8 Assessment methods

This chapter summarises the numerical modelling and other methods used in the water assessment.

AR 15: Full technical details and data of all surface and groundwater modelling, and an independent peer review of the groundwater model

AR 58: The results of any models or predictive tools used

Numerical modelling and analytical techniques were used for this water assessment to develop the site water balance, investigate potential changes in flood extent, and predict water quantity and quality changes to surface water and groundwater resources. Full technical reports detailing methods are included for each assessment in Appendices D, F, I and J.

8.1 Surface water runoff

The four stormwater basins (SBs), four mine water dams (MWDs), and the primary water dam (PWD) manage rainfall-runoff from catchments affected by the project. The locations of the basins and dams were chosen to minimise interception of runoff from the broader catchment areas not affected by mining, material handling, or processing operations. A rainfall-runoff model was used to simulate expected runoff using historical rainfall data from 1889 to 2015 from the SILO Data Drill dataset (DSITIA 2015). The volume of surface water runoff from SB, MWD and PWD catchments was estimated using the Australian Water Balance Model (AWBM) rainfall-runoff model (Boughton 1993).

Full details of the AWMB rainfall-runoff model, including calibration and results, are discussed in Appendix D (WSP PB 2016a).

The model was compared against flow duration curves developed from the flow gauge record at SW08, on Oldbury Creek, and nearby WaterNSW gauges. The model compares very well for high flows. Low flow situations become less comparable, when the contribution from baseflow and Berrima sewage treatment plant discharge becomes significant. The calibration result indicates the model is conservative with respect to low flows as it predicts lower harvestable volumes available from site runoff for reuse in mining operations during dry periods. Good calibration to high flows means the model is capable of reliable predictions of potential uncontrolled spill risk from storages during wet periods.

Average long-term runoff coefficients from the AWBM model for both wet and dry climate examples were simulated for the various landform types present within the surface infrastructure area catchment (Table 8.1). The model output was incorporated into the project's water balance model to directly simulate daily reservoir water balances for each SB, MWD and the PWD (Section 8.2).

Table 8.1 Simulated average long-term (1889 to 2015) runoff coefficients from AWBM model for various landform types within surface infrastructure area catchment

Climate	Impervious	Undisturbed	Active spoil	Hardstand
Wet (1949 – 1967)	79%	47%	54%	59%
Dry (1991 – 2009)	74%	35%	46%	49%

8.2 Water balance

AR 12: A detailed and consolidated site water balance

AR 26: Provide a description of any site water use (amount of water to be taken from each water source) and management including all sediment dams, clear water diversion structures with detail on the location, design specifications and storage capacities for all the existing and proposed water management structures

AR 28: Provide a detailed and consolidated site water balance

AR 30: Identification of water requirements for the life of the project in terms of both volume and timing (including predictions of potential ongoing groundwater take following the cessation of operations at the site – such as evaporative loss from open voids or inflows)

AR 42: Description of all works and surface infrastructure that will intercept, store, convey, or otherwise interact with surface water resources

AR 57: Proposed methods of the disposal of waste water and approval from the relevant authority

AR 79: A full description of the development including those aspects which have the potential to impact on the quality and quantity of surface and groundwaters at and adjacent to the site, including:

- *the mining proposal and mine layout*
- *the location, mapping and geomorphology of all creeks and water resources overlying and adjacent to the proposed mining area*
- *the hydrogeological fluxes between surface and groundwaters, including the filling of pine feather voids*
- *the location, management and storage of all hazardous materials- the disposal of wastes from the treatment of mine waters in the mine water treatment plant*
- *the management of dirty water from the washing and preparation of coal for transport*
- *the location, sizing and description of all water quality management measures*
- *the location and description of all water monitoring points (surface and ground waters)*
- *on-site domestic (sewage) wastewater management*

8.2.1 Overview

A water balance model of the project's water management system was developed for the EIS using GoldSim software to assess the dynamics of the mine water balance under varying climatic conditions throughout the project's operation. The model was configured to simulate the daily operations of all major components of the water management system.

The water balance model developed for the EIS has been revised to incorporate the revised groundwater inflow estimates from post-EIS numerical groundwater modelling undertaken by HydroSimulations (2018) (refer to Section 8.6). No other changes were made to the water balance model.

The GoldSim model was simulated with a daily time step for a 19-year duration. The model was run (simulated) 107 times. Each individual model simulation is called a 'realisation'. Each of the 107 realisations used a different 19-year sequence of historical rainfall and evaporation data (or climate sequences), developed by 'stepping through' the SILO Data Drill sourced historical climate data from 1 January 1889 to 1 January 2015 (DSITI 2015). The first realisation started on 1 January 1889, the second realisation started a year later on 1 January 1890 and so on. The model inputs (demands and groundwater inflows) were varied in the model over the 19-year simulation period. Probability distributions were then developed using the daily and annual results from all of the 107 realisations.

The simulated inflows and outflows included in the model are shown in Table 8.2. Refer to Section 2.3 for discussion on the water management system components and operating philosophy. The model assumptions, input/output estimates, and results are summarised in the following sections; full details are included in Appendix D (WSP 2018 and WSP PB 2016a).

The water balance model (WSP 2018 and WSP PB 2016a) has been conservatively designed and demonstrates that water surpluses and deficits can be managed successfully for all climate sequences. The operational water balance model will be optimised during detailed design, mainly fine tuning the stored water levels within the PWD to optimise water efficiency and pumping volumes. This will be included in the Water Management Plan, and is discussed Chapter 13.

Table 8.2 Modelled inflows and outflows of the water management system

Inflows	Outflows
Direct rainfall on water surface or storages	Evaporation from water surface or storages
Surface water runoff captured within each basin or dam	SB03 and SB04 release to Oldbury Creek (post first flush)
Groundwater inflow to mine sump	
Groundwater inflow to void	Underground mine operations water supply
	Product coal handling water supply
	CPP process water supply
	ROM stockpile water supply
	Co-disposed make-up water supply
	Administration and workshop area fire water supply

Notes: 1.The following are not included in the model: potable water supply, supply from licensed bores and MWD08.

8.2.2 Model assumptions

The following assumptions were made in the water balance analysis for the adopted water management strategy:

- Water that cannot be stored within the PWD or the void spaces will be treated and released to Oldbury Creek (this is a provisional assumption that by modelling has demonstrated is not required).
    - Most of the groundwater collected in the sump will be used in meeting the project water demand. The sump will collect return water from the underground mining equipment, decant from co-disposed reject and runoff from MWD07. The mixed water from these sources will be pumped to the PWD for reuse.

- The sump will aim to pump out all water to the PWD for project use. When the PWD is at the maximum level set for operations of 124 ML, the water in the sump will be pumped into the void space behind the bulkheads. If the void space is full and cannot take the excess water then the sump will continue pumping to the PWD.

- Similarly, if the water volume in the PWD is very low and unable to meet water demands then additional water will be sourced from the pumped and natural groundwater that will be stored in the void spaces. This is analogous to extracting water from a licensed groundwater bore.

- A pumping strategy has been included in the water balance model.

- It is assumed the 'sediment zone' of SBs and MWDs is 50% full of sediment throughout the simulation. It is assumed SBs and MWDs cannot be pumped out below the 'sediment zone' and that the only outflows from the remaining 'sediment zone' is evaporation.

- The initial volume at the start of the 19-year period simulation was assumed to be 100 ML for the PWD and 6 ML for the underground sump so that mining operation could be supplied with water until rainfall-runoff or groundwater could be harvested. Other basins and dams were assumed empty at the start of the simulations.

- No allowance has been made for seepage from water storages, which would be minor.

- Annual void space behind the bulkheads was estimated from the ROM production schedule and provided by Hume Coal.

- Annual groundwater inflows to the sump and the void spaces were assessed by the groundwater model. The co-disposed reject volumes and annual groundwater inflows to the void spaces were subtracted from the total void space volume created annually due to mining to obtain net void space available for pumped water. This input data was provided by Hume Coal.

- Annual groundwater inflow to the sump was distributed uniformly to obtain average daily inflow rates.

- Annual demand estimates have been distributed uniformly to obtain average daily demands.

- Water is pumped from the void to the PWD at a rate that is adequate to meet peak daily demands when required.

- Inflows to MWD08 are not considered in the water balance as the dam is part of the provisional WTP and independent of the mine water balance which covers water transfers between the SBs, other MWDs, the underground mine and the PWD, if required.

- The water balance modelling is focussed on the operational phase and does not consider sediment dams that will be required at the construction phase.

- While the basecase model assesses the performance of the system under historical extremes that may reasonably be expected to reoccur in the future, it does not quantify the potential impact of future climate change on the site water balance. However, climate sensitivity analysis has been undertaken with respect to modelled predictions of groundwater inflow variations (refer to Section 8.2.5).

8.2.3 Site water balance

Figure 8.1 shows the concept that was input into GoldSim for the site water balance.

i Inflow estimates

Surface water runoff from mine site catchments was calculated using the AWBM rainfall-runoff model using the SILO Data Drill daily rainfall and evapotranspiration data (DSITIA 2015). The AWBM rainfall-runoff model is described in Section 8.1.

Direct rainfall onto water storages (dams and stormwater basins) was determined based on assumed dam stage-storage-area relationships (refer to Section 2.3.2 for dam capacities and Appendix D (WSP PB 2016a) for stage-storage relationships).

Modelled groundwater inflow estimates for inflow into the mine sump and void were provided from the revised numerical groundwater model (Sections 8.6 and 11.1.1). Annual groundwater inflow for the mine operation period is shown in Figure 12.1.

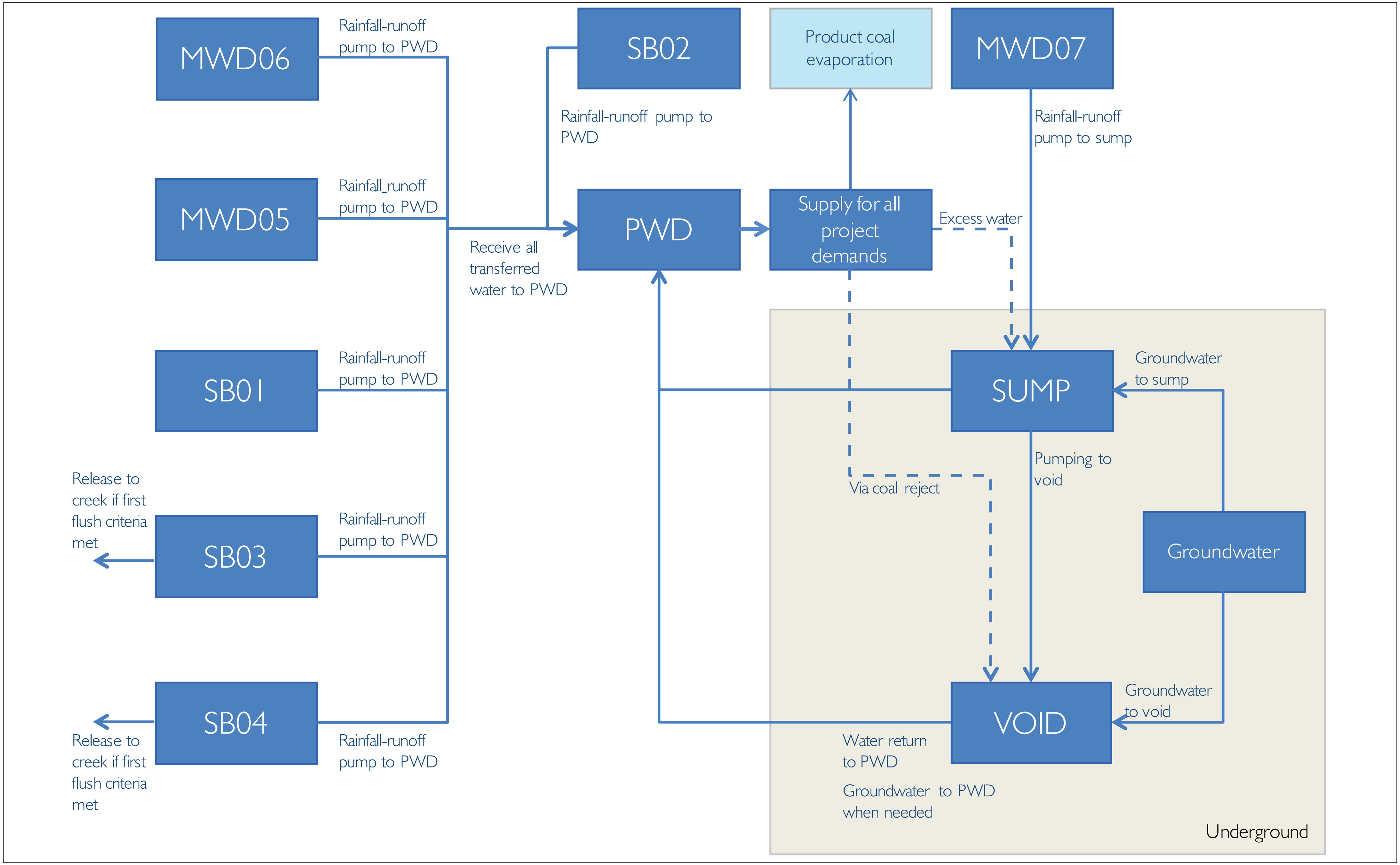
Water imported from licensed groundwater bores is available if additional water is required during the project (eg prior to water in the sealed void becomes available).

ii Outflow estimates

Individual water demands for the project are calculated or estimated for the life of the mine. Demand components are shown in Figure 2.6 and discussed in Section 2.3.1. The total annual net demand (water supplied minus water returned) is estimated to peak in Year 15 at 886 ML. Refer to Appendix D (WSP PB 2016a) for details on how these demands were derived.

Evaporation estimates for open water storages were based on SILO Data Drill sourced daily Morton's Lake evaporation data (Morton 1983; DSITIA 2015). Evaporative surface area for dams and stormwater basins were determined based on assumed dam stage-storage-area relationships (refer to Section 2.3.2 for dam capacities and Appendix D (WSP PB 2016a) for stage-storage relationships).

For assessment of the pumping volumes of surplus water to the mine void, the void space availability was calculated by assessing total void space available after co-disposed reject volumes emplacement per year. Pumping to and from the void space behind the bulkheads is assumed to occur in accordance with rules governing the PWD level and the net site water demands (as listed in Section 8.2.3iii below).



Water balance model flow schematic

Hume Coal Project

Revised Water Assessment

Figure 8.1

iii Operating rules

The following operating rules have been assumed for the water balance assessment:

- MWDs and SBs:
  - All SBs and MWDs except MWD07 and MWD08 pump directly to the PWD at defined peak daily pumping rates.
  - All SBs and MWDs can only pump water to the PWD when the sediment store is fully saturated and water is above the sediment store volume. The sediment store is assumed to contain water volume equal to half the volume of the sediment store.
  - Water transfer from SB01 to the PWD and from SB02 to the PWD is not restricted by any volumetric constraint in the PWD.
  - No overflows from SB01 and SB02 are allowed to occur in the model; however, spillways have been provided to direct overflows from these dams to nearby watercourses (overflows may occur under very high rainfall conditions, such as those that significantly exceed the 500 year ARI event).
  - Water transfer from other SBs and MWDs into the PWD is stopped when the PWD water volume is greater than 730 ML.
  - Releases to Oldbury Creek from SB03 and SB04 are assumed to occur when the first flush criteria are satisfied. If first flush criteria are not met, the water will be pumped to the PWD.
- Primary water dam (PWD):
  - The PWD is the main dam that will supply water to meet all demands except the potable water requirement, which will be sourced from registered bores.
  - The PWD operating levels are between 83 and 124 ML. The PWD is designed, however, to store all water on site and has a storage limit of 730 ML.
  - The water balance has been optimised to avoid overflows from the PWD. If there is a risk of overflow from the PWD, water will be treated in the WTP and then released to Oldbury Creek.
- Sump:
  - The underground sump is the ultimate point of water collection from all underground water sources and includes transfer from MWD07, groundwater, decant from the co-disposed reject emplacement and unused water from the underground mining operation.
  - When the PWD level is less than 124 ML, water accumulated daily at the sump is pumped to the PWD.
  - When the PWD level is more than 124 ML, the water accumulated at the sump is pumped into the void space behind the bulk heads. If there is no void space available, then the water accumulated at the sump will continue to be pumped to the PWD.

- The underground mine sump is assumed to be 6 ML and will maintain this volume in the sump most of the time unless water deficit occurs.

- Void:
  - Water transfer from the void spaces behind the bulkheads to the PWD occurs when the PWD level is less than 83 ML and occurs at a daily rate that ensures the level of the PWD remains at 83 ML at the end of each daily time step.

8.2.4 Water balance model results

Full details of the revised water balance results are contained in Appendix D (WSP 2018).

The average annual project water balance summary from 107 climate sequences is shown in Figure 8.2. The average total inflows and outflows for the surfaces storages (not including MWD07 inputs) over the life of the mine are modelled to be 27,009 ML and 26,957 ML respectively, with an initial volume of 100 ML in storage and a final volume of 152 ML. For the underground mine (including MWD07 inputs) over the life of the mine the total inflows and outflows are modelled to be equal at 19,294 ML for each. The total inflows and outflows for the void over the life of the mine are modelled to be 28,547 ML and 4,449 ML respectively. The relatively higher inflows than outflows modelled for the void is due to groundwater inflow filling the void. MWD08 is excluded from the water balance as it is a small storage associated with the provisional water treatment plan.

As discussed in Section 2.3.1 and shown in Figure 2.7, the project water demand will be fully met by using:

- harvestable rainfall-runoff from the mine water dams;
- groundwater collected in the underground mine sump; and
- groundwater harvested from the void, when required in times of deficit.

The water balance model was used to check if uncontrolled overflows would occur from any of the storages under the assumed AWBM estimated rainfall-runoff volumes. The model has predicted that none of the basins or dams will overflow under all 107 climate realisations.

The volumes of groundwater pumped into the underground void over time were investigated in the water balance model. The investigation included assessment of available void space over time and project water demands. Based on the 107 climate sequences, it is most likely (75% chance) that less than 3,300 ML of water would be pumped into the void throughout the 19-year mining period. The pumping rate would not be constant and would depend on available void space and the amount of excess water.

Simulations undertaken for 107 climate sequences showed that the excess water can be managed by either pumping into the void or by pumping into the PWD, and there is no requirement for disposing of excess water by treatment and release to Oldbury Creek.

The water balance modelling indicates that the groundwater from the underground mine will be enough to meet demand and additional water from licensed bores will not be required during operation, other than for potable water supply.

8.2.5 Water balance climate sensitivity analysis

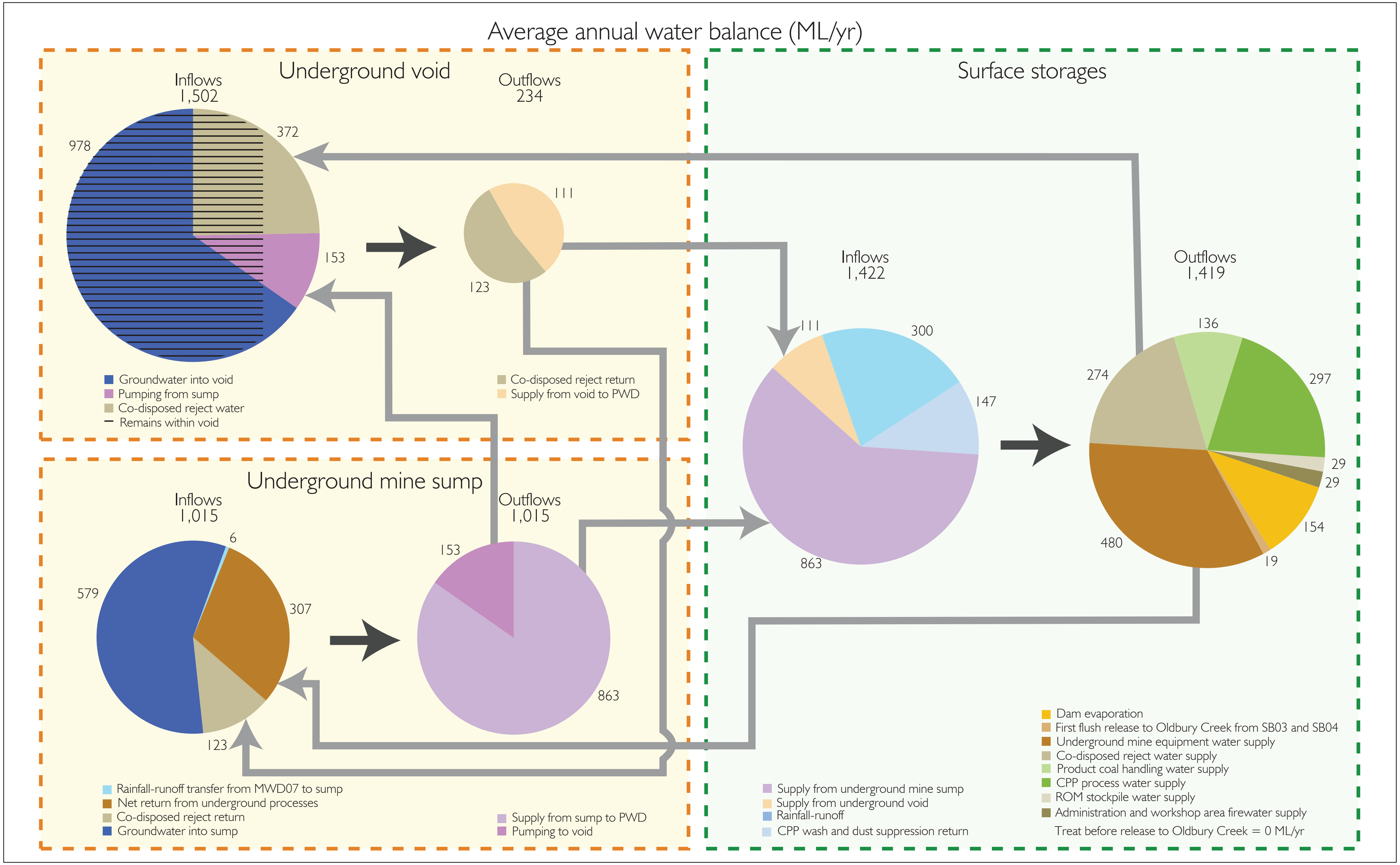
The water balance model uses groundwater inflow data from the numerical groundwater model based on an average climate scenario. In order to understand how sensitive the water balance is to changes in groundwater inflows as a result of varied climate scenarios, climate scenario analysis was undertaken. Groundwater inflows generated from climate scenario analysis (wet, dry, and average climate scenarios) from the Modified EIS numerical groundwater model (Section 8.6.4ia) were input into the water balance model and the water balance was run for the full 107 realisations for comparision. Other than varied groundwater inflow volumes, no other changes were made to the water balance model.

No uncontrolled overflows occurred from any of the basins or dams over the life of mine in any of the climate sensitivity analysis model scenarios. Compared to the groundwater inflows generated from an average climate scenario, there was very little difference in the results when groundwater inflows generated under wet and/or dry scenarios were used in the water balance model.

There was no change to the simulated peak stored volume in SB01, SB02, SB03, SB04, MWD05 and MWD06 between the climate sensitivity analysis wet and dry climate scenarios compared to the climate average climate scenario. This is because these SBs and MWDs transfer water to the PWD, and the stored volume in the PWD does not exceed the volume at which water transfer into the PWD is stopped for any of the realisations or scenarios modelled. The only change in the simulated peak stored volumes between the wet and dry climate scenarios compared to the average climate is a slight difference in the stored volume in the PWD. The peak stored volume in the PWD is +0.01% higher (equivalent to less than 1 ML higher) for the wet climate scenario compared to the average climate scenario. The results from the dry climate scenario are the same as the average climate scenario.

This indicates that the influence of changing climate on groundwater inflows has negligible effect on the project's water balance.

Full details of the climate sensitivity analysis results are contained in Appendix D (WSP 2018).



Based on mean annual climate sequence from 107 climate sequences

Average annual water balance summary
Hume Coal Project
Revised Water Assessment
Figure 8.2

8.3 Flow impact assessment methods

Flow effects have been assessed for:

- Medway Rivulet sub-catchment (not including Oldbury Creek) and Oldbury Creek sub-catchment where the project is located; and
- Lower Wingecarribee River, Upper Wingecarribee River, Lower Wollondilly River, Bundanoon Creek, and Nattai River management zones. Although these catchments are located outside of the project area, baseflow reduction, albeit small, is predicted to occur as a result of depressurisation associated with the underground mining.

For the flow impact assessment, the Medway Rivulet sub-catchment is defined as the blue areas in Figure 2.4 and the Oldbury Creek sub-catchment is defined as the purple area in Figure 2.4.

Existing (pre-mining) flow conditions for Medway Rivulet and Oldbury Creek were established using the AWBM rainfall-runoff model (refer to Section 8.1 and Appendix D (WSP PB 2016a)). The following flow conditions were assessed during the mine's operation:

- reduction in catchment area associated with project storages;
- release of water, following containment of first flush, from SB03 and SB04 to Oldbury Creek, estimated for dry and wet years, using the revised water balance model (Section 8.2 and Appendix D (WSP 2018)); and
- interception of natural baseflow to streams associated with depressurising groundwater systems during underground mining, estimated using the revised numerical groundwater flow model (Section 8.6 and Appendix F (HydroSimulations 2018)).

The resulting changes in flow were analysed by comparison to the relevant flow duration curve for Medway Rivulet and Oldbury Creek. A flow impact assessment for Medway Rivulet was made including and also excluding discharge from the Moss Vale sewage treatment plant. Changes in yield were estimated for both wet and dry climate sequences for the Medway Dam catchment, Medway Rivulet catchment (excluding Oldbury Creek sub-catchment), Oldbury Creek sub-catchment, and the Medway Rivulet Management Zone. The results are shown in Section 10.1.3 and 10.1.3.

Existing (pre-mining) flow conditions for the Lower Wingecarribee River, Upper Wingecarribee River, Lower Wollondilly River, Bundanoon Creek, and Nattai River management zones were approximated using the AWBM results modelled for the Medway Rivulet Management Zone and scaled appropriately for each catchment area. This was considered a reasonable approach given that the AWBM model was calibrated to observed flows at gauge 212009 on the Wingecarribee River (Figure 4.1), which receives runoff from a total catchment area of 58 km^2 and so represents regional scale flows (refer to Appendix F for further details). These pre-mining flows were then compared against the intercepted baseflow volumes estimated by the revised groundwater model (Section 8.6, Section 11.1.3, and Appendix F (HydroSimulations 2018)) to assess the potential change in yield for these catchments. The results are shown in 10.1.3.

The flow assessment uses baseflow reduction data from the numerical groundwater model based on an average climate scenario. Baseflow reductions generated from the numerical groundwater model climate scenario analysis (wet, dry, and average climate scenarios) from the Modified EIS numerical groundwater model (Section 8.6.4ia) were used with the equivalent climate scenario in the flow assessment for comparison, in order to understand how sensitive the flow assessment is to changes in baseflow reduction. Other than varied baseflow reduction rates, no other changes were made to the flow assessment for this sensitivity analysis.

8.4 Surface water quality

The following project activities have been assessed for potential surface water quality changes:

- release from SB03 and SB04 (when first flush and water quality criteria are met) to Oldbury Creek;
- runoff from access roads outside of the mine water management system;
- depressurisation of deeper groundwater from underground mining, and
- coal dust deposition in surface water catchments.

As the water balance model (refer to Section 8.2) demonstrates that the PWD has adequate capacity to contain all surplus water and treatment and release of water from the PWD is not required for all climate sequences, the scenario of treating and releasing water from the PWD is, therefore, not assessed.

Refer to Section 10.1.5 for further details.

The methods used for assessment are summarised below and described in detail in Appendix D (WSP 2018).

8.4.1 Release from stormwater basins to Oldbury Creek

MUSIC (Model for Urban Stormwater Improvement Conceptualisation) modelling was used to assess water quality changes following release of post-first flush water from SB03 and SB04 into Oldbury Creek. Total suspended solids (TSS) and nutrient (total phosphorus (TP) and total nitrogen (TN)) loads and concentrations were assessed in accordance with NorBE (neutral or beneficial effect) criteria. In addition, the maximum concentrations of other constituents were calculated in order to achieve 10% reduction in mean annual pollutant loads as a result of release from SB03 and SB04, to provide a basis for management (WSP PB 2016b).

The MUSIC modelling was in accordance with the WaterNSW standards (SCA 2012b, SCA 2015, and WaterNSW 2015).

Details of the MUSIC modelling undertaken for the EIS are provided in the Hume Coal Project Surface Water Quality Assessment report (Section 5.2.2 of WSP PB 2016b).

The following revisions have been made to the MUSIC modelling undertaken following the EIS:

- The predicted time series for releases from SB03 and SB04 to Oldbury Creek has been revised to reflect the results of the revised water balance modelling, which was modified to incorporate the revised groundwater modelling results (HydroSimulations 2018).

- Existing flows have been modelled as a mix of base flow and storm flow. This revision was made to address matters raised in submissions from government agencies.
- The MUSIC model timestep has been changed from daily to 6-minute. This revision was made to address matters raised in submissions from government agencies.

i TSS and nutrients

MUSIC model nodes were set for SB03 and SB04, which will release to Oldbury Creek, and for SB01, SB02, PWD and MWD08, which are sub-catchments of Oldbury Creek that will be removed from the catchment during the project's operation. Each node was set to represent the existing conditions of the catchment (assumed to be fully pervious and agricultural land use) and conditions during mine operation (a mix of pervious and impervious areas, with sizes based on the surface infrastructure design, and industrial land use). For the operational phase, the sub-catchments of SB01, SB02, PWD, and MWD08 are not included as they will not contribute runoff to Oldbury Creek (but will report to the mine water management system).

Climate data input was obtained from WaterNSW, as per the WaterNSW standard (2012) template, and included a range of wet and dry periods between 1997 and 2001 at 6-minute intervals. This data was converted to daily data for the GoldSim water balance model (Section 8.2) to generate outflow time series for the SB01, SB02, PWD, and MWD08 catchments in their existing conditions, and for SB03 and SB04 in their operational conditions. In the revised water quality assessment, this daily time series data was then converted back to averaged 6-minute intervals for input into MUSIC.

It is noted that the areas that will become SB03 and SB04 sub-catchments in the operational phase drain to Medway Rivulet in the existing case. For the operational phase, the release volumes from SB03 and SB04 took into account the first flush pumping to PWD. Existing and operational flows were modelled as a mix of baseflow and stormwater flow.

The stormwater pollutant parameters used for industrial land were in accordance with the WaterNSW standard (2012). Results are discussed in Section 10.1.2ii.

As the water balance model climate sensitivity analysis (Section 8.2.5) predicted the same releases from SB03 and SB04 to Oldbury Creek for all wet, dry and average climate scenarios, no additional climate scenario analysis (relating to changes in groundwater inflow volumes affecting the water balance) was undertaken for this aspect of the water quality assessment.

ii Other constituents

Runoff from the catchments of SB03 and SB04 has a low risk of contact with small amounts of coal that may be brought into the catchments via mine vehicle traffic. Capturing the first flush and pumping to PWD for storage and reuse is likely to account for this low risk of coal contact, and the remaining volume released into Oldbury Creek would be clean water. Nevertheless, an assessment has been conducted to develop preliminary concentration targets for other (coal-derived) constituents that may be present considered (in addition to TSS and nutrients) in case the first flush does not remove all constituents. This assessment has not changed since what was presented the EIS (WSP PB 2016b).

A leachate test was performed by RGS (2016) on coal and coal reject materials to assess the potential mobilisation of contaminants in runoff. Comparison of average leachate concentrations with average baseline concentration in Oldbury Creek (at SW08 (Figure 4.1)) shows that some dissolved components are higher in the coal leachate than in the receiving environment (Table 8.3). These constituents were selected for further assessment.

Table 8.3 Comparison of baseline surface water and leachate concentrations

Constituents	Units	Mean baseline concentration (Oldbury Creek)	Mean leachate concentration
Major ions			
Calcium	**mg/L**	**27**	**31**
Chloride	mg/L	56	43
Magnesium	mg/L	**10**	**11**
Sodium	mg/L	38	3.7
Sulfate as SO4	mg/L	**45**	**126**
Dissolved metals			
Aluminium	**mg/L**	**0.08**	**0.99**
Antimony	mg/L	<0.001	no value reported
Arsenic	mg/L	**<0.001**	**0.006**
Barium	mg/L	0.04	no value reported
Beryllium	mg/L	<0.001	no value reported
Boron	mg/L	<0.05	<0.05
Cadmium	mg/L	**<0.0001**	**0.005**
Chromium	**mg/L**	**<0.001**	**0.001**
Cobalt	mg/L	**<0.001**	**0.55**
Copper	mg/L	**0.001**	**0.26**
Iron	mg/L	**0.25**	**5.9**
Lead	mg/L	**<0.001**	**0.11**
Manganese	mg/L	**0.17**	**2.2**
Mercury	mg/L	<0.0001	no value reported
Molybdenum	**mg/L**	**<0.001**	**0.002**
Nickel	mg/L	**<0.001**	**1.2**
Selenium	mg/L	**<0.01**	**0.04**
Silver	mg/L	0.01	no value reported
Zinc	mg/L	**0.01**	**2.8**
Physicochemical			
Electrical Conductivity	µS/cm	476	402
pH	pH units	**7.4**	**3.7**
Total Dissolved Solids	mg/L	291	241

Notes: 1.Bold text indicates where results in leachate were higher than baseline conditions; these constituents were selected for further assessment.

MUSIC modelling was used to assess the mean annual pollutant loads for the 17 constituents emphasised in bold in Table 8.3 from the SB03 and SB04 catchments under existing conditions. The loads were calculated using the MUSIC model described in Section 8.4.1i as a mass balance model, with the mean concentration for each constituent specified as the mean baseline concentration measured at SW08.

The MUSIC model was then used to identify the mean concentration of each constituent that would need to be achieved in the releases under the operational scenario to meet the NorBE criterion of a 10% reduction in the mean annual pollutant load for conservatism.

The results are provided in Table 8.4, which identifies the preferred levels of mean concentration in the releases from SB03 and SB04 for each of the 17 water quality constituents. Concentrations of these that were below the laboratory limit of detection during the baseline monitoring would also need to remain at or below the laboratory limit of detection in the releases from SB03 and SB04. Comparison of these levels with samples collected from SB03 and SB04 as part of the routine monitoring program will establish release of an appropriate water quality. Actual limits will be developed in consultation with the relevant agencies post approval.

Table 8.4 Preliminary preferred levels of mean concentrations for constituents in releases from SB03 and SB04

Dissolved species	Oldbury Creek baseline mean concentration (mg/L)	Preferred levels of mean concentration in combined SB03 and SB04 releases (mg/L)	% load reduction from existing to operation
Calcium	27	175	-11%
Magnesium	10	65	-11%
Sulfate as SO_4	45	290	-11%
Aluminium	0.08	0.48	-10%
Arsenic	<0.001	0.001	*N/A*
Cadmium	<0.0001	0.0001	*N/A*
Cobalt	<0.001	0.001	*N/A*
Copper	0.001	0.0065	-11%
Iron	0.25	1.6	-13%
Lead	<0.001	0.001	*N/A*
Manganese	0.17	1.1	-11%
Molybdenum	<0.001	0.001	*N/A*
Nickel	<0.001	0.001	*N/A*
Selenium	<0.01	0.01	*N/A*
Zinc	0.01	0.065	-11%

8.4.2 Mine access roads

There are two mine access roads located outside the water management system (see Figure 1.6):

- the main mine access road from Mereworth Road to the administration and workshop area; and
- the access road between the ventilation shaft and the man and materials portal.

Vehicles using the roads will not be transporting coal and vehicles leaving the site via the main mine access road will use the drive-through wheel wash at the administration and workshop area to prevent coal dust from contaminating surfaces outside the water management system.

MUSIC modelling has been used to assess the potential water quality effects of the runoff from these roads on surface water quality in the receiving environment and assess compliance with the NorBE criteria.

Existing and operational scenarios were modelled using MUSIC by representing the sub-catchments of the road corridors in their existing conditions, as a mix of existing sealed and unsealed roads and agricultural land; and proposed conditions, as sealed/unsealed roads and industrial land for road cut/fill embankments. Adopting industrial land type for embankments is a post-EIS assessment revision. The operational phase scenarios included simulation of stormwater quality treatment measures to achieve the NorBE criteria. Modelling was in accordance with the WaterNSW standards (2012).

Model nodes were established for the two mine access roads. The main mine access road follows a ridge line between Medway Rivulet and Oldbury Creek, draining to Medway Rivulet, and is a sealed road, with a total road corridor area (including embankments) of 5.02 ha. The other access road also drains to Medway Rivulet and is an unsealed road with a total (not including embankments) area of 1.32 ha. The assessment of the sealed road included the road embankments as it warranted a more detailed assessment and sub-catchment breakdown due to the relatively higher impact of a sealed road on the local catchments. The unsealed road was assessed more simplistically by modelling the impact of the area of the trafficked surface only. Modelling was undertaken at 6 minute timestep.

Each model node was designed to represent the part of the catchment taken up by the proposed road corridors under existing and also operational conditions. Input climate data was the meteorological template obtained from WaterNSW, as described in Section 8.4.1.

The existing conditions scenario was set up for each of the sub-catchments using a combination of the ‘agricultural’ and existing ‘sealed road’ MUSIC source nodes. The operational scenario was set up for each of the sub-catchments using the ‘sealed/unsealed roads’ and ‘industrial’ MUSIC source nodes and assumed to be 100% impervious for sealed roads, and 50% pervious and 50% impervious for unsealed roads, and 100% pervious for embankments. The source node parameters are shown in Table 8.5. The stormwater parameters are in accordance with the WaterNSW standards (2012).

Table 8.5 Source node parameter inputs for mine access road MUSIC model (log mg/L)

Land use	TSS		TP		TN	
	Mean	SD	Mean	SD	Mean	SD
Baseflow						
Agricultural	1.30	0.13	-1.05	0.13	0.04	0.13
Industrial	1.20	0.17	-0.85	0.19	0.11	0.12
Unsealed roads	1.20	0.17	-0.85	0.19	0.11	0.12
Sealed roads	1.20	0.17	-0.85	0.19	0.11	0.12
Stormflow						
Agricultural	2.15	0.31	-0.22	0.3	0.48	0.26
Industrial	2.15	0.32	-0.60	0.25	0.30	0.19
Unsealed roads	3.00	0.32	-0.3	0.25	0.34	0.19
Sealed roads	2.43	0.32	-0.3	0.25	0.34	0.19

Notes: 1. SD – standard deviation.

For the operational scenario, vegetated swales were included in the MUSIC model to treat road runoff. Vegetated swales are typically broad, shallow channels that convey and filter stormwater runoff using vegetation to remove coarse sediment (ie reduce TSS). The performance of swales largely depends on the vegetation height, and the gradient and length of the swale. MUSIC has default parameters for vegetated swales. For the EIS assessment (WSP PB 2016b), the exfiltration rate was increased from the default value, however, for the revised assessment the default rate of 0 mm/hr has been adopted (WSP 2018). The background concentration for a swale is defaulted to be relatively high; these values were adjusted in both the EIS and the revised assessment in accordance with the approach detailed in Fletcher et al. (2004) so that a more realistic reduction of pollutant load would be determined. The adopted parameters for the swales in the EIS and the revised assessment are given shown in Table 8.6.

Table 8.6 Swale parameters used in MUSIC model for mine access road assessment

Swale parameter	EIS Adopted values (WSP PB 2016b)	Revised assessment adopted values (WSP 2018)
Length (m)	Varied to meet NorBE criteria	Varied to meet NorBE criteria (length increased from EIS assessment)
Bed slope (%)	3	3
Base width (m)	1	1
Top width (m)	5	5
Swale side slopes	1:3.33	1:3.33
Depth (m)	0.6	0.6
Vegetation height (m)	0.3	0.25
Exfiltration rate (mm/hr)	2	0
Background concentration TN (mg/L)	0.89	0.89
Background concentration TP (mg/L)	0.096	0.096

8.4.3 Depressurisation of groundwater systems from underground mining

Numerical groundwater modelling predicts that baseflow in some surface water systems will be decreased as a result of depressurisation of groundwater systems from the underground mining activities. This is discussed in detail in Section 11.1.3 and Appendix F (HydroSimulations 2018). A reduction in baseflow will result in reduced loadings of all water quality constituents. However, some constituent concentrations may increase as a result of decreased baseflow. This would occur where concentrations in groundwater are lower than surface water (ie reduction in baseflow results in less dilution of surface water concentrations). On the other hand, some constituent concentrations may decrease as a result of reduced baseflow where concentrations in groundwater are higher than surface water (ie reduction in baseflow results in less total constituent mass present in streamflow). In this latter case, surface water quality would be improved with a reduction in baseflow.

To assess the influence of decreased baseflow on surface water quality, 80^{th} percentile baseline water quality data were compared to 80^{th} percentile baseline groundwater quality data. A qualitative comparison is shown in Appendix D (WSP 2018). Use of the 80^{th} percentile is recommended in the ANZECC and ARMCANZ water quality guidelines (2000).

The results indicate that concentrations are generally higher in groundwater than surface water, with the exception of the following parameters which were generally higher in surface water:

- nitrate and nitrite;
- calcium, sodium and sulfate; and
- aluminium.

For the revised assessment, a daily mass balance model was developed in GoldSim to quantitatively assess the potential changes in constituents for the Medway Rivulet Management Zone. Daily mass balance modelling was undertaken for the parameters shown above that have higher baseline concentrations in surface water than in groundwater, as there is the potential for streamflow concentrations for these parameters to increase, relatively, following baseflow reduction. The GoldSim model was simulated at a daily time step for the 127-year period 1889 to 2015 using Data Drill (DSITIA 2015) sourced historical rainfall and evaporation data.

Existing flow conditions for the Medway Rivulet Management Zone were modelled in GoldSim using the AWBM rainfall-runoff model (refer to 8.1) (WSP PB 2016a). The AWBM rainfall-runoff model provides estimates of surface flow and baseflow (and total streamflow) at a daily timestep. For the operational scenario, the baseflow predicted by the AWBM rainfall-runoff model was reduced by 0.982 ML/day when baseflow occurs, which is the peak baseflow reduction for the Medway Rivulet Management Zone predicted by the groundwater model (refer to Table 11.3). The peak reduction of 0.982 ML/day was applied over the 127-year simulation period, which is conservative as the predicted baseflow reduction varies over the life of the mine with an average reduction of 0.661 ML/day over the 19-year period of mining (refer to Figure 11.5).

The 80th percentile of the baseline groundwater data for the Hawkesbury Sandstone was adopted in the GoldSim model for baseflow for the existing and operational scenarios. The 80th percentile of the baseline surface water data for the Medway Rivulet was adopted, however, as the baseline surface water data represents total stream flow (ie surface flow and baseflow), a mass balance calculation was undertaken to estimate surface water concentrations to be adopted in the GoldSim model.

The following key assumptions have been made in the mass balance modelling for baseflow reduction:

- The analysis considers changes to concentrations resulting from reduced dilution from baseflow only.
- The mass balance model mixes the water from the baseflow and surface flow and calculates the concentration of total streamflow. This calculation does not include any form of physical or chemical process within the watercourse. No allowance has been made for change in pH within the watercourse resulting from baseflow reduction.
- The analysis has adopted the 80th percentile of the baseline surface water data for the Medway Rivulet and the 80th percentile of the baseline groundwater data for the Hawkesbury Sandstone.
- Where the baseline monitoring result was less than the laboratory limit of reporting, a value of half the limit of reporting was adopted.

Details regarding the mass balance equations used are in Appendix D. The results are discussed in Section 10.2.2iii.

8.4.4 Dust deposition

An additional analysis was undertaken for the revised surface water quality assessment to assess potential water quality impacts associated with coal dust deposition in Oldbury Creek and Wells Creek catchments.

The coal dust deposition analysis applied the results of water extract testing of coal samples to predicted catchment average dust deposition rates and runoff volumes to estimate the concentration of contaminants in surface water runoff resulting from dust deposition. The predicted contaminant concentrations were then compared to baseline surface water quality monitoring results and guideline values.

Predicted annual average incremental dust deposition rates for the operational scenario are provided in the *Hume Coal Project Air Quality Impacts and Greenhouse Gas Assessment* (Ramboll Environ 2017). Post-EIS analysis of the air quality modelling results has been undertaken by Ramboll Environ (S Fishwick, pers. comm., November 2017) to estimate catchment average incremental dust deposition rates for the Oldbury Creek and Wells Creek catchments during the project's operations phase. The estimated catchment averaged incremental dust deposition rates for the Oldbury Creek and Wells Creek catchments are 2.067 $g/m^2/yr$ and 0.569 $g/m^2/yr$, respectively.

Water leachate results from coal and reject samples (RGS 2016) were used to represent the composition of coal dust. The mass of leachable metals in deposited coal dust was estimated by multiplying the catchment average dust deposition rates by the mass of each metal element in the leachate results. It was conservatively assumed that all leachable metals in deposited coal dust are leached and that there is no influence in concentration from other physical or chemical processes within the surface water system.

Using average annual rainfall of 824 mm/yr (WSP PB 2016a), and a runoff coefficient of 0.18, based on the Wingecarribee River (212009) (Section 5.2), estimated concentrations of contaminants in the Oldbury Creek and Wells Creek catchments from dust deposition were calculated. Results are presented in WSP (2018) and discussed in Section 10.2.3.

8.5 Flood modelling

SEAR 3: An assessment of the potential flooding impacts of the development

The study area for the numerical flooding assessment included the areas where surface infrastructure is proposed. The surface infrastructure area includes the administration and workshop area, the CPP area and supporting infrastructure (ie access roads, bridges, conveyors). The administration and workshop area is in the Medway Rivulet sub-catchment and the CPP area is in the Oldbury Creek sub-catchment. The administration and workshop and CPP areas have the potential to modify flooding in local catchments and are also subject to flooding.

For the purpose of the flooding assessment, the Medway Rivulet sub-catchment is defined as the blue areas in Figure 2.4 and the Oldbury Creek sub-catchment is defined as the purple area in Figure 2.4.

The area above the proposed underground mining area is not part of the study area for the flooding assessment. The underground mine workings will result in negligible impacts on flooding in overlying catchments. Worst case estimates of subsidence associated with the proposed non-caving mining method predict 'imperceptible' surface disturbance due to mining, with predicted settlement of less than 20 mm (EMM 2017e; Mine Advice 2016). Such disturbances are low enough in magnitude as to not affect flooding regimes.

The flooding assessment considered potential flooding associated with surface infrastructure during operation and the final landform at completion of rehabilitation. The surface infrastructure will generally remain unchanged throughout mine operation.

Flood modelling was not used for the construction phase as the layout of temporary construction facilities will generally match the surface infrastructure layout used during operations. A layout with the maximum footprint and elevation was considered so as to assess potential flooding events. In relation to construction, the proposed surface infrastructure is all located outside of the 1 in 100 year floodplain with the exception of the access road crossings and the conveyor crossing. Management of construction of these two pieces of infrastructure with respect to flooding will be determined during detailed design when the construction method and staging is known and the outcomes and management measures, if required, will be documented in the Construction Environmental Management Plan (CEMP).

The flooding assessment has not been revised since that presented in the EIS (WSP PB 2016d), and is summarised in the following sections and discussed in detail in Appendix D (WSP PB 2016d).

8.5.1 Hydrologic analysis

Hydrologic modelling determines runoff generated from rainfall on a catchment. The runoff estimates are then used by the hydraulic analysis (Section 8.5.2). Hydrologic models of the Medway Rivulet and Oldbury Creek sub-catchments were developed using the XP-RAFTS software program. Both sub-catchments were further divided into smaller sub-catchments, each with individual input parameters for the model.

The models of the Medway Rivulet and Oldbury Creek sub-catchments developed for this study were used to estimate flow generated from the catchment for the 5 year ARI, 20 year ARI, 100 year ARI and the probable maximum flood (PMF) design storm events to represent a reasonable range of extreme event flood conditions. The models estimated flow for the following scenarios:

- existing scenario – which represents the current state of the Medway Rivulet and Oldbury Creek sub-catchments based on LiDAR data collected on 25 October 2013;
- operational scenario – which incorporates the proposed surface infrastructure for the mine and associated mitigation measures; and
- rehabilitation scenario – which is the final landform at completion of the project.

Model input parameters and calibration are outlined in detail in Appendix D (WSP PB 2016d).

Design rainfall hyetographs for storm events up to the 100 year ARI were generated, and probable maximum precipitation (PMP) was calculated.

Calibration used rainfall data from nearby weather stations and streamflow data from baseline surface water level gauges. Initial and continuing rainfall losses and B factor were adjusted within reasonable ranges until the model was calibrated.

The hydrologic model was checked by comparing the model flow estimates against probabilistic rational method (PRM) calculations for the 5 year, 20 year and 100 year ARI events for Medway Rivulet.

The Medway Rivulet and Oldbury Creek hydrologic models were run for the 5 year, 20 year and 100 year ARIs and the PMP rainfall events for the existing, operation and rehabilitation scenarios. The 5 year, 20 year and 100 year events were run for durations of 15 minutes to 48 hours, and the PMF event was run for durations up to 96 hours, to determine the critical duration for each event. Peak flows generated within the Medway Rivulet and Oldbury Creek sub-catchments that are input to the hydraulic model and the critical duration identified for each return period are included in Appendix D (WSP PB 2016d). Results indicate the PMP critical duration for the Medway Rivulet catchment was the 4 hour event, and for Oldbury Creek it was the 2.5 hour event.

8.5.2 Hydraulic assessment

HEC-RAS hydraulic models were developed for Medway Rivulet, Oldbury Creek, and their tributaries to assess extreme flood levels in the project area. HEC-RAS is a one-dimensional hydraulic model that can simulate steady or unsteady flow in rivers and open channels. The river channel and floodplain is represented in HEC-RAS as a series of topographic cross-sections. The model can assess the effects of obstructions, such as bridges, culverts, weirs, and structures in the channel and floodplain.

Cross sections of the river channel and flood plain were extracted from a digital terrain model derived from LiDAR data collected in late 2013. Cross sections were extracted about every 100 m along the length of Medway Rivulet and Oldbury Creek and tributaries. Additional cross sections were extracted at locations where there is hydraulic constraint, eg road crossings, to provide additional level of detail in the model. Cross sections varied in length from about 300 m to 1,500 m depending on the depth and size of channel and width of floodplain. Junctions were modelled where tributaries join main channels; equal water levels were assumed across the junctions. Locations are shown in Figure 8.3.

Cross section surveys conducted at SW04 (in 2013 and 2015) and SW08 (in only) were included in the model to aid development of rating curves and to provide calibration.

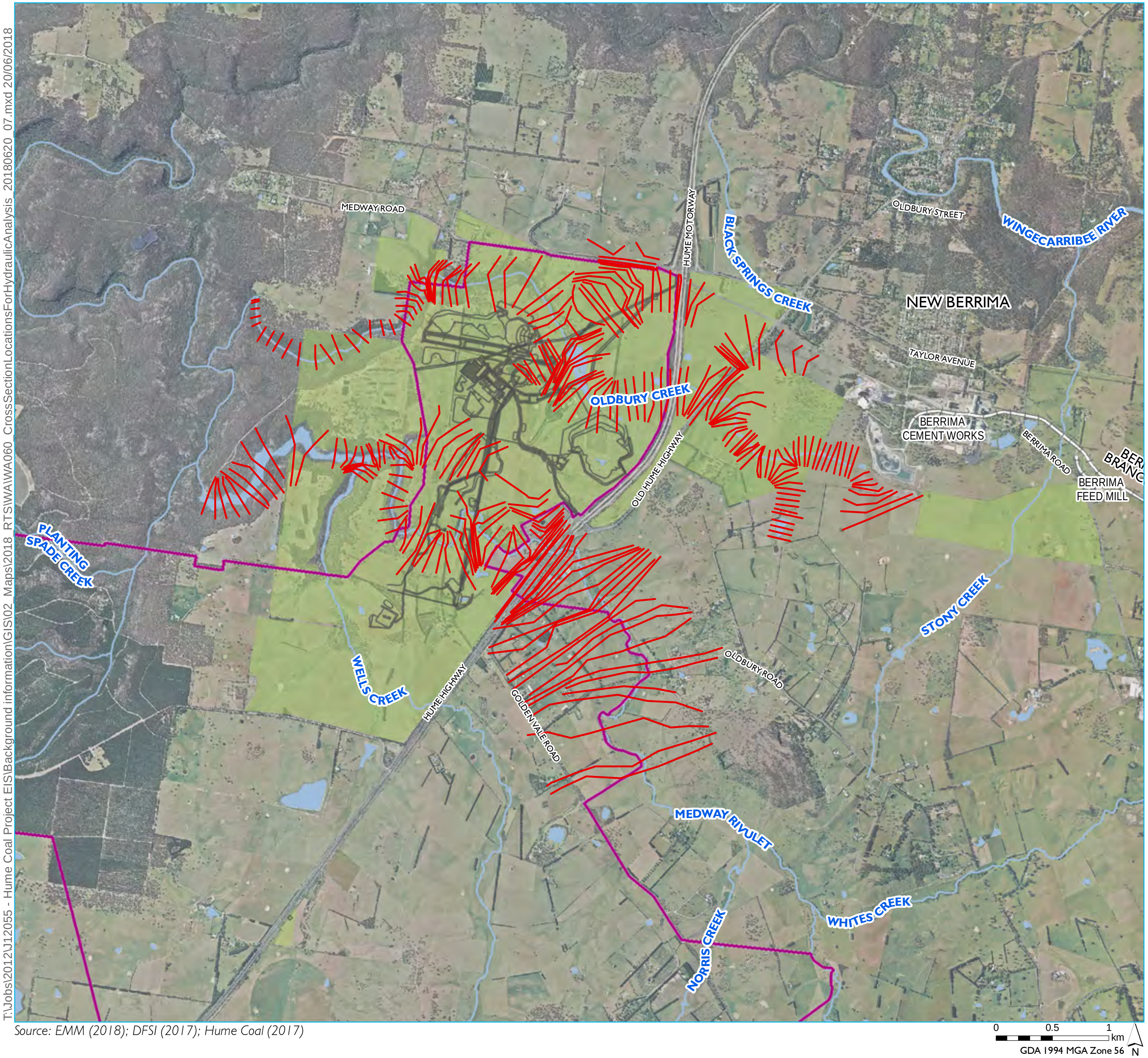
Inflows were assigned to reaches of the hydraulic model for each stream/tributary, based on the flow outputs of the hydrologic model. Boundary conditions and hydraulic roughness parameters implemented in the model are discussed in Appendix D (WSP PB 2016d).

The Medway Rivulet and Oldbury Creek models were run for the 2 year, 5 year, 100 year ARI and PMF events for the existing, operation and rehabilitation scenarios detailed in Section 8.5.1. The surface infrastructure is assumed to generally remain the same throughout mine operation; a maximum footprint and elevation layout and has been considered so as to assess potential worst case flooding.

Flood modelling was not used for the construction phase as the layout of temporary construction facilities will generally match the surface infrastructure layout used during operations. The temporary accommodation village is proposed only during the project's construction phase and will not be used during the operation phase. The temporary village has not been assessed as it will be on a ridge and will not influence flooding regimes in Medway Rivulet.

Existing structures (including Medway Dam, bridges, instream storages, and culverts) along Medway Rivulet and/or Oldbury Creek and a proposed culvert along Medway Rivulet were included in the HEC-RAS models.

The model results are discussed in Section 10.3 and Appendix D (WSP PB 2016d).



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Source: EMM (2018); DFSI (2017); Hume Coal (2017)

Cross section locations for hydraulic analysis

Hume Coal Project
Revised Water Assessment
Figure 8.3

HUMECOAL PROJECT
EMM

8.6 Groundwater numerical flow model

AR 2: A groundwater assessment to determine the likelihood and associated impacts of groundwater accumulating and subsequently discharging from the workings post cessation of mining, including consideration of the likely controls require to prevent or mitigate against these risks as part of the closure plan for the site

A regional numerical groundwater flow model was developed for the project and presented in the original EIS (EMM 2017a). This model was built to determine the effects of mining on the groundwater and surface water systems in the region and whether these effects complied with the AIP; in particular, to determine mine inflows and water table drawdown and deeper depressurisation due to sub-surface mining. It was used to determine landholder bore drawdown interference and influence on other environmental users during mining and the post-mine recovery period. A substantial database of Hume Coal data and data from published sources was used as a basis to develop and calibrate the numerical groundwater model.

