11 September 2020

Director
EMM Consulting
Ground floor, 20 Chandos Street
St Leonards NSW 2065
Attention: Brett McLennan

Brett,

Re: Tahmoor South Amended Project – Surface Water Impacts – Department of Planning, Industry & Environment Request for Information No. 1

Further to your email of 4 September, we have prepared the following responses to the above Request for Information (RFI) that relate to surface water issues for the Tahmoor South Amended Project.

RFI Issue

"Clarify the number and location of pools along Tea Tree Hollow, Tea Tree Hollow Tributary 1 and Dog Trap Creek that would potentially be impacted by the proposed development, including the likelihood of "Type 3" impacts to each pool. Note: the numbers referenced in Surface Water Impact Assessment (SWIA) (Section 6.2, Appendix D of the Amended Project Report) are incomplete/inconsistent (refer to table below).

Clarify the percentage of pools that are predicted to be impacted for valley closure greater than 475mm.

Updated Figures 36 and 37 of the SWIA to include all potentially impacted pools, as well as a location reference for Wirrimbirra Sanctuary."

Response

Figures 36 and 37 of the SWIA have been updated (expanded) to include all pools. These are given as Figure 1 and Figure 2 below. The table given in the RFI has been completed and is provided as Table 1 below.

Table 1 Summary of Pool Numbers – Tea Tree Hollow and Dog Trap Creek

Stream	Total Number of Pools above or near† Longwalls	Likelihood of "Type 3" Impact				
		<10% (<210 mm*)	<20% (210-290 mm*)	<30% (290-420 mm*)	<40% (420-475 mm*)	>40% (>475 mm*)
Tea Tree Hollow	4	3	1	0	0	0
Tea Tree Hollow Tributary 1	5	2	1	2	0	0
Dog Trap Creek	53	6	15	18	7	7

* millimetres of predicted total valley closure

† Includes all pools in Figure 1 and Figure 2 except those more than 200 m north-east of LW101

HYDRO ENGINEERING & CONSULTING PTY LTD
38a Nash Street
Rosalie QLD 4064
p (07) 3367 2388

PO Box 1575
Carindale QLD 4152
www.hecons.com
ABN 11 247 282 058

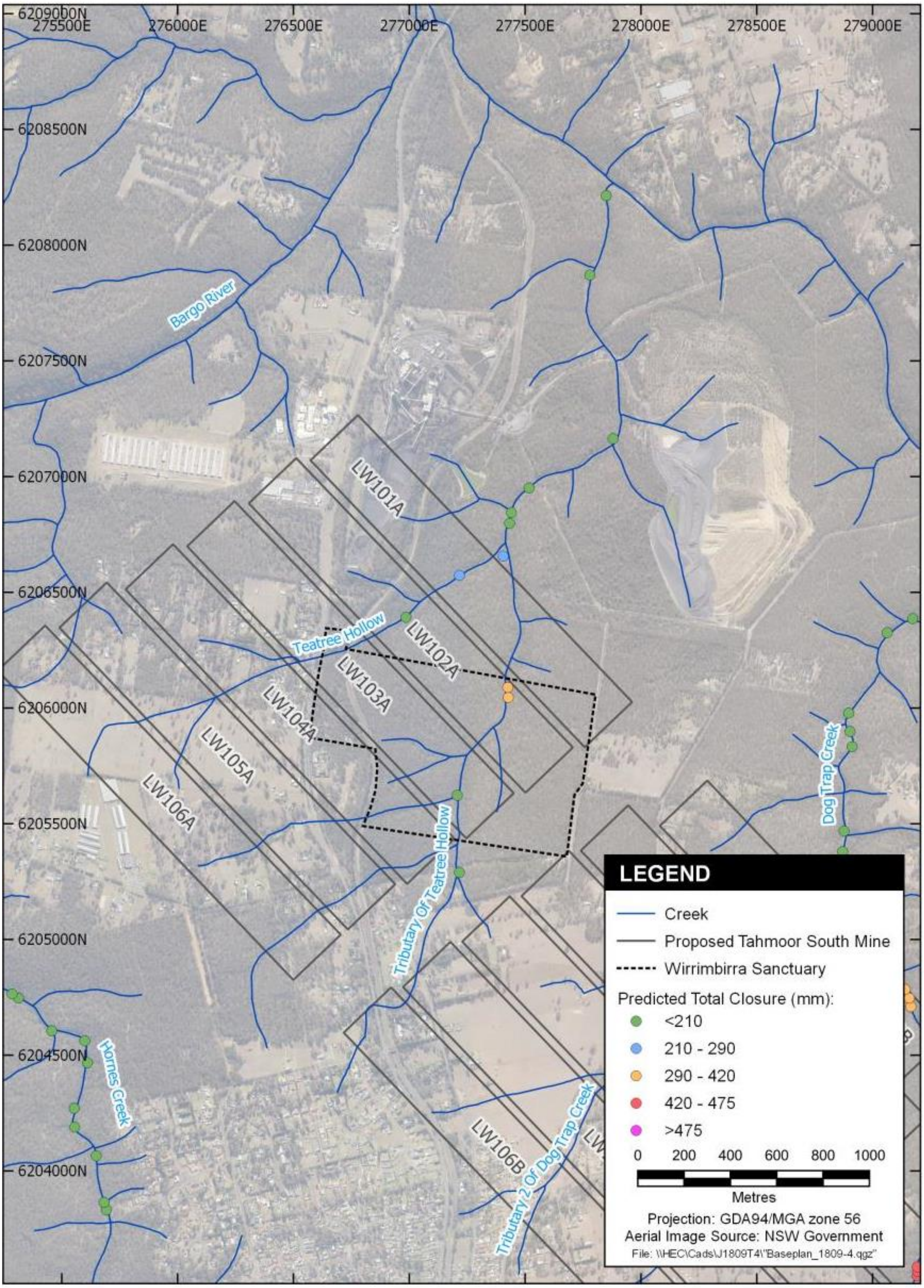

Figure 1 Qualitative Risk to Pools in Tea Tree Hollow

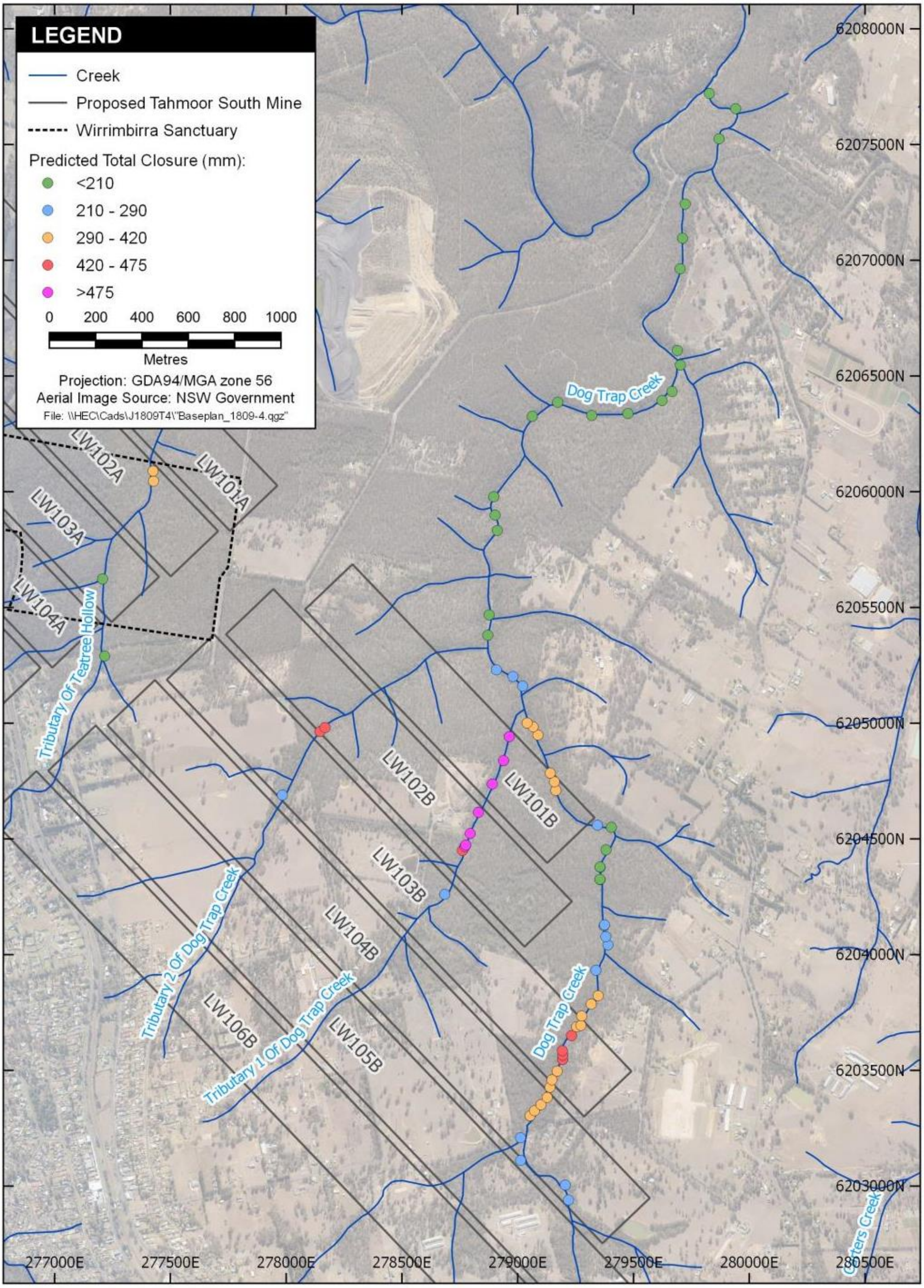

Figure 2 Qualitative Risk to Pools in Dog Trap Creek

There were eight pools mapped in Tea Tree Hollow and five pools mapped on the tributary of Tea Tree Hollow (refer Figure 1). Four of the pools mapped in the lower reaches of Tea Tree Hollow were more than 200 m north-east of LW101A and are therefore highly unlikely to be affected by subsidence-induced fracturing caused by the Tahmoor South Project. Therefore there are four pools mapped in Tea Tree Hollow that are upstream of a point 200 m north-east of LW101A. The predicted valley closure for three of these four pools mapped in Tea Tree Hollow and two of the five pools mapped on the tributary of Tea Tree Hollow is less than 210 mm, indicating that less than 10% of these pools are expected to be impacted. One pool on Tea Tree Hollow and one pool on the tributary of Tea Tree Hollow are predicted to have a total closure of less than 290 mm (less than 20% of pools are expected to be impacted). Two pools on the tributary of Tea Tree Hollow have a predicted total closure of 300 mm and 325 mm respectively. At this total closure prediction, less than 30% of pools are expected to be impacted.

The largest number of pools were mapped on Dog Trap Creek (refer Figure 2). Of these 53 were mapped upstream of a point 200 m north-east of LW101B (pools located further downstream are highly unlikely to be affected by subsidence-induced fracturing caused by the Tahmoor South Project). Six of these 53 pools are predicted to experience closure of less than 210 mm, indicating that less than 10% of these pools are expected to be impacted. Of the 53, 15 pools are predicted to experience total closure of less than 290 mm, indicating less than 20% of pools are expected to be impacted. Of the 53, 18 pools are predicted to experience total closure of less than 420 mm, indicating less than 30% of pools are expected to be impacted. Seven of the 53 pools are predicted to experience closure of less than 475 mm, indicating that less than 40% of these pools are expected to be impacted. The remaining seven of the 53 pools are predicted to experience total closure of more than 475 mm, indicating that more than 40% of these pools are expected to be impacted.

RFI Issue

"Provide a summary of the response and material provided to the Biodiversity and Conservation Division on 17 August 2020 regarding flow losses to creeks and adequacy of baseline data."

Response

The issues raised in the Biodiversity and Conservation Division presentation of 17 August and subsequent correspondence are addressed in the subsections bellow.

Slide No: 7

Issue Description:

"Flows = 0 ML/d majority of the time while LW31 was being mined. Model says there should have been flows". It is presumed that the first reference to "flows" refers to recorded flows at Redbank Creek Site R11.

