Attachment B

Draft Baseline Hydrology Report

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1.0 Introduction

Stevenson Mining is evaluating the Te Kuha coal deposit located in the Buller Coalfield 10 km southeast of Westport with the objective of developing and operating an open-cut mine. The site is currently undeveloped.

CRL Energy Ltd has been engaged by Stevenson Mining to determine the current baseline hydrology conditions at the site and to prepare a water management plan to minimise impacts to surface water and groundwater. This report is a preliminary assessment of the baseline hydrology. Additional data on surface water and groundwater to be collected over the next 12 months is necessary to assist with preparation of the water management plan.

The site in located on the foothills of the Mt William Range north of the Buller River. Topography of the area varies from moderate to steep and the highest elevation is 805 metres above mean sea level (mamsl). The dominant dip direction of the geologic units is to the west-northwest, resulting in an asymmetric ridge trending southwest to northeast, with a moderately steep dip slope on the northwestern side (Dutton et al., 2013). The northwestern and southeastern sides of the ridge are deeply incised by numerous streams which ultimately drain to the Buller River.

The aim of this work is to determine the water budget for the area, which involves quantifying the water inputs and water outputs to the hydrologic system. Water enters the site via precipitation and leaves via surface runoff in streams, evapotranspiration and infiltration to groundwater some of which discharges to streams downslope. An assessment of the current baseline hydrology is necessary to determine potential impacts of mining on the hydrology. In addition to quantifying the water budget, an additional aim of this work is to determine the baseline chemistry of surface water and groundwater.

1.1 Scope of work

The scope of work included:

- collation of rainfall data;
- a general survey of the catchments likely to be impacted by mining;
- determination of flow rates and water chemistry of streams likely to be impacted by mining;
- determination of the groundwater potentiometric surface, including groundwater elevation and groundwater flow direction;
- determination of aquifer hydraulic conductivity through a falling head test;
- analysis of the data and comparison to precipitation.

2.0 Methods

2.1 Precipitation

A Davis Vantage Pro2™ weather station with an integrated sensor suite (Model 6327c) coupled to a Davis weather envoy datalogger (Model 6316c) was installed at the site on 15 November 2012 at an elevation of 460 mamsl. The station records temperature, humidity, dew point, wind speed, wind direction, barometric pressure, precipitation and solar radiation on an hourly basis. Data from the instrumentation is transmitted by telemetry via a cellphone link to a web server using a Davis Vantage Connect Retrofit Kit (Model 6626).

2.2 Surface water

The proposed mining activities will be limited to the top and the northwestern side of the ridge, likely affecting streams draining this area. The mine plan includes avoiding impact to streams draining the southeastern and southern sides of the ridge, therefore, these streams are not included in the assessment of surface water in the area.

To determine the layout of the streams, a general survey of the uppermost parts of the ridge was conducted. This involved walking the top of the ridge line and along the northwestern side of the ridge to document the location of all streams and water bodies. The base of the ridge was also explored to determine the downstream locations of all the streams draining off the northwestern side of the ridge.

Data were collected at seven locations at the headwaters of streams on the northwestern side of the ridge and at five locations downstream on two occasions. Flow rates were measured using a Global Flow Probe flow meter with a Turbo Prop propeller, a SonTek Flow Tracker Handheld Acoustic Doppler Velocimeter or by bucket and stopwatch. The field parameters of pH, conductivity, temperature, dissolved oxygen and electrical conductivity were determined at each location using a YSI 650 multiparameter display system. Water samples were collected at each location for laboratory analysis by ICP-MS of 31 metals (total and dissolved via field filtering), pH, total acidity, total alkalinity, bicarbonate, total hardness, electrical conductivity, total suspended solids, chloride, nitrate nitrogen, nitrite nitrogen, dissolved reactive phosphorus, anion/cation balance and sulphate.

Water samples will be collected and flow rates determined for the upstream locations on at least one additional occasion, and from the downstream locations on a monthly basis for one year. In addition, a datalogger will be installed at a downstream location to record flow rate, pH, temperature and electrical conductivity on a continuous basis.

2.3 Groundwater

There is the potential for mining activities to affect groundwater in the area. It is also likely that groundwater will contribute to water inflow into open pits during mining operations. To determine pre-mining groundwater conditions, including location of potentiometric surface, aquifer hydraulic conductivity, groundwater flow rates and response of groundwater to precipitation events, data were collected from drillholes at the site by Aqualinc (Appendix A).

Drillholes TK-1 to TK-16 are completed with one-inch PVC casing and are not screened or capped on the bottom. Boreholes TK-17 to TK-28 are completed with 65 mm PCV casing and capped at the end. These caps were dislodged by punching with a steel rod to allow water levels to equilibrate with formation water levels. Water level data loggers were installed in five boreholes to record water levels over time. Water levels were measured in 17 boreholes using a water level sounder on one occasion.

Recovery rates tests were performed on one borehole (TK-28) on one occasion to estimate aquifer hydraulic conductivity.

Additional site visits are planned to collect groundwater data from boreholes, download data from water level loggers, conduct additional recovery rate tests, and collect water samples for laboratory analyses.

3.0 Precipitation

Over time period of 2 January 2013 to 17 June 2013 the daily average rainfall was 7.7 mm; the extrapolated yearly average rainfall based on six months of data is 2.81 m. Similarly to elsewhere on the West Coast, precipitation was characterised by dry periods followed by large, brief rainfall events (Figure 2). This leads to large variations in streamflow above baseline for short periods of time.

The data for the site to date show that the maximum 24 h precipitation recorded is 134 mm (2/1/2013). The 99th percentile for precipitation is 64 mm per day, the 95th percentile is 46 mm per day, and the 90th percentile is 21 mm per day (Figure 3). For comparison purposes, the High Intensity Rainfall Design System (HIRDS) was used to estimate the frequency of high-intensity rainfall events at the site (Thomson, 2011). The system predicts the maximum precipitation over a 24-hour period for different recurrence intervals as follows:

- 137 mm for a 1 in 2 year event
- 185 mm for a 1 in 10 year event
- 240 mm for a 1 in 50 year event
- 268 mm for a 1 in 100 year event

This suggests that the maximum precipitation recorded at the site to date is a 1 in 2 year event.

