OGMCOAL - Re: AP request

From: Steve Christensen
To: Paul Foy; foy100@gmail.com
Date: 10/26/2010 3:24 PM
Subject: Re: AP request
CC: Jim Springer; OGMCOAL
Attachments: Crandall_Hydro_Eval_7June2010.pdf

Paul,

Per your request, I've attached the Hydrologic Evaluation of the Crandall Canyon Mine Discharge report.

Regards,
Steve

Steve Christensen
Environmental Scientist III
Utah Division of Oil, Gas and Mining
(801) 538-5350

>>> "Foy, Paul" <pfoy@ap.org> 10/26/2010 2:53 PM >>>
Steve: can you send me a copy of a hydrology report on Crandall Canyon?
I spoke to Steve Alder about this agenda item, and started asking technical questions that Alder says the report can answer.
Please double email to pfoy@ap.org and foy100@gmail.com in case our company account kicks back the file as being too large.

Paul Foy
Business Writer
The Associated Press
Salt Lake City
Office 801-322-3405
Cell 801-450-1224

2. Docket No. 2010-026 Cause No. C/015/0032F - In The Matter of the Request for Agency Action of Genwal Resources, Inc., Petitioner and Permittee; Division of Oil, Gas and Mining, Respondent - Request for Board Review of Division Order DO10A, Requiring Bonding for the Perpetual Treatment of Mine Water Discharge at the Crandall Canyon Mine in Emery County, Utah.

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Hydrologic Evaluation of the Crandall Canyon Mine Discharge

June 7, 2010

Prepared By:
State of Utah
Department of Natural Resources
Division of Oil, Gas & Mining

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Attachment 2. September 20, 2007 Letter re: Temporary Cessation of Coal Mining and Reclamation Operations Genwal Mine 015/032

Attachment 3. March 30, 2010 Letter re: Minor Modification to Resource Recovery and Protection Plan (R2P2), Revised Mining Plans with Timing, North and South Crandall Mines, UtahAmerican Energy, Inc. (UEI)

Attachment 4. Geochemist's Workbench Input & Output Summary

Hydrologic Evaluation – Crandall Canyon Mine Discharge

1 Introduction

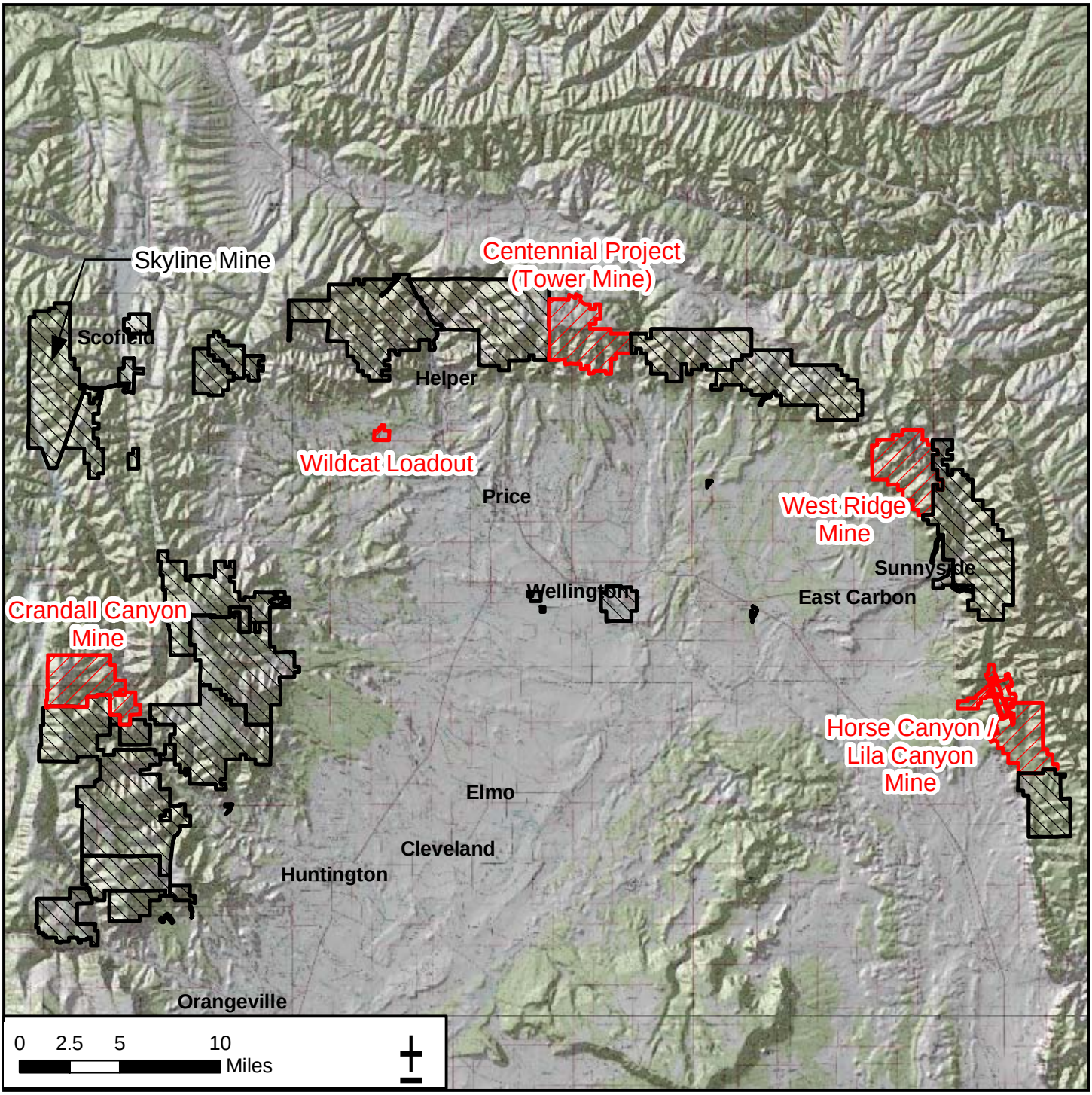
This report presents a hydrologic evaluation of the mine water discharge from the Crandall Canyon Mine. Mine water discharge is currently being treated to address elevated concentrations of iron in the discharge. The Operator has successfully implemented a water treatment approach which reduces iron concentrations to below their UPDES discharge criterion; however, to date the Operator has not posted additional bond to provide for perpetual treatment of the discharge, nor has the Operator evaluated alternative treatment options. The Operator has expressed that they believe the iron to be a temporary problem and that concentrations will decline over a relatively short timeframe (i.e., a few years) and has delayed posting additional bond. The Operator's position conflicts with the policy of the Office of Surface Mining (OSM) on acid/toxic mine drainage, which states that "[i]n the absence of definitive knowledge about the duration of postmining pollutional discharges, the financial assurance would have to provide for perpetual treatment" (OSM 1997).

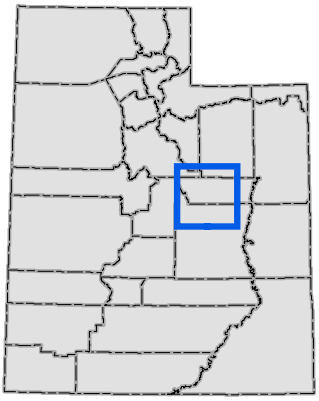
The Utah Division of Oil, Gas and Mining (the Division) has prepared this hydrologic evaluation to address the conditions at the Crandall Canyon Mine and the potential for perpetual discharge of mine water containing elevated concentrations of iron. Site water quality data used for this report were collected by the operator and submitted to the Division. Previous hydrologic investigations completed at the site and included in the Mining and Reclamation Plan are available through the Division's Public Information Center.

2 Background

The Crandall Canyon Mine is located in Huntington Canyon on the eastern edge of the Wasatch Plateau Coal Field approximately 16 miles west of Huntington, Utah in Emery County (Figure 1). The permit area encompasses over 5,000 acres within a combination of federal leases, state leases and fee land. The mine is located entirely within the Manti-LaSal National Forest with an associated 10 acres of disturbed land where surface operations were conducted in T16S R7E S7E.

The permit area is in mountainous terrain, with ground elevations ranging from approximately 7,800 feet above mean sea level (ft amsl) at the surface facilities to over 10,700 ft amsl a long East Mountain. Coal is accessed from portals on the north and south sides of Crandall Canyon, with portal elevations being approximately 7,900 ft amsl. Crandall Canyon creek is a perennial stream which discharges to Huntington Creek, a tributary of the Price River and a popular destination for anglers. The Utah Division of Water Rights currently has on file over 80 water right claims on Huntington Creek for irrigation, stock, domestic, municipal, industrial, power generation, and fish culture uses. A portion of flow from Huntington Creek is diverted to a municipal water treatment system near Huntington operated by the Castle Valley Special Services District. The high-value aquatic habitat and municipal water supply downstream of the Crandall Canyon mine outfall underscore the sensitivity of the environment to the iron and associated stream discoloration from the mine discharge and the use of chemicals for water treatment.





LEGEND

UtahAmerican Energy Inc (UEI) Permits

Other Coal Mine Permit Areas

Figure 1. Map Showing Crandall Canyon Mine Location and Other UtahAmerican Energy Inc (UEI) Coal Mine Permit Areas

Huntington Creek and its tributaries (including Crandall Creek) are designated with the following use classifications under the Standards of Quality for Waters of the State, UAC Rule R317-2:

Class 1C - Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water

Class 2B - Protected for infrequent primary contact recreation. Also protected for secondary contact recreation where there is a low likelihood of ingestion of water or a low degree of bodily contact with the water. Examples include, but are not limited to, wading, hunting, and fishing.

Class 3A - Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.

Class 4 - Protected for agricultural uses including irrigation of crops and stock watering.

2.1 Mine History

Historically, mining was conducted in the area from November of 1939 to September of 1955 utilizing the room and pillar method. Genwal Coal Company resumed mining in 1983 with production ranging from 100,000 to 230,000 tons per year. In 1989, the mine was purchased by NEICO, and in 1990 Intermountain Power Agency (IPA) purchased a 50% interest. A continuous haulage system was incorporated into the room and pillar mining method in 1991, which allowed an increase in production ranging from 1,000,000 to 1,500,000 tons per year. In March 1995, the mine was transferred to Genwal Resources, Inc. (which is owned by IPA and Andalex Resources, Inc.). A longwall was installed that same year which nearly doubled the capacity of the mine. An additional longwall was purchased in 1997 to increase production from 2,500,000 tons to 3,500,000 tons per year (http://ogm.utah.gov/coal/mines/C015032.htm). A figure showing the mine development history is provided as Attachment 1.

In August of 2006, Murray Energy Corporation purchased all of the shares of the common stock of Andalex and its subsidiaries. Operations of the Andalex mining operations are conducted by UtahAmerican Energy Inc. (UEI), the Utah subsidiary of parent Murray Energy Corporation. To this day, UtahAmerican Energy continues to operate the Crandall Canyon Project as well as the West Ridge Project, Tower Division (Centennial Mine) and the Wildcat Loadout (http://ogm.utah.gov/coal/mines/C015032.htm). The locations of UEI mining operations are shown on Figure 1.

On August 6th, 2007, a major collapse occurred in the Crandall Canyon coal mine. The collapse resulted in the loss of six miners. Ten days later, a smaller collapse in the mine resulted in the deaths of three rescue workers and injured six others (Stricklin, 2007). University of Utah seismologists reported that a local magnitude (M_L) 3.9 seismic event occurred at approximately the same time and place as the Crandall Canyon Mine Collapse (Pechmann et al., 2008). The University of Utah seismologists concluded that the seismological evidence indicated that most of the seismic wave energy was produced by the mine collapse and not by a naturally occurring

earthquake. The University of Utah seismologists utilized a "high-quality" data set in analyzing the Crandall Canyon seismic event. The data was obtained from surrounding stations of the University of Utah regional seismic network, a 5-station temporary network that was deployed in the mine area following the August 6th collapse, the National Science Foundation Earthscope Transportable Array as well as other networks (Pechmann et al, 2008). The Mine Safety and Health Administration (MSHA) found that the August 6th, 2007 collapse was the result of an inadequate mine design and cited, among other factors, a flawed engineering analysis and unauthorized mining practices by the Operator who was mining coal in areas with unsafe conditions (MSHA 2008).