Response:

We have consulted with the organisation who maintain the station (Hydrometric Consulting Services Pty Ltd – HCS). The station logger was identified as being potentially defective in late 2017, with the logger eventually replaced in March 2018. The period of suspect data is highlighted in the hydrograph shown in Figure 3 below. The period highlighted in red corresponds to the period from 15 January to 21 March 2018 inclusive. This 64 day period corresponds to 1.8% of the total data period.

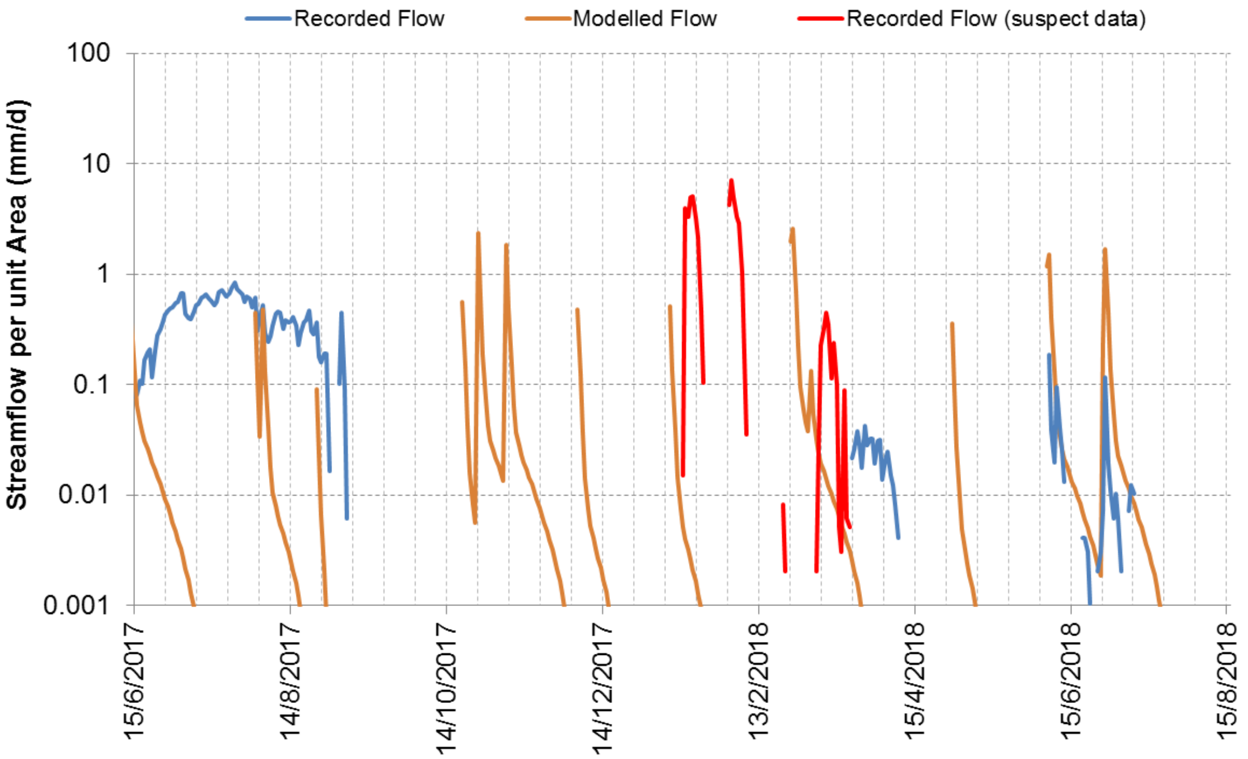

Figure 3 **Streamflow – Redbank Creek Site R11 during Mining of LW31**

If this period of flow is excluded, the total recorded flow for the period of mining of LW31 is approximately 164 ML compared with a modelled volume of 86 ML.

The period of mining of LW31 represents 12% of the period of available recorded flow. A complete set of modelled versus recorded flow totals for Redbank Creek at Site R11 is shown Figure 4, with each plotted point representing a longwall mining period. The green points represent the period of mining of LW25 and LW26 – the period of recorded data that the model was calibrated to.

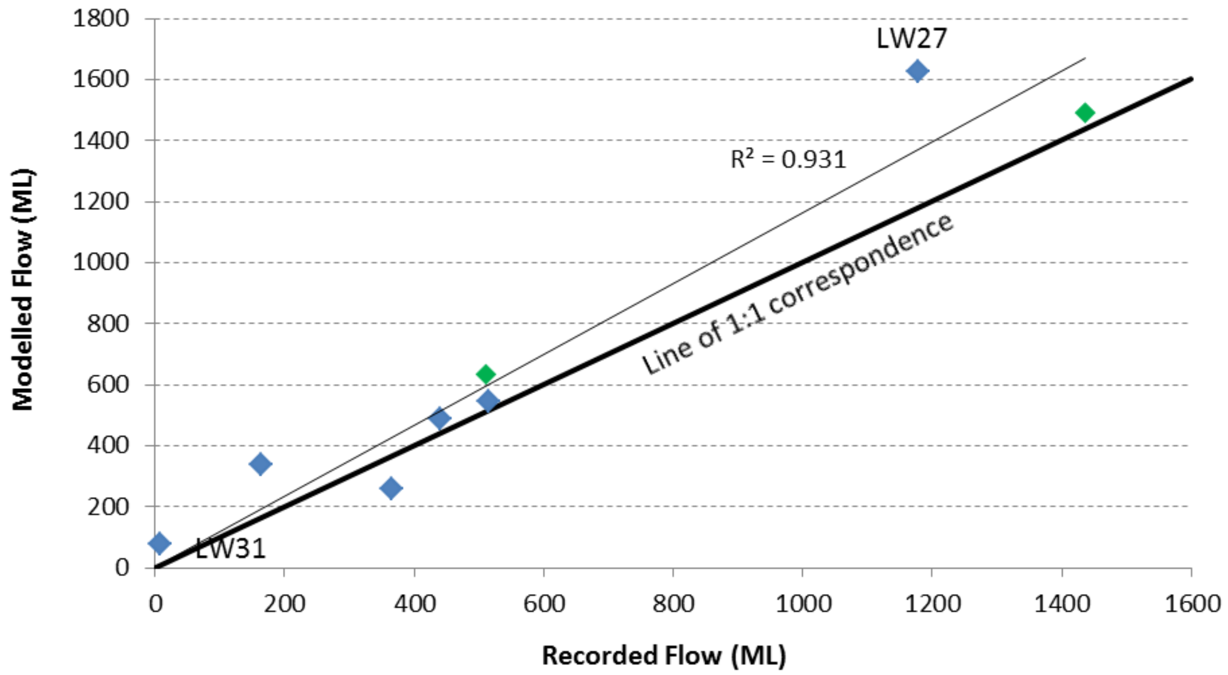

Figure 4 **Modelled and Recorded Streamflow - Redbank Creek Site R11**

The following points are made with regard to the above:

1. It is not realistic to expect a catchment yield model to accurately replicate recorded flows on each day. Such models require (typically) years of data to achieve a calibration and are aimed at assessing catchment behaviour over an extended period of time – measured in weeks, months and years rather than days. The purpose of developing such models for use in in the mining context is to use them to assess if there is any clear loss of catchment yield as a result of mining impacts. The fact that a model does not reproduce flows recorded each and every day does not make it a 'bad' model (refer also response to Slide No. 11).
2. Recording of streamflow in natural streams is subject to the vagaries of electronic recording equipment – instrumentation can and does malfunction – as well as other issues such as vandalism, temporary blockage of controls, extraction from or discharge to the stream. Short periods of poor data do not invalidate data collected over a long period of time.
3. The data plotted in Figure 4 shows there is no evident trend of loss of catchment yield over time. The data plot close to the line of 1:1 correspondence with a high value of the coefficient of determination (r^2) of 0.9276.
4. On Figure 4, the data pair for the period of mining of LW27 is a notable outlier, corresponding to high flow conditions in early 2013 which would have been subject to rainfall variability between the catchment and the rainfall stations used as input to the model - being the average of data from the Tahmoor Colliery pit top weather station and the Bureau of Meteorology rainfall station no. 68052 (Picton Council Depot). Note that rainfall data from the (nearer) Water NSW Stonequarry Creek gauging station (GS 212053) was not used because of potential issues with proximity of trees to the pluviometer – refer Google street view image in Plate 1 below.

Plate 1 Google Street View Image of GS 212053 Gauge Hut with Pluviometer

5. On Figure 4, the data pair for the period of mining of LW31 (excluding the period of data now removed - refer also response to Slide No. 10) indicates that this period corresponded to dry conditions.
6. Two other periods of potentially erroneous data were also detected during the mining of LW 31 and LW29 (July - August 2017 and from approximately 9 February 2016 to 3 April 2016 – refer response to Slide 10) and removed from the analysis. The removal of short periods of data during mining of LW31 and LW29 is not significant to the conclusions made in the Surface Water

Impact Assessment (SWIA) report demonstrating change in flow regime which span the period of time from the mining of LW27 in early 2013 until the period of mining of LW31 in late 2017.

Slide No: 9

Issue Description:

“Model predicts much lower flows than what is measured”. It is assumed that this refers again to Redbank Creek Site R11.

Response:

This assertion is not borne out by the total flows plotted Figure 4 above. It is difficult to discern the modelled and recorded daily flow data in the graphs presented in this slide because they are plotted as points. The data in one of the plots presented (excluding the recorded data for GS 212053) for the 2014 calendar year is reproduced in Figure 5 below.

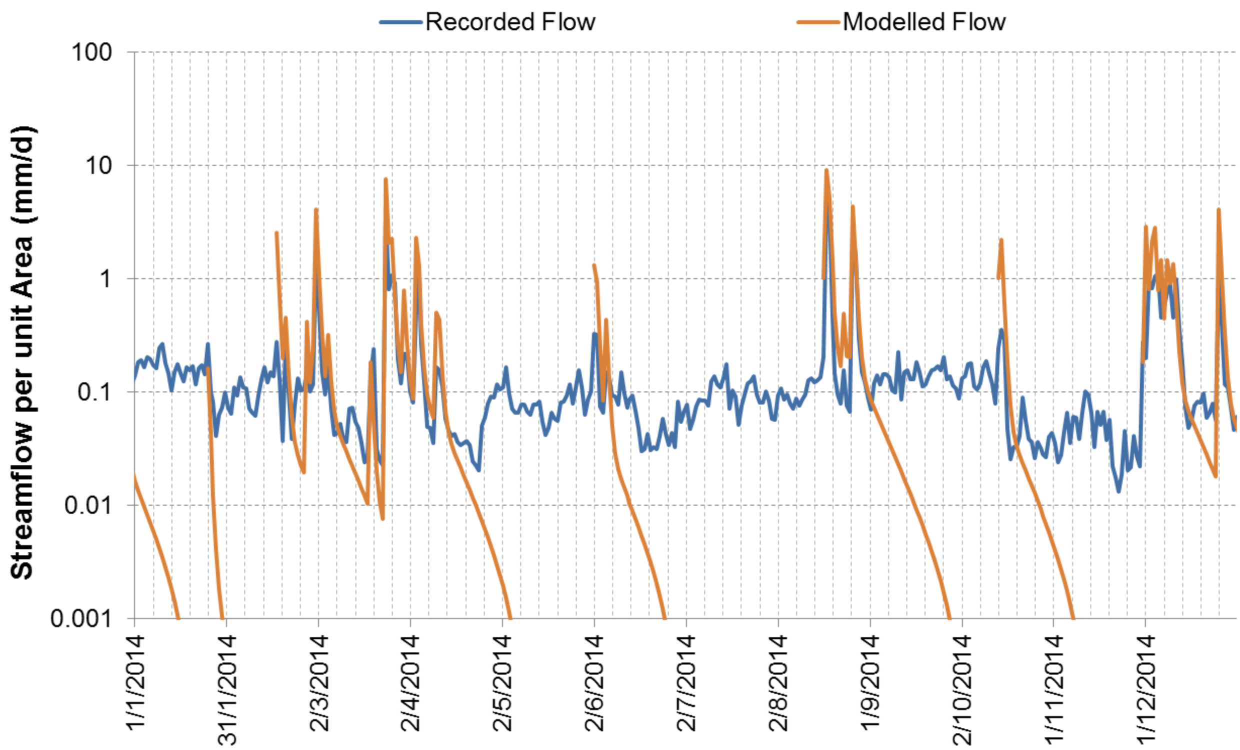

Figure 5 Modelled and Recorded Streamflow - Redbank Creek Site R11 - 2014

As discussed in the SWIA report, the above hydrograph demonstrates a clear change in the low flow regime compared with earlier years (upon which the model calibration was based), with the modelled high flow events mostly exceeding recorded flow peaks but with a persistent baseflow component. The model is not meant to replicate the previous flow patterns during this period when an impact to the catchment flow regime is apparent. The model was calibrated for the period up to the end of LW26 (11 October 2012). The data in Figure 5 and the majority of the plots shown on Slide 9 show the ‘after’ impact period - when flow patterns had changed. Note that the total recorded flow for 2014 (Figure 5) was 350 ML while the modelled flow was 462 ML.