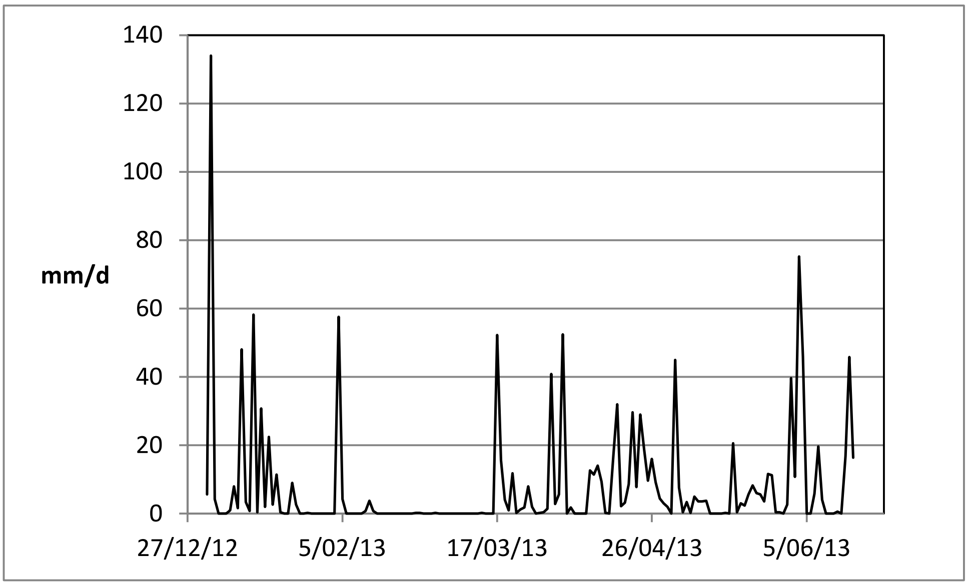

Figure 1: Precipitation record for Te Kuha for the period 2 January to 17 June 2013. Data is collected on an hourly basis.

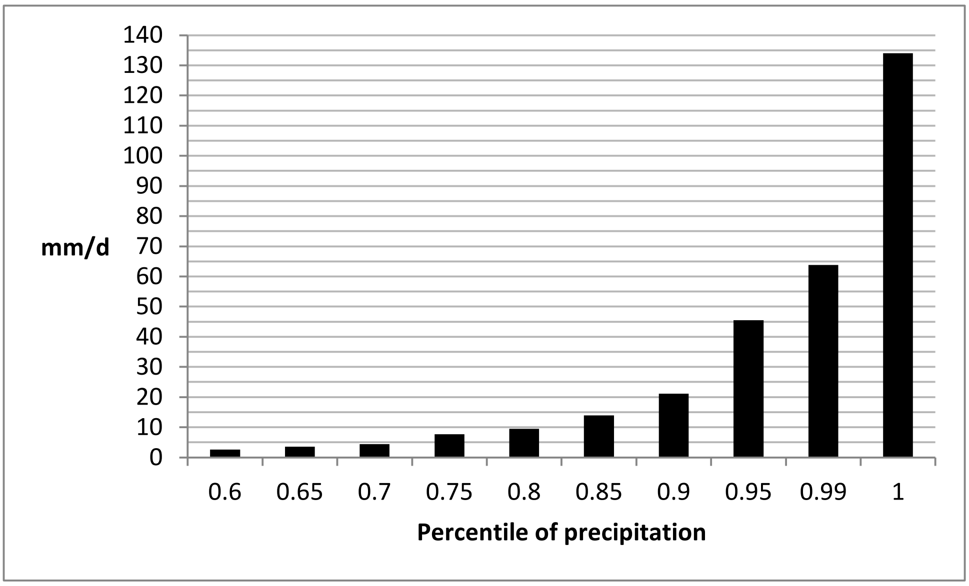

Figure 2: Percentiles of precipitation record for Te Kuha for the period 2 January to 17 June 2013.

4.0 Surface water

4.1 Layout of streams

Four streams drain off the top of the ridge down to the northwest (Figure 3). The northern-most stream is Coal Creek. The two streams immediately south of Coal Creek join with each other and with a smaller stream at the bottom of the ridge to form a tributary of Coal Creek. The fourth stream on the ridge line, West Creek, flows mostly west off the ridge and joins Coal Creek downstream of the other tributaries. Coal Creek then flows on to join the Buller River. In addition to the streams, there is a small ephemeral tarn near the top of the ridge that has no surface outlet.

Other streams drain off the ridgeline to the south, east and north, however as the current proposed mining activities will be limited to the northwest, these streams will likely not be impacted. They are not included in this assessment.

4.2 Baseline flow rates

Flow rates at the upstream sampling sites along the ridge range from <0.1 L/s (TKS-3) to up to 50 L/s (TKS-7) and at the downstream sites range from 1 L/s (TKS-10) to up to 90 L/s (TKS-11) (Table 1). With the exception of Coal Creek sampling location TKS-7 and the northern-most tributary to Coal Creek (TKS-8), all locations showed higher flow rates on the second sampling event (29 and 30 May 2013) compared to the first sampling event (21 March 2013). Precipitation records show that there was much more precipitation over the 48 hours preceding the second sampling event (11.6 mm preceding the May sampling event, 5.0 mm preceding the March sampling event), which explains the higher flow rates.

Flow rates increase downstream for each tributary, likely due to additional runoff into each stream and due to discharge from groundwater into the streams.

