80	1274.80	628.00	KB	KB	300	SHALE	WITH SANDSTONE INTERBEDS: .
1274.80	1275.80	1.00	UNN	UNN	900	COAL	: .
1275.80	1295.40	19.60			300	SHALE	WITH SANDSTONE INTERBEDS: .
1295.40	1296.50	1.10	UNN	UNN	900	COAL	: .
1296.50	1371.00	74.50			300	SHALE	WITH SANDSTONE INTERBEDS: .
1371.00	1373.00	2.00	UNN	UNN	900	COAL	: .
1373.00	1385.00	12.00			300	SHALE	WITH SANDSTONE INTERBEDS: .
1385.00	1391.60	6.60			500	SANDSTONE	WITH SHALE INTERBEDS: .
1391.60	1392.80	1.20			513	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINED GRAINED, RIPPLE BEDDED: .
1392.80	1393.20	0.40			513	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINED GRAINED, RIPPLE BEDDED: .
1393.20	1393.50	0.30			420	SILTSTONE	DARK: FG INTBDS SOFT SED. DEFORMATION
1393.50	1394.00	0.50			163	CLAYSTONE	DARK, HARD, ABUNDANT SLICKENSIDES: COAL STREAKS
1394.00	1394.20	0.20			922	COAL	MEDIUM BRIGHT-BRIGHT, BLOCKY: BANDED RESINOUS
1394.20	1394.50	0.30			252	SHALE	BLACK, HARD, PLATY: CARB COAL STREAKS
1394.50	1399.00	4.50	} 6.5' Coal	Bld Cyn.	933	COAL	DULL-MEDIUM BRIGHT, BLOCKY WITH CALCITE CLEAT FILL: RESINOUS
1399.00	1399.20	0.20			970	FUSAIN	: RESINOUS
1399.20	1399.40	0.20			920	COAL	MEDIUM BRIGHT-BRIGHT: V.BROKEN
1399.40	1401.00	1.60	}		0	LOST	: COAL-GEOPHYSICAL LOG
1401.00	1402.30	1.30			160	CLAYSTONE	DARK, HARD: COAL SPARS
1402.30	1402.70	0.40			252	SHALE	BLACK, HARD, PLATY: CARB COAL STREAKS RESINOUS
1402.70	1403.20	0.50	Coal		920	COAL	MEDIUM BRIGHT-BRIGHT: RESINOUS
1403.20	1403.30	0.10			252	SHALE	BLACK, HARD, PLATY: CARB COAL STREAKS
1403.30	1403.50	0.20			163	CLAYSTONE	DARK, HARD, ABUNDANT SLICKENSIDES: COAL BANDS
1403.50	1404.20	0.70			163	CLAYSTONE	DARK, HARD, ABUNDANT SLICKENSIDES: COAL BANDS
1404.20	1405.30	1.10	BLDCYN	BLDCYN	923	COAL	MEDIUM BRIGHT-BRIGHT, BLOCKY WITH CALCITE CLEAT FILL: RESINOUS
1405.30	1405.90	0.60	BLDCYN	BLDCYN	923	COAL	MEDIUM BRIGHT-BRIGHT, BLOCKY WITH CALCITE CLEAT FILL: RESINOUS V.BROKEN
1405.90	1406.20	0.30	BLDCYN	BLDCYN	0	LOST	: COAL-GEOPHYSICAL LOG
1406.20	1406.80	0.60			428	SILTSTONE	DARK, ROOTED: .
1406.80	1407.20	0.40			252	SHALE	BLACK, HARD, PLATY: CARB SLKN
1407.20	1409.10	1.90	BLDCYN	BLDCYN	922	COAL	MEDIUM BRIGHT-BRIGHT, BLOCKY: RESINOUS
1409.10	1409.60	0.50			252	SHALE	BLACK, HARD, PLATY: CARB SLKN
1409.60	1413.80	4.20			428	SILTSTONE	DARK, ROOTED: CARB COAL BANDS COARSENS UPWARD
1413.80	1423.80	10.00			438	SILTSTONE	LIGHT, ROOTED: BURROWED AT BASE
1423.80	1427.60	3.80			517	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINE GRAINED, BURROWED: .
1427.60	1429.00	1.40			722	CONGLOMERATE	SANDSTONE MATRIX, SHALE PEBBLES: FG MATRIX LT GREY
1429.00	1429.80	0.80			540	SANDSTONE	W/SHALE INTBDS., 25-50% SHALE, MED. TO COARSE GR.: .
1429.80	1434.00	4.20			674	SANDSTONE	LIGHT, MEDIUM - COARSE GRAINED, CROSS-BEDDED: COAL SPARS SOFT SED.DEFORMATION
1434.00	1437.70	3.70			664	SANDSTONE	DARK, MEDIUM - COARSE GRAINED, CROSS-BEDDED: COARSE FOS CALCAREOUS SHALE AND QTZ PEBBLES
1437.70	1439.10	1.40			676	SANDSTONE	LIGHT, MEDIUM - COARSE GRAINED, WITH COAL INCLUSIONS: MEDIUM GRNED COAL SPARS AT BASE CALCAREOUS
1439.10	1440.10	1.00			252	SHALE	BLACK, HARD, PLATY: COAL BANDS
1440.10	1444.40	4.30			428	SILTSTONE	DARK, ROOTED: BURROWED AT BASE CALCAREOUS. FINES UP
1444.40	1449.70	5.30			438	SILTSTONE	LIGHT, ROOTED: FG INTBDS CALCAREOUS

