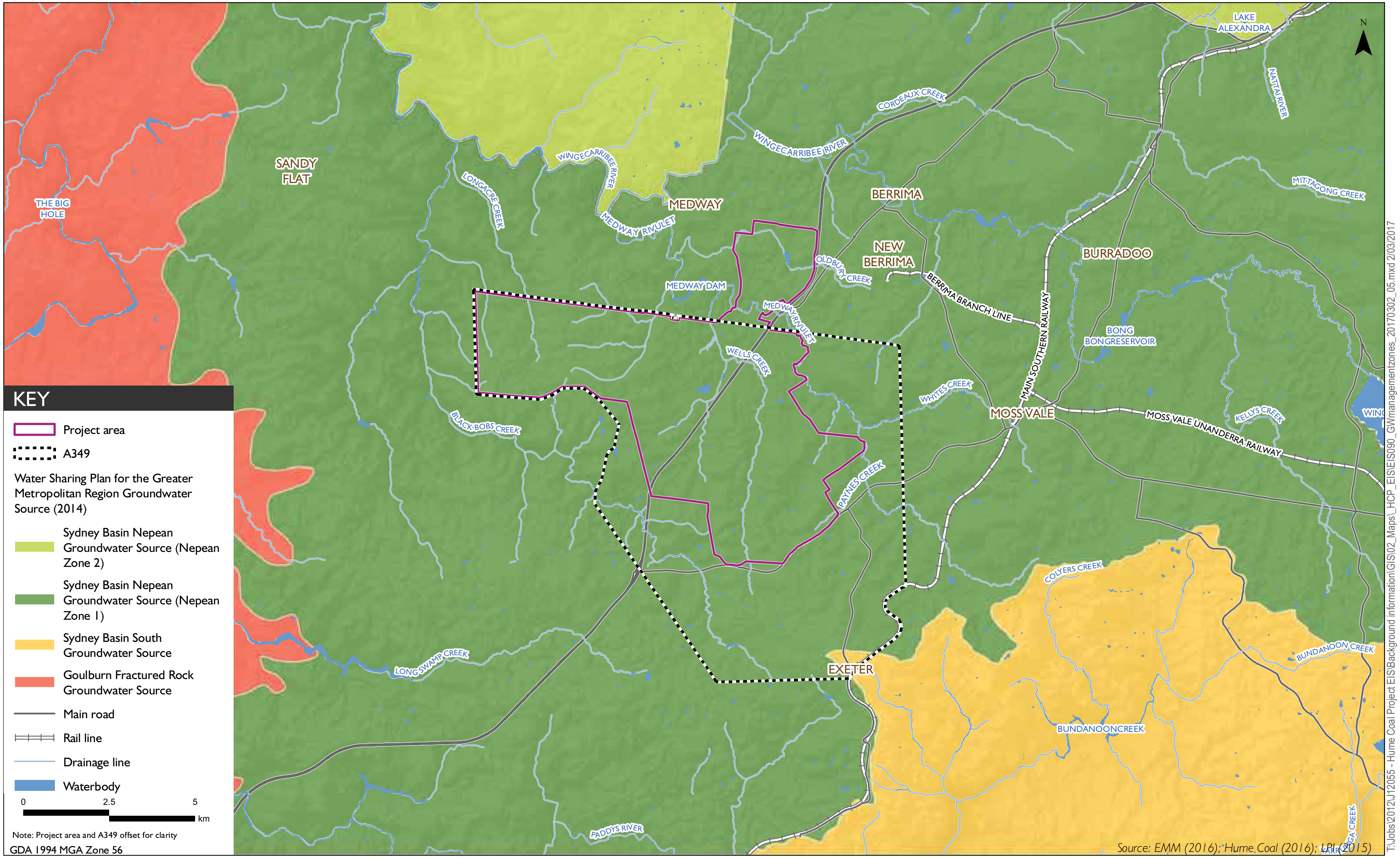

Groundwater management zones

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Figure 7.2

7.2.3 Surface water resources

i Surface water features

The project area is located within the catchment of the Wingecarribee River; part of the Upper Nepean and Upstream Warragamba Water Source.

The Wingecarribee River catchment is an upstream sub-catchment of the larger Hawkesbury-Nepean catchment, and is approximately 225 km^2 in area. It forms part of the 9,051 km^2 Warragamba Dam catchment which supplies water to Sydney.

The project area is traversed by several drainage lines generally flowing in a north to north-westerly direction, all of which discharge to the Wingecarribee River, at least 5 km downstream (north west) of the project boundary. Surface water features in and surrounding the project area are shown in Figure 5.2, and include the following local sub-catchments of the Wingecarribee River catchment:

- Medway Rivulet catchment, incorporating the Oldbury Creek sub-catchment, where a majority of the project area and the surface infrastructure is located; and
- Black Bobs Creek catchment, incorporating Red Arm Creek and Longacre Creek catchments.

Further discussion on surface water features in the project area is provided in Chapter 5.

ii Surface water quality

Hume Coal has been monitoring surface water quality in and around the project area since 2012. Figure 5.2 illustrates this surface water monitoring network.

Collected baseline data has been compared against the *Australian Drinking Water Guidelines* (NHMRC/NRMMC 2016) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000) and nutrients were compared against the recommended water quality objectives in *Healthy Rivers Commission Independent Inquiry into the Hawkesbury Nepean River System* (HRC 1998).

The data collected to date shows that all streams in the project area are fresh, with total dissolved solids (TDS) less than 500 mg/L. Belanglo Creek, Planting Spade Creek, Longacre Creek, Long Swamp Creek and Hanging Rock Swamp Creek are typically fresher than other streams in the project area with TDS generally less than 100 mg/L.

pH is generally between 5.5 to 8.0. It is typically higher in drainage lines within agricultural land (eg Medway Rivulet, Oldbury Creek and Stony Creek) and lower in streams within natural or forested catchments (eg Belanglo Creek, Planting Spade Creek, Longacre Creek, Long Swamp Creek and Hanging Rock Swamp Creek). pH can be below the lower guideline value of 6.5 in some of the drainage lines within natural or forested catchments.

Surface water quality within Medway Rivulet and Oldbury Creek in the project area typically complies with the most conservative guideline values, with the exception of the following:

- Salinity – although water is typically fresh, electrical conductivity (EC), a measure of salinity, typically exceeds the ANZECC/ARMCANZ (2000) guideline for aquatic ecosystems. The shale geology which underlies much of the project area is a likely contributor to the salinity levels in surface water systems.
- Nutrients – the majority of nitrogen and phosphorus samples exceed the water quality objectives recommended in HRC (1998). Agricultural practices and town effluent discharges into local streams is a likely contributor to elevated nutrient levels.

- Metals – elevated levels of iron are typically observed compared to the ANZECC/ARMCANZ (2000) guideline for irrigation. Silver is typically elevated in Oldbury Creek compared with the ANZECC/ARMCANZ (2000) guideline for aquatic ecosystems. Some elevated levels of copper have been observed in the Medway Rivulet and some elevated levels of aluminium in both Medway Rivulet and Oldbury Creek compared with the ANZECC/ARMCANZ (2000) guideline for aquatic ecosystems. Some elevated levels of manganese have been observed in both Medway Rivulet and Oldbury Creek compared with the ANZECC/ARMCANZ (2000) guideline for recreation. The Triassic rocks (shale and sandstone) underlying much of the project area are typically high in iron and manganese and are a likely contributor to elevated metals.

No BTEX chemicals (benzene, toluene, ethylbenzene, and xylene) were detected in baseline samples in either the Medway Rivulet or Oldbury Creek.

Medway Dam is prone to algal blooms in summer due to catchment runoff and nutrient loading. Algal toxins are associated with taste and odour issues in the treated water. Toxic cyanobacteria (blue-green algae) species have been demonstrated to be present and have been prevalent in historic blooms, resulting in the Medway water treatment plant having to be shut down for prolonged periods. The last shut down, which lasted nearly two years, was used to change the filter media and install a temporary Poly Aluminium Chloride plant to help reduce taste and odour effects from released algal toxins (Beca 2010).

iii Surface water users

Surface water is utilised by a number of users within and downstream of the project area, including landholders, council and ecosystems. Surface water diversion works (pumps) and storages are used to extract and store surface water for water supply. There are 188 water access licences (WALs) within the six surface water management zones applicable to the project area.

The surface water-related assets in the region are:

- storages used for town water supply - Medway Reservoir (Medway Dam) (1,350 ML) and Lake Burragorang (Warragamba Dam) (more than 2,000,000 ML) downstream of the project area; and Wingecarribee Reservoir (24,130 ML), Bundanoon Creek Dam (2,000 ML) and Fitzroy Reservoir (9,950 ML) upstream of the project area;

- Shoalhaven transfer scheme - a dual-purpose water supply and hydro-electric power generation scheme that allows for water collected in the Fitzroy and Wingecarribee Reservoirs and the Tallowa Reservoir (on the Shoalhaven River) to be transferred to the Sydney water supply;

- Highlands Source Pipeline - an 80 km pipeline linking Wingecarribee Reservoir to Goulburn;

- town sewage treatment plants, including Bowral, Robertson, Berrima and Moss Vale sewage treatment plants;

- various weirs on Wingecarribee River;

- pumps and storages used by local water users to extract surface water for water supply;

- landholders with basic water rights; and

- ecosystems with potential to be impacted by changes in surface water quality including:

    - in stream ecosystems; and

    - riparian ecosystems exposed to overbank flows and flooding.

There are a number of sewage treatment plants within the Wingecarribee LGA that discharge into local creeks, and these are summarised in Table 7.3.

Table 7.3 Sewerage treatment discharges within Wingecarribee LGA

Treatment plant	Capacity (as per EPL)	Discharge location
Berrima	100 - 219 ML	Oldbury Creek
Bowral	1,000 - 5,000 ML	Wingecarribee River (with wet weather overflows into Mittagong Creek)
Bundanoon	219 - 1,000 ML	Reedy Creek (which drains into Paddys River, which drains into Wollondilly River)
Mittagong	1,000 - 5,000 ML	Sheepwash Creek and Iron Mines Creek (which drain into Nattai River)
Moss Vale	219 - 1,000 ML	Whites Creek (which drains into Medway Rivulet upstream of Medway Dam)
Robertson	15 - 150 ML	Wingecarribee River

There are 11 pumps and 6 dams associated with WALs within the Medway Rivulet Management Zone. The diversion works and storages with associated WALs in the Medway Rivulet, Lower Wingecarribee River, Lower Wollondilly, and Bundanoon Creek management zones are presented in Table 7.4.

Table 7.4 Water management zones and users

Water Source	Management zone	Number of diversion works (pumps)	Number of storages (dams)	Total annual volume (ML)
Shoalhaven	Bundanoon Creek	5	4	1,007
Upper Nepean and Warragamba	Lower Wingecarribee River	29	12	1,072
	Lower Wollondilly River	86	32	4,138
	Medway Rivulet	13	7	1,027

Within the Upstream Warragamba and Upper Nepean, and the Shoalhaven Unregulated River Water Sources, basic water rights include:

- domestic and stock rights - landholders with stream frontage can take water without a licence for use in households, gardens and/or stock drinking water. The *Greater Metropolitan Region Unregulated Water Sources Water Sharing Plan 2011* estimates water requirements for domestic and stock rights to be:
  - 13.6 ML/day in the Shoalhaven Unregulated River Water Source;
  - 21 ML/day in the Upstream Warragamba and Upper Nepean and Water Source;
- harvestable rights – landholders are allowed to build dams on minor streams that capture 10% of the average regional rainfall-runoff on their property; and
- native title water rights - there are no native title water rights within the region.

7.2.4 Groundwater resources

i Hydrogeological environment

As noted in Chapter 5, the groundwater systems within the project area are defined as:

1. localised low permeability groundwater systems associated with the Robertson Basalt and Wianamatta Group shales.

2. regional porous fractured rock groundwater system associated with the Hawkesbury Sandstone.

3. localised water bearing zones associated with the Permian aged Illawarra Coal Measures and the Shoalhaven Group.

Both the Robertson Basalt and the Wianamatta Shale are isolated low permeability systems. Within the project area, the Robertson Basalt overlies the Wianamatta Shale in most locations with a few exceptions in the northern part of the project area. Spring discharge is observed at the contact between the basalt and underlying Wianamatta Group Shale (McLean & David 2006). The basalt is likely to be a stable, low volume source of recharge to the shale (Coffey 2016b). The Wianamatta Group shale has low permeability and acts as a regional aquitard, suppressing direct groundwater recharge and downward vertical flow. Fracturing within the shale can allow minor hydraulic connection with the underlying Hawkesbury Sandstone and minor supplies of poor quality water (Ross 2014). Groundwater within the shale is generally brackish to saline and bores within the shale are generally very low yielding (DNR 2006).

The Hawkesbury Sandstone forms a major unconfined to semi-confined porous rock groundwater system and constitutes most of the groundwater storage volume in the Southern Coalfields (McLean & David, 2006). Groundwater within the Hawkesbury Sandstone in the project area is generally fresh and bores range in yield from low to high (Ross 2014). The median bore yield for bores in and around the project area, as reported in the DPI Water groundwater database, is 2 L/sec.

The low permeability and porosity of the Permian aged rock units generally restrict groundwater flow; however, there are some water bearing zones associated with the Illawarra Coal Measures. Hydraulic connection between the Wongawilli Coal Seam and the Hawkesbury Sandstone potentially occurs where there is no interburden between the two units (ie in the southern part of the project area).

Direct rainfall infiltration is the primary recharge mechanism across the project area. Rainfall recharge is greater in un-forested areas and where the Hawkesbury Sandstone outcrops (in the western part of the project area), rather than where the lower permeability Wianamatta Group shales outcrop (in the eastern part of the project area). Lower rainfall recharge is expected for the Wianamatta Group as compared to the Hawkesbury Sandstone and the basalt. Average annual recharge to the water table across the project area was estimated to be approximately 2% of annual rainfall for the numerical groundwater model developed for the project (Coffey 2016a).

The majority of the drainage lines in the project area are considered to be gaining streams, as the groundwater level is typically higher than the stream beds (Coffey 2016a). Direct recharge of groundwater from streams in the project area is therefore likely to be very minor.

Groundwater discharges via several mechanisms in the region. The discharge mechanisms include:

- drainage to surface water (baseflow): estimated to be approximately 1.5% of annual rainfall and is the largest component of discharge (Coffey 2016a). The lower reaches of Black Bobs Creek and Medway Rivulet flow consistently during dry periods, indicating groundwater discharges into these surface water bodies; Wingecarribee River is also considered a groundwater discharge area (Coffey 2016a);

- extraction of groundwater through existing landholder bores;

- evapotranspiration from the water table, depending on land use and depth to groundwater;

- seepage/springs and increased evaporation along the escarpments, particularly along unit boundaries with contrasting vertical hydraulic conductivity (ie the interface between the Hawkesbury Sandstone and Illawarra Coal Measures, and the Wianamatta Shale and Hawkesbury Sandstone), particularly along the cliff lines in the downstream reaches of Black Bobs Creek and Medway Rivulet;

- groundwater drainage into the existing underground workings of the decommissioned Berrima Colliery to the north of the project area; and

- regional groundwater throughflow, to the south-east.

