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DATE:	29 January 2014
TO:	Jamie Lees Wilpinjong Coal Pty Ltd
	Peabody Energy Australia Locked Bag 2005 Mudgee NSW 2850
FROM:	Noel Merrick and Will Minchin
RE:	Review of Hydrogeological Data for Wilpinjong Licensing Audit
OUR REF:	WIL008 - HC2014/021

This letter report provides a summary of HydroSimulations' review of hydrological and hydrogeological data to support the Wilpinjong Coal Mine (WCM) Licensing Audit.

HydroSimulations (HS) has been engaged to provide support to the appointed independent environmental auditor in assessing Conditions 9c and 9d attached to the water licences for Open Cut Pits 1 to 5:

- Condition 9c: Review actual impacts of the extractions on any aquifers, groundwater dependant eco-systems and any streams in the area;
- Condition 9d: Make comparisons between actual and predicted impacts (modelled results).

This report is broken into the following sections:

- Review of dewatering records;
- Review of surface water monitoring data;
- Review of groundwater level data;
- Review of groundwater quality;
- Comparison of predicted and observed groundwater drawdowns;
- Groundwater dependent ecosystems; and
- Conclusions.

To assist in reading this report, a map of the monitoring locations and pit areas is presented as **Figure 1**.

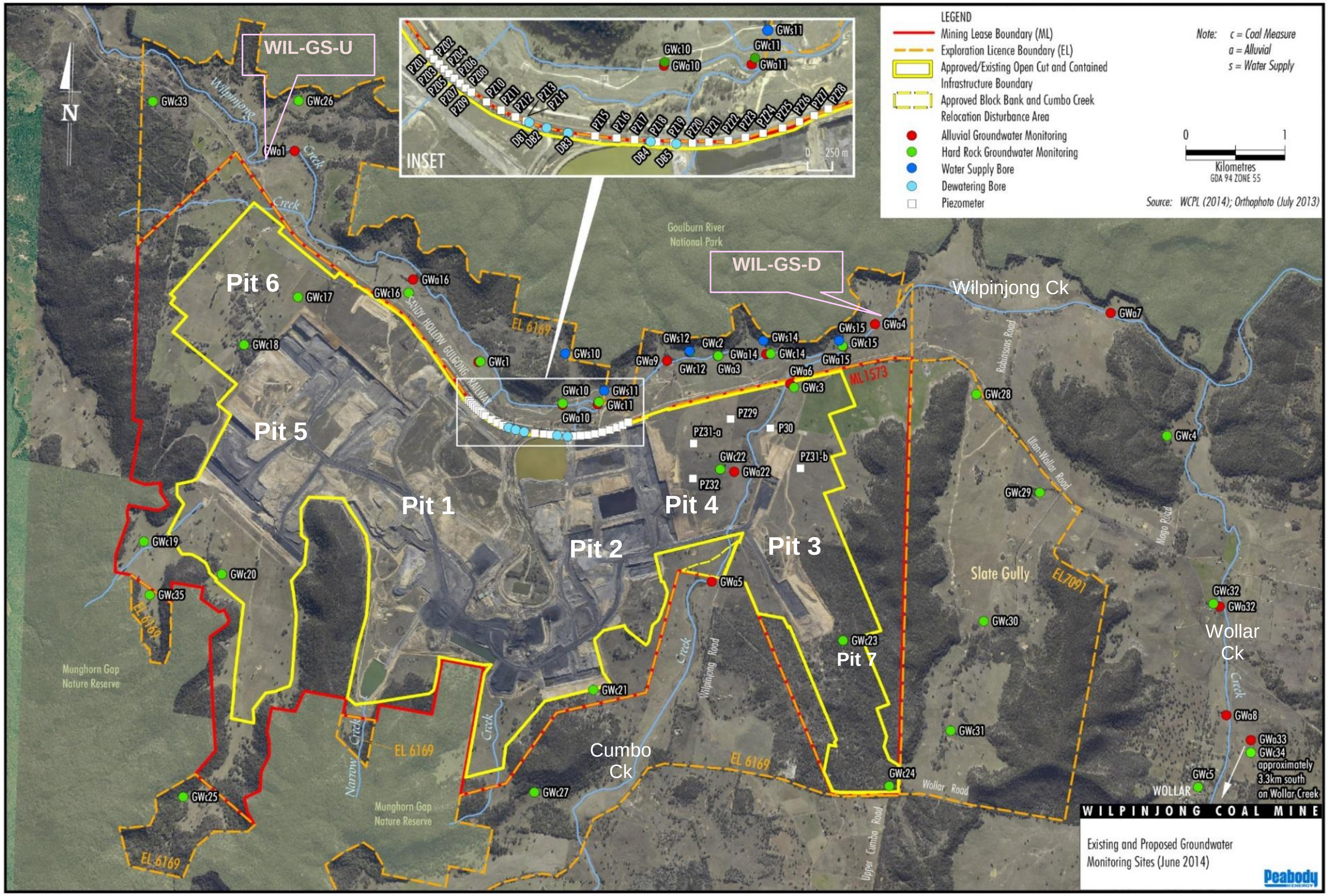


Figure 1 Existing and Proposed Monitoring Sites at Wilpinjong Mine

REVIEW OF DEWATERING DATA

The following describes a review of dewatering or pumping records from the site, and the method to estimate 'groundwater take' from those records.

Available Data

Meters to allow the direct measurement of the pumping rates from the open cut pits to mine water storages have recently been installed (i.e. mid-2014) at the WCM. For the 2013-14 water year, which is the subject of this current review, there was no direct metering of the rates of pumping from the pits for use in estimating groundwater take from the open cut pits.

However, alternative sources of data are available to estimate the pumping from the open cut pits. Pumping data was supplied to HS in two datasets (spreadsheets):

1. "SumpPump.xls" - contains pit (sump) pumping and dewatering bore pumped volumes for 2006-2011 on a monthly frequency. It presents this data aggregated for the whole mine for that period.
2. "WCM - Processed Pumping Records (Nov 2012- July 2014) Rev 2.xlsx" - contains data November 2012 to July 2014, on a daily frequency. This dataset provides data for each of the monitored pumps around the mine site, including 'pumping from' and 'pumping to' attributes. There is also summation of the total pump-out and pump-in volumes, and calculation of the net pump-out volume, for each of the active pits (Pits 2, 3, 4 and 5). There has been no pumping from Pit 1 for at least two years.

Dataset #2 (listed above) relies upon pump-by-pump data that is collected on the daily operational activity of pump sets by staff at the site. This is then applied to nominal estimates of a fixed duty rate for these pumps to infer the volume of water transferred over a particular period. Review of the pumping data available from the two data sources indicates that there was a significant change in the estimated volume of pumped water using the Dataset #2, as compared to the previous aggregated data collected 2006-11 (Dataset #1).

Based on Dataset #2, the total pump-in and pump-out volumes for the period November 2012 to July 2014 for each pit were:

- Nothing pumped into or out of Pits 1 and 6;
- Pit 2: total In = 309 ML; total Out = 0 ML;
- Pit 3: total In = 0 ML; total Out = 1,273 ML;
- Pit 4: total In = 209 ML; total Out = 16,913 ML;
- Pit 5: total In = 56 ML; total Out = 2,405 ML.

It is clear from these figures that the volume pumped from Pit 4 during 2012-14 was anomalously high compared with volumes pumped into or out of other pits.

In order to evaluate potential causes for the quantum of increased pumping that is apparent in the data collected in Dataset #2, particularly pumping from Pit 4, WRM Water & Environment has completed some additional supplementary analysis as follows:

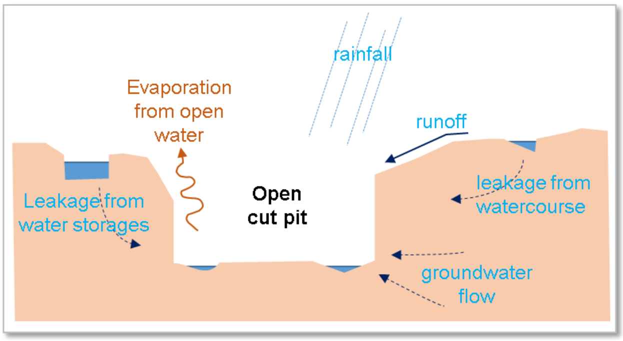
- Water balance analysis of pumping volumes to/from Pit 4 and nearby water storages by WRM Water and Environment (WRM, 2014a); and
- Site-wide comparison and analysis by WRM Water and Environment (2014b) of volumes from newly installed flow meters (aimed at improving the measurement of on-site water transfers) against pump hours-pumping capacity.

WRM Water & Environment's analysis of coincident periods of pumping data and metered data in the second half of 2014 found significant variability between the two methods.