Slide No: 10

Issue Description:

(a) “Bad Data” – appears to refer to period of record during the mining of LW29 (from approximately 9 February 2016 to 3 April 2016).

(b) “Up to 30 ML/d ‘observed flow’ when there’s been no rain” – appears to refer to the period of data to the period from 15 January to 21 March 2018.

(c) “More flow in Redbank Creek than there is in Stonequarry Creek” – appears to refer to data in July and August 2017.

(d) “No flow data at all” – appears to refer to data in late 2017.

Response:

Issue (a) is addressed in response to the issues in Slide 8 above – the issue with the data was recognised and the data was removed from the analysis (approximately 53 days).

Issue (b) is also addressed in response to the issues in Slide 8 above – with the data from 15 January to 21 March 2018 removed from the analysis (64 days).

The period of data in Issue (c) spans approximately 2 months (62 days). It is uncertain if this is a data error or due to higher rainfall in the Redbank Creek catchment at this time combined with a higher rate of runoff in the Redbank Creek catchment due to a higher degree of development in the catchment, although review of rainfall data suggests this is unlikely. This period of data was removed from the analysis

Issue (d) relates to the period leading to the replacement of a defective logger as outlined in the response to the issues in Slide 8 above and appears to correspond to a period of approximately 90 days. As noted in the response to the issues in Slide 8, this was a low (and possibly spatially varying) rainfall period (during mining of LW31) and it is uncertain if this is a data error.

As noted in the response to the issues in Slide 8, recording of streamflow in natural streams is subject to the vagaries of electronic recording equipment and such periods of poor data can and do occur. The total of the four periods listed above corresponds to approximately 7.5% of the total period of data and, even if all the data during these four periods was inaccurate, does not invalidate data collected over the remainder of the period and is not significant to the conclusions made in the Surface Water Impact Assessment report demonstrating change in flow regime.

Slide No: 11

Issue Description:

“Very poor correlation between Measured Flow and Modelled for R11”

Response:

It is not realistic to expect a catchment yield model to accurately replicate recorded flows on each day. Catchment response is dependent on rainfall temporal and spatial patterns. Temporally, if rainfall occurs in a burst in the late evening of a given day (as is typical in summer) the majority of the flow and the flow peak is unlikely to reach the gauging station until the next day and therefore there will be a significant disparity between rainfall and recorded flow on either day. Spatially, if a rainfall event occurs primarily near the edge of a catchment, runoff will take longer to reach the gauging station than it would if rainfall occurred near the station and again the flow peak may not occur until the next day.

Moreover catchment response to rainfall is non-linear and reliant on antecedent moisture (how much rain occurred in the day and days preceding the given day). To illustrate, a catchment’s rainfall runoff response on a day after a prolonged dry spell would be much less than on a day after a period of wet weather.

When calibrating and verifying a model, it is important that the objective function is selected based on the intended application. While ‘matching’ daily monitored and modelled catchment yield may produce solutions that match high and moderate flows well, this approach often produces a poor fit to low flows (Vaze et al., 2011)[1]. As the objective function for calibration of the catchment yield model for site R11 included producing a 'good' fit between monitored and modelled low flow catchment yield, calibration of daily monitored and modelled catchment yield was not appropriate. For the above reasons comparing monitored and modelled daily catchment yield is inappropriate to assess model veracity and is misleading.

It is unclear what period of data the plot in Slide 11 is for. As noted above the catchment yield model for Site R11 was calibrated for the period of mining of LW25 and LW26 and then used to assess the impact of mining on the flow regime in subsequent years. If the plots in Slide 11 are for the full data period, then a poor fit would be expected particularly given the issues with replicating flows on each day highlighted above. Figure 6 below shows a plot of modelled and recorded monthly streamflow for the period of calibration. This indicates a good calibration with a coefficient of determination of 0.934.

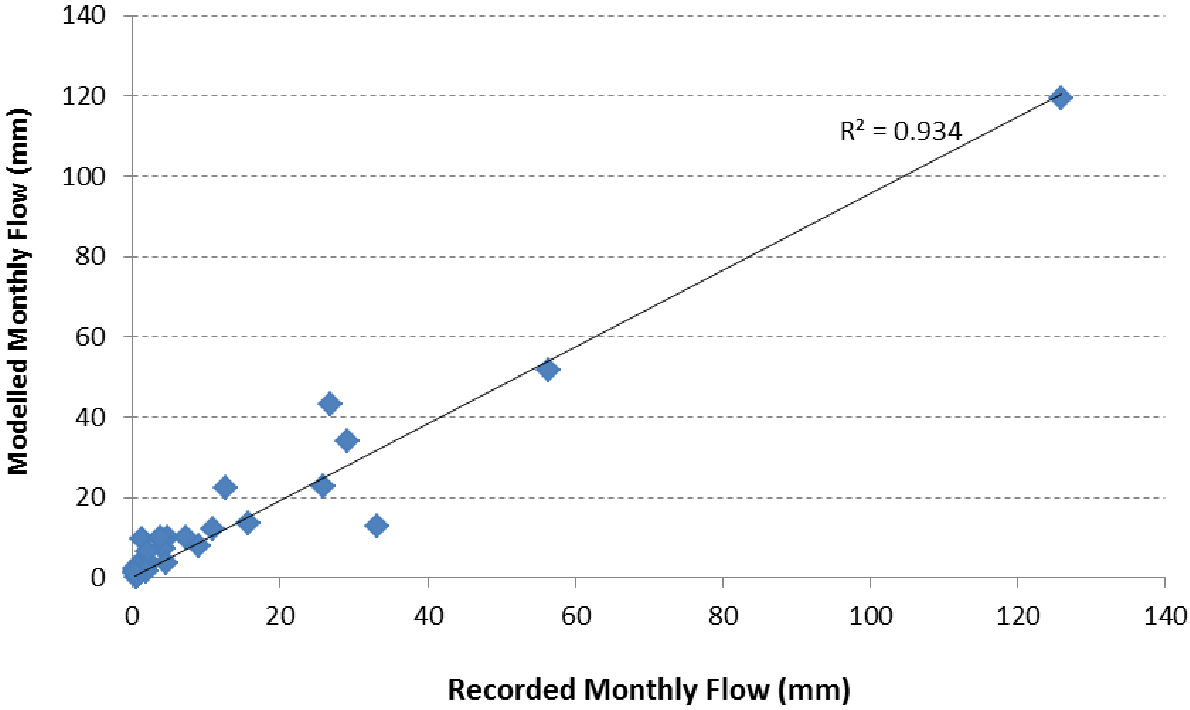

Figure 6 Modelled and Recorded Monthly Streamflow - Redbank Creek Site R11 – Calibration Period

<u>Slide No: 12</u>

Issue Description:

Flow exceedance curve presented indicating a mis-match between recorded and modelled flows in the range of flow less than about 1.2 ML/d.

Response:

It is assumed that this plot is for the full data period of 3,547 days. If so then a mis-match would be expected. As noted above the catchment yield model for Site R11 was calibrated for the period of mining of LW25 and LW26 and then used to assess the impact of mining on the flow regime in subsequent years. This is described in the SWIA report together with a series of flow duration curves which illustrate both the 'goodness of fit' for the calibration period, the change in catchment response

[1] Vaze, J., Jordan, P., Beecham, R., Frost, A., Summerell, G. (eWater Cooperative Research Centre) (2011). "Guidelines for Rainfall-Runoff Modelling: Towards Best Practice Model Application".

from the period of mining of LW27 (with greater prevalence of baseflow) and a second change in the flow regime during the mining of LW31, with the prevalence of baseflow diminishing and more ephemeral flow prevailing. The flow duration curve from the SWIA for the period of mining of LW25 (part of the period of model calibration) is reproduced below as Figure 7. This indicates a particularly good replication of low flows by the model for this period (consistent with the objective function of matching monitored to modelled low flow catchment yield). Subsequent flow duration curves given in the SWIA report illustrate the change in flow regime following the calibration period.

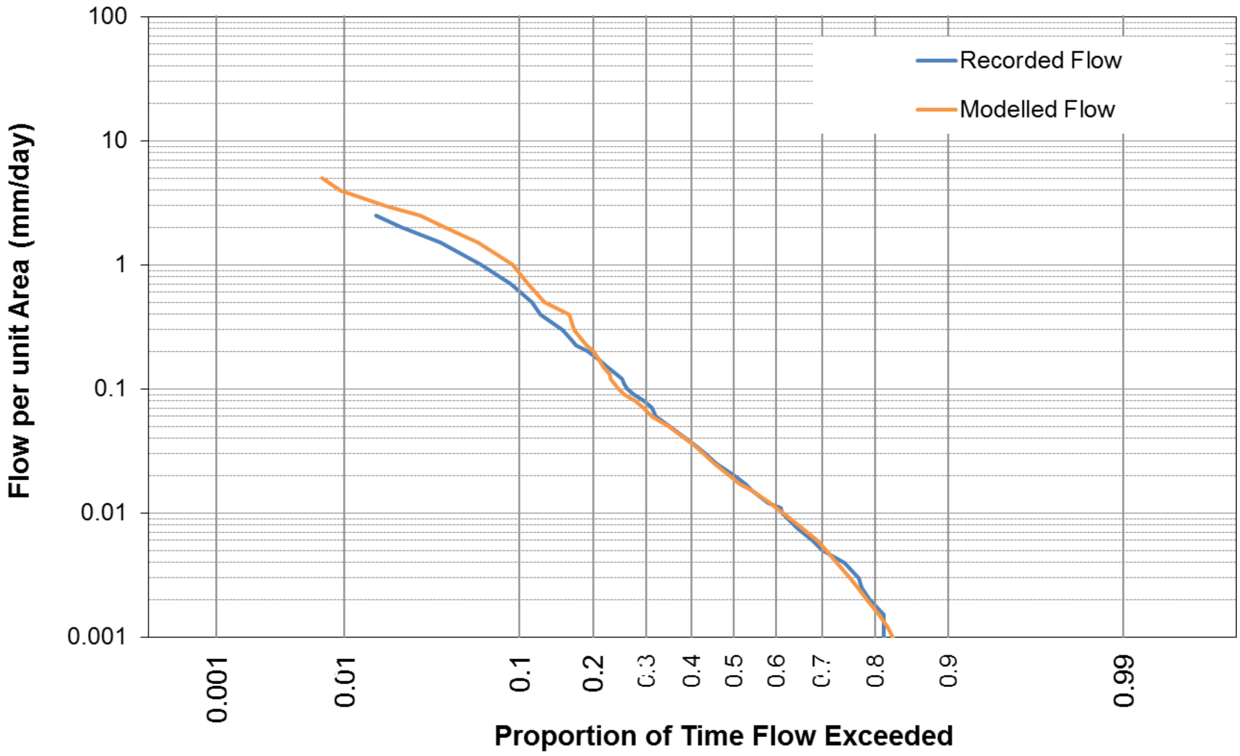

Figure 7 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW25

<u>Slide No: 13</u>

Issue Description	Response
Quality of Observed flows is at times poor	Assuming this refers to recorded flows, periods where data is in error have been excluded from the analysis. These periods represent a small percentage of the total period of record.
Calibration of model to observed data is poor	Disagree. The model calibration has been demonstrated as good (refer Figure 6 above) with a coefficient of determination of 0.934 on monthly total flows for the period of calibration. It is not realistic, nor appropriate with respect to the objective function, to compare daily modelled and recorded flows.
Model can estimate 10 Ml/day at R11 when measured data says 0 ML/day	Unclear what period of record this refers to. It is not realistic to expect a catchment yield model to accurately replicate recorded flows on each day. Such models are aimed at assessing catchment behaviour over an extended period of time – measured in months and years.
Conversely, Model estimates 0 Ml/day at R11 when measured data says 10 ML/day	Assume this refers to data in early 2016. This short period of data was not included in the analysis.
Up to 30 ML/d flow recorded (observed) at R11 when there has been no rain	Assume this refers to data in early 2018. This short period of data was not included in the analysis.