An analysis of groundwater baseflow (the component of stream flow that is groundwater) in the project area was undertaken by Coffey (2016a). Baseflow from the Hawkesbury Sandstone was calculated to be approximately 3% of annual rainfall. Baseflow from the Wianamatta Group is lower and was calculated to be 1–1.5% of annual rainfall. Basalt has significantly enhanced baseflow capacity compared to the sedimentary rocks and was calculated to be up to 30% of annual rainfall. Approximately 15% of the project area has outcropping basalt (Coffey 2016a).

ii Hydraulic conductivity

Tectonic disturbance and igneous activity within the project area has resulted in overall relatively higher hydraulic conductivity (K) compared to elsewhere in the Southern Coalfield and also in the Western Coalfield. There is a general decrease in K and also storativity with depth due to increasing overburden pressure, except where deformation and intrusions are present (Coffey 2016a).

The K values for each hydrogeological unit in the project area are provided in Table 7.5. The heterogeneous nature of the Hawkesbury Sandstone is reflected by a wide range of measured K values (0.001 – 10 m/day). The ratio between vertical K and horizontal K (Kv/Kh) is approximately 0.01 (Coffey 2016a).

Table 7.5 Hydraulic conductivity for hydrogeological units in the project area

Hydrogeological unit	Hydraulic conductivity K (m/day)	Source
Basalt	6	derived from government records and reports
Wianamatta Group	0.9	derived from government records and reports
Hawkesbury Sandstone	0.001 – 10	measured values from within and nearby the project area
Illawarra Coal Measures	0.01 - 0.9	measured values from within and nearby the project area

iii Groundwater levels and flow

The groundwater flow direction in the Hawkesbury Sandstone is regionally towards the east, away from areas of higher elevation in the west, which is consistent with the regional stratigraphic dip. However, there is some minor, localised groundwater flow to the north towards Medway Dam, to the west from the Wingecarribee Reservoir, and to the west towards the deeply incised gullies of Black Bobs Creek consistent with local topographic gradients. The groundwater flow directions in the overlying low permeability shale and basalt groundwater systems are controlled by local topography and the gradient of low permeability features. Groundwater flow in the basalt is likely to radiate outward from the centre of the basalt outcrop, with the majority of flow moving via fractures and joint networks and negligible flow through the pore spaces.

Groundwater levels (or hydraulic head) measured by the Hume Coal groundwater monitoring network show relative stability over time, except for periodic drawdown as a result of pumping from private landholder bores. North of the project area, around Berrima Colliery, drawdown and significant vertical hydraulic head gradients are seen in the monitoring data from monitoring bores and private landholder bores as a result of the last phases of the full extraction mining at Berrima Colliery (up to 2013) (Coffey 2016a). The hydraulic head data from bores in the Berrima mine area provide valuable insight on the hydrogeological systems and their response to dewatering during mining activities. The secondary extraction mining method employed at Berrima mine has significantly more impact to the overlying groundwater systems than the low-impact first workings method proposed for the Hume Coal Project due to the formation of caved goaves.

In relation to vertical hydraulic head, differences between different groundwater units are variable across the project area, reflecting recharge areas, cliff line discharge, and local systems within the Hawkesbury Sandstone. Coffey 2016a reports that:

- downward trending vertical gradients are present in the north-western part of the project area, consistent with areas of recharge;
- significant vertical hydraulic head gradients exist north of the project area, and desaturation associated with the full extraction mining and related deformation in the overlying units at the Berrima Colliery. This effect has not migrated south into the northern end of the project area due to incised watercourses that act as groundwater flow barriers;
- steep vertical hydraulic gradients generated by discharge at seepage faces are present adjacent to escarpments;
- significant, downward vertical hydraulic gradients are present in the Wianamatta Group where overlain with Robertson Basalt;
- small vertical hydraulic head gradients in the central part of the project area, due to distance from mining and escarpments and minimal recharge at this location; and
- negligible vertical hydraulic head gradients exist within the Robertson Basalt. However, there is a large vertical hydraulic head gradient between the basalt and the underlying sedimentary units (note this large vertical head does not translate to large flow due to the very low permeability of the Wianamatta shales).

The connectivity between the overlying shale and the Hawkesbury Sandstone is conceptualised as a stable low volume of leakage from the above low permeability system into the below high permeability regional sandstone system. Conservatively, it is assumed that there is a direct hydraulic connection between the base of the Wianamatta Group shale, and the underlying upper Hawkesbury Sandstone. The two formations could be separated by a desaturated zone in some areas, in which case leakage from the shale into the underlying sandstone would be already occurring at a maximum rate. Daily leakage from the Wianamatta Group shales to the Hawkesbury Sandstone was modelled and found to be equivalent to a very small rainfall event of 0.04 mm (refer to Appendix K of the water assessment report provided in Appendix E).

iv Groundwater quality

Groundwater quality was monitored in 44 bores. Table 7.6 summarises the groundwater quality monitoring network.

Table 7.6 Summary of baseline water quality data per groundwater system

Groundwater system	Number of monitoring bores	Total number of water quality samples collected	Data range
Robertson Basalt	2	9	December 2012 – September 2015
Wianamatta Group	1	7	December 2013 – September 2015
Hawkesbury Sandstone	23	131	October 2011 – September 2015
Wongawilli Seam	15	93	October 2011 – September 2015
Illawarra Coal Measures	3	14	March 2013 – September 2015

Groundwater quality data collected between October 2011 and September 2015 is presented and comprehensively analysed in Appendix K of the water assessment report (refer to Appendix E).

A summary of key water quality characteristics of the groundwater within the project area is as follows:

- pH - pH conditions are typically neutral in the Robertson Basalt and Wianamatta Group, and slightly more acidic in the Hawkesbury Sandstone and Wongawilli Seam.
- salinity (TDS) - Groundwater is generally fresh in the Hawkesbury Sandstone and Illawarra Coal Measures, and comparable to surface water, indicating proximity to recharge areas. Groundwater quality is also fresh in the Robertson Basalt, although the mean TDS is slightly higher compared to the sandstone and coal. The Wianamatta Group hosts brackish groundwater remnant from the marine depositional setting.
- dissolved metal concentrations were typically low for all groundwater systems, with many measurements below detection limits.
- no organic compounds were detected above the limit of detection in the Wianamatta Group and Illawarra Coal Measures groundwater. Minor detections of naturally occurring toluene and petroleum hydrocarbons were observed in the Hawkesbury Sandstone and Wongawilli Seam groundwater.

The results of groundwater quality monitoring indicate that groundwater associated with the basalt intrusions in the project area is likely to be suitable for a broad range of beneficial uses, from a water quality perspective. Groundwater associated with the Wianamatta Group shales is typically too saline and the yield is too low to support a broad range of beneficial uses.

Groundwater in the Hawkesbury Sandstone is an important local water supply resource, and is heavily developed to support domestic and stock supply, and irrigation. It is characterised by a low solute load and, in combination with reasonable yields, makes it suitable to support most beneficial uses. Environmental values associated with the Hawkesbury Sandstone are likely to include primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods), drinking water, and, in places of discharge to streams, aquatic ecosystems.

v Groundwater users

a. Landholder and DPI Water bores

A search of DPI Water's groundwater bore database (December 2015) identified less than 400 registered landholder bores and three DPI Water monitoring sites within a 9 km radius from the middle of the project area (refer to Figure 7.3) (DPI Water 2015).

The median bore depth of the private landholder bores is approximately 85 m, with a majority of bores targeting the Hawkesbury Sandstone. Landholder groundwater extraction from the basalt is concentrated around Exeter, south-east of the project area, and south of the major sub-vertical feature in the area (a structural feature underlying the main Robertson Basalt outcrop around Exeter which runs approximately east-north-east to west-south-west). Landholder bores are mainly associated with the farmed areas, with very few bores observed in the Belanglo State Forest. The dominant landholder licence purpose is for domestic and stock use.

Coffey (2016a) identified 83 private water bore access licences within the 9 km radius of the project area. These bores have a combined entitlement of 5300 ML/year. Actual usage from registered bores is not known as no metering of usage is undertaken by regulatory agencies for the area. A number of basic rights bores (registered for stock and domestic use) also exist. There is no volumetric entitlement associated with these bores; however their total usage within a 9 km radius from the middle of the project area is estimated to be about 950 ML/year.

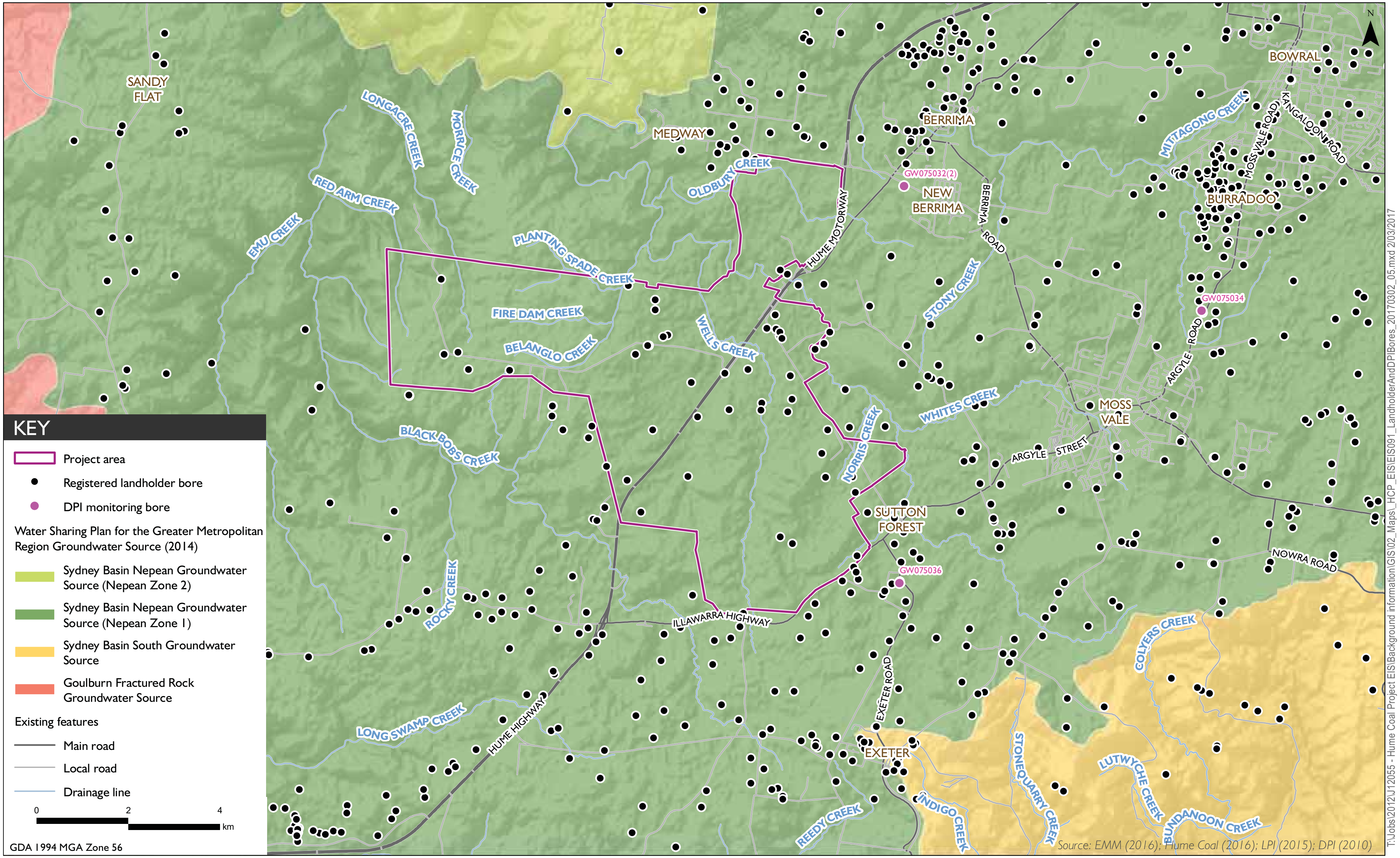
b. Groundwater dependant ecosystems

Ecosystems with potential for reliance on either the surface or subsurface expression of groundwater (GDEs) within or surrounding the project area were identified as part of the biodiversity assessment (refer to Chapter 10), and are those associated with:

- creeks where groundwater is connected and provides baseflow at times, for instance Medway Rivulet and some drainage lines in incised gullies in the north and west of the project area;
- groundwater systems;
- springs associated with basalt hills south of the project area and springs at the shale/sandstone boundary near creeks;
- upland swamps in the wider locality, namely Stingray Swamp and Long Swamp; and
- terrestrial vegetation overlying shallow groundwater (within the vegetation's root zone).

These ecosystems have been classified into three categories according to their dependence on groundwater: non-dependent, facultative (have some degree of dependence on groundwater, further categorised into opportunistic, proportional and highly dependent), or entirely dependent/obligate. None of the identified ecosystems in the study area have a facultative (highly dependent) or obligate dependence on groundwater.

NSW water sharing plans also include schedules with lists of high priority GDEs, which are required to be assessed using the minimal impact criteria outlined in the AIP. There are no high priority GDEs identified within the project area in the Metropolitan Groundwater WSP. Paddys River Swamps (comprising Long, Hanging Rock, Mindego, and Stingray Swamps) which contain the Temperate Highland Peat Swamps on Sandstone listed in the NSW TSC Act are approximately 9 km to the south-west of the project area. These swamps are also listed in the *Directory of Important Wetlands in Australia* (Environment Australia 2001).The Wingecarribee Swamps are 13 km to the east. Peat swamps rely on both groundwater baseflow to the drainage channels in which these swamps occur and surface water runoff.



Landholder bores and DPI Water monitoring bores

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Figure 7.3

EMM HUMECOAL

One spring was recorded in cleared land on a basalt hill in the south of the project area; however, given its location in a cleared area, there are no surrounding drainage lines that would be reliant on spring flow. Several springs were also recorded in cleared areas during surveys north and south of Oldbury Creek and Medway Rivulet. These springs would make a minor contribution to surface flows in the area to Oldbury Creek and Medway Rivulet, and therefore these systems are considered to be non-dependent.

Terrestrial vegetation overlies shallow groundwater (0 to 10 m below ground level) in some places in the project area, mainly along rivers and drainage lines. These include Medway Rivulet, Wells Creek, Belanglo Creek, Longacre Creek and Red Arm Creek. Six of the native vegetation types defined by the biodiversity assessment in the study area occur where the depth to groundwater is less than 10 m and, therefore, have potential to access groundwater sporadically at these locations. One of these, the Broad-leaved Peppermint Argyle Apple grassy woodland, contains the endangered Paddy's River Box. Terrestrial vegetation also overlies shallow groundwater south of the project area, along Bundanoon Creek, and to the north along Wingecarribee River.