Compared to estimates based on the newly installed flow meters, pumped volumes estimated from pumping hours were overestimated at Pit 5 (by 70%), Pit 4 (54%) or 11% underestimated at Pit 2. On average, estimates from all pumps used in the analysis (WRM, 2014b) were 30% greater than those based on data from the flow meters in the coincident period examined.

The dewatering bores were used only in May and June 2006, at the time mining commenced in Pit 1. The volume of water that was pumped from these standby bores was solely groundwater. However the volume of water that is pumped from pit sumps in the base of the open cut pits (pits) is derived from:

- direct rainfall;
- any runoff that enters the pits from upslope;
- groundwater entering the pits through the walls and floor;
- 'recirculated' leakage from neighbouring storages, especially into Pit 4; and
- the water in the pits will have been subject to evaporation, which will have reduced the volume pumped out.



This means the volume pumped out of the pits is not solely groundwater, but contains water from other sources. For the purpose of this audit, an inferred groundwater inflow volume has been calculated from the net volume pumped out from the various pits and, accounting for direct rainfall, an estimate of runoff (based on total runoff in Table 10 of Gilbert & Associates, 2013) and an estimate of recirculated leakage from storages/tailings dams (TD) that are near to active mine areas. **Figure 2** (originally Figure 11 of Gilbert and Associates, 2013), shows the spatial relationship between open cut pits and water storages and tailings dams, as well as an idea of the catchments over which runoff can be generated. It is clear from **Figure 2** that Pit 5 has the largest upslope catchment of all the open cut pits.

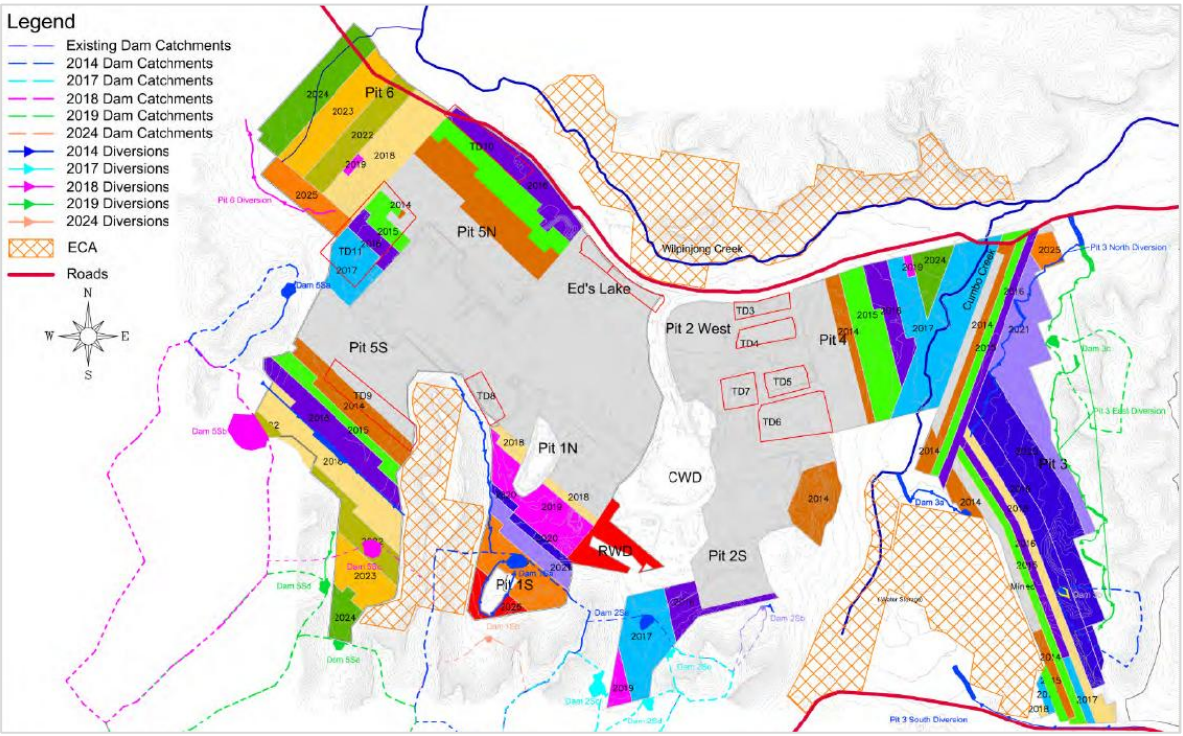


Figure 2 **Layout of Open Cut Development and Water Storages** (Gilbert & Associates, 2013)

Leakage recirculation is known to occur from 'Pit 2 TD2'[1], 'Pit 2 TD3', 'Pit 2 TD4', and 'Pit 2 dam' (storage). **Figure 2** shows these water storages are all close to the active mine area of Pit 4, from which large volumes of water are pumped. There are no records for pumping to and from Pit 2 TD 5 and 6, which are also near to the mining area in Pit 4, despite aerial photos showing that these have been partially or completely filled at times. Similarly, it is thought that leakage from the 'Ed's Lake' storage could enter the northern Pit 5 workings.

Another factor that may confuse the use of pumping records for inferring groundwater inflow is that water from the various sources (above) may enter a pit, but may not be pumped out (and recorded) for some time afterwards. This then makes it appear as though the inflow occurred at a particular time, but in reality may have taken place much earlier, and over an extended period. For example, pumping data at the start of the water year may contain water that had accumulated in the pit from the previous water year, resulting in an overestimate of pumped volumes for this water year.

Therefore, there are several assumptions in calculating the inferred groundwater inflows. As a result, there remains significant uncertainty in the calculated or inferred groundwater inflows, especially in Pit 4 and, to a lesser degree, in Pit 3.

Based on pre-2012 data, HydroSimulations (2013) estimated that 60% of the net water balance could be attributed to groundwater inflow. Within the constraints of data accuracy, WRM's analysis of the Pit 4 water balance stated that "seepage from Pit 2 West to Pit 4 may account for 80-95% of the total water pumped back from Pit 4" (WRM, 2014a), which therefore means groundwater, runoff and seepage from tailings would have constituted 5-20% of the volume pumped from Pit 4. Groundwater could therefore be *up to* 20% of the net pump-out, but more likely to be somewhat lower.

Trends in Inflow across WCM

Figure 3 presents the 'inferred groundwater inflow', based on Data Sources #1 and #2 (see above), noting that the 2006-11 data is not corrected for runoff or other processes, and so represents the inferred maximum groundwater inflow. The monthly data for 2006 to 2011 is distinguishable from the daily data in the period late-2012 to 2014. Moving average trends of 6-months and 12-months have been plotted, as well as the 'Rainfall Residual Mass' (rainfall trend) curve, which is a means of filtering out short-term variability in rainfall and displaying the longer term trends. Where the rainfall trend curve rises, rainfall was above average, and where the curve declines, rainfall was below average. Steeper gradients in either direction are indicative of more extreme rainfall patterns.

The results suggest that there is some correlation between mine inflow trend (12-monthly trend line) and the rainfall trend, e.g. there is a rise in mine inflow in 2006-2009 which is congruent with above average rainfall in this period. However this period is also congruent with the commencement of several of the pits at Wilpinjong Mine. In 2009-10, the inflow hydrograph and trend lines decline in line with the rainfall trend curve, along with a short-term rise in 2011.

From late 2012 the hydrograph on **Figure** 3 is based on the net pump-out from each of the pits (Dataset #2), minus an estimate of runoff to each area, minus the water accumulated in storages and tailings dams near to active pits (as an attempt to account for recirculation from these). After 2012 the pumping rates appear to have increased (**Figure** 3).

