APPENDIX J

Appendix J - Surface Water Baseline Study, Flood Study, Water Management System and Site Water Balance, Surface Water Impact Assessment

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HYDRO ENGINEERING
& CONSULTING PTY LTD

REPORT

Tahmoor South Project
Surface Water Baseline Study

Prepared for: Tahmoor Coal Pty Ltd

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1.0 INTRODUCTION

Hydro Engineering & Consulting Pty Ltd (HEC) has been commissioned by Tahmoor Coal Pty Limited (Tahmoor Coal) to complete a surface water assessment for the Tahmoor South Project (the Project). The purpose of this assessment is to complete the surface water assessment component of the Environmental Impact Statement (EIS) for the Project under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Surface Water Assessment has been undertaken in four parts.

- Baseline Assessment Report (BA) which documents the available baseline and background information and analysis of the climate, hydrology and water quality characteristics of local and regional water resources of relevance to the Tahmoor South Project.
- Water Management System and Site Water Balance Report (WMS/SWB) which describes the existing water management system, the proposed changes to site water management and the results of a water balance model simulation of the proposed water management system over the Project life including water supply reliability, the adequacy of the current discharge licence to Tea Tree Hollow to manage disposal of water during periods/circumstances when excesses are predicted and the risk of overflows under a wide range of climatic conditions which could occur during the Project life.
- Flood Study Report (FS) comprising an assessment of the effects of the Tahmoor South Project on flooding in overlying watercourses and their floodplains.
- Surface Water Impact Assessment Report (SWIA) which contains a detailed qualitative and quantitative assessment of the potential impacts which are either predicted to occur or could occur from the Project - including the effect of predicted subsidence on natural stream features, potential effects to catchment yield, flow diversion and stream water quality

This report details the Baseline Assessment for the Tahmoor South Project Area.

1.1 BACKGROUND AND OVERVIEW

Tahmoor Coal owns and operates the Tahmoor Mine, an underground coal mine approximately 80 kilometres (km) south-west of Sydney, in the Southern Coalfields of NSW. Tahmoor Coal produces up to three million tonnes per annum of product coal from its existing operations at the Tahmoor Mine and undertakes underground mining under existing development consents, licences and the conditions of relevant mining leases.

Tahmoor Coal is seeking approval for the Project, being the extension of underground coal mining at Tahmoor Mine, to the south and east of the existing Tahmoor Mine surface facilities area. The proposed development would continue to be accessed via the existing surface facilities at Tahmoor Mine, located between the towns of Tahmoor and Bargo.

The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2035. The proposal would enable mining to be undertaken within the southern portion of Tahmoor Coal's existing lease areas and for operations and employment of the current workforce to continue for a further 13 years.

The proposed development would extend mining at Tahmoor Mine within the Project Area, using longwall methods, with the continued use of ancillary infrastructure at the existing Tahmoor Mine surface facilities area. The Project Area is adjacent and to the south of the Existing Tahmoor Approved Mining Area. It also overlaps a small area of the Existing Tahmoor Approved Mining Area comprising the surface facilities area, historical workings and other existing mine infrastructure.

1.2 PROPOSED DEVELOPMENT

The proposed development would use longwall mining to extract coal from the Bulli seam within the bounds of CCL 716 and CCL 747. Coal extraction of up to 4 Mtpa ROM is proposed as part of the development. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing Coal Handling and Preparation Plant (CHPP) and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla for export to the international market.

The key components of the proposed development comprise:

- Mine development including underground redevelopment, ventilation shaft construction, pre-gas drainage and service connection;
- Longwall mining in the Project Area;
- Upgrades to the existing surface facilities area including:
    - upgrades to the CHPP;
    - expansion of the existing reject emplacement area (REA);
    - relocation of the rejects bin and extension of the rejects conveyor;
    - additional mobile plant for coal handling;
    - additions to the existing bathhouses, stores and associated access ways;
    - upgrades to onsite and offsite service infrastructure, including electrical supply;
- Rail transport of product coal to Port Kembla, and Newcastle (from time to time);
- Mine closure and rehabilitation; and
- Environmental management.

1.3 STUDY REQUIREMENTS

The Tahmoor South Project EIS has been prepared in accordance with Division 4.1, Part 4 of the EP&A Act which ensures that the potential environmental effects of a proposal are properly assessed and considered in the decision-making process.

The Surface Water Assessment is guided by the Secretary's Environmental Assessment Requirements (SEARs) for SSD 17_8445, including the amendment dated 14 February 2018 to incorporate the requirements of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The requirements are outlined in Table 1, including where they have been addressed. Detailed agency comments have also been addressed in this report including comments from the NSW Environment Protection Authority (EPA), NSW Office of Environment & Heritage (OEH) and WaterNSW – as given in Table 1. All groundwater and aquatic ecosystem related requirements have been addressed in reports by others.

The Surface Water Assessment has also taken cognisance of the "Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals" (IESC Information Guidelines). The checklist of specific information needs relating to surface water provided in the IESC Information Guidelines is given in Table 2, including where these have been addressed.

Table 1 Secretary's Environmental Assessment Requirements – Surface Water

Agency	Requirement	Where Addressed or Why not Addressed
Department of Planning and Environment	**Water** - including: - an assessment of the likely impacts of the development on the quantity and quality of surface and groundwater resources, having regard to EPA's, DPI Water's and Water NSW's requirements and recommendations (see Attachment 2); - an assessment of the likely impacts of the development on aquifers, watercourses, swamps, riparian land, water supply infrastructure and systems and other water users; - an assessment of any drinking water catchment losses from mining, and whether the development can be operated to achieve a neutral or beneficial effect on water quality in the Sydney Drinking Water Catchment, consistent with the provisions of State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011; - a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply and transfer infrastructure and water storage structures; - a detailed description of the proposed water management system (including sewerage), beneficial water re-use program and all other proposed measures to mitigate surface water and groundwater impacts; - the proposed surface water and groundwater monitoring regime, which should include a comprehensive array of shallow and deep piezometers and extensometers across the underground mining area which are capable of detecting fluctuations in groundwater levels and the influence of fracture networks on regional groundwater resources; and - an assessment of the potential flooding impacts of the development.	SWIA Report Sections 7 to 10 & 12 SWIA Report Sections 7 to 10, 12 & HydroSimulations (2018) SWIA Report Section 13 WMS/SWB Sections 5 to 7 WMS/SWB Section 4; SWIA Report Sections 10.1 & 11 SWIA Report Section 11 & HydroSimulations (2018) FS Report Sections 6 & 7
Environment Protection Authority	Specific Issues to be addressed in the Tahmoor South Project EIS: PRP 22 - Tahmoor Water Treatment Plant required a new plant to be built to reduce levels of nickel, arsenic and zinc in the discharge to meet the 95%-ile ANZECC 2000 trigger values for protection of aquatic ecosystems in the Bargo River. Interim licence limits reflecting current performance are in place until these ANZECC requirements are achieved. Construction of the treatment plant was completed, however, the plant does not appear to have met performance expectations and is running at reduced capacity. In developing the Environmental Impact Statement (EIS), the proponent should describe the improvements achieved in water treatment and discharges at the site in recent years. This includes the performance of the new treatment plant constructed under PRP 22. The EIS should determine whether environmental values for the Bargo River are now being met downstream of the discharge or will be met following full commissioning of the plant. The EIS should assess whether additional treatment may be required to meet environmental values.	SWIA Report Section 10.1

Table 1 (Cont.) Secretary's Environmental Assessment Requirements – Surface Water

Agency	Requirement	Where Addressed or Why not Addressed
Office of Environment & Heritage	**Water and soils**:	
	The EIS must map the following features relevant to water and soils including: - Rivers, streams, wetlands, estuaries - Proposed intake and discharge locations	This report Section 5
	The EIS must describe background conditions for any water resource likely to be affected by the development, including:	
	a. Existing surface and groundwater.	This report Sections 5 to 8
	b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.	This report Sections 5 to 8
	c. Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htrn) including groundwater as appropriate that represent the community's uses and values for the receiving waters.	This report Section 8
	d. Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	This report Section 8
	The EIS must assess the impacts of the development on water quality, including:	
	a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.	SWIA Report Section 10
	b. Identification of proposed monitoring of water quality.	SWIA Report Section 11
	The EIS must assess the impact of the development on hydrology, including:	
	a. Water balance including quantity, quality and source.	WMS/SWB Section 7
	b. Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas	SWIA Report Section 9 & FS Report Section 6
	d. Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches).	SWIA Report Section 10 & FS Report Section 6 & Niche Environment and Heritage (2018)
	e. Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water.	WMS/SWB Section 7
	f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options.	WMS/SWB Section 7
	g. Identification of proposed monitoring of hydrological attributes.	SWIA Report Section 12 & Niche Environment and Heritage (2018)

Table 1 (Cont.) Secretary's Environmental Assessment Requirements – Surface Water

Agency	Requirement	Where Addressed or Why not Addressed
Office of Environment & Heritage (Cont.)	**Flooding and Coastal Erosion** The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including: a. Flood prone land. b. Hydraulic categorisation (floodways and flood storage areas). c. Flood planning area, the area below the flood planning level (areas below the 1 in 100 flood level plus a freeboard).	FS Report Section 6.9
	The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 1 in 10 year, 1 in 100 year flood levels and the probable maximum flood PMF.	FS Report Section 6
	The EIS must consider the impact of mine subsidence on flooding as it affects both existing and future development of flood prone land within the catchment over a full range of flooding to a PMF level. The EIS must model the effect of the proposed project on the flood behaviour under the following by incorporating the estimated mine subsidence into the hydraulic model under the following scenario:	FS Report Section 6.9 & Appendix A
	a. Current flood behaviour for a range of design events as identified above. b. The 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	FS Report Section 6 & Appendix A
	Modelling in the EIS must consider and document: a. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood. b. Impacts of mine subsidence, earthworks and stockpiles within the flood prone land up to the PMF level. The assessment should be based on understanding of cumulative flood impacts resulting from mining.	FS Report Section 6 & Appendix A
	c. Whether appropriate mitigation measures required to offset potential flood risk arise from the project. Any proposed mitigation work should be modelled and assessed on the overall catchment basis in order to ensure it fit its purpose and meets the criteria of the Council where it is located, and to ensure it has no adverse impact to surrounding areas.	FS Report Section 6, 7 & SWIA Report Sections 7.5, 9 & 11
	The EIS must address the following floodplain risk management issues, including:	
	a. Consistency with Wollondilly Councils' floodplain risk management plans.	No floodplains in Project Area
	b. Compatibility with the flood hazard of the land.	FS Report Section 6.9
	c. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	FS Report Section 6.9 & SWIA Report Section 9
	d. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	No floodplains in Project Area

Table 1 (Cont.) Secretary's Environmental Assessment Requirements – Surface Water

Agency	Requirement	Where Addressed or Why not Addressed
Office of Environment & Heritage (Cont.)	**Flooding and Coastal Erosion (Cont.)** The EIS must address the following floodplain risk management issues, including e. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and relevant Councils. f. Emergency management, evacuation and access, and specific measures to manage risk to life from rarer flood during both construction and operational phases considering the full range of flood risk up to the probable maximum flood. These matters are to be discussed with and have the support of Council and the SES. g. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	Not undertaken – no significant changes to flood extent – per FS Report Sections 6 & Appendix A Not undertaken – no significant changes to flood extent – per FS Report Sections 6 & Appendix A SWIA Report Section 9
WaterNSW	As the development is partly located within the Sydney Drinking Water Catchment, clauses 9(1) and (2) and 10(1) of the State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011 apply. The EIS specifically address these clauses. In particular, the EIS must describe with clarity and justify how the development would have a neutral or beneficial effect on water quality. The full description of the development and existing environment should also include those aspects which have the potential to impact on the quality and quantity of surface and ground waters at and adjacent to the site. This includes: • the location and description of all water monitoring locations/points (surface and ground waters). The detailed assessment of the mining proposal on water resources including groundwater and surface water associated with subsidence should also consider the design, construction, operational, decommissioning phases and cumulative impacts and include: • impacts on water quantity and quality of overlying and adjacent water resources including Pheasant's Nest Weir, Nepean River, Cow Creek and their tributaries and groundwater systems connected to the catchments of Pheasants Nest Weir and to Warragamba Dam using scientifically sound and rigorous numerically modelling and sufficient, appropriate and representative baseline data • impacts of the proposed mining on receiving water quantity and quality, both surface and groundwater systems and associated impacts on interaction and baseflows of surface waters	This report Sections 5.2 & 5.3 & HydroSimulations (2018) This section (refer below) & SWIA Report Section 13 SWIA Report Sections 7 to 10 SWIA Report Section 11.4

Table 1 (Cont.) Secretary's Environmental Assessment Requirements – Surface Water