Stygofauna studies undertaken in 2013 and 2014 (EMM 2017h) collected a total of one specimen of aquatic fauna (a crustacean) and three of terrestrial (commonly, an ant, a springtail, and a water strider) from 19 groundwater bores (eight within the project area and 11 outside of the project area). The crustacean was collected from a shallow groundwater monitoring bore (5 m bgl), while the remainder were from three deeper bores (between 78 and 87 m bgl); all four bores target the Hawkesbury Sandstone. No stygofauna was found in any of the seven sampled bores that target the Illawarra Coal Measures within the project area. No rare or significant stygofauna was identified.

7.3 Methods

7.3.1 Assessment criteria

The first step in identifying assessment criteria against which the results of the surface water and groundwater assessments of the project could be assessed was to identify the potential impacts to water resources and water users that could arise from the project. These were identified as:

- the construction and use of site infrastructure;
- interception and take of groundwater;
- injection 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;
- changes to surface water quality, including changes in salinity, including salt balance, and concentrations of other important water quality parameters (such as pH, major cations and anions and dissolved metals);
- changes to flooding regime;
- changes in groundwater quantity, including changes to groundwater levels/pressures and flux; and
- changes in groundwater quality, including changes in salinity, including salt balance, and concentrations of other important water quality parameters (such as pH, major cations and anions and dissolved metals).

As per the *Significant impact guidelines* (DoE 2013), the direct impacts listed above have been 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).

The site appropriate assessment criteria that was developed for both surface water and groundwater related impacts, as outlined in the relevant policies and guidelines are presented below.

i Surface water

Surface water assessment criteria is summarised in Table 7.7.

Table 7.7 Surface water assessment criteria

Aspect	Criteria
Water quantity, including flow, levels and availability	• percent reduction in yield in surface water quantity • increase in number of no-flow days
Water quality	To assess whether the project and associated treatment measures will have a neutral or beneficial effect (NorBE) on surface water quality, pollutant loads (for both the existing conditions and operational phase and concentrations predicted by the MUSIC model have been assessed against the following criteria outlined in the WaterNSW standards (SCA 2012): 1. 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. For gross pollutants, the post-development load only needs to be equal to or less than pre-development load. 2. 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 impact. 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.
Water quality – reduction in baseflow effects	Relevant ANZECC/ARMCANZ and ADW guidelines (as per the *National Water Quality Management Strategy Guidelines* (ANZECC/ARMCANZ 2000)) and water quality objectives recommended by *Healthy Rivers Commission into the Hawkesbury-Nepean River* (HRC 1998) were used as criteria to compare against both baseline surface water quality and groundwater quality data.
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 condition velocities are below the threshold. No more than a 10% increase in velocity where existing conditions velocities are above this threshold.

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

ii Groundwater criteria

The project was assessed in detail against the minimal impact thresholds defined in the AIP (NOW 2012) and DPI Water's assessment framework.

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 (NOW 2012) mapped areas of groundwater productivity in NSW, the project is considered within a highly productive porous fractured rock source. The applicable minimal impact considerations are shown in Table 7.8.

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 variation assessment was undertaken, but for the assessment of impacts as per the AIP, the Hume Coal Project influenced drawdown is referenced. 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 were therefore excluded from the assessment under the AIP.

Table 7.8 Minimal impact criteria for 'highly productive' porous fractured rock water source

Water table	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic post-water sharing plan variations, 40m 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. 2. If more than 10% cumulative variation in the water table, allowing for typical climatic post-water sharing plan variations, 40m 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 2m decline cumulatively at any water supply work then make good provisions should apply	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. 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.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity. 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: *1. 'post-WSP' – refers to the period after the commencement of the first WSP in the water source, including the highest pressure head (allowing for typical climatic variations) within the first year after commencement of the first WSP.*

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.

Source: *AIP (NOW 2012).*

Once the assessment criteria was established, numerical modelling and analytical techniques were utilised to develop a site water balance, a numerical groundwater model, investigate potential changes in flood extent, and predict quantity and quality impacts to groundwater and surface water resources. These modelling and analytical techniques are outlined in the sub-sections below.

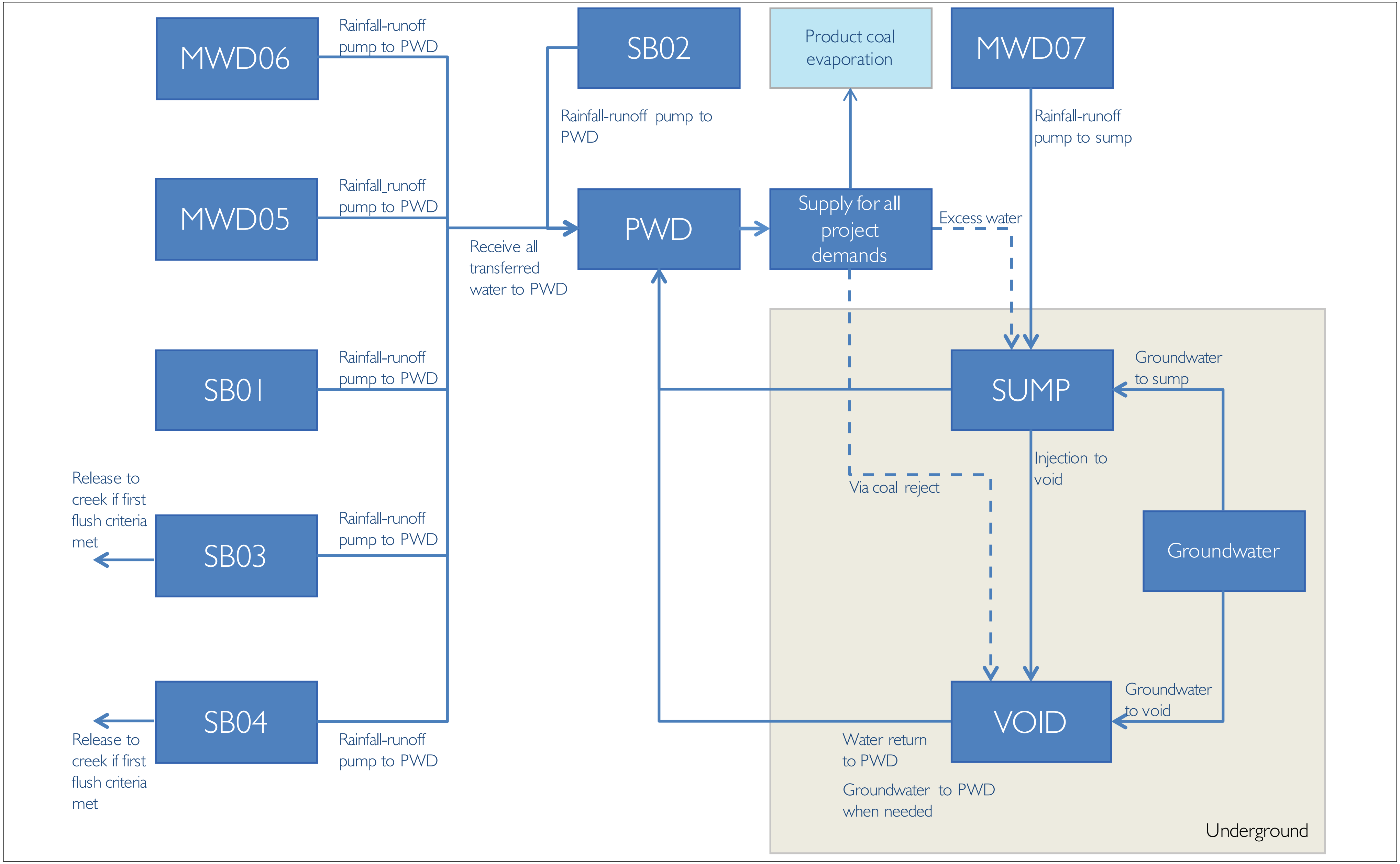
7.3.2 Surface water and site water balance

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

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.

A water balance schematic representing the inputs to GoldSim is presented in Figure 7.4.

A rainfall-runoff model was used to simulate expected runoff using historical rainfall data from 1889 to 2015 from the SILO Data Drill dataset (DSITI 2015). The volume of surface water runoff from SB and MWD catchments was estimated using the Australian Water Balance Model (AWBM) rainfall-runoff model (Boughton 1993). The AWBM model is suitable for unregulated runoff estimation and does not account for instream water storages directly. Full details of the AWMB rainfall-runoff model, including calibration and results, are discussed in Appendix D of the water assessment report (refer to Appendix E).



Water balance model flow schematic

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Figure 7.4

7.3.3 Surface water quality modelling

MUSIC (Model for Urban Stormwater Improvement Conceptualisation) modelling was undertaken to assess the potential TSS and nutrient (TP and TN) loads and concentrations in Oldbury Creek in accordance with NorBE criteria, and to calculate the maximum concentrations of other contaminants to achieve NorBE criteria for mean annual pollutant loads as a result of discharge from SB03 and SB04. MUSIC modelling was also undertaken to assess the potential impacts of runoff from mine access roads, located outside of the water management system, on surface water quality in the receiving environment and assess compliance with the NorBE criteria.

The MUSIC modelling was undertaken in accordance with the WaterNSW standards (SCA 2012).

Baseline surface water quality data was compared to baseline groundwater quality data to the impact of reduced baseflow on surface water quality.

7.3.4 Flood modelling

As described in Section 7.1.2, the study area for the numerical flooding assessment included the areas where surface infrastructure will be constructed, which includes the administration and workshop area, the CPP area and supporting infrastructure (ie access roads, bridges, conveyors). The administration and workshop area will be located in the Medway Rivulet sub-catchment and the CPP area in the Oldbury Creek sub-catchment.

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 developed of the Medway Rivulet and Oldbury Creek sub-catchments were used to estimate flow generated from the catchment for the 5 year Annual Recurrence Interval (ARI), 20 year ARI, 100 year ARI and PMF (probable maximum flood) design storm events to represent a reasonable range of extreme event flood conditions. 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, in order to determine the critical duration for each event. Results indicate that the PMP (probable maximum precipitation) critical duration for the Medway Rivulet catchment was the 4 hour event and for Oldbury Creek was the 2.5 hour event.

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 surface infrastructure for the mine and associated mitigation measures; and
- rehabilitation scenario - which is the final landform at completion of the project.

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).

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 were extracted approximately 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.

Flood modelling was not undertaken for the construction phase as the layout of temporary construction facilities will generally match the surface infrastructure layout used during operations. In addition, the temporary accommodation village was not assessed in the flood model as it will be located on a ridge and will not impact on flooding regimes in Medway Rivulet.

7.3.5 Groundwater numerical model

A regional numerical groundwater flow model using MODFLOW-SURFACT Version 3 (Hydrogeologic) was developed for the project to assess potential groundwater impacts. Analysis of a substantial database of Hume Coal data and data from published sources was undertaken to build the numerical model, and subsequently calibrate and refine it. The model was developed in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al 2012) and conforms to the majority of criteria for Class 3 models, with the remaining criteria conforming to Class 2.

An additional, smaller numerical basalt model was developed to calculate depressurisation in the basalt associated with the Hume Coal mine. The model was developed with MODFLOW-SURFACT Version 3, with a model domain on 15 km^2 and a boundary that followed the south-eastern basalt body.

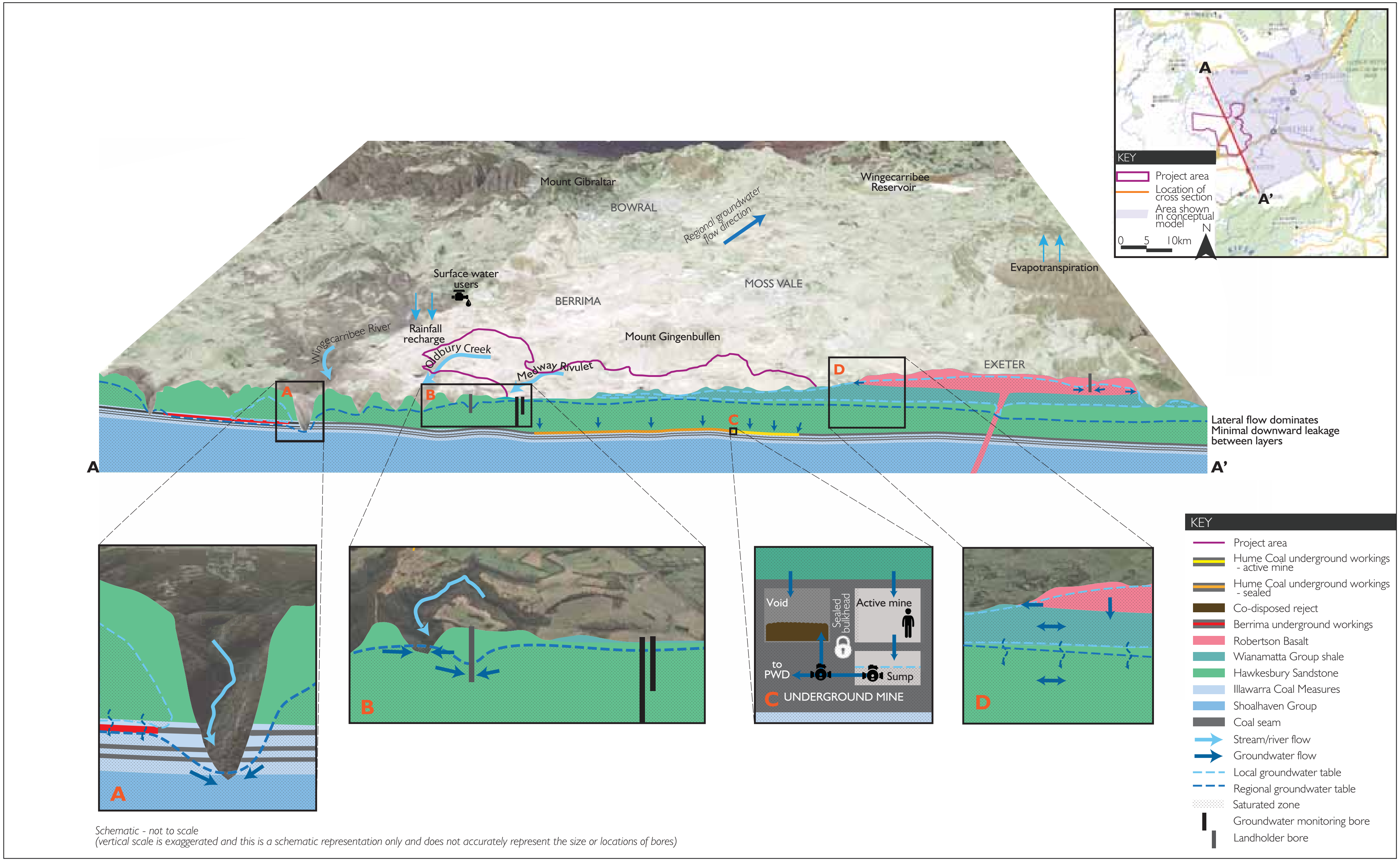
Full details of the model design and calibration are provided in Appendix I of the water assessment report (refer to Appendix E).