[1] TD = tailings dam

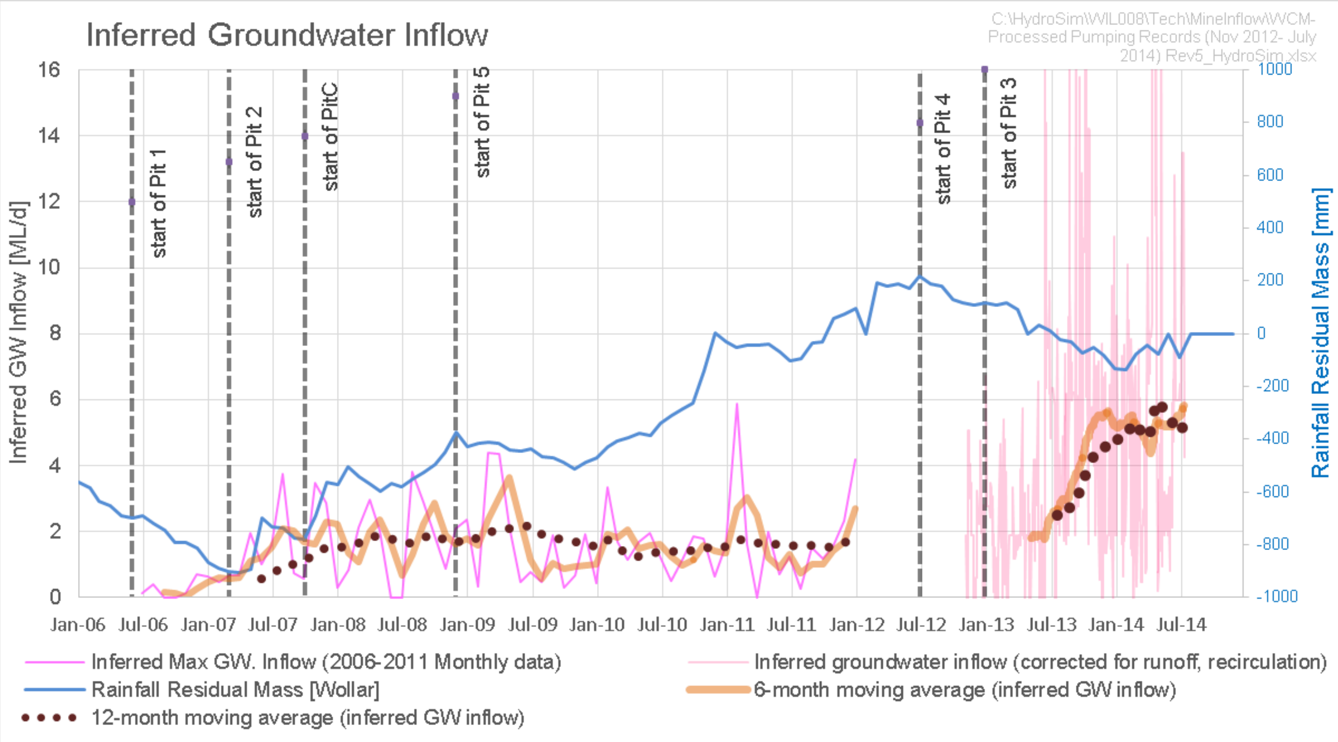


Figure 3 **Historical Trends in Inferred Groundwater Inflow (based on Net Pump Out)**

As discussed previously, unaccounted volumes of recirculation from storages and tailings dams (Pit 5 and especially Pit 4) and from lags between inflow to pits and their subsequent pump-out (Pit 3) are the likely causes of some of the apparently higher groundwater inflows experienced in 2012-onward.

It should also be noted that surface water diversions are being installed or improved around much of the site (as shown on **Figure 2**), and management practices have changed in some areas (e.g. WCM no longer using Ed's Lake, near Pit 5 north open cut, as a storage, which had probably been contributing recirculated flow back to the pit). These changes are likely to factor in the plateau and then decline in 'inflow' in 2014 shown on **Figure** 3.

Comparison of Pit-by-pit Groundwater Inflow

Figure 4 presents annualised predicted inflow volumes from groundwater modelling (from HydroSimulations, 2013, using a groundwater model built and calibrated in 2005) against the annualised total new pump-out for each pit, noting that the pit-by-pit data are only available for 2012-2014; 2013-14 is a complete year of data, while results for 2012-13 are scaled to 12 months for presentation on subsequent figures. The totals presented are for 'water years', i.e. July to June.

The range in values shown for Pit 3 and Pit 5 is derived from the Dataset #2 alone, or Dataset #2 having been scaled using the variance between pumping hours-based estimates and flow meter-based estimates for that pit (see earlier discussion).

The following findings are evident from the data in **Figure 4**:

- Pit 2 – active mining ceased in 2011-12, so minimal inflow for the period of better data (2012-onward);
- Pit 3 – pump-out (inferred groundwater inflow) higher than predicted, although timing of pump-out versus the actual timing of groundwater inflow or runoff to the pit may cause this discrepancy (further comment later).

- Pit 4 –inferred inflow in 2012-13 higher than predicted, and same in 2013-14, although **Figure 4** shows significant uncertainty associated with Pit 4 inflow (the sources of which are discussed previously, and also in the following section). The range in inflow presented in **Figure 4** is based on the commentary by WRM (2014a), suggesting groundwater accounts for less than 20% of net pump-out. See **Table 1** and subsequent discussion, below.
- Pit 5 – inferred inflows lower than predicted.

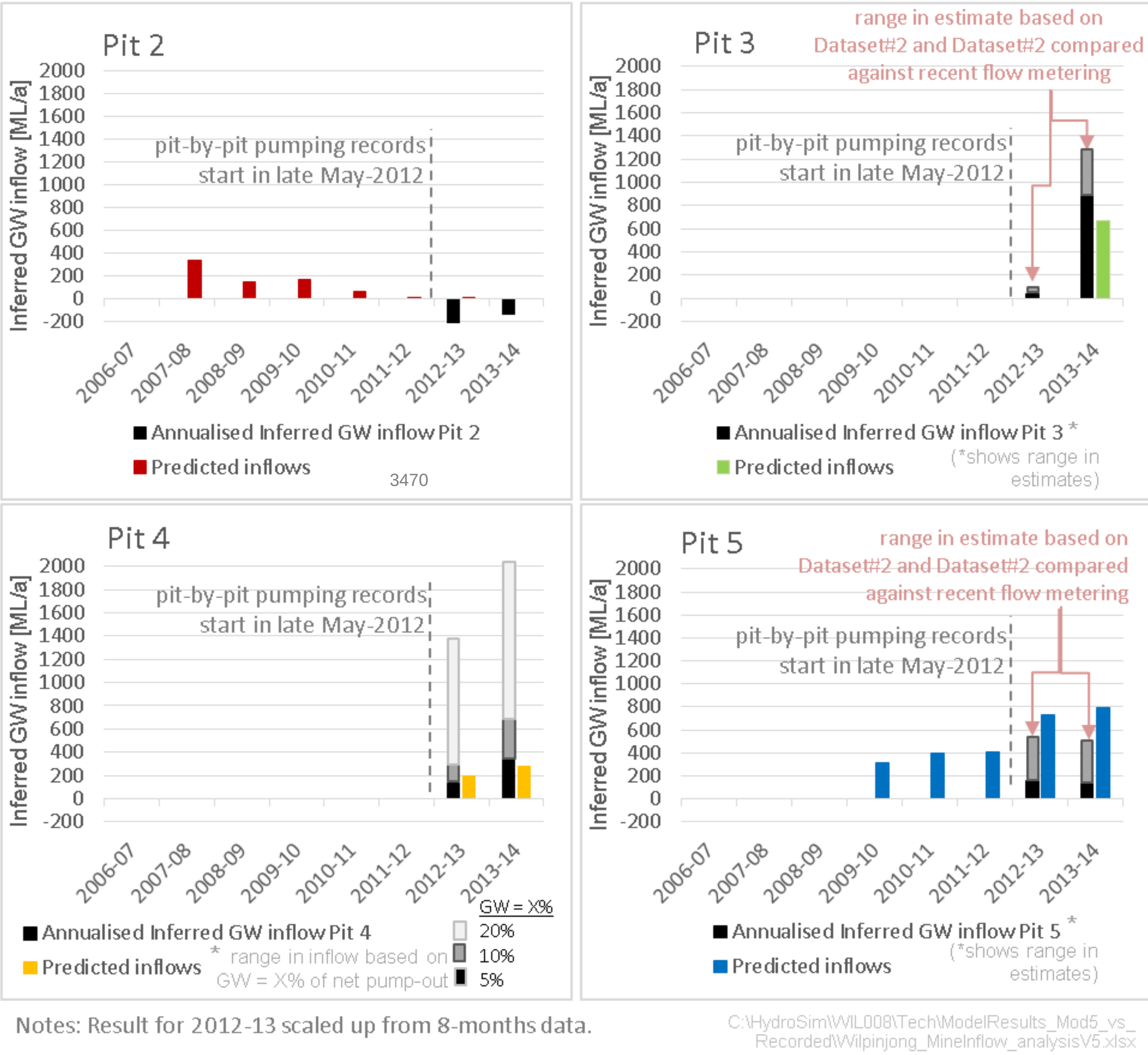


Figure 4 Comparison of Predicted Inflows and Pumped Volumes

Assessment of Annualised Groundwater Inflow against Licence

HS' understanding of WCPL's groundwater licences is that WCPL:

- Held two licences from 2006 until 2008 that entitled a combined groundwater take of 697 ML in any 12-month period. A third licence was added in 2008 that covered another mine pit, but without additional volume attached (i.e. still a combined 697 ML).
- In 2013 WCPL sought additional licensed volume, to a total of 1,730 ML/a, and that licences were granted to cover each of the five active or soon-to-be-active pits (Pits 1-5). The total entitlement now held by WCPL is 2021 ML/a.

