APPENDIX D

HUME COAL PROJECT EIS FLOODING ASSESSMENT

Hume Coal

Flooding Assessment

Hume Coal Project

PARSONS BRINCKERHOFF

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Glossary

Annual exceedence probability (AEP)	Chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, there is a 5% chance (that is, a one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see 'average recurrence interval').
Australian Height Datum (AHD)	Reference point (very close to mean sea level) for all elevation measurements, and used for correlating depths of channels and water levels.
Average recurrence interval (ARI)	Long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20-year ARI flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	Land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Digital terrain model (DTM)	Digital representation of ground surface topography or terrain. It is also widely known as a digital elevation model (DEM).
Discharge	Rate of flow of water measured in terms of volume per unit time — for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving — for example, metres per second (m/s).
Flood	Relatively high streamflow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam; and/or local overland flooding associated with major drainage before it enters a watercourse; and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences, excluding tsunami.
Floodplain	Area of land that is subject to inundation by floods up to and including the probable maximum flood event — that is, flood-prone land.
Hydrologic Engineering Centre River Analysis System (HEC-RAS) model	Software package that allows modellers to perform one-dimensional steady and unsteady flow river hydraulics calculations, sediment transport – mobile bed modelling and water temperature analysis.
Hydraulics	Study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	Graph that shows how the discharge or flood level at a particular location varies with time during a flood.
Hydrology	Study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Hyetograph	A graphical representation of the distribution of rainfall over time.
Light detection and ranging (LiDAR)	Optical remote-sensing technology that can measure the distance to, or other properties of, a target by illuminating the target with light (often pulses from a laser).

Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second. A unit of measurement for flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Model	Mathematical representation of the physical processes involved in runoff generation and streamflow. Models are often run on computers, due to the complexity of the mathematical relationships between runoff, streamflow and the distribution of flows across the floodplain.
Peak discharge	Maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	Largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood-producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land — that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study.
Probable maximum precipitation (PMP)	Greatest depth of precipitation for a given duration that is meteorologically possible over a given size of storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends. It is the primary input to PMF estimation.
Runoff	Amount of rainfall that actually ends up as streamflow; also known as rainfall excess.
Velocity	Speed of floodwaters, usually in m/s (metres per second).
XP-RAFTS	Software package used for runoff routing for hydrologic and hydraulic analysis of drainage and conveyance systems.

Abbreviations

AEP	Annual exceedence probability
AHD	Australian Height Datum
ARI	Average recurrence interval
AR&R	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
CPP	Coal preparation plant
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCP	Development control plan
DEM	Digital elevation model
DTM	Digital terrain model
EAF	Elevation adjustment factor
EIS	Environmental impact statement
EPW	Extreme perceptible water
GSAM	Generalised Southeast Australia Method
GSDM	Generalised Short-Duration Method
ha	Hectares
HEC-RAS model	Hydrologic Engineering Centre River Analysis System model
IFD	Intensity frequency duration
LiDAR	Light detection and ranging
MAF	Moisture adjustment factor
m/s	Metres per second
m^3/s	Cubic metres per second
MHL	Manly Hydraulics Laboratory
mm/hr	Millimetres per hour
Mt	Million tonnes
Mtpa	Million tonnes per annum
Q	Discharge
PMF	Probable maximum flood
PMP	Probable maximum precipitation
PRM	Probabilistic rational method
PWD	Primary water dam
RCBC	Reinforced concrete box culvert
ROM	Run of mine
SEARs	Secretary's Environmental Assessment Requirements

TAF	Topographic adjustment factor
WLEP	Wingecarribee Local Environmental Plan
WSC	Wingecarribee Shire Council
WTP	Water treatment plant

Executive summary

Parsons Brinckerhoff has been commissioned by Hume Coal to prepare a flooding assessment as part of the Environmental Impact Statement (EIS) for the Hume Coal Project (the project). This report provides an assessment of the existing flood behaviour and the impacts of the Project on flooding in the local catchments, and mitigation measures required to minimise potential impacts and to protect the mine infrastructure during flood events.

Mine infrastructure is located within two stream catchments: Medway Rivulet and Oldbury Creek. Medway Rivulet is located to the south of the proposed administration and workshop area (AWA) precinct. Oldbury Creek is located to the north of the proposed coal preparation plant (CPP) precinct.

Hydrologic and hydraulic models using XP-RAFTS and HEC-RAS respectively were used to define the flood levels and extents for existing conditions and mining scenarios for the 5, 20 and 100 year average recurrence interval (ARI) events and the probable maximum flood.

The assessment considered the existing conditions and operation and rehabilitation scenarios of the Project. A cumulative assessment including the Berrima Rail Project was also undertaken.

The assessment found that the impacts on flooding for the operation and rehabilitation scenario are within proposed acceptability criteria, with the exception of a localised area of land owned by Hume Coal on Oldbury Creek adjacent to the surface infrastructure area.

Comparison of the cumulative 100 year ARI flood extents shows that changes in flood extent during operation of the mine and rail will occur in the vicinity of the rail loop and upstream of the rail crossings on Oldbury Creek. Any significant changes in flood extent occur on land owned by Hume Coal or Boral. The impacts of both projects were found to be hydraulically independent.

Peak velocities are expected to increase immediately downstream of the conveyor piers and culverts. Erosion and scour protection measures will be required around piers and culvert inlets and outlets so that locally increased velocities do not cause erosion of the adjacent channel sections.

A drainage easement with buried pipe exists that appears to drain a small catchment from east to west across the Hume Motorway into a farm dam on land owned by Hume Coal. The downstream section of this pipe will be intercepted by the proposed Primary Water Dam (PWD). It is proposed to modify the existing drainage arrangement within land owned by Hume Coal to allow the pipe to discharge around the PWD and allow this drainage line to continue to function unimpeded and ultimately discharge to Oldbury Creek as it does currently.

1. Introduction

Parsons Brinckerhoff has been commissioned by Hume Coal to prepare a flooding assessment as part of the Environmental Impact Statement (EIS) for the Hume Coal Project (the project).

This report provides an assessment of the impacts of the project on flooding in the local catchments and mitigation measures required to minimise potential impacts and protect the mine infrastructure during flood events. The assessment of potential impacts of the project on the dominant flow regime in the catchments (i.e. on normal to low flows) is addressed in the Flow and Geomorphology Assessment Report (Parsons Brinckerhoff 2016).

1.1 Project description

The project involves developing and operating an underground coal mine and associated infrastructure over a total estimated project life of 23 years. Indicative mine and surface infrastructure plans are provided in Figure 1.1 and Figure 1.2. A full description of the project, as assessed in this report, is provided in Chapter 2 of the main EIS (EMM 2016a).

In summary it involves:

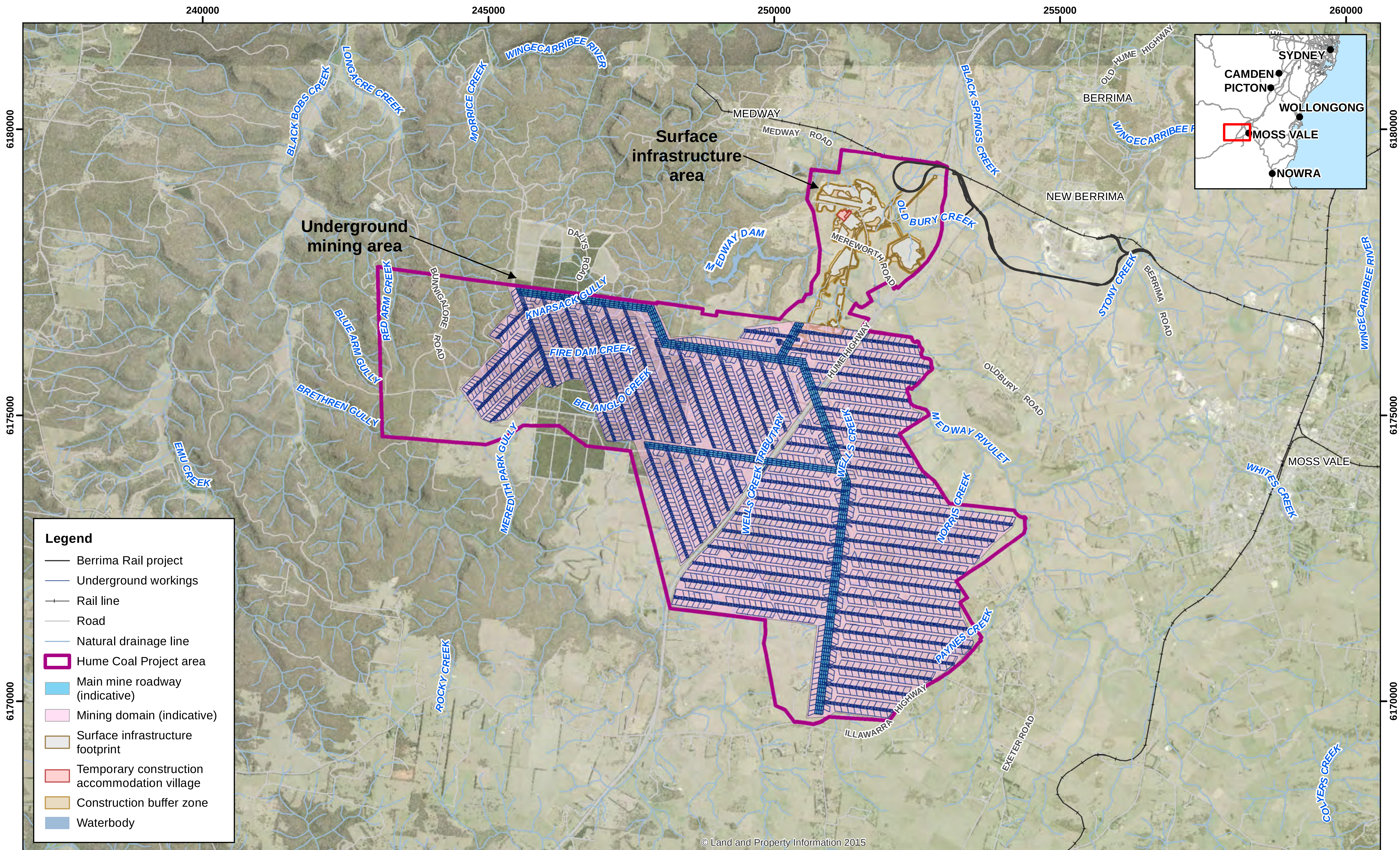
- Ongoing resource definition activities, along with geotechnical and engineering testing, and other low impact fieldwork to facilitate detailed design.
- Establishment of a temporary construction accommodation village.
- Development and operation of an underground coal mine, comprising of approximately two years of construction and 19 years of mining, followed by a closure and rehabilitation phase of up to two years, leading to a total project life of 23 years. Some coal extraction will commence during the second year of construction during installation of the drifts, and hence there will be some overlap between the construction and operational phases.
- Extraction of approximately 50 million tonnes (Mt) of run-of-mine (ROM) coal from the Wongawilli Seam, at a rate of up to 3.5 million tonnes per annum (Mtpa). Low impact mining methods will be used, which will have negligible subsidence impacts.
- Following processing of ROM coal in the coal preparation plant (CPP), production of up to 3 Mtpa of metallurgical and thermal coal for sale to international and domestic markets.
- Construction and operation of associated mine infrastructure, mostly on cleared land, including:
  - one personnel and materials drift access and one conveyor drift access from the surface to the coal seam;
  - ventilation shafts, comprising one upcast ventilation shaft and fans, and up to two downcast shafts installed over the life of the mine, depending on ventilation requirements as the mine progresses;
  - a surface infrastructure area, including administration, bathhouse, washdown and workshop facilities, fuel and lubrication storage, warehouses, laydown areas, and other facilities. The surface infrastructure area will also comprise the CPP and ROM coal, product coal and emergency reject stockpiles;
  - surface and groundwater management and treatment facilities, including storages, pipelines, pumps and associated infrastructure;
  - overland conveyors;
  - rail load-out facilities;

  - explosives magazine;
  - ancillary facilities, including fences, access roads, car parking areas, helipad and communications infrastructure; and
  - environmental management and monitoring equipment.
- Establishment of site access from Mereworth Road, and minor internal road modifications and relocation of some existing utilities.
- Coal reject emplacement underground, in the mined-out voids.
- Peak workforces of approximately 414 full-time equivalent employees during construction and approximately 300 full-time equivalent employees during operations.
- Decommissioning of mine infrastructure and rehabilitating the area once mining is complete, so that it can support land uses similar to current land uses.

The project area, shown in Figure 1.1, is approximately 5,051 hectares (ha). Surface disturbance will mainly be restricted to the surface infrastructure areas shown indicatively on Figure 1.2, though will include some other areas above the underground mine, such as drill pads and access tracks. The project area generally comprises direct surface disturbance areas of up to approximately 117 ha, and an underground mining area of approximately 3,472 ha, where negligible subsidence impacts are anticipated.

A construction buffer zone will be provided around the direct disturbance areas. The buffer zone will provide an area for construction vehicle and equipment movements, minor stockpiling and equipment laydown, as well as allowing for minor realignments of surface infrastructure. Ground disturbance will generally be minor and associated with temporary vehicle tracks and sediment controls as well as minor works such as backfilled trenches associated with realignment of existing services. Notwithstanding, environmental features identified in the relevant technical assessments will be marked as avoidance zones so that activities in this area do not have an environmental impact.

Product coal will be transported by rail, primarily to Port Kembla terminal for the international market, and possibly to the domestic market depending on market demand. Rail works and use are the subject of a separate EIS and State significant development application for the Berrima Rail Project.



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Author: RP

Date: 24/10/2016

Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Flooding Assessment
Figure 1.1
Project area

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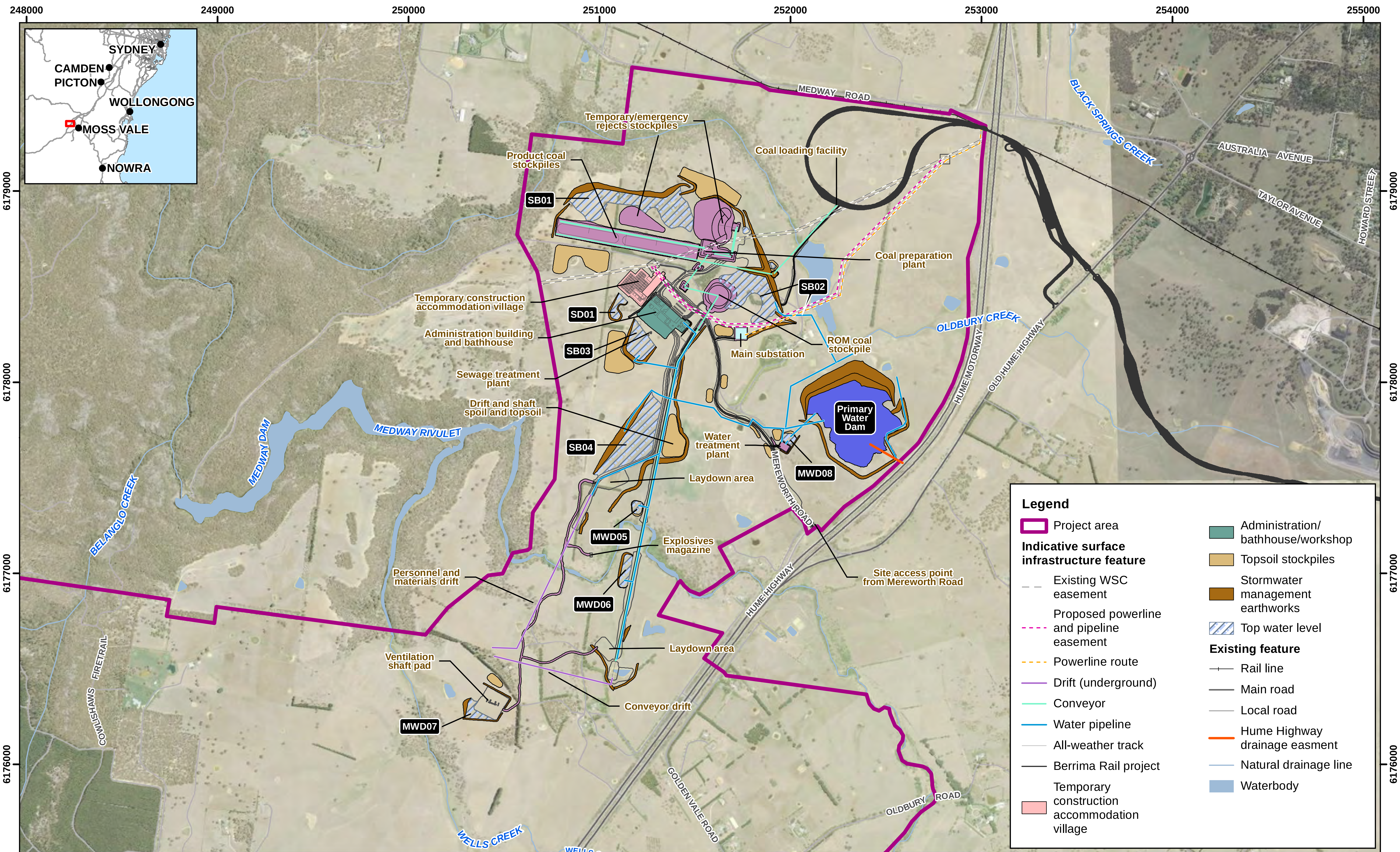

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Hume Coal Flooding Assessment
Figure 1.2
Surface infrastructure layout

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1.2 Project area

The project area is approximately 100 kilometres (km) south-west of Sydney and 3 km west of Moss Vale in the Wingecarribee LGA (refer to Figure 1.1 and Figure 1.2). It is in the Southern Highlands region of NSW and the Sydney Basin Biogeographic Region.

The project area is in a semi-rural setting, with the wider region characterised by grazing properties, small-scale farm businesses, hobby farms, natural areas, forestry, scattered rural residences, villages and towns, industrial activities such as the Berrima Cement Works and Berrima Feed Mill, and some extractive industry and major transport infrastructure such as the Hume Highway.

Surface infrastructure is proposed to be developed on predominately cleared land owned by Hume Coal or affiliated entities, or for which there are appropriate access agreements in place with the landowner. Over half of the remainder of the project area (principally land above the underground mining area) comprises cleared land that is, and will continue to be, used for livestock grazing, small-scale farm businesses and hobby farms. Belanglo State Forest covers the north-western portion of the study area and contains introduced pine forest plantations, areas of native vegetation and several creeks that flow through deep sandstone gorges. Native vegetation within the project area is largely restricted to parts of Belanglo State Forest and riparian corridors along some watercourses.

The project area is traversed by several drainage lines including Oldbury Creek, Medway Rivulet, Wells Creek, Wells Creek Tributary, Belanglo Creek and Longacre Creek, all of which ultimately discharge to the Wingecarribee River, located around 1.5 km north of the project area (Figure 1.1). The Wingecarribee River's catchment forms part of the broader Warragamba Dam and Hawkesbury-Nepean catchments. Medway Dam is also adjacent to the northern portion of the project area (Figure 1.1).

Most of the central and eastern parts of the project area have very low rolling hills with occasional elevated ridge lines. However, there are steeper slopes and deep gorges in the west in Belanglo State Forest.

Existing built features across the project area include scattered rural residences and farm improvements such as outbuildings, dams, access tracks, fences, yards and gardens, as well as infrastructure and utilities including roads, electricity lines, communications cables and water and gas pipelines. Key roads that traverse the project area are the Hume Highway and Golden Vale Road. The Illawarra Highway borders the south-east section of the project area.

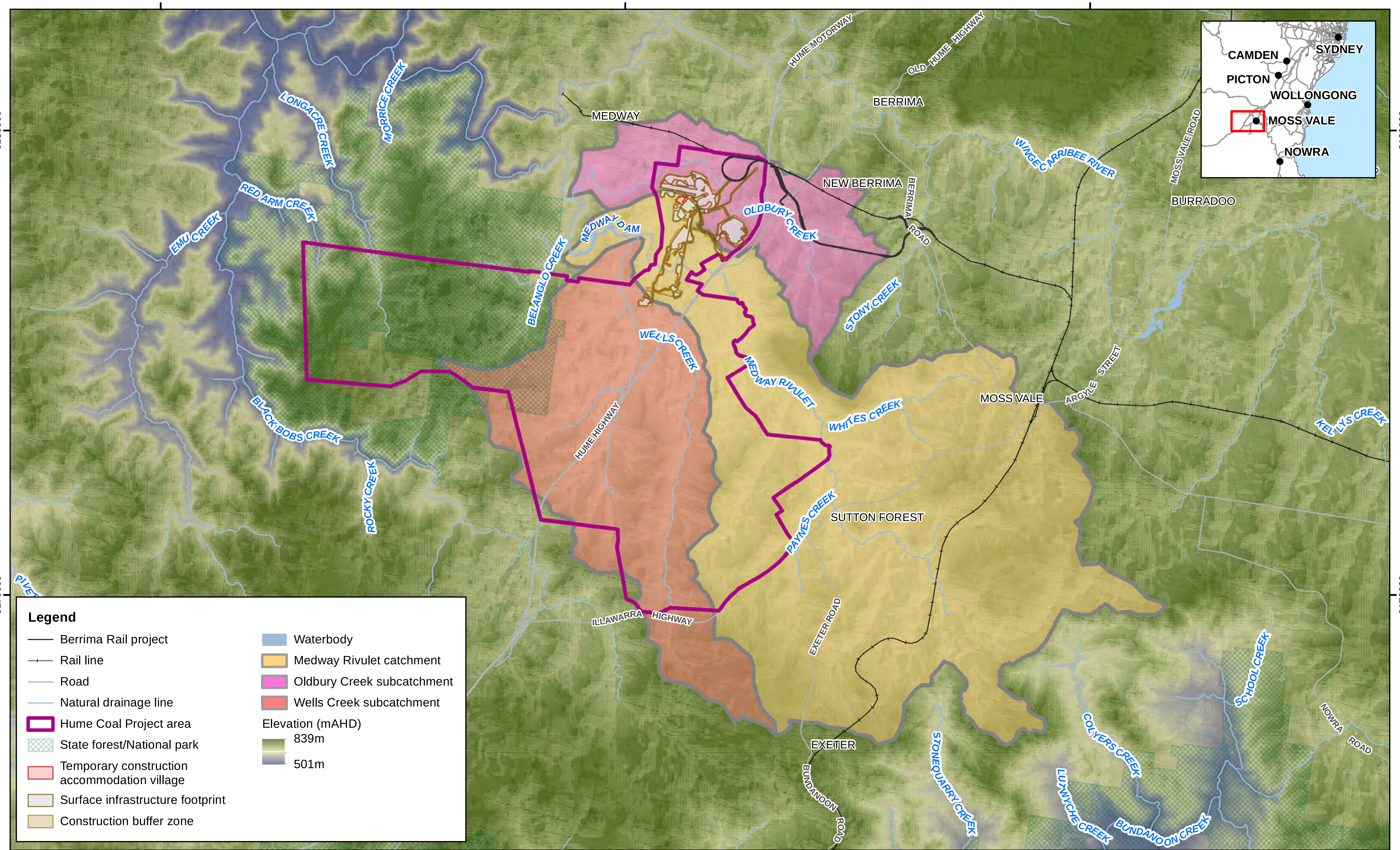
Industrial and manufacturing facilities adjacent to the project area include the Berrima Cement Works and Berrima Feed Mill on the fringe of New Berrima. Berrima Colliery's mining lease (CCL 748) also adjoins the project area's northern boundary. Berrima Colliery is currently undergoing closure having ceased production in 2013 after almost one hundred years of operation.

1.3 Study area definition

The flooding assessment study area is shown on Figure 1.3 and includes the surface infrastructure area and surrounding Medway Rivulet and Oldbury Creek catchments. The surface infrastructure area includes the AWA precinct, the CPP precinct and supporting infrastructure.

The area located above the proposed underground mining area is not part of the study area for the flooding assessment as the underground mine workings will result in negligible subsidence and therefore negligible impacts on flooding in overlying catchments. Worst case estimates of subsidence associated with the proposed first workings mining method predict 'imperceptible' surface disturbance due to mining, with predicted settlement less than 20 mm (Mine Advice 2016). Such low magnitude subsidence will not impact on flooding regimes.

The Berrima Rail Project is located in the Oldbury Creek catchment to the north of the project (refer Figure 1.2) and has been considered for assessment of potential cumulative impacts (refer Section 6.2).



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Hume Coal Flooding Assessment
Figure 1.3
Study area

1.4 Catchment description

1.4.1 Medway Rivulet

Medway Rivulet is located to the south of the proposed AWA precinct. The Medway Rivulet catchment used in this assessment covers an area of approximately 103 km^2 (excluding the Oldbury Creek catchment). The downstream limit of the catchment is just downstream of Medway Dam (Figure 1.3).

Medway Rivulet flows in a north-westerly direction from its headwaters in Moss Vale to its discharge to the Wingecarribee River approximately 5.5 km downstream of the study area. Medway Rivulet's major tributaries are Wells Creek, Whites Creek, Paynes Creek, Oldbury Creek and Belanglo Creek (Figure 1.3).

East of the Hume Highway, Medway Rivulet is characterised by run/riffle sequences and its natural flow is impeded by several instream farm dams. West of the Hume Highway, Medway Rivulet is confined by Hawkesbury Sandstone banks which form a steep gully to the west of the study area.

Downstream of the surface infrastructure area, Medway Rivulet has been dammed to create a 1,350 ML reservoir. The reservoir is commonly referred to as 'Medway Dam' and is part of Wingecarribee Shire Council's (WSC's) water supply system.

Land use within the catchment is predominantly cleared farm land for grazing with some irrigation. The Belanglo State Forest, an exotic pine plantation, occurs in the north-western part of the catchment. Urban areas are associated with Sutton Forest, Exeter and Moss Vale (Figure 1.3).

1.4.2 Oldbury Creek

Oldbury Creek is located to the north of the proposed CPP precinct. The Oldbury Creek catchment used in this assessment covers an area of approximately 13.3 km^2. The downstream limit of the catchment is just upstream of the confluence with Medway Rivulet (Figure 1.3).

Oldbury Creek flows in a westerly direction from its headwaters in New Berrima to its discharge to Medway Rivulet (Figure 1.3). Its natural flow is impeded by several instream farm dams used for agricultural water supply, including a large storage to the east of the CPP precinct. West of the Hume Highway, Oldbury Creek is confined by Hawkesbury Sandstone banks which form a steep gully to the west of the study area.

Land use within the catchment is predominantly cleared farm land for grazing with some irrigation. Urban areas are associated with Medway and New Berrima (Figure 1.3).

1.5 Environmental assessment requirements

This assessment has been prepared in accordance with the relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies. Guidelines and policies considered are as follows:

- Floodplain Development Manual (NSW Government 2005)
- Practical Consideration of Climate Change (Department of Environment and Climate Change 2007)
- Australian Rainfall and Runoff – A Guide to Flood Estimation (Engineers Australia 1987)
- Wingecarribee Local Environmental Plan (Wingecarribee Shire Council 2010).

Further details of these legislation, policy and guideline documents, and how they apply to this assessment, are provided in Section 2 of this report.

The Secretary's Environmental Assessment Requirements (SEARs) related to flooding, and the section of this report where the requirement is addressed, are provided in Table 1.1.

Table 1.1 Flooding assessment related SEARs

Requirement	Section addressed
An assessment of the potential flooding impacts of the development	Section 6

To inform preparation of the SEARs, the Department of Planning and Environment (DP&E) invited other government agencies to recommend matters for address in the Environmental Impact Statement (EIS). These matters were then taken into account by the Secretary for DP&E when preparing the SEARs. Copies of the government agencies' advice to DP&E was attached to the SEARs.

One agency, the Department of Primary Industries (DPI), raised matters relevant to the flooding assessment. These were mainly their standard requirements for projects of this nature, though included some project-specific requirements. These matters are listed in Table 1.2 and have been taken into account in preparing this report, as indicated in the tables.

Table 1.2 Agency requirements

Requirement	Section addressed
DPI Water	
The predictive assessment of the impact of the proposed project on surface water sources should include assessment of predicted impacts on: ▪ Flow of surface water (including floodwater) ▪ Flood regime.	Section 6

The Hume Coal Project was declared as a controlled action on 1 December 2015 by the then Commonwealth Department of the Environment (now Department of Environment and Energy). The project will be assessed under the Bilateral Agreement between the NSW Government and the Commonwealth Government. Accordingly, the Commonwealth Department of the Environment and Energy has issued supplementary SEARs to address matters of national environmental significance relevant to the project. There were no supplementary SEARs specifically relating to the flooding assessment.

2. Design objectives and criteria

2.1 Terminology

AR&R has indicated that the annual exceedance probability (AEP) terminology is preferred to the average recurrence interval (ARI) terminology. The ARI and the AEP are both a measure of the probability of occurrence of a rainfall event. The ARI terminology has been used throughout this report.

ARI is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that the periods between exceedances are generally random. AEP is defined as the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.

With ARI expressed in years, the relationship is:

$$AEP = 1 - \exp\left(\frac{-1}{ARI}\right)$$

A summary of the conversion between ARI and AEP is shown in Table 2.1.

Table 2.1 Conversion from ARI to AEP

ARI (years)	AEP
1	0.632
2	0.393
5	0.181
10	0.095
20	0.049
50	0.020
100	0.010

ARIs greater than 10 years are very closely approximated by the reciprocal of the AEP.

2.2 Legislation, policy and guidelines

This section details the legislation, policy and guidelines that were used for the flooding assessment.

2.2.1 Floodplain Development Manual (NSW Government 2005)

The Floodplain Development Manual (NSW Government 2005) was prepared in accordance with the NSW Government's Flood Prone Land Policy. The objective of the Flood Prone Land Policy is to reduce flooding impacts and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods.

The purpose of the Floodplain Development Manual (NSW Government 2005) is to provide guidance to local councils during the development and implementation of detailed local floodplain risk management plans in order to produce effective floodplain risk management outcomes. The manual identifies the need to consider the full range of flood sizes up to and including the probable maximum flood (PMF) when developing floodplain risk management plans; to recognise flood risk on a strategic basis; to manage not only riverine flooding but local overland flooding and to promote the preparation and adoption of local flood plans that address flood response and recovery. The manual clearly sets out the floodplain risk management process undertaken by local councils.