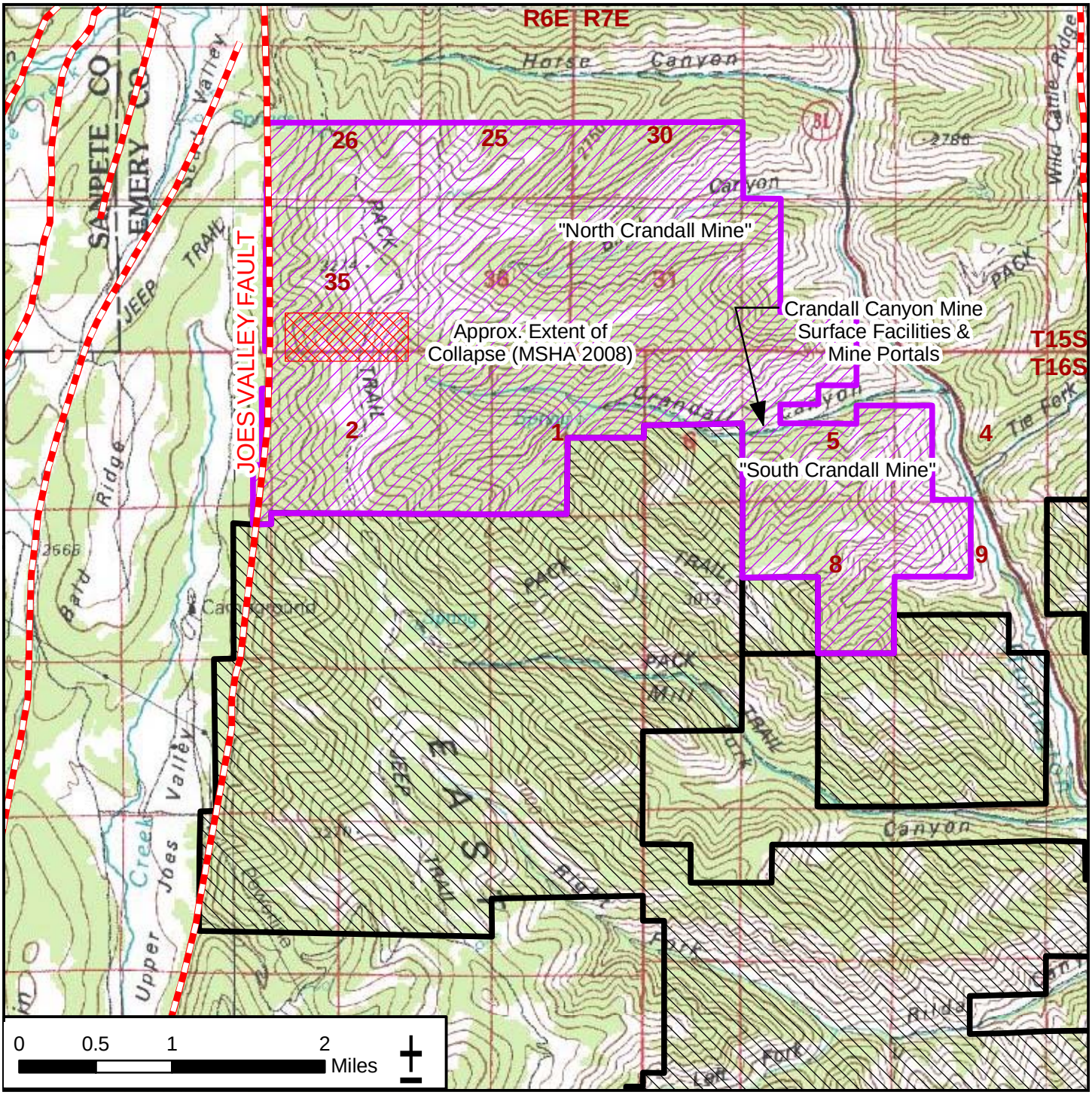
The August 6th, 2007 collapse occurred in the west mains section of the mine. This portion of the mine works was developed in the Hiawatha coal seam at depths of approximately 1,000-2,200 feet below the surface (Hucka, 1991; MSHA, 2008). Based on the information gathered by Pechmann et al. (2008), the minimum collapsed area of the underground workings is approximately 40 acres. The approximate location of the collapse is shown on Figure 2.

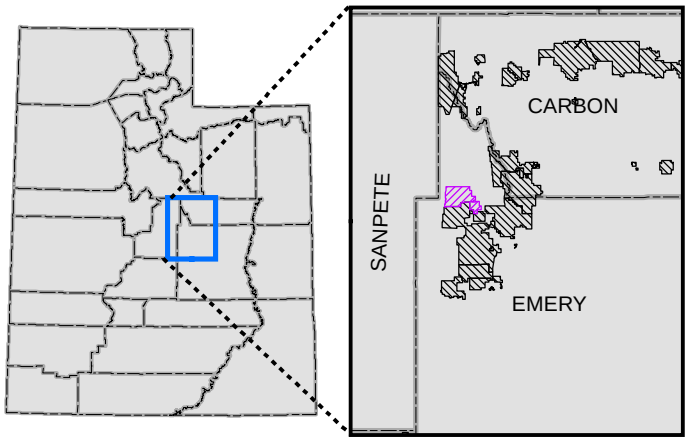
In a letter dated September 20th, 2007, the Permittee notified the Division that the Crandall Canyon Mine was entering into a period of temporary cessation of coal mining and reclamation operations (Attachment 2). All equipment that could be accessed safely was removed from both the North and South Crandall Canyon mines as part of the cessation process, and temporary concrete block walls (as opposed to permanent closure seals requiring BLM approval) were installed in all mine openings. Environmental monitoring is conducted as approved under the Mining and Reclamation Plan (MRP) and will continue during the temporary cessation period. At present, the mine remains idle.

However, on March 20th, 2010, the Bureau of Land Management (BLM) approved a modification to the Resource Recovery and Protection Plan (R2P2) for the Crandall Canyon Mine (Attachment 3). According to the modification, a restart of mining operations will begin in 2012. The 2012 mining is to occur within the south lease area (Federal Lease UTU-78953) and continue in the southern lease area through 2018. Additionally, the revised R2P2 calls for mining operations to resume within the north federal lease (Federal Lease UTU-68082) in the year 2019 and continue through 2022.

2.2 Mine Discharge Violations

In January 2008 the mine began discharging by gravity flow and has been discharging continuously since. The mine water discharge contained elevated concentrations of iron which resulted in precipitation of iron in Crandall Creek and orange-staining of the creek channel. The discharge of iron-containing mine water to Crandall Creek resulted in the Permittee being issued several violations from both the Utah Division of Water Quality (DWQ) and the Division. Non-compliant conditions have been cited by DWQ and the Division under the regulatory framework outlined by the Utah Pollutant Discharge Elimination System (UPDES) and the State of Utah R645-Coal Mining Rules, respectively, as follow:





LEGEND

- Major Fault
- Crandall Canyon Mine Permit Area
- Other Coal Mine Permit Areas

Figure 2. Map Showing Crandall Canyon Mine and Joes Valley Fault

DWQ Violation History

- DWQ issued its first Notice of Violation (NOV) to the Permittee on February 26th, 2009 (Docket No. I09-02). The NOV was issued due to effluent samples obtained from Outfall 002 (mine-water discharge) exceeding compliance levels for total iron (T-Fe).
- DWQ issued a second NOV to the Permittee on August 10th, 2009 for violating the Narrative Standard for water quality for Crandall Creek (Docket No. I09-18). At the time of the second DWQ NOV issuance, the mine-water discharge continued to produce T-Fe concentrations greater than that allowed by the Permittee's UPDES permit (#UT0024368). In addition, the continual discharge of non-compliant iron concentrations from Outfall 002 had begun to stain the substrate of the Crandall Creek channel with a rust-colored appearance.
- On February 10th, 2010, the Permittee and DWQ finalized a settlement agreement for the two NOV's. The settlement agreement required a 30-day public notice, full payment of the penalty amount within 30 days and a requirement for the Permittee to fund a Supplemental Environmental Project no later than one year from the effective date of the settlement. On March 8th, 2010, DWQ had received full payment of the penalty amount resulting in the closure of Docket No. I09-02. Final closure of Docket No. I09-18 will occur upon the completion of the Supplemental Environmental Project.

DOGM Violation History

- The Division issued two NOV's at the onset of the gravity discharge of mine-water from the temporary seals of the north portals. Citations #10016 and #10017 were issued on January 14th, 2008 for gravity mine water flow from the north portals of the Crandall Canyon Mine and for said discharge entering the disturbed drainage system. The two NOV's were terminated on January 24th, 2008 once the Permittee was successful in re-routing the mine-water discharge into the authorized conveyance structure and discharge point.
- The Division issued NOV Citation #10043 on August 10th, 2009 for failing to minimize disturbance to the hydrologic balance and diminution or degradation of the quality of surface water. As with the second DWQ NOV discussed previously, Citation #10043 was issued due to the orange staining that was occurring within the Crandall Creek channel. On January 1st, 2010, NOV Citation #10043 was terminated upon the Division's conditional approval of the operational water treatment system.

The Division has been working with the Permittee since April of 2008 in developing a long-term water treatment plan to be utilized upon final reclamation of the site. To that end, the Division has issued the Permittee a Division Order to address mine water treatment. As this process has developed, additional information, concerns and site considerations have been identified that warranted revisions to the Division Orders.

3 Hydrologic Evaluation

The hydrologic evaluation included in the following sections presents information relative to the mine water discharge rate and chemistry. This evaluation is based primarily on data collected by the operator during operations and following the 2007 mine collapse. Relevant information on regional geology and hydrology is also presented.

3.1 Crandall Canyon Mine Water Discharge

Discharges from the Mine were intermittent prior to 1996. As mining progressed to the west towards the Joes Valley fault, more water was encountered by the workings, and beginning in 1996 the mine began continuously discharging water. Upon reviewing Division records and information submitted by the Permittee, it's unclear as to the precise timing/date when significant inflows of water were encountered. However, based upon information supplied by the Permittee in the 1996 and 1997 annual reports, first and secondary mining activity was occurring within T15S R6E, Sections 26 and 35 located adjacent to the Joe's Valley Fault system. Water encountered during mining operations was pumped to the portals and discharged to Crandall Creek under UPDES Permit No. UTU0024368. Discharges to Crandall Creek were within the limitations established by the permit with rare exceptions. For example, prior to 2008 the only sample containing iron at greater than 1 mg/L was on July 26, 2004, when iron was 1.08 mg/L.

Following the mine collapse in August 2007, the pumps were removed from the mine and discharge ceased temporarily. From September 2007 through December 2007 water pooled within the mine, flooding the underground workings. In January 2008 the mine began discharging by gravity flow and has been discharging continuously since. The temporary seals placed in the portals following the collapse required modification for the mine water discharge. Iron concentrations in the mine water discharge occasionally exceeded 1 mg/L from January to November 2008; and have been greater than 1 mg/L continuously since December 2008. In response to NOV Citation #10043 issued August 10, 2009, a water treatment system was constructed at the site in December 2009 to treat the mine water discharge.