Agency	Requirement	Where Addressed or Why not Addressed
WaterNSW (Cont.)	• details of proposed monitoring of groundwater levels, surface water flows, groundwater and surface water quality, along with information as to how the proposed monitoring will be used to monitor and, if necessary, mitigate impacts on surface water and groundwater resources, and • details of the contingency plans to manage risks.	SWIA Report Section 11 & HydroSimulations (2018)
Commonwealth Department of the Environment and Energy	**Water resource in relation to coal seam gas development and large coal mining development** 16. The EIS should provide a description of the location, extent and ecological characteristics and values of the identified water resource potentially affected by the project. 17. The assessment of impacts should include information on: - any substantial and measurable changes to the hydrological regime of the water resource, for example a substantial change to the volume, timing, duration or frequency of ground and surface water flows; - substantial and measurable change in the water quality and quantity of the water resource	This report Section 5 & Niche Environment and Heritage (2018) FS Report Sections 6 & 7 SWIA Report Sections 7 & 10

Table 2 IESC Information Guidelines Information Needs – Surface Water

Information Need	Where Addressed or Why not Addressed
Surface Water - Context and conceptualisation	
A description of the hydrological regime of all watercourses, standing waters and springs across the site including:	
• Geomorphology, including drainage patterns, sediment regime and floodplain features.	Gippel (2013)
• Spatial, temporal and seasonal trends in streamflow and/or standing water levels.	This report Sections 5.1, 5.3 & 7
• Spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals and metalloids and radionuclides).	This report Section 8
• Current stressors on watercourses, including impacts from any currently approved projects.	This report Sections 5.1, 5.2 & SWIA Report Section 6
A description of the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities, and flood hydrographs and maps identifying peak flood extent, depth and velocity.	FS Report
Assessments of the frequency, volume and direction of interactions between water resources, including surface water/groundwater connectivity and connectivity with sea water.	This report Section 6 & HydroSimulations (2018)
Surface Water - Analytical and numerical modelling	
Conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	This report Section 6 & WMS/SWB Sections 5 & 6
Methods in accordance with the most recent publication of Australian Rainfall and Runoff	FS Report
A programme for review and update of the models as more data and information becomes available	SWIA Report Section 11.2
Description and justification of model assumptions and limitations and calibration with appropriate surface water monitoring data.	This report Section 6 & WMS/SWB Sections 5 & 6
An assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios	This report Section 6 & WMS/SWB Sections 5 & 6
A detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	SWIA Report Section 6
Surface Water - Impacts to water resources and water-related assets	
Description of all potential impacts of the proposed project on surface waters, including a clear description of the impact to the resource, the resultant impact to any water-related assets dependent on the resource, and the consequence or significance of the impact, including:	
• Impacts on streamflow under different flow conditions.	SWIA Report Section 7
• Impacts associated with surface water diversions.	Not relevant
• Impacts to water quality, including consideration of mixing zones.	SWIA Report Section 10
• Estimates of the quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges and the likely impacts on water resources and water-related assets.	SWIA Report Section 10.1, WMS/SWB Section 7 & Niche Environment and Heritage (2018)

Table 2 (Cont.) IESC Information Guidelines Information Needs – Surface Water

Information Need	Where Addressed or Why not Addressed
• Identification and consideration of landscape modifications, for example, subsidence, voids, onsite earthworks including disturbance of acid-forming or sodic soils, roadway and pipeline networks through effects on surface water flow, surface water quality, erosion and habitat fragmentation of water-dependent species and communities.	SWIA Report Sections 7 to 10, MSEC (2018) & Niche Environment and Heritage (2018)
Identified processes to determine surface water quality and quantity triggers which incorporate seasonal variation but provide early indication of potential impacts to assets.	This report Section 8 & SWIA Report Sections 11.1 to 11.3
Proposed mitigation actions for each trigger and identified significant impact.	SWIA Sections 9.1.3 & 11.4
Description and adequacy of proposed measures to prevent/minimise impacts on water resources and water-related assets.	SWIA Sections 9.1.3 & 11.4
Description of the cumulative impact of the proposal on surface water resources and water-related assets when all developments (past, present and/or reasonably foreseeable) are considered in combination.	SWIA Section 13
Surface Water - Data and monitoring	
Water quality monitoring complying with relevant National Water Quality Management Strategy (NWQMS) guidelines5 and relevant legislated state protocols.	This report Section 8
A surface water monitoring programme collecting sufficient data to detect and identify the cause of any changes from established baseline conditions, and assessing the effectiveness of mitigation and management measure.	This report Section 8 & SWIA Sections 11.1 to 11.3
Identification of dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the development proposal and beyond.	This report Section 8 & SWIA Sections 11.1 to 11.3
Monitoring sites representative of the diversity of potentially affected water-related assets and the nature and scale of potential impacts, and matched with suitable replicated control and reference sites (i.e. BACI design) to enable detection and monitoring of potential impacts.	This report Section 8 & SWIA Sections 11.1 to 11.3
The rationale for selected monitoring variables, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts	ANZECC (2000) guideline variables – this report Section 8 & SWIA Sections 11.1 to 11.3
Ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate.	Niche Environment and Heritage (2018)
Specified data sources, including streamflow data, proximity to rainfall stations, data record duration and a description of data methods, including whether missing data has been patched.	This report Sections 4 & 5
Water-related assets - Context and conceptualisation	
Identification of water-related assets, including: • Water-dependent fauna and flora supported by habitat, flora and fauna (including stygofauna) surveys. • Public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	Niche Environment and Heritage (2018) This report Sections 5.1 & 8, SWIA Section 3

Table 2 (Cont.) IESC Information Guidelines Information Needs – Surface Water

Information Need	Where Addressed or Why not Addressed
An outline of the water-related assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	This report Sections 5 & 8, SWIA Section 4
A description of the process employed to determine water quality and quantity triggers and impact thresholds for water-related assets (e.g. threshold at which a significant impact on an asset may occur).	This report Section 8 & SWIA Sections 11.1 to 11.3
Identification of GDEs in accordance with the method outlined by Eamus et al. (2006). Information from the GDE Toolbox12 and GDE Atlas13 may assist in identification of GDEs.	HydroSimulations (2018)
Identification of the hydrogeological units on which any identified GDEs are dependent.	HydroSimulations (2018)
An estimation of the ecological water requirements of identified GDEs and other water-dependent assets.	Niche Environment and Heritage (2018)
Conceptualisation and rationale for likely water-dependence, impact pathways, tolerance and resilience of water-related assets.	Niche Environment and Heritage (2018)
Water-related assets - Impacts, risk assessment and management of risks	
An assessment of direct and indirect impacts on water-related assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs.	SWIA Sections 5 to 10, Niche Environment and Heritage (2018) & HydroSimulations (2018)
Estimates of the impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-related assets and ecological processes.	SWIA Section 10.1
Indication of the vulnerability to contamination (for example, from salt production and salinity) and the likely impacts of contamination on the identified water-related assets and ecological processes.	This report Section 8, SWIA Section 10 & Niche Environment and Heritage (2018)
A description of the potential range of drawdown at each affected bore, and a clear articulation of the scale of impacts to other water users.	HydroSimulations (2018)
Identification and consideration of landscape modifications (for example, voids, onsite earthworks, roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	SWIA Sections 5, 7, 9 & 10 & Niche Environment and Heritage (2018)
Water-related assets - Data and monitoring	
Ecological monitoring complying with relevant state or national monitoring guidelines	Niche Environment and Heritage (2018)
Sampling sites at an appropriate frequency and spatial coverage to establish pre-development (baseline) conditions, and test hypothesised responses to impacts of the proposal.	This report Sections 5.3 & 8
Concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design).	This report Sections 5.3 & 8
Monitoring that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change.	SWIA Sections 11.1 to 11.3 & Niche Environment and Heritage (2018)
Regular reporting, review and revisions to the monitoring programme.	SWIA Sections 11.1 to 11.3

Table 2 (Cont.) IESC Information Guidelines Information Needs – Surface Water

Information Need	Where Addressed or Why not Addressed
Water and salt balance and water management strategy	
Quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.	WMS/SWB Sections 5 to 7
Description of water requirements and onsite water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	WMS/SWB Sections 3, 4 & 7
Estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-related assets	WMS/SWB Section 7 & SWIA Sections 7.5 & 10.1
Salt balance modelling, including stores and the movement of salt between stores taking into account seasonal and long-term variation.	Modelling undertaken as part of the PRP23 Report by Cardno (2016) indicated that salinity (electrical conductivity) levels at LDP1 had limited influence on salinity levels in the Bargo River compared with flow and background salinity levels in the Bargo itself. Therefore detailed salinity modelling of the water management system is not considered justified.

It is noted that since the preparation of the preliminary environmental assessment (PEA) for the Project (AECOM, 2012a), the proposed mine plan for Tahmoor South has been amended to preclude mining and related subsidence within the Sydney Drinking Water Catchment, that is, within the catchment of Cow Creek, a tributary of the Nepean River upstream of Pheasant's Nest Weir. It is therefore concluded that there would be no surface water related impacts resulting from the Project on these catchments – refer also SWIA Report Section 14.

2.0 PROJECT DESCRIPTION

2.1 OVERVIEW

Tahmoor Coal is seeking approval for the continuation of mining at Tahmoor Mine, extending underground operations and associated infrastructure south within the Bargo area and to the east within the Pheasants Nest area (refer Figure 1). The proposed development seeks to extend the life of underground mining at Tahmoor Mine for an additional 13 years until approximately 2035.

The proposed development will use longwall mining to extract coal from the Bulli seam within the bounds of CCL716 and CCL747. Coal extraction of up to 4 million tonnes of run-of-mine (ROM) coal per annum is proposed as part of the development with extraction of up to 37 Mt of ROM coal over the life of the Project.

The proposed Project would utilise the existing surface infrastructure at the Tahmoor Mine surface facilities area, with some upgrades proposed to facilitate the extension. The proposed Project also incorporates the planning for rehabilitation and mine closure once mining ceases.

2.2 UNDERGROUND MINING OPERATIONS

2.2.1 Mining Area

Tahmoor Coal holds CCL 747 and CCL 716. The Project proposes to mine coal from the Bulli seam at a depth of between approximately 375 m and 430 m below ground level. The proposed mining area is bounded by known geological fault zones.

During the mine planning process, a constraints analysis, risk assessment and preliminary fieldwork were undertaken to identify sensitive natural surface features (such as waterways, cliffs, and Aboriginal heritage sites) and to develop Risk Management Zones (RMZs). Subsequent to the risk assessment the proposed longwall layout was modified to minimise significant subsidence impacts to these natural features. The underground extent of the mine proposed on Figure 1 represents this configuration.

The longwalls would be orientated in a south-east/north-west direction and would be located within the Bargo area. The longwall layout would continue to be refined during the detailed design phase of the proposed development. However, the maximum extent of longwall mining for the proposed development would be as depicted on Figure 1.