4.3 Baseline stream water quality

Surface water quality for upstream locations typically exhibit lower pH water compared to downstream locations (Table 1). For the 21 March 2013 sampling event, the pH for upstream sites ranged from 3.94 (TKS-3) to 5.33 (TKS-2), and the pH for downstream sites ranged from 5.3 (TKS-11) to 6.2 (TKS-12). For the 29 and 30 May sampling event, the pH for upstream sites ranged from 4.3 (TKS-3) to 5.46 (TKS-7), and the pH for downstream sites ranged from 5.0 (TKS-10) to 6.0 (TKS-13).

This increase in pH downstream may be due to dissolution of carbonate minerals present in the lithologies underlying the coal seam measures. Upstream locations drain coal seam measures, which contain sulphides and contribute to acidic drainage. In support of this theory, calcium concentrations in the water increase downstream (0.16 to 0.36 mg/L upstream to 0.82 to 4.5 mg/L downstream on 21 March 2013; 0.15 to 0.28 mg/L upstream to 0.59 to 2.8 mg/L downstream on 29 and 30 May 2013).

Table 1. Flow rates and water quality parameters for surface water sampling locations.

Stream	Location	Site	Date	Flow (L/s)	pH	sulphate	Al	Fe	Mn	Ni	Zn	Alkalinity	Net Acidity	Acid (mg/s)	Acid (tonnes/yr)	Alkalinity (tonnes/yr)
Coal Creek	upstream	TKS-7	21/03/13	50	4.72	1.5	0.139	0.35	0.0131	<0.0005	0.0011	2.5	0.2	9.5	0.30	
Coal Creek North Tributary	upstream	TKS-6 (tarn)	21/03/13	0	4.28	1.4	0.250	0.08	0.0058	<0.0005	0.0024	1.3	2.9			
	downstream	TKS-8	21/03/13	80	5.78	7.5	0.063	1.07	0.35	0.0012	0.0034	10.5	-6.6	-524		17
Coal Creek Middle Tributary	upstream	TKS-4	21/03/13	1.6	4.43	1.5	0.200	0.23	0.0044	0.0005	0.0039	1.6	2.0	3.2	0.10	
	upstream	TKS-5	21/03/13	0.4	4.16	1.8	0.230	0.22	<0.0005	<0.0005	<0.0010	<1	5.3	2.1	0.067	
	upstream	TKS-2	21/03/13	9	5.33	1.4	0.133	0.25	0.0049	<0.0005	0.0038	2.1	-0.4	-4.0		0.13
	upstream	TKS-3	21/03/13	0.1	3.94	1.8	0.380	0.21	0.0009	<0.0005	0.0011	<1	8.4	0.8	0.027	
	downstream	TKS-9	21/03/13	20	5.6	8.8	0.056	0.13	0.0032	0.0007	<0.0010	10.8	-10.0	-200		6.3
Coal Creek South Tributary	downstream	TKS-10	21/03/13	1	5.59	2.4	0.081	0.06	0.0016	<0.0005	<0.0010	12.3	-11.6	-12		0.36
West Creek	upstream	TKS-1	21/03/13	1	4.18	1.7	0.250	0.54	0.0014	<0.0005	<0.0010	1	5.1	5.1	0.16	
	downstream	TKS-11	21/03/13	40	5.3	1.9	0.073	0.06	0.0032	<0.0005	0.0015	8.3	-7.5	-299		9.4
	tributary	TKS-12	21/03/13	2.5	6.2	3.4	0.122	0.09	0.0043	<0.0005	0.0012	4.8	-3.8	-9.6		0.30

Stream	Location	Site	Date	Flow (L/s)	pH	sulphate	Al	Fe	Mn	Ni	Zn	Alkalinity	Net Acidity	Acid (mg/s)	Acid (tonnes/yr)	Alkalinity (tonnes/yr)
Coal Creek	upstream	TKS-7	29/05/13	2	5.46	<5	0.174	0.32	0.0108	<0.0005	0.0077	2.5	-0.5	-1.0		0.03
	downstream	TKS-13	30/05/13	8.8	6	<5	0.120	0.26	0.0067	<0.0005	0.0015	13.1	-11.7	-102.7		3.24
Coal Creek North Tributary	upstream	TKS-6 (tarn)	29/05/13	0	4.4	<5	0.210	0.07	0.0024	<0.0005	0.0036	<1	3.4			
	downstream	TKS-8	30/05/13	35	5.95	9	0.083	0.21	0.099	0.002	0.0085	7.1	-5.8	-204		6
Coal Creek Middle Tributary	upstream	TKS-4	29/05/13	7.9	4.71	<5	0.191	0.19	0.0033	0.0005	0.0047	1.5	1.1	8.3	0.26	
	upstream	TKS-5	29/05/13	5.1	4.41	<5	0.280	0.23	<0.0005	<0.0005	0.0015	<1	4.1	21.0	0.66	
	upstream	TKS-2	29/05/13	9.1	4.81	<5	0.148	0.23	0.0031	<0.0005	0.0039	2.1	0.1	1.1	0.03	
	upstream	TKS-3	29/05/13	0.25	4.3	<5	0.380	0.24	0.0005	<0.0005	0.0026	<1	5.3	1.3	0.042	
	downstream	TKS-9	30/05/13	45	5.8	7	0.098	0.15	0.0037	0.0009	0.0026	7.4	-6.4	-286		9.0
Coal Creek South Tributary	downstream	TKS-10	30/05/13	5.3	5	<5	0.198	0.14	0.0058	<0.0005	0.0025	4.2	-2.2	-12		0.37
West Creek	upstream	TKS-1	29/05/13	1	4.33	12	0.290	0.41	0.0011	<0.0005	<0.0010	1.8	3.3	3.3	0.10	
	downstream	TKS-11	30/05/13	90	5.45	<5	0.106	0.11	0.0021	<0.0005	0.0059	10.1	-9.0	-813		25.6

