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ATTACHMENT 4

JH Rekker Consulting Ltd 16 December 2019: Response on Hydrological Matters

16 December 2019

Bathurst Coal Limited
Level 12
1 Willeston Street
Wellington 6011

Attn: Eden Sinclair

Dear Eden

RE CRC201366-8 Request for Further Information (RFI) – Response on Hydrological Matters

In reply to your request for assistance with the response to the Request for Further Information (RFI) within application number CRC201366-8 as received by BCL on 18 October 2019, I have the following hydrological assessments relating primarily to changes in the catchment divide positions produced in mining-related earthworks. Environment Canterbury in its 18 October 2019 RFI notice letter made several requests with bearing on hydrology that you have asked me to respond to, including background from questions 2 and 9 (in *italics*) since they have bearings on the main question 10.

2. *Using the map and information in response to question 10, an assessment of the potential ecological effects on seeps/wetlands and a description of any measures to avoid, remedy, mitigate or offset adverse effects.*

9. *An assessment of the effects on surface water flows (7dMALF and mean flows) in the Waianiwaniwa catchment and Selwyn River catchment. This assessment should consider the natural and post-mining topography, runoff co-efficients and meteorological conditions of the site and the influence of the water treatment system and take of water for dust suppression.*

10. Based on the assessment above and knowledge of the localised natural drainage of the site and surrounding area, please provide an assessment of potential effects of altering drainage patterns on any seepages or wetlands on the north-west slopes, the south-east gullies and Tara Stream and any subsequent changes in lows flows to receiving waterbodies. This assessment should identify any retrospective effects and future effects and also effects both inside and outside of the MOA.

The information requested in question 10 has two principal components –

- Delineation of "seepages or wetlands on the north-west slopes, the south-east gullies and Tara Stream", and
- Potential effects on these and wider catchment-level effects on flow rates.

Once question 10 requirements are satisfied, the derived information would be available for ecological assessment with respect to RFI question 2.

Hydrological Background

Canterbury Coal Mine (CCM) is located in the foothills to Cairn Ridge and within the Waianiwaniwa River sub-catchment of the Selwyn – Waihora Catchment. These hills are on the margin of the Central Plains and are distant outriders to the Southern Alps to the west, although the upper Selwyn river catchments do not extend to the Main Divide. Land within the Mine Operations Area (MOA) land reaches up to 426 m AMSL in elevation along an unnamed ridgeline that is drained by Bush Gully Stream to the north and Surveyors, Oyster and Tara Stream to the south.

Topélen (2007) characterised the upper Selwyn River as follows:

Most rainfall in the Selwyn River catchment is associated with cold southerly air masses (Sturman, 1986). However, the upper parts of the catchment receive some spill over from northwest winds, which are responsible for bringing most precipitation to the Southern Alps. Average rainfall in the Selwyn River catchment is highly variable (spatially)*, ranging from an estimated 2000 mm in the headwaters of the Selwyn River catchment, to about 700 mm across the plains. The rainfall isohyds show a rain shadow starting in the gorge in the Selwyn River upstream of the recorder site at Whitecliffs and extending approximately to the confluence with Bush Stream.*

The Waianiwaniwa (Waireka) River has its headwaters in the Wyndle Hills, which have a highest peak of about 800 m. The hills consist of greywacke. The river continues through a valley, where gravel sediments are covered by a thick layer of loess. It flows south around Cairn Hill, which consists of greywacke. Below the confluence with Bush Gully Stream the riverbed widens into coarse gravel sediments. In the sub-catchment of Bush Gully Stream soft sandstone sediments are found. The hills surrounding the valley are predominantly gravel sediments covered by a layer of loess, except for Homebush Ridge, which is formed of volcanic sediments. Homebush Ridge forms a small barrier after which the river flows out into the plains. The higher parts of the catchment are mostly used for forestry.

Topélen (*ibid*) also mapped the distribution of specific Mean Flow and Mean Annual Low Flow (7 day) across the upper Selwyn catchment as a set of contours of interpolated mean and mean annual low flows measured or calculated from 18 gauging sites across the wider catchment. The mean and mean annual low flow statistics were also normalised and naturalised to remove or minimise abstraction influences. I have rasterised the contour maps and re-orientated them to centre on the CCM gully catchments. Nonetheless, the contour maps display the distribution of these two hydrological statistics for all parts of the catchment.

The objective in rasterising these hydrological statistical distributions spatially was to be in a position to define specific catchment discharges for mean flow and MALF7d at most points within sub-catchments, especially the CCM mine operations area. Figure 1 and Figure 2 display the contours generated from the interpolated mean flow and MALF7d values, respectively.