3.1.1 Discharge Characteristics

A summary of the available flow, temperature, and dissolved oxygen data for the mine water discharge is provided in Table 1 and plotted in Figure 3. Data are separated into the period prior to mine collapse (1996 – 2007) and following the collapse (2008 – present). The data in Table 1 indicate that discharge conditions were more variable prior to the mine collapse and flooding, as evident by a comparison of the ranges of values reported. During the operational period of the mine, however, the mine water discharge was controlled by pumping, therefore the variability in discharge rates is likely influenced by the operation of pumps and may not reflect variability in the amount of groundwater discharging into the mine. The discharge has averaged 490 gpm with and average temperature of 11.7 degrees C and average dissolved oxygen concentration of 8.7 mg/L.

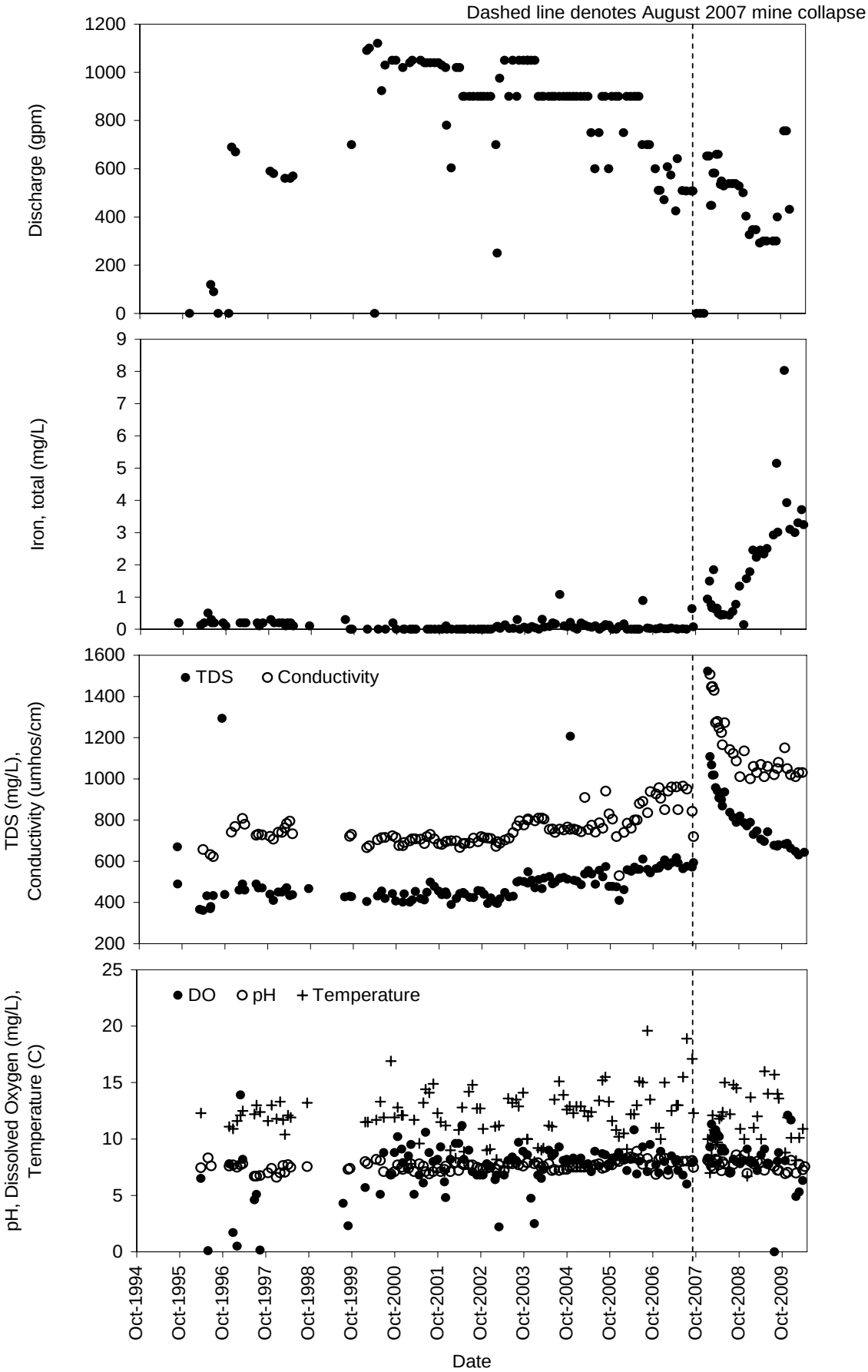


Figure 3. Plots Showing Selected Crandall Canyon Mine Water Discharge Monitoring Parameters, 1995 – Present

Table 1. Mine Water Discharge Rate Summary, 1996 – 2009

	Discharge (gpm)		Temperature (degrees C)		Dissolved Oxygen (mg/L)	
Period	No. Measure-ments	Average (Range)	No. Measure-ments	Average (Range)	No. Measure-ments	Average (Range)
Pumping 1996 – 2007	102	804 (0 – 1120)	108	12.1 (7.1 – 19.6)	102	7.4 (0.1 – 13.9)
Gravity Discharge 2008 – 2009	29	490 (292 – 757)	29	11.7 (6.7 – 16.0)	29	8.7 (0 – 12.1)

Source: Monitoring data submitted by the Operator to the Division

The flow data shown in Figure 3 do not illustrate a trend or seasonal variability in flow rates from the mine. The operator has reported that since the 2007 collapse, mine flow rates fluctuate as a function of barometric pressure and/or air temperature changes. The absence of a continuous monitoring record of mine discharge rate to date prevent the validation of these observations. An electronic flow meter (Grayline AVFM-100 area-velocity flow meter) capable of supporting a data logger and telemetry was installed by the operator during 1st quarter 2010. It is hoped that a continuous or daily flow record will be obtained from the new flow meter, which will improve the understanding of flow characteristics and which may enable correlation between flow and weather conditions.

3.1.2 Potential Water Sources

The source of the mine water has not been confirmed. Potential sources of the mine water include Joes Valley fault, local recharge of precipitation, regional / perched aquifers or other sources. Prior to the mine collapse, the largest inflows to the mine were reportedly from sandstone channels intercepted near the Joes Valley fault. The interaction between Crandall Canyon Mine and the Joes Valley fault groundwater system was investigated during the 1990s, as described in Section 3.2.4.

Detailed discharge studies, geochemical characterization (including isotopic and dissolved gas composition), or other investigations of the potential source of the mine discharge have not been performed, although the most likely source of mine water appears to be the Joes Valley fault system. Based on the available data, the source of the mine water appears to be capable of supporting a continuous discharge, and the source does not appear to be diminishing over time.

3.2 Crandall Canyon Mine Water Chemistry

This section provides a description of the chemistry of the mine water discharge at Crandall Canyon Mine as relating to the occurrence and trend in iron concentrations. Data relevant to the source of the iron contamination are presented, and water quality monitoring data are presented and discussed. A literature review relevant to mine discharges in the Wasatch Plateau region and long-term trends in iron concentrations from other coal mining regions is

provided, along with a summary of previous geochemical investigations completed for the Crandall Canyon Mine.

3.2.1 Potential Iron Sources

The most likely source of the iron in the mine water is pyrite (FeS_2) oxidation. Pyrite oxidation is widely accepted as the principal cause of ferruginous (iron-containing) drainage from coal mines. Pyrite oxidation generates sulfate, acidity, and dissolved iron, as described by the following reaction:

$$FeS_2 + 7/2O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$$

The reaction shows the product of pyrite oxidation is a solution containing ferrous iron and sulfate, which is consistent with the water quality discharging from the Crandall Canyon Mine. The acidity generated from pyrite oxidation is consumed by dissolution of carbonate minerals, which are prevalent in the Wasatch Plateau.

The average sulfur and pyrite composition of coal from the Wasatch Plateau region and from the Hiawatha NW Quadrangle sub-region (which includes the Crandall Canyon Mine) are shown in Table 2. The average sulfur content reported for the Hiawatha NW Quadrangle is consistent with the coal sulfur content of coal from the Crandall Canyon Mine as reported to the Utah Geologic Survey by the Operator for years 2004 to 2007 (Table 3). Coal in the Crandall Canyon Mine area may therefore be characterized as containing about 0.5 percent total sulfur and about 0.08 percent pyritic sulfur.

Pyrite is also present in the strata above and below the Hiawatha and Blind Canyon coal seams mined at the Crandall Canyon Mine. The Hiawatha and Blind Canyon coal seams are both within the Blackhawk formation, with the Blind Canyon seam lying 55 to 100 feet above the Hiawatha. Only the Hiawatha seam was mined in the North Crandall leases due to the low thickness (generally less than three foot) of the Blind Canyon seam (MSHA 2008). Table 4 presents a summary of the chemical composition of the strata above and below the Hiawatha and Blind Canyon coal seams, as reported by the Operator in the MRP. The pyrite composition is greatest (0.09 percent) in the stratum overlying the Blind Canyon coal seam. The August 2007 mine collapse occurred as miners were removing coal from pillars in the Hiawatha coal seam.

The available data demonstrate that pyrite is present within the coal and the strata above and below the coal seams at the Crandall Canyon Mine. The total amount of pyrite present and the amount accessible to oxygenated groundwater have not been estimated; indeed this calculation is not feasible given the unknown extent of the mine collapse. Coal reserves at the Crandall Canyon Mine are believed to be sufficient to re-initiate mining in the future. The Operator has not collected any information or demonstrated that the pyrite available for oxidation within the collapsed Crandall Canyon Mine will be consumed in the foreseeable future. Absent such a demonstration, it is assumed that pyrite oxidation and the associated liberation of iron will continue perpetually.

Table 2. Regional Sulfur Content in Coal from the Wasatch Plateau and the Hiawatha NW Quadrangle

Area	No. Samples	Average Percent Content (Range)				Source
		Total Sulfur	Sulfate	Pyritic	Organic	
Wasatch Plateau	722	0.60 (0.23 – 1.60)				1
	37	0.52 (0.36 – 0.89)	0.01 (0.00 – 0.03)	0.10 (0.01 – 0.20)	0.41 (0.18 – 0.69)	2
Hiawatha NW Quadrangle	40	0.55 (0.23 – 0.80)				1
	6	0.52 (0.38 – 0.77)	0.01 (0.01 – 0.02)	0.08 (0.05 – 0.11)	0.42 (0.32 – 0.66)	2

Sources:
1. Doelling 1972
2. U.S. Bureau of Mines (Walker and Hartner, 1966)

Table 3. Sulfur Content in Genwal Coal, 2004 – 2007

Year	Mine	Seam(s)	Heat Content	Sulfur	Ash	Moisture
2004	Crandall Canyon and South CC	Hiawatha	12,300	0.6%	9.0%	7.5%
2005	Crandall Canyon and South CC	Hiawatha/ Blind Canyon	11,305	0.6%	14.2%	8.6%
2006	Crandall Canyon and South CC.	Hiawatha/ Blind Canyon	11,655	0.6%	11.7%	8.8%
2007	Crandall Canyon	Hiawatha	12,014	0.4%	9.0%	5.0%

Source: UGS http://geology.utah.gov/emp/energydata/coaldata.htm

Table 4. Pyrite Content in Strata Above and Below Coal Seams

Coal Seam	Stratum	Pyrite	Paste pH	Alkalinity
Blind Canyon	Above	0.09%	7.25	87.4 mg/L
	Below	0.07%	3.90	0 mg/L
Hiawatha	Above	0.03%	7.6	63.3 mg/L
	Below	0.06%	3.95	4.0 mg/L

Source: Crandall Canyon Mine MRP Section 6.24.32

3.2.2 Literature Review

Literature on the occurrence and mechanisms of acid and toxic mine drainage is widely available; however, the majority of the available literature addresses acid mine drainage. Coal fields in the western U.S. generally do not have net acidic discharges due to buffering by carbonate minerals. The mine water discharge at Crandall Canyon Mine is categorized as an

alkaline mine drainage due to its pH of greater than 6.0 and its alkalinity content (greater than zero).