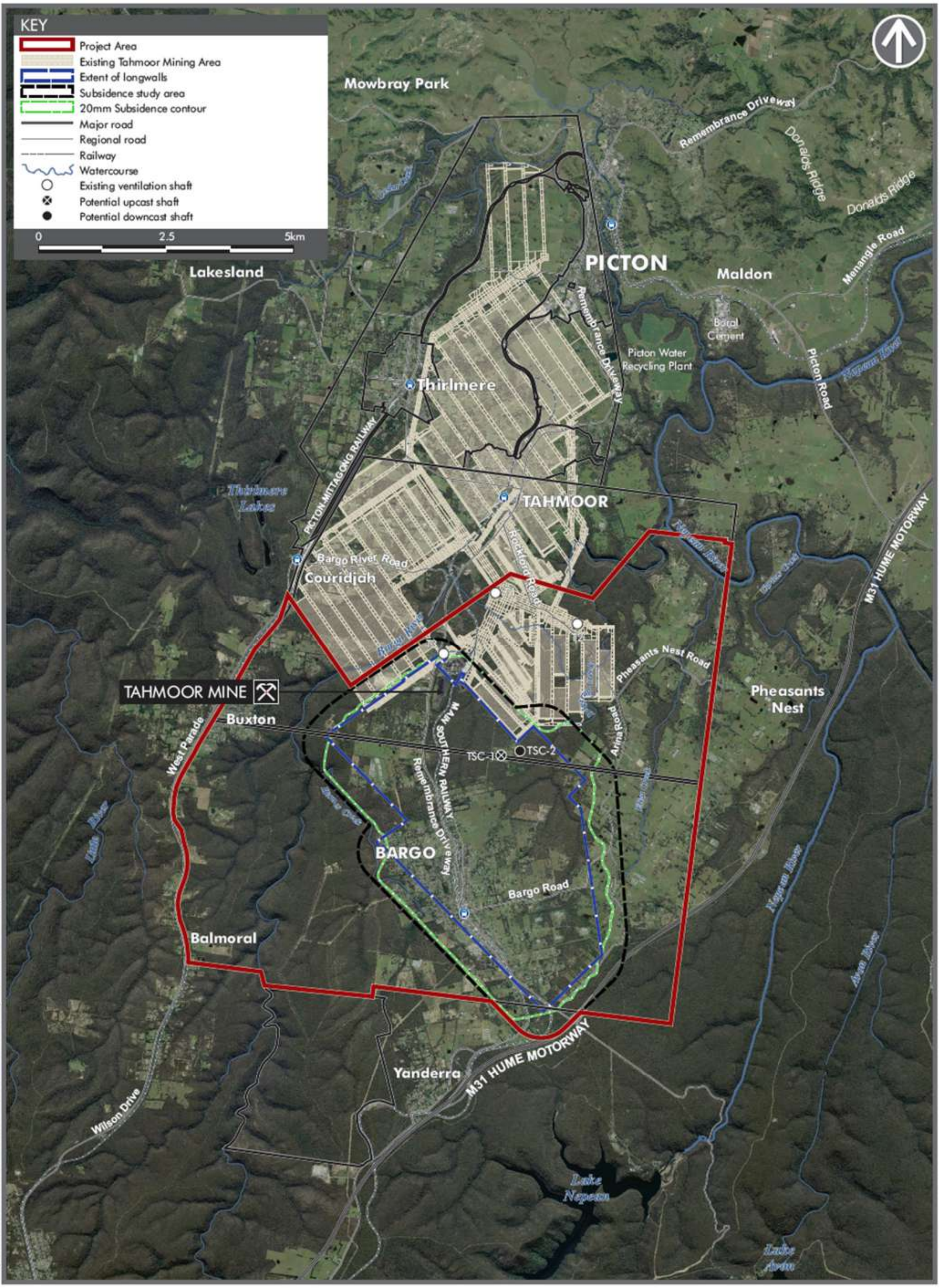

Figure 1 Locality Plan and Project Layout

As part of the proposed development, subsidence predictions have been undertaken for residential, commercial and business structures, public infrastructure such as pools and public amenities, utility services such as water and gas mains and other associated infrastructure. These predictions and potential impacts would be captured within a subsidence management plan (SMP) prior to longwall mining for the proposed development and would incorporate the management measures identified herein.

2.2.2 Mine Development

To enable the continuation of mining to occur sequentially with the current mining operations in Tahmoor North, which are scheduled for completion in approximately 2022, the Project's development works need to commence in approximately 2019. Pre-development activities include:

- recovery of existing underground development roadways;
- redevelopment of the underground pit bottom;
- pre-gas drainage;
- longwall development including establishment of gate roads;
- installation of electrical, water and gas management networks; and
- the purchase and installation of equipment.

An additional 50 to 175 personnel would be required for the Project's development works, which may occur concurrently with the ongoing mining operations at Tahmoor North. Additional site amenities, including bath houses and additional onsite car parks would be required to accommodate the increased workforce during the transition period from mining operations at Tahmoor North and the Project's development works.

During this transition period, other site infrastructure required for longwall mining at the Project would be constructed. Specifically, this would include construction of new mine ventilation shafts, construction of a hardstand area for longwall machinery set up and upgrades to the CHPP.

2.2.3 Mine Ventilation

The proposed development would utilise the existing mine's ventilation system, including the existing three ventilation shafts, being one upcast (T2) and two downcast shafts (T1 and T3). Additionally, the proposed development would require the construction of two ventilation shafts to provide a reliable and adequate supply of ventilation air to personnel in the mine. The two additional vent shafts proposed for the Project are:

- TSC1: an upcast ventilation shaft that will be located on Tahmoor Coal's Charlies Point Road property; and
- TSC2: a downcast ventilation shaft that will be located on Crown Land adjacent to Tahmoor Coal's Charlies Point Road property.

The construction of the ventilation shafts would require the disturbance of an area of between four to six hectares in area at each location. Access to TSC1 and TSC2 would be from the existing road network.

The construction of each of the proposed ventilation shafts would involve the following:

- Construction of internal roads to allow access for construction and operational maintenance vehicles.
- Establishment of the construction site to allow sufficient space for stockpiling of shaft liners for TSC1 and TSC2, temporary spoil emplacement for TSC2, water management, storage

and safe movement on-site during construction activities. Establishment of the ventilation shaft site would involve:

- Installation of environmental controls such as silt fences, fencing with lockable gates, as well as display of signage relating to restricted entry.
- Clearing of vegetation and stripping of topsoil. Topsoil would be temporarily stockpiled for rehabilitation post construction.
- Excavation and construction of a temporary hardstand area for operation of drilling equipment. The area of hardstand would be determined by the size and number of liner pieces to be manufactured and excavated to a depth of approximately 0.2 m. The temporary hardstand areas would include:
    - approximately 2,000m² of road base surrounding the site compound area and drill rig slab for site facilities;
    - approximately 2,000m² for laydown areas and a 4,500m² levelled hardstand area for storage of the ventilation shaft liners;
    - a stable access way between the liner storage area and the shaft to facilitate transport of the cured liner segments on purpose built trailers; and
    - a concrete pad 20 m by 15 m is to be constructed around the top of the shaft as a foundation for the drill rig and to provide a clean work area.
- Connection of 66 kV electrical power and establishment of electrical substations at ventilation shaft sites.
- Sinking of the shaft using blind boring methods (or similar method), and lining of the shafts using a composite concrete and steel liner (or similar method).
- Construction of fan buildings and installation of ventilation fans. The upcast shaft site fan would also incorporate a fan outlet stack, approximately 30 m high, to control odour discharge from the mine.

Runoff from site TSC1 would report to storages within the existing pit top water management system. Site TSC2 would incorporate water treatment sedimentation controls, with the settled water from the ventilation shaft being pumped via overland pipeline to a final sedimentation pond on the surface facilities area for further treatment and discharge though LDP1. Alternatively water may be discharged via a new licensed discharge point, which would require a variation to EPL 1389.

2.2.4 Gas Drainage Operations

Coal mines need to control underground gas concentration levels to below safe limits so that miners are able to work in a safe environment and mining operations can be undertaken as efficiently as possible.

The coal seams within the Southern Coalfield are generally known to be gassy, with methane and carbon dioxide released from the goaf during mining. Gas in the underground workings would be managed by a series of gas drainage operations including:

- pre-gas drainage, whereby gas would be extracted from the coal seam prior to longwall mining;
- post-gas drainage, whereby gas would be extracted from the goaf; and
- gas extraction via the mine ventilation system, which would occur throughout mining.

Gas management would continue to use the existing infrastructure, including the Tahmoor Mine Gas Plant, Gas Plant Vent and Flare Plant, as well as the WCMG Power Plant when it is available. Some components of the existing gas management infrastructure may need to be upgraded throughout the life of the proposed development

2.2.5 Pre-Gas Drainage

The purpose of pre-gas drainage is to reduce gas volumes in the coal seams prior to mining, with the Bulli, Wongawilli and Balgownie seams targeted for pre-gas drainage at Tahmoor Mine. Pre-gas drainage of the gas levels in the seams is required to facilitate the timely commencement and progression of mining as well as to reduce the demands on the mine ventilation system for the purpose of gas dilution during operations.

Pre-gas drainage activities are mainly undertaken underground, via drilling and drainage from the roadways developed for longwall panels. Underground pre-gas drainage works at Tahmoor Mine would drain gas following development of the mine roadways and prior to longwall development. Gas would be drawn from the coal seam by vacuum and piped to the Gas Plant at the surface facilities area via the underground pipe network. Underground gas drainage of the coal seam would continue ahead of longwall development for the life of mining.

Surface pre-gas drainage works are proposed for the eastern portion of the Project Area. Extracted gas would be brought to the surface and transferred via a pipeline to the existing gas plant at the Tahmoor Mine. To enable gas to be released from the seam during pre-gas drainage, the coal seam would be dewatered via horizontal drilling within the seam. The drained water would be collected on the surface and transferred to the existing water management system at the surface facilities area via an overland pipeline or truck.

Two Surface to Inseam (SIS) drilling sites and gas well sites are proposed, subject to the final detailed design of the development mains. SIS drilling and gas well sites are subject to obtaining land access agreements and therefore flexibility is required for the location of these works. The gas collection pipeline is proposed to be constructed within a trench alongside the public roadway and potential exists for alternative locations.

Gas from the coal seam would be drained using pumps, collected at the surface and piped to the existing Gas Plant at the Tahmoor Mine surface facilities area to be used in the WCMG Power Plant or Gas Fare Plant.

2.2.6 Post-Gas Drainage

Post-gas drainage would be required as strata relaxation caused by the retreating underground longwall face would liberate volumes of gas into the mine workings from the underlying Wongawilli seam and from overlying strata, released due to fracturing of the goaf. To capture this gas during the proposed development, cross-measure boreholes are proposed to be drilled from the mine workings into the Wongawilli seam. These boreholes would be designed to collect the gas at its source or to intercept gas before it migrates into the mine workings. At the conclusion of mining from each panel, the panel would be sealed and gas drawn from the sealed areas as part of the post-gas drainage operations. The gas collected from the in-seam and cross-measure boreholes would be drawn by vacuum via the underground pipe network to the Gas Plant located at the surface facilities area.

2.2.7 Gas in Ventilation

The ventilation system would deliver fresh air into the mine from the existing and proposed downcast vent shafts and would extract stale air from the mine via the existing and proposed upcast vent shafts

(refer Section 2.2.3). Similar to the existing operations, the ventilation system would carry the remaining diluted gases out of the mine via the upcast mine vent shafts.

2.2.8 Mining Method and Equipment

Underground mining would be undertaken via main roadway and longwall development using continuous miners. Longwall development refers to the mining of a series of roadways (gate roads) and cut-throughs, to form pillars of coal that would support the overlying strata during the extraction of coal. Longwalls would be up to 305 m wide. The gate roads would be approximately 5.2 m wide and approximately 3 m high.

Coal would be cut from the coal face by the longwall shearer, loaded onto the armoured face conveyor and transported to the surface facilities area via a series of underground conveyors. The longwall would retreat as coal is mined and the overlying rock strata would collapse into the void left by the coal extraction, forming the goaf.

A new hardstand area would be constructed adjacent to the existing southern coal stockpile at the surface facilities area to cater for the delivery and assemblage of mining equipment and the storage of equipment.

Tahmoor Coal would continue to investigate improved or alternate mining methods and technology throughout the life of the proposed development. Improved methods would be utilised where available to allow for the efficient and economically viable extraction of the coal resource. Tahmoor Coal would ensure that the resulting environmental and social impacts of improved or alternate methods are consistent with those predicted in this EIS

2.2.9 Mine Access

The proposed development would use the existing infrastructure at Tahmoor Mine for employee and material access to the mine. Access to the mine would be via the existing Tahmoor Mine surface facilities area, the existing drift, and men and materials travel lift installed within the T3 downcast shaft. The T3 vertical men and material travel lift has a capacity for 70 persons and approximately 12 tonnes of materials.

2.2.10 Coal Production

Tahmoor Coal is a shareholder of Port Kembla Coal Terminal and has contractual arrangements in place for coal export associated with the proposed output from the Project.

The proposed development would transport product coal from Tahmoor Mine to Port Kembla, via the existing mine rail load out, rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway.

Tahmoor Mine currently has four allocated train paths per day from ARTC for the rail network between the Tahmoor Mine and Port Kembla. This current allocation is equivalent to the transport of approximately four million tonnes of product coal per annum and is sufficient for the life of the Tahmoor South Project. A rail transport study has been undertaken for the proposed development, which indicates that the existing rail capacity would be sufficient for the proposed transport of product coal to Port Kembla under the proposed development, and no increase in rail capacity between Tahmoor Mine and Port Kembla would be required. As such, existing rail infrastructure and the number of allowable train movements would remain unchanged.

2.3 SURFACE FACILITIES AREA

The existing surface facilities and infrastructure at the Tahmoor Mine surface facilities area, operating within surface CCL 716 and Mining Lease 1642, would be utilised for the proposed development.

Upgrades to some aspects of the surface facilities area would be required and are associated with the increase in annual coal production for the proposed development. Upgrades to existing surface infrastructure would be undertaken within the existing Tahmoor Mine surface lease area (Mining Lease 1642) and additional surface lease areas required for the proposed development. The proposed upgrades are described in the following sub-sections.

2.3.1 Coal Handling and Preparation Plant

The existing CHPP would be utilised for the proposed development. The existing CHPP would be upgraded including the installation of:

- a new coarse rejects screen,
- additional belt press filter capacity, and
- an increase in thickener capacity.

The existing ROM stockpile area would continue to be utilised by the proposed development. During peak production ROM coal may be trucked from the ROM stockpile to the coal product stockpiles and re-trucked back to the ROM stockpile when required. Reject material generated from the coal washing process at the CHPP would be transported to the expanded REA via the existing reject conveyor to the reject bin for disposal, then transported by haul truck to the REA.