Table 1 presents details for the five licences and the relevant entitlement volume, as well as a summary of the groundwater take from each of the pits, as inferred for 2012-13 and, 2013-14. 2012-13 records were only for part of the year (230 days, or approximately 8 months)

Table 1 Summary of Annual Volume of Inferred Maximum Groundwater Take (2012-14)

LICENCE	PIT	LIMIT [ML]	INFERRED GROUNDWATER INFLOW [ML]	
			2012-13 *	2013-14
20BL176517	Pit 1	1	0	0
20BL176516	Pit 2	190	<1	<1
20BL176515	Pit 3	680	38 to 54	890 to 1270 ^
20BL176514	Pit 4	350	best 136-273 ^#	best: 345-695^##
20BL176513	Pit 5	800	160 to 453	140 to 405
--	Pit 6		not yet mined (commencement in 2018)	
TOTAL		2021	335 to 780 +	1375 to 2370 ++

Full year (or scaled full year) of pumping data assessed: Compliant (based on available pumping data)

* scaled up to annual from the available seven months data; ^ see text below for further comment

\# maximum, assuming groundwater constitutes 20% of net pump-out, is 1360 ML.

\## maximum, assuming groundwater constitutes 20% of net pump-out, is 3470 ML.

\+ maximum 2012-13 annual could be up to 1870 ML/a.

++ maximum 2013-14 annual could be up to 5150 ML/a.

Table 1 shows an assessment of compliance across each pit for 2012-13 and 2013-14. This should be considered in light of previous comments regarding the uncertainty surrounding some of the data (e.g. no pumping records for certain tailings dams), and uncertainty surrounding the hydrologic processes that are at play (e.g. recirculation, and lag between inflow to a pit and subsequent pump-out). This includes a wide range of estimates for Pit 4 – more discussion below.

Pumping from the other active pits (Pits 2 and 5) has been less than predicted and licensed. Accordingly, **Table 1** shows compliance at Pits 1, 2 and 5.

In considering the uncertainties, some additional commentary and analysis on Pits 3 and 4 is presented here.

Factors considered when interpreting the inferred inflows to Pits 3 and 4 were:

- The period 2011-12 was a wetter period than most in the recent record (see rainfall trend on **Figure 3**). The higher pumping volumes could be related to this due to higher groundwater levels, additional runoff or additional inputs from other sources (recirculation).
- Pits 3 and 4 only commenced in 2012 and 2013 respectively, and hydrogeological conditions (hydraulic conductivity, aquifer storage properties) encountered may vary somewhat from those simulated, but minor variances in these parameters would not account for the apparent 5- to 10-fold variance between predicted and ‘actual’ inflow.
- Lags between inflow (groundwater or runoff) to an excavation and any subsequent pumping from that pit;
- Recirculation from nearby storages and tailings dams to nearby pits.

Pit 3

Based on the data available at this time our conclusion is that it is *likely* that Pit 3 is also compliant. Pit 3 commenced early 2013, i.e. before the beginning of the 2013-14 'water' year, but only a small volume of water was pumped out prior to July 2013 (38-54 ML over the period of about 6 months), and then much greater volumes pumped out 2013-14. This higher volume is likely due to the pump-out having to account for groundwater accumulated prior to 2013-14. This conclusion should be reviewed once the 2014-15 water year is complete.

Pit 4

A total of 7,000-8,000 ML/a was pumped from Pit 4 in both 2012-13 and 2013-14. This is significantly higher than the predicted groundwater inflow in HydroSimulations (2013), and is due to inflow from other, non-groundwater sources.

Recent analysis considering the site water balance (WRM, 2014a) and comparing recent metering against pumping hours/pump capacity (WRM, 2014b) forced further analysis. WRM (2014a) indicated that 80-95% of the net pump-out was returned flow from neighbouring water storages (e.g. Pit 2 West storage). This analysis suggested that the remaining 5-20% would include groundwater inflow, runoff from up-gradient areas, recirculation from nearby tailings dams and direct rainfall.

Taking the WRM analysis into account, i.e. taking groundwater inflow as being around 5-10% but possibly up to 20% of net pump-out, gives the range in inferred groundwater inflow to Pit 4 presented in **Table 1** (also **Figure 4**). Those estimates for the two recent water years are:

- 2012-13: Best estimate 136 to 273 ML/a (range up to 1,360 ML/a); and
- 2013-14: Best estimate 345 to 695 ML/a (range up to 3,470 ML/a).

Acknowledging the uncertainty surrounding these estimates, and noting again that WCM have steps in place to improve the management and monitoring of water around the site, it is considered that Pit 4 (licence: 350 ML/a) was probably compliant in 2012-13. Based on the data available at this time, it is difficult to conclude compliance in 2013-14, or conversely to conclude there was definitely a non-compliance.

Assessment of Annualised Total Groundwater Take

Figure 5 shows the annualised total inflow to the mine (based on pumping records) against WCPL's groundwater licence(s) and against the predicted total annual inflows from previous groundwater modelling.

The total entitlement volumes are displayed on **Figure 5** (red dashed line). The bar charts show the annualised inflow volumes from groundwater modelling (HydroSimulations, 2013).

On **Figure 5** the inferred groundwater inflow (dark brown line) tracks the total predicted inflow quite well for the period 2006-2011, with the exception of 2007. With the exception of that year, during this period, inflows peak at about 600 ML/a (in 2009), just less than the licensed volume at that time.

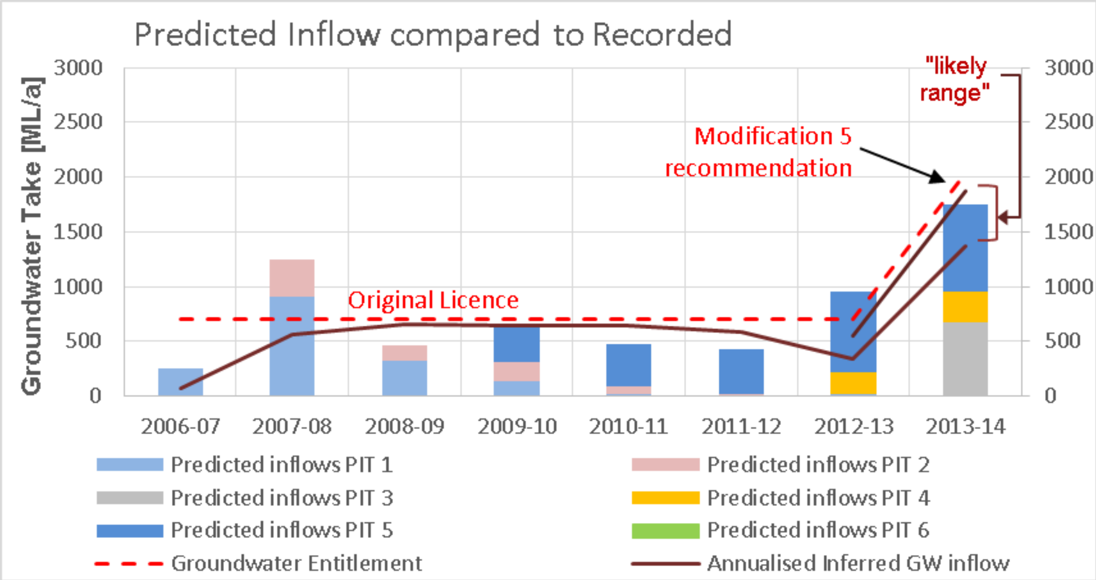


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Figure 5 Comparison of Predicted and Pumped Volumes against Groundwater Entitlement

As discussed previously, pumping records suggest increased inflows from 2012, and two lines (on **Figure 5**) are used to indicate the likely range in groundwater inflow for 2012-13 and 2013-14. In 2013-14 a total of 1,870 ML (the upper estimate in the likely range) was estimated as being pumped from all the pits, compared to a total, site-wide entitlement of 2,021 ML.

Predicted inflows increased materially from 2012 due to concurrent progression of Pits 3, 4 and 5 to the north (HydroSimulations, 2013). Pit pumping rates are likely to have been exacerbated by the problems with recirculating water after it is pumped from open cuts to nearby storages (i.e. water storages and tailings dams) (see discussion in previous subsections).

Recommendations for Monitoring Groundwater 'Take'

The following points are made in light of WCM's on-going work to improve water management and data recording.

- Continued expansion of the use of flow metering at the site, including further calibration of the metered rates/volumes, and to consider recording volumes of material being pumped to the tailings dams;
- It is noted that, if pump-out from mine workings is not carried out after water ingress (i.e. within a month) there is potential for recording periods of artificially low groundwater inflow, followed by periods of artificially high groundwater inflow (i.e. when operators pump the pit out and have to make up for earlier periods of inflow that were not pumped out); and
- While this situation is often unavoidable due to operational reasons (i.e. campaign dewatering), this factor should be considered when future licensing reviews are undertaken. WCPL records noting that significant volumes of water have been stored in-pit for a period may assist in this respect.

REVIEW OF SURFACE WATER DATA

Data from Jan-2012 to May-2014 for two continuous surface water monitoring gauges, both on Wilpinjong Creek, are presented on **Figure 6**. The locations of these gauges are shown on **Figure 1**; one is upstream to the northwest (marked WIL-GS-U) and the other is downstream to the northeast marked WIL-GS-D) of Wilpinjong Mine. Flow, electrical conductivity and pH are all measured and presented against the rainfall trend from the local (Wollar) rainfall station.