The EIS model has been independently peer reviewed by two experienced groundwater modellers. The peer reviewers agree that the model objectives have been satisfied, the model calibration is satisfactory, the model predictions conform to best practice, and the model is fit for purpose.

The EIS model was prepared in accordance with the *Australian Groundwater Modelling Guidelines* (AGMG) (Barnett et al. 2012) was used to develop the model. The EIS model boundaries were developed in consultation the NSW Government, and in accordance with the Australian Modelling Guidelines (Barnett 2012). The NSW Government independent expert peer concludes that:

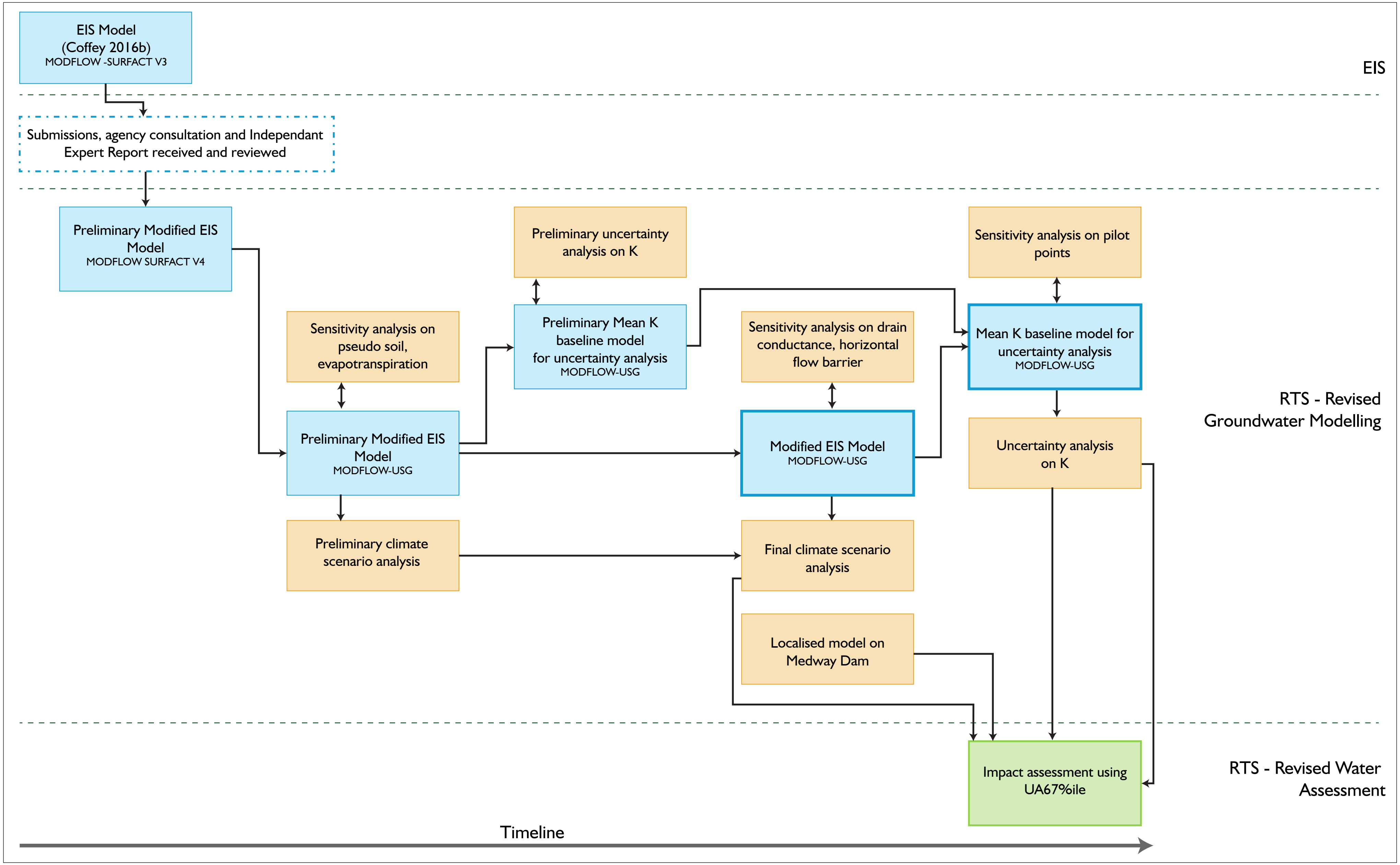
> "The model software, design, extent, grid, boundaries and parameters form a good example of best practice in design and execution." (Hydrogeologic 2017)

The current model according to AGMG conforms to most criteria for Class 3 model classification, with the remaining criteria conforming to Class 2. The NSW Government independent expert peer review (Hydrogeologic 2017) concluded that the EIS model was Class 2 based on a holistic interpretation of the guidelines. Hydrogeologic states that the development of the original EIS model, and impact assessment, was in accordance with best practice guidelines and the NSW Government independent expert peer of the original EIS model states that:

> "The Hume Coal model itself is suitable for the mining impact assessment purpose (Class 2 confidence level)' and 'the EIS presents reasonable predictions of dewatering volumes and drawdown extent/magnitude." (Hydrogeologic 2017)

Following submission of the EIS, and upon receipt of the submissions from the NSW Government, interest groups and the business and local community, additional groundwater modelling work was commissioned. A detailed EIS groundwater model audit was undertaken by Noel Merrick of HydroSimulations, which evolved into a model revision, upgraded software and solvers and a detailed uncertainty analysis. A visual description of the steps involved in the post-EIS groundwater modelling work is shown in Figure 8.4.

The model design, calibration, and detailed uncertainty are summarised in the following sections; full details are included in Appendix F (HydroSimulations 2018). The results of the model are discussed in Chapter 11.



Post-EIS groundwater modelling work process

Hume Coal Project

Revised Water Assessment

Figure 8.4

Table 8.7 Model alterations and features (EIS to RTS)

Topic	Discussion	Outcome
Model checks and verification		
Model layer thickness In particular Interburden layer thickness (specifically the layer between the Hawkesbury Sandstone and the Wongawilli Seam)	EIS reporting reported the thickness of the modelled interburden layer thickness as an average.	The thickness of the interburden is accurate and reflects geological data. It was not fully explained in the EIS report.
	Detailed review revealed that the thickness varied across the model domain in accordance with data available	
Alterations to the model		
Software engine and solver upgrades	Upgrade to Groundwater Vistas, and to MODFLOW SURFACT v4, and to MODFLOW USG	More suitable for: data extraction, changes to model layers properties with mining, significantly improved mass balance error (<1%), better convergence and more realistic representation of the water table.
	More up to date software, more functions and options such as (time varying materials and psudeosoil function)	
Calibration reporting	Inclusion of all data	Achieved <1 %RMS (ie reduction from EIS model which was >10%).
	Exclusion of outlier VWP data and perched water table data	
	Display of spatial residuals	
Specific storage	Increased layers 1-5 by 3 times Increased layers 6-13 by 4 times Closer alignment with pumping test data	Based on sensitivity analysis - more defensible. Tighter 2m drawdown extent; less mine inflow. Marginal calibration benefit.
Specific Yield	Increased by 3 times in all model layers Closer alignment to pumping test data	Based on sensitivity analysis - more defensible Marginal calibration improvement.
Mine drain (DRN) duration and up-dip mining	Cessation following mining rather than at the point of complete void refill	Overall reduction in "to sump" mine inflow.
	New function available in new software	
New model features		
TMV package	Coal void modelled using TMV (ie properties of coal vary over time and space as mining progresses	More realistic void refill times, Overall minimal change to 2m drawdown extent and slower recovery of groundwater levels.
Time varying materials (K, Sy, and Ss) and timing	More accurate representation of mining, better distribution of stresses during mining	
'To void' accounting	ZONEBUDGET accounting rather than drain cells to provide more realistic modelling of this (function available with new software)	More realistic and show temporal profile.
Pseudo-soil function	Available with upgraded software, and provides for better representation of groundwater recovery following depressurisation and dewatering	More realistic simulation of groundwater recovery and water tables.

Table 8.7 Model alterations and features (EIS to RTS)

Topic	Discussion	Outcome
Additional studies and analysis		
Sensitivity analysis – parameter sensitivity	Specific storage Specific yield Pseudo-soil (function on and off) Drain conductance (one order of magnitude higher considered) Vertical basalt barrier (effect of presence or absence Evapotranspiration and extinction depth	**Specific storage and specific yield:** sensitivity analysis resulted in changes to these parameters being made in the model. **Outputs focused on:** calibration (%RMS), mine inflow, number of bores impacted, and changes to baseflow. **Results:** Pseudo soil was enabled in the updated USG model and was required to remain enabled to achieve conversion. **Drain conductance** sensitivity of 10x resulted in 2x mine inflow, but this increased conductance was unrealistic and not then calibrated to known data (ie inflow to Berrima Mine). EIS drain conductance therefore retained in revised model. **Basalt flow barrier:** sensitivity demonstrated that the structure was interpreted correctly in original EIS model. The structure does not prevent impacts (as was the concerns raised in submissions). **Evapotranspiration:** Model insensitivity to changes in extinction depth of evapotranspiration.
Sensitivity Analysis – climate sensitivity	Both sensitivity and uncertainty analysis was undertaken to consider climate flux between wet and dry periods	Drawdown in landholder bores and mine inflow are very insensitive to climate changes.
Uncertainty analysis hydraulic conductivity	*Monte Carlo* simulations for different model predictions Most sensitive parameter (hydraulic conductivity) range was considered	Uncertainty results for mine inflow, drawdown in landholder bores and drawdown in water table results. Very similar results to original Coffey EIS model, but uncertainty bounds and statistics available.

8.6.1 Model objectives

The numerical groundwater flow model's objectives are to quantify potential mining impacts to groundwater and surface water, and compare the impacts with the AIP requirements. These were considered in the model's design, construction, calibration and then in more detailed in the subsequent sensitivity and uncertainty analysis.

8.6.2 Model development

i Extent and boundary conditions

The regional groundwater flow model was originally developed using MODFLOW-SURFACT Version 3 (Hydrogeologic) in early 2015 by Coffey (2016b), and was published in the Hume Coal EIS (EMM 2017a). Subsequent to the lodgement of the EIS and receipt of submissions Hume has undertaken additional more modelling, sensitivity analysis, uncertainty analysis and made refinements to the original EIS model.

The model revisions were undertaken in consultation and agreement with the NSW Government regulators (DPE and DI Water), and the NSW Government appointed independent expert peer reviewer. The NSW Government independent expert peer review considered the EIS model initially, and stated it was 'fit for purpose'. The review raised some questions and required clarifications which were collated in 'issues log'. The issues log was worked through with both the DI Water personnel the NSW Government independent expert peer reviewer and the Hume Coal project modelling team. Model refinements and modifications were undertaken by HydroSimulations, in consultation with the original modeller, Paul Tammetta (Coffey 2016b). As well as model refinements, HydroSimulations undertook a detailed model audit, sensitivity analysis, and a detailed uncertainty analysis in accordance with recently released IESC draft guidelines. The revised model report is provided in Appendix F.

The EIS model remains valid, but was revised and enhanced to address aspects raised in the submissions process. The model extent, calibration and other key model features were not adjusted. The model extent (752 km^2) (Figure 8.4) remained the same as the EIS and was selected to represent a significant area around the project area to determine in detail and model potential impacts from the project.

The model domain extends across two groundwater sources: Sydney Basin Nepean Groundwater Source, and the Sydney Basin South Groundwater Source. Within the Sydney Basin Nepean Groundwater Source there are two management zones: the Nepean Management Zone; and, Nepean Management Zone 2 (Figure 8.6). The model domain extends across several surface water sources: Upper Wingecarribee River, Lower Wingecarribee River, Medway Rivulet, Lower Wollondilly River, Nattai River, and Bundanoon Creek (Figure 8.6). For this assessment, the Lower Wingecarribee River and Medway Rivulet water sources have been further divided into sub-catchments. Model boundaries were set far enough away from the mining region to not interfere with drawdown/depressurisation created by mining.

ii Layers

The EIS model (Coffey 2016) was constructed with thirteen active model layers, and the revised model uses eleven active layers. The base two layers were not required as they are below the active mining layer and were therefore inactivated to improve model run times and model efficiency. The eleven layers represent the differences between hydrostratigraphic units to maintain adequate layer depth resolution, and so changes arising from mine extraction can be modelled. These layers and properties are shown in Table 8.8.

The grid cell dimensions used were 50 x 50 m over the project area, 50 x 100 m over the Berrima Colliery lease, and 200 x 200 m over the rest of the model domain. The cell spacing was reduced for greater detail in the mining zone.

The Hawkesbury Sandstone was represented by six layers to allow the suitable development of hydraulic head profiles and allow the depressurisation effects of mining to be incorporated.

A detailed examination of the interburden layer between the base of the Hawkesbury Sandstone and the proposed working section of the Wongawilli Seam was undertaken by HydroSimulations in their model audit (HydroSimulations 2018).

The model geometry was examined and it was confirmed that the interburden between the bottom of the Hawkesbury Sandstone and the top of the working section of the Wongawilli Seam is spatially variable. This actual spatial variability closely matches the model layer, which is the interpolated interburden thickness figure shown in the EIS groundwater report; (Figure 4.3 in Coffey 2016a). Both the EIS model and the revised model (HydroSimulations 2018), adopt the correct representation of the conceptual model which is spatially variable and aligned to the data collected.

Based on hydraulic head observations, the Robertson Basalt was not explicitly simulated in the regional model; however, its presence has been incorporated in the recharge rate for the Wianamatta Group, where it underlies the basalt. The Mount Gingenbullen intrusion was also not explicitly modelled based on the observed extents of drawdown created from the Berrima Colliery and coal mines from other regions.

An additional, smaller numerical basalt model was developed to calculate depressurisation in the basalt associated with the Hume Coal mine. The model was initially developed with MODFLOW-SURFACT Version 3, but was later converted to Version 4, and the converted to MODFLOW-USG at the request of the NSW DI Water. The model domain area is 15 km^2 and a boundary that followed the south-eastern basalt geological unit. The model grid comprised two layers (Robertson Basalt and notional underlying layer) with cell dimensions of 100 x 100 m (Coffey 2016b).

iii Hydraulic parameters

Hydraulic parameters were assigned to each layer based on lithology and depth below ground surface. Both horizontal and vertical hydraulic conductivity were included. The hydraulic parameters adopted for the EIS model (Coffey 2016b) were reviewed in great details following submissions and were tested and adjusted in the revised model (HydroSimulations 2018).

a. Specific Storage

The specific storage of an aquifer is the amount of water a unit mass or unit volume of aquifer releases, per unit change in hydraulic head while remaining fully saturated (HydroSimulations 2018).

The specific storage values adopted in the EIS model were subject of a detailed review by HydroSimulations. This review was undertaken due to feedback within submissions on the EIS. Although the specific storage values in the EIS model are supported by literature review, they have been raised in the Modified-EIS model for better consistency with derived pumping test values (HydroSimulations 2018).

Lower model layers (Layers 6 to 13) underwent a multiplication of the original specific storage values by a factor of 4 while Hawkesbury Sandstone layers and above (Layers 1 – 5) were increased by a factor of 3. The revised and adopted specific storage values by HydroSimulations in the Modified-EIS Model are in Table 6.7. The values adopted within the model revision are much closer to the average optimised value provided by the pumping tests (HydroSimulations 2018).

Increasing the specific storage values made no practical difference to the SRMS statistic or the RMS statistic within the revised calibration model. However, the updated values more closely align to field measurements and are therefore retained in the modified-EIS model (HydroSimulations 2018).

b. Specific yield

The specific yield of a rock mass (also known as drainable porosity), is a ratio indicating the volumetric fraction of the bulk rock mass volume that a given rock mass will yield when the water is allowed to drain out under gravity.

The specific yield values adopted in the EIS model (Coffey 2016b) were questioned within submissions. During the model audit and update, a sensitivity run was conducted that used specific yield values in all model layers 3 times (3x) greater than the values from the EIS model. A multiplier of 3 represents approximately a half-order of magnitude, standard practice for Sy (as a full order of magnitude increase can give non-physical values).

The resulting range in values from 0.9% to 3.0% gives better consistency with the pumping test estimate, and was undertaken following review of submissions and more detailed consideration of the available data in the area. The changes resulted in improvements to the SRMS statistic in the calibration model of 0.25%. The increased the specific yield adopted within the revised model (Table 8.7) are now, on average, much closer to the values reported within the Coffey (2016a).

c. Drain conductance

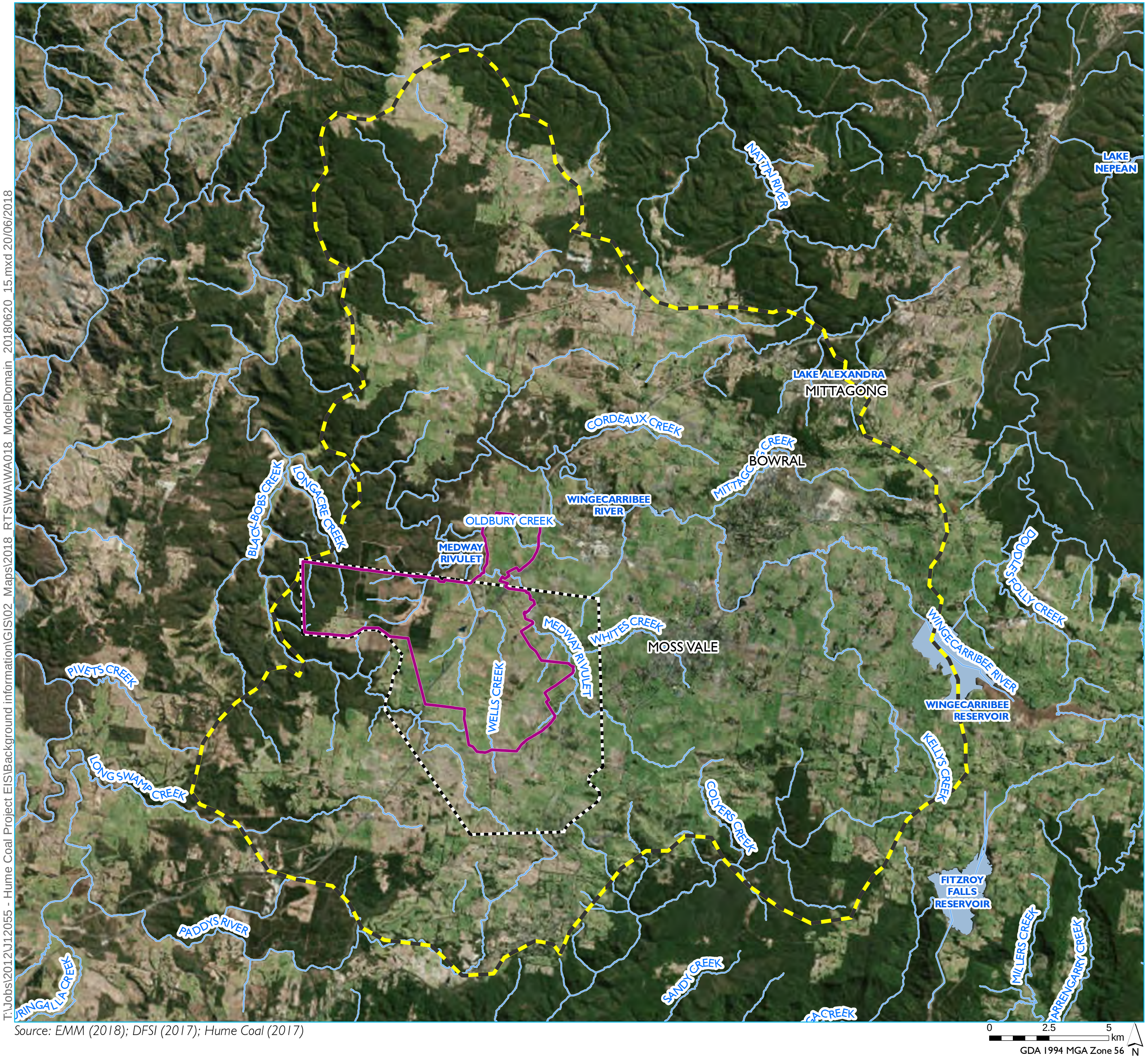
The EIS model had a conductance value that was calibrated to known data (ie inflow to Berrima Mine). The EIS model adopted 0.05 m^2/day. The value considered the relative area of the cell sizes between the Berrima mine model and the Hume Coal model within the model domain (Coffey 2016b). The EIS (Coffey 2016b) highlights that similar drain conductance values (0.1 m^2/day) were used to simulate non-collapsing development headings for proposed mining at Dendrobium Area 3B (Coffey 2012).

Drain conductance of 0.05 m^2/day can be converted to more meaningful terms such as hydraulic conductivity (K) or leakage coefficient (K/b) by taking into account the dimensions of plunges and roadways relative to model cell dimensions, and allowing for the area of seeps from the roof or sidewalls being much less than roof or wall face areas. When this is done, the effective leakage coefficient adopted in the Hume model is $5x10^{-5}$ d^{-1} at Hume and $2x10^{-5}$ d^{-1} at Berrima, where drain conductance has been calibrated. This compares favourably with estimates applied at other Southern Coalfield mines which range from $4x10^{-5}$ to $1x10^{-3}$ d^{-1}. Consultation on this matter with DI Water (formerly DPI Water) occurred on 25 August 2017.

As part of the groundwater model revision, a parameter sensitivity run that increased the drain conductance to 0.5 m^2/day (a factor of 10) was conducted. The results of the sensitivity run near doubling of the 'to sump' mine inflow but not the 'to void' inflow. Overall the increases in total mine inflow the number of impacted bores are small considering the 10 times increase in drain conductance. This demonstrates the model is overall not particularly sensitive to changes in mine drain conductance.

Importantly, if the increase in conductance was similarly applied to the drains simulating mining at Berrima, the modelled inflow would far exceed the observed discharge from the Berrima mine void and the conductance values would no longer be calibrated. This clearly demonstrates that the higher value is an unrealistic mine conductance value and the original value adopted in the EIS is accurate.

The similarities in the adopted conductance values with other models within the Southern Coalfield, as well as the indication that conductance can become uncalibrated with an order of magnitude change, serve to show that the calibrated conductance values used in the EIS model are reasonable and fit for the purpose of predicting the impacts of the mine. These values are therefore retained in the revised model (HydroSimulations 2018).



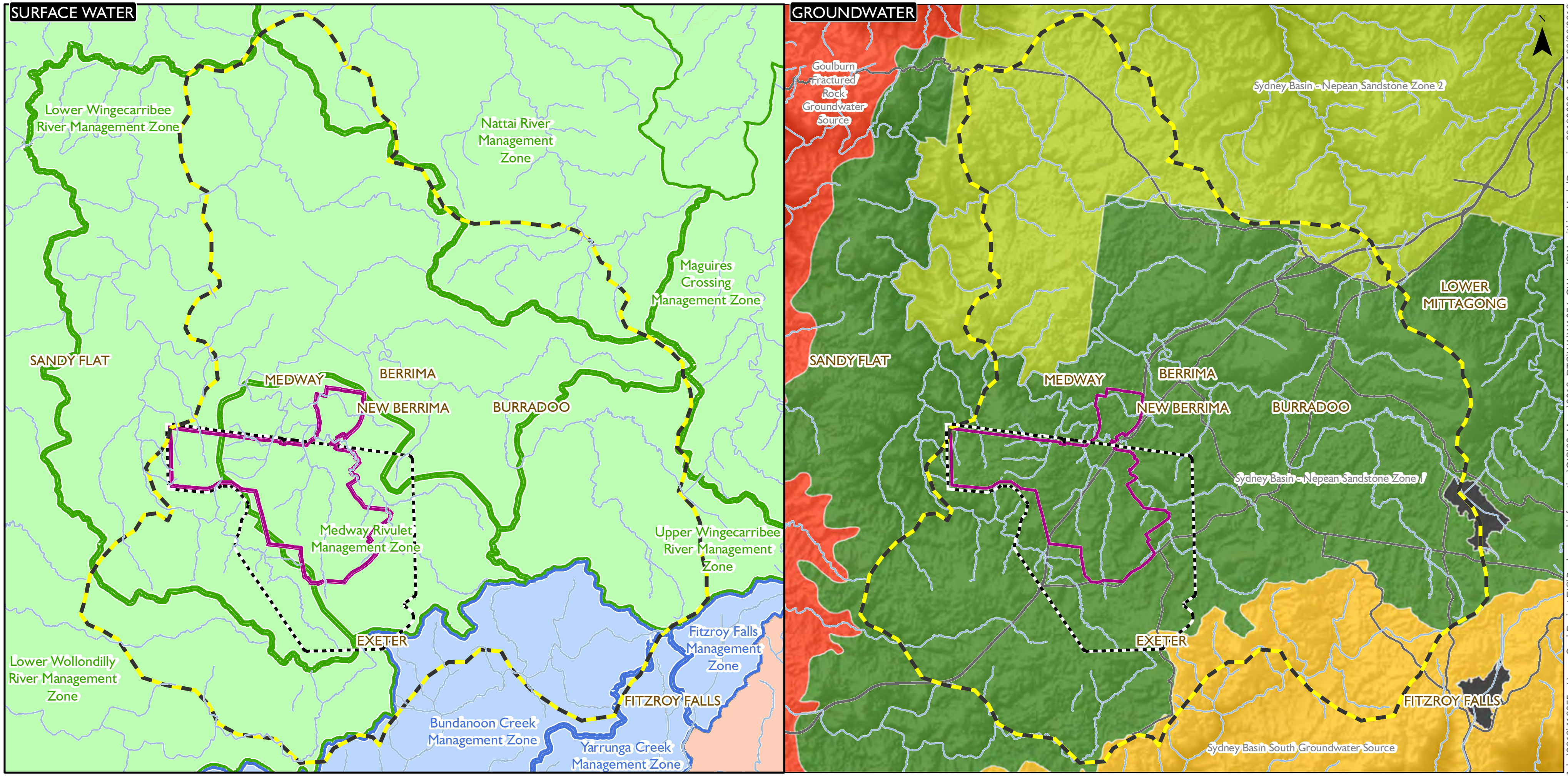
T:\Jobs\2012\J12055 - Hume Coal Project EIS\Background information\GIS\02_Maps\2018_RTS\WA\WA018_ModelDomain_20180620_15.mxd 20/06/2018

KEY
- Project area
- A349
- Model domain
- Lakes and reservoirs
- Drainage line

Source: EMM (2018); DFSI (2017); Hume Coal (2017)

Numerical groundwater model domain

Hume Coal Project
Revised Water Assessment
Figure 8.5



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Source: EMM (2018); DFSI (2017); Hume Coal (2017); Coffey (2013); DPI (2013, 2014)

0 2.5 5 km

GDA 1994 MGA Zone 56

KEY

- Project area
- A349
- Model domain
- Waterbody
- Drainage line

Greater Metropolitan Water Sharing Plan, Unregulated Rivers

- Shoalhaven River Water Source
- Management zone within the Shoalhaven River Water Source

Greater Metropolitan Water Sharing Plan, Unregulated Rivers

- Upper Nepean and Upstream Warragamba Water Source
- Management zone within the Upper Nepean and Upstream Warragamba Water Source

Water Sharing Plan for the Greater Metropolitan Region Groundwater Source (2014)

- Sydney Basin - Nepean Sandstone Zone 2
- Sydney Basin - Nepean Sandstone Zone 1
- Sydney Basin South Groundwater Source
- Goulburn Fractured Rock Groundwater Source

Note: Project area and A349 boundaries have been offset for clarity

Groundwater and surface water sources within model domain

Hume Coal Project

Revised Water Assessment

Figure 8.6

Table 8.8 Active model layers and parameters

Model layer	Geology	Average depth to base^ (mbgl)	Average thickness (m)	Specific Storage	Specific yield
1	Wianamatta Group	30	55 (where present)	3 x 10^{-6}	0.03
2	Hawkesbury Sandstone	56	53 where overlain by Wianamatta Group Shale. Decreases to nil from edge of Wianamatta Group to limit of sandstone	3 x 10^{-6}	0.03
3		86	30	2.1 x 10^{-6}	0.024
4		120	34	2.1 x 10^{-6}	0.024
5		127	7	2.1 x 10^{-6}	0.015
6		129	2	2 x 10^{-6}	0.015
7		131	2	2 x 10^{-6}	0.009
8	Interburden (Unnamed Member 3, WWR Ply & Farmborough Claystone)	133	4*	2 x 10^{-6}	0.009
9	Wongawilli Seam above mined section	135	2* Note average 2m, some areas less than 0.3m)	2 x 10^{-6}	0.009
10		137	2* Note average 2m, some areas less than 0.3m)	2 x 10^{-6}	0.009
11	Wongawilli Seam mined section	140	3.5	2 x 10^{-6}	0.009
12	Illawarra Coal Measures	160	19	2 x 10^{-6}	0.009
13	Shoalhaven Group	250	120	2 x 10^{-6}	0.009

Notes: ** = applied only within project area, not present everywhere so a minimum model thickness of 0.1 m is applied.*

 # = modelled parameters.

^ = average depth to base in project area.

mbgl = metres below ground level.

K = hydraulic conductivity.

iv Recharge, discharge, and flow

a. Rainfall and evapotranspiration

Rainfall recharge to the model domain was applied as a constant percentage of rainfall estimated for the project area based on BoM rainfall data (2% of 957 mm/yr). Evapotranspiration was applied across the model domain at a maximum rate of 3 mm/day (1,095 mm/year), to 1.5 m deep, based on land surface types and proportions.

The rainfall recharge rate was not varied from the calibrated value used in the EIS model and remained at a constant value of 1.8% of rainfall throughout each simulation (HydroSimulations 2018). No change was considered necessary as the value was constrained by calibration to baseflows.

b. Rivers, drainage lines, reservoirs

The Wingecarribee River and the Medway Dam were simulated using the MODFLOW River package, which allowed two-way transfer of water between the creeks and groundwater. A river cell that is in a groundwater system with an elevation above the stage height of the river cell will 'gain' water from the groundwater system. If the groundwater level is below the stage height but above the defined base, the river cell will 'lose' water from the river cell at a rate that increases with an increasing difference between the stage height and groundwater level. The maximum loss rate occurs when the simulated groundwater level is below the base elevation of the river cell.

Wingecarribee Reservoir was simulated with a constant head condition in the top model layer. This assignment was based on water level data that indicate a relatively constant level for the past several years. Water was allowed to exchange with the subsurface in either direction depending on groundwater levels.

An investigation was conducted to determine the necessity or otherwise of varying the Wingecarribee River stage between modelled climate scenarios. It was found that the Wingecarribee River maintains a relatively consistent stage height independent of climatic conditions and it is justifiable to maintain the stage originally set in the EIS model (Coffey 2016b) in all climate scenario runs. No data was readily available for the water level elevation or storage volumes of Medway Dam, the stage height set originally in the EIS model (Coffey 2016b) was therefore maintained for climate scenario runs.

The applied vertical hydraulic conductivities (Kv) of the stream beds were set at a high value to allow free interaction between the surface and groundwater.

A localised model for Medway Dam was developed to enable Medway Dam to be considered in more detail than is typically required (or available) within the more regional model. This localised model considered in detail the connectivity between Medway Dam and the groundwater system. Medway Dam is modelled using the MODFLOW River package, and is gaining system under natural conditions (ie receives groundwater baseflow).

All other drainage channels were simulated using the MODFLOW Drain package, indicating their predominantly ephemeral nature, with the elevation of the drain inverts set using topographic data. Therefore, any groundwater intercepting the stream as baseflow is removed from the model.

c. Alluvium

Alluvium is confined to the upper reaches of the Wingecarribee River and represents a small proportion of the total recharge area. It is assumed that recharge to the alluvium would discharge mainly to the river rather than to underlying clay dominant Wianamatta Group. Based on the alluvium's limited extent, recharge to underlying rock is considered a negligible component of the total recharge to the Wianamatta Group. The alluvium is not considered a separate groundwater source in the WSP. Hence, the alluvium has not been considered a separate unit from the Wianamatta Group in the model.

d. Groundwater bores

The model simulates pumping from 83 high extraction, irrigation or industrial use bores associated with water access licences (WALs) of 5,300 ML/yr, and 299 stock and domestic bores. As there is no measured usage for the stock and domestic bores, they were assigned a constant pumping rate of 3 ML/yr each. Following calibration, the rate of extraction for the high extraction bores was varied to an optimal rate of 5,147 ML/yr, which likely accounts for over-pumping and pumping from unlicensed bores. For bores that extract groundwater from more than one model layer, the pumping rate was split proportionally based on the transmissivity of each layer.

v Mine workings

Relaxation effects in the rock immediately above the mine were set to nominally 2 m for layer 10, immediately above the workings in the EIS model. This is also the adopted height of groundwater drainage (desaturation). This approximate height of deformation has been described as typical for other first workings mines around the world and depends on road width, horizontal stress, roof rock strength, and rock bolting (Coffey 2016b). It is significantly less than the deformation zone for full extraction mining. In the model, there is assumed to be negligible change in hydraulic conductivity above the deformation zone within the project area. This is not the case for full extraction mines at Berrima Colliery and Loch Catherine to the north of the project. The parts of the Berrima and Loch Catherine mines that underwent full extraction mining, and subsequent caving, have been modelled with an average height of desaturation of 53 m above the roof.

In the model audit and revision the 2 m was deemed appropriate, but the revised model ensured that the 2 m relaxation extended into layers above layer 10, if layer 10 was less than 2 m. Therefore the revised model has increased the thickness of relaxation zone to 2m regardless of layer. The result of this is likely to be a marginally higher level of connection between the Hawkesbury Sandstone and the mine workings.

vi Structure

The net influence of fractures and faults in the area was considered during developing and running the groundwater model. Hydraulic conductivity estimates from the long-term pumping tests (of which there were eight) largely incorporate the influence of nearby faults and fractures in their results. In addition, the Berrima mine inflow data, which has been used as an input to the numerical groundwater model (Coffey 2016b), inherently includes consideration of the influence of faults and fractures on groundwater flow.

To replicate the hydraulic head field within the Robertson Basalt, the EIS model (Coffey 2016b) utilised both the MODFLOW Horizontal Flow Barrier and MODFLOW Drain packages to simulate the interpreted structural feature and the underlying unsaturated zone to the south of the feature (Coffey 2016a). HydroSimulations finds this conceptualisation and the supporting evidence, as detailed within Coffey (2016a and 2016b), to be robust, and the method of implementation within the groundwater model to be justifiable.

A sensitivity analysis was conducted to assess the ability of the Horizontal Flow Barriers to restrict the movement of drawdown in to the basalt. These sensitivity runs show that the method used to simulate the interpreted structure and associated unsaturated zone has resulted in a limited ability of drawdown to propagate through the basalt. This is consistent with the Coffey (2016a and 2016b) conceptualisation that is a robust interpretation of the available evidence. The barriers in the model are not impacting on the overall groundwater flow.

vii Hydraulic connection (shale to sandstone)

The model was also used to quantify the simulated flow of groundwater between the low permeability Wianamatta Group shale and the upper Hawkesbury Sandstone. Within the numerical groundwater model area (Figure 8.5), baseline movement of groundwater from the Wianamatta Group shales to the upper Hawkesbury Sandstone was modelled to be consistently around 11.1 ML/day using the numerical groundwater model (discussed in Sections 8.6 and 11.2.1). As a comparison to provide perspective, across the area where the Wianamatta Group is conceptualised to be hydraulically connected to the Hawkesbury Sandstone (28,118 ha), the amount of water movement of 11.1 ML/day from the shale to the underlying sandstone is equivalent to a very small rainfall event of 0.04 mm.

8.6.3 Calibration

The model was calibrated in two stages: transient simulation over a notional period of 32 years (approximating the effects of mining between 1926 and 2011, when the Berrima Colliery mine was active) to obtain a starting head distribution, and transient calibration over the main calibration period (between 2011 and 2014, the last stages of Berrima Colliery). The measured discharge from the Berrima Colliery void also provided an additional calibration aid for the model (Coffey 2016b). Verification was between the period 1 January 2015 to 27 August 2015.

Calibration targets included:

- hydraulic head data (49 points at 23 locations, including the Berrima Colliery, with monitoring intervals between 1 and 3 years) showing both seasonal changes and mine-induced drawdown;
- shallow groundwater discharge or baseflow to drainage channels and creeks;
- deep groundwater discharge (discharge to the Berrima Colliery void); and
- the measured hydraulic conductivity values across the region.

Inclusion of sub-vertical groundwater flow barriers associated with, but not penetrating, the Robertson Basalt (inferred from airborne geophysics and hydraulic head observations) helped to successfully calibrate the measured hydraulic head values from piezometers in the southern portion of the model domain.

Modelled results compare reasonably well with observed hydraulic heads. Further details about the calibration and verification results are included in Appendix F (Coffey 2016b and HydroSimulations 2018).

The review by HydroSimulations lead to a re-run of the model using a later version of MODFLOW-SURFACT with better solver settings, which reduced the high mass balance errors in the EIS model. Additionally, calibration statistics were re-calculated for the entire observed dataset, rather than a subset, without the inclusion of less reliable vibrating wire piezometer (VWP) data.

A conversion to MODFLOW-USG was later undertaken which further reduced mass balance errors and runtimes and therefore MODFLOW-USG was retained as the software utilised for the model update, revision and sensitivity analysis detailed in this report.

A comparison between key calibration metrics between the original EIS model and the revised model by HydroSimulations is provided (Table 8.9).

Table 8.9 Comparison of key calibration statistics between the EIS model and the revised groundwater model

Key statistic	EIS model (Coffey 2016b)	Revised groundwater model (Preliminary Modified EIS Model MODFLOW-USG) (HydroSimulations 2018)
Number of Data Points	49	2,502
Residual Mean (m)	3.11	3.70
Absolute Residual Mean (m)	12.14	12.19
Root Mean Square (m)	17.06	15.41
Scale Root Mean Square (%)	11.9	10.76

8.6.4 Uncertainty and sensitivity analysis

The EIS model (Coffey 2016b) undertook sensitivity analysis on a number of parameters, including the relaxation height, vertical hydraulic conductivity (Kv), and mine drain conductance. The sensitivity analysis indicated the Kv distribution was the most sensitive parameters in the simulations. The final calibrated Kv distribution was also aided by a combination of observations from pumping tests, stream baseflow, and Berrima Colliery inflow discharge observations. The calibrated Kv distribution is therefore considered to have a high level of reliability. Coffey (2016b) has concluded this reduced uncertainty in the model's outputs.

The submissions on the original EIS from the NSW Government and interest groups suggested that additional sensitivity and uncertainty analysis be undertaken. In addition, over recent months (post lodgement of the EIS), the IESC have released a draft IESC Explanatory Note for Uncertainty Analysis in Groundwater Modelling (Middlemis & Peeters 2018) to inform both the industry and the regulators on expectations, types, results and interpretation of uncertainty analysis in groundwater modelling.

The rework of the model by HydroSimulations involved a significant focus on undertaking additional sensitivity analysis on many model input parameters and also undertook a very detailed *Monte Carlo* style uncertainty analysis, in line with the IESC guideline. It is noted that this work was very complex, time consuming and onerous, and the results of the work provide an exceptional example of how to apply the IESC guidelines to undertaken very detailed uncertainty analysis and reporting of results.

i Sensitivity Analysis

a. Climate sensitivity

While defensible, the EIS model predictions were based on average climate into the future. This is a standard and proper approach for predictive modelling to ascertain mining effects exclusive of potential climate effects. However, a climate scenario analysis was undertaken utilising 108 climate sequences similar to those adopted in the surface water assessment in the EIS submitted in March 2017. Simulating the variation in impacts from 108 climate scenarios using conventional techniques is not feasible, so complex programming and cloud computing techniques were adopted.

Outputs are presented as percentage differences between 5th and 95th percentile aggregate outputs from all scenarios, and are:

- mine inflow;
- Baseflow reduction for simulated streams;
- number of bores impacted by 2 m or greater drawdown; and
- 2 m drawdown extent.

Further model runs were completed that used the 'wettest' and 'driest' climate scenarios, based on maximum and minimum average daily rainfall. These are compared against outputs based on the average climate values.

b. Parameter sensitivity analysis

In consultation with the NSW Government and the NSW independent peer reviewer, additional sensitivity analysis was conducted. Several aspects of the groundwater model were considered, being:

- magnitudes of formation specific storages and specific yields;
- simulation with/without pseudo-soil;
- drain conductance – adjusted to be higher by 1 order of magnitude; and
- vertical basalt barrier -effect of its presence/absence.

The results of the sensitivity analysis focused on the following model outputs:

- calibration %RMS;
- mine inflows;
- water table drawdown – 2 m extent;
- number of bores impacted by 2 m or greater drawdown; and
- baseflow interception at simulated streams.

ii Uncertainty analysis

a. Overview uncertainty analysis

The EIS model undertook a high level uncertainty analysis that focused on the main contributors to the uncertainty of the model. These features are more conceptual in nature and need to be fully understood to ensure that model results are interpreted accurately. The EIS model considered that there were four main contributors for uncertainty at a local scale between observed and modelled hydraulic heads, which were:

- the accuracy of the vibrating wire piezometer data, which is considered to be within ± 10 m;
- layer thickness in the model and the vertical position of piezometer screen intervals;

- the variable size of piezometer screen intervals leading to variations in pressure head readings; and
- the uncertain Berrima Colliery mining schedule and extraction that stopped in 2013.

b. Detailed uncertainty analysis on hydraulic conductivity

Detailed uncertainty analysis by stochastic modelling using the *Monte Carlo* method as prescribed in the IESC explanatory note is not often undertaken in the groundwater modelling industry. The reason being is the time requirements, high cost implications and technical requirements to develop tailored software codes for each project.

Stochastic modelling using *Monte Carlo* operates by generating numerous alternative sets of input parameters for the groundwater flow model run (realisation), executes the model independently for each realisation, and then aggregates the results for statistical analysis.

It requires many hundreds or thousands of model runs, each of which may take several hours of run time on an individual modern computer. Therefore, logistically this work therefore needs to be undertaken on cloud based platforms. Recent developments (past 6-12 months) with cloud based computing and modelling software have provided a pathway for uncertainty analysis to be more available.

To assess uncertainty in the hydraulic conductivity parameters in the model, a *pilot point* approach was applied. Lateral hydraulic conductivity (Kx) and vertical hydraulic conductivity (Kz) values were permitted to vary spatially throughout the model domain by taking representative values at 256 locations (pilot points) in each of the 13 model layers and giving each point a depth value based on the depth below ground to the middle of the layer for the cell the pilot point is in.

The locations of the pilot points was determined using the optimisation algorithm for mesh generation in the AlgoMesh software tool (Merrick and Merrick 2015) to distribute the points according to a uniform distance function.

For each realisation generated by the *Monte Carlo* process, every pilot point was assigned a Kx value and a Kx/Kz ratio. This equates to a total of 6,656 parameters (256 points by 13 layers by 2 parameters). Each model cell is then assigned a Kx and a Kz value through interpolation from surrounding pilot point values by using the contouring method *kriging*.

The model outputs and post processing from the uncertainty analysis provided the following results:

- mine inflow;
- bore drawdown;
- baseflow interception for four streams;
- water table drawdown - at 50th percentile;
- water table drawdown contours at 2 m at 33rd, 50th, and 67th percentiles; and
- risk map - showing the cell-by-cell confidence that water table drawdown would be less than 2 m.

8.6.5 Scenario modelling

Predictive model simulations were run for a 100 year period for the most probable future scenario and included the non-caving mine layout, average rainfall, pumping behind bulkheads, and co-disposal reject filling.

Changes to groundwater hydraulic head simulated by the numerical model were calculated as:

- the drawdown as a result of the project only; and
- total drawdown as a result of existing stresses (ie drainage to the Berrima Colliery mine void, and landholder bore pumping), and the project.

The model results and predicted groundwater impacts are discussed in Chapter 11.

8.7 Groundwater quality

The groundwater model simulations and review of the project activities and design indicate the potential for groundwater quality changes as a result of:

- induced transfer of water between groundwater systems;
- co-disposed reject emplacement in sealed mined voids; and
- seepage from stockpiles to the shallow water table.

The methods used to assess these changes for each of the above potential sources and processes are summarised in the following sections and discussed in detail in Appendix I and J.

8.7.1 Water quality change from induced transfer between groundwater systems

Underground mining will result in temporary depressurisation of the overlying groundwater system. This is predicted to temporarily increase the vertical (downward) hydraulic gradients in the water bearing formations immediately above the mine footprint. The depressurisation effects in the shallow Hawkesbury Sandstone will result in a temporary increase in the vertical gradient between the Wianamatta Group shale and the Hawkesbury Sandstone, with a resultant increase in the flow of more saline groundwater from the shale, downward, into the upper Hawkesbury Sandstone. This effect is expected to be most pronounced during the peak mining years, and will decrease as mined panels are sealed (ie dewatering is no longer necessary) and the panels are allowed to hydraulically re-equilibrate to background conditions.

To assess the magnitude of transfer of higher salinity water from the Wianamatta Group shale into the upper Hawkesbury Sandstone and the change in salt balance, time-series flow data were obtained from the numerical groundwater model (Section Figure 8.6). Two scenarios were investigated: the existing case (ie no project influence), and the case with project influence. This allows for assessment of the incremental increase in transfer as a result of mining activities. This assessment has been updated using the revised groundwater model results (67th percentile uncertainty analysis results) (HydroSimulations 2018).

A mixing model was used to assess the resultant groundwater quality from mixing different proportions of groundwater from the Wianamatta Group shale and the Hawkesbury Sandstone.

The connectivity between the overlying shale and the Hawkesbury Sandstone is conceptualised as a consistent low volume of leakage from the above low permeability system into the below high permeability regional sandstone system. This assessment conservatively assumes a direct hydraulic connection between the base of the Wianamatta Group shale, and the underlying upper Hawkesbury Sandstone. Although it has also been interpreted from vertical head distributions that a desaturated zone in some areas could separate the two formations, in which case leakage from the shale into the underlying sandstone would be expected to already be occurring at a maximum flow rate.

The results are summarised in Section 11.2.1.

8.7.2 Water quality effects relating to reject materials

During the initial 12–18 months as the project is developed, the coal reject will be stored temporarily in a coal reject stockpile, next to the CPP, until enough void space is available underground and underground emplacement of fresh reject material can begin. The temporary stockpile will be placed underground once the last remaining panels have been mined-out – ie it will be maintained at surface for the duration of mining, but will not be added to once there is enough space underground to commence emplacement of freshly generated reject. The stockpile will consist of combined filtered fines and coarse reject. The stockpile will be progressively constructed, contoured and, when full, top-dressed and re-vegetated. An additional temporary reject stockpile may also be required at times when the underground reject emplacement operations are interrupted due, for example, to maintenance.

Stormwater controls will be implemented for the surface operations of the mine, including the coal reject stockpile location, to prevent the stockpile management area from receiving stormwater runoff from the surrounding areas. However the stockpile(s) will still be exposed to rainfall, a portion of which could infiltrate the stockpile, contribute to the oxidation of sulfide minerals present in the reject, and potentially mobilise acid and solutes generated from the water-reject interaction.

An assessment of the potential water quality effects from underground seepage from the temporary reject stockpile was included in the EIS utilising the KLC testing results.

Once the void is sealed and re-saturated with natural groundwater, it is expected the groundwater will chemically interact with the emplaced reject material. Any dissolved species leached from the reject material will be transported with the natural flow of groundwater in the direction of the prevailing hydraulic gradient in the coal seam. Accordingly, the anticipated change to groundwater quality arising from this process has been assessed through consideration of the geochemical testing results (specifically, kinetic leach column (KLC) testing) as a preliminary assessment included in the EIS, and subsequently post-EIS, via the use of additional hydrogeochemical models constructed in Geochemist's Workbench (GWB) and PHREEQC. The purpose of the additional modelling was to ultimately estimate the range of water qualities likely to exist in the PWD over time and to determine the likely water qualities resulting from co-disposed reject emplaced in the mined-out voids and interaction with the natural groundwater.

The methods used are described in the following sections.

i Preliminary assessment – underground emplacement of co-disposed reject

The results of KLC testing were used as a conservative indication of the resultant groundwater quality following interaction with the reject material emplaced in the void. Data were selected from the leach columns that were considered to provide the closest representation to the expected conditions in the subsurface. Namely, columns were selected that used fine reject material (for conservatism), leached with groundwater obtained from the Wongawilli seam, in fully saturated columns (ie as opposed to intermittently wet and dry columns). Data from two columns with these specifications were assessed: one column that was amended with limestone (KLC 24; as proposed for the reject material before emplacement), and one column without limestone amendment (KLC 22) to assess whether leaching from mine reject material could result in degrading the beneficial use status of the groundwater resources. The use of limestone is intended to increase the acid buffering capacity of the reject material. This will aim to retain a near-neutral pH and reduce mobilisation of metals in groundwater if sulfide minerals in the rejects are subject to oxidation.

A detailed methodology for the KLC tests is provided in RGS (2016). The columns were prepared with representative samples of reject material generated from drill core recovered from the Wongawilli Seam within and around the project area. The columns were then continuously saturated with groundwater sampled from the coal seam. Leachate samples were collected at the start of the test and then monthly for six months. Samples were submitted to ALS Environmental, a NATA-accredited analytical laboratory, to analyse pH, EC, major ions, speciated alkalinity, acidity, and metals.

The results of the KLC tests were compared to groundwater quality in the Wianamatta Group shale and the Hawkesbury Sandstone from the baseline monitoring program. This allowed for assessment of whether the leachate from the KLC tests had the potential to degrade the natural groundwater quality and, thus, potentially reduce its beneficial uses. An important assumption is that under post-mining conditions, once hydraulic pressures are re-established, the groundwater that comes in contact with the co-disposed reject in the void is likely to be groundwater flowing laterally through the coal seam, and will continue to flow laterally through the coal seam following contact with the reject materials. Hence, the receiving environment is considered to be the groundwater resources within the Wongawilli coal seam, down hydraulic gradient from the co-disposed reject materials. However, for conservatism, the KLC results were also compared to baseline Hawkesbury Sandstone water quality as this is the primary groundwater resource accessed in the project area and surrounds.

The results of the unamended column leaching test indicated leachate water quality exceeded one or more of the beneficial use criteria for a number of parameters that were generally also exceeded in the baseline groundwater quality; although the magnitude of the exceedance was substantially larger for certain metals in the leachate results. The final leachate pH of the unamended column was relatively low, indicating that acid generation was a potential concern.

The leachate quality from the limestone amended reject material was very favourable. pH was close to neutral throughout the test and leachate analyte concentrations were acceptable for most beneficial use criteria, including many that were originally exceeded in the baseline groundwater quality. Accordingly, the assessment indicates that limestone amendment of the reject material before emplacement in the mine void is likely to produce leachate that is indistinguishable from natural groundwater quality, and is considered unlikely to change the beneficial use status of the groundwater resources.

This preliminary assessment indicated that limestone amendment of the reject material prior to emplacement in the mine void is likely to produce leachate that is indistinguishable from natural groundwater quality.

ii Underground seepage from temporary reject stockpile runoff

As with the assessment of underground emplacement of coal reject material discussed in the preceding section, the results of KLC testing were used as a conservative indication of the water quality that would result from the interaction of rainfall with the stockpiled reject material. Data were selected from the leach columns that were considered to provide the closest representation of intermittent rainfall on a reject stockpile. Namely, columns were selected that used fine reject material (for conservatism), leached with deionised water as a proxy for rain water, in intermittently wet and dry columns that approximate the conditions of periodic rainfall on the reject stockpile with drying cycles between storms. Data from three columns with these specifications were assessed:

- one column containing only the composite reject material (KLC 10);
- one column that was amended with 1% limestone (KLC 16); and
- one column that was amended with 2% limestone (KLC 18).

Limestone increases the acid buffering capacity of the reject material, to prevent excessive generation of acidity and mobilisation of metals in infiltrating rain water if sulfide minerals in the reject are subject to oxidation.

The methods used to conduct the KLC tests are summarised in Section 8.7.2.

The results of the KLC tests were assessed relative to the appropriate water quality criteria for drinking water, primary industries and aquatic ecosystems. The results were also compared to groundwater quality in the Hawkesbury Sandstone from the baseline monitoring program (refer to Section 4.2), to assess whether the leachate from the KLC tests had the potential to degrade the natural groundwater quality and potentially reduce its beneficial uses if water from the reject stockpile drained into the underlying formation.

It is important to note that the assumption of monthly rainfall infiltration into the reject stockpile, particularly once it is top dressed and revegetated, is inherently conservative for the following reasons:

- Review of average rainfall and evaporation patterns in the study area presented in Coffey (2016a) indicated that a soil moisture deficit is likely to occur for eight months of an average year (from September to April), when pan evaporation exceeds the average monthly rainfall.
- The re-vegetation of the stockpile will also introduce transpiration as an added impediment to deep drainage of rainfall into the reject stockpile.
- The stockpile will be contoured to promote efficient surface runoff of rainfall falling on the stockpile, further reducing the potential for rainfall to infiltrate the reject stockpile.

The results are summarised in Section 11.2.2i.

iii Additional hydrogeochemical modelling

As discussed above, several hydrogeochemical models constructed in Geochemist's Workbench (GWB) and PHREEQC to build on the assessment presented in the EIS (Geosyntec 2016) by ultimately estimating the range of water qualities likely to exist in the PWD over time, and determining the likely water qualities resulting from co-disposed reject emplaced in the mined-out voids and interaction with the natural groundwater, in response to submissions raised in the EIS exhibition process. The objective of the modelling work was to predict whether the project would result in material changes in groundwater quality as a result of emplacement of co-disposed reject underground.

There were several sequential components (steps) to the modelling, including:

1. modelling stockpile seepage and runoff for the temporary reject stockpile, ROM pad, and product stockpiles;
2. modelling stormwater basins (SBs) and mine water dams (MWD) water qualities to determine the surface water contribution to the PWD;
3. modelling the range of PWD water qualities;
4. modelling reject slurry water qualities for two different scenarios;
    a) scenario 1: during mining (operation phase) – involving freshly produced reject material treated with 1% limestone mixed with PWD water to produce a reject slurry;
    b) scenario 2: after mining has completed – reject material treated with 2% limestone and stored in the temporary reject stockpile from the first year or so of mining until the end of mining before being mixed with PWD water to produce a reject slurry; and
5. modelling the interaction of reject slurry with natural groundwater in a mined-out void.

The modelling inputs are typically conservative by using 95th percentile rainfall and groundwater data.

Full details relating to the models conceptualisations, designs, assumptions, and outputs are included in Appendix J (RGS 2018). The methods and results for each model step are briefly summarised in the following sections. A summary of the results is discussed in Section 11.2.2.

a. Step 1: modelling stockpile geochemical response

This component of the modelling work was undertaken to provide an indication of the likely impacts of the mined/processed materials (reject, raw ore, and product coal) on the quality of water in the SBs and MWDs. It utilised the data from the static and kinetic leach column tests (RGS 2016) and rainfall data, and was undertaken using the hydrogeochemical modelling software GWB (Bethke 2016) and PHREEQC (Parkhurst and Appello 1999). The models compared measured water quality data with theoretically solubility limits of a number of minerals under different physical and chemical conditions (eg variations in pH, oxidation/reduction, and temperature), in order to deduce whether minerals would dissolve or precipitate from solution and ultimately determine the concentrations of elements in the water.

A seepage and runoff model was constructed for each of the stockpiles (temporary reject stockpile, product stockpile and ROM stockpile). The resulting seepage and runoff water qualities for each stockpile at a particular time intervals were then mixed using PHREEQC to provide a water quality of the contribution of water in each catchment. The results used for the subsequent step were geochemical trends, rather than absolute values.

The result for the potential acid forming (PAF) and non-acid forming (NAF) rejects in the temporary reject stockpile indicate seepage and runoff water qualities with a near-neutral pH (pH 7.73–8.22), which is maintained through mine's life. This is due to the addition of 2% limestone within the CPP circuit, which is added to neutralise any acid (eg sulfuric acid) which may be produced as a result oxidation of pyrite present in the coal reject. The major ion and metal/metalloid concentrations were moderate and generally reduced over time (ie 'flushed' from temporary stockpile over time). However, some seepage metal/metalloid concentrations, which are mobile under near neutral pH conditions, are predicted to be elevated and increase over time – eg aluminium, selenium and zinc.

