

**OGMCOAL - Crandall Canyon Stipulations: Docket No. 2010-026 Cause No. C015/0032F**

---

**From:** Steve Christensen  
**To:** OGMCOAL  
**Date:** 12/6/2011 10:50 AM  
**Subject:** Crandall Canyon Stipulations: Docket No. 2010-026 Cause No. C015/0032F  
**Attachments:** 2010-026\_20111205\_StipulatedMotion.pdf

---

>>> Julie Ann Carter 12/6/2011 9:44 AM >>>  
Attached is:

-Stipulated Motion to Admit the Parties' Expert Reports on Hydrology into Evidence and to Recognize Kevin Lundmark and Erik Petersen as Experts in Hydrology, filed Dec. 5, 2011.

The Division and Genwal jointly stipulate to a Motion to Admit into evidence their respective expert reports ("Reports") on hydrology as evidence on the potential duration of the unanticipated mine water discharge at Genwal's Crandall Canyon Mine site. The parties have entered into this Stipulation, subject to the Board of Oil, Gas and Mining's ("Board") approval, to expedite the December 7, 2011, evidentiary hearing regarding the annual costs of water treatment at the current Crandall Canyon treatment facility. The Reports are offered in lieu of live testimony on the matter.

Julie Ann Carter  
Utah Oil, Gas and Mining  
1594 W North Temple, Ste 1210  
PO Box 145801  
Salt Lake City, UT 84114  
Ph: (801) 538-5277  
Fx: (801) 359-3940  
[juliecarter@utah.gov](mailto:juliecarter@utah.gov)



1. The investigation conducted by Erik Petersen of Petersen Hydrologic sent to Dave Shaver of Genwal Resources (“Petersen 2009 Investigation”) dated February 25, 2009, is offered for admission into the record as an expert report on the potential duration of the mine water discharge at the Crandall Canyon Mine site. Please reference page 3 of Exhibit I of Petitioner’s Request for Agency Action.
2. The report entitled “Hydrologic Evaluation of the Crandall Canyon Mine Discharge” (“Division’s 2010 Report”) dated June 7, 2010, prepared by Kevin Lundmark on behalf of the Utah Division of Oil, Gas and Mining is offered for admission into the record as an expert report on the potential duration of the mine water discharge at the Crandall Canyon Mine site. Please reference page 8 of Exhibit J of Petitioner’s Request for Agency Action.
3. The report entitled “Hydrologic Evaluation Update” (“Division’s 2011 Update”) dated June 2, 2011, prepared by Kevin Lundmark on behalf of the Utah Division of Oil, Gas and Mining is offered for admission into the record as an expert report on the potential duration of the mine water discharge at the Crandall Canyon Mine site. Attached as Exhibit A.
4. The report entitled “Investigation of Iron Concentrations in the Genwal Resources, Inc. Crandall Canyon Mine Discharge Water” (“Peterson 2011 Investigation”) dated November 7, 2011, prepared by Erik Petersen of Petersen Hydrologic, LLC, is offered for admission into the record as an expert report on the potential duration of the mine water discharge at the Crandall Canyon Mine site. Attached as Exhibit B.

5. The document entitled "Division of Oil, Gas and Mining Response to: Investigation of Iron Concentrations in the Genwal Resources, Inc. Crandall Canyon Mine Discharge Water, November 7<sup>th</sup>, 2011 prepared by Petersen Hydrologic, LLC," ("Division's 2011 Response") dated November 22, 2011, prepared by Kevin Lundmark on behalf of the Division is offered for admission into the record as a response to Exhibit B. Attached as Exhibit C.

6. The document from Petersen Hydrologic to Denise Dragoo, counsel for Genwal Resources ("Petersen 2011 Response") dated December 2, 2011, prepared by Erik Petersen of Petersen Hydrologic is offered for admission into the record as a response to Exhibit C. Attached as Exhibit D.

7. For the purposes of this matter, the parties waive any objections to the Board recognizing Kevin Lundmark as an expert in hydrology. Kevin Lundmark's CV is attached as Exhibit E.

8. For the purposes of this matter, the parties waive any objections to the Board recognizing Erik Petersen as an expert in hydrology. Erik Petersen's resume is attached as Exhibit F.

5. If called as a witness, the authors of the Reports would testify to the authorship of, contents, and accuracy of the facts in their respective report.

6. The parties agree to waive any objections to the foundation or authenticity of the Reports.

7. The parties stipulate only to the admission of the form of the Reports and preserve all arguments regarding the expert opinions contained within.

The foregoing Stipulation is approved by signature of counsel as of the date shown.

Dated: December 5 2011

**GENWAL RESOURCES, INC.**

BY: 

SNELL & WILMER, LLP  
Denise A. Dragoo  
15 West South Temple  
Suite 1200  
Salt Lake City, Utah 84101  
Telephone: (801) 257-1900

FABIAN & CLENDENIN  
Kevin N. Anderson  
215 South State Street  
Suite 1200  
Salt Lake City, Utah 84111  
Telephone: (801) 531-8900

**Utah Division of Oil, Gas and  
Mining**

BY: 

Steven F. Alder  
Emily E. Lewis  
Utah Assistant Attorneys General  
1594 West North Temple St. #300  
Salt Lake City, Utah 84118  
Telephone: (801) 538-5348

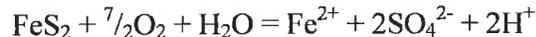
**EXHIBIT A**

## **Crandall Canyon Mine Hydrologic Evaluation Update June 2, 2011**

### **Introduction**

The Division of Oil, Gas and Mining (the Division) completed a Hydrologic Evaluation of the Crandall Canyon Minewater Discharge in June 2010 (attached). Since that time, additional minewater flow and chemistry data have been collected by Genwal Resources, Inc. (Genwal) and the Division. This report presents an update to the Hydrologic Evaluation based on data collected through mid-May 2011.

It has been generally accepted by Genwal and the Division that the source of the elevated iron concentrations in the minewater discharge is the oxidation of sulfide minerals (e.g., pyrite). The oxidation of pyrite ( $\text{FeS}_2$ ) in an oxygenated aqueous environment proceeds according to the following reaction:



The reaction above shows that when pyrite is oxidized, ferrous iron ( $\text{Fe}^{2+}$ ), sulfate ( $\text{SO}_4^{2-}$ ) and acidity ( $\text{H}^+$ ) are released. Acidity generated by the reaction is consumed by excess alkalinity available from the dissolution of carbonate minerals, which are prevalent in the Wasatch plateau.

Genwal's consultant has opined that elevated iron concentrations will not persist for more than approximately 10 years (Task ID 3724, received January 6, 2010) and that iron concentrations will decline as a result of either depletion of pyrite or oxygen, which are the reactants for pyrite oxidation. Genwal's consultant has not offered any other potential explanation for variation in minewater iron concentrations over time, nor has a stoichiometric analysis of minewater chemistry been performed.

The following sections of this update report describe the data which have been collected and the plots which have been prepared to examine the data. A series of conclusions are then presented which describe the characteristics of the Crandall Canyon minewater discharge based on the monitoring data.

### **Presentation of Data**

Genwal has continued to perform monthly sampling and analysis of the minewater discharge in accordance with the Crandall Canyon Mining and Reclamation Plan (MRP). Minewater chemistry analytical results are tabulated in Table 1. Beginning in March 2011, additional sampling was performed by both the Genwal and the Division to gain additional information on the variability in minewater chemistry during the 90-day negotiation period established by the Board of Oil, Gas and Mining (the Board) during the February 2011 Board Hearing. Samples collected as part of the weekly sampling program were analyzed for a reduced set of parameters, including only total iron and sulfate. Weekly sampling results from Genwal's laboratory are included in Table 1. Iron and sulfate concentrations from January 2008 through

May 2011 are plotted in Figure 1. Additional detail for total iron and sulfate concentrations from the Negotiation Period sampling is shown in Figure 2. A side-by-side comparison of Genwal's results and results obtained by the Division for samples analyzed at the Utah Unified State Laboratory is presented in Table 2.

To evaluate the potential correlation of total iron concentrations with other variables, a series of scatter plots is presented in Figure 3. Scatter plots a through c present the total iron concentration in minewater (y-axis) versus discharge rate, sulfate concentration and total dissolved solids (TDS) (x-axes). Scatter plot d presents TDS versus sulfate concentration. The minewater which initially discharged from the portals contained elevated concentrations of total iron, sulfate and TDS (Table 1 and Figure 1). Concentrations of these constituents dissipated, then began increasing in July 2008. The scatter plots for total iron versus discharge rate (plot a) and TDS (plot c) differentiate between the initial flush water (prior to July 2008) as opposed to minewater discharge since July 2008. Minewater was not analyzed for sulfate until January 2010.

The Operator began recording the minewater discharge rate daily (in gallons per minute, or gpm) in January 2010, and began recording the discharge rate twice per day in April 2010. Flow measurements prior to March 19, 2010 were read from a malfunctioning flow meter and are suspect. A new flow meter was installed on March 19, 2010 at the outlet of the oxidizer unit. At this location, measured flows reflect both the minewater discharge rate and sludge recirculation. Between March and June 2010, the Operator was experimenting with sludge recirculation at varying rates. After June 10, 2010, sludge recirculation was performed continuously at a rate of approximately 520 gpm. Minewater discharge rates for January 2010 to May 2011 are shown in Figure 4. These discharge rates have been corrected for sludge recirculation, when possible.

### **Minewater Discharge Characteristics**

The following conclusions are drawn from the data presented in Tables 1 and 2 and the plots presented in Figures 1 through 4:

1. Total iron concentrations in minewater have exceeded the UPDES discharge limit (1.0 mg/L prior to May 1, 2011; 1.2 mg/L after May 1, 2011) continuously since December 2008. Total iron concentrations detected during the March to May 2011 Negotiation Period ranged from 2.05 mg/L to 6.68 mg/L<sup>1</sup>.
2. The plot of total iron concentrations over time (Figure 1) shows that iron levels have been generally lower during the four-month period February 2011 to May 2011 (usually in the range of 2 mg/L to 2.5 mg/L) than during the previous four months (between about 2.8 to 3.3 mg/L October 2010 to January 2011). However, the minewater sample from April 27, 2011 contained 6.68 mg/L total iron, which is the second highest concentration detected in the minewater to date. Recent sulfate concentrations are not lower than earlier results.

---

<sup>1</sup> This is the range of concentrations reported for samples analyzed by Genwal. Total iron concentrations in samples analyzed by the Division ranged from 1.98 mg/L to 5.0 mg/L. For simplicity and consistency, concentrations discussed in this section are for monitoring data collected by Genwal.

3. Iron and sulfate concentrations in the minewater are variable, although iron concentrations are much more highly variable than sulfate concentrations. The coefficients of variation (standard deviation divided by average, unitless) for data collected by Genwal March 10 through May 17, 2011 (Figure 2) are 0.45 for total iron and 0.03 for sulfate.
4. The scatter plots presented in Figure 3 suggest that total iron concentration is not correlated with minewater discharge rate (plot a) or with sulfate concentrations (plot b). Total iron concentrations show a potential negatively correlation with TDS concentrations (plot c). A strong correlation between TDS and sulfate concentration is not indicated (plot d), although the data do suggest that TDS may be positively correlated with sulfate concentrations.
5. Visual inspection of the plot of total iron concentrations from the March to May 2011 Negotiation Period (Figure 2) does not suggest that iron concentrations are decreasing over time. Sulfate concentrations reported for March to May 2011 also do not appear to be decreasing.
6. The analytical results for general chemistry parameters in Table 1 (sodium, potassium, calcium, magnesium, chloride, silica, aluminum, manganese, alkalinity) have been consistent since whole-water analysis of the minewater was initiated in April 2010.
7. Iron oxidation and precipitation is occurring within the mine, prior to treatment. This conclusion is based on the dissolved oxygen content of the minewater, lower concentrations of dissolved iron / ferrous iron compared to total iron, and the chemical behavior of iron at the pH and redox conditions of the minewater (Hem 1985). As such, iron is considered a non-conservative parameter. Sulfate is considered to be much more conservative. The geochemical evaluation presented as Attachment 4 of the June 2010 Hydrologic Evaluation Report found the minewater to be undersaturated for sulfate minerals, therefore sulfate precipitation is not expected to be occurring within the mine workings. If depletion of pyritic source material or dissolved oxygen were occurring, then the concentration of sulfate, which is a product of pyrite oxidation and more conservative than iron, would be expected to decrease<sup>2</sup>. Monitoring data have not shown a decrease in sulfate concentrations since sulfate analysis was initiated in January 2010 (Figure 1).
8. The relatively stable concentrations of sulfate, a product of pyrite oxidation and a quasi-conservative dissolved constituent, indicate that reductions in total iron concentrations may not be due to depletion of either available pyrite or dissolved oxygen contacting pyrite. The total iron concentrations may be attenuated by other processes, such as precipitation within the mine workings (as iron oxy-hydroxide or iron carbonate), adsorption to iron hydroxides, or cation exchange. Whereas depletion of pyrite reactant is essentially an irreversible reaction, the other potential attenuation mechanisms (adsorption, precipitation) retain iron within the mine workings and could allow the mobilization of iron as a result of physical or chemical changes in the mine workings.

---

<sup>2</sup> Pyrite oxidation is not the only source of sulfate present in the hydrologic system potentially contributing to the minewater discharge; however, in a study completed for the SUFCO mine in the Wasatch Plateau, Mayo, Petersen and Krazitz (2000) found that most sulfate in minewater discharge results from pyrite oxidation.

9. Minewater discharge rates are variable (Figure 4). The average discharge rate for the period January 2010 to May 2011 was 457 gpm, with a standard deviation of 79 gpm. The time series data for minewater discharge shown on Figure 4 do not suggest a trend in discharge rates over time, but do indicate potential seasonal or weather-related variability.

## **Conclusions**

Monitoring data collected since the June 2010 Hydrologic Evaluation Report have shown total iron concentrations in the minewater discharge to be quite variable. The recent detections of iron at concentrations of about 2 mg/L (compared to previous detections of about 3 mg/L) is encouraging, as this suggests attenuation may be occurring within the mine and that iron levels may drop below the UPDES criterion of 1.2 mg/L. However, the available monitoring data do not show a strong decreasing trend in minewater iron concentrations. The attenuation mechanisms proposed by Genwal - depletion of either pyrite or oxygen – are not supported by the minewater chemistry data. Furthermore, Genwal has not submitted a technical demonstration supporting a known timeframe for iron concentrations to decline, and stay below, the UPDES criterion. Absent such a demonstration, and based on the minewater discharge chemistry observed to date, it is reasonable to assume that continued treatment of minewater discharge will be required and that the duration of the treatment is unknown at this time.

## **References**

- Hem, J.D. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water, Third Edition. U.S. Geological Survey Water-Supply Paper 2254. 264 pages.
- Mayo, A.L., Petersen, E.C., and C. Kravatis. 2000. Chemical Evolution of Coal Mine Drainage in a Non-Acid Producing Environment, Wasatch Plateau, Utah, USA. *Journal of Hydrology* 236 (2000) 1-16.

O:\015032.CRA\Hydrologic Evaluation- Mine Water Discharge\Update June 2011\Hydro\_Eval\_2.doc