The catchment areas of the two gauges are 89 and 216 km^2 respectively (Gilbert and Associates, 2013). A reverse osmosis plant to treat wastewater at the mine has discharged treated water to Wilpinjong Creek, upstream of GS-D, since June 2012.

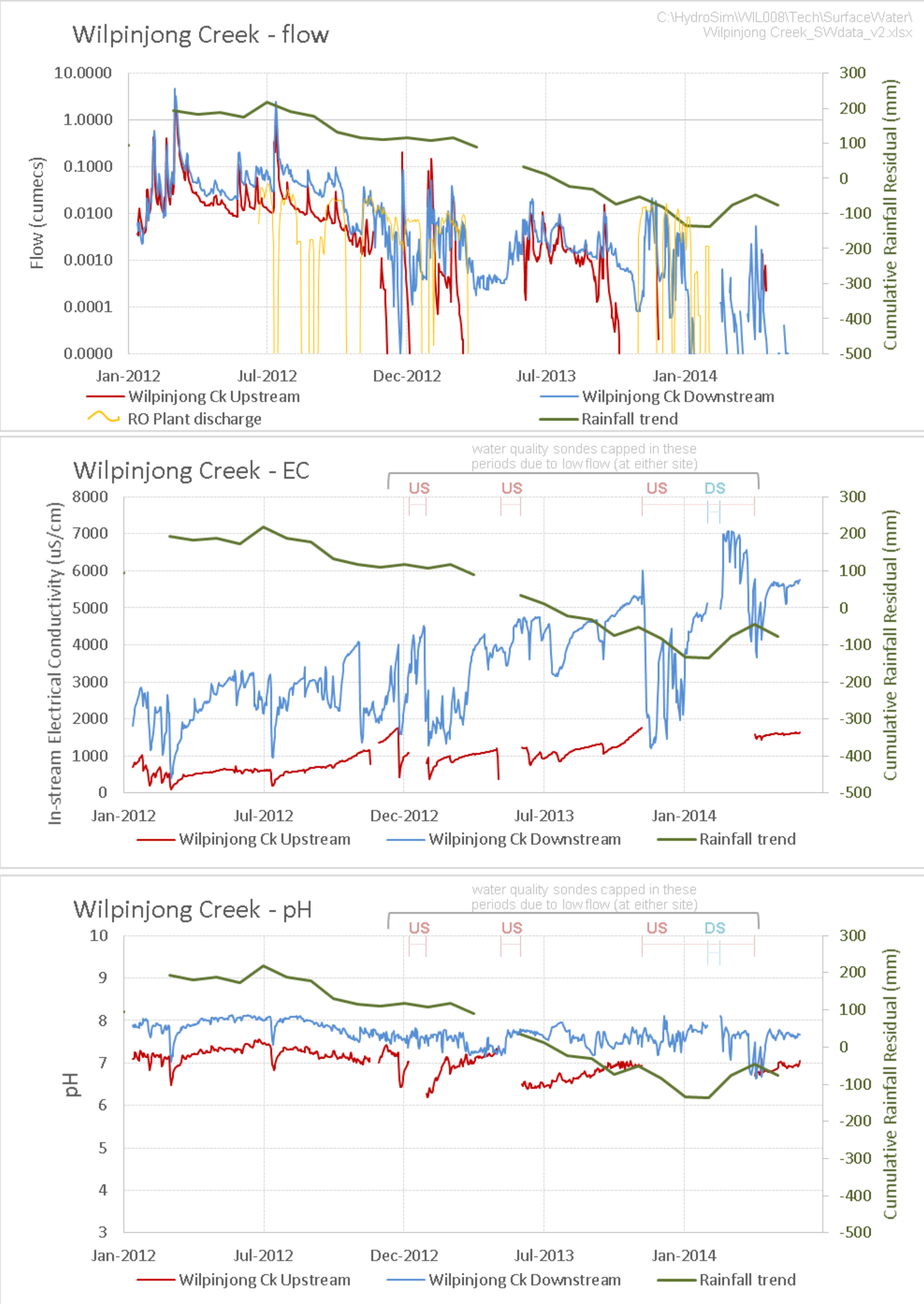

Figure 6 **Summary of Surface Water Monitoring on Wilpinjong Creek**

The main findings from the data shown in **Figure 6** are as follows:

Flows at both gauges, upstream (GS-U) and downstream (GS-D), show correlation with the long-term rainfall trend, with a decline from 2012 to July 2014. Flows at both gauges have been less than 0.001 cumecs (<100 m^3/d) 50% of the time since early 2013 and for most of 2014 to date. Because this occurs at both gauges, and the rainfall trend has been declining consistently, climate rather than mining is the primary cause.

Correlation between the flows at the two gauges is high, with essentially a 1:1 relationship until about April-June 2012, followed by a period until 2014 when the flows at GS-D are consistently higher than those at GS-U. The change in proportionality is suggestive of the influence of the RO plant discharge above GS-D (RO plant discharges shown in orange on **Figure 6**). It is worth noting that an average of approximately 0.006 and 0.001 cumecs respectively were discharged from the Reverse Osmosis (RO) Plant in 2012-13 and 2013-14 respectively, or about 185 ML/a (average 0.5 ML/d) and 42 ML/a (0.1 ML/d) in each of those water years.

A flow trigger was proposed by Gilbert and Associates (2013) to monitor losses along Wilpinjong Creek where its course is adjacent to the mine. The trigger was deemed to have failed, i.e. further investigation is necessary, where:

[average daily flow at GS-D] < F x [average daily flow at GS-U]

where factor F = (1 – 0.11) x ([catchment area GS-D] / [catchment area GS-U]) = 2.16.

This rule is designed to check if the average loss of flow from upstream to downstream, allowing for the increased catchment size, is <=11%, as predicted in the original EIS (WCPL, 2005). A check on flow for the period June-2013 to May-2014 inclusive has been made. Mean daily flow at GS-U was 0.0007 cumecs, leading to a trigger of 0.00145 cumecs. Mean daily flow at GS-D was 0.0024 cumecs, which means that further investigation is not required.

Water quality is monitored at these two sites, with the sondes measuring EC, pH (and temperature, which is not shown here). When water levels decline in dry periods, sondes may be ‘banked’ or capped to protect the instrument. These periods are marked on the EC and pH charts on **Figure 6** (red, labelled “US” = GS-U; blue, labelled “DS” = GS-D).

Trends in Electrical Conductivity (EC) are a mirror of the flow and rainfall trends, and the daily EC data at each station are highly correlated to the flow data. EC is consistently higher at GS-D than at GS-U, with the exception of the period Nov-2013 to Mar-2014. The usual pattern of higher EC at GS-D is suggestive of a higher baseflow index at GS-D (groundwater being typically more saline than runoff) than at GS-U, the influence of stream flow from Cumbo Creek (in which the average EC is about 6,000 µS/cm, compared to about 3,000 µS/cm in Wilpinjong Creek). During late 2013 and early 2014, the EC pattern reverses, which is probably due to a much greater proportion of flow at GS-D being from the RO plant, which is less saline than the natural dry-weather EC of Wilpinjong Creek, which is shown at GS-U.

pH shows a steadier pattern at both gauging stations, and does appear correlated to the long-term trend in rainfall and flow. However it also shows a response to short-term variation in flow, and does exhibit signals depending on the source of the water in the river. For example, during storm events (e.g. March 2012, July-2012) pH is shown to decline sharply by about 0.5-1 pH unit, before recovering over a period of weeks, back to the baseline of about 7 (upstream) and 7.5-8 (downstream). The two main periods for which the pH trends deviate from their ‘baseline pattern’ are January 2013 and April-June 2013. During both periods the water quality sonde at GS-U is capped due to low water levels at the site (i.e. not monitoring). However it is clear that across each period, in-stream pH responds to the low flow conditions. In the first of these periods, pH at GS-U declines to 6.2 and then recovers to over 7-7.5 within two months. pH at GS-D appears unaffected at this time. In the second period pH at GS-D declines to about 7, in response to a marked decline in flow and recovers to almost 8 by

June, while at GS-U the pH falls to 6.5 in May, with a slow recovery back to pH 7 over a period of 5 months.

It is likely that the measured decline in pH is due to natural processes which can lead to saline groundwaters or groundwater discharge in creeks hosting chemical changes such as conversion of sulfates to sulfides and then leading to acid generation. Such processes are not necessarily mining-related, but can be exacerbated by human activities, such as land clearing or water demand (e.g. irrigation, potable supply, mining).

The pH and EC values recorded at the Wilpinjong Creek site, even those around pH 6 or EC of 7,000 µS/cm, are consistent with those reported in Gilbert and Associates (2013). Gilbert and Associates (2013) concluded that pH, EC (and other parameters) recorded in Wilpinjong Creek did not show any discernible changes due to mining. The recent data does not contradict that conclusion.