The results for each of the ROM pad and the product stockpile models indicate that both are likely to produce acidic seepage and runoff water qualities through the mine's life, with estimated pH values ranging from pH 4.34 to 4.74 and pH 3.92 to 4.08 respectively. This reduced pH is due to the presence of pyrite in the materials, which oxidises to produce sulfuric acid without the presence of substantial acid buffering materials. Due to the lower pH of the seepage and runoff water, the concentrations of metals/metalloids will be higher than the temporary reject stockpile seepage/runoff water.

b. Step 2: modelling SB and MWD water qualities

This component of the modelling work was undertaken to identify the range of water qualities that would be in each SB and MWD.

Models were constructed using PHREEQC to represent each SB and MWD of the water management system (Section 2.3) to simulate the effects of mixing:

- rainwater falling directly on the catchment (but not intersecting a stockpile) with stockpile seepage and runoff water, to produce the individual SB or MWD water quality; and
- variable fractions of the resulting SB and MWD water qualities that then report to the PWD.

SB03 and SB04 collect runoff from areas with low risk of coal contact. As such, for simplicity, all SB03 and SB04 water was assumed to be clean and able to be released to Oldbury Creek and not contribute to the PWD. MWD08 was not included in this modelling work as it is provisional infrastructure and, based on the results of the water balance model (Section 8.2), is unlikely to be required.

The results of this modelling work indicate that the surface water input to the PWD will be composed of approximately 89% of water from SB01 and SB02, which includes 18% of seepage and runoff water from stockpiles. The SB01 and SB02 modelled water qualities are slightly acidic, ranging from pH 4.93 to 5.00 and pH 5.05 to 5.13 respectively. The concentrations of metals/metalloids were predicted to be diluted versions of the stockpile seepage/runoff water qualities derived in Step 1.

These results were then used to determine the quality of water inputs to the PWD in Step 3.

c. Step 3: modelling the range of PWD qualities

This component of the modelling work was undertaken using several PHREEQC and GWB models to identify the potential range of water quality in the PWD as a result of mixing the various input waters (including direct rainfall (not including evaporation), surface water from SBs and MWDs, and groundwater under atmospheric conditions) for select years. Select models were also used to assess the effects of climatic conditions on PWD water quality (eg temperature, rainfall and evaporation).

Groundwater contains higher partial pressures of dissolved carbon dioxide gas, so when it is exposed to surface conditions the water will 'loose' carbon dioxide gas to the atmosphere resulting in a change in water quality (due to becoming more oxidising, higher pH, and a decrease in alkalinity). In addition, iron and manganese concentrations (and some other metals/metalloids to a lesser degree) also decrease when groundwater is exposed to atmosphere, due to precipitations of certain minerals. These atmospheric adjustments were accommodated for in the models.

The resultant PWD modelled water qualities were predicted to be near neutral (pH 6.03–8.25) and to remain that way over the life of the mine. All components were within the range of baseline groundwater conditions for the Wongawilli Coal Seam, with the exception of chromium and nickel. The near neutral pH values and the concentrations of the metals/metalloids reflect the large proportion of near-neutral groundwater (48–78%) and non-coal contact rainfall/runoff (15–49%) within the PWD over the mine life, with only small proportions of slightly acidic water (1–4%) from SB01 and SB02.

d. Step 4 and 5: modelling reject slurry quality and interaction with groundwater

These components of the modelling work were undertaken using the 'React' module in GWB and parameter checks in PHREEQC. The purpose of these steps was to firstly (Step 4) estimating the range of reject slurry water quality for two different scenarios:

a) scenario 1: during mining (operation phase) – involving freshly produced reject material treated with 1% limestone mixed with PWD water to produce a reject slurry; and

b) scenario 2: after mining has completed – reject material treated with 2% limestone and stored in the temporary reject stockpile from the first year or so of mining until the end of mining before being mixed with PWD water to produce a reject slurry.

After modelling the slurry compositions, Step 5 involved investigating the placement of the reject slurry underground in a mined-out void and its interaction with the natural groundwater (baseline Wongawilli Coal Seam water quality data) to determine whether the potential for groundwater contamination. The models were run at select years of the mine operation to identify a representative range of water qualities.

The modelled reject water qualities for both scenario 1 and scenario 2 are near-neutral with a range of pH from 6.33 to 6.82 and pH 6.57 to 8.09, respectively. The slurry water qualities are generally comparable to baseline groundwater conditions.

The modelled groundwater conditions for scenario 1 and scenario 2, are near-neutral with a range of pH from 6.06 to 6.11 and 6.06 to 6.11, respectively, and are close to the initial average groundwater pH for the Wongawilli Coal Seam (pH 5.5).

Although, concentrations of some metals/metalloids in the modelled groundwater conditions exceed certain aspects of the generic guidelines (NHMRC 2016, ANZECC & ARMCANZ 2000), it is noted that the baseline groundwater quality in the Wongawilli Coal Seam also exceeds the same aspects of the respective guidelines. The resultant concentrations of metals/metalloids are generally lower than or equal to average baseline groundwater conditions for the Wongawilli Coal Seam. For example, for scenario 1, aluminium, arsenic, cadmium, chromium, copper, selenium and zinc typically decrease in concentration as a result of the reject slurry placement. Nickel is the only metal/metalloid that slightly increases above average baseline concentration of the Wongawilli Coal Seam as a result of reject slurry emplacement in scenario 1, but remains still within the range of baseline concentrations.

9 Assessment criteria

This chapter outlines the adopted assessment approach for project related impacts to water resources and water users. Potential impacts and assessment criteria are discussed.

The assessment of project-related impacts to water resources and water users considers the requirements of the *WMA 2000*, the relevant water sharing plans, the NSW Aquifer Interference Policy 2012 (the AIP), the Commonwealth Department of Environment *Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (DoE 2013) and the *Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (IESC 2015).

The assessment also considers consultation undertaken with the NSW Government through the submissions process. Consultation on assessment criteria expectations were discussed with the NSW Department of Planning, the NSW DI Water and Water for NSW.

9.1 Compliance with water licensing requirements

This project has been assessed against the licensing requirements of the WMA 2000, and of the relevant water sharing plans.

9.2 Potential impacts and water users

Potential impacts to water resources and water users due to the project are as follows:

- the construction and use of site infrastructure;
- interception of groundwater;
- pumping of water behind the bulkheads; and
- on-site water storage.

Changes to the baseline conditions caused by these activities are termed 'direct impacts'. Direct impacts in relation to groundwater and surface water could be changes:

- in surface water quantity, including changes to surface water flow and levels, and water availability;
- to surface water quality, including changes in salinity and salt balance, and concentrations of other important water quality parameters (such as pH, major cations and anions and dissolved metals);
- to flooding regime;
- in groundwater quantity, including changes to groundwater levels/pressures and flow; and
- in groundwater quality, including changes in salinity and salt balance, and concentrations of other important water quality parameters (such as pH, major cations and anions and dissolved metals).

According to the *Significant impact guidelines* (DoE 2013), the direct impacts listed above would be classified as significant if they "are of sufficient scale or intensity as to significantly reduce the current or future utility of the water resource for third party users, including environmental and other public benefit outcomes, or to create a material risk of such reduction in utility occurring" (p16).

Users identified that would be potentially affected by mining water impacts in the region include:

- high priority ecosystems that rely on groundwater (GDEs as listed in a water sharing plan);
- ecosystems that potentially rely on groundwater;
- watercourses, drainage lines, creeks and swamps that receive baseflow;
- groundwater users (private landholder bores and associated infrastructure);
- surface water users; and
- stream environments.

9.3 Adopted criteria

Based on the discussion in Chapter 3 about assessment requirements outlined in the relevant policies and guidelines, site appropriate assessment criteria have been developed for both surface water and groundwater-related impacts. These are presented in the following sections.

In addition, reference to the *Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals, including completion of the information requirements checklist* has also been considered in this assessment. The completed checklist is included in Appendix B.

9.3.1 Surface water

i Water quantity, including flow, levels and availability

Potential impacts associated with the change in flow regime as a result of the project could include:

- erosion of stream banks from increases in stream energy as a result of sporadic water releases from the operations;
- decreased access for water users as a result of decreased streamflow due to reduced catchment areas and intercepted baseflow; and
- decreased availability of water for instream and riparian ecosystems as a result of decreased streamflow due to reduced catchment area and intercepted baseflow.

Criteria for assessing impacts to water quantity are:

- percentage reduction in yield in surface water quantity; and
- increase in number of no-flow days.

ii Water quality

To assess whether the project and associated treatment measures will have a NorBE on surface water quality, pollutant loads (for both the existing conditions (pre-development) and operational phase (post-development) and concentrations the MUSIC model predicted have been assessed against the following criteria outlined in the WaterNSW standards (SCA 2012b):

- The mean annual pollutant loads for the post-development case (including mitigation measures) must be 10% less than the pre-development case for TSS, TP and TN.

- Pollutant concentrations for TP and TN for the post-development case (including mitigation measures) must be equal to or better compared to the pre-development case for between the 50th and 98th percentiles over the five-year modelling period when runoff occurs. Periods of zero flow are not accounted for in the statistical analysis as there is no downstream water quality change. To demonstrate this, comparative cumulative frequency graphs, which use the Flow-Based Sub-Sample Threshold for both the pre- and post-development cases, must be provided. As meeting the pollutant percentile concentrations for TP generally also meets the requirements for TSS, cumulative frequency analysis is not required for TSS. Cumulative frequency is also not applied to gross pollutants.

A third criterion is provided in the WaterNSW standards (2012); however, it only applies to developments where the catchment is more than 70% impervious. This is not the case for the catchments that may release water to the environment (SB03 and SB04, which are 57% and 44% impervious respectively). As such, this criterion does not apply.

To assess the reduction of baseflow and potential dust deposition on surface water quality, the relevant ANZECC and ARMCANZ, and ADW guidelines (as per the *National Water Quality Management Strategy Guidelines* (ANZECC & ARMCANZ (2000) and NHMRC (2016)) and water quality objectives recommended by *Healthy Rivers Commission into the Hawkesbury-Nepean River* (HRC 1998) have been used as criteria to compare against both baseline surface water quality and groundwater quality data to determine whether a neutral or beneficial effect is achieved as a result of the project.

iii Flooding

Changes to the flood regime may affect local land users within and next to the project area. The following acceptability criteria are used to assess the flooding impact at different land uses (for flooding events up to the 100 year ARI):

- Flood level:
    - Buildings – less than 50 mm increase in flood level (afflux) if the building is already flooded and no new flooding of buildings not currently flooded due to proposed works unless owner’s consent is obtained;
    - Public roads/rail – less than 100 mm afflux if the road/rail is already flooded and no new flooding of public roads/rail that are not currently flooded; and
    - Private properties – less than 250 mm afflux.

- Flood velocity:

  - No increase in velocity above a threshold of 1.5 m/s where existing conditions' velocities are below the threshold. No more than a 10% increase in velocity where existing conditions velocities are above this threshold.

These criteria have been developed with the consideration of the Wingecarribee Local Environment Plan (WSC 2010), the *Australian Rainfall and Runoff – A guide to flood estimation* (IEA 1987), *Floodplain Development Manual* (DIPNR 2005), and *Practical Consideration of Climate Change* (DECC 2007).

9.3.2 Groundwater

AR 13: A detailed assessment against the NSW Aquifer Interference Policy (2012) using DPI Water's assessment framework

The project has been assessed in detail against the minimal impact thresholds defined in the AIP, and DI Water's assessment framework has been completed and is included in Appendix C. The assessment framework table has been completed in detail by copying across relevant aspects of this Water Assessment. This is in accordance with the Minister's requirements for approval and administration of the WMA 2000. Impacts to groundwater are assessed via the consideration of high priority groundwater dependent ecosystems, high priority culturally significant sites, and landholder bores.

The AIP divides groundwater sources into 'highly productive' or 'less productive' based on the yield (>5 L/s for highly productive) and water quality (<1,500 mg/L total dissolved solids for highly productive). Thresholds are set in the AIP for the different groundwater sources for the different minimal impact considerations.

Based on DPI Water's mapped areas of groundwater productivity in NSW (NOW 2012b), the project is considered to be within 'highly productive' porous and fractured rock source. The applicable minimal impact considerations are shown in Table 9.1.

Cumulative variation in the water table and/or pressure head decline criteria in the AIP are for 'post-water sharing plan' variations only. The cumulative assessment has been conducted and results are also included in this document. However, for the assessment of impacts as per the AIP, the project influenced drawdown (only) is relevant. Other stresses within the system (eg landholder bore pumping and Berrima Colliery drainage) were present 'pre-water sharing plan' and are considered relatively constant; their influences on the groundwater systems are therefore excluded from the assessment under the AIP.

Table 9.1 Minimal impact criteria for 'highly productive' porous rock water source

Impact level	Water table	Water pressure	Water quality
Level 1 impact (ie less than minimal)	1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.
Level 2 impact (ie greater than minimal)	2. If more than 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan then appropriate studies (including the hydrogeology, ecological condition and cultural function) will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.	2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.	2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Notes: Source: AIP 2012.

1. 'post-WSP'– refers to the period after the first WSP in the water source begins, including the highest pressure head (allowing for typical climatic variations) within the first year after the first WSP begins.

2. 'Appropriate studies' on the potential impacts of water table changes greater than 10% are to include an identification of the extent and location of the asset, the predicted range of water table changes at the asset due to the activity, the groundwater interaction processes that affect the asset, the reliance of the asset on groundwater, the condition and resilience of the asset in relation to water table changes and the long-term state of the asset due to these changes.

3. All cumulative impacts are to be based on the combined impacts of all 'post-water sharing plan' activities within the water source.

The project, in accordance with the AIP minimal impact criteria, is assessed to trigger 'Level 2 impact' for drawdown in landholder bores and a 'Level 1' impact for in groundwater quality.

Based on the AIP definition of minimal harm criteria and the associated 'Levels' of impact there is one definition of minimal harm criteria category, two levels of impact, and three categories into which the impacts are then classified into for consideration of actions required. The impact levels are summarised in Table 9.2 to provide clarity as to how the project has been assessed under the AIP.

Table 9.2 Impact levels and actions as defined in the AIP

Level of impact	Definition	Action required
Less than Level 1 Less than minimal impact criteria	Impacts that are predicted to be less than the 'minimal impact criteria'	Impacts considered acceptable
Level 1 - Slightly greater than minimal impact criteria	Impacts are in excess of the Level 1 minimal harm criteria but no more than the accuracy of an otherwise robust model	Impacts within the range of acceptability Additional monitoring required and potential additional mitigation and remediation during operation
Level 2 Greater than minimal impact criteria	Impacts are in excess of Level 1 by more than the accuracy of an otherwise robust model	Additional studies required. Impacts then considered within the range of acceptability if the additional studies can demonstrate that the long term viability of the resource is not compromised

Hume Coal agrees with the classification of Level 2 impact for drawdown in landholder bores, and assumed this classification in the EIS. Hume have taken a conservative approach and included all bores that are impacted by 2m (ie no discount for model accuracy was made) and these 93 bores are all included in the detailed make good assessment. The Make Good Assessment which forms the 'additional studies required' by the AIP, to demonstrate that the long term viability of the resource of the water dependent asset is not compromised.

The triggering of minimal impact criteria (formerly referred to as 'minimal harm') does not mean a project cannot be approved under the NSW legislation, but it does mean that additional studies, conditions and mitigation measures may be required for the project before it is approved. The reference to the precautionary principle as being triggered if the proposal poses both a 'threat or irreversible damage to the environment' and 'scientific uncertainty'. The Hume Coal project is assessed as not meeting either of these, with full recovery of groundwater pressures over a relatively short period of time (ie compared to many other mines that have recovery times in the hundreds and thousands of years), and the very detailed uncertainty analysis undertaken in accordance with detailed the draft uncertainty analysis guidelines released by the IESC. The uncertainty analysis reduced the uncertainty of the project significantly, with detailed discussion of this in Appendix F (HydroSimulations 2018).

9.4 Cumulative impacts

Cumulative water-related impacts have been assessed for the project within the following context:

- existing pre-project cumulative drawdown of existing works(baseline);
- cumulative drawdown of the project and of existing works (project plus baseline);
- the drawdown interference of the project only (ie removing other existing impacts); and
- the drawdown influence of the project, and due to other existing works and potential future projects in planning process.

For surface water, the Berrima Rail Project is the only relevant additional project to consider for cumulative impacts.

For groundwater, the existing works include landholder bore pumping and the Berrima Colliery. The groundwater model considers the combined baseline (landholder pumping and Berrima Colliery and the project effects, as well as the effects of the project only (ie not including baseline landholder pumping and the Berrima Colliery). The AIP assessment criteria require proponents to consider post water sharing plan impacts. As the landholder pumping and Berrima Colliery effects are already considered as part of the baseline, the project's influence has been used for assessment against the AIP criteria.

As described in Chapter 5 of the *Hume Coal Project EIS* (EMM 2017a), a number of industrial, extractive and manufacturing facilities occur in the locality. The proposed or recently approved developments in the region include:

- Berrima Cement Works (Mod 9 use of waste derived fuels);
- New Berrima Clay/Shale Quarry;
- Green Valley Sand Quarry; and
- Sutton Forest Quarry.

However, there are no water-related aspects of these projects that would contribute to cumulative drawdown or water quality changes for the project. For the surface water assessment the only relevant project that is considered as part of the cumulative assessment is the Berrima Rail Project (EMM 2017d), which has been considered both independently and cumulatively with the project in the *Berrima Rail Project Environmental Impact Statement* (EMM 2017d).

For groundwater, there are no potential future projects in the planning process that would influence the assessment of the project.

10 Surface water assessment

This chapter outlines the results of the impact assessments undertaken for project-related impacts to surface water resources and water users.

SEAR 1: As assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's, DPI's and Water NSW requirements and recommendations

SEAR 2: An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users

AR 4: Analysis of impacts of groundwater interference and drawdown on water quality, water flow and aquatic and riparian environments within and downstream of all waterways within the proposal area

AR 14: Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, wetlands, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts

AR 20: Assessment of whether the activity may have a significant impact on water resources, with reference to the Commonwealth Department of Environment Significant Impact Guidelines

AR 21: If the activity may have a significant impact on water resources, then provision of information in accordance with the Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals, including completion of the information requirements checklist

AR 22: A detailed assessment of riparian and watercourse impacts, particularly with respect to watercourse crossings. The project should be designed to minimise impacts on watercourses and riparian land, and must have regard to the Department of Primary Industries' Guidelines for Controlled Activities on Waterfront Land – in particular the guideline on watercourse crossings.

AR 29: The EIS should take into account the following policies (as applicable):
· NSW Guidelines for Controlled Activities on Waterfront Land (NOW, 2012)
· NSW Aquifer Interference Policy (NOW, 2012)
· Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW, 2012)
· Australian Groundwater Modelling Guidelines (NWC, 2012)
· Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals (IESC, 2014)
· Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments - impacts on water resources (Australian Govt. 2014)
· NSW State Rivers and Estuary Policy (1993)
· NSW Wetlands Policy (2010)
· NSW State Groundwater Policy Framework Document (1997)
· NSW State Groundwater Quality Protection Policy (1998)
· NSW State Groundwater Dependent Ecosystems Policy (2002)
· NSW Water Extraction Monitoring Policy (2007)
· Groundwater Monitoring and Modelling Plans - Information for prospective mining and petroleum exploration activities (NOW, 2014)
· NSW Code of Practice for Coal Seam Gas Well Integrity (DTIRIS 2012)
· NSW Code of Practice for Coal Seam Gas Fracture Stimulation (DTIRIS 2012)

AR 45: *Assessment of predicted impacts on the following:*

- *flow of surface water (including floodwater), sediment movement, channel stability, and hydraulic regime*
- *water quality*
- *flood regime*
- *dependent ecosystems*
- *existing surface water users*
- *planned environmental water and water sharing arrangements prescribed in the relevant water sharing plans*

AR 58: The results of any models or predictive tools used.

AR 59: Where potential impact/s are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on:

- *Any proposed monitoring programs, including water levels and quality data. Reporting procedures for any monitoring program including mechanism for transfer of information*
- *An assessment of any groundwater source/aquifer that may be sterilised from future use as a water supply as a consequence of the proposal*
- *Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category)*
- *Description of the remedial measures or contingency plans proposed*
- *Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period*

AR 62: A detailed description of all potential impacts on the watercourses/riparian land

AR 63: A detailed description of all potential impacts on the wetlands, including potential impacts to the wetlands hydrologic regime; groundwater recharge; habitat and any species that depend on the wetlands

AR 68: The EIS must describe background conditions for any water resource likely to be affected by the development, including:
a. Existing surface and groundwater.
b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.
c. Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters.
d. Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.

AR 69: The EIS must assess the impacts of the development on water quality, including:
a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.
b. Identification of proposed monitoring of water quality.

AR 70: The EIS must assess the impact of the development on hydrology, including:

a. Water balance including quantity, quality and source.
b. Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas.
c. Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems.
d. Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (eg river benches).
e. Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water.
f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options.
g. Identification of proposed monitoring of hydrological attributes.

AR 75: If WQO's cannot be met for the project, demonstrate that all practical options to avoid water discharge have been implemented and outline any measures taken to reduce the pollutant loads where a discharge is necessary. Where a discharge is proposed, analyse the expected discharges in terms of impact on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm.

AR 79: A full description of the development including those aspects which have the potential to impact on the quality and quantity of surface and groundwaters at and adjacent to the site, including:

- *the mining proposal and mine layout*
- *the location, mapping and geomorphology of all creeks and water resources overlying and adjacent to the proposed mining area*
- *the hydrogeological fluxes between surface and groundwaters, including the filling of pine feather voids*
- *the location, management and storage of all hazardous materials- the disposal of wastes from the treatment of mine waters in the mine water treatment plant*
- *the management of dirty water from the washing and preparation of coal for transport*
- *the location, sizing and description of all water quality management measures*
- *the location and description of all water monitoring points (surface and ground waters)*
- *on-site domestic (sewage) wastewater management*

AR 80: A detailed assessment of the development on water resources which considers the design, construction, operational and decommissioning phases and have regard for operation during periods of wet weather and include:

- *details of measured and predicted coal mine, preparation area and stockpile area performance with respect to water quality management*
- *details of measures proposed to be adopted to offset impacts associated with construction activities eg earthworks, vegetation clearing and track construction*
- *impacts on overlying and adjacent creeks and water resources within risk management zone associated with subsidence*
- *impact of the proposed on-site domestic (sewage) wastewater management and associated effluent disposal area*
- *pre-development and post development run off volumes and pollutant loads from the site*
- *details of the measures to manage site water associated with processing coal and coal reject, general stormwater runoff and any human activities likely to affect water quality at the site, and how neutral or beneficial effect on water quality (NorBE) principles will be assessed and applied*
- *assessment of the impacts of the development on receiving water quality and volume, both surface and groundwater including from the filling of pine feather voids and associated impact on interaction and baseflows of surface waters*
- *details of the structural stability, integrity, ongoing maintenance and monitoring of all site water management measures including dams over the life of the project*
- *details of proposed monitoring of groundwater levels, surface water flows, groundwater and surface water quality, along with information as to how the proposed monitoring will be used to monitor, and, if necessary, mitigate impacts on surface water and groundwater resources*
- *the principles outlined in the 'Managing Urban Stormwater - Soils and Construction - Mines and Quarries' Manual prepared by the Department of Environment and Climate Change (2008).*

AR 82: An assessment of the relevant impacts of the action on water resources including:

- *a description and detailed assessment of the nature and extent of the likely direct, indirect and consequential impacts, including short term and long term relevant impacts*
- *a statement whether any relevant impacts are likely to be known, unpredictable or irreversible, and analysis of the significance of the impacts*
- *any technical data and other information used or needed to make a detailed assessment of the impacts*

AR 85: The assessment of impacts should include information on:

- *any substantial and measureable changes to the hydrological regime of the water resource, for example a substantial change to the volume, timing, duration or frequency of ground and surface water flows*
- *the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the water resource being seriously affected*
- *substantial and measureable change in the water quality and quantity of the water resource – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland; or water temperature that may adversely impact on biodiversity, ecological integrity, social amenity or human health*

10.1 Water quantity

10.1.1 Introduction

Surface water quantity assessment results are presented and discussed in detail in Appendix D (WSP PB 2016c). The results and impact assessment are summarised in the following sections.

Flow and yield impacts have been assessed for the following two climate sequences:

- Climate sequence 58 (1946 to 1964) – wettest sequence: maximum volume of water treated and released to Oldbury Creek of the 107 realisations simulated in the water balance model.
- Climate sequence 103 (1991 to 2009) – driest sequence: lowest simulated rainfall-runoff volume of the 107 realisations simulated in the water balance model.

10.1.2 Project activities with potential to affect surface water flows

AR 3: Analysis of impacts of subsidence upon water flow within and downstream of all waterways within the proposal area.

The natural flow regimes of Medway Rivulet, Oldbury Creek and their tributaries are highly disturbed; the catchments have been extensively cleared for agriculture and multiple instream storages, which impede the natural flow, have been constructed along the length of the streams. The project has the potential to further impact on the flow regime of local streams due to:

- reduction in catchment area and runoff associated with the water management system for the project;
- releases from selected stormwater basins (SB03 and SB04) following containment of the first flush within the water management system; and
- interception of natural baseflow to streams associated with depressurisation of groundwater systems during underground mining.

These activities are discussed further in the following sections.

The underground mine workings will result in negligible impacts on the flow and geomorphology in overlying catchments. Worst case estimates of subsidence associated with the proposed low impact, non-caving mining method predict 'imperceptible' surface disturbance due to mining, with predicted settlement of less than 20 mm (EMM 2017e; Mine Advice 2016). Such disturbances are low enough in magnitude as to not affect streamflow regimes or geomorphology.

The mine water management system is detailed in Section 2.3.2, and is summarised as:

- runoff from undisturbed areas will be diverted around or away from the infrastructure and remain within the natural catchment;
- surface water runoff from disturbed areas will be collected in stormwater basins (SBs) and mine water dams (MWDs) and reused as much as possible as part of the operational demands; or
- runoff from disturbed areas not in direct contact with coal (SB03 and SB04 catchments) may be released to Oldbury Creek after first flush and water quality criteria have been met;
- water in excess of operational needs will be pumped underground into the sealed void areas; and
- excess water on site (likely in last few years of mining) to be treated by the provisional WTP at MWD08 before controlled release at Oldbury Creek. The water balance (Section 8.2) demonstrates that this is unlikely to be required and, therefore, this scenario has not been assessed.

i Reduction in catchment area

Containment and reuse of water from operational areas of the project will result in a reduction in catchment area and runoff to local streams. A reduction in runoff has the potential to alter the flow regime of the stream.

The catchment areas associated with the project storages are provided in Table 10.1. The reduction in catchment area for Medway Rivulet sub-catchment (not including Oldbury Creek) is estimated to be 26.6 ha, which represents 0.2% of the catchment area to its confluence with Wingecarribee River. A reduction in catchment area for Oldbury Creek is estimated to be 67.6 ha, which is 5.0% of the total catchment area. The Medway Rivulet and Oldbury Creek sub-catchments are shown on Figure 2.4.

Table 10.1 Reduction in catchment areas associated with project dams and basins

Dam/ basin	Description	Dam / basin catchment area (ha)	Existing area drains to (pre-project)	Total catchment area (ha)	% reduction in catchment area
SB03	Captures runoff from administration and workshop area	5.91	Medway Rivulet (including Wells Creek and Belanglo Creek sub-catchments, not including Oldbury Creek sub-catchment)	10,909	0.2%
SB04	Captures runoff from mine road and conveyor embankment	14.73			
MWD05	Captures runoff from north of Medway Rivulet – overland conveyor no. 1	0.64			
MWD06	Captures runoff from south of Medway Rivulet – conveyor portal	2.69			
MWD07	Captures runoff from ventilation shaft pad dam	2.60			
SB01	Captures runoff from product stockpile area	26.36	Oldbury Creek	1,355	5.0%
SB02	Captures runoff from CPP and ROM areas	22.64			
MWD08 (provisional)	Stores water before treatment and release to Oldbury Creek	0.27			
PWD	Stores water pumped from SBs and MWDs and underground mine sump dewatering	18.28			
Total Medway Rivulet catchment (including Oldbury Creek)		94.12	Medway Rivulet and Oldbury Creek	12,264	0.8%

ii Release from SB03 and SB04 to Oldbury Creek

The revised water balance model developed for the project (Section 8.2) was used to predict the volume of release from SB03 and SB04, once first flush criteria have been met. Details of the releases from SB03 and SB04 are presented in Appendix D (WSP 2018). Total releases for the entire 19 year period are expected to be in the range of 112 ML to 277 ML from SB03, with a maximum annual release of 31 ML/yr; and 87 ML to 302 ML from SB04, with a maximum annual release of 41 ML/yr.

iii Depressurisation of groundwater systems from underground mining

The data available and hence the conceptual model for the project area demonstrates that most drainage lines are gaining streams and receive baseflow from groundwater (Chapter 7). In dry conditions, where surface rainfall and runoff is insufficient to sustain substantial flow, the smaller tributaries may receive groundwater as baseflow in persistent unconnected or connected pools. Many of the drainage lines are gaining due to shallow groundwater which may or may not be connected to deeper regional systems. A clear example of this is the shallow (sometimes perched) water in basalt and shale that sustains baseflow for most up-catchment streams.

As a result of mining, some drainage lines (mostly those gaining streams via the regional water table) will potentially receive less baseflow. This will be particularly noticeable during low flows, or dry conditions. The overall impact to baseflow is considered insignificant and results are presented in Section 11.1.3.

10.1.3 Flow impacts

Flow duration curves for the wet and dry climate scenarios in the Medway Rivulet sub-catchment (excluding the Oldbury Creek sub-catchment) are presented in Figure 10.1. The flow duration curves for the operation case include:

- reduction in catchment area associated with the project water management system basins and dams; and
- reduction of baseflow to Medway Rivulet and its tributaries as a result of underground mining.

The flow duration curves on the right in Figure 10.1 include low flow discharges from the Moss Vale sewage treatment plant (STP) located on Whites Creek for both the existing and operation cases. The STP discharges are approximated at 2.3 ML/day based on effluent data provided by Wingecarribee Shire Council.

The results show that with constant low flow discharges from the Moss Vale STP, the flow regimes in Medway Rivulet for the existing and operation cases are similar, consistently exceeding flow of 1 ML/day and zero low flow days. If the constant discharges from the Moss Vale STP are excluded, changes in the low flow regime below about 5 ML/day may occur and the number of no flow days may increase by approximately 25% under the wet climatic scenario and by about 35% under the dry climatic scenario. These results are slightly increased compared to that presented in the EIS (WSP PB 2016c), as they have been modified to include the baseflow reduction predictions from the revised numerical groundwater model (HydroSimulations 2018). Yield impacts for Medway Rivulet are discussed in Section 10.1.3.

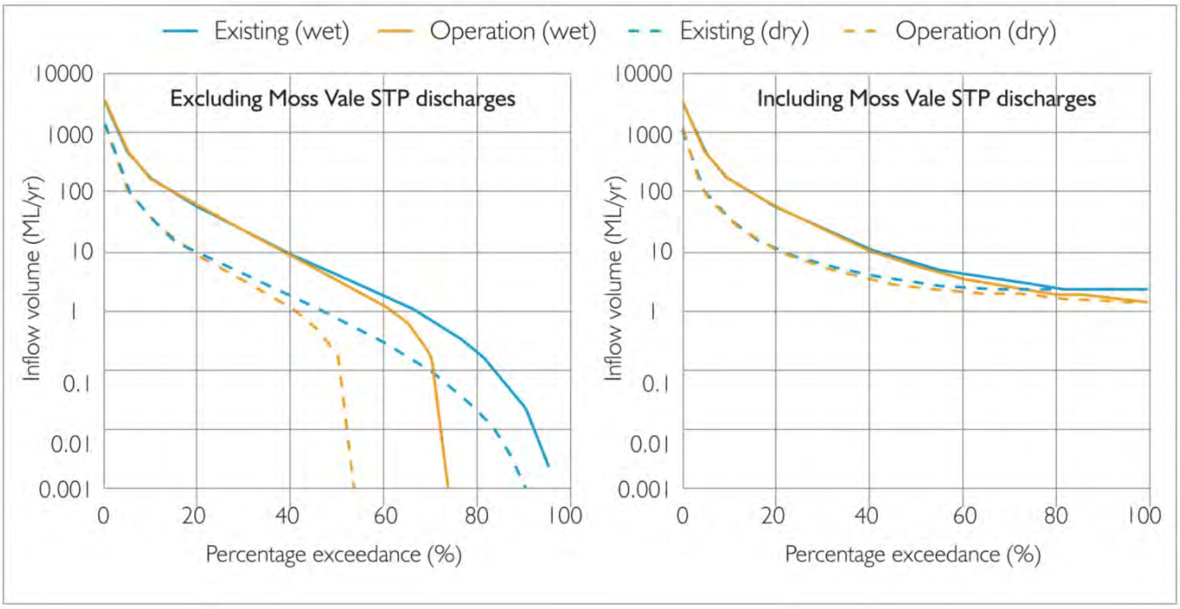


Figure 10.1 Flow duration curves for Medway Rivulet for wet and dry climate sequences

Flow duration curves for the wet and dry climate scenarios in Oldbury Creek are presented in Figure 10.2. The flow duration curves for the operation case include:

- reduction in catchment area associated with the project water management system basins and dams;
- release of water from SB03 and SB04 after the first flush; and
- reduction of natural baseflow to Oldbury Creek as a result of underground mining.

The flow duration curves for Oldbury Creek with and without constant low flow discharges from the Berrima STP are approximately the same. This is because discharges from the Berrima STP to Oldbury Creek are low, at about 0.2 ML/day.

The results show that alteration of the flow regime in Oldbury Creek during operation of the mine will be minor compared to pre-mining conditions, with releases from SB03 and SB04 to some extent offsetting changes to flow associated with a reduction in catchment for project storages and interception of baseflow associated with depressurisation of groundwater systems. Flow modification in Oldbury Creek is discussed in Section 5.4.2.2.

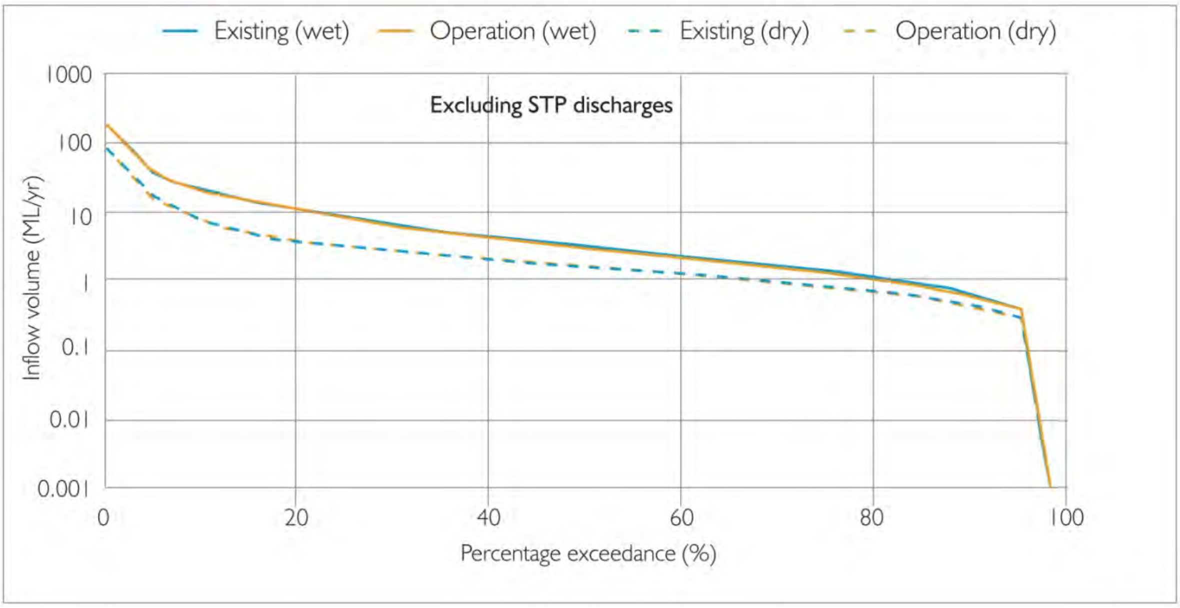


Figure 10.2 Flow duration curves for Oldbury Creek for wet and dry climate sequences

10.1.4 Yield impacts

i Medway Rivulet Management Zone and Medway Dam

The change in streamflow due to the project, with and without STP discharges, has been estimated for wet and dry climate sequences to assess the change in surface water yield for:

- the Medway Dam catchment;
- the Medway Rivulet catchment, excluding the Oldbury Creek sub-catchment;
- the Oldbury Creek sub-catchment; and
- the Medway Rivulet Management Zone.

The catchments are shown in Figure 2.4 and results are shown in Table 10.2. The results indicate that under wet conditions, the project will result in a 0.9% reduction in yield for the Medway Rivulet Management Zone, and under dry conditions the project will result in a 1.6% reduction in yield. Locally, yield loss will be greater in the Oldbury Creek sub-catchment, with up to a 4.3% reduction in yield under wet conditions and up to a 4.5% reduction in yield under dry conditions, however there are no known or probably stream water users in this sub-catchment other than the farming operation affiliated with Hume Coal properties.

Table 10.2 Yield impacts for Medway Rivulet

Catchment	Included sub-catchments	Impact due to	Yield impact (% reduction)	
			Wet climate sequence	Dry climate sequence
Medway Dam	Medway Rivulet Wells Creek	Reduction in catchment area due to project storages (SB03, SB04, MWD05, MWD06 and MWD07) Intercepted baseflow for Medway Rivulet and Wells Creek	0.3%	0.3%
Medway Rivulet at the confluence with Wingecarribee River (excluding Oldbury Creek)	Medway Rivulet Wells Creek Belanglo Creek	Reduction in catchment area due to project storages (SB03, SB04, MWD05, MWD06 and MWD07) Intercepted baseflow for Medway Rivulet, Wells Creek and Belanglo Creek	0.6%	1.2%
Oldbury Creek	Oldbury Creek	Reduction in catchment area due to project storages (SB01, SB02, MWD08 and PWD) Releases from SB03 and SB04 after a first flush Intercepted baseflow for Oldbury Creek	4.3%	4.5%
Medway Rivulet Management Zone		Reduction in catchment area due to project storages (SB01, SB02, SB03, SB04, MWD05, MWD06, MWD07, MWD08, and PWD) Releases from SB03 and SB04 to Oldbury Creek after a first flush Intercepted baseflow for Medway Rivulet, Wells Creek, Belanglo Creek and Oldbury Creek	0.9%	1.6%

ii Other catchments

Reduction in yields, occurring as a result of baseflow reduction, for the Lower Wingecarribee River, Upper Wingecarribee River, Lower Wollondilly River, Bundanoon Creek and Nattai River management zones are shown in Table 5.3. These calculations incorporated baseflow reduction predictions from the revised numerical groundwater model (HydroSimulations 2018). Refer to Section 8.3 for method.

Results from the yield assessment indicate that under wet conditions, the loss of baseflow will result in a 0.02% reduction in yield for the Lower Wingecarribee River catchment, and under dry conditions the loss of baseflow will result in a 0.05% reduction in yield. The reduction in yield for the Upper Wingecarribee River, Lower Wollondilly River, Bundanoon Creek and Nattai River management zones are all predicted to be several orders of magnitude smaller.

Table 10.3 Reduction in yield due to reduction in baseflow – Lower Wollondilly and Bundanoon Management Zones

Water Management Zone	Catchment area (ha)	Reduction in yield (% reduction)	
		Wet conditions	Dry conditions
Lower Wingecarribee River	50,546	0.02%	0.05%
Upper Wingecarribee River	13,419	0.0009%	0.002%
Bundanoon Creek	31,947	0.00009%	0.0002%
Nattai River	44,697	0.000008%	0.00003%
Lower Wollondilly River	265,763	0.00004%	0.0001%

10.1.5 Baseflow reduction climate sensitivity analysis

In the baseflow reduction sensitivity analysis for the yield assessment, baseflow reductions for the Medway Rivulet and Oldbury Creek catchments generated from the numerical groundwater model climate scenario analysis (wet, dry, and average climate scenarios) were used with the equivalent climate scenario in the yield assessment for comparison.

The results from the wet and dry scenarios are compared to the average scenario in terms of percent change in percentage reduction in yield in Table 10.4.

The wet climate scenario results in slightly more yield reduction than the average climate scenario and the dry climate scenario results in slightly less yield reduction than the average climate scenario for all catchments. This is expected as the predicted baseflow reduction for the wet climate scenario is slightly higher than the average climate scenario, which is slightly higher, again, than the dry climate scenario. The total volume of flow in the drainage lines is increased in the wet climate scenario, so these predicted increased reductions in yield are considered inconsequential.

Table 10.4 Comparison of wet and dry climate scenario yield reductions compared to average climate scenario

Catchment	Sub-catchments included	Change in reduction in yield (% change in reduction of yield)	
		Wet climate scenario compared to average climate scenario	Dry climate scenario compared to average climate scenario
Medway Dam	Medway Rivulet Wells Creek	-0.004%	+0.08%
Medway Rivulet at the confluence with Wingecarribee River (excluding Oldbury Creek)	Medway Rivulet Wells Creek Belanglo Creek	-0.008%	+0.2%
Oldbury Creek	Oldbury Creek	-0.0004%	+0.03%
Medway Rivulet Management Zone		-0.007%	+0.2%

10.2 Surface water quality

AR 73: Estimate the chemical composition and load of chemical and physical stressors and toxicants in any discharge with ANZECC 2000 trigger values for the various environmental values of the waterway

AR 77: Demonstrate that the proposed measures to capture and treat water impacted by the proposal will have no impact on water quality within the Wingecarribee River

AR 78: Specifically address clauses 9(1) and (2) and 10(1) of State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011. In particular, the EIS must describe and justify how the development would have a neutral or beneficial effect on water quality

10.2.1 Introduction

Surface water quality assessment results are presented and discussed in detail in Appendix D (WSP 2018). The results and assessment are summarised in the following sections.

10.2.2 Project activities with potential for water quality variation

During the project's construction and rehabilitation phases, the following activities that have the potential to vary water quality:

- earthworks, which have the potential to cause erosion and sedimentation of local waterways;
- use of vehicles and heavy machinery, storage of fuels, oils and lubricants and equipment maintenance, which have the potential to cause hydrocarbon contamination of local waterways; and
- a construction camp, which has the potential to contaminate local waterways with general waste and sewage.

The construction and rehabilitation phases of the project will be short-term and the potential variation in surface water quality can be suitably managed through the preparation and implementation of site environmental management plans (discussed in Chapter 13); these have not been assessed in this report. Sediment dams required during construction will be designed in accordance with the *Managing Urban Stormwater– Soils and Construction– Volume 2E Mines and Quarries* (DECC 2008) and managed under a Soil and Water Management sub-plan (which incorporates sediment and erosion control measures).

During the project's operation phase, most project activities will be managed as part of the mine water management system. Refer to Section 2.3.2 and 10.1.2 for further details.

During the project's operation phase, project activities outside the mine water management system with the potential to vary water quality include:

- vehicle and heavy machinery movements on access roads, resulting in potentially contaminated runoff to local waterways (TSS and hydrocarbons);
- operation of the WTP, if required (water balance modelling demonstrates treatment and release of water will not be required);
- ongoing resource definition activities along with geotechnical and engineering testing and fieldwork for detailed design;
- depressurisation of the groundwater systems during underground mining resulting in a reduction in baseflow to streams and possible increased concentrations in some constituents; and
- coal dust deposition in surface water catchments.

Potential impacts to surface water quality associated with the first three activities listed above can be suitably managed through implementing a project-specific environmental management plan (discussed in Chapter 13).

The following project activities have been further assessed for resulting in potential water quality variation:

- releases from SB03 and SB04 (when first flush and water quality criteria are met) to Oldbury Creek;
- runoff from access roads outside of the mine water management system;
- depressurisation of groundwater systems from underground mining; and
- coal dust deposition in surface water catchments.

The change in the surface water salt balance as a result of the project is expected to be negligible, as the project is predicted to be a zero discharge site for most of the time. Releases to Oldbury Creek would only occur during times of high flow from post-first flush releases from SB03 and SB04 during times of high rainfall. As such, the changes in salt balance have not been considered further.

i Release from SB03 and SB04 to Oldbury Creek

The results of the MUSIC modelling undertaken to assess the potential TSS and nutrient loads and concentrations in Oldbury Creek show releases will be in accordance with the NorBE criteria (Section 8.4.1), and indicate a significant reduction of more than 10%, of the mean annual TSS and nutrient loads for the operations phase compared with the existing situation (ie pre-Hume Coal Project) (Table 10.5). This reduction is due to the smaller area of the agricultural catchment draining to Oldbury Creek during operation.

Cumulative frequency plots of TN and TP concentrations in runoff to Oldbury Creek for the existing (runoff from SB01, SB02, SB03, SB04, MWD08, and PWD catchments) and operation (runoff from SB03 and SB04 catchments) scenario are shown in Figure 10.3 and Figure 10.4. The results indicate that pollutant concentrations modelled during Hume Coal Project operations (operation scenario) are equal to or lower than the pre-mining scenario (existing scenario) between the 50th and 98th percentiles, and are therefore compliant with NorBE criteria.

Table 10.5 Mean annual loads in Oldbury Creek during existing and operation scenarios, and NorBE criteria

Parameter	Mean annual load		% reduction	NorBE criteria
	Existing scenario (Oldbury Creek receives runoff from the areas where future SB01, SB02, MWD08, and PWD catchments will be located)	Operation scenario (Oldbury Creek receives releases from SB03 and SB04 and not the other surface infrastructure areas)		
TSS (kg/yr)	15,000	3,900	74%	≥10% reduction
TP (kg/yr)	63.7	6.19	90%	≥10% reduction
TN (kg/yr)	347	45.9	87%	≥10% reduction
Flow (ML/yr)	146	20.9	86%	-

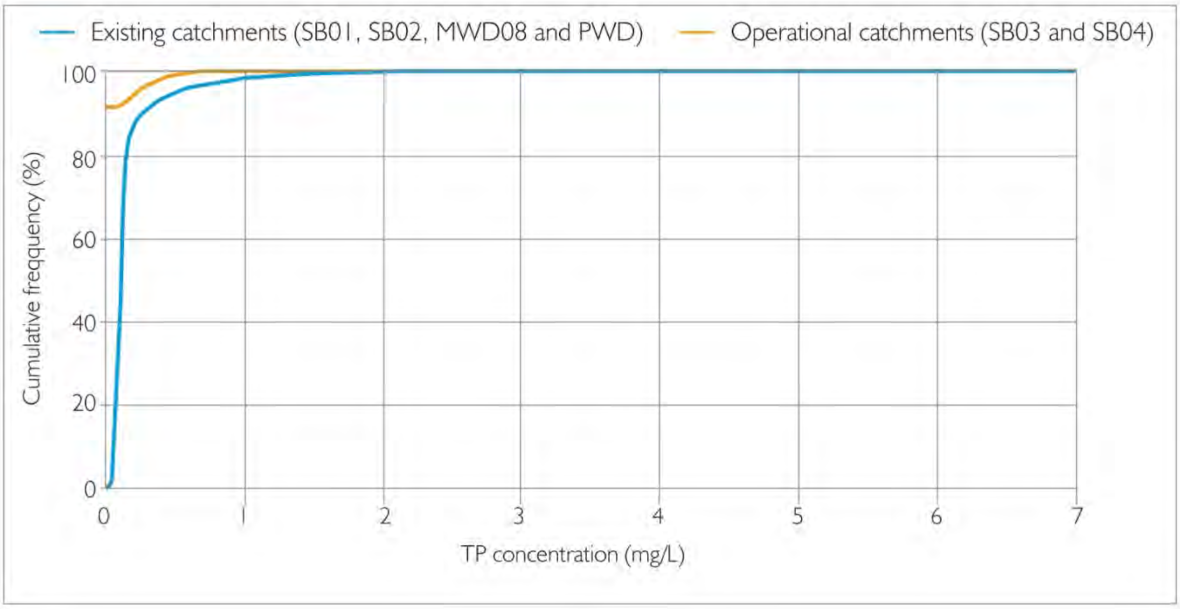


Figure 10.3 Cumulative frequency graph for stormwater release to Oldbury Creek – TP

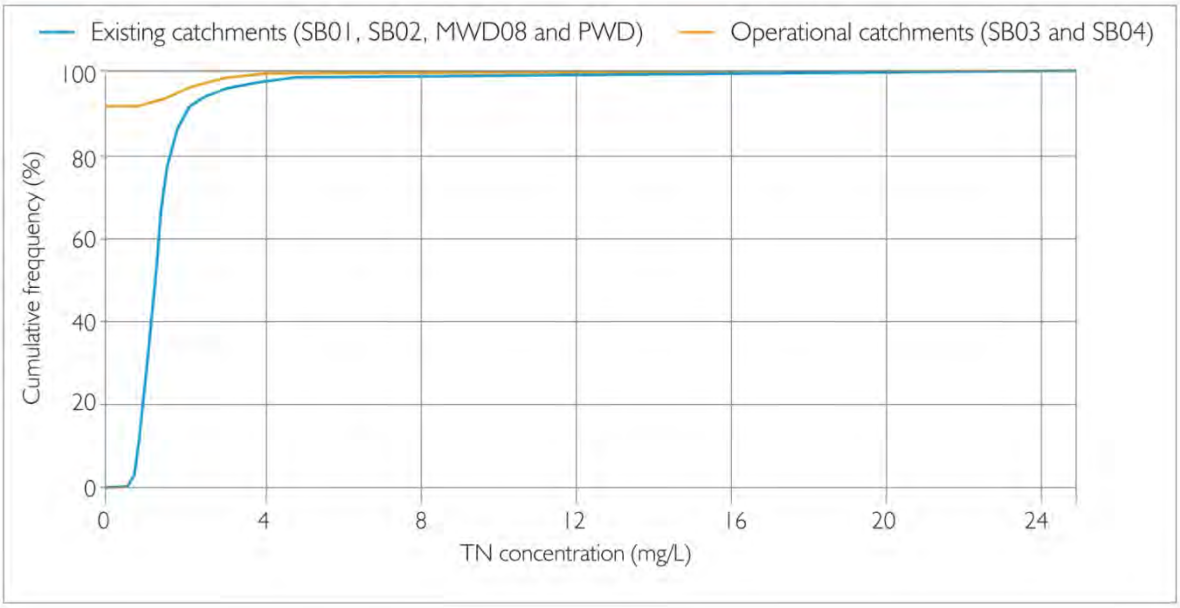


Figure 10.4 Cumulative frequency graph for stormwater release to Oldbury Creek – TN

Although the first flush is expected to remove most potential contaminants from the catchment, some contaminants may still be present in the runoff collected in SB03 and SB04 after first flush has been captured (and pumped to the PWD). While the risk of coal contact in these catchments is expected to be minimal, this potential source of contamination has still been assessed. Based on comparing a coal and reject leachate test with baseline water quality results from the natural catchment, the contaminants that could be at elevated concentrations are: calcium, magnesium, sulfate, aluminium, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, zinc, and lower pH. Preferred levels of mean concentrations of key indicator parameters (pH, TDS, TSS, and Oil and Grease) SB03 and SB04 are proposed (refer to Table 6.3 of WSP PB (2016b)). Final trigger values would be developed post-approval, in consultation with the relevant agencies. It is proposed that these contaminants would be monitored at SB03 and SB04 as part of the routine monitoring program and the levels managed, with the option to treat before release where required. Testing for TDS and pH will be undertaken to inform decisions on whether to release water. As such, water quality effects are expected to be negligible.

ii Mine access roads

The results of MUSIC modelling to assess the potential changes of runoff from the two mine access roads outside the water management system indicate that, with vegetated swales and constructed wetlands used as a treatment measure, NorBE criteria will be met.

Results indicate a significant reduction of 10% or more, and therefore acceptable within NorBE criteria, of the mean annual TSS and nutrient loads for the operations phase compared with the existing situation (Table 10.6). The reduction is achieved through providing vegetated swales and constructed wetlands to treat the road runoff. To meet the NorBE criteria, the swales must be the following dimensions:

- 750 m, 15 m and 5 m long for the northern, middle and southern sealed road catchment, respectively; and
- 1,250 m long for the unsealed road catchment.

Constructed wetlands were modelled downstream of the swales and were nominally sized at 50 m^2 each. Constructed wetlands were not required in order to meet the NorBE annual pollutant load criteria but were required in order to meet the TN and TP concentration criteria.

A sample of the cumulative frequency plots of TN and TP concentrations for the existing and operational scenarios are shown in Figure 10.5 and Figure 10.6. The results indicate that pollutant concentrations for the operational scenario are equal to or better than the existing scenario between the 50^{th} and 98^{th} percentiles, and are therefore compliant with NorBE criteria.

Table 10.6 Mean annual loads from access road catchments during existing and operation scenarios, and NorBE criteria

Catchment	Parameter	Existing	Operation (no swale or wetland treatment)		Operation, with swale treatment		Operation, with swale and wetland treatment		NorBE Criteria
		Mean annual load (kg/yr)	Mean annual load (kg/yr)	% reduction compared to existing	Mean annual load (kg/yr)	% reduction compared to existing	Mean annual load (kg/yr)	% reduction compared to existing	
Sealed road northern catchment (3.47 ha)	TSS	1800	4140	-130%	226	87%	201	89%	≥10% reduction
	TP	3.87	7.06	-82%	1.46	62%	1.35	65%	≥10% reduction
	TN	20.4	32.1	-57%	18	12%	18.1	11%	≥10% reduction
Sealed road middle catchment (0.99 ha)	TSS	422	630	-49%	208	51%	160	62%	≥10% reduction
	TP	1.18	1.18	0%	0.564	52%	0.427	64%	≥10% reduction
	TN	5.94	6.18	-4%	5.31	11%	4.77	20%	≥10% reduction
Sealed road southern catchment (0.56 ha)	TSS	351	431	-23%	230	34%	135	62%	≥10% reduction
	TP	0.845	0.775	8%	0.497	41%	0.307	64%	≥10% reduction
	TN	4.09	3.93	4%	3.61	12%	2.92	29%	≥10% reduction
Unsealed road (1.32 ha)	TSS	287	7050	-2356%	86.8	70%	67.8	76%	≥10% reduction
	TP	1.24	3.33	-169%	0.593	52%	0.509	59%	≥10% reduction
	TN	6.73	13.9	-107%	5.95	12%	6.06	10%	≥10% reduction

Notes: A negative % reduction implies an increase in mean annual load.