The long-term effects of underground coal mining on groundwater in Utah have not been well documented; however, some information is available. In a report describing the hydrology and potential effects of coal mining at the Castle Valley coal-lease tract in the Wasatch Plateau, which is located approximately 5 miles northeast of Crandall Canyon, Seiler and Baskin (1988) reported that water quality changes soon after a mine is abandoned, and that groundwater from an area where roof collapse has occurred is more acidic, more mineralized, and contains a greater concentration of sulfate compared to water encountered in the active portion of a mine. The authors also identified that water quality from a recently abandoned portion of the King mine resembles that of water discharging from a nearby mine which had been abandoned for more than 30 years, and concluded that "[t]hus, water quality may not return to its original state for a long time after mining has caused the quality to change".

Mayo et al. (2000) described chemical evolution of coal mine drainage at the SUFCO Mine, located in the Wasatch Plateau coal field approximately 40 miles south of Crandall Canyon. Geochemical modeling results indicate that flooding mine openings with oxygen is a critical element for the chemical evolution of mine drainage, and that most sulfate results from pyrite oxidation. Mine water chemistry is greatly influenced by the water-rock ratio, where a decrease in the water-rock ratio increases the groundwater-mineral contact time and promotes kinetically-limited pyrite oxidation. The declining discharge rate from older mined areas has resulted in increased TDS in the mine water over a nine-year monitoring period (Mayo et al. 2000).

3.2.3 Available Crandall Canyon Mine Discharge Chemistry Data

The chemistry of the mine water discharge from the Crandall Canyon Mine has been monitored over the life of the mine by the Operator per the monitoring program described in the MRP and as a condition of their UPDES permit. Required monitoring parameters under the permit include discharge rate, pH, total dissolved solids (TDS), total suspended solids (TSS), total iron, dissolved oxygen, sanitary waste, whole effluent toxicity and oil & grease. UPDES monitoring includes collection of samples for laboratory analyses and measurement of field parameters (pH, temperature, conductivity and dissolved oxygen) are also monitored. Plots showing total iron, TDS, conductivity, pH, dissolved oxygen and temperature from 1995 to present are shown in Figure 3. Water monitoring data for the mine discharge from January 2008 to April 2010 are provided in Table 5. Recent trends in total iron and TDS concentrations are shown in Figure 4.

Table 5. Mine Water Discharge Chemistry, January 2008 - April 2010

Parameter		Units	1/10/2008	1/21/2008	1/28/2008	2/4/2008	2/11/2008	2/18/2008	3/3/2008	3/17/2008	4/1/2008	4/15/2008	5/5/2008	5/14/2008	6/1/2008
Discharge		gpm	653	--	653	--	448	448	582	582	660	660	535	549	528
pH			8.12	--	7.9	--	7.6	7.92	7.4	8.22	8.09	7.71	7.19	7.98	7.77
Dissolved Oxygen		mg/L	8.3	--	9.3	--	11.3	10.1	10.6	10.8	10.4	10.2	8.9	9.2	8.9
Conductivity		uS	0	--	1507	--	1446	1448	1429	1272	1279	1248	1225	1165	1272
Temperature		C	10	--	7	--	8.5	12.1	10.8	9.5	9.7	11.8	12	12.4	15
Calcium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Sodium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Potassium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron	Total	mg/L	0.937	2.204	1.494	0.815	0.765	0.668	1.846	0.626	0.653	0.491	0.433	0.457	0.448
	Dissolved	mg/L	--	0.161	0.034	0.111	0.036	0.021	0.01	0.02	0.027	0.019	<0.010	0.01	--
	Ferrous	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	Total	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
	Dissolved	mg/L	--		0.06	0.09	0.05	0.17	0.17	0.14	0.14	0.14	0.15	0.16	--
Manganese	Total	mg/L	--	0.138	0.121	0.107	0.109	0.107	0.101	0.096	--	--	--	--	--
	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Boron	Dissolved	mg/L	--	0.19	0.19	0.18	0.17	0.17	0.17	0.17	--	--	--	--	--
Nickel	Dissolved	mg/L	--	0.201	0.155	0.128	0.122	0.118	0.101	0.092	0.086	0.081	0.068	0.067	--
Selenium	Dissolved	mg/L	--	<0.01	<0.01	--	--	--	--	--	--	--	--	--	--
Zinc	Dissolved	mg/L	--	0.34	0.282	0.242	0.219	0.227	0.188	0.172	0.153	0.127	0.089	0.074	--
Sulfate	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloride	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Silica	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Alkalinity	Bicarbonate	mg/L CaCO3	--	--	--	--	--	--	--	--	--	--	--	--	--
	Carbonate	mg/L CaCO3	--	--	--	--	--	--	--	--	--	--	--	--	--
	Total	mg/L CaCO3	--	--	--	--	--	--	--	--	--	--	--	--	--
Hot Acidity		mg/L CaCO3	--	--	--	--	--	--	--	--	--	--	--	--	--
Total Dissolved Solids		mg/L	1523	1218	1108	1025	1068	1018	1019	957	941	907	899	868	936
Total Suspended Solids		mg/L	6	--	12	<4	<4	<4	35	4	4	4	<4	<4	4

Table 5 (continued). Mine Water Discharge Chemistry, January 2008 - April 2010

Parameter		Units	7/16/2008	8/8/2008	9/9/2008	10/10/2008	11/15/2008	12/9/2008	1/7/2009	2/3/2009	3/4/2009	4/6/2009	5/6/2009	6/3/2009	7/29/2009
Discharge		gpm	538	--	538	528	500	403	326	347	347	292	300	300	300
pH			7.04	--	8.6	8.2	8.6	6.95	7.99	7.78	8.01	7.9	7.22	7.78	7.55
Dissolved Oxygen		mg/L	7.1	--	8	7.8	8.09	9.1	8.1	7.9	7.2	8.6	9.1	7.79	<0.0
Conductivity		uS	1142	--	1087	1010	1135	0	1000	1060	1030	1070	1010	1060	1020
Temperature		C	12.2	--	14.5	10.9	10	6.7	13.7	11	12	10	16	14.02	15.7
Calcium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Sodium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Potassium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron	Total	mg/L	0.434	0.546	0.775	1.335	0.141	1.569	1.783	2.454	2.23	2.455	2.331	2.501	2.924
	Dissolved	mg/L	--	--	--	--	--	--	--	0.256	0.51	0.486	<0.010	0.748	0.849
	Ferrous	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Aluminum	Total	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
	Dissolved	mg/L	--	--	--	--	--	--	--	0.14	--	0.12	--	--	--
Manganese	Total	mg/L	--	--	--	--	--	--	--	0.173	--	0.162	--	--	--
	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Boron	Dissolved	mg/L	--	--	--	--	--	--	--	0.16	--	0.16	--	--	--
Nickel	Dissolved	mg/L	--	--	--	--	--	--	--	0.033	--	0.032	--	--	--
Selenium	Dissolved	mg/L	--	--	--	--	--	--	--	<0.01	--	<0.01	--	--	--
Zinc	Dissolved	mg/L	--	--	--	--	--	--	--	0.011	--	0.015	--	--	--
Sulfate	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloride	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Silica	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	--	--	--	--
Alkalinity	Bicarbonate	mg/L CaCO3	--	--	--	--	--	--	--	--	--	--	--	--	--
	Carbonate	mg/L CaCO3	--	--	--	--	--	--	--	--	--	--	--	--	--
	Total	mg/L CaCO3	--	--	--	--	--	--	--	--	--	--	--	--	--
Hot Acidity		mg/L CaCO3	--	--	--	--	--	--	--	--	--	--	--	--	--
Total Dissolved Solids		mg/L	837	813	789	819	786	772	789	730	747	707	696	743	677
Total Suspended Solids		mg/L	<4	<4	<4	5	<4	<4	4	<4	6	5	<4	9	7

Table 5 (continued). Mine Water Discharge Chemistry, January 2008 - April 2010

Parameter		Units	8/24/2009	9/3/2009	10/28/2009	11/18/2009	12/16/2009	1/28/2010	2/23/2010	3/26/2010	3/30/2010	4/12/2010	4/21/2010
Discharge		gpm	300	400	757	757	431	--	393	481	587	--	568
pH			7.23	7.23	6.92	7.04	8.12	6.98	7.76	--	--	7.55	6.91
Dissolved Oxygen		mg/L	8.03	8.8	8.07	12.1	11.68	4.89	5.3	--	--	--	6.53
Conductivity		uS	1050	1080	1150	1050	1020	1010	1030	--	--	--	1000
Temperature		C	14	13.6	8.8	11.9	10.1	8.1	10.1	--	--	--	10.2
Calcium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	99.88	--
Magnesium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	55.52	--
Sodium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	34.34	--
Potassium	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	8.43	--
Iron	Total	mg/L	5.151	3.012	8.03	3.927	3.1	3.0	3.3	3.709	--	3.245	4.268
	Dissolved	mg/L	0.654	0.885	--	--	--	0.9	1.3	1.531	--	1.034	1.11
	Ferrous	mg/L	--	--	--	--	--	< 0.1 (Lab)	0.77 (Lab)	--	1.2	1.23	1.23
Aluminum	Total	mg/L	--	--	--	--	--	< 0.1	< 0.1	0.13	--	0.1	<0.02
	Dissolved	mg/L	--	0.1	--	--	--	< 0.1	< 0.1	0.11	--	<0.02	<0.02
Manganese	Total	mg/L	--	0.143	--	--	--	0.14	0.13	0.13	--	0.128	0.114
	Dissolved	mg/L	--	--	--	--	--	0.14	0.13	0.13	--	0.122	0.124
Boron	Dissolved	mg/L	--	0.15	--	--	--	--	--	--	--	--	--
Nickel	Dissolved	mg/L	--	0.024	--	--	--	--	--	--	--	--	--
Selenium	Dissolved	mg/L	--	<0.01	--	--	--	--	--	--	--	--	--
Zinc	Dissolved	mg/L	--	0.014	--	--	--	--	--	--	--	--	--
Sulfate	Dissolved	mg/L	--	--	--	--	--	159	170	174	--	183	182.2
Chloride	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	10.76	10.76
Silica	Dissolved	mg/L	--	--	--	--	--	--	--	--	--	7.6	--
Alkalinity	Bicarbonate	mg/L CaCO3	--	--	--	--	--	381	379	374	--	380	380
	Carbonate	mg/L CaCO3	--	--	--	--	--	<10	<10	<10	--	<10	<10
	Total	mg/L CaCO3	--	--	--	--	--	381	379	374	--	380	380
Hot Acidity		mg/L CaCO3	--	--	--	--	--	--	--	--	--	-350	--
Total Dissolved Solids		mg/L	673	680	683	687	664	648	631	--	--	643	--
Total Suspended Solids		mg/L	6	6	9	7	5	7	6	--	--	7	--