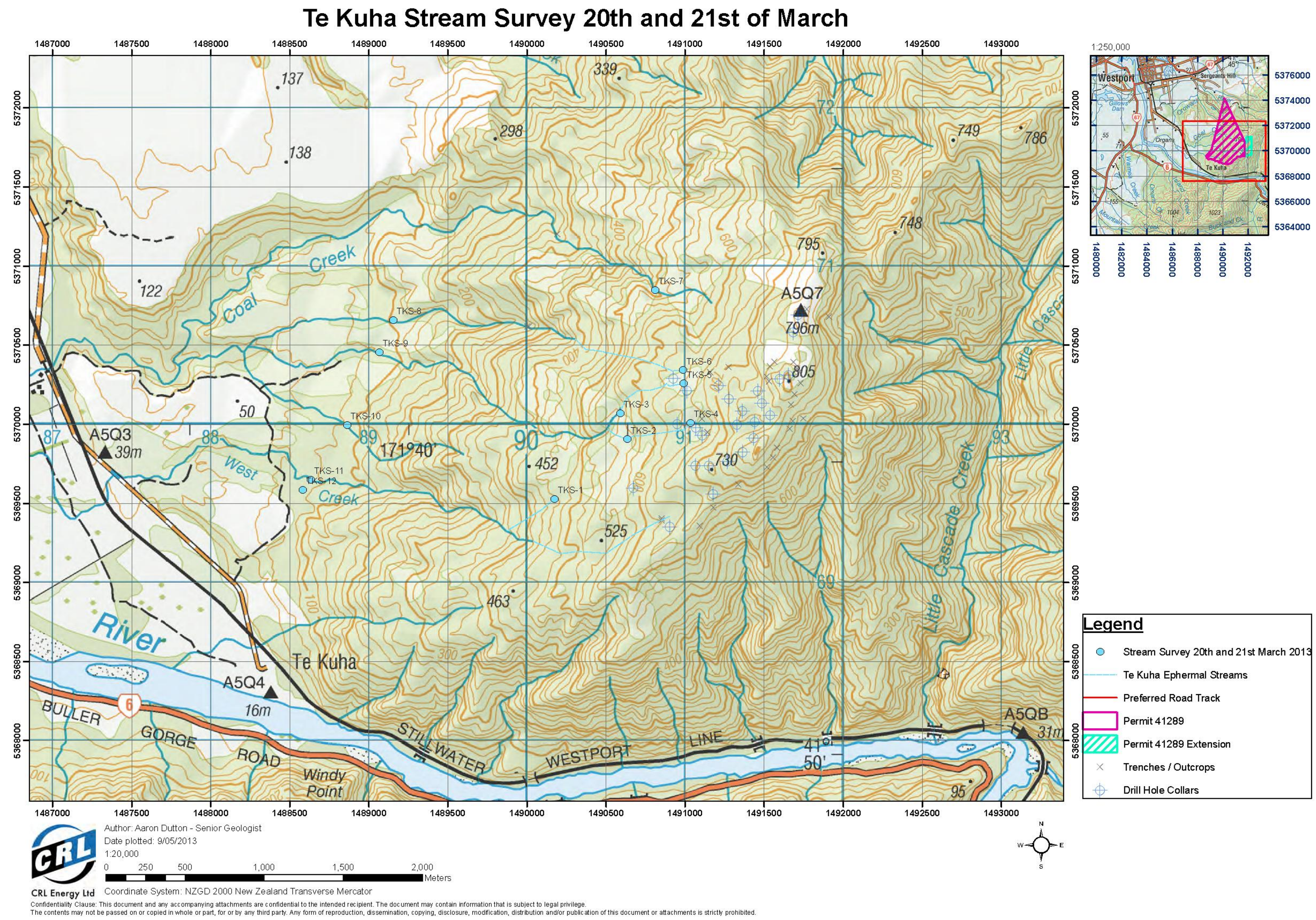

Figure 3. Topography map of site showing stream locations and sampling sites.

In general, net acidity in the headwaters of the streams is neutralised resulting in net alkalinity downstream (Table 1). For the 21 March 2013 sampling event, acid load in the headwaters ranged from 0.027 t/y to up to 0.30 t/y and alkalinity load at the downstream locations ranged from 0.30 t/y to up to 17 t/y. A similar pattern was documented for the 29 and 30 May 2013 sampling event.

5.0 Groundwater

Investigation into the groundwater systems at the site is being conducted by Aqualinc. A preliminary report on the findings is included in Appendix A and summary of the conclusions is included here.

The data collected to date suggest that there are two groundwater systems in the study area. The first is a discontinuous, perched, rainfall driven, shallow system. The second is a deeper, more extensive system, also rainfall driven.

5.1 Deep groundwater system

Data from the boreholes show that the deep groundwater system is approximately 30 to 80 m below the land surface with a groundwater flow direction to the northwest (Figure 4). Groundwater intersects the surface at approximately the 600 m contour, which coincides in general with the locations of streams marked on the topographic map of the area (Figure 3). This suggests that groundwater may discharge to the surface at around this elevation.

Data suggest that primary permeability through the strata is less than secondary permeability through fractures in the rocks. Hydraulic conductivity is estimated to be between 0.21 and 3.48 m/d, based on recovery rate tests from a single borehole. Datalogger data from boreholes suggest response of groundwater levels to rainfall is rapid, likely due to high secondary permeability.

5.2 Shallow groundwater system

Observations at the site suggest that fracture bound expanses of sandstone and areas associated with mass movements may be providing a discontinuous surface for an ephemeral perched groundwater system. Mass movements and slumps have created areas with depressions that occasionally retain precipitation, such as the tarn at site TKS-6 and surface water near borehole TK-10. Small streams near the crest of the ridge are perched upon solid sandstone.

The shallow groundwater features are predominately rain fed but there is likely to be water storage in the humic soil layer, or sediments close to the surface, that sustains flow between rainfall events.