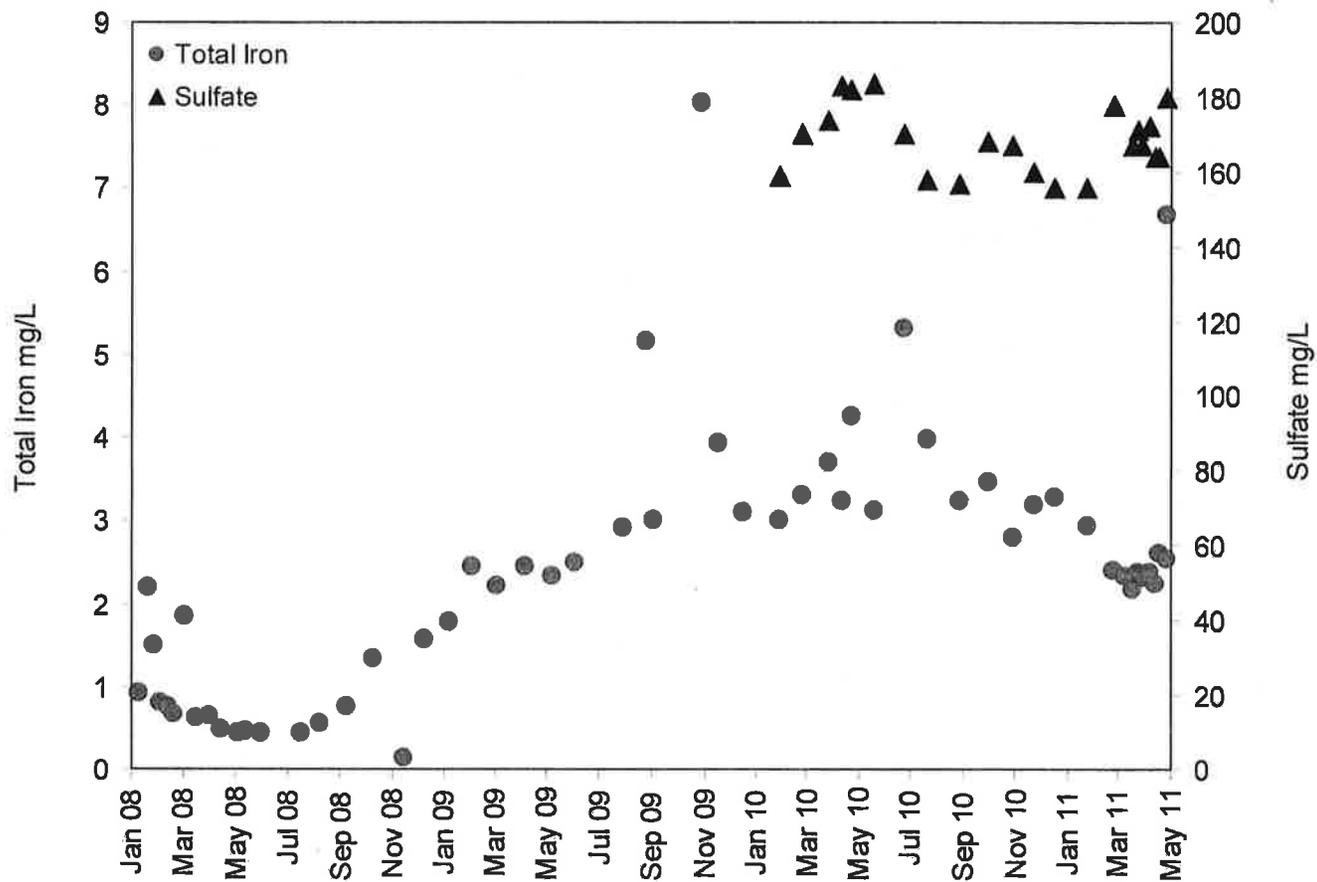
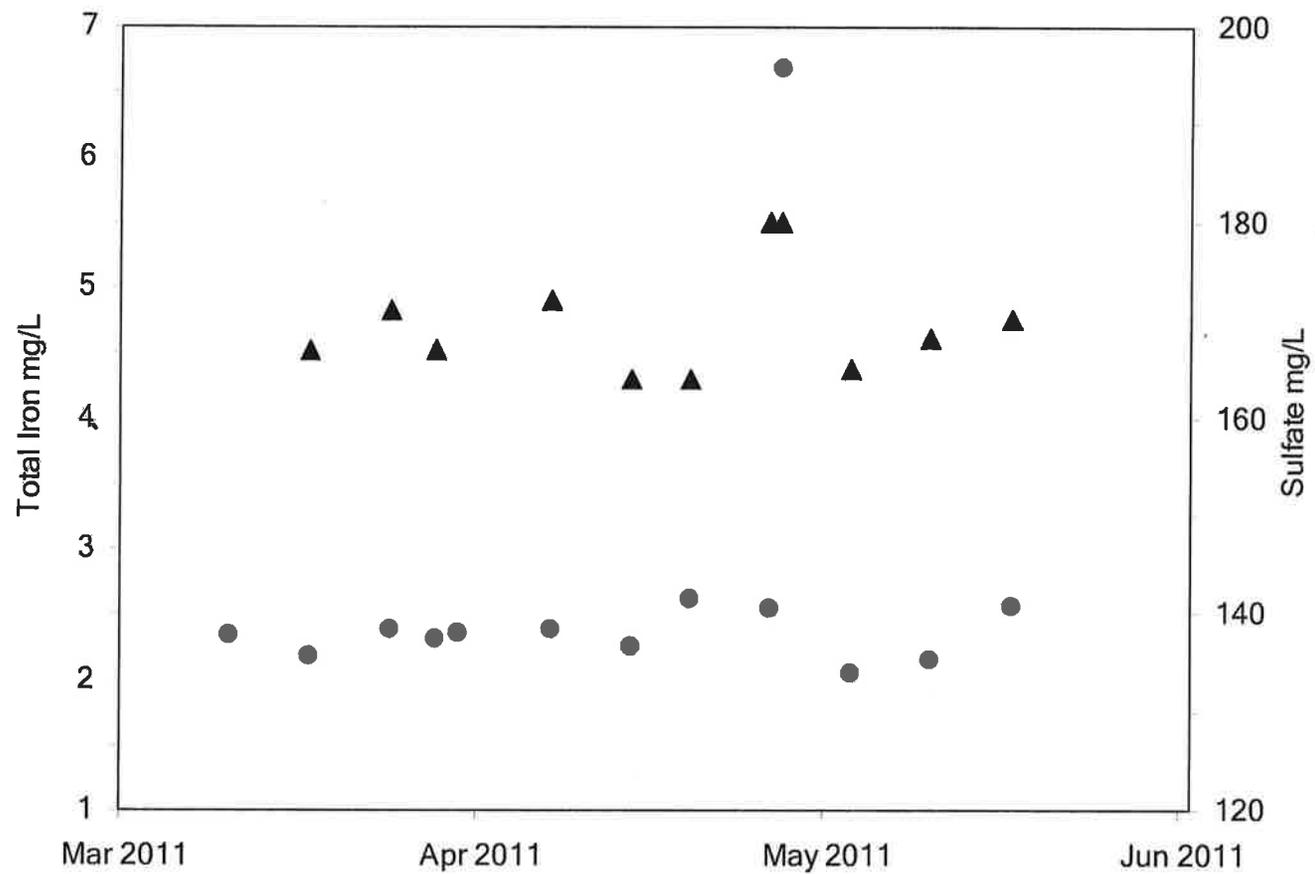
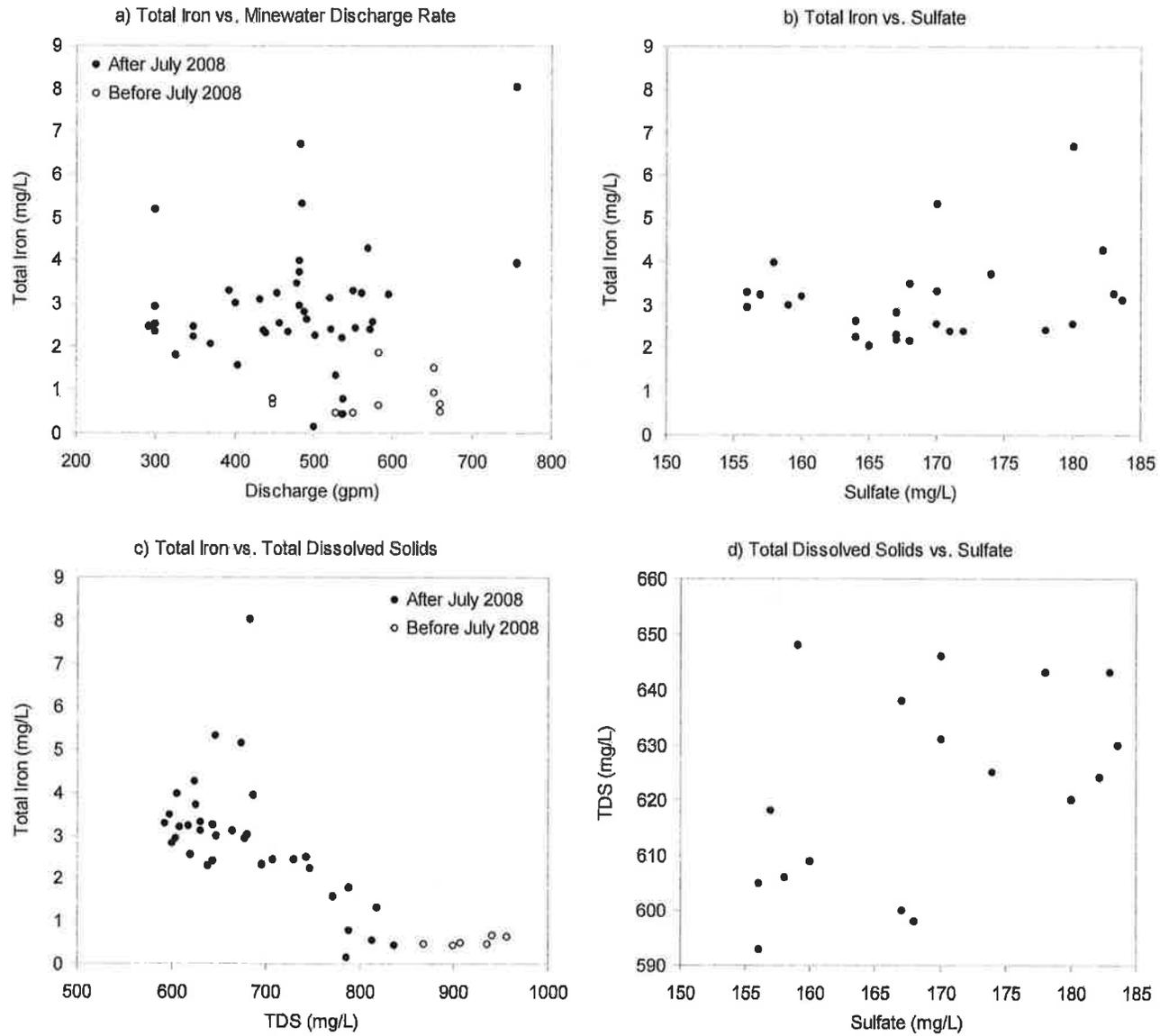


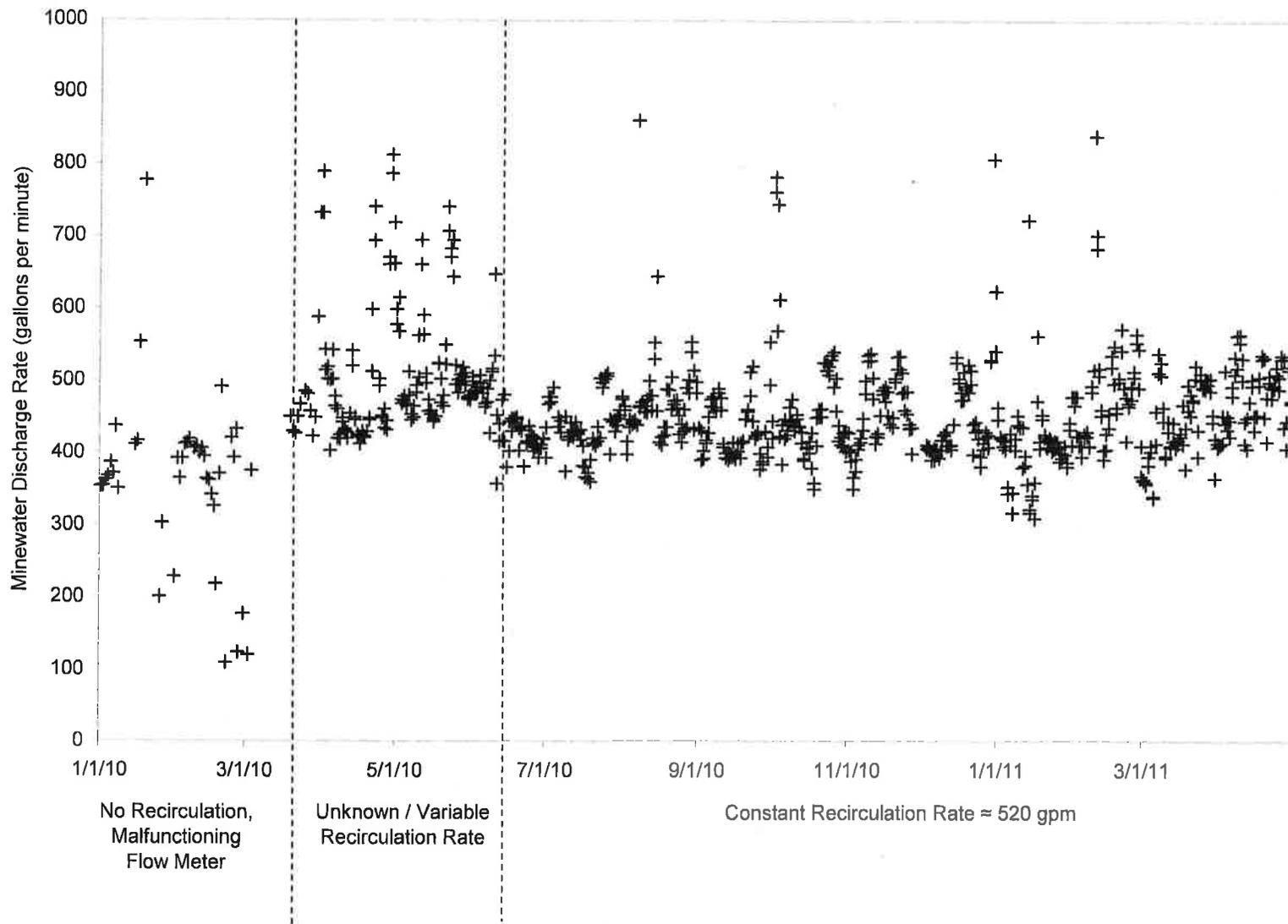
Figure 1. Minewater Total Iron and Sulfate Concentrations January 2008 to May 2011 (Data Collected by Operator)



**Figure 2. Minewater Total Iron and Sulfate Concentrations March 2011 to May 2011 (Data Collected by Operator)**



**Figure 3. Scatter Plots for Minewater Discharge Characteristics Showing: a) Total Iron vs. Flow, b) Total Iron vs. Sulfate, c) Total Iron vs. TDS, and d) TDS vs. Sulfate.**



**Figure 4. Minewater Discharge Rate January 2008 through May 2011.**

**Table 1. Mine Water Discharge Chemistry, 2008 – Present**

Date	Discharge gpm	pH (std. units)	Dissolved Oxygen (mg/L)	Spec. Cond. (µS/cm)	Temp (C)	Calcium, Dissolved (mg/L)	Magnesium, Dissolved (mg/L)	Sodium, Dissolved (mg/L)	Potassium, Dissolved (mg/L)	Total (mg/L)	Iron Dissolved (mg/L)	Ferrous (mg/L)	Aluminum Total (mg/L)	Aluminum Dissolved (mg/L)	Manganese Total (mg/L)	Manganese Dissolved (mg/L)
1/10/2008	653	8.12	8.3	--	10	--	--	--	--	0.937	--	--	--	--	--	--
1/21/2008	--	--	--	--	--	--	--	--	--	2.204	0.161	--	--	0.138	--	--
1/28/2008	653	7.9	9.3	1507	7	--	--	--	--	1.494	0.034	--	0.06	0.121	--	--
2/4/2008	--	--	--	--	--	--	--	--	--	0.815	0.111	--	0.09	0.107	--	--
2/11/2008	448	7.6	11.3	1446	8.5	--	--	--	--	0.765	0.036	--	0.05	0.109	--	--
2/18/2008	448	7.92	10.1	1448	12.1	--	--	--	--	0.668	0.021	--	0.17	0.107	--	--
3/3/2008	582	7.4	10.6	1429	10.8	--	--	--	--	1.846	0.01	--	0.17	0.101	--	--
3/17/2008	582	8.22	10.8	1272	9.5	--	--	--	--	0.626	0.02	--	0.14	0.096	--	--
4/1/2008	660	8.09	10.4	1279	9.7	--	--	--	--	0.653	0.027	--	0.14	--	--	--
4/15/2008	660	7.71	10.2	1248	11.8	--	--	--	--	0.491	0.019	--	0.14	--	--	--
5/5/2008	535	7.19	8.9	1225	12	--	--	--	--	0.433	<0.010	--	0.15	--	--	--
5/14/2008	549	7.98	9.2	1165	12.4	--	--	--	--	0.457	0.01	--	0.16	--	--	--
6/1/2008	528	7.77	8.9	1272	15	--	--	--	--	0.448	--	--	--	--	--	--
7/16/2008	538	7.04	7.1	1142	12.2	--	--	--	--	0.434	--	--	--	--	--	--
8/8/2008	--	--	--	--	--	--	--	--	--	0.546	--	--	--	--	--	--
9/9/2008	538	8.6	8	1087	14.5	--	--	--	--	0.775	--	--	--	--	--	--
10/10/2008	528	8.2	7.8	1010	10.9	--	--	--	--	1.335	--	--	--	--	--	--
11/15/2008	500	8.6	8.09	1135	10	--	--	--	--	0.141	--	--	--	--	--	--
12/9/2008	403	6.95	9.1	--	6.7	--	--	--	--	1.569	--	--	--	--	--	--
1/7/2009	326	7.99	8.1	1000	13.7	--	--	--	--	1.783	--	--	--	--	--	--
2/3/2009	347	7.78	7.9	1060	11	--	--	--	--	2.454	0.256	--	0.14	0.173	--	--
3/4/2009	347	8.01	7.2	1030	12	--	--	--	--	2.23	0.51	--	--	--	--	--
4/6/2009	292	7.9	8.6	1070	10	--	--	--	--	2.455	0.486	--	0.12	0.162	--	--
5/6/2009	300	7.22	9.1	1010	16	--	--	--	--	2.331	<0.010	--	--	--	--	--
6/3/2009	300	7.78	7.79	1060	14.02	--	--	--	--	2.501	0.748	--	--	--	--	--
7/29/2009	300	7.55	<0.0	1020	15.7	--	--	--	--	2.924	0.849	--	--	--	--	--
8/24/2009	300	7.23	8.03	1050	14	--	--	--	--	5.151	0.654	--	--	--	--	--
9/3/2009	400	7.23	8.8	1080	13.6	--	--	--	--	3.012	0.885	--	0.1	0.143	--	--
10/28/2009	757	6.92	8.07	1150	8.8	--	--	--	--	8.03	--	--	--	--	--	--
11/18/2009	757	7.04	12.1	1050	11.9	--	--	--	--	3.927	--	--	--	--	--	--
12/16/2009	431	8.12	11.68	1020	10.1	--	--	--	--	3.1	--	--	--	--	--	--
1/28/2010	--	6.98	4.89	1010	8.1	--	--	--	--	3.0	0.9	<0.1 (Lab)	<0.1	0.14	0.14	0.14
2/23/2010	393	7.76	5.3	1030	10.1	--	--	--	--	3.3	1.3	0.77 (Lab)	<0.1	0.13	0.13	0.13
3/26/2010	481	--	--	--	--	--	--	--	--	3.709	1.531	--	0.13	0.11	0.13	0.13
3/30/2010	587	--	--	--	--	--	--	--	--	--	1.2	--	--	--	--	--
4/12/2010	454	7.55	--	--	--	99.98	55.52	34.34	8.43	3.245	1.034	1.23	0.1	<0.02	0.128	0.122
4/21/2010	568	6.91	6.53	1000	10.2	--	--	--	--	4.268	1.11	1.23	<0.02	<0.02	0.114	0.124
5/18/2010	520	6.93	5.23	1000	11	--	--	--	--	3.119	0.965	--	0.04	<0.02	0.126	0.126
6/23/2010	485	7.26	4.3	981	13.5	--	--	--	--	5.312	0.689	0.848	0.06	<0.02	0.134	0.114
7/21/2010	482	7.27	4.48	956	16	--	--	--	--	3.97	0.73	1.04	<0.03	<0.03	0.113	0.113
8/27/2010	560	7.1	4.53	554	11	100.41	55.69	35.06	8.24	3.23	0.83	1.187	<0.03	<0.03	0.113	0.113
9/29/2010	478	7.05	4.58	950	12	100.85	55.31	34.59	8.27	3.47	0.69	1.004	<0.03	<0.03	0.112	0.112
10/29/2010	487	6.97	4.35	937	11	100.2	55.17	35.88	8.27	2.81	0.61	0.912	0.06	<0.03	0.11	0.11
11/22/2010	595	7.21	6.73	939	11	97.67	54.35	34.37	8	3.19	<0.03	1.29	<0.03	<0.03	0.104	0.104
12/17/2010	549	7.5	5.63	895	10	98.65	54.3	35.79	7.96	3.29	0.07	1.018	<0.03	<0.03	0.108	0.108
1/24/2011	482	7.02	4.27	926	11	99.16	55.33	36.36	8.29	2.93	0.54	0.781	<0.03	<0.03	0.108	0.108
2/23/2011	553	7.1	5.77	955	10	104.5	57.99	35.49	8.32	2.41	0.12	0.346	<0.03	<0.03	0.113	0.11
3/10/2011	468	--	--	--	--	--	--	--	--	2.34	--	--	--	--	--	--
3/17/2011	536	--	--	--	--	--	--	--	--	2.18	--	--	--	--	--	--
3/24/2011	571	--	--	--	--	--	--	--	--	2.39	--	--	--	--	--	--
3/28/2011	440	7.2	4.47	943	11	100.87	55.51	34.86	8.45	2.31	0.31	0.432	<0.03	<0.03	0.11	0.11
3/30/2011	437	7.3	--	--	--	--	--	--	--	2.36	--	--	--	--	--	--
4/7/2011	521	--	--	--	--	--	--	--	--	2.39	--	--	--	--	--	--
4/14/2011	502	--	--	--	--	--	--	--	--	2.25	--	--	--	--	--	--
4/19/2011	491	--	--	--	--	--	--	--	--	2.62	--	--	--	--	--	--
4/26/2011	457	7.1	7.15	904	10	100.06	55.89	34.22	7.98	2.55	0.46	0.703	<0.03	<0.03	0.107	0.107
4/27/2011	484	--	--	--	--	--	--	--	--	6.68	--	--	--	--	--	--
5/3/2011	370	--	--	--	--	--	--	--	--	2.05	--	--	--	--	--	--
5/12/2011	--	--	--	--	--	--	--	--	--	2.16	--	--	--	--	--	--
5/17/2011	574	--	--	--	--	--	--	--	--	2.56	--	--	--	--	--	--

**Table 2. Minewater Total Iron and Sulfate Analytical Results for Samples Analyzed by Genwal and the Division, March 2011 to May 2011**

Sample Date	Total Iron (mg/L)		Sulfate (mg/L)	
	Genwal	Division	Genwal	Division
3/10/2011	2.34	1.98	na	189
3/17/2011	2.18	2.06	167	190
3/24/2011	2.39	2.28	171	187
3/30/2011	2.36	2.04	na	191
4/7/2011	2.39	2.15	172	183
4/14/2011	2.25	2.11	164	181
4/19/2011	2.62	2.43	164	171
4/27/2011	6.68	5.0	180	172
5/3/2011	2.05	2.02	165	162
5/12/2011	2.16	2.0	168	182
5/17/2011	2.56	2.33	170	188

**Notes:**

na = not analyzed

**EXHIBIT B**

**Investigation of Iron  
Concentrations in the  
Genwal Resources, Inc.  
Crandall Canyon Mine  
Discharge Water**

7 November 2011

Genwal Resources, Inc.  
Crandall Canyon Mine  
East Carbon, Utah



**PETERSEN HYDROLOGIC, LLC**  
CONSULTANTS IN HYDROGEOLOGY

**Investigation of Iron  
Concentrations in the  
Genwal Resources, Inc.  
Crandall Canyon Mine  
Discharge Water**

7 November 2011

Genwal Resources, Inc.  
Crandall Canyon Mine  
East Carbon, Utah

Prepared by:



---

Erik C. Petersen, P.G.  
Senior Hydrogeologist  
Utah P.G. No. 5373615-2250



**PETERSEN HYDROLOGIC**  
CONSULTANTS IN HYDROGEOLOGY

2695 N. 600 E.  
LEHI, UTAH 84043  
(801) 766-4006  
PETERSEN@RELIA.NET

## Table of Contents

1.0 Introduction.....	1
2.0 New Hydrologic Data .....	3
3.0 Presentation of Data.....	5
4.0 Discussion.....	6
5.0 Projections of Likely Future Iron Concentrations .....	18
6.0 Conclusions.....	19
7.0 References Cited .....	22

## List of Figures

Figure 1	Location of the Genwal Resources, Inc. Crandall Canyon Mine
Figure 2	Plots of total iron concentrations in Crandall Canyon Mine discharge water and treated mine discharge water.
Figure 3	Plot of 6-month running average of total iron concentrations in untreated Crandall Canyon Mine discharge water.
Figure 4	Plot of Crandall Canyon Mine discharge rates.
Figure 5	Plot of Crandall Canyon Mine discharge rates, 6-month running average.
Figure 6	Average yearly mine water discharge rates for the Crandall Canyon Mine.
Figure 7	Possible future trends for iron concentrations in untreated mine discharge water (based on pre-treatment data).
Figure 8	Measured total iron concentrations in mine discharge pre-treatment samples collected from 10 March 2011 to 31 May 2011.