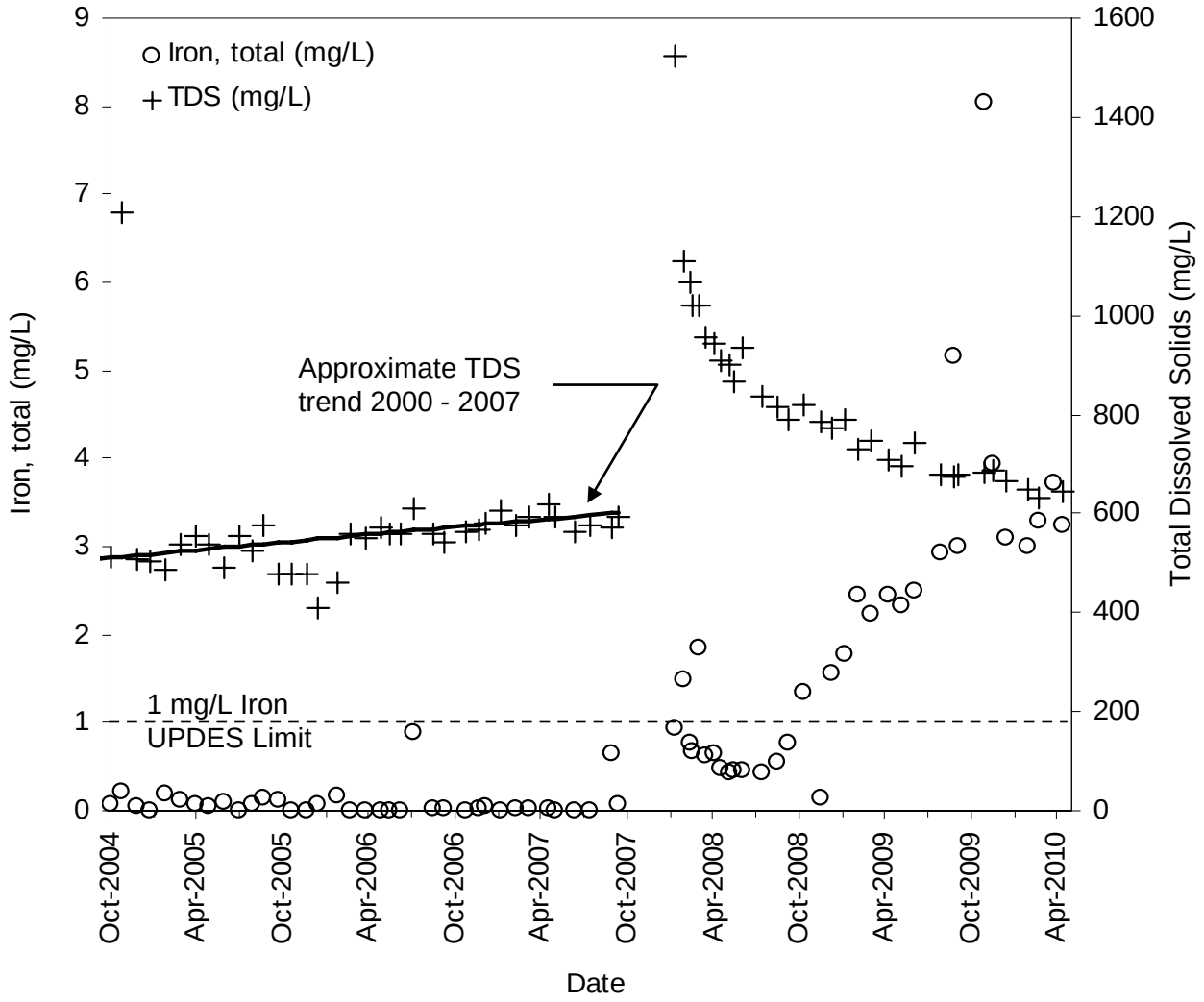


Figure 4. Recent Trends in Iron and Total Dissolved Solids Concentrations in Discharge from the Crandall Canyon Mine

A review of the plots of mine discharge monitoring data before and after the August 2007 mine collapse reveals three patterns:

1. Dissolved oxygen, pH and temperature show no discernable change prior to and following the collapse (Figure 3). Average values of dissolved oxygen, pH, and temperature in the mine discharge are 7.7 mg/L, 7.6 standard units, and 11.9 degrees C, respectively. The mine water has remained circum-neutral over the period of discharge, and no decrease in pH was recorded following the mine collapse.
2. Conductivity and TDS show a large spike after the collapse followed by a decline. Prior to the collapse, an increasing trend was evident for conductivity and TDS, as shown in Figures 3 and 4. The initial spikes in TDS and conductivity are presumably due to the flushing of readily soluble salts as the mine workings and rubble zones became flooded after the collapse and cessation of pumping at the mine. TDS and conductivity values declined as the solutes were flushed from the mine; however, values remain elevated above conditions prior to the mine collapse.
3. After the 2007 collapse total iron shows an initial, minor spike which declines and then increases (Figure 4). Prior to the mine collapse, total iron concentrations were generally non-detected or well below the UPDES discharge limitation of 1 mg/L. Samples of the mine water discharge collected from January through early March 2008 contained iron at concentrations near or greater than 1 mg/L (Table 5). Iron concentrations declined from mid-March 2008 through mid-July 2008, and then began increasing. Recent monitoring results show the mine water iron concentration to be approximately 3 to 4 mg/L (Table 5).

At the request of the Division, the Operator collected a sample of the mine discharge on April 12, 2010 for a whole-water chemical analysis. Results of this analysis are shown in Table 5. The analytical results were evaluated using AqQA and Geochemist's Workbench software. The calculated cation-anion balance for the analysis (0.94 percent) indicates that the analysis is of good quality. The mine water is of a calcium-bicarbonate type, and is supersaturated with calcium carbonate. Mineral saturation states calculated using Geochemist's Workbench are summarized in Table 6. Input and output information for the Geochemist's Workbench analysis is provided in Attachment 4.

Table 6. Crandall Canyon Mine Discharge Saturation States for Selected Mineral Species

Mineral	Saturation State (log Q/K)
Dolomite $CaMg(CO_3)_2$	1.95
Calcite $CaCO_3$	0.570
Aragonite $CaCO_3$	0.403
Siderite $FeCO_3$	0.273
Magnesite $MgCO_3$	-0.345
Silica (amorphous) SiO_2	-0.368
Gypsum $CaSO_4 \cdot 2H_2O$	-1.50
Anhydrite $CaSO_4$	-1.82
Pyrite FeS_2	<< -3

Note: A saturation state (log Q/K) of zero indicates saturation; a value greater than zero indicate super-saturation and a value less than zero indicates under-saturation.

The saturation states shown in Table 6 indicate that the mine water chemistry is principally controlled by carbonate minerals (e.g., dolomite, calcite, and aragonite). The near-saturation value for amorphous silica may be a result of silicate dissolution in areas where pyrite oxidation results in localized, acidic conditions. The partial pressure of carbon dioxide calculated from the mine water chemistry is approximately 10^{-2}, which is significantly greater than the partial pressure under atmospheric conditions ($10^{-3.5}$). The super-saturation of carbon dioxide is attributed to the dissolution of carbonate minerals.

3.2.4 Previous Geochemical Evaluations at the Crandall Canyon Mine

Multiple investigations have evaluated groundwater system associated with the Crandall Canyon Mine. These previous investigations are summarized below, followed by a comparison of the results from these previous investigations to the current mine water characteristics.

<u>EarthFax Engineering 1992</u>

EarthFax Engineering (1992) performed tritium and geochemical analyses on water samples to evaluate water sources in Joes Valley (Indian Creek) and the west-facing slope of East Mountain. Tritium analyses were performed for four springs along Indian Creek in Joes Valley: SP1-1a and SP1-47 in T15S R8E S34 and SP1-42a and SP1-37 in T16S R8E S3. Results of the tritium analyses ranged from 19.2 to 38.2 tritium units (TU), indicating mixture of old (pre-1952) and new water. Geochemical analyses were also performed for the four springs along Indian Creek plus three spring samples from the west-facing slope of East Mountain: springs SP1-31 and SP1-30a in T16S R8E S2 and an unnamed drainage in T15S R6E S35 N1/2 SW1/4. All groundwater samples were found to be a calcium-magnesium-bicarbonate type.

Mayo and Associates 1997

Mayo and Associates (1997a, 1997b) investigated groundwater conditions within Crandall Canyon Mine and the Joes Valley fault system. Isotope and geochemical analyses were performed for samples of groundwater collected in the Crandall Canyon #1 (Genwal) Mine February and June 1997. The 1997 study found that groundwater within the Joes Valley Fault system within the mine is generally thousands of years old with no component of modern water, and that the groundwater within the fault system is dissimilar to springs and creeks in the vicinity of the mine (Mayo and Associates 1997a, 1997b). A notable exception is a sample collected of water issuing from a fractured sandstone channel in the 5th West Fault approximately 100 m from Joes Valley fault, which had a tritium content of 0.95 TU, indicating hydraulic communication with surface water (Mayo et al. 2003). Monitoring wells (two) completed in 1997 to a depth of 105 feet each in the Spring Canyon member of the Star Point Sandstone in the mine found water to be ancient and calcium-magnesium-bicarbonate type. A monitoring well completed to 352 feet in the Panther Sandstone member of the Star Point Sandstone was found to be ancient and calcium-hydroxide type, with the chemical composition related to an adjacent igneous dike. Groundwater sampled from a well drilled upward approximately 94 feet into the Blind Canyon seam was found to be ancient and of calcium-magnesium-bicarbonate type (Mayo and Associates 1997b).

Petersen Hydrologic 2010

Petersen Hydrologic (2010) prepared a report attempting to demonstrate that iron concentrations in the mine water discharge are temporary and would decline within a few years. The report provides a series of plots showing total iron and total dissolved solids (TDS) concentrations queried from the Division's Water Quality Database. No sampling, analyses, calculations or geochemical modeling was performed to evaluate the nature and future trends of iron in the discharge.

The assessment of potential future trends of iron concentrations from the Crandall Canyon Mine was based on a comparison to a temporary increase in iron and total dissolved solids (TDS) following flooding of a portion of the Skyline Mine, located within the Wasatch Plateau coal field approximately 15 miles north of Crandall Canyon (Figure 1). Monitoring data from Skyline Mine sample location CS-14 illustrate a decline in iron concentrations beginning approximately four years after flooding. The 2010 Petersen Hydrologic report does not identify the area or extent of flooded workings at Skyline Mine used in the assessment; however, location CS-14 used for the assessment reportedly represents the mine discharge from "Mine No. 1" of the Skyline complex (Skyline MRP Section 2.3.7). The workings of Mine No. 1 are within the Upper O'Connor Seam, which is also referred to as the Wattis Seam (Tabet et al. 1999).

The four-year timeframe of elevated iron in mine water at Skyline is encouraging for the situation at Crandall; however, there are some significant differences between the mine water discharges at the two mines:

- The coal seam mined at Skyline Mine No. 1 is a different coal seam than mined at Crandall Canyon Mine;
- The mined-out areas of Skyline Mine which flooded dipped away from the mine portals, whereas at Crandall Canyon the mine portals are at a lower elevation than most of the mine workings.

- The Skyline discharge and its elevated iron concentrations were not brought about due to a catastrophic mine collapse, but were the result of a planned flooding of a mined-out area.
- Plots of water quality data from the Crandall Canyon Mine discharge and Skyline Mine CS-14 show noticeably different trends and magnitudes for TDS and total iron concentrations (Figure 5). The 2010 Petersen Hydrologic report does not offer an explanation of the variation in TDS and total iron concentrations and trends exhibited at the Skyline Mine compared to Crandall Canyon Mine.

Petersen Hydrologic's assertion that the there is a finite amount of reactants within the mine and that the total iron concentrations will begin to decline within a few years as the pyrite minerals are consumed through oxidation processes may very well be correct. However, asserting that the process will "likely occur within a few years" is problematic due to several unknown variables:

- The extent of pyritic material now exposed to oxygenated water is unknown;
- The actual source of the mine-water has never been determined. As a result, the amount of water that could potentially enter the mine and it's inherent oxygen content is also unknown;
- Whether the current flow path of the mine-water will remain in its current configuration is unknown. Due to the extensive faulting and mining in the area, it's likely that additional settling/movement of the mine will continue into the future. As a result, the flow path of the mine-water could be easily altered and previously non-exposed areas of pyritic material could become inundated with mine-water thus producing another spike in total iron;
- The observation that mine conditions did not support elevated iron concentrations during operation of the mine, therefore the mine is not expected to support iron discharge in the future neglects the considerations that mine water was carefully managed during operations and that the hydrologic system in the underground mine is now different due to the collapse and subsequent mine flooding. Since water management during active operations limits the interaction between the water and minerals, the water quality produced during active operations has limited use in predicting the water quality once water management ceases .