The model has been independently peer reviewed by two pre-eminent hydrogeologists (Dr Noel Merrick and Dr Frans Kalf). 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 peer review reports are also included in Appendix J of the water assessment report (refer to Appendix E).

The model extent (752 km^2) was selected to represent a significant area around the project area (50.51 km^2) in order to be able to fully describe and model potential impacts from the project. The boundary follows natural features selected so the hydraulic heads within the model are controlled by recharge and discharge components along the boundaries. This reduced the potential for external hydraulic head influences on the model domain.

The model domain extends across three groundwater sources: Nepean Management Zone 1, Nepean Management Zone 2, and the Sydney Basin South, and across several surface water sources: Upper Wingecarribee River, Lower Wingecarribee River, Medway Rivulet, Lower Wollondilly River, Nattai River, and Bundanoon Creek.

The conceptual hydrological model developed for the project is illustrated in Figure 7.5, and the model domain shown in Figure 7.6.



Conceptual hydrological model

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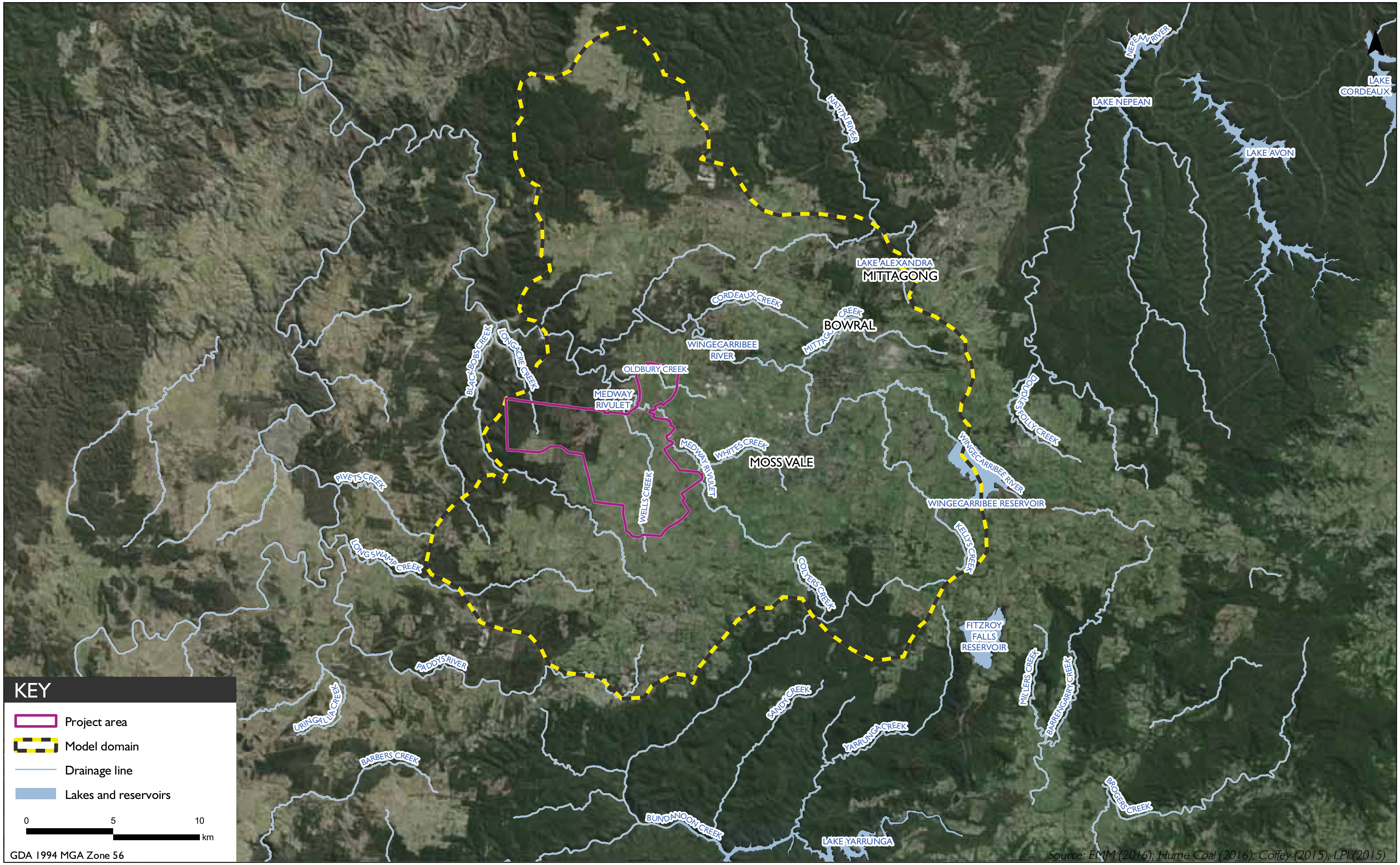
Figure 7.5

EMM HUMECOAL PROJECT



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Numerical groundwater model domain

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Figure 7.6

EMM HUMECOAL

The numerical model was interrogated for sensitivity to certain parameters, including the relaxation height, vertical hydraulic conductivity (Kv), and mine drain conductance. The sensitivity analysis indicated that the Kv distribution is one of the most important parameters for the simulations. Following, the calibrated Kv distribution was appropriately defined based on a combination of observations from pumping tests, and shallow (stream baseflow) and deep (Berrima Colliery inflow) discharge observations. The calibrated Kv distribution is considered to have a high level of reliability as a result, reducing uncertainty in the model's outputs.

Predictive drawdown assessment simulations were run for a 100 year period for the most probable future scenario and included the first workings mine layout, average rainfall, bulkhead injection, and co-disposal reject filling.

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

- project drawdown - the drawdown as a result of the Hume Coal Project only; and
- total drawdown – drawdown as a result of existing stresses, drainage to the Berrima Colliery mine void, and landholder bore pumping, and the Hume Coal project.

The outputs of the numerical modelling and analytical techniques used, including the numerical groundwater model and site water balance, were then analysed in combination to provide an understanding of the projects potential impacts on water resources in and surrounding the project area. The results are summarised in the sub-sections below.

7.4 Impact assessment – surface water

7.4.1 Water quantity

The surface infrastructure area is within the Medway Rivulet and Oldbury Creek sub-catchments. The natural flow regimes of these two waterways and their tributaries are highly disturbed as a result of extensive clearing within their catchments for agriculture and the multiple in-stream storages constructed along the length of the streams which impede the natural flow. The project has the potential to further impact on the flow regime of local streams due to:

- a reduction in catchment area and runoff associated with the water management system for the project;
- releases from 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.

The predicted impacts as a result of the above activities, including flow and yield impacts, are summarised below.

i Reduction in catchment area

Containment and reuse of surface runoff water from operational areas of the mine 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 7.9. The reduction in the catchment area of Medway Rivulet (including Oldbury Creek sub-catchment), in which the surface infrastructure area is situated, is estimated to be 94.12 ha, which equates to 0.8% of its total catchment area. These changes in the Medway Rivulet Management Zone would produce negligible impacts downstream in the substantially larger Lower Wingecarribee Management Zone.

Table 7.9 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			
MW08	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 Discharge from SB03 and SB04 to Oldbury Creek

During years with high rainfall, annual releases from SB03 are expected to range from 29 ML to 31 ML, and 38 ML to 41 ML from SB04. During years with low rainfall, releases are expected to be less than 1 ML per year.

During the operational phase of the project, the risk of stream bank erosion associated with these discharges is low. Discharges to Oldbury Creek will occur in a reach of the creek classified as 'confined valley setting – occasional floodplain pockets'. Discharge will occur as piped outflows from SB03 and SB04 (combined) 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.

iii Changes to surface water flow from depressurisation of groundwater systems

The underground mine workings will result in negligible impacts on flow and geomorphology in overlying catchments. Worst case estimates of subsidence associated with the proposed low impact, first workings mining method predict 'imperceptible' surface disturbance due to mining. Such disturbances are sufficiently low in magnitude and are not expected to impact on stream flow regimes or geomorphology.

The conceptual model for the project area infers that drainage lines receive baseflow from groundwater. In dry conditions, where surface rainfall and runoff is insufficient to sustain substantial flow, the smaller tributaries will receive groundwater as baseflow in persistent unconnected or connected pools. Groundwater systems are depressurised as a result of water inflows during underground mining. As a result, drainage lines, although still receiving baseflow, may receive a reduced rate of baseflow and experience an overall reduction in streamflow/water level in pools. This will be particularly noticeable during low flows, or dry conditions.

The predicted reduction in baseflow, and subsequent impact on streamflow, is discussed in Section 7.5.3.

iv Flow impacts

Flow duration curves were produced for both the Medway Rivulet sub-catchment (excluding the Oldbury Creek sub-catchment) and the Oldbury Creek sub-catchment for existing and operational scenarios. Discharge from the Moss Vale and Berrima sewage treatment plants were also included in the assessment for the Medway Rivulet sub-catchment. The flow duration curves for the operational scenarios included impacts of reduction in catchment areas, reduction in baseflow and discharge of water from SB03 and SB04 after first flush.

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; and that alteration of the flow regime in Oldbury Creek during operation of the mine will be minor compared to pre-mining conditions.

v Yield impacts

The change in streamflow due to the project, both with and without sewage treatment discharges, has been estimated to assess the change in surface water yield in the local sub-catchments. The results indicate that under wet conditions, the project will result in a 0.8% reduction in yield for the Medway Rivulet Management Zone, and under dry conditions the project will result in a 1.4% reduction in yield. Locally, impacts to yield will be slightly greater in the Oldbury Creek sub-catchment, with up to a 4.1% reduction in yield under wet conditions and up to a 4.2% reduction in yield under dry conditions.

The numerical groundwater model for the project indicates that under existing (pre-mining) conditions, Medway Dam loses approximately 0.5 ML/day to underlying aquifers. The model predicts that during operation of the mine, losses from Medway Dam to underlying groundwater systems will increase to 0.6 ML/day (ie an increase of 0.1 ML/day). These additional losses from Medway Dam over the life of the project are approximated at 36.5 ML/year. For comparison, annual evaporation from Medway Dam is estimated to be approximately 100 ML/year.

Licensing requirements associated with the predicted surface water loss is discussed in Section 7.6.

7.4.2 Water quality

i Overview

The following activities have the potential to affect surface water quality during the construction and rehabilitation phases of the project:

- earthworks activities, 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 in duration and the potential impacts to surface water quality can be suitably managed through the preparation and implementation of site environmental management plans. Therefore, these have not been assessed further. Sediment basins required during construction will be designed in accordance with the *Managing Urban Stormwater - Soils and Construction - Volume 2E Mines and Quarries* (DECCW 2008) and managed under a Soil and Water Management sub-plan (which incorporates sediment and erosion control measures).

During the operation phase of the project, project activities within the mine water management system will be managed as part of the mine water management system. Project activities outside the mine water management system with the potential to impact on 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 to facilitate detailed design; and
- depressurisation of groundwater systems during underground mining resulting in a reduction in baseflow to streams and possible increased concentrations in some contaminants.

Potential impacts to surface water quality associated with the first three activities listed above can be suitably managed through the implementation of standard environmental controls.

The following project activities have been further assessed in relation to potential water quality impacts:

- discharge 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; and
- depressurisation of groundwater systems from underground mining.

ii Oldbury Creek

The results of the MUSIC modelling undertaken to assess the potential TSS and nutrient loads and concentrations in Oldbury Creek show discharge will be in accordance with the NorBE criteria. A smaller area of the agricultural catchment will drain to Oldbury Creek during the operational phase, which will result in a significant reduction of more than 10%, and therefore acceptable within NorBE criteria, of the mean annual TSS and nutrient loads reporting to the creek compared with the existing situation.

Existing mean annual pollutant loads in Oldbury Creek and modelled loads during operation of the project are presented in Table 7.10, showing compliance with NorBE criteria for discharges from SB03 and SB04.

Table 7.10 Mean annual loads in Oldbury creek during existing and operation scenarios, and NorBE criteria

Parameter	Mean annual load		% reduction	NorBE criteria
	Existing (Oldbury Creek receives runoff from future SB01, SB02, SB03, SB04, MWD08, and PWD catchments)	Operation (Oldbury Creek receives runoff from SB03 and SB04 catchments)		
TSS (kg/yr)	25,500	4,130	84%	≥10% reduction
TP (kg/yr)	125	8	93%	≥10% reduction
TN (kg/yr)	483	61	87%	≥10% reduction
Flow (ML/yr)	149	20	86%	-

Further investigation of potential contaminants in water discharged from SB03 and SB04 was undertaken. Although the first flush is expected to remove the majority of potential contaminants from the catchment, some contaminants may still be present in the runoff collected in SB03 and SB04 after the first flush has been captured (and pumped to PWD or treated). Although the risk of coal contact is expected to be minimal, this potential source of contamination has still been assessed. Based on comparison of 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, sulphate, aluminium, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, zinc, and lower pH. Target mean concentrations of key indicator parameters (pH, TDS, TSS, and Oil and Grease) in SB03 and SB04 have been proposed. These contaminants will be monitored at SB03 and SB04 as part of the routine monitoring program, with the option to treat before release where required. As such, impact is expected to be negligible.

iii Access roads

MUSIC modelling was performed to assess the potential impacts of runoff from the two mine access roads located outside of the water management system. Results show that, with the implementation of appropriate vegetated swales as a treatment measure, NorBE criteria will be met. To meet the NorBE criteria, the swales must be 730 m and 500 m long for the sealed road catchment and the unsealed road catchment, respectively.

Table 7.11 summarises the mean annual pollutant loads from access road catchments, all of which meet NorBE criteria.

Table 7.11 Mean annual loads from access road catchments during existing and operation scenarios, and NorBE criteria

Catchment	Parameter	Mean annual load			% reduction (no swales)	% reduction (with swales)	NorBE criteria
		Existing	Operation	Operation with swale treatment			
Sealed road northern catchment (3.07 ha)	TSS (kg/yr)	1250	3940	215%	410	-67%	≥10% reduction
	TP (kg/yr)	3.77	6.79	80%	1.55	-59%	≥10% reduction
	TN (kg/yr)	19.7	31.6	60%	17.5	-11%	≥10% reduction
Sealed road middle catchment (0.99 ha)	TSS (kg/yr)	413	580	40%	176	-57%	≥10% reduction
	TP (kg/yr)	1.18	1.06	-10%	0.484	-59%	≥10% reduction
	TN (kg/yr)	5.9	31.6	2%	5.2	-10%	≥10% reduction
Sealed road southern catchment (0.56 ha)	TSS (kg/yr)	357	413	16%	189	-47%	≥10% reduction
	TP (kg/yr)	0.846	0.735	-13%	0.442	-48%	≥10% reduction
	TN (kg/yr)	4.02	3.73	-7%	3.53	-12%	≥10% reduction
Unsealed road (1.32 ha)	TSS (kg/yr)	276	7,240	79.1	-2,523%	71%	≥10% reduction
	TP (kg/yr)	1.19	3.32	0.454	-179%	62%	≥10% reduction
	TN (kg/yr)	6.66	14	5.79	-110%	13%	≥10% reduction

iv Depressurisation of groundwater systems from underground mining

Numerical groundwater modelling predicts that baseflow in drainage lines will be reduced as a result of depressurisation of groundwater systems from the underground mining activities (refer Section 7.5.3). A reduction in baseflow will result in reduced loadings in all parameters. However, some contaminant 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 contaminant 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 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 indicates that the majority of monitored analytes were generally higher in concentration in groundwater than in surface water. Therefore, a reduction in baseflow (ie the groundwater component of streamflow) would improve surface water quality. However, nitrate, phosphorus, calcium, sodium, sulphate, and aluminium were generally higher in surface water than groundwater and therefore a reduction in baseflow would increase concentrations of these contaminants.