REVIEW OF GROUNDWATER LEVEL DATA

A groundwater monitoring network has been in place at the WCM since April 2006, as illustrated in **Figure 1**. The approved Groundwater Monitoring Programme is articulated in Document No. GWMP-R01-H dated March 2006 (WCPL, 2006a) and was updated in December 2010 (WCPL, 2010). Additional monitoring of production bore responses is outlined in the Surface and Groundwater Response Plan, Document No. SGWRP-R01-I dated July 2006 (WCPL, 2006b). Also, a Groundwater Monitoring and Modelling Plan (GWMMP) has been prepared for exploration activities at Wilpinjong in accordance with Condition 12 of EL 7091 and Condition 12 of EL 6169 (WCPL, 2013).

Many paired monitoring bores have been drilled along the Wilpinjong Creek alluvium, with a shallow bore screened in the alluvium and a deeper bore screened across the coal seam. More recently, since late 2013, a number of new bores has been drilled around the periphery of the site, in Slate Gully and along Wollar Creek (**Figure 1**).

For bores with sufficient record, groundwater levels around the WCM site have been investigated in detail to check for cause-and-effect responses in temporal water level changes which could result from rainfall recharge, creek dynamics, short-term dewatering/production pumping or a mining effect. The detailed analysis and presentation of hydrographs are included in **Attachment A**.

Summary bore hydrographs are shown in **Figure 7** (alluvial) and **Figure 8** (coal seam).

Figure 7 presents the groundwater hydrographs for all alluvial bores from the west (higher elevations) to the east (lower elevations), in relation to the rainfall residual mass curve (RMC), along Wilpinjong Creek. There was a pronounced dry period from July 2006 to March 2007 which coincided with the commencement of Pit 1. Pit 2 commenced under normal climatic conditions but within two months was exposed to a very wet period. Both pits were exposed to another very wet period that commenced in October 2007. The transition from a very dry period to a very wet period explains the initial experience of unexpectedly low pit inflows followed by excessive groundwater discharges. Additional wet periods are indicated by the RMC, especially from 2010 onwards. Since the commencement of Pit 4, conditions have been drier than normal. This means that groundwater levels have been naturally lower since then, which complicates the detection of possible mining effects due to Pit 4 and/or Pit 3. Where mining effects are considered a possibility, the individual hydrographs in **Attachment A** are annotated to that effect.

The groundwater table in the alluvium varies from about 385 mAHD to about 345 mAHD over a distance of 8.4 km from GWa1 to GWa7, with hydraulic gradient 0.5% (0.005). Groundwater responds to this gradient by flowing to the east through the alluvium.

Water table rises are evident at most bores in correlation with rises in the RMC. This confirms the expectation that rainfall is an important source of recharge for the alluvial aquifer. Given the proximity of the alluvium to the elevated Goulburn River National Park to the north, groundwater discharge from the Park's Narrabeen sediments will provide another stable source of recharge to the alluvium.

Based on the analysis of the hydrographs in **Attachment A**, some mining effects are considered to have occurred at the following bores located in the Wilpinjong Creek alluvium (**Figure 7**) (albeit these effects are minor and therefore are difficult to discern from climatic variations):

- GWa3 at 450 m north of Pit 4, in the order of 1 m during 2014;
- GWa14 at 300 m north of Pit 4, less than 1 m during 2013 and 2014 (this bore may have gone dry, probably due to a combination of climate and mining drivers, and so the estimate of drawdown is uncertain); and
- GWa6 at the northern junction of Pits 3 and 4, less than 1 m during 2014.

The other bore hydrographs from the Wilpinjong Creek alluvium (e.g. GWa1, GWa2, GWa4, GWa11, GWa12 and GWa15) show no discernible mining effects.

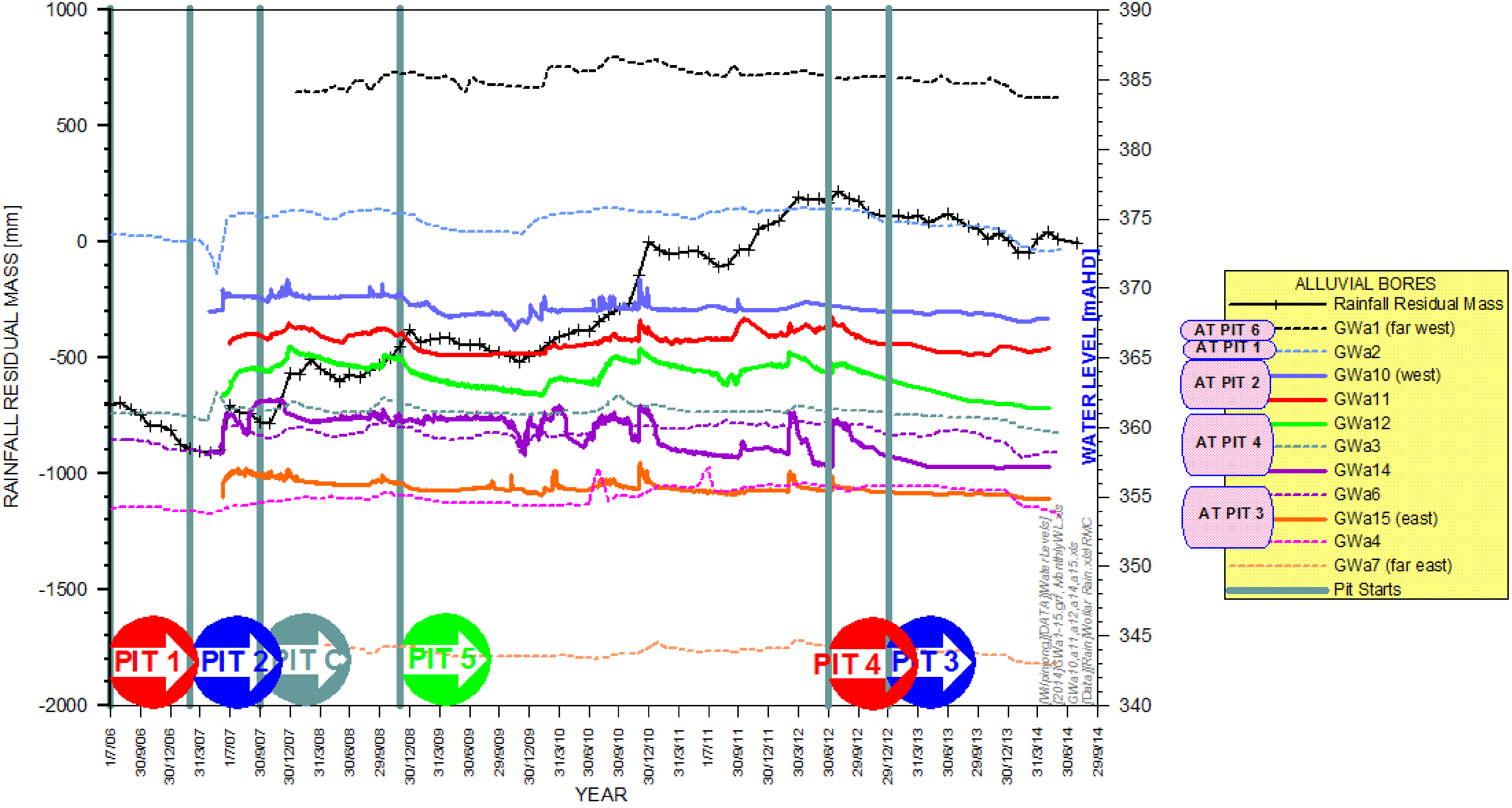

Figure 7. Transition in Alluvial Bore Groundwater Levels from West to East along Wilpinjong Creek