2.2.2 Practical Consideration of Climate Change in Floodplain Risk Management (Department of Environment and Climate Change 2007)

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Bureau of Meteorology (BOM) are currently undertaking research on climate change impacts with the objective of estimating rainfall intensities for a range of events under current climatic conditions (1960 to 2000) and under increased greenhouse gas concentrations for future conditions (2030 and 2070). This document outlines current advice on how to incorporate climate change impacts into flooding assessments.

This document also provides guidance on the evaluation of climate change impacts and their significance. Management options and strategies that should be considered are also outlined in the document.

2.2.3 Australian Rainfall and Runoff – A Guide to Flood Estimation (Engineers Australia 1987)

Australian Rainfall and Runoff (AR&R) is a national guideline for the estimation of design flood characteristics in Australia developed by Engineers Australia. It provides robust estimates of flood risk to ensure development does not occur in high risk areas and that infrastructure is appropriately designed.

A number of research projects are currently underway to fill knowledge gaps that have arisen since the 1987 edition was published. The projects are being completed progressively and a number were launched at the Water Resources Symposium in Hobart in 2015. However, the sections released so far are insufficient to be used for flooding assessment, and AR&R (1987) has been used as the basis for this assessment.

2.2.4 Wingecarribee Local Environmental Plan (Wingecarribee Shire Council 2010)

The Wingecarribee Local Environmental Plan (WLEP) was approved in 2010. The plan was prepared in accordance with the *Environmental Planning and Assessment Act 1997* and *Environmental Planning and Assessment Regulation 2000*. The WLEP aims to minimise flood risk to life and property associated with the use of the land, allow development that is compatible with the land's flood risk (taking into account projected climate change), and avoid significant adverse impacts on flood behaviour and the environment.

Clause 7.9 of the WLEP states that development consent must not be granted to development in a Flood Planning Area or other land at or below the flood planning level, unless the consent authority is satisfied that the development:

- is compatible with the flood hazard of the land;

- will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties;
- incorporates appropriate measures to manage risk to life from flood;
- will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and
- will not be likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

The WLEP includes Flood Planning Area Maps (refer Appendix A). The flood planning level is the level of the 100 year ARI flood event plus 0.5 m freeboard.

2.2.4.1 Development Control Plans

A Development Control Plan (DCP) provides detailed guidelines for the assessment of development applications at a local level. DCPs applicable under the WLEP and within the Medway Rivulet and Oldbury Creek catchments include:

- Rural Lands and Living DCP;
- New Berrima and Medway DCP;
- Moss Vale DCP (including the Moss Vale Flood Map);
- Sutton Forest DCP; and
- Industrial Lands DCP.

The DCPs identify types of development and outline controls that will guide the development to suitable areas. These specific elements follow an overarching control mechanism that is presented in a matrix containing degrees of flood risk (Flood Risk Precincts), land use categories and planning considerations. The matrix provides a consolidated list of preferred controls.

The development controls are graded relative to the severity and frequency of the potential floods based on the findings of the Floodplain Risk Management Plan.

Council does not have flood risk mapping available for rural areas, therefore it is the applicant’s responsibility to provide evidence of the relevant flood risk category for their development in potentially flood liable areas.

2.2.5 Floodplain Risk Management Study and Plan, Wingecarribee Shire Council, in progress

WSC is currently developing floodplain risk management studies and plans in accordance with the Floodplain Development Manual (NSW Government 2005).

WSC has completed a flood study of the Whites Creek catchment, which is located to the south east of the study area (URS 2008). The flood study was completed in 2008 and assessed various potential floods in the study area, including the 5 year, 10 year, 20 year, 50 year, 100 year, 200 year ARI and PMF event flood extents. A draft Floodplain Risk Management Study and Plan for the Whites Creek Catchment was prepared in 2013.

WSC has also completed a flood study for the Wingecarribee River catchment, covering the area between Wingecarribee Dam and Wallaby Rocks in Berrima (SMEC 2014). The study was completed in 2014 and considered the 1100 year ARI flood depths and provisional hydraulic hazard. A Floodplain Risk Management Study and Plan was prepared for the Wingecarribee River at Berrima in 2002 based on the results of an earlier flood study undertaken in 2000.

2.3 Flood design criteria for mine infrastructure

Preliminary flood modelling was undertaken during the mine design phase to inform the siting and design of mine infrastructure. Surface infrastructure for the mine has been located and designed to minimise potential flooding impacts and ensure critical mine infrastructure is protected during extreme flood events.

The flood immunity criteria adopted for siting of surface infrastructure is provided in Table 2.2. The main drifts and ventilation shaft are located above the PMF level to prevent ingress of flood waters into the underground mine workings.

Table 2.2 Flood immunity criteria for mine infrastructure

Infrastructure	Design criteria
Main drifts and ventilation shafts	PMF
AWA precinct	100 year ARI
CPP precinct	100 year ARI
PWD and WTP	100 year ARI

2.4 Flood impact criteria

To ensure that the flooding impact is acceptable to land users adjacent to the Project, for flooding events up to the 100 year ARI the following acceptability criteria are proposed:

- Buildings – less than 50 mm increase in flood level (or afflux) if the building is already flooded and no new flooding of buildings not currently flooded due to proposed works is allowed 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.
- Private properties – less than 250 mm afflux.
- No increase in velocity above a threshold of 1.5 m/s, where existing conditions velocities are below the threshold. No more than a 10% increase in velocity where existing conditions velocities are above this threshold.

3. Data sources

3.1 Topography, aerial photography and survey

Catchment delineation for the hydrological modelling and development of a digital terrain model (DTM) for the hydraulic modelling used light detection and ranging (LiDAR) data obtained from aerial laser survey of the project area on 25 October 2013 (Hume Coal 2013). The data were supplied as thinned ground points in ASCII format, and a triangulated irregular network was created to form the DTM.

Aerial photography was used for catchment delineation and to estimate channel and floodplain roughness in the hydraulic model.

Surveys of significant culvert crossings of roads and rail lines within the study area were surveyed and represented in the hydraulic model. Cross-section surveys undertaken by Xylem and Manly Hydraulics Laboratory (MHL) during installation of Hume Coal stream gauges SW04 on Medway Rivulet and SW08 on Oldbury Creek (Parsons Brinckerhoff 2016) were included in the hydraulic model. Two inline storages on Oldbury Creek were surveyed so that embankment height and water levels could be input to the hydrological model.

3.2 Design rainfall intensity data

Design rainfall intensity estimates were derived for the range of storm events up to the 100 year ARI using AR&R (Engineers Australia 2001) as discussed in Section 2.2.3.

Intensity frequency duration (IFD) input parameters adopted in the hydrologic models for the Medway Rivulet and Oldbury Creek catchments are provided in Table 3.1. The IFD data for Medway Rivulet and Oldbury Creek are provided in Tables 3.2 and 3.3 respectively.

Table 3.1 IFD parameters

Variable	Symbol	Medway Rivulet	Oldbury Creek
Rainfall intensity (mm/hr) (2-year ARI; 1-hour storm duration)	${}^{2}I_{1}$	30.8	28.8
Rainfall intensity (mm/hr) (2-year ARI; 12-hour storm duration)	${}^{2}I_{12}$	7.11	6.28
Rainfall intensity (mm/hr) (2-year ARI; 72-hour storm duration)	${}^{2}I_{72}$	2.27	1.87
Rainfall intensity (mm/hr) (50-year ARI; 1-hour storm duration)	${}^{50}I_{1}$	62.9	58.46
Rainfall intensity (mm/hr) (50-year ARI; 12-hour storm duration)	${}^{50}I_{12}$	14.4	12.78
Rainfall intensity (mm/hr) (50-year ARI; 72-hour storm duration)	${}^{50}I_{72}$	4.84	3.84
Average coefficient of skewness	G	0.04	0.04
Geographical factor (2-year ARI)	F2	4.28	4.29
Geographical factor (50-year ARI)	F50	15.73	15.73

Table 3.2 IFD data for Medway Rivulet

Duration	Rainfall intensity (mm/hr)						
	1 year ARI	2 year ARI	5 year ARI	10 year ARI	20 year ARI	50 year ARI	100 year ARI
5 mins	77.1	99.7	130	147	171	202	225
6 mins	72.3	93.6	122	138	160	189	212
10 mins	59.1	76.5	99.6	113	131	155	173
20 mins	43	55.6	72.4	82.4	95.6	113	126
30 mins	34.9	45.2	58.9	67.1	77.8	92	103
1 hr	23.8	30.8	40.2	45.8	53.2	62.9	70.4
2 hrs	15.9	20.6	26.9	30.6	35.5	42	47
3 hrs	12.5	16.2	21.1	24	27.8	32.9	36.8
6 hrs	8.28	10.7	14	15.9	18.4	21.7	24.3
12 hrs	5.49	7.11	9.26	10.5	12.2	14.4	16.1
24 hrs	3.61	4.69	6.14	7.01	8.15	9.66	10.8
48 hrs	2.32	3.02	3.99	4.58	5.34	6.36	7.15
72 hrs	1.74	2.27	3.02	3.47	4.06	4.84	5.45

Table 3.3 IFD data for Oldbury Creek

Duration	Rainfall intensity (mm/hr)						
	1 year ARI	2 year ARI	5 year ARI	10 year ARI	20 year ARI	50 year ARI	100 year ARI
5 mins	72.3	93.9	123	141	164	195	218
6 mins	67.6	87.9	115	132	153	182	204
10 mins	55.2	71.8	94.2	108	125	149	167
20 mins	40.2	52.2	68.4	78.1	90.8	108	121
30 mins	32.6	42.3	55.5	63.3	73.5	87.1	97.7
1 hr	22.1	28.7	37.5	42.8	49.7	58.9	66
2 hrs	14.6	18.9	24.8	28.2	32.8	38.9	43.5
3 hrs	11.4	14.7	19.3	22	25.6	30.3	33.9
6 hrs	7.41	9.6	12.6	14.3	16.7	19.7	22.1
12 hrs	4.82	6.25	8.19	9.35	10.9	12.9	14.4
24 hrs	3.1	4.03	5.28	6.03	7.02	8.32	9.33
48 hrs	1.94	2.52	3.31	3.78	4.4	5.23	5.86
72 hrs	1.44	1.86	2.45	2.8	3.26	3.87	4.35

3.3 Probable maximum precipitation

The probable maximum precipitation (PMP) design rainfall intensity was determined using the method outlined by the BOM (2003, 2006) publications detailing the Generalised Short-Duration Method (GSDM) for durations from 15 minutes up to 6 hours and the Generalised Southeast Australia Method (GSAM) for longer durations from 24 hours up to 96 hours. The 12 hour event was estimated through interpolation. Table 3.4 shows the parameters used in the PMP calculation for Medway Rivulet (excluding the Oldbury Creek catchment) and Oldbury Creek and Table 3.5 provides a summary of the resulting PMP rainfall depths.

Table 3.4 Parameters used for PMP calculation

Parameter	Medway Rivulet (excluding the Oldbury Creek catchment)	Oldbury Creek
Catchment area	103 km^2	13.3 km^2
GSDM parameters		
Elevation adjustment factor (EAF)	1 (below 1500 m elevation)	1 (below 1500 m elevation)
Moisture adjustment factor (MAF)	0.67	0.68
Portion of catchment area considered smooth	0 (entire catchment considered rough because there are elevation changes of 50 m or more within horizontal distances of 400 m within the catchment.)	0 (entire catchment considered rough because there are no elevation changes of 50 m or more within horizontal distances of 400 m within the catchment.)
GSAM parameters		
Topographic adjustment factor (TAF)	1.51	1.51
Extreme perceptible water (EPW) - summer (annual)	70.87	70.87
EPW – autumn	57.05	57.05
Annual MAF - summer	0.88	0.88
Annual MAF - autumn	0.80	0.80

Table 3.5 PMP rainfall depths

Storm duration	PMP rainfall depth (mm)	
	Medway Rivulet	Oldbury Creek
15 minutes	110	150
30 minutes	160	210
45 minutes	210	270
1 hour	250	320
1.5 hours	320	410
2 hours	370	470
2.5 hours	420	520
3 hours	450	570

Storm duration	PMP rainfall depth (mm)	
	Medway Rivulet	Oldbury Creek
4 hours	510	650
5 hours	560	710
6 hours	590	820
12 hours	820	930
24 hours	1,060	1,150
36 hours	1,180	1,290
48 hours	1,250	1,360
72 hours	1,310	1,420
96 hours	1,360	1,470

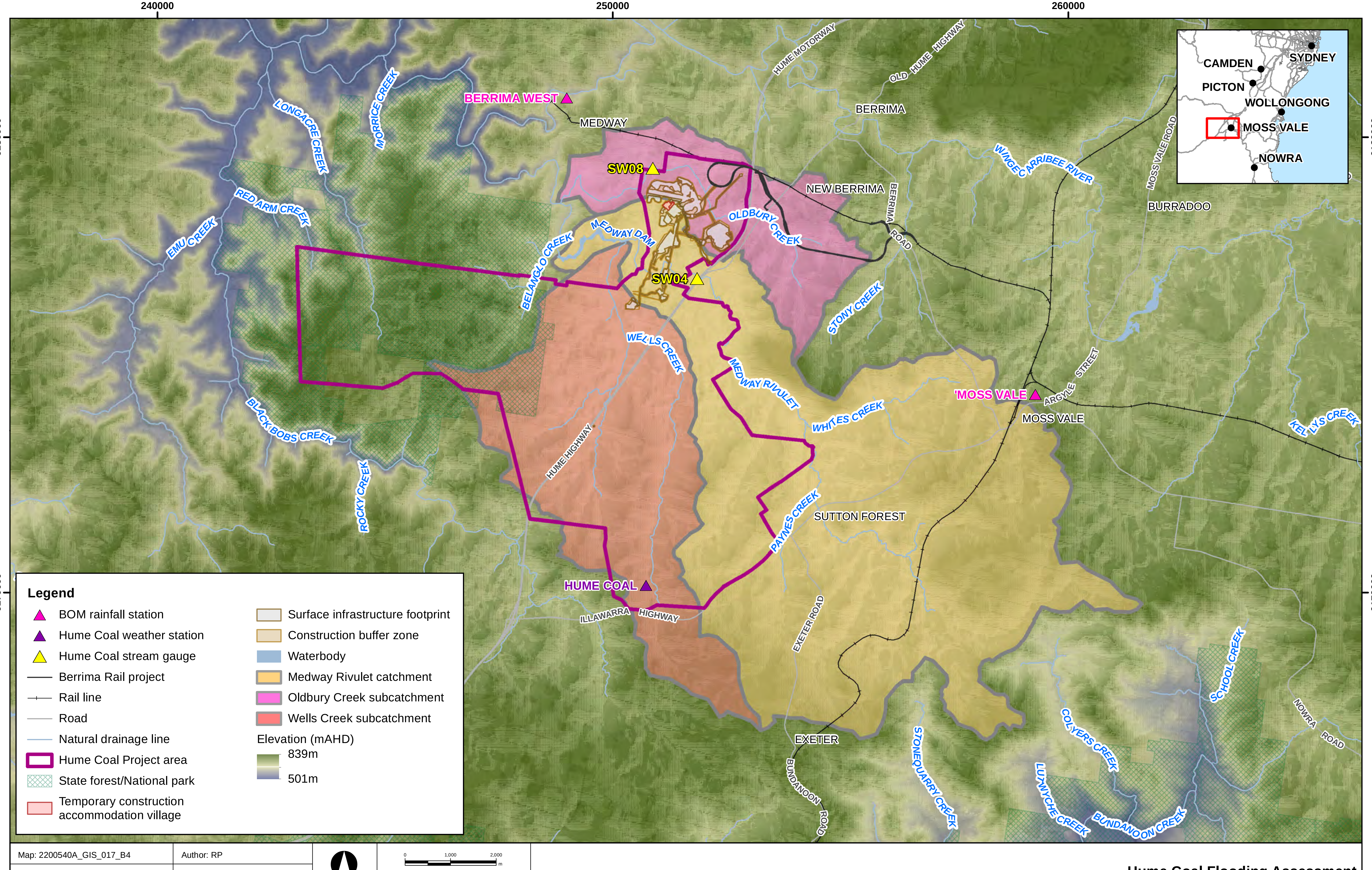
3.4 Rainfall data

The rainfall data used in the flooding assessment was collected from BOM rainfall stations in the vicinity of the study and the Hume Coal weather station installed in the project area in February 2012. The locations of the stations are shown on Figure 3.1 while details of each are provided in Table 3.6.

Table 3.6 Summary of rainfall stations

Station	Station number	Easting	Northing	Elevation (mAHD)	Period of record#	Data frequency
Moss Vale (BOM)	68045	259560.3	6174849	675	1870 – 2015	Daily
Berrima West (BOM)	68186	251120.2	6181286.9	655	1970 - 2015	Daily
Hume Coal	n/a	250727	6170163	675	2012 – 2015	10 minute

All weather stations have some data gaps, however data is available each month in each year



Map: 2200540A_GIS_017_B4
Author: RP
Date: 25/10/2016
Approved by: LR

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Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A3

Data source: © Land and Property Information 2015, Hume Coal

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Figure 3.1
Rainfall stations and stream gauge locations

The nearest BOM weather station to the surface infrastructure area is the station at Berrima West (68186). Daily rainfall data collected at this station for the baseline monitoring period from 2013 to 2015 is presented in Figure 3.2. Peak rainfall events during the baseline monitoring period occurred on:

- 26 June 2013
- 8 August 2014
- 7 December 2014
- 5 January 2015
- 25 August 2015.

The largest event occurred on 25 August 2015. Data from the Hume Coal MET01 station for this event was used for calibration of the hydrologic models for Medway Rivulet and Oldbury Creek. IFD rainfall data (refer Section 3.2) was used to identify the duration and ARI of the August 2015 rainfall event. Given the Berrima West rainfall station only records daily totals, analysis of 10 minute rainfall data from the Hume Coal weather station MET01 was carried out instead and concluded the August 2015 event was approximately a 1 year ARI 2 hour storm event.

Ideally for calibration, a larger event is preferred given the hydrologic models are simulating storm events up to the 100 year ARI. Data from local rainfall stations and flow gauges on the Wingecarribee River with a longer period of record were reviewed to assess whether a relationship could be established between the flow gauge on the Wingecarribee River, flow gauge SW04 on Medway Rivulet and local rainfall stations with sub-daily rainfall data. There were no rainfall stations with sub-daily data within 20 km of SW04 recording rainfall data before the year 2000. The rainfall depth recorded in the August 2015 event was similar to the depth of other major storm events in the early 2000's, and therefore the August 2015 event was considered to be a representative major storm event in the recent flood history for calibration.

The Hume Coal MET01 weather station was selected for calibration as it recorded sub-daily rainfall data during the August 2015 event. The station is located within the Wells Creek catchment (a tributary of Medway Rivulet) approximately 4km south west of the centroid of the Medway Rivulet catchment and approximately 9km south west of the centroid of the Oldbury Creek catchment (refer to Figure 3.1). Given its proximity to the Medway Rivulet catchment the temporal pattern of the rainfall at MET01 was assumed to be an accurate representation of the rainfall that would fall on the Medway Rivulet catchment and at SW04.

The Berrima West station (68186) is the closest weather station to the Oldbury Creek catchment. Comparison of rainfall at the Berrima West station to rainfall at the Hume Coal MET01 weather station indicated that rainfall at the Hume Coal station is higher than at Berrima West. The total rainfall for each day during the August 2015 storm event at the Hume Coal MET01 station was therefore factored down accordingly for the purpose of developing a calibration rainfall dataset for Oldbury Creek. The adjustment factor was determined by comparing total daily rainfall at the Berrima West station with total daily rainfall at the Hume Coal station during the August 2015 event (Table 3.5).

Table 3.7 Total daily rainfall at the Berrima West and Hume Coal rainfall stations

Date	Berrima West 68186	Hume Coal MET01 station
24/08/2015 9:00am	1.2	0.1
25/08/2015 9:00am	52.2	78.8
26/08/2015 9:00am	96.2	200.6
27/08/2015 9:00am	9.6	0.0
Total	159.2	279.5
Factor	**0.57**	

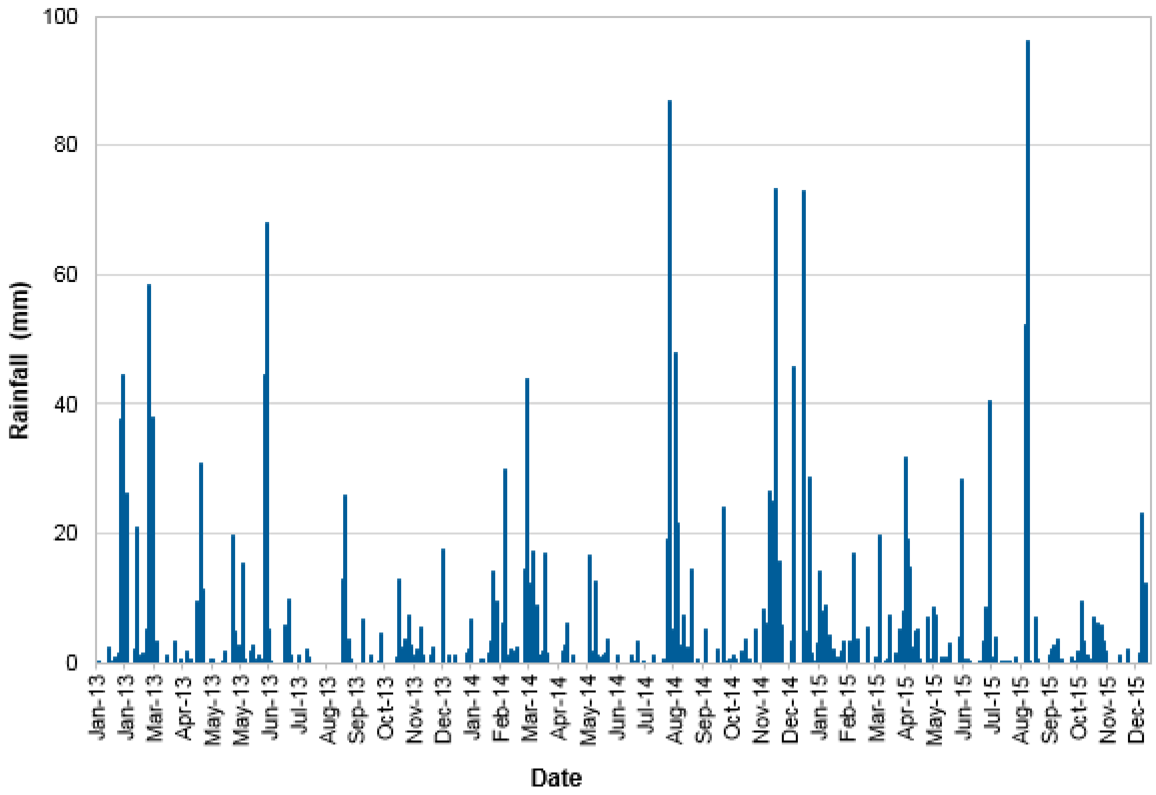


Figure 3.2 Daily rainfall at the Berrima West weather station (2013 - 2015)

The highest daily rainfall data in each month for the baseline monitoring period (2013 – 2015) at the BOM station at Berrima West (68186) was compared against the data for the period of record (1970 – 2015) as well as data for the period of record (1870 – 2015) at the BOM rainfall station at Moss Vale (68045) (Figure 3.3). The comparison indicates that the highest daily rainfall in each month has been lower during the baseline monitoring period.

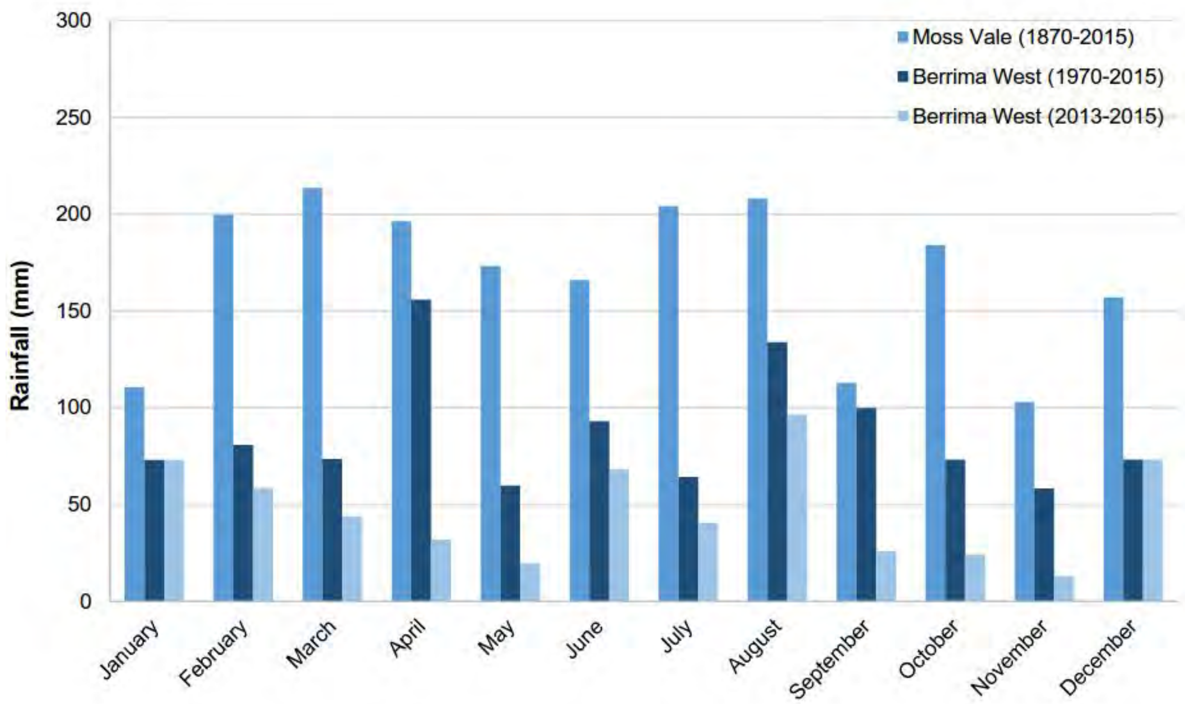


Figure 3.3 Highest daily rainfall in each month

3.5 Streamflow

A dedicated surface water monitoring network was installed by Hume Coal to provide baseline data for the project. The network includes 11 operational stream gauges installed by Xylem and MHL. Details of the stream gauge network are provided in the project's Water Fieldwork and Monitoring Report (Parsons Brinckerhoff 2016).

The streamflow data used in the flooding assessment for hydrologic model calibration was collected from the stream gauges located closest to the proposed surface infrastructure as shown on Figure 3.1 and in Table 3.8.

Table 3.8 Stream gauges

Location	Stream gauge ID	Easting	Northing	Elevation of cease to flow (mAHD)	Data available for this assessment	Data frequency
Medway Rivulet at Hume Highway	SW04	251847	6176898	627.451	21/01/2012* – 30/09/2016	15 minute
Oldbury Creek	SW08	250876	6179319	627.074	14/05/2015* – 30/09/2016	15 minute

* Date monitoring at this stream gauge commenced

Water level data collected at SW04 and SW08 during the August 2015 event was converted to flow data using rating curves (Figure 3.4 and Figure 3.5) generated using the HEC-RAS models for the Medway Rivulet and Oldbury Creek catchments (refer Section 5).

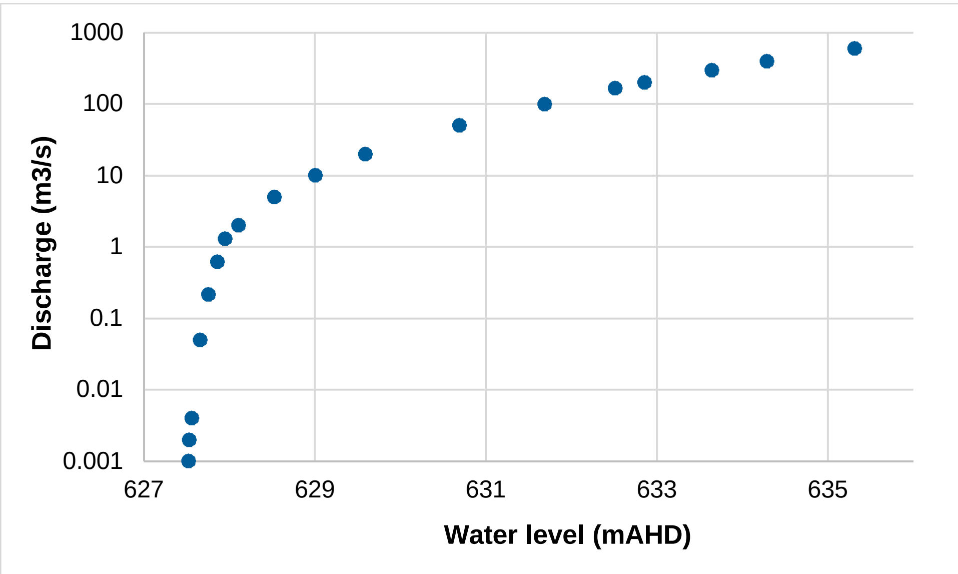


Figure 3.4 SW04 rating curve

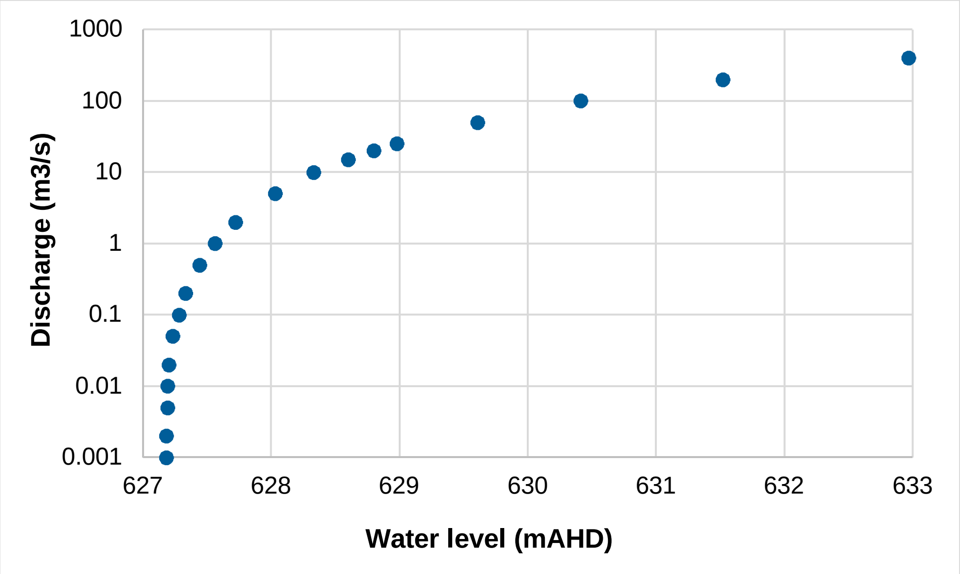


Figure 3.5 SW08 rating curve

Figure 3.6 and Figure 3.7 present streamflow data for SW04 and SW08 respectively. The hydrographs show that both streams are ephemeral waterways.