Based on the discussion presented in the Petersen Hydrologic report, if an evaluation of the amount of pyrite available for reacting and the availability of dissolved oxygen in the mine-water cannot be accomplished, it follows that the timeframe, rate and magnitude of reduction in iron concentrations cannot be predicted.

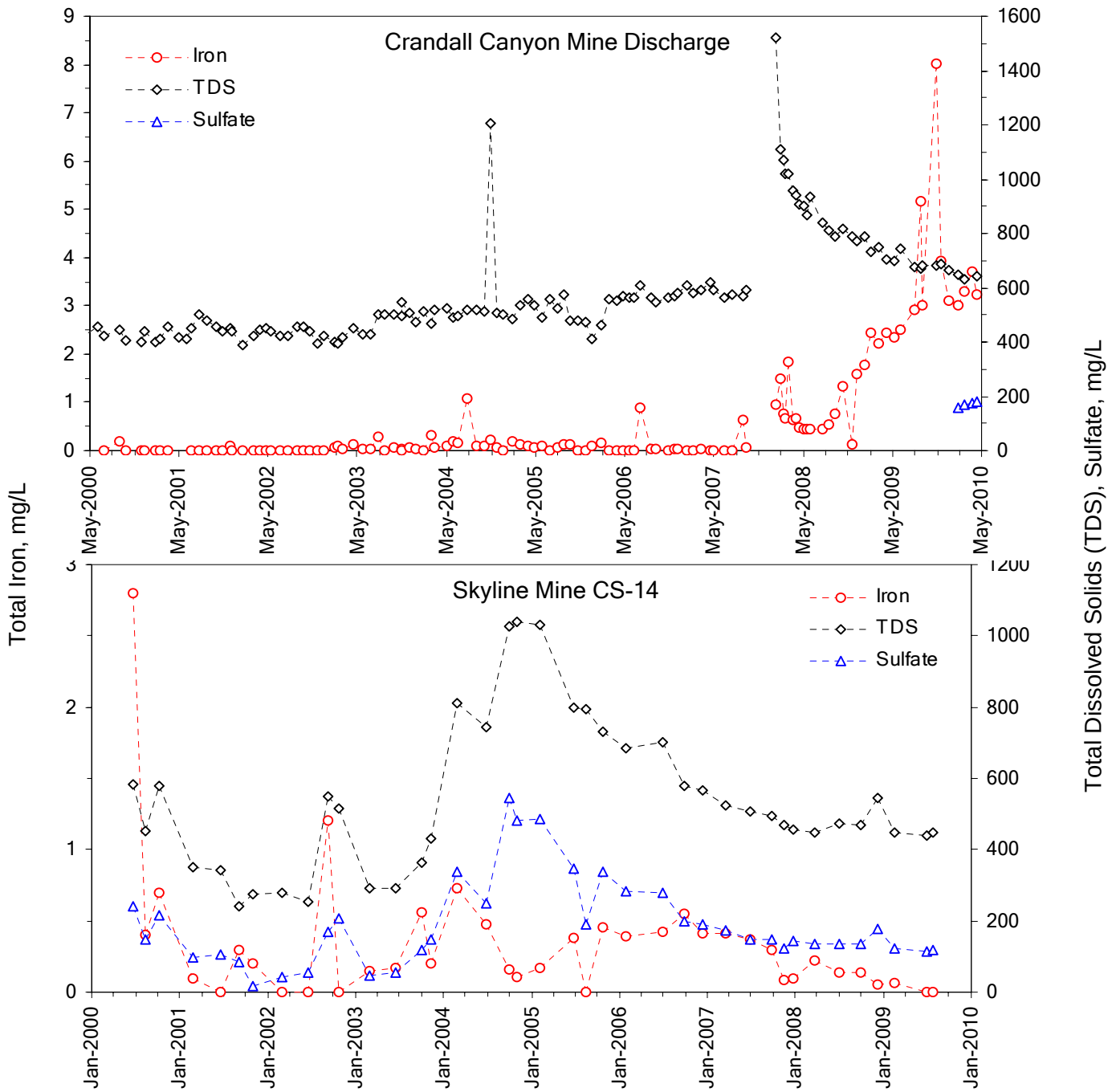


Figure 5. Plots Showing Water Quality Data from Crandall Canyon Mine and Skyline Mine CS-14

3.2.5 Comparison of Current Water Quality to Previous Investigations

The sulfate concentration measured in the mine discharge during January to March 2010 ranged from 159 mg/L to 183 mg/L (Table 5). Baseline sampling of the mine water discharge was not performed, therefore few sulfate data are available from prior to the 2007 mine collapse. Four mine water samples were analyzed in 1997 with reported sulfate concentrations ranging from not detected to 67 mg/L (Mayo and Associates 1997b). Danielson et al. (1981) evaluated the average sulfate composition of water-bearing units in the upper drainages of Huntington Creek and Cottonwood Creek and reported average sulfate concentrations ranging from 21 mg/L in the Blackhawk Formation to 77 mg/L in the Star Point Sandstone (Table 7).

Table 7. Sulfate Composition of Spring Waters from Different Water-Bearing Zones In and Adjacent to the Upper Drainages of Huntington and Cottonwood Creeks

Unit		Dissolved Sulfate, mg/L			
		No. Samples	Average	Minimum	Maximum
Above Coal Seams	North Horn Formation	51	32	2.1	180
	Price River Formation	18	23	3.7	120
	Castlegate Sandstone	9	33	4.0	110
Contains Coal Seams	Blackhawk Formation	31	21	2.1	120
Below Coal Seams	Star Point Sandstone	19	77	13	300
	All Units	128	34	2.1	300

Source: Danielson et al. 1981

Based on the data identified, the sulfate composition of the mine water discharge is elevated compared to regional concentrations and mine water concentrations prior to the August 2007 collapse. The increased sulfate composition is likely a result of pyrite oxidation, which released sulfate and has been shown to contribute the majority of the increase in TDS and sulfate in an underground coal mine in the Wasatch Plateau (Mayo et al. 2000).

4 Mine Water Treatment System

In December 2009 the Operator began constructing a water treatment system to address the iron contamination in the mine water discharge. The water treatment system as built initially included a mechanical aeration unit (Maelstrom Oxidizer) and a lined settling basin. The Operator reportedly approached several engineering companies to discuss reverse osmosis, fine element filtration, and mechanical oxidation prior to selecting the aeration approach; however, no information from this screening process has been provided to the Division. No passive treatment technologies have been evaluated by the Operator. The design for the treatment

system was based on a single bench test by the oxidizer unit manufacturer which indicated that following aeration, a settling time of 5.5 hours was sufficient to reduce total iron concentrations to below 1 mg/L. The treatment system came on-line January 2010, and it was immediately apparent that the iron precipitate generated by the oxidizer unit did not settle within the settling basin, which has a theoretical maximum retention time of approximately 9 hours at a flow rate of 500 gpm.

During February and March 2010 the Operator experimented with a variety of water treatment chemicals in an attempt to improve the settling of iron precipitate within the settling basin. The Operator was eventually able to achieve particle settling by using a combination of a polyaluminum chloride coagulant and a polyacrylamide flocculant in conjunction with the oxidizer unit. The treatment residual (sludge) generated by this process has a low solids content and accumulated rapidly within the settling basin. The sludge was cleaned out of the settling basin using vacuum trucks during April and May 2010. Prior to cleanout, the sludge was sampled and analyzed for RCRA metals, which were non-detected except for a low concentration of barium (0.825 mg/L).

In May 2010 the Operator installed a sludge recirculation system in an effort to reduce the amount of treatment chemicals and improve the density of the sludge. The sludge recirculation system has been difficult to realize due to short circuiting within the settling basin, which has a relatively flat bottom. Sludge is recirculated from the settling basin into the oxidizer unit. A process flow diagram showing the key components of the water treatment system is shown in Figure 6.

The treatment system operating at the site has been successful at reducing iron concentrations in the effluent to within the UPDES discharge limitation. However, the Division has several concerns about the treatment system, as follow:

- The operating cost for the treatment is not known with certainty; however, at current injection rates, the cost of the treatment chemicals alone is reported to be in the range of $100,000 to $200,000 annually.
- The system requires constant monitoring by the Operator in order to prevent release of iron to Crandall Creek. The system is highly mechanized, including three pumps, a blower, a mixer and heated storage unit, all of which require maintenance and are susceptible to power outages or other utility interruptions.
- Based on the initial operation results, sludge cleanout will be required as often as monthly. The low density of the sludge results in large quantities of sludge-water slurry, which requires disposal. No disposal facility is available at the Crandall Canyon Mine. Based upon a conversation between Division personnel and an on-site contractor at the Crandall Canyon water-treatment site (Division Inspection Report #2358, May 13th, 2010), 38 vacuum trucks, ranging in size from 5,000 gallon to 6,000 gallon capacities, were filled with sludge-water slurry from the treatment system's settling basin.