Increases in contaminant concentrations would not necessarily have detrimental effect on the beneficial use of the surface water. Comparison of 80^{th} percentile baseline surface water quality results with the relevant ANZECC/ARMCANZ, Australian Drinking Water (ADW) guidelines, and HRC guidelines indicates that:

- Nitrate results were below and calcium, sodium, sulphate results were well below guideline values. Changes in these concentrations are therefore unlikely to affect the beneficial use of the surface water;
- Phosphorus results exceeded the HRC guideline value; 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.

Increases in aluminium concentrations are unlikely to affect the beneficial use for irrigation and livestock within the project area. Although phosphorus concentrations are higher in surface water than groundwater, there is little difference between the two in most cases. Minor increases in concentrations of phosphorus as a result of reduction in baseflow are, therefore, unlikely to significantly alter the beneficial use of the surface water.

7.4.3 Flooding

i Flood extent

Results of the hydrologic modelling indicate that there will be a minor change in the 100 year ARI flood extents for the operational 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. The predicted maximum flood extents for the 100 year ARI event, comparing the operation and rehabilitation project phases to the existing situation, are shown in Figure 7.7 and Figure 7.8, respectively.

ii Flood levels

Changes in flood levels (afflux) between the existing and operation phase, and between the existing and rehabilitation phase, were assessed for targeted cross sections generated from the hydrologic model. The cross sections targeted areas of interest, including privately owned land, locations where existing roads cross streams, and locations where new infrastructure is proposed to cross streams.

The predicted affluxes for the operation phase are within the assessment criteria presented in Section 7.3.1, 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. This afflux has been considered in the design of the surface infrastructure area and water management system so that flood levels will be effectively managed without impact on the project infrastructure.

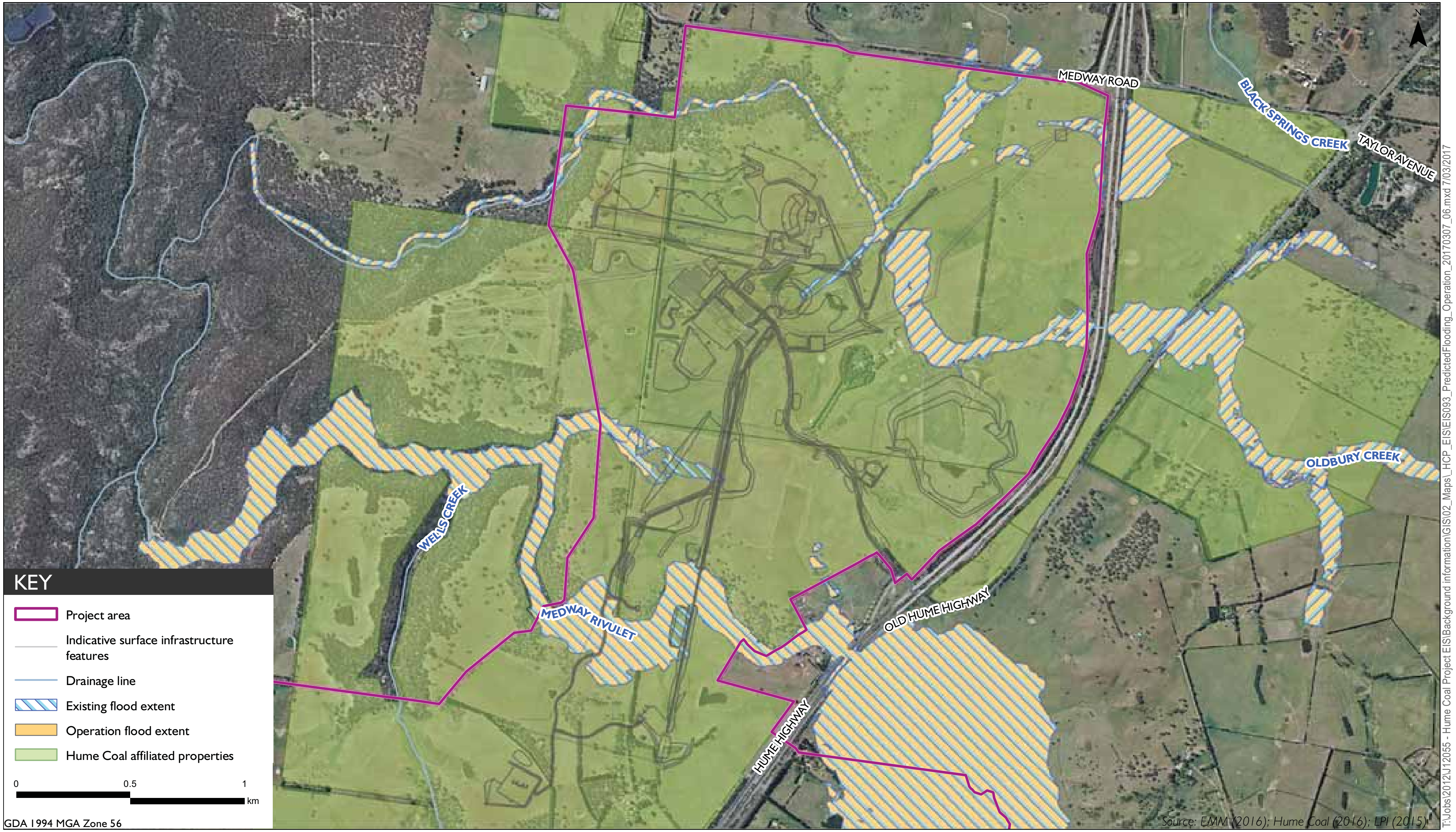
The predicted affluxes for the rehabilitation phase are negligible and considered acceptable for land outside of Hume Coal's ownership. The impact noted above between PWD and SB02 is reduced during the rehabilitation stage; however, a localised afflux impact of up to 400 mm remains downstream of the instream storage on Oldbury Creek (Hume Coal owned land).

iii Flood velocities

Infrastructure crossing streams, including bridges and culverts, have the potential to change the velocity of streamflow 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. Proposed infrastructure that could affect the flow velocity are:

- 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 will be raised and used to provide access between the CPP area and the train load out facility. The embankment will have an access road, a conveyor to transport coal and poles for electricity lines.

The results show that the impact on velocity at these downstream locations is minor and considered acceptable. The above structures will not pose significant obstruction to or constriction of flood flows. Notwithstanding, peak velocities are expected to increase immediately downstream of the conveyor piers and box culverts in Medway Rivulet, and therefore scour protection measures will be implemented.



Predicted flooding extent (1 in 100 year) – operation

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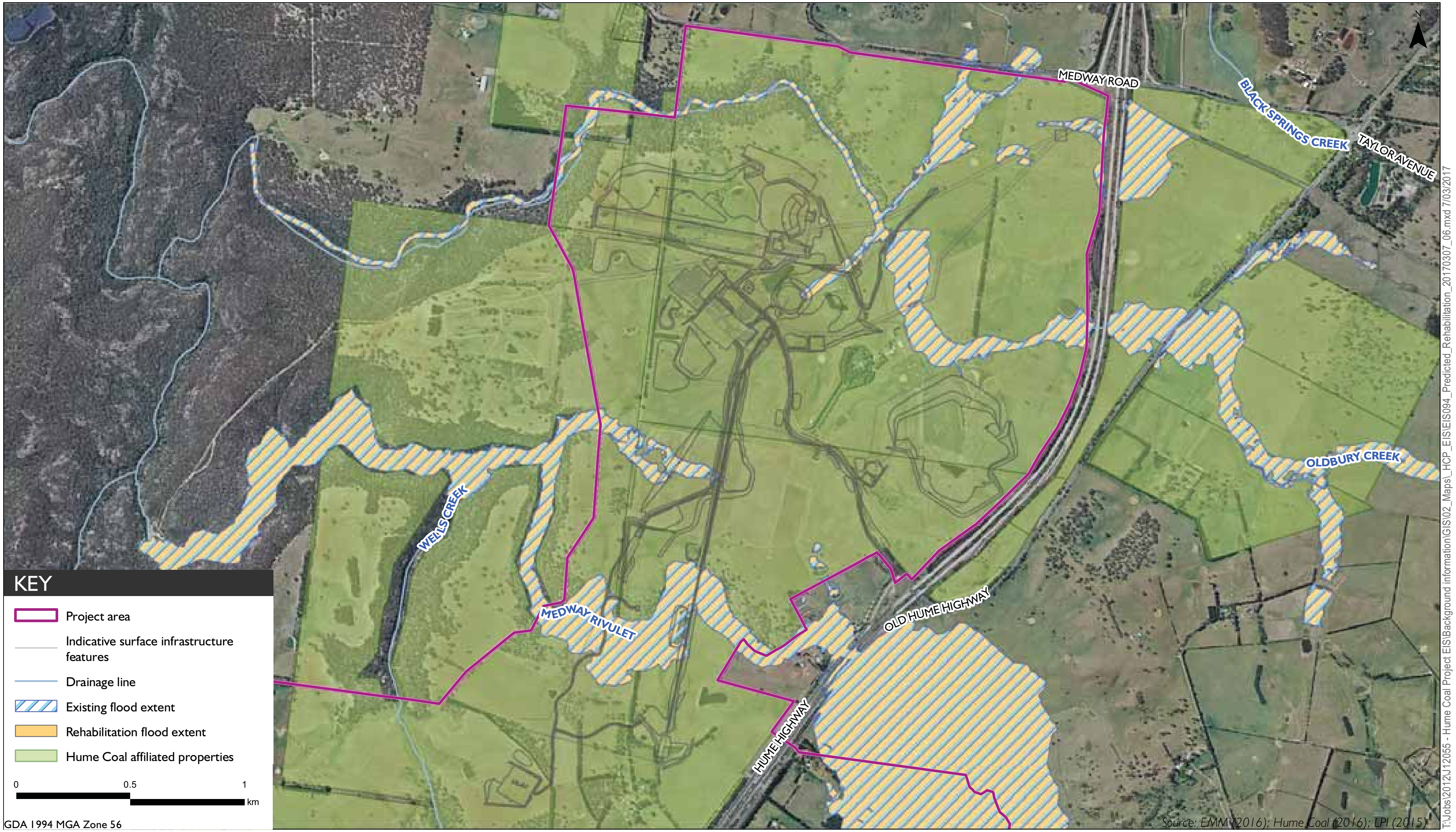
Figure 7.7



Predicted flooding extent (1 in 100 year) – rehabilitation

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Figure 7.8

7.4.4 Predicted impacts on surface water users

A summary of the predicted impacts on sensitive surface water users, based on the results described in Sections 7.4.1-7.4.3 are summarised below:

- surface water users and stream environments:
    - flow impacts on 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. Yield impacts on 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 impacts are considered **insignificant**.
    - stream bank erosion impacts can be mitigated via an erosion and sedimentation control plan (refer to Section 7.7). As per the *Significant impact guidelines* (DoE 2013), this impact is considered **insignificant**.
    - where predicted, water quality impacts as a result of discharges from SB03 and SB04 can be mitigated by the implementation of discharge limits and criteria; discharges that will occur are predicted to be compliant with NorBE criteria. With provision of vegetated swales, runoff from access roads outside of the water management system is predicted to be compliant with NorBE criteria. Potential increases in contaminants in surface water flow as a result of reduction in baseflow are predicted to be within the appropriate guideline values or are relatively minor increases to an already elevated baseline situation, and are not predicted to alter the beneficial use of the resource. As per the *Significant impact guidelines* (DoE 2013), surface water quality impacts 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 impacts are considered **insignificant**.

7.4.5 Cumulative impacts

The Berrima Rail Project is located upstream of the Hume Coal Project in the Oldbury Creek catchment, and is therefore relevant to consider in relation to cumulative impacts on surface water resources.

The Berrima Rail Project will not involve take of water from streams, water discharge to streams or groundwater impacts that would reduce baseflow to streams. In addition, the rail infrastructure for the Berrima Rail Project will not reduce the volume of flow in drainage lines in and surrounding the project area as culvert structures will be constructed where the rail crosses waterways. Surface water flows will therefore not be impacted by the construction, operation or rehabilitation of the Berrima Rail Project.

The surface water quality assessment undertaken for the Berrima Rail Project indicates that with the implementation of appropriate management plans and treatment measures such as swales, the water quality in Oldbury Creek will also not be impacted by construction, operation, or rehabilitation of the Berrima Rail Project.

Given the negligible impact of the Berrima Rail Project on surface water resources, it follows that the project will not contribute to cumulative impacts on surface water with the Hume Coal Project.

The potential for cumulative impacts on the local flood regime were also investigated in the Oldbury Creek catchment where infrastructure from both projects will be located. 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 the Berrima Cement Works;
- just upstream of the Hume Highway on a tributary of Oldbury Creek; and
- in the vicinity of 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.

The impacts around the rail loop, the Hume Highway and around the Berrima Cement Works are all impacts related to the rail infrastructure only. Impacts downstream in the vicinity of the Hume Coal Project do not contribute to these. Similarly, localised impacts on flooding caused by the Hume Coal Project will not contribute to these areas upstream that are affected by the rail infrastructure. Therefore, there will be no cumulative impact of both projects on flooding in Oldbury Creek.

7.5 Impact assessment – groundwater

7.5.1 Inflows to the underground mine

The predicted average yearly inflow to the underground mine sump is 440 ML/yr and to the void is 1,157 ML/yr. Inflows will occur during the period when the project causes stress on the groundwater system, which will be throughout the operational mine life and continuing for three years after coal extraction ceases (ie for 22 years after the start of mining). Whilst inflows to the sump cease after year 19 when mining ceases, inflows to the void will cease after year 22, after which the water table and groundwater system storage will recover.

The model results indicate that inflow to the Hume Coal mine workings will be sourced primarily from groundwater systems as a release from groundwater storage and from baseflow intercepted prior to discharge into streams. There is also a small volume of loss predicted from surface water (Medway Dam).

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 presented in Table 7.12. As shown, 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 located entirely within this water source.