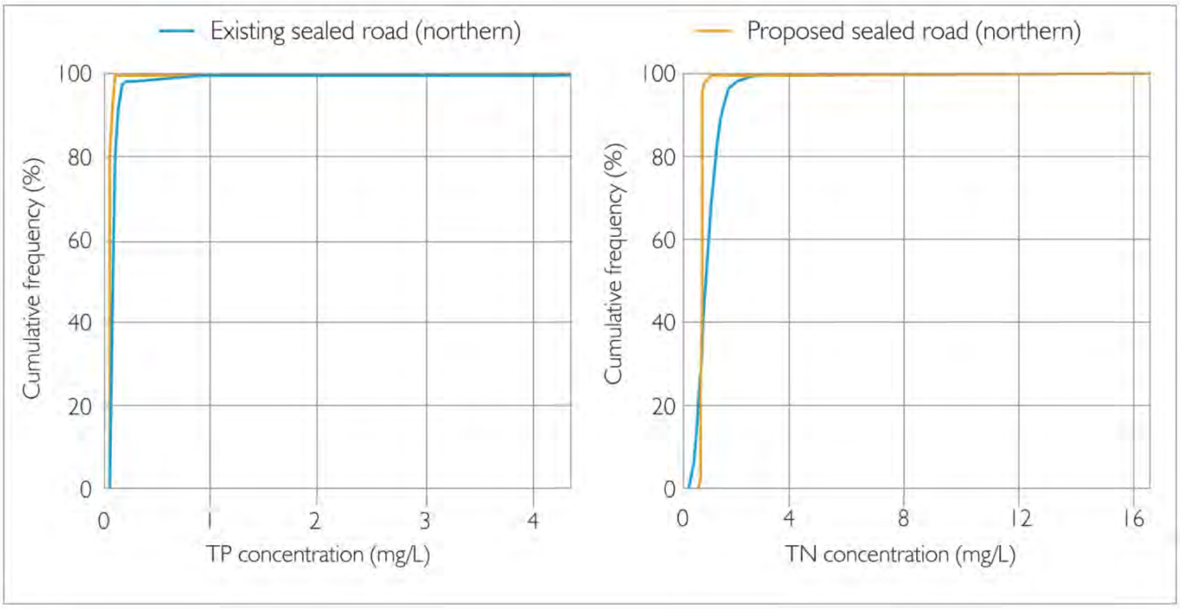


Figure 10.5 Cumulative frequency graph for northern sealed road – TP and TN

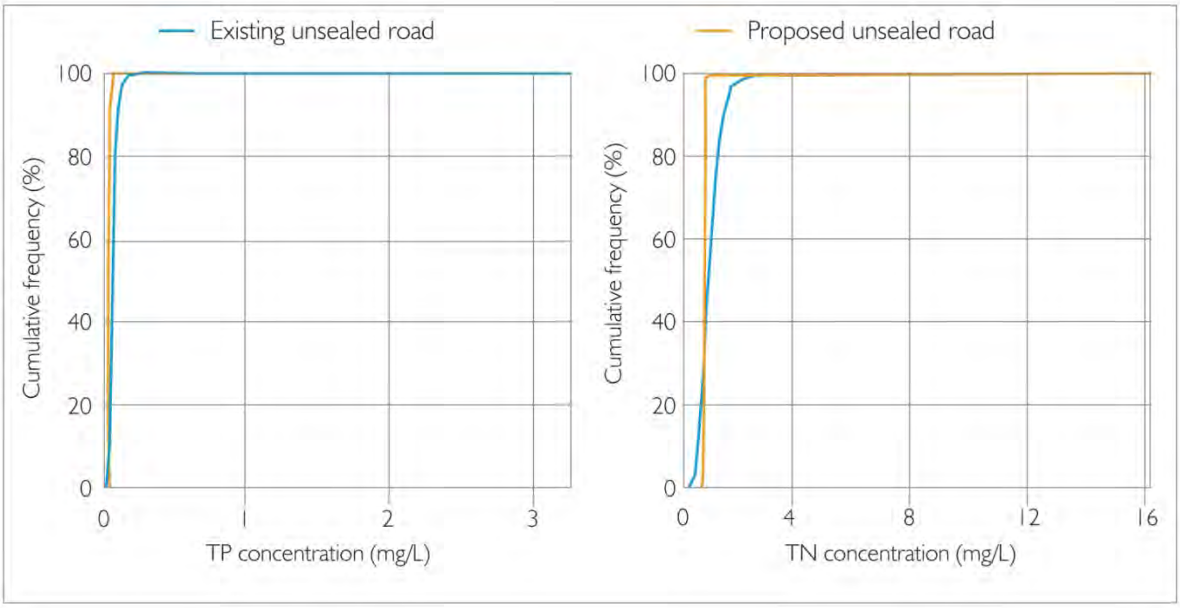


Figure 10.6 Cumulative frequency graph for unsealed road – TP and TN

iii Depressurisation of groundwater systems from underground mining

Numerical groundwater modelling predicts that baseflow in drainage lines will be decreased as a result of the underground mining activities depressurising groundwater systems. This is discussed in detail in Section 11.1.3. A reduction in baseflow will result in reduced loadings in all water quality components. However, some component concentrations may increase as a result of reduced baseflow. This occurs where concentrations in groundwater are lower than surface water (ie reduction in baseflow results in less dilution of surface water concentrations). On the other hand, some component concentrations may decrease as a result of decreased baseflow where concentrations in groundwater are higher than surface water (ie reduction in baseflow results in less total contaminant mass present in streamflow). In this latter case, surface water quality would be improved with a reduction in baseflow.

Comparison of baseline groundwater and surface water results indicate most components (monitored analytes) were generally higher in concentration in groundwater than in surface water; ie a reduction in baseflow would improve surface water quality. However, nitrate, calcium, sodium, sulfate, and aluminium were generally higher in surface water than groundwater; ie a reduction in baseflow would likely increase concentrations of these components.

- nitrate results were below and calcium, sodium, sulfate results were well below guideline values, and, therefore, changes in these concentrations will not affect the beneficial use of the surface water; and
- aluminium results exceeded the guideline values for aquatic ecosystems and, in some locations, the ADW guidelines, but not the guidelines for irrigation or livestock.

For the revised assessment, a daily mass balance GoldSim model quantitatively assessed the potential changes in water quality for the Medway Rivulet Management Zone with respect to the above mentioned components that will potentially increase in concentration as a result of baseflow reduction. Refer to Section 8.4.3 for method.

The results show that mean annual pollutant loads for these components are slightly reduced (between approximately 0.5% and 1.7%) for the operational scenario compared to the existing situation. This result is due to the reduction in overall pollutant loads from the reduction in baseflow.

Cumulative frequency graphs for each component are included in Section 5.5 of WSP (2018). The change in concentration between the existing and operational scenarios is almost undetectable; these graphs are very similar (identical until the 99th percentile) between the existing and operational scenarios. Comparisons of predicted peak concentrations (ie 100th percentile), derived from 80th percentile baseline monitoring data, for the existing and operational scenarios are shown in Table 10.7

Increases in concentrations would not necessarily have a detrimental effect on the beneficial use of the surface water. Comparison to of the predicted concentrations in Table 10.7to the relevant ANZECC (ANZECC and ARMCANZ 2000) and ADW (NHMRC 2016), guidelines indicates that (WSP 2018):

- nitrate, nitrite, calcium, sodium, and sulfate results were well below guideline values, for both existing and operational scenarios; and
- aluminium results exceeded the ANZECC (2000) guideline value for aquatic ecosystems for both the existing and operational scenarios but was below the ADW guideline value for health and well below the ANZECC guideline for irrigation and livestock for both existing and operational scenarios.

These results suggest that changes in surface water concentrations as a result of baseflow reduction will not affect the existing beneficial use of surface water in the project area. The project will have a neutral or, for some components, a beneficial effect on surface water quality within the project area as a result of baseflow reduction due to underground mining.

As a new management measure to offset potential water quality impacts associated with baseflow reduction, protection zones are proposed on the Evandale and Mereworth properties (total protection area is 42.5 ha). Clearing, farming and industrial activities (including roads, infrastructure etc) will be restricted within the proposed protection zones. These restrictions within proposed protection zones will also reduce pollutant loads and have a positive impact on water quality.

Table 10.7 Predicted peak concentrations in streamflow for Medway Rivulet Management zone

Component	Existing	Operation[1]	
	Predicted peak concentration[2] (mg/L)	Predicted peak concentration[2] (mg/L)	Difference compared to existing situation (%)
Nitrate (as N)	0.115	0.117	1.7%
Nitrite (as N)	0.011	0.012	1.8%
Calcium	32.5	32.7	0.4%
Sodium	56.0	56.4	0.8%
Sulfate (as SO_4)	30.4	31.2	2.5%
Aluminium	0.138	0.142	2.9%

Notes: 1.Operation scenario is different due to reduction in baseflow.
2. Based on 80th percentile baseline monitoring data.

10.2.3 Dust deposition

Estimated concentrations of contaminants in the Oldbury Creek and Wells Creek catchments from dust deposition calculated based on the method outlined in Section 8.4.4 are significantly lower than the mean baseline concentrations and the relevant guideline values. As such, dust deposition in the Oldbury Creek and Wells Creek catchments is therefore considered to be insignificant in terms of surface water quality and will not affect the beneficial use of surface water in the project area.

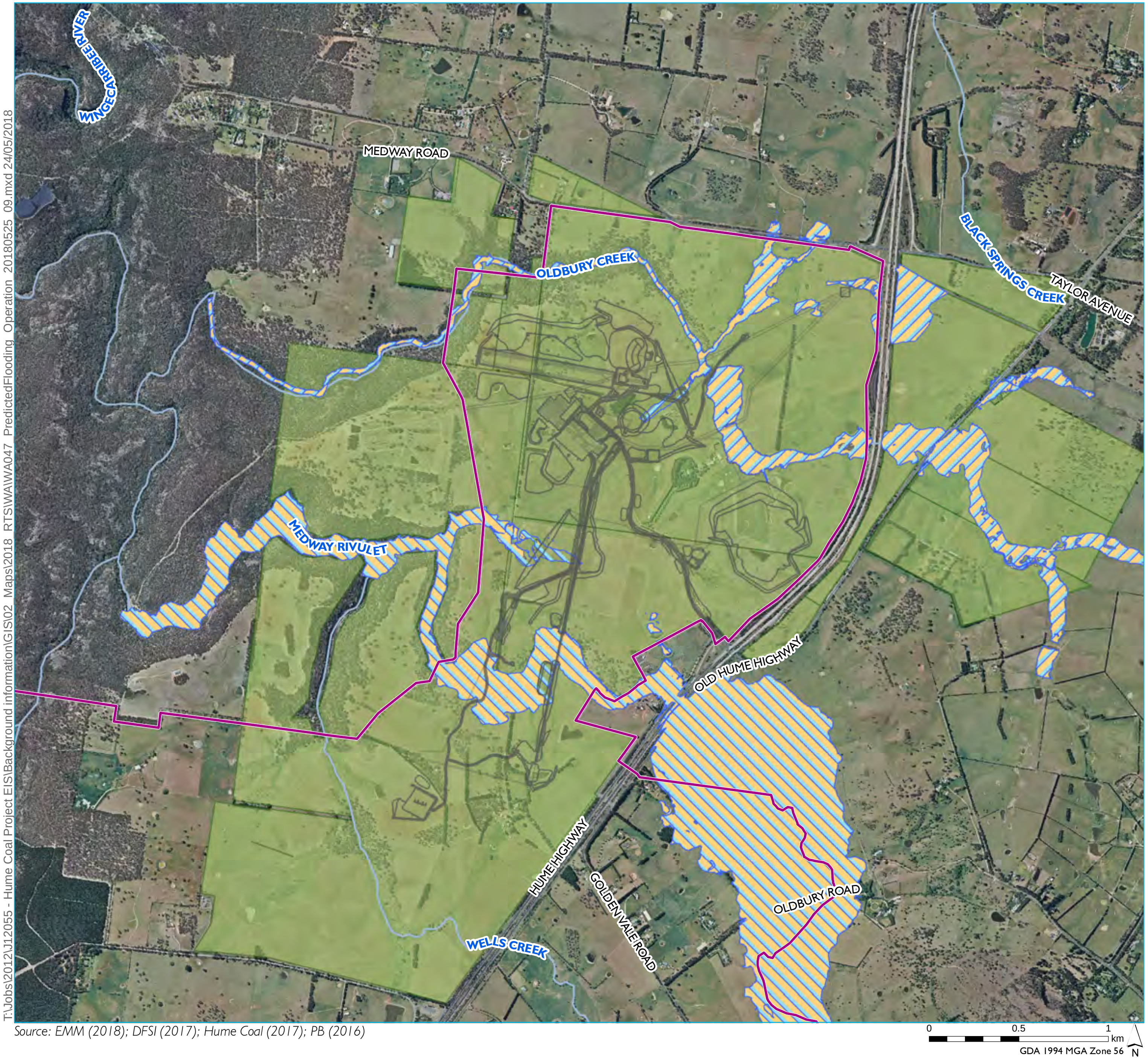
Section 5.6 of WSP (2018) presents detailed results of the assessment.

10.3 Flood regime

SEAR 3: An assessment of the potential flooding impacts of the development

10.3.1 Flood extent

The predicted maximum flood (PMF) extents for the 100 year ARI event are shown comparing the existing, and operation, and the existing and rehabilitation project phases in Figure 10.7 and Figure 10.8, respectively. Predicted flood extents comparing the 5 year and 20 year ARI and PMF for existing, operation, and rehabilitation scenarios are included in Appendix D (WSP PB 2016d). Results of the hydrologic modelling indicated there will be minor change in the 100 year ARI flood extents for the operation phase compared to the existing, pre-project, situation. Changes in flood extents following mine rehabilitation, compared to the existing situation, are only predicted in the area where SB02 will be located during mine operation.



T:\Jobs\2012\J12055 - Hume Coal Project EIS\Background information\GIS\02_Maps\2018_RTS\WA\WA047_PredictedFlooding_Operation_20180525_09.mxd 24/05/2018

Source: EMM (2018); DFSI (2017); Hume Coal (2017); PB (2016)

KEY

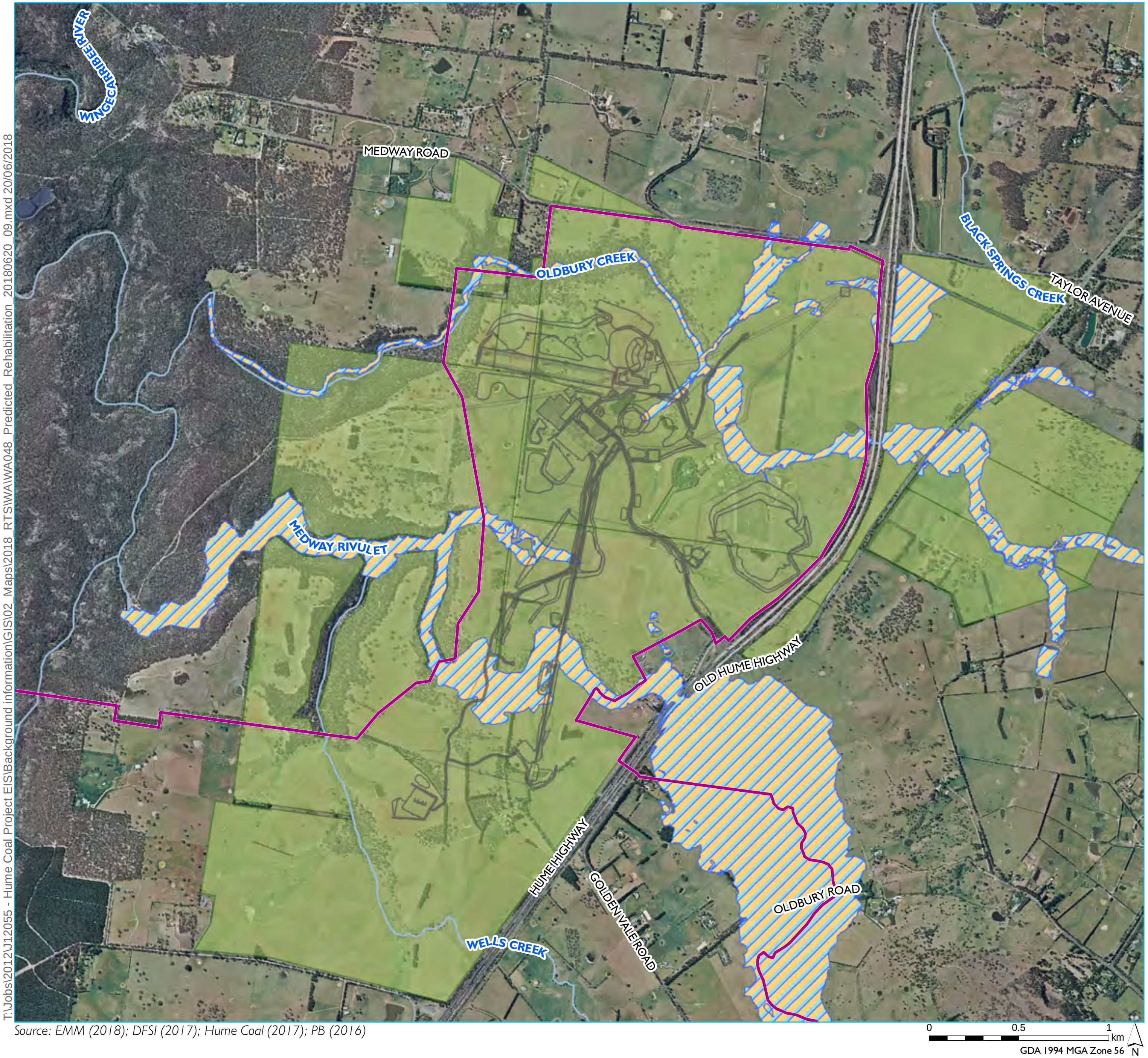
- Project area
- Indicative surface infrastructure features
- Drainage line
- Existing flood extent
- Operation flood extent
- Hume Coal affiliated properties

Predicted flooding extent
(1 in 100 year) - operation

Hume Coal Project
Revised Water Assessment
Figure 10.7

HUMECOAL PROJECT

EMM



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KEY

- Project area
- Indicative surface infrastructure features
- Drainage line
- Existing flood extent
- Rehabilitation flood extent
- Hume Coal affiliated properties

Source: EMM (2018); DFSI (2017); Hume Coal (2017); PB (2016)

Predicted flooding extent
(1 in 100 year) - rehabilitation

Hume Coal Project
Revised Water Assessment
Figure 10.8

HUMECOAL PROJECT

EMM

10.3.2 Flood levels

Changes in flood levels (afflux) between the existing and operation phase, and between the existing and rehabilitation phase have been assessed for cross sections generated from the hydrologic model. The selected cross sections are located across areas of interest, including privately owned land, locations where existing roads cross streams, and locations where new infrastructure is proposed to cross streams. Detailed results for the 5 year, 20 year, and 100 year ARI, and PMF extents are included in Appendix D (WSP PB 2016d).

The predicted affluxes for the operation phase are within the assessment criteria presented in a 9.3.1iii, with the exception of localised afflux values of up to 340 mm in Oldbury Creek on land owned by Hume Coal between the PWD and SB02. The areas with predicted localised afflux values greater than the assessment criteria have been considered in the design of the surface infrastructure area and water management system, so that flood levels are effectively managed without impacts on project infrastructure or surrounds.

The predicted affluxes for the rehabilitation phase are negligible and considered acceptable, with reference to the assessment criteria presented in a 9.3.1iii, for land outside of Hume Coal's ownership. The difference noted above between PWD and SB02 will be reduced during the rehabilitation stage, however, a localised afflux of up to 400 mm remains downstream of the instream storage on Oldbury Creek (Hume Coal owned land).

10.3.3 Flood velocities

Infrastructure crossing streams, including bridges and culverts, can change the velocity of stream flow local to the infrastructure. An increase in the velocity of streamflow can cause erosion and scour of bed sediments and impact on surface water quality and the stability of instream structures.

Peak velocities downstream of new infrastructure crossing streams in the flooding assessment study area (refer to Section 1.7) are shown in Appendix D (WSP PB 2016d). Peak velocities are presented for the following new infrastructure:

- the conveyor crossing Medway Rivulet to transport coal from the conveyor drift to the administration and workshop area;

- the road crossing Medway Rivulet to provide access between the conveyor drift and ventilation shaft and the administration and workshop area, which includes 17 box culverts; and

- the embankment at the downstream end of the instream storages on Oldbury Creek, which may be widened and used to provide access between the CPP area and the train load out facility. The embankment will have an access road and a conveyor to transport coal. (It is noted that EMM (2017g) and WSP PB (2016d) incorrectly reported that the embankment would be raised and would also have poles for electricity lines).

The project will not include any structures that pose significant obstruction to or constriction of flood flows. Peak velocities are expected to increase locally around the conveyor piers and box culverts and scour protection measures will need to be implemented.

The changes in peak velocities presented in Appendix D (WSP PB 2016d) are for cross-sections immediately downstream of the new infrastructure. Changes in peak velocity are in the range ± 0.3 m/s. The results show that the change in velocity at these downstream locations is minor and considered acceptable, with reference to the assessment criteria presented in a 9.3.1iii.

10.4 Cumulative impacts

AR 18: Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts

The proposed Berrima Rail Project is upstream of the project in the Oldbury Creek catchment (Figure 1.2).

Surface water flows will not be influenced by construction, operation or rehabilitation of the Berrima Rail Project. The Berrima Rail Project will not take water from streams, discharge water to streams or cause groundwater impacts that would decrease baseflow to streams. In addition, the rail infrastructure for the Berrima Rail Project will not reduce the volume of flow because culvert structures will be built where the rail crosses waterways. Cumulative impacts to flow and bed and bank stability associated with the Hume Coal and Berrima Rail projects is predicted to be negligible. Refer to the Berrima Rail Project EIS (EMM 2017d).

The surface water quality assessment for the Berrima Rail Project (EMM 2017d) indicates that with appropriate management plans and treatment measures in place (ie swales and constructed wetlands), the water quality in Oldbury Creek will not be influenced by constructing, operating, or rehabilitating the Berrima Rail Project. Cumulative changes to surface water quality associated with the Hume Coal and Berrima Rail projects will therefore be negligible. Refer to the Berrima Rail Project EIS (EMM 2017d) for details of the surface water assessment presented in the EIS and to WSP (2018) for revisions regarding the Berrima Rail water quality assessment.

The cumulative impacts of the project and Berrima Rail Project were assessed in the Oldbury Creek catchment where infrastructure from both projects is located. Refer to Appendix D for assessment (WSP PB 2016d). Comparison of the 100 year ARI flood extents shows that changes in flood extent during operation will occur:

- upstream of where the rail line crosses Oldbury Creek south west of Berrima Cement Works;
- just upstream of the Hume Highway on a tributary of Oldbury Creek; and
- near the rail loop.

The majority of changes in flood extent occur on land owned by Hume Coal or Boral. The increased flood extent upstream of the Hume Highway is minor.

Around the rail loop, the Hume Highway and around Berrima Cement Works disturbance are all only related to the rail infrastructure. Downstream near the project these works are not relevant. Similarly, localised flooding caused by the project does not contribute to these areas upstream that are affected by the rail infrastructure. Therefore, both projects do not have a cumulative impact on flooding in Oldbury Creek. Further details of the flooding effects of the Berrima Rail Project are addressed in the Berrima Rail Project EIS (EMM 2017d).

10.5 Predicted impacts on surface water users, drainage lines and riparian land

The possible predicted effects on sensitive surface water users, as defined in Section 9.2, are described below. In summary:

- Surface water users and stream environments:
  - Changes to flow for licensed and basic rights users due to the reduction in catchment area and reduction in baseflow are predicted to be minor or negligible in the Medway Rivulet and Oldbury Creek, with the assumption that Moss Vale STP continues low flow discharge in the Medway Rivulet tributary. Changes in yield for licensed and basic rights users due to the reduction in catchment area and reduction in baseflow are predicted to be minor or negligible. As per the *Significant impact guidelines* (DoE 2013), surface water flow and yield changes are considered **insignificant**.
  - Stream bank erosion changes can be mitigated via an erosion and sedimentation control plan. This is further discussed in Section 10.5.1. As per the *Significant impact guidelines* (DoE 2013), these changes are considered **insignificant**.
  - Where predicted, water quality changes as a result of releases from SB03 and SB04 can be mitigated by the implementation of release limits and criteria; releases that will occur are predicted to be compliant with NorBE criteria. With provision of vegetated swales and constructed wetlands, runoff from access roads outside of the water management system is predicted to be compliant with NorBE criteria. Although the overall annual loads are predicted to be reduced, potential increases in concentrations of certain components in surface water flow as a result of reduction in baseflow are not predicted to alter the beneficial use of the resource. The effects of baseflow reduction and, separately, coal dust deposition on streamflow water quality are predicted to have a neutral effect with respect to the existing beneficial use category. As per the *Significant impact guidelines* (DoE 2013), surface water quality changes are considered **insignificant**.
  - Changes in flood levels as a result of the project for land not owned by Hume Coal are considered acceptable with reference to the assessment criteria. Changes to flood peak velocities are considered acceptable with reference to the assessment criteria. As per the *Significant impact guidelines* (DoE 2013), flooding changes are considered **insignificant**.

Predicted effects to the remaining users defined in Section 9.2 (including "watercourses, drainage lines, creeks, and swamps that receive baseflow") are discussed in Section 11.4.

Potential impacts to users associated with changes in the flow regime that have been assessed include:

- erosion of stream banks associated with an increase in stream energy and bank full flow events (due to water releases from SB03 and SB04, and the WTP, if required);
- decreased access for water users associated with a decrease in streamflow (due to reduced catchment area and intercepted baseflow); and
- decreased availability of water for instream and riparian ecosystems associated with a decrease in streamflow (due to reduced catchment area and intercepted baseflow).

Decrease in streamflow associated with project storage catchments and decrease in baseflow as a result of underground mining has the potential to decrease streamflow available to instream ecosystems and overbank flows and flooding available to riparian ecosystems. Potential ecological impacts associated with the predicted changes in flow regime and sedimentation has been assessed in the *Hume Coal Project Biodiversity Assessment Report* (refer to Chapter 13 of EMM (2018) and EMM (2017c)).

10.5.1 Stream bank erosion

Drainage lines identified as prone to erosion are located upstream of the surface infrastructure area (refer to drainage lines identified as 'laterally unconfined valley setting', 'partly-confined valley setting', and 'laterally unconfined' in Figure 5.2). Whereas, next to and downstream of the surface infrastructure area, Medway Rivulet and Oldbury Creek are in confined valley settings and the channels are bedrock controlled.

During the project's operational phase, the risk of stream bank erosion would be low and could be managed by appropriate mitigation measures. Releases to Oldbury Creek would occur in a reach classified as 'confined valley setting – occasional floodplain pockets' (Figure 5.2). Release would occur as piped outflows from SB03 and SB04 (combined) and from the WTP if required, into or just upstream of the existing instream storage north of the PWD. Scour protection will be required at the release outlets and potentially reinforcement of the existing spillways following assessment. Downstream, the channel is bedrock controlled and the risk of stream bank erosion due to this release is considered negligible.

During construction and rehabilitation, an erosion and sedimentation control plan, developed in accordance with Landcom (2004) and DECC (2008) guidelines, will be prepared to manage and mitigate potential erosion and sedimentation induced by the project so as not to adversely affect the surrounding environment. With the implementation of this plan, erosion and sedimentation changes during the construction and rehabilitation phases are expected to be minimal. Temporary erosion and sedimentation control measures include: sediment basins, sediment fences, diversion banks, check dams, batter chutes, temporary culverts, and scour protection. This is discussed further in Chapter 13.

Based on the above, the predicted changes to stream banks as a result of erosion induced by the project are considered **insignificant**.

10.5.2 Reduced access for water users

i Flow

A marginal reduction in streamflow associated with reduced catchment size and reduction of baseflow due to underground mining is predicted in the downstream sections of Medway Rivulet. As discussed in Section 5.5, downstream of the surface infrastructure area, Medway Dam is the only licensed user in the Medway Rivulet; although the associated treatment plant was operated for town water supply it is not currently being used. Landholders with basic water rights are located downstream and upstream of the surface infrastructure area, and although there is potential for a reduction in streamflow in the Medway Rivulet the reduction is minor and therefore imperceptible changes for water for users.

The potential for a low flow regime is mainly attributable to the interception of baseflow associated with underground mining depressurising groundwater systems. The interception of baseflow in the Medway Rivulet catchment is consider minor but extends over a long period of time. It peaks at 0.982 ML/day 19 years after mining begins (Figure 11.5), and will decrease to less than 0.1 ML/day 66 years after mining begins as groundwater levels recover (HydroSimulations 2018).

Based on the information above, licensed and basic rights flow changes are predicted to be minor and impacts therefore are negligible.

The reduction in low flows in the Medway Rivulet catchment if discharges from the Moss Vale STP do not occur has the potential to decrease the connectivity of pools and increase the potential for pools to dry out. This has the potential to affect access for landholders with basic water rights. However, the Moss Vale STP discharges are likely to continue throughout the mining operations and therefore impacts on access for landholders with basic water rights are unlikely (refer to Figure 10.1). The potential impacts to instream ecosystems associated with these predicted changes are discussed in the *Hume Coal Project Biodiversity Assessment Report* (refer to Chapter 13 of EMM (2018) and EMM (2017c)).

ii Yield

Under wet and dry conditions, the project will result in up to a 0.3% reduction in surface water yield in the Medway Dam catchment. These values represent the approximate reduction in yield to Medway Dam, which is considered negligible.

The localised groundwater model of Medway Dam (HydroSimulations 2018) indicates that impacts from depressurisation of the underlying groundwater system on Medway Dam itself are small. The changes in volume of Medway Dam peaks at less than 0.1 ML/day.

Locally, changes to yield will be largest in the Oldbury Creek sub-catchment, with up to a 4.3% reduction in yield under wet conditions and up to a 4.5% reduction in yield under dry conditions. Most of the creek where this impact would occur is fronted by land owned by Hume Coal, and downstream of it, the creek geomorphology is typically confined valleys. As such, the effect on basic rights use is expected to be minimal or negligible. There are no licensed users on Oldbury Creek other than on Hume Coal property.

The Medway Rivulet Management Zone (Figure 2.4) is upstream of the Lower Wingecarribee River Management Zone. Under wet conditions, the project will result in a 0.9% reduction in yield for the Medway Rivulet Management Zone, and under dry conditions the project will result in a 1.6% reduction in yield. These changes in the Medway Rivulet Management Zone would produce negligible effects downstream in the substantially larger Lower Wingecarribee Management Zone and, similarly, negligible effects on Sydney's drinking water catchment.

Reduction in baseflow from the groundwater system are similarly minor, and therefore based on the information above, changes in yield for licensed and basic rights users due to the reduction in catchment area and reduction in baseflow are predicted to be minor or negligible. WAL licences are held by Hume Coal in accordance with the AIP to account for water taken (Chapter 12).

11 Groundwater assessment

This chapter outlines the results of the impact assessments for project-related impacts to groundwater resources and water users.

SEAR 1: As assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's, DPI's and Water NSW requirements and recommendations

SEAR 2: An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users

AR 2: A groundwater assessment to determine the likelihood and associated impacts of groundwater accumulating and subsequently discharging from the workings post cessation of mining, including consideration of the likely controls require to prevent or mitigate against these risks as part of the closure plan for the site

AR 14: Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, wetlands, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts

AR 20: Assessment of whether the activity may have a significant impact on water resources, with reference to the Commonwealth Department of Environment Significant Impact Guidelines

AR 21: If the activity may have a significant impact on water resources, then provision of information in accordance with the Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals, including completion of the information requirements checklist.

AR 29: The EIS should take into account the following policies (as applicable):
· NSW Guidelines for Controlled Activities on Waterfront Land (NOW, 2012)
· NSW Aquifer Interference Policy (NOW, 2012)
· Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW, 2012)
· Australian Groundwater Modelling Guidelines (NWC, 2012)
· Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals (IESC, 2014)
· Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments - impacts on water resources (Australian Govt. 2014)
· NSW State Rivers and Estuary Policy (1993)
· NSW Wetlands Policy (2010)
· NSW State Groundwater Policy Framework Document (1997)
· NSW State Groundwater Quality Protection Policy (1998)
· NSW State Groundwater Dependent Ecosystems Policy (2002)
· NSW Water Extraction Monitoring Policy (2007)
· Groundwater Monitoring and Modelling Plans - Information for prospective mining and petroleum exploration activities (NOW, 2014)
· NSW Code of Practice for Coal Seam Gas Well Integrity (DTIRIS 2012)
· NSW Code of Practice for Coal Seam Gas Fracture Stimulation (DTIRIS 2012)

AR 45: *Assessment of predicted impacts on the following:*
- *flow of surface water (including floodwater), sediment movement, channel stability, and hydraulic regime,*
- *water quality*
- *flood regime*
- *dependent ecosystems*
- *existing surface water users*
- *planned environmental water and water sharing arrangements prescribed in the relevant water sharing plans*

AR 50: The predicted impacts of any final landform on the groundwater regime

AR 58: The results of any models or predictive tools used

AR 59: Where potential impact/s are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on:
- *Any proposed monitoring programs, including water levels and quality data. Reporting procedures for any monitoring program including mechanism for transfer of information*
- *An assessment of any groundwater source/aquifer that may be sterilised from future use as a water supply as a consequence of the proposal*
- *Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category)*
- *Description of the remedial measures or contingency plans proposed*
- *Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period*

AR 66: Detailed modelling of potential groundwater volume, flow and quality impacts of the presence of an inundated final void (where relevant) on identified receptors specifically considering those environmental systems that are likely to be groundwater dependent

AR 69: The EIS must assess the impacts of the development on water quality, including:
a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.
b. Identification of proposed monitoring of water quality.

AR 75: If WQO's cannot be met for the project, demonstrate that all practical options to avoid water discharge have been implemented and outline any measures taken to reduce the pollutant loads where a discharge is necessary. Where a discharge is proposed, analyse the expected discharges in terms of impact on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm.

AR 79: A full description of the development including those aspects which have the potential to impact on the quality and quantity of surface and groundwaters at and adjacent to the site, including:
- *the mining proposal and mine layout*
- *the location, mapping and geomorphology of all creeks and water resources overlying and adjacent to the proposed mining area*
- *the hydrogeological fluxes between surface and groundwaters, including the filling of pine feather voids*
- *the location, management and storage of all hazardous materials- the disposal of wastes from the treatment of mine waters in the mine water treatment plant*
- *the management of dirty water from the washing and preparation of coal for transport*
- *the location, sizing and description of all water quality management measures*
- *the location and description of all water monitoring points (surface and ground waters)*
- *on-site domestic (sewage) wastewater management*

AR 80: A detailed assessment of the development on water resources which considers the design, construction, operational and decommissioning phases and have regard for operation during periods of wet weather and include:
-details of measured and predicted coal mine, preparation area and stockpile area performance with respect to water quality management
-details of measures proposed to be adopted to offset impacts associated with construction activities eg earthworks, vegetation clearing and track construction
-impacts on overlying and adjacent creeks and water resources within risk management zone associated with subsidence
-impact of the proposed on-site domestic (sewage) wastewater management and associated effluent disposal area
-pre-development and post development run off volumes and pollutant loads from the site
-details of the measures to manage site water associated with processing coal and coal reject, general stormwater runoff and any human activities likely to affect water quality at the site, and how neutral or beneficial effect on water quality (NorBE) principles will be assessed and applied
-assessment of the impacts of the development on receiving water quality and volume, both surface and groundwater including from the filling of pine feather voids and associated impact on interaction and baseflows of surface waters
-details of the structural stability, integrity, ongoing maintenance and monitoring of all site water management measures including dams over the life of the project
-details of proposed monitoring of groundwater levels, surface water flows, groundwater and surface water quality, along with information as to how the proposed monitoring will be used to monitor, and, if necessary, mitigate impacts on surface water and groundwater resources
-the principles outlined in the 'Managing Urban Stormwater - Soils and Construction - Mines and Quarries' Manual prepared by the Department of Environment and Climate Change (2008)

AR 82: An assessment of the relevant impacts of the action on water resources including:
- a description and detailed assessment of the nature and extent of the likely direct, indirect and consequential impacts, including short term and long term relevant impacts

- *a statement whether any relevant impacts are likely to be known, unpredictable or irreversible, and analysis of the significance of the impacts;*
- *any technical data and other information used or needed to make a detailed assessment of the impacts*

AR 85: The assessment of impacts should include information on:

- *any substantial and measureable changes to the hydrological regime of the water resource, for example a substantial change to the volume, timing, duration or frequency of ground and surface water flows*
- *the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the water resource being seriously affected*
- *substantial and measureable change in the water quality and quantity of the water resource – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland; or water temperature that may adversely impact on biodiversity, ecological integrity, social amenity or human health*

11.1 Numerical groundwater model predictions

Detailed results of the revised numerical groundwater model are included in Appendix F (HydroSimulations 2018). The numerical groundwater modelling results have been updated since what was presented in the EIS (the EIS model: Coffey 2016b) following review, audit and consideration feedback received during the submissions period.

Both the conceptual model, and the numerical model design and calibration presented in the EIS are data driven with field data from the site itself as well as data, results and learnings from nearby mines within the Sydney Basin. The numerical model was designed in accordance with the Australian Modelling Guidelines (Barnett et. al 2012) and the boundaries were developed in consultation the NSW Government. The NSW Government independent expert peer reviewer also concluded that:

> "The model software, design, extent, grid, boundaries and parameters form a good example of best practice in design and execution." (Hydrogeologic 2017)

Consultation with NSW regulators regarding the model and the monitoring network has followed industry best practice guidelines. The long period of baseline data collection (well in excess of 2 years for groundwater levels) enables robust model calibration and conceptualisation.

The numerical model has been updated and improved in consultation with the NSW Regulator, and the NSW Government independent expert peer reviewer. The revised model prediction of impacts is based upon detailed and robust uncertainty analysis in accordance with the draft IESC Explanatory Note on Uncertainty Analysis in Groundwater Modelling (Middlemis & Peeters 2018).

Within the draft explanatory note, the importance of effective communication in the presentation of model results was highlighted. Narrative descriptors that directly relate to probability classes reflecting uncertainty have been combined with risk-based visualisation methods (HydroSimulations 2018).

The quantitative ranges from the uncertainty analysis (from Middlemis & Peeters 2018; and HydroSimulations 2018) are presented. Note that this report references the uncertainty analysis 'percentile class', which, in this case, is inversely comparable to the probability class referenced within the draft explanatory note (Middlemis & Peeters 2018) (Table 11.1).

Table 11.1 Combined numeric, narrative and visual approach to describing 'likelihood'

Narrative Descriptor	Probability Class	HydroSimulations Percentile Class	Description	Colour Code
Very likely	90-100%	0-10%ile	Likely to occur even in extreme conditions	
Likely	67-90%	10-33%ile	Expected to occur in normal conditions	
About as likely as not	33-67%	33-**67%ile**	About an equal chance of occurring as not	
Unlikely	10-33%	**67**-90%ile	Not expected to occur in normal conditions	
Very unlikely	0-10%	90-100%ile	Not likely to occur even in extreme conditions	

Notes: "%ile" = percentile

While the 50th percentile represents the median of the uncertainty analysis, all results used in the impact assessment are the more conservative 67th percentile results. The 67th percentile provides a 'worst case realistic' scenario. For mine inflow volumes, for example, the 67th percentile class represents the maximum volume of groundwater inflow into the mine predicted for normal conditions – inflow volumes above this are 'not expected to occur in normal conditions' or 'not likely to occur even in extreme conditions'. While, similarly, for the number of individual bores predicted to be impacted, the 67th percentile class represents the maximum number of bores predicted to be impacted under normal conditions and impacts to additional bores above the 67th percentile are unlikely to occur in normal conditions.

The 67th percentile represents the boundary between two defined IESC probability classes: the 'about as likely as not' range (represented by the 33rd percentile to the 67th percentile values and described as 'about an equal chance of occurring as not'); and the 'unlikely' range (represented by the 67th percentile to 90th percentile values and described as 'not expected to occur in normal conditions').

Statistics on a number of key metrics were computed from the results of the 481 accepted model runs (out of 510 total runs) (including mine inflow volumes and number of individual bores impacted, as mentioned above). The Hume Coal Project impact assessment, derived from the 67th percentile of uncertainty analysis, is an 'overestimate' of likely impacts based on 481 uncertainty runs. The results are presented and discussed in the following sections.

11.1.1 Inflows to mine

The average yearly inflow to the mine sump is 463 ML/yr and 798 ML/yr to the sealed underground void.

Inflows to the sump occur over a period of 19 years until the end of mining. Inflows to the void, however, continue after this period for approximately 3-5 years. Groundwater pressures above the mine area then recover. The model predicts that depressurisation of the groundwater system as a result of the project will return to pre mining conditions within 76 years from commencement of mining.

Modelled annual inflows to the sump and the void are shown in Figure 12.1.

The model results indicate that inflow to the Hume Coal mine workings is sourced from groundwater, and the major water sources contributing is the Sydney Basin – Nepean Groundwater Source.

The predicted maximum rate of release of groundwater from groundwater storage, and the respective percentage contribution from each source, as a result of the project is shown in Table 11.2. The vast majority of groundwater inflow to the mine is sourced from the Nepean Management Zone 1; which is to be expected given the project area is entirely within this management zone of the water source.

The rate of baseflow reduction from the respective groundwater source predictions are discussed in Section 11.1.2.

Table 11.2 Maximum rate of release of groundwater from groundwater storage

Groundwater source	Maximum rate of release of groundwater from groundwater storage (ML/day)[1]	Maximum rate of release of groundwater from groundwater storage (ML/year)
Nepean Management Zone 1 (NMZ1)	5.64	2,059
Nepean Management Zone 2 (NMZ2)	0.02	6.45
Sydney Basin South (SBS)	0.02	7.13

Notes: 1.Not including baseflow reduction (refer to Table 11.3).

11.1.2 Groundwater levels

Changes to groundwater pressures were modelled to provide the area of drawdown influence within the groundwater source and effect on existing users (both extractive and environmental users). The simulation was used to determine the drawdown in the water table and in bores where drawdown exceeded 2 m, which is the indicator of a 'Level 2' impact as stipulated in the Aquifer Interference Policy (AIP).

a. Water table drawdown

The water table drawdown from the original EIS model (Coffey 2016b), indicated an irregular shaped drawdown pattern overlying the mine workings, with very slow recovery in some parts of the mine. This was investigated thoroughly by HydroSimulations as part of their detailed model audit. It was found that this pattern was primarily a result of how the model software mathematically calculates dewatering and resaturation within adjoining layers.

Modelled head data from the EIS model was exported and compared with later model revisions following the upgrades to MODFLOW-SURFACT V4 and then MODFLOW-USG with the pseudo-soil function enabled. Following conversion to MODFLOW-USG and the implementation of the pseudo soil function, more regular concentric spatial patterns of water table drawdown were observed.

Either enabling the pseudo-soil function or using the more sophisticated mathematical software in MODFLOW-USG means the model more correctly simulates groundwater levels when it is near the base of a layer and increases the realism in the interaction between two vertically connected model layers.

The maximum water table drawdown extent for the revised model represents the maximum value of water table drawdown predicted for each model cell (where maximum drawdown is greater than 2 m) from the 67th percentile uncertainty analysis results. The 2 m contour representing the maximum water table drawdown extent for the revised model (HydroSimulations 2018) is shown overlaying the 2 m contour representing the maximum water table drawdown extent from the original EIS model (Coffey 2016b); the size of the two are relatively similar. The main difference is the more regular shape of the revised model (HydroSimulations 2018) (Figure 11.1).

The water table drawdown pattern (Figure 11.2) indicates a concentric shape with the maximum drawdown logically being experienced towards the centre of the mine workings. The drawdown extent is localised to the mine footprint, and demonstrates minimal lateral extent of drawdown during mining and that most of the impacts are restricted to those areas immediately overlying the mine workings.

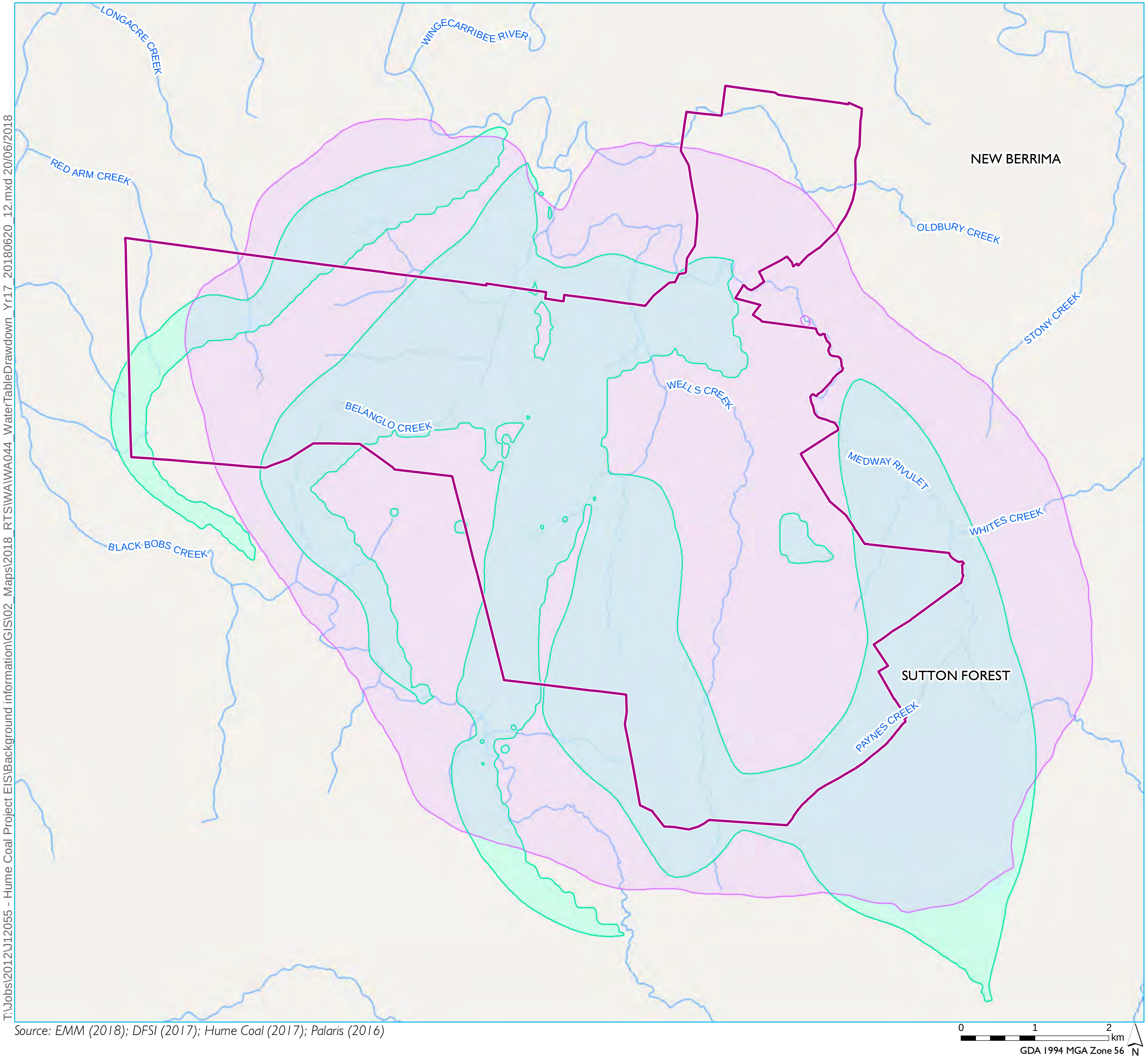
The maximum water table drawdown is less than 30 m and is directly above the mine workings. The zone where the water table is affected by 2 m or more total drawdown extends up to approximately 2 km beyond the mine footprint.

Undertaking detailed uncertainty analysis allows for the visual representation of the level of 'confidence' in the predictions (Figure 11.3). The distance between the levels of confidence in the predictions shown in Figure 11.3 is small, indicating that the degree of uncertainty in the model predictions is low. Movement from one 'confidence' category to the next (ie from 'likely' to 'as likely as not') does not result in a significant number of additional bores or additional area being affected by the 2 m drawdown trigger. This demonstrates a high level of reliability in the model predictions with respect to actual impacts to users.

b. Drawdown predictions in landholder bores

The area affected by drawdown migrates according to the location of active mine working through time. Pumping of water into the void increases the time for recovery of the depressurisation above the mine workings. Half of the affected bores recover to within 2 m by 45 years from mining commencing; and all bores recover from the project drawdown by 76 years after mining begins. The recovery time for the project (ie 76 years for bores) is significantly less than some mines in the Hunter Valley and Gunnedah Basin, with some having recovery times in excess of 1,000 years, and many not recovering to pre mining conditions at all (as is the case for some open cut mines with final voids where groundwater continues to be taken).

Refer to Section 11.4 for further discussion on impacts to landholder bores.

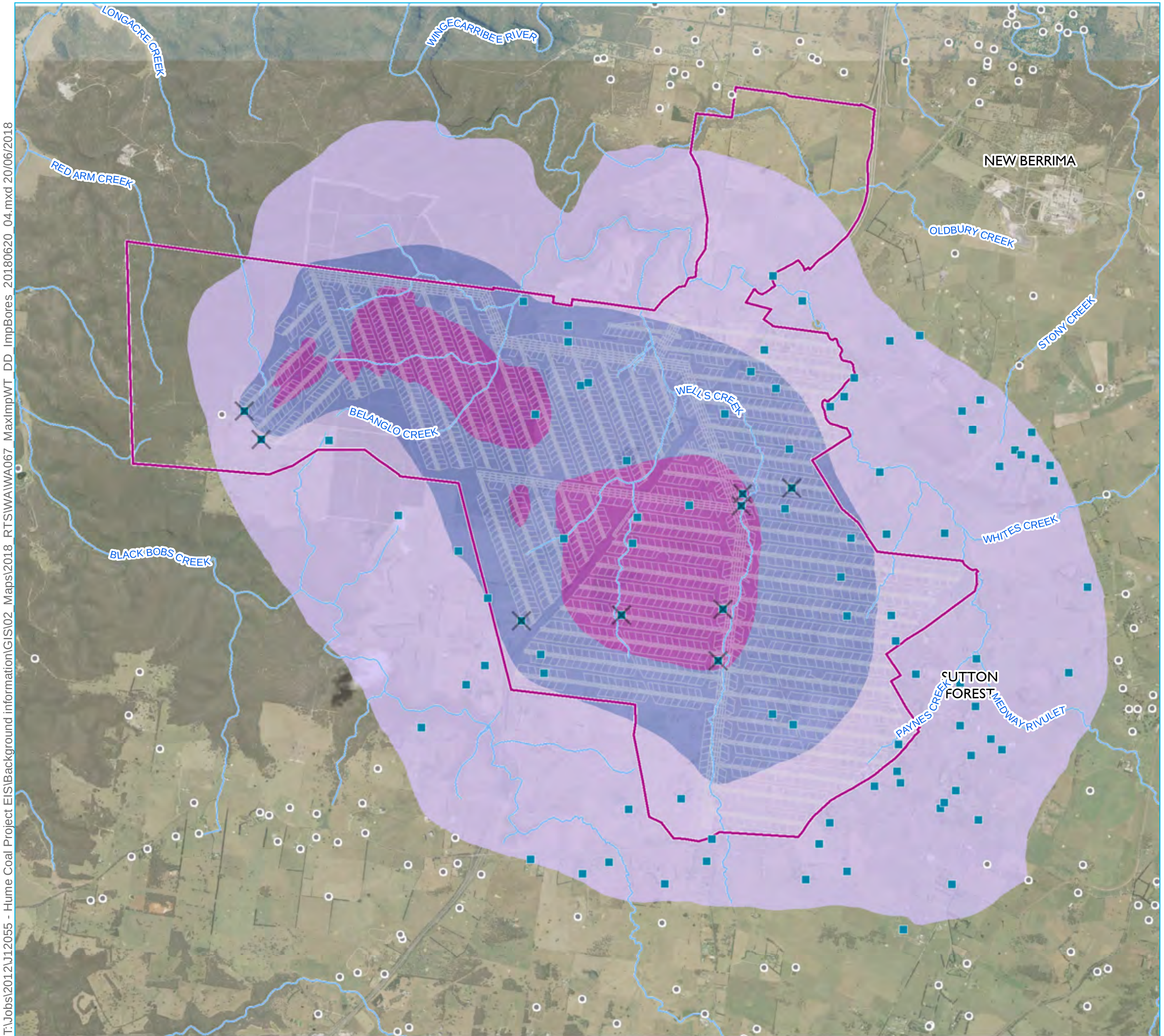


Source: EMM (2018); DFSI (2017); Hume Coal (2017); Palaris (2016)

T:\Jobs\2012\J12055 - Hume Coal Project EIS\Background information\GIS\02_Maps\2018_RTS\WA\WA044_WaterTableDrawdown_Yr17_20180620_12.mxd 20/06/2018

Comparison of water table drawdown (EIS model vs revised model)

Hume Coal Project
Revised Water Assessment
Figure 11.1



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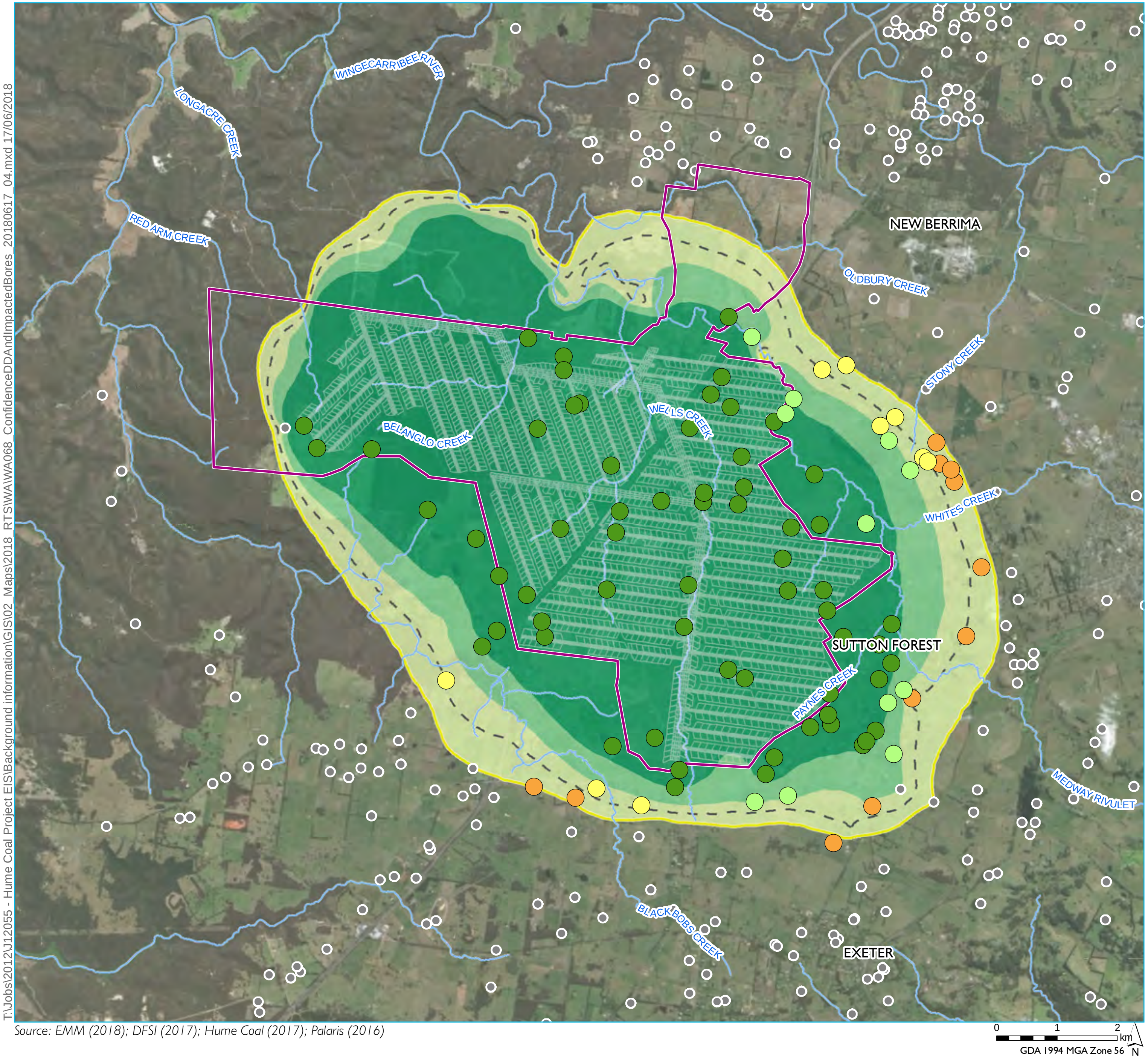
Source: EMM (2018); DFSI (2017); Hume Coal (2017); Palaris (2016)

Maximum water table drawdown and impacted bores

Hume Coal Project
Revised Water Assessment
Figure 11.2

HUMECOAL PROJECT

EMM



KEY

- Non-affected bores
- Project area
- Underground mine workings
- Drainage line

Confidence of 2m or more drawdown in landholder bore

- Very likely
- Likely
- Median
- As likely as not

Confidence of 2m or more water table drawdown

- Very likely
- Likely
- As likely as not
- Median (as likely as not)
- Watertable drawdown unlikely to occur outside this contour

T:\Jobs\2012\J12055 - Hume Coal Project EIS\Background information\GIS\02_Maps\2018_RTS\WA\WA068_ConfidenceDDAndImpactedBores_20180617_04.mxd 17/06/2018

Source: EMM (2018); DFSI (2017); Hume Coal (2017); Palaris (2016)

Confidence of predicted drawdown and impacted bores

Hume Coal Project
Revised Water Assessment
Figure 11.3

11.1.3 Changes to surface water flow

i Baseflow reduction

Changes to surface water flows are negligible overall. The dominant reason for any change is a slightly reduced volume of baseflow from the groundwater source to streams.

The maximum rates of baseflow reduction as a result of the project for each management zone are shown in Table 11.3 (refer to Figure 8.6 for location). The Lower Wingecarribee River and Medway Rivulet management zones have been subdivided into smaller, sub-catchments for the purpose of this assessment. The model results indicate no reduction in baseflow for the Belangalo Creek, Wells Creek and Wells Creek tributary sub-catchments, and negligible reduction in baseflow for the Nattai River management zones due to the project.