Issue Description	Response
3 months of observed flow = 0 ML/d from 7/9/17 –27/12/17 during mining of LW31 when model says there should have been flow at times	Assume this refers to data in late 2017 (Slide 10). This may correspond to a short (90 day) period of inaccurate data but it also corresponds to a low rainfall period.
3 months of observed flow = 0 ML/d from 7/9/17 –27/12/17 during mining of LW31 when model says there should have been flow at times	Assume this refers to data in late 2017 (Slide 10). This may correspond to a short (90 day) period of inaccurate data but it also corresponds to a low rainfall period.
The experimental design is poor, lacking appropriate baseline or contrasts to reference locations	Comparison to nearby streamflow behaviour (GS 212053 – Stonequarry Creek at Picton) was undertaken and documented in the RTS report. By comparing flow duration curves, it was apparent that the flow characteristics of Stonequarry Creek vary markedly from those of Redbank Creek. The Stonequarry Creek flow duration curves exhibit a much longer 'tail', indicative of a much slower recession, with baseflow sustained for longer periods after rainfall. The flow behaviour of Stonequarry Creek is therefore not considered useful for comparison with the flow characteristics of Redbank Creek. Best use has been made of the available data to develop a baseline (calibration period) – during mining of LW25 and LW26. LW25 resulted in undermining of less than 5% of the catchment area of site R11.
There has been no objective statistical test (eg BACI) applied to the data	Refer extended response below.
The model is considered unreliable and insensitive to what are obvious upstream impacts (dried and desiccated pools) and lack of flow	Disagree. The model does demonstrate change in catchment response as documented in SWIA report. The model is well calibrated (refer Figure 6). Upstream pool impacts are presented and discussed in the SWIA report, including comparison of the monitored and modelled catchment yield at site R4. Upstream pool impacts resulting from underflow are not relevant to flow at a downstream point where flow has re-emerged, as evidenced through comparison of the monitored and modelled long-term catchment yields at site R11.
The data do NOT support the contention that this behaviour has been observed and is evident in the recorded streamflow data from Redbank Creek (referring to "…it is unlikely that there would be any resulting net loss of flow from the catchment")	The data does support this conclusion – refer Figure 6 above. The data plotted in Figure 6 shows there is no evident trend of loss of catchment yield over time.

In a Before-After Control-Impact (BACI) design, assessment of streamflow records is undertaken before and after the putative impact commences at both an 'impact' and 'control' site. In this way the BACI design is flawed as any location-specific temporal difference that occurs between the impact and control site location will be interpreted as an impact. As such, assessing impacts relating only to mining activities is challenging to identify (in isolation of other catchment influences) using a BACI design and assessment approach (Underwood, 1992)[2].

In order to effectively adopt a BACI design approach for streamflow monitoring and analysis, the control site needs to be located in a catchment with very similar temporal, land-use and hydrological characteristics (excepting the presence of mining in the impact site catchment as compared with the

[2] Underwood, A.J. (1992). "Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world". *Journal of Experimental Marine Biology and Ecology*. 161:2, pp. 145-178.

control site catchment). For the analysis to be valid, the change in the measurements must be due to the activity only (Smith, 2002)[3]. In the Tahmoor South region, such a control site for comparison with Redbank Creek is not present.

An alternative approach to the BACI design and analysis, comprises comparison of gauged and simulated flow statistics where the simulated flows serve as a control – referred to as a Control-Impact (CI) design (Piniewski, 2016)[4]. The CI design approach was adopted for assessment of the Redbank Creek streamflow records where the recorded flows evidenced potential mining effects and the simulated flows represented 'control' flows which were negligibly influenced by mining (i.e. model calibrated to a period where mining effects were at a minimum - the period of mining of LW25 and LW26).

The streamflow assessment for Redbank Creek focussed on the records for Site R11 which are considered to be reliable and reflective of the cumulative change in streamflow characteristics associated with upstream mining. Site R11 is located approximately 240 m downstream of LW32 and less than 10 mm subsidence has been recorded at this site following completion of LW32 (MSEC, 2020)[5].

Mining of LW25 commenced in August 2008 with LW32 completed in September 2019. Streamflow monitoring has been conducted at Site R11 on Redbank Creek since December 2009. As such, the streamflow assessment was undertaken for the period December 2009 to September 2019, which encompasses the period of mining of LW25 to completion of LW32. As the period of data record does not incorporate a pre-mining period, model calibration was undertaken for the period Dec 2009 to the end of 2012 – up to the end of mining of LW26. This represents the period of record for which streamflow in Redbank Creek at Site R11 would be least influenced by mining.

The catchment flow model used was the Australian Water Balance Model (AWBM) (Boughton, 2004)[6], which is a nationally recognised catchment-scale water balance model for simulating surface runoff and baseflow processes on gauged and un-gauged catchments. Model parameters were varied as part of calibration, with a focus on obtaining a good fit to low flows and low flow recession (the objective function).

Plots and metrics identified from the eWater CRC Guidelines for Rainfall-Runoff Modelling: Towards Best Practice Model Application (Vaze et al., 2011)[7] were used as assessment techniques and measures for calibration and validation of the hydrological model. The plots and metrics included comparison of flow duration curves, ratio of modelled to recorded streamflow volume, coefficient of determination on monthly flows (r^2) and the Nash Sutcliffe Coefficient of Efficiency on monthly flows.

The outcomes of the CI assessment were presented in the SWIA report as time series plots and flow duration curves enabling a comparison between the recorded and simulated streamflow records at different periods in time over the duration of mining LW27 to LW32. A graphical analysis of the

---

[3] Smith, E.P. (2002). "BACI Design", *Encyclopedia of Environmetrics*, vol. 1, pp 141-148. John Wiley & Sons, Ltd, Chichester, 2002.

[4] Piniewski, M. (2016). "Natural streamflow simulation for two largest river basins in Poland: a baseline for identification of flow alterations". *Proceedings of the International Association of Hydrological Sciences*, vol. 373, pp. 101-107.

[5] MSEC (2020a). "Tahmoor South SW Sites - Observed Total Subsidence (MSEC 200813)". Prepared for HEC, August, 2020.

[6] Boughton, W.C. (2004). "The Australian Water Balance Model", *Environmental Modelling and Software*, vol.19, pp. 943-956.

[7] Vaze, J., Jordan, P., Beecham, R., Frost, A., Summerell, G. (eWater Cooperative Research Centre) (2011). "Guidelines for Rainfall-Runoff Modelling: Towards Best Practice Model Application".

assessment results was considered appropriate for illustrating patterns in streamflow behaviour over time and for summarising the assessment findings (Helsel et al., 2020)[8].

Hypothesis testing, such as Analysis of Variance (ANOVA), was not undertaken as such tests were not considered to be hydrologically or practically significant in the context of the assessment undertaken. Streamflow data regularly defies the underlying assumptions required for application of ANOVA, including normality, homogeneity of variance and independence (Helsel et al., 2020). As such, identifying a significant difference in streamflow data through such statistical methods may be mistakenly interpreted as a mine-related change unless temporal variation and other potential non-mining related trends are appropriately accounted for.

Slide No: 16

Issue Description:

Bargo River US – “Model overestimating flows at times”.

Response:

Agreed. The modelled streamflows underestimate recorded data at times and overestimate recorded data at other times. No hydrological model can reliably reproduce recorded behaviour at all times. Figure 8 below shows examples for the same period as the third plot on this slide.

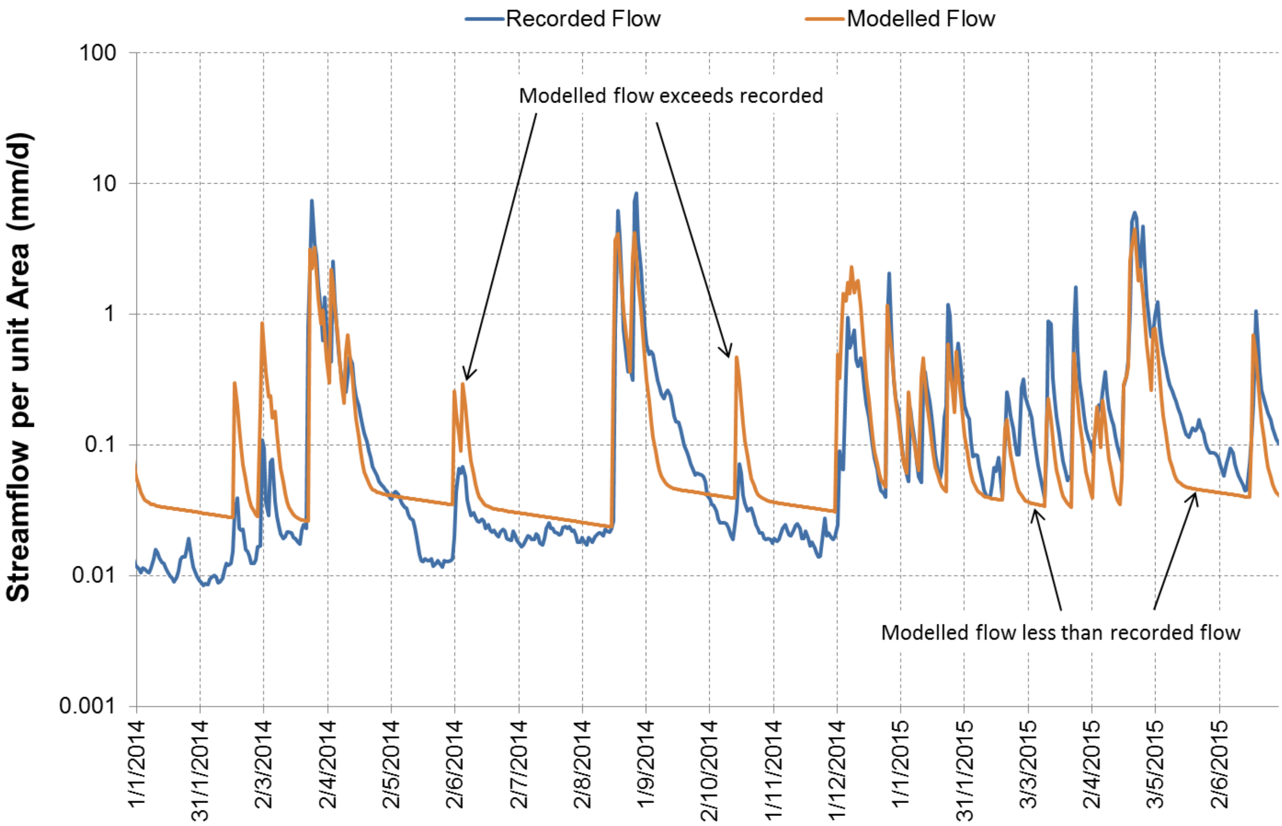

Figure 8 Recorded and Modelled Flows Bargo River Upstream (GS 300010a) – 2014/15

8 Helsel, D.R., Hirsch, R.M., Ryberg, K.R., Archfield, S.A., and Gilroy, E.J. (2020). “Statistical methods in water resources: U.S. Geological Survey Techniques and Methods”, book 4, chapter A3, 458 p., https://doi.org/10.3133/tm4a3. [Supersedes USGS Techniques of Water-Resources Investigations, book 4, chapter A3, version 1.1.]

Slide No: 17

Issue Description:

"Looks like serious datum change"

"What's this??"

Response:

This comment appears to relate to the period of recorded data from December 2018 to August 2019. The hydrograph is shown in Figure 9 below for completeness.