2.3.2 Rejects Management

The existing REA would be expanded onto adjacent areas to accommodate the reject material associated with the proposed development. The expansion area is anticipated to cover up to an additional 43 hectares, providing an additional emplacement capacity of approximately 12 Mt for the rejects generated during the operation of the proposed development.

Construction and maintenance of new internal haul roads would be required to cater for the REA expansion.

The stormwater management system and infrastructure at the existing REA would be augmented with the construction of additional sedimentation dams, drains and pumping station. These are described in the WMS/SWB Report.

2.3.3 Plant and Equipment

The proposed development would utilise existing plant and equipment at the surface facilities area and would also require additional mobile plant for coal material handling at the surface facilities area. The proposed additional plant would include:

- a secondary bulldozer at the product coal stockpile.
- additional ancillary equipment such as trucks, cranes and forklifts for use around the surface facilities area to manage product and equipment stores.

2.3.4 Hours of Operation

The proposed development, including construction activities, would to operate 24 hours a day, seven days per week, consistent with the working hours of the current operations at the Tahmoor Mine.

3.0 SCOPE OF BASELINE STUDY REPORT

This report provides a summary of the available streamflow and water quality data in the Project and regional areas. Outcomes comprise the characterisation of the surface water resources which could be affected by the Project. Data sources used in the assessment comprise published data on climate, catchment hydrology, water quality and data obtained from the baseline surface water monitoring program conducted by Tahmoor Coal which commenced in early 2012 to June 2015.

Baseline data collected and used within this report includes the following

- Meteorological information – comprising mine site climate stations, local climate stations operated by the Bureau of Meteorology (BoM) and long term synthetic rainfall and evaporation records obtained from the SILO Data Drill[1] system for the Project Area.
- Streamflow data.
- Stream water chemistry.

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[1] The SILO Data Drill is a system which provides synthetic data sets for a specified point by interpolation between surrounding point records held by the BoM. Refer https://legacy.longpaddock.qld.gov.au/silo/datadrill/

4.0 PROJECT AREA CLIMATE

4.1 GENERAL

The Project Area experiences a temperate climate with mild to warm summers and cool to cold winters. Mean maximum daily temperatures range from 29.3 ºC in January to 16.8 ºC in July. Mean minimum daily temperatures range from 15.4 ºC in February to 1.7 ºC in July. Rainfall is distributed throughout the year with higher falls being experienced during the summer months and drier conditions usually prevailing during winter. Tahmoor Coal operates two climate stations in and near the pit top area with data available from February 2007.

Monthly average temperature, cloud cover, wind statistics for have been obtained from the BoM's Picton Council Depot Automatic Weather Station which is the closest climate station to the Project Area with long term data. These data statistics are summarised in Table 3 to Table 5 below.

Table 3 Monthly Mean Maximum and Minimum Temperatures – Picton (BoM Station 068052)

Month	Mean Maximum Temperature (°C)	Mean Minimum Temperature (°C)
January	29.3	15.2
February	28.6	15.4
March	27	13.1
April	23.7	9.2
May	20.2	5.7
June	17.3	3.2
July	16.8	1.7
August	18.2	2.9
September	21.4	5.2
October	24	8.8
November	26.3	11.5
December	28.5	14
Annual	23.4	8.8
No. Years Data	61*	61*

* 1907 to 1975

Table 4 Monthly Mean Cloud Cover – Picton (BoM Station 068052)

Month	Mean Number of Clear[†] Days	Mean Number of Cloudy[†] Days
January	4.7	13.3
February	4.5	9.7
March	7	11.1
April	10.2	7.7
May	9.8	7.3
June	8.4	7.8
July	13.4	4.8
August	10.9	9
September	11	7.8
October	7.5	10.3
November	6.7	10.1
December	6	11.8
Annual	100.1	110.7
No. Years Data	10*	10*

* 1965 to 1975

[†] These statistics are derived from cloud cover observations, which are measured in oktas (eighths). The sky is visually inspected to produce an estimate of the number of eighths of the dome of the sky covered by cloud. A clear day is recorded when the mean of the 9 am and 3 pm cloud observations is less than or equal to 2 oktas. A cloudy day is recorded when the mean of the 9 am and 3 pm cloud observations is greater than or equal to 6 oktas.

Table 5 Monthly Mean Wind Speed and Direction – Picton (BoM Station 068052)

Month	Mean 9am Wind Speed (km/h)	Mean 9am Wind Direction
January	6.8	South
February	4.5	Southeast
March	5.1	Southeast
April	4.6	South
May	6	South
June	4.7	South
July	5.1	West
August	7.3	Southwest
September	7.8	South and West
October	8.6	South
November	9	South and Northwest
December	6.5	Northwest
Annual	6.3	South
No. Years Data	10*	10*

*1965 to 1975

4.2 RAINFALL

Regional rainfall monitoring stations in the vicinity of the Tahmoor Mine area have varying periods of record (Table 6). The Buxton and Picton stations are the closest BoM stations with long term records without significant gaps in the data record.

Table 6 Summary of Regional Rainfall Monitoring Stations

BoM Station Number	Station Name	Year of Establishment & Closure	Percent Complete Record	Latitude (degrees south)	Longitude (degrees east)	Elevation (m AHD*)	Distance from Pit Top (km)
068166	Buxton	1967 - Open	92%	34.24	150.52	420	5.5
068052	Picton	1880 - Open	91%	34.17	150.61	165	9.3
068016	Cataract Dam	1904 - 2013	93%	34.26	150.81	340	21.3
068159	Wedderburn	1964 - Open	62%	34.17	150.81	250	23.1
068122	Cawdor	1962 - Open	88%	34.1	150.64	132	17.6
068216	Menangle Bridge	1963 - Open	94%	34.12	150.74	-	20.7
068200	Douglas Park	1974 - Open	98%	34.21	150.71	165	12.9

* Australian Height Datum. The existing Tahmoor pit top is at approximately 290m AHD.

Monthly long-term average rainfalls for the BoM stations and the record obtained for the Project site from the SILO Data Drill are summarised in Table 7. A comparison of monthly average rainfall totals from the Data Drill and local BoM rainfall data sites indicates that the Data Drill data are similar to nearby BoM station records.

Table 7 Summary of Mean Rainfall Statistics

Data Source	Data Drill for Project Site	Picton Council Depot	Buxton	Douglas Park
Number of Years of Record	129	116	51	44
BoM Station Number	-	068052	068166	068200
	Rainfall (mm)	Rainfall (mm)	Rainfall (mm)	Rainfall (mm)
January	89.5	87	92.2	69.6
February	95.4	89.9	125.5	88.1
March	89.3	89.3	82.2	85.4
April	74.5	69.6	74	64.2
May	64.0	55.8	51.6	57.4
June	77.9	67.6	67.3	70.8
July	55.1	49.4	35.8	41
August	50.0	44.8	51.2	43.8
September	47.0	43.7	44.4	41.2
October	60.4	62.7	62	54.9
November	70.0	71.6	90.2	72.3
December	72.1	70.1	78	57.1
Annual Average	845.2	805	858.8	758.6

The spatial distribution of average annual rainfall over the region is shown on Figure 2, which was derived from multiple Data Drill data points, plotted as average annual rainfall contours or isohyets. On average, annual rainfall is highest (940 mm/annum) in the south eastern part of the Project Area and reduces further north and west to about 850 mm/annum near the existing surface facilities and 790 mm in Thirlmere.

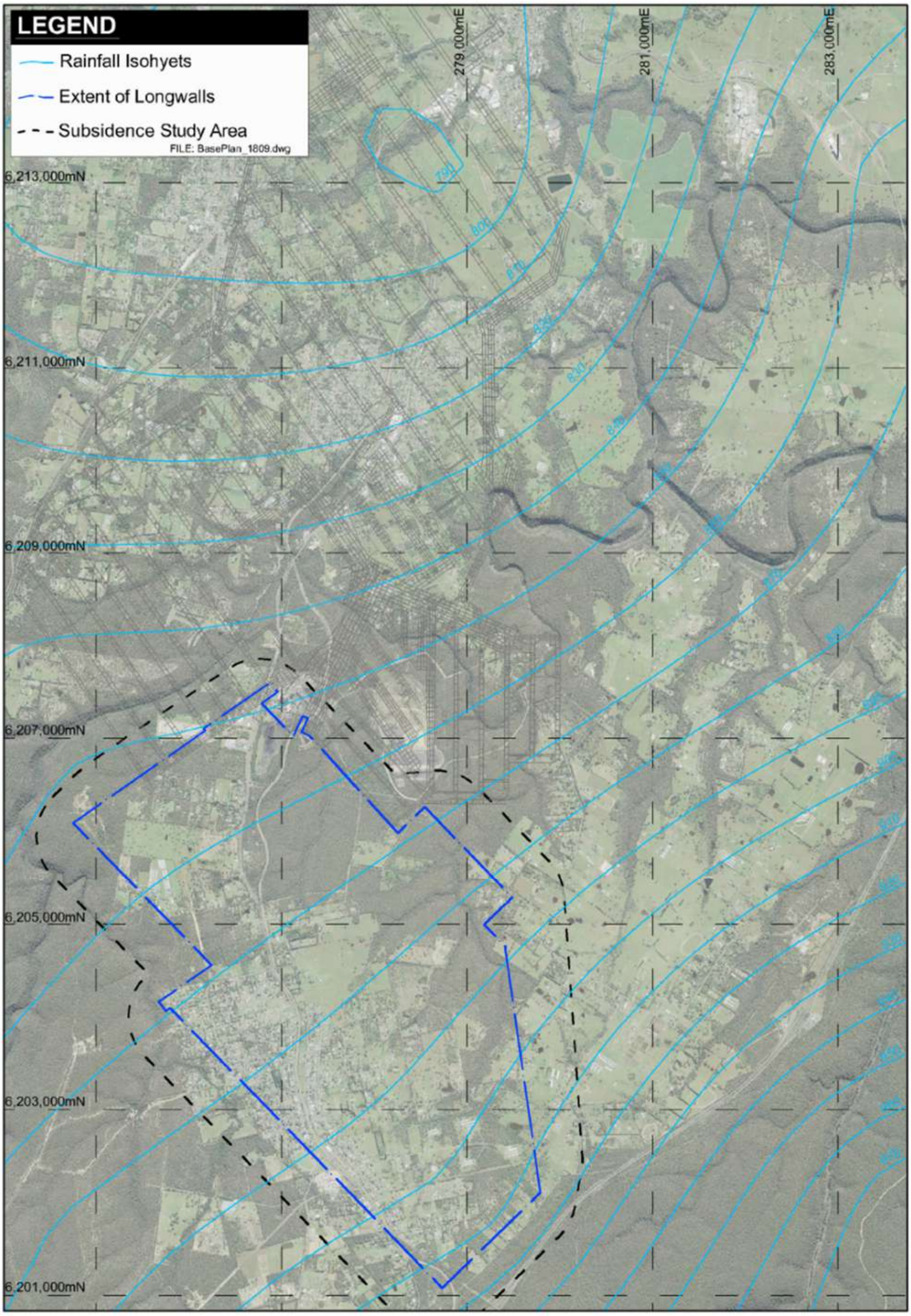

Figure 2 Average Annual Rainfall Isohyets Tahmoor Mine Site Area

The probability of low rainfall has been assessed using the Data Drill data suite obtained for the Project Area. Figure 3 shows the probability of low rainfall periods as the percentage of time that the total rainfall for different numbers of consecutive day periods has been less than or equal to the amount shown. For example there is a 50% chance that 20mm of rainfall or less will fall in any 30 day period. There is also a 30% chance that 5mm or less will fall in any 10 day period. These statistics show that the Project Area has a relatively low probability of persistent dry/low rainfall.