Flow events exceeding 50 m^3/s at SW04 on Medway Rivulet have been recorded during the baseline monitoring period on the following days:

- 24 February 2013
- 26 June 2013
- 26 August 2014
- 22 April 2015
- 28 August 2015.

The largest event occurred on 25 August 2015 and data from this event (along with rainfall data – refer Section 3.4) was used to calibrate the hydrologic models for Medway Rivulet and Oldbury Creek.

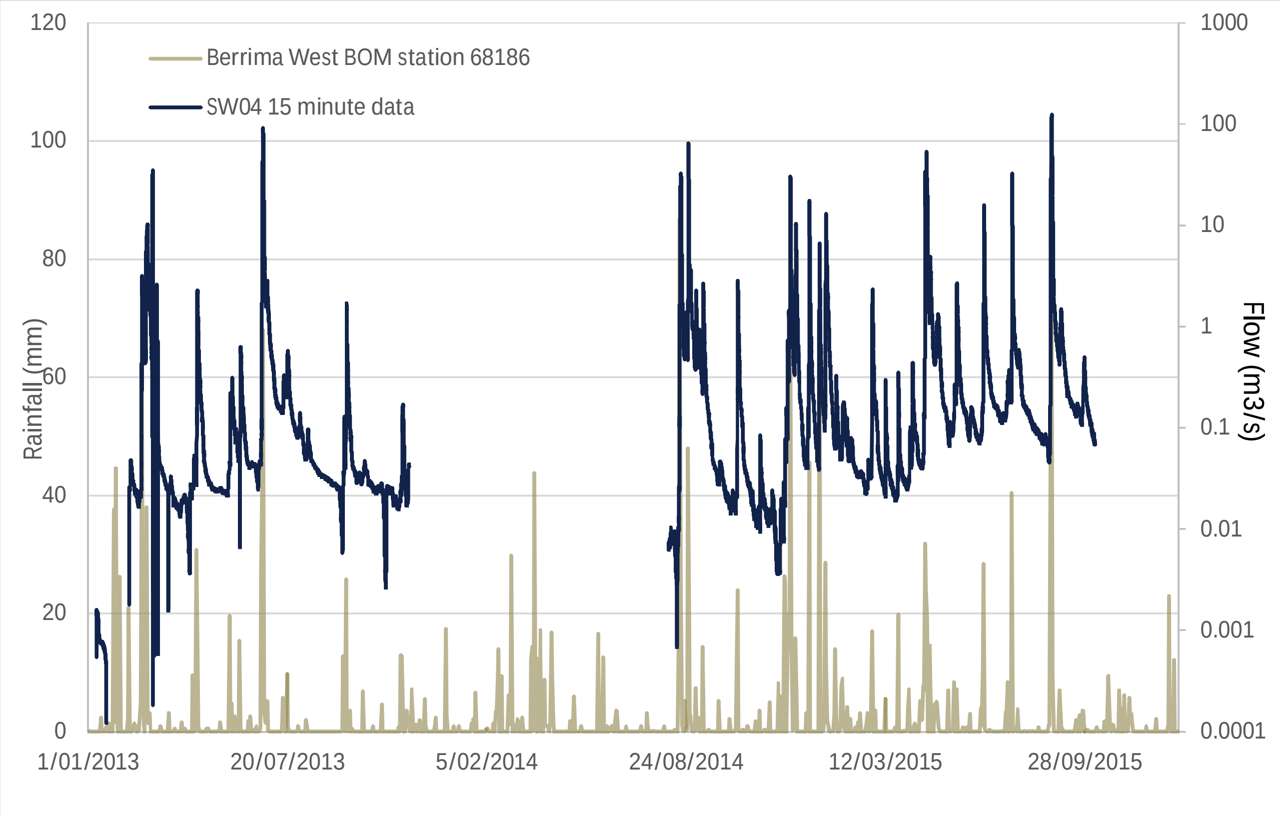


Figure 3.6 Streamflow at SW04

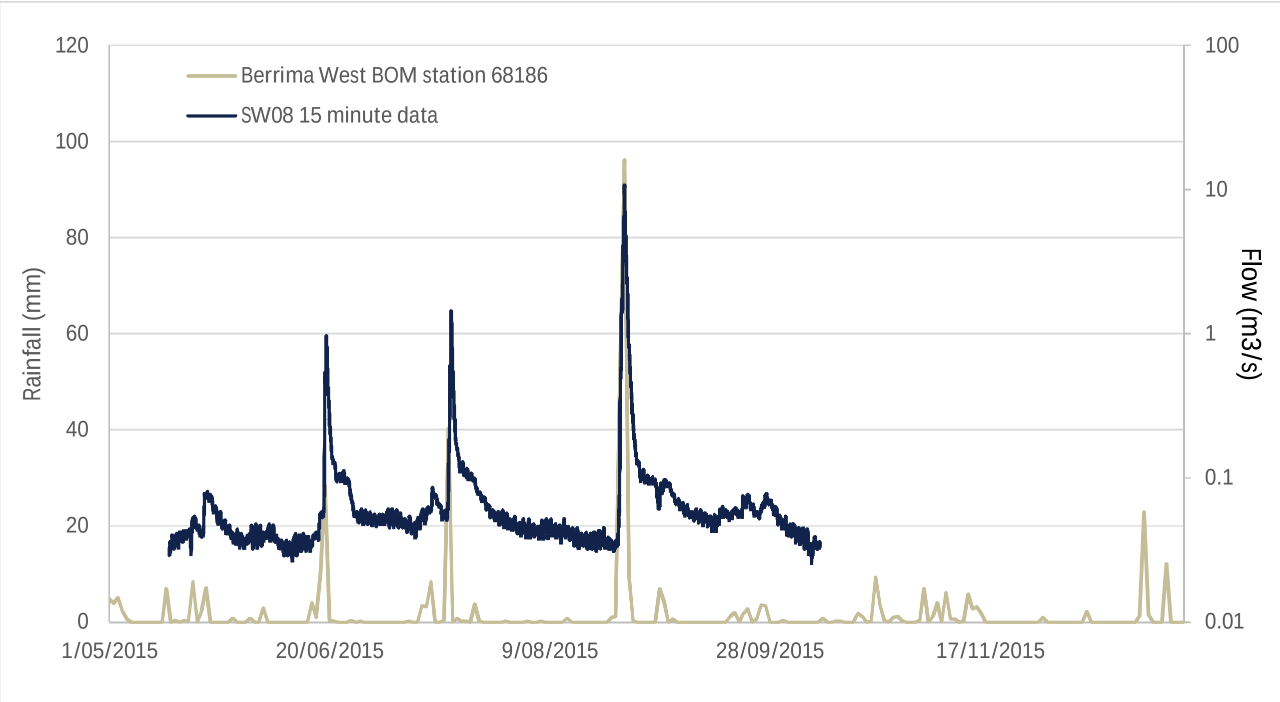


Figure 3.7 Streamflow at SW08

4. Hydrologic analysis

Hydrologic modelling is the process of determining runoff generated from rainfall on a catchment. The runoff estimates are then used by the hydraulic analysis, as described in Section 5. Factors affecting the volume and peak of runoff generated include:

- size and slope of the catchment and adjoining channels;
- level of development (fraction impervious) and type of catchment land use;
- condition of the catchment (dry or saturated) when the rainfall starts;
- intensity and temporal pattern of rainfall; and
- ability of the catchment and other features to store runoff.

Simple analytical methods exist for estimating the amount of runoff from a catchment (i.e. peak flow methods like the Probabilistic Rational Method [PRM]). However, a rainfall-runoff model is necessary to allow more accurate prediction of the response of large and complex catchments to rainfall over time, and the interaction between sub-catchments. For this assessment, hydrologic models of the Medway Rivulet and Oldbury Creek catchments were developed using the XP-RAFTS software program.

XP-RAFTS has been used extensively across NSW for urban and rural flood investigations. XP-RAFTS is an event-based hydrologic model that calculates flood hydrographs from either recorded storm rainfall hyetographs or design storm rainfall parameters. The catchment is represented in the model as a series of sub-catchments for which factors affecting runoff, such as land use (proportion of pervious versus impervious land surfaces), rainfall losses, and runoff routing through the catchment and channels, are defined.

Details of how XP-RAFTS was used to represent the Medway Rivulet and Oldbury Creek catchments are provided below. The models of the Medway Rivulet and Oldbury Creek catchments developed for this study were used to estimate flow generated from the catchment for the 5 year ARI, 20 year ARI, 100 year ARI and PMF design storm events to represent a reasonable range of extreme event flood conditions. The models estimated flow for the following scenarios:

- The existing scenario, which represents the current state of the Medway Rivulet and Oldbury Creek catchments based on LiDAR data collected on 25 October 2013.
- The operational scenario, which incorporates the proposed surface infrastructure for the mine and associated mitigation measures. DWG files of the proposed surface infrastructure were merged with LiDAR data to create the landform to be modelled.
- The rehabilitation scenario, which is the final landform at completion of the project. DWG files of the final landform were merged with LiDAR data to create the landform to be modelled.

Calibration was undertaken using the rainfall and streamflow data discussed in Section 3, and the results are provided in Section 4.2.

4.1 Model set up

4.1.1 Catchment area

The Medway Rivulet catchment was divided into 19 sub-catchments (refer Figure 4.1) and the Oldbury Creek catchment was divided into 15 sub-catchments (refer Figure 4.2) for greater definition of catchment parameters within the XP-RAFTS models. For the Medway Rivulet model, a lumped inflow from the Wells Creek catchment was included in the model for the purposes of setting downstream boundary water levels.

Catchment parameters for the existing scenario, including sub-catchment area, percentage imperviousness, sub-catchment links and channel definition, were defined using the project LiDAR data and a review of aerial photography of the area. Operational 3D drawings and plans were used for the operational scenario and final landform 3D drawings and plans were used for the final landform scenario along with LiDAR and aerial photography.

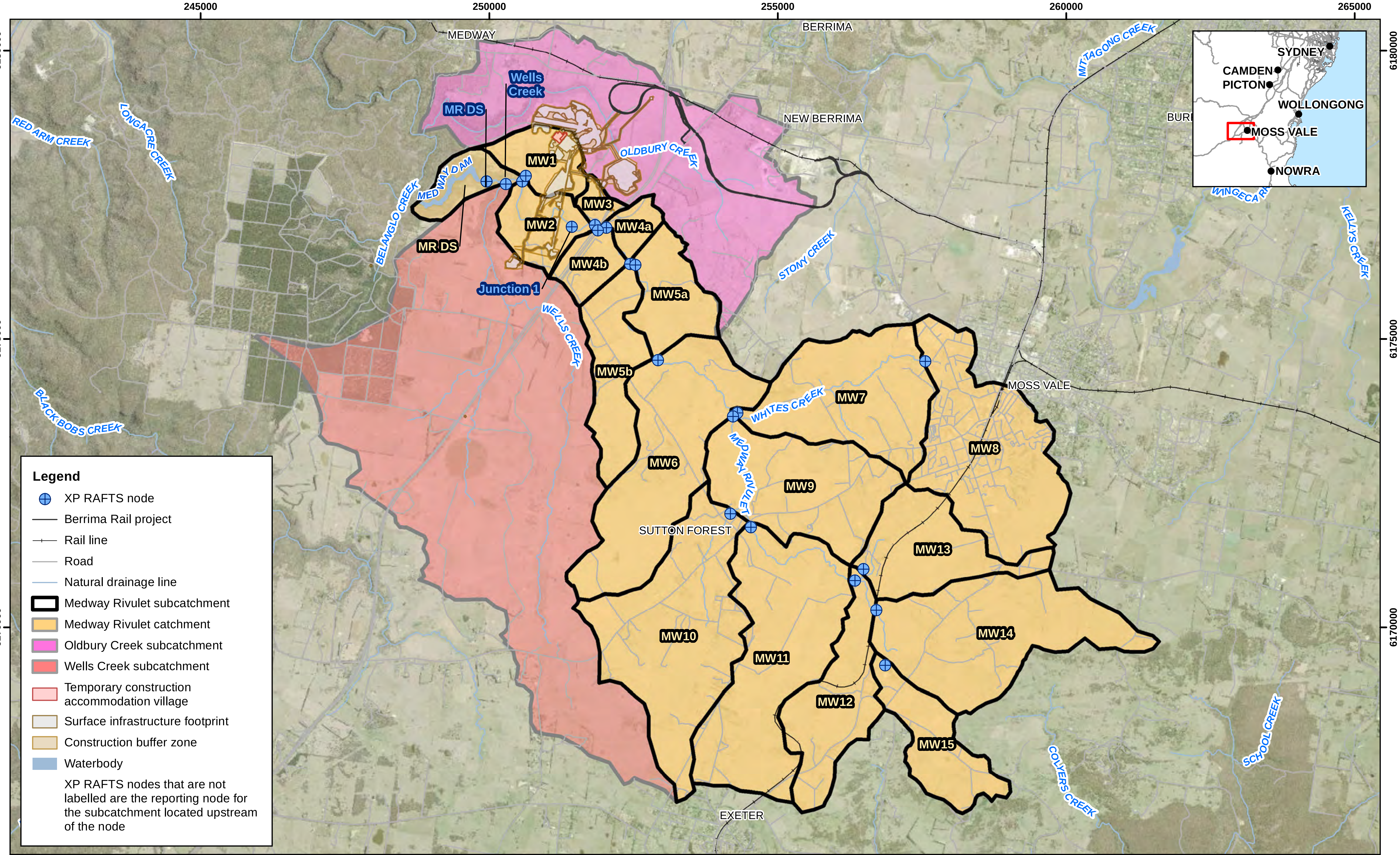
Catchment parameters adopted in the model are provided in Appendix C. The catchment parameters for the existing and final landform cases are the same. Catchment parameters, such as percent impervious and catchment area (excluding areas referring to stormwater basins and mine water dams), were varied for the operation case in sub-catchments MW1, MW2, OC6, OC7, OC8 and SW08 where the proposed infrastructure is to be located.

4.1.2 Model parameters

Initial loss and continuing loss refer to rainfall loss parameters which are input to the hydrologic model. Initially, rainfall losses adopted were in line with standard values; 2.5 mm/hr continuing loss rate and 20 mm initial loss.

The storage delay coefficient is another hydrologic model input parameter and was calculated for each sub-catchment using the average vectored slope of the catchment together with catchment area, percentage impervious, Manning's *n* value, loss rates and rainfall data. The average vectored slope of each sub-catchment was measured using the DTM.

Translation, or lagging of the hydrograph was applied to links within the models to represent the routing of flow through the stream network. The lag times were estimated by dividing the channel length (measured using the DTM) by an estimated channel velocity based on the slope of the channel (measured using the DTM) and corresponding approximate velocity in AR&R (Engineers Australia 2001).



Map: 2200540A_GIS_023_B4	Author: RP
Date: 25/10/2016	Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal

0 1,000 2,000 m

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

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Figure 4.1
XP-RAFTS model layout - Medway Rivulet

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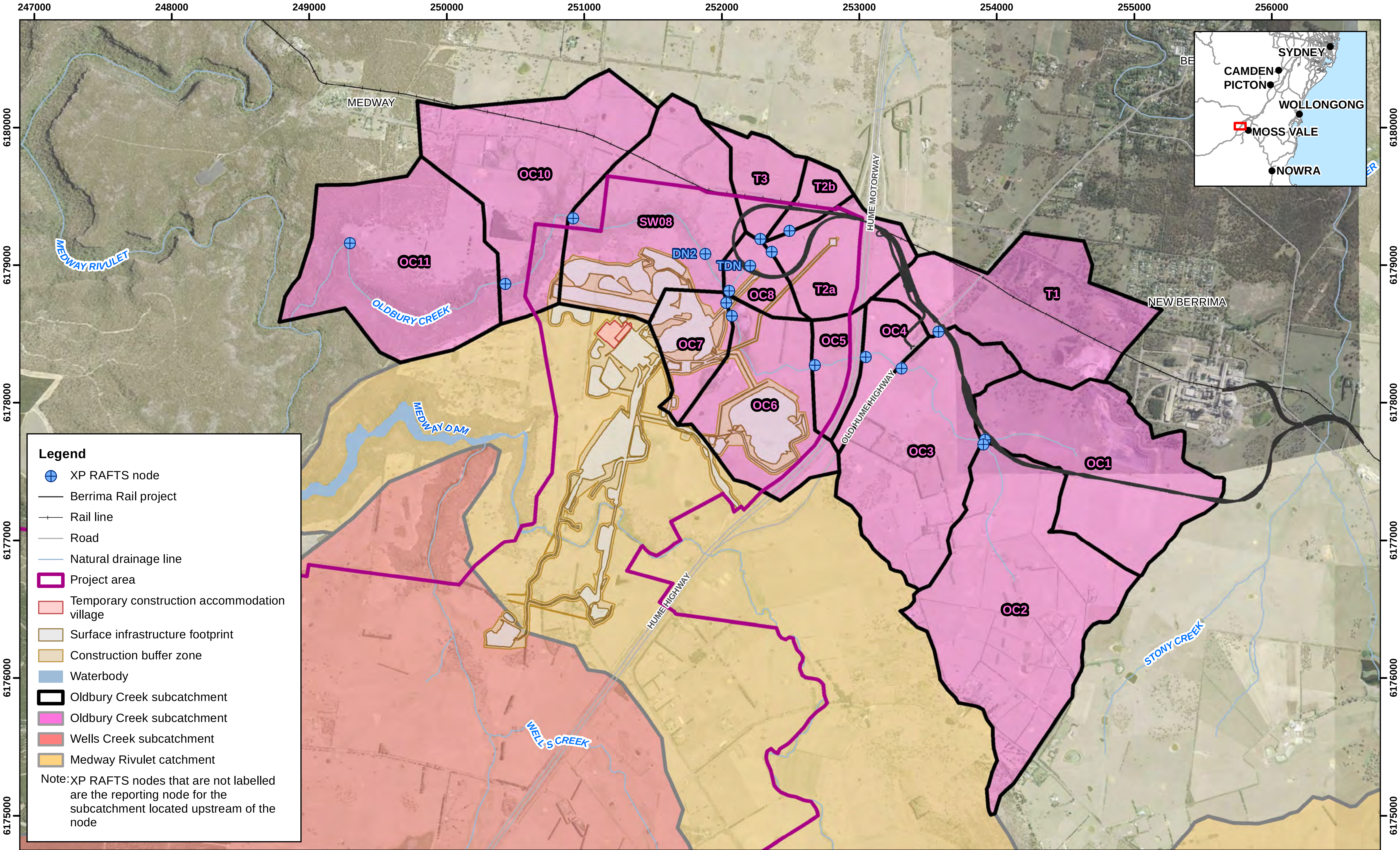

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Figure 4.2

XP-RAFTS model layout - Oldbury Creek

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4.1.3 Estimation of design rainfall

Design rainfall hyetographs for storm events up to the 100 year ARI were generated in XP-RAFTS using the IFDs (refer Section 3.2).

4.1.4 Probable maximum precipitation design rainfall

The parameters used in the PMP calculation for Medway Rivulet and Oldbury Creek are provided in Table 3.4 and the PMP rainfall depths are provided in Table 3.5. PMP rainfall depths were distributed into hyetographs using the GSDM temporal pattern for the 15 minute to 6 hour and the GSAM temporal pattern for the 24 hour to 96 hour events. The GSDM temporal pattern was used for the 12 hour event. These rainfall hyetographs were used as input to the XP-RAFTS models for the PMP rainfall event.

4.2 Model Calibration

Initial and continuing rainfall losses and B factor were adjusted within reasonable ranges based on values within AR&R (Engineers Australia 2001) until model calibration was achieved.

To achieve a reasonable calibration a B factor of 2.8 and initial loss of 20mm and continuing loss rate of 3.7 mm/hr were adopted for Medway Rivulet. For Oldbury Creek a B factor of 1.0 and initial loss of 20mm and continuing loss rate of 3.7 mm/hr were adopted.

The results from the calibration are presented in Figures 4.3 and 4.4. The results show that the models achieved a good predictive estimate of the observed event.

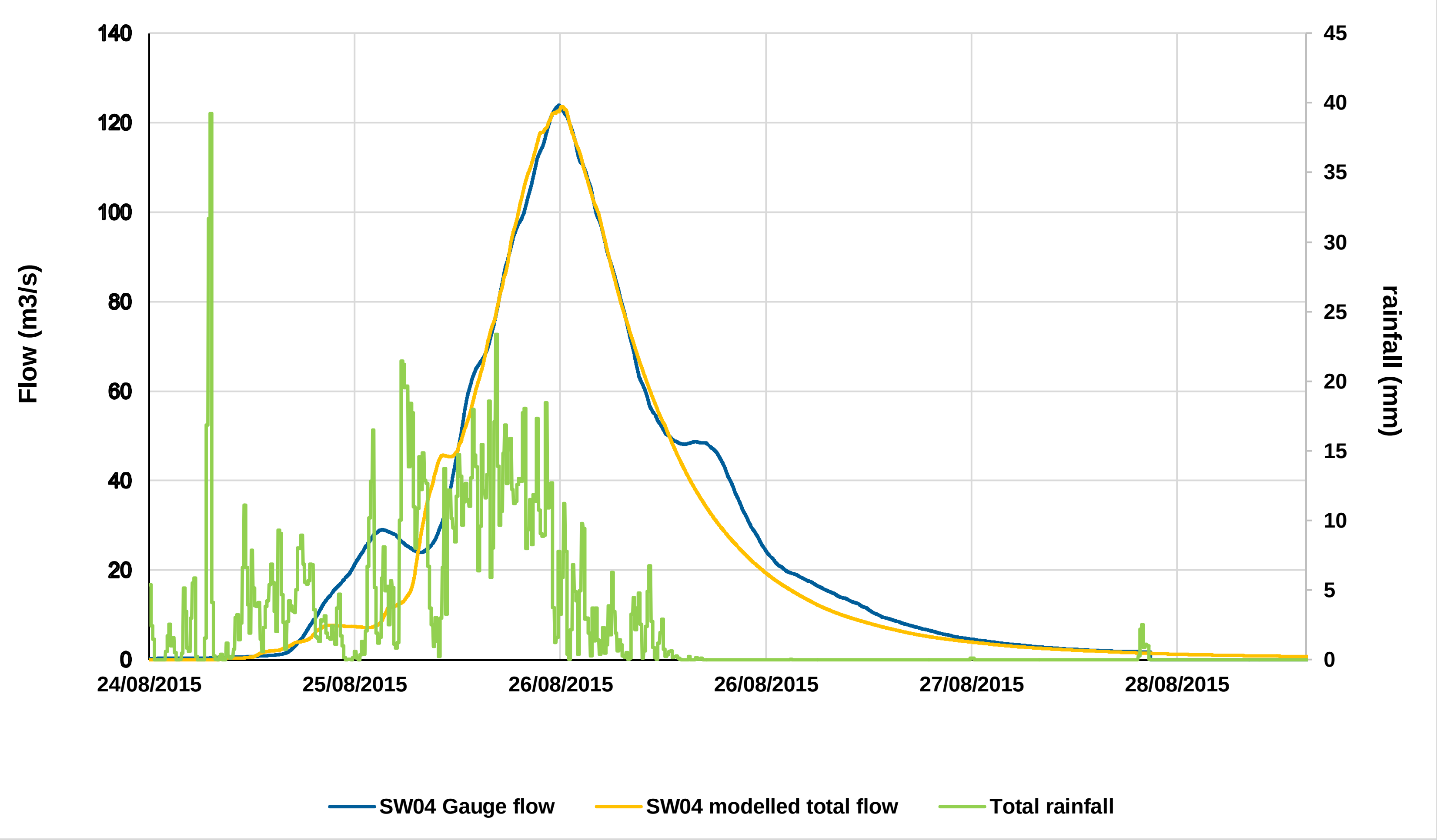


Figure 4.3 **Medway Rivulet XP-RAFTS calibration output**

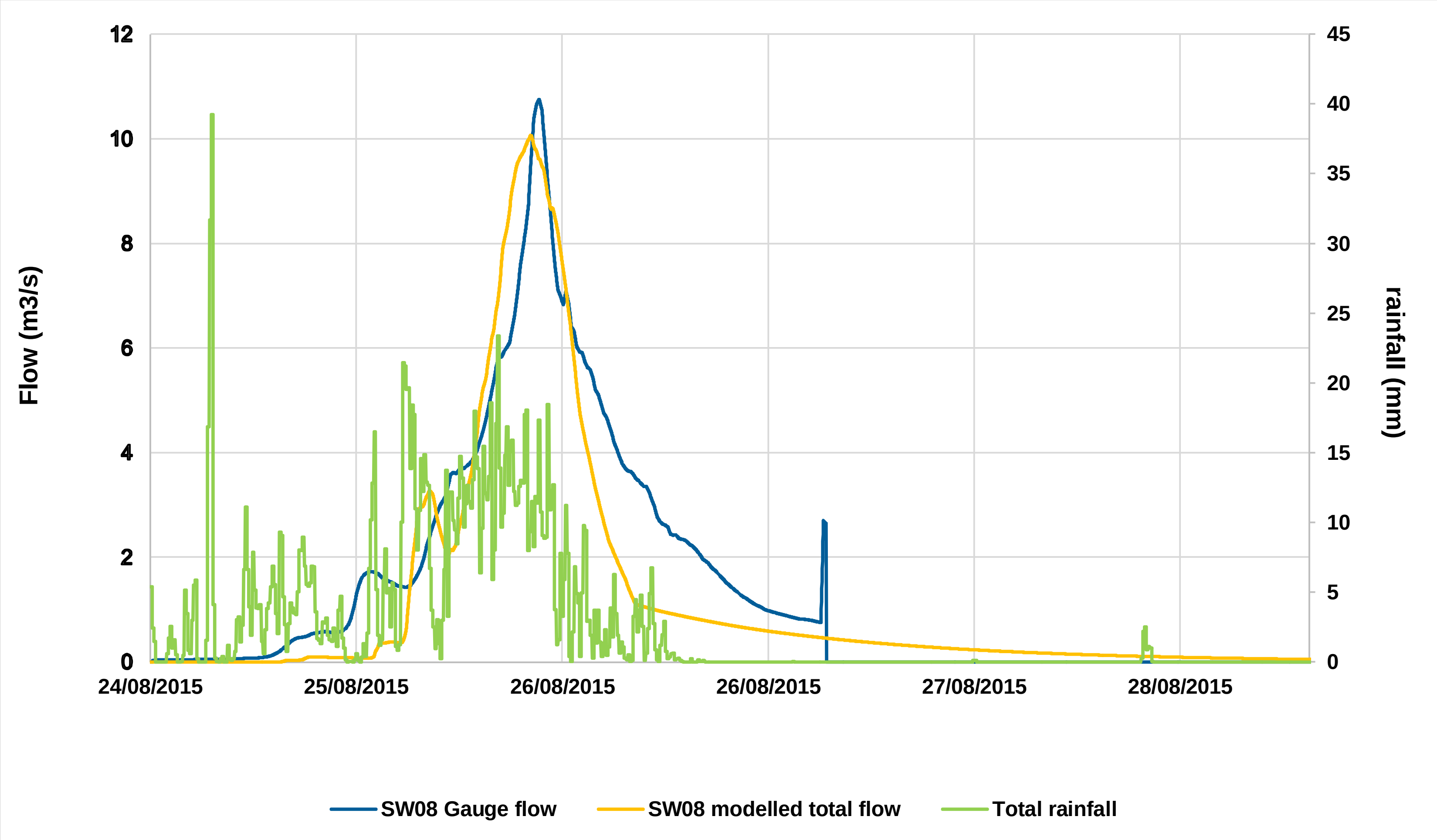


Figure 4.4 Oldbury Creek XP-RAFTS calibration output

4.3 Model check

A check of the hydrologic model was undertaken by comparing the model flow estimates against PRM calculations for the 5 year, 20 year and 100 year ARI events for Medway Rivulet. It was found that the model compared well to the PRM flow estimates for a B factor of 1.0 and did not compare well for the B factor of 2.8 that was used for calibration (Table 4.1).

Table 4.1 Validation of peak flows using PRM

Peak flow event	PRM flow estimates (m^3/s)	RAFTS B factor 2.8		RAFTS B factor 1.0	
		Flow estimates (m^3/s)	Difference to PRM (%)	Flow estimates (m^3/s)	Difference to PRM (%)
100 year ARI	691	287	-58	638	-8
20 year ARI	417	260	-38	443	+6
5 year ARI	259	150	-42	290	+12

4.4 Design event modelling

The rainfall losses used in calibration of the model were adopted for design event modelling. The high B factor used in calibration of the Medway Rivulet model was not adopted for design event modelling as it did not correlate well with the PRM flow estimates. Given that the calibration event was a relatively low order event (estimated to be a 1 year ARI event) there was no justification to adopt the B factor of 2.8 for design events of up to the 100 year ARI event. A B factor of 1.0 was therefore adopted for design event modelling of Medway Rivulet.

The adopted hydrological model parameters for design event modelling are provided in Table 4.2.

Table 4.2 Adopted loss and B factor values

XP-RAFTS input	Medway Rivulet and Oldbury Creek model values
Initial loss* (mm)	20
Continuing loss (mm/hr)	3.7
B factor	1.0
* Initial loss was set to zero in the PMP	

The Medway Rivulet and Oldbury Creek hydrologic models were run for the 5 year, 20 year and 100 year ARIs and the PMP rainfall events for the existing, operation and rehabilitation scenarios. The 5 year, 20 year and 100 year events were run for durations of 15 minutes to 48 hours, and the PMF event was run for durations up to 96 hours, in order to determine the critical duration for each event. Peak flows generated within the Medway Rivulet and Oldbury Creek catchments that are input to the hydraulic model are presented in Tables 4.3 and 4.4 along with the critical duration identified for each return period. Results indicate that the PMP critical duration for the Medway Rivulet catchment was the 4 hour event and for Oldbury Creek was the 2.5 hour event.