## List of Tables

Table 1	Water quality data for gravity groundwater discharge associated with abandoned coal mines in the Wasatch Plateau coal district.
---------	---

## Photograph Section

Photo 1	Raw Crandall Canyon Mine discharge water collected from sampling port on 18 October 2011 (containers 1, 2, and 3).
Photo 2	Raw Crandall Canyon Mine discharge water collected from sampling port on 18 October 2011 (containers 1, and 3).

## List of Appendices

Appendix	Laboratory reporting sheets
----------	-----------------------------

## 1.0 Introduction

The Genwal Resources Inc. Crandall Canyon Mine is located in the Wasatch Plateau coal field approximately 15 miles northwest of the town of Huntington, Utah (Figure 1). On August 6, 2007, a major event occurred near the Main West pillar section of the Crandall Canyon Mine. The Crandall Canyon Mine is in a period of approved temporary cessation. Because of the obvious unplanned nature of this event, the routing of mine waters in some portions of the mine could no longer be controlled as these areas were rendered inaccessible. On 12 September 2007 the mine pumps were shut-off and discharge of mine water to the surface ceased. During October, November, and December 2007, no mine water discharged from the Crandall Canyon Mine. Commencing in early 2008, mine water began to spill from the mine portals as portions of the sealed mine workings became filled to a topographic level that allowed gravity discharge of the mine water to the surface through the mine portals.

In early 2010, Petersen Hydrologic, LLC performed an initial investigation of iron concentrations in water discharging from the Crandall Canyon Mine. The results of our initial investigation were summarized in a letter report submitted to Mr. Dave Shaver of Genwal Resources Inc.

At the time this initial investigation was performed, iron concentrations in the mine discharge water had recently been increasing. The conclusions of our 25 February 2010 investigation are summarized as follows:

- The initial spike in TDS concentrations observed in the gravity discharge from the Crandall Canyon Mine in early 2008 was believed to be attributable to the dissolution

of soluble minerals or other matter in inundated portions of the mine. Upon flushing of these materials from the flooded mine areas over time, the TDS concentrations of mine discharge water were at that time gradually returning to near-previous levels.

- It was our opinion that the elevated iron concentrations observed in Crandall Canyon Mine discharge waters subsequent to the commencement of gravity drainage from the mine were likely attributable to the oxidation of pyrite or other sulfide minerals in newly inundated mining areas. We believe that the Division is now in agreement with this conclusion. It should be noted that at that time of our initial consultations with the Division, it had been their opinion that the primary source of the iron in the Crandall Canyon Mine discharge water was likely from the rusting of mining machinery and other metals left underground.
- It was considered unlikely that substantially elevated iron concentrations ( $> 1 \text{ mg/L}$ )<sup>1</sup> would persist over long periods of time in the mine discharge water. This conclusion was based on the assumption that either 1) the available pyrite in the flooded mine workings would eventually be consumed through oxidation reactions, and/or 2) the underground environment would eventually become oxygen depleted, minimizing the chemical potential for future pyrite oxidation. Consequently, prolonged discharges of mine waters with concentrations exceeding about 1 mg/L were considered unlikely. This conclusion was also based largely on 1) the fact that sustained, elevated concentrations of iron were not observed in Crandall Canyon Mine discharge water in the roughly 10 years of mine discharge prior to the mine flooding event, and 2) the concept that there is no reason to believe that any substantial change to the fundamental geochemical regime of the rocks and coals in the mine environment occurred during the August 2007 mine collapse event – other than the subsequent

---

<sup>1</sup> At the time of the previous report production, the Crandall Canyon Mine UPDES limit for total iron was 1.0 mg/L. The Utah Division of Water Quality has now assigned a total iron UPDES limit of 1.2 mg/L.

flooding of some mine areas that had not previously been flooded with mine groundwaters when the mine pumps ceased their operation, and the emplacement of rubblized coal in mine openings in the mine collapse area.

## 2.0 New Hydrologic Data

Subsequent to the time of the production of our initial report, continuing routine collection of hydrologic data, including mine discharge water chemical compositions and mine discharge rate data, has occurred.

Genwal Resources, Inc. (Genwal) has continued to perform routine monitoring of mine water discharge rates and mine discharge water quality at the Crandall Canyon Mine (including sites UPDES 002 and the mine discharge water pre-treatment site. The requirements of the UPDES discharge permit specify a monthly monitoring frequency (12 per year) for the mine discharge water. Additionally, personnel from the Division collected 11 supplemental samples on a near-weekly basis during the period 10 March 2011 to 17 May 2011. During the last eight sampling events carried out by Division personnel, Genwal Resources, Inc. and Division personnel collected contemporaneous replicate samples. The mine discharge water samples (pre-treatment) were collected from a sampling manifold that is connected to the bottom of a raw mine water feed pipe at the iron treatment facility.

The Division-collected samples were analyzed by the Utah Unified State Laboratory. The Genwal samples were analyzed by an independent certified laboratory (SGS Mineral Services of Huntington, Utah). The total iron concentrations reported for the samples collected by Genwal and DOGM were generally in good agreement (although the results reported for the DOGM collected samples were always slightly lower than were the Genwal collected samples).

Samples of untreated mine discharge water were collected for laboratory analysis from a sampling port installed on a raw mine discharge water supply line at the Crandall Canyon

Mine iron treatment facility. The sampling port is plumbed into the raw mine water discharge line such that it ‘tees’ from the bottom of the pipe. The port is constructed with a vertical length of pipe (projecting downward) with two gate valves installed to control the flow of water through the port. Water samples are collected from a length of flexible plastic tubing attached to the lower gate valve. While raw mine water flows continuously through the mine water discharge pipe, the attached gate valves are almost always left in the “off” position, being opened only immediately prior to the collection of water samples. A written sampling protocol was not incorporated into the sampling program.

As a part of this investigation, samples of groundwater discharging by gravity drainage from three nearby abandoned coal mines in the Wasatch Plateau coal district were collected and analyzed for iron content. The purpose of this investigation was to gain insight into whether the coal seams of the Blackhawk Formation locally support sustained, long-term discharge of groundwaters with elevated iron concentrations. The three mine sites sampled included the following:

1. Mohrland Portal (King Mine No. 2) located in Cedar Creek Canyon approximately 7 miles east of the Crandall Canyon Mine. The King Mine No. 2 was active from 1896 to 1938. Together with the King Mine, Hiawatha Mine, Blackhawk Mine, and the Miller Canyon prospects, this mining complex produced more than 51 million tons of coal.
2. Winter Quarters Mine, located in Winter Quarters Canyon approximately 16 miles north of the Crandall Canyon Mine. The Winter Quarters Mines were active from 1878 to 1940s. The total coal production has been estimated at 10.8 million tons.
3. Unnamed mine near the Joes Valley Fault in the upper Left Fork of Huntington Creek drainage approximately 4 miles north of the Crandall Canyon Mine (the period of operation and the total coal production amount is unknown).

The nearby Huntington No. 4 Mine, located in Mill Fork Canyon approximately 2 miles south of the Crandall Canyon Mine was also inspected. The Huntington No. 4 Mine was reclaimed in the early 1980s. However, while gravity drainage of water from the reclaimed mine portal area had been observed by the author during the late 1990s, when the site was visited during late 2010, the discharge was no longer occurring.

### 3.0 Presentation of Data

The recent and historic discharge and water quality data from the Genwal Resources, Inc. monitoring activities at the Crandall Canyon Mine have been submitted electronically to the Division's coal water quality database. These data, which are utilized in this investigation, are freely available on the Division's internet site at: <http://ogm.utah.gov/coal/edi/wqdb.htm>.

A time-series plot of total iron concentration data for the Crandall Canyon Mine discharge waters are plotted on Figure 2 (For UPDES 002, Pre-Treatment Water, and Division-collected samples). A plot of the 6-month running average total iron concentrations in untreated Crandall Canyon Mine discharge water is presented in Figure 3. The 6-month running average data analysis technique for total iron concentrations in Figure 3 was implemented to simplify the analysis of longer term trends in the iron data. A 6-month running average value for a given month is obtained by calculating the average of the current month's laboratory result and the five preceding month's laboratory results. (It should be noted that during the second quarter of 2011, during which time a more frequent sampling interval was performed, the running average was calculated using the current and the five most recent data points). The running average data analysis technique typically results in a smoothed data plot which simplifies the identification of long-term trends while minimizing the noise and clutter of short-term data anomalies (such as potential sampling errors).

A plot of the monthly mine water discharge rates at the Crandall Canyon Mine is presented in Figure 4. A plot of the 6-month running average values for the mine discharge is presented in Figure 5 (the period during which there was no discharge from the mine during

late 2007 was omitted from the running average flow rate calculation). A bar graph summarizing the average yearly mine water discharge rates are presented in Figure 6.

As mentioned by the Division in their 2 June 2011 Hydrologic Evaluation Update, several factors have complicated the performance of the mine water discharge flow measurements subsequent to the commencement of gravity mine water discharge at the Crandall Canyon Mine. (Prior to the temporary cessation of mining in 2007, flow measurements were generally performed using an in-line totalizing flow meter and are believed to be accurate). Accordingly, to independently determine the current discharge rate, an instantaneous discharge rate measurement was performed by Petersen Hydrologic, LLC on 18 October 2011. This measurement was performed at the outflow from the treatment facility to the UPDES 002 outflow point using a Marsh McBirney brand electromagnetic current velocity meter and wading rod. The result of that measurement (427 gpm) is similar to values recently reported to the Division by Genwal.

The results of the sampling of gravity mine water discharges from nearby abandoned coal mines is summarized in Table 1.

Laboratory reporting sheets are provided in the Appendix.

#### **4.0 Discussion**

As shown on Figure 2, after peaking in late 2009 and 2010, total iron concentrations in the mine discharge water have shown a gradual declining trend (see also 6-month running average plot in Figure 3). It remains our opinion that the iron in the discharge water is primarily derived from pyrite oxidation reactions in the flooded portions of the now sealed Crandall Canyon Mine. The Division is in agreement with this determination of the source of the iron (see the Division's Crandall Canyon Mine Hydrologic Evaluation Update, June 2, 2011). The observed general downward trend of the iron concentration data are consistent with our initial conclusion regarding the source of the iron and the conclusion that iron

concentrations would decline over time. This decline is likely attributable to the combined affects of 1) chemical reactant depletion and reactant product flushing, and 2) the effects of preferential groundwater flow pathways.

The establishment of preferential groundwater flow pathways in an underground mining environment tends to enhance the effective flushing capacity of a given flow of groundwater as water is flushed continuously along the established pathways. Because of the relatively low rock/water ratio in an actively flushing preferential pathway area, there is an increased flushing potential in the actively flowing areas relative to the more stagnant, portions of the underground mine environment. In contrast, in the more stagnant portions of the underground flow regime (the “dead-end” mine entries for example) there is appreciably less movement of water passing the area, resulting in increased contact time of the stagnant water with surrounding rocks and coals and a greatly diminished potential for the transport of chemical reaction products away from the area.

In the professional experience of the author, it is not uncommon in Utah coal mines for waters gravity flowing from sealed mining areas to have appreciably better water quality characteristics (including lower iron concentrations) than do waters produced from relatively stagnant sealed areas by aggressive pumping and drawing down of pool levels. This effect is likely attributable primarily to the large differences in the rock/water ratios (See Mayo, Petersen, and Kravits, 2000) and increased residence times that exist between relatively stagnant, back-water portions of flooded mine workings and those portions of the flooded mine workings where water flow is actively occurring. In a similar way, it is likely that groundwater quality in those portions of the flooded Crandall Canyon Mine workings where preferential flow pathways to the surface have been established and active water flow conditions exist likely have improved water quality characteristics relative to the more stagnant, isolated portions of the mine.

The Division is wrong to conclude that somewhat elevated sulfate concentrations in the mine discharge water necessarily indicate that the rate of pyrite oxidation is not slowing. It is true

that in some coal-mine geochemical regimes, the oxidation of pyrite is a dominant source of sulfate in associated mine discharge waters (and indeed, such may be the case in the Crandall Canyon Mine). However, it is not uncommon in coal mining environments that the dissolution of the evaporate minerals such as gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) or anhydrite ( $\text{CaSO}_4$ ) can also be a major or principal source of sulfate in mine discharge waters. Locally in the Wasatch Plateau and adjacent areas, dissolution of other mineral species including thenardite ( $\text{Na}_2\text{SO}_4$ ), mirabilite ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ), and epsomite ( $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ) may also be important sources of sulfate in groundwater. In the Division's analysis they incorrectly interpret Mayo, Petersen, and Kravits (2000) as stating that "*most sulfate in minewater discharge results from pyrite oxidation*". The findings of that investigation were from a case study of the Sufco Mine. In that study, while sulfide mineral oxidation was the primary source of sulfate in some portions of that mine, in other locations it was probably less significant than from the dissolution of gypsum or from other sources. The relative contribution of pyrite dissolution to sulfate concentrations described in the Journal of Hydrology paper was determined using site-specific solute and isotopic geochemical modeling (including  $\delta^{34}\text{S}$  isotopic analysis). Indeed, as cited in the journal article, "Dissolution of gypsum, both native and gypsum dust previously used as rock dust, is also a significant contributor of  $\text{SO}_4^{2-}$ ." Accordingly, it would not be correct to assume, as the Division did, that the modest increases in the sulfate concentrations in the Crandall Canyon Mine discharge water relative to surrounding groundwaters is wholly derived from pyrite oxidation.

As indicated in our previous report (Petersen Hydrologic, 2010), groundwater that flooded a large, sealed portion of the Skyline Mine (located about 11 miles north of the Crandall Canyon Mine) did not result in sustained discharges of mine water with elevated iron concentrations (see Figure 6 in Petersen Hydrologic (2010)). At the Skyline Mine location, fault-related groundwater inflow sources flowed into the mine workings and subsequently filled the sealed mining area by gravity flow. Upon reaching the elevation of the pumping station by gravity flow, the mine water was then pumped to the surface. After peaking in mid-2006, the iron concentrations in the mine discharge water declined gradually until

reaching non-detect levels in mid 2009 (a period of approximately 3 years). It is noteworthy that this time frame is not inconsistent with the current trends in declining total iron concentrations at the Crandall Canyon Mine. The fact that the peak total iron concentration in the Skyline CS-14 discharge water was lower than that at the Crandall Canyon Mine may be a result of the appreciably greater magnitude of the flows encountered at the Skyline Mine location (several thousand gallons per minute at Skyline as compared to several hundred gallons per minute at Genwal – which is reflective of a considerably different rock/water ratio).

It is noteworthy that sulfate concentrations in the Crandall Canyon Mine discharge water (which ranged from 156 to 185 mg/L during the first 6 months of 2011) are not elevated relative to mine discharge waters from other Utah coal mines. Based on public information available from surrounding coal mines (UDOGM, 2011), it is evident that sulfate concentrations in mine discharge waters from surrounding coal mines that appreciably exceed 200 mg/L with total iron concentrations well below 1.2 mg/L are common. Notably, the sulfate concentration of mine water discharging from the Mohrland Portal (as monitored by the Bear Canyon Mine from 1994 to 2010; UDOGM 2011) averaged 329 mg/L, while total iron concentrations were consistently low (averaging less than 0.06 mg/L and not exceeding 0.10 mg/L). Most importantly, it should be stressed that regardless of the geochemical evolutionary pathway by which some of the sulfate in the Crandall Canyon Mine is derived, it is readily apparent that the total iron concentrations in the mine discharge water have declined appreciably in recent months (Figures 1 and 2) which is consistent with our previous projections of future declining total iron concentrations. The Division is wrong to conclude that iron concentrations have not declined and that the observed sulfate levels confirm that conclusion.

The Division's emphasis on geochemical reactions to explain the total iron content of the mine discharge is misplaced. The concentration of iron hydroxide particles in the mine discharge water at the mine mouth is largely controlled by the fluid flow regime within the mine, and not by the availability of chemical reactants or rates of reaction throughout the

mine. The emergence of most of the iron in the discharge as solid iron hydroxide, rather than as aqueous dissolved iron species, demonstrates that the sequence of geochemical reactions discussed has largely reached its (irreversible) endpoint within the mine prior to discharge to the mine mouth. While the chemical reactions discussed at length by the Division predict that pyrite will dissolve upon contact with oxygenated water, and that a corresponding amount of solid iron hydroxide will subsequently form, they cannot predict the concentration of solid iron hydroxide in the discharge water.

The iron hydroxide particles emerge in the discharge because they are flushed from the mine workings by flowing water. Accordingly, they are only flushed from those portions of the flooded mine workings where the current velocity exceeds the settling velocity of the solid particles. If oxygenated water has reached the remainder of the flooded workings, and if pyrite is present, any iron dissolved and subsequently precipitated simply settles to the floor and does not contribute to the amount of iron reaching the surface (assuming an ample availability of oxygen as the Division asserts).

The flushing mechanism is significant because it demonstrates that only those portions of the flooded mine workings where the water current is strong enough to suspend iron hydroxide particles will contribute to observed total iron levels in the discharge (assuming a complete precipitation to ferric hydroxide in the presence of oxygenated water). Even if a large supply of unreacted pyrite exists elsewhere in the flooded workings, any iron liberated by its oxidation will not contribute to the observed iron discharge. Therefore, the Division's (unsupported) assumption that large amounts of pyrite exist in the mine has little value in predicting the extent and duration of iron-containing discharge at the mine mouth. It is more reasonable to conclude that the discharge of iron will persist only until the available precipitated iron has been flushed out of that portion of the mine where the current is swift enough to keep the particles suspended in the flow.