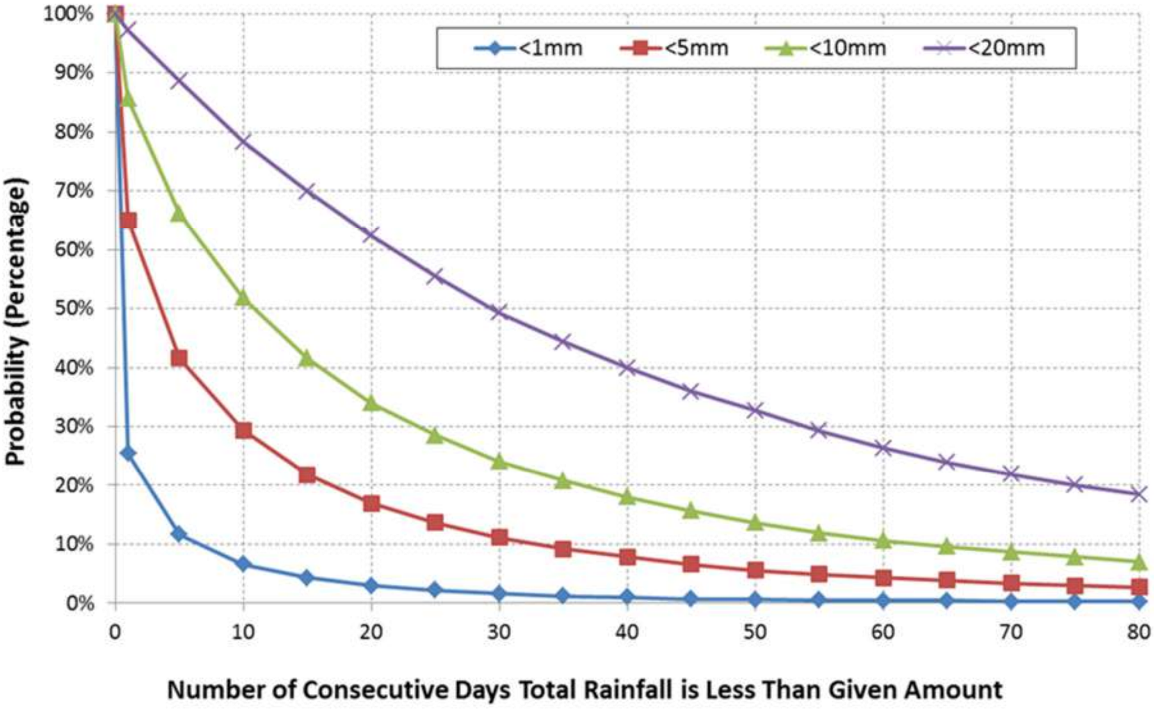

Figure 3 Low Rainfall Persistence Characteristics – Tahmoor South Project Area

4.3 EVAPORATION

The closest BoM climate station with pan evaporation (PE) data is Prospect Reservoir (0670191), which is located about 40 km to the northeast of the Project Area. Mean annual pan evaporation at Prospect is 1,314 mm. Pan evaporation data was obtained from the SILO Data Drill for the site location and monthly estimates of point potential evapotranspiration[2] were also taken from BoM mapping[3].

A summary of monthly average Data Drill estimated pan evaporation and average monthly point potential evapotranspiration from BoM mapping are presented in Table 8 along with the average monthly rainfall derived from the nearest Data Drill point.

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[2] Point potential evapotranspiration is the evapotranspiration that would take place if there was unlimited water available from a small area were the evapotranspiration would not affect the properties of the overlying air mass. Evapotranspiration is the collective term for the rate of transfer of water from vegetation and the land surface to the atmosphere and is normally expressed in mm/day.

[3] “Climatic Atlas of Australia Evapotranspiration”, Bureau of Meteorology 2001.

Table 8 Summary of Average Rainfall and Evaporation (mm)

Month	Average Evaporation Data Drill	Climate Atlas of Australia (Point Potential Evapotranspiration)	Average Data Drill Rainfall
January	177.7	195	89.5
February	154.7	160	95.4
March	127.7	150	89.3
April	94.9	105	74.5
May	65.0	75	64.0
June	55.7	60	77.9
July	56.3	60	55.1
August	79.8	90	50.0
September	107.3	120	47.0
October	133.0	160	60.4
November	162.2	180	70.0
December	181.6	195	72.1
Annual Average	1,368	1,500	845.2

The average site evaporation from the SILO Data Drill is consistently lower than the point potential evapotranspiration taken from the Climatic Atlas of Australia. Average evaporation exceeds average rainfall in all months except June when there is an average excess of rainfall. The greatest evaporation deficit occurs in June and the greatest excess occurs in December.

5.0 CATCHMENTS AND DRAINAGE

5.1 REGIONAL CATCHMENTS

The existing Tahmoor Mine and the Project Area are located within the Bargo River catchment. From its headwaters near the townships of Hill Top and Yerrinbool, the Bargo River flows in a generally north-easterly direction through incised valleys and gorges to its confluence with the Nepean River, near the Pheasants Nest Weir (refer Figure 4).

The lower 4 kilometres (km) of the river pass through the Bargo River Gorge, which is characterized by steep rock faces up to 110 m high. The river consists of a sequence of pools, glides and rock bars across sandstone bedrock, with occasional boulder fields and cobblestone riffles. The Bargo River drains a total catchment of some 130 square kilometres (km^2) at its confluence with the Nepean River, which has a catchment area of approximately 710 km^2 at this point.

The Bargo River has intermittent flow in its upstream reaches. In its upper reaches flows are, to some degree[4], regulated by the Picton Weir which is located approximately 14 km upstream of the Nepean River confluence. Downstream of the Tahmoor Mine pit top (i.e. downstream of the Tea Tree Hollow confluence) flow is perennial due to persistent licensed discharges from Tahmoor Mine. The lower reaches of the Bargo River have been previously affected by mining-induced subsidence associated with the Tahmoor Mine. The Bargo River flows into the Nepean River 9 km downstream of the Tea Tree Hollow confluence.

The Nepean River rises in the Great Dividing Range to the west of the Project Area. Its headwaters also lie in the coastal ranges to the east of the Project Area. Flows in the upper reaches of the Nepean River are highly regulated by the Upper Nepean Water Supply Scheme, operated by WaterNSW, which incorporates four major water supply dams on the Cataract, Cordeaux, Avon and Nepean Rivers. Releases from the Cordeaux, Avon and Nepean Dams are made to enable withdrawal for water supply purposes from the Pheasant's Nest Weir located further downstream on the Nepean River. The Nepean Dam is situated some 18 km upstream of the Bargo River confluence, while the Pheasant's Nest Weir is located approximately 7 km upstream of the confluence. Flows in the Nepean River near and downstream of the Project Area (downstream of the Peasant's Nest Weir) are not part of a WaterNSW Drinking Water Catchment Area.

Further downstream, the Nepean River has been extensively modified by the construction of a series of in-stream weirs which have created a series of pondages - the closest to the Project Area being the Maldon Weir. Ponding behind the Maldon Weir does not affect water levels as far upstream as the Project Area.

The Nepean River flows into the Warragamba River near Wallacia downstream of which it is referred to as the Hawkesbury-Nepean River. The Hawkesbury- Nepean catchment is one of the largest coastal catchments in NSW with an area of some 21,400 km^2 at its mouth in Broken Bay on the northern side of the Sydney Metropolitan area.

5.2 PROJECT AREA CATCHMENTS

The Project Area major streams and associated monitoring sites are shown in Figure 4. Topography in the Project Area is varied, ranging from gently undulating plateaux, ridges and low hills in the upland areas, to a rugged landscape of deeply dissected valleys and gorges in Hawkesbury Sandstone. The upland areas, including Bargo Township, are drained by headwater streams of Hornes Creek, Tea Tree Hollow, Dog Trap Creek, Eliza Creek and Carters Creek. The lower reaches of Tea Tree Hollow and Dog Trap Creek have previously been affected by mining-induced

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[4] The weir was constructed in the late 19th century to supply the township of Bargo, is now heavily silted and no longer in use.

subsidence associated with the Tahmoor Mine. The catchment boundaries of the creeks overlying the proposed longwall mining areas are shown in Figure 5.