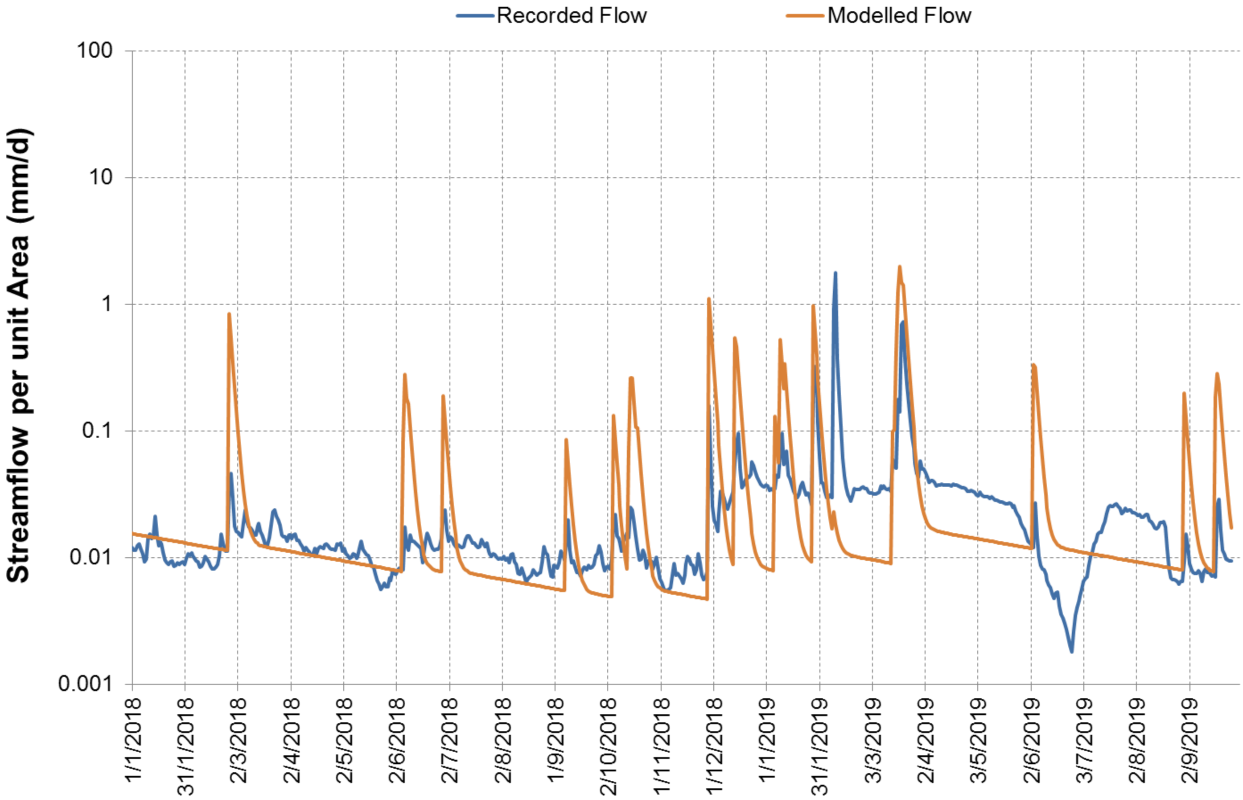

Figure 9 Recorded and Modelled Flows Bargo River Upstream (GS 300010a) – 2018/19

There is a clear increase in recorded flow (stream water level – of approximately 5 cm) in December 2018 and a clear drop in around June 2019. HCS were unable to explain the rise, although they indicated that the behaviour in around June 2019 may be related to flow extraction from the river upstream.

The period of data in question is approximately 266 days in duration which represents less than 10% of the recorded data period presented. Recording of streamflow in natural streams is subject to the vagaries of electronic recording equipment – instrumentation can and does malfunction – as well as other issues such as vandalism, temporary blockage of controls, extraction from or discharge to the stream. Short periods of poor data do not invalidate data collected over a long period of time. The removal of this period of data does not change the coefficient of determination on monthly flows of 0.72 given in the SWIA report. It is noted that the calibration metrics given in Vaze et al. (2011) indicate that a satisfactory performance rating has been achieved for model calibration for this gauging station.

Slide No: 18

Issue Description:

Flow exceedance curve presented indicating a mis-match between recorded and modelled flows for Bargo River Upstream (GS 300010a).

Response:

The plot shows a very narrow flow range (less than 5 ML/d), with flow plotted on an arithmetic scale. It is common and standard practice in hydrology to plot flows on a log scale so that the full range of flows can be readily assessed. The full flow duration curve is shown in Figure 10 below.

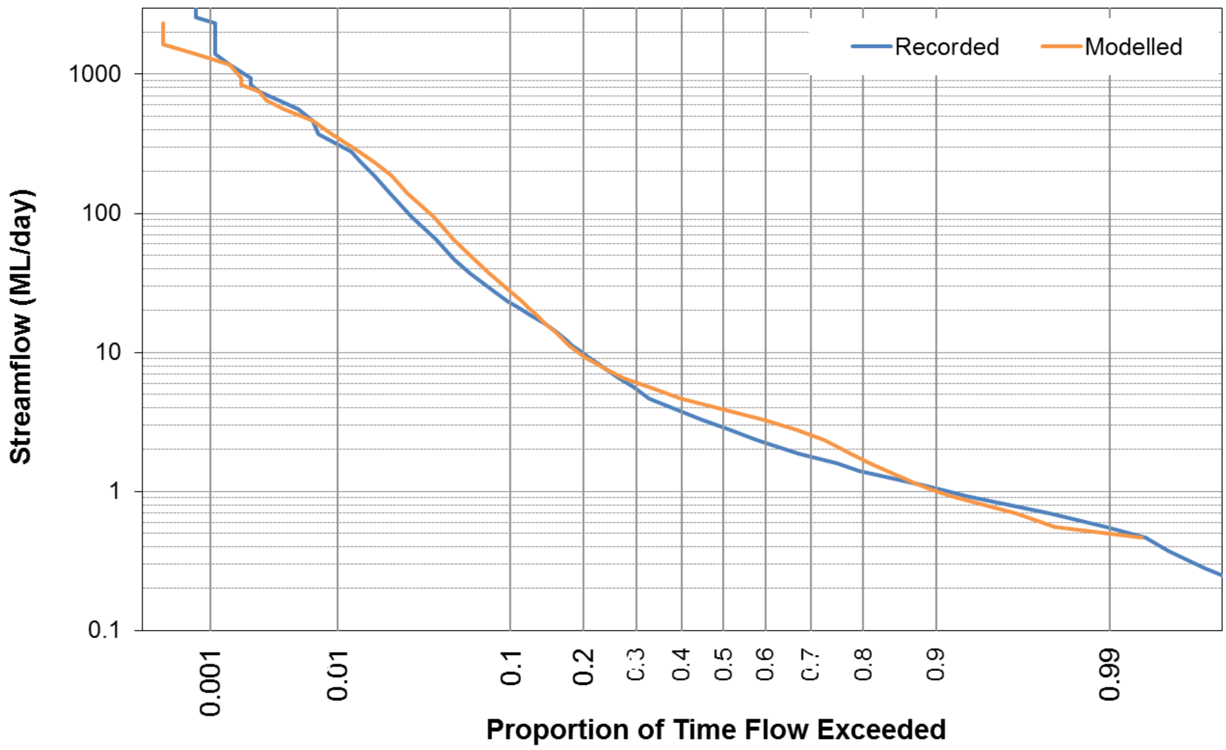

Figure 10 Flow Frequency Duration Plots – Bargo River Upstream (GS 300010a)

When considering the full range of flows, including low flows (less than 1 ML/d) it may be seen that there are ranges of flows where the model overestimates recorded flows and other flows where recorded data are underestimated. Over the full flow range the modelled flow exceeds recorded flow by 5% which is in line with recommendations in Vaze et al. (2011). Model calibration was confounded by the lack of rainfall data from within the catchment (model calibration used SILO Point Data[9] for the catchment) – refer response to Slide 19 below.

Slide No: 19

Issue Description:

"Poor correlation between Measured Flow and Modelled Flow for Bargo US"

[9] https://www.longpaddock.qld.gov.au/silo/point-data/ for 34° 18'S 150° 33'E

Response:

It is not realistic to expect a catchment yield model to accurately replicate recorded flows on each day. Catchment response is dependent on rainfall temporal and spatial patterns. Moreover catchment response to rainfall is non-linear and reliant on antecedent moisture. These issues are elucidated further in the response to Slide 11.

For the above reasons comparing monitored and modelled daily catchment yield is inappropriate to assess model veracity and is misleading.

Figure 11 below shows a plot of modelled and recorded monthly streamflow for the period of calibration.

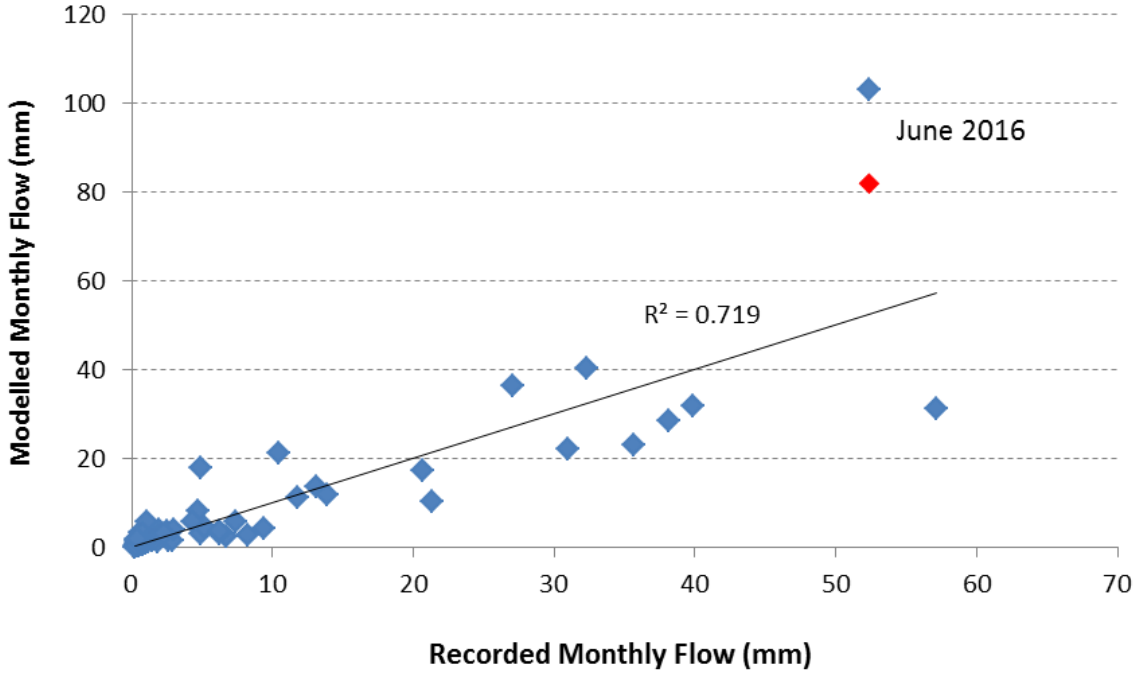

Figure 11 Modelled and Recorded Monthly Streamflow - Bargo River Upstream (GS 300010a)

The data in Figure 11 show an outlier in the month of June 2016. The majority of the rainfall in that month occurred on the first weekend when the coast of New South Wales was affected by an East Coast Low. Table 1 summarises daily rainfall totals for that period from various nearby rainfall stations. The locations of the rainfall stations relative to creek catchment areas are shown in Figure 12.

Table 1 Recorded Daily Rainfall Totals Tahmoor Area – June 2016 Long Weekend

Date	Rainfall (mm) at Given Rainfall Station or Record				
	SILO Point Data	Buxton (BoM 68166)	Picton (BoM 68052)	Lakesland (WaterNSW 568295)	Tahmoor Pit Top
4 June	27.7	6.8	7	0.5	1
5 June	154.4	150.6	107.2	62	61
6 June	152.5	187.8	130.8	237.5	253.5

It should be noted that the Bureau of Meteorology (BoM) data are 9am totals whereas the WaterNSW and Tahmoor Pit Top data is totalled at midnight. The SILO Point Data has been used in the model, because none of the stations are located within the catchment (refer Figure 12), although the Tahmoor Pit Top is located near the edge of the catchment. If the Tahmoor Pit Top rainfall data for the month of June 2016 is used in the model, the effect on modelled streamflow in that month is significant, with modelled flow reducing (refer red point in Figure 11), the coefficient of determination on monthly flows for the calibration period increasing to 0.789 and the model matching recorded flows to within 0.6%.