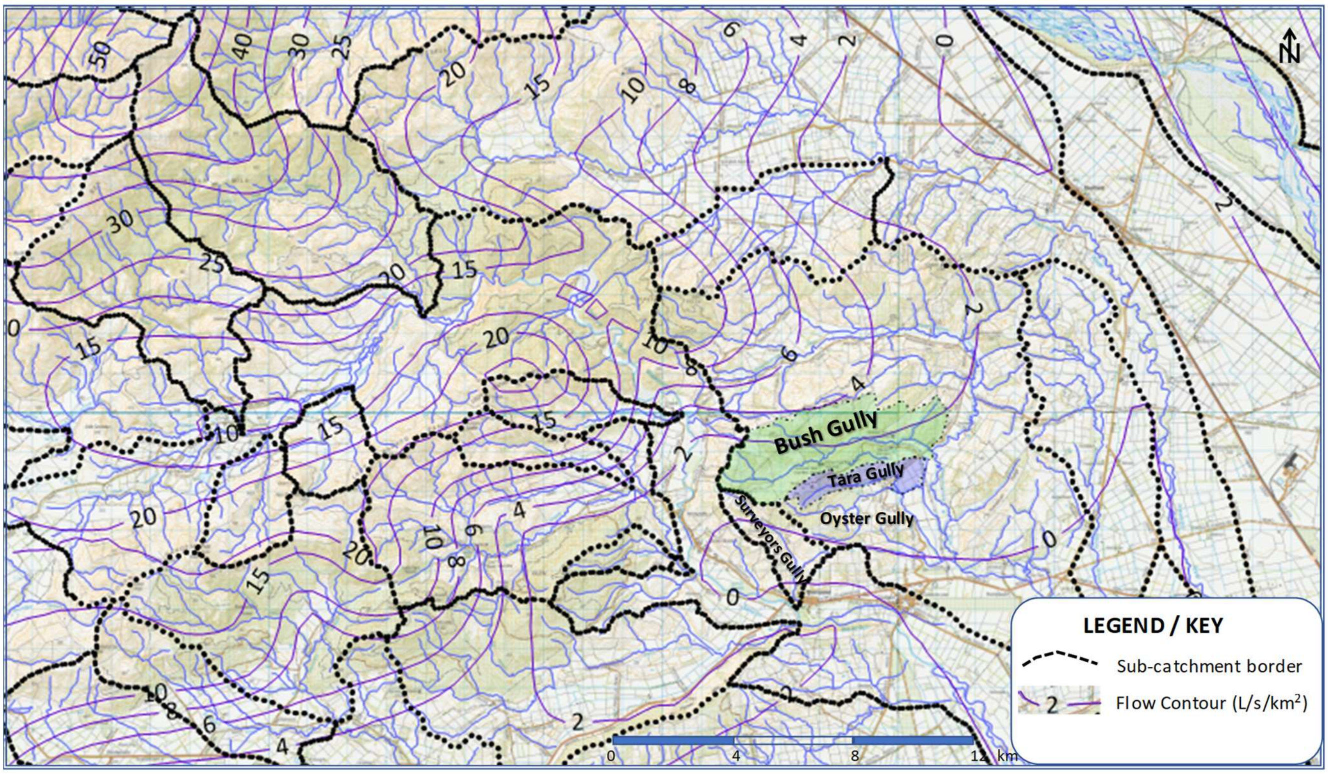

Figure 1: Mean Flow contours of the Upper Selwyn with CCM gully catchments for orientation