Table 4.3 Design peak flow results – Medway Rivulet

Model node	Peak flow (m^3/s)							
	Existing and rehabilitation cases				Operational case			
	5 year ARI (36 hr)	20 year ARI (36 hr)	100 year ARI (9 hr)	PMF (4 hr)	5 year ARI (36 hr)	20 year ARI (36 hr)	100 year ARI (9 hr)	PMF (4 hr)
MW6	157.6	239.5	367.1	1,612.0	157.6	239.5	367.1	1,612.0
Junction 1	175.8	268.3	411.9	1,771.3	175.8	268.3	411.9	1,771.3
MW1 local + US flow (half MW2 local + Junction1 total)*	184.2	280.7	433.0	1,853.0	183.7	279.7	432.0	1,851.8
MW2 total	266.3	406.1	584.4	2,407.7	265.8	405.1	583.0	2,399.9
MW3	1.7	2.5	5.1	16.1	1.7	2.5	5.1	16.1
MW1	6.1	8.9	15.9	57.4	5.5	7.9	14.6	57.4
Wells Creek	97.6	146.1	243.6	1,002.6	97.6	146.1	243.6	1,002.6
MW2 local	4.7	7.1	10.4	48.5	4.7	7.1	10.9	46.0

Notes:
The table only shows model node flows (or combinations of flows) that are input to the hydraulic model.
**This combination of flows is calculated to provide flow input to the hydraulic model at this location.*
Local flow from a model node is the flow from the sub-catchment represented by that node; total flow at a model node is the cumulative flow from all upstream sub-catchments to that node.

Table 4.4 Design peak flow results – Oldbury Creek

Model node	Peak flow (m^3/s)							
	Existing and rehabilitation cases				Operation case			
	5 year ARI (9 hr)	20 year ARI (9 hr)	100 year ARI (9 hr)	PMF (2.5 hr)	5 year ARI (9 hr)	20 year ARI (9 hr)	100 year ARI (9 hr)	PMF (2.5 hr)
OC2	9.3	14.2	19.6	166.1	9.3	14.2	19.6	166.1
T3	2.0	2.7	3.6	26.8	2.0	2.7	3.6	26.8
OC1	6.9	10.2	13.9	113.9	6.9	10.2	13.9	113.9
OC4	28.6	42.3	57.2	484.6	28.6	42.3	57.2	484.6
DN2	29.3	50.5	73.9	671.4	27.4	47.9	70.1	641.8
SW08	32.9	56.8	83.2	753.9	30.2	52.8	77.2	707.1
T2a	3.2	4.6	6.1	49.4	3.2	4.6	6.1	49.4
TDN	6.1	8.6	11.3	88.8	6.1	8.6	11.3	88.8
OC8	7.3	10.5	13.7	107.1	7.4	10.5	13.7	107.0
T2b	1.0	1.4	1.9	13.7	1.0	1.4	1.9	13.7
T1	5.1	7.7	10.3	86.3	5.1	7.7	10.3	86.3
OC7	2.3	3.3	4.3	33.6	1.2	1.6	2.1	16.1

Notes:
The table only shows model node flows that are input to the hydraulic model.

5. Hydraulic analysis

HEC-RAS hydraulic models were developed for Medway Rivulet, Oldbury Creek and their tributaries to assess extreme flood levels in the project area. This section describes the set-up of the hydraulic model and the key parameters specified in the model. The results from the hydraulic analysis are presented in Section 6.

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.

5.1 Cross-section geometry

A DTM covering the extent of the hydraulic models was constructed using LiDAR data from 25 October 2013 (see Section 3.1).

Cross-sections of the river channel and floodplain were extracted from the DTM approximately every 100 m along the length of Medway Rivulet and Oldbury Creek and minor tributaries. Cross-sections were added to locations where there is hydraulic constraint, such as road crossings, to ensure all topographical features critical to hydraulic conveyance characteristics of the waterways are captured in the model. Cross-sections varied in length from about 300 m to 1500 m depending on the depth and size of the channel and width of floodplain. Junctions were modelled where tributaries join main channels and equal water levels were assumed across the junctions. Figures 5.1 and 5.2 show the modelled reaches and cross-sections.

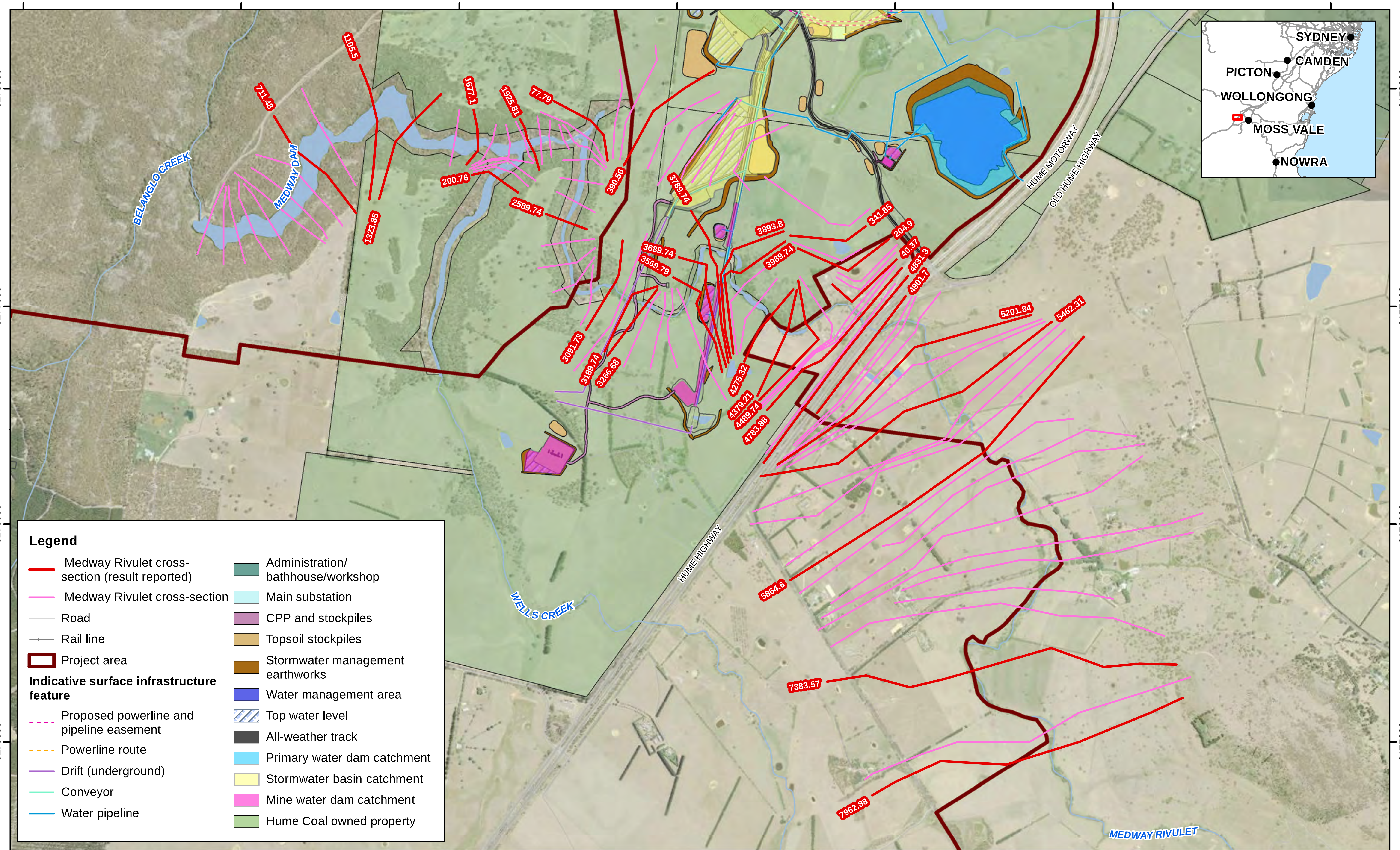
Detailed cross-sections at stream gauge SW04 were surveyed by Xylem in 2013 and MHL in 2015. Cross-sections at stream gauge SW08 were surveyed by MHL in 2015. Cross-section surveys were undertaken at the control and at the pool where the gauge is located. These cross-section surveys aim to measure low to medium flow, so their applicability to flood modelling is limited. However, the cross-sections at each of the surface water gauge locations were added into the HEC-RAS models to add more detail to the model for the development of rating curves and calibration of the hydrologic model (refer Section 3.5).

5.2 Boundary conditions

Inflows were assigned to reaches of the hydraulic model for each stream/tributary, based on the flow outputs of the hydrologic model (refer Tables 4.3 and 4.4).

The downstream limit of the hydraulic model for Medway Rivulet is located downstream of Medway Dam. The model was run using a normal depth boundary based on a downstream channel slope of 0.8%, determined using the DTM. Since the 25 m high spillway and dam wall of Medway Dam is the hydraulic control of the water level upstream of the dam, the hydraulic model is not sensitive to the downstream boundary conditions assumption.

A normal depth boundary condition was applied at the downstream end of the Oldbury Creek model at a location sufficiently far downstream of the study area so that the effect of hydraulic change is fully realised within the modelled extent. A channel slope of 0.07% was determined using the DTM.



Map: 2200540A_GIS_021_B4

Author: RP

Date: 24/10/2016

Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal

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Coordinate system: GDA 1994 MGA Zone 56

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Hume Coal Flooding Assessment

Figure 5.1

Medway Rivulet cross-sections

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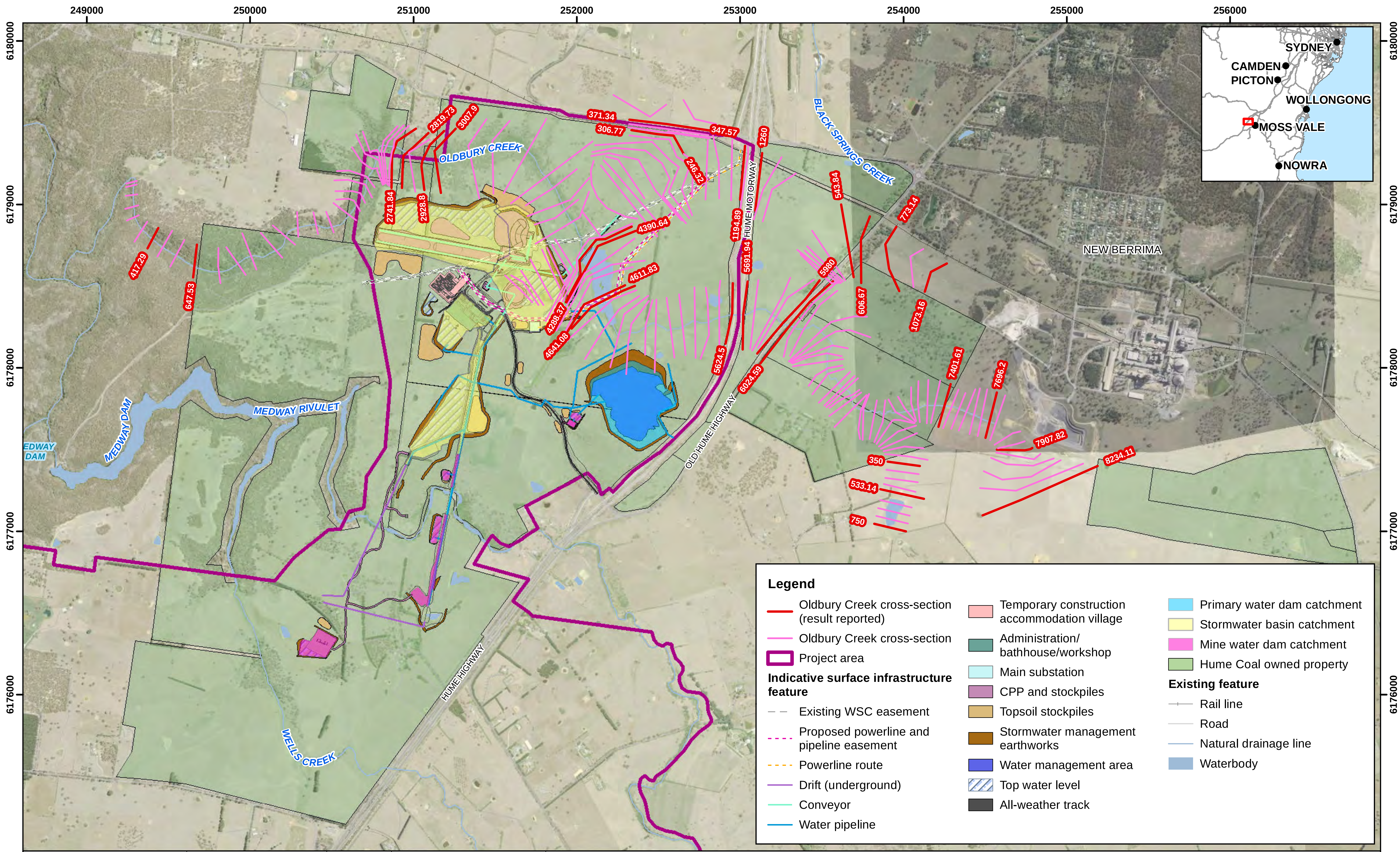

Map: 2200540A_GIS_022_B4

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Hume Coal Flooding Assessment
Figure 5.2
Oldbury Creek cross-sections

5.3 Hydraulic roughness

Manning's *n* roughness parameters are used to represent the type of channel and varying land cover across a floodplain to allow the model to simulate changes in flow behaviour as water crosses different surfaces. Each cross-section is assigned Manning's *n* roughness values based on the channel characteristics and land cover across the floodplain. The Manning's *n* values adopted for the modelled channels and overbank sections were based on knowledge of the site developed during site inspections, aerial photograph interpretation and engineering judgement and experience.

The predominant Manning's *n* values adopted in the Medway Rivulet and Oldbury Creek hydraulic models for the channel and overbank areas are given in Table 5.1. In some sections more vegetation / trees were evident in the channel when compared to the cleared agricultural land in the adjacent overbank areas and in these cases the Manning's *n* value was set higher in the creek channel than in the overbank.

Table 5.1 Manning's n values used in HEC-RAS models

Location	Description	Manning's *n*
In channel	Eroded gully	0.035
	Grassed channel, clean and straight	0.035-0.04
	Grassed channel with some pools and shoals	0.04
	Channel with some vegetation	0.05
	Densely vegetated with deep pools	0.08
Overbank areas	Short grass	0.035
	Mature crop field	0.04
	Light bush and trees	0.05
	Dense vegetation/ trees	0.10

5.4 Modelled scenarios

The Medway Rivulet and Oldbury Creek models were run for the 2 year, 5 year, 100 year ARI and PMF events for the existing, operation and rehabilitation scenarios detailed in Section 4.

The surface infrastructure will generally remain the same throughout mine operation. A layout with the maximum footprint and elevation has been considered for the purposes of assessing potential worst case flooding impacts.

Flood modelling has not been undertaken for the construction phase as the layout of temporary construction facilities will generally match the surface infrastructure layout used during operations. The temporary accommodation village is proposed only during the construction phase of the project and will not be used during the operation phase. The temporary village has not been assessed as it will be located on a ridge immediately to the south of the CPP precinct and will not impact on flooding regimes in Medway Rivulet.

5.5 Modelled structures

5.5.1 Existing structures

The HEC-RAS model for Medway Rivulet included the following existing structures:

- Medway Dam, located on Medway Rivulet downstream of the surface infrastructure area
- The ‘Three Legs O’Man Bridge’ located where the Hume Highway crosses Medway Rivulet upstream of the surface infrastructure area.

The HEC-RAS model for Oldbury Creek included the following existing structures:

- the two inline storages and associated embankments on Oldbury Creek downstream of the proposed rail infrastructure
- the box culverts located where the Hume Highway crosses Oldbury Creek downstream of the proposed rail infrastructure
- the plank bridge located where the Old Hume Highway crosses Oldbury Creek downstream of the proposed rail infrastructure
- the culverts located where Medway Road crosses the tributaries of Oldbury Creek north of the proposed rail loop
- the culverts located where the old rail embankment near Medway Road crosses the tributaries of Oldbury Creek north of the proposed rail loop
- the culvert located where the Hume Highway crosses a tributary of Oldbury Creek to the east of the proposed rail loop

Details of these structures are provided in Appendix B.

5.5.2 Proposed structures

The proposed structures associated with the operation scenario are described in Table 5.2. There are no proposed structures for the rehabilitation scenario.

Table 5.2 Proposed structures modelled

Waterway	Crossing type and location	Design option	Proposed structure
Medway Rivulet	Road between the conveyor drift and ventilation shaft	Hume Coal Project	17 x 1800 mm x 1200 mm Reinforced Concrete Box Culvert (RCBC)

6. Hydraulic modelling results and impact assessment

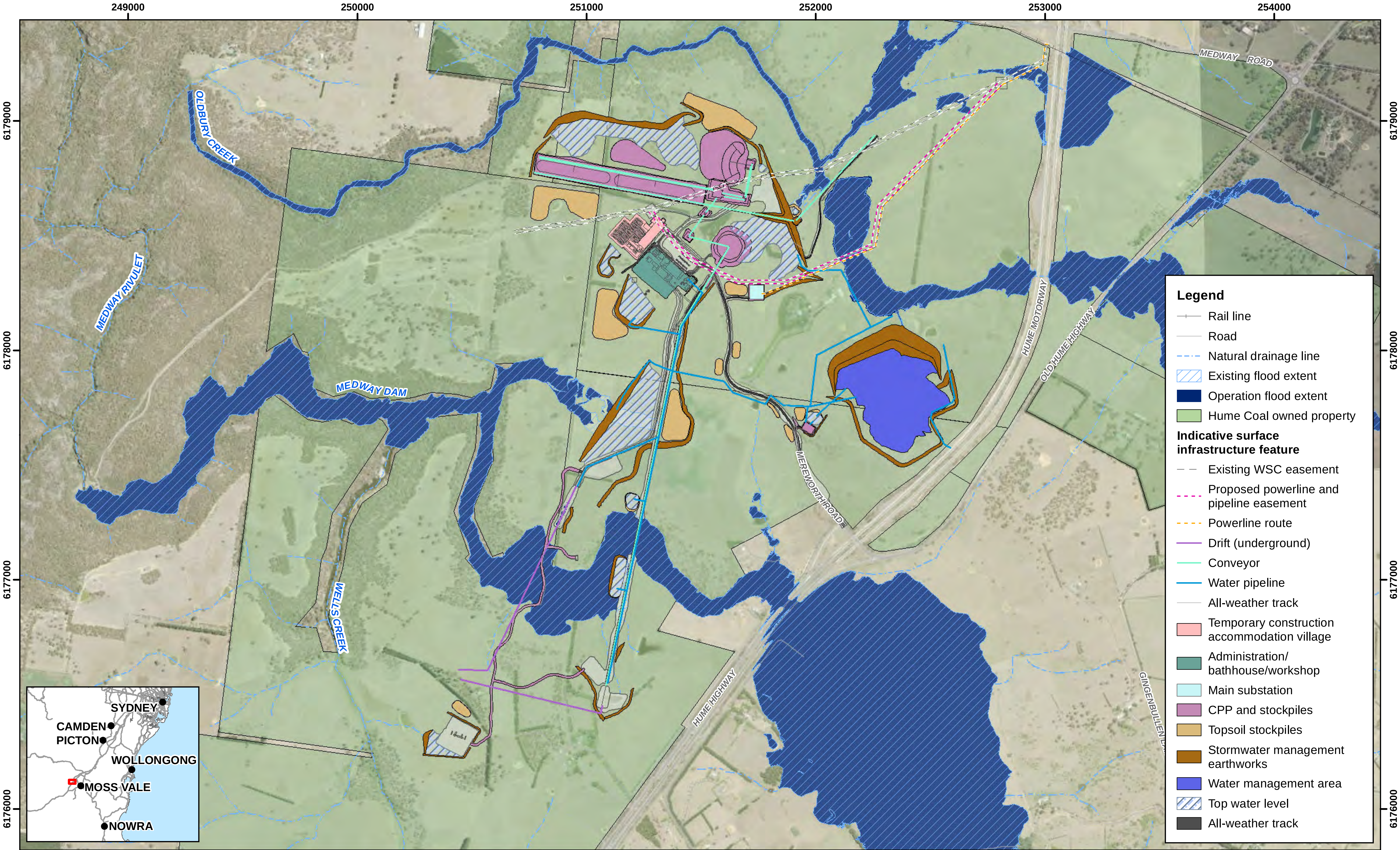
6.1 Hume Coal Project results and impact assessment

6.1.1 Flood extent

Figure 6.1 presents a comparison of the 100 year ARI flood extent for the existing and operation scenarios. Figures comparing the 5 year and 20 year ARI and PMF extents for the existing and operation scenarios are presented in Appendix D.

Figure 6.2 presents a comparison of the 100 year ARI flood extent for the existing and rehabilitation scenarios. Figures comparing the 5 year and 20 year ARI and PMF extents for the existing and rehabilitation scenarios are presented in Appendix E.

Comparison of the 100 year ARI flood extents shows that changes in flood extent during operation of the mine will be minor. Changes in flood extent following rehabilitation of the mine are only predicted in the area where SB02 was located.



Map: 2200540A_GIS_019_B4	Author: RP
Date: 14/11/2016	Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal

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Coordinate system: GDA 1994 MGA Zone 56

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Hume Coal Flooding Assessment

Figure 6.1

100 year ARI flood extent - Operation

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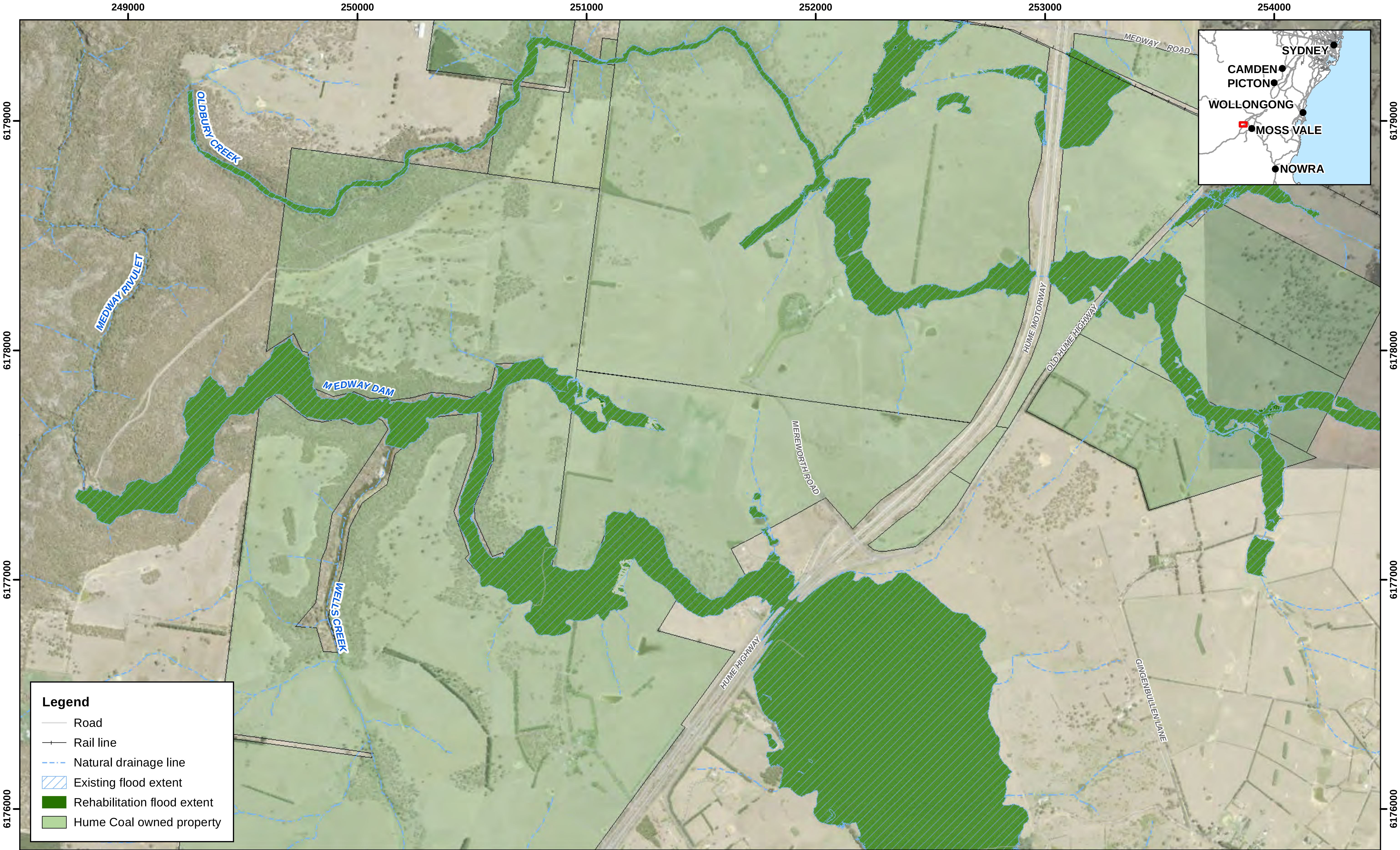

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Hume Coal Flooding Assessment

Figure 6.2

100 year ARI flood extent - Rehabilitation

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6.1.2 Flood levels

Afflux results for the operation and rehabilitation cases for Medway Rivulet and Oldbury Creek are presented in Table 6.1 and Table 6.2 respectively. The results are the difference between the flood levels under the operational or rehabilitation and existing conditions. A positive afflux value indicates an increase in flood level and a negative afflux value indicates a decrease in flood level. During operation, decreases in flood level occur as the project reduces flows to the creeks due to reductions in the undisturbed catchments in areas taken up by the stormwater basins and mine water dams, which are designed to contain runoff and not spill to the receiving environment. Results are presented for the cross-sections shown on Figure 5.1 and Figure 5.2. The result cross-sections target key areas of interest including privately owned land, locations where existing roads cross streams and locations where new infrastructure is proposed to cross streams.

Table 6.1 and Table 6.2 show the afflux is within the proposed acceptability criteria set out in Section 2.2, with the exception of localised afflux values of up to 340mm in Oldbury Creek on land owned by Hume Coal between the PWD and SB02 for the operational case.

For the rehabilitation scenario the impacts on Oldbury Creek are negligible on land outside of Hume Coal's ownership. The impact noted above between the PWD and SB02 occurs over a reduced extent of the creek at the rehabilitation stage but a localised afflux impact of up to 400 mm remains at the downstream embankment of the inline storages on Oldbury Creek.

Table 6.1 Medway Rivulet catchment afflux results

Cross-section number	Stream	Location	Operation				Rehabilitation			
			5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)	5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)
40.37	Tributary OF1	Private land	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
77.79	Tributary OF2	US Medway Dam	0.00	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00
200.76	Wells Creek	US Medway Dam	0.00	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00
204.9	Tributary OF1	Private land	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
341.85	Tributary OF1	Private land	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00
390.56	Tributary OF2	US Medway Dam	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
711.48	Medway Rivulet	Medway Dam	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00
1105.5	Medway Rivulet	Medway Dam	-0.01	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00
1323.85	Medway Rivulet	Medway Dam	0.00	0.00	-0.01	-0.02	0.00	0.00	0.00	0.00
1677.1	Medway Rivulet	Medway Dam	-0.01	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00
1925.81	Medway Rivulet	Medway Dam	0.00	0.00	-0.01	-0.02	0.00	0.00	0.00	0.00
2589.74	Medway Rivulet	Medway Dam	0.00	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00
3091.73	Medway Rivulet	Private land	0.00	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
3189.74	Medway Rivulet	Road crossing	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00
3266.68	Medway Rivulet	Private land	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
3569.79	Medway Rivulet	Private land	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
3689.74	Medway Rivulet	Private land	-0.01	-0.01	-0.01	0.01	0.00	0.00	0.00	0.00
3789.74	Medway Rivulet	Private land	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
3893.8	Medway Rivulet	Conveyor gantry	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00

Cross-section number	Stream	Location	Operation				Rehabilitation			
			5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)	5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)
3989.74	Medway Rivulet	Private land	-0.01	-0.01	-0.01	0.01	0.00	0.00	0.00	0.00
4275.32	Medway Rivulet	Private land	-0.01	-0.01	0.00	0.01	0.00	0.00	0.00	0.00
4379.21	Medway Rivulet	Private land	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
4489.74	Medway Rivulet	Private land	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
4783.88	Medway Rivulet	Private land	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
4831.3	Medway Rivulet	DS Hume Hwy	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
4901.7	Medway Rivulet	US Hume Hwy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5201.84	Medway Rivulet	Private land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5462.31	Medway Rivulet	Private land	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00
5864.6	Medway Rivulet	Private land	0.00	0.00	-0.01	0.01	0.00	0.00	0.00	0.00
7383.57	Medway Rivulet	Private land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7962.88	Medway Rivulet	Private land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: US = upstream; DS = downstream; Hwy = Highway

Table 6.2 Oldbury Creek catchment afflux results

Cross-section number	Stream	Location	Operation				Rehabilitation			
			5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)	5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)
246.32	Tributary 2b	DS Medway Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
306.77	Catchment tributary 2	DS Medway Road	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
347.57	Tributary 2b	US Medway Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
350	Branch	Private land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
371.34	Catchment tributary 2	US Medway Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
417.29	Oldbury Creek	Private land	0.02	0.05	0.03	0.35	0.00	0.00	0.00	0.00
533.19	Branch	Private land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
543.84	Tributary T1	Old Hume Hwy	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
606.67	Tributary T1	Private land and Old Hume Hwy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
647.53	Oldbury Creek	Private land	0.02	0.03	0.05	0.22	0.00	0.00	0.00	0.00
750	Branch	Private land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
773.14	Tributary T1	Private land	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1073.16	Tributary T1	Private land	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
1194.89	Tributary 2	DS Hume Hwy	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01
1260	Tributary 2	US Hume Hwy	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
2741.84	Oldbury Creek	Private land	0.03	0.04	0.05	0.12	0.00	0.00	0.00	0.00
2819.73	Oldbury Creek	Private land	0.01	0.04	0.06	0.18	0.00	0.00	0.00	0.00

Cross-section number	Stream	Location	Operation				Rehabilitation			
			5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)	5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)
2928.8	Oldbury Creek	Private land	-0.03	0.00	0.01	0.19	0.00	0.00	0.00	0.00
3007.9	Oldbury Creek	Private land	-0.05	-0.06	-0.08	-0.01	0.00	0.00	0.00	0.00
4288.37	Oldbury Creek	Embankment DS inline storage	0.34	0.31	0.28	0.00	0.39	0.37	0.34	0.10
4390.64	Oldbury Creek	Embankment US inline storage	0.21	0.21	0.19	0.16	0.00	0.00	0.00	0.00
4611.83	Oldbury Creek	US inline storage	0.21	0.21	0.19	0.15	0.00	0.00	0.00	0.00
4641.08	Oldbury Creek	US inline storage	0.19	0.18	0.18	0.00	0.00	0.00	0.00	0.00
5624.5	Oldbury Creek	DS Hume Hwy	0.00	0.00	-0.01	0.03	0.00	0.00	0.00	0.00
5691.94	Oldbury Creek	US Hume Hwy	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
5980	Oldbury Creek	DS Old Hume Hwy	0.00	0.00	-0.03	0.03	0.00	0.00	0.00	0.00
6024.59	Oldbury Creek	US Old Hume Hwy	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
7401.61	Oldbury Creek	Private land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7696.2	Oldbury Creek	Private land	0.00	-0.01	0.00	-0.08	0.00	0.00	0.00	0.00
7907.82	Oldbury Creek	Private land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8234.11	Oldbury Creek	Private land	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00

Notes: US = upstream; DS = downstream; Hwy = Highway

6.1.3 Peak 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.

Peak velocities downstream of new infrastructure crossing streams in the study area are presented in Table 6.3. Peak velocities are presented for the following new infrastructure:

- The conveyor crossing Medway Rivulet to transport coal from the conveyor drift to the AWA precinct.
- The road crossing Medway Rivulet to provide access between the conveyor drift and ventilation shaft and the AWA precinct, which includes 17 box culverts.
- The embankment at the downstream end of the inline storages on Oldbury Creek which will be raised and used to provide access between the CPP precinct and the train load out facility. The embankment will have an access road, a conveyor to transport coal and poles for electricity lines.