The Division is wrong to conclude that the recent total iron data, and in particular the single data point associated with a spike in total iron concentration observed on 27 April 2011,

provide a scientific basis for concluding that total iron concentrations are not declining in the Crandall Canyon Mine discharge water. It is noteworthy that sharp, short-lived upward spikes in the total iron concentrations in samples from the mine discharge water have occurred periodically in the sampling history (Figure 2). However, downward spikes (relative to a more constant lower base concentration) are only rarely observed. It is my professional opinion that these upward spikes are likely a result of the inclusion of solid iron-bearing particulates in the collected water samples which elevate the measured total iron concentration above the current base (non-spike) level. This conclusion is supported by a close examination of the iron concentration data associated with a total iron spike (6.68 mg/L) that occurred on 27 April 2011 (UDOGM, 2011). When the total iron concentration was monitored only six days later (on 3 May 2011), the concentration was only 2.05 mg/L. It seems exceedingly unlikely that the bulk chemical composition of the iron concentration of the large volume of water held in the mine varied by more than 325% during that six day period. Rather, it seems much more likely that the measured spike was attributable to the inclusion of suspended iron hydroxide particulate matter in the collected water sample, which could have originated from any of several possible sources. As shown on Figure 8, for the Division to conclude that data from an anomalous single sampling event, which is bracketed both prior to and after the anomalous event by relatively constant data with a much lower total iron concentration from at least 12 monitoring events (22 laboratory analyses) over a time period of just 82 days does not seem justified.

To understand this condition, it should be remembered that the iron measured in a total iron (or total recoverable iron) analysis includes two fractions. These include 1) the iron that is present in the dissolved (filterable) form in the water, and 2) any additional iron that may be included in the water sample, which can include solid, iron-bearing particulate matter. A laboratory dissolved iron analysis measures the dissolved iron (ferrous and/or ferric ionic species) in a water sample. The dissolved iron analysis is performed by first filtering the water sample through a 0.45 $\mu$ m filter which removes any particles larger than 0.45 $\mu$ m (which would include any suspended iron hydroxide particles present in the sample), leaving only the dissolved ionic iron species in the water sample (note that the average dissolved iron

concentration in the Crandall Canyon Mine discharge water for the first six months of 2011 is only 0.36 mg/L).

By comparison, a total iron analysis is performed on a raw water sample that includes the dissolved fraction plus any particulate matter that may be present at the time of sampling. Such matter could include dirt, rust particles from metal pipes, or suspended iron-hydroxide precipitate which is pervasive throughout the Crandall Canyon Mine discharge piping, treatment system, and sampling ports and apparatus. Prior to the performance of the total iron analysis, the contents of the sample (water and any included particulate matter) are digested under heat using a strong acid to convert solid iron-containing matter into ionic iron species that are included in the analysis. Accordingly, any iron contained in the particulate matter at the time of sampling is included in the total iron laboratory result.

As part of this investigation, we have specifically evaluated the 27 April 2011 total iron spike in the Crandall Canyon Mine discharge pre-treatment water sample (Figure 2). On 18 October 2011 the mine discharge pre-treatment sampling site located at the Crandall Canyon Mine iron treatment facility was visited and inspected by the author. Information regarding previous sampling procedures followed by Genwal and Division personnel during the collection of pre-treatment water samples was reviewed with Genwal personnel (Personal communication, Dana Marrelli, 2011). During this visit, a sample of the raw mine water (pre-treatment) was collected. In order to assure that as much particulate matter was flushed from the sampling port as possible, an extended purging of the sampling port was performed during this sampling event. For visual inspection of the progression and completeness of the purge, new, unpreserved plastic bottles were filled with the purge water at approximately 15-minute intervals. Sample containers filled with water from the first approximately 45 minutes of the purge were subsequently photographed (See Photograph Section of this report). Upon visual inspection, it is immediately apparent that the bottle filled with water after a purge period of approximately 15 minutes contained appreciably more suspended iron hydroxide particulate matter than did the sample collected after 30 minutes of purging. After approximately 45 minutes of purging, the collected sample contained visibly less iron

particulate matter than did the sample collected after approximately 30 minutes of purging, though the difference was less substantial than between the first two samples.

The significance of this observation is that it clearly suggests that iron hydroxide particulates were being flushed from the sampling apparatus for at least the first ½ hour subsequent to the opening of the sampling port valve. This condition is likely related to the design of the sampling port, with the apparatus (which likely contains lots of “nooks and crannies” associated with the valves and couplings) being suspended below the larger raw water feed line. In other words, iron hydroxide particles can accumulate in this “sump” during the extended periods of time the valve is left in the “off” position. Depending on the fluid velocities, the degree of solidification or compaction of the particulate matter within the port, and the amount of iron particulate that may have accumulated since the port was last purged, it may require an appreciable amount of time for the particulate matter to be completely flushed from the sampling system. Additionally, it is possible that iron hydroxide particulate matter may accumulate in some locations within the raw water feed pipes upstream of the sampling port. While some particles may adhere to the inside of a pipe under the constant, laminar flow conditions, when the fluid dynamics in the pipe are altered by the opening of the sampling port valve (e.g. inducing turbulence) some of these particles may become dislodged and flow into the sampling port. In the absence of any written protocol, Genwal personnel have routinely collected samples of the pre-treatment water after a purge of only a few to several minutes. It is apparent that in collecting their replicate samples of mine discharge pre-treatment water, Division personnel likewise may not have allowed a sufficient purge time before collecting their samples (Personal communication, Dana Marrelli, 2011). It is interesting to note that, as indicated by Genwal personnel, it was generally the case that when the replicate samples of the pre-treatment water were collected by Genwal and the Division, the Division samples were typically collected after the Genwal sampling had been completed. Whether the additional purge time that transpired between the collection of the Genwal samples and the later collection of the Division samples contributed to the observed uniformly lower total iron concentrations determined from the Division’s samples is unknown. However, it seems likely that during the 27 April 2011 replicate monitoring event,

the purge state of the sampling port at the time of sampling was likely not complete and this condition may have resulted in the iron spike determined at the laboratory. This conclusion is based on the fact that the total iron samples from that date were collected perhaps a few minutes apart. However, the total iron concentrations measured by Genwal and the Division (6.68 mg/L and 5.0 mg/L) vary by 1.68 mg/L. The analytical laboratory utilized by Genwal (SGS Minerals Services of Huntington, Utah) reports a detection limit of 0.05 mg/L for the total iron analysis. Assuming similar accuracy in the total iron determination performed by the Utah Unified State Laboratory, then it follows that the total iron concentrations in the two sample containers at the time of collection were not the same, and that the sample collected by the Division after the collection of Genwal's sample contained less total iron. This observation suggests the possibility that the samples collected on 27 April 2011 were likely collected prior to the complete flushing of the sampling port apparatus. Accordingly, the elevated iron concentrations measured on that date were likely associated with the inclusion of an unrepresentative amount of iron hydroxide particulate matter flushing from the sampling port, and not as a result of a spike in the total iron concentration in the Crandall Canyon mine discharge water itself (in other words, this was likely a sampling error).

While we cannot determine with certainty the causes of all of the total iron spikes that have occurred in the past, it is my professional opinion that the lack of an adequate purging of the sampling port, raw mine water feed piping, or other portions of the sampling apparatus could likely have been largely responsible for the observed spikes that have occurred while the sampling apparatus has been operative in its current condition.

It should be noted that since March 2010 total iron concentrations of the mine discharge waters monitored at UPDES 002, which have undergone chemical treatment at the mine's iron treatment facility, have been continuously below 1 mg/L and in compliance with the UPDES permit requirements.

While it seems to be the position of the Division that extreme, unprecedented changes to the groundwater regimes at the Crandall Canyon Mine occurred as a result of the August 2007

“catastrophic mine collapse”, we do not see evidence that such is the case. This conclusion is based on the fact that:

1) The rate of discharge from the Crandall Canyon Mine at the commencement of mine water gravity discharge is essentially the same as it was just prior to the 2007 collapse event, and the gradual decline in discharge rates that began in the early 2000s (Figures 4, 5, and 6) continues, suggesting that interception of groundwater from any potential newly-fractured overlying horizons resulting from the collapse has not occurred. It is noteworthy that in down-hole videos of the emergency mine rescue drill holes in the collapse area that were reviewed by the author, it was apparent that the coal rubble present in the entryways likely originated primarily from rib bursts, while the mine roof rock appeared to be largely intact. Observations of video footage of the rock strata within the boreholes immediately overlying the coal seam likewise did not appear to have been catastrophically impacted.

2) The Division cites an MSHA report<sup>2</sup> indicating that the area of collapsed pillars associated with the 2007 event is on the order of 40 acres, which is not dissimilar in general scale to the size of a typical Crandall Canyon Mine longwall panel, and is much smaller than the adjacent mining areas situated immediately to both the north and south, which experienced years of longwall-related subsidence,

3) Four years of quarterly hydrologic monitoring data collected from springs and streams overlying and surrounding the area of the collapse event have not shown any pronounced changes in discharge rates, water quality characteristics, or any other observable conditions that could be attributed to the 2007 collapse event (UDOGM, 2011).

---

<sup>2</sup> Genwal Resources, Inc. does not endorse the accuracy or the conclusions in the MSHA report referenced by the Division.

The Division indicates in its 7 June 2010 report that in the future “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”. Their conclusion is entirely speculative. While it is possible that some additional subsidence of the overburden overlying the Crandall Canyon Mine workings could occur in the future, the fact that now more than four years have transpired without the occurrence of any major ground movement seems to minimize the likelihood of such an occurrence in the future. Particularly, the potential for movement within the mine workings of a magnitude that would cause a substantial change to the topographic gradient of the mine floor, to the extent that previously dry mining areas would become flooded, seems highly unlikely.

In the findings section of their 2 June 2011 hydrologic evaluation update, the Division finds that “The Crandall Canyon Mine has been discharging 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”. This conclusion is incorrect. As plotted in Figure 4, it is readily apparent that after peaking in the early 2000s, the mine discharge rate plot indicates a downward trend beginning around 2004. This trend is more readily discernable in the 6-month running average plot for mine discharge shown in Figure 5. Additionally, the yearly-average mine discharge rates plotted in Figure 6 show an obvious generally declining trend, and do not correlate with recent climatic trends. It is notable from Figure 6 that the average yearly discharge rate for 2011 (first 6 months) is less than half the average rate for 2001, clearly demonstrating the declining trend in mine water discharge rates. Although a detailed analysis of the reasons for the declining mine discharge water flow rates is beyond the scope of this investigation, the observed declines are likely the result of two main factors. These include 1) with a decrease in the mining rate or a cessation of mining activities, the potential for the underground interception and exposure of water-bearing features in the subsurface is minimized or ceases, and 2) over time it is common for discharge rates from intercepted underground water-bearing features in the Wasatch Plateau coal district to decline as the contained water is gradually drained.

Genwal Resources personnel indicate that recent increases in the mine discharge rate seem to correlate with the passage of weather fronts or the onset of cold weather (Personal communication, Dana Marrelli, 2011). It is important to note that these flow rate changes occur even in the absence of *any* associated precipitation. This seems to suggest the likelihood that the temporary increases in mine water discharge rate are associated with barometric pressure effects acting on the underground mine pool. There is no indication that the occasionally observed increases in flow are in any way tied to any potential nearly immediate infiltration of precipitation waters into the underground mine workings.

Long-term iron discharges from coal mines in the Blackhawk Formation in Utah's Wasatch Plateau mining district are not known to occur. In order to better understand whether the coal seams of the Blackhawk Formation locally support sustained, long-term discharge of groundwaters with elevated iron concentrations (as assumed by the Division), gravity discharges from three abandoned coal mines were inspected and sampled as part of this investigation. Gravity discharge of mine groundwater has occurred from each of the three visited mines for many years. The discharge rates for these mines range from a few gallons per minute at the Winter Quarters and Left Fork mines to several hundred gallons per minute at the Mohrland Portal. Neither total nor dissolved iron concentrations at any of the three mine discharges exceeded 0.05 mg/L (Table 1). In other words, the iron concentrations in these abandoned mine discharges are at least *24 times* below a 1.2 mg/L UPDES limit. While this information does not of itself indicate when discharge of groundwater with elevated iron concentrations at the Crandall Canyon Mine will abate, it does strongly support the conclusion that the geochemical regimes in these three surrounding lower Blackhawk Formation coal mines do not support long-term discharges with elevated iron concentrations.

## 5.0 Projections of Likely Future Iron Concentrations

Prior to a discussion of potential future iron concentration trends at the Crandall Canyon Mine, it is important to emphasize that because the mine workings are sealed, it is not

possible to observe physical conditions within the Crandall Canyon Mine workings. Consequently, our capability to fully characterize the underground hydrogeochemical regime is limited. However, based on the existing data set and upon our previous professional experience relating to iron geochemical behavior in underground mining environments, as part of this investigation, we have provided projections of possible future trends in iron concentrations in the Crandall Canyon Mine discharge water. It should be emphasized that the projections provided here should not be considered to be absolute predictors of future iron concentrations over time in the mine. Rather the plotted trends are provided to show reasonably plausible future trends for future iron concentrations based on the existing data and professional experience. Importantly, these trends are provided to illustrate the likely magnitude of future trends (i.e., with concentrations likely declining to levels below 1.2 mg/L within in a few years, not decades). These trends are shown graphically on Figure 7.

The first projection shown on Figure 7 (in blue) shows a mathematically calculated statistical linear regression of the pre-treatment data for the period 21 April 2010 through 18 October 2011. The linear regression line (which essentially assumes that the recent total iron concentration trends will continue into the future) intercepts the 1.2 mg/L UPDES limit at approximately mid-2012. This projection appears visually consistent with the existing historical data assuming that the declining concentration limb of the recession curve is quasi-symmetrical with the increasing limb of the curve.

It is likely that the future trend in the total iron concentration will follow an exponential decay curve. Such a decay curve was observed previously in the Crandall Canyon Mine discharge data for the total dissolved solids concentration of mine discharge water subsequent to the onset of gravity drainage (See Figure 3 of the Petersen Hydrologic (2010) report). A reasonably plausible exponential decay curve trend for total iron concentrations in the Crandall Canyon Mine discharge water is shown in green on Figure 7. The plotted exponential decay curve trend intersects the 1.2 mg/L total iron concentration line at approximately the end of 2013. Again, it should be emphasized that this projection is intended for use as a reasonable predictor of the order of future decline rates and is not

intended as an absolute prediction of future concentrations. However, it should be noted that because the most recent total iron concentration in the mine discharge water (2.15 mg/L) is only 0.95 mg/L above the UPDES discharge limit, it would be difficult to draw a reasonable hypothetical decay curve that would intersect the 1.2 mg/L line at a time significantly further in the future than that plotted on Figure 7.

## 6.0 Conclusions

- It remains our opinion that the elevated iron concentrations observed in Crandall Canyon Mine discharge waters are likely attributable to the oxidation of pyrite or other sulfide minerals in flooded portions of the mine. While the minor dissolved iron fraction of the total iron present in the mine discharge water is transported in the aqueous solution, the more substantial iron hydroxide particulate fraction is transported only where the water current is sufficient to flush the solid particles to the discharge location.
- We are not aware of any special geologic conditions at the Crandall Canyon Mine that would result in probable long-term elevated concentrations of total iron in the mine discharge water. The fact that historic (pre-2007) total iron concentrations in Crandall Canyon Mine discharge waters were consistently low, even though most of the mine discharge water was historically collected from the mine floor after running considerable distances through mine longwall gob areas and elsewhere over the mine floor, does not suggest that there is any unusual iron-generating potential in the Crandall Canyon Mine geochemical environment relative to other mines in the region.
- An investigation of gravity mine-water discharges from three surrounding abandoned coal mines suggests that long-term discharges with elevated iron concentrations from the coal seams of the lower Blackhawk Formation will not occur.

- It remains my professional opinion that the iron concentrations in the Crandall Canyon Mine discharge water will likely continue to decline over time as the necessary reactants are gradually consumed and flushed from actively flowing portions of the flooded underground mine workings. It is also my professional opinion that iron concentrations in the mine discharge water will likely not exceed the UPDES limit of 1.2 mg/L for a prolonged period of time.
- Based on the projections presented in Figure 7, it is apparent that the iron concentrations in the Crandall Canyon Mine discharge water will likely drop below 1.2 mg/L within a reasonable timeframe, likely on the order of a few years (not decades). Extrapolating a future exponential decay curve from recent trends, as shown on Figure 7, this condition could occur perhaps by the end of 2013. In my professional opinion, there is no reasonable potential for a “perpetual” discharge of mine water with elevated total iron concentrations.
- Elevated sulfate concentrations do not necessarily evidence high rates of continuing pyrite oxidation. In their 2 June 2011 findings, the Division indicates that “there is no indication that the rate of pyrite oxidation is slowing”. In the general sense, this conclusion is not consistent with the total iron data that has been presented to the Division, which clearly shows a declining iron concentration in mine water since about early 2010. The Division apparently bases this conclusion largely on the sulfate concentrations of the mine discharge water (which conclusions are based at least in part on a flawed interpretation of the Mayo, Petersen, and Kravits (2000) *Journal of Hydrology* article). Regardless of the geochemical evolutionary pathway by which some of the sulfate in the Crandall Canyon Mine is derived, it is readily apparent that the total iron concentrations in the mine discharge water have declined appreciably in recent months, which is consistent with our previous projections of future declining total iron concentrations.

- Iron concentrations are declining toward compliance levels. We find no basis for the Division’s assertion in their 2 June 2011 finding that “iron concentrations have not declined”. This conclusion appears entirely inconsistent with the data plotted in Figures 2 and 3. We vigorously disagree with this finding.
- There are no data to support an expectation of perpetual iron-containing discharge from the Crandall Canyon Mine. The Division’s 2 June 2011 finding that “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” seems to ignore the current trends in total iron data as plotted in Figures 2 and 3. We vigorously disagree with this finding.

## 7.0 References Cited

Mayo, A.L., Petersen, E.C., Kravits, C., 2000, Chemical evolution of coal mine drainage in a non-acid producing environment, Wasatch Plateau, Ut., Journal of Hydrology 236: 1-16.

Petersen Hydrologic, LLC, 2010, Investigation of iron concentrations in mine discharge waters from the Genwal Resources, Inc. Crandall Canyon Mine, unpublished consulting letter report to Mr. Dave Shaver of Genwal Resources, Inc.