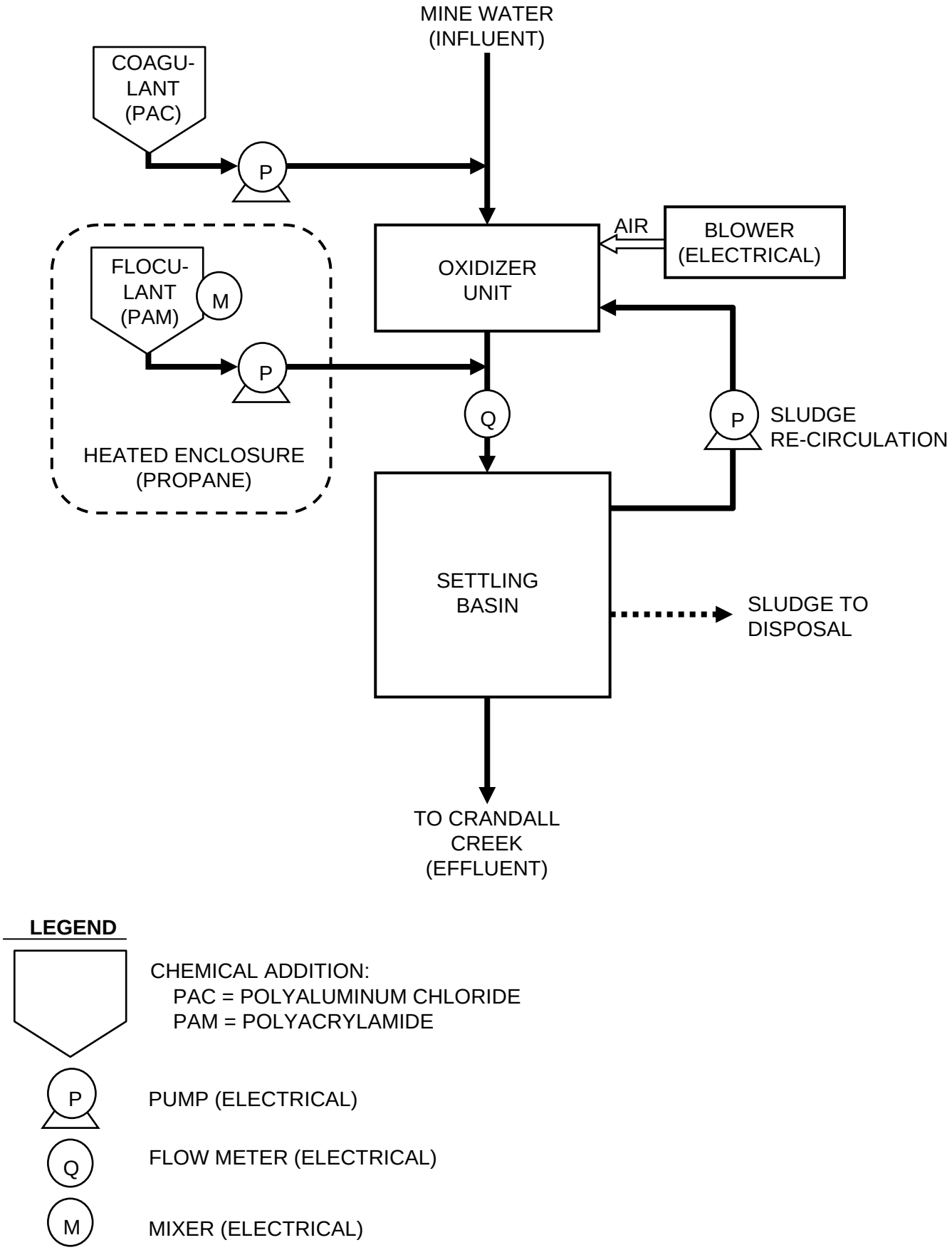


Figure 6. Crandall Canyon Mine Water Treatment System Process Flow Diagram

- Sludge-water slurry removed from the settling basin has been transported 45 miles to UEI's Wildcat Loadout facility (Figure 1). At Wildcat Loadout, the sludge-water slurry is transferred from the vacuum trucks directly into sediment pond "C" for drying and eventual disposal. UEI has indicated that ownership of the Wildcat Loadout facility will likely be transferred to IPA in the near future. An alternative disposal location for treatment residuals from the Crandall Canyon Mine has not been identified by UEI.
- The high-value aquatic habitat and municipal water supply downstream of the Crandall Canyon mine outfall heighten the sensitivity to the use of treatment chemicals. The treatment chemicals used contain constituents which are hazardous to aquatic life and human health. The polyacrylamide flocculant contains low-levels of acrylamide monomer, which is a known human carcinogen. The polyaluminum chloride coagulant contains aluminum, which can be highly toxic to aquatic life. Crandall Creek is classified as a cold water fishery, and is tributary to Huntington Creek, a popular destination for anglers. Flow from Huntington Creek is also diverted to a municipal water treatment system operated by the Castle Valley Special Services District.
- To date the Operator has not evaluated alternative treatment options for post-operational (e.g., reclamation) water treatment system at the site.

5 Findings

This hydrologic evaluation was prepared to address the conditions at the Crandall Canyon Mine and the potential for perpetual discharge of mine water containing elevated concentrations of iron. Based on this hydrologic evaluation, the Division makes the following findings:

- The Crandall Canyon Mine has been discharging water for approximately 14 years. There has been no indication of diminution of flow, nor is there any indication that the flow will diminish in the foreseeable future.
- Pyrite is present in the coal and the strata above and below coal seams at the Crandall Canyon Mine. The amount of pyrite available underground and the extent to which this pyrite has become exposed to groundwater as a result of the mine collapse is unknown.
- The mine water contains elevated concentrations of iron and sulfate, consistent with the oxidation of pyrite. There has been no indication that the rate of pyrite oxidation is slowing; sulfate concentrations have been relatively constant and iron concentrations have not declined.
- The available data support the likelihood of a perpetual discharge of mine water containing elevated concentrations of iron which will require treatment into the foreseeable future.

6 Recommendations

The following recommendations are based on the Hydrologic Evaluation completed by the Division for the Crandall Canyon Mine water discharge:

I. The Operator has not collected sufficient hydrologic information for the mine water discharge. The hydrologic information is necessary to plan remedial and reclamation activities that will effectively address adverse impacts from the mine water discharge. The Operator must collect additional information on the chemistry and flow of the mine water discharge in accordance with R645-301-724.500. The discharge rate from the sealed portals must be monitored either continuously (e.g., using a data logger) or at a minimum recorded daily. Whole-water chemical analysis and field measurements of the untreated mine discharge must be performed monthly and shall include the following parameters:

- calcium (dissolved)
- potassium (dissolved)
- sodium (dissolved)
- magnesium (dissolved)
- silica
- chloride
- hot acidity by Standard Method 2310B 4(a)
- aluminum (total & dissolved)
- iron (total & dissolved)
- manganese (total & dissolved)
- sulfate
- alkalinity (total, carbonate & bicarbonate)
- TDS
- suspended solids
- ferrous iron (field)
- pH (field)
- dissolved oxygen (field)
- conductivity (field)
- temperature (field)
- flow (field)

The Operator currently samples the mine water discharge prior to and following treatment for a subset of the parameters listed above. The additional parameters are necessary to evaluate the feasibility of treatment options, to provide information for treatment system design, and to provide baseline information for evaluating potential changes in the discharge over time.

II. The Probable Hydrologic Consequences (PHC) determination in the Crandall Canyon Mine MRP clearly does not reflect the conditions at the site. Toxic-forming materials are present at the site and coal-mining operations have resulted in impacts to surface water. In accordance with R645-301-728.400, the Operator must prepare a new or updated PHC determination to address mine water discharge. The PHC must address impacts to both water quality and aquatic habitat within Crandall Creek and Huntington Creek and incorporate results from macroinvertebrate surveys and stream surveys to be completed per MRP Section 3 and Appendix 7-65, respectively. In accordance with R645-301-731.221, the new or revised PHC must include recommendations for surface water monitoring. The Division will revisit the Cumulative Hydrologic Impact Analysis (CHIA) for the site to determine whether an update is required, based on the revised PHC.

III. In accordance with R645-301-724.500, the Operator must conduct and submit to the Division the results of investigations and studies relevant to the feasibility of additional options for perpetual treatment of the mine discharge by completing a Treatment Study. The purpose of the Treatment Study is to provide the data required for designing and bonding a perpetual treatment system at Crandall Canyon mine. The Treatment Study must be completed by a qualified professional or firm with direct experience in the treatment of alkaline mine drainage.

The Treatment Study must include technology pre-screening and treatability testing:

Technology pre-screening - A technology pre-screening evaluation will be completed to assess the potential feasibility of treatment technologies. The pre-screening evaluation should include a review of site data, treatment technology literature and case study review, and consultation with technology experts. The technology pre-screening must evaluate passive, low-energy and active conventional treatment technologies and may include innovative treatment technologies. A list of treatment technologies to be evaluated in the pre-screening will be provided to the Division and the USFS for review. For each treatment technology, the pre-screening evaluation will provide a basic description, feasibility for implementation, potential for modifications, and cost data. The pre-screening evaluation will also identify data needs when additional data or testing is necessary to assess the feasibility of treatment technologies.

Treatability testing - Treatability testing will be performed to address the data needs identified by the pre-screening evaluation and to generate data for assessing the potential effectiveness and costs associated with treatment alternatives. Treatability testing is not necessary for technologies when site conditions and/or available literature are adequate for assessing the feasibility of a technology; however, any technology recommended for the perpetual treatment system must be supported by treatability testing to evaluate the effectiveness and costs.

IV. In accordance with R645-301-526, the Operator must revise the MRP to accurately describe the Operational treatment system, including as-built figures, treatment chemical information, and system operations and maintenance.

V. Genwal Resources, Inc. is required in accordance with R645-301-830.140 to provide the Division a detailed summary of the costs associated with the operational system for the purpose of updating the bond required for the permit. Costs must include capital, operations, and maintenance.

7 References

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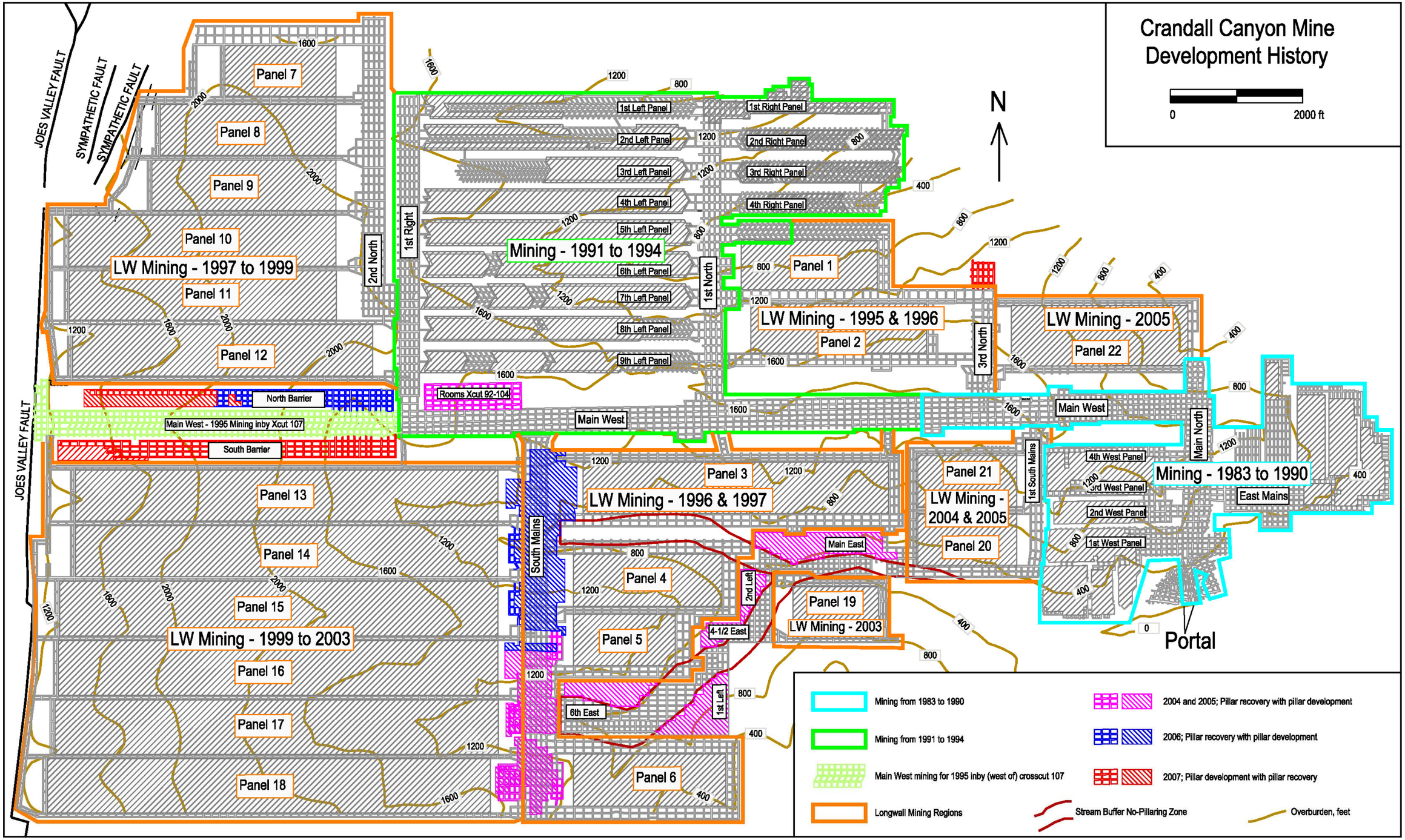
Attachment 1.

Crandall Canyon Mine Development History

Source: MSHA 2008



Attachment 2.

September 20, 2007 Letter re: Temporary Cessation of Coal Mining and Reclamation Operations Genwal Mine 015/032

0038

GENWAL™ RESOURCES, INC.

PO Box 1077, Price Utah 84501
(435) 888-4000 Fax (435) 888-4002

CONFIDENTIAL

This is not Confidential pgl 10/2/07

Incoming C/015/0032 copy PGL

September 20, 2007

Pam Grubaugh-Littig
Permit Supervisor
1594 West North Temple, Suite 1210
P.O. Box 145801
Salt Lake City, Utah 84114-5801

Re: Temporary Cessation of Coal Mining and Reclamation Operations Genwal Mine 015/032

Dear Ms. Grubaugh-Littig,

As per R645-301-515.300 to R645-301-515.321 and R645-301-320 the following notice is given:

As you are aware, the Crandall Canyon #1 Mine experienced a severe seismic event on August 6, 2007. Another significant seismic event was experienced on August 16, 2007. These events have lead to production being idled at both Crandall Canyon #1 and South Crandall Mines. At this time the extent of the damage caused by the accident and the corrective action to be taken is unknown. This idling or cessation is to be considered temporary but its duration is unknown.