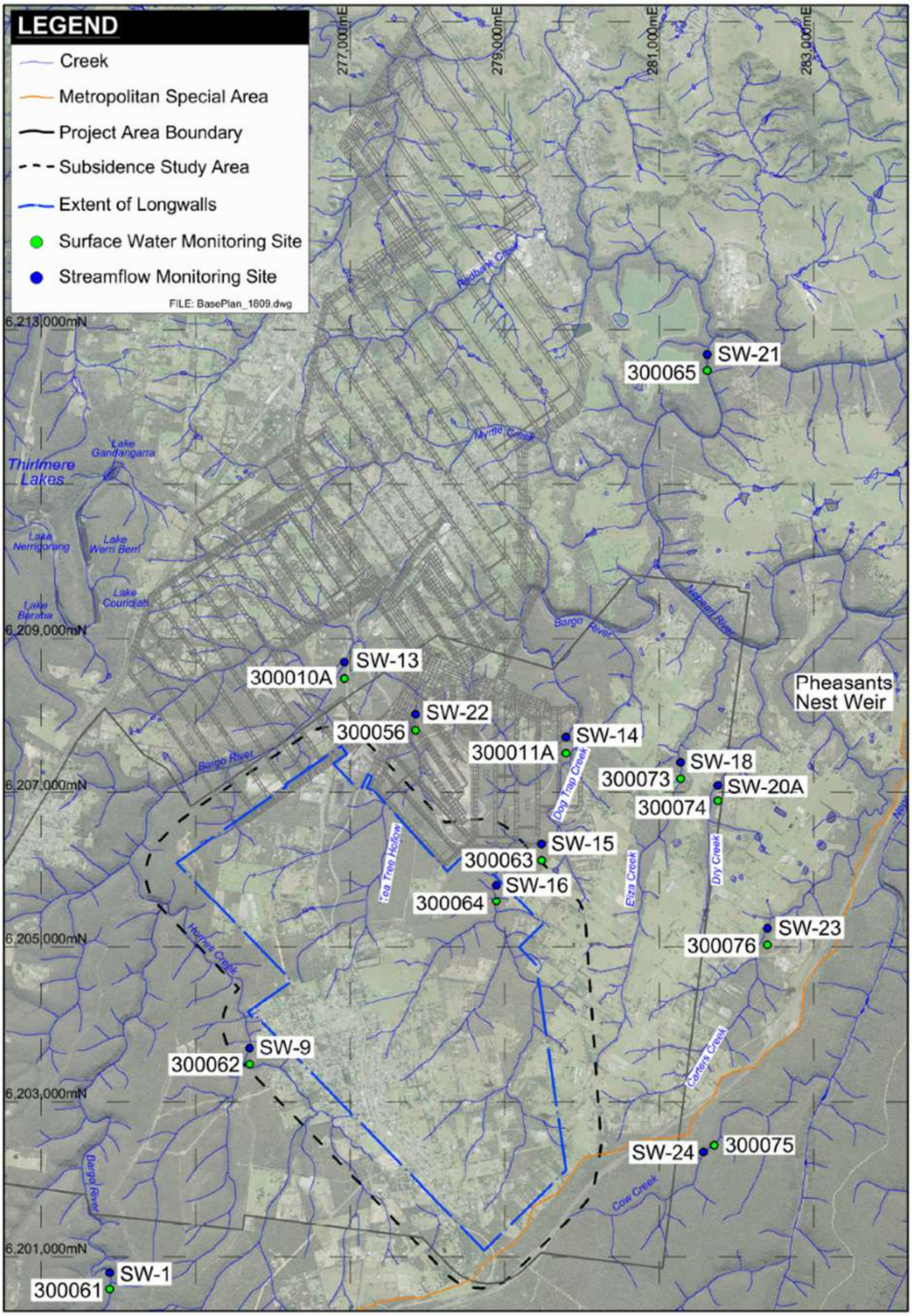

Figure 4 Project Area Drainages and Surface Water Monitoring Sites

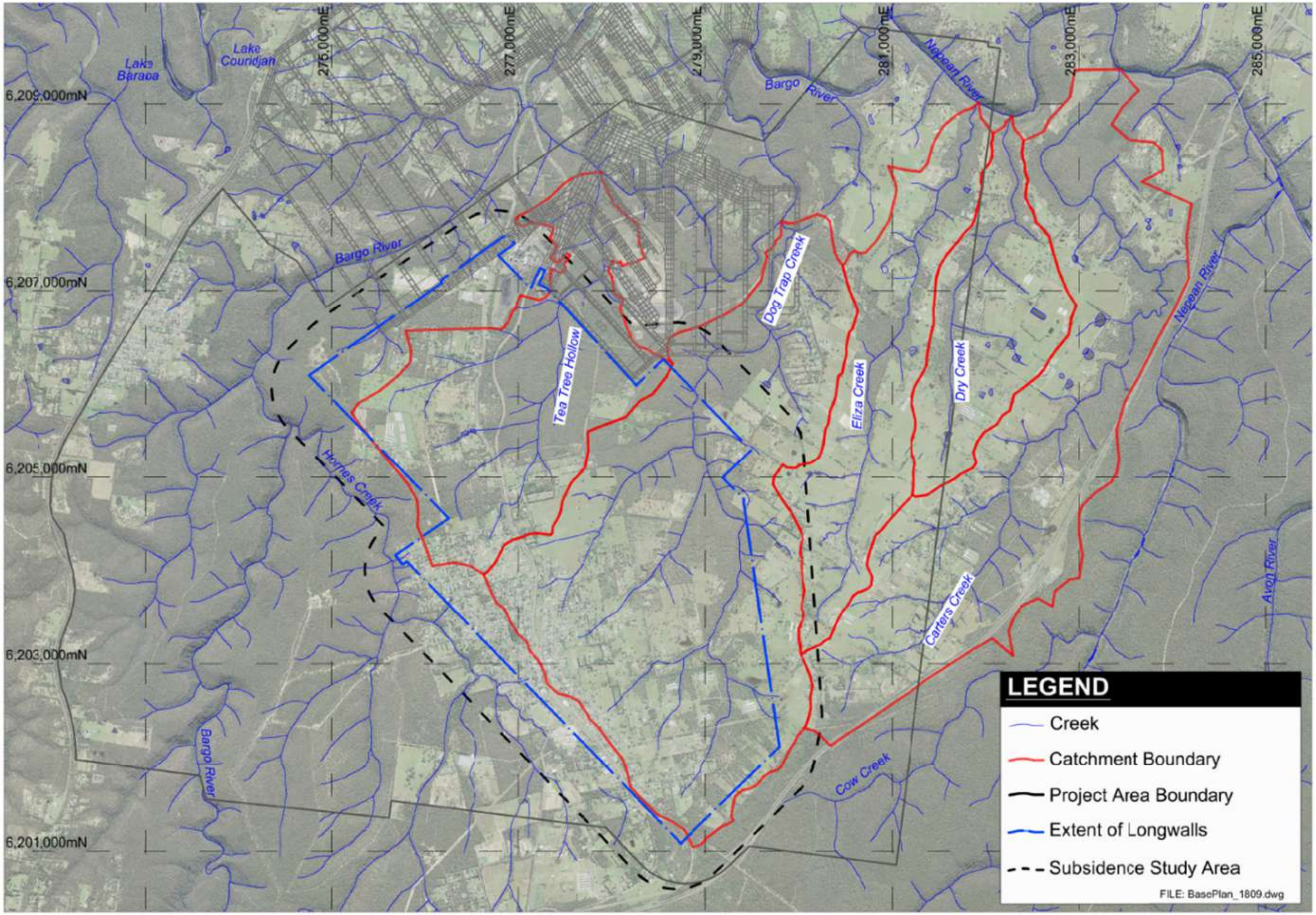

Figure 5 Project Area Creek Catchment Boundaries

The Project Area is predominantly drained by Tea Tree Hollow and Dog Trap Creek which flow generally north and eastward toward the Bargo River. A small area on the south western side of the proposed longwall panels is drained by headwater tributaries of Hornes Creek which flows into the Bargo River at Picton Weir. The eastern portion of the Project Area is predominantly drained by Eliza Creek which flows generally northward to the Nepean River. A small part of the eastern portion of the Project Area is also drained by Carters Creek which flows north-eastward to the Nepean River. Cow Creek, which is within the Metropolitan Special Area, lies to the east of the Project Area and is a tributary of the Nepean River upstream of Pheasant's Nest Weir.

A summary of the hydrological characteristics of these drainages is provided in the sub-sections below.

Tahmoor Coal established gauging stations on each of these creeks at various times as indicated below and undertook a flow gauging program to develop flow ratings5 for each station. A baseline water quality monitoring program has also been undertaken at each gauging station – i.e. gauging station sites were paired with water quality monitoring sites as shown in Figure 4.

Results of this monitoring are summarised in Section 0 and Section 8.0 below. In terms of locations, the sites were either categorised as (AECOM, 2012b):

Control site:	a site which is to provide control data against which future Project impacts could be compared; or
Baseline/impact site:	a site which is to be used to compare conditions before, during and after the Project.

A summary of the sites selected and their category is given in Table 9.

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[5] Flow rating is a calibration relationship specific to each gauging station site which enables flow rate to be derived from recorded water level at that particular site location. A period of time is required following station establishment to develop a rating relationship. Manual flow gaugings were undertaken using an OSS-PC1 'Pygmy' current meter which was calibrated annually and serviced weekly. All gaugings conformed to the relevant Australian Standard (AS 3778.3.1-2001). The ratings were extended to high flows by theoretical means using surveyed stream cross-sections and hydraulic modelling.

Table 9 Summary of Surface Water Monitoring Site Selection

Site	Site Description	Category
SW-1 / 300061 Bargo River	Long pool with flat hydraulic control	Control site
SW-9 / 300062 Hornes Creek	Rock bar and pool	Control site
SW-13 / 300010A Bargo River Upstream Bargo	Rock bar and pool	Baseline/impact site
SW-14 / 300011A Bargo River Downstream Rockford Road Bridge	Rock bar and pool	Baseline/impact site
SW-15 / 300063 Dog Trap Creek Downstream	Long rock bar and pool	Baseline/impact site
SW-16 / 300064 Dog Trap Creek Upstream	Rock/mud bar and large pool	Baseline/impact site
SW-18 / 300073 Eliza Creek	Rock bar and pool	Baseline site
SW-20A / 300074 Dry Creek	Rock bar and large deep pool	Baseline site
SW-21 / 300065 Nepean River at Maldon Weir	Pool behind weir	Baseline/impact site
SW-22 / 300056 Tea Tree Hollow	Rock bar	Baseline/impact site
SW-23 / 300076 Carters Creek	Rock bar	Baseline site
SW-24 / 300075 Cow Creek	Rock bar	Baseline site

5.2.1 Hornes Creek

Hornes Creek is a 4th order stream[6] with a total catchment of 19.5 km^2, some 3% of which lies within the Project Area. Creek flows are likely to be affected by stormwater runoff from the southern part of the township of Bargo.

Tahmoor Coal established a streamflow gauging station on Hornes Creek in February 2012 and undertook water quality sampling between May 2012 and June 2015. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid 2013.

5.2.2 Tea Tree Hollow

Tea Tree Hollow is a 3rd order stream which drains the portion of the Project Area overlying the western part of the Tahmoor South mine area. Tea Tree Hollow flows from its headwaters in the northern part of the Bargo Township, through the Project Area and on past the existing Tahmoor pit top and rejects emplacement areas to the Bargo River. In total, it drains an area of some 6.8 km^2. Tea Tree Hollow comprises two main tributary arms which join upstream of the Tahmoor rejects emplacement area.

Licensed discharges from the Tahmoor mine pit top enter Tea Tree Hollow from EPL 1389 LDP1 some 800 m upstream of the confluence with the Bargo River.

Tahmoor Coal established a streamflow gauging station on Tea Tree Hollow in February 2010 and undertook water quality sampling between September 2012 and June 2015. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during July 2013. Water quality monitoring was undertaken in accordance with EPL 1389 requirements.

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[6] Strahler stream order classification scheme

5.2.3 Dog Trap Creek

Dog Trap Creek drains the portion of the Project Area overlying the eastern part of the Tahmoor South mine area. The catchment rises along a low ridge line which runs through the centre of the Bargo Township. Dog Trap Creek is a 3rd order stream. It drains a total area of 13.6 km^2 at its confluence with the Bargo River. The upper reaches of Dog Trap Creek comprise three main tributaries.

Tahmoor Coal established two gauging stations on Dog Trap Creek in February - March 2012 and undertook water quality sampling at two sites between April 2012 and June 2015. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid 2013.

5.2.4 Eliza Creek

Eliza Creek drains much of the eastern portion of the Project Area. Mining is not proposed within the catchment of Eliza Creek. The catchment rises along a low ridge line to the south of the Project Area. The creek is a 2nd order stream. It drains a total area of 4.9 km^2 at its confluence with the Bargo River.

Tahmoor Coal established a gauging station on Eliza Creek in October 2012 and undertook water quality sampling between September 2012 and June 2015. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid 2013.

5.2.5 Carters Creek

The upper reaches of Carters Creek drain a small area on the south-eastern side of the Project Area. Mining is not proposed within the catchment of Carters Creek. The catchment rises along low ridge line on the eastern side of the Project Area. The creek comprises a 3rd order stream at the Project Area boundary. It drains a total area of 6.4 km^2 at its confluence with the Nepean River.

Tahmoor Coal established a gauging station on Carters Creek in October 2013 and undertook water quality sampling between September 2012 and June 2015. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid 2013.

5.2.6 Dry Creek

The upper reaches of Dry Creek drain a small area on the eastern side of the Project Area. Mining is not proposed within the catchment of Dry Creek. The catchment rises along low ridge line on the eastern side of the Project Area. The creek comprises a 3rd order stream at its confluence with the Nepean River where it has a total catchment area of 3.6 km^2.

Tahmoor Coal established a gauging station on Dry Creek in January 2013 and undertook water quality sampling between September 2012 and June 2015. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid 2013.

5.2.7 Cow Creek

The upper reaches of Cow Creek are adjacent to the south-eastern side of the Project Area. Mining is not proposed within the catchment of Cow Creek. The catchment rises along a low ridge line on the eastern side of the Project Area approximately coincident with the Hume Highway. The creek is a 3rd order stream at the Project Area boundary. It drains a total area of 10.1 km^2 at its confluence with the Nepean River.

Tahmoor Coal established a gauging station in February 2013 and undertook water quality sampling on Cow Creek between February 2013 and June 2015. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid 2013.

5.3 BASELINE STREAMFLOW DATA

Details of gauging stations on Project Area streams established by Tahmoor Coal are summarised in Table 10 below. Some of these had been established some years ahead of Project baseline monitoring (i.e. Tea Tree Hollow, two on the Bargo River). Most of those established for Project baseline monitoring (in 2012/13) were located either just downstream of or near the downstream limit of the Project Area (refer Figure 4 and Table 9). The majority of these baseline flow monitoring stations were decommissioned in February 2016.

Table 10 Summary of Baseline Flow Monitoring Stations

Gauging Station Number	Name	Catchment Area (km^2)	Date Station Commenced Recording Water Level
300010a	Bargo River Upstream Bargo	93.1	4/5/2008
300011a	Bargo River Downstream Rockford Road Bridge	108.5	4/7/2007
300061	Bargo River	42.2	17/3/2012
300062	Hornes Creek	16.5	16/2/2012
300063	Dog Trap Creek Downstream	11.3	29/2/2012
300064	Dog Trap Creek Upstream	9.7	3/3/2012
300056	Tea Tree Hollow	6.7	8/2/2010
300075	Cow Creek	4.5	13/2/2013

Low to moderate flow ratings have been developed for all stations and extended ratings (to the limits of recorded water levels) have been established for Tea Tree Hollow (GS 300056), Dog Trap Creek Downstream (GS 300063) and Eliza Creek (GS 300073), given that these are likely to be the main affected catchments within the Project Area.

Cumulative rainfall sourced from the SILO Data Drill (refer Figure 6) has included 4 periods of intense, protracted rainfall up to late 2013 (indicated by red arrows in Figure 6) - interspersed by drier weather. The rainfall periods occurred between:

- 17th February 2012 and 10th March 2012
- 21st January 2013 and 2nd February 2013
- 19th February 2013 and 3rd March 2013
- 21st June 2013 and 29th June 2013

These rainfall patterns have been reflected in the streamflow data recorded at the baseline flow monitoring stations which include periods of moderate to high flows as well as long recessions. The first significant, recorded flow event commenced on 28th February 2012 and ceased around 12th March 2012. Recorded streamflow was then predominantly recessionary until January 2013 when the second significant flow event was recorded from approximately 28th January 2013 until 1st February 2013. Recessionary flows were then experienced through until approximately 23rd February 2013 when the third significant flow event was recorded through to approximately 4th March 2013. Recessionary flows then again predominated through until approximately 25th June 2013 when the fourth significant flow event was recorded lasting through to about 1st July 2013.