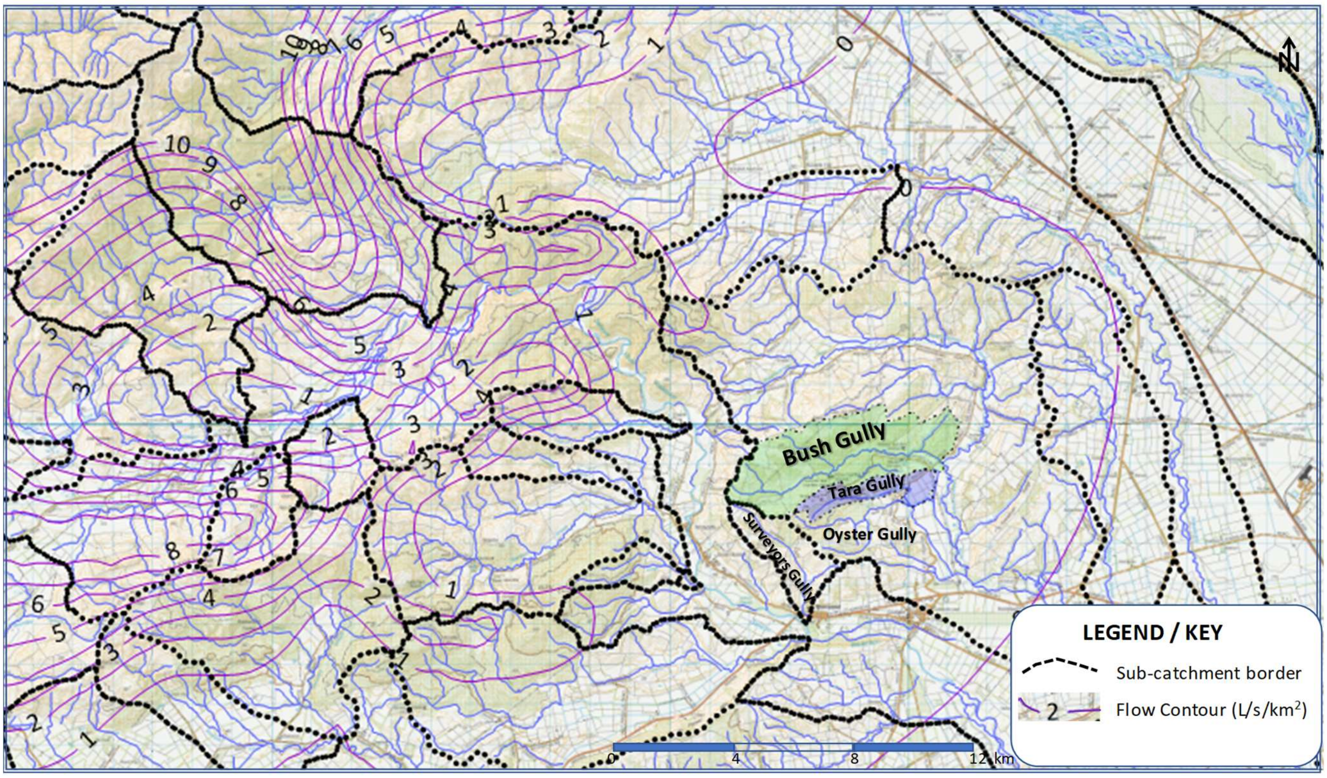

Figure 2 Mean Annual Low Flow 7 Day (MALF7d) contours of the Upper Selwyn

The distribution of mean flow contours proved to show marked similarities with the pattern of mean annual rainfall contouring, as illustrated in a figure reproduced from Topélen (2007) shown below in a map exert within Figure 3. The rain shadowing effects referred to by Topélen (ibid) are evident in the bending of the 1000 and 1200 mm per annum isohyets in Figure 3. Conversely, the contours of mean annual low flow (MALF7d) suggest stronger influences from local geological variations, particularly permeable gravels or low permeability sediments. This is inferred to be due to MALF7d being gauged within baseflow conditions when losses or gains with groundwater are more significant. The mapping of Topélen (*ibid*) included indication in her figures that the upper Waianiwaniwa lost water, middle reaches gained water and lower reaches of the Waianiwaniwa once again lost water to its gravel bed during MALF7d low flow conditions. At mean flow magnitudes of flow the middle and lower reaches both lost water to the gravels. These interactions were considered in drawing up flow statistic contours, so contours of zero specific flow (i.e. 0 L/s/km^2) are evident in the lower Hawkins, Waianiwaniwa and Selwyn river catchments. These low specific flows have direct influence on the rasterised flow contours for lower Surveyors Gully and may be less than representative of localised conditions as a result of the interpolation method used by Topélen (*ibid*).