The maximum rates of baseflow reduction are not consistent throughout the mining period. The time taken to reach the maximum rate for each management zone are shown in Table 11.3. The timing and duration of baseflow impact for each management zone is presented in Figure 11.5. It can be seen that the rate of baseflow reduction gradually increases at the Medway Rivulet water source to a peak in year 19. A sharp decline in baseflow reduction occurs after years 20 (ie 20 years from start of mining and following cessation of active mining).

The Lower Wingecarribee River and the Medway Rivulet surface water sources are predicted to have the highest sustained rates of baseflow reduction (Figure 11.5).

The average Medway Rivulet baseflow rate estimated from baseline monitoring data is 3.3 ML/day at SW04 during average rainfall conditions (Coffey 2016b). This is more than three times larger than the predicted maximum rate of baseflow reduction (0.961 ML/day). The model results suggest the reduction in baseflow in the Medway Rivulet will be a minor proportion of the total baseflow for the whole management zone and is, therefore, unlikely to be measurable, or to influence other users of the surface water source, during a range of climate conditions (Coffey 2016b).

The predicted drawdown in the groundwater regime due to the mine would extend beyond the 19 years of active mining activities but would decrease progressively, mitigated by rainfall and runoff.

Table 11.3 Maximum rate of baseflow reduction from surface water sources

Surface water management zone / sub-catchments	Underlying groundwater source	Maximum rate of baseflow interception (ML/day)		Time to maximum rate (years since start of mining)
		ML/day	ML/year	
Upper Wingecarribee River	NMZ1	0.008	3	42
Lower Wingecarribee River (whole zone)		0.254	93	22.5
Lower Wingecarribee River excluding Black Bobs and Longacre Creeks	NMZ1, NMZ2	0.184	67	23
Black Bobs Creek	NMZ1	0.063	23	26.5
Longacre Creek	NMZ1	0.018	7	13.5

Table 11.3 Maximum rate of baseflow reduction from surface water sources

Surface water management zone / sub-catchments	Underlying groundwater source	Maximum rate of baseflow interception (ML/day)		Time to maximum rate (years since start of mining)
		ML/day	ML/year	
Medway Rivulet (whole zone)		0.982	359	19
Medway Rivulet excluding Oldbury, Belanglo, and Wells Creeks, and Wells Creek tributary	NMZ1	0.961	351	19
Oldbury Creek	NMZ1	0.021	8	20.5
Belanglo Creek	NMZ1	0	0	-
Wells Creek	NMZ1	0	0	-
Wells Creek tributary	NMZ1	0	0	-
Lower Wollondilly River	NMZ1	0.008	3	76
Nattai River	NMZ1, NMZ2	0*	0*	-
Bundanoon Creek	SBS	0.007	3	64

Notes: *NMZ1– Sydney Basin Nepean Groundwater Source Nepean Management Zone 1.*
NMZ2 – Sydney Basin Nepean Groundwater Source Nepean Management Zone 2.
SBS – Sydney Basin South Groundwater Source.
** – negligible.*

ii Leakage from surface water

As discussed above, slightly reduced baseflow is the main reason for changes to surface water flows, however the changes in flow overall are negligible. There is also a very minor component of direct leakage and this has been considered in detail for the Medway Dam. A detailed localised model simulation analysis was undertaken for Medway Dam to ensure that the connectivity at the local scale was being considered at a local scale. Based on flux analysis, there is a reversal of status from a gaining (ie baseflow reduction) to a losing system (ie leakage) at about 10 years since start of mining.

The reduction in baseflow is considered within the overall reduction numbers for Medway Rivulet, and the additional leakage volume is a small percentage from the dam itself, when the groundwater table is lowered below the base of the dam (ie year 10). This leakage volume is calculated as an average leakage of 12 ML between years 11 and 35, and a peak of approximately 19 ML in year 21 since start of mining. The leakage volume over time is provided (Figure 11.4).

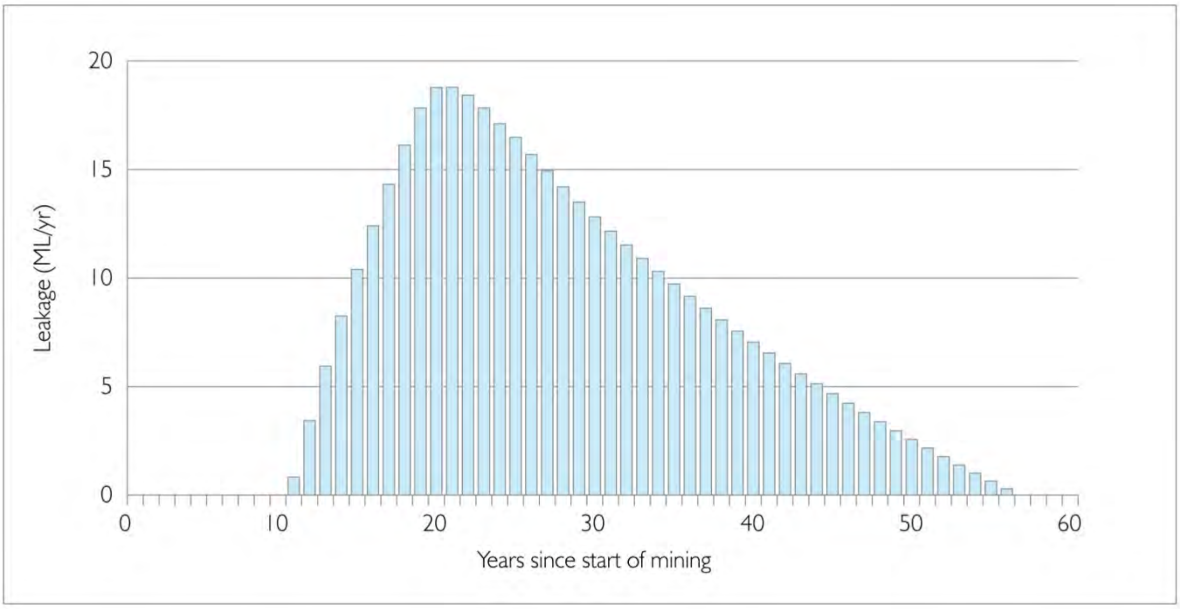


Figure 11.4 Volume of surface water leakage over time

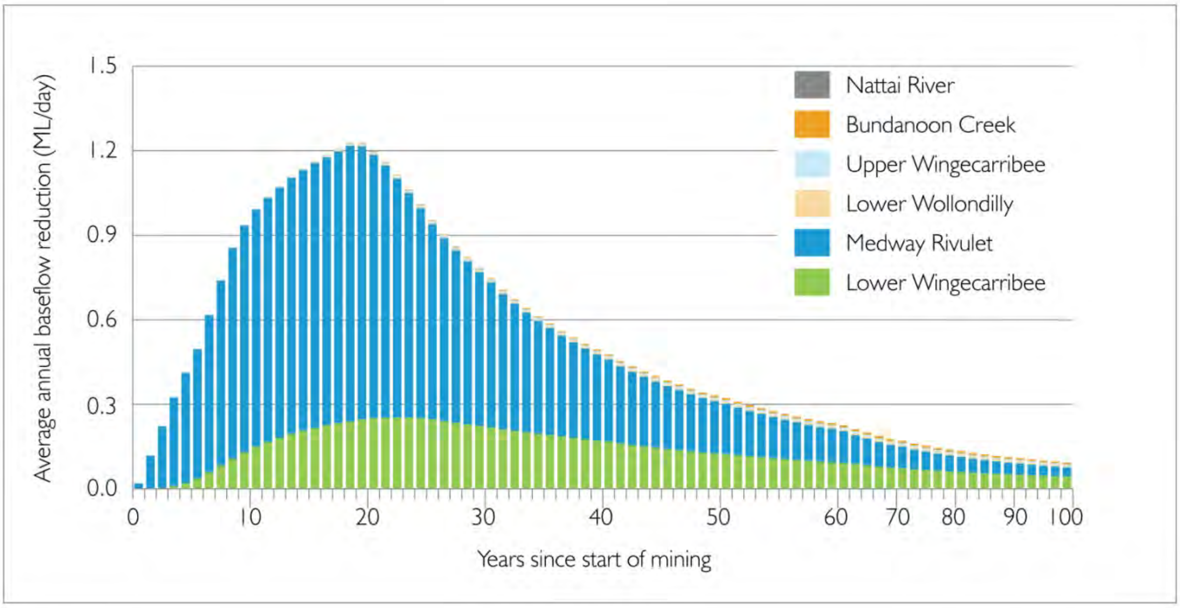


Figure 11.5 Timing and duration of baseflow impact for each management zone

11.2 Groundwater quality

AR 52: An assessment of groundwater quality, its beneficial use classification and prediction of any impacts on groundwater quality

AR 53: An assessment of the potential for groundwater contamination (considering both the impacts of the proposal on groundwater contamination and the impacts of contamination on the proposal)

AR 73: Estimate the chemical composition and load of chemical and physical stressors and toxicants in any discharge with ANZECC 2000 trigger values for the various environmental values of the waterway

Groundwater quality assessment results are presented and discussed in detail in Appendices I and J. The results and impact assessment are summarised in the following sections.

11.2.1 Effects of induced leakage from Wianamatta Group to Hawkesbury Sandstone

The groundwater numerical model was used to quantify the simulated flow of groundwater from the low permeability Wianamatta Group shale to the upper Hawkesbury Sandstone. Simulations were run for a 100 year time period, both with and without the influence of the project's activities, to provide a baseline groundwater flux in the absence of the project influences and with mining. This assessment has been updated using the revised groundwater model results (67th percentile uncertainty analysis results) (HydroSimulations 2018).

The baseline migration of groundwater with higher salinity from the Wianamatta Group shales to the upper Hawkesbury Sandstone was around 5–6 ML/day for the entire simulation period. This rate for comparison is equivalent to a very small rainfall event of 0.02 mm per day.

The Hume Coal Project is predicted to induce an incremental increase in the vertical flow was predicted between years 1 and 56, peaking in the year 14.5 year time step at 0.6 ML/day, (~10%) increase above the baseline conditions. For comparison an additional 0.6 ML/day of groundwater migration from the Wianamatta Group shale to the Hawkesbury Sandstone is equivalent to a rainfall event of 0.002 mm per day. The incremental flow over the simulation period is presented in Figure 11.6.

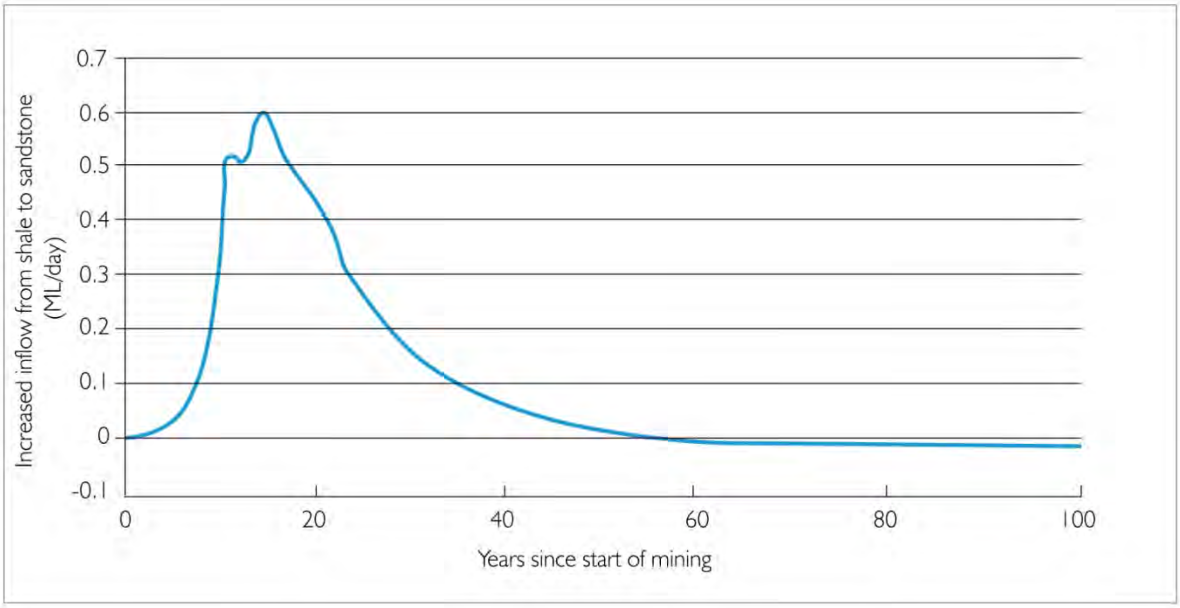


Figure 11.6 Predicted increase in groundwater flow from Wianamatta Group shale to upper Hawkesbury Sandstone due to mining

The temporary increase in groundwater flow from the shale to the upper Hawkesbury Sandstone could result in an increased solute (salt) load in the upper water bearing formations within the affected portion of the Hawkesbury.

The potential influence of the temporary increase in vertical groundwater migration, over approximately thirty years, should be considered in the context of the baseline conditions. According to the revised numerical groundwater modelling, there is currently a ~5–6 ML/day flux of groundwater between these two formations due to existing downward vertical hydraulic gradients. The downward gradients are attributable to the effects of mounding in recharge areas and depressurisation from discharge as baseflow or from escarpment faces, as well as the ongoing depressurisation/dewatering effects of the Berrima and Loch Catherine mine voids to the north.

Water quality data from the multi-level monitoring bores, installed in areas where the shale outcrops, was reviewed to assess whether the shale influences the baseline salinity of the underlying Hawkesbury Sandstone. In all cases, the water quality in Hawkesbury Sandstone bores installed beneath areas of shale outcrop were characterised by low TDS conditions (typically below 1,000 mg/L). Bores installed in areas of Hawkesbury Sandstone outcrop generally exhibited slightly lower TDS values, but all were within the range of very low to low EC with respect to the ANZECC and ARMCANZ (2000) irrigation criteria, and consistent with 'good quality' drinking water according to the TDS criteria in the ADWG (NHMRC 2016). In addition, TDS concentrations were generally either stable or increasing with depth at each monitoring location. Whereas, the opposite distribution would be expected if the downward flow of shale groundwater were imparting a significant water quality effect on the underlying Hawkesbury Sandstone.

A mixing model was used to assess solute concentrations that would result from mixing different proportions of Wianamatta Group and Hawkesbury Sandstone groundwater, considering average groundwater quality from the two formations. With respect to the potential to diminish the beneficial uses of the Hawkesbury Sandstone groundwater resource, EC and also, therefore, TDS were the most sensitive parameters, as the other analytes were generally substantially below the relevant beneficial use criteria even when a high proportion of shale groundwater was considered in a mixing scenario. The mixing analysis indicated that a ratio consisting of >40% Wianamatta Group shale groundwater would be required to produce a mixed TDS value that exceeds 900 mg/L (the threshold at which groundwater is considered 'poor quality' from a drinking water perspective). The same ratio would result in groundwater considered to be suitable for irrigation of 'moderately tolerant crops', from an EC perspective.

The flux model results were also used to estimate salt load transferred (ie salt balance) from the Wianamatta Group shale to the underlying Hawkesbury Sandstone. Under baseline conditions, the groundwater flux from the shale to the sandstone was ~5–6 ML/day, with an average TDS of 1,700 mg/L. Therefore, the baseline salt transfer under pre-mining conditions equates to 9,350 kg/day, or 3,415,088 kg/year. Under conditions influenced by mining, the increase in salt flux is proportional to the increase in groundwater flux, peaking at an additional 372,555 kg/yr at the Year 14.5 time step (or an additional ~10% above baseline conditions). Over the full 56-year period during which the model results indicated an incremental increase in groundwater flux from mining influences (including the post-mining recovery period), the net increase in salt flux from the Wianamatta Group shale to the Hawkesbury Sandstone is less than 4% above baseline conditions.

Given groundwater flow between the Wianamatta Group shale and underlying Hawkesbury Sandstone increases by 10% within a limited period, and the current baseline flux has not significantly affected the underlying Hawkesbury Sandstone water quality, it is considered unlikely a material change to Hawkesbury Sandstone groundwater quality with the potential to reduce the beneficial uses of the groundwater resource would occur as a result of the additional mining-induced flux.

According to the baseline hydrogeological interpretation of the project area, the saturated thickness of the shale formations imparts a natural downward hydraulic gradient between the shale and the underlying Hawkesbury Sandstone. This is because the height of the saturated water column in the shale significantly exceeds the hydraulic pressure, or "pressure head", in the sandstone formations immediately below the shale.

The magnitude of groundwater flux between the shale formations and the underlying sandstone is a function of the hydraulic conductivity of the shale (which can reasonably be assumed to remain constant over time), and the height of the saturated water column in the shale in excess of the "pressure head" at the top of the sandstone formation. The greater the pressure head in the upper Hawkesbury Sandstone formations, the smaller the downward flux of groundwater from the shale formations and vice versa.

According to the current hydrogeological interpretation of the mine lease area, a relatively small pressure head exists at the top of the Hawkesbury Sandstone formation (~10 m), such that the downward hydraulic gradient (and groundwater flux) between the Wianamatta Group shale and the sandstone is close to its full potential under pre-mining conditions. The temporary loss of this pressure head due to depressurisation as a result of underground would result in a marginal increase in the downward gradient in the affected area; however, the absolute change in the downward groundwater flux would be relatively small (since the magnitude of the vertical gradient change would be relatively small). Hence, the maximum mining-induced depressurisation at the top of the sandstone can only ever result in a small incremental increase in the downward flux of groundwater from the Wianamatta shale formation, as indicated by the modelled flux results during the life of mining.

Accordingly, the influence of the groundwater salinity in the shale formations on the salinity of the upper Hawkesbury Sandstone is close to its full potential in pre-mining conditions, due to the downward gradient within the shale, and the small pressure head at the top of the sandstone. Irrespective of the potential spatial variability of salinity in the shale, the potential incremental difference in groundwater flux attributable to mining-induced depressurisation is inconsequential and small.

11.2.2 Water quality relating to reject materials

i Underground seepage from temporary reject stockpile runoff

The results of the assessment are summarised in Appendix I, including the water quality criteria for the foreseeable beneficial uses of groundwater in the study area, the results of the KLC tests for the limestone-amended and the unamended columns, and the average groundwater quality for the Hawkesbury Sandstone, calculated from the baseline monitoring data.

The main observations are as follows:

- In all cases, the final EC values from the KLC tests were below the average baseline EC values of Hawkesbury Sandstone groundwater. The results suggest that leachate from the three column scenarios would have a negligible influence on natural groundwater quality.

- The results for KLC 10, the unamended column (no limestone added), indicated that acid is generated through exposure to atmospheric oxygen and flushing with oxidised water. The final pH value of 4.7, was slightly lower than even the slightly acidic pH value of the natural Hawkesbury Sandstone groundwater (pH average of 5.3). The lower pH evidently also resulted in mobilising certain metals in the leachate. About half of the metals analysed exceeded one or more of the beneficial use assessment criteria.

- The results for KLC 16 and 18, with 1% and 2% limestone amendment respectively, indicated the limestone had enough buffering capacity to manage the acid generated though water-reject contact. The pH values remained close to neutral throughout the test, and the column leachate analytical results were similar to or more favourable than the native groundwater quality, with respect to exceeding water quality criteria. The final sample from KLC 16 presented an equivalent beneficial use status to the Hawkesbury Sandstone groundwater. The final sample from KLC 18 only exceeded the selenium criterion because the limit of recording was higher than the criterion; all other analytes are below the various assessment criteria.

The results of the limestone-amended KLC tests indicated that the expected water quality resulting from underground seepage from the reject stockpile presents a negligible risk to the baseline beneficial uses of Hawkesbury Sandstone groundwater resource. The temporary reject stockpile will be located on a suitable pad following stripping of approximately 150 mm of topsoil (which will be stockpiled for post mining rehabilitation). Management of the temporary reject stockpile will be in line with site procedures for waste management and water management.

ii Water quality effects of underground emplacement of co-disposed reject

Additional post-EIS hydrogeochemical modelling (utilising PHREEQC and Geochemist's Workbench) was undertaken to ultimately determine the likely effects on groundwater qualities resulting from emplacement of co-disposed reject (reject slurry) in underground mined-out voids. The method and results of individual modelling steps are presented in Section 8.7.2iii. Full discussion and presentation of results are included in Appendix J.

The key results are summarised as follows:

- The PWD modelled water qualities were near-neutral (pH 6.03–8.25) and are likely to remain neutral over the mine's life. All components were within the range of baseline groundwater conditions for the Wongawilli Coal Seam, with the exception of chromium and nickel.

- Two separate scenarios were modelled for the emplacement of co-disposed reject in mined-out panels:

  a) scenario 1: during mining (operation phase) – involving freshly produced reject material treated with 1% limestone mixed with PWD water to produce a reject slurry;

  b) scenario 2: after mining has completed – reject material treated with 2% limestone and stored in the temporary reject stockpile from the first year or so of mining until the end of mining before being mixed with PWD water to produce a reject slurry.

  The modelled reject water qualities for both scenario 1 and scenario 2 are near-neutral with a range of pH from 6.33 to 6.82 and pH 6.57 to 8.09, respectively. The slurry water qualities are generally comparable to baseline groundwater conditions.

  Although, concentrations of some metals/metalloids in the modelled groundwater conditions exceed certain aspects of the generic guidelines (NHMRC 2016, ANZECC & ARMCANZ 2000), it is important to recognise that the baseline groundwater quality in the Wongawilli Coal Seam also exceeds the same aspects of the respective guidelines. The resultant concentrations of metals/metalloids are generally lower than or equal to average baseline groundwater conditions for the Wongawilli Coal Seam. For example, for scenario 1, aluminium, arsenic, cadmium, chromium, copper, selenium and zinc typically decrease in concentration as a result of the reject slurry placement. Nickel is the only metal/metalloid that slightly increases above average baseline concentration of the Wongawilli Coal Seam as a result of reject slurry emplacement in scenario 1, but remains still within the range of baseline concentrations.

- The modelling inputs are typically conservative, with rainfall and groundwater inputs utilising the 95th percentile values. Some minerals were also 'suppressed' (prevented from precipitating) during the modelling based on observations of the KLC tests and prior experience; this may result in higher predictions of dissolved metal/metalloid concentrations than would occur in the field.

  If the coal rejects are managed appropriately the potential for adverse impacts to receiving groundwater is considered low as the water quality resulting from the reject emplacement is similar to the natural groundwater quality of the Wongawilli Coal seam.

11.2.3 Summary of groundwater quality impacts

With regard to the requirements of the AIP in relation to groundwater quality, it is not anticipated that the project activities will lower the beneficial use category of the groundwater source beyond 40 m from the mining zone, provided the mitigation measures discussed in Chapter 13 are implemented. No cumulative changes to groundwater quality are predicted to occur as a result of mining activities.

11.3 Cumulative impacts

AR 18 Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts

As discussed in Section 9.4, there are no potential future projects being assessed in the NSW planning process that would influence the assessment of the project. Therefore, no additional cumulative groundwater impacts are predicted.

The existing drawdown within the groundwater system includes landholder bore pumping and the Berrima Colliery mining effects. The groundwater model considers the combined drawdown of landholder pumping and Berrima Colliery mining and the project, as well as the project. The AIP assessment criteria require proponents to consider post water sharing plan impacts. As the landholder pumping and Berrima Colliery impacts are already considered as part of the baseline, the Hume Coal Project influence (in isolation) has been assessed against the AIP criteria.

With reference to the NSW State Groundwater Quality Protection (1998), cumulative groundwater quality changes due to the project are assessed to be negligible and there are also no potential future projects in the planning process.

11.4 Predicted impact on groundwater users

AR 51: The existing groundwater users within the area (including the environment), any potential impacts on these users and safeguard measures to mitigate impacts

AR 76: The impacts of groundwater flows, including changes in the water table configuration through such things as new dam construction, re-routing of waterways, groundwater behavioural changes, and changes to the catchment areas that feed to or away from the Hume Highway. Any change in the water table has the potential to affect the structural integrity of the Hume Highway

The possible predicted effects on sensitive groundwater users, as defined in Section 9.2, are described below. In summary:

- High priority ecosystems that rely on groundwater (GDEs listed in a water sharing plan):
  - there are **no predicted impacts** to GDEs as a result of the project.
- Ecosystems that potentially rely on groundwater:
  - potentially groundwater dependent ecosystems are considered to have facultative (opportunistic) dependency on groundwater. Where water table drawdown is predicted to occur, the ecosystems are expected to be able to adapt and, therefore, influence would be minimal. As per the *Significant impact guidelines* (DoE 2013), this impact is considered **insignificant**.

- Watercourses such as creeks, drainage lines, and swamps that receive baseflow:
  - baseflow reduction is expected to occur in most drainage lines near the project. The rate of reduction is not constant over time. The maximum rate of reduction is expected to be a minor proportion of the total baseflow. The impact on baseflow has been assessed (WSP 2018) and is expected to be minimal on surface water uses during a range of climatic conditions. As per the *Significant impact guidelines* (DoE 2013), this impact is considered **insignificant**.
- Private landholder bores and associated infrastructure:
  - groundwater quality changes in landholder bores are considered negligible based on assessments of potential increased flow from poorer water quality groundwater systems and solute transport assessments on co-disposed rejects to be emplaced underground. As per the *Significant impact guidelines* (DoE 2013), this impact is considered **insignificant**.
  - 94 landholder bores on 72 properties will be directly impacted by 2 m or more of temporary drawdown over a period of 76 years as a result of the project. Nine of these bores are predicted to be intersected by the mine workings. As per the *Significant impact guidelines* (DoE 2013), this impact is considered **significant**.

In addition, the predicted change to the water table was assessed for influence on the Hume Highway. Based on the maximum water table drawdown map presented in Figure 11.2, drawdown below the Hume Highway is expected to be less than 25 m. However, the water table appears to be around 25–30 m below ground under the Hume Highway within the project area, based on observations during drilling of monitoring bores located proximate to the Hume Highway (HU0032LDA/B and HU0072PZA/B/C: Appendix K) and the calibrated initial water table from the revised groundwater model (Appendix F). As such, drawdown on the water table, being initially located at least 25 mbgl, is unlikely to have observable affects on the highway's road base at surface. In addition, subsidence impacts as a result of mining and dewatering are predicted to be negligible or imperceptible to built and natural features at surface (Hume Coal Project Hazard and Risk Assessment (EMM 2017e; Mine Advice 2016)). The predicted depressurisation of groundwater systems as a result of underground mining is not predicted to influence the Hume Highway, including through such things as new dam construction, re-routing of waterways, groundwater behavioural changes (eg flow), and changes to the catchment areas associated with this highway.

11.4.1 Ecosystems that rely or potentially rely on groundwater

Although terrestrial vegetation, Long Swamp, and Stingray Swamp were identified as potentially affected GDEs by the project (EMM 2017c), the groundwater model drawdown predictions indicated these swamps and associated vegetation will not be influenced by the project.

Terrestrial vegetation has been classified as having a facultative (opportunistic) dependence on groundwater. Facultative (opportunistic) ecosystems will use groundwater during droughts (ie when surface water is not available), but exist without groundwater most of the time. Long Swamp and Stingray Swamp have been classified as having a facultative (proportional) dependence on groundwater (EMM 2017c). Facultative (proportional) ecosystems take a proportion of their water requirements from groundwater; however, there is no absolute threshold for groundwater availability below which ecosystem structure or function is impaired, and can respond to changes in groundwater.

Long Swamp is assessed to be a valley infill swamp, which is likely to source water from perched groundwater above the regional water table and also potentially from the water table. Although the water table is predicted to be shallow at Long Swamp (Figure 6.24), it is at least 6 km from the maximum extent of drawdown predicted by the numerical model. Drawdown of the water table upstream of this location is not predicted to impact Long Swamp. Therefore, it follows that Temperate Highland Peat Swamps and the threatened species it supports at Long Swamp would not be impacted by the project.

Stingray Swamp is assessed as a headwater swamp, which is likely to rely on perched groundwater sourced from local rainfall and runoff, and is not connected with the regional water table. As such, no drawdown-related impacts from the Hume Coal Project are predicted to occur at Stingray Swamp.

The *Hume Coal Project Biodiversity Assessment Report* (EMM 2017c) assessed the potential effects of predicted groundwater drawdown on potential terrestrial vegetation GDE locations. The assessment compared areas where the pre-mining water table is 10 mbgl or less (the assumed average eucalypt root depth limit) against the predicted maximum project impact drawdown from the water table. The assessment took into consideration the ecosystem's level of dependence on groundwater. Accordingly, no influence is expected to ecosystems identified if periods of prolonged drought are not experienced during mining.

11.4.2 Watercourses, creeks, drainage lines, and swamps that receive baseflow

Baseflow reduction is expected to occur in most drainage lines within near the project. The rate of reduction is not constant over time. The maximum rate of reduction is expected to be a minor proportion of the total baseflow (Section 11.1.3 and Appendix F (HydroSimulations 2018)). As such, the impact of reduction in baseflow is expected to be minimal on watercourses, drainage lines, and swamps during a range of climate conditions.

11.4.3 Landholder bores

Predictive simulations were used to quantify the potential impact for registered landholder bores. Impacts to landholder bores have been assessed against the AIP minimal impact requirements of a maximum 2 m decline cumulatively at any water supply work for 'post-water sharing plan' variations.

The predicted bore water levels at each bore over time are plotted in hydrographs in Appendix M. With reference to the AIP, 94 landholder bores (not including Hume Coal owned bores) on 72 properties are predicted to be subject to a drawdown of 2 m or more as a result of the project.

The revised groundwater model report (HydroSimulations 2018) refers to 93 bores experiencing drawdown of greater than 2 m as a result of the project. However, this Revised Water Assessment and 'make good assessment' (Appendix M) refers to 94 bores. The discrepancy relates to the groundwater model considering the same listing of landholder bores that were used in the EIS (data provided by the NSW Government in December 2015).

Hume Coal requested clarification from DP&E regarding the bore dataset on 23 Jan 2018, prior to completing the RTS groundwater model runs, and was provided with an up-to-date extraction from the NSW government's water licence and approvals database on 27 April 2018. By this time, the modelling work for the response to submissions had been completed. When the two datasets were compared, they were considered to be sufficiently similar not to require the modelling work to be re-done, however, the updated dataset was used to perform the make good desktop assessment. The new database contained a list of all registered bores with currently active approvals and additional active approvals not associated with registered bores. When compared to the December 2015 database, the updated version had one bore removed, (ie the bore is no longer valid), and contained two additional bores that are now included in the make-good assessment. The make good assessment was therefore updated to include a net total of 94 bores. These two additional bores have been assessed in the make good assessment by using the model predictions from similar nearby bores. Future model runs will include these two new bores.

Table 11.4 summarises drawdown statistics for the 94 landholder bores predicted to be affected by the project.

Table 11.4 Landholder bores – summary of drawdown statistics

Number of bores impacted	94[1]
Maximum drawdown range	2–47 m
Median maximum drawdown	6 m
Number of landholders (properties) with impacted bores	72
Average time for a bore to recover by 75% since impact begins	20 years
Time until all impacted bores recover, after mining starts	76 years

Notes: 1. Not including bores located on properties owned by Hume Coal.

The majority of the impacted bores (79% of bores) are predicted to experience a maximum drawdown of less than 15 m. The maximum drawdown for individual bores is summarised in Figure 11.7.

The numbers of impacted bores referenced in this report do not include bores on land owned by Hume Coal. The magnitude and timing of the drawdown at each bore depends on its location and depth with respect to the mine workings. Shallower and/or remote bores are predicted to experience smaller drawdown than deeper and/or closer bores. For example, the maximum project drawdown in a bore is 46.7 m, and this is for a deep bore very close to the mined workings.

With reference to the AIP assessment criteria, 94 landholder bores (not including bores owned by Hume Coal) on 72 properties are predicted to be subject to a project drawdown of 2 m or more (Figure 11.8), which triggers the Level 2 AIP criteria, of 'greater than minimal impact'. This has triggered additional assessment of the model predictions for each individual bore. This additional work (as required by the AIP) is presented in Appendix M.

Nine bores are predicted to be intercepted or potentially intercepted by mining. A histogram of the maximum project drawdown for the landholder bores is shown in Figure 11.7. The median project drawdown is predicted to be 6 m and the median duration of drawdown on the 94 affected bores is 46 years, with the maximum duration being 65 years.

The results of the 'make good' assessment are included in Appendix M. All bores having greater than 2 m drawdown are subject to receiving contributions from Hume Coal to account for increased pumping costs or other compensatory measures. About a third of those bores would not require bore pump intake deepening or replacement. Another third are assessed as potentially needing submersible pump intake depths repositioned for a certain period of time depending on the duration of drawdown. The final third are assessed as potentially requiring bore replacement of an alternative source of supply.

A table detailing the bore IDs, dates of construction, depths and assumed screened formation is also included in Appendix M.

With regard to the AIP requirements in relation to groundwater quality, the project activities will not result in a lowering of the beneficial use category of the groundwater source beyond 40 m from the activity, provided the mitigation measures discussed in the Section 13 are implemented. Cumulative impacts to groundwater quality are not anticipated as a result of mining activities.

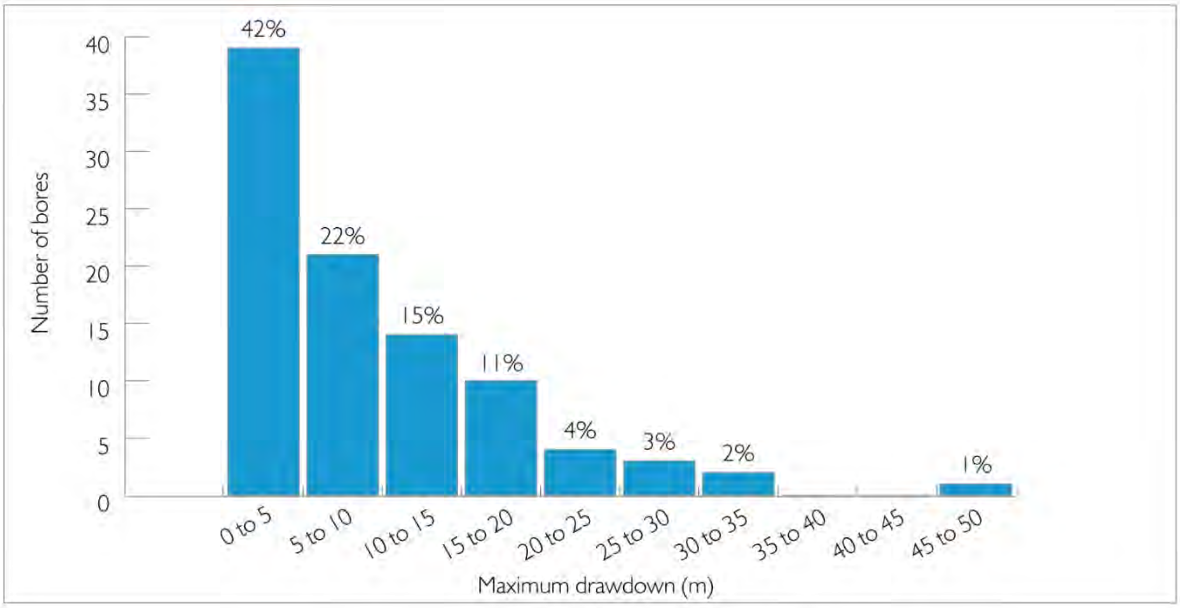


Figure 11.7 Maximum drawdown on landholder bores

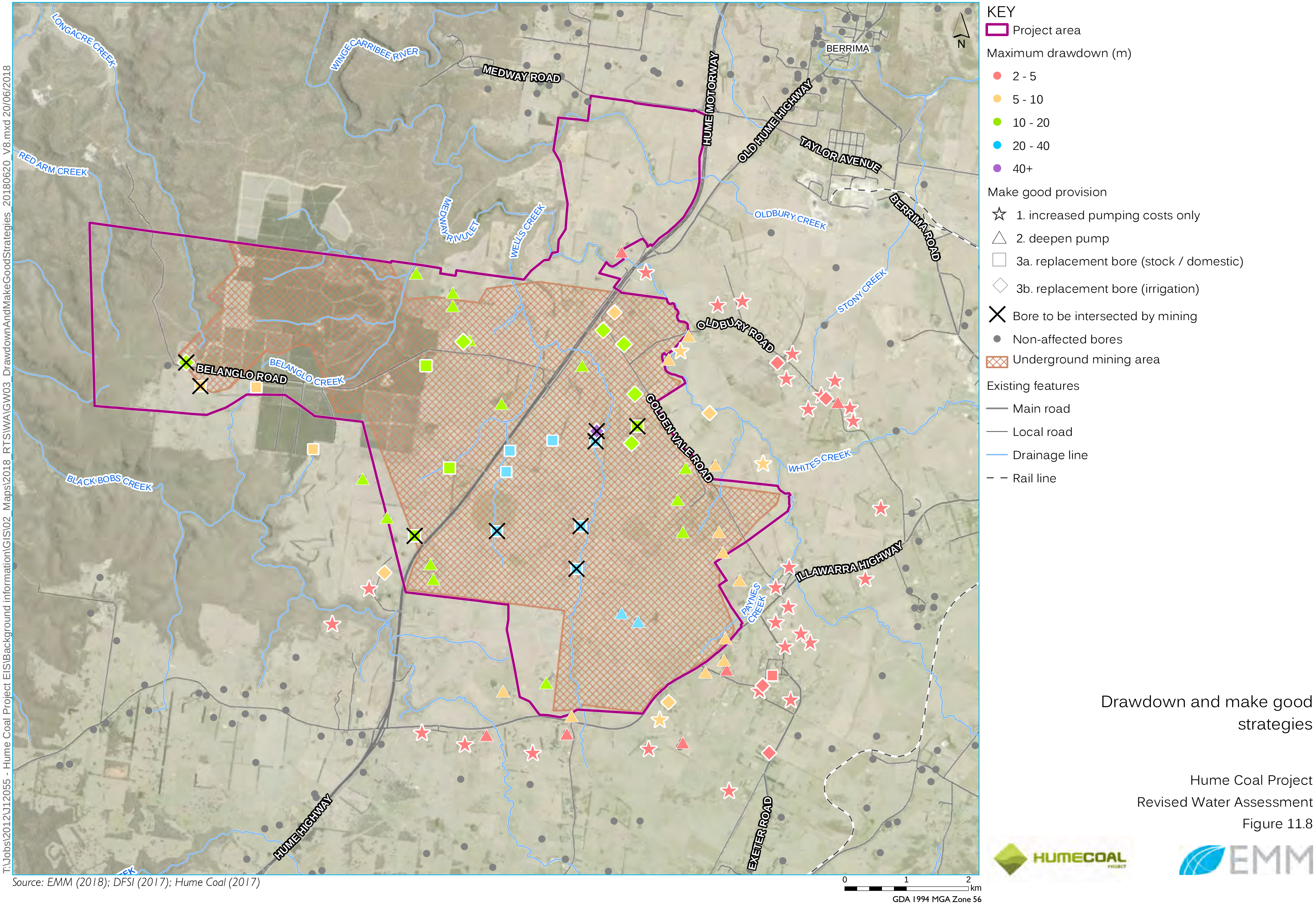
For implementation of make good in landholder bores, a staged approach will be adopted. The timing of when the drawdown exceeds the AIP Level 2 at each of the 94 bores predicted varies depending on the depth of the bore and its proximity to the mine area.

Table 11.5 presents the distribution of bores predicted to be impacted within 5-year stages. Bores identified in Stage 1 are bores predicted to be first affected by 2 m drawdown within the first 5 years of mining; Stage 2 bores are bores predicted to be first affected within 5-10 years of mining, and so on.

The make good process for each subsequent stage will be implemented every subsequent 5-year period in order for each bore to be incorporated into the make good process prior to the Level 2 impacts occurring. The spatial distribution of the make good bores within each stage is summarised in Figure 11.9.

Table 11.5 Make good bores within individual stages

Stage	1	2	3	4	5	6	Total
Time when bore first impacted by 2 drawdown	**0-5 yrs**	**5-10 yrs**	**10-15 yrs**	**15-20 yrs**	**20-25 yrs**	**+25 years**	
Make good provision							
1. increased pumping costs	-	3	7	9	5	7	31
2. deepen pump	6	9	13	3	2	-	33
3a. replace a stock / domestic bore	5	4	2	2	1	1	15
3b. replace an irrigation bore	5	8	1	1	-	-	15
	16	**24**	**23**	**15**	**8**	**8**	**94**



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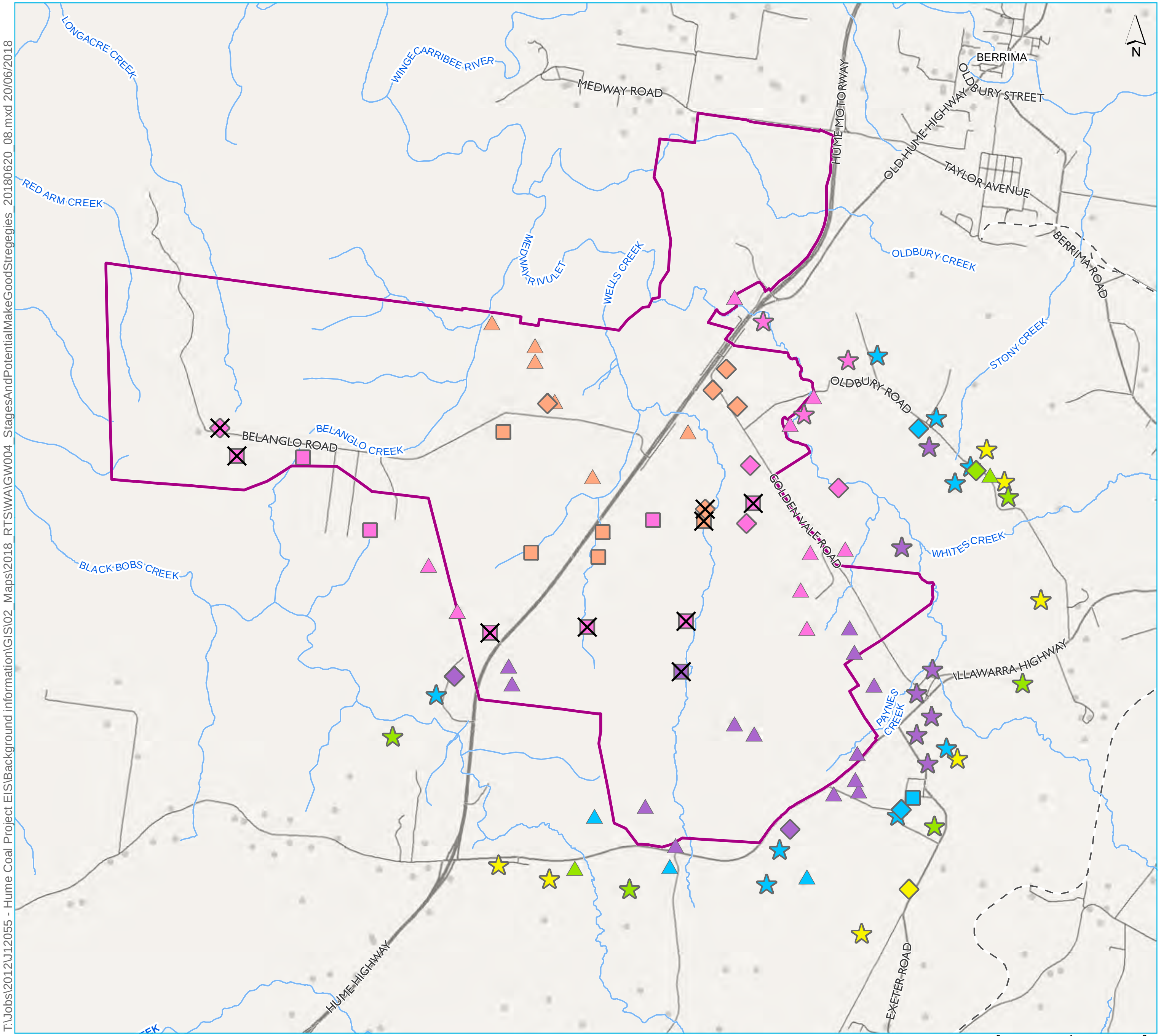
Source: EMM (2018); DFSI (2017); Hume Coal (2017)

Drawdown and make good strategies

Hume Coal Project
Revised Water Assessment
Figure 11.8



Source: EMM (2018); DFSI (2017); Hume Coal (2017)

KEY

- Project area

Make Good stage

- Stage 1 impact observed <5 years
- Stage 2 impact observed 5-10 years
- Stage 3 impact observed 10-15 years
- Stage 4 impact observed 15-20 years
- Stage 5 impact observed 20-25 years
- Stage 6 impact observed 25+ years

Make good provision

- 1. increased pumping costs only
- 2. deepen pump
- 3a. replacement bore (stock / domestic)
- 3b. replacement bore (irrigation)
- Bore to be intersected by mining
- Non-affected bores

Existing features

- Main road
- Local road
- Drainage line
- Rail line

Stages of make good bores

Hume Coal Project
Revised Water Assessment
Figure 11.9

HUMECOAL PROJECT

EMM

12 Water licences

This chapter provides a summary of the water licensing required for and already held by the project.

AR 8: Annual volumes of surface water and groundwater proposed to be taken by the activity (including through inflow and seepage) from each surface and groundwater source as defined by the relevant water sharing plan

AR 9: Assessment of any volumetric water licensing requirements (including those for ongoing water take following completion of the project)

AR 10: The identification of an adequate and secure water supply for the life of the project

AR 11: Confirmation that water can be sourced from an appropriately authorised and reliable supply. This is to include an assessment of the current market depth where water entitlement is required to be purchased

AR 25: Demonstrate how the proposal is consistent with the relevant rules of the Water Sharing Plan including rules for access licences, distance restrictions for water supply works and rules for the management of local impacts in respect of surface water and groundwater sources, ecosystem protection (including groundwater dependent ecosystems), water quality and surface-groundwater connectivity

AR 27: Provide an analysis of the proposed water supply arrangements against the rules for access licences and other applicable requirements of any relevant WSP, including:

- *Sufficient market depth to acquire the necessary entitlements for each water source*
- *Ability to carry out a "dealing" to transfer the water to relevant location under the rules of the WSP*
- *Daily and long-term access rules*
- *Account management and carryover provisions*

AR 32: Explanation of how the required water entitlements will be obtained (i.e. through a new or existing licence/s, trading on the water market, controlled allocations etc)

AR 34: Details on all bores and excavations for the purpose of investigation, extraction, dewatering, testing and monitoring. All predicted groundwater take must be accounted for through adequate licensing

AR 38: Consideration of water allocation account management rules, total daily extraction limits and rules governing environmental protection and access license dealings

AR 46: Any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes

AR 31: Details of the water supply source(s) for the proposal including any proposed surface water and groundwater extraction from each water source as defined in the relevant Water Sharing Plan/s and all water supply works to take water

12.1 NSW Water legislation and policies for licensing water

Hume Coal is required to licence surface water and groundwater in accordance with the Aquifer Interference Policy (AIP), the WMA 2000, and the relevant statutory water sharing plans. This includes water taken for use as well as water intercepted and managed as a result of mining activities. Enough water access licences (WALs) must be held to account for water intercepted from all water sources (directly or indirectly).

The AIP specifies the project licence requirement needs to consider adjacent and overlying water sources. Should the project cause water to inflow and subsequently capture an adjacent water source, a licence for that volume is required from that adjacent water source. The numerical groundwater model predicts the total volume of water intercepted during mining and the ultimate sources of that water.

12.2 Modelled water inflows

12.2.1 Inflow to mine workings

A conventional underground mine (ie one where workings remain open over the mine life) would cause inflows to the active workings sourced from continually draining upgradient areas of the mine.

Conventional mining methods can be inefficient in the volume of groundwater intercepted, and often also results in the release of excess water to the environment at the surface. The Hume Coal project has a considered mine design that specifically addresses water interception inefficiency by compartmentalising the mine into panels, and then promptly progressively sealing panels with water-retaining bulkheads. These design features minimise the removal of water from the groundwater source and minimises the volume of excess mine water released to the surface environment.

The project's compartmentalised water-efficient mine design results in most groundwater that would have otherwise flowed into the active mine remaining within the rock matrix of the groundwater source.

The numerical groundwater model for the project (HydroSimulations 2018) predicts groundwater inflows into the different parts of the mine from the surrounding water sources: both to active areas of the mine (sump) and to the sealed void (void). The model considers inflows during mining, immediately following mining and then recovery.

Modelled groundwater inflow to the sump (active mine area) and the sealed void are illustrated in Figure 12.1. The volume of inflow to the active mining area (ie water that is physically taken) is represented in blue in Figure 12.1. The majority of groundwater that inflows into the sealed void remains within the groundwater source and is not physically taken; this is represented in white on Figure 12.1. A small volume of the inflow to void will be harvested in some years to make-up operational water supply in those years (refer to Section 2.3.1).

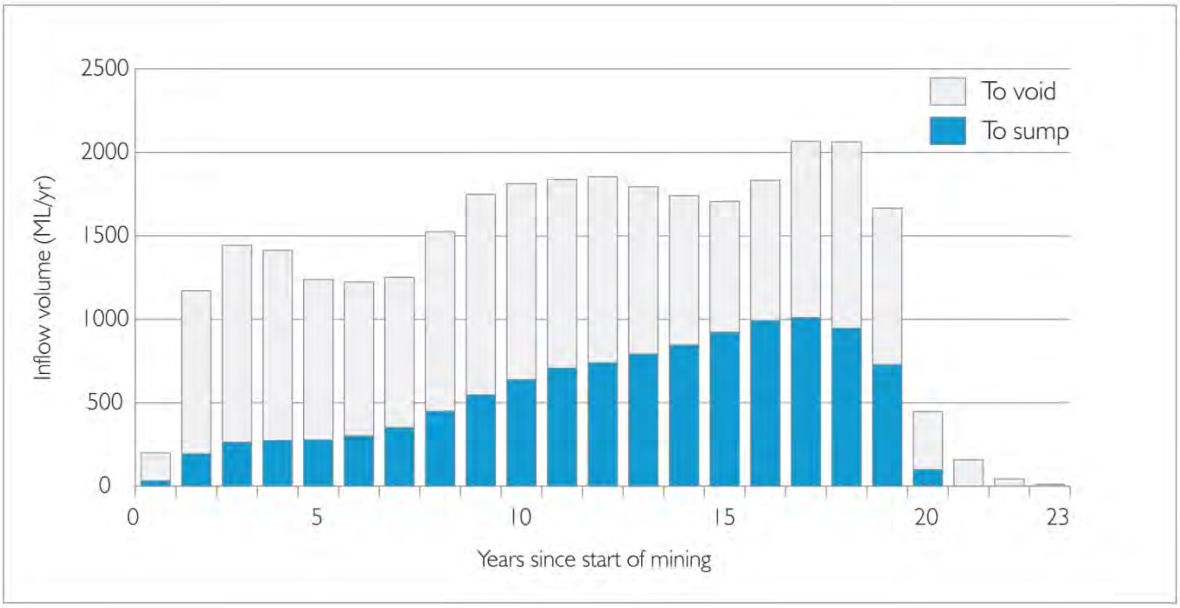


Figure 12.1 Expected inflow volumes over active mining and refilling of voids

12.2.2 Source of water

Water that inflows to the mine sump and void is mainly sourced from the Nepean Management Zone 1 of the Sydney Basin Nepean Groundwater Source. By the end of year 23 there is no additional groundwater take occurring from within Zone 1. However, there is minor throughflow from Sydney Basin Nepean Management Zone 2, the Sydney Basin South Groundwater Source, and induced leakage from surface water.

The throughflow from adjacent groundwater sources is estimated in the groundwater model; the average yearly throughflow from adjacent groundwater sources is 6.2 ML/yr and the peak is 13.6 ML/yr. The throughflow from the Sydney Basin Nepean Management Zone 2 Groundwater Source and from the Sydney Basin South Groundwater Source is 0.35% and 0.31% of the overall peak inflow, respectively.

There is a time lag between taking water from the groundwater system and a response in the adjacent groundwater sources. Figure 12.2 highlights the time lag for the volumetric contribution from the two adjacent groundwater sources to be realised. The majority, of the inflow to the mine sump each year is sourced from the Sydney Basin Nepean Groundwater Source Nepean Management Zone 1.

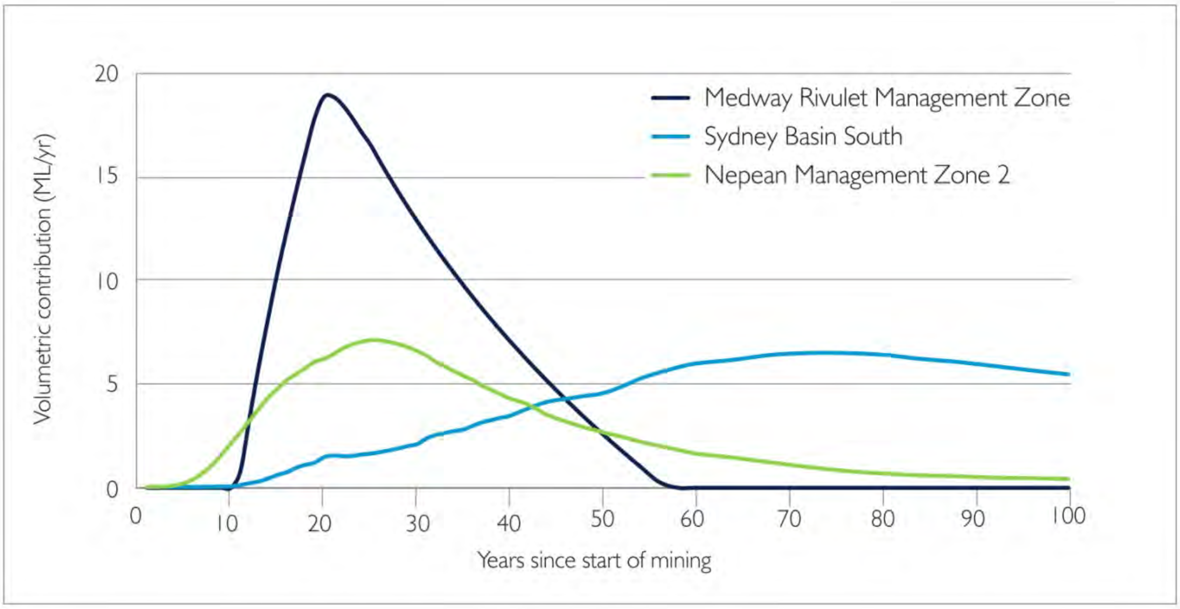


Figure 12.2 Volumetric contribution over time from adjacent sources

12.2.3 Intercepted baseflow and induced leakage

Baseflow is the component of streamflow that is groundwater. Baseflow is defined as a withdrawal of groundwater from storage and is part of groundwater recession inflow to the stream (Domenico & Schwartz 1990). Ephemeral streams are defined as those streams that do not flow continuously year round, and mainly flow following rain.

The groundwater table (which in many areas is perched) in the project area is generally higher than the beds of intersected streams for most of the stream length and for most of the time. Hence, the streams in the project area are generally classified as gaining streams and receive baseflow from groundwater. In much of the project area the drainage lines are also considered ephemeral.

Although most streams are classified as gaining, it is important to note that many are gaining from shallow perched or interflow groundwater which is disconnected from the regional groundwater table, while others are gaining from the regional water table.

The effects of extracted groundwater in a gaining stream connected to the regional groundwater table will only occur if there is clear connection between the shallow groundwater systems and the regional groundwater system (Figure 12.3).

In streams that overlie low permeability units (ie shale), there is a reduced degree of connection between the shallow and deep groundwater (sometimes the shallow is considered perched) and therefore stream baseflow is unlikely to be influenced by mining or drawdown of the regional water table (Figure 12.4).

Should groundwater extraction continue to a point where the regional groundwater level is below the stream height of overlying streams, a reversal of potential hydraulic gradient will occur and the stream will make a transition from a gaining stream to a losing stream.

Groundwater extraction from a groundwater system underlying a connected losing stream will result in induced leakage (Figure 12.5). It is noted that this is no longer considered baseflow reduction – it is induced leakage and is considered a 'take' from the surface water resource. Connected losing streams are those where the groundwater level is between the stream stage height and the capillary fringe below the base of the stream bed (approximately 2 m). Continued groundwater pumping may further induce leakage (ie increased rates of leakage as the groundwater table lowers), until such time that the groundwater system becomes disconnected (ie the groundwater table is below the level of the capillary fringe - approximately 2 m below the base of the stream).

In groundwater systems that are disconnected, the surface water system is already losing at a maximum rate, and additional groundwater pumping or lowering of the water table has no further impact on the overlying surface water system (Figure 12.6).