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TOP	BOTTOM	THICK	FORM-ATION	SEAM	ROCK CODE	ROCK TYPE	DESCRIPTION
1449.70	1450.70	1.00			426	SILTSTONE	DARK, WITH COAL INCLUSIONS: FOSSILIZED BONE PYR CALCAREOUS
1450.70	1451.80	1.10			160	CLAYSTONE	DARK, HARD: .
1451.80	1452.50	0.70			252	SHALE	BLACK, HARD, PLATY: RESINOUS COAL BANDS
1452.50	1452.60	0.10			920	COAL	MEDIUM BRIGHT-BRIGHT: BANDED
1452.60	1452.90	0.30			252	SHALE	BLACK, HARD, PLATY: COAL BANDS
1452.90	1454.20	1.30			422	SILTSTONE	DARK, MASSIVE: .
1454.20	1454.50	0.30			513	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINED GRAINED, RIPPLE BEDDED: CALCAREOUS
1454.50	1458.60	4.10			513	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINED GRAINED, RIPPLE BEDDED: CALCAREOUS COAL STKAT BASE
1458.60	1458.80	0.20	UNN	UNN	965	BONE	BLOCKY WITH PYRITE CLEAT FILL: COAL BANDS RESINOUSO.05 BLACK CARB SH AT BASE
1458.80	1460.30	1.50	UNN	UNN	922	COAL	MEDIUM BRIGHT-BRIGHT, BLOCKY: RESINOUS BROKEN
1460.30	1463.70	3.40			252	SHALE	BLACK, HARD, PLATY: 50% COAL STREAKS
1463.70	1465.10	1.40			426	SILTSTONE	DARK, WITH COAL INCLUSIONS: CARB
1465.10	1469.10	4.00			426	SILTSTONE	DARK, WITH COAL INCLUSIONS: .
1469.10	1470.60	1.50			517	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINE GRAINED, BURROWED: COAL STREAKS
1470.60	1473.10	2.50			426	SILTSTONE	DARK, WITH COAL INCLUSIONS: FOS
1473.10	1475.30	2.20			518	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINE GRAINED, ROOTED: BURROWED CALCAREOUS V.HD
1475.30	1479.30	4.00			634	SANDSTONE	LIGHT, VERY FINE-FINE GRAINED, CROSS-BEDDED: CALCAREOUS HD
1479.30	1481.70	2.40			517	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINE GRAINED, BURROWED: CALCAREOUS HD
1481.70	1483.30	1.60			514	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINED GRAINED, CROSS-BEDDED: CALCAREOUS
1483.30	1484.30	1.00			634	SANDSTONE	LIGHT, VERY FINE-FINE GRAINED, CROSS-BEDDED: CALCAREOUS
1484.30	1490.00	5.70			513	SANDSTONE	WITH SHALE INTBDS., 5 - 25% SHALE VERY FINE TO FINED GRAINED, RIPPLE BEDDED: SH PEBBLE CLASTS FINING UPWARD CALCAREOUS
1490.00	1494.50	4.50			534	SANDSTONE	W/SHALE INTBDS., 5-25% SHALE, MED. TO COARSE GRAINED, CROSS-BEDDED: FINING UPWARD
1494.50	1504.60	10.10			534	SANDSTONE	W/SHALE INTBDS., 5-25% SHALE, MED. TO COARSE GRAINED, CROSS-BEDDED: CALCAREOUS
1504.60	1510.00	5.40			534	SANDSTONE	W/SHALE INTBDS., 5-25% SHALE, MED. TO COARSE GRAINED, CROSS-BEDDED: CALCAREOUS
1510.00	1515.00	5.00	HIA	HIA	925	COAL	MEDIUM BRIGHT-BRIGHT, BLOCKY WITH PYRITE CLEAT FILL: BANDED RESINOUS CALCITE CLEAT FILL
1515.00	1515.50	0.50			538	SANDSTONE	W/SHALE INTBDS., 5-25% SHALE, MED. TO COARSE GRAINED, ROOTED: CHURNED CARB
1515.50	1515.60	0.10	UNN	UNN	923	COAL	MEDIUM BRIGHT-BRIGHT, BLOCKY WITH CALCITE CLEAT FILL: .
1515.60	1520.00	4.40	KSP	KSP	538	SANDSTONE	W/SHALE INTBDS., 5-25% SHALE, MED. TO COARSE GRAINED, ROOTED: RIPPLED CALCAREOUS
1520.00	1525.00	5.00			534	SANDSTONE	W/SHALE INTBDS., 5-25% SHALE, MED. TO COARSE GRAINED, CROSS-BEDDED: CARB DEBRIS CALCAREOUS
1525.00	1564.50	39.50			534	SANDSTONE	W/SHALE INTBDS., 5-25% SHALE, MED. TO COARSE GRAINED, CROSS-BEDDED: CARB DEBRIS, OPHIOMORPHA, CALCAREOUS