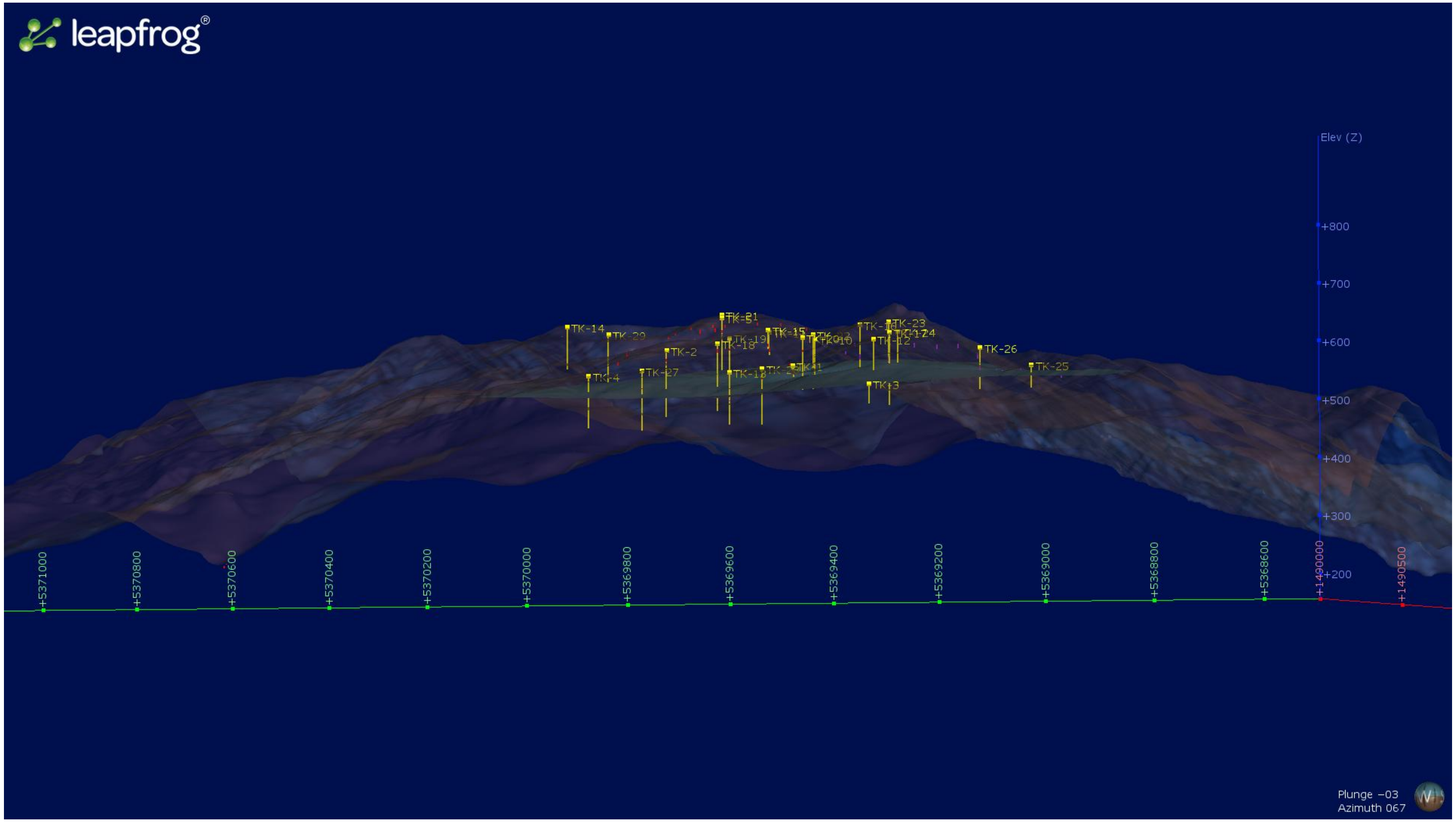

Figure 4. Approximate potentiometric surface of deep groundwater aquifer. Topographic surface generated from Lidar data is shown as well as boreholes from which the data was obtained.

6.0 Further work

6.1 Surface water

To complete the assessment of the baseline surface hydrology, at least one additional site visit will be conducted to the sampling points near the top of ridge. Flow rates will be determined, and water samples will be collected and laboratory analysed for the full suite of parameters as was completed for the first two site visits. Water samples and flow rate data will be collected on a monthly basis from the sampling sites downstream. In addition to this, a datalogger has been installed at a downstream location on Coal Creek to record pH, conductivity, temperature and flow rate on a continuous basis. The weather station will continue to record climatic conditions at the site.

The data collected from surface water streams and the weather station will be analysed to define the response of surface hydrology to precipitation events, including runoff behaviour, evapotranspiration, and infiltration rates into groundwater. Chemistry data will be analysed to determine the baseline background chemistry for the area.

6.2 Groundwater

Additional data will be collected from groundwater at the site. This will include recording groundwater levels to quantify variations, both short term and seasonal, retrieving data records from installed water level recorders to compare with the rainfall record, conducting additional recovery rate tests to determine aquifer parameters, laboratory analysis of groundwater samples to determine background chemistry, and calculation of potential inflows into open pits during mining.

6.3 Water management plan

Once the additional data from surface water and groundwater systems have been analysed, a complete water balance of the study area will be completed. The data from surface water, groundwater, and precipitation records will be used to prepare a water management plan for the proposed mine. This will include predicting the effects of mining on the current background water flow rates and quality and recommending a water management infrastructure to ensure effects are acceptable.

7.0 References

Dutton A, Newman J, Newman N, Field A, Pope J 2013. The Te Kuha Sector, Buller Coalfiled: A revised model. Proceedings of the 46th annual conference, New Zealand Branch of the Australasian Institute of Mining and Metallurgy. 26-28 August 2013, Nelson, New Zealand.