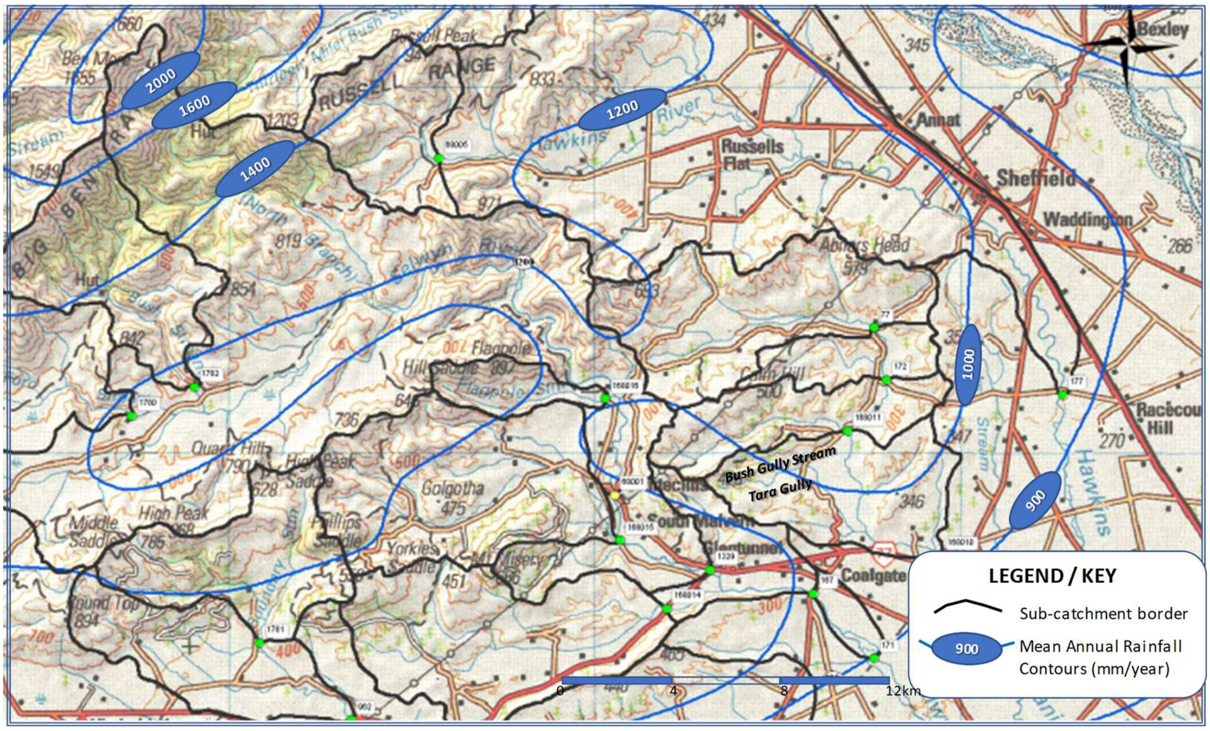

Figure 3: Mean annual rainfall total contours (isohyets) for the Upper Selwyn catchment (Topélen, 2007)

Changes to Sub-Catchment Divides

One result of proposed mining earthworks referenced in application CRC201366-8 ("various consents to undertake mining activities at the Canterbury Coal Mine"), the operational and permanent sub-catchment divide positions will shift between the Bush Gully, Tara Gully, Oyster Gully and Surveyors Gully catchments. Slivers of land area will be traded between these sub-catchments. The Bush Gully and Surveyors Gully sub-catchments are net recipients of new catchment area, while Tara Gully and Oyster Gully are net losers of area. All sub-catchments rest within the Selwyn – Waihora Catchment and water management zone. However, Surveyors Gully flows into the Selwyn River near Glentunnel resulting in the loss of land from adjoining catchments that previously drained to the Waianiwaniwa River. There is thus a net shift from the Waianiwaniwa sub-catchment to the Selwyn main stem catchment amounting to 4.78 ha.

Table 1 indicates the net changes in sub-catchment area in hectares (ha).

The Bush Gully and Surveyors Gully sub-catchments are net recipients of new catchment area, while Tara Gully and Oyster Gully are net losers of area. All sub-catchments rest within the Selwyn – Waihora Catchment and water management zone. However, Surveyors Gully flows into the Selwyn River near Glentunnel resulting in the loss of land from adjoining catchments that previously drained to the Waianiwaniwa River. There is thus a net shift from the Waianiwaniwa sub-catchment to the Selwyn main stem catchment amounting to 4.78 ha.

Table 1: Indicated sub-catchment changes for CCM mine operations area

Sub-Catchment	Sub-Catchment Area (km^2)	Net Adjusted Area (ha)
Bush Gully Stream	9.028	+2.40
Tara Gully stream	1.947	-5.39
Oyster Gully Stream	3.771	-1.79
Surveyors Gully Stream	3.219	+4.78
Selwyn River Main Stem*	200.300	+4.78

Note: Positive (+) net adjusted areas indicate gains, while negative (-) indicate losses.
*Waianiwaniwa River catchment loses 4.78 ha of area to the Selwyn River main stem.

The areas affected are shown in Figure 4 as colour coded zones indicating shift from one catchment to another, e.g. 'Tara to Bush'.