UDOGM, 2011, DOGM on-line water quality database,  
<http://ogm.utah.gov/coal/edi/wqdb.htm>

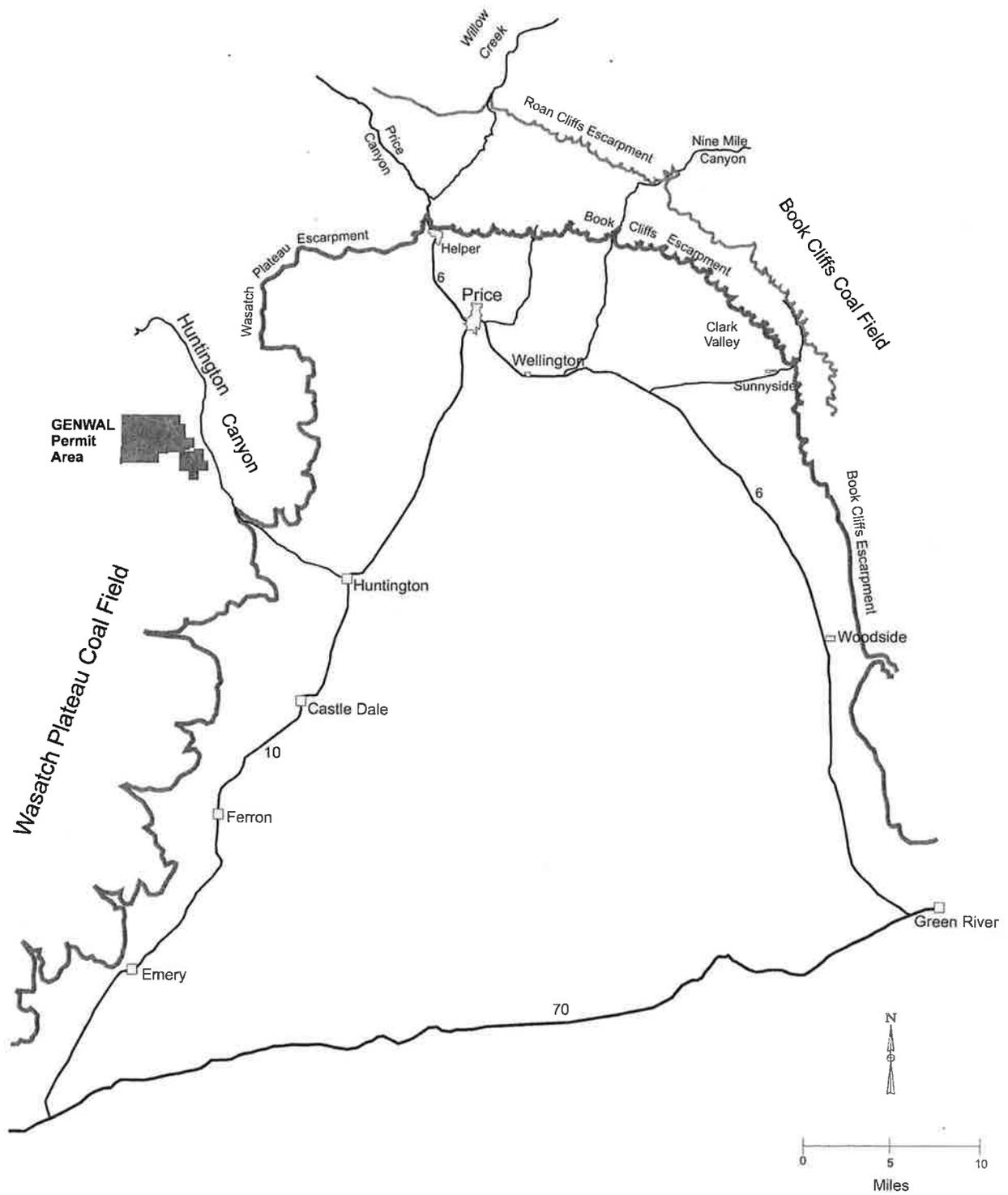


Figure 1 Location of the Genwal Resources, Inc. Crandall Canyon Mine.

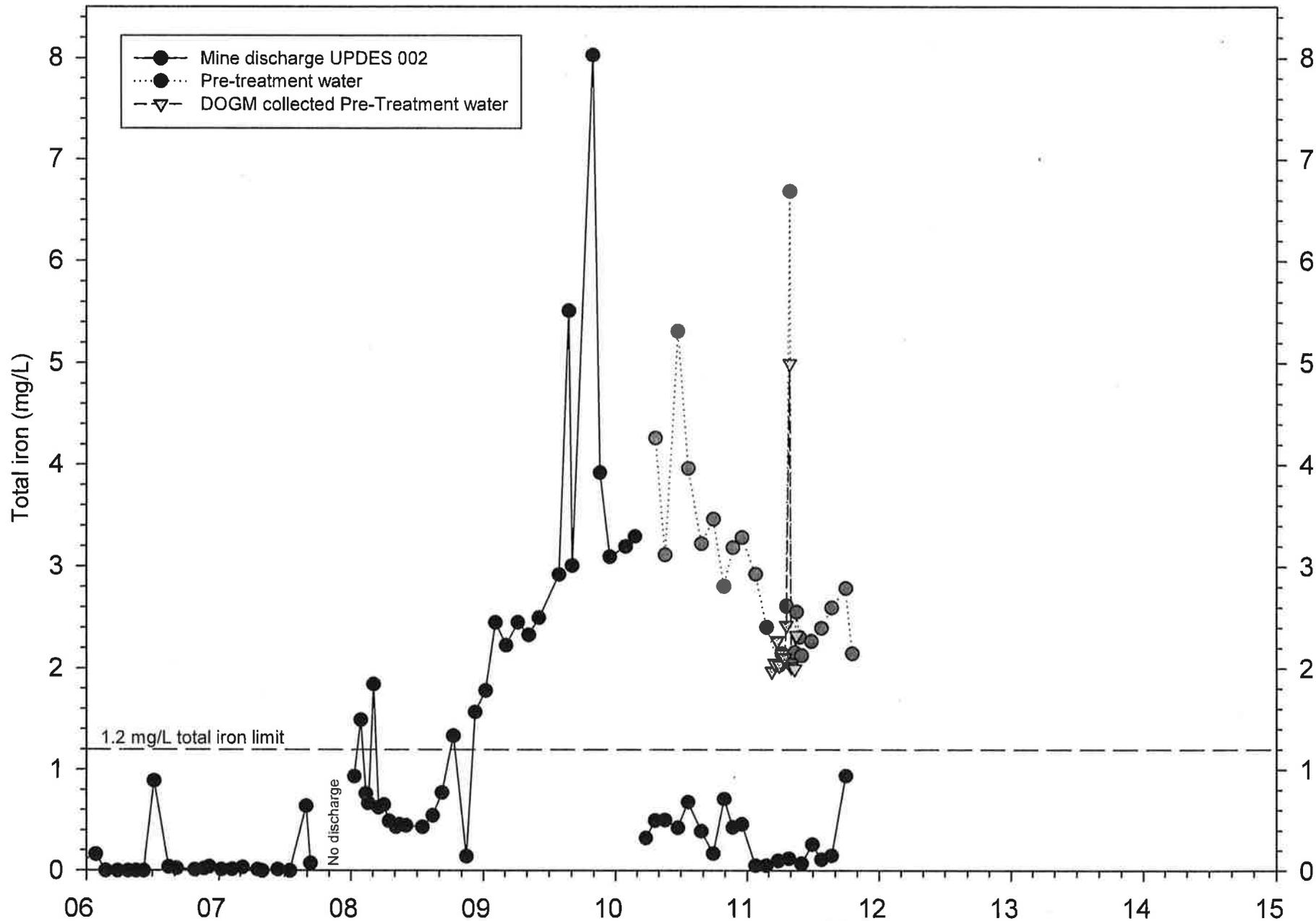


Figure 2 Plots of total iron concentrations in Crandall Canyon Mine discharge water and treated mine discharge water.

### UPDES 002 and UPDES 002 Pre-Treatment (6-month running average)

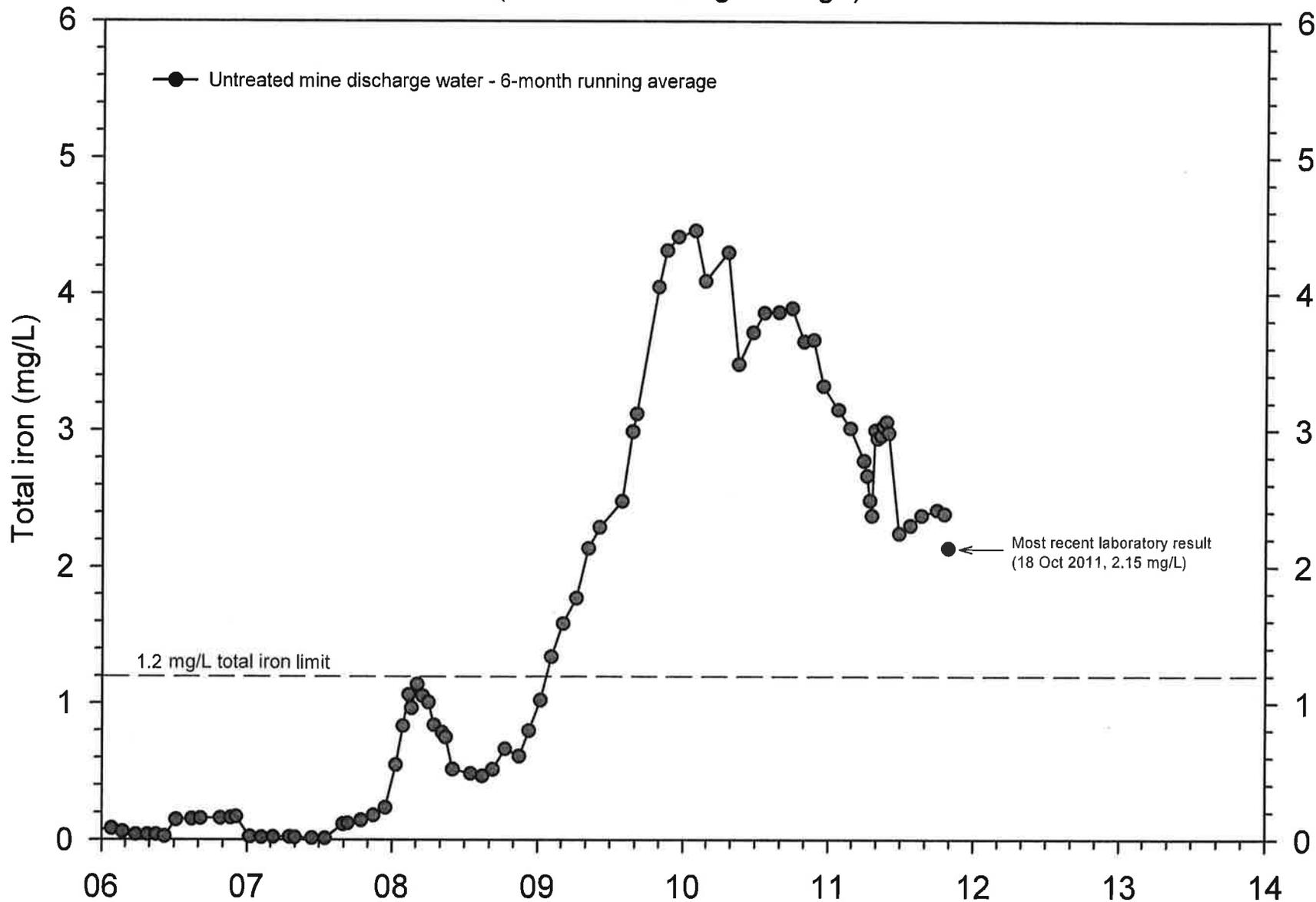


Figure 3 Plot of 6-month running average of total iron concentrations in untreated Crandall Canyon Mine discharge water.



# Crandall Canyon Mine Mine water discharge rate (6-month running average)

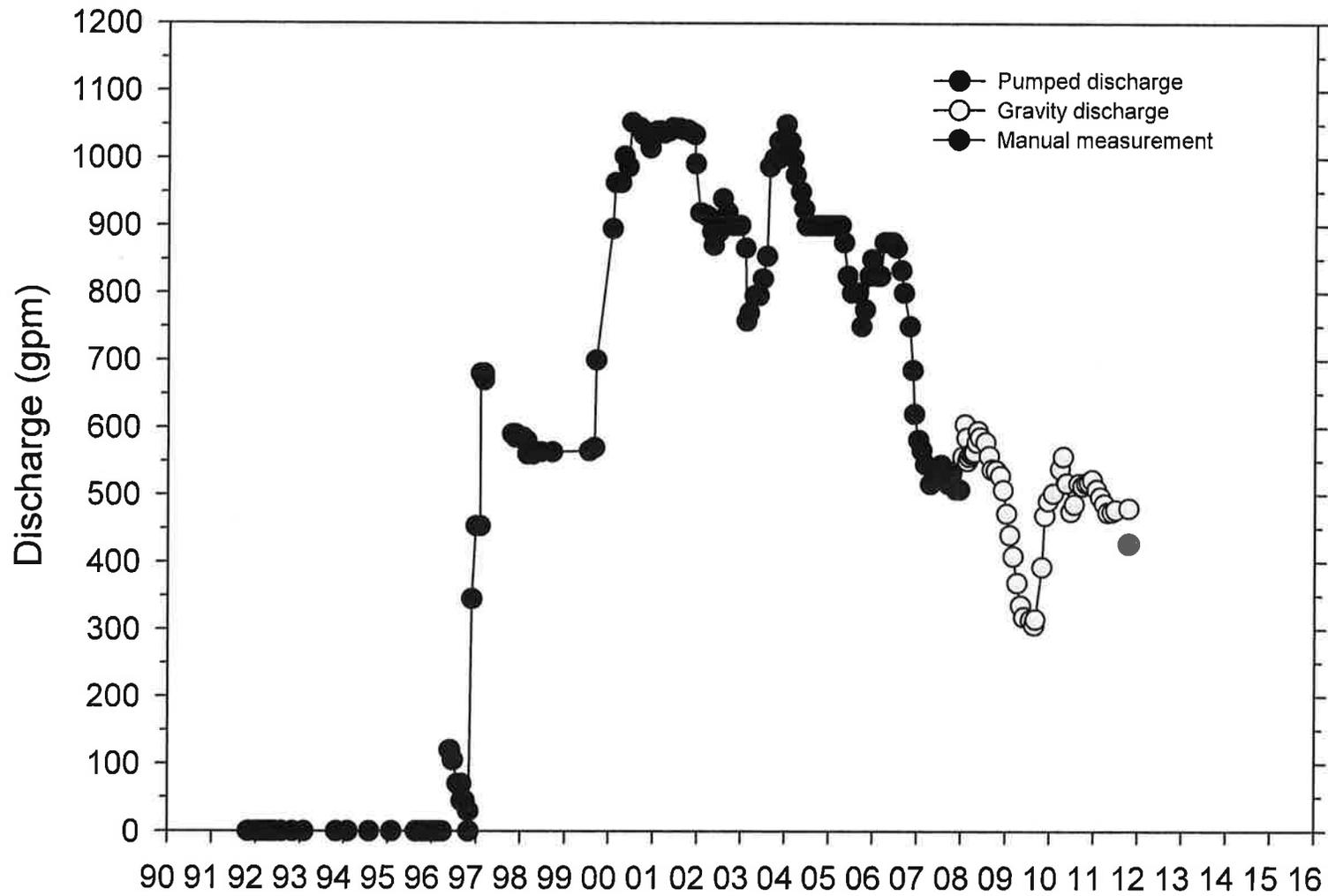


Figure 5 Plot of Crandall Canyon Mine discharge rates, 6-month running average.

## Crandall Canyon Mine Average yearly mine discharge rate

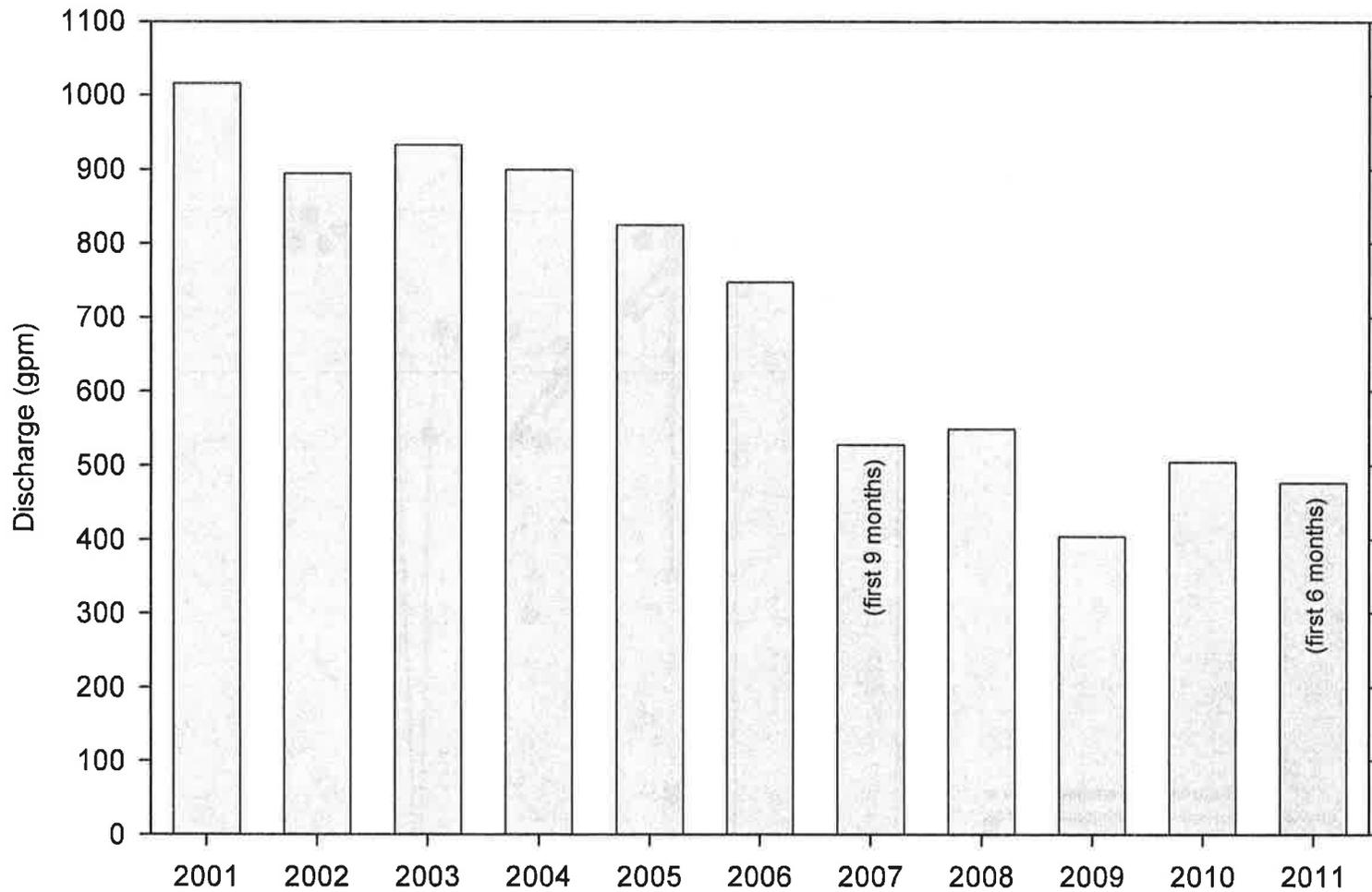


Figure 6 Average yearly mine water discharge rates for the Crandall Canyon Mine.