The project will not include any structures that pose significant obstruction to or constriction of flood flows. Peak velocities are expected to increase immediately downstream of the conveyor piers and box culverts and scour protection measures will need to be designed as part of the detailed civil works design.

The peak velocities reported in Table 6.3 are for cross-sections located immediately downstream of the new infrastructure. The results show that the impact on velocity at these downstream locations during operation is minor, with changes in velocity in the range +/- 0.3 m/s.

In the rehabilitation case the infrastructure will be removed and the ground levels around crossing structures will be restored to existing levels which will restore the existing conditions velocity regimes.

Table 6.3 Peak velocities at new infrastructure

Cross-section	Stream	Infrastructure	Cross-section distance downstream from infrastructure (m)	5-year			20-year			100-year			PMF		
				Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff
3789.74	MR	Conveyor gantry	0	0.48	0.44	-0.04	0.52	0.48	-0.02	0.58	0.54	-0.04	0.58	0.54	-0.04
3189.74	MR	Road crossing with 17 x 1800 mm x 1200 mm RCBC	0	0.37	0.48	0.11	0.40	0.50	0.10	0.43	0.52	0.09	0.64	0.75	0.11
4288.37	OC	Embankment inline storage	12	1.05	0.73	-0.32	1.09	0.84	-0.25	1.12	0.94	-0.18	1.35	1.51	0.16
4611.83	OC	Embankment inline storage	0.5	0.21	0.18	-0.03	0.28	0.24	-0.04	0.35	0.31	-0.04	1.65	1.56	-0.09

Notes: Ex = existing; Op = operation; Diff = difference; MR = Medway Rivulet; OC = Oldbury Creek

6.2 Cumulative results and impact assessment

The cumulative impacts of the Hume Coal Project and Berrima Rail Project were assessed in the Oldbury Creek catchment where infrastructure from both projects is located. The Berrima Rail Project has preferred and alternate options; however, there is no difference between these options in the Oldbury Creek catchment – refer to the Berrima Rail EIS (EMM 2016b) Chapter 14 for further details.

The Oldbury Creek hydrologic model (refer Section 4) was used to generate peak flows for the cumulative Oldbury Creek HEC-RAS model.

The Oldbury Creek HEC-RAS model, as described in Section 5, was revised to include cross-sections targeting key infrastructure for both the project and Berrima Rail Project during operation and rehabilitation. The cumulative Oldbury Creek HEC-RAS model cross-sections are shown on Figure 6.3.

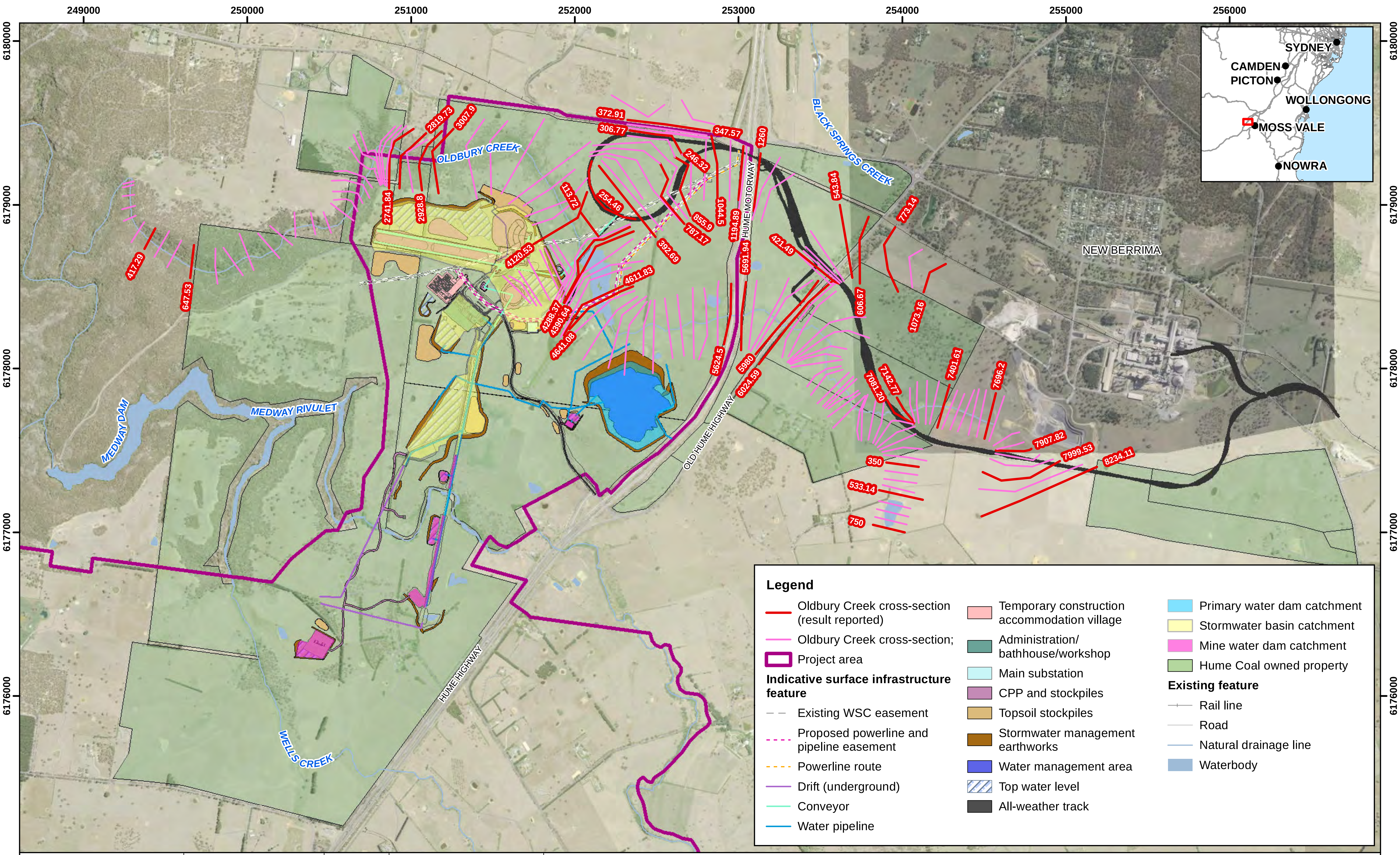
The cumulative Oldbury Creek HEC-RAS model was run for the 5 year, 20 year, 100 year ARI and PMF events for the following scenarios:

- The cumulative operation scenario, which incorporates the proposed surface infrastructure for the Hume Coal Project and the proposed infrastructure for the Berrima Rail Project.
- The cumulative rehabilitation scenario, which incorporates the proposed final landform at completion of the Hume Coal Project and the Berrima Rail Project.

Additional proposed structures were included in the cumulative Oldbury Creek HEC-RAS model. The proposed structures are described in Table 6.4.

Table 6.4 Proposed structures for the cumulative operation scenario

Waterway	Crossing type and location	Design option	Mitigation measure
Tributary of Oldbury Creek	Culverts on south eastern side of rail loop	Berrima Rail Project	2 x 1400 mm diameter pipe
Oldbury Creek	Culverts to the east of Old Hume Highway	Berrima Rail Project	5 x 2000 mm x 2000 mm RCBC
Drainage depression alongside Hume Highway	Culverts immediately east of Old Hume Highway	Berrima Rail Project	4 x 1800 mm x 900 mm RCBC
Overland flow path (flowing to tributary of Oldbury Creek)	Culvert on eastern side of rail loop	Berrima Rail Project	1400 mm diameter pipe
Oldbury Creek	Culverts to the south east of Berrima Cement Works	Berrima Rail Project	5 x 2000 mm x 1200 mm RCBC



Map: 2200540A_GIS_038_A5	Author: RP
Date: 14/11/2016	Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Flooding Assessment
Figure 6.3
Cumulative Oldbury Creek model cross-sections

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6.2.1 Cumulative flood extent

Figure 6.4 presents a comparison of the cumulative 100 year ARI flood extent for the existing and operation scenarios. Figures comparing the cumulative 5 year and 20 year ARI and PMF extents for the existing and operation scenarios are presented in Appendix F.

Figure 6.5 presents a comparison of the cumulative 100 year ARI flood extent for the existing and rehabilitation scenarios. Figures comparing the cumulative 5 year and 20 year ARI and PMF extents for the existing and rehabilitation scenarios are presented in Appendix G.

Comparison of the 100 year ARI flood extents shows that changes in flood extent during operation will occur:

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

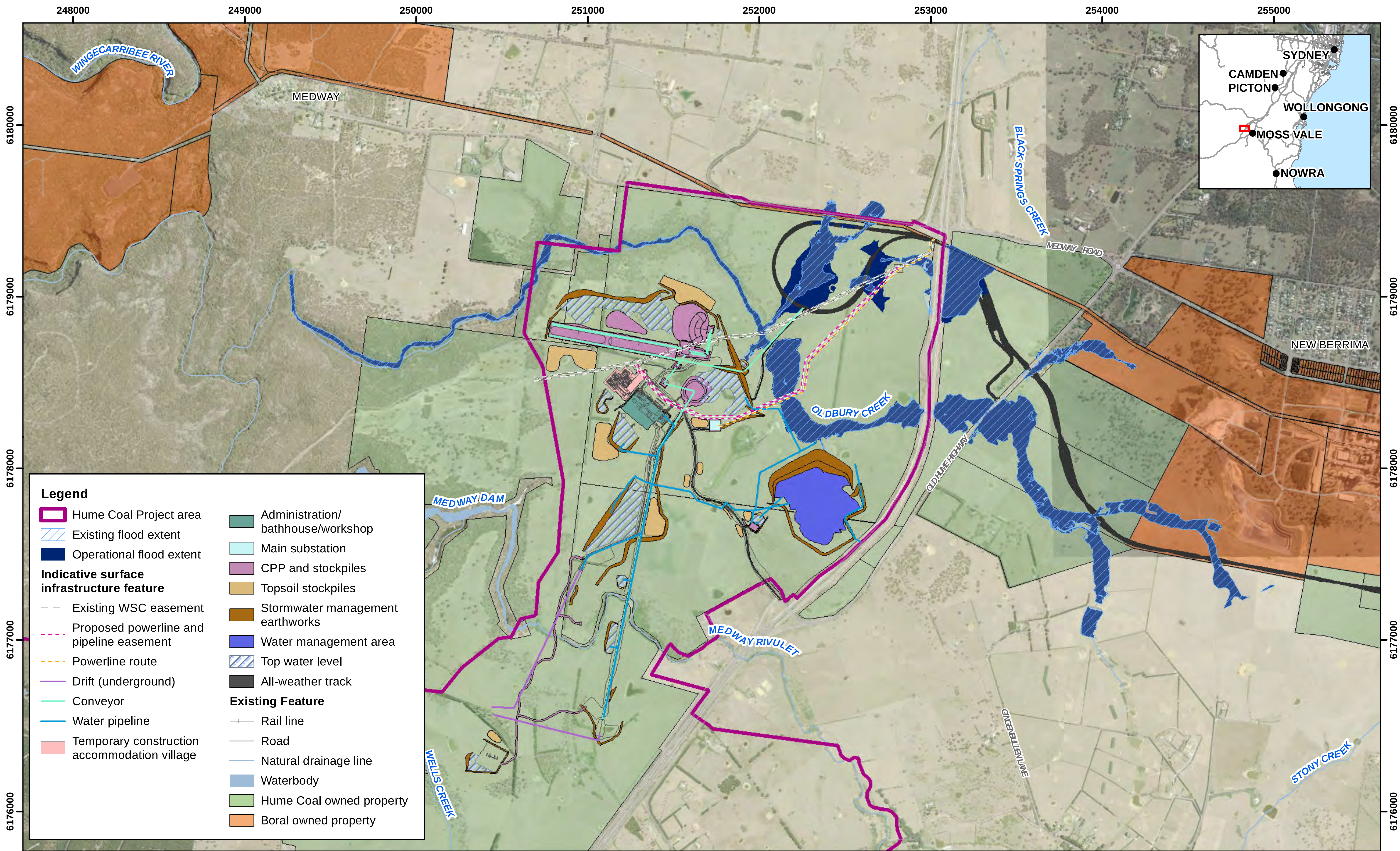
The changes in flood extent all occur on land owned by Hume Coal or Boral. The increased flood extent upstream of the Hume Highway is minor.

The increase in flood levels up to the PMF to the south west of Berrima Cement Works has no impact on the works or the pit.

The high order flood event behaviour will change within the rail loop in the area containing the colony of Paddy's River Box trees. Refer to the Hume Coal EIS Ecology Report (EMM 2016c) for discussion on the impact of flow / flood regime changes on these trees.

As shown in Figure 6.5, once the infrastructure is removed during rehabilitation, the flood extent in these areas will return to existing conditions, apart from just upstream of the Hume Highway where the minor increase in flood extent will remain.

The impacts around the rail loop, the Hume Highway and around 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 do not contribute to these areas upstream that are affected by the rail infrastructure. Therefore, there is no cumulative impact of both projects on flooding in Oldbury Creek. Further details of the flooding impacts of the Berrima Rail Project are addressed in the Berrima Rail Project EIS.



Map: 2200540A_GIS_039_A5	Author: RP	
Date: 14/11/2016	Approved by: LR	
Data source: © Land and Property Information 2015, Hume Coal		

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Flooding Assessment

Figure 6.4

Cumulative 100 Year ARI flood extent - Operation

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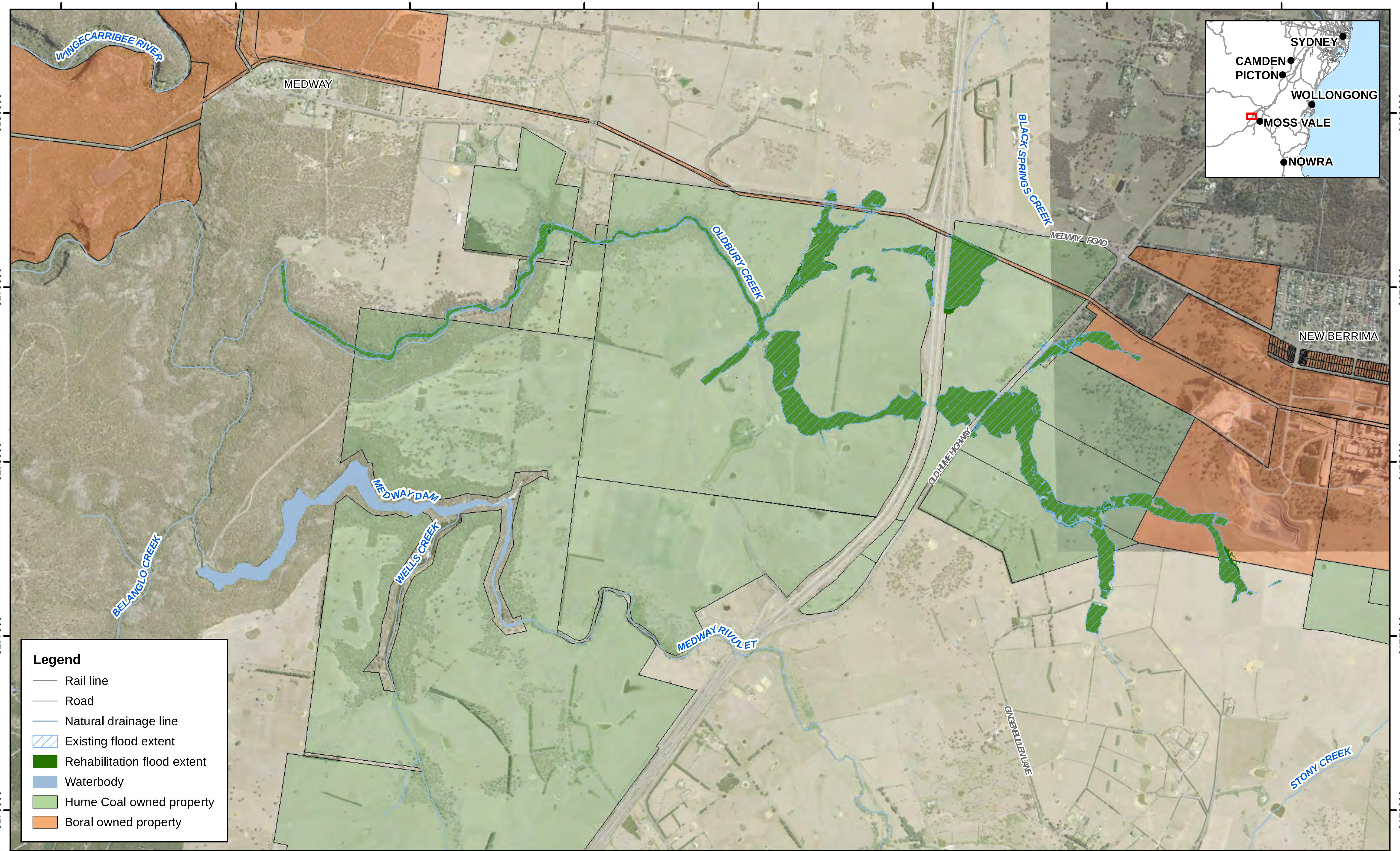

Map: 2200540A_GIS_040_A4	Author: RP
Date: 14/11/2016	Approved by: LR

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Hume Coal Flooding Assessment

Figure 6.5

Cumulative 100 Year ARI flood extent - Rehabilitation

6.2.2 Cumulative flood levels

Cumulative afflux results for the operation and rehabilitation cases for Oldbury Creek are presented in Table 6.5 for the cross-sections shown in Figure 6.3. The cross-sections target key areas of interest including privately owned land, locations where existing roads cross streams and locations where new infrastructure is proposed to cross streams. The results are the difference between the flood levels under the operational or rehabilitation and existing cases.

As discussed in the previous section, the impacts of both projects are not hydraulically linked and there is therefore no cumulative impact. Details of the impacts associated with the rail infrastructure are presented in the Berrima Rail EIS. Impacts on flood level related to the Hume Coal Project under the cumulative scenario are similar to those reported in Section 6.1.2.

Table 6.5 Cumulative afflux results

Cross-section number	Stream	Location	Operation				Rehabilitation			
			5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)	5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)
246.32	Tributary 2b	DS Medway Road	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.05
306.77	Catchment tributary 2	DS Medway Road	0.01	0.02	0.03	0.53	0.00	0.00	0.00	0.00
347.57	Tributary 2b	US Medway Road	-0.02	-0.01	0.00	-0.01	0.01	0.00	0.00	0.01
350	Branch	Private land	-0.13	-0.16	-0.20	-0.62	0.00	0.00	0.00	0.00
372.91	Catchment tributary 2	US Medway Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
417.29	Oldbury Creek	Private land	-0.16	-0.25	-0.33	-1.95	0.00	0.00	0.00	0.00
533.19	Branch	Private land	-0.17	-0.19	-0.21	-0.62	0.00	0.00	0.00	0.00
543.84	Tributary T1	Old Hume Hwy	-0.05	-0.06	-0.07	0.8	0.04	0.06	0.06	0.00
606.67	Tributary T1	Private land and Old Hume Hwy	0.03	0.05	0.06	1.05	0.00	0.00	0.00	0.00
647.53	Oldbury Creek	Private land	-0.05	-0.09	-0.18	0.00	0.00	0.00	0.00	0.00
750	Branch	Private land	-0.18	-0.22	-0.25	-0.67	0.00	0.00	0.00	0.00
773.14	Tributary T1	Private land	-0.04	-0.04	-0.04	-0.10	0.01	0.01	0.01	0.03
1073.16	Tributary T1	Private land	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
1194.89	Tributary 2	DS Hume Hwy	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
1260	Tributary 2	US Hume Hwy	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
2741.84	Oldbury Creek	Private land	0.00	-0.13	-0.2	-0.04	0.00	0.00	0.00	0.00
2819.73	Oldbury Creek	Private land	0.009	0.01	-0.04	-0.31	0.00	0.00	0.00	0.00
2928.8	Oldbury Creek	Private land	-0.06	0.01	-0.05	-0.31	0.00	0.00	0.00	0.00

Cross-section number	Stream	Location	Operation				Rehabilitation			
			5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)	5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)
3007.9	Oldbury Creek	Hume Coal land	0.00	0.02	0.03	-0.16	0.00	0.00	0.00	0.00
4288.37	Oldbury Creek	Embankment DS inline storage	0.34	0.30	0.27	0.00	0.39	0.37	0.34	0.10
4390.64	Oldbury Creek	Embankment US inline storage	0.22	0.22	0.19	0.16	0.00	0.00	0.00	0.00
4611.83	Oldbury Creek	US inline storage	0.22	0.22	0.19	0.15	0.00	0.00	0.00	0.00
4641.08	Oldbury Creek	US inline storage	0.20	0.20	0.16	0.02	0.00	0.00	0.00	0.00
5624.5	Oldbury Creek	DS Hume Hwy	0.01	0.01	0.01	0.08	0.00	0.00	0.00	0.00
5691.94	Oldbury Creek	US Hume Hwy	0.02	0.03	0.04	-0.01	0.00	0.00	0.00	0.00
5980	Oldbury Creek	DS Old Hume Hwy	0.01	0.02	0.04	-0.01	0.00	0.00	0.00	0.00
6024.59	Oldbury Creek	US Old Hume Hwy	0.02	0.02	0.02	-0.01	0.01	0.01	0.10	0.00
7081.2	Oldbury Creek	DS 5 x 2000 mm x 2000 mm RCBC on Oldbury Creek	0.03	0.02	0.01	0.06	0.05	0.04	0.02	0.00
7142.77	Oldbury Creek	Hume Coal Land	0.02	0.01	0.01	2.86	0.00	0.00	0.00	0.00
7401.61	Oldbury Creek	Hume Coal Land	0.01	0.00	0.01	1.32	0.00	0.00	0.00	0.01
7696.2	Oldbury Creek	Private land (Boral)	0.01	0.02	0.01	0.05	0.00	0.00	0.00	0.01
7907.82	Oldbury Creek	Private land (Boral)	0.01	0.02	0.02	0.03	0.07	0.10	0.14	0.26
7999.53	Oldbury Creek	US 5 x 2000 mm x 1200 mm RCBC on Oldbury Creek Private Land	0.00	0.00	0.00	2.04	0.15	0.18	0.23	0.47
8234.11	Oldbury Creek	Private land	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00

Cross-section number	Stream	Location	Operation				Rehabilitation			
			5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)	5-year afflux (m)	20-year afflux (m)	100-year afflux (m)	PMF afflux (m)
421.49	Oldbury Creek	DS drainage depression alongside Hume Highway with 4 x 1800 mm x 900 mm RCBC	0.10	0.11	0.12	0.28	0.00	0.00	0.01	0.19
392.69	Tributary 2	US 2 x 1400 mm diameter pipe under rail loop	0.00	0.62	1.78	4.09	0.03	0.04	0.05	0.15
855.9	Tributary 2	US 1400 mm diameter pipe under rail loop	3.42	3.88	4.74	5.89	0.00	0.00	0.00	0.00
787.17	Tributary 2	DS 1400 mm diameter pipe under rail loop	0.01	0.03	0.04	0.30	0.03	0.03	0.02	0.30
254.46	Tributary 2	US 2 x 1400 mm diameter pipe on tributary of Oldbury Creek	1.32	1.9	3.02	4.81	0.14	0.16	0.17	0.02
113.72	Tributary 2	DS 2 x 1400 mm diameter pipe on tributary of Oldbury Creek	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes: US = upstream; DS = downstream; Hwy = Highway

6.2.3 Cumulative peak velocities

Cumulative peak velocities downstream of new infrastructure crossing streams in the study area are presented in Table 6.6.

High velocity changes are predicted at culvert outlets on Oldbury Creek at cross sections 7907.82 and 7081.2 and at the rail loop culvert outlets on a tributary of Oldbury Creek at cross sections 787.17 and 113.72. However, the table shows that these velocity changes reduce further downstream of the culvert outlets and the velocity changes can therefore be managed locally at the outlets. The velocity increases at these locations exceed the acceptability criterion, but these exceedances are local to the culvert outlets and can be managed through appropriate energy dissipating structures. At detailed design opportunities to reduce pipe and/or channel grades at the inlet and outlet of the structures should be investigated to reduce the high velocities at these locations.

Table 6.6 Cumulative peak velocities at new infrastructure

Cross-section	Infrastructure	Cross-section distance downstream from infrastructure (m)	5-year			20-year			100-year			PMF		
			Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff	Ex	Op	Diff
4288.37	Embankment inline storage	12	1.05	0.74	-0.31	1.09	0.86	-0.23	1.12	0.96	-0.16	1.35	1.55	0.20
4611.83	Embankment inline storage	0.5	0.21	0.18	-0.30	0.28	0.24	-0.40	0.35	0.31	-0.40	1.65	1.56	-0.09
421.49	Drainage depression alongside Hume Highway with 4 x 1800 mm x 900 mm RCBC	3	1.05	1.74	0.69	1.13	1.90	0.77	1.21	2.03	0.82	2.85	5.68	2.83
		19	1.33	1.27	-0.06	1.59	1.53	-0.06	1.84	1.68	-0.16	2.68	3.49	0.81
787.17	1400 mm diameter pipe under rail loop	2	0.00	0.97	0.97	0.01	1.06	1.05	0.01	1.13	1.12	0.03	1.84	1.81
		22	0.57	0.52	-0.05	0.72	0.59	-0.13	0.78	0.66	-0.12	1.33	0.72	-0.61
113.72	2 x 1400 mm diameter pipe under rail loop	0	0.71	3.08	2.37	0.78	3.77	2.99	0.86	5.49	4.63	1.52	7.29	5.77
		2	0.71	1.71	0.10	0.78	1.86	1.08	0.86	2.04	1.18	1.52	3.56	2.04
7907.82	5 x 2000 mm x 1200 mm RCBC on Oldbury Creek	0	0.88	1.93	1.13	1.00	2.19	1.19	1.1	2.41	1.31	1.94	5.36	3.42
		2	0.88	0.95	0.07	1.00	1.06	0.06	1.1	1.11	0.01	1.94	2.16	0.22
		14	1.06	1.05	-0.01	1.21	1.18	-0.03	1.35	1.29	-0.06	2.63	2.29	-0.34
7081.2	5 x 2000 mm x 2000 mm RCBC on Oldbury Creek	0	1.86	1.2	-0.66	1.88	1.33	-0.55	1.91	1.48	-0.43	1.32	5.79	4.47
		82	0.87	0.87	0.00	0.96	0.95	-0.01	1.06	1.05	-0.01	1.55	1.86	0.31

Notes: Ex = Existing; Op = Operation; Diff = Difference

6.3 Potential impacts on mine assets outside the modelled areas

The ventilation shaft pad is located outside the modelled area within the catchment of Wells Creek (see Figure 1.2). The pad is located on high ground at a level of approximately 645 to 650 mAHD, which is approximately 20 m above the adjacent channel of Wells Creek. This infrastructure is therefore well above the PMF level of this watercourse and not at risk of flooding, and will not have an impact on flooding in the Wells Creek catchment.

6.4 Potential impacts on other drainage features

In addition to impacts on main stream flooding, a review of potential impacts on other localised drainage features was also undertaken. A key feature relating to local drainage processes is an existing easement in place that appears to drain a small catchment from east of the Hume Motorway across the road and into a farm dam on land owned by Hume Coal (see Figure 1.2). This easement contains a buried pipe and passes through the site of the proposed PWD. The PWD will incorporate a diversion drain to intercept clean water from the catchment external to the dam and divert it around the dam and into Oldbury Creek.

To allow this existing drainage pipe to continue to function unimpeded it is proposed to modify the section of pipe within land owned by Hume Coal to relocate and extend it around the PWD and either discharge into the clean water diversion drain around the PWD or further downstream towards Oldbury Creek. A new outlet headwall and scour resistant connection will be required at the new pipe outlet. Scour protection will be provided in the form of a rock apron downstream of the headwall, and extending across the floor and walls of the diversion drain if required to discharge to the drain. The pipe hydraulics and associated scour protection at the outlet would be determined at the detailed design stage of the Project, with a hydraulic analysis of the changed tailwater condition for the drainage line. The pipe extension will be design to ensure no impact on the cross drainage system upstream.

6.5 Potential impacts on ecology

There are no significant changes to flood hydrology caused by the Hume Coal Project. The flood regime is essentially unchanged by the project, with only minor changes in flood levels for high order events. The potential impacts of the minor changes are addressed in the Hume Coal Project Biodiversity Assessment Report (EMM 2016c).