Thomson, C 2011. HIRDS.V3: High Intensity Rainfall Design System – The method underpinning the development of regional frequency analysis of extreme rainfalls for New Zealand. A report for the New Zealand Foundation

for Research, Science and Technology. The HIRDS system is available at: http://hirds.niwa.co.nz

Appendix A

Aqualinc Preliminary Groundwater Investigation Report

AQUALINC RESEARCH LIMITED

Te Kuha
- Preliminary Groundwater investigation

Prepared for CRL Energy limited

Report No C13079/1

June 2013

AQUALINC RESEARCH LIMITED

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1 INTRODUCTION

Aqualinc Research carried out preliminary investigations on the groundwater resources and interactions at the Te Kuha Sector, Buller Coalfield site, including a review of relevant information and field work. Two field trips were undertaken to the site, the first on 7/5/2013, and the second on 29/5/2013 and 30/5/2013.

Previous groundwater work at the site included measurement of groundwater levels and water sampling from the old bores (Cement Holdings, 1986). These levels are presented in this report. Kingett Mitchell Limited (2002) also provide a brief comment on the hydrogeology of the area stating that hydraulic transmissivity of 0.02-6.7 m^2/d and hydraulic conductivities of 0.02-0.83 m/d have been reported regionally for the Brunner Coal measures. They also state that these high transmissivities are not expected to have significant effect on water inflow into pits (which are near both surface and groundwater divides) which will primarily be driven by rainfall. Aqualinc agree that the primary porosity will result in little inflow into the pit, but due to the fractured nature of the sediments at the site, secondary porosity will be able to transmit large amounts of water.

Aqualinc recorded water levels for all accessible bores at the site and water level was logged in a selection of bores. Aqualinc used this data to generate a piezometric surface and conceptual model of the area

2 WORK UNDERTAKEN TO DATE

- Review of previous reports and bore logs supplied to obtain background information on the hydrological system
- Initial field work to install level loggers in bores TK-10, TK-18, TK-22 and TK-28 on 7/5/2013.
- Second field visit (29/5/2013 and 30/5/2013) to record water levels in TK-1, TK-2,TK-4, TK-5, TK-10 TK-11, TK-12 TK-13, TK-15, TK-17, TK-18, TK-21, TK-22, TK-23, TK-24, TK-26 and Tk-28. Loggers in TK-10, TK-18, TK-22 and TK-28 were checked and downloaded and an additional logger was installed in TK-17
- Slug tests performed in TK-28 and analysed to estimate formation conductivity

3 DEEP GROUNDWATER

One of the aims of the field visits was to determine depth to groundwater. Water levels in all accessible bores were measured with a dipper (Figure 1). Total current bore depths were also measured.

Figure 1: *Water level measurement at TK-26*

3.1 Bores used

The bores in the study site were drilled for geological purposes and therefore are not ideal for hydrogeological studies. These bores were not screened or developed, which may mean that drilling mud or other fines may inhibit or prevent, hydraulic connection between the bores and the formation. No annular seal was installed between the casing and the bore wall, and therefore the section of the formation that contributes the water present in the bores is not known. The lack of an annulus may also provide a pathway that rainfall and/or surface runoff to enter the bores, also producing a false indication of the water level. Another related factor is that voids intercepted by the bore may also be contributing water. Thus the bores may act as sumps that drain slowly.

The older bores (TK-1 to TK-16) were finished with 1 inch PVC and were presumed not to be screened or capped. The old bores were dipped directly and were assumed to be in hydraulic connection with the surrounding groundwater. The newer bores (TK-17 to TK-28) were finished with 65 mm PVC and capped at the end. These caps were dislodged by punching with a steel rod, after which water levels dropped. Due to the low permeability of the sediments water levels took a long time to stabilise.

3.2 Water levels

Water levels were obtained for TK-1, TK-2, TK-4, TK-5, TK-10 TK-11, TK-12 TK-13, TK-15, TK-17, TK-18, TK-21, TK-22, TK-23, TK-24, TK-26 and Tk-28. A peizometric surface of the deep groundwater was developed from the measured water levels. Loggers were installed in TK-10, TK-18, TK-22 and TK-28 and the data analysed.

A table of the measured water levels with reference to the coal seam depths at each bore is shown in Table 1. The groundwater levels obtained in 1985, again with reference to coal seam depth are shown in Table 2.

Table 1: Bore locations, relative levels, and 29-30 May 2013 water levels

ID	Easting (NZGD 2000)	Northing (NZDG 2000)	Elevation (LIDAR elevation surface)	Water Level May 2013	Relative Level May 2013	Depth (m) (measured May 2013)	Coal seam top (m)	Coal seam base (m)
TK-1	1491113	5369762	853.91	dry		25	10	16.5
TK-2	1491206	5370245	698.86	dry		26.8	17	24
TK-4	1490925	5370284	632.1	31.48	600.62	33.9	no	No
TK-5	1491605	5369788	790.27	dry		35.6	25	33.2
TK-10	1491438	5370013	729.21	87.078	642.132	90	79.7	90.7
TK-11	1491484	5370132	749.12	dry		46.2*	32	40
Tk-12	1491064	5369739	698.76	59.96		64.4	0	7.4
Tk-13	1490949	5369998	633	dry		15.5	30.8	32.4
TK-15	1491381	5370080	746	dry		14.7	27.3	34.5
TK-17	1491148	5369737	717.83	57.45	660.38	147.1	no	No
TK-18	1491276	5370160	713.12	85.84	627.28	136 *	9	18
TK-21	1491651	5370308	796.67	dry		119.1	27	35
TK-22	1491537	5370057	746.42	64.98	681.44	77.6	63	67
TK-23	1491361	5369822	755.28	dry		40.9	72	82
TK-24	1491265	5369765	727.54	dry		110.2	5	7
TK-26	1491175	5369556	684.89	47.44	637.45	75.9	37	50
TK-28	1491066	5369977	647.18	40.14	607.04	111	16	21