Table 7.12 Maximum rate of release of groundwater from groundwater storage as a result of the Hume Coal Project

Groundwater source	Maximum rate of release of groundwater from groundwater storage (ML/day)[1]	Percentage contribution to mine inflow
Nepean Management Zone 1 (NMZ1)	5.206	99.14%
Nepean Management Zone 2 (NMZ2)	0.003	0.06%
Sydney Basin South (SBS)	0.042	0.8%

Notes: *1. Not including baseflow reduction.*

2. The peak daily inflows are not calculated on a yearly time step, and therefore do not necessarily correlate to a peak annual flow.

The rate of predicted baseflow reduction as a result of the Hume Coal Project is discussed in Section 7.5.3 below, and the source of this is also groundwater. Leakage from Medway Dam, at an average of 36.5 ML/yr, is also considered.

Licensing requirements associated with the predicted groundwater take is discussed in Section 7.6.

7.5.2 Groundwater levels

Changes to hydraulic pressures and water levels were modelled for both the project drawdown (i.e drawdown as a result of the project influence only) and total drawdown (project drawdown and effects of existing landholder bore pumping and Berrima Colliery drainage). The project drawdown has been used for assessment against the AIP.

The area affected by water table drawdown migrates according to the location of active mine working areas. The depressurisation effects of the mine are somewhat compensated by rainfall recharge in the western part of the project area, so the drawdown extent is less expansive in the west. The maximum project drawdown of the water table of 45 m is reached at year 17, but is localised in a small area (less than a quarter hectare) above the western part of the mine workings. At year 17, the area where the water table is affected by 2 m or more total drawdown extends to a maximum of 2 km beyond the mine footprint to the south-east.

The maximum water table drawdown as a result of the project is predicted to occur in year 17 and is illustrated in Figure 7.9.

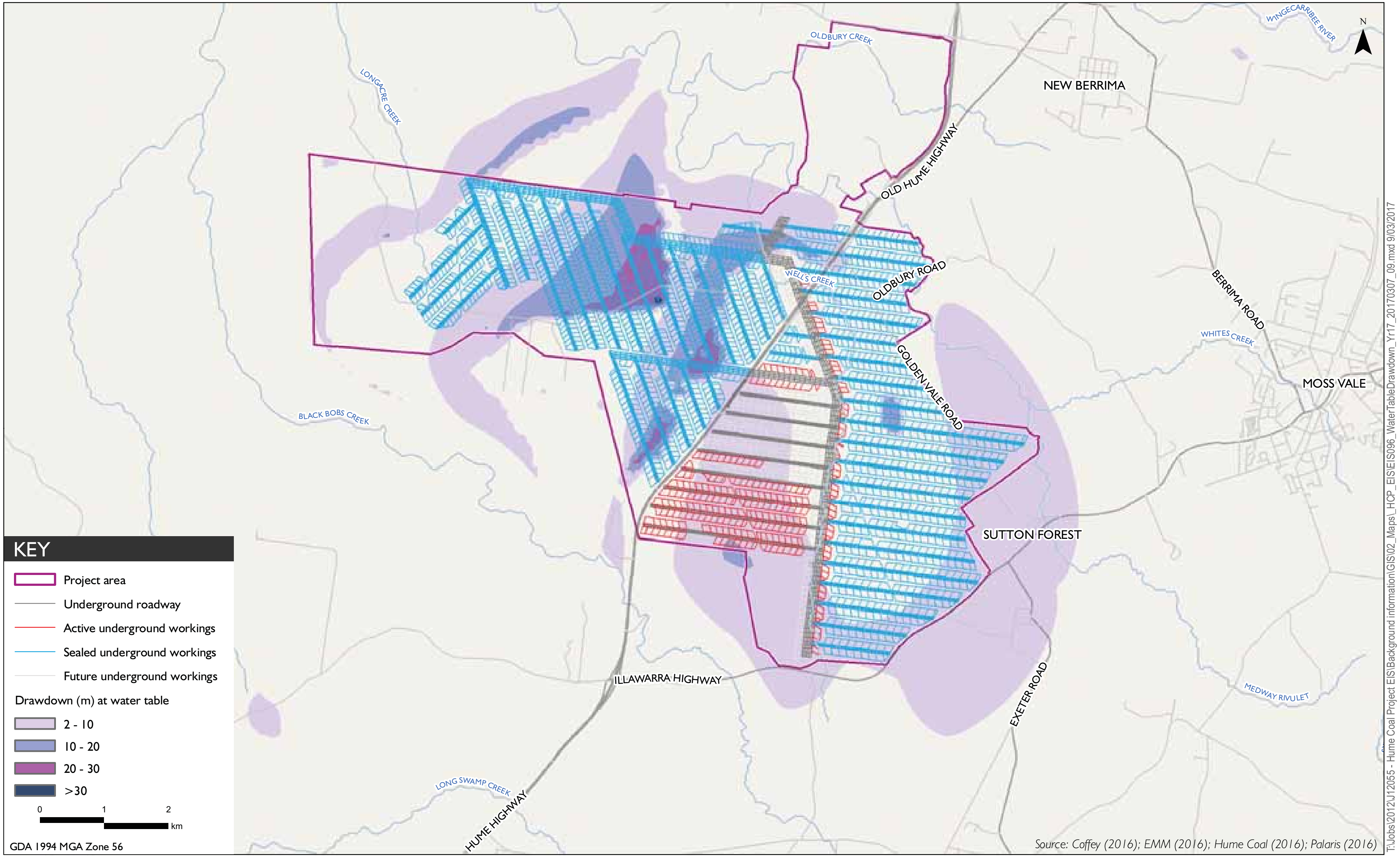
The predicted change in the hydraulic head at the base of the Hawkesbury Sandstone is considerable above the mine workings, but is temporary. Injection of water into the sealed void greatly reduces the amount of depressurisation above the mine workings. After 30 years since the start of mining, significant recovery of project water table drawdown will already have occurred across many areas of the model domain.

Half of the affected bores recover from the project impact by 43 years after the start of mining. Refer to Section 7.5.5 ii for further discussion on impacts to landholder bores.

7.5.3 Reduction in baseflow

Rates of reduction in baseflow have been calculated from the numerical groundwater model. The groundwater model found that under existing (pre-mining) conditions, Medway Dam loses approximately 0.5 ML/day to underlying aquifers. The model for the project predicts that during operation of the mine, losses from Medway Dam to underlying aquifers will increase by approximately 20% to 0.6 ML/day. These daily additional losses from the dam over the life of the project equate to a loss of 36.5 ML/year.

The maximum rates of baseflow reduction as a result of the project for each water source are shown in Table 7.13. The Lower Wingecarribee River and Medway Rivulet surface water sources have been subdivided into smaller catchments for the purpose of this assessment. The model results indicate no reduction in baseflow for the Upper Wingecarribee River, Black Bobs Creek, or Nattai River as a result of the project.



Extent of project impact water table drawdown - Year 17

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Figure 7.9

The maximum rates of baseflow reduction are not consistent throughout the mining period. For example, the rate of baseflow reduction at the Medway Rivulet water source only exceeds 0.9 ML/day for less than a year (at 11 years since the start of mining). A sharp decline in baseflow reduction occurs after 17 years of mining when groundwater levels start to recover.

The Lower Wingecarribee River and the Medway Rivulet surface water sources are predicted to experience the highest sustained rates of baseflow reduction, although the majority of drainage lines will see recovery towards pre-mining baseflow conditions by approximately year 18.

The average Medway Rivulet baseflow rate estimated from baseline monitoring data is approximately 3.3 ML/day at SW04 during average rainfall conditions (Coffey 2016b). This is approximately three times larger than the predicted maximum rate of baseflow reduction (0.9 ML/day). The model results suggest that the reduction in baseflow in Medway Rivulet will be a minor proportion of the total baseflow and is, therefore, unlikely to impact other users of the surface water source, during a range of climate conditions (Coffey 2016b).

The licensing of water take occurs at the time water is physically taken (ie within the 22 year period where mining occurs). The theoretical impact of that take occurs over a longer period of time, but will in reality be mitigated by rainfall and runoff over that longer period of time.

Table 7.13 Maximum rate of baseflow reduction from surface water sources as a result of the Hume Coal Project

Surface water source	Corresponding groundwater source	Maximum rate of baseflow interception (ML/day)	Time to maximum rate (years since start of mining)
Upper Wingecarribee River	NMZ1	0	-
Lower Wingecarribee River (whole source)		0.849	13
Lower Wingecarribee River excluding Black Bobs and Longacre Creeks	NMZ1, NMZ2	0.800	17
Black Bobs Creek	NMZ1	0	-
Longacre Creek	NMZ1	0.311	13
Medway Rivulet (whole source)		0.927	11
Medway Rivulet excluding Oldbury, Belanglo, and Wells Creeks, and Wells Creek Tributary	NMZ1	0.841	11
Oldbury Creek	NMZ1	0.002	11
Belanglo Creek	NMZ1	0.017	9.5
Wells Creek	NMZ1	0.075	1.5
Wells Creek Tributary	NMZ1	0.033	1.5
Lower Wollondilly River	NMZ1	0.050	26
Nattai River	NMZ1, NMZ2	0	-
Bundanoon Creek	SBS	0.024	28

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.

7.5.4 Groundwater quality

i Water quality change from induced transfer from Wianamatta Group shale to Hawkesbury Sandstone

The groundwater numerical model was used to quantify the simulated flux (flow) of groundwater between the low permeability Wianamatta Group shale and the upper Hawkesbury Sandstone. Simulations were run for a 100 year time period, both with and without the influence of the project.

The baseline movement of groundwater from the Wianamatta Group shales to the upper Hawkesbury Sandstone was consistently around 11.1 ML/day for the entire simulation period. With the introduction of the project, an incremental increase in the vertical flux was predicted between years 1 and 74 from mining commencement, peaking in the year 14.5 time step at 12.1 ML/day. This represents a 1 ML/day (9%) increase from the baseline conditions and is equivalent to a very small 0.004 mm rainfall event.

The temporary increase in groundwater flux from the Wianamatta Group shales 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 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 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.

Given that maximum predicted increase in groundwater flux between the Wianamatta Group shale and underlying Hawkesbury Sandstone is 9% with a short duration peak, and the current baseline flux has not significantly affected the underlying Hawkesbury Sandstone water quality, it is considered unlikely that 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.

ii Co-disposal of rejects and water quality

The potential change to groundwater quality resulting from groundwater interaction with co-disposed reject material in the void and from seepage of temporary reject stockpile runoff was assessed via laboratory tests (kinetic leachate columns) undertaken on physical representative samples of reject material (RGS 2016) and groundwater.

Data from two columns were considered; one with mine reject material amended with limestone as an additional alkalinity source (which represents the proposed process for the project), and the other unamended. The results were compared to baseline water quality for the Hawkesbury Sandstone and Wongawilli Seam to assess whether leaching from mine reject material could result in degradation of the beneficial use status of the groundwater resources.

Leachate water quality in the unamended column exceeded one or more of the beneficial use criteria for a number of parameters. This criteria was also generally 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.

However, the pH in the limestone amended reject material was close to neutral throughout the test, and leachate analyte concentrations were acceptable for the majority of beneficial use criteria, including many that were originally exceeded in the baseline groundwater quality. Limestone amendment of the reject material prior to temporary stockpile storage and emplacement in the mine void is therefore likely to produce leachate that is indistinguishable from in situ groundwater quality, and is considered unlikely to change the beneficial use status of the groundwater resources.

7.5.5 Predicted impacts on groundwater users

i Summary

The predicted impacts on sensitive groundwater users, as defined in Section 7.2.3v, are summarised as follows:

- 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:
  - as the potentially groundwater dependent ecosystems are considered to have facultative (opportunistic) dependency on groundwater, where water table drawdowns are predicted to occur the ecosystems are expected to be able to adapt and impact would be minimal. As per the *Significant impact guidelines* (DoE 2013), this impact is considered **insignificant**.
- watercourses, drainage lines, and swamps that receive baseflow:
  - baseflow reduction is expected to occur in the majority of drainage lines within the vicinity of the project area. 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. As such, the impact of reduction in baseflow 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 impacts on 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**.
  - 93 landholder bores on 71 properties will be directly impacted by 2 m or more of temporary drawdown as a result of the project. Four 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**.

Given the significant impact predicted on a number of landholder bores, further discussion on this aspect, and mitigation measures proposed, are provided below.

ii Landholder bores

Predictive drawdown simulations provided the extent of the depressurisation effects as a result of the project under two scenarios:

- total drawdown, including the existing stresses of Berrima Colliery and landholder pumping as well as the project drawdown; and
- the project drawdown (not including the existing stresses).

A summary of the results for both scenarios is presented in Table 7.14. The maximum predicted project drawdown on landholder bores, and the time taken to reach this maximum where this is greater than 2 m, is illustrated in Figure 7.10.

Table 7.14 Summary statistics of landholder bore impacts – comparing project and total impact exceeding AIP criteria

	Project impact	**Total impact**
	Hume Coal Project impact only	Hume Coal Project, landholder pumping and Berrima Colliery impacts
Number of bores impacted	93[1]	109[1]
Maximum drawdown range	2 - 80 m	2 - 84 m
Median maximum drawdown	12 m	14 m
Number of landholders (properties) with impacted bores	71	84
Average time for a bore to recover by 75% since start of impact	23 years	33 years[2]
Time until all impacted bores recover since start of mining	72 years	(not all bores will recover from total drawdown due to impacts from landholder pumping and Berrima Colliery)
Number of bores predicted not to recover in 100 years post start of mining	0 bores	44 of 109 bores