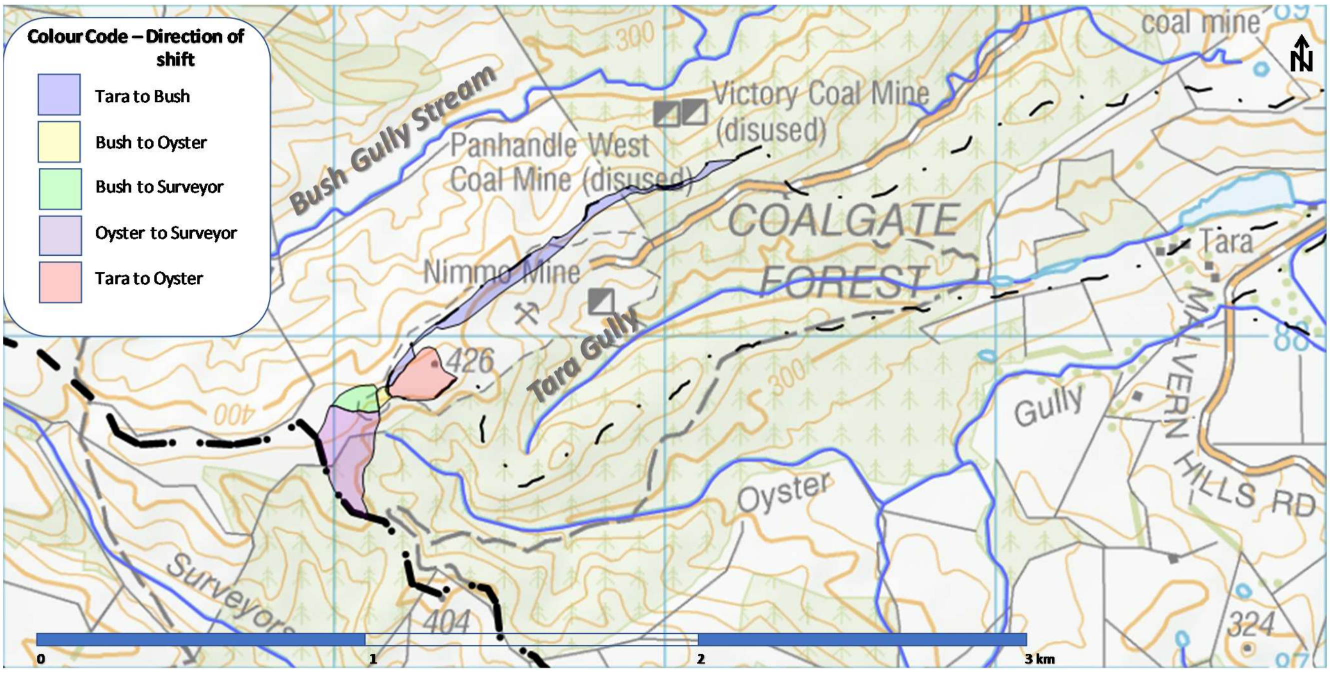

Figure 4: Location of mining related catchment flow divide shifts

The exchange of catchment area would have an effect that can be estimated by calculations on the mean flow and mean annual low flow of the watersheds affected.

Changes to Sub-Catchment Flow Statistics

RFI question 9 asks for the assessment of changes to mean flow and mean annual low flow resulting from mining related earthworks and re-alignment of the land surface. This question can be assessed by extracting the relevant flow statistics for the catchment zone associated with the shifts. Methodologically, this entailed interrogating the contoured surfaces of mean and mean annual low flow shown in Figure 1 and Figure 2 within the sub-catchment shift areas shown in Figure 4. A sample 'cloud' of points within each zone was synthesised and values of flow statistics were generated for each point within the cloud. The returned values were averaged for each distinct zone and tabulated in Table 2.

Table 2: Incremental, Accumulated and Percentage Mean & Mean Annual Low Flows

Sub-Catchment	Net Adjusted area (ha)	Incremental $MALF_{7d}$ (L/s)	Incremental Mean flow (L/s)	$MALF_{7d}$ (L/s)	Mean Flow (L/s)	MALF Change (%)	Mean Flow Change (%)
Bush Gully	2.40	0.01069	0.01610	4.10682	16.16	0.26%	0.10%
Tara Gully	-5.39	-0.02416	-0.04060	0.79690	2.25	-3.03%	-1.80%
Oyster Gully	-1.79	-0.00783	-0.00897	1.43148	2.53	-0.55%	-0.35%
Surveyors Gully	4.78	0.02074	0.02079	1.27870	2.16	1.62%	0.96%

Note: Positive (+) net adjusted areas indicate gains, while negative (-) indicate losses, similarly incremental flows, accumulated flows or percentage changes in flow are gains or losses from the specified sub-catchment.

Referring to Table 2 it is possible to ascertain that the Selwyn River main stem at Glentunnel receives additional mean flow and MALF7d of 0.021 L/s from Surveyors Gully as a result of sub-catchment shifts in the CCM mine operational area. Mean flow and MALF7d in the Selwyn River at Whitecliffs (immediately upstream of Glentunnel) are 3,236 and 792 L/s, respectively. Bush Gully benefits from an additional 0.01 L/s by the same mechanism, at the expense of Tara and Oyster gullies. Mean flow and MALF7d in the Waianiwaniwa River at the Bush Gully Stream confluence are estimated as 17.4 and 155 L/s, respectively. Hence, sub-catchment shifts would have a larger depleting effect on the Waianiwaniwa River than the compensating effect of increased flow on the Selwyn River main stem. The effects on the two sub-catchments is shown in context in Table 3.