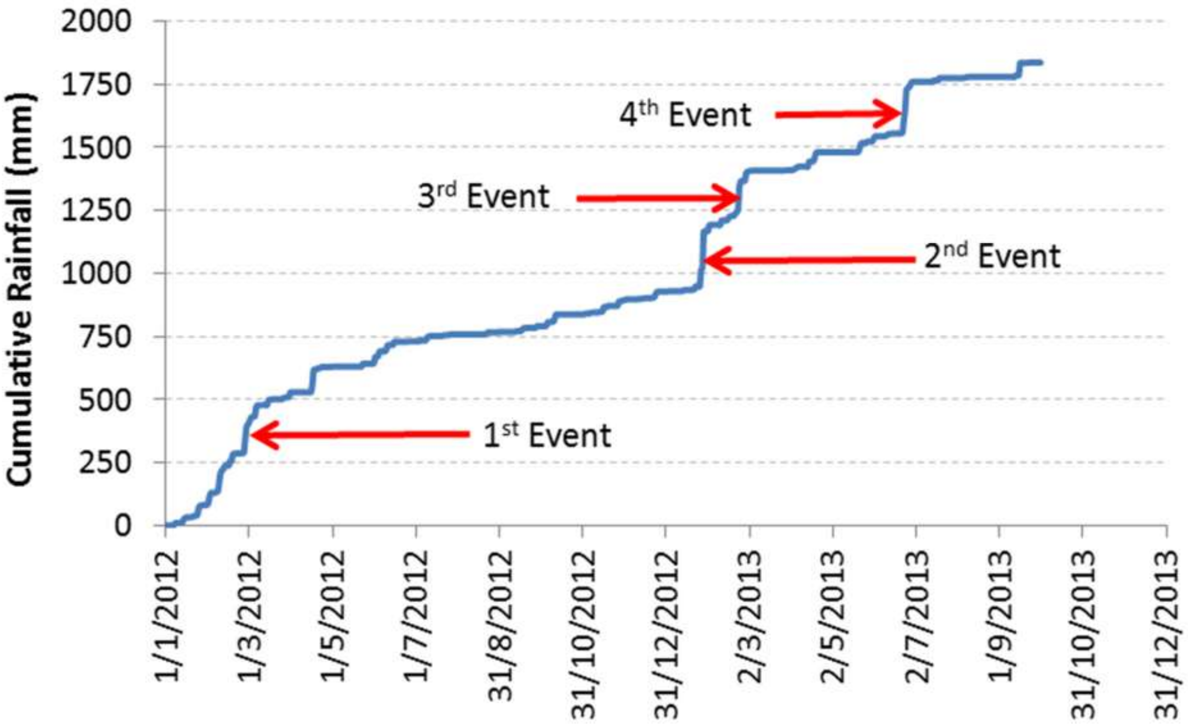

Figure 6 Cumulative Rainfall 2012 to 2013

The flows recorded at the gauging stations on Tea Tree Hollow and Dog Trap Creek during these four periods[7] are depicted as daily streamflow hydrographs (expressed as flow per unit catchment area in mm/day) in Figure 7 to Figure 10 below.

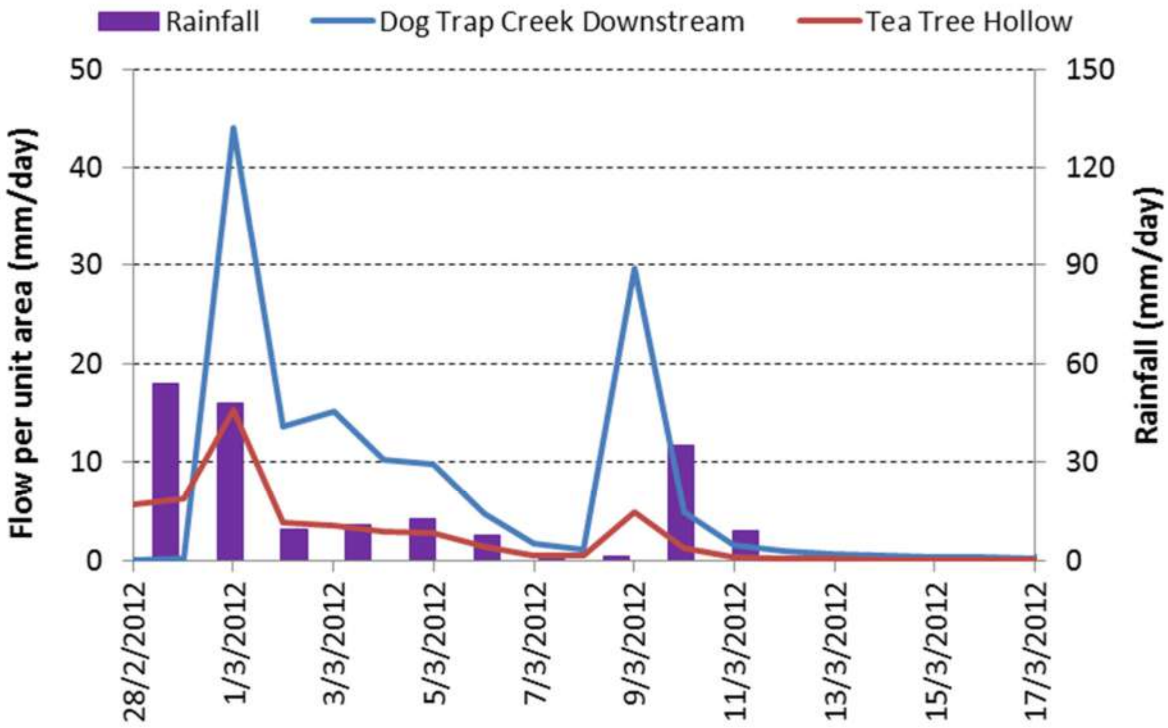

Figure 7 Streamflow Response to 28th February to 12th March 2012 Rainfall Event

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[7] Note Eliza Creek was commissioned on 1st November 2012 - after the first flow event.

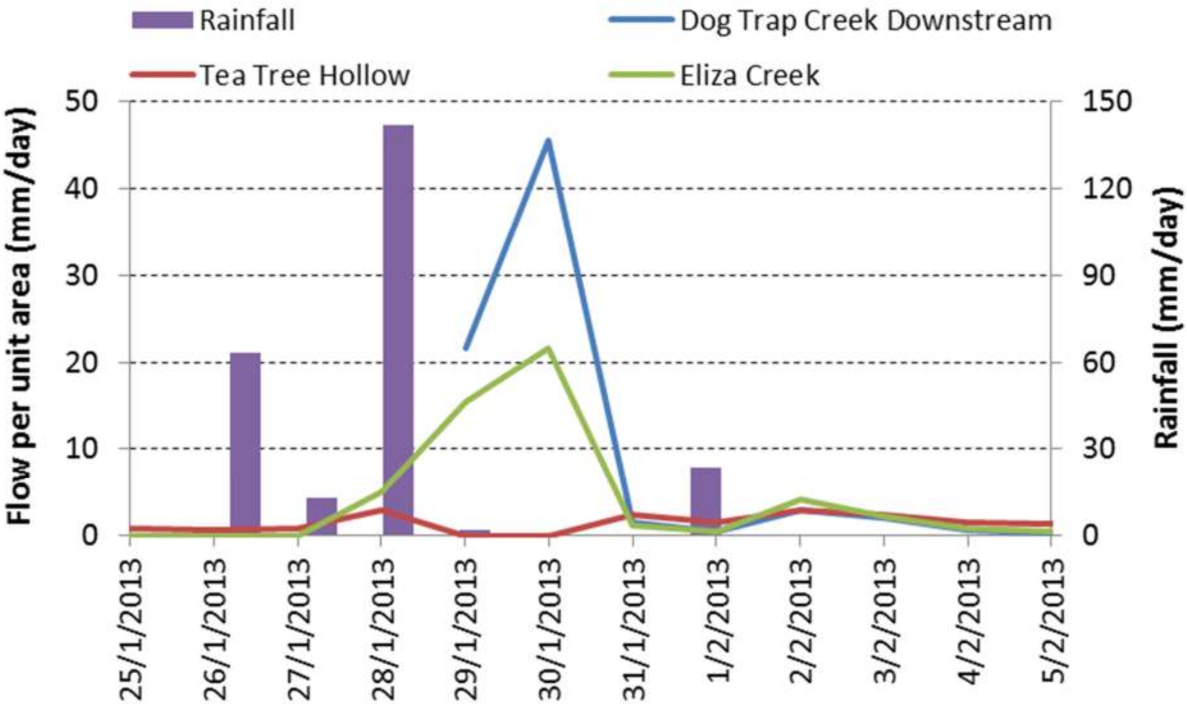

Figure 8 Streamflow Response to 28th January to 1st February 2013 Rainfall Event

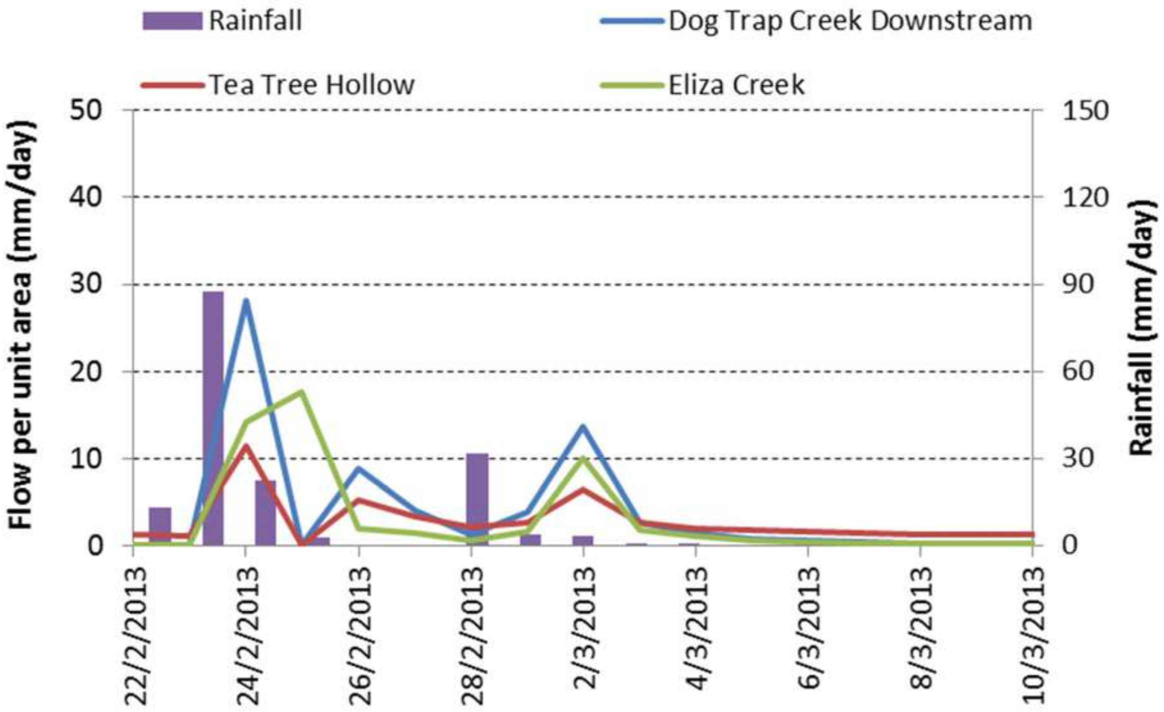

Figure 9 Streamflow Response to 23rd February to 4th March 2013 Rainfall Event

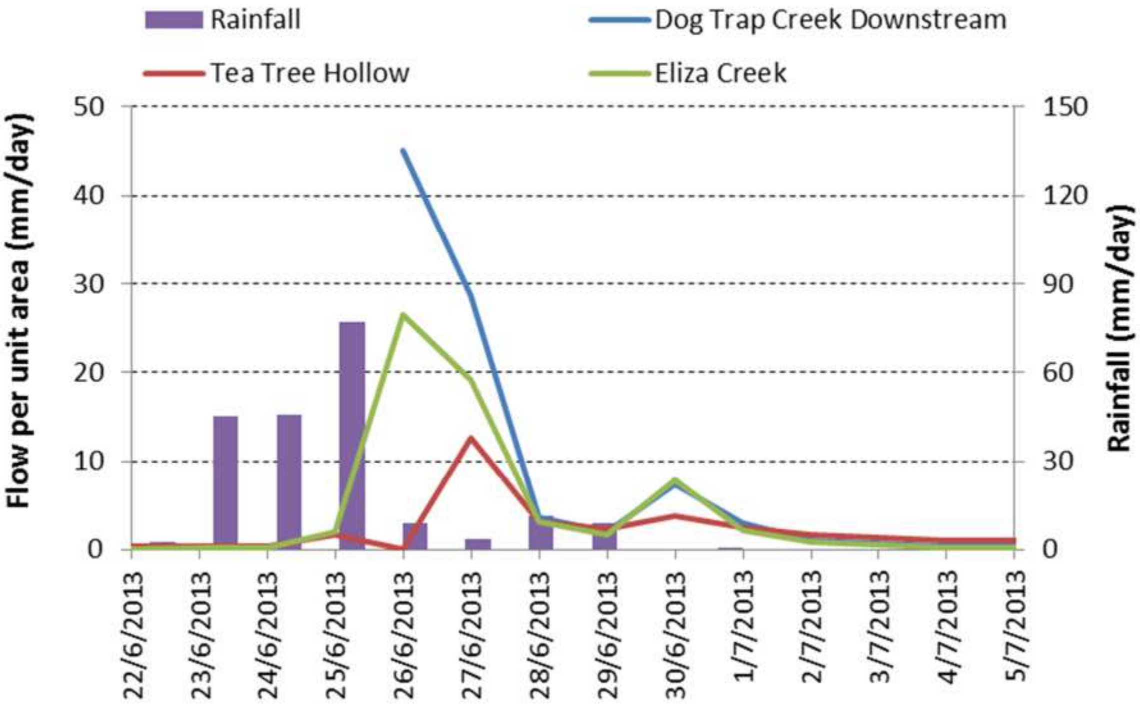

Figure 10 Streamflow Response to 25th June 2013 to 1st July 2013 Rainfall Event

These rainfall event stream hydrographs indicate that local creeks respond rapidly to rainfall. They also suggest that the Dog Trap Creek catchment produced greater flow in response to these rainfall events than either Eliza Creek or Tea Tree Hollow and that Tea Tree Hollow had the lowest streamflow in response to these rainfall events.