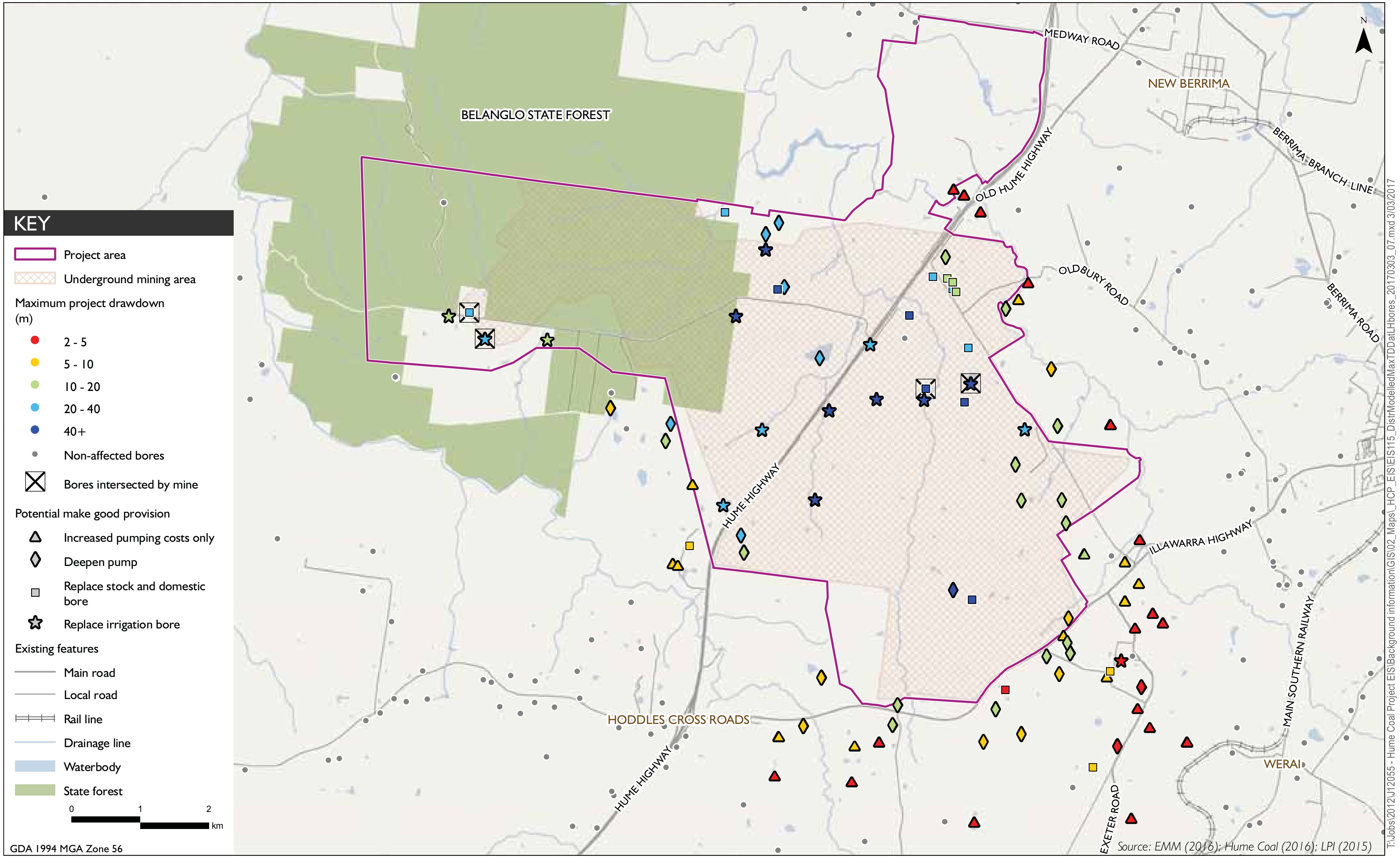
Notes: 1. Does not include bores located on properties owned by Hume Coal.

2. Average calculated for bores where recovery is predicted within 100 years post start of mining and does not include bores where recovery to 2 m drawdown is not predicted to occur in this time frame.

A maximum total drawdown of between 2 m and 84 m is predicted for 109 landholder bores (not including Hume Coal bores). An additional six bores located on Hume Coal property will be affected by drawdown, and therefore the total number of impacted bores above the AIP 2 m threshold is 115. As these six bores are owned by Hume Coal and no make good provisions are required, they are not considered further.

All bores except one intersect the Wianamatta Group, Hawkesbury Sandstone and/or Illawarra Coal Measures, with the bulk intersecting the Hawkesbury Sandstone. One bore intersects the basalt, and the total drawdown in this bore is predicted to be 0.14 m, less than the AIP 2 m drawdown.

87% of the total drawdown predicted to be experienced by the bores will be as a result of the Hume Coal Project. At least half of the bores will recover from the project effects within 43 years of the start of mining, or earlier. All bores recover from the project effects within 72 years. The magnitude and timing of the drawdown at each bore is dependent on the location and depth of the bore with respect to the mine workings; shallower and/or remote bores are predicted to experience smaller drawdown than deeper and/or closer bores. The average duration of drawdown on the 93 affected bores is 36 years, with the maximum duration being 65 years; however, most of the recovery occurs in a far shorter time period. On average, a bore will recover by 75% within 23 years after it is first impacted.



Project drawdown and potential make good provisions

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Figure 7.10

With reference to the AIP assessment criteria, 93 private landholder bores on 71 properties are predicted to be subject to a project impact drawdown of 2 m or more, as shown in Figure 7.10. A make good assessment was conducted to address the residual project impacts on these 93 bores, the results of which are included in detail Appendix O of the water assessment report (refer to Appendix E). All bores impacted by more than 2 m are assessed as eligible for increased pumping costs. Approximately a third of the affected bores only require increased pumping costs and no capital works proposed. Another third are assessed as potentially needing repositioning of submersible pump intake depths for certain periods of time. The final third are assessed as potentially needing redrilling, or repositioning to maintain water supply.

In relation to the groundwater quality requirements of the AIP, it is not anticipated that the project activities will 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 7.7 are implemented.

7.5.6 Cumulative impacts

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

- existing pre-project impact - cumulative impact of existing impacts(baseline);
- cumulative impact of the project and existing impacts (project plus baseline);
- the impact of the project itself (ie removing other existing impacts); and
- the impact of the project, other existing impacts and potential future projects in planning process.

Both the groundwater and surface water assessments consider the baseline situation (ie pre mining), and the impact of the project within the existing baseline conditions. The groundwater assessment also considers the impact of the project individually; separate from existing stress in the baseline condition. Both the groundwater and surface water assessments have also considered future potential impacts.

Existing impacts within the hydrogeological environment are landholder bore pumping and the old workings of Berrima Colliery. The groundwater model developed for the project considers the combined baseline (ie impacts of landholder pumping and Berrima Colliery) and the Hume Coal Project impact, as well as the Hume Coal Project only impact (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 impacts are already considered as part of the baseline, the Hume Coal Project only impact is what has been assessed against the AIP criteria.

There are no potential future projects in the planning process that would influence the assessment of the Hume Coal Project in relation to potential groundwater impacts. Therefore, no cumulative groundwater impacts are predicted.

Cumulative groundwater quality impacts are not predicted to occur given the predicted groundwater quality impact as a result of the project is assessed to be negligible.

For the surface water assessment the only relevant project that is considered as part of the cumulative impact assessment is the Berrima Rail Project (EMM 2017a), which has been considered both independently and cumulatively. Surface water flows and quality will not be impacted by construction, operation, or rehabilitation of the Berrima Rail Project, with the implementation of the appropriate management and treatment measures in place (vegetated swales). There is no cumulative impact on flood extent in Oldbury Creek catchment.

7.6 Licensing

7.6.1 Approach to licensing

As described in Chapter 3, Hume Coal is required to licence the volume of predicted volume of water taken from both surface water and groundwater sources in accordance with the AIP and the WMA 2000. This includes water taken for use as well as water intercepted and managed as a result of mining activities. Sufficient WALs must be held to account for water sources that have water taken (directly or indirectly).

The AIP specifies that the project licence requirement needs to consider adjacent and overlying water sources. Should the project cause water to inflow and subsequently take from 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.

The volume of water required to be licensed for the project is the sum of the water that inflows to the mine sump (that is physically handled by the mine's water management system), plus the groundwater that inflows into the mined voids, even though the majority of this groundwater remains physically within the groundwater source. The yearly licence requirements predicted over the operational life of the project for surface water and groundwater are illustrated in Figure 7.11.

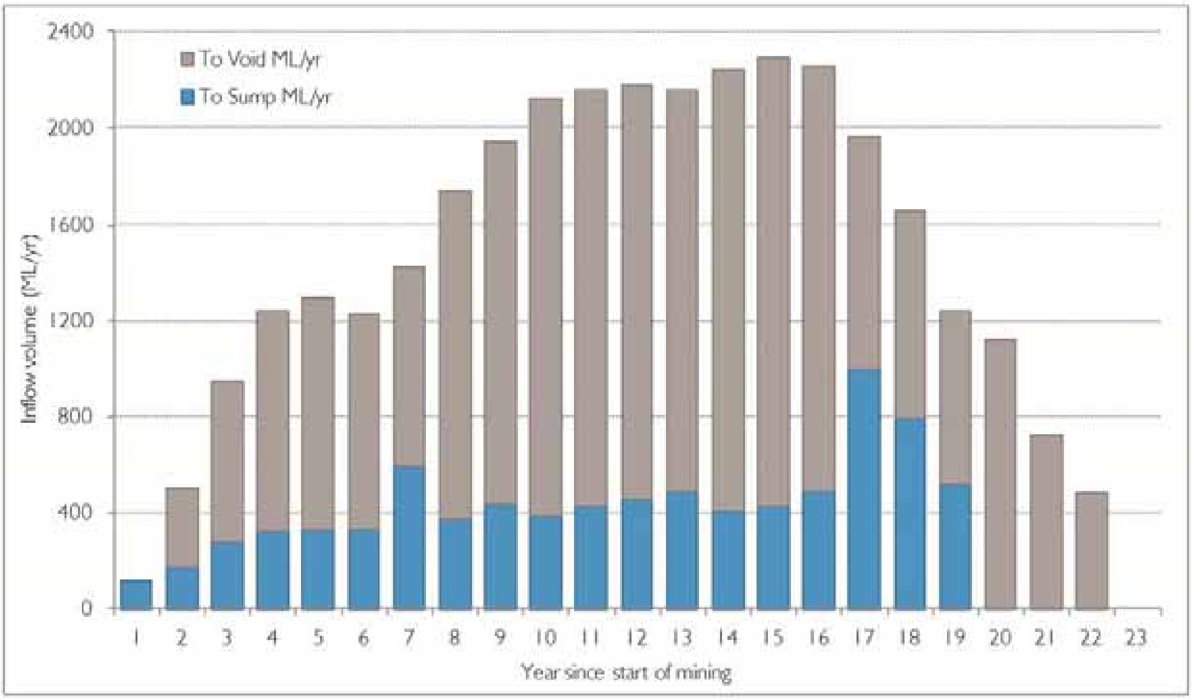

Figure 7.11 Expected inflow volumes over time

Water that inflows to the mine sump and void will be primarily from the Nepean Management Zone 1 of the Sydney Basin Nepean Groundwater Source. However, there is some induced leakage of surface water from Medway Dam, and minor throughflow from Sydney Basin Nepean Management Zone 2, and the Sydney Basin South Groundwater Source.

The numerical groundwater model predicts that, during operation of the mine, leakage from Medway Dam to underlying groundwater systems will increase by 0.1 ML/day. This additional leakage from Medway Dam is predicted to be an average of 36.5 ML/year. The throughflow from adjacent groundwater sources is estimated in the groundwater model, and these throughflow numbers have been averaged, and then applied as a percentage to the yearly inflow. The throughflow from the Sydney Basin Nepean Management Zone 2 Groundwater Source is 0.01%, and from the Sydney Basin South Groundwater Source it is 0.80% of the overall take.

There is a time lag between taking water from the groundwater system at depth and a response in the overlying surface water. To off-set the time lag, and to account for all induced leakage from the overlying Medway Dam, the average volume of surface water intercepted is assumed to occur every year of mining, and until the void is full (year 22).

The remainder, and by far the majority, of the inflow to the mine sump each year will be sourced from the Sydney Basin Nepean Groundwater Source- Nepean Management Zone 1.

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, pursuant to Section 60 I (2) of the WMA 2000. In a gaining stream scenario (as is the case for the project) this source is the groundwater source.

The project will therefore need to licence:

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

This aligns to the NSW Government AIP Fact Sheet 3 (NOW 2013a) that describes in detail the licensing of water. This 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 a surface water licence requirement.

7.6.2 Summary of licence volumes required

The project's water take is defined as the inflow to the sump, plus the volume of water harvested from the void to make up water to supply for operational requirements. Based on the numerical groundwater model and the water balance model results, the maximum volume required for licensing is 2,290.5ML/yr in year 15 and for each individual source is:

- Nepean Management Zone 1 Sydney Basin Nepean Groundwater Source - 2,235 ML/yr in year 15;
- Nepean Management Zone 2 Sydney Basin Nepean Groundwater Source - 1 ML/yr from years 5 through to 18;
- Sydney Basin South Groundwater Source - 18 ML/yr for years 14 through to 16; and
- Medway Rivulet Management Zone of the Upper Nepean and Upstream Warragamba Unregulated River Water Source 36.5 ML/yr for all years of mining and rehabilitation.

The project's yearly licence requirements are illustrated in Figure 7.12. The maximum volume required for licensing for each groundwater source as a portion of the long-term average annual extraction limit (LTAAEL) defined in the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources is shown in Figure 7.13.