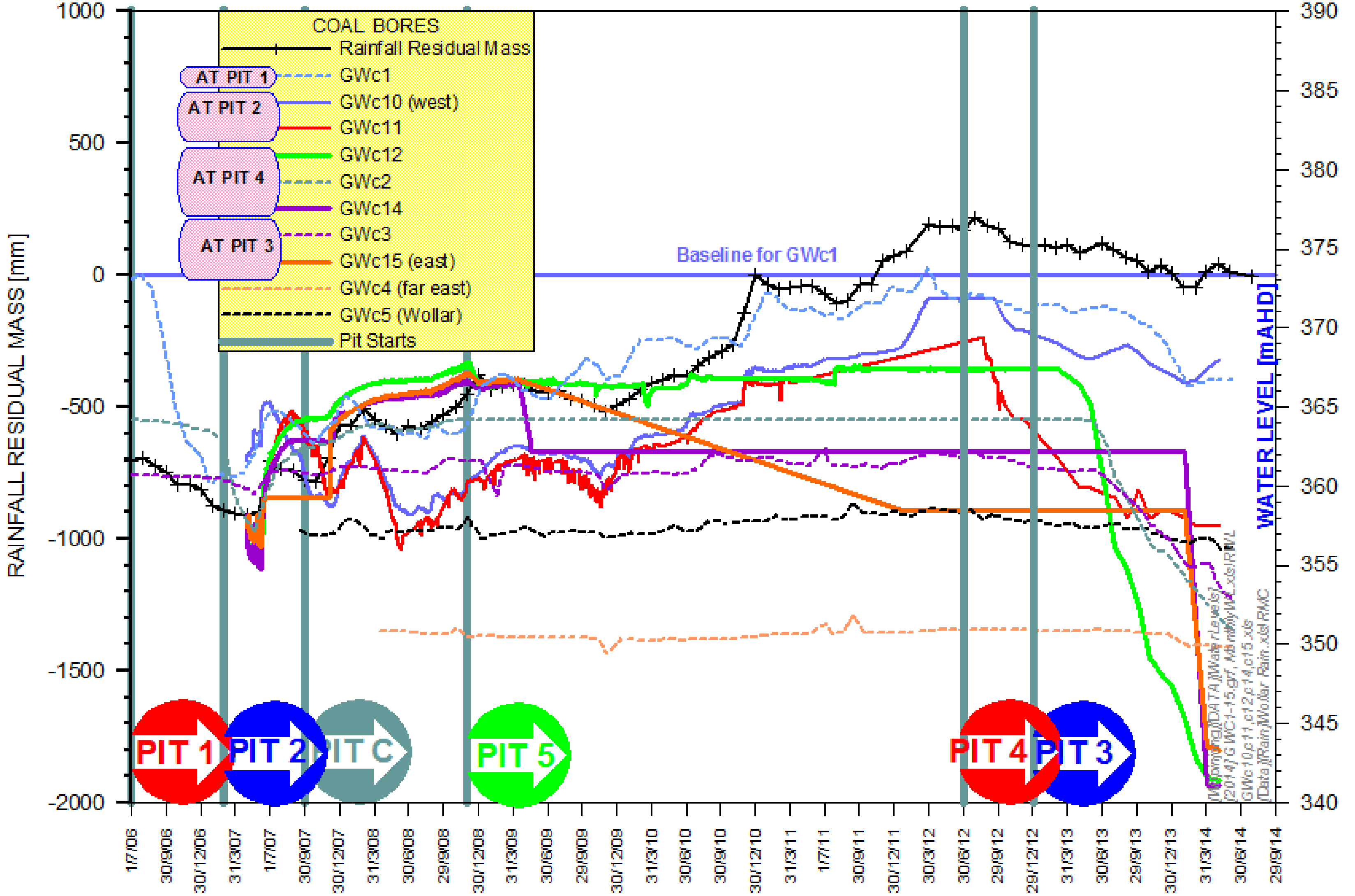

Figure 8. Transition in Coal Bore Groundwater Levels from West to East along Wilpinjong Creek

Figure 8 presents the groundwater hydrographs for all coal bores from the west (higher elevations) to the east (lower elevations), in relation to rainfall residual mass and the commencement of mining in each pit. Three bores (GWc1, GWc2 and GWc3) have records extending back to 2006. These hydrographs show clearly the drawdown caused by excavation of Pit 1 and Pit 2. At the bore closest to mining in Pit 1 (GWc1), the drawdown is about 13 m. At the bores closest to Pit 2 mining (GWc2, GWc3), the drawdowns are about 7 m and 1 m respectively. The water level at GWc1 commenced recovering in mid-2007 and had returned to pre-mining levels by 2012.

At the other coal bores, the pre-mining water levels are not known exactly. The hydrographs show the expected response of drawdown contingent upon the distance from mining, with gradual recovery over about five years in line with the increasing residual mass trend. The most distant site (GWc5 at Wollar) shows no discernible drawdown effect from mining.

Three of the monitored coal sites are considered to be unreliable (GWc14, GWc15 and possibly GWc12) at high pressures. It is noted that they display artesian conditions. However, recent readings in 2014 appear plausible in response to depressurisation caused by Pits 3 and 4.

In **Attachment A**, definite mining effects on monitored coal groundwater levels are noted at the following bores:

- GWc1 - due to Pit 5 (Figure A-5) - drawdown about 2-3 m;
- GWc11 - due to Pit 4 (Figure A-7) - drawdown about 11 m;
- GWc12 - due to Pit 4 (Figure A-8) - drawdown about 15 m;
- GWc2 - due to Pit 4 (Figure A-9) - drawdown about 13 m;
- GWc14 - due to Pit 4 (Figure A-10) - drawdown more than 12 m;
- GWc3 - due to Pits 3 and 4 (Figure A-11) - drawdown about 8 m; and
- GWc15 - due to Pits 3 and 4 (Figure A-12) - drawdown more than 10 m.

For bores not displayed in **Figure 7** or **Figure 8**:

- There is a definite mining effect at alluvial bore GWa5 located between Pit 2 and Pit 3, adjacent to Cumbo Creek upstream (Figure A-4). The drawdown is in the order of 2.5 m during 2013 and 2014. It is noted that WCPL is approved to relocate and excavate the lower reaches of Cumbo Creek;
- There is a probable mining effect on the coal bore GWc22 adjacent to Cumbo Creek but no effect on the companion alluvial bore GWa22 (Figure A-16);
- There are definite mining effects at coal bores GWc28 and GWc29 in Slate Gully (Figure A-17); and
- There are no obvious mining effects at any other bores.

The general trend is for mining-related drawdown to be apparent in coal seam hydrographs, typically within a few hundred metres of active mine areas, but drawdown is much less, if apparent at all, in alluvial bore hydrographs. This is due to the following properties:

- Alluvial bodies not being directly connected to mined areas;
- Rock strata overlying the coal seams and underlying the alluvium serving to mitigate the drawdown response because of low vertical hydraulic conductivity;
- Unconfined conditions and a greater aquifer storage in the alluvium than in the confined coal seams resulting in much lower head variation (drawdown) in the alluvium.

REVIEW OF GROUNDWATER QUALITY DATA

Groundwater electrical conductivity statistics have been computed from 1,197 measurements from April 2006 to June 2014 (**Table 2**). The median value of the measurements at the 13 monitoring sites is about 2,500 microSiemens per centimetre (µS/cm). The average of about 4,000 µS/cm is considerably higher than the median, and the standard deviation (3,200 µS/cm) is commensurate with the mean.

The lowest mean salinity in the alluvium holes is 1,500 µS/cm at GWa2, whereas the highest mean is 9,900 µS/cm at GWa5. The lowest mean salinity in the coal holes is 1,100 µS/cm at GWc2, whereas the highest mean is 4,900 µS/cm at GWc5. On the whole, the alluvial groundwaters are more saline than the coal seam waters. This suggests that the alluvial waters are sourced from Permian sediments and are concentrated through evapotranspiration which is expected to be an active process.

Table 2 Groundwater Electrical Conductivity Statistics (µS/cm)

	Mean	Standard Deviation		Mean	Standard Deviation	Location
ALLUVIUM:			***COAL:***			
GWa1	7900	3200				North of Pit 6: Far west
GWa2	1500	560	**GWc1**	2200	500	North of Pit 1
GWa3	1700	420	**GWc2**	1100	130	North of Pit 4
GWa4	2200	470				North-east of Pit 3
GWa5	9900	2800				South of Pit 4 on Cumbo Ck
GWa6	5500	2300	**GWc3**	3400	480	Northern end of Cumbo Ck
GWa7	9500	1700	**GWc4**	2400	530	North-east of Slate Gully
GWa8	2100	480	**GWc5**	4900	520	Wollar: SE of Slate Gully

The highest salinities occur on Cumbo Creek to the south of Pit 4, on Wilpinjong Creek near Pit 6 and on Wilpinjong Creek to the north-east of Slate Gully. The lowest salinities are along Wilpinjong Creek from Pit 1 to Pit 4, upstream of the Cumbo Creek junction, and on Wollar Creek.

Temporal variations in groundwater salinity are illustrated in **Attachment A** (Figure A-20 for alluvium and Figure A-21 for coal) and are compared with rainfall residual mass and pit commencements. Some alluvial sites have very high salinities and very large fluctuations that bear no apparent relationship with rainfall or mining. The salinities in the coal holes are consistently stable. The different signatures for shallow and deep waters reflect dynamic evapotranspiration acting preferentially on shallow groundwater.

REVIEW OF GROUNDWATER MODEL PREDICTIONS

The current groundwater model is described in HydroSimulations (2013). At each alluvium monitoring site along the Wilpinjong Creek, no more than 0.1 m drawdown is expected for the life of approved mining. However, significant drawdowns are expected at most of the coal monitoring holes.

At all but three alluvium monitoring bores, there are no observed drawdowns that are clearly due to mining, and therefore for most alluvium bores, the observed drawdowns are close to the predicted range (<0.1 m). However observed or actual drawdown at GWa3 is greater than predicted in HydroSimulations (2013), and the same conclusion is drawn at GWa6 and GWa14 (acknowledging, as earlier, that the mining effect cannot be clearly isolated from climatic effects).