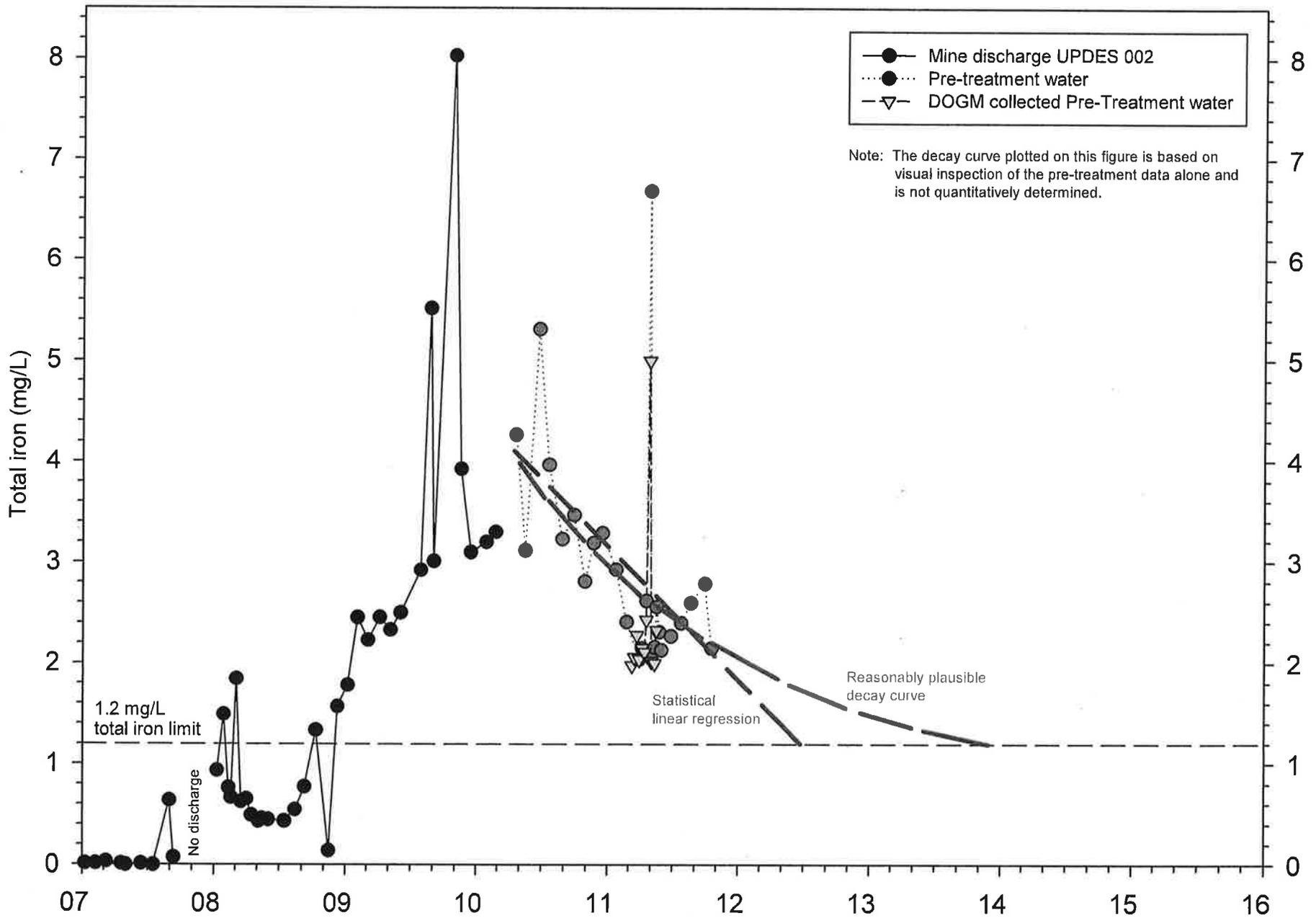


Figure 7 Possible future trends for iron concentrations in untreated mine discharge water (based on pre-treatment data).

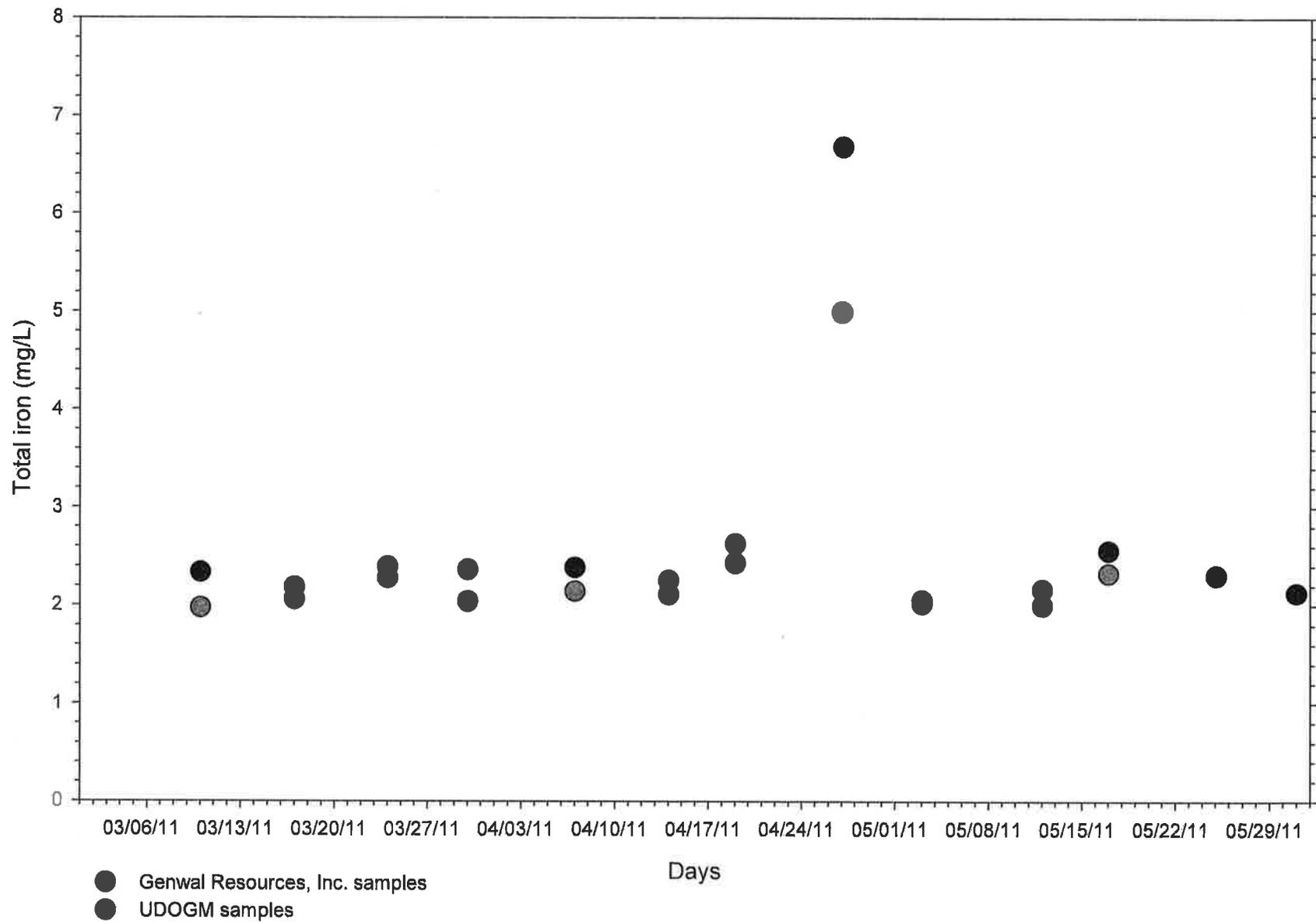


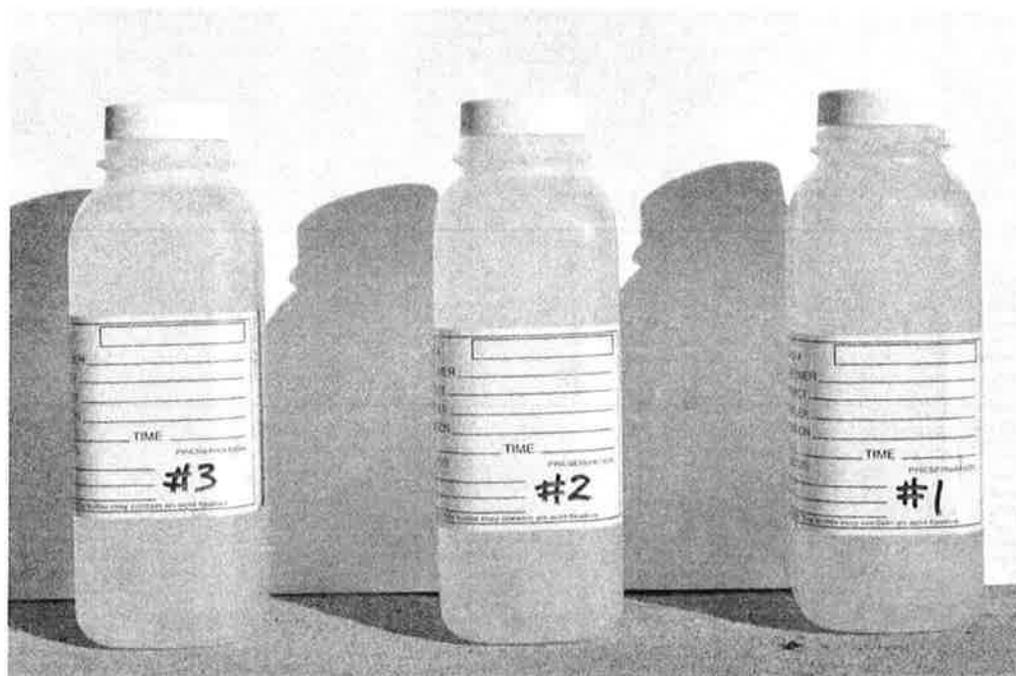
Figure 8 Measured total iron concentrations in mine discharge pre-treatment samples collected from 10 March 2011 to 31 May 2011.

**Table 1 Water quality data for gravity groundwater discharges associated with abandoned coal mines in the Wasatch Plateau coal district.**

	Location	UTM, Nad 27		Sample date	T (°C)	pH S.U.	Cond. (µS/cm)	D.O. (mg/L)	Fe (d) (mg/L)	Fe (t) (mg/L)
Mohrland Portal	Sec. 8, T. 16 S., R. 8 E.	496623	4365707	23-Sep-10	12.0	7.02	1052	7.37	<0.03	0.05
Winter Quarters Mine portal	Sec. 6, T. 13 S., R. 7 E.	483785	4396466	17-Sep-10	8.5	6.65	1285	6.41	<0.03	<0.05
Joes Valley Mine spring (Left Fork Huntington)*	Sec. 2, T. 15 S., R. 6 E.	480985	4376891	20-Oct-10	10.7	8.25	528	7.75	<0.03	<0.05

\* Note: The groundwater discharge observed at this location emanates near the reclaimed mine portal.  
However, it is not certain that this water is directly sourced from the old mine workings.

# Photographs Section

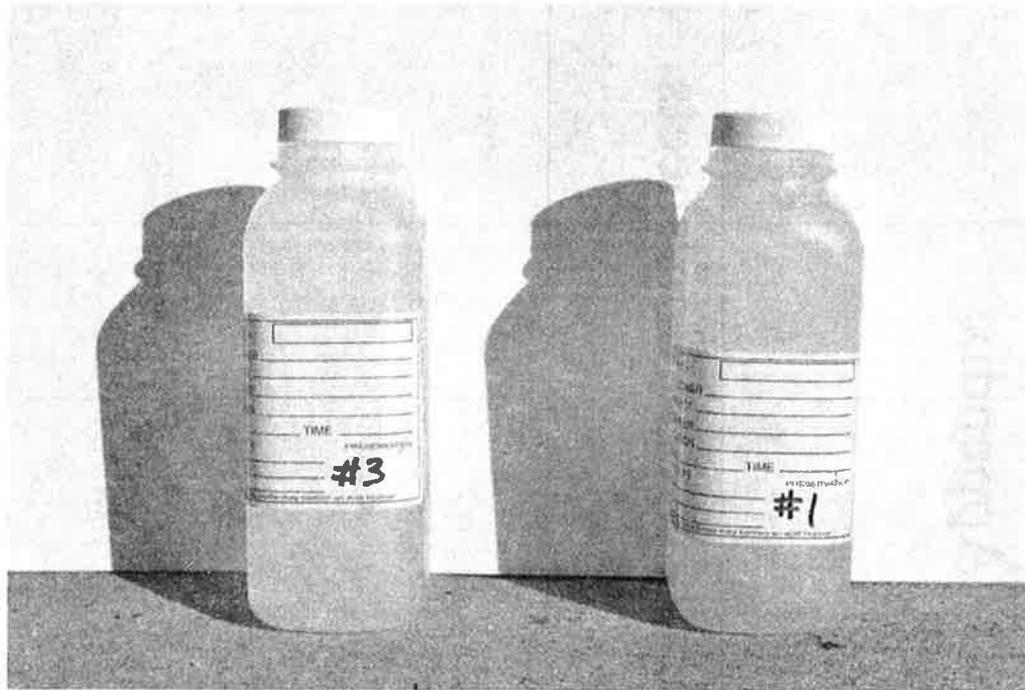


Sampling port purged  
Approx. 45 Minutes

Sampling port purged  
Approx. 30 Minutes

Sampling port purged  
Approx. 15 Minutes

Photograph 1 Raw Crandall Canyon Mine discharge water collected from sampling port on 18 October 2011.



Sampling port purged  
Approx. 45 Minutes

Sampling port purged  
Approx. 15 Minutes

Photograph 2 Raw Crandall Canyon Mine discharge water collected from sampling port on 18 October 2011.

# Appendix

## Laboratory reporting sheets



Analysis Report

October 26, 2011

GENWAL RESOURCES INC
794 "C" CANYON ROAD
EAST CARBON UT 84520

Page 1 of 1

Client Sample ID: PRE 002
Date Sampled: Oct 18, 2011
Date Received: Oct 19, 2011
Product Description: WATER
Sample ID By: Genwal Resources Inc.
Sample Taken At: PRE 002
Sample Taken By: E.Peterson
Time Received: 1325
Time Sampled: 1645
Mine: 8

Comments: Dissolved Metals Field Filtered

SGS Minerals Sample ID: 782-1110378-001

Table with columns: TESTS, RESULT, UNIT, METHOD, REPORTING LIMIT, ANALYZED DATE, TIME, ANALYST. Rows include Sulfate, SO4, Total Dissolved Solids, Chloride, Cl, Alkalinity, mg CaCO3/L (pH 4.5), Carbonate Alkalinity as CaCO3, Bicarbonate Alkalinity as CaCO3, METALS BY ICP, Calcium, Ca - Dissolved, Iron, Fe - Dissolved, Iron, Fe - Total, Magnesium, Mg - Dissolved, Potassium, K - Dissolved, Sodium, Na - Dissolved.

Handwritten signature of Lab Supervisor

Lab Supervisor
Domenic Ibanez
Lab Supervisor

SGS North America Inc. Minerals Services Division
2035 North Airport Road Huntington UT 84528 t (435) 653-2311 f (435)-653-2436 www.sgs.com/minerals

Member of the SGS Group (Société Générale de Surveillance)

This document is issued by the Company under its General Conditions of Service accessible at http://www.sgs.com/terms\_and\_conditions.htm. Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. Any



Analysis Report

March 07, 2011

PETERSEN HYDROLOGIC LLC  
2695 NORTH 600 EAST  
LEHI UT 84043

Page 1 of 1

Client Sample ID:	Joes Valley Mine Spring	Sample ID By:	Petesen Hydrologic LLC
Date Sampled:	Oct 20, 2010	Sample Taken At:	Joes Valley Mine Spring
Date Received:	Nov 18, 2010	Sample Taken By:	E. Petersen
Product Description:	WATER	Time Received:	1720
		Time Sampled:	1830

SGS Minerals Sample ID: 782-1106855-001

<u>TESTS</u>	<u>RESULT</u>	<u>UNIT</u>	<u>METHOD</u>	<u>REPORTING</u>	<u>ANALYZED</u>		
				<u>LIMIT</u>	<u>DATE</u>	<u>TIME</u>	<u>ANALYST</u>
<b>METALS BY ICP</b>							
Iron, Fe - Dissolved	<0.03	mg/L	EPA 200.7	0.030	2010-11-23	15:45:00	CM
Iron, Fe - Total	<0.05	mg/L	EPA 200.7	0.050	2010-11-23	12:24:00	CM



Lab Supervisor

Domenic Ibanez  
Lab Supervisor

SGS North America Inc. Minerals Services Division  
2035 North Airport Road Huntington t (435) 653-2311 f (435)-653-2436 www.sgs.com/minerals

Member of the SGS Group (Société Générale de Surveillance)

This document is issued by the Company under its General Conditions of Service accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. Any



Analysis Report

March 07, 2011

PETERSEN HYDROLOGIC LLC  
2695 NORTH 600 EAST  
LEHI UT 84043

Page 1 of 1

Client Sample ID: Snell & Wilmer, LLP  
Date Sampled: Sep 17, 2010  
Date Received: Oct 4, 2010  
Product Description: WATER

Sample ID By: Petesen Hydrologic LLC  
Sample Taken At: Winter Quarters Portal  
Sample Taken By: E. Petersen  
Time Received: 0730  
Time Sampled: 1830

SGS Minerals Sample ID: 782-1106854-001

<u>TESTS</u>	<u>RESULT</u>	<u>UNIT</u>	<u>METHOD</u>	<u>REPORTING</u>		<u>ANALYZED</u>	
				<u>LIMIT</u>	<u>DATE</u>	<u>TIME</u>	<u>ANALYST</u>
<b>METALS BY ICP</b>							
Iron, Fe - Dissolved	<0.03	mg/L	EPA 200.7	0.030	2010-10-12	14:18:00	CM
Iron, Fe - Total	<0.05	mg/L	EPA 200.7	0.050	2010-10-08	10:47:00	CM

Lab Supervisor

Domenic Ibanez  
Lab Supervisor

SGS North America Inc. Minerals Services Division  
2035 North Airport Road Huntington t (435) 653-2311 f (435)-653-2436 www.sgs.com/minerals

Member of the SGS Group (Société Générale de Surveillance)

This document is issued by the Company under its General Conditions of Service accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. Any



Analysis Report

March 07, 2011

PETERSEN HYDROLOGIC LLC
2695 NORTH 600 EAST
LEHI UT 84043

Page 1 of 1

Client Sample ID: Snell & Wilmer, LLP
Date Sampled: Sep 23, 2010
Date Received: Oct 4, 2010
Product Description: WATER
Sample ID By: Petesen Hydrologic LLC
Sample Taken At: Mohrland Portal
Sample Taken By: E. Petersen
Time Received: 0730
Time Sampled: 1240

SGS Minerals Sample ID: 782-1106854-002

Table with columns: TESTS, RESULT, UNIT, METHOD, REPORTING LIMIT, DATE, ANALYZED TIME, ANALYST. Rows include METALS BY ICP, Iron, Fe - Dissolved, and Iron, Fe - Total.

Handwritten signature of Domenic Ibanez

Lab Supervisor

Domenic Ibanez
Lab Supervisor

SGS North America Inc. Minerals Services Division
2035 North Airport Road Huntington t (435) 653-2311 f (435)-653-2436 www.sgs.com/minerals

Member of the SGS Group (Société Générale de Surveillance)

This document is issued by the Company under its General Conditions of Service accessible at http://www.sgs.com/terms\_and\_conditions.htm. Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. Any

**EXHIBIT C**

**Division of Oil, Gas and Mining Response to:  
*Investigation of Iron Concentrations in the Genwal Resources, Inc. Crandall Canyon Mine Discharge  
Water, November 7<sup>th</sup>, 2011 prepared by Petersen Hydrologic, LLC*  
By Kevin Lundmark**

**11/22/11**

## General Comments

The objective of the report is not stated. A fair read of the text suggests that this report was prepared primarily to attempt to discredit previous findings made by the Division of Oil, Gas and Mining (Division).

The level of effort made by Genwal's consultant, Petersen Hydrologic, in preparing the text of this report is commendable. It is concerning, however, that Petersen Hydrologic has still not collected a single supplemental sample at Crandall Canyon (beyond what has been requested by the Division), nor undertaken any geochemical modeling to support their attempt to demonstrate, with certainty, that minewater iron levels will not require long term treatment.

It is clear that Petersen Hydrologic does not agree with statements made by the Division in their June 2010 Hydrologic Evaluation Report and the subsequent June 2011 Hydrologic Evaluation Update. If these points of disagreement are deemed noteworthy by the Board, a more detailed response to the November 2011 Petersen Hydrologic report or testimony may be appropriate.

### 1.0 Introduction

Petersen Hydrologic's statement that "[i]t was considered unlikely that substantially elevated iron concentrations (>1 mg/L) would persist over long periods of time" at the time the February 2010 letter report was prepared correctly reflects the character of that report. However, in Appendix 7-65 of their approved MRP, Genwal clearly stated that there was "every reason to believe" that mine water treatment at the Crandall Canyon mine would be a perpetual problem. It was only after The Division required bonding (in accordance with OSM's Ten Day Notice) that the iron pollution in the mine water discharge became "unlikely" to persist.