The number of disturbed acres in the permit is 15.264 the total permit acres is 6,287.74 this will not change during the temporary cessation.

After the equipment is removed from both North and South Crandall mines, Concrete block walls will be installed in all openings to underground operations. The block walls will be constructed to prevent water from being impounded behind the walls. Mine discharge, if any, is expected to meet NPDS discharge standards. Environmental monitoring will continue as per approved MRP during the temporary cessation.

All equipment will be removed from both mines. Most but not all of the conveyor belting, conveyor structure, and water pipe will be removed. A certified list of best known locations of equipment being left underground will be provided as required for CIRCLA certification.

A chain link fence will be installed a minimum of 50 feet from the mine portals to prevent unauthorized access. The building and surface facilities will be locked and plating installed to prevent unauthorized access. In addition, a security guard will patrol the site around the clock.

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SEP 27 2007
DIV. OF OIL, GAS & MINING

GENWAL™ RESOURCES, INC.

PO Box 1077, Price Utah 84501
(435) 888-4000 Fax (435) 888-4002

The actions outlined in this letter are being implemented to protect the mine through out the investigation and pending studies. All applicable information from the investigation and studies will be forwarded to DOGM when they are finalized. DOGM will be kept informed of all developments that occur at the aforeferenced mines.

Sincerely,

David W. Hibbs

David W. Hibbs
Director, Engineering

Mile Post 33, Huntington Canyon
Huntington, Utah 84528

Attachment 3.

March 30, 2010 Letter re: Minor Modification to Resource Recovery and Protection Plan (R2P2), Revised Mining Plans with Timing, North and South Crandall Mines, UtahAmerican Energy, Inc. (UEI)

0018

C/015/032 Incoming
map to Confidential
cc: Steve C,
Karl

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Utah State Office
P.O. Box 45155
Salt Lake City, UT 84145-0155
http://www.blm.gov

TAKE PRIDE IN AMERICA

MAR 30 2010

IN REPLY REFER TO:

3480
UT (923)
SL-062648
UTU-68082
UTU-78953

File in:
C0150032 2010 Incoming
Refer to:
☒ Confidential
☐ Shelf
☐ Expandable
Date 03 30 10 For additional information

Certified Mail—Return Receipt Requested 7008 1140 0002 1095 0824

Mr. David W. Hibbs
Director, Engineering
UtahAmerican Energy, Inc.
P.O. Box 910
East Carbon, Utah 84520

RECEIVED
APR 01 2010
DIV. OF OIL, GAS & MINING

Re: Minor Modification to Resource Recovery and Protection Plan (R2P2), Revised Mining Plans with Timing, North and South Crandall Mines, UtahAmerican Energy, Inc. (UEI)

Dear Mr. Hibbs:

The Bureau of Land Management (BLM) has received submissions to modify the R2P2 for both subject mines that comprise the Crandall Canyon Logical Mining Unit (LMU) application. The modification revises the timing of the mining plan for a projected mine start-up date in 2012 and changes the mining method in the South Crandall Mine from longwall mining to room and pillar mining. The proposed revisions are on Federal coal leases UTU-68082 and UTU-78953.

Proposed Plan: With the idling of the Crandall Mines, UEI has now submitted revised mining plans for a projected restart of mining operations in 2012. They also propose changing the mining method for the South Crandall Mine to room and pillar panels in the areas where longwall panels were previously approved.

Approval: The BLM has reviewed the revised R2P2 and is in agreement with the proposal. The change from longwall mining panels to room and pillar panels in the South Crandall Mine will provide for Maximum Economic Recovery (MER) in thin coal conditions. BLM approved a cessation of longwall operations in South Crandall in 2006 as the existing longwall equipment was producing coal that was not meeting quality limits. Coal thickness was less than anticipated

and was thinner than the minimum cutting range of the longwall shearer. Changing over to room and pillar panels in the same area that was planned for longwall mining, will afford a better chance of mining an acceptable coal quality product with low profile continuous mining equipment.

Maximum Economic Recovery (MER): The extraction of the Federal coal following this plan will achieve MER.

Recoverable Reserve: For the dated locations shown in color on the attached approved map dated March 30th 2010, the remaining Federal recoverable reserves are 990,000 tons for the North Crandall Mine and 2,036,000 tons for the South Crandall Mine. However, the mine plan approved previously (approval dated February 23rd 2004) continues in effect for all other areas of the Crandall Mines which contain additional recoverable reserves.

National Environmental Policy Act (NEPA): As mining will occur in the same areas that were previously approved for mining, no new surface disturbance is predicted and is therefore Categorically Excluded (CX) from NEPA analysis under DM 516 chapter 11.5, paragraph F. (8): Approval of minor modifications to, or minor variances from, activities described in an approved underground or surface mine plan for leasable minerals.

This R2P2 modification complies with the Mineral Leasing Act of 1920, as amended, the regulations at 43 CFR 3480, and the lease terms and conditions. If you have any questions, please contact Stephen Falk at the Price Field Office at (435) 636-3605 or Jeff McKenzie of my staff at (801) 539-4038.

/s/ Roger L. Bankert

Roger L. Bankert
Chief, Branch of Minerals

Enclosure: Approved Mine Map

cc: PFO
Utah Division of Oil, Gas, and Mining (Attn. Daron Haddock), 1594 West North Temple, Suite 1210, Box 145801, Salt Lake City, UT 84114-5801
Files - UTU-68082
Chron File

N and S crandalnewtimining 25 Mar 2010JM-SA

Attachment 4.

Geochemist's Workbench Input & Output Summary

```
Step #     0             Xi = 0.0000
Temperature =  10.5 C    Pressure =  1.013 bars
pH =  7.550
Ionic strength      =    0.015755
Activity of water   =    0.999992
Solvent mass        =    1.000000 kg
Solution mass       =    1.000896 kg
Solution density    =    1.023    g/cm3
Chlorinity          =    0.000215 molal
Dissolved solids    =         895 mg/kg sol'n
Hardness            =      478.06 mg/kg sol'n as CaCO3
  carbonate         =      380.00 mg/kg sol'n as CaCO3
  non-carbonate     =       98.06 mg/kg sol'n as CaCO3
Rock mass           =    0.000000 kg
Carbonate alkalinity=      380.00 mg/kg sol'n as CaCO3
Water type          =    Ca-HCO3
```

No minerals in system.

Aqueous species	molality	mg/kg sol'n	act. coef.	log act.
HCO3-	0.007315	445.9	0.8866	-2.1881
Ca++	0.002119	84.86	0.6310	-2.8738
Mg++	0.002019	49.03	0.6492	-2.8825
Na+	0.001474	33.86	0.8847	-2.8846
SO4--	0.001343	128.8	0.6108	-3.0862
SiO2(aq)	0.0005769	34.63	1.0043	-3.2371
CO2(aq)	0.0005341	23.48	1.0000	-3.2724
K+	0.0002146	8.383	0.8807	-3.7235
Cl-	0.0002121	7.513	0.8807	-3.7286
CaSO4	0.0002113	28.74	1.0000	-3.6751
MgSO4	0.0001669	20.06	1.0000	-3.7777
CaHCO3+	0.0001483	14.98	0.8892	-3.8798
MgHCO3+	9.368e-005	7.986	0.8847	-4.0816
NaHCO3	1.524e-005	1.279	1.0000	-4.8171
Fe++	1.455e-005	0.8117	0.6310	-5.0372
CaCO3	1.331e-005	1.331	1.0000	-4.8758
CO3--	1.218e-005	0.7300	0.6160	-5.1249
MgCO3	5.861e-006	0.4937	1.0000	-5.2320
NaSO4-	5.538e-006	0.6587	0.8847	-5.3098
H3SiO4-	2.257e-006	0.2145	0.8847	-5.6997
FeHCO3+	1.965e-006	0.2295	0.8847	-5.7597
CaCl+	1.960e-006	0.1479	0.8847	-5.7610
Mn++	1.883e-006	0.1033	0.6310	-5.9252
KSO4-	1.199e-006	0.1619	0.8847	-5.9744
FeSO4	1.179e-006	0.1790	1.0000	-5.9284
FeCO3	8.271e-007	0.09574	1.0000	-6.0825
MgCl+	4.964e-007	0.02964	0.8847	-6.3574
MgH3SiO4+	1.557e-007	0.01857	0.8847	-6.8610
MnHCO3+	1.530e-007	0.01772	0.8847	-6.8686
MnSO4	1.455e-007	0.02196	1.0000	-6.8370
OH-	1.243e-007	0.002113	0.8828	-6.9596
CaH3SiO4+	9.020e-008	0.01218	0.8847	-7.0980
Mg2CO3++	5.771e-008	0.006263	0.6211	-7.4456
NaCO3-	5.105e-008	0.004234	0.8847	-7.3452
MnCO3	4.085e-008	0.004692	1.0000	-7.3888
NaH3SiO4	3.821e-008	0.004509	1.0000	-7.4178
H+	3.127e-008	3.149e-005	0.9012	-7.5500
MgOH+	2.179e-008	0.0008994	0.8847	-7.7149
FeOH+	1.053e-008	0.0007663	0.8847	-8.0308
MgH2SiO4	1.007e-008	0.001191	1.0000	-7.9969

(only species > 1e-8 molal listed)

Mineral saturation states

	log Q/K		log Q/K
Minnesotaite	2.3495s/sat	Magnesite	-0.3454
Dolomite-ord	1.9452s/sat	Amrph^silica	-0.3676
Dolomite	1.9452s/sat	Greenalite	-0.3730
Quartz	1.0407s/sat	Monohydrocalcite	-0.3982
Tridymite	0.8607s/sat	Rhodochrosite	-0.4930
Chalcedony	0.7555s/sat	Ferrosilite	-1.1219
Talc	0.7289s/sat	Gypsum	-1.4968
Calcite	0.5695s/sat	Anhydrite	-1.8191
Cristobalite	0.4562s/sat	FeO(c)	-2.1348
Aragonite	0.4029s/sat	Huntite	-2.3143
Dolomite-dis	0.2906s/sat	Bassanite	-2.4521
Siderite	0.2728s/sat	CaSO4^1/2H2O(bet	-2.6391

(only minerals with log Q/K > -3 listed)

Gases	fugacity	log fug.
Steam	0.01249	-1.903
CO2(g)	0.009933	-2.003

		In fluid		Sorbed		Kd
Original basis	total moles	moles	mg/kg	moles	mg/kg	L/kg
Ca++	0.00249	0.00249	99.9			
Cl-	0.000215	0.000215	7.60			
Fe++	1.85e-005	1.85e-005	1.03			
H+	0.000499	0.000499	0.503			
H2O	55.5	55.5	9.99e+005			
HCO3-	0.00814	0.00814	496.			
K+	0.000216	0.000216	8.43			
Mg++	0.00229	0.00229	55.5			
Mn++	2.22e-006	2.22e-006	0.122			
Na+	0.00150	0.00150	34.3			
SO4--	0.00173	0.00173	166.			
SiO2(aq)	0.000579	0.000579	34.8			

Elemental composition		In fluid		Sorbed	
	total moles	moles	mg/kg	moles	mg/kg
Calcium	0.002494	0.002494	99.88		
Carbon	0.008140	0.008140	97.69		
Chlorine	0.0002146	0.0002146	7.600		
Hydrogen	111.0	111.0	1.118e+005		
Iron	1.853e-005	1.853e-005	1.034		
Magnesium	0.002286	0.002286	55.52		
Manganese	2.223e-006	2.223e-006	0.1220		
Oxygen	55.54	55.54	8.878e+005		
Potassium	0.0002158	0.0002158	8.430		
Silicon	0.0005794	0.0005794	16.26		
Sodium	0.001495	0.001495	34.34		
Sulfur	0.001729	0.001729	55.37		