6.6 Mitigation measures

The impacts of the project on flood extent, level and velocity are minor and no specific flood mitigation measures are required.

Peak velocities are expected to increase immediately upstream and downstream of the conveyor piers and culverts hence erosion and scour protection measures will be required at these locations, which will typically take the form of rock rip-rap protection. For crossings where waterways are ill-defined, a flow spreader should be provided to transition concentrated flow back to more a natural overland flow pattern. The erosion and scour protection should be nominated as part of detailed civil design.

6.7 Sensitivity analyses

Sensitivity analyses were undertaken for key hydrologic and hydraulic parameters in order to understand the sensitivity of the model predictions of the flood behaviour to variations in these parameters. This section provides an understanding of the range of results possible due to model uncertainty. This has focussed on the Oldbury Creek catchment as this catchment will experience most change in flood hydraulics due to the impact of the surface infrastructure.

6.7.1 Rainfall continuing losses

Sensitivity testing was undertaken for the continuing loss rate for the Oldbury Creek catchment. A continuing loss of 2.5 mm/hr was simulated and the results were compared to those for the simulated value of 3.7 mm/hr that was adopted from the model calibration (refer Table 4.2). The results were compared in both the hydrologic and hydraulic models for the existing and operation scenarios and are given in Table 6.7.

Table 6.7 Sensitivity of continuing loss values

ARI	RAFTS node DN2		HEC-RAS cross-section 3007.9 on Oldbury Creek					
	Existing peak flow (m^3/s)	Operation peak flow (m^3/s)	Existing water level (mAHD)	Operation water level (mAHD)	Afflux (m)	Existing velocity (m/s)	Operation velocity (m/s)	Difference (m/s)
Continuing loss 3.7mm/hr								
5	29.3	27.4	631.10	631.05	-0.05	1.83	1.82	-0.01
20	50.5	47.9	631.55	631.49	-0.06	2.08	2.08	0.00
100	*73.9*	70.1	631.98	631.90	-0.08	2.24	2.23	-0.01
Continuing loss 2.5mm/hr								
5	33.8	31.7	631.19	631.15	-0.04	1.92	1.89	-0.03
20	54.4	51.7	631.61	631.57	-0.04	2.14	2.11	-0.03
100	77.6	73.6	632.03	631.96	-0.07	2.27	2.25	-0.02

The results show that while peak flows differ by up to 15% and water levels differ by up to 100 mm, the afflux result only differs by up to 20 mm, with higher afflux predicted for the adopted continuing loss value of 3.7 mm/hr. Velocity differences are very minor at 0.01 to 0.03 m/s. A difference in 100mm in water level does not produce a perceptible difference in flood extent across the catchment. The results show that flood levels and extents are not sensitive to variation in continuing loss and the afflux predictions are higher for the adopted value, indicating that the impact prediction is conservative with respect to the continuing loss parameter.

6.7.2 Hydraulic roughness

Sensitivity testing was undertaken on the hydraulic roughness by varying the adopted Manning's *n* values in Table 5.1 by +/-20%. The results are provided below at a sample of cross sections in Tables 6.8 and 6.9.

Table 6.8 Results of sensitivity tests on hydraulic roughness (cross section 4120.53 on Oldbury Creek)

ARI	Cross-section 4120.53 on Oldbury Creek					
	Existing water level (mAHD)	Operation water level (mAHD)	Afflux (m)	Existing velocity (m/s)	Operation velocity (m/s)	Difference (m/s)
Mannings values unchanged						
5	640.10	640.14	0.04	1.34	1.30	-0.04
20	640.45	640.52	0.07	1.65	1.54	-0.09
100	640.77	640.85	0.08	1.88	1.72	-0.16
PMF	644.47	644.45	-0.02	3.41	3.00	-0.41
Mannings values increased by 20%						
5	640.19	640.23	0.04	1.22	1.18	-0.04
20	640.57	640.63	0.06	1.50	1.40	-0.10
100	640.90	640.98	0.08	1.72	1.57	-0.15
PMF	644.63	644.60	-0.03	3.26	2.88	-0.38
Mannings values decreased by 20%						
5	640.02	640.04	0.02	1.48	1.46	-0.02
20	640.35	640.39	0.04	1.80	1.72	-0.08
100	640.65	640.72	0.07	2.06	1.90	-0.16
PMF	644.25	644.22	-0.03	3.64	3.20	-0.44

Table 6.9 Results of sensitivity tests on hydraulic roughness (cross section 1044.5 on Oldbury Creek Tributary)

ARI	Cross-section 1044.5 on Oldbury Creek tributary					
	Existing water level (mAHD)	Operation water level (mAHD)	Afflux (m)	Existing velocity (m/s)	Operation velocity (m/s)	Difference (m/s)
Mannings values unchanged						
5	657.84	657.84	0.00	0.61	0.60	-0.01
20	657.88	657.88	0.00	0.68	0.67	-0.01
100	657.91	657.91	0.00	0.75	0.75	0.00
PMF	658.38	658.44	0.06	1.30	1.19	-0.11
Mannings values increased by 20%						
5	657.86	657.87	0.01	0.54	0.50	-0.04
20	657.90	657.91	0.01	0.60	0.57	-0.03
100	657.94	657.94	0.00	0.64	0.63	-0.01
PMF	658.45	658.49	0.04	1.13	1.08	-0.05
Mannings values decreased by 20%						
5	657.81	657.82	0.01	0.77	0.74	-0.03
20	657.84	657.84	0.00	0.85	0.85	0.00
100	657.87	657.87	0.00	0.95	0.95	0.00
PMF	658.28	658.39	0.11	1.61	1.30	-0.31

The sensitivity test demonstrated that water levels and afflux levels are not particularly sensitive to significant variations in the Mannings *n* values, with differences of less than 100mm predicted for water level and less than 50mm predicted for afflux. A difference in 100mm in water level does not produce a perceptible difference in flood extent across the catchment. Velocities are also not sensitive to the change in roughness, with maximum differences of 0.3m/s between the varied roughness scenarios observed.

7. Conclusions

7.1 Conclusions

The flooding assessment has been based on flood models developed from recent LiDAR and ground survey data and calibrated against a single recently observed flood event. The models achieved a good fit to the calibration event and can be considered to provide reliable predictions of flood behaviour for the given event in Medway Rivulet and Oldbury Creek. A check against the PRM confirmed model parameters for use in hydrologic modelling. Sensitivity analyses on the key parameters of continuing loss and hydraulic roughness have been carried out with only minor changes to model results of water level, afflux and velocity.

Culverts will be constructed in a number of locations to allow water to pass the proposed infrastructure and reduce flooding impacts on nearby land. The modelling results indicate that with these culverts in place:

- the project will have negligible impacts on flood levels in the Medway Rivulet catchment for both operational and rehabilitation scenarios up to the 100 year ARI event.
- the impacts of the project on flood levels in the Oldbury Creek catchment will be within proposed acceptable limits for public roads and private land for the operational scenario, apart from a localised impact on Oldbury Creek between the PWD and SB02 downstream of the inline storage on Hume Coal land.
- the project will have negligible impacts on flood levels in the Oldbury Creek catchment for the rehabilitation scenario, apart from a localised impact downstream of the inline storage on Hume Coal land.

The cumulative modelling results for the Hume Coal Project and Berrima Rail Project indicate that the impacts of the two projects are hydraulically independent. The main impacts on flood behaviour due to the rail project are located around the rail loop and upstream crossings on Oldbury Creek. The localised impacts on flood behaviour caused by the mine surface infrastructure do not contribute to the impacts caused by the rail infrastructure.

Peak velocities are expected to increase immediately downstream of the conveyor piers and culverts. Erosion and scour protection measures will be required around piers and culvert inlets and outlets so that the locally increased velocities do not cause erosion of the channel lining downstream of the infrastructure.

A drainage easement with buried pipe exists that appears to drain a small catchment from east to west across the Hume Motorway into a farm dam on land owned by Hume Coal. The downstream section of this pipe will be intercepted by the proposed PWD. It is proposed to modify the existing drainage arrangement to allow the pipe to discharge around the PWD and allow this drainage line to continue to function unimpeded and ultimately discharge to Oldbury Creek as it does currently.

The project does not significantly alter flooding regimes. Potential impacts of the minor changes on ecology are addressed in the Hume Coal Project Biodiversity Assessment Report (EMM 2016c).

7.2 Limitations

The limitations of this flooding assessment are as follows:

- The XP-RAFTS models for the Medway Rivulet and Oldbury Creek catchments rely on the stream gauge rating curves in Section 3.5.

- The XP-RAFTS models for the Medway Rivulet and Oldbury Creek catchments were only calibrated to one rainfall event.
- The HEC-RAS models for the Medway Rivulet and Oldbury Creek catchments are steady state models which assume that peak flow will occur simultaneously in all locations and storage effect is ignored. The models will over predict water levels and are therefore conservative.
- HEC-RAS provides a one dimensional representation of open channel flow which results in estimates of cross-section averaged velocity. In reality flows downstream of culverts and other constrictions will vary locally and with depth and will have complex turbulent flow distributions. This needs to be considered during detailed civil design of scour protection works.
- The existing landform modelled relies on the accuracy of the LiDAR, which is in the order of +/-150mm.

8. References

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Appendix A

WLEP Flood Planning Area Maps

Wingecarribee Local Environmental Plan 2010

Wingecarribee Shire Council

Flood Planning Area Map -

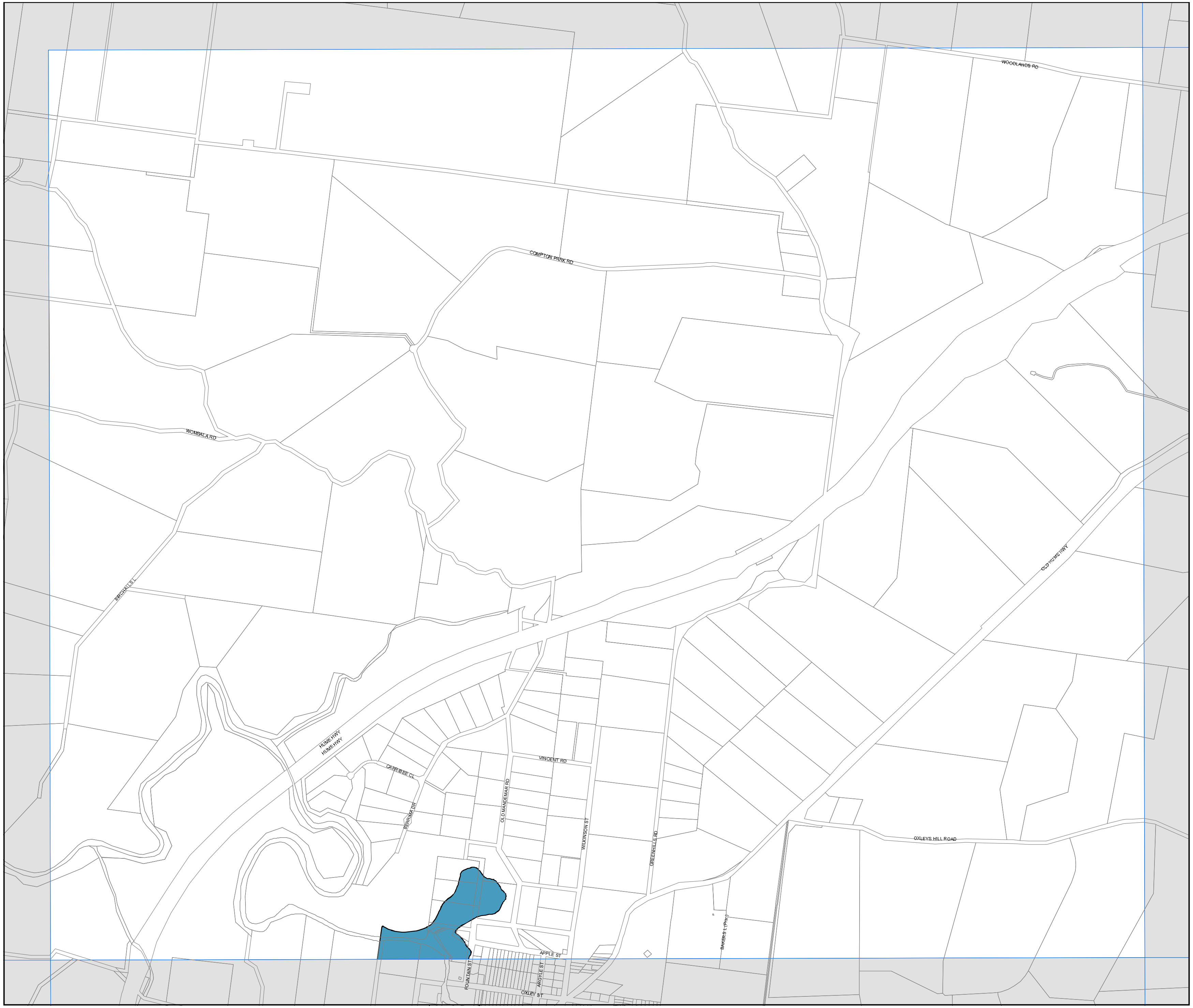
Sheet FLD_007A

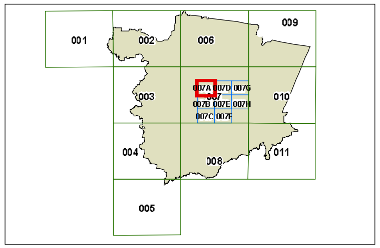
Flood Planning Area

100yr +0.5m Flood Extent

Cadastre

Cadastre 04/05/10 © Land and Property Management Authority





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Metres

Projection: MGA (GDA94) Zone 56

Scale 1:20,000 @ A3

Map identification number:

8350_COM_FLD_007A_020_20100520

Wingecarribee Local Environmental Plan 2010

Flood Planning Area Map -

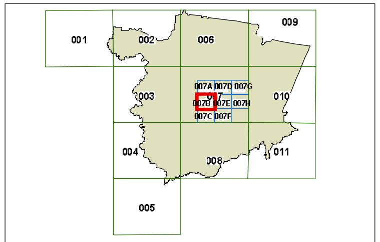
Sheet FLD_007B

Flood Planning Area

100yr +0.5m Flood Extent

Cadastre

Cadastre 04/05/10 © Land and Property Management Authority



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Metres

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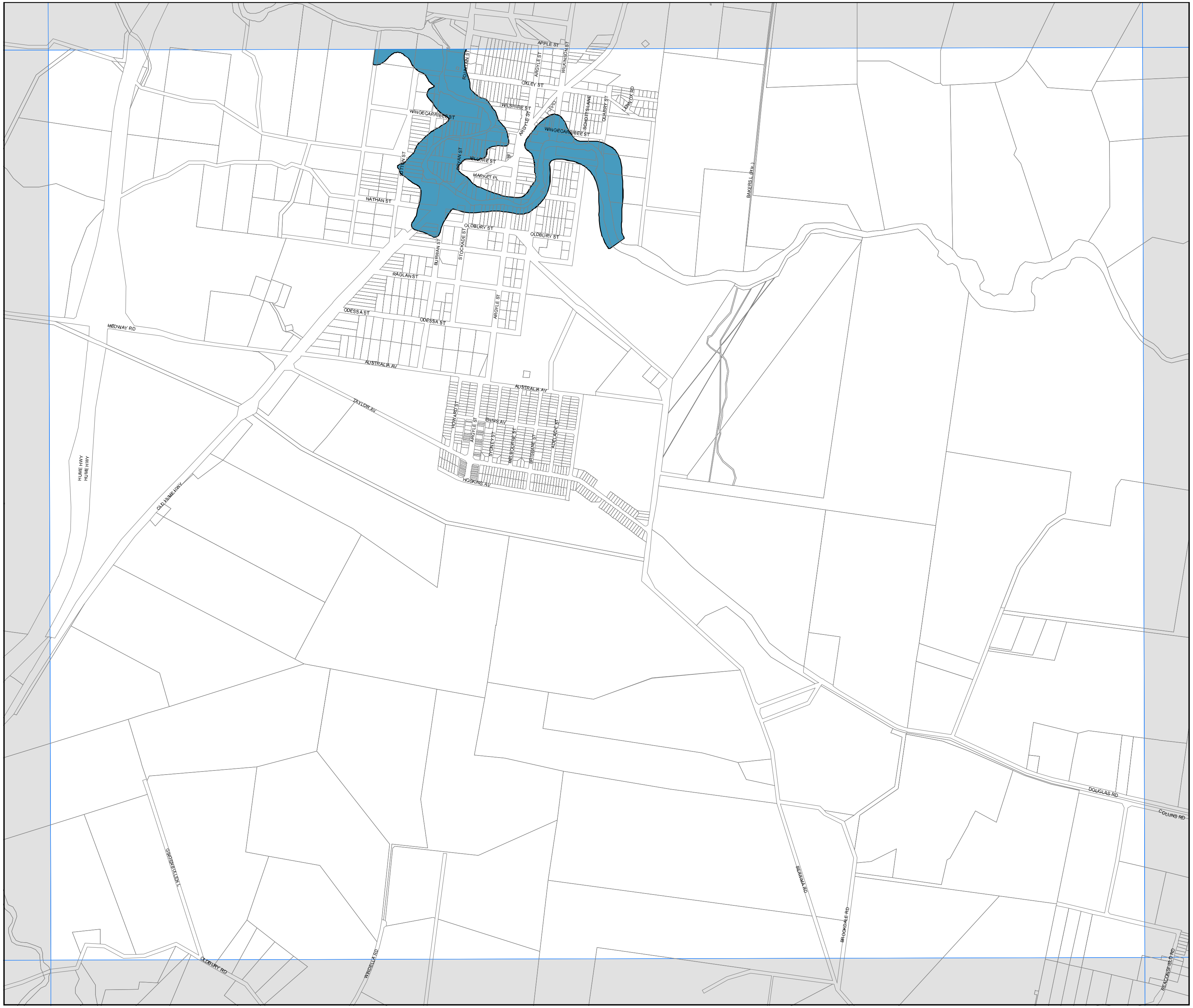

Wingecarribee Local Environmental Plan 2010

Flood Planning Area Map -

Sheet FLD_007C

Flood Planning Area

100yr +0.5m Flood Extent

Cadastre

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Projection: MGA (GDA94) Zone 56

Scale 1:20,000 @ A3

Map identification number:

8350_COM_FLD_007C_020_20100520

Wingecarribee Local Environmental Plan 2010

Flood Planning Area Map -

Sheet FLD_007D

Flood Planning Area

100yr +0.5m Flood Extent

Cadastre

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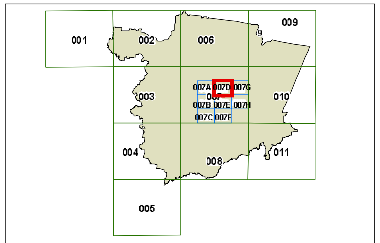

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Scale 1:20,000 @ A3

Map identification number:

8350_COM_FLD_007D_020_20100520

Wingecarribee Local Environmental Plan 2010

WINGECARRIBEE SHIRE COUNCIL

Flood Planning Area Map -

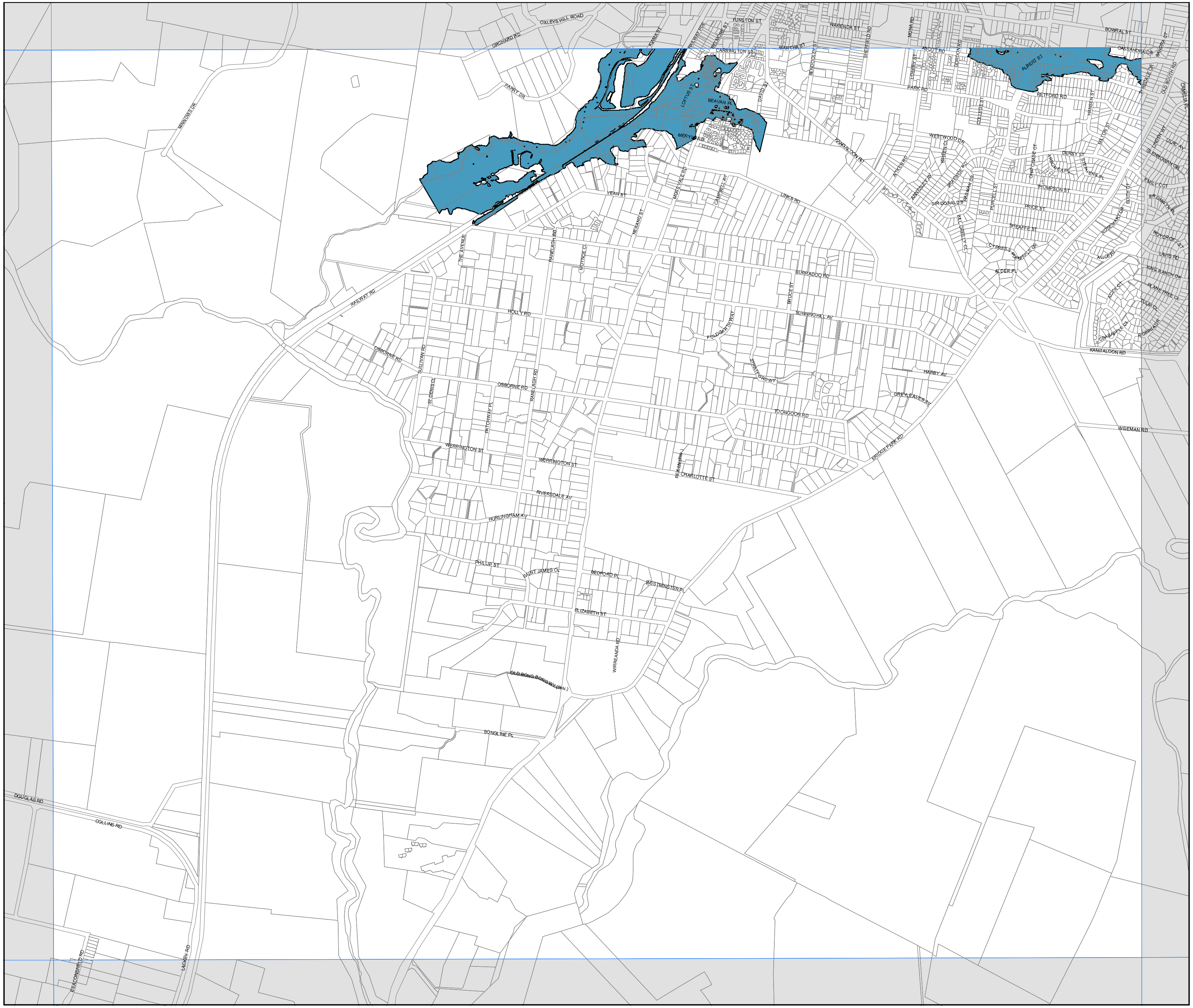
Sheet FLD_007E

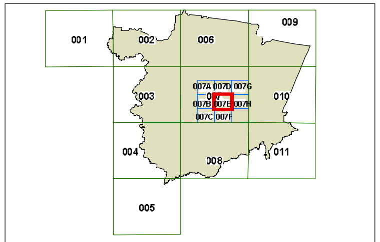
Flood Planning Area

100yr +0.5m Flood Extent

Cadastre

Cadastre 04/05/10 © Land and Property Management Authority





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Map identification number:

8350_COM_FLD_007E_020_20100520

Wingecarribee Local Environmental Plan 2010

WINGECARRIBEE SHIRE COUNCIL

Flood Planning Area Map -

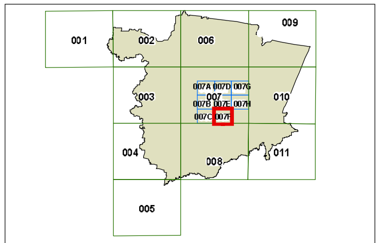
Sheet FLD_007F

Flood Planning Area

100yr +0.5m Flood Extent

Cadastre

Cadastre 04/05/10 © Land and Property Management Authority



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Metres

Projection: MGA (GDA94) Zone 56

Scale 1:20,000 @ A3

Map identification number:

8350_COM_FLD_007F_020_20100520

Wingecarribee Local Environmental Plan 2010

Flood Planning Area Map -

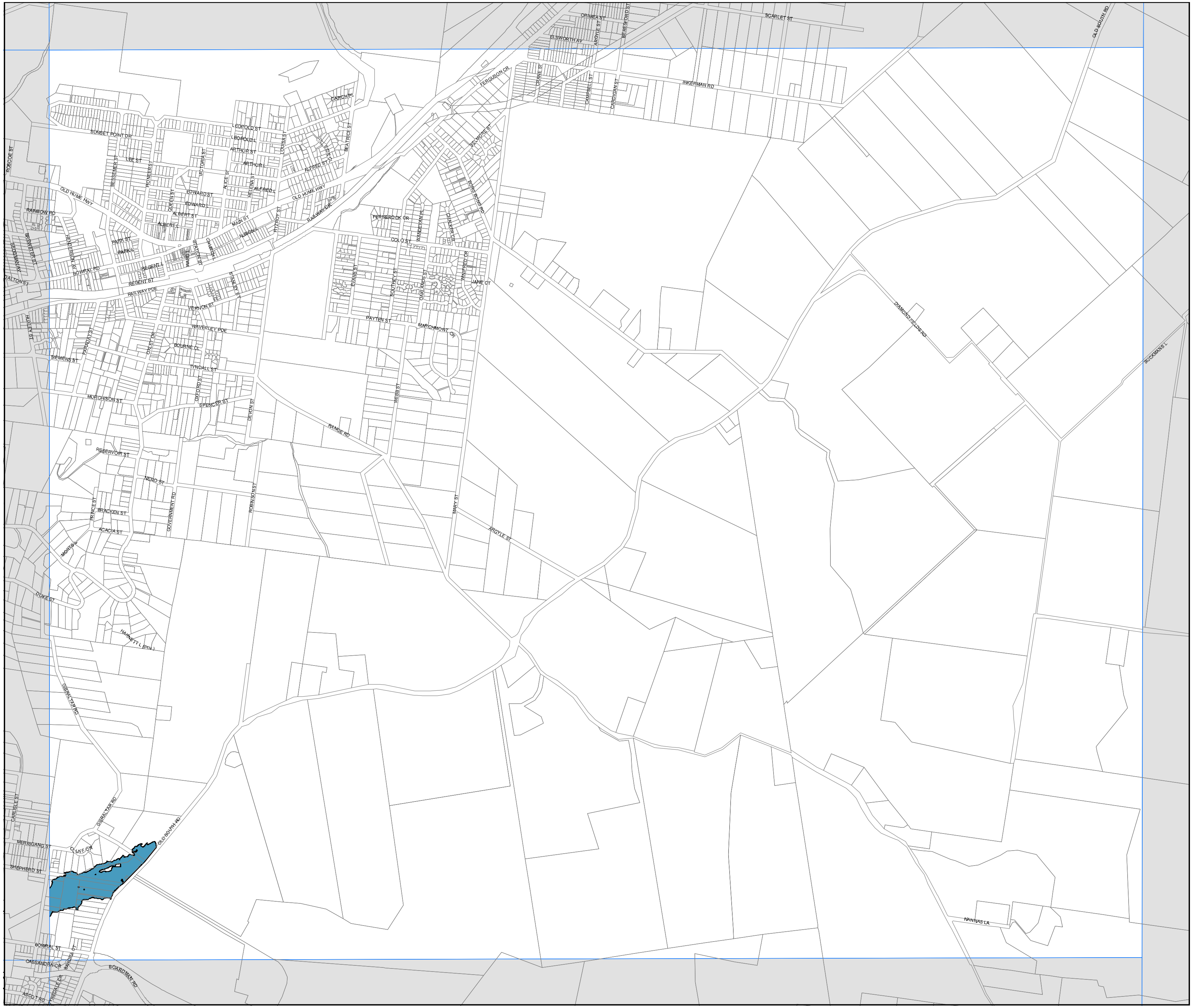
Sheet FLD_007G

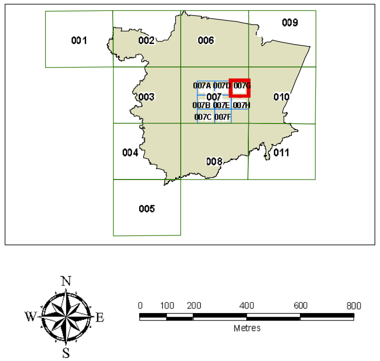
Flood Planning Area

100yr +0.5m Flood Extent

Cadastre

Cadastre 04/05/10 © Land and Property Management Authority





Projection: MGA (GDA94) Zone 56

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Map identification number:

8350_COM_FLD_007G_020_20100520

Wingecarribee Local Environmental Plan 2010

WINGECARRIBEE SHIRE COUNCIL

Flood Planning Area Map -

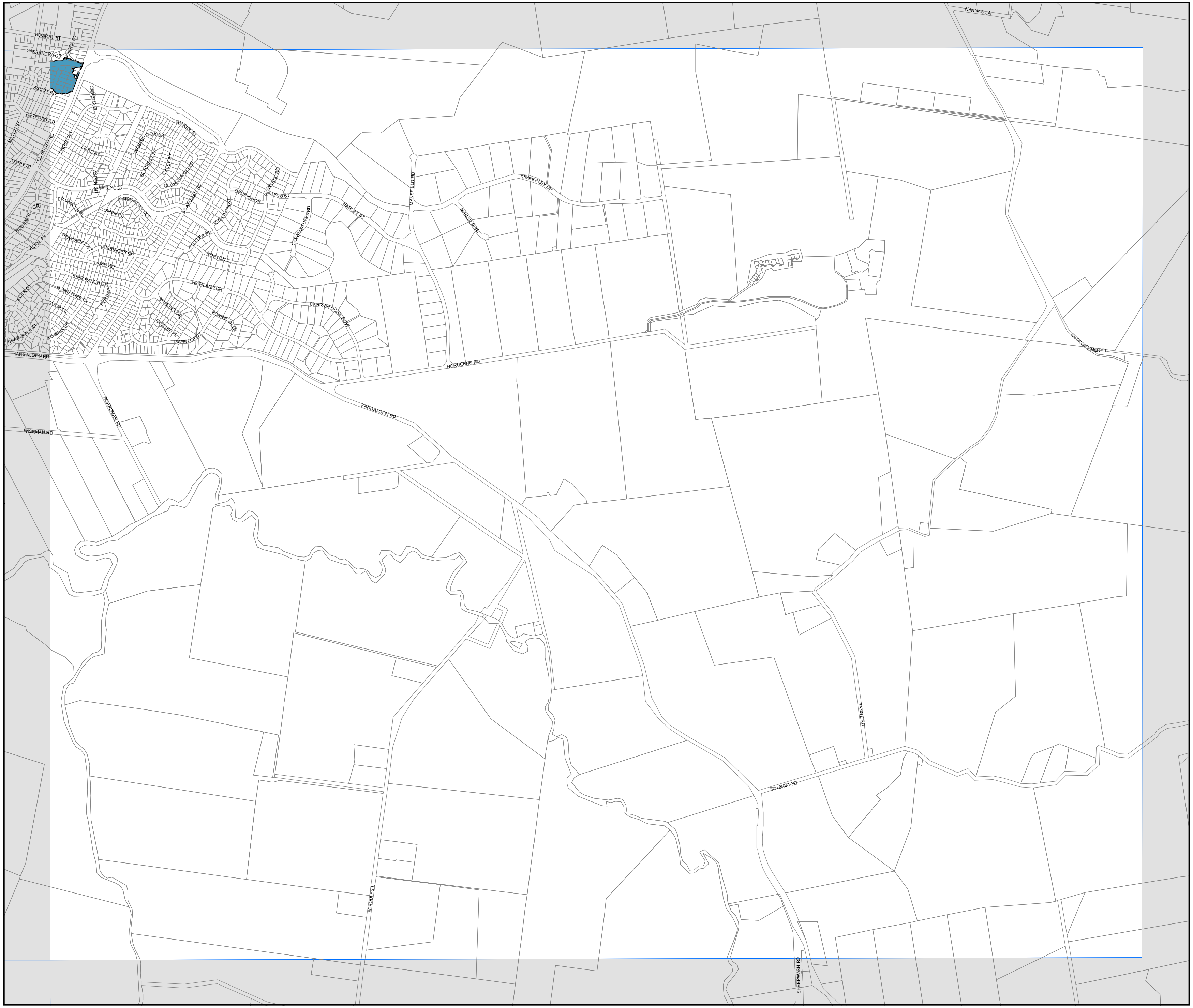
Sheet FLD_007H

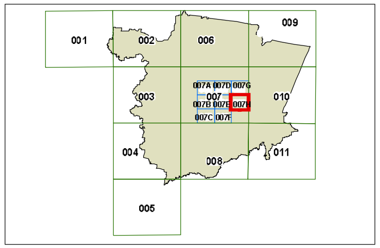
Flood Planning Area

100yr +0.5m Flood Extent

Cadastre

Cadastre 04/05/10 © Land and Property Management Authority





N
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0 100 200 400 600 800
Metres

Projection: MGA (GDA94) Zone 56

Scale 1:20,000 @ A3

Map identification number:

8350_COM_FLD_007H_020_20100520

Appendix B

Surveyed structures

1.1 Medway Rivulet structures

1.1.1 Medway Dam

For the Medway Rivulet model the Medway Dam was included at the downstream end of the model. The Medway Dam structure was determined from drawing number B-40088 (also attached) in Medway Dam Second Surveillance Report (1991). Medway Dam provided the downstream boundary condition and was able to replicate the backwater levels upstream of the dam during the 1% AEP and PMF flood events. It has been assumed that the datum in the drawing is Australian High Datum (AHD) that the RLs of dam crest and spillway are correct when converted from feet to metres. A sanity check shows that the converted elevations are compatible to LiDAR survey levels.