### 3.0 Presentation of Data

2<sup>nd</sup> paragraph The graphing method presented by Petersen Hydrologic as a "6-month running average" would be more accurately described as a "6-event" running average. The smoothing of data through this averaging technique does result in less noise on the plot. However, the fluctuations of iron concentrations in the mine water discharge are an important characteristic to consider when evaluating the potential timeframe for iron concentrations to attenuate below compliance (UPDES permit) levels. The total iron criterion in Genwal's UPDES permit is for the daily maximum; not the 6-month average, 6-point average, or other statistical measure. The data clearly show spikes in iron content of the mine water, and these spikes would result in violations of the UPDES permit if the minewater were not treated.

### 4.0 Discussion

4<sup>th</sup> paragraph Petersen Hydrologic has apparently misread the June 2011 Hydrologic Update report. In that report the Division summarizes the Mayo et al. 2000 report as follows:

“Pyrite oxidation is not the only source of sulfate present in the hydrologic system potentially contributing to the minewater discharge; however, in a study completed for the SUFCO mine in the Wasatch Plateau, Mayo, Petersen and Kravitz (2000) found that most sulfate in minewater discharge results from pyrite oxidation.” Footnote 2, p 7

The Mayo et al. 2000 report did identify other potentially significant sulfate sources (e.g. gypsum); however, the report clearly indicated that sulfide mineral oxidation was shown to contribute the majority of the increase in TDS and sulfate mine water.

Bottom of Page 9 Petersen Hydrologic has previously attempted to demonstrate that iron concentrations will decrease to below compliance levels based on geochemical reactions (i.e., depletion of dissolved oxygen or pyrite source material). Now, Petersen Hydrologic has reversed course and asserts that iron concentrations will be controlled by flow regimes, not geochemistry. This reversal in basis for predicting future mine water chemistry was made without performing any supplemental analysis (beyond what was requested by the Division), or without performing any modeling. I agree with Petersen Hydrologic’s statement that the concentrations of iron hydroxide cannot be predicted. Using the available mine water data, neither the Division, nor Petersen Hydrologic, are able to predict with any certainty the concentration of iron hydroxide in the mine water discharge.

Bottom of Page 10 As stated in the comment for Section 3.0, the UPDES criterion for total iron is based on the daily maximum concentration. Therefore, spikes in iron concentration are a valid concern when evaluating whether or not minewater treatment is required.

Page 12, 2<sup>nd</sup> full paragraph The notion that a series of visual observations collected October 2011 can “specifically evaluate” conditions present in April 2011 does not reflect good science. The October 2011 observations could provide insight into minewater chemistry variability and/or the effects of sampling procedure; however, even here Petersen Hydrologic fails to follow good scientific procedure. If the hypothesis to be tested is whether purge rate affects total iron content, water samples should be analyzed (in a lab or using a field kit) for total iron, not merely observed and photographed. It has been commonly observed that the amount of coloration in the mine water samples varies as a function of time. If the hypothesis being tested is whether the plumbing of the water line/sample port affects the iron concentration of the minewater sample, then synoptic samples should be collected – one from the sample port and one from the main mine water discharge line. This approach would require some modification to the water routing infrastructure. Petersen Hydrologic apparently relies on lengthy discussion, rather than scientific experiment design, as a basis for their conclusions.

Page 17 Petersen Hydrologic correctly states that the information collected from nearby mines with postmining gravity discharge “does not of itself indicate when discharge of groundwater with elevated iron concentrations at the Crandall Canyon Mine will abate”. It is not known whether these mines ever had pollutional discharges. These historic mines also likely employed different mining methods than at Crandall Canyon, where longwall mining with planned subsidence occurred.

## 5.0 Projections of Likely Future Iron Concentrations

General comments 1 Statistical analysis of trends is a common and well described practice. Any regression or other trend analysis should be fully described, including the method of regression and some indication of the residual error. Petersen Hydrologic has not provided any

documentation for their regression analyses. Nor have they performed basic tests for trend that are well documented and readily available (e.g. Mann-Kendall). Such documentation is necessary, both to enable review and to document the basis for their conclusions.

## 6.0 Conclusions

2<sup>nd</sup> bullet Petersen Hydrologic states that “[w]e are not aware of any special geologic conditions at the Crandall Canyon Mine that would result in probable long-term elevated” iron concentrations in the minewater. A geologist from the UGS has reported observing a pyrite-rich zone within the southwestern portion of the mine workings, and collected a pyrite mineral sample in this area. Personnel from the Deer Creek Mine are also familiar with this geologic condition. This is an area that may be flooded as a result of the mine collapse, and therefore seems quite reasonably to represent a geologic condition that may influence minewater chemistry.

**EXHIBIT D**



## PETERSEN HYDROLOGIC

2 December 2011

Ms. Denise A. Dragoo, Esq.  
Snell & Wilmer, L.L.P.  
15 West South Temple, Suite 1200  
Salt Lake City, Utah 84101

Denise,

At your request I have evaluated the "Division of Oil, Gas and Mining Response to: Investigation of Iron Concentrations in the Genwal Resources, Inc. Crandall Canyon Mine Discharge Water, November 7<sup>th</sup>, 2011 prepared by Peteresen Hydrologic, LLC By Kevin Lundmark" (undated). My comments in this regard are summarized below.

- The Division of Oil, Gas and Mining (Division) cites previous notations in Appendix 7-65 of the Crandall Canyon Mine MRP regarding the likelihood of the need for long-term treatment of the mine discharge water. These references (which are not in the current MRP) were made during the period of initial consultations with the Division regarding the proposed design specifications and operating plan of a mine water treatment facility. Acting in good faith and in cooperation with the Division, and in the absence of a geochemical investigation suggesting otherwise, it was reasonable for Genwal to plan for a potential ongoing treatment necessity. At the time of these initial consultations with the Division, Peteresen Hydrologic, LLC had had no involvement with the situation. Subsequently, Peteresen Hydrologic was commissioned to perform a geochemical investigation of the mine discharge water. The stated conclusions of our investigation are based entirely on the results of our best scientific analysis. We have never experienced efforts to change or influence any of our conclusions.

- The Division states that iron “spikes would result in violations of the UPDES permit if the minewater were not treated.” While this is technically correct, it should be noted that it is our opinion that these spikes are likely associated with sampling errors attributable to incomplete purging of the sampling apparatus. In other words, the water collected in the laboratory sample bottle was likely not representative of water discharging from the mine workings.
- The Division suggests that we have “reversed course” regarding our initial findings regarding the mechanism controlling the currently observed declines in total iron concentrations in the mine water discharge (i.e., iron declines due to flow regimes rather than geochemistry). This is not the case. In our preliminary 2010 letter report (page 6), we concluded the following:

*It is considered likely that the pyrite currently in contact with mine waters will eventually be consumed by oxidation reactions (i.e., there is not an unlimited supply of pyrite in the inundated mine environment). The amount of time that will be required for the oxidation of the available pyrite in inundated areas will likely be a function of the amount of pyrite available for reacting, water flushing rates, and the availability of dissolved oxygen in the reacting mine waters.*

In our November 2011 report (page 20) we concluded the following:

*It remains my professional opinion that the iron concentrations in the Crandall Canyon Mine discharge water will likely continue to decline over time as the necessary reactants are gradually consumed and flushed from actively flowing portions of the flooded underground mine workings.*

- The Division states on page 2 of their response that “It has been commonly observed that the amount of coloration in the mine water samples varies as a function of time.” The reddish-orange “coloration” is almost certainly solid, iron-bearing iron hydroxide particulate matter. Given that the Division’s qualified hydrologists were previously aware of this condition, it is unclear why they apparently did nothing to further investigate this situation, but rather, proceeded to collect their mine water discharge samples without allowing the discharge to adequately clear after a thorough purging of the sampling port.
- The Division notes that mining methods in the surrounding mines from which gravity discharge of iron-free water now occurs may have been different from those implemented at the Crandall Canyon Mine. While the mining methods used at the various mines may not have been similar, what is important in this regard is the geochemistry of the materials in the mine environment (i.e. the rock and water chemistry). Differences in mining techniques, whether planned or not, may influence the post-mining competence of the surrounding geologic material, but generally not the overall geochemical reactions taking place.

- The Division notes in their response that documentation of the statistical method used for determining the linear regression line should have been mentioned. The simple linear regression was performed using SigmaPlot™ version 9.01 scientific graphing software using a quadratic equation. SigmaPlot is a widely utilized and accepted tool for graphical analysis of scientific data. It should be noted that the linear regression shown on Figure 7 was simply utilized as a means to approximately project past trends into the future without human bias. There is no implied geochemical significance to the line itself.
- The Division indicates that the 6-month running average iron concentration plot presented in our report would be more accurately described as a “6-event” running average. Information in this regard was provided on page 5 of the text of our 7 November 2011 report. The data presented in Figure 3 of our report do reflect a “6-month” running average for the 63-month period from January 2006 to March 2011. During April and May 2011, data were collected on a more frequent basis. The assigning of an equivalent unit weight to each of the more frequent April and May 2011 samples was considered as a conservative approach. Had a true monthly running average been calculated using the data for those two months, this would have had the effect of further smoothing the trendline and minimizing the upward effect of the spike(s).
- The Division suggests that there is a “pyrite-rich” zone in a portion of the Crandall Canyon Mine workings. This is apparently the first mention by the Division of the notion of a pyrite-rich zone. It should be noted that the southwestern portion of the mine is not within the area believed to have been affected by the August 2007 event (see Figure 2 of Division’s June 2, 2011 report). In the author’s experience, spatial variability in pyritic sulfur content in coal mines is the norm for Utah coal mines. Indeed, as we have previously indicated, pyrite oxidation is the very probable source of the iron in the mine discharge water. We are aware that it is present in the Crandall Canyon Mine. However, our fundamental, previously stated conclusion is that pyrite that is exposed to oxygenated water will eventually be consumed through oxidation reactions (or rendered non-reactive as the oxidizing potential becomes depleted). The recent declining trends in the total iron concentrations, which are approaching compliance levels (see Figures 2 and 3 of our report), strongly support this conclusion.
- Subsequent to the completion of our 7 November 2011 report, additional iron concentration data for the Crandall Canyon Mine discharge water has become available. The most recent laboratory result for total iron concentration in the mine discharge pre-treatment (PRE 002) water was 1.75 mg/L, sampled by Genwal Resources, Inc. personnel on 24 October 2011 (laboratory reporting sheet attached). The discharge port was purged for approximately one hour prior to the collection of the sample.

Ms. Denise Dragoo  
Page 4 of 4

Please feel free to contact me with any questions you may have in this matter.

Regards,



Erik C. Petersen  
Senior Hydrogeologist  
Petersen Hydrologic, LLC



Analysis Report

November 17, 2011

GENWAL RESOURCES INC
794 "C" CANYON ROAD
EAST CARBON UT 84520

Page 1 of 2

Client Sample ID: PRE 002
Date Sampled: Oct 24, 2011
Date Received: Oct 25, 2011
Product Description: WATER
Sample ID By: Genwal Resources Inc.
Sample Taken At: Pre-002
Sample Taken By: Dana
Time Received: 1230
Time Sampled: 1415
Mine: 8
Site: 77
Field - pH: 7.10 pH
Field - Dis. Oxygen: 6.47 MG/L
Field - Conductivity: 965 UMHOS/CM
Field - Temperature: 12 DEG. C

Comments: Silica Analyzed at A.W.A.L.; Acidity Digested per Request
Dissolved Metals Filtered at Lab; Total Metals Preserved at Lab

SGS Minerals Sample ID: 782-1110458-001

Table with columns: TESTS, RESULT, UNIT, METHOD, REPORTING LIMIT, DATE, ANALYZED TIME, ANALYST. Rows include tests like Oil and Grease, Sulfate, Acidity, and metals like Silica, Aluminum, Calcium, Iron, Magnesium.

Handwritten signature of Domenic Ibanez

Lab Supervisor

Domenic Ibanez
Lab Supervisor

SGS North America Inc. Minerals Services Division
2035 North Airport Road Huntington UT 84528 t(435) 853-2311 f(435)-853-2438 www.sgs.com/minerals

Member of the SGS Group (Société Générale de Surveillance)

This document is issued by the Company under its General Conditions of Service accessible at http://www.sgs.com/terms\_and\_conditions.htm. Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any holder of this document is advised that information contained hereon reflects the Company's findings of the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. Any unauthorized alteration, forgery or falsification of the content or appearance of this document is unlawful and offenders may be prosecuted to the fullest extent of the law.



Analysis Report

November 17, 2011

GENVAL RESOURCES INC
794 "C" CANYON ROAD
EAST CARBON UT 84520

Page 2 of 2

Client Sample ID: PRE 002
Date Sampled: Oct 24, 2011
Date Received: Oct 25, 2011
Product Description: WATER
Sample ID By: Genval Resources Inc.
Sample Taken At: Pre-002
Sample Taken By: Dana
Time Received: 1230
Time Sampled: 1415
Mine: 8
Site: 77
Field - pH: 7.10 pH
Field - Dis. Oxygen: 6.47 MG/L
Field - Conductivity: 965 UMHOS/CM
Field - Temperature: 12 DEG. C

Comments: Silica Analyzed at A.W.A.L.; Acidity Digested per Request
Dissolved Metals Filtered at Lab; Total Metals Preserved at Lab

SGS Minerals Sample ID: 782-1110458-001

Table with columns: TESTS, RESULT, UNIT, METHOD, REPORTING LIMIT, DATE, ANALYZED TIME, ANALYST. Rows include METALS BY ICP (continued) with data for Manganese, Potassium, and Sodium.

Handwritten signature of Domenic Ibanez

Lab Supervisor

Domenic Ibanez
Lab Supervisor

SGS North America Inc. Minerals Services Division
2035 North Airport Road Huntington UT 84528 t (435) 853-2311 f (435)-653-2436 www.sgs.com/minerals

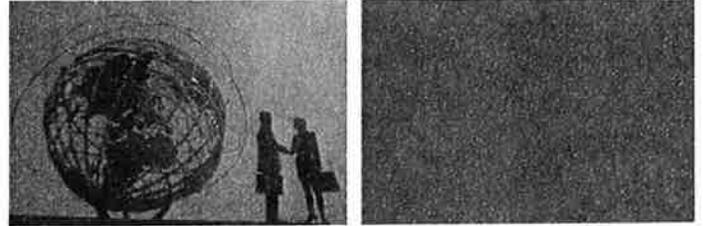
Member of the SGS Group (Société Générale de Surveillance)

This document is issued by the Company under its General Conditions of Service accessible at http://www.sgs.com/terms\_and\_conditions.htm. Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

Any holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. Any unauthorized alteration, forgery or falsification of the content or appearance of this document is unlawful and offenders may be prosecuted to the fullest extent of the law

**EXHIBIT E**

# Kevin Lundmark



Mr. Kevin Lundmark is a water scientist with thirteen years of experience in the fields of mine permitting and remediation, surface water and groundwater modeling, uncertainty analysis, environmental sampling and analysis, soil and groundwater remediation projects, and waste characterization. He has contributed to site assessments and modeling for contaminated sites, including commercial, industrial, and mining sites at scales from hundreds of square feet to hundreds of square miles. Prior to joining ERM, Mr. Lundmark was employed by the Utah Division of Oil Gas and Mining where he worked in the Coal Regulatory Program.

Modeling performed by Mr. Lundmark has been used for evaluating remedial alternative effectiveness for mine cleanup, evaluating effectiveness of groundwater extraction systems for VOC contaminant capture, and to evaluate rates and associated uncertainty for regional groundwater flow systems. Mr. Lundmark's hydrologic modeling skills are coupled with a strong background in environmental chemistry and extensive experience in sampling and analysis plan development, and environmental data interpretation.

## Fields of Competence

- Mine Permitting and Reclamation
- Groundwater and Surface Water Modeling
- Uncertainty Analyses
- Data Reduction and Statistical Analysis
- Data Quality Objective Development and Quality Assurance for Environmental Sampling and Analysis
- Contaminated Site Management
- Environmental Site Assessment

## Education

- MS, Hydrology, University of Nevada, Reno, NV, 2007
- BS, Chemistry with Environmental Science minor, Colorado School of Mines, Golden, CO, 1998

## Languages

- English, native speaker

## Key Industry Sectors

- Mining
- Manufacturing
- Water Resources Development and Management

## Publications

- Lundmark, K.W., G.M. Pohl, and R.W.H. Carroll. 2007. A Steady-State Water Budget Accounting Model for the Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah. Division of Hydrologic Sciences, Desert Research Institute, Publication No. 41233.
- Hershey, R.L., Heilweil, V.M., Gardner, P., Lyles, B.F., Earman, S., Thomas, J.M., and K.W. Lundmark. 2007. Ground-water Chemistry Interpretations Supporting the Basin and Range Carbonate-rock Aquifer System (BARCAS) Study, Eastern Nevada and Western Utah. Division of Hydrologic Sciences, Desert Research Institute, Publication No. 41230.

## **Selected Projects**

### **Crandall Canyon Mine Hydrologic Evaluation, 2010-2011**

#### **Hydrologist/Geochemist**

Author of a hydrologic evaluation of the groundwater system sustaining a post-mining gravity discharge from the Crandall Canyon coal mine in Huntington, Utah. The evaluation considered the geochemistry of the minewater discharge and the potential for attenuation of elevated concentration of iron being discharged to a cold-water fishery.

### **White Oak Mine Reclamation Design, 2010**

#### **Surface Water Modeler**

reclamation design near Scofield, Utah. Modeling completed using SEDCAD and HEC-RAS evaluated the expected performance of stream restoration and erosion controls at a former surface and underground coal mine.

### **Mine Tailings Stabilization, 2009**

#### **Surface Water Modeler**

Surface water modeler for bank stabilization project at a historic tailings repository in Arizona. Modeling completed using HEC-RAS evaluated the expected changes in stream hydraulics following installation of a gabion wall. Modeling results were presented in the permit application which was approved by the local regulators.

### **Abandoned Mine Site Liability Valuation, 2008**

#### **Site Assessor**

Evaluated potential environmental and safety liability for abandoned mine sites in Utah, Nevada, and Idaho as part of a bankruptcy transaction. Site assessments included a summary of potential environmental and safety liabilities and cost estimates for site reclamation.

### **Underground mine remediation feasibility study, 2002 - 2009.**

#### **Analyst**

Primary computational analyst for a feasibility study prepared for a mine site located in Washington State. Responsibilities included development of a mathematical conceptual model quantifying the mass loading of heavy metals to adjacent surface water and the effects of proposed remedial actions. Applications of the model included the calculation of estimated post-remediation metals concentrations as a function of remedial alternative, a probabilistic uncertainty analysis to quantify

the variability associated with model output, sensitivity analyses, and treatment system operational criteria.

### **U.S. Air National Guard Facilities, National Guard Bureau, 2008 - 2009**

#### **Groundwater Modeler**

Groundwater modeler for the Remedial Investigation and Feasibility Study at 153<sup>rd</sup> Airlift Wing in Cheyenne, WY and groundwater remediation and monitoring project at 162<sup>nd</sup> Fighter Wing, part of Tucson International Airport Area NPL Superfund site in Tucson, AZ. Modeling included steady-state and transient groundwater flow and contaminant transport for chlorinated VOC plumes. Modeling also evaluated effects of groundwater injection, extraction and cutoff wall placement and operation on contaminant migration.

### **Basin and Range Carbonate-rock Aquifer System Study, U.S. Bureau of Land Management, 2005-2007.**

#### **Groundwater Modeler**

Modeler for a regional water resources accounting model for a twelve-basin study area in White Pine County, Nevada and adjacent areas in Nevada and Utah. Model development incorporated regional geology, hydrology, and a geochemical database compiled from historic and recent data. Modeling provided a description of uncertainty via multiple optimization approaches and a Monte Carlo uncertainty analysis performed on model inputs.