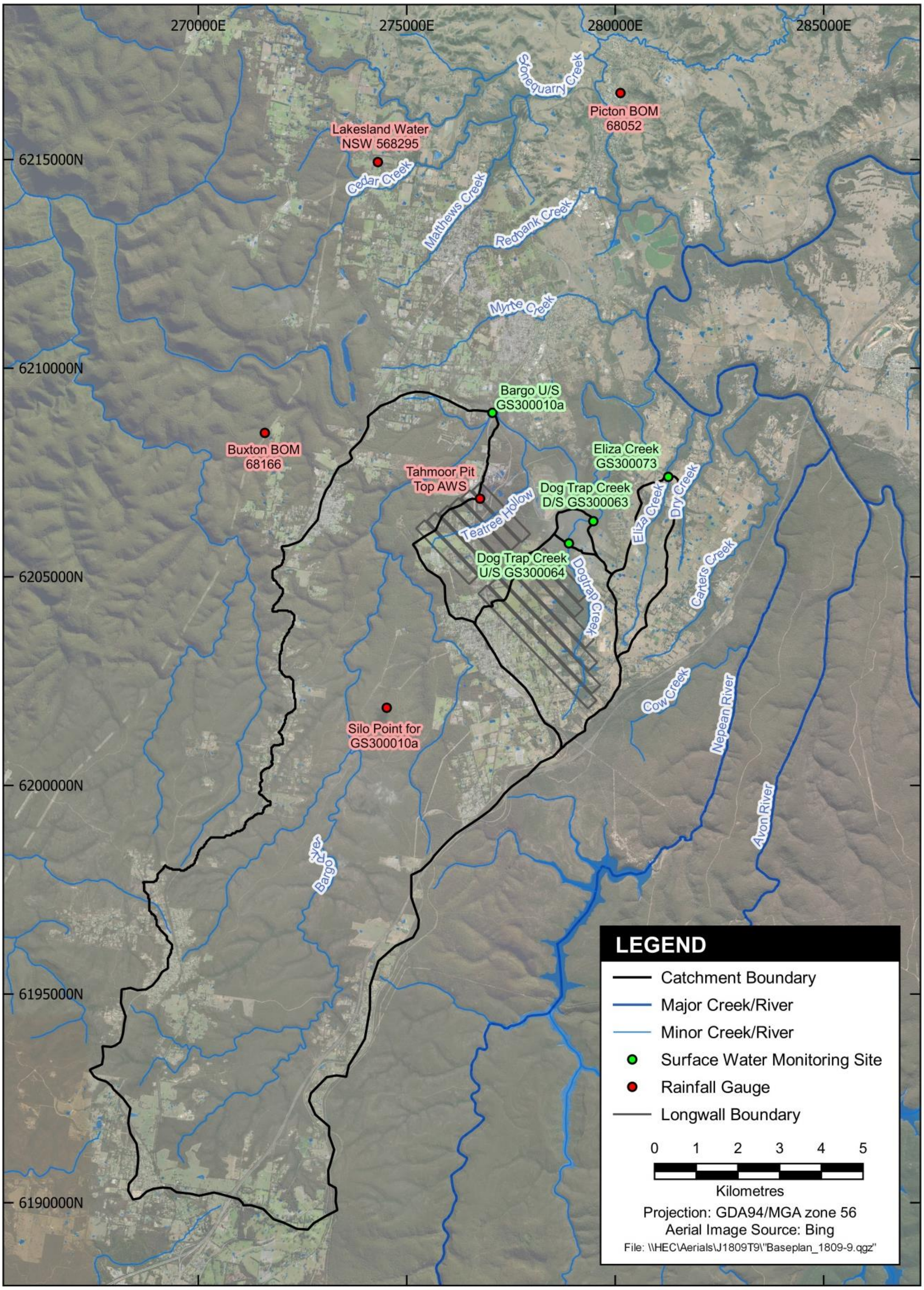

Figure 12 Monitored Stream Catchments and Rainfall Stations

The above illustrates the sensitivity of model calibration metrics to large flows and the need to target model calibration to the purpose of the model (the objective function) – in this instance to focus on low flows because the potential effects of subsidence on streamflow would be to reduce low flows and to increase low flow recession rates. The model match to low flows (less than 1 ML/d) illustrated in Figure 10 is good.

<u>Slide No: 20</u>

Issue Description:

"Eliza Ck – Poor fit between observed and modelled data. No observed data at all"

Response:

The Eliza Creek gauging station was commissioned in late 2012 and then decommissioned in late 2015 (just over 3 years of data recorded). The station was recommissioned in mid-2018. There is no data record for the intervening period. The initial period of data (to late 2015) was used for model calibration.

Figure 13 below shows a plot of modelled and recorded monthly streamflow for the period of calibration, indicating a generally good model fit. Model calibration was confounded by the lack of rainfall data from within the catchment (model calibration used SILO Point Data[10] for the catchment).

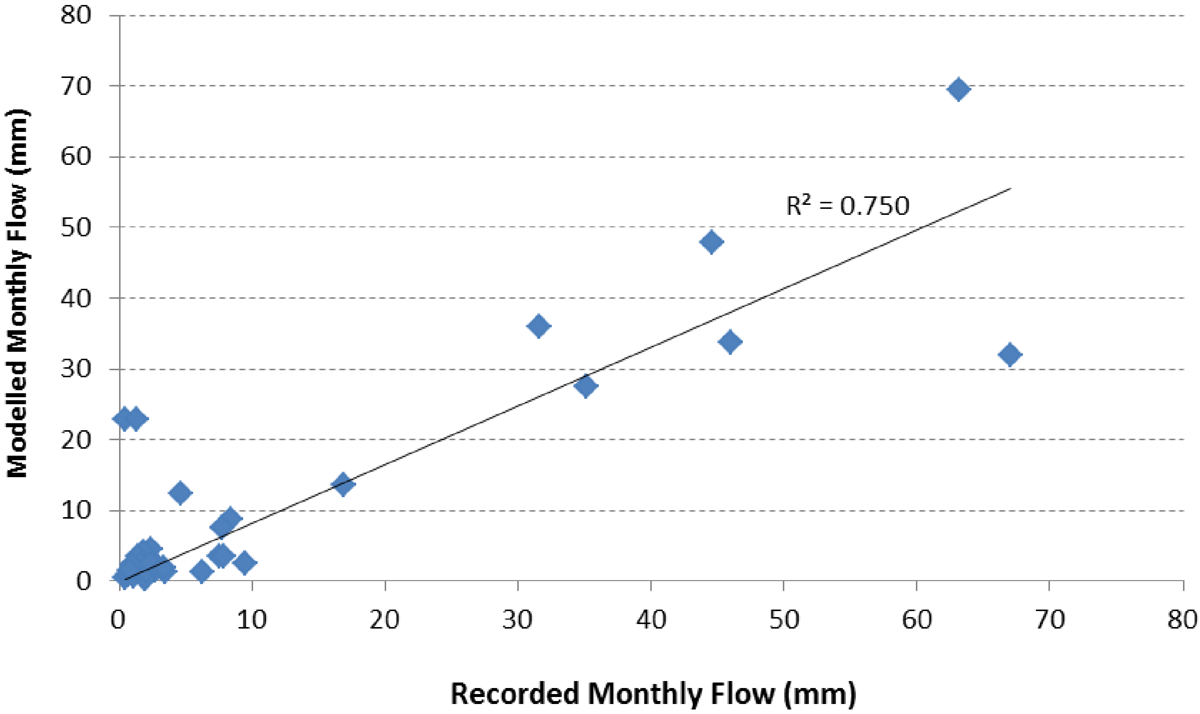

Figure 13 Modelled and Recorded Monthly Streamflow – Eliza Creek (GS 300073)

It is agreed that at times there is a mis-match between recorded and modelled daily flows for periods of time greater than a day (i.e. more than would result from rainfall temporal and spatial variability). It is noted that the catchment of Eliza Creek comprises mainly of rural acreage properties and that flows may be affected by the presence of farm dams on these properties as well as by creek extraction. As more data is recorded, the calibration of the Eliza Creek model should be refined ahead of the development of the Tahmoor South Project.

[10] https://www.longpaddock.qld.gov.au/silo/point-data/ for 34° 18'S 150° 36'E

Slide No: 21

Issue Description:

Flow exceedance curve presented indicating a mis-match between recorded and modelled flows for Eliza Creek (GS 300073).

Response:

The plot shows a very narrow flow range (less than 5 ML/d), with flow plotted on an arithmetic scale. It is common and standard practice in hydrology to plot flows on a log scale so that the full range of flows can be readily assessed. The full flow duration curve is shown in Figure 14 below.

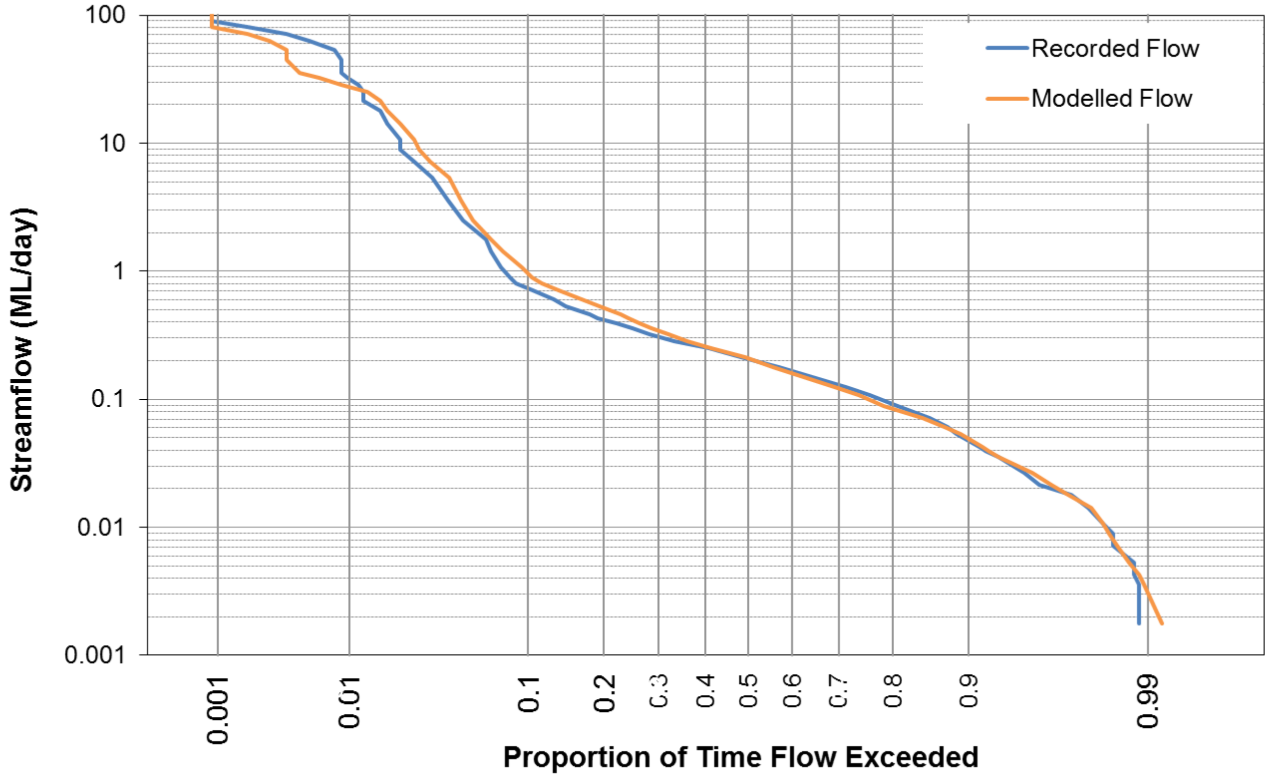

Figure 14 Flow Frequency Duration Plots – Eliza Creek (GS 300073)

The median flow rates stated in Slide 21 (presumably based on daily data) are 0.21 ML/d (recorded) and 0.13 ML/d (modelled). Our calculations indicate median flow rates of 0.21 ML/d for both recorded and modelled data for the period of model calibration. The median modelled value of 0.13 ML/d given in Slide 21 appears to have been calculated for the entire period of modelled data spanning November 2012 to September 2018 including the more than 2½ year period of no data record. It is inappropriate and misleading to compare two median values that have been calculated over different periods of record. The plots shown on Slide 21 similarly appear to compare two different periods of data – such a comparison is meaningless.