Table 3: Analysis of effects of sub-catchment shifts on the Selwyn and Waianiwaniwa rivers

	$MALF_{7d}$ (L/s)	Mean Flow (L/s)	Incremental Mean Flow and $MALF_{7d}$ (L/s)	MALF Change (%)	Mean Flow Change (%)
Selwyn River Main Stem @ Glentunnel	792*	3236*	+0.021	+0.0027%	+0.0006%
Waianiwaniwa @ Bush Gully confluence	17.4¥	155¥	-0.021	-0.1207%	-0.0135%

Note: * as measured at Selwyn @ Whitecliffs; ¥ as estimated by Topélen (*ibid*) by regression analysis (*Table 3.1: Regression results and estimated MALF (7d), median and mean values for the study area*).

The overall greatest magnitude of effect from the sub-catchment shifts would be a diminution in MALF7d of the Waianiwaniwa River of 0.021 L/s (1.8 m^3/d) or 0.12%. Such flow effects are beyond the limits of detection for modern flow gauging (typically ± 5%) and negligible in terms of any change in habitat conditions for aquatic organisms.

Changes in Land Cover

Changes in land cover in the Waianiwaniwa River catchment near the CCM MOAhas been assessed in the context of afforestation of grassland by hydrologists of NIWA (Duncan and Collins, 2013). The staged planting of Pinus radiata plantation forest within the upper river catchment was estimated to result in substantial reductions in MALF7d and mean flow. For example, the progression from 1% to 100% forestry within upstream catchment suitable for forestry would result in a reduction in the 15 L/s MALF7d at Auchenflower Road to 0 L/s. The afforestation effect is not as severe for reductions calculated for mean flow; from 154 L/s to 131 L/s, a reduction of 23 L/s (15%). It should be noted that afforestation imposes significant catchment flow yield reductions due to the characteristic of interception of precipitation by trees, in addition to evapotranspiration removals of adherent water and soil moisture. In Canterbury the Natural Resources Regional Plan (NRRP) set limits on the amount of new afforestation of short grassland for selected catchments "sensitive" to land use change, so that 7-day mean annual low flows (7-day MALF) will not be reduced by more than 5% and the mean flow by more than 10%.

The current and proposed changes in land cover from low producing pasture to mine terrain and back to pasture represents substantially less change to hydrological parameters such as runoff coefficients. Open cast or surface mining has general effects of slightly increasing storm runoff coefficients, but indeterminant effects on baseflow discharge from actively mined catchments (Bonta et al, 1997). Where the land use change is from low productivity pasture to forestry, significant reduction in the runoff coefficient would be expected for both short-term and longer period flow durations. Conversely, land use change from forestry to almost any other land use would be expected to increase runoff coefficients and catchment yield. It is not expected that the current or proposed CCM land cover changes would have any more than minor effect on catchment yield in either direction. Sub-catchment areas changes assessed above (see "Changes to Sub-Catchment Flow Statistics") are considered to result in a higher level of effect on catchment yield, and these are assessed to be less than minor.

Seeps, Wetlands and Wet Gullies

The RFI questions 2 and 10 refer to seeps, wetlands and south-eastern gullies in relation to potentially Groundwater Dependent Ecosystems (GDEs) within and around the CCM mine operations area.

Boffa Miskell terrestrial ecologists identified one such class of wetlands as 'wiwi rushland', essentially wiwi rushes that have colonised areas of water seepage on the north-western slopes of the mine operations area. Figure 5 maps the distribution of wiwi rushland that is an analogue for seepage wetlands within the mine operations area. These wetlands are located on the mid and lower slopes of the ridge flank draining to Bush Gully Stream.