It was assumed that the spillway tail water level (TWL) is located at 2055 feet (625mAHD) and top of dam wall at 2065 feet (629mAHD). Notes in Drawing B-40088 (attached) state that the arch section of the dam is designed for raising to TWL 2065 feet (629mAHD). It has been assumed that this is a dam wall crest of 2075 feet (632mAHD). A future case scenario for the 1% AEP and PMF flood events was run to determine the increase in flood levels due to the raising of the dam wall, if it were to happen in the future.

An inflow from Well's Creek and the residual catchment at Medway Dam was included at the downstream end of the model, to account for all inflow into the Dam. Catchment lumped in so that account for all inflow

1.1.2 Hume Highway – 3 Legs O'Man Bridge

Medway Rivulet crosses the Hume Highway just upstream of the proposed surface infrastructure. The twin bridge structure is locally known as the "Three Legs O'Man Bridge". Survey of the twin bridge for both lanes of the Hume Highway was undertaken by Southern Cross Consulting Surveyors on 25 September 2014. The dimensions of the bridge structures included in the HEC-RAS model are:

- 1.5 m thick concrete deck
- Four piers under each of the northbound and southbound spans
- 41.3 m opening.

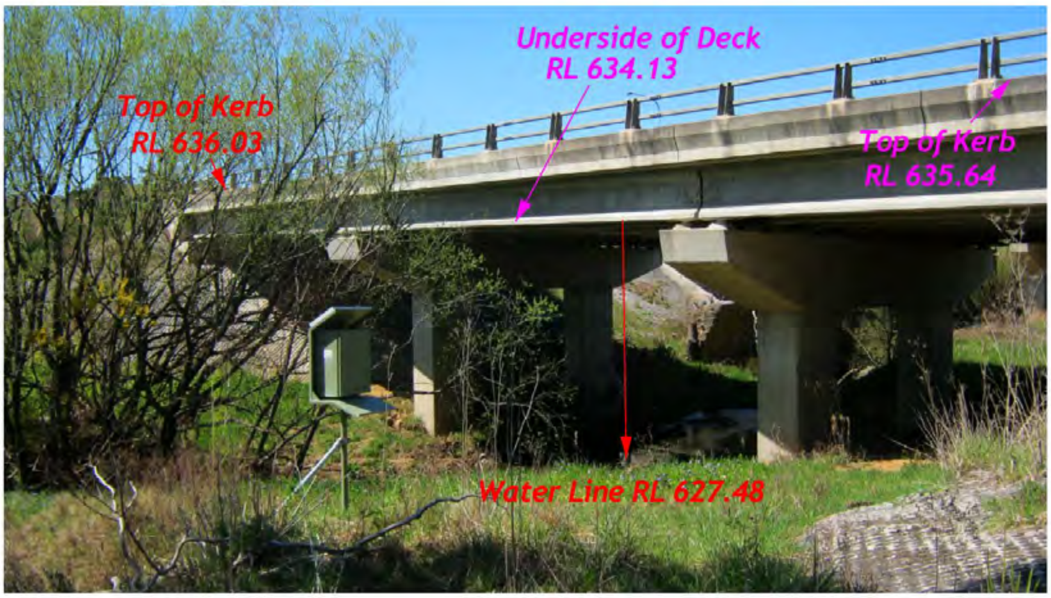


Photo 1 Hume Highway Three Legs O'Man Bridge (northbound looking upstream)

1.2 Oldbury Creek structures

1.2.1 Old Hume Highway plank bridge

Oldbury Creek flows under a plank bridge at the Old Hume Highway. The HEC-RAS model has included this structure based on a survey undertaken by Southern Cross Consulting Surveyors on 21 March 2014. The dimensions of the bridge structures included in the HEC-RAS model are:

- 650 mm thick plank
- No piers
- 5.4 m opening.

Photo 2 Old Hume Highway plank bridge

1.2.2 Hume Highway box culverts

Oldbury Creek flows through three large box culverts under the Hume Highway. The HEC-RAS model has included these structures based on a survey undertaken by Southern Cross Consulting Surveyors on 21 March 2014. The dimensions of the culvert structures included in the HEC-RAS model are:

- Three cells, each 2 m high by 3 m wide.

Photo 3 **Hume Highway box culverts**

1.2.3 Inline structures

There are two inline structures on Oldbury Creek. The most upstream one is a concrete pad, and dirt mound. Under the concrete pad there are 5,300 mm pipes.

Photo 4 **Upstream inline structure on Oldbury Creek**

The downstream inline structure has a high embankment and the spillway is located near the road. There is a single1.6 diameter pipe. The pipe inlet is located at an RL 644.4 mAHD. Only when the water level is above this, will water be able to go through the pipe.

At the time of survey the water level was 644.17 mAHD. This was assumed the initial water level in the XP RAFTS model.

Photo 5 Downstream inline structure on Oldbury Creek

1.2.4 Culverts under Medway Road

There are two 600mm pipes located under Medway Road to the west and a 900mm x 350mm box culvert located to the east.

Photo 6 Western twin pipe culvert looking upstream

Photo 7 **Eastern box culvert looking downstream**

1.2.5 Culvert under rail embankment to the south of Medway Road

There is are two 600 mm pipes located under the old rail embankment to the south of Medway Road.

Photo 8 **Culvert under old rail embankment to the south of Medway Road**

1.2.6 Culvert under Hume Highway

There is a single 1.2 diameter pipe located under the Hume Highway, on a tributary that is North of Oldbury Creek. The culvert is located under a steep embankment.

Photo 9 Culvert under Hume Highway on western side

Appendix C

Catchment parameters

1. MEDWAY RIVULET CATCHMENT PARAMETERS

XP-RAFTS catchment inputs – Existing and final landform case

Subcatchment	Total area [ha]	Catchment slope [%]	Catchment Manning's 'n'	Percentage impervious [%]
MR0	114.7	0.6	0.05	5
MR1	148.6	1.8	0.05	5
MR2	160.6	0.7	0.075	5
MR3	39.1	3.7	0.05	5
MR4 a	64	2.02	0.06	5
MR4 b	100.9	0.7	0.06	5
MR5 a	216.6	3.5	0.075	5
MR5 b	273	0.9	0.075	10
MR6	677.8	0.6	0.05	5
MR7	545.8	0.7	0.05	5
MR8	669	0.8	0.05	30
MR9	519.4	0.9	0.05	5
MR10	763.6	1.2	0.05	5
MR11	740.3	0.7	0.05	5
MR12	349	1.1	0.075	5
MR13	338.6	1.6	0.075	5
MR14	665	0.6	0.075	5
MR15	246.8	1.2	0.075	5
WC	3667	3.2	0.05	5

XP-RAFTS catchment inputs – Operation case

Subcatchment	Total area [ha]	Catchment slope [%]	Catchment Manning's 'n'	Percentage impervious [%]
MR0	114.7	0.6	0.05	5
MR1	**129.5**	1.8	0.05	**7**
MR2	**154.0**	0.7	0.075	**8**
MR3	39.1	3.7	0.05	5
MR4 a	64	2.02	0.06	5

Subcatchment	Total area [ha]	Catchment slope [%]	Catchment Manning's 'n'	Percentage impervious [%]
MR4 b	100.9	0.7	0.06	5
MR5 a	216.6	3.5	0.075	5
MR5 b	273	0.9	0.075	10
MR6	677.8	0.6	0.05	5
MR7	545.8	0.7	0.05	5
MR8	669	0.8	0.05	30
MR9	519.4	0.9	0.05	5
MR10	763.6	1.2	0.05	5
MR11	740.3	0.7	0.05	5
MR12	349	1.1	0.075	5
MR13	338.6	1.6	0.075	5
MR14	665	0.6	0.075	5
MR15	246.8	1.2	0.075	5
WC	3667	3.2	0.05	5

Bold – factors adjusted for operation case

2. OLDBURY CREEK CATCHMENT PARAMETERS

XP-RAFTS catchment inputs – Existing and final landform case

Subcatchment	Total area [ha]	Catchment slope [%]	Catchment Manning's 'n'	Percentage impervious [%]
SC1	138.35	1.6	0.04	5
SC2	210.43	1.4	0.04	5
SC3	136.51	1.5	0.04	5
SC4	27.26	2.7	0.04	5
SC5	27.15	3.4	0.04	20
SC6	95.06	2.0	0.05	15
SC7	39.21	2.3	0.05	5
SC8	21.81	1.5	0.04	5
SW08	134.88	2.2	0.075	7
SC10	156.89	2.4	0.08	7
SC11	134.32	4.6	0.09	5
T1	105.76	0.86	0.05	15
T2a	58.30	1.4	0.04	5
T2b	15.48	1.4	0.04	10
T3	30.57	2.4	0.04	5

XP-RAFTS catchment inputs – Operation case

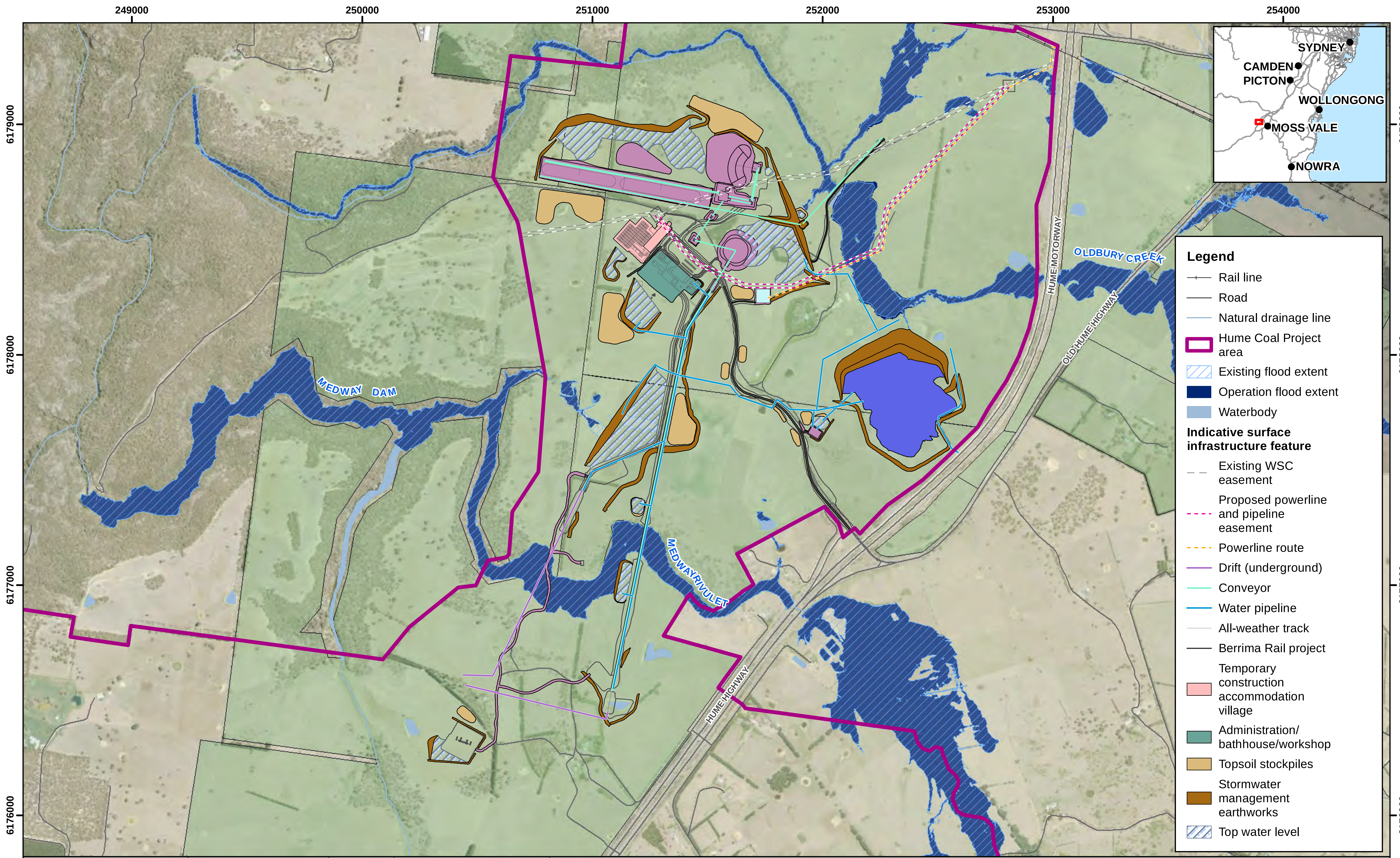
Subcatchment	Total area [ha]	Catchment slope [%]	Catchment Manning's 'n'	Percentage impervious [%]
SC1	138.35	1.6	0.04	5
SC2	210.43	1.4	0.04	5
SC3	136.51	1.5	0.04	5
SC4	27.26	2.7	0.04	5
SC5	27.15	3.4	0.04	20
SC6	**70**	**2.0**	0.05	**5**
SC7	**20**	**1.9**	0.05	**7**
SC8	**20**	**1.5**	0.04	**7**
SW08	**107**	**2.2**	0.075	**5**
SC10	156.89	2.4	0.08	7

Subcatchment	Total area [ha]	Catchment slope [%]	Catchment Manning’s 'n'	Percentage impervious [%]
SC11	134.32	4.6	0.09	5
T1	105.76	0.86	0.05	15
T2a	58.30	1.4	0.04	5
T2b	15.48	1.4	0.04	10
T3	30.57	2.4	0.04	5

Bold – factors adjusted for operation case

Appendix D

Flood extents - Operation



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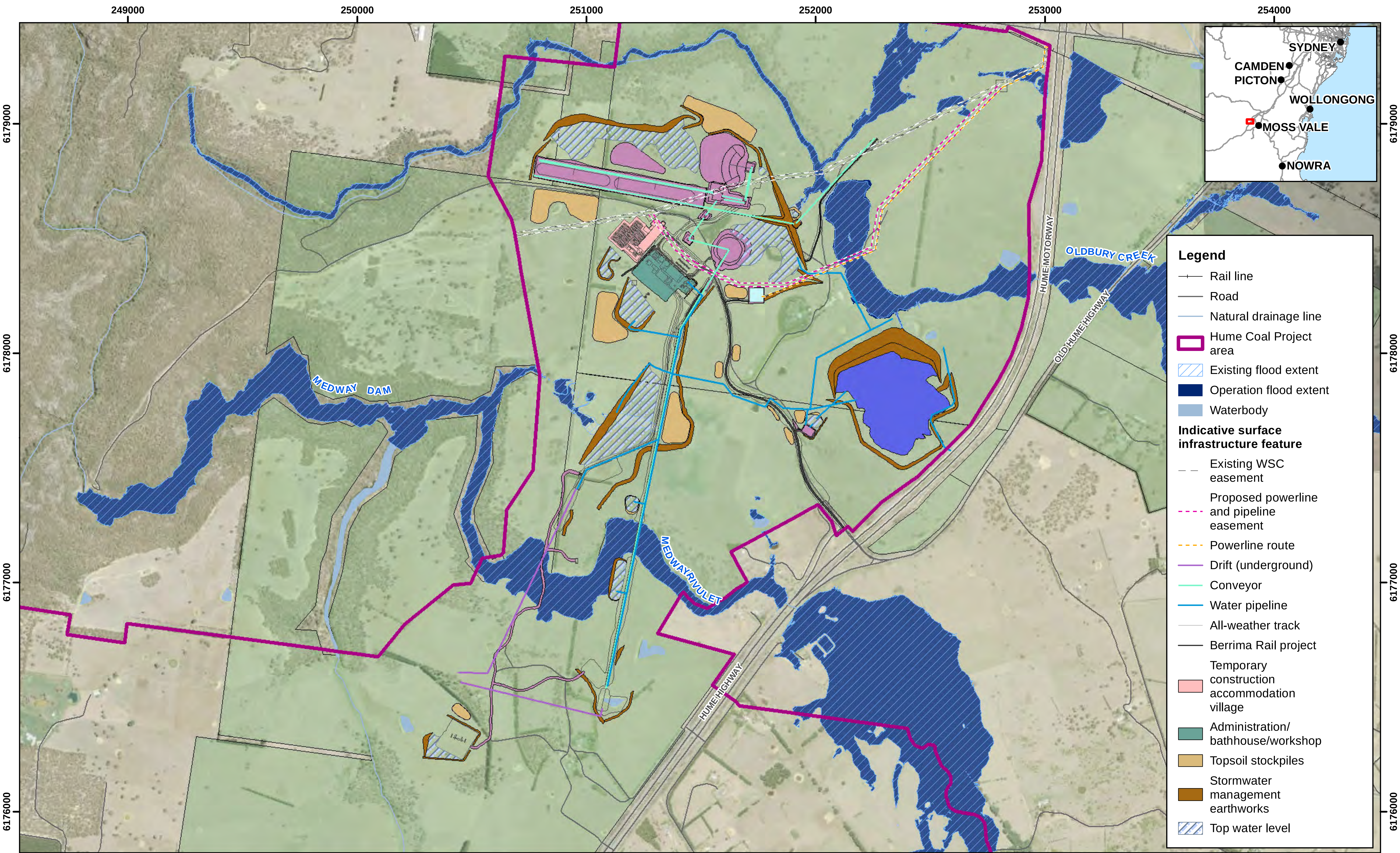
Data source: © Land and Property Information 2015, Hume Coal, Google Earth			Scale ratio correct when printed at A3

Hume Coal Flooding Assessment
Appendix D1
5 year ARI flood extent - Operation



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Data source: © Land and Property Information 2015, Hume Coal, Google Earth

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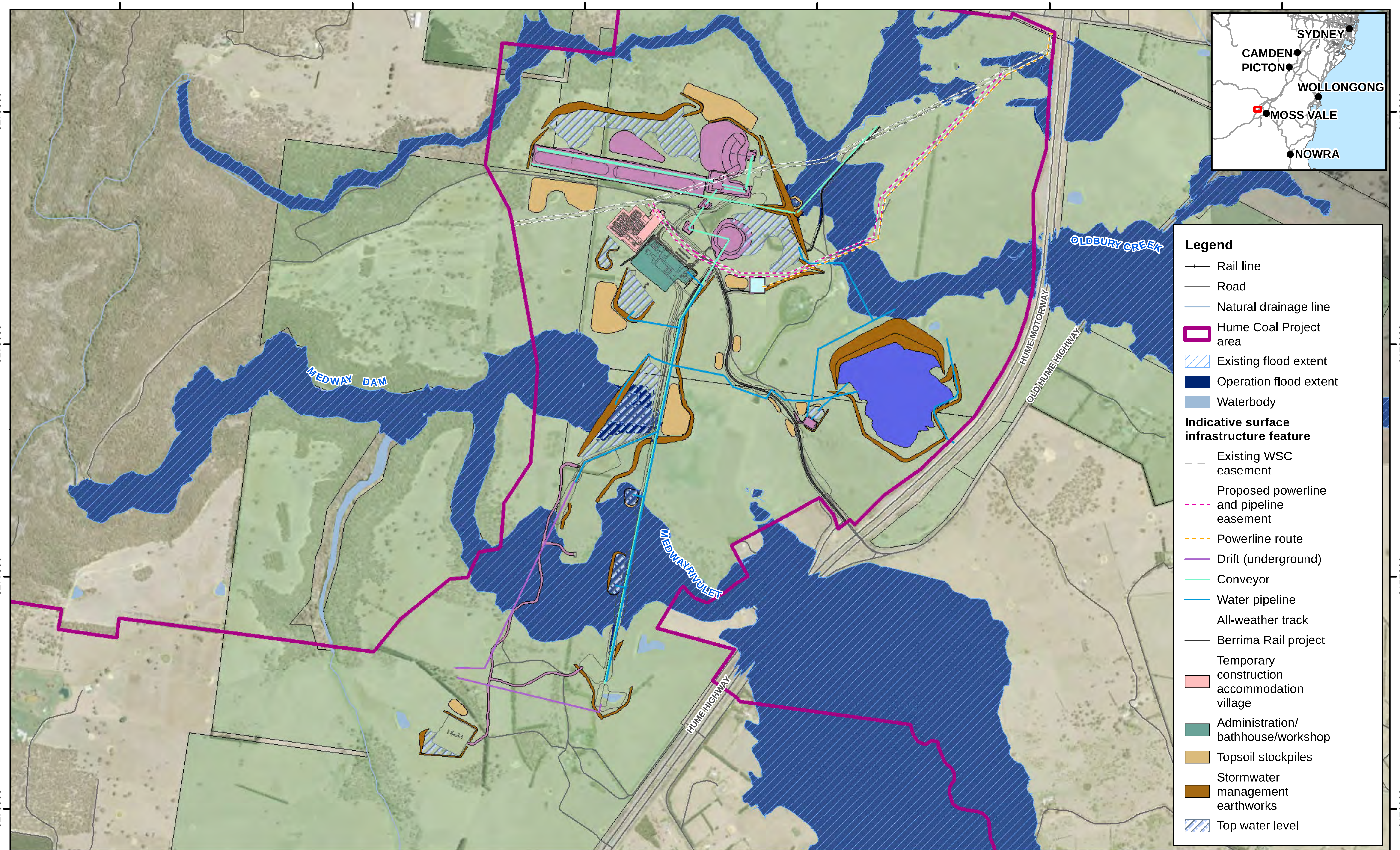
Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Flooding Assessment
Appendix D2
20 year ARI flood extent - Operation



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Data source: © Land and Property Information 2015, Hume Coal, Google Earth

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

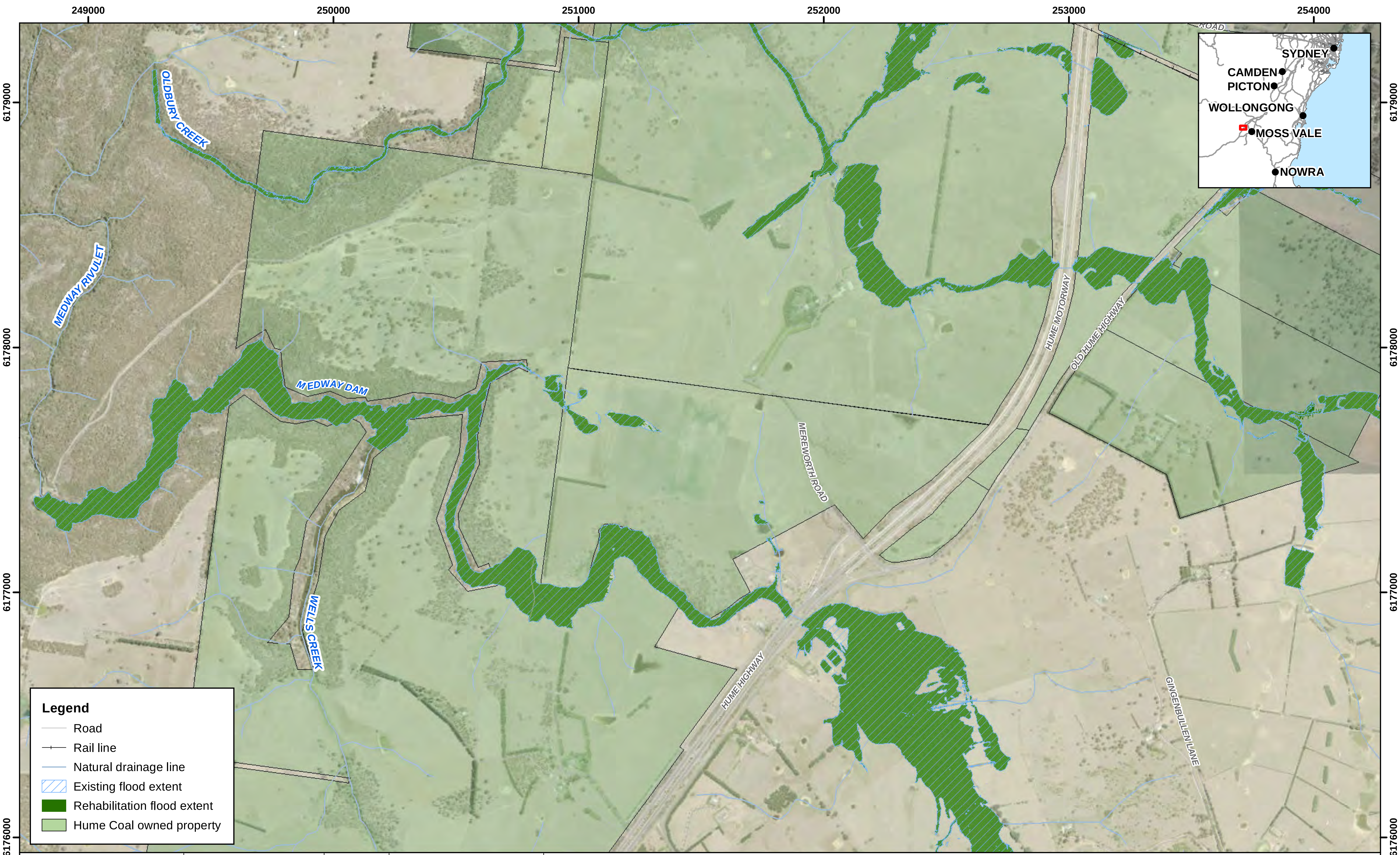
Hume Coal Flooding Assessment

Appendix D3

PMF Flood Extent - Operation

Appendix E

Flood extents - Rehabilitation



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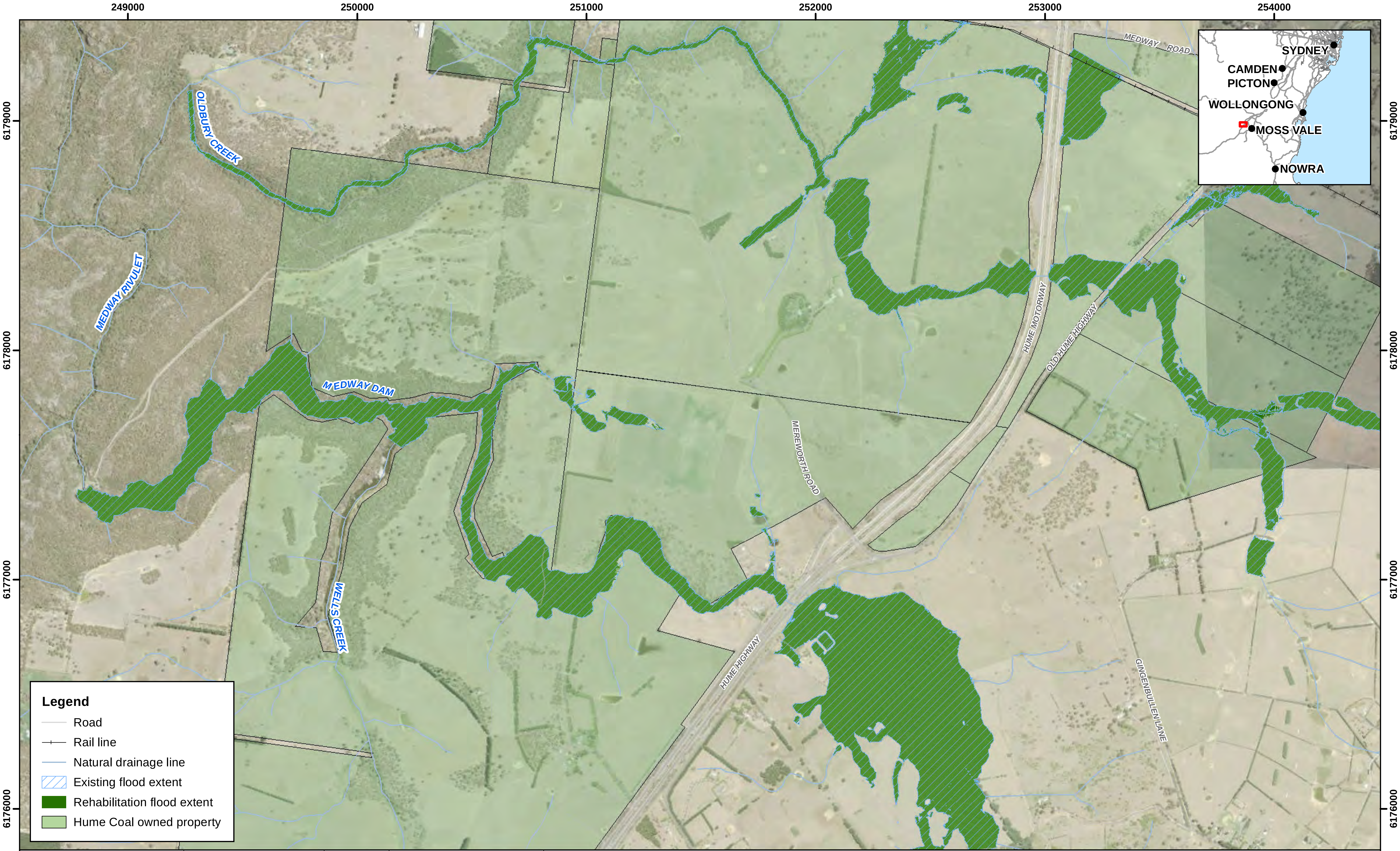
Scale ratio correct when printed at A3