For the Hume Coal project, most streams are classified as gaining streams which continue to be gaining streams throughout the project (ie even after the regional groundwater table is lowered). This is due to many streams overlying perched shallow groundwater systems that are not affected by the regional water table. The main exception is Medway Dam, which transitions from a gaining to a losing system during mining (likely due to the artificial elevation of the water surface). There is a time lag for induced leakage from Medway Dam and this is shown in Figure 12.2 above.

12.2.4 NSW approach to licensing intercepted baseflow

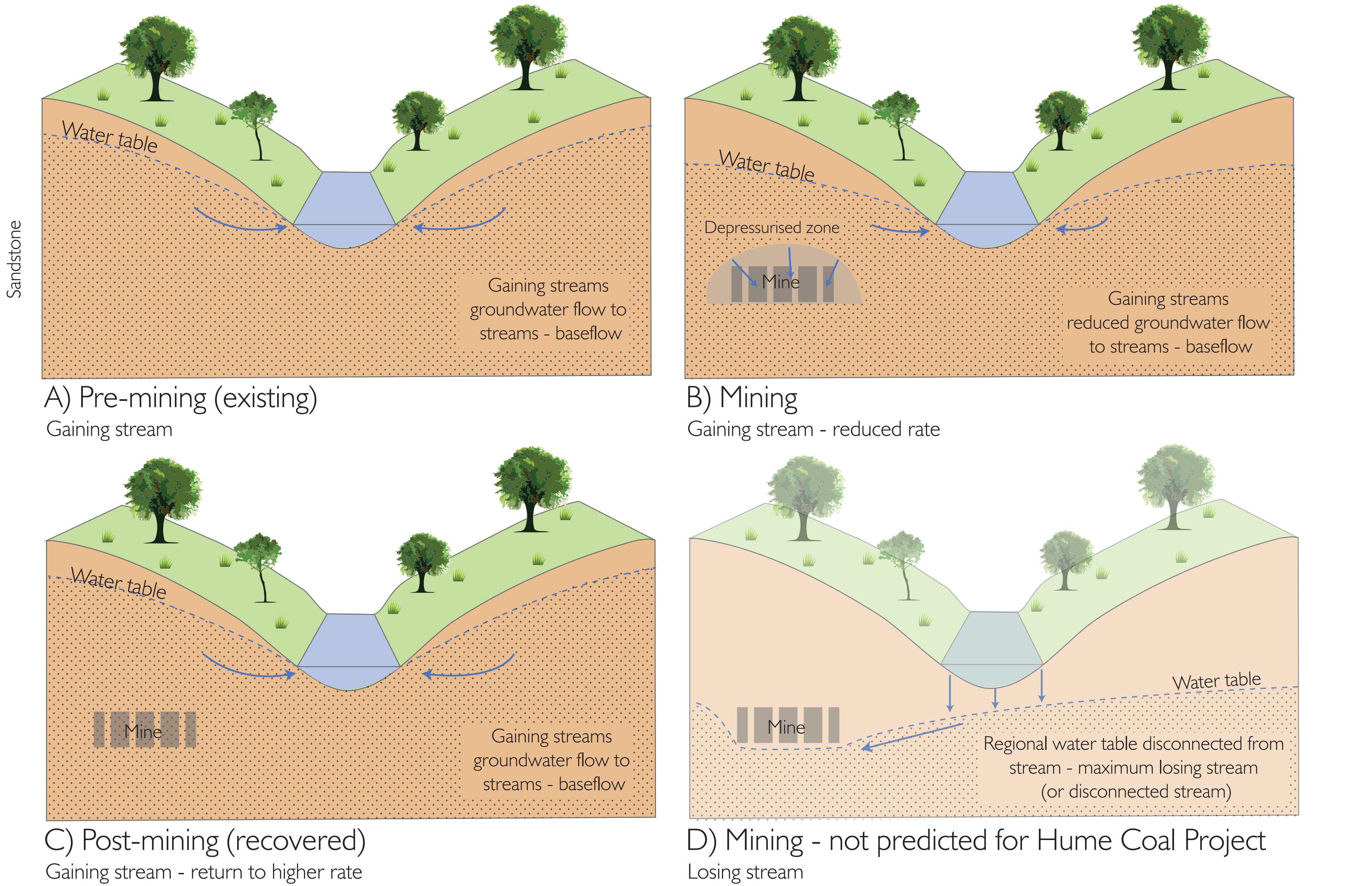
The sustainable limit for extraction has been defined for each water source in each water sharing plan (WSP) across NSW. This considers acceptable levels of regional impact for both groundwater and surface water users, including reduction of baseflow to streams regionally. Long-term average annual extraction limits (LTAAEL) set for individual surface and groundwater systems within the WSPs take into account potential reduction of baseflow should 100% of the LTAAEL be extracted.

Historically in NSW, water inflow to mines was always licensed solely as groundwater. Mining projects are required to determine the ultimate source of mine inflow and licence accordingly: Section 60 I (2) of the WMA 2000. In a gaining stream scenario this source is groundwater.

The project will therefore licence:

- intercepted groundwater as groundwater;
- intercepted baseflow as groundwater; and
- leakage from surface water sources as surface water.

This aligns with the NSW Government AIP Fact Sheet 3 (NOW 2013a) that describes in detail the licensing of water. The fact sheet discusses and illustrates when surface water licences are required, and only discusses induced leakage from a stream; interception of baseflow is not described as requiring a surface water licence.



Schematic surface water – groundwater interaction during phases of mining: connected gaining

Hume Coal Project
Revised Water Assessment

Figure 12.3

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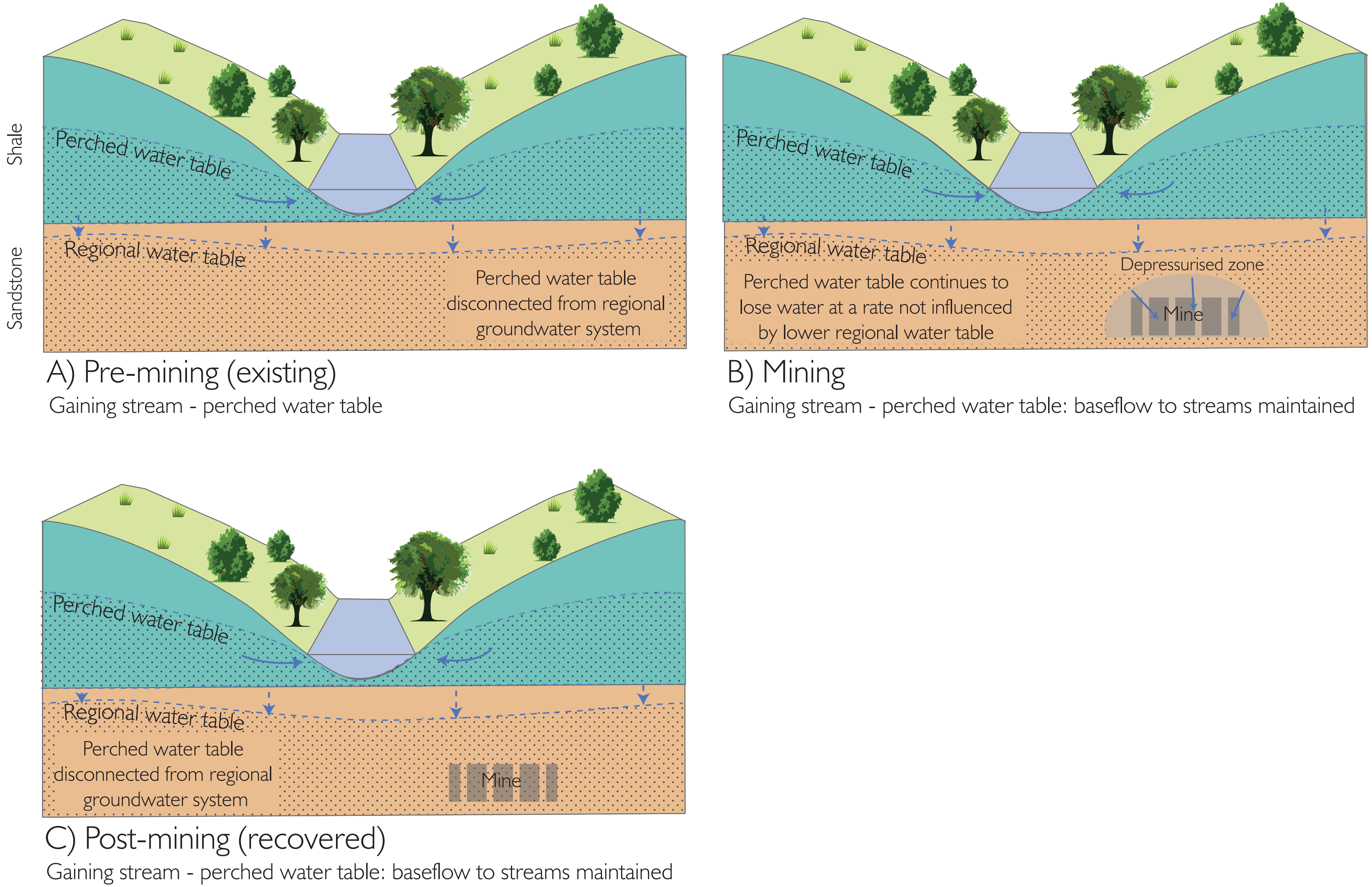
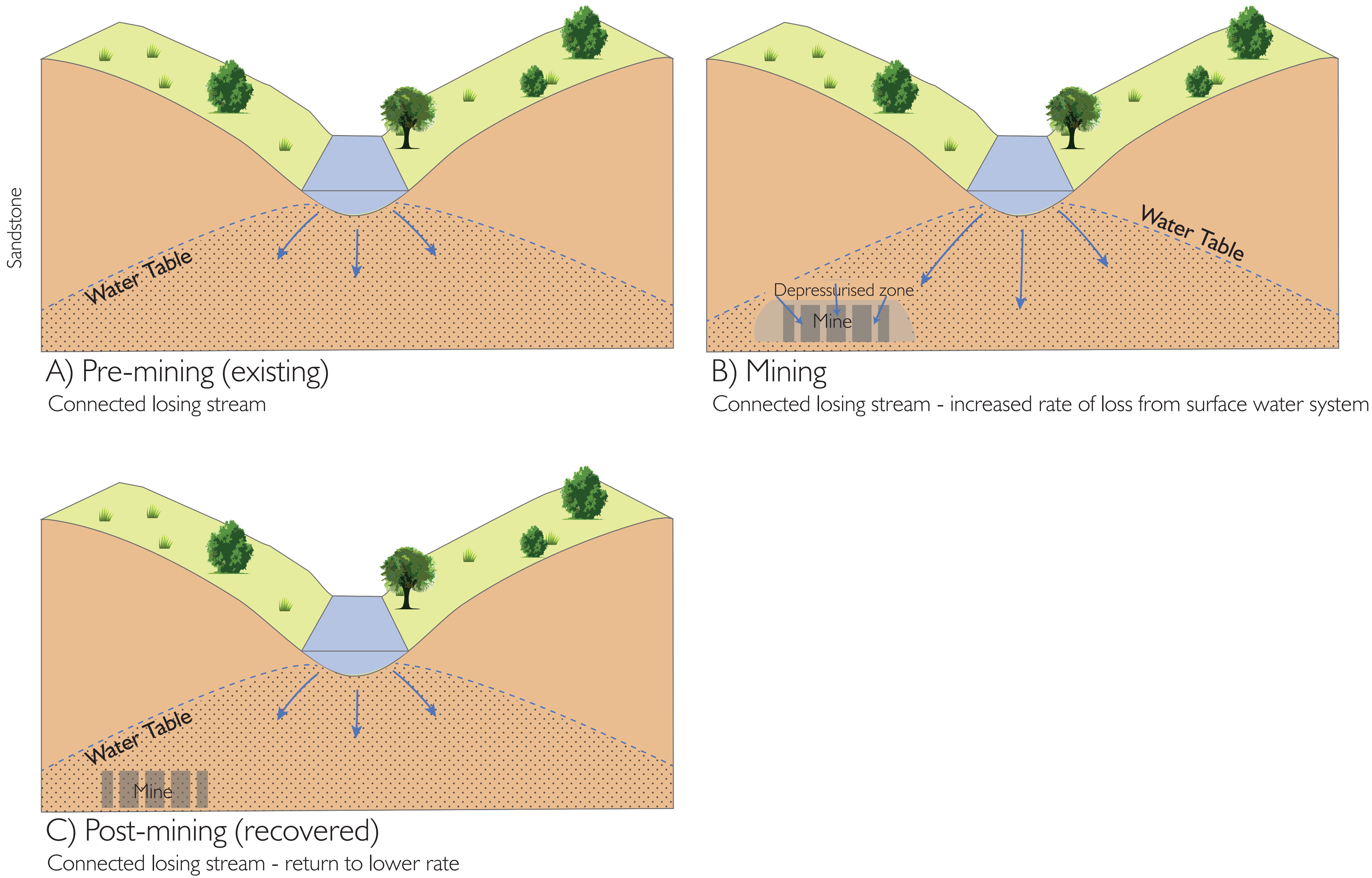


Schematic surface water – groundwater interaction during phases of mining: perched gaining

Hume Coal Project
Water Assessment

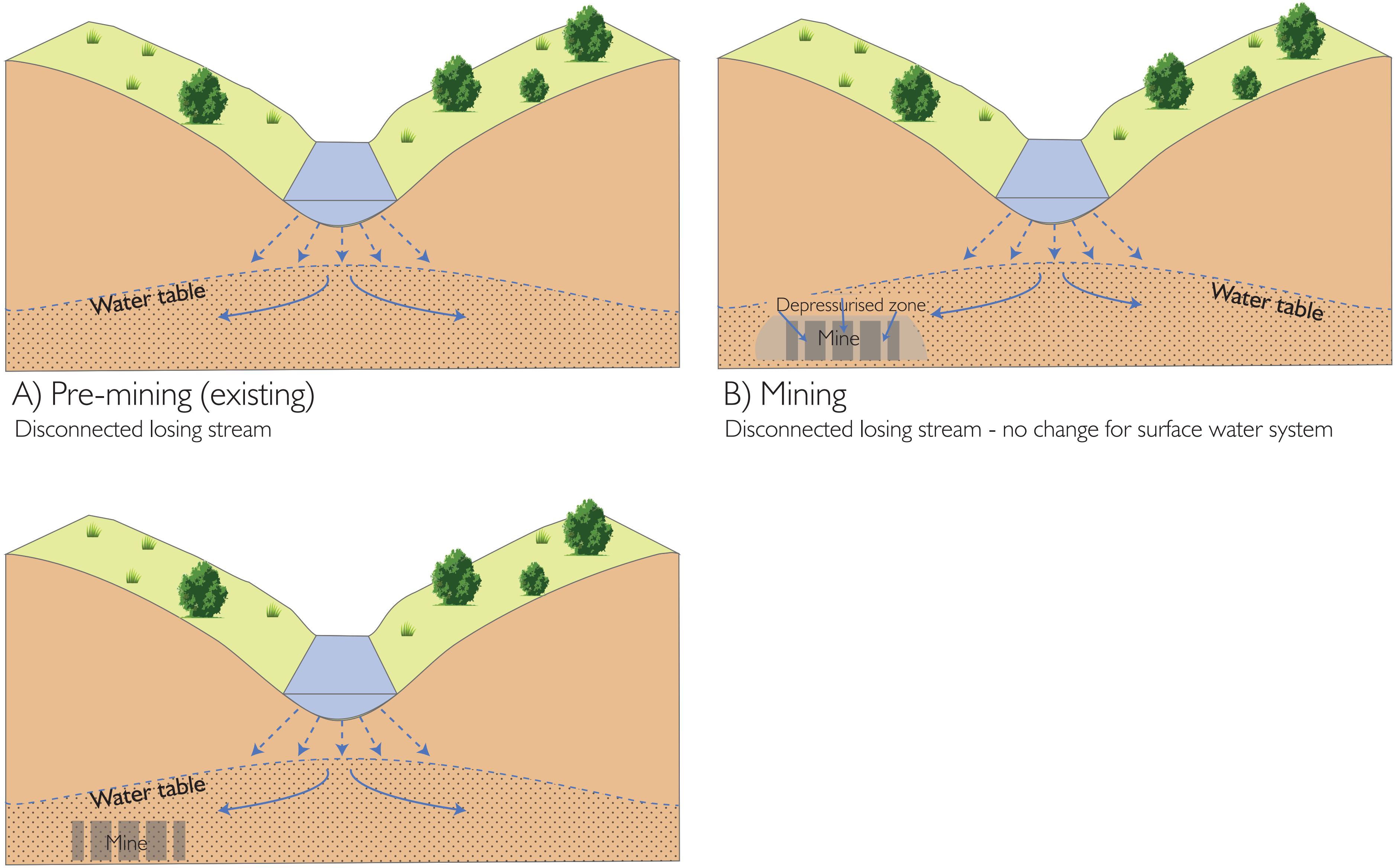
Figure 12.4



Schematic surface water – groundwater interaction during phases of mining: connected losing

Hume Coal Project
Water Assessment

Figure 12.5



A) Pre-mining (existing)
Disconnected losing stream

B) Mining
Disconnected losing stream - no change for surface water system

C) Post-mining (recovered)
Disconnected losing stream - no change for surface water system

Schematic surface water – groundwater interaction during phases of mining: disconnected losing

Hume Coal Project
Revised Water Assessment

Figure 12.6

12.3 Harvestable rights

Rural landholders in the project area are entitled to have dams on minor streams that capture 10% of the average regional rainfall runoff on land. The maximum harvestable right dam capacity (MHRDC) is the total dam capacity allowed under the harvestable right for properties and takes into account rainfall and variations in rainfall pattern. The NSW Government maintains an online MHRDC calculator (DI Water 2018). A MHRDC calculation has been undertaken for Hume Coal owned properties for the Hume Coal Project.

Stormwater basins SB01 and SB02, mine water dams MWD05, MWD06, MWD07 and the PWD are all classified as "special dams which are not included in harvestable right calculations" as they either do not have a catchment (ie PWD) or they are dams for the purpose of preventing contamination of a water source (ie PWD, SB01, SB02, MWD05-07) (NOW 2015). As such, the catchments of these dams (where applicable) are not included in the harvestable rights calculations. Catchments of SB03 and SB04 are included in harvestable rights calculations, however; the dams themselves are not (as the water captured will be released following collection of first flush and capturing and retaining first flush is classified as preventing contamination to a water source).

Considering the above, the MHRDC for Hume Coal owned properties is 111 ML per year (calculated using DI Water (2018)). Existing farm dams located on these properties will not be utilised for the project. To ensure MHRDC requirements are adhered to if required, existing dams can be converted to turkey's nest dams (ie dams with no catchments), with the exception of the instream storages located on Oldbury Creek. The capacity of the instream storages on Oldbury Creek is approximately 40 ML (based on an average depth of 2 m), which is significantly less than the MHRDC for the properties. As such, Hume Coal properties are in compliance with the harvestable rights requirements for dams.

12.4 Required licence volumes

The project's mining method progressively seals off the mine void from the active mine workings with bulkheads, so most groundwater that would have otherwise flowed into the mine is not extracted and pumped to the surface, but physically remains in the groundwater source and is available to other groundwater users.

The volume of water required to be licensed for the project is defined as the groundwater inflow to the sump that is physically handled by the mine's water management system, **plus** the groundwater inflow to the void, even though the majority of the groundwater in the void remains physically within the groundwater source.

Based on the results of the numerical groundwater model (HydroSimulations 2018), the water balance model (WSP 2018), and the localised model of Medway Dam, the maximum volume required for licensing is 2,093 ML/yr, and for each individual source is:

- Nepean Management Zone 1 Sydney Basin Nepean Groundwater Source 2,059 ML/yr in year 17;
- Nepean Management Zone 2 Sydney Basin Nepean Groundwater Source 7.1 ML/yr in year 25 (rounded up to 8 ML/yr); and
- Sydney Basin South Groundwater Source 6.5 ML/yr in year 72 (rounded up to 7 ML/yr); and
- Medway Rivulet Management Zone of the Upper Nepean and Upstream Warragamba Water Source, 19 ML/yr in year 21.

The yearly licence requirements during mining are shown in Table 12.1.

Table 12.1 Required licence volumes from water sources during mining

Year	Surface water leakage Medway Rivulet Management Zone of the Upper Nepean and Upstream Warragamba Water Source (ML)	Groundwater interception Sydney Basin South Groundwater Source (ML)	Groundwater interception Sydney Basin Nepean Groundwater Source Nepean Management Zone 2(ML)	 Nepean Management Zone 1 (ML)
1	0.0	0.0	0.0	200
2	0.0	0.0	0.0	1171
3	0.0	0.0	0.0	1443
4	0.0	0.0	0.1	1413
5	0.0	0.0	0.2	1238
6	0.0	0.0	0.4	1222
7	0.0	0.0	0.7	1251
8	0.0	0.0	1.1	1523
9	0.0	0.0	1.6	1747
10	0.0	0.0	2.1	1810
11	0.8	0.1	2.7	1835
12	3.4	0.2	3.2	1850
13	5.9	0.3	3.8	1790
14	8.2	0.4	4.3	1736
15	10.4	0.6	4.8	1701
16	12.4	0.7	5.2	1826
17	14.3	0.9	5.5	**2059**
18	16.1	1.1	5.8	2056
19	17.8	1.2	6.1	1660
20	18.8	1.4	6.2	440
21	18.8	1.5	6.5	151
22	18.4	1.5	6.7	36
23	17.8	1.5	6.9	3
Maximum (during mining and void filling)	**18.8**	**1.5**	**6.9**	**2,059**
Maximum impact (ML in year from commencement)	**18.8 (in year 21)**	**6.5 (in year 72)**	**7.1 (in year 25)**	**2,059 (in year 17)**

For groundwater, carryover provisions in the plan provide for up to 10% carryover of unused account water from previous years, and up to 110% use from an account (provided the account water is there). For surface water, carryover provisions in the plan provide for 100% of entitlement, plus accrued allocations, over a three-year rolling period.

Post mining and void filling there is a need to hold licences to account for the longer term recovery of groundwater levels; the volumes of these licence requirements are shown in Figure 12.7.

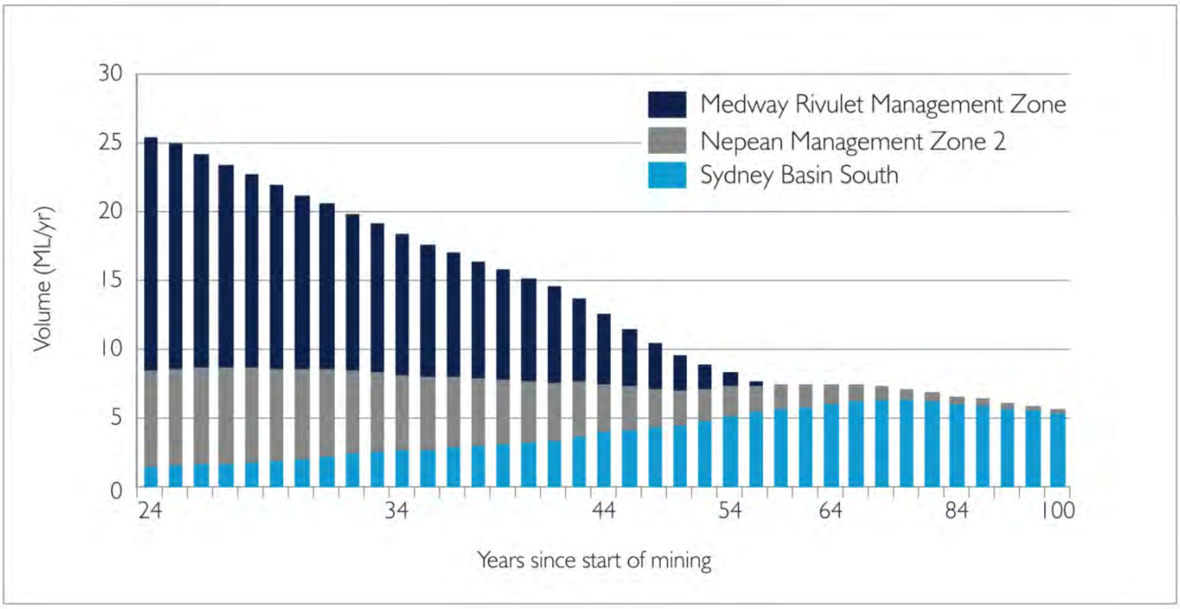


Figure 12.7 Post mining and void filling licence requirements

12.5 Licences currently held by Hume Coal

Hume Coal and its subsidiaries currently hold Water Access Licences shares for several water sources:

- 31 shares of unregulated river surface water in the Medway Rivulet Zone;
- 1,909 ML of groundwater share components for Sydney Basin Nepean Management Zone 1;
- 5 ML of groundwater share components for Sydney Basin Nepean Management Zone 2; and
- 25 ML of groundwater share components for Sydney Basin South.

12.6 Mechanism used to secure sufficient water licences

Hume Coal has already secured in 93% of the total licence requirement for the project, with a clear pathway for how the remaining licence volume will be secured to meet extraction requirements.

Hume Coal proposes to trade existing water licences from the Nepean Management Zone 1 on the open market to secure the remaining 150 ML (remaining 7%) of the licence requirement from that zone. For the additional 3ML of share component required from the Nepean Management Zone 2 of the Sydney Basin Nepean Groundwater Source either an application through the next controlled allocation order, or trading from within that zone is proposed.

Table 12.2 summarises the secured and remaining required licence volumes for respective water sources and zones.

Table 12.2 Secured water licences

Water source	Management zone	Total volume required for project (ML/yr)	Volume currently held in licences (ML/yr)	Outstanding volume required to be secured (ML/yr)	Method for acquisition	Total available trading pool in management zone(ML/yr)
Sydney Basin Nepean	Nepean Management Zone 1	2,059	1,909 (93%)	150	Trade	12,553[a]
	Nepean Management Zone 2	8	5 (63%)	3	Controlled allocation or trade	50,000 [b]
Sydney Basin South		7	25 (>100%)	0	**No more required**	69,892
Upper Nepean and Upstream Warragamba	Medway Rivulet Management Zone	19	31 (>100%)	0	**No more required**	
Total		**2,093**	**1,970**	**153**		

Notes: *a. From an October 2016 search of the online Water Licence Register (town water supply volumes removed).*
b. Approximated for Zone 2 from the 99,658 ML of LTAAEL in the Metro Groundwater WSP and areas of Zones 1 and 2.

12.7 Water market depth

The water market in Zone 1 of the Sydney Basin Nepean Groundwater Source has been sufficiently deep that Hume Coal has already secured in excess of 93% of the required licence volume for the project to date. There is minimal remaining volume to be purchased or applied for via controlled allocation with the NSW Government.

Water trading in the area often happens without separating the water licence from the land. There were 33 such transactions of land with accompanying water licence during 2016 and 2017 within Nepean Management Zone 1 of the Sydney Basin Nepean Groundwater Source. The total volume of water involved in these transactions during this same period was 1,975 ML of groundwater. Of this, a total 1,383 ML were unrelated to the project.

Water licences are also traded separately from land in the area, and these are recorded on the NSW Water Licence Register. A number of groundwater share assignment of rights dealings (permanent trades) have occurred in the Sydney Basin Nepean Groundwater Source within the previous three water years of 2014/15, 2015/16, and 2016/17 (Table 12.3). There have been three registered water allocation assignments (temporary trades) in the water year 2016/17 for a total volume of 52 ML, and one in 2017/18 for 50 ML.

Table 12.3 Groundwater share assignment trades (permanent trades) – Sydney Basin Nepean Groundwater Source

Assigned from WAL No.	Category	Assigned to WAL No.	Date transferred	Share (ML)	Price paid ($ per ML)
24925	Aquifer	36566	13-Nov-14	6	1,000
24802	Aquifer	37100	30-Oct-15	40	2,000
24809	Aquifer	37505	11-Mar-16	30	2,750
35537	Aquifer	37305	24-May-16	10	null
24915[a]	Aquifer	24915	June 2016	75	1,500
24865	Aquifer	37767	23-Nov-16	5	2,000
36487	Aquifer	36488	18-Jan-17	150	null
24941	Aquifer	40965	09-Feb-17	19	2,944.05
24842	Aquifer	40965	27-Apr-17	15	2944.05
25021	Aquifer	40965	26-Jun-17	78	3202.30
24882	Aquifer	41101	17-Aug-17	50	2892.40

Notes: a. WAL 24915 was a property sale (ie not registered on the Land and Property Information database), but the water licence was independently valued.

The water market depth is sufficient to secure remaining required licence volumes. The maximum volume required for licensing for each groundwater source as a portion of the LTAAEL is shown in Figure 12.8.

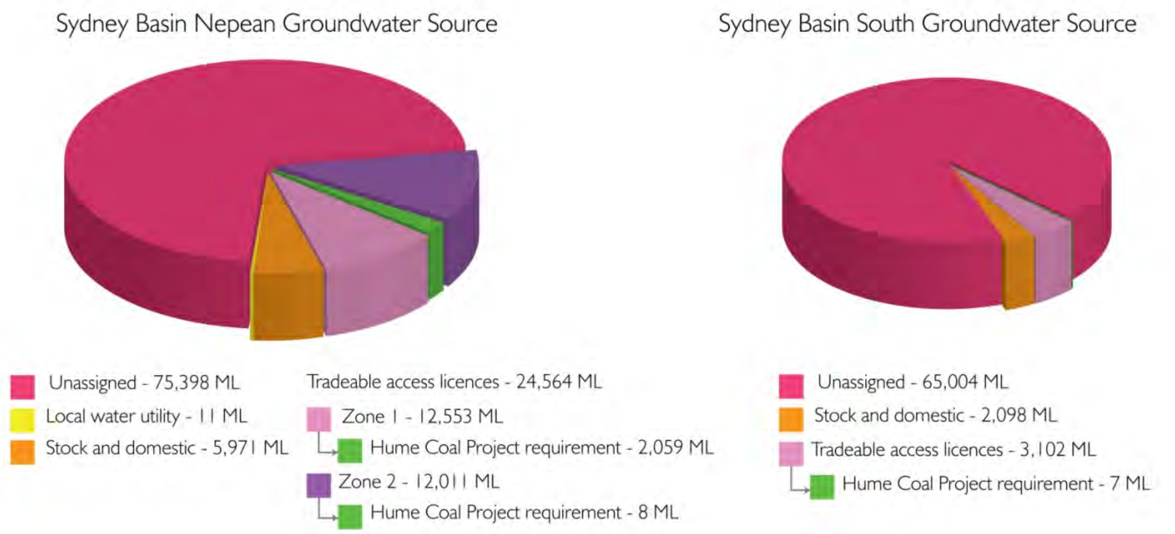


Figure 12.8 Project groundwater licence requirements as a portion of total LTAAEL in each groundwater source

12.8 Compliance with Water Sharing Plan rules

A requirement of the AIP is to comply with the relevant water source rules. A compliance assessment against the rules for the relevant water sources of the Metropolitan groundwater WSP is provided in Table 12.4.

Table 12.4 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Hume Coal Project compliance assessment
<u>**Access rules**</u>	
Rules for granting of access licences:	
Management Zone 1 & Management Zone 2 of Sydney Basin Nepean Groundwater Source and the Sydney Basin South Groundwater Source Granting of access licences may be considered for the following: • Local water utility, major water utility, domestic and stock, and town water supply *These are specific purpose access licences in Clause 19 of the Water Management (General) Regulation 2004*. • Aquifer (Aboriginal cultural), up to 10 ML/yr • Commercial access licences under a controlled allocation order made in relation to any unassigned water in this water source. Note: If water is made available through controlled allocation in this water source it is unlikely to be made available for extraction in Management Zone	Hume Coal has secured in 93% of the total access licence requirement for the project through • groundwater share components for Sydney Basin Nepean Management Zone 1; • groundwater share components for Sydney Basin Nepean Management Zone 2; and • groundwater share components for Sydney Basin South Trading of water from the Nepean Management Zone 1 is proposed to secure an additional 151 ML (remaining 7%) of the licence requirement from that zone, and an additional 3ML of share component from the Nepean Management Zone. Licences from Nepean Management Zone2 will be secured by either an application through the next controlled allocation order, or trading from within that zone.
<u>**Rules for managing water allocation accounts**</u>	
Carryover: • Up to 10% entitlement allowed. Carryover is not allowed for domestic and stock, major utility, local water utility or specific purpose access licences.	Hume Coal intends to hold 100% of the peak total licence requirement and, as such, carryover is unlikely to be required. Regardless, Hume Coal notes that carryover of up to 10% of entitlement is allowed.
<u>**Rules for managing access licences**</u>	

Managing surface and groundwater connectivity:
• From year 7 of the plan, for areas adjoining unregulated water sources (i.e. rivers and creeks), **existing** works within 40 metres of the top of the high bank of a river or creek, **except existing** works for, local water utility, town water supply, food safety or essential dairy care purposes, will have conditions which establish:
  • the flow class of the river established under the water sharing plan for the corresponding unregulated water source, or
  • in the absence of a flow class, visible flow in the river at the closest point of the water supply works to the river.
• These distances and rules may be varied for an applicant if the work is drilled into the underlying parent material and the slotted intervals of the works commences deeper than 30 metres or no minimal impact on base flows in the stream can be demonstrated.
• For major utility and local water utility access licences these rules apply to new water supply works from plan commencement.
	Noted. Hume Coal will comply with the relevant conditions. However, it is noted that conditions as applied to 'works' assume a 'bore' and are not necessarily always directly appropriate or transferrable to mining activities.
	
	The project is declared a State Significant Development, and as such is exempt from requiring a 'work and use approval' under the Water Management Act 2000. However, the essence of the rules will be applied as appropriate to the mine and associated works, and or groundwater bores for water supply.

Table 12.4 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Hume Coal Project compliance assessment
Rules for granting and amending water supply works approvals	
To minimise interference between neighbouring works:	
No water supply works (bores) to be granted or amended within the following distances of existing bores: • 400 m from an aquifer access licence bore on another landholding, or • 100 m from a basic landholder rights bore on another landholding, or • 50 m from a property boundary (unless written consent from neighbour), or • 1,000 m from a local or major water utility bore, or • 200 m from a NSW Office of Water monitoring bore (unless written consent from NSW Office of Water). The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	The mine workings will be conducted outside of the distances outlined, and where there are exceptions, make good provisions will be provided to impacted landholders.
To protect bores located near contamination: No water supply works (bores) are to be granted or amended within: • 250 m of contamination as identified within the plan, or • 250 m to 500 m of contamination as identified within the plan unless no drawdown of water will occur within 250 m of the contamination source, • a distance greater than 500 m of contamination as identified within the plan if necessary to protect the water source, the environment or public health and safety. The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	There are no identified contaminated sites identified within 500 m of the project area.
To protect water quality To minimise the impact on water quality from saline interception in the shale aquifers overlying Sydney basin sandstone, the bore being used to take groundwater must be constructed with pressure cement to seal off the shale aquifer as specified by the Minister.	Hume Coal has predicted that no water quality changes to the beneficial use category to landholder bores as a result of the mine. Hume Coal also commits that should water quality changes be observed in a landholder bores as a result of Hume Coal operations so that the beneficial use is compromised, additional sampling and investigations will be conducted to determine the cause of the change and to confirm whether the change will prevent the long-term viability of the impacted aquifer and/or bore. If it is found the long-term viability of the water supply is compromised as a result of the project then make good obligations will be negotiated and implemented. Any replacement bore will be constructed as per this rule, and in accordance with the Minimum construction requirements for water bores in Australia (NUDLC 2012). Access to the underground mine will be constructed in a manner to prevent significant interaction between the shale aquifers and Hawkesbury Sandstone where required.

Table 12.4 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Hume Coal Project compliance assessment
To protect bores located near sensitive environmental areas: No water supply works (bores) to be granted or amended within the following distances of high priority Groundwater Dependent Ecosystems (GDEs) (non Karst) as identified within the plan: • 100m for bores used solely for extracting basic landholder rights, or • 200m for bores used for all other access licences. The above distance restrictions for the location of works from high priority GDEs do not apply where the GDE is a high priority endangered ecological vegetation community and the work is constructed and maintained using an impermeable pressure cement plug from the surface of the land to a minimum depth of 30m. No water supply works (bores) to be granted or amended within the following distances from these identified features: • 500m of high priority karst environment GDEs, or • a distance greater than 500m of a high priority karst environment GDE if the Minister is satisfied that the work is likely to cause drawdown at the perimeter of the high priority karst GDE, or • 40m of a river or stream or lagoon (3rd order or above), • 40m of a 1st or 2nd order stream, unless drilled into underlying parent material and slotted intervals commence deeper than 30m. (30m may be amended if demonstrate minimal impact on base flows in the stream.), or • 100m from the top of an escarpment. The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	Hume Coal is not proposing to apply for a water supply work (bore) within 200 m of a High Priority GDE or the specified distances from sensitive environmental areas.
To protect groundwater dependent culturally significant sites: No water supply works (bores) to be granted or amended within the following distances of groundwater dependent cultural significant sites as identified within the plan: • 100m for bores used for extracting for basic landholder rights, or • 200m for bores used for all other aquifer access licences The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	Hume Coal is not proposing to apply for a water supply work (bore) within 200 m of a groundwater dependant culturally sensitive site.

Table 12.4 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Hume Coal Project compliance assessment
Rules for replacement groundwater works: A replacement groundwater work must be constructed to take water from the same water source as the existing bore and to a depth specified by the Minister. A replacement work must be located within: • 20 metres of the existing bore; or • If the existing bore is located within 40 metres of the high bank of a river the replacement bore must be located within: • 20 metres of the existing bore but no closer to the high bank of the river or a distance greater if the Minister is satisfied that it will result in no greater impact Replacement works may be at a greater distance than 20 metres if the Minister is satisfied that doing so will result in no greater impact on the groundwater source and its dependent ecosystem. The replacement work must not have a greater internal diameter or excavation footprint than the existing work unless it is no longer manufactured. If no longer manufactured the internal diameter of the replacement work must be no greater than 110% of the existing work.	All landholder bores assigned with a 'make good' provision of having a replacement bore installed will align with the rules stated for replacement groundwater works.
Rules for the use of water supply works approvals	
To manage bores located near contaminated sites: The maximum amount of water that can be taken in any one year from an existing work within 500 metres of a contamination source is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.	N/A
To manage the use of bores within restricted distances: The maximum amount of water that can be taken in any one year from an **existing** work within the restricted distances to minimise interference between works, protect sensitive environmental areas and groundwater dependant culturally significant sites is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.	N/A
To manage the impacts of extraction: The Minister may impose restrictions on the rate and timing of extraction of water from a water supply work to mitigate the impacts of extraction.	**Hume Coal will comply with relevant restrictions where imposed by the Minister.**

Table 12.4 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Hume Coal Project compliance assessment
Limits to the availability of water **Available Water Determinations (AWDs):** • 100% stock and domestic, local and major utilities and specific purpose access licences • 1ML/unit of share aquifer access licences AWD for aquifer access licences may be reduced in response to a growth in use.	Hume Coal will comply with the applicable available water determination.
Trading rules	
INTO groundwater source: Not permitted	Noted
WITHIN groundwater source: • Trading within groundwater source, from Management Zone 2 to Management Zone 1 is prohibited if the trade will increase the total licensed entitlement for the management zone from that at the commencement of the plan. • Trading within management zones permitted subject to local impact assessment.	Noted. To secure the remaining required licence volumes for the project, Hume Coal will source trades (and/or controlled allocation, in the case of Management Zone 2) from within the relevant management zones, subject to local impact assessment where relevant.
Conversion to another category of access licence: Not permitted	Noted

13 Monitoring, mitigation and management

This chapter provides a summary of the mitigation, proposed ongoing monitoring and management measures to be used to manage the potential environmental and social impacts of the project and validate the predictions of this assessment.

AR 2: A groundwater assessment to determine the likelihood and associated impacts of groundwater accumulating and subsequently discharging from the workings post cessation of mining, including consideration of the likely controls require to prevent or mitigate against these risks as part of the closure plan for the site

AR 5: Fisheries NSW recommend the use of best practice sediment and erosion control, and water quality and stormwater management provisions to safeguard and mitigate impacts on water quality at the site and downstream. They also recommend inclusion of appropriate riparian corridors to provide a buffer between the development areas and adjacent waterways or natural drainage lines to provide protection to riparian and aquatic habitats

AR 6: Details of ongoing monitoring programs to assess any impacts upon water quality, water flow and aquatic and riparian environments within and downstream of all waterways within the proposal area

AR 7: Safeguards to mitigate any impacts upon water quality, water flow and aquatic and riparian environments within and downstream of all waterways within the proposal area during construction and ongoing operation of the proposed coal mine. In particular, provide details on proposals for erosion and sediment control (to be incorporated into a Construction Environmental Management Plan - CEMP) and proposed stormwater and ongoing drainage management measures. Water quality management for the project should be designed to achieve no net increase in pollutant run-off to receiving waters within the proposal site.

AR 13: A detailed assessment against the NSW Aquifer Interference Policy (2012) using DPI Water's assessment framework

AR 16: Proposed surface and groundwater monitoring activities and methodologies

AR 51: The existing groundwater users within the area (including the environment), any potential impacts on these users and safeguard measures to mitigate impacts

AR 54: Measures proposed to protect groundwater quality, both in the short and long term

AR 55: Measures for preventing groundwater pollution so that remediation is not required

AR 56: Protective measures for any groundwater dependent ecosystems (GDEs)

AR 57: Proposed methods of the disposal of waste water and approval from the relevant authority

AR 59: Where potential impact/s are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on:

- *Any proposed monitoring programs, including water levels and quality data.*
  Reporting procedures for any monitoring program including mechanism for transfer of information
- *An assessment of any groundwater source/aquifer that may be sterilised from future use as a water supply as a consequence of the proposal*
- *Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category)*
- *Description of the remedial measures or contingency plans proposed*
- *Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period*

AR 59: A description of the design features and measures to be incorporated to mitigate potential impacts

AR 67: The measures that would be established for the long-term protection of local and regional aquifer systems and for the ongoing management of the site following the cessation of the project

AR 69: The EIS must assess the impacts of the development on water quality, including:
a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.
b. Identification of proposed monitoring of water quality.

AR 70: The EIS must assess the impact of the development on hydrology, including:

- *a. Water balance including quantity, quality and source*
- *b. Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas*
- *c. Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems.*
- *d. Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (eg river benches)*
- *e. Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water*
- *f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options*
- *g. Identification of proposed monitoring of hydrological attributes*

AR 74: Investigate options to reduce the levels of pollutants in the discharge of water to protect the environment from harm as a result of that pollution. Identify all practical measures to control or reduce pollutants in the surface or groundwater discharges. Identify preferred measures and their justification

AR 75: If WQO's cannot be met for the project, demonstrate that all practical options to avoid water discharge have been implemented and outline any measures taken to reduce the pollutant loads where a discharge is necessary. Where a discharge is proposed, analyse the expected discharges in terms of impact on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm

AR 80: A detailed assessment of the development on water resources which considers the design, construction, operational and decommissioning phases and have regard for operation during periods of wet weather and include:
- *details of measured and predicted coal mine, preparation area and stockpile area performance with respect to water quality management*
- *details of measures proposed to be adopted to offset impacts associated with construction activities eg earthworks, vegetation clearing and track construction*
- *impacts on overlying and adjacent creeks and water resources within risk management zone associated with subsidence*
- *impact of the proposed on-site domestic (sewage) wastewater management and associated effluent disposal area*
- *pre-development and post development run off volumes and pollutant loads from the site*
- *details of the measures to manage site water associated with processing coal and coal reject, general stormwater runoff and any human activities likely to affect water quality at the site, and how neutral or beneficial effect on water quality (NorBE) principles will be assessed and applied*
- *assessment of the impacts of the development on receiving water quality and volume, both surface and groundwater including from the filling of pine feather voids and associated impact on interaction and baseflows of surface waters*
- *details of the structural stability, integrity, ongoing maintenance and monitoring of all site water management measures including dams over the life of the project*
- *details of proposed monitoring of groundwater levels, surface water flows, groundwater and surface water quality, along with information as to how the proposed monitoring will be used to monitor, and, if necessary, mitigate impacts on surface water and groundwater resources*
- *the principles outlined in the 'Managing Urban Stormwater - Soils and Construction - Mines and Quarries' Manual prepared by the Department of Environment and Climate Change (2008)*

AR 83: Information on proposed avoidance and mitigation measures to manage the relevant impacts of the action including:
- *a description of the proposed avoidance and mitigation measures to address the impacts of the action*
- *assessment of the expected or predicted effectiveness of the mitigation measures*
- *the cost of mitigation measures;*
- *a description of the outcomes that the avoidance and mitigation measures will achieve:*
- *a description of the offsets proposed to address the residual adverse significant impacts and how these offsets will be established*

13.1 Avoidance and mitigation

13.1.1 Introduction

The design of the mine layout and method, and the associated water management system, was iterative, with early results of surface water and groundwater modelling providing input into the mine design. The water management system was optimised via this iteration to minimise physical water interception and inflow, conserve and reuse water, minimise evaporation losses, and minimise discharge to surface water systems. As a result, a number of avoidance and mitigation measures have been incorporated into the overall project design.

The specific mitigation and avoidance measures adopted by the project, and related environmental and social benefits, are presented in Table 13.1 . These mitigation and avoidance measures will be combined with management plans, management measures and the monitoring regime (outlined in the following sections).

An additional mitigation measure to those discussed below that was considered in detail is to pump surplus water back into the Hawkesbury Sandstone. Injection of surplus water into the Hawkesbury Sandstone provides an excellent mitigation measure to minimise groundwater drawdown in landholder bores, and enhance recovery times following mining. However, a trial of this activity (ie injection into a water source) was unable to be licensed by DPI Water, and as such, this mitigation measure will not be included in the proposed project.

Table 13.1 Mitigation and avoidance measures and benefits

Mitigation measure	Environmental benefit	Social benefit
Diversion of runoff from undisturbed catchments back into natural system	Minimises unnecessary water capture. Reduces water volume to be stored.	Water remains available to other users.
In non-direct coal contact areas (ie sub-catchments with roads and building infrastructure only) non-contaminated water to be released to natural surface water systems following first flush	Minimises unnecessary water capture.	Water remains available to other users.
Underground mine footprint with considered design	The mine footprint has been considered and tested to minimise impacts to water assets. The mine footprint has been reduced from initial concept stage to achieve lower groundwater inflows.	Overall lower impact to surface and groundwater resources.
Non-caving mining method and design of barrier pillars – designed to have zero caving, negligible subsidence, and no surface cracking	Minimised structural deformation. Minimises both lateral and vertical extent of groundwater depressurisation (area affected by drawdown is a relatively small (Coffey 2016b)). Minimises duration of groundwater depressurisation. No surface water losses from cracking of stream beds. No structural changes to Hawkesbury Sandstone, therefore, no change to potential groundwater flow rates.	No losses from surface water systems due to cracking. Water therefore still available for surface water users.
Sealing of panels as mining progresses	Maintain greater volume of groundwater in natural groundwater source. Minimise the physical interception and inflow of groundwater to the mine's water management system. Allows groundwater system to commence recovery immediately after panel sealed (ie while active mining continues in other areas).	Provides more rapid recovery to overlying landholder bores that may be impacted.
Underground co-disposal of reject	Removes potential for runoff from permanent surface stockpiles into surface streams in high rainfall events.	
Addition of limestone to reject prior to co-disposal	Limestone neutralises the leachate quality of underground reject so that water is indistinguishable from the natural groundwater. No short or long-terms changes to water quality in or next to underground working or below reject stockpiles.	Landholders can access water within or next to the workings at the conclusion of mining without concerns over quality changes from current (pre-mining) quality.
Optimised water management regime	The water management for the site is optimised to: minimise water use, minimise physical water take and inflow of groundwater, conserve and reuse water, minimise evaporation losses, and minimise discharge to surface water systems.	Minimise impact to surface and groundwater resources.

Table 13.1 Mitigation and avoidance measures and benefits

Mitigation measure	Environmental benefit	Social benefit
Pump water into sealed panels - in excess of operational need	Provides for a more rapid recovery of groundwater levels following mining. Removes need to release excess water to surface water systems. Minimises evaporation losses from surface storages.	Provides more rapid recovery to overlying landholder bores that may be impacted.
Sufficient capacity in the primary water dam (PWD) to hold all water on site	Removes need to treat and release excess water to surface water systems.	Minimises water quality effects on users.
Clay lined PWD	Prevents seepage.	
Use of water from within the void as required for mine operations	Water from external source is not required for the mine, even in very dry climate sequences (other than potable water).	No additional draw on alternate water sources for project operation is required (other than potable water).
Scour protection measures downstream of the conveyor piers and box culverts in Medway Rivulet. (Scour protection measures, where appropriate, will also be implemented on mine access roads.)	Water quality in Medway Rivulet is not impacted by erosion and sedimentation.	Water quality in Medway Rivulet is maintained for downstream users.
Install of vegetated swales and constructed wetlands along the two mine access roads outside the water management system. Swales will be 730 m, 15 m and 5 m long for the sealed road catchment and 1,250 m long for the unsealed road catchment. The constructed wetlands are nominally 50 m^2 each.	NorBE criteria will be met.	NorBE criteria will be met.
Creation of 45 ha of protection zones on the Evandale and Mereworth properties, within which clearing, farming and industrial activities/infrastructure will be restricted, to offset potential water quality impacts.	NorBE criteria will be met.	NorBE criteria will be met.

13.1.2 Make good provisions

Where predicted drawdown in bores are greater than the minimal impact criteria within the Aquifer Interference Policy (AIP) a level 2 impact is triggered (refer to Section 3.2.2 and 9.3.2). This is a trigger for potential or perceived long-term viability of the water-dependent asset. Additional assessment requirements then apply which include 'make good' provisions to be negotiated with the relevant landholders. Make good provisions for those landholder bores affected are proposed in Appendix M. As actual 'make good provisions' are not defined in the AIP or other NSW legislation, guidance has been sought from an AIP Fact Sheet 4 (NOW 2013b) and guidelines from other states. Strategies for make good provisions would be assessed case-by-case and would depend on the existing infrastructure, the degree of drawdown at each site and the outcomes of landholder consultation. Potential strategies and a desktop analysis of proposed measures are discussed in Appendix M.

13.2 Water management

13.2.1 Water Management Strategy

SEAR 4: A water management strategy, having regard to the EPA's, DPI's and WaterNSW requirements

The water management strategy for the project is based on diverting clean water around the mining disturbance areas, retaining water that lies within disturbed areas on-site for recycling and reuse, and replenishing groundwater into sealed voids to allow for increased recovery rate and reduced drawdown. The water management strategy also minimises evaporation losses by storing water excesses in underground voids to accelerate the groundwater recovery time and/or use in operations in very dry years.

The general principles guiding water management for the project are:

- maximise diversion of clean surface water flows around the mining operations;
- minimise the volume of imported water for site use by maximising recycling of mine-affected water, and minimising evaporation losses;
- harvest water only from within the active mining areas (basins, dams, and sump), and seal off mined-out panels so water into the void area does not enter the mine water management system;
- pump surplus water into the void (ie behind sealed bulkheads) to provide for a more rapid recovery of groundwater pressures and efficient storage of water in surplus years;
- avoid the discharge of water from site to surface water systems, with the exception of stormwater releases after first flush and water quality criteria are met;
- manage sediment affected water (ie not mine affected) within an Erosion and Sediment Control Plan;
- maximise pumping of excess water into void to allow for increased recovery rate of groundwater systems;
- achieve NorBE for construction and operation activities;
- monitor and analyse results of monitoring for water resources;

- maximise protection of the environmental values of the receiving waters; and
- achieve and maintain regulatory compliance.

13.2.2 Management Plans

AR 81: The EIS should provide plans/protocols/procedures for:
- *environmental management plan*
- *soils and water management plan*
- *spill management*

Two main water management plans (WMPs) will be developed for the project, one for the construction phase (CWMP) and one for the operational phase (OWMP). The WMPs will be a sub-plan of the environmental management system. The WMPs will document the proposed mitigation and management measures for the approved project, and will include the surface and groundwater monitoring program, reporting requirements, spill management and response, water quality trigger levels, corrective actions, contingencies, and responsibilities for all management measures.

The WMPs will be prepared in consultation with DPI Water, EPA, WaterNSW, and the local council, and would consider concerns raised during the exhibition and approvals process for the project. Table 13.2 includes aspects that will be considered and potentially included in the WMPs. The list in Table 13.2 is by no means exhaustive.

Table 13.2 Water Management Plan considerations

Item	Construction Water Management Plan	Operational Water Management Plan
Surface water monitoring program	Review whether additional sites required to consider local construction (ie dams and roads) Consider frequency of sampling at key project construction stages and consideration of wet weather sampling events if applicable Consider suite of parameters dependent on construction activities and likely pollutants	Review whether additional sites required in downstream areas to ensure log term trends can be recognised Consider installing additional stream gauges (in consultation with DI Water and Water for NSW) Consider revising sampling suite for long-term requirements
Groundwater monitoring program	Review whether additional sites are required (particularly shallow) to consider construction monitoring activities Metering and monitoring of groundwater bores that provide water supply for operational requirements during construction	Consider expansion of monitoring network in accordance with predicted impacts to water table and users Consider Stage 1 'make good' bores and whether sufficient independent monitoring of groundwater levels is occurring at locations between mine footprint and potentially affected landholder bores Consider monitoring bore (existing and new) construction and location to provide for model verification over time (consider model layers and screen interval to ensure model predictions can be compared to actual levels) Consider suite of sampling analytes for long term trend analysis Consider frequency of monitoring
Development of triggers	Consider appropriate triggers for construction activities based on existing baseline data	Consider development of long-term triggers and potential trigger to recognise short and long-term trends in the data

Table 13.2 Water Management Plan considerations

Item	Construction Water Management Plan	Operational Water Management Plan
Metering of water take and flow	Consider installation of meters and flow gauges at appropriate locations within water network to record information on water volumes taken (both surface and groundwater), and volumes used during different construction activities.	Longer term operation water take and movement metering and monitoring is required in accordance with the water balance predictions. Need to ensure that sufficient flow gauges and meters are installed at various locations to provide this detailed information to both allow compliance and efficient operation and management of operational water requirements in the mine. Annual verification of water take against predictions
Erosion and sediment control	Consider localised construction erosion and sediment control requirements	Consider longer term and ongoing operational erosion and sediment control requirements. As mining progresses and rehabilitation commences, erosion and sediment control activities to be adjusted accordingly.
Effluent reuse	Consider expected pollutant concentrations and loads, volume of effluent to be reused, locations and characteristics of reuse areas, monitoring and management measures.	Consider expected pollutant concentrations and loads, volume of effluent to be reused, locations and characteristics of reuse areas, monitoring and management measures.
Numerical groundwater model review		Model verification - annual as part of AEMR report requirements Model recalibration (as required – ie if verification proves model is not performing to the expected level of accuracy, then recalibration of the model may be required) Model revision (as required – ie if verification and recalibration are not sufficient to resolve model predictions then model rebuild in suitable and the latest available software considered at that time.
Water balance model review	Consideration of construction water balance needs and management requirements	Model verification/revision – as required

The WMPs will include details of the surface water and groundwater monitoring program, which will incorporate and update the existing monitoring network, monitoring frequencies and water quality constituents, and physical water take and pumping volumes between water storage structures (including the void, the sump, mine water dams and stormwater basins). Reporting frameworks for the above will be prepared in accordance with licensing and agency requirements. Trigger levels for water quality parameters will be developed as part of the WMPs to assist in early identification of water quality trends and to assist in providing confirmation (or otherwise) of the NorBE predictions. The monitoring program will be prepared in accordance with the approved project's environment protection licence (EPL), once enacted. Further details on the monitoring program are included in Section 13.3.

The WMPs will also identify erosion and sediment control measures to be implemented on site, which will be included as Soil and Water Management sub-plan (which incorporates the sediment and erosion control measures). The CWMP will account for the staging of construction and development works. Management measures will be designed in accordance with the relevant standards and best practice guidelines, including *Managing Urban Stormwater – Soils and Construction – Volume 2E Mines and Quarries* (DECC 2008). The WMPs will also identify requirements for storing fuels and other potential contaminants on site to minimise the risk of spill.

As part of the WMP, the water balance model will be reconsidered and optimised for water efficiency throughout all years of mining. The optimising of the water balance model will focus on more efficient operation and the water level in the PWD. It is expected these updates will result in minor changes to volumes of water required to be harvested from the void and therefore will not have material implications in the overall project assessment or licensing (impacts and licence requirements would be less under an optimised scenario). Consideration for installation of the WTP and MWD08 provisional infrastructure would be revisited following review of water balance model revisions if predictions indicate the PWD will have insufficient storage and during the detailed design stage. The WMP will also provide a program for reviewing and updating the numerical groundwater model as more data and information become available; this program would include reporting requirements.