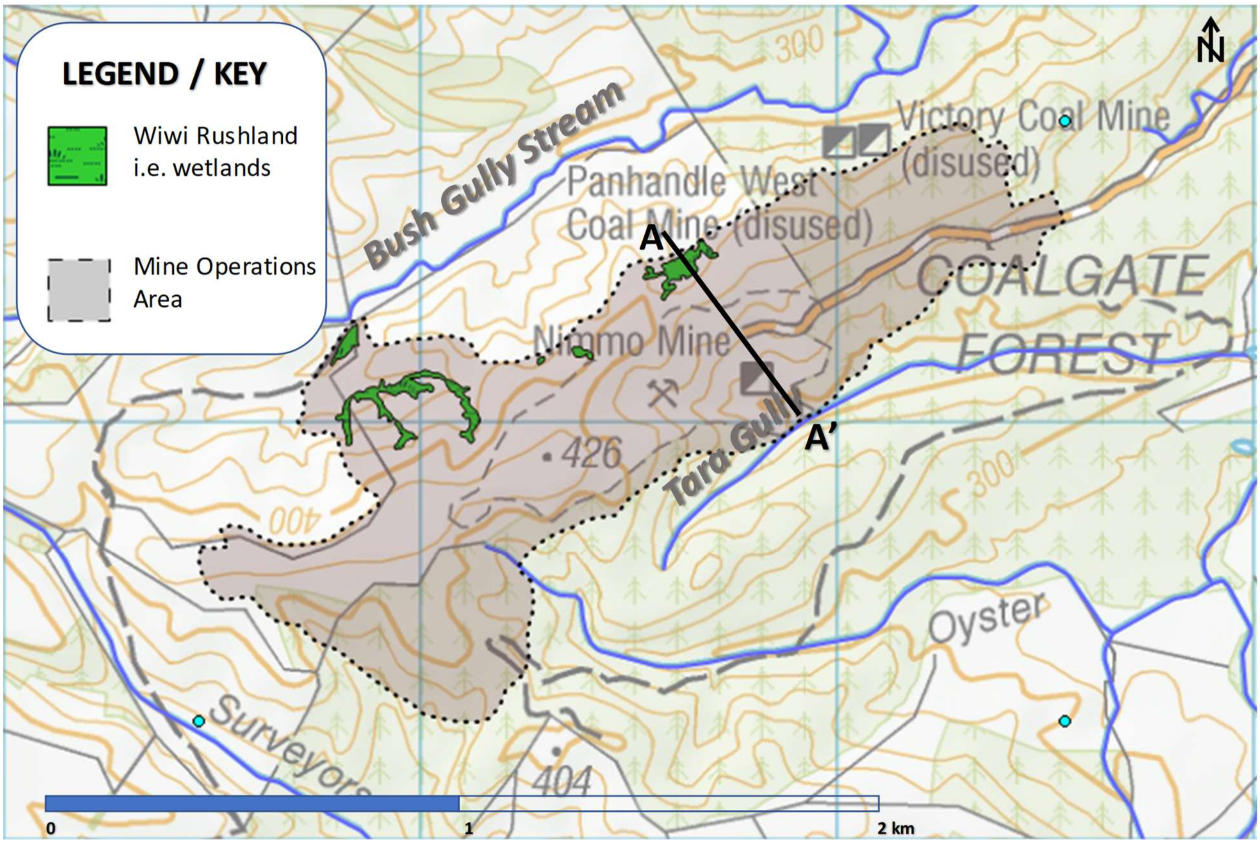

Figure 5: Location map of wetlands identified within the Boffa Miskell ecological mapping inside Mine Operations Area

The topographic significance of the wetlands' positions inside the MOAis revealed in Figure 6 and Figure 7, which illustrate the profile along the cross-section A – A', including the north-eastern seepage wetlands and End Of Mine Life (EOML) final landform with the probable seepage wetland formed in the Tara Gully catchment at the terminus of the in-pit drain.

The MOAridge is aligned with the strike of strata in the Broken River Formation and Munro Conglomerate, and the A – A' cross-section is perpendicular to the strike of these strata. Hydraulic conductivity in both strata is highly anisotropic resulting in preferential permeability along strike. Accordingly, moderate depth and deep groundwater circulation is highly restricted to any cross-strike flow parallel to the line of the cross-section. The seepage wetlands are thus likely to be sustained by shallow, even superficial, groundwater movement downslope. The rehabilitated final landform will restore the pre-existing shallow, downslope seepage.