Hume Coal Flooding Assessment

Appendix E1

5 year ARI flood extent - Rehabilitation



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Data source: © Land and Property Information 2015, Hume Coal

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Coordinate system: GDA 1994 MGA Zone 56

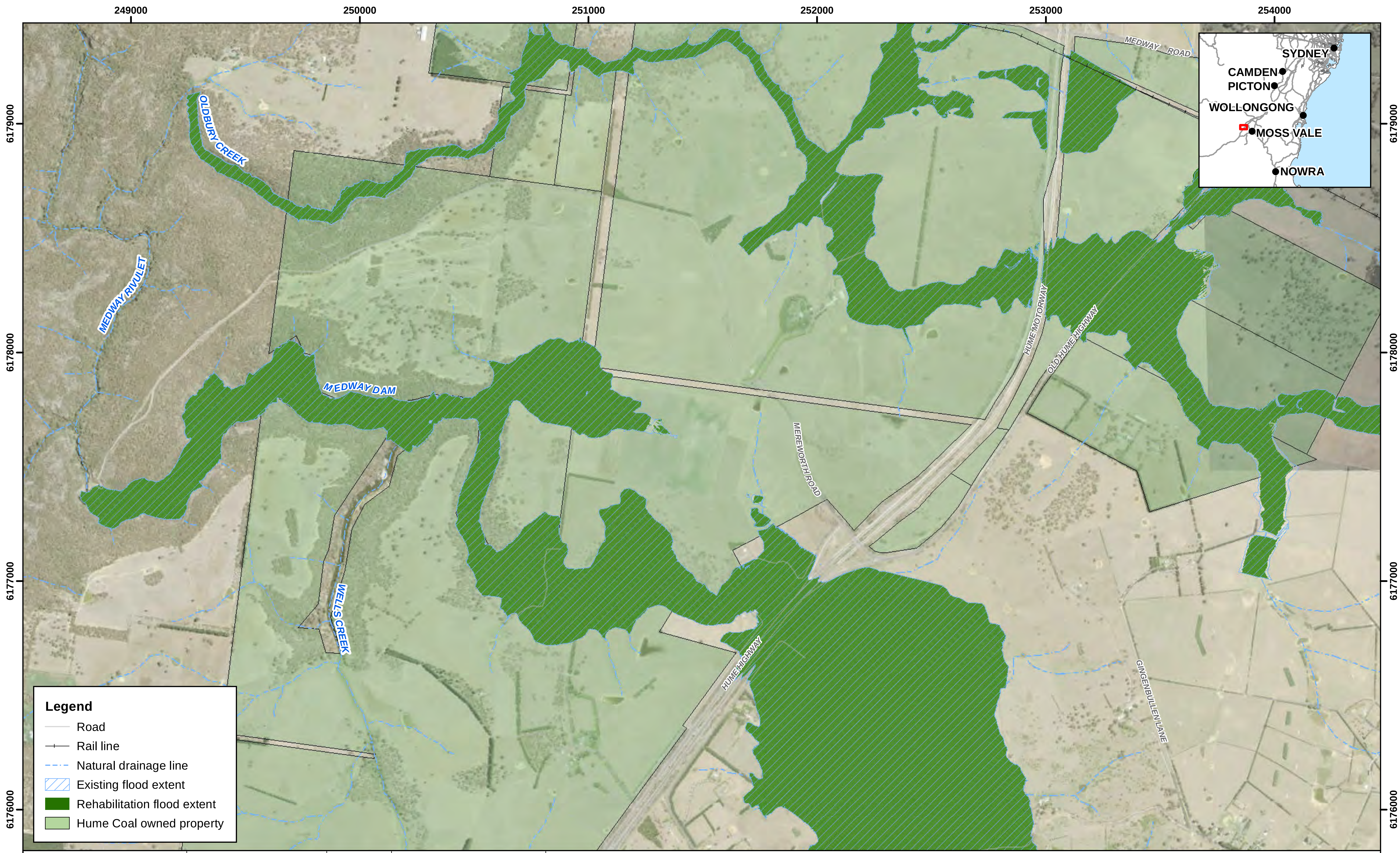
Scale ratio correct when printed at A3

Hume Coal Flooding Assessment

Appendix E2

20 year ARI flood extent - Rehabilitation

WSP | PARSONS BRINCKERHOFF



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Approved by: LR

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Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Data source: © Land and Property Information 2015, Hume Coal

Hume Coal Flooding Assessment

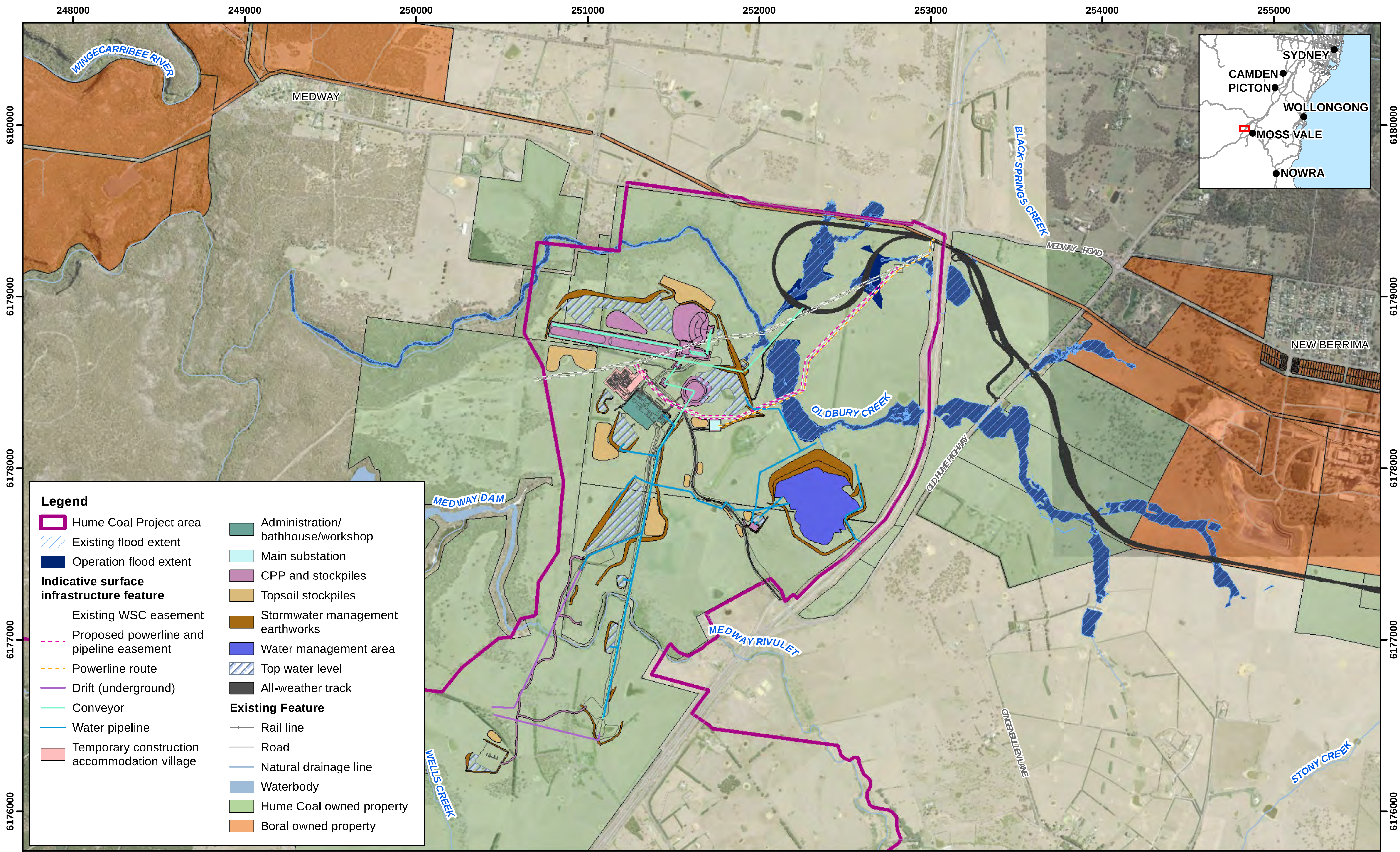
Appendix E3

PMF flood extent - Rehabilitation

WSP | PARSONS BRINCKERHOFF

Appendix F

Cumulative flood extents - Operation



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Author: RP

Date: 14/11/2016

Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal

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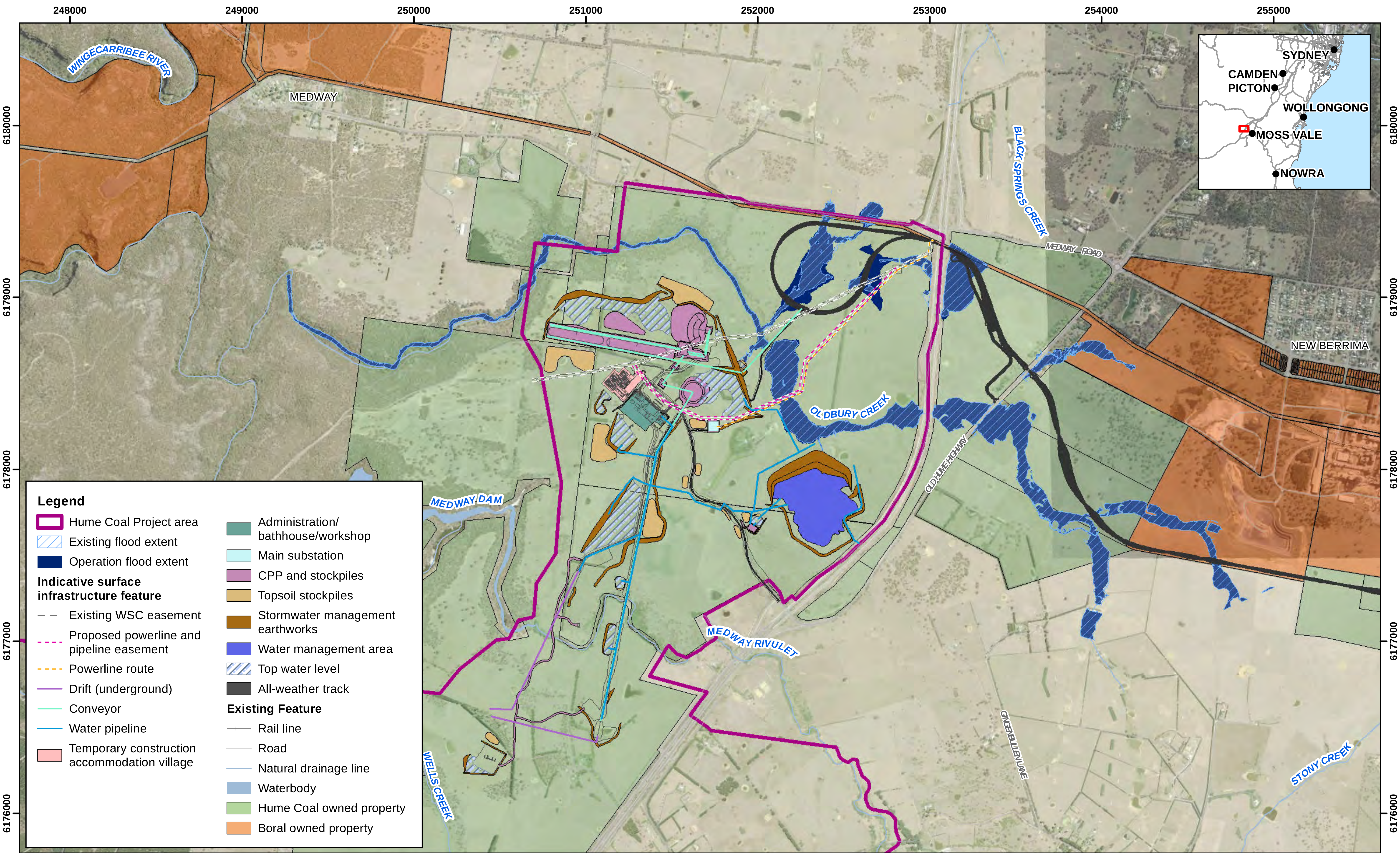
Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Flooding Assessment
Appendix F1
Cumulative 5 Year ARI flood extent - Operation



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Data source: © Land and Property Information 2015, Hume Coal

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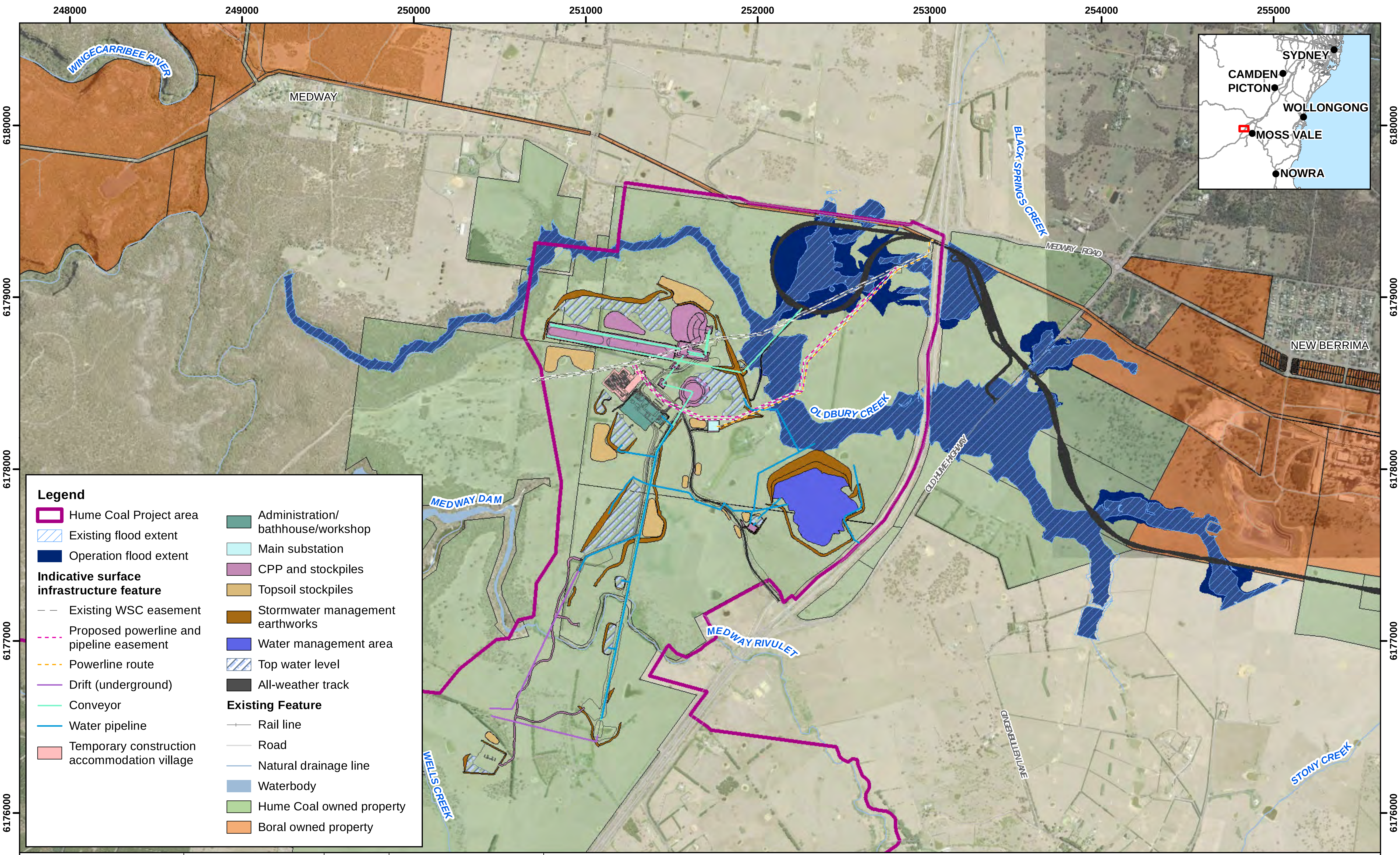
Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

Hume Coal Flooding Assessment
Appendix F2
Cumulative 20 Year ARI flood extent - Operation

WSP | PARSONS BRINCKERHOFF



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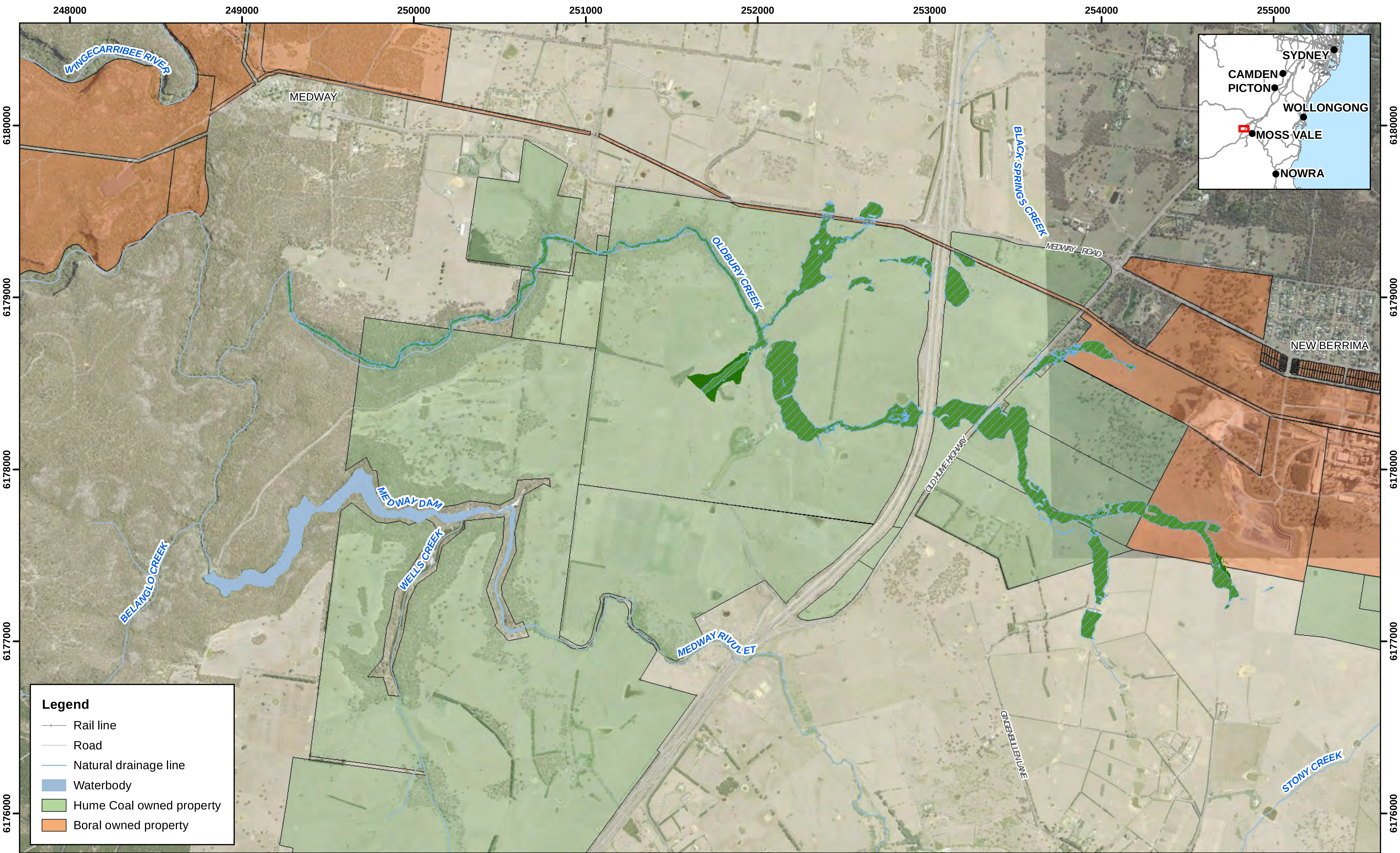
Hume Coal Flooding Assessment
Appendix F3
Cumulative PMF flood extent - Operation

WSP | PARSONS BRINCKERHOFF

Appendix G

Cumulative flood extents - Rehabilitation



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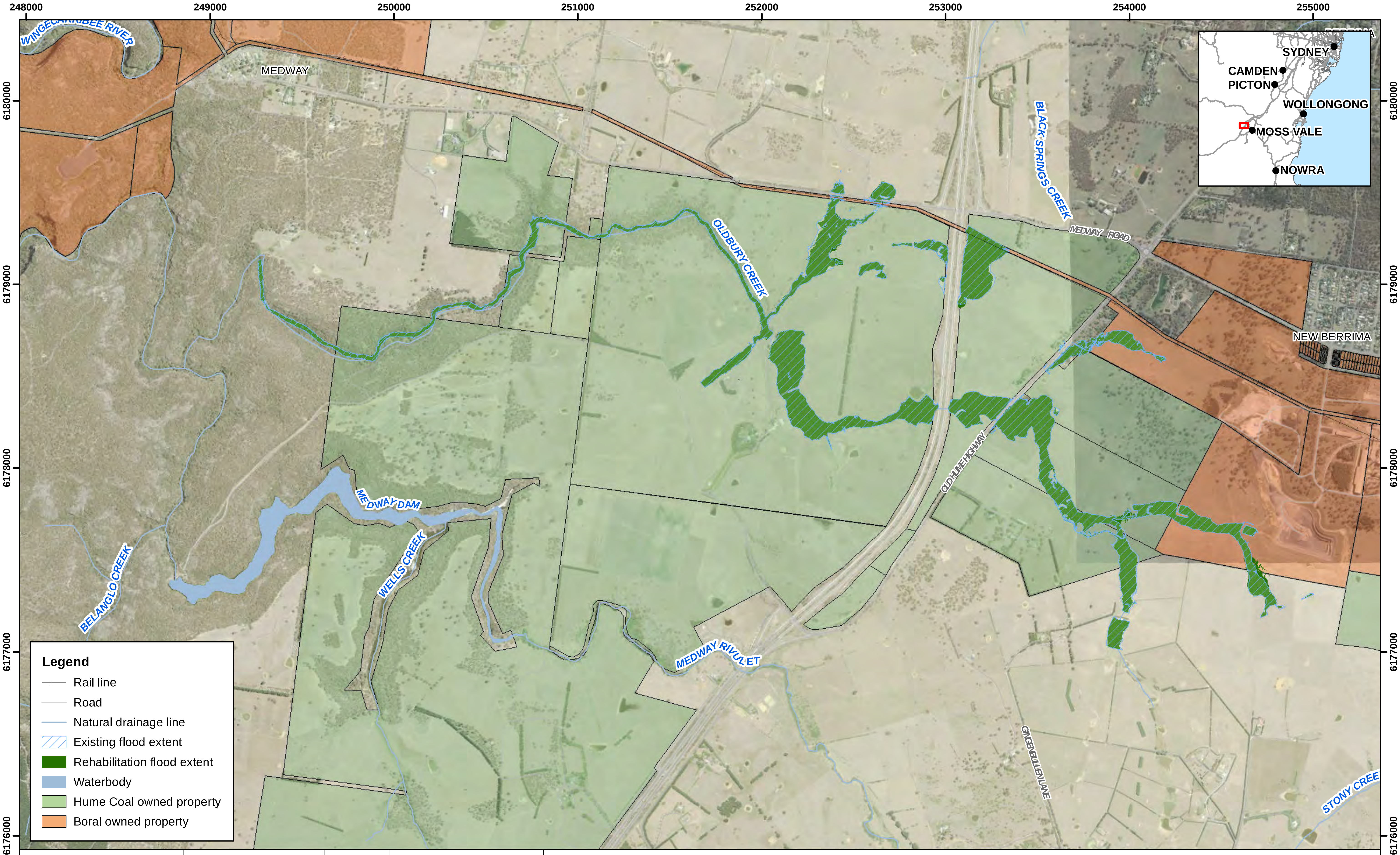
Hume Coal Flooding Assessment
Appendix G1
Cumulative 5 Year ARI flood extent - Rehabilitation

WSP | PARSONS BRINCKERHOFF



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Hume Coal Flooding Assessment
Appendix G2
Cumulative 20 Year ARI flood extent - Rehabilitation

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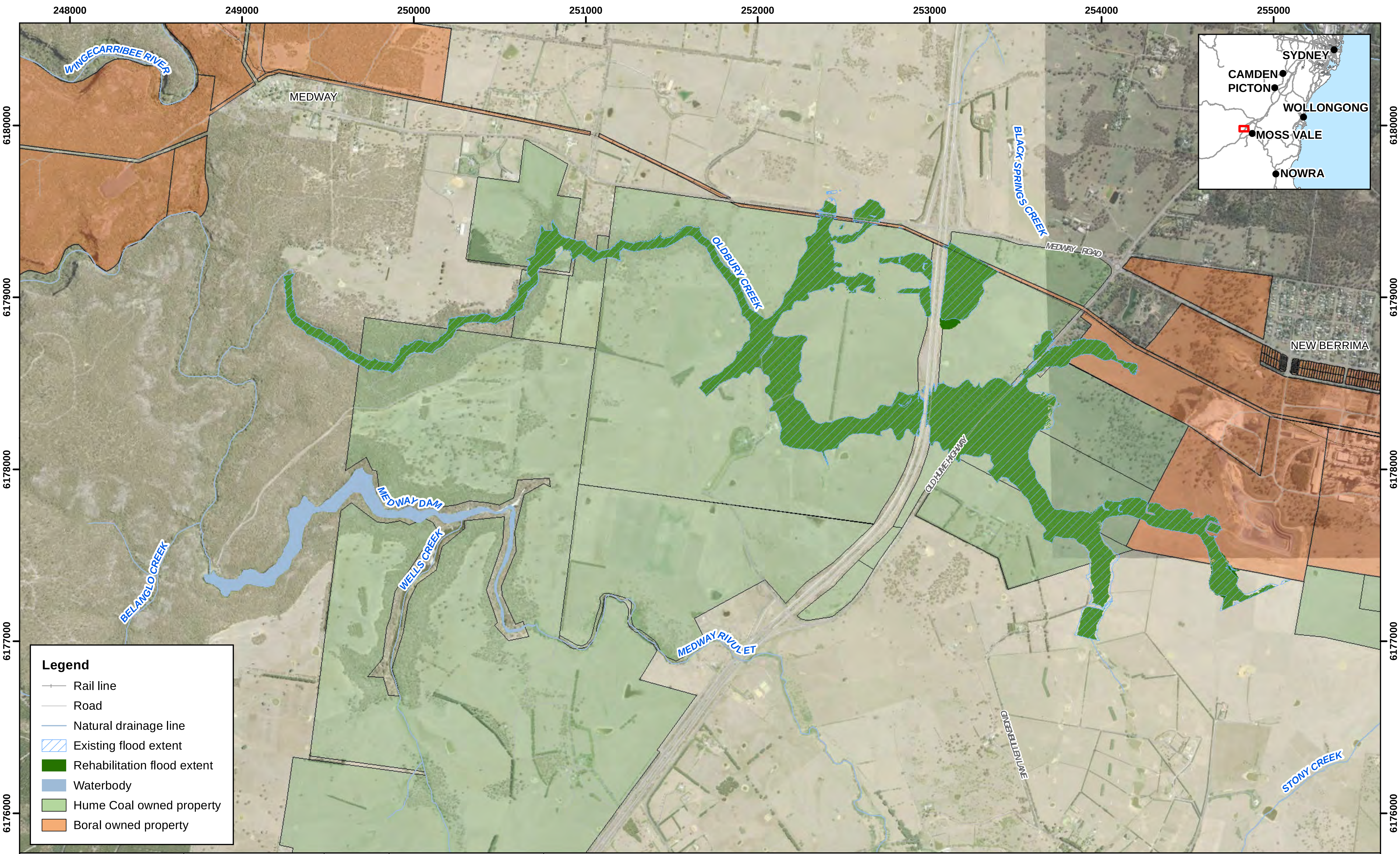

Map: 2200540A_GIS_046_B1	Author: RP
Date: 14/11/2016	Approved by: LR

Data source: © Land and Property Information 2015, Hume Coal

1:20,000

Coordinate system: GDA 1994 MGA Zone 56

Scale ratio correct when printed at A3

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Hume Coal Flooding Assessment
Appendix G3
Cumulative PMF flood extent - Rehabilitation