13.3 Monitoring and thresholds

The baseline water monitoring network and data gathered is extensive with over four years of baseline hydrological data collected. The network has been developed with ongoing consultation with DPI Water. The water monitoring network is positioned to provide spatial coverage across the project area and beyond, investigate the major hydrological and hydrogeological environments, and monitor potentially sensitive features.

The baseline groundwater monitoring network consists of 54 groundwater monitoring bores at 22 nested locations, 11 vibrating wire piezometers (VWP) sensors in three bores, and three landholder bores. The baseline surface water monitoring network consists of 11 stream flow gauging locations and 24 water quality monitoring locations.

Baseline data will continue to be collected from this network throughout the life of the mine. Expansion of the network may be considered once the project starts construction and then operation, and may expand to include aspects such as (pending site access):

- groundwater seepage monitoring next to the PWD;
- groundwater monitoring next to landholder bores predicted to be impacted by the project;
- shallow groundwater monitoring next to Medway Dam;
- water quality monitoring of mine water dams (including the PWD which receives recycled water) and stormwater basins;
- water metering and recording of pumped volumes to/ from MWDs, SBs, PWD, sump and the void;
- real-time flow and water quality (TDS and pH) monitoring of the transfer pipe from SB03 and SB04 in accordance with the first flush threshold criteria;
- shallow groundwater monitoring in areas identified as having shallow groundwater and known ecosystems with possibly affected species;
- monitoring quality and metering the volume of water releases to Oldbury Creek from SB03 and SB04 or WTP (if required);
- monitoring water quality within temporary sediment basins during construction;
- monitoring of wastewater quality, soils and groundwater within the vicinity of the wastewater management infrastructure;

- monitoring of seepage around temporary reject stockpile;
- additional surface water monitoring sites on Oldbury Creek (downstream of where releases from SB03 and SB04 will occur), and on Medway Rivulet downstream of the junctions with Wells Creek and Oldbury Creek; and
- monitoring quality of water in sump and the rate and quality of water pumped into sealed voids.

The suite of water quality analytes (ie constituents) to be sampled and the frequency of sampling will be reviewed and updated in the WMPs developed for the project's construction and operation. Data loggers that currently monitor water levels will continue to operate. The ongoing development and expansion of the monitoring network will occur in consultation with WaterNSW and DPI Water, and as per the guidelines for the GMMP, which will evolve as the project progresses.

Thresholds levels have been proposed for the management of various water-related aspects of the project, and more will be proposed in monitoring plans as they are developed. Existing thresholds that have been identified are:

- achieving neutral or beneficial effect (NorBE) and water quality objectives for releases and changes in catchment water quality (refer to Appendix D (WSP PB 2016b));
- first flush criteria for releases from SB03 and SB04 following the first flush (refer to Appendix D (WSP PB 2016b));
- actual groundwater level changes within an agreed threshold of model predictions;
- water balance, and in particular physical water take and groundwater inflow contributions (refer to Chapter 12); and
- beneficial use of the groundwater system, which is classified as suitable for irrigation, not being compromised (refer to Appendix I).

In relation to post-closure water monitoring, there will be no ongoing water discharge from the mine workings as panels will be sealed progressively over the life of the mine. There will be no permanent surface reject emplacements and therefore no ongoing risk of leachate on the surface. All dams used as part of mine water management system will be rehabilitated upon cessation of operations and, unlike an open cut mine, there will be no surface voids and therefore no potential for evaporative concentration of salts in voids over time. Notwithstanding, Hume Coal will continue the water monitoring program post closure for a nominal period of five years, the cost of which will be accounted for in the mine's security deposit which will be required under the mining lease. The need for, and methodology of, ongoing water monitoring after mining has ceased will be confirmed during development of the detailed mine closure plan.

13.4 Management measures

Monitoring each component of the water management system would form the basis of how and when management responses are required. The monitoring network is fundamental to achieving effective management of project impacts and as such has been designed (and will continue to be designed) with this objective.

To help analyse monitoring data, triggers and thresholds will be developed to provide context when and what management measures are to be implemented.

A risk assessment has been undertaken, with potential risks and management measures discussed in Table 13.3.

Table 13.3 Potential risks and management measures

Potential risk	Management measure
Proposed releases from SB03 and SB04 following first flush to Oldbury Creek are not consistent with achieving NorBE	Do not release, store in PWD instead. Water balance modelling demonstrates that PWD has enough capacity to contain all runoff from SB03 and SB04.
Drawdown in landholder bores are significantly larger than predicted	Consider if additional make good measures should apply to the bore to maintain existing water supply (refer to Appendix M). Analyse the model, and predictions and potential recalibration of the model using most recent data.
Higher than predicted sediment loads occur during construction and/or operation	Compliance with NorBE and the Soil and Water Management Sub-plan.
Groundwater inflow rates to the underground sump are higher than predicted	Consider options to seal voids as mining progresses at a rate faster than originally planned (ie the groundwater model allows for sealing within 12 months from cessation of mining in an individual panel) – sealing voids within 6 months or less from ceasing to mine a panel could reduce groundwater inflow to sump.
High rainfall and storm events coinciding with high groundwater inflow years, and PWD and sealed void are at or reaching capacity	Consider options to more rapidly fill void spaces. Consider options to commission WTP and MWD08, and treat and release excess water from PWD to Oldbury Creek.
Spills of petroleum products or other hazardous material	Comply with operating procedures relating to storing and handling of hazardous materials, including spill response plans. Avoid handling hazardous materials next to waterways. Immediately rehabilitate impacted area in line with relevant protocols.
Accumulation/concentration of potential contaminants in the PWD as a result of recycling water on site	Monitoring of water quality in the PWD will indicate if and when management measures need to be applied. Consider water management practices to reduce the volume of water needing to be recycled back into the PWD (ie optimise water efficiency in coal processing) Consider alternate options for water from coal processing (ie treatment/disposal off site
Acidification of sealed voids	Additional dosing of reject with limestone before underground emplacement. Consider filling and sealing individual voids more rapidly following mining.
Greater than predicted drawdown next to areas of shallow groundwater that ecosystems are potentially relying on	Assess ecosystem health, assess time for recovery of shallow groundwater at the location, consider to temporary irrigation to these systems until groundwater recovers to acceptable limits (ie the level at which the ecosystem can again access the groundwater).

13.5 Groundwater model validation

The groundwater model predictions would be validated by installing custom-designed groundwater monitoring sites at key selected virtual piezometers used in the model. Should sites be unsuitable (ie access restrictions), then the model will be re-run with additional virtual piezometers in accessible sites. The model can be regularly validated. Significant deviations from the predicted impacts will be investigated. Reporting on this is proposed annually. Model verification is considered annually, with recalibration undertaken as required (ie if verification demonstrates model is performing accurately, then there is no need for model recalibration).

Predicted impacts on landholder bores will be considered via monitoring these bores manually, and/or via installing dedicated monitoring bores next to key landholder bores.

14 Conclusions

This chapter summarises the project based on the findings of this water assessment.

Effective and efficient water management is essential to the project's operation. The mine design and associated water management system were developed iteratively, with early results of surface water and groundwater modelling providing input into the mine design. The resulting water management system and mine design (non-caving and progressively sealing panels) minimises physical water extraction and groundwater inflow, conserves and reuses water, minimises evaporation losses, and minimises discharge to surface water systems.

The effects on surface water resources as a result of the project will be minimal. A temporary 0.8% reduction in the catchment area of Medway Rivulet, in which the surface infrastructure area will be located, will occur as a result of constructing and operating the project.

Potential TSS and nutrient loads and concentrations in Oldbury Creek show releases from stormwater basins will be in accordance with the neutral or beneficial effect (NorBE) criteria. Swales and constructed wetlands can be used to provide an effective treatment system for runoff from access roads to meet the NorBE criteria for TSS and nutrients. The water balance model demonstrates that the PWD has enough capacity to contain all surplus water and treatment and release of water from the PWD is not required.

Changes in flood levels as a result of the project for land Hume Coal does not own are minor or negligible and considered acceptable with reference to the assessment criteria. Changes to flood peak velocities are considered acceptable with reference to the assessment criteria.

Groundwater inflows to the active mine sump area will occur throughout the operational mine life, and this water will be reused for mining operations with the excess pumped into the sealed void area to enhance the groundwater recovery time. The sealed void remains part of the groundwater source, with water available for other users.

The Aquifer Interference Policy (AIP) requires landholder bores affected by greater than 2 m drawdown as a result of the project are subject to 'make good' provisions. There are 94 private landholder bores on 72 properties that are predicted to drawdown 2 m or more as a result of the project.

A 'make good' assessment addressed the project's effects on these 94 bores. All bores affected by more than 2 m drawdown are likely to be subject to increased pumping costs (or other compensatory measures). About a third of those affected bores would not require bore intake deepening or replacement. Another third are assessed as potentially needing submersible pump intake depths repositioned for certain periods of time, and the final third may require bore replacement or an alternative source of supply.

With regard to the AIP's groundwater quality requirements, the project is not anticipated to result in a lowering of the beneficial use category of the groundwater source beyond 40 m from the activity, provided the mitigation measures discussed in Chapter 13 are implemented.

No cumulative impacts to groundwater and surface water quality are predicted to occur as a result of the project.

Monitoring the extensive surface water and groundwater network will continue. Monitoring each component of the water management system underpins if, how, and when management responses are required. Triggers and thresholds will be developed to provide context on if, how, and when management measures are required as part of the water management plan for the project.

Hume Coal has already secured 93% of the total water licence requirement for the project. The remaining volume required can be sourced by controlled allocation and via the trading market. The remaining licence volume will be secured so that all water taken is adequately licensed.

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List of units

Unit	Description
$	Australian dollar
%	percent
%ile	percentile
°C	degrees Celsius
µm	micrometre
µS/cm	microsiemens per centimetre
$g/m^2/yr$	grams per square meters per year
ha	hectare
kg/yr	kilograms per year
L/s	litres per second
km	kilometre
km^2	square kilometres
m	metres
m/day	metres per day
m/yr	metres per year
mm/yr	millimetres per year
m^3/day	cubic metres per day
mAHD	metres Australian Height Datum
mbgl	metres below ground level
mbtoc	metres below top of casing
meq/L	milliequivalents per litre
mg/L	milligrams per litre
mh/L	milligrams per litre
ML	megalitres
ML/day	megalitres per day
ML/yr	megalitres per year
mm/day	millimetres per day
mm/hr	millimetres per hour
Mt	million tonnes
Mtpa	million tonnes per annum
pH	pH, unit of acidity and alkalinity

Abbreviations

Abbreviation	Description
ADWG	Australian Drinking Water Guidelines
AHD	Australian height datum
AIP	Aquifer Interference Policy 2012
ALS	Australian Laboratory Services
ANZECC and ARMCANZ	Australian and New Zealand guidelines for fresh and marine water quality
AR	Agency recommendation
ARI	Average recurrence interval
AWBM	Australian Water Balance Model
BOD	Biochemical oxygen demand
BoM	Bureau of Meteorology
BTEXN	Benzene, toluene, ethyl-benzene, and xylene
BTEXN	benzene, toluene, ethyl-benzene, xylene and naphthalene
CCL	Consolidated Coal Lease
CDFM	Cumulative deviation from the mean
CM	Coal measures
CPP	Coal processing plant
CWMP	Construction water management plan
DECC	Department of Environment and Climate Change NSW
DECCW	Department of Environment, Climate Change, and Water NSW
DEHP	Department of Environment and Heritage Protection (QLD)
DIPNR	Department of Infrastructure, Planning and Natural Resources NSW
DLWC	Department of Land and Water Conservation NSW
DNR	Natural Resources Department NSW
DO	Dissolved oxygen
DPI	Department of Primary Industries
DSITAI	Department of Science, Information Technology, Innovation and the Arts QLD
DTIRIS	Department of Trade and Investment, Regional Infrastructure and Services NSW
DWE	Department of Water and Energy NSW
EC	Electrical conductivity
EIS	Environmental Impact Statement
EP&A Act	Environmental Planning and Assessment Act
EPA	Environment Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act
EPL	Environment protection licence
EV	Environmental value
GDE	Groundwater dependent ecosystem
GMMP	Groundwater monitoring and modelling plan
HRC	Healthy Rivers Commission of NSW
ICM	Illawarra Coal Measures
IEA	Institution of Engineers, Australia

Abbreviation	Description
IESC	Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development
K	Hydraulic conductivity
Kh	Horizontal hydraulic conductivity
KLC	Kinetic leach column
Kv	Vertical hydraulic conductivity
LGA	Local government area
LPI	Land and Property Information NSW
LTAAEL	Long-term average annual extraction limit
MAR	Managed aquifer recharge
MLA	Mining Lease Application
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
MWD	Mine water dam
N	Nitrogen
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
NMZ1	Sydney Basin Nepean Groundwater Source Nepean Management Zone 1
NMZ2	Sydney Basin Nepean Groundwater Source Nepean Management Zone 2
NorBE	Neutral or beneficial effect
NOW	NSW Office of Water, now DPI Water
NSW	New South Wales
NUDLC	National Uniform Drillers Licensing Committee
NWC	National Water Commission
NWQMS	National Water Quality Management Strategy
OCP	Organochlorine pesticides
OEH	Office of Environment and Heritage
OPPP	Organophosphorus pesticides
ORM	Probabilistic rational method
OWMP	Operation water management plan
PAH	Polycyclic aromatic hydrocarbons
PMF	Predicted maximum flood
PMP	Probable maximum precipitation
POEO Act	*Protection of the Environment Operations Act 1997*
PWD	Primary water dam
QA/QC	Quality assurance/quality control
QLD	Queensland
RC	Riparian corridors
REF	Review of Environmental Factors
ROM	Run of mine
SB	Stormwater basin
SBS	Sydney Basin South Groundwater Source
SCA	Sydney Catchment Authority
SD	Standard deviation
SEARs	Secretary’s environmental assessment requirements
SEPP	State Environmental Planning Policy
SILO	Scientific information for land owners, a database of historical climate records for Australia

Abbreviation	Description
SST	Sandstone
STP	Sewage treatment plant
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TRH	Total recoverable hydrocarbons
TSS	Total suspended solids
VRC	Vegetated riparian corridors
VWP	Vibrating wire piezometer
WA 1912	*Water Act 1912*
WAL	Water access licence
WMA 2000	*Water Management Act 2000*
WMP	Water management plan
WR ply	Wongawilli Coal Seam ply
WRC	Water Resources Council NSW
WSP	Water sharing plan
WTP	Water treatment plant

Glossary of Terms

Acidity	Base neutralising capacity.
Alkalinity	Acid neutralising capacity.
Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on riverbeds, floodplains, and alluvial fans.
Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.
Analytical model	Mathematical models that have a closed form solution, ie the solution to the equations used to describe changes in a system can be expressed as a mathematical analytic function.
Anion	An ion with a negative charge.
Anthropogenic	Occurring because of, or influenced by, human activity.
Annual Exceedance Probability (AEP)	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Annual Recurrence Interval (ARI)	The ARI is the average number of years between exceedances of a given rainfall depth for a given duration at a specific point location. The relationship between AEP and ARIs is: $$AEP = 1 - exp\left(\frac{-1}{ARI\ (years)}\right)$$ ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP.
Aquatic ecosystem	The stream channel, lake or estuary bed, water, and (or) biotic communities and the habitat features that occur therein.
Aquifer	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.
Aquitard	A low permeability unit that can store groundwater and also transmit it slowly from one formation to another. Aquitards retard but do not prevent the movement of water to or from adjacent aquifers.
Baseflow	The part of stream discharge that originates from groundwater seeping into the stream.
Bore	A structure drilled below the surface to obtain or monitor water from an aquifer or series of aquifers.
Borehole	A hole in the ground drilled by a drill rig for constructing a bore.
Boundary	A lateral discontinuity or change in the formation resulting in a significant change in hydraulic conductivity, storativity or recharge.
Cation	An ion with a positive charge – usually metal ions when disassociated and dissolved in water.
Confined formation	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
Concentration	The amount or mass of a substance present in a given volume or mass of sample, usually expressed as microgram per litre (water sample) or micrograms per kilogram (sediment sample).
Conceptual model	A simplified and idealised representation (usually graphical) of the physical hydrogeologic and/or hydrologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.

Confining layer	Low permeability strata that may be saturated but will not allow water to move through it under natural hydraulic gradients.
Contamination	Contamination is the presence of a non-natural compound in soil or water, or unwanted compound in chemicals or other mixtures.
Cross bedded	Characteristic bedding structure produced by the migration of bedforms with inclined depositional surfaces.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
Discharge area	An area in which there are upward or lateral components of flow in an aquifer.
Drawdown	The change in the groundwater head (level) as measured in a bore or at the water table. The groundwater level reflects the pressure of the groundwater at the depth the bore is open/screened. Drawdown refers to the change (lowering) in the groundwater level over time. Note that nearby monitoring bores with different screen depths would be subject to different drawdown.
Dyke	A sheet- like, near vertical minor igneous instruction that cuts across horizontal to gently dipping planar structures in the country rock
Electrical conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and an estimation of the total ions dissolved. It is often used as a measure of water salinity.
Elevation	The height above a given level, often sea level (Australian Height Datum)
Fault	A fracture in rock along which there has been an observable amount of displacement. Faults are rarely single planar units; normally they occur as parallel to sub-parallel sets of planes along which movement has taken place to a greater or lesser extent. Such sets are called fault or fracture zones.
Fracture	Breakage in a rock or mineral along a direction or directions that are not cleavage or fissility directions.
Fractured rock aquifer	These occur in sedimentary, igneous and metamorphosed rocks that have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary rock aquifers.
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
Groundwater dependent (or potentially dependent) ecosystems (GDEs)	Groundwater dependent ecosystems are communities of plants, animals and other organisms whose extent and life processes depend (or partially depend) on groundwater.
Groundwater flow	The movement of water through openings in sediment and rock within the zone of saturation.
Groundwater system	A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations.
Hydraulic conductivity	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water).
Hydraulic gradient	The change in total hydraulic head with a change in distance in a given direction.
Hydraulic head	A specific measurement of water pressure above a datum. It is usually measured as a water surface elevation, expressed in units of length. In an aquifer, it can be calculated from the depth to water in a monitoring bore. The hydraulic head can be used to determine a hydraulic gradient between two or more points.
Hydrochemistry	Chemical characterisation of water (both surface water and groundwater).
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrology	The study of the occurrence, distribution, and chemistry of all surface waters.
Igneous	A rock that has solidified from molten or partially molten material (ie volcanic)

Infiltration	The downward flow of water from the land surface into and through the upper soil layers.
Interbedded	Deposited between units.
Jurassic	The middle geological time period of the Mesozoic era c. 208–145 million years ago.
Lithic	Formed of rock, either sedimentary or volcanic.
Major ions	Constituents commonly present in concentrations exceeding 10 milligram per litre. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulfate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate.
MicroSiemens per centimetre (µS/cm)	A measure of water salinity commonly referred to as EC (see also electrical conductivity). Most commonly measured in the field with calibrated water quality meter.
Monitoring bore	A non-pumping bore, which is generally small in diameter and used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which groundwater can enter.
Numerical model	A model of groundwater flow in which the aquifer is described by numerical equations (with specified values for boundary conditions) that are usually solved in a computer program. In this approach, the continuous differential terms in the governing hydraulic flow equation are replaced by finite quantities. Computational power is used to solve the resulting algebraic equations by matrix arithmetic. In this way, problems with complex geometry, dynamic response effects and spatial and temporal variability may be solved accurately. It must be used in cases where the essential aquifer features form a complex system (ie high complexity models).
Outcrop	The area where a particular rock unit or formation occurs at surface.
Overburden	The rock units that are above a particular rock unit. Usually used in reference to the rock above the particular target mining unit (ie the coal seam).
Packer test	An aquifer test performed in an open borehole; the segment of the borehole to be tested is sealed off from the rest of the borehole by inflating seals, called packers, both above and below the segment.
Permeability	The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature.
Permeability test	An aquifer test performed in a laboratory on a sample of aquifer rock (core) to determine the permeability. Liquid or gas is allowed to flow through at different rates and the inflow and outflow pressures are measured.
Permeable material	Material that permits water to move through it at perceptible rates under the hydraulic gradients normally present.
Permian	The youngest geological time period of the Palaeozoic era c. 290-245 million years ago.
pH	Potential of hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; and provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic).
Porosity	The proportion of open space within an aquifer, comprised of intergranular space, pores, vesicles and fractures.
Porous rock	Consolidated sedimentary rock containing voids, pores or other openings (joints, cleats, fractures), which are interconnected in the rock mass and may be capable of storing and transmitting water.
Precipitation	(1) in meteorology and hydrology, rain, snow and other forms of water falling from the sky (2) the formation of a suspension of an insoluble compound by mixing two solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral.

Pumping test	An aquifer test made by pumping a bore for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the bore and the hydraulic characteristics of the aquifer.
Quaternary	The most recent geological period extending from about 2.5 million years ago to the present day.
Quartz arenite	A sandstone comprised of greater than 90% of detrital quartz, with limited amounts of other framework grains
Reach	An uninterrupted length of a stream, creek, or river.
Recharge	The process that replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.
Recharge area	A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or deeper aquifer zones.
Recovery	The difference between the observed water level during the recovery period after pumping stopped and the water level measured immediately before pumping stopped.
Residence time	The time that groundwater spends in storage before moving to a different part of the hydrological cycle (ie it could be argued it is a rate of replenishment).
Salinity	The concentration of dissolved salts in water, usually expressed in electrical conductivity as total dissolved solids.
Salinity classification (Australia Water Resources s Council 1988)	Fresh water quality – water with a salinity <800 µS/cm. Marginal water quality – water that is more saline than freshwater and generally waters between 800 and 1,600 µS/cm. Brackish quality – water that is more saline than freshwater and generally waters between 1,600 and 4,800 µS/cm. Slightly saline quality – water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 µS/cm. Moderately saline quality – water that is more saline than brackish water and generally waters between 10,000 and 20,000 µS/cm. Saline quality – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 µS/cm. Seawater quality – water that is generally around 55,000 µS/cm.
Saturated zone	The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric pressure.
Screen	A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material.
Semi-confined formation	An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the leaky confining layer – also known as a leaky artesian or leaky confined aquifer.
Sill	A tubular or sheet-like igneous body from a few centimetres to hundreds of metres long.
Slug test	An aquifer test made either by pouring a small instantaneous charge of water into a well or by withdrawing a slug of water from the well.
Specific storage	Relating to the volume of water that is released from an aquifer following a unit change in the hydraulic head. Specific storage normally relates to confined aquifers.
Specific yield	The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Specific yield generally relates to unconfined aquifers. Gravity drainage may take many months to occur.

Standing water level (SWL)	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to specific yield.
Stratigraphy	The depositional order of sedimentary rocks in layers.
Stygofauna	Animals that live in groundwater systems.
Surface water–groundwater interaction	This occurs in two ways: (1) streams gain water from groundwater through the streambed when the elevation of the water table next to the streambed is greater than the water level in the stream; and (2) streams lose water to groundwater through streambeds when the elevation of the water table is lower than the water level in the stream.
Tertiary	a geological time period of the Cenozoic era c. 65–1.6 million years ago.
Total Dissolved Solids (TDS)	A measure of the salinity of water, usually expressed in milligrams per litre (mg/L). See also EC.
Transmissivity	The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.
Triassic	The oldest geological time period of the Mesozoic era c. 245–208 million years ago.
Unconfined formation	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.
Unconformity	A break in the stratigraphic record, representing a period of no deposition
Unsaturated zone	The rock, soil, sediments, or regolith between the land surface and water table. It includes the root zone, intermediate zone and capillary fringe.
Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water quality data	Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists.
Water table	The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water.

Appendix A

SEARs and agency recommendations

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
SEAR 1	DP&E	As assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's, DPI's and Water NSW requirements and recommendations.	10, 11
SEAR 2	DP&E	An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users.	10, 11
SEAR 3	DP&E	An assessment of the potential flooding impacts of the development.	8.4.4, 10.3
SEAR 4	DP&E	A water management strategy, having regard to the EPA's, DPI's and WaterNSW requirements.	13.2.1
AR 1	DRE	Surface and groundwater usage and management.	2.3
AR 2	DRE	A groundwater assessment to determine the likelihood and associated impacts of groundwater accumulating and subsequently discharging from the workings post cessation of mining, including consideration of the likely controls require to prevent or mitigate against these risks as part of the closure plan for the site.	8.6 11, 13
AR 3	Fisheries NSW	Analysis of impacts of subsidence upon water flow within and downstream of all waterways within the proposal area.	10.1.2
AR 4	Fisheries NSW	Analysis of impacts of groundwater interference and drawdown on water quality, water flow and aquatic and riparian environments within and downstream of all waterways within the proposal area.	10
AR 5	Fisheries NSW	Fisheries NSW recommend the use of best practice sediment and erosion control, and water quality and stormwater management provisions to safeguard and mitigate impacts on water quality at the site and downstream. They also recommend inclusion of appropriate riparian corridors to provide a buffer between the development areas and adjacent waterways or natural drainage lines to provide protection to riparian and aquatic habitats.	13
AR 6	Fisheries NSW	Details of ongoing monitoring programs to assess any impacts upon water quality, water flow and aquatic and riparian environments within and downstream of all waterways within the proposal area.	13
AR 7	Fisheries NSW	Safeguards to mitigate any impacts upon water quality, water flow and aquatic and riparian environments within and downstream of all waterways within the proposal area during construction and ongoing operation of the proposed coal mine. In particular, provide details on proposals for erosion and sediment control (to be incorporated into a Construction Environmental Management Plan - CEMP) and proposed stormwater and ongoing drainage management measures. Water quality management for the project should be designed to achieve no net increase in pollutant run-off to receiving waters within the proposal site.	13
AR 8	DPI Water	Annual volumes of surface water and groundwater proposed to be taken by the activity (including through inflow and seepage) from each surface and groundwater source as defined by the relevant water sharing plan.	12
AR 9	DPI Water	Assessment of any volumetric water licensing requirements (including those for ongoing water take following completion of the project).	12
AR 10	DPI Water	The identification of an adequate and secure water supply for the life of the project.	12
AR 11	DPI Water	Confirmation that water can be sourced from an appropriately authorised and reliable supply. This is to include an assessment of the current market depth where water entitlement is required to be purchased.	12

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 12	DPI Water	A detailed and consolidated site water balance.	8.2
AR 13	DPI Water	A detailed assessment against the NSW Aquifer Interference Policy (2012) using DPI Water's assessment framework.	9.3.2 11, Appendix C
AR 14	DPI Water	Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, wetlands, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts.	10, 11
AR 15	DPI Water	Full technical details and data of all surface and groundwater modelling, and an independent peer review of the groundwater model.	8 and Appendices D, F, G, I, J
AR 16	DPI Water	Proposed surface and groundwater monitoring activities and methodologies.	13
AR 17	DPI Water	Proposed management and disposal of produced or incidental water.	2.3
AR 18	DPI Water	Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts.	10.4, 11.3
AR 19	DPI Water	Consideration of relevant policies and guidelines.	3
AR 20	DPI Water	Assessment of whether the activity may have a significant impact on water resources, with reference to the Commonwealth Department of Environment Significant Impact Guidelines.	10, 11
AR 21	DPI Water	If the activity may have a significant impact on water resources, then provision of information in accordance with the Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals, including completion of the information requirements checklist.	10, 11, Appendix B
AR 22	DPI Water	A detailed assessment of riparian and watercourse impacts, particularly with respect to watercourse crossings. The project should be designed to minimise impacts on watercourses and riparian land, and must have regard to the Department of Primary Industries' Guidelines for Controlled Activities on Waterfront Land – in particular the guideline on watercourse crossings.	10
AR 23	DPI Water	The EIS should take into account the objects and regulatory requirements of the Water Act 1912 (WA 1912) and Water Management Act 2000 (WMA 2000), and associated regulations and instruments, as applicable.	3
AR 24	DPI Water	Describe the ground and surface water sharing plans, water sources, and management zones that apply to the project. Multiple water sharing plans may apply and these must all be described.	3.2.1
AR 25	DPI Water	Demonstrate how the proposal is consistent with the relevant rules of the Water Sharing Plan including rules for access licences, distance restrictions for water supply works and rules for the management of local impacts in respect of surface water and groundwater sources, ecosystem protection (including groundwater dependent ecosystems), water quality and surface-groundwater connectivity.	3, 12
AR 26	DPI Water	Provide a description of any site water use (amount of water to be taken from each water source) and management including all sediment dams, clear water diversion structures with detail on the location, design specifications and storage capacities for all the existing and proposed water management structures.	2.3, 8.2

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 27	DPI Water	Provide an analysis of the proposed water supply arrangements against the rules for access licences and other applicable requirements of any relevant WSP, including: - Sufficient market depth to acquire the necessary entitlements for each water source. - Ability to carry out a "dealing" to transfer the water to relevant location under the rules of the WSP. - Daily and long-term access rules. - Account management and carryover provisions.	3, 12
AR 28	DPI Water	Provide a detailed and consolidated site water balance.	8.2
AR 29	DPI Water	The EIS should take into account the following policies (as applicable): · NSW Guidelines for Controlled Activities on Waterfront Land (NOW, 2012) · NSW Aquifer Interference Policy (NOW, 2012) · Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW, 2012) · Australian Groundwater Modelling Guidelines (NWC, 2012) · Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals (IESC, 2014) · Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments - impacts on water resources (Australian Govt. 2014) · NSW State Rivers and Estuary Policy (1993) · NSW Wetlands Policy (2010) · NSW State Groundwater Policy Framework Document (1997) · NSW State Groundwater Quality Protection Policy (1998) · NSW State Groundwater Dependent Ecosystems Policy (2002) · NSW Water Extraction Monitoring Policy (2007) · Groundwater Monitoring and Modelling Plans - Information for prospective mining and petroleum exploration activities (NOW, 2014) · NSW Code of Practice for Coal Seam Gas Well Integrity (DTIRIS 2012) · NSW Code of Practice for Coal Seam Gas Fracture Stimulation (DTIRIS 2012)	3, 10, 11

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 30	DPI Water	Identification of water requirements for the life of the project in terms of both volume and timing (including predictions of potential ongoing groundwater take following the cessation of operations at the site – such as evaporative loss from open voids or inflows).	8.2
AR 31	DPI Water	Details of the water supply source(s) for the proposal including any proposed surface water and groundwater extraction from each water source as defined in the relevant Water Sharing Plan/s and all water supply works to take water.	12
AR 32	DPI Water	Explanation of how the required water entitlements will be obtained (ie through a new or existing licence/s, trading on the water market, controlled allocations etc).	12
AR 33	DPI Water	Information on the purpose, location, construction and expected annual extraction volumes including details on all existing and proposed water supply works which take surface water, (pumps, dams, diversions, etc).	2.3.2
AR 34	DPI Water	Details on all bores and excavations for the purpose of investigation, extraction, dewatering, testing and monitoring. All predicted groundwater take must be accounted for through adequate licensing.	2.3.2, 4.2.2iii 12
AR 35	DPI Water	Details on existing dams/storages (including the date of construction, location, purpose, size and capacity) and any proposal to change the purpose of existing dams/storages.	2.3.2, 5.5
AR 36	DPI Water	Details on the location, purpose, size and capacity of any new proposed dams/storages.	2.3.2
AR 37	DPI Water	Applicability of any exemptions under the Water Management (General) Regulation 2011 to the project.	3.5.17
AR 38	DPI Water	Consideration of water allocation account management rules, total daily extraction limits and rules governing environmental protection and access license dealings.	12
AR 39	DPI Water	Identification of all surface water features including watercourses, wetlands and floodplains transected by or adjacent to the proposed project.	5.1
AR 40	DPI Water	Identification of all surface water sources as described by the relevant water sharing plan.	3.2.1, 5.1
AR 41	DPI Water	Detailed description of dependent ecosystems and existing surface water users within the area, including basic landholder rights to water and adjacent/downstream licensed water users.	5.5, 6.10.2
AR 42	DPI Water	Description of all works and surface infrastructure that will intercept, store, convey, or otherwise interact with surface water resources.	2.3, 8.2

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 43	DPI Water	Assessment of predicted impacts on the following: - flow of surface water (including floodwater), sediment movement, channel stability, and hydraulic regime, - water quality, - flood regime, - dependent ecosystems, - existing surface water users, and - planned environmental water and water sharing arrangements prescribed in the relevant water sharing plans.	10, 11
AR 44	DPI Water	The known or predicted highest groundwater table at the site.	6.3
AR 45	DPI Water	Works likely to intercept, connect with or infiltrate the groundwater sources.	2.3
AR 46	DPI Water	Any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes.	2.3, 12
AR 47	DPI Water	Bore construction information is to be supplied to DPI Water by submitting a "Form A" template. DPI Water will supply "GW" registration numbers (and licence/approval numbers if required) which must be used as consistent and unique bore identifiers for all future reporting.	4.2.2
AR 48	DPI Water	A description of the water table and groundwater pressure configuration, flow directions and rates and physical and chemical characteristics of the groundwater source (including connectivity with other groundwater and surface water sources).	6
AR 49	DPI Water	Sufficient baseline monitoring for groundwater quantity and quality for all aquifers and GDEs to establish a baseline incorporating typical temporal and spatial variations.	4
AR 50	DPI Water	The predicted impacts of any final landform on the groundwater regime.	11
AR 51	DPI Water	The existing groundwater users within the area (including the environment), any potential impacts on these users and safeguard measures to mitigate impacts.	6.10, 11.4, 13, Appendices L, M
AR 52	DPI Water	An assessment of groundwater quality, its beneficial use classification and prediction of any impacts on groundwater quality.	6.10, 11.2
AR 53	DPI Water	An assessment of the potential for groundwater contamination (considering both the impacts of the proposal on groundwater contamination and the impacts of contamination on the proposal).	11.2
AR 54	DPI Water	Measures proposed to protect groundwater quality, both in the short and long term.	13
AR 55	DPI Water	Measures for preventing groundwater pollution so that remediation is not required.	13
AR 56	DPI Water	Protective measures for any groundwater dependent ecosystems (GDEs).	13

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 57	DPI Water	Proposed methods of the disposal of waste water and approval from the relevant authority.	2.3, 8.2, 13
AR 58	DPI Water	The results of any models or predictive tools used.	8, 10, 11, Appendices D, F, I, J,
AR 59	DPI Water	Where potential impact/s are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduce or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on: - Any proposed monitoring programs, including water levels and quality data. - Reporting procedures for any monitoring program including mechanism for transfer of information. - An assessment of any groundwater source/aquifer that may be sterilised from future use as a water supply as a consequence of the proposal. - Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or a beneficial use category). - Description of the remedial measures or contingency plans proposed. - Any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period.	10, 11, 13
AR 60	DPI Water	Scaled plans showing the location of: - wetlands/swamps, watercourses and top of bank; - riparian corridor widths to be established along the creeks; - existing riparian vegetation surrounding the watercourses (identify any areas to be protected and any riparian vegetation proposed to be removed); - the site boundary, the footprint of the proposal in relation to the watercourses and riparian areas; and - proposed location of any asset protection zones.	5 and *Hume Coal Project Biodiversity Assessment Report* (EMM 2017c)
AR 61	DPI Water	Photographs of the watercourses/wetlands and a map showing the point from which the photos were taken.	5 and Appendix D

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 62	DPI Water	A detailed description of all potential impacts on the watercourses/riparian land.	10 and *Hume Coal Project Biodiversity Assessment Report* (EMM 2017c)
AR 63	DPI Water	A detailed description of all potential impacts on the wetlands, including potential impacts to the wetlands hydrologic regime; groundwater recharge; habitat and any species that depend on the wetlands.	10 and *Hume Coal Project Biodiversity Assessment Report* (EMM 2017c)
AR 64	DPI Water	A description of the design features and measures to be incorporated to mitigate potential impacts.	13
AR 65	DPI Water	Geomorphic and hydrological assessment of water courses including details of stream order (Strahler System), river style and energy regimes both in channel and on adjacent floodplains.	5.2, Appendix D
AR 66	DPI Water	Detailed modelling of potential groundwater volume, flow and quality impacts of the presence of an inundated final void (where relevant) on identified receptors specifically considering those environmental systems that are likely to be groundwater dependent.	8.6, 8.7, 11, Appendices F, J
AR 67	DPI Water	The measures that would be established for the long-term protection of local and regional aquifer systems and for the ongoing management of the site following the cessation of the project.	13
AR 68	OEH	The EIS must describe background conditions for any water resource likely to be affected by the development, including: a. Existing surface and groundwater. b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations. c. Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters. d. Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	 5 and 6 5 5 5, 10 and Appendix D
AR 69	OEH	The EIS must assess the impacts of the development on water quality, including: a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction. b. Identification of proposed monitoring of water quality.	4, 10, 11, 13

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 70	OEH	The EIS must assess the impact of the development on hydrology, including: a. Water balance including quantity, quality and source. b. Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas. c. Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems. d. Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (eg river benches). e. Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water. f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options. g. Identification of proposed monitoring of hydrological attributes.	4, 10, 13
AR 71	OEH	The EIS must map the following features relevant to water and soils including: a. Acid Sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Planning Map). b. Rivers, streams, wetlands, estuaries (as described in Appendix 2 of the Framework for Biodiversity Assessment). c. Groundwater. d. Groundwater dependent ecosystems. e. Proposed intake and discharge locations.	5, 6, and *Hume Coal Project Land and Soil Assessment* (EMM 2017f), *Hume Coal Project Biodiversity Assessment* (EMM 2017c)
AR 72	EPA	Identify relevant water quality objectives for surface and groundwater, including indicators and associated trigger values or criteria, in accordance with National Water Quality Management Strategy Guidelines. Reference the water quality objectives for the Wingecarribee River catchment in the "NSW Healthy Rivers Commission of Inquiry into the Hawkesbury Nepean Catchment". Identify any downstream users and uses of the discharged water classified in accordance with relevant ANZECC 2000.	5, 6
AR 73	EPA	Estimate the chemical composition and load of chemical and physical stressors and toxicants in any discharge with ANZECC 2000 trigger values for the various environmental values of the waterway.	10.1.5, 11.2

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 74	EPA	Investigate options to reduce the levels of pollutants in the discharge of water to protect the environment from harm as a result of that pollution. Identify all practical measures to control or reduce pollutants in the surface or groundwater discharges. Identify preferred measures and their justification.	13
AR 75	EPA	If WQO's cannot be met for the project, demonstrate that all practical options to avoid water discharge have been implemented and outline any measures taken to reduce the pollutant loads where a discharge is necessary. Where a discharge is proposed, analyse the expected discharges in terms of impact on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm.	10, 11, 13
AR 76	RMS	The impacts of groundwater flows, including changes in the water table configuration through such things as new dam construction, re-routing of waterways, groundwater behavioural changes, and changes to the catchment areas that feed to or away from the Hume Highway. Any change in the water table has the potential to affect the structural integrity of the Hume Highway.	11.4
AR 77	WaterNSW	Demonstrate that the proposed measures to capture and treat water impacted by the proposal will have no impact on water quality within the Wingecarribee River.	10.1.5
AR 78	WaterNSW	Specifically address clauses 9(1) and (2) and 10(1) of State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011. In particular, the EIS must describe and justify how the development would have a neutral or beneficial effect on water quality.	3.5.12, 10.1.5
AR 79	WaterNSW	A full description of the development including those aspects which have the potential to impact on the quality and quantity of surface and groundwaters at and adjacent to the site, including:	
		- the mining proposal and mine layout	2
		- the location, mapping and geomorphology of all creeks and water resources overlying and adjacent to the proposed mining area	5, Appendix D
		- the hydrogeological fluxes between surface and groundwaters, including the filling of pine feather voids	7.3, 10, 11,
		- the location, management and storage of all hazardous materials	*Hume Coal Project Hazard and Risk Assessment Report* (EMM 2017e)
		- the disposal of wastes from the treatment of mine waters in the mine water treatment plant	2.3, 8.2
		- the management of dirty water from the washing and preparation of coal for transport	2.3, 8.2
		- the location, sizing and description of all water quality management measures	2.3, 8.2
		- the location and description of all water monitoring points (surface and ground waters)	4
		- on-site domestic (sewage) wastewater management	2.3

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 80	WaterNSW	A detailed assessment of the development on water resources which considers the design, construction, operational and decommissioning phases and have regard for operation during periods of wet weather and include:	
		-details of measured and predicted coal mine, preparation area and stockpile area performance with respect to water quality management	10, 11, 13
		-details of measures proposed to be adopted to offset impacts associated with construction activities eg earthworks, vegetation clearing and track construction	*Hume Coal Project Biodiversity Assessment* (EMM 2017c)
		-impacts on overlying and adjacent creeks and water resources within risk management zone associated with subsidence	10
		-impact of the proposed on-site domestic (sewage) waste water management and associated effluent disposal area	2.3, Appendix E
		-pre-development and post development run off volumes and pollutant loads from the site	5, 10, Appendix D, 10, 13
		-details of the measures to manage site water associated with processing coal and coal reject, general stormwater runoff and any human activities likely to affect water quality at the site, and how neutral or beneficial effect on water quality (NorBE) principles will be assessed and applied	10, 11
		-assessment of the impacts of the development on receiving water quality and volume, both surface and groundwater including from the filling of pine feather voids and associated impact on interaction and baseflows of surface waters	2.3, 13
		-details of the structural stability, integrity, ongoing maintenance and monitoring of all site water management measures including dams over the life of the project	4, 13
		-details of proposed monitoring of groundwater levels, surface water flows, groundwater and surface water quality, along with information as to how the proposed monitoring will be used to monitor, and, if necessary, mitigate impacts on surface water and groundwater resources	2.3, 10, 13
		-the principles outlined in the 'Managing Urban Stormwater - Soils and Construction - Mines and Quarries' Manual prepared by the Department of Environment and Climate Change (2008).	2.3
AR 81	WaterNSW	The EIS should provide plans/protocols/procedures for: - environmental management plan; - soils and water management plan; - spill management.	13.2.2, Chapter 23 of the *Hume Coal Project EIS* (EMM 2017a)

Table A.1 SEARs and agency recommendations addressed in the water assessment

Water Assessment ID	Agency	Requirement	Section addressed
AR 82	DoEE	An assessment of the relevant impacts of the action on water resources including: - a description and detailed assessment of the nature and extent of the likely direct, indirect and consequential impacts, including short term and long term relevant impacts; - a statement whether any relevant impacts are likely to be known, unpredictable or irreversible, and analysis of the significance of the impacts; and - any technical data and other information used or needed to make a detailed assessment of the impacts.	10, 11, Appendices D, F, G, I, J
AR 83	DoEE	Information on proposed avoidance and mitigation measures to manage the relevant impacts of the action including: - a description of the proposed avoidance and mitigation measures to address the impacts of the action; - assessment of the expected or predicted effectiveness of the mitigation measures; - the cost of mitigation measures; - a description of the outcomes that the avoidance and mitigation measures will achieve: and - a description of the offsets proposed to address the residual adverse significant impacts and how these offsets will be established.	13, Appendix M
AR 84	DoEE	The EIS should provide a description of the location, extent and ecological characteristics and values of the identified water resources potentially affected by the project.	5, 6
AR 85	DoEE	The assessment of impacts should include information on: - any substantial and measureable changes to the hydrological regime of the water resource, for example a substantial change to the volume, timing, duration or frequency of ground and surface water flows; - the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the water resource being seriously affected; and - substantial and measureable change in the water quality and quantity of the water resource – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland; or water temperature that may adversely impact on biodiversity, ecological integrity, social amenity or human health.	10, 11
AR 86	DoEE	The EIS must provide adequate information to allow the project to be reviewed by the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, as outlined in the Information *Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (2015).	Appendix B

Notes: *DRE – Department of Industry, Resources and Energy.*
DPI W – Department of Primary Industries, Water.
OEH – Office of Environment and Heritage.
EPA – Environment Protection Agency.
RMS – Roads and Maritime Services.
IESC- Independent Expert Scientific Committee.
DoEE – Commonwealth Department of Environment and Energy.
SEAR – Secretary's environment assessment requirement.
AR – Agency recommendation.
The SEARs and agency recommendations have been allocated a unique ID (water assessment ID) for the purpose of reference within the water assessment.

Appendix B

IESC guidelines checklist

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
Description of the proposal	
A regional overview of the proposed project area including a description of the geological basin, coal resource, surface water catchments, groundwater systems, water-dependent assets, and past, current and reasonably foreseeable coal mining and CSG developments.	2, 5, 6
A description of the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	2.3, 10, 11, Chapter 2 of Hume Coal Project EIS (EMM 2017a)
A description of the statutory context, including information on the proposal's status within the regulatory assessment process and on any water management policies or regulations applicable to the proposal.	3
A description of how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	3
Groundwater	
Context and conceptualisation	
Descriptions and mapping of geology at an appropriate level of horizontal and vertical resolution including:	6.2
definition of the geological sequence/s in the area, with names and descriptions of the formations with accompanying surface geology and cross-sections.	6.2
definitions of any significant geological structures (eg faults) in the area and their influence on groundwater, in particular, groundwater flow, discharge or recharge.	6.2
Data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, hydrographs and hydrochemical characteristics (eg acidity/alkalinity, electrical conductivity, metals, major ions). Time series data representative of seasonal and climatic cycles.	5 and 6
Description of the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	6.5, 6.6
Values for hydraulic parameters (eg vertical and horizontal hydraulic conductivity and storage characteristics) for each hydrogeological unit.	Table 8.8, Appendix F
Assessment of the frequency, location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	6.7, 7.3, Appendix F
Analytical and numerical modelling	
A detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	8.6, Appendices D, F, H, J
Identification of the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	12
Undertaken in accordance with the Australian Groundwater Modelling Guidelines[10], including peer review.	8.6, Appendices F and G
An explanation of the model conceptualisation of the hydrogeological system or systems, including key assumptions and model limitations, with any consequences described.	8.6, Appendix F
Calibration with adequate monitoring data, ideally with calibration targets related to model prediction (eg use baseflow calibration targets where predicting changes to baseflow).	8.6, 11, Appendix F
Consideration of a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	8.6, 11, Appendix F

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
Representations of each hydrogeological unit, the thickness, storage and hydraulic characteristics of each unit, and linkages between units, if any.	6, 8.6, 11, Appendix F
Sensitivity analysis of boundary conditions and hydraulic and storage parameters, and justification for the conditions applied in the final groundwater model.	8.6, 11.1, Appendix F
Representation of the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the development activities.	6.5, 8.6, 11.1, Appendix F
An assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	8.6, Appendices D, F
Incorporation of the various stages of the proposed development (construction, operation and rehabilitation) with predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps.	11.1, Appendix F
A programme for review and update of the models as more data and information become available, including reporting requirements.	13
Information on the time for maximum drawdown and post-development drawdown equilibrium to be reached.	11.1, Appendix F
Impacts to water resources and water-dependent assets	
An assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts:	11, Appendix F
Description of any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	11, Appendix F
The effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance.	11, Appendices F, L and M
Description of potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units.	8.7.1, 11, Appendices F and J
Consideration of possible fracturing of and other damage to confining layers.	*Hume Coal EIS (Chapter 18 EMM 2017a)*
For each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the development proposal, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.	3.1, 3.2 and 12
Description of the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	6
For each potentially impacted water resource, a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	11, Appendix F
Description of existing water quality guidelines and targets, environmental flow objectives and other requirements (e.g. water planning rules) for the groundwater basin(s) within which the development proposal is based.	3, 12

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
An assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.	11 and Appendix F
Proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.	12, Appendix M
Description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	12
Data and monitoring	
Sufficient physical aquifer parameters and hydrogeochemical data to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	4 and 6
Long-term groundwater monitoring, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	4, 6 and Appendix J
A robust groundwater monitoring programme, utilising dedicated groundwater monitoring wells and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	4, 12
Water quality monitoring complying with relevant National Water Quality Management Strategy (NWQMS) guidelines[11] and relevant legislated state protocols[12].	4
Surface water	
Context and conceptualisation	
A description of the hydrological regime of all watercourses, standing waters and springs across the site including:	5
Geomorphology, including drainage patterns, sediment regime and floodplain features.	5, Appendix D
Spatial, temporal and seasonal trends in streamflow and/or standing water levels.	5, Appendix D
Spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals and metalloids and radionuclides).	5, Appendix D
Current stressors on watercourses, including impacts from any currently approved projects.	5, 12 and Appendix D
A description of the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities, and flood hydrographs and maps identifying peak flood extent, depth and velocity.	5, Appendix D
Assessments of the frequency, volume and direction of interactions between water resources, including surface water/ groundwater connectivity and connectivity with sea water.	5, 6, 7 and Appendix F
Analytical and numerical modelling	
Conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	7, 8
Methods in accordance with the most recent publication of Australian Rainfall and Runoff[13].	8
Description and justification of model assumptions and limitations, and calibration with appropriate surface water monitoring data.	8 and Appendix F
An assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.	8.6.4 and Appendix F
A programme for review and update of the models as more data and information becomes available.	13
A detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Appendix F

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
Impacts to water resources and water-dependent assets	
Description of all potential impacts of the proposed project on surface waters, including a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact, including:	10
Impacts on streamflow under different flow conditions.	10
Impacts associated with surface water diversions.	10
Impacts to water quality, including consideration of mixing zones.	10
Estimates of the quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets	10, Appendices D and J, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and *Hume Coal Project Response to Submissions* Chapter 13 (EMM 2018a)
Identification and consideration of landscape modifications, for example, subsidence, voids, onsite earthworks including disturbance of acid-forming or sodic soils, roadway and pipeline networks through effects on surface water flow, surface water quality, erosion and habitat fragmentation of water-dependent species and communities.	10, Appendix D and *Hume Coal Project Land and Soil Assessment Report (*EMM 2017f*)*
Existing water quality guidelines and targets, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.	2, 5, Appendix D
Identified processes to determine surface water quality and quantity triggers which incorporate seasonal variation but provide early indication of potential impacts to assets.	8.4, 10, 13, Appendix D.
Proposed mitigation actions for each trigger and identified significant impact.	13
Description and adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	13
Description of the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present and/or reasonably foreseeable) are considered in combination.	1.9, 13.1.1, 10.4
An assessment of the risks of flooding, including channel form and stability, water level, depth, extent, velocity, shear stress and stream power, and impacts to ecosystems, project infrastructure and the final project landform.	10, Appendix D
Data and monitoring	
Monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts, and matched with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	4, 13
Water quality monitoring complying with relevant National Water Quality Management Strategy (NWQMS) guidelines[5] and relevant legislated state protocols[8].	4, 13, Appendix D
Specified data sources, including streamflow data, proximity to rainfall stations, data record duration and a description of data methods, including whether missing data has been patched.	2, 4, Appendix D
A surface water monitoring programme collecting sufficient data to detect and identify the cause of any changes from established baseline conditions, and assessing the effectiveness of mitigation and management measures.	4, 13

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
The rationale for selected monitoring variables, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.	4, Appendix D
Ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate.	NA
Identification of dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the development proposal and beyond.	4 and 13
Water-dependent assets	
Context and conceptualisation	
Identification of water-dependent assets, including:	
Water-dependent fauna and flora supported by habitat, flora and fauna (including stygofauna) surveys.	4.2.6, 5.5.2, 6.10.2, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	5.4, 5.5.1, 6.9
An estimation of the ecological water requirements of identified GDEs and other water-dependent assets.	5.5.2, 6.10.2, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Identification of GDEs in accordance with the method outlined by Eamus et al. (2006)[14]. Information from the GDE Toolbox[15] and GDE Atlas[16] may assist in identification of GDEs.	6.10.2, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Identification of the hydrogeological units on which any identified GDEs are dependent.	4.2.6, and 6.10.2
An outline of the water-dependent assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	4.2.6, 4.2.7, 5.4, 5.5, 6.10.2, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Conceptualisation and rationale for likely water-dependence, impact pathways, tolerance and resilience of water-dependent assets. Examples of ecological conceptual models can be found in Commonwealth of Australia (2015)[2].	4.2.6, 4.2.7, 5.4, 5.5, 6.10, 7.3, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
A description of the process employed to determine water quality and quantity triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).	4.2.6, 4.2.7, 5.4, 5.5, 6.10, 8.7 *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Impacts, risk assessment and management of risks	
An assessment of direct and indirect impacts on water-dependent assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs.	10, 11, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Estimates of the impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-dependent assets and ecological processes.	10, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
A description of the potential range of drawdown at each affected bore, and a clear articulation of the scale of impacts to other water users.	11, Appendices L and M
An assessment of the overall level of risk to water-dependent assets that combines probability of occurrence with severity of impact.	10, 11, Appendices D, L and M
Indication of the vulnerability to contamination (for example, from salt production and salinity) and the likely impacts of contamination on the identified water-dependent assets and ecological processes.	10, 11, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
The proposed acceptable level of impact for each water-dependent asset based on the best available science and site-specific data, and ideally developed in conjunction with stakeholders.	9
Identification and consideration of landscape modifications (for example, voids, onsite earthworks, roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	10
Proposed mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.	13, Appendix M
Data and monitoring	
Sampling sites at an appropriate frequency and spatial coverage to establish pre-development (baseline) conditions, and test hypothesised responses to impacts of the proposal.	4.1, 4.2, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
Monitoring that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change.	4.1, 4.2, *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Regular reporting, review and revisions to the monitoring programme.	13
Concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design).	4.1, 4.2, 13 *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Ecological monitoring complying with relevant state or national monitoring guidelines.	4.2, 13 *Hume Coal Project Biodiversity Assessment* (EMM 2017c), and Hume Coal Project Response to Submissions Chapter 13 (EMM 2018a)
Water and salt balance and water management strategy	
Quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc), including all sources and uses.	2.3, 7, 8.2, Appendix D
Estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	2.3, 7, 8.2, 8.6 4, 8.6.5, Appendix D.
Description of water requirements and onsite water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	2.3, 7, 8.2, 8.6 4, 8.6.5, Appendix D.
Salt balance modelling, including stores and the movement of salt between stores taking into account seasonal and long-term variation.	8.6.4, 8.7.1
Cumulative Impacts	
Context and conceptualisation	
Cumulative impact analysis with sufficient geographic and time boundaries to include all potentially significant water-related impacts.	10, 11, *Hume Coal Project Biodiversity Assessment* (EMM 2017c)
Cumulative impact analysis identifies all past, present, and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern.	10, 11
Impacts	
An assessment of the condition of affected water resources which includes:	
Identification of all water resources likely to be cumulatively impacted by the proposed development.	5, 6
A description of the current condition and quality of water resources and information on condition trends.	5, 6

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
Identification of ecological characteristics, processes, conditions, trends and values of water resources.	5, 6, *Hume Coal Project Biodiversity Assessment* (EMM 2017c)
Adequate water and salt balances.	8.2, 8.6.4, 8.7.1, 11.2.1
Identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	5, 6
An assessment of cumulative impacts to water resources which considers:	
The full extent of potential impacts from the proposed development, including alternatives, and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally.	10, 11, *Hume Coal Project Biodiversity Assessment* (EMM 2017c)
An assessment of impacts considered at all stages of the development, including exploration, operations and post closure / decommissioning.	10, 11, Appendices D, F, and J
An assessment of impacts, utilising appropriately robust, repeatable and transparent methods.	8, 10, 11, Appendices D, F, and J
Identification of the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts.	10, 11, Appendices D, F, and J
Identification of opportunities to work with others to avoid, minimise or mitigate potential cumulative impacts.	13, Appendix M
Mitigation, monitoring and management	
Identification of modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts.	13, Appendix M
Identification of cumulative impact environmental objectives.	9
Appropriate reporting mechanisms .	13
Identification of measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	13
Proposed adaptive management measures and management responses.	13, Appendix M
Subsidence – underground coal mines and coal seam gas	
Predictions of subsidence impact on surface topography, water-dependent assets, groundwater (including enhanced connectivity between aquifers) and movement of water across the landscape[17, 18]	8.3, 8.5, Appendix D. *Hume Coal Project Subsidence Assessment (Mine Advice 2016)*
Description of subsidence monitoring methods, including use of remote or on-ground techniques and explanation of predicted accuracy of such techniques.	*Hume Coal Project Subsidence Assessment (Mine Advice 2016)*
Consideration of geological layers and their properties (strength/hardness/fracture propagation) in subsidence modelling.	*Hume Coal Project Subsidence Assessment (Mine Advice 2016)*
Final landform and voids – coal mines	
Identification and consideration of landscape modifications (for example, voids, onsite earthworks, roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	10, Chapter 18 of Hume Coal Project EIS (EMM 2017a)
An assessment of the adequacy of modelling, including surface water and groundwater quantity and quality, lake behaviour, timeframes and calibration.	8.6, Appendices F and G

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
An assessment of the long-term impacts to water resources posed by various options for the final landform design, including complete or partial backfilling of mining voids, which considers:	10 and 11
Groundwater behaviour – sink or lateral flow from void.	11, Appendices F and J
Water level recovery – rate, depth, and stabilisation point (e.g. timeframe and level in relation to existing groundwater level, surface elevation).	11, Appendices F and J
Seepage – geochemistry and potential impacts.	11, Appendices I and J
Long-term water quality, including salinity, pH, metals and toxicity.	10, 11, Appendices I and J
Measures to prevent migration of void water off-site.	2.3, 10, 11, 13
Acid-forming materials and other contaminants of concern	
Identification of the presence and potential exposure of acid-sulfate soils (including oxidation from groundwater drawdown).	Appendix I, *Hume Coal Project Land and Soil Assessment Report (*EMM 2017f*)*
Handling and storage plans for acid-forming material (co-disposal, tailings dam, encapsulation).	2.3, 8, 10, 11, Appendix I
Identification of the presence and volume of potentially acid-forming waste rock and coal reject/tailings material and exposure pathways.	11, Appendix I *Hume Coal Project Land and Soil Assessment Report (*EMM 2017f*)*
Assessment of the potential impact to water-dependent assets, taking into account dilution factors, and including solute transport modelling where relevant, representative and statistically valid sampling, and appropriate analytical techniques.	11, Appendix D
Identification of other sources of contaminants, such as high metal concentrations in groundwater, leachate generation potential and seepage paths.	6, Appendix I and J
Description of proposed measures to prevent/minimise impacts on water resources, water users and water-dependent ecosystems and species.	13
Hydraulic stimulation – coal seam gas	
A description of the scale of fracturing (number of wells, number of fracturing events per well), types of wells to be stimulated (vertical versus horizontal), and other forms of well stimulation (cavitation, acid flushing).	N/A
Measuring and monitoring of fracture propagation.	N/A
A description of the water source for hydraulic stimulation, volume of fluid and mass balance (quantities/volumes).	N/A
A description of the rules (e.g. water sharing plans) covering access to each water source for hydraulic stimulation and how the project proposes to comply with them.	N/A
Quantification of flowback water and a description of how it will be managed.	N/A
Potential for inter-aquifer leakage or contamination.	N/A
A list of chemicals proposed for use in hydraulic fracturing including:	N/A
names of the companies producing fracturing fluids and associated products	N/A
proprietary names (trade names) of compounds (fracturing fluid additives) being produced	N/A
chemical names of each additive used in each of the fluids	N/A
Chemical Abstract Service (CAS) numbers of each of the chemical components used in each of the fluids	N/A

Table B.1 IESC Guidelines checklist of specific information needs (IESC 2015) and section where addressed in this document

Specific information needs	Section where addressed in the document
general purpose and function of each of the chemicals used	N/A
mass or volume proposed for use	N/A
maximum concentration (mg / L or g / kg) of the chemicals used	N/A
chemical half-life data, partitioning data, and volatilisation data	N/A
ecotoxicology	N/A
any material safety data sheets for the chemicals or chemical products used.	N/A
The use of chemicals should be informed by appropriately tiered deterministic and/or probabilistic hazard and risk assessments, based on ecotoxicological testing consistent with Australian Government testing guidelines[5, 19, 20]	N/A
Chemicals for use in hydraulic fracturing must be identified as being approved for import, manufacture or use in Australia (that is, confirmed by NICNAS as being listed in the Australian Inventory of Chemical Substances[21]).	N/A

Supporting documents:

1. Commonwealth of Australia 2015, Bioregional Assessments, http://www.bioregionalassessments.gov.au/

2. Commonwealth of Australia 2015, Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, http://iesc.environment.gov.au/

3. Commonwealth of Australia 2015, Modelling water-related ecological responses to coal seam gas extraction and coal mining, prepared by Auricht Projects and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for the Department of the Environment, Commonwealth of Australia, http://www.environment.gov.au/system/files/resources/83770681-a40b-4fa2-bf6e-8d41022873bd/files/modelling-water-related-ecological-responses-csg-extraction.pdf

4. Commonwealth Scientific and Industrial Research Organisation 2015, Australian Climate Futures, Climate Change in Australia Projections for Australia's NRM Regions, http://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/introduction-climate-futures/

5. Minerals Council of Australia 2012, Water Accounting Framework for the Minerals Industry User Guide, http://www.minerals.org.au/file_upload/files/resources/water_accounting/WAF_UserGuide_v1.2.pdf

6. Environmental Protection Authority Western Australia 2013, Environmental Assessment Guideline for Environmental principles, factors and objectives, http://edit.epa.wa.gov.au/EPADocLib/EAG8-Principles-factors-objectives-RevJan2015.pdf

7. Environmental Protection Authority Western Australia 2013, Environmental Assessment Guideline for Recommending environmental conditions, http://edit.epa.wa.gov.au/EPADocLib/EAG%2011%20Recommending%20environmental%20conditions%20130913.pdf

8. Commonwealth of Australia 2013, Significant Impact Guidelines1.3: Coal seam gas and large coal mining developments - impacts on water resources, http://www.environment.gov.au/system/files/resources/42f84df4-720b-4dcf-b262-48679a3aba58/files/nes-guidelines_1.pdf

9. Barrett DJ, Couch CA, Metcalfe DJ, Lytton L, Adhikary DP and Schmidt RK 2013, Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment, Commonwealth of Australia, http://www.iesc.environment.gov.au/system/files/resources/139a0230-d4ed-43f1-b919-8c2f5f5da3d2/files/methodology-bioregional-assessments.pdf

10. Barnett et al, 2012, Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra, http://www.groundwater.com.au/media/W1siZiIsIjIwMTIvMTAvMTcvMjFfNDFfMzZfOTYwX0F1c3RyYWxpYW5fZ3JvdW5kd2F0ZXJfbW9kZWxsaW5nX2d1aWRlbGluZXMucGRmIl1d/Australian-groundwater-modelling-guidelines.pdf

11. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, 2000. Australian and New Zealand guidelines for fresh and marine water quality volume 1, http://www.environment.gov.au/system/files/resources/53cda9ea-7ec2-49d4-af29-d1dde09e96ef/files/nwqms-guidelines-4-vol1.pdf

12. Department of Environment and Heritage Protection 2009, Monitoring and Sampling Manual 2009, Version 2, July 2013 format edits, https://www.ehp.qld.gov.au/water/pdf/monitoring-man-2009-v2.pdf

13. Pilgrim, DH, (ed)., Australian Rainfall & Runoff – A Guide to Flood Estimation, Institution of Engineers, Australia, Barton, ACT, 1987. Most recent version available from: http://www.arr.org.au/

14. Eamus et al, 2006, A functional methodology for determining the groundwater regime needed to maintain the health of groundwater-dependent vegetation, Australian Journal of Botany, 2006, 54: 97–114.