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APPENDIX 6-7

GENERALIZED GEOLOGIC CROSS SECTION
SOUTH CRANDALL LEASE AREA

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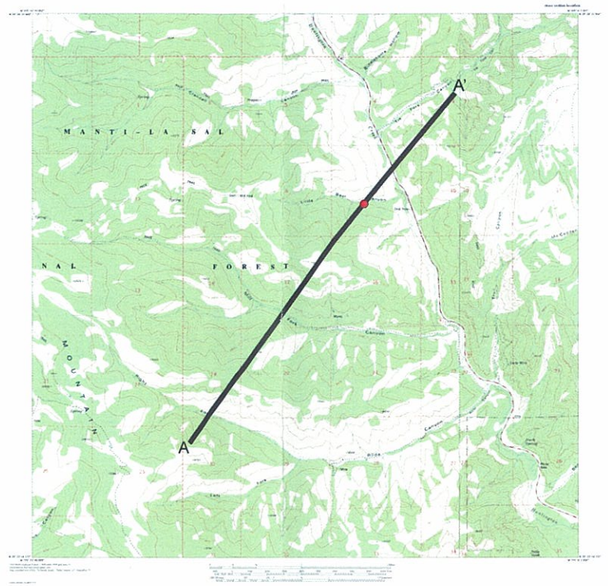
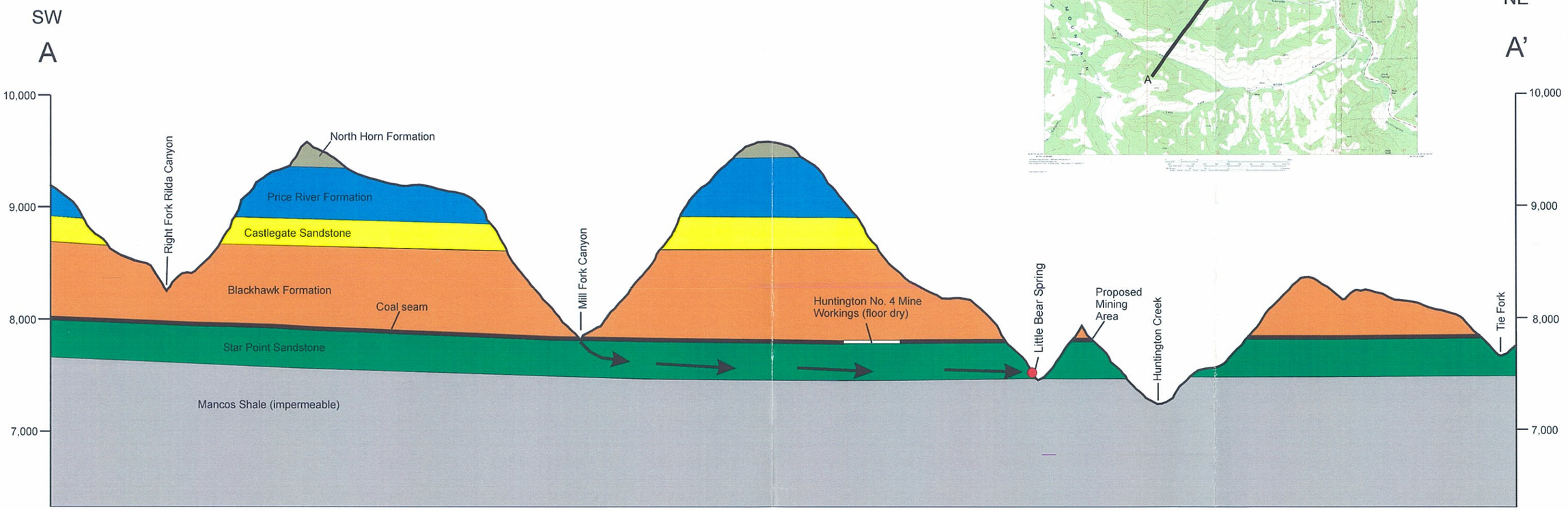
PETERSEN HYDROLOGIC
CONSULTANTS IN HYDROGEOLOGY





Generalized cross-section along the trace of the fracture system from which Little Bear Spring discharges. Note that the elevation of the bottom of the Mill Fork drainage is approximately 200 feet higher than Little Bear Spring.

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