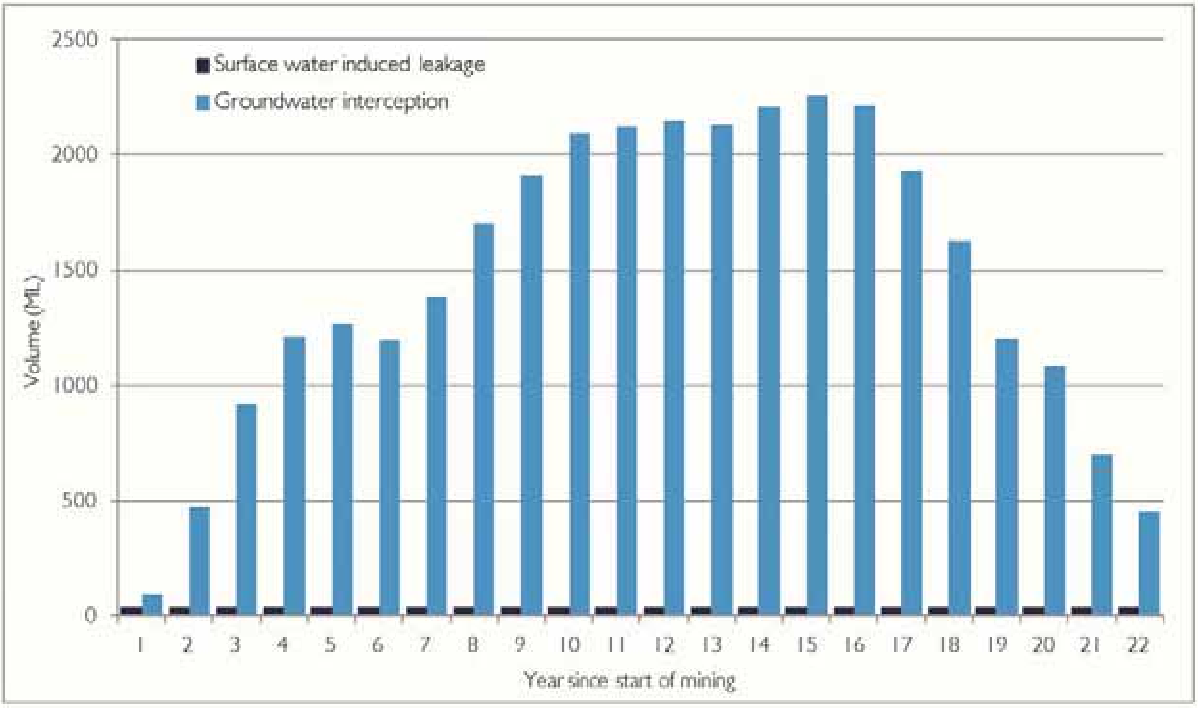

Figure 7.12 Yearly licence requirements

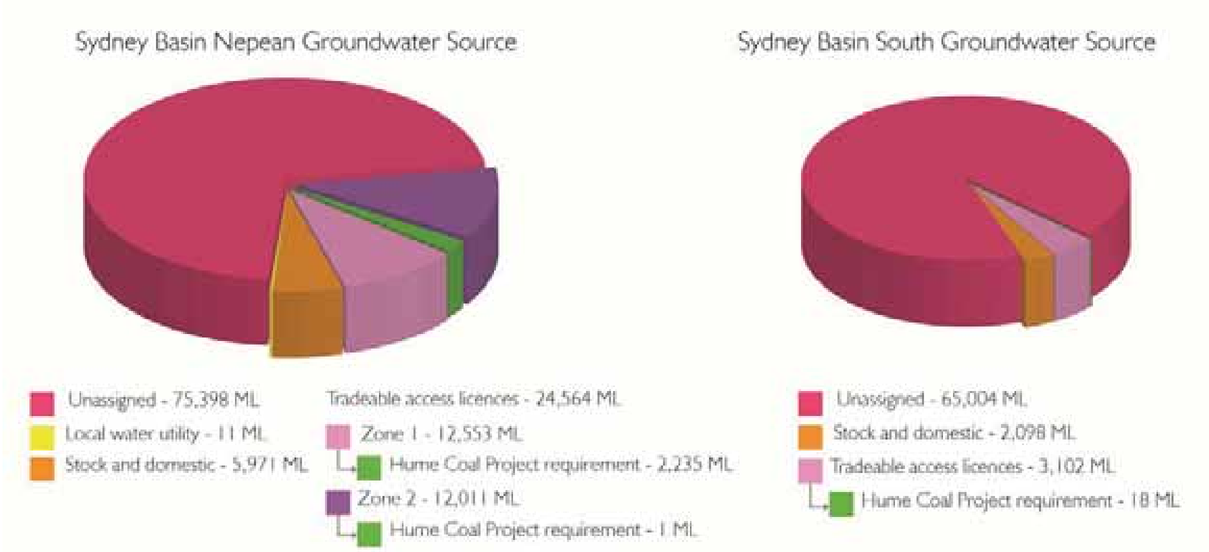

Figure 7.13 Project groundwater licence requirements as a portion of total LTAAEL in each groundwater source

7.6.3 Licences held by Hume Coal

Hume Coal currently holds 31 shares of unregulated river surface water in the Medway Rivulet Zone and 1,391 ML of groundwater share components for Sydney Basin Nepean Management Zone 1. Licence details are provided in Table 7.15, as at February 2017.

Table 7.15 Water licences currently held by Hume Coal

Water Source	Licence		WAL	Share component	Management Zone	Purpose
Upper Nepean and Upstream Warragamba Unregulated River Water Source	10CA102776	Unregulated river	25665	14	Medway Rivulet	
	10CA102875	Unregulated river	25630	17	Medway Rivulet	
Total Surface water				**31**		
Sydney Basin Nepean Groundwater Source	10CA111696	GW053331	24773	488	Nepean Zone 1	domestic, stock, irrigation
		GW031686				
		GW059306				
	10CA111712	GW057908	24908 & 24915	179	Nepean Zone 1	stock, irrigation, domestic
	10CA112150	GW106491	24938	100	Nepean Zone 1	irrigation
	10CA112196	GW108195	24765	120	Nepean Zone 1	irrigation
		GW108194				
	10WA109649	GW025588	0	0	Nepean Zone 1	stock
	10WA109694	GW031684	0	0	Nepean Zone 1	domestic
	10WA109707	GW031685	0	0	Nepean Zone 1	domestic
	10WA109708	GW031687	0	0	Nepean Zone 1	domestic
	10WA111035	GW109084	0	0	Nepean Zone 1	stock, domestic
		Other licences		504	Nepean Zone 1	
Total groundwater				**1,391**		

Hume Coal has therefore already secured in excess of 60% of the total licence requirement for the project, with a clear pathway for how the remaining volume is to be secured to meet extraction requirements.

Trading of water from the Nepean Management Zone 1 is proposed to secure the majority of the remaining licence requirement. Application for water from the Nepean Management Zone 2 of the Sydney Basin Nepean Groundwater Source and from the Sydney Basin South Groundwater Source through controlled allocation order is proposed to secure adequate licence volumes held. An alternative option to secure this water is via the trading market.

Trading of 5.5 ML of water from the Medway Rivulet Zone of the Upper Nepean and Upstream Warragamba Unregulated River Water Source is proposed to secure the remaining adequate licence volumes. Trading of water is required to be from within the same respective management zone, as water cannot be traded between different management zones. Table 7.16 summarises the secured and remaining required licence volumes for respective water sources and zones.

Table 7.16 Secured water licences and remaining volumes required

Water Source	Management Zone	Total volume required for project (ML/yr)	Volume currently held in licences (ML/yr)	Volume required (ML/yr)	Method for acquisition	Total available to trade (ML/yr)
Sydney Basin Nepean	Nepean Management Zone 1	2,235	1,391 (62%)	844	Controlled allocation or trade	12,553[a]
	Nepean Management Zone 2	1	0 (0%)	1		50,000 [b]
Sydney Basin South		18	0 (0%)	18	Controlled allocation or trade	69,892
Upper Nepean and Upstream Warragamba	Medway Rivulet Management Zone	36.5	31 (85%)	5.5	Trade	127[c]
Total		**2,290.5**	**1,422 (62%)**	**868.5 (38%)**		

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.

c. town water supply volume of 900ML within this Zone is removed.

7.7 Management and mitigation

7.7.1 Avoidance and mitigation measures

The design of the mine layout and method, and the associated water management system, was an iterative process, with early results of surface water and groundwater modelling providing input into the mine design. The water management system was optimised via this iterative process to minimise water interception, 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, which are summarised in Table 7.17.

Table 7.17 Mitigation and avoidance measures and benefits

Mitigation measure	Environmental benefit	Social benefit
Diversion of runoff from undisturbed catchments back into the natural system.	Minimises unnecessary water capture. Reduces water volume to be stored and treated.	Water remains available to other users.
In non-direct coal contact areas (ie sub-catchments with roads and building infrastructure only) non-contaminated water will 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 was reduced from initial concept stage to achieve lower groundwater inflows.	Overall lower impact to surface and groundwater resources.

Table 7.17 Mitigation and avoidance measures and benefits

Mitigation measure	Environmental benefit	Social benefit
First workings mining method and design of barrier pillars to have no surface cracking and imperceptible fracturing.	Minimised structural deformation. Minimises both lateral and vertical extent of groundwater depressurisation (area affected by drawdown is a relatively small (Coffey 2016)). Duration of groundwater depressurisation is minimised. 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	Minimise the interception and inflow of groundwater to the mine's water management system. Allows groundwater system to commence recovery immediately after panel is 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 rejects.	Removes potential for runoff from permanent surface stockpiles into surface streams in high rainfall events.	
Addition of limestone to underground emplacement of rejects.	Limestone neutralises the leachate quality of underground rejects so that water is indistinguishable from the native groundwater. No short or long-term changes to water quality in or adjacent to underground workings.	Landholders can access water within or adjacent 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, conserve and reuse water, minimise evaporation losses, and minimise discharge to surface water systems.	Minimise impact to surface and groundwater resources.
Pump water that is in excess of operational need into sealed panels-	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.
Clay lined PWD.	Prevents seepage.	
Use of water from within the void as required for mine operations.	Water from an 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.	Water quality in Medway Rivulet is not impacted by erosion and sedimentation.	Water quality in Medway Rivulet is maintained for downstream users.
Installation of vegetated swales along the two mine access roads located outside of the water management system. Swales will be 730 m and 500 m long for the sealed road catchment and the unsealed road catchment, respectively.	NorBE criteria will be met.	NorBE criteria will be met.

7.7.2 Make good provisions

Where predicted impacts are greater than the minimal AIP impact criteria and the long-term viability of the water-dependent asset is compromised, then the impact is subject to make good provisions following consultation with the relevant landholder. Make good provisions for those bores to be affected by the project, as identified in Section 7.5.5ii, are outlined in Appendix O of the water assessment report (refer to Appendix E). As actual 'make good provisions' are not defined in the AIP or other NSW legislation, guidance has been sought from an AIP Fact Sheet (NOW 2013b) and Queesnland make good guidelines (DEHP 2016). Strategies for make good provisions will be assessed on a case by case basis and dependent on the existing infrastructure, the degree of impact at each site and the outcomes of landholder consultation.

7.7.3 Monitoring

As described in Section 7.2.2, the baseline water monitoring network and data gathered for the project is extensive, with up to four years of baseline hydrological data collected. The network has been developed with ongoing consultation with DPI Water and 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 locations, 11 vibrating wire piezometer 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.

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 commences construction and then operation, and may expand to include aspects such as:

- groundwater seepage monitoring adjacent to the PWD;
- groundwater monitoring adjacent to landholder bores predicted to be impacted by the project;
- shallow groundwater monitoring adjacent to Medway Dam;
- water quality monitoring of mine water dams and sediment basins;
- water metering and recording of pumped volumes to/ from mine water dams and sediment basins, PWD, the underground sump and the void;
- real time 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 threatened species;
- monitoring quality and metering the volume of water releases to Oldbury Creek;
- monitoring water quality within temporary sediment basins during construction;
- monitoring quality of water in sump and the rate and quality of water injected into sealed voids; and
- additional surface water monitoring sites on Oldbury Creek (downstream of where releases will occur), and on Medway Rivulet downstream of the junctions with Wells Creek and Oldbury Creek.

The suite of analytes to be sampled and the frequency of sampling will be reviewed and updated in the water management plans (WMPs) developed for construction and operation of the project (refer to Section 7.7.5). Data loggers that currently monitor water levels will continue to operate. The ongoing development and expansion of the monitoring network will be undertaken in consultation with WaterNSW and DPI Water, and as per the guidelines for the Groundwater Monitoring and Modelling Plan, which will evolve as the project progresses.

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.

7.7.4 Management measures

Monitoring of each component of the water management system underpins if, 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 with this objective.

To assist in the analysis of monitoring data, triggers and thresholds will be developed to provide context on if, how, and when management measures are required. Contingency measures have been identified in the event that impacts above those predicted by the water assessment occur, and are summarised in Table 7.18.

Table 7.18 Potential impacts and management measures

Potential impact	Management measure
Proposed releases from SB03 and SB04 following first flush to Oldbury Creek are not consistent with achieving NorBE	Don't release, store in PWD instead. Water balance modelling demonstrates that PWD has enough capacity to contain all runoff from SB03 and SB04. Inject surplus water back into the Hawkesbury Sandstone (this is the preferred option for management of surplus water, however, to date DPI Water have been unable to licence this activity).
Drawdown in landholder bores is significantly larger than predicted	Consider if additional make good measures should apply to the bore to maintain existing water supply. Analysis of 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 of voids within 6 months or less from cessation of mining a panel could reduce groundwater inflow to sump. Inject surplus water back into the Hawkesbury Sandstone (this is the preferred option for management of surplus water, however, to date DPI Water have been unable to licence this activity).
Additional releases to surface water occur as a result of very high rainfall and storm events coinciding with high groundwater inflow years	Consider options to more rapidly fill void spaces. and treatment of water prior to release to Oldbury Creek. Consider options to commission WTP and MWD08, and treat and release excess water from PWD to Oldbury Creek. Inject surplus water back into the Hawkesbury Sandstone (this is the preferred option for management of surplus water, however, to date DPI Water have been unable to licence this activity).

Table 7.18 Potential impacts and management measures

Potential impact	Management measure
Spills of petroleum products or other hazardous material	Compliance with operating procedures relating to storing and handling of hazardous materials, including spill response plans. Avoid handling of hazardous materials adjacent to waterways. Immediate rehabilitation of 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 tailings with limestone prior to underground emplacement. Consider filling and sealing individual voids more rapidly following mining.
Greater than predicted drawdown adjacent to areas of shallow groundwater that ecosystems are potentially relying on	Assess ecosystem health, assess time for recovery of shallow groundwater at the location, consideration to temporary irrigation to these systems until groundwater recovers to acceptable limits (ie the level at which the ecosystem can again access the groundwater).

7.7.5 Groundwater model validation

Validation of the groundwater model predictions is proposed to be undertaken regularly, and could be carried out by installing groundwater monitoring sites at selected virtual piezometers used in the model. Significant deviations from the predicted impacts will be investigated, and results reported annually in the Annual Review. Model recalibration will be considered every two years, and undertaken as required pending the outcomes of model validation over time.

Predicted impacts on landholder bores will be confirmed via manual monitoring of these bores, and/or via installation of dedicated monitoring bores adjacent to key landholder bores.

7.7.6 Water management plan

Two overarching WMPs will be developed for the project, one for the construction phase and one for the operational phase. The WMPs will document the proposed mitigation and management measures for the project, and will describe:

- the surface and groundwater monitoring program;
- reporting requirements;
- spill management and response;
- trigger levels for water quality parameters to assist in early identification of water quality trends;
- corrective actions and contingencies;
- a programme for reviewing and updating the numerical groundwater model as more data and information become available; and
- responsibilities for all management measures.

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). 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* (DECCW 2008).

7.8 Conclusion

Effective and efficient water management is essential to the operation of the project. The design of the water management system was an iterative process, with early results of surface water and groundwater modelling providing input into the mine design. The mine design and associated water management system was optimised via this iterative process to minimise water extraction and groundwater inflow, conserve and reuse water, minimise evaporation losses, and minimise discharge to surface water systems.

The impacts 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 the construction and operation of the project.

Potential TSS and nutrient loads and concentrations in Oldbury Creek show that discharge from sediment basins will be in accordance with the NorBE criteria. Swales 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 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.

Groundwater inflows to the mine will occur during the period when the project causes stress on the groundwater system, which will be throughout the operational mine life and continuing for three years after coal extraction ceases (ie for 22 years after the start of mining). 93 private landholder bores on 71 properties are predicted to be subject to a project impact drawdown of 2 m or more. The average duration of impact on the 93 affected bores is 36 years, with the maximum duration being 65 years; however, most of the recovery occurs in a far shorter time period. Typically, a bore will recover by 75% within 23 years since it was first impacted.

A make good assessment was conducted to address the project impacts on these 93 bores. All bores impacted by more than 2 m are assessed as eligible for increased pumping costs. Approximately a third of the impacted bores only require increased pumping costs and no capital works are proposed. Another third are assessed as potentially needing repositioning of submersible pump intake depths for certain periods of time, and the final third may need redrilling, or repositioning to maintain water supply.

With regard to the groundwater quality requirements of the AIP, 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 Section 7.7 are implemented.

Cumulative impacts to groundwater and surface water quality are not anticipated as a result of the project.

Monitoring of the extensive surface water and groundwater network will continue. Monitoring of 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 approximately 60% of the total water licence requirement for the project, with a clear pathway for how the remaining licence volume will be secured so that all water taken is adequately licensed.