Slide No: 22

Issue Description:

"Very poor correlation between Measured Flow and Modelled Flow for Eliza Ck"

Response:

It is not realistic to expect a catchment yield model to accurately replicate recorded flows on each day. Catchment response is dependent on rainfall temporal and spatial patterns. Moreover catchment response to rainfall is non-linear and reliant on antecedent moisture. These issues are elucidated further in the response to Slide 11.

For the above reasons comparing monitored and modelled daily catchment yield is inappropriate to assess model veracity and is misleading.

Figure 13 shows a plot of modelled and recorded monthly streamflow for the period of calibration, indicating a generally good model fit.

Slide No: 24

Issue Description:

Dog Trap Creek "Very Poor fit between observed and modelled data – or is it datum change? No observed data at all"

Response:

The plots are captioned "Datex vs Dogtrap16_Flow_300064". There are two gauging stations on Dog Trap Creek (refer Figure 12):

- GS 300064 – Dog Trap Creek U/S (upstream); and
- GS 300063 – Dog Trap Creek D/S (downstream).

The daily data provided was for GS 300063 not GS 300064 and therefore the legend caption in Slide 23 appears to be incorrect. The focus of modelling effort has been GS 300063 because this is located well downstream of the planned Tahmoor South mine area and will therefore provide information on streamflow beyond the effects of subsidence, whereas GS 300064 is located closer to the area likely to be affected by mine subsidence.

Gauging station GS 300063 was commissioned in early 2012 and then decommissioned in late 2015 (3¾ years of data recorded). The station was recommissioned in early 2019. There is no data record for the intervening period. The initial period of data (to late 2015) was used for model calibration. Model calibration was confounded by the lack of rainfall data from within the catchment (model calibration used a combination of SILO Point Data and recorded rainfall at the Tahmoor Pit Top).

The period of data highlighted as "Very Poor fit between observed and modelled data – or is it datum change?" is interpreted as being from July 2013 to September 2014. The hydrographs for this period are plotted in Figure 15 below.

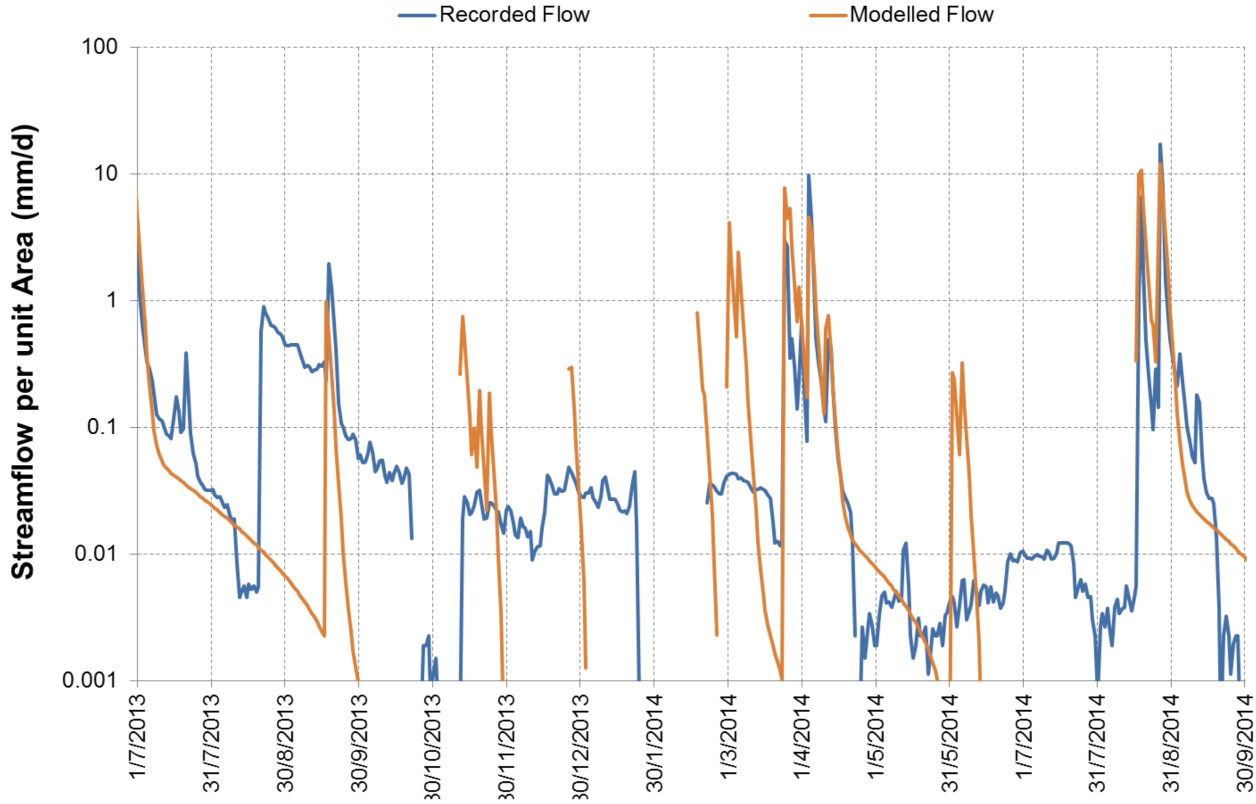

Figure 15 Recorded and Modelled Flows Dog Trap Creek D/S (GS 300063) – 2013/14

There is a clear rise in recorded water level (used to calculate streamflow) on 21 August 2013. For the period up to late March 2014 HCS have indicated that there was no flow observed during their visits to the station. This is confirmed by comparison with the concurrent streamflow record from GS 300064 (Dog Trap Creek U/S) – plotted in Figure 16. Therefore it is concluded that the recorded data is erroneous for this period (of approximately 216 days).

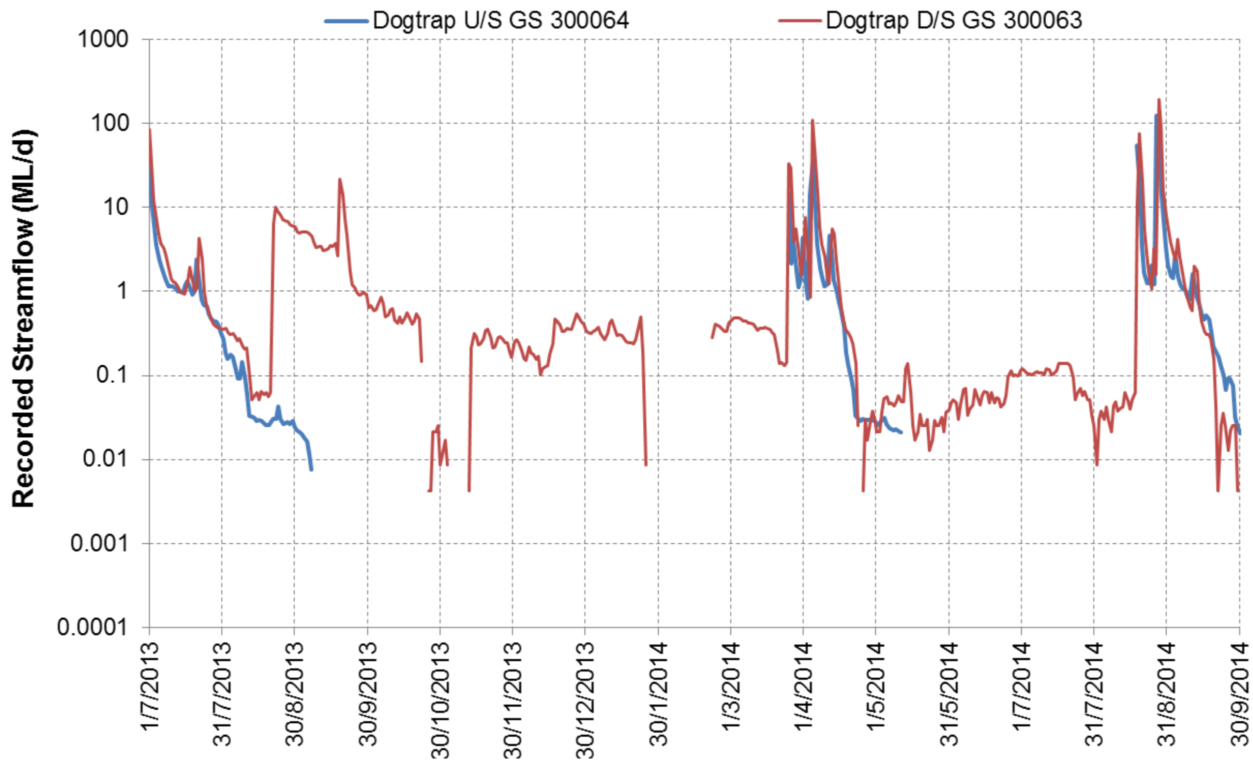

Figure 16 Recorded Streamflow Dog Trap Creek D/S and Dog Trap Creek U/S – 2013/14

A flow event is evident in late March/early April 2014, followed by quite steady flow at GS 300063 with a slight rise in the winter months – there is no sudden rise as there was in August 2013. The flow rise in the GS 300063 record through winter 2014 is credible, given the reduced evapotranspiration during that period, therefore it cannot be concluded that the data in this period is clearly in error.

The 214 day period of erroneous data represents less than 16% of the 3¾ years of data recorded. The removal of this period of data from the record does not invalidate data collected over the remainder of (the majority of) the period.

The removal of this period of data from the record does not significantly change the coefficient of determination on monthly flows, with the value reducing from 0.77 (as given in the SWIA report) to 0.76.

Slide No: 25

Issue Description:

“Going Forward – Very Poor Baseline of Observed Data”

Response:

An erroneous data period amounting to less than 16% of the 3¾ years of data recorded has been identified. The data recorded in winter of 2014 which also appears to have been questioned is credible data. The remaining data has not been questioned. The assertion of “very poor baseline of observed data” is not supported by the data.

GS 300063 and GS 300064 have been recommissioned in early 2019 and will continue to provide baseline data up to the commencement of the Tahmoor South Project. As more data becomes available, the calibration of the Dog Trap Creek model should be refined ahead of the development of the Tahmoor South Project.

Slide No: 26

Issue Description:

Flow exceedance curves presented. Second plot appears to be for data for GS 300064 and GS 300063 for the period March 2014 to August 2015. The following is unclear:

- how a plot of data for GS 300064 was generated – only recorded data for GS 300063 was provided; and
- the significance of the period March 2014 to August 2015.

It is not possible to comment further on the second plot provided in Slide 26.

The first plot shows a narrow flow range (less than 5 ML/d), with flow plotted on an arithmetic scale. It is common and standard practice in hydrology to plot flows on a log scale so that the full range of flows can be readily assessed. The full flow duration curve is shown in Figure 17 below.