* Levels from bore logs

Table 2: Bore locations, relative levels, and 1985 water levels

ID	Easting	Northing	Elevation (LIDAR elevation surface)	Water Level Apr 85	Relative Level Apr 85	Depth (m) (measured May 2013)	Coal seam top (m)	Coal seam base (m)
TK-1	1491112.8	5369762.4	853.91	20.7	833.21	25	10	16.5
TK-2	1491205.8	5370244.8	698.86	27.2	671.66	26.8	17	24
TK-4	1490925.2	5370284.2	632.1	16.6	615.5	33.9	no	No
TK-5	1491605.3	5369787.5	790.27	28.8	761.47	35.6	25	33.2
TK-10	1491437.6	5370012.7	729.21	56	673.21	90	79.7	90.7
TK-11	1491483.6	5370132.4	749.12	16.3	732.82	46.2*	32	40

*Levels from bore logs

In the May 2013 sampling, bores TK-10, TK-22 and TK-26 indicate that the water levels are within the coal seam. The 1985 levels indicate that TK-5 and again TK-10 have water levels within or above the coal seam. If these levels are confirmed, this water will have to be taken into account during mine planning. The summer of 2012-2013 was unusually dry and therefore the above measurements should be regarded as minimum water levels.

The only usable data from the loggers was obtained from TK-28. This data was corrected for barometric pressure and plotted against available rainfall data (Figure 2). The water level in the bore increased by approximately 1.5 m, and maintained this level, between the first and second field visits. This increase in level is likely to be part of water level recovery in the area from the dry summer. It can be seen that the water level in this bore is responding to rainfall, although the water level response does not appear to be proportional to the amount of rainfall received. The large responses are early in the month, and then the response is damped later as the water level rises in the bore. This may be because the water level is reaching a stable level and additional rainfall moves out of the system, potentially into the stream or further down slope, or this could be related to the interception of higher permeability layers (most likely fractures) at higher water level elevations.

The response of groundwater to rainfall is within a few hours in TK-28 (Figure 2). This corresponds to rapid infiltration of the water through the large fractures that are present at the site.

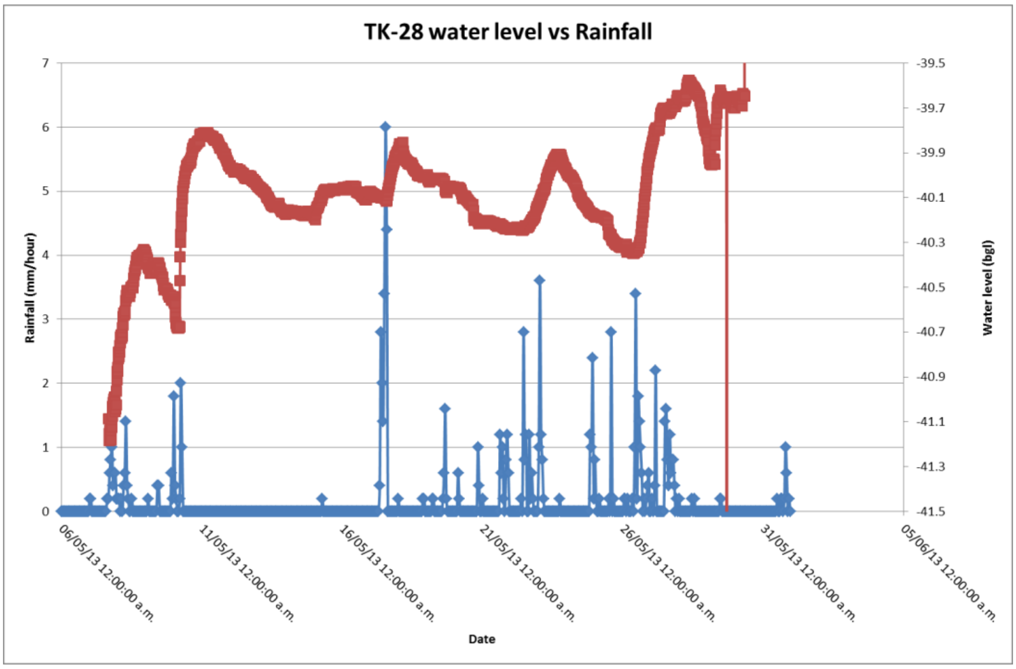

Figure 2: Water level vs. Rainfall in TK-28

3.3 Issues with water level data

Loggers were installed in TK-10, TK-18, TK-22 and TK-28 on the first field visit on 7/5/2013. It was found on the second field visit that water levels had continued to drop in bores TK-10, TK-18 and TK-22 after the loggers were installed. This resulted in the loggers in TK-10 and TK-22 being out of the water and TK -18 recording a continuous decline in water level (Figure 3). The length of time taken for the water levels in these bores to stabilise may indicate two possibilities, the first, that the formation surrounding these bores has very low permeability, or secondly, that there are fines inhibiting flow in these bores. It is more likely that these bores are choked with fines, either from drilling mud or other eroded material because when the caps were punched off the bores soft sediment was encountered in the base of the bores. These bores were not developed after drilling which would explain the presence of these fines. These bores could be pumped or air sparged to remove the fines and improve the hydraulic connection between the bore and the formation.

It was also found that bore TK-10 had drilling mud or another fluid of a higher density in the casing making level measurement difficult. Measuring water level in this bore produced a different level than that recorded by the transducer indicating that the liquid in this bore was not pure water.

Loggers were reinstalled in TK-10, TK-18 and TK-22 and an additional logger was installed in TK-26. Data will be retrieved on the next field visit.