15. Richardson S, et al. 2011, Australian groundwater-dependent ecosystem toolbox part 1: assessment framework, Waterlines report, National Water Commission, Canberra, http://archive.nwc.gov.au/__data/assets/pdf_file/0006/19905/GDE-toolbox-part-1.pdf

16. Bureau of Meteorology, 2015, Atlas of Groundwater Dependent Ecosystems, http://www.bom.gov.au/water/groundwater/gde/map.shtml

17. Commonwealth of Australia, 2014, Subsidence from coal seam gas in Australia, Background review, http://www.environment.gov.au/water/publications/background-review-subsidence-coal-seam-gas-extraction-australia

18. Commonwealth of Australia, 2014, Subsidence from coal mining activities, Background review, http://www.environment.gov.au/water/publications/background-review-subsidence-from-coal-mining-activities

19. Priestly B, et al. 2012, Environmental health risk assessment: guidelines for assessing human health risks from environmental hazards, enHealth, Canberra, http://www.health.gov.au/internet/main/publishing.nsf/Content/A12B57E41EC9F326CA257BF0001F9E7D/$File/DoHA-EHRA-120910.pdf

20. NRMMC-EPHC-NHMRC 2009a, Australian Guidelines for Water Recycling (Phase 2): Managed aquifer recharge, Natural Resource Ministerial Management Council, Environmental Protection and Heritage Council and National Health and Medical Research Council, Canberra, http://www.environment.gov.au/system/files/resources/d464c044-4c3b-48fa-ab8b-108d56e3ea20/files/water-recycling-guidelines-mar-24.pdf

21. Department of Health, Australian Inventory of Chemical Substances (ACIS), http://www.nicnas.gov.au/regulation-and-compliance/aics

Appendix C

AIP checklist

Assessment against the NSW Aquifer Interference Policy

The Hume Coal Project has been assessed against the Aquifer Interference Policy (AIP) based on the *Aquifer Interference Assessment Framework* (NOW 2013c). The tables contained in NOW (2013c) have been reproduced with responses relevant to the Hume Coal Project included. A similar assessment was included in the Appendix C of the *Hume Coal Project Water Assessment* (EMM 2017g) as part of the EIS. This assessment has been revised with respect to changes made following the EIS (EMM 2017a) and more detail has also been included.

An assessment has also been included against the rules of the Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source of the Water Sharing Plan for the Greater Metropolitan Region, Groundwater Sources 2011.

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Tables

Table 1 Does the activity require detailed assessment under the AIP?

	Consideration	Hume Coal response
1	Is the activity defined as an aquifer interference activity? If No, then no assessment is required under the AIP If Yes, continue to Question 2	**YES**
2	Is the activity a defined minimal impact aquifer interference activity according to section 3.3 of the AIP? If yes, then no further assessment against this policy is required. Volumetric licensing still required for any water taken, unless exempt. If No, then continue on for a full assessment of the Activity	**NO**

1 Accounting for, or preventing the take of water

Where a proposed activity will take water, adequate arrangements must be in place to account for this water. It is the proponent's responsibility to ensure that the necessary licences are held. These requirements are detailed in Section 2 of the AIP, with the specific considerations in Section 2.1 addressed systematically below.

Where a proponent is unable to demonstrate that they will be able to meet the requirements for the licensing of the take of water, consideration should be given to modification of the proposal to prevent the take of water.

Table 2 Accounting for, or preventing the take of water

	AIP requirement Has the proponent:	Hume Coal response	Where addressed in Revised Water Assessment
1	Described the water source(s) the activity will take water from?	The project area, and most of A349, is primarily within the Wingecarribee River catchment, a sub-catchment of the Hawkesbury-Nepean River catchment. A small portion of the south-eastern corner of A349 is within the Bundanoon Creek catchment, a sub-catchment of the Shoalhaven River catchment (WSP PB 2016c). The surface water resources of both these sub-catchments are managed under the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011. The Wingecarribee River catchment is part of the Upper Nepean and Upstream Warragamba Water source in this water sharing plan. The groundwater resources of the project are entirely within the Sydney geological basin, and are managed under the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011. This water sharing plan divides the Sydney geological basin, with the project area being situated primarily within the Nepean Management Zone 1 of the Sydney Basin Nepean Groundwater Source. Water take for the project is predicted within the following water sources: • Nepean Management Zone 1 Sydney Basin Nepean Groundwater Source; • Nepean Management Zone 2 Sydney Basin Nepean Groundwater Source; and • Sydney Basin South Groundwater Source.	Section 2.1 & 6.3
2	Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Based on the results of the numerical groundwater model (Appendix F) and the water balance model (Appendix D), the maximum volume required for licensing is 2,066 ML/yr in year 17, and for each individual source is: • Nepean Management Zone 1 Sydney Basin Nepean Groundwater Source 2,059 ML/yr in year 15; • Nepean Management Zone 2 Sydney Basin Nepean Groundwater Source 7.2 ML/yr in year 25; • Sydney Basin South Groundwater Source 6.5 ML/yr in year 72; and • Medway Rivulet Management Zone of the Upper Nepean and Upstream Warragamba Water Source, 19 ML/yr in year 21.	Section 12.3

Table 2 Accounting for, or preventing the take of water

AIP requirement Has the proponent:	Hume Coal response	Where addressed in Revised Water Assessment
	Table 12.1 from Revised Water Assessment Report	

Year	Surface water leakage Medway Rivulet Management Zone of the Upper Nepean and Upstream Warragamba Water Source (ML)	Groundwater interception Sydney Basin South Groundwater Source (ML)	Groundwater interception Sydney Basin Nepean Groundwater Source	
			Nepean Management Zone 2(ML)	Nepean Management Zone 1 (ML)
1	0.0	0.0	0.0	200
2	0.0	0.0	0.0	1171
3	0.0	0.0	0.0	1443
4	0.0	0.0	0.1	1413
5	0.0	0.0	0.2	1238
6	0.0	0.0	0.4	1222
7	0.0	0.0	0.7	1251
8	0.0	0.0	1.1	1523
9	0.0	0.0	1.6	1747
10	0.0	0.0	2.1	1810
11	0.8	0.1	2.7	1835
12	3.4	0.2	3.2	1850
13	5.9	0.3	3.8	1790
14	8.2	0.4	4.3	1736
15	10.4	0.6	4.8	1701
16	12.4	0.7	5.2	1826
17	14.3	0.9	5.5	**2059**
18	16.1	1.1	5.8	2056
19	17.8	1.2	6.1	1660
20	18.8	1.4	6.2	440
21	18.8	1.5	6.5	151
22	18.4	1.5	6.7	36
23	17.8	1.5	6.9	3

Table 2 Accounting for, or preventing the take of water

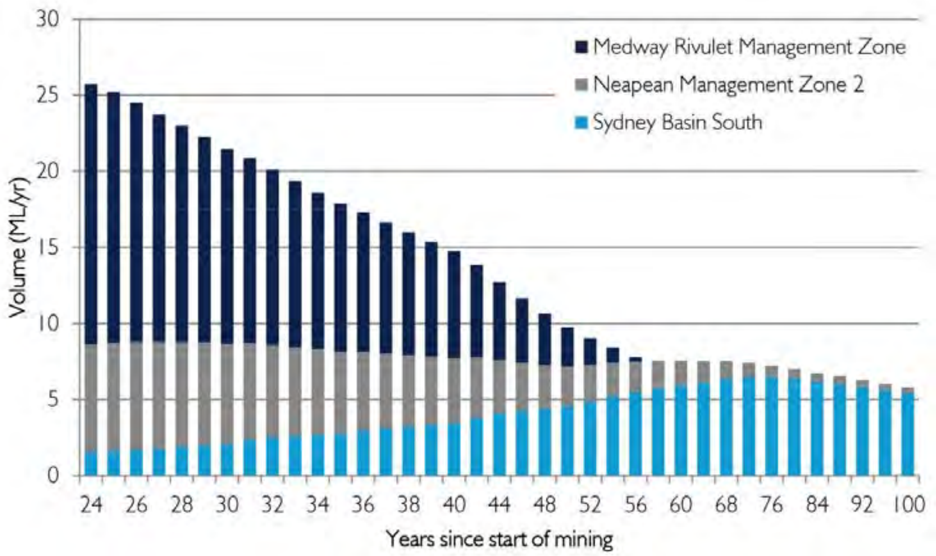
	AIP requirement Has the proponent:	Hume Coal response					Where addressed in Revised Water Assessment
		Maximum (during mining and void filling)	**18.8**	**1.5**	**6.9**	**2,059**	
		Maximum impact (ML in year from commencement)	**18.8 (in year 21)**	**6.5 (in year 72)**	**7.1 (in year 25)**	**2,059 (in year 17)**	
3	Predicted the total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	For both groundwater and surface water, the table in response 2(3) above presents the total volume take/induced leakage during mining and void filling, up to the end of year 24, noting that mining operations cease in year 19 and that the take volumes predicted in years 20 through to 24 are attributed to void filling. The final row of this table lists the maximum peak take from each source and the year it occurs in (as some peak takes occur following active mining). The graph below illustrates the water take from each respective source following mine closure and up to a full 100 years since the start of mining. 					Section 12.3 and Figure 12.7

Table 2 Accounting for, or preventing the take of water

	AIP requirement Has the proponent:	Hume Coal response	Where addressed in Revised Water Assessment
4	Made these predictions in accordance with Section 3.2.3 of the AIP? (refer to Table 3, below)	Yes, numerical modelling and analytical techniques adopted for the water assessment were based on baseline data for the site and in accordance with the relevant best practice modelling guidelines. The regional numerical groundwater model developed for the project was undertaken in accordance with the three requirements in AIP Section 3.2.3 being: • calibrated and validated numerical model determine the effects of mining on the groundwater and surface water systems in the region and whether these effects complied with the Aquifer Interference Policy (AIP); in particular, to determine mine inflows and water table drawdown, and deeper depressurisation due to sub-surface mining. It was used to determine landholder bore drawdown interference and influence on other environmental users during mining and the post-mine recovery period. A substantial database of Hume Coal data and data from published sources was used as a basis to develop and calibrate the numerical groundwater model. • The model was prepared in accordance with the Australian Groundwater Modelling Guidelines (AGMG) (Barnett et al. 2012). The current model according to AGMG conforms to a combination of Class 2 and Class 3 criteria, and is confirmed as a Class 2 model. • The independent peer review by Middlemis (2017) concluded that the EIS model was Class 2 based on a holistic interpretation of the guidelines and that development of the original EIS model, and impact assessment, was in accordance with best practice guidelines. Middlemis draft review (2017) of the original EIS model stated that the Hume Coal model itself is suitable for the mining impact assessment purpose (Class 2 confidence level)' and 'the EIS presents reasonable predictions of dewatering volumes and drawdown extent/magnitude.'	Section 8.6
5	Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	The underground mining method proposed will result in groundwater inflow to the workings during mining, and then as mining progresses panels are sealed and groundwater will continue to inflow to sealed panels until they are full. The volume of water physically extracted for mining and the volume that inflows to sealed panels has been determined. The ultimate source of this water and the time taken for effects on adjacent water sources has also been determined. The numerical groundwater model for the project (HydroSimulations 2018) predicts groundwater inflows into the different parts of the mine from the surrounding water sources, both to active areas of the mine, and to the sealed void. The model considers inflows during and immediately following mining and then recovery. The table in response 2(3) above presents the predicted take from the three groundwater sources. The majority, of the inflow to the mine sump each year is sourced from the Sydney Basin Nepean Groundwater Source – Nepean Management Zone 1. There is a time lag between taking water from the groundwater system and a response in the adjacent groundwater sources, as shown in Figure 12.2 of the Water Assessment. The volumetric rates of baseflow impact over the course of the project for the impacted surface water sources are shown in the Figures presented in Chapter 11.1.3 of the Water Assessment.	Sections 12.2, 12.3, and 11.1.3

Table 2 Accounting for, or preventing the take of water

	AIP requirement Has the proponent:	Hume Coal response	Where addressed in Revised Water Assessment
6	Described how any licence exemptions might apply?	Licence exemptions are not applicable. Hume Coal has secured in excess of 90% (1,970 ML/yr) of the total licence requirement for the project, with a clear pathway for how the remaining licence volume (153 ML/yr) will be secured to meet extraction requirements.	Section 12.5
7	Described the characteristics of the water requirements?	During construction, the project's water needs will be sourced via licensed groundwater bores, located on land owned by Hume Coal. Potable water will also be sourced from water supply bores and/or trucked to site and stored in tanks, both at construction sites and the accommodation village. During operations, water will be supplied from intercepted mine inflow (ie groundwater inflow to the sump which will be pumped to surface), and water intercepted at surface within the mine footprint area (direct rainfall and recycling of water used on site). Additional groundwater may be abstracted from behind the sealed mine void bulkheads if required. Water during operations is required for: • coal preparation plant (CPP) process water; • co-disposed reject make-up water; • product coal handling water; • ROM stockpile water; • underground operations water; • administration and workshop area water; and • accommodation village consumption and cleaning. Potable water for both construction and operation will continue to be sourced from bores and/or trucked to site and stored in tanks during the mine's 19 years of operation. Water for use in amenities (non-potable) will be sourced from bores.	Sections 2.3.1, 2.3.2, and 8.2.3
8	Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	Hume Coal has secured in excess of 90% (1,970 ML/yr) of the total licence requirement for the project, with a clear pathway for how the remaining licence volume (153 ML/yr) will be secured to meet extraction requirements. Trading of water from the Nepean Management Zone 1 is proposed to secure the remaining 151 ML (remaining 7%) of the licence requirement from that zone. For the additional 2ML of share component required from the Nepean Management Zone 2 of the Sydney Basin Nepean Groundwater Source, either an application through the next controlled allocation order or trading from within that zone is proposed.	Sections 12.4 and 12.5
9	Considered the rules of the relevant water sharing plan and if it can meet these rules?	The rules of the relevant water sharing plans have been considered in detail when preparing this assessment. Volumetric considerations for availability of water and licensing within respective water sources and management zones have been strictly adhered to. Rules governing the granting and management of licences, including rules for work approvals, mandatory conditions and dealings is considered in detail in Table 8 below.	Sections 3.2.1 & 12.2.4

Table 2 Accounting for, or preventing the take of water

	AIP requirement Has the proponent:	Hume Coal response	Where addressed in Revised Water Assessment
10	Determined how it will obtain the required water?	Physically obtaining water during construction, the project's water needs will be sourced via licensed groundwater bores, located on land owned by Hume Coal. Potable water will also be sourced from water supply bores and/or trucked to site and stored in tanks, both at construction sites and the accommodation village. Potable water will continue to be sourced from bores and/or trucked to site and stored in tanks during mine operation. Water for use in amenities (non-potable) will be sourced from bores. From a licensing perspective, the Hume Coal has secured in excess of 90% (1,970 ML/yr) of the total licence requirement for the project. The remaining amount is to be secured through the trading of water from the Nepean Management Zone 1 (151 ML) and the Nepean Management Zone 2 (2 ML) of the Sydney Basin Nepean Groundwater Source.	Section 12.5
11	Considered the effect that activation of existing entitlement may have on future available water determinations?	The water market in Zone 1 of the Sydney Basin Nepean Groundwater Source has been sufficiently deep that Hume Coal has already secured in excess of 90% of the required licence volume for the project to date. There is minimal remaining volume to be purchased or applied for. The water purchased was active licences, and therefore limited if any impacts is predicted to available water determinations. The actual usage of water is significantly less than the licence volume required from Zone 1. Hume Coal will only physically extract the water that enters the sump, with the void water remaining within the groundwater source. The volume of water physically extracted is on average only 28% (peak 54%) of the total licence volume held. Water trading in the area often occurs without separating the water licence from the land. There were 33 such transactions of land with accompanying water licence during 2016 and 2017 within Nepean Management Zone 1 of the Sydney Basin Nepean Groundwater Source. The total volume of water involved in these transactions during this same period was 1,975 ML of groundwater. Of this, a total 1,383 ML were unrelated to the project. Water licences are also traded separately from land in the area, and these are recorded on the NSW Water Licence Register. A number of groundwater share assignment of rights dealings (permanent trades) have occurred in the Sydney Basin Nepean Groundwater Source.	Section 12.6
12	Considered actions required both during and post-closure to minimize the risk of inflows to a mine void as a result of flooding?	Hume Coal proposes to develop and operate an underground coal mine. There will be no open mine void, and no conduit to the surface following mine closure. Post mine closure there is no risk of flood waters accumulating underground, or for outflow from underground workings. Mining will occur sequentially in panels that are separated by solid barriers of unmined coal. Once mined, the panels will be backfilled with co-disposal reject (comprised of crushed rock rejects and water from the coal processing plant mixed with up to 1% limestone to buffer any potential oxidation reaction of sulphur in the coal). It is estimated that reject and other rock wastes will fill some 36% of the total mined volume. Results of the hydrologic modelling indicated there will be minor change in the 100 year ARI flood extents for the operation phase compared to the existing, pre-project, situation. These changes are due solely to surface infrastructure works and not mine voids (which are all underground). Changes in flood extents following mine rehabilitation, compared to the existing situation, are only predicted in the area where the proposed stormwater basin capturing runoff will be located during mine operation.	Section 10.3

Table 2 Accounting for, or preventing the take of water

	AIP requirement Has the proponent:	Hume Coal response	Where addressed in Revised Water Assessment
13	Developed a strategy to account for any water taken beyond the life of the operation of the project?	At mine closure, there will be no ongoing water discharge from the mine workings as panels will be sealed progressively over the life of the mine. There will be no permanent surface reject emplacements and therefore no ongoing risk of leachate on the surface and all dams will be rehabilitated upon cessation of operations. As indicated in the response to 2(2) above, the licence requirements for the project (both during and following mine closure) have been determined and are provided for each water source. The majority (in excess of 90%) of the peak estimated water take is already accounted for with Hume Coal holding these licences. The minimal additional water required can be obtained from the water market. Carryover provisions in the for groundwater allow for 10% carryover of unused account water from previous years, and up to 110% use from an account (provided the account water is there). For surface water, carryover provisions in the plan provide for 100% of entitlement, plus accrued allocations, over a three-year rolling period.	Sections 12.4 and 12.5
Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users? If **YES,** items 14-16 must be addressed		**YES**	
14	Considered any potential for causing or enhancing hydraulic connections, and quantified the risk?	A non-caving, first workings mining layout and method are planned. Mining will occur sequentially in panels (not longwall panels) that are separated from each other by approximately 50 m wide solid barriers (pillars) of unmined coal to aid geotechnical stability. The proposed method is low impact and will have negligible surface and subsurface subsidence, and minimal overburden fracturing Minimal overburden deformation is expected to occur. Most will be small amounts of elastic deformation of the rock mass, while non-elastic deformation will be restricted to the immediate roof over the openings. Quantification of this risk, including a sensitivity analysis enhanced fracturing was undertaken in the revised modelling. The height of deformation is estimated to be 2 m into the roof above the panel (Coffey 2016b). Sensitivity analysis undertaken by HydroSimulations (2018) demonstrated that groundwater inflows are not sensitive to doubling this height of deformation. Within the deformation (dilated) zone, existing cleats or defects may become enlarged and minor cracking may occur, which could increase hydraulic conductivity. The deformation zone is likely to become desaturated during mining activities. Above this zone, deformation will be negligible and groundwater saturation of the strata would be maintained (Coffey 2016b and HydroSimulations 2018).	Sections 2.2 and 8.6.4

Table 2 Accounting for, or preventing the take of water

	AIP requirement Has the proponent:	Hume Coal response	Where addressed in Revised Water Assessment
15	Quantified any other uncertainties in the groundwater or surface water impact modelling conducted for the activity?	Both surface and groundwater assessments have considered sensitivity and uncertainty. Surface water assessments have closely considered climate uncertainty, and the groundwater model has considered both climate uncertainty, sensitivity of the model to climate and aquifer parameters, and also detailed *Monte Carlo* uncertainty analysis on hydraulic conductivity. For the groundwater model, a detailed uncertainty analysis by stochastic modelling using the *Monte Carlo* method as prescribed in the IESC explanatory note was undertaken. This approach is industry best practice and is rarely undertaken for projects such as this. The results generated numerous alternative sets of input parameters for the groundwater flow model run (realisation). The model is the executed independently for each realisation, and then aggregates the results for statistical analysis. For each realisation generated by the *Monte Carlo* process, every pilot point was assigned a Kx value and a Kx/Kz ratio. This equates to a total of 6,656 parameters (256 points by 13 layers by 2 parameters). Each model cell is then assigned a Kx and a Kz value through interpolation from surrounding pilot point values by using the contouring method *kriging*. The model outputs and post processing from the uncertainty analysis provided the following results: • mine inflow; • bore drawdown; • baseflow interception for four streams; • water table drawdown - at 50th percentile; • water table drawdown contours at 2 m at 33rd, 50th, and 67th percentiles; and • risk map - showing the cell-by-cell confidence that water table drawdown would be less than 2 m. Outcomes of the uncertainty analysis are presented in Section 8.6 of the Water Assessment and Appendix F: Revised Groundwater Model Report.	Sections 8.2.5 & 8.6.4 (ii)

Table 2 Accounting for, or preventing the take of water

	AIP requirement Has the proponent:	Hume Coal response	Where addressed in Revised Water Assessment
16	Considered strategies for monitoring actual and reassessing any predicted take of water throughout the life of the project, and how these requirements will be accounted for?	Water management plans (WMPs) will be prepared and include details of the surface water and groundwater monitoring program, which will incorporate and update the existing monitoring network, monitoring frequencies and water quality constituents, and physical water take and pumping volumes between water storage structures (including the void, the sump, mine water dams and sediment basins). The monitoring program will be prepared in accordance with the approved project's environment protection licence (EPL), once enacted. The groundwater model will undergo model frequent verification (ie comparison of predicted versus actual impacts), and then be recalibrated if and when required. Linked surface water models (ie water balance) will also be undertaken as required based on verification to actual data collected in accordance with the WMP's. The water balance model will be reconsidered and optimised for water efficiency throughout all years of mining. The optimising of the water balance model will focus on more efficient operation and the water level in the PWD. It is expected these updates will result in minor changes to volumes of water required to be harvested from the void and will not have implications in the overall project assessment or licensing requirements. The WMP will also provide a program for reviewing and updating the numerical groundwater model as more data and information become available. The WMPs will be prepared in consultation with DPI Water, EPA, WaterNSW, and the local council and the reporting frameworks for the above will be prepared in accordance with licensing and agency requirements	Sections 13.2

Table 3 Determining water predictions in accordance with Section 3.2.3 of the AIP (consider during and following completion of activity)

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
1	~~For the Gateway process, is the estimate based on a simple modelling platform, using suitable baseline data, that is, fit-for-purpose?~~	N/A	N/A
2	For State Significant Development or mining or coal seam gas production, is the estimate based on a complex modelling platform that is: • Calibrated against suitable baseline data, and in the case of a reliable water source, over at least two years? • Consistent with the Australian Modelling Guidelines? • Independently reviewed, robust and reliable, and deemed fit-for-purpose?	The Hume Coal Project is a State Significant Development Project – SSD 7172. The project has a monitoring network, developed in consultation with DI Water (and former departments), that includes 54 conventional groundwater monitoring bores at 22 nested locations, 11 vibrating wire piezometer (VWP) sensors at three locations, three private landholder bores, 11 stream gauges, and 24 water quality monitoring sites. Groundwater monitoring began in 2011 and surface water monitoring began in 2012. Baseline data has been collected continuously since that time and there is up to 8 years of monitoring at many locations within and surrounding the project area. The model was prepared in accordance with the Australian Groundwater Modelling Guidelines (AGMG) (Barnett et al. 2012). The current model conforms to most criteria for Class 3 model classification, with the remaining criteria conforming to Class 2. The independent NSW Government peer review by Hydrogeologic (Middlemis 2017) concluded that the EIS model was Class 2 based on a holistic interpretation of the guidelines and that development of the original EIS model, and impact assessment, was in accordance with best practice guidelines. The Hydrogeologic draft review (Middlemis 2017) of the original EIS model stated that "*the Hume Coal model itself is suitable for the mining impact assessment purpose (Class 2 confidence level)' and 'the EIS presents reasonable predictions of dewatering volumes and drawdown extent/magnitude*." The baseline water monitoring network is positioned to provide spatial coverage across the project area and beyond, investigates the major hydrological and hydrogeological environments, and monitor potentially sensitive features.	Sections 8.2 & 8.6 Appendix F Appendix G

Table 3 Determining water predictions in accordance with Section 3.2.3 of the AIP (consider during and following completion of activity)

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
3	~~In all other processes, estimate based on a desk-top analysis that is:~~ ~~Developed using the available baseline data that has been collected at an appropriate frequency and scale; and~~ ~~Fit-for-purpose~~?	N/A	N/A

1.1 Other requirements to be reported on under Section 3.2.3

Table 4 Additional detail to be reported on under Section 3.2.3

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
1	Establishment of baseline groundwater conditions?	Baseline groundwater conditions are well known within the project area, with all key geologies and water sources considered and monitored in detail. Groundwater baseline data has been collected continuously since 2011, and there is currently up to 8 years of monitoring at many locations within and surrounding the project area. The monitoring network, developed in consultation with DPI Water (and former departments), includes 54 conventional groundwater monitoring bores at 22 nested locations, 11 vibrating wire piezometer (VWP) sensors at three locations, and three private landholder bores. Encompassing the data collected, the regional and local geological and hydrogeological settings for the project are provided in Chapter 6 of the Water Assessment.	Section 6.3
2	A strategy for complying with any water access rules?	The Hume Coal Project is compliant with the Water Access Rules for the applicable Water Sharing Plan for the greater metropolitan region groundwater sources, considering both the Sydney Basin Nepean groundwater source and the Sydney Basin South groundwater source. The compliance strategy is outlined in Table 8 below.	Section 3.2.1iii
3	Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	Predictive simulations were used to quantify the potential drawdown in registered landholder bores as a result of the project activities. These simulations were undertaken in detail using uncertainty analysis techniques as outlined by the draft IESC guidelines for modelling uncertainty. Impacts to landholder bores were assessed against the AIP Level 1 impact of a maximum 2 m decline at any water supply work. As a result of the project, a total of 94 landholder bores on 72 properties are predicted to experience temporary drawdown in excess of 2 m. Full recovery of bores is predicted following cessation of mining and full recovery of the groundwater resource. Nine bores are predicted to be intercepted by mining operations. Number of bores impacted: 94[1] Maximum drawdown range: 2–47 m Median maximum drawdown: 9.9 m Number of landholders (properties) with impacted bores: 72 Time until all impacted bores recover, after mining starts: 76 years *Notes: 1. Does not include bores located on properties owned by Hume Coal.* With regard to water quality, it is not anticipated the project activities will result in a lowering of the beneficial use category of the groundwater source beyond 40 m from the activity, provided mitigation measures are implemented. Groundwater quality changes in landholder bores will be negligible based on assessments of potential increased flow from poorer water quality groundwater systems and solute transport assessments on co-disposed rejects to be emplaced underground. Impacts to potential surface water users and stream environments were also considered, however as outlined in Chapter 10.5 of the Water Assessment, the identified changes are considered insignificant.	Section 11.4.3

Table 4 Additional detail to be reported on under Section 3.2.3

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
4	Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	Drawdown in adjacent groundwater sources (ie outside of the Sydney Basin Nepean Groundwater Source) will result in less minimal impact to landholder bores. There is a small volumetric contribution over time from adjacent sources and this is included in licence requirements. There is no water quality impact predicted in adjacent groundwater sources. Overlying surface water resources are subject to both reduced baseflow and in the Medway Dam, some surface water losses. The groundwater numerical flow model predicts this in detail (ie total volume, peak take and timeframes). It is noted that changes to surface water flows are negligible overall. The dominant reason for any change is a slightly reduced volume of baseflow from the groundwater source to streams, with a small component of surface water loss to the underlying groundwater system in the Medway Dam area. The maximum rates of baseflow reduction as a result of the project for each management zone is summarised in the below table.	Sections 11.1.2, 11.1.3 and 10.5.2

Surface water management zone	Maximum rate of baseflow interception		Time to maximum rate (years since start of mining)
	ML/day	ML/year	
Upper Wingecarribee River	0.008	3	42
Lower Wingecarribee River (whole zone)	0.254	93	22.5
Medway Rivulet (whole zone)	0.982	359	19
Lower Wollondilly River	0.008	3	76
Nattai River	0*	0*	-
Bundanoon Creek	0.007	3	64

A marginal reduction in streamflow associated with reduced catchment size and reduction of baseflow due to underground mining is predicted in the downstream sections of Medway Rivulet. Downstream of the surface infrastructure area, Medway Dam is the only licensed user in the Medway Rivulet; although the associated treatment plant was operated for town water supply it is not currently being used. Landholders with basic water rights are located downstream and upstream of the surface infrastructure area, and although there is potential for a reduction in streamflow in the Medway Rivulet the reduction is minor and therefore imperceptible changes for water for users.

Table 4 Additional detail to be reported on under Section 3.2.3

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
5	Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	N/A There are no predicted impacts to high priority ecosystems that rely on groundwater (groundwater dependent ecosystems (GDEs) listed in a water sharing plan) as a result of the project. Paddys River Swamps (comprising Long, Hanging Rock, Mundego, and Stingray Swamps) and Wingecarribee Swamps are identified as high priority GDEs in the Metropolitan Groundwater WSP; however, they are located some kilometres from the mine area and beyond 9 km to the south-west and 17 km to the east, respectively.	Section 11.4
6	Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	The hydrogeochemical assessment completed for the RTS (RGS 2018) concludes that the project would not result in significant changes to the groundwater chemistry and would thus not change the beneficial use class of the aquifers or connected river systems. The baseline migration of groundwater with higher salinity from the Wianamatta Group shales to the upper Hawkesbury Sandstone was consistently around 11.1 ML/day for the entire simulation period. This rate for comparison is equivalent to a very small rainfall event of 0.04 mm per day.	Sections 8.7.1 & 11.2.1
7	Potential to cause or enhance hydraulic connection between aquifers?	As presented in the response to Table 2(14) above, a non-caving, first workings mining layout and method are planned. Mining will occur sequentially in panels (not longwall panels) that are separated from each other by solid barriers of unmined coal. The proposed method is low impact and will have negligible surface and subsurface subsidence, and minimal overburden fracturing, and therefore, negligible enhancement of hydraulic connection between aquifers. Subsidence and fracturing of overlying strata is considered in detail in specialists report and independent peer reviews commissioned by the NSW Government (Galvin 2017). Galvin confirms that the first working mining approach is plausible and that any subsidence (if it occurred) would be minimal and manageable.	

Table 4 Additional detail to be reported on under Section 3.2.3

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
8	Potential for river bank instability, or high wall instability or failure to occur?	N/A – the Hume Coal Project is an underground mining and, therefore, there is no high wall. Drainage lines identified as prone to erosion are located upstream of the surface infrastructure area (refer to drainage lines identified as 'laterally unconfined valley setting', 'partly-confined valley setting', and 'laterally unconfined'. Whereas, next to and downstream of the surface infrastructure area, Medway Rivulet and Oldbury Creek are in confined valley settings and the channels are bedrock controlled. During the project's operational phase, the risk of stream bank erosion would be low and could be managed by appropriate mitigation measures. Discharges to Oldbury Creek would occur in a reach classified as 'confined valley setting – occasional floodplain pockets'. Discharge would occur as piped outflows from SB03 and SB04 (combined) and from the WTP if required, into or just upstream of the existing instream storage north of the PWD. Scour protection will be required at the discharge outlets and potentially reinforcement of the existing spillways following assessment. Downstream, the channel is bedrock controlled and the risk of stream bank erosion due to this discharge is considered negligible. During construction and rehabilitation, an erosion and sedimentation control plan, developed in accordance with Landcom (2004) and DECC (2008) guidelines, will be prepared to manage and mitigate potential erosion and sedimentation induced by the project so as not to adversely affect the surrounding environment. With the implementation of this plan, erosion and sedimentation changes during the construction and rehabilitation phases are expected to be minimal. Temporary erosion and sedimentation control measures include: sediment basins, sediment fences, diversion banks, check dams, batter chutes, temporary culverts, and scour protection. This is discussed further in Chapter 13. Based on the above, the predicted changes to stream banks as a result of erosion induced by the project are considered insignificant.	Sections 5.2, 9.3, and 10.5.1
9	Details of the method for disposing of extracted activities (for coal seam gas activities)?	N/A – Mining project, not coal seam gas.	N/A

Notes: N/A = not applicable

2 Addressing the minimal impact considerations

Based on DPI Water's mapped areas of groundwater productivity in NSW (NOW 2012b), the project is considered to be within 'highly productive' porous and fractured rock water source.

Table 5 Minimal impact considerations

Aquifer	Porous rock or fractured rock	Where addressed in Revised Water Assessment
Category	**Highly productive**	
Level 1 minimal impact consideration	**Assessment**	
<u>Water table</u> Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 metres from any: • high priority groundwater dependent ecosystem or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. OR A maximum of a 2 metre water table decline cumulatively at any water supply work.	**N/A** There are no high priority GDEs or high priority culturally significant site within the project area.	Section 4
<u>Water pressure</u> A cumulative pressure head decline of not more than a 2 metre decline, at any water supply work.	**Level 2** Based on numerical groundwater modelling, 94 landholder bores on 72 properties are predicted to be directly impacted by more than 2 m drawdown as a result of the project. The project will not dewater the groundwater systems in the Hawkesbury Sandstone (the regional groundwater system); rather the aquifer will undergo some degree of depressurisation depending on proximity to the mine workings desaturated zone. The groundwater supply potential of the Hawkesbury Sandstone will remain largely viable in the vicinity of the project.	Section 11.4

Table 5 Minimal impact considerations

Aquifer	Porous rock or fractured rock	Where addressed in Revised Water Assessment
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	**Level 1 – Acceptable** The hydrogeochemical assessment conducted by RGS (2018) concluded that the project would not result in significant changes to the groundwater chemistry and would thus not change the beneficial use class of the aquifers. The hydrogeochemistry study considered interaction of reject slurry with groundwater in the mined out voids. The modelling results, which incorporated significant conservatism, indicated that the leachate (from emplacement of the limestone amended reject slurry into the mine voids the quality would be nearly indistinguishable from ambient groundwater, and would maintain the same beneficial use status (RGS 2018). While the assessments conclude that there are no predicted chemistry changes to groundwater source beyond 40 m from project activities, Hume Coal is committed to monitoring groundwater quality in various aquifers in the vicinity of the mine footprint as part of the project's ongoing monitoring program (Refer to Section 13 of the Revised Water Assessment (EMM 2018)).	Section 8.7

Notes: N/A = not applicable

3 Proposed remedial actions where impacts are greater than predicted

Table 6 Proposed remedial actions where impacts are greater than predicted

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
1	Considered types, scale, and likelihood of unforeseen impacts *during operation*?	A conservative approach was adopted for groundwater modelling. Sensitivity is well understood and a detailed uncertainty analysis provides additional assurance to the accuracy and minimal sensitivity range of groundwater inflow and drawdown in landholder bore predictions. The adopted and assumed drawdown in landholder bores is taken to be the more conservative 67th percentile (and not the most likely 50th percentile). Monitoring of mining as it progresses will occur and model verification undertaken, and model predictions can be reforecast (if needed) ahead of the maximum mine inflow (year 17) and subsequent maximum drawdown impact (ie post mining). Mitigation and management options can be adjusted and adopted if and as required to manage 'unforseen' impacts ahead of them occurring. Options for additional make good measures are always available and Hume Coal commits to maintain existing water supply for landholders that experience in excess of 2m drawdown in their bore as a result of the project. In the unlikely event that groundwater inflow rates to the underground sump or void are higher than predicted, the options considered will be to seal voids as mining progresses at a rate faster than originally planned (ie the groundwater model allows for sealing within 12 months from cessation of mining in an individual panel).	Section 11.1.2
2	Considered types, scale, and likelihood of unforeseen impacts *post closure*?	Post-closure, there will be no ongoing water discharge from the mine workings as panels will be sealed progressively over the life of the mine. There will be no permanent surface reject emplacements and therefore no ongoing risk of leachate on the surface. All dams used as part of mine water management system will be rehabilitated upon cessation of operations and, unlike an open cut mine, there will be no surface voids and therefore no potential for evaporative concentration of salts in voids over time. Therefore the likelihood of impacts post-closure is low. Drawdown exceeding the AIP Level 1 criteria (2 m) in the affected aquifers are predicted to persist beyond the 22 years of mining activities but the degree of impact would decrease progressively (recover), mitigated by rainfall and runoff. Hume Coal is committed to continue the water monitoring program post closure for a nominal period of five years	Sections 11.1.3 & 13.3

Table 6 Proposed remedial actions where impacts are greater than predicted

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
3	Proposed mitigation, prevention or avoidance strategies for each of these potential impacts?	Prior to mining and during mining activities, the monitoring program will confirm the expected impact to groundwater levels. Avoidance and mitigation measures have been incorporated into the overall project design. Mitigation and avoidance measures include: • Diversion of runoff from undisturbed catchments back into natural system. • Minimise unnecessary water capture. • Mine footprint has been considered and tested to minimise impacts to water assets (ie footprint reduced from initial concept stage to achieve lower groundwater inflows). • First workings mining method and design of barrier pillars – designed to have zero caving, negligible subsidence, and no surface cracking. • Sealing of panels as mining progresses. • Addition of limestone to reject prior to co-disposal underground. Where the Project drawdown in a bore is predicted to be greater than the minimal impact criteria (2m), it has been considered as a trigger for potential or perceived long-term viability of the water-dependent asset. Additional assessment requirements apply which include 'make good' provisions to be negotiated with the relevant landholders. Strategies for make good provisions would be assessed on a case-by-case basis and would depend on the existing infrastructure, the degree of drawdown at each site and the outcomes of landholder consultation.	Sections 13.1.1

Table 6 Proposed remedial actions where impacts are greater than predicted

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
4	Proposed remedial actions should the risk minimization strategies fail?	The risk minimisation strategies are conservative measures and it is not likely that failure of these can occur. The mine is an underground first workings mine, and full recovery of the groundwater system post mining is anticipated. Conservative modelling approaches have been adopted and drawdown is not likely to be in excess of predictions. However, should remedial actions fail, advanced knowledge of drawdown in landholder bores will be able to be predicted and known prior to the impact occurring. This is possible due to ongoing monitoring, model verification and recalibration/re-forecasting of impacts if required (ie in advance of them occurring). Additional make good measures can also be applied to maintain existing water supply. If groundwater inflow rates to the underground sump are higher than predicted, considered options could include sealing the mine voids at a rate faster than originally or inject surplus water back into the Hawkesbury Sandstone. If greater than predicted drawdown is observed in areas of shallow groundwater that ecosystems are potentially relying on, an assessment of the ecosystem's health will be completed and an assessment of time for recovery of shallow groundwater, considering temporary irrigation to these systems until groundwater recovers to acceptable limits (ie the level at which the ecosystem can again access the groundwater.	Section 13.4
5	Considered what further mitigation, prevention, avoidance or remedial actions might be required?	Mitigation measures and remedial actions will be implemented as described above, and will be developed case by case basis with consultation with the individual landholders affected to maintain their water supply. Further mitigation, prevention avoidance and remedial actions that may be required include: • more frequent model verification; • additional monitoring (ie expanded network); and • review and revisions, if applicable, to make good strategy for individual bores.	Section 13
6	Considered what conditions might be appropriate?	Further conditions may align with the above options and could include model verification and calibration, and expansion of the monitoring network. These will be developed in consultation with WaterNSW and DI Water.	-

4 Other considerations

Table 7 Additional considerations

	AIP requirement	Hume Coal response	Where addressed in Revised Water Assessment
1	Has the proponent addressed how it will measure and monitor volumetric take? (page 4 of the AIP)	Yes. During construction, Hume Coal will consider installation of meters and flow gauges at appropriate locations within water network to record information on water volumes taken (both surface and groundwater), and volumes used during different construction activities. During the operational phase of the project, longer term operation water take and movement metering and monitoring is required in accordance with the water balance predictions. Hume Coal propose to expand their monitoring network to include water metering and recording of pumped volumes to/ from sediment basins, the primary water dam, the sump and the voids.	Sections 13.2 & 13.3
2	Has the proponent outlined a reporting framework for volumetric take? (page 4 of the AIP)	Yes. The Water Management Plans (WMPs) will include details of the surface water and groundwater monitoring program, which will incorporate and update the existing monitoring network, monitoring frequencies and water quality constituents, and physical water take and pumping volumes between water storage structures (including the void, the sump, mine water dams and sediment basins). Reporting frameworks for the above will be prepared in accordance with licensing and agency requirements. Threshold levels, related to the water balance and in particular physical water take and groundwater inflow contributions, have been proposed for the management of various water-related aspects of the project, and more will be proposed in monitoring plans as they are developed.	Section 13.3

5 Compliance against rules of the Water Sharing Plan

Table 8 below is a replication of Table 12.4 in the Revised Water Assessment.

Table 8 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Assessment
<u>Access rules</u>	
Rules for granting of access licences:	
Management Zone 1 & Management Zone 2 of Sydney Basin Nepean Groundwater Source and the Sydney Basin South Groundwater Source Granting of access licences may be considered for the following: • Local water utility, major water utility, domestic and stock, and town water supply *These are specific purpose access licences in clause 19 of the Water Management (General) Regulation 2004*. • Aquifer (Aboriginal cultural), up to 10ML/yr • Commercial access licences under a controlled allocation order made in relation to any unassigned water in this water source. Note: If water is made available through controlled allocation in this water source it is unlikely to be made available for extraction in Management Zone 1.	Hume Coal has secured in excess of 90% of the total access licence requirement for the project through • groundwater share components for Sydney Basin Nepean Management Zone 1; • groundwater share components for Sydney Basin Nepean Management Zone 2; and • groundwater share components for Sydney Basin South Trading of water from the Nepean Management Zone 1 is proposed to secure an additional 151 ML (remaining 7%) of the licence requirement from that zone, and an additional 3ML of share component from the Nepean Management Zone. Licences from Nepean Management Zone2 will be secured by either an application through the next controlled allocation order, or trading from within that zone.
<u>Rules for managing water allocation accounts</u>	
Carryover: • Up to 10% entitlement allowed. Carryover is not allowed for domestic and stock, major utility, local water utility or specific purpose access licences.	Hume Coal intends to hold 100% of the peak total licence requirement and, as such, carryover is unlikely to be required. Regardless, Hume Coal notes that carryover of up to 10% of entitlement is allowed.

Table 8 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Assessment
<u>Rules for managing access licenceS</u>	

Managing surface and groundwater connectivity:
• From year 7 of the plan, for areas adjoining unregulated water sources (i.e. rivers and creeks), **existing** works within 40 metres of the top of the high bank of a river or creek, **except existing** works for, local water utility, town water supply, food safety or essential dairy care purposes, will have conditions which establish:
  • the flow class of the river established under the water sharing plan for the corresponding unregulated water source, or
  • in the absence of a flow class, visible flow in the river at the closest point of the water supply works to the river.
• These distances and rules may be varied for an applicant if the work is drilled into the underlying parent material and the slotted intervals of the works commences deeper than 30 metres or no minimal impact on base flows in the stream can be demonstrated.
• For major utility and local water utility access licences these rules apply to new water supply works from plan commencement.
	Noted. Hume Coal will comply with the relevant conditions. However, it is noted that conditions as applied to 'works' assume a 'bore' and are not necessarily always directly appropriate or transferrable to mining activities.
	
	The project is declared a State Significant Development, and as such is exempt from requiring a 'work and use approval' under the Water Management Act 2000. However, the essence of the rules will be applied as appropriate to the mine and associated works, and or groundwater bores for water supply.

<u>Rules for granting and amending water supply works approvals</u>	
To minimise interference between neighbouring works:	
No water supply works (bores) to be granted or amended within the following distances of existing bores: • 400m from an aquifer access licence bore on another landholding, or • 100m from a basic landholder rights bore on another landholding, or • 50m from a property boundary (unless written consent from neighbour), or • 1,000m from a local or major water utility bore, or • 200m from a NSW Office of Water monitoring bore (unless written consent from NSW Office of Water). The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	The mine workings will be conducted outside of the distances outlined, and where there are exceptions, make good provisions will be provided to impacted landholders.

Table 8 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Assessment
To protect bores located near contamination: No water supply works (bores) are to be granted or amended within: • 250m of contamination as identified within the plan, or • 250m to 500m of contamination as identified within the plan unless no drawdown of water will occur within 250m of the contamination source, • a distance greater than 500m of contamination as identified within the plan if necessary to protect the water source, the environment or public health and safety. The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	There are no identified contaminated sites identified within 500 m of the project area.
To protect water quality To minimise the impact on water quality from saline interception in the shale aquifers overlying Sydney basin sandstone, the bore being used to take groundwater must be constructed with pressure cement to seal off the shale aquifer as specified by the Minister.	Hume Coal has predicted that no water quality changes to the beneficial use category to landholder bores as a result of the mine. Hume Coal also commits that should water quality changes be observed in a landholder bores as a result of Hume Coal operations so that the beneficial use is compromised, additional sampling and investigations will be conducted to determine the cause of the change and to confirm whether the change will prevent the long-term viability of the impacted aquifer and/or bore. If it is found the long-term viability of the water supply is compromised as a result of the project then make good obligations will be negotiated and implemented. Any replacement bore will be constructed as per this rule, and in accordance with the Minimum construction requirements for water bores in Australia (NUDLC 2012). Access to the underground mine will be constructed in a manner to prevent significant interaction between the shale aquifers and Hawkesbury Sandstone where required.

Table 8 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Assessment
To protect bores located near sensitive environmental areas: No water supply works (bores) to be granted or amended within the following distances of high priority Groundwater Dependent Ecosystems (GDEs) (non Karst) as identified within the plan: • 100m for bores used solely for extracting basic landholder rights, or • 200m for bores used for all other access licences. The above distance restrictions for the location of works from high priority GDEs do not apply where the GDE is a high priority endangered ecological vegetation community and the work is constructed and maintained using an impermeable pressure cement plug from the surface of the land to a minimum depth of 30m. No water supply works (bores) to be granted or amended within the following distances from these identified features: • 500m of high priority karst environment GDEs, or • a distance greater than 500m of a high priority karst environment GDE if the Minister is satisfied that the work is likely to cause drawdown at the perimeter of the high priority karst GDE, or • 40m of a river or stream or lagoon (3rd order or above), • 40m of a 1st or 2nd order stream, unless drilled into underlying parent material and slotted intervals commence deeper than 30m. (30m may be amended if demonstrate minimal impact on base flows in the stream.), or • 100m from the top of an escarpment. The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	Hume Coal is not proposing to apply for a water supply work (bore) within 200 m of a High Priority GDE or the specified distances from sensitive environmental areas.
To protect groundwater dependent culturally significant sites: No water supply works (bores) to be granted or amended within the following distances of groundwater dependent cultural significant sites as identified within the plan: • 100m for bores used for extracting for BLR, or • 200m for bores used for all other aquifer access licences The plan lists circumstances in which these distance rules may be varied and exemptions from these rules.	Hume Coal is not proposing to apply for a water supply work (bore) within 200 m of a groundwater dependant culturally sensitive site.

Table 8 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Assessment
Rules for replacement groundwater works: A replacement groundwater work must be constructed to take water from the same water source as the existing bore and to a depth specified by the Minister. A replacement work must be located within: • 20 metres of the existing bore; or • If the existing bore is located within 40 metres of the high bank of a river the replacement bore must be located within: • 20 metres of the existing bore but no closer to the high bank of the river or a distance greater if the Minister is satisfied that it will result in no greater impact Replacement works may be at a greater distance than 20 metres if the Minister is satisfied that doing so will result in no greater impact on the groundwater source and its dependent ecosystem. The replacement work must not have a greater internal diameter or excavation footprint than the existing work unless it is no longer manufactured. If no longer manufactured the internal diameter of the replacement work must be no greater than 110% of the existing work.	All landholder bores assigned with a 'make good' provision of having a replacement bore installed will align with the rules stated for replacement groundwater works.
Rules for the use of water supply works approvals	
To manage bores located near contaminated sites: The maximum amount of water that can be taken in any one year from an existing work within 500 metres of a contamination source is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.	N/A
To manage the use of bores within restricted distances: The maximum amount of water that can be taken in any one year from an **existing** work within the restricted distances to minimise interference between works, protect sensitive environmental areas and groundwater dependant culturally significant sites is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.	N/A
To manage the impacts of extraction: The Minister may impose restrictions on the rate and timing of extraction of water from a water supply work to mitigate the impacts of extraction.	Hume Coal will comply with relevant restrictions where imposed by the Minister.

Table 8 Compliance with rules of Sydney Basin Nepean Groundwater Source and Sydney Basin South Groundwater Source

Rule	Assessment
Limits to the availability of water **Available Water Determinations (AWDs):** • 100% stock and domestic, local and major utilities and specific purpose access licences • 1ML/unit of share aquifer access licences AWD for aquifer access licences may be reduced in response to a growth in use.	Hume Coal will comply with the applicable available water determination.
Trading rules **INTO groundwater source:** Not permitted	Noted.
WITHIN groundwater source: • Trading within groundwater source, from Management Zone 2 to Management Zone 1 is prohibited if the trade will increase the total licensed entitlement for the management zone from that at the commencement of the plan. • Trading within management zones permitted subject to local impact assessment.	Noted. To secure the remaining required licence volumes for the project, Hume Coal will source trades (and/or controlled allocation, in the case of Management Zone 2) from within the relevant management zones, subject to local impact assessment where relevant.
Conversion to another category of access licence: Not permitted	Noted.

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