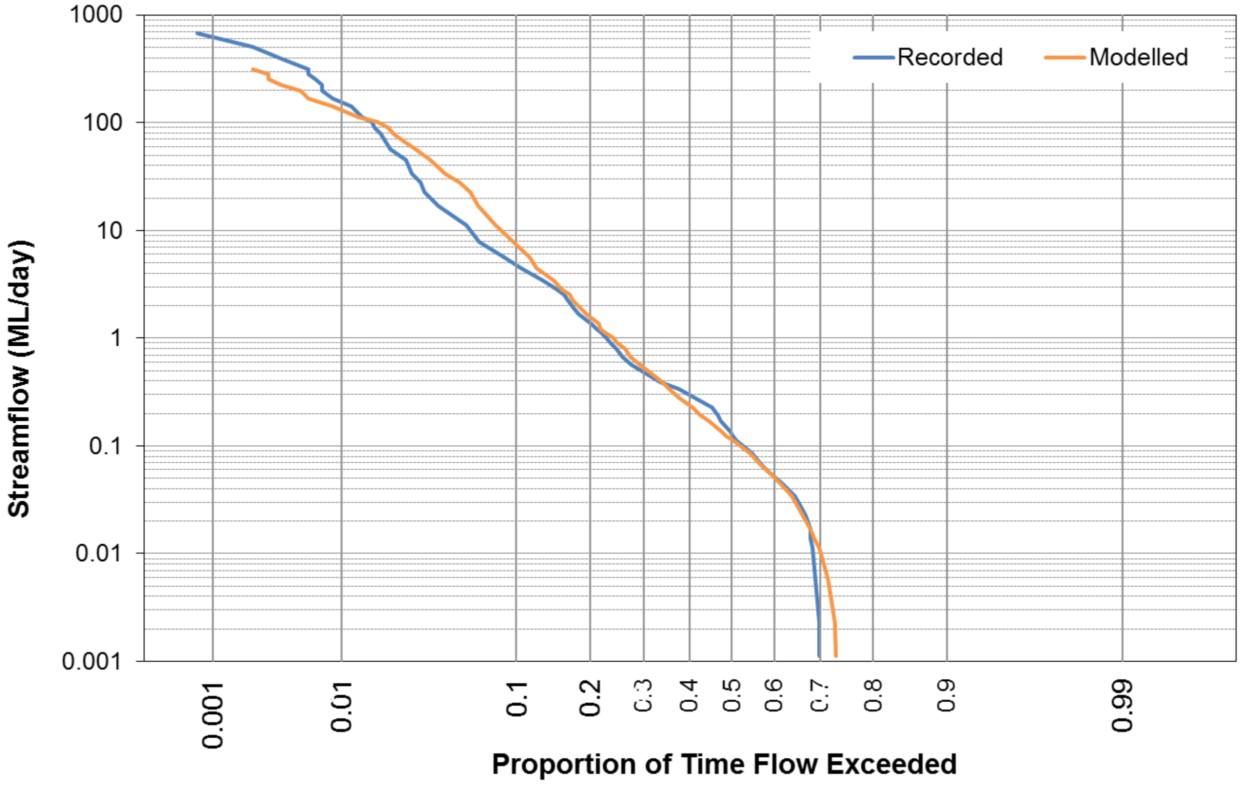

Figure 17 Flow Frequency Duration Plots – Dog Trap Creek (GS 300063)

The median flow rates stated in Slide 26 (presumably based on daily data) are 0.12 ML/d (recorded) and 0.04 ML/d (modelled). Our calculations indicate a median flow rate of 0.13 ML/d (recorded) and 0.11 ML/d (modelled) for the period of model calibration. The median modelled value of 0.04 ML/d given in Slide 26 appears to have been calculated for the entire period of modelled data spanning February 2012 to April 2019 including the 3¼ year period of no data record. It is inappropriate and misleading to compare two median values that have been calculated over different periods. The plots shown on Slide 26 similarly appear to compare two different periods of data and such a comparison is meaningless.

Slide No: 27

Issue Description:

“Very poor correlation between Measured Flow and Modelled Flow for Dog Trap Creek”

Response:

It is not realistic to expect a catchment yield model to accurately replicate recorded flows on each day. Catchment response is dependent on rainfall temporal and spatial patterns. Moreover catchment response to rainfall is non-linear and reliant on antecedent moisture. These issues are elucidated further in the response to Slide 11.

For the above reasons comparing monitored and modelled daily catchment yield is inappropriate to assess model veracity and is misleading.

Figure 18 shows a plot of modelled and recorded monthly streamflow for the period of calibration, excluding the period of erroneous data described in the response to Slide 24, indicating a generally good model fit.

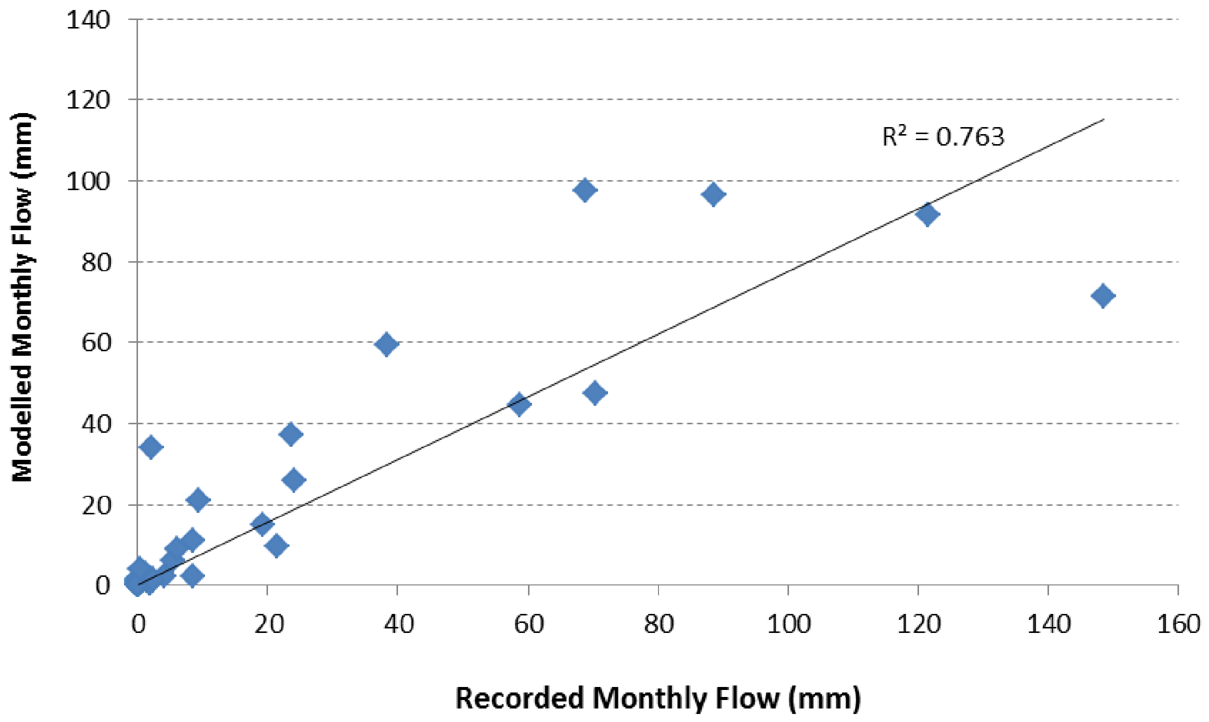

Figure 18 Modelled and Recorded Monthly Streamflow – Dog Trap Creek (GS 300063)

Slide No: 28

Issue Description:

Flow exceedance curve presented for Dog Trap Creek with recorded and monitored data and with subtraction of 0.5 ML/d and 1 ML/d flow. The maximum baseflow reduction as a result of the Tahmoor South Project is given as 0.59 ML/d.

"Potential flow impacts to Dog Trap Creek will mean the Creek will likely cease to flow almost 75-85% of the time."

Response:

As explained above in the response to Slide 26 the flow exceedance curves for recorded and modelled data appear to have been developed for different periods of data and are therefore meaningless to compare.

The value of 0.59 ML/d was stated as the maximum total baseflow reduction as a result of the Project in the Tahmoor South Second Project Amendment Report (SIMEC, 2020)[11]. This was derived from original EIS estimates. As a result of groundwater model refinements and a reduction in the extent of mining proposed as part of the Tahmoor South Amended Project, the predicted maximum baseflow reduction has reduced. The maximum baseflow reduction predicted as a result of the Project in Hydrosimulations (2020)[12] totals approximately 0.37 ML/d (comprising 0.34 ML/d at the Nepean River [SW-21] plus 0.03 ML/d for other streams not upstream of SW-21).

The application of a 0.5 ML/d baseflow loss to Dog Trap Creek alone is a significant over estimate of the forecast maximum baseflow reduction of 0.1 ML/d for Dog Trap Creek that is predicted to occur as result of the Tahmoor South Project (SWIA report Table 15) and 1 ML/d even more so. The 0.59 ML/d rate is the purported total for the entire Project area and it is incorrect to apply this to Dog Trap Creek alone.

[11] SIMEC (2020). :"Tahmoor South Project Second Amendment Report and Response to Submissions", v1 Final, 3 August.
[12] Hydrosimulations (2020). "Tahmoor South Amended Project Report: Groundwater Assessment", Report HS2019/42, v3.0, February

Simply subtracting a fixed daily flow from every point on a flow duration curve is overly simplistic – the asserted flow loss should be subtracted from each daily data value and the statistical curve then regenerated using the revised data. Therefore the flow exceedance graphs given as blue, purple orange and light blue plots in Slide 27 are inaccurate and misleading.

The effect of a baseflow reduction of 0.1 ML/d (forecast maximum) on the flow duration behaviour of Dog Trap Creek is discussed in Section 6.3 of the SWIA report and illustrated in Figure 40 of that report.

<u>Slide No: 30</u>

Issue Description	Response
Potential serious issues with Observed flows at times	Assuming this refers to recorded flows, periods where data is in error have been excluded from the analysis. These periods represent a small percentage of the total period of record and do not affect model calibration.
Model can estimate 10 Ml/day when measured data says 0 ML/day	Unclear which gauging station and which period of data this is referring to. Erroneous data periods have been identified in the response to Slides 16 to 24. It is not realistic to expect a catchment yield model to accurately replicate recorded flows on each day. Such models are aimed at assessing catchment behaviour over an extended period of time – measured in months and years.
Conversely, Model estimates 0 Ml/day when measured data says 10 ML/day	Unclear which gauging station and which period of data this is referring to. Refer previous response.
Large amounts of missing data – Poor Baseline Record for future assessment of impacts or remediation	Data is not missing – stations were decommissioned for a period of time and have now been recommissioned. Unclear what "poor baseline period" refers to. The following summarises the period of data available at each gauging station to which the models have been calibrated (excluding the minor periods of erroneous data): • Bargo River Upstream (GS 300010a): 6¾ years • Eliza Creek (GS 300073): more than 3 years • Dog Trap Creek D/S (GS 300063): 3¼ years Additional data is being recorded ahead of commencement of the Tahmoor South Project and will allow refinement of model predictions.
The experimental design is poor, lacking appropriate baseline or contrasts to reference locations	The sites are unimpacted by mining in their catchments. Therefore the data that has and is being recorded is baseline data. Comparison with other sites could be undertaken but, as described in the RTS report (with reference to the comparison between Redbank Creek site R11 and GS 212053 [Stonequarry Creek at Picton]), this simply highlighted the differences between these catchments and did not contribute to the hydrological assessment.
The model is considered unreliable and insensitive to potential impacts and lack of flow	Disagree. Model "reliability" (taken to mean calibration accuracy) has been demonstrated with calibration parameters within acceptable ranges given in Vaze et al. (2011). A reduction in recorded flow as a consequence of mining (should this occur) will become apparent in a departure from modelled behaviour – as has been demonstrated at Redbank Creek Site R11.

Response to Additional Issues Document Entitled "EES Methodology Flow Data.docx" Provided Subsequent to Presentation 17 August 2020

Issues Identified Under Heading "Potential Baseflow Loss"

Issue:

"If the lower 0.1 ML/d predicted baseflow loss was considered, then its suggests that Dog Trap Ck would cease to flow approximately 50% of the time (up from approximately 30% of the time if using observed data) or approximately 60% of the time (up from approximately 45% of the time if using the modelled flow data; see figure in Appendix)."

Response:

The effect of a baseflow reduction of 0.1 ML/d (forecast maximum) on the flow duration behaviour of Dog Trap Creek is discussed in Section 6.3 of the SWIA report and illustrated in Figure 40 of that report. Figure 40 illustrates that there is no apparent effect for flows greater than approximately 1 ML/day. The largest effect is seen on flows below about 0.1 ML/day. The probability that flow would be greater than 0.1 ML/day would reduce from 48% to 40% of days based on the maximum predicted reduction in baseflow. The probability of non-negligible (effectively zero flow) would reduce from 66% to 48% (i.e. by 18%). This level of change would likely be detectable during normal periods of low flow and would likely be distinguishable from natural variability in catchment conditions.

Issue:

"Fracturing of the creek bed itself will also lead to loss of pool holding capacity and loss of flow (as seen in numerous other mining impacted areas, including in Redbank Creek)"

In the context of Dog Trap Creek at GS 300063 the statement regarding loss of pool holding capacity and underflow are not relevant because GS 300063 is located well downstream of the proposed Tahmoor South Project area and the predicted subsidence impact area. Underflow (or flow diversion) should not be confused with baseflow reduction. The former does not contribute to a reduction in catchment yield.

Please contact the undersigned if you have any queries.

Yours faithfully,

Tony Marszalek
Director