### **Canyon Creek Treatability Study, U.S. Environmental Protection Agency, 2005.**

#### **Project Chemist**

Project chemist for a treatability study to identify and evaluate technologies to reduce heavy metals loading in Canyon Creek near Wallace, Idaho. Responsibilities include preparation of sampling, quality assurance, and laboratory (bench-scale) treatability study plans; field and laboratory oversight; and evaluation and interpretation of results. Study included the evaluation of treatment trains ranging from only pH adjustment to coagulation/flocculation with microsand ballast.

### **Environmental Baseline Study and the Environmental Data Summary: Ordot Dump, Guam, 2005. Guam Department of Public Works, 2005.**

Task coordinator and primary author for the Environmental Baseline Study and the Environmental Data Summary Report for the Ordot Dump in Ordot/Chalan Pago, Guam. Responsibilities included compilation and interpretation of historical hydrogeologic

data and analytical data for surface water, groundwater, and soil media. The assessment included the limitations of existing data and the development of additional data requirements to perform a limited remedial investigation to support dump closure.

**Basin Environmental Monitoring Plan: Bunker Hill Mining and Metallurgical Complex Operable Unit 3, U.S. Environmental Protection Agency, 2004.**

**Task Manager**

Task manager for development of a long-term monitoring plan for the Coeur d'Alene Basin in Idaho and Washington states. Responsibilities include coordination with government agencies and development of a 30-year monitoring plan to address ecological conditions on a basin-wide scale in support of CERCLA-required five-year reviews. Media addressed by the monitoring plan include surface water, soil/sediment, and biological resources.

**Various commercial and industrial sites, 2001-2005.**

**Task Manager**

Task manager for several soil and groundwater remediation projects for commercial/industrial clients at sites impacted by chlorinated organic solvents and/or petroleum hydrocarbons. Remediation technologies include dual vapor extraction (DVE), density-driven circulation (DDC), in-situ chemical oxidation, and enhanced in-situ biodegradation. Duties included assessment of remedial alternatives, system design, installation supervision, performance groundwater monitoring, system operations and maintenance, performance optimization, water discharge and air permit compliance, management of investigation-derived wastes (IDW), waste characterization and disposal, and final report preparation.

**EXHIBIT F**



## PETERSEN HYDROLOGIC, LLC

**Erik C. Petersen, P.G.**  
Principal, Senior Hydrogeologist

---

### **Education**

M.S. Hydrogeology, 1993  
Brigham Young University

B.S. Geology, 1988  
Brigham Young University

### **Graduate Thesis**

Petersen, E.C., 1993, Geochemical evolution of groundwater with implications for groundwater flow patterns in the Pilot Valley closed basin, Utah and Nevada, Brigham Young University, Department of Geology.

### **Honors**

Outstanding graduate thesis, 1994, Sigma Xi, for the College of Physical and Mathematical Sciences, Brigham Young University, Provo, Utah.

Outstanding graduate thesis, 1993-1994, Department of Geology, Brigham Young University, Provo, Utah.

### **Registration**

Licensed Utah Professional Geologist #5373615-2250

Licensed Wyoming Professional Geologist PG-2966

### **Selected Project Experience**

#### ***Petersen Hydrologic (2000-Present)***

*Principal, Senior Hydrogeologist*

- Performed several hydrogeochemical evaluations of geochemical conditions in underground coal mines in Utah's Wasatch Plateau and Book Cliffs coal districts. We performed investigations regarding iron and sulfide mineral geochemistry, sources of sulfur and iron species and excess TDS concentrations in mine discharge waters, geochemical evolution of in-mine groundwaters, carbonate system dissolution and precipitation reactions, and corrosion characteristics of mine waters.
- Performed a geochemical analysis of the potential for treating mine water using a lime injection technique at an underground coal mining operation in Utah. This investigation included determinations of the optimal reactant injection rates and



## PETERSEN HYDROLOGIC, LLC

predictions of post treatment geochemical compositions of mine discharge waters. The geochemical analysis was performed using the program PHREEQC.

- Performed hydrogeologic investigations of groundwater systems at several Utah coal mines (including Canyon Fuel Company, LLC's Skyline, Sufco, and Dugout Mines, RAG's Willow Creek Mine, Andalex Resources' Crandall Canyon, West Ridge, and Centennial Mines, and the Coal Hollow Project of Alton Coal Development, LLC). These investigations have included groundwater and surface-water flow characterizations, analysis of large amounts of solute chemical and discharge data, characterizations of groundwater – surface-water interactions, groundwater stable isotopic compositions, and tritium and radiocarbon age dating analysis.
- Performed an analysis of the potential to produce industrial water from large-diameter pumping wells completed in flooded, abandoned coal mine workings in central Utah. This investigation included projections of long-term groundwater discharge rates from individual geologic formations present in the area. We also provided projections of likely geochemical compositions of mine water held in underground coal mine sumps and gobs based on the hydrogeochemical environment of the abandoned mine workings.
- Performed a series of investigations for the Canyon Fuel Company, LLC Skyline Mine regarding large fault-related groundwater mine inflows near Electric Lake at the Skyline Mine, Utah. This work a multi-year project that was performed for the law firm of Manning, Curtis, Bradshaw, and Bednar of Salt Lake City, Utah.
- Performed an evaluation of the acid/base generation potential at the surface mining operations of the Coal Hollow Mine at the Alton Coal field in southern Utah. This investigation included an evaluation of the geochemical composition of the coal deposits and overburden materials and the likely character of evolved mine waters. We also performed an investigation of the geochemical evolution of groundwaters and surface waters as they interact with the Cretaceous rocks and Quaternary alluvial sediments in the mine and surrounding areas.
- Provided expert witness testimony in support of the Mining and Reclamation Plan for the Alton Coal Development, LLC Coal Hollow Mine. The Utah Division of Oil, Gas and Mining had previously approved the permit application, which was subsequently appealed to the Utah Board of Oil, Gas and Mining by the Southern Utah Wilderness Alliance, the Sierra Club, and other entities. The permit was successfully upheld by the Board.
- Evaluated sulfate and heavy metal contamination and contaminant plume migration in groundwater in the Principle Alluvial Aquifer in southwestern Salt



## PETERSEN HYDROLOGIC, LLC

Lake Valley for Kennecott Utah Copper Corporation. The effectiveness of ongoing remedial activities at the site was also evaluated.

- Prepared the Geology and Hydrology chapters of the Mining and Reclamation plan for the Coal Hollow Project, Alton Coal Development, LLC located in the Alton Coal Field in Kayne County Utah. The permit application was successful and the Coal Hollow Mine is now operational. The Coal Hollow Mine is the first major surface coal mine in Utah and is the first modern mining operation in the Alton Coal Field. This project was large in scope and was completed over a period of more than five years.
- Performed an investigation of the chemical suitability and availability of potential water sources for the underground coal mine workings at PacifiCorp's Bridger Mine. This included an analysis of the geochemical character and corrosion potential of the various waters.
- Performed an analysis of groundwater and surface water systems and potential contaminant migration in the Mancos Shale near the combustion waste landfill at PacifiCorp's Hunter Power Plant, Castle Dale, Utah. This included an analysis of the geochemical evolution of groundwaters residing in the Mancos Shale geologic formation and coal combustion product disposal facilities, and the likely fate of contaminant species.
- Performed a hydrologic investigation of the potential for mining-related impacts to the South Fork of Quitchupah Creek as a result of longwall undermining and subsidence of the stream channel. The work was performed in support of a permit amendment for the Canyon Fuel Company, LLC Sufco Mine. The application to undermine the stream has been approved by the Manti-LaSal National Forest.
- Performed a hydrogeologic characterization of thermal and non-thermal groundwater and surface-water systems in the Eagle Mountain, Utah area in support of the development of a municipal water supply system.
- Performed an investigation of sulfate and trace metal contamination, transport, and remediation in alluvial groundwater at the Praxair Acid Tank Farm site, Kennecott Utah Copper Corporation smelter, Magna, Utah.
- Performed a regional water-rights inventory for Arch Reclamation Services, Inc. This included the evaluation of approximately 200 water rights located in central Utah. As part of this investigation, water rights documents were reviewed, locations were verified in the field, and certified discharge measurements from each of these water rights were performed.



## PETERSEN HYDROLOGIC, LLC

- Provided expert witness testimony for the Kane County Water Conservancy District. Performed an investigation of potential well interference associated with pumping of groundwater from the Lamb Point Tongue of the Navajo Sandstone in the Johnson Canyon area in Kane County, Utah in association with a proposed water rights transfer application. The water rights application was approved by the Utah Division of Water Rights.
- Performed hydraulic testing and geologic logging of coreholes at diamond exploration projects in the Canadian sub-arctic, northern Northwest Territories. Also performed geological logging of core holes for hydrogeologic system characterization at a diamond exploration project in northern Ontario, Canada. These projects were performed during the wintertime under extreme environmental conditions.
- Performed a comprehensive Alluvial Valley Floor investigation for the Coal Hollow Project, proposed Coal Hollow Mine in the Alton Coal Field, Kane County, Utah. This investigation included the analysis of groundwater solute and potentiometric data, geologic data, agricultural land use data. Largely as a result of our findings, a previous positive AVF determination made by the Division was overturned and the mining project was allowed to go forward.
- Performed a series of investigations dealing with the recharge location and mechanism of the Star Point Sandstone Little Bear Spring, Emery County, Utah for GENWAL Resources, Inc. These investigations were performed using solute geochemical and isotopic geochemical techniques, stream gain-loss measurements, a fluorescent dye tracing study, basin yield analysis, and geophysical techniques.
- Performed an investigation of the effects of undermining and subsiding of the East Fork of Box Canyon at the Canyon Fuel Company, LLC Sufco Mine. These investigations included a characterization of pre-subsidence groundwater and surface-water systems, projections of likely impacts of mining-related subsidence on groundwater and surface-water systems, and characterizations of post-subsidence conditions.
- Performed an investigation of water circulation patterns in the tailings pond at Kennecott Utah Copper's Bingham Canyon Mine operation. This investigation was performed using visual fluorescent dye tracing.
- Performed an investigation of projected future potentiometric levels and the potential for mine discharge from the abandoned RAG Willow Creek Mine, Carbon County, Utah.



## PETERSEN HYDROLOGIC, LLC

- Currently performing a hydrologic investigation and performing modifications of the Mining and Reclamation Plan for the West Ridge coal mine. This includes an investigation of the potential for impacts associated with the undermining of the Right Fork of Whitmore Canyon Creek.
- Honeycomb Project, Colorado (Oil shale development); Co-author of Hydrologic Monitoring Plan and Standard Operating Procedures (2001); Co-author of Environmental Assessment for the BLM Exchange Area; Performed spring and seep surveys and flowing stream reach surveys (2000-2007); Performed baseline monitoring at various project sites (2001-2007). Work performed for Norwest Corp. of Salt Lake City, Utah.
- Performed an analysis of the potential impacts to the hydrologic balance resulting from the construction of the emergency rescue drill holes drilled on East Mountain by Genwal Resources, Inc. as part of mine rescue efforts.
- Performed an investigation of the groundwater and surface-water hydrology of potential wetland areas at the Alton Coal Development, LLC Coal Hollow Mine permit and surrounding area. We co-authored a report that provided the information on which a U.S. Army Corps of Engineers wetland jurisdiction determination was based.
- Performed an investigation of Castlegate Sandstone groundwater systems that support springs in the North Water Canyon area overlying the Sufco Mine. This investigation has included analysis of Castlegate Sandstone spring recharge and discharge mechanisms, characterization of subsidence-related impacts to spring discharges, groundwater-surface-water interactions, characterization of associated alluvial groundwater systems, and the development of proposed mitigation activities for the North Water Canyon area. This investigation included the installation and monitoring of a network of more than 50 piezometers in the North Water Canyon area to monitor hydrologic conditions in the canyon and to facilitate the evaluation of the effectiveness of proposed mitigation activities.
- Prepared portions of the geology and hydrology sections of SMCRA coal mining permits and prepared statements of probable hydrologic consequences of coal mining documents for several Utah coal mines.
- Performed a hydrogeologic investigation of groundwater and surface water systems in the SITLA Muddy Tract area. This included analysis of solute chemical, discharge, potentiometric, geologic, and stable and unstable isotopic data from streams, springs, and wells in the SITLA Muddy Tract and adjacent areas. This investigation also included a determination of probable hydrologic



## **PETERSEN HYDROLOGIC, LLC**

consequences (PHC) of coal mining at the tract by Canyon Fuel Company, LLC's Sufco Mine.

- Performed a reconnaissance Alluvial Valley Floor investigation for the Alton Coal Tract LBA area in Kane County, Utah near the town of Alton, Utah. This work was performed as part of the Environmental Impact Statement for the coal tract LBA.
- Performed an analysis of hydrologic monitoring data from the Canyon Fuel Company, LLC Dugout and Soldier Canyon Mines. This included an evaluation of historic groundwater and surface-water discharge, solute geochemical and isotopic data to evaluate the impacts of coal mining activities on groundwater and surface-water resources in the mine areas.
- Performed hydrologic investigations and prepared Drinking Water Source Protection Plans for a water supply well at Canyon Fuel Company, LLC's Skyline Mine and a developed Star Point Sandstone culinary spring at Canyon Fuel Company, LLC's Sufco Mine.
- Performed groundwater and surface-water investigations and was co-author of the Groundwater and Surface-Water Technical Report for the Flat Canyon Coal Tract EIS, Manti-La Sal National Forest.
- Performed an investigation of projected future potentiometric levels and the potential for mine discharge from the Canyon Fuel Company, LLC Dugout Canyon Mine, Wellington, Utah.
- Currently performing quarterly hydrologic discharge and water-quality monitoring at the Crandall Canyon Mine, Skyline Mine, and Sufco Mine in the Wasatch Plateau coal district. We also performed baseline hydrologic monitoring for the Coal Hollow Project (proposed surface-mining operation in the Alton, Utah coal field) and for an oil shale development in northwestern Colorado.
- Performed an intercepted groundwater study for the Canyon Fuel Company, LLC Dugout Mine.
- Performed hydrologic investigations and performed baseline hydrologic monitoring in support of mine permitting actions at Canyon Fuel Company, LLC's Sufco Mine (Pines Tract), Skyline Mine (Flat Canyon and Winter Quarters Tracts), and GENWAL Resources, Inc.'s South Crandall Tract and Shingle Creek Canyon Tracts.



## PETERSEN HYDROLOGIC, LLC

- Performed an intercepted groundwater study for the RAG, Willow Creek Mine, Carbon County, Utah.
- Performed high-accuracy flow measurements in a hard-rock mining tunnel in northern Utah in support of potential water rights litigation. The purpose of this investigation was to obtain highly accurate measurements in the difficult terrain of the mine that could withstand legal scrutiny.
- Performed hydraulic testing and geologic logging of alluvial sediments in a desert basin environment in the north-central Nevada gold mining district.

### *Mayo and Associates (1992-2000)*

#### *Senior Hydrogeologist, General Project Manager*

- Managed and performed field investigations for the hydrogeologic characterization of the mine area, the preparation of the description of Probable Hydrologic Consequences, and the preparation of a surface water and groundwater monitoring program for several coal mines in Utah and Western Colorado.
- Managed the data collection and preparation of the Data Adequacy package for the Pines Tract EIS, Manti-La Sal National Forest.
- Performed analysis and field investigations for a multi-year characterization of the hydrogeology of the 5,000 square-mile northern San Luis Valley. The project was conducted for the Rio Grande Water Conservancy District, Alamosa, Colorado.
- Performed analysis for the hydrogeologic characterization and evaluation of the extent of hexavalent chromium contamination of an alluvial aquifer at Hinkley, California. The work was performed in support of the lawsuit Anderson v. PG&E.
- Performed an investigation of the natural causes and mining practices that contributed to excess TDS in Utah Fuel Company's Skyline Mine discharge water, Helper, Utah.
- Performed an analysis of the sources of elevated TDS in Canyon Fuel Company's SUFCO Mine, Salina, Utah.
- Developed drinking water source protection plans for several sources in Utah. This included performing pump tests and analyzing pump test data, determination



## PETERSEN HYDROLOGIC, LLC

of groundwater flow rates and directions, and calculation of groundwater travel times.

- Managed the characterization of groundwater flow regimes and the fate of hydrocarbon contamination in the Big Piney Oil and Natural Gas Field, Wyoming for Mobil Exploration and Producing, US. This characterization included solute and isotopic investigations and slug testing of shallow piezometers.
- Managed the investigation of the groundwater production potential of the Stavros Property, Lucerne Valley, California. The investigation included the characterization of a groundwater flow regime in crystalline rocks, pump test analysis, and determination of safe yield.
- Performed an investigation of background water quality and infiltration potential for a commercial sewage treatment facility, Cedar Valley, Utah. The investigation included the installation of a monitoring well and permeability tests using infiltrometers.
- Managed an investigation of hydrocarbon contamination at Questar Corporation's Naples, Utah facility. The investigation included the installation of monitoring wells, slug test analyses, calculation of the plume migration rate and direction, and hydrodynamic calculations for the design of a remedial action plan.

### *Western Mining, USA (1989) Exploration Geologist*

- Conducted the evaluation of precious metal mining claim areas. This included detailed geological mapping, sample collection and analysis, target delineation, drill-hole planning, and conventional and computer interpretation of data collected during field activities.

### *Consulting Hydrogeologist (1990-1992)*

- Provided consulting hydrogeologist services for the hydrogeologic investigation of the Timpanogos Cave National Monument, U.S. National Park Service.



## PETERSEN HYDROLOGIC, LLC

### **Publications**

- Petersen, E.C., Mayo A.L., and Forster, C.B., 1992, Chemical evolution of ground water in the Pilot Valley area, UT-NV and some implications to ground water flow: Geol. Soc. Am., Abs. W/Programs, v. 24, n. 6, p. 57.
- Mayo, A.L., Petersen, E.C., Kravits, C., 2000, Chemical evolution of coal mine drainage in a non-acid producing environment, Wasatch Plateau, Ut., Journal of Hydrology 236: 1-16.
- Mayo, A.L., Morris, T.H., Petersen, E.C., and Payne, K.L., 1999, Heterogeneity and groundwater flow in the Wasatch Plateau and Book Cliffs, Utah: Geological Society of America, 1999 Annual Meeting, Abstracts with Programs, v.31, n.8, p. A148.
- Mayo, A.L., Petersen, E.C., and Kravits, C. 1999, Chemical evolution of groundwater in a non-acid producing underground coal mine: 1999 SME Annual Meeting, Technical Program, p. 170.
- Mayo, A.L., Morris, T.H., Petersen, E.C., and Payne, K.L., 1997, Groundwater flow systems in the Utah Coal District: Proceedings Rocky Mountain Ground Water Conference, Boise, Idaho.
- Mayo, A.L., Morris, T.H., Peltier, S., Petersen, E.C., Payne, K., Holman, L.S., Tingey, D., Fogel, T., Black, B.J., and Gibbs, T.D., in press, Active and inactive groundwater flow systems: evidence from stratified mountainous terrain: Bulletin Geological Society of America
- Mayo, A.L., Morris, T.H., Petersen, E.C., and Payne, K., 2000, The effects of large scale stratigraphic heterogeneity on groundwater flow in the Utah Coal District: 2000 SME Annual Meeting, Technical Program, p. 54.

### ***Geochemistry computer software***

- Petersen, E.C., Mayo, A.L., 1992, WATEQ pre-processor and post-processor, for the geochemical program WATEQF.
- Payne, K, Petersen, E.C., 1997, StiffCAD, A computer program for constructing Stiff diagrams for analysis of geochemical water types, Mayo and Associates, Lindon, Utah.