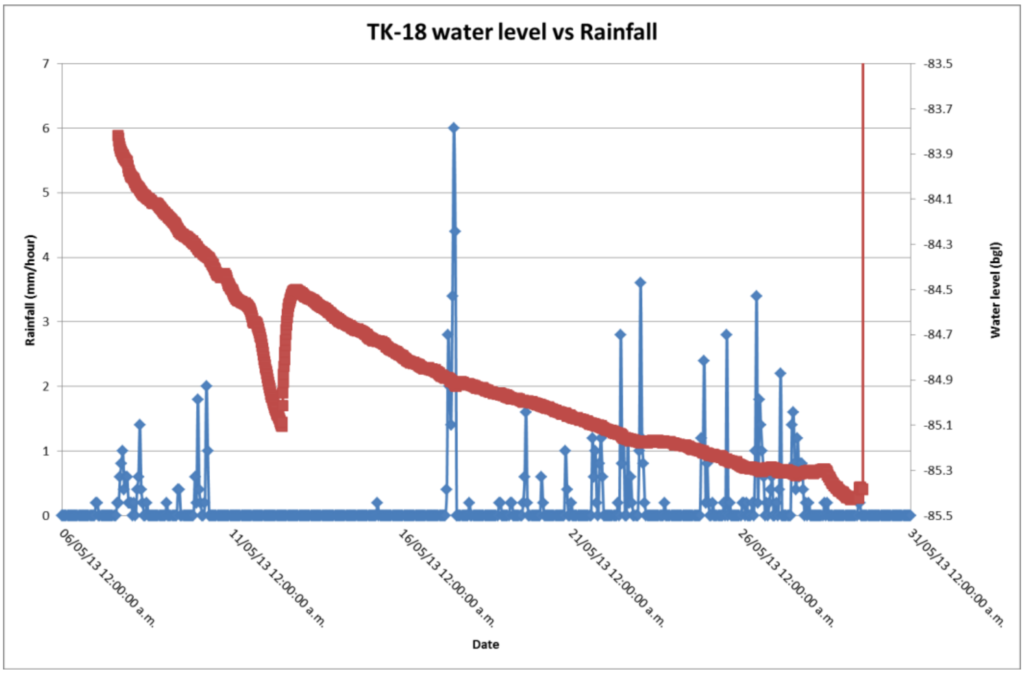

Figure 3: Water level vs. Rainfall in TK-18

4 SHALLOW GROUNDWATER

A visual assessment of the shallow groundwater system was under taken. It was noted the system is perched on solid expanses of sandstone, or on eroded material, or a combination. The system is not continuous, being confined to the more level areas of the site associated with slumps. It is more likely that the small streams towards the crest of the ridge are perched on solid sandstone (Figure 4) and the lower streams are perched on either sandstone and/or fine eroded material. This was observed at numerous locations. Water perched near TK-10 (Figure 5), and at the large tarn, is associated with mass movements, forming depressions, in which eroded sediment accumulates. The bore log for TK-10 shows 5 m of sand, which is eroded material that has accumulated at this location.

Figure 4: Stream flow over sandstone near TK-5

These shallow groundwater features are predominately rain fed but there is likely to be water storage in the humic soil layer, or sediments close to the surface, which is sustaining some flow between rainfall events. Also, the tarn was dry during summer and quickly refilled after rain, which also supports this hypothesis.

Figure 5: Swampy ground around TK-10

5 HYDRAULIC CONDUCTIVITY

A slug test was undertaken on bore TK-28 to obtain an estimate of the hydraulic conductivity of the material at the tip of the casing. This bore is cased with 65 mm PVC to a depth of 111.3 m. Bore logs indicate that at this level is basement sandstone. The bore had an initial water level of 39.74 m below ground level. A pressure transducer set to 10 second logging was installed in the bore at approximately 5 m below the water level. A slug (volume 640 ml) was then instantaneously introduced into bore to induce a change in water level, and then the bore was allowed to recover. The slug was then instantaneously removed from the bore and allowed to recover to obtain another data set.

The data was analysed using the Hvorslev and Juul (1951) method for bores with open ends. This is an approximate method for determining hydraulic conductivity in open ended casing, subject to a number of conditions. The analysis resulted in hydraulic conductivity values from 0.21 - 3.48 m/d. This is within less than an order of magnitude variation from hydraulic conductivity values reported by for the Brunner Formation. This is the only bore that was slug tested as it was the only one that the levels were connected to the formation.

The primary hydraulic conductivity is likely to be contributing a small fraction of water transmitted in the study area. The major flow will be contributed by secondary porosity through fractures in the rock. Secondary hydraulic conductivity is difficult to quantify unless a pump test with observation bores is carried out in the area.

6 CONCEPTUAL MODEL OF GROUNDWATER SYSTEM

From the above data and site visits, a conceptual model of groundwater flow has been created. We propose that there are two groundwater systems in the study area. The first is a discontinuous, perched, rainfall driven, shallow system. The second is a deeper, more extensive system, also rainfall driven.

The deep groundwater system is extensive over the site and is approximately 30 - 80 m below the land surface depending on the location (assuming the recorded water levels are accurate). Using the available data, an approximate piezometric surface was generated in Leapfrog. The water level surface roughly follows the land surface which is related to the dipping planes of the underlying geological strata.

The piezometric surface also intersects the eastern slope of the study area at around the 600m contour. This intersection is approximate because of the lack of data points on the eastern boundary of the study. This contour roughly coincides with the origins of the streams marked on the topographic map of the area. This is the likely out to the deep aquifer.

Rainfall infiltrates into the deep groundwater at a rapid rate through the large fractures present in the area. The blocky nature and extensive voids in the terrain (Figure 6) mean that the bulk of the rainfall is funnelled into the deep groundwater system and there would be little overland flow.

Figure 6: Large block fractures between TK-26 and TK 17

7 FURTHER WORK

- Further recording of groundwater levels to understand variations, both short term and seasonal.
- Retrieve data records from installed water level recorders and further analyse levels and compare with the rainfall record.
- Perform further slug tests on selected bores
- Take and analyse water quality samples from selected bores
- Further correlation of groundwater levels with topography, geology and stream flow.
- Calculation of potential pit inflow

8 REFERENCES

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