The predicted hydrographs for the coal monitoring bores, to June 2014, are displayed in **Attachment A** at Figure A-22 as water levels (mAHD) and at Figure A-23 as drawdowns (m). The largest drawdowns are expected to occur while Pit 3 and Pit 4 are being excavated.

A comparison of predicted and observed drawdowns (from July 2006 to June 2014) is offered in **Table 3**. The agreement is generally good.

Table 3 Predicted and Observed Drawdown (m) at Coal Monitoring Bores at June 2014

	GWc1	GWc10	GWc11	GWc12	GWc2	GWc14	GWc15
Predicted	10	9	10	9	28	12	9
Observed	2-3	<2	11	15	13	>12	>10

GROUNDWATER DEPENDENT ECOSYSTEMS (GDES)

A review of the BoM GDE Atlas[2] and relevant legislation and other literature has been conducted.

The BoM GDE Atlas provides mapping of two main feature classes: potential GDEs that are reliant on the *surface* expression of groundwater (e.g. rivers, springs, wetlands), and potential GDEs that are reliant on *subsurface* groundwater (vegetation).

Inspection of the BoM GDE Atlas indicates that potential GDEs reliant on the surface expression of groundwater have been mapped in the upper Goulburn area around WCM, while there is no available mapping of those potential GDEs reliant on subsurface groundwater. Stretches of Moolarben Creek (approximately 4-5 km from the WCM) and the upper Goulburn River (8-10 km) are mapped on the GDE Atlas, and are classified with Low-Medium potential for interaction with groundwater. Other watercourses are also mapped as potential GDEs, but at further from the WCM than the two watercourses stated here.

A search of legislation (Water Sharing Plans or WSPs) was carried out to identify any declared High Priority GDEs in the region:

- The *Hunter Unregulated and Alluvial* WSP specifies a number of High Priority GDEs. The nearest of these are 130 km north-east and 155 km east;
- Because the *North Coast Fractured and Porous Rock* WSP is not yet commenced, earlier documents were reviewed for information on that region. However a GIS dataset of all currently identified High Priority GDEs was obtained from NOW. The nearest High Priority GDE is Wild Bull Spring, in the upper Wollar Creek catchment (17 km due south of WCM);
- The *NSW Murray Darling Basin* WSP specifies a number of High Priority GDEs and High Priority Karst features. The nearest to Wilpinjong are the Cooyal Karst feature (13 km south-west of WCM), and Baileys Springs (16 km west of WCM).

Other high profile sites are ‘the Drip’ and associated features on the Goulburn River, which are ecologically and culturally significant, but not specified or declared as High Priority. These are located 11 km north of WCM.

[2] http://www.bom.gov.au/water/groundwater/gde/map.shtml

Based on the preceding review of data, no groundwater dependent ecosystems are known or likely to occur within the WCM mining lease area. There are several significant sites in regions to the north, west and south of WCM; however, they are generally 5-10 km distant, if not further afield, and therefore are not considered relevant to this review. Additionally, Wilpinjong Creek and Cumbo Creek have been examined in terms of baseflow/leakage impact assessment (e.g. HydroSimulations, 2013).

For the purposes of impact assessments and monitoring, Wilpinjong Creek is currently the main feature considered in terms of groundwater-surface water interaction. Inconsequential drawdown has been observed at alluvial monitoring bores along Wilpinjong Creek, therefore indicating minimal impact on creek-alluvium interactions for this watercourse.

CONCLUSION

Groundwater model predictions of historical inflows to WCM match well with pumping records except for the last two years where net pump-out has exceeded predicted volumes. To some extent this increase in the pumped volume is likely to be due to the variable accuracy of the method used to estimate pumping rates.

For Pit 5, it is likely that elevated pump-out volumes are due to ingress of runoff (to be remedied) and recirculation of flow from nearby storages (e.g. Ed's Lake) into the open cut. In Pit 4 the reasons for high pump-out volumes are believed to be dominated by recirculation from storages (especially those in the Pit 2 area, neighbouring Pit 4), but there is uncertainty in the quantification of this based on the available pumping records. The reason for the large volume pumped out from Pit 3 in 2013-14 is unknown at this time, however it is likely that a lag between inflow and subsequent pump-out has resulted in an underestimate in inferred groundwater inflow in 2012-13 followed by an overestimate of the inferred groundwater inflow volume in 2013-14.

Based on previous groundwater modelling, the total current licensed groundwater entitlement at WCM is sufficient to cover current and projected groundwater take at the mine. The currently available data suggest that 'groundwater take', as far as it can be determined, from Pits 3 and 4 may have exceeded the pit-by-pit groundwater entitlement held by WCPL; however this cannot be determined categorically. Based on the available data, it is estimated that in 2013-14 a total of about 1,870 ML of groundwater was pumped from all the pits, compared to a total, site-wide groundwater entitlement of 2,021 ML. In other words, gross groundwater extraction from all pits is likely compliant.

Analysis of continuous surface water flow data shows that recent rainfall trends are playing a significant role in declining flows in Wilpinjong Creek, both upstream and downstream of WCM. During much of 2013-14 it seems that discharge from WCM may have been preserving flow downstream of the mine, while the upstream gauge has been showing zero flow.

Electrical conductivity (EC), which is a measure of water salinity, is generally well correlated with flow in Wilpinjong Creek. The recent dry conditions have led to increasing salinity in the creek, with salinities reaching 5,000-7,000 µS/cm for much of March 2014. The differential in EC between the upstream and downstream gauging sites is likely due to a combination of a greater proportion of stream flow being sourced from discharge from saline groundwater, and inflow from potentially more saline tributaries (e.g. Cumbo Creek). Salinities recorded in recent years are consistent with those from both early in the life of the WCM and from pre-mining monitoring. Accordingly, the WCM has had no discernible effect on in-stream salinity.

Unlike EC, pH seems relatively unaffected by the long-term (climatic) trends, and generally holds to a steady baseline level at each site on Wilpinjong Creek. However, natural cease-to-flow conditions in Wilpinjong Creek have led to short periods of slightly reduced pH, particularly upstream of the mine. There is no discernible impact of the WCM on in-stream pH.

Drawdowns in the order of 10 m or more have been observed at coal monitoring bores GWc2, GWc11, GWc12, GWc14 and GWc15. At the alluvial monitoring bores, there are possible mining effects at three bores (GWa3, GWa14, GWa6) along Wilpinjong Creek in the order of 1 m or less; however, small drawdowns of this magnitude are often difficult to separate from climatic effects. The 1 m (or less) drawdown associated with mining at these sites is less than the 2 m drawdown specified in the *Minimal Impact Considerations* in the NSW Aquifer Interference Policy (NSW DPI, 2012)[3]. There is a definite mining effect at alluvial bore GWa5 located between Pit 2 and Pit 3, adjacent to Cumbo Creek upstream. The drawdown there was in the order of 2.5 m during 2013 and 2014; however, it is noted that WCPL is approved to relocate and excavate the lower reaches of Cumbo Creek, which is adjacent to where GWa5 is located. There are no obvious mining effects at any other bores.

The current groundwater model predicts minimal drawdown (in the order of 0.1 m at most) at alluvial bores along Wilpinjong Creek. This is consistent with most observed drawdowns, although three sites on Wilpinjong Creek could have experienced up to 1 m drawdown.

The drawdowns predicted by the groundwater model at coal monitoring bores along Wilpinjong Creek are in reasonable agreement with what has been observed by mid-2014, although the model has overestimated the drawdown in half the cases.

Although groundwater level changes alone are not definitive, the alluvial and coal monitoring bore drawdowns observed do not suggest any gross change in the groundwater contributions to the open cuts. The increased rates of pit pumping are therefore considered to be due to increasing contributions of other water sources (e.g. significant levels of recirculation within the mine water management system) and the current reliance on inferred pumping data (i.e. recorded pump hours and estimated pump duty).

Based on the available data, the impacts of the mine extractions on aquifers, groundwater dependant ecosystems and streams, appear generally consistent with previous predictions.

It should be noted that HydroSimulations is currently undertaking a major re-build and re-calibration of the Wilpinjong groundwater model in line with the Groundwater Monitoring and Modelling Plan. The additional data that are now being collected from the site water metering implemented in 2014 are expected to assist in resolving a number of the data issues identified in this review.

Lastly, following discussion with WCPL staff, HydroSimulations recommends some minor enhancement to data management and data provisioning at site. This is outside the scope of this document, so will be provided separately. It is also recommended that WCPL consider seeking an amalgamated licence for all pits from NSW Office of Water.

Please contact me if further clarification required.

Yours sincerely

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[3] this threshold is specified in the Aquifer Interference Policy as applying to drawdown at nearby water supply works (bores), and has been used here for comparative purposes.

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