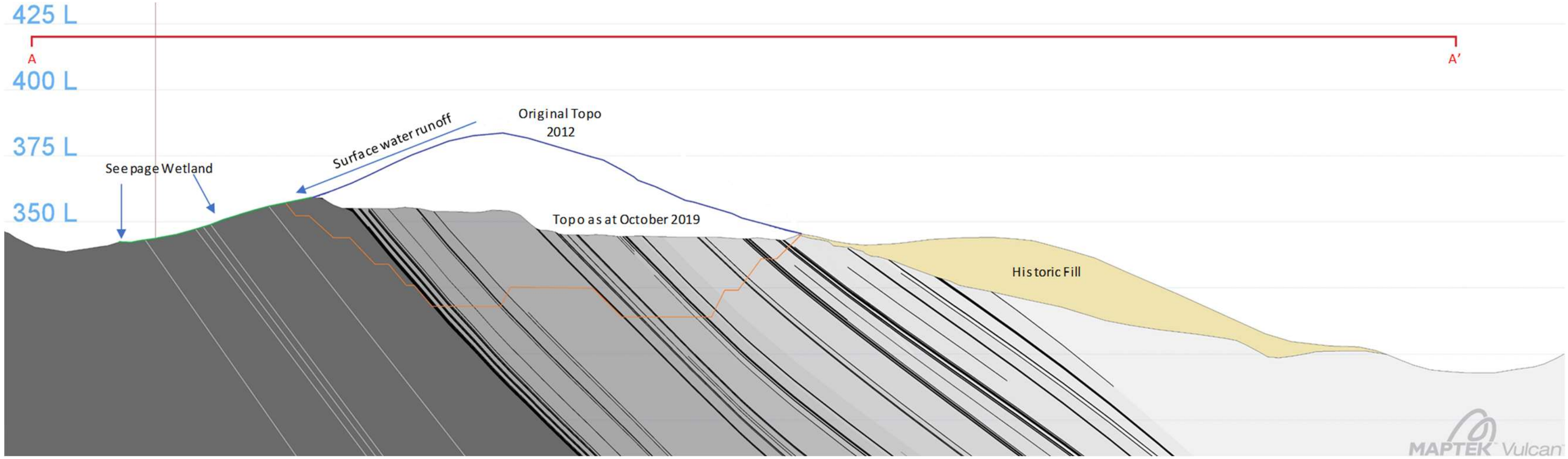

Figure 6: Profile through Section A – A' with pit development at October 2019, highlighting topographic position of wiwi rushlands that mark seepage wetlands

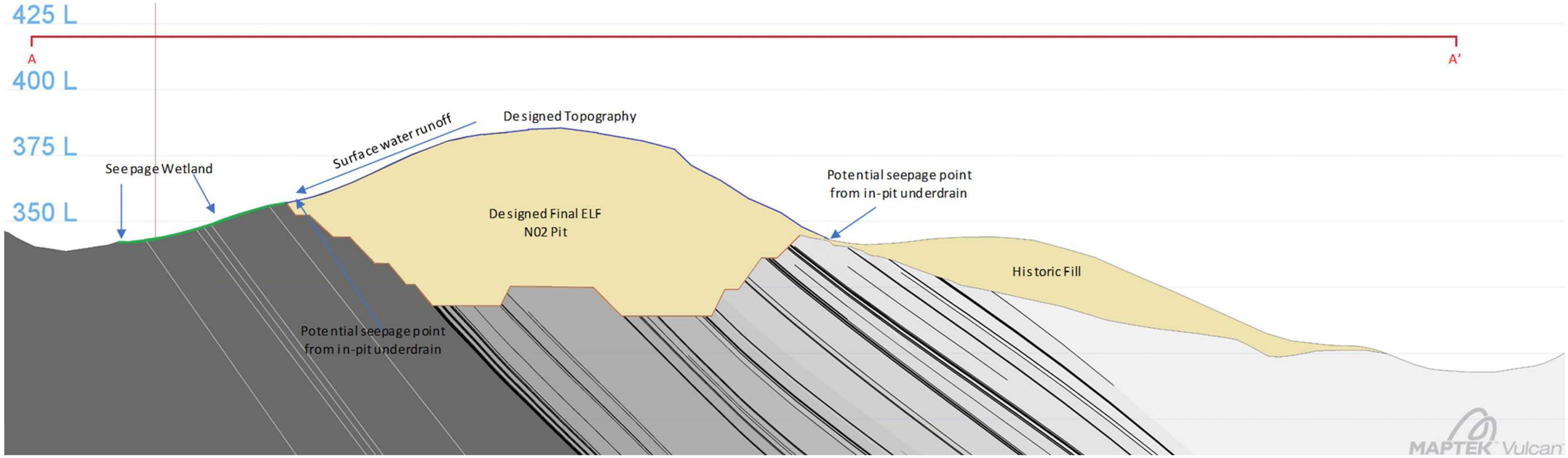

Figure 7: Profile through Section A – A' with ultimate pit excavation of NO2 pit-shell backfilled to the final Engineered Land Form (ELF) and potential seepage points at in-pit drain discharge

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Hydro – Geo – Environmental

Conclusions

In relation to movements of surface water flow divides related to mining activities, the overall greatest magnitude of effect from the sub-catchment shifts would be a diminution in MALF7d of the Waianiwaniwa River of 0.021 L/s (1.8 m^3/d) or 0.12%. Such flow effects are beyond the limits of detection for modern flow gauging (typically ± 5%) and negligible in terms of any change in habitat conditions for aquatic organisms.

In relation to changes in land cover, it is not expected that the current or proposed CCM land cover changes would have any more than minor effect on catchment yield in either direction. Sub-catchment areas changes assessed above are considered to result in a higher level of effect on catchment yield, and these are assessed to be less than minor.

Addressing the effects on “seepages or wetlands on the north-west slopes, the south-east gullies and Tara Stream”, there is little indication that flow divide shifts or changes to land surface and groundwater drainage dynamics would affect these phreatic zones.

Closure

I would be happy to expand on any of the matters outlined above. In the meantime, I am contactable at mobile **027 836 4442** or jens@rekker.co.nz

Yours sincerely

Jens Rekker
Hydrogeologist

References

Bonta, J V; Amerman, C R; Harlukowic, T J; and Dick, W A. 1997. Impact of Coal Surface Mining on three Ohio Watersheds - Surface-Water Hydrology. Journal of the American Water Resources Association, Vol 33, No.4, August 1997. pp907-917.

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