Figure 11 shows the recorded streamflow per unit catchment area, over the period 23rd January 2013 to 16th September 2013 for the Bargo River Upstream, Tea Tree Hollow, Dog Trap Creek Downstream, Carters Creek, Cow Creek and Eliza Creek. Streamflow per unit catchment area has been plotted on a logarithmic scale to accentuate the recessionary and low flow parts of the hydrographs. It is evident from Figure 11 that there is less low flow (baseflow) in Dog Trap Creek and Carters Creek compared to the other streams. Low flows and the recessionary behaviour of Hornes Creek, Cow Creek, Eliza Creek and the Bargo River upstream were similar over this period. Persistent low flows in Tea Tree Hollow reflect the effects of licensed discharge from Tahmoor which maintained low flow at elevated levels over this period.

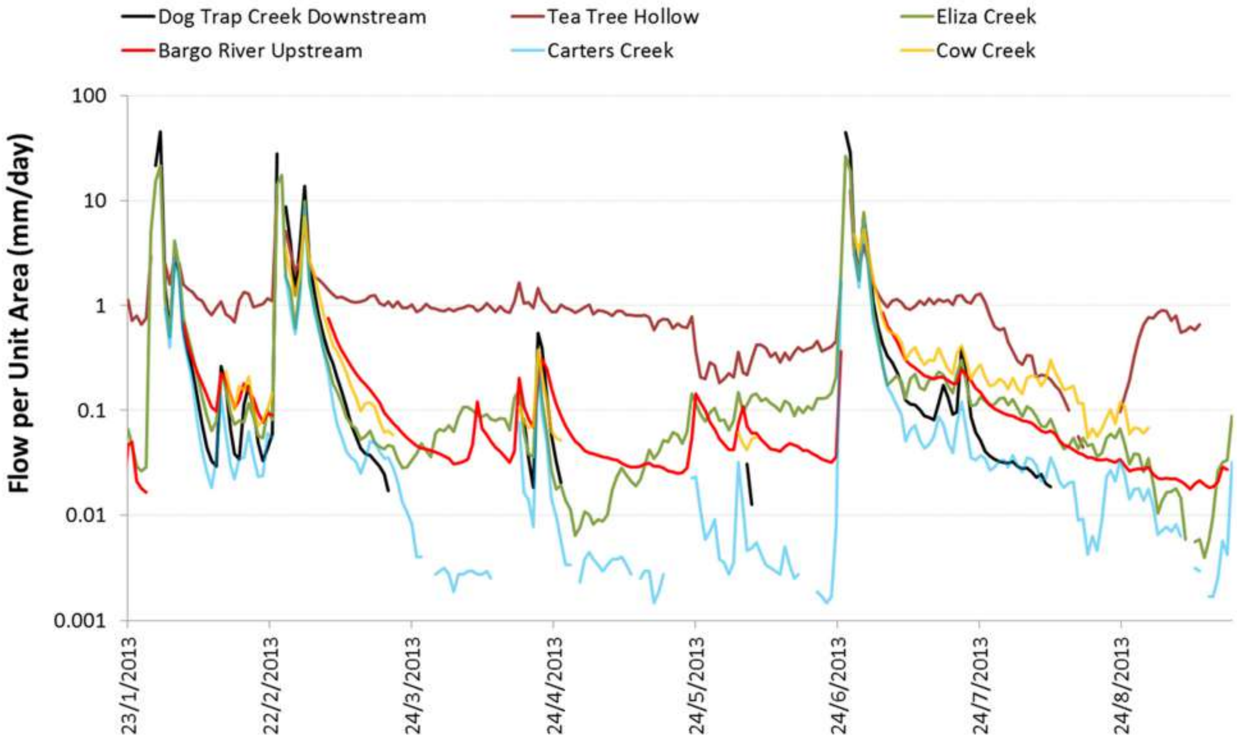

Figure 11 2013 Streamflow Hydrographs – Project Area

6.0 CATCHMENT MODELLING OF LOCAL WATERCOURSES

Catchment modelling has been undertaken using deterministic models which are configured to simulate catchment characteristics that are important to the environmental assessment. This is an accepted method of investigating these characteristics on a catchment by catchment basis. Modelling is also a method of developing a fuller understanding of the baseline hydrology of the catchments over a wide range of climatic conditions. The potential effects of subsidence on streamflow would be to reduce low flows and to increase low flow recession rates. Therefore simulation of low flows and low flow recession has been a particular focus of the modelling described in this section. Modelling has been conducted for the Bargo River Upstream (GS 300010a), Dog Trap Creek Downstream (GS 300063) and Eliza Creek (GS 300073) catchments.

Catchment modelling has been undertaken using the Australian Water Balance Model (AWBM) (Boughton, 2004), which is a nationally-recognised catchment-scale water balance model for simulating surface runoff and baseflow processes on gauged and un-gauged catchments. The AWBM simulation of recorded flows in the Bargo River Upstream, Dog Trap Creek and Eliza Creek are shown in the sub-sections below.

The gauging stations on Eliza and Dog Trap Creeks have been rated over the full range of recorded water levels enabling flows to be produced over the entire water level record. Modelling of flows at the Tea Tree Hollow gauging station site is confounded by the significant releases which dominate low flows. There is insufficient data to support independent models for Carters and Cow Creeks. As discussed below, the available streamflow data for Cow Creek indicates it has close hydrological similarity to Eliza Creek, while Carters Creek has a close similarity to the hydrological characteristics of Dog Trap Creek. This similarity has enabled the streamflow characteristics to be assessed using the results produced from these nearby catchment models.

6.1 DOG TRAP CREEK DOWNSTREAM (GS 300063)

AWBM simulated and monitored flow between February 2012 and September 2013 are shown in Figure 12.

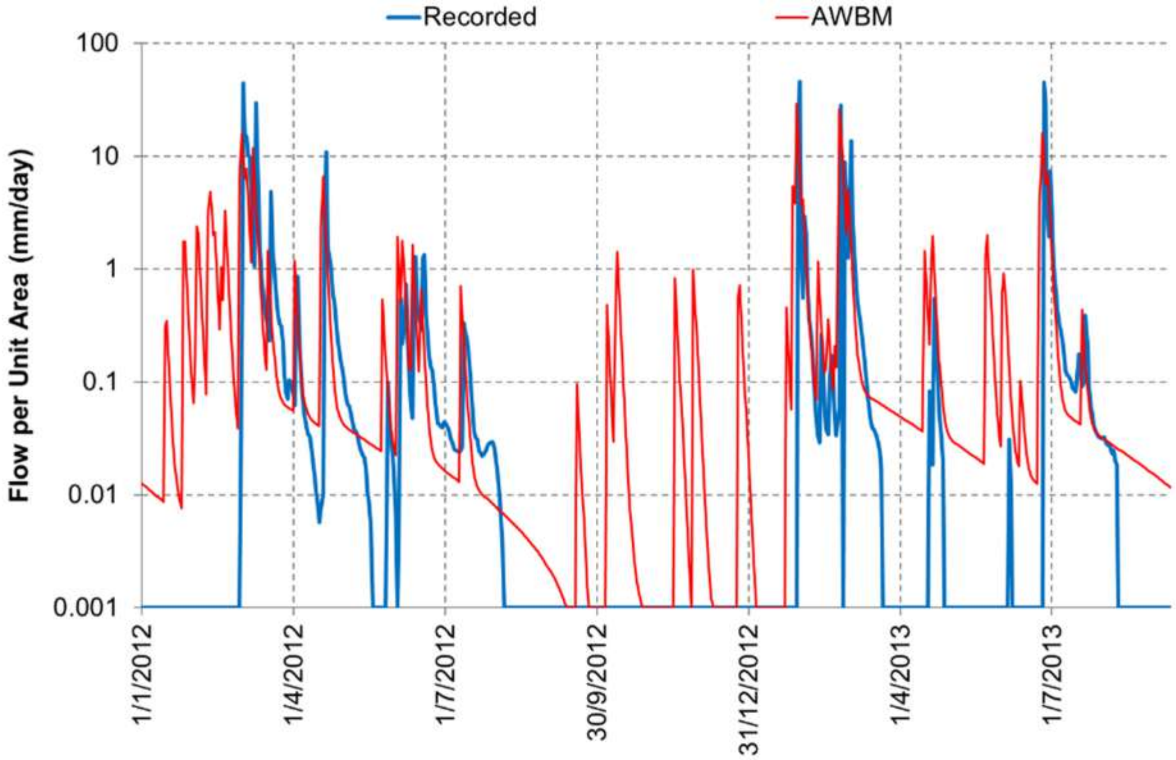

Figure 12 Recorded and Modelled Flows - Dog Trap Creek Downstream (GS 300063)

The AWBM match to recorded flows is generally close although very low flows are over estimated particularly in mid-2013. There was a period between August 2012 and January 2013 when no flows were recorded. Similar behaviour was also observed at the other Dog Trap Creek gauging station site (upstream) although flow events were recorded at the Eliza Creek and Bargo River Upstream gauging stations over this same period – refer Figure 11. The model however simulates several small flows during this period. This suggests that there was either loss of data at both the Dog Trap Creek gauging stations or there may be some flow diversion or underflow at these locations.

The AWBM match can also be assessed by comparing the flow duration curves of recorded and modelled flows – refer Figure 13 which has been compiled ignoring the period of no flow between August 2008 and January 2013. The model match is generally considered fair. All three AWBM surface stores overflowed during the calibration period, indicating that the period includes a representative range of flow rates.

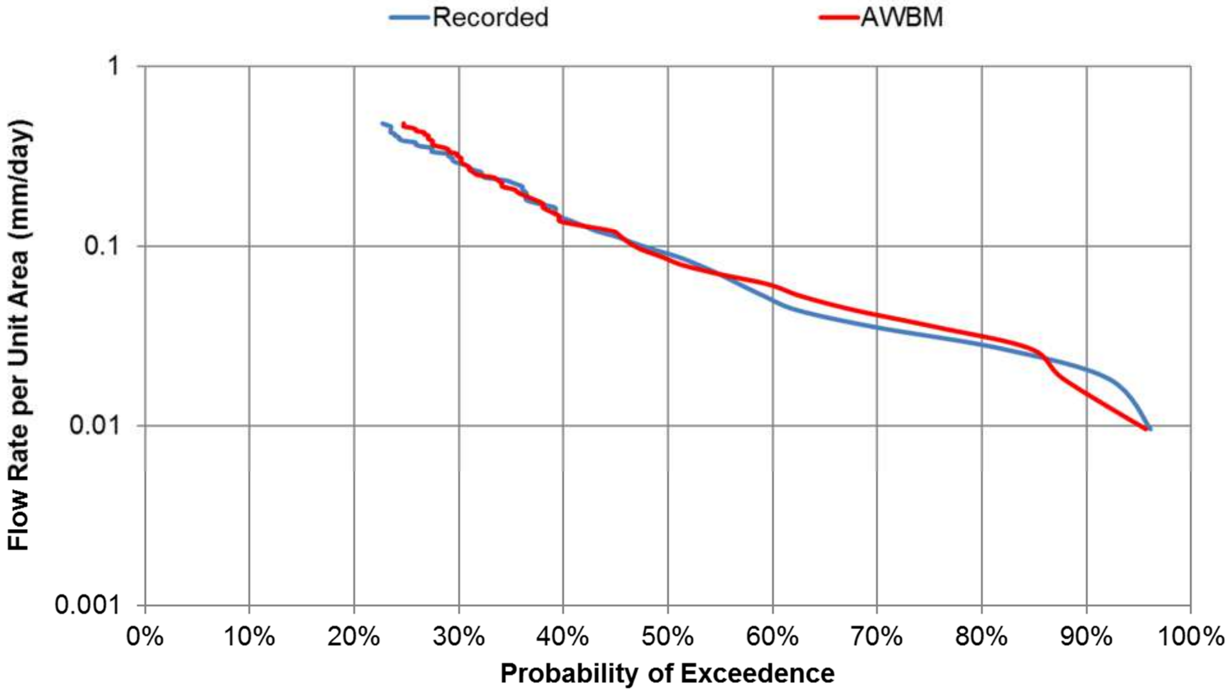

Figure 13 Modelled and Recorded Flow Duration Curves - Dog Trap Creek Downstream (GS 300063)

6.2 ELIZA CREEK (GS 300073)

AWBM simulated and monitored flow between October 2012 and September 2013 is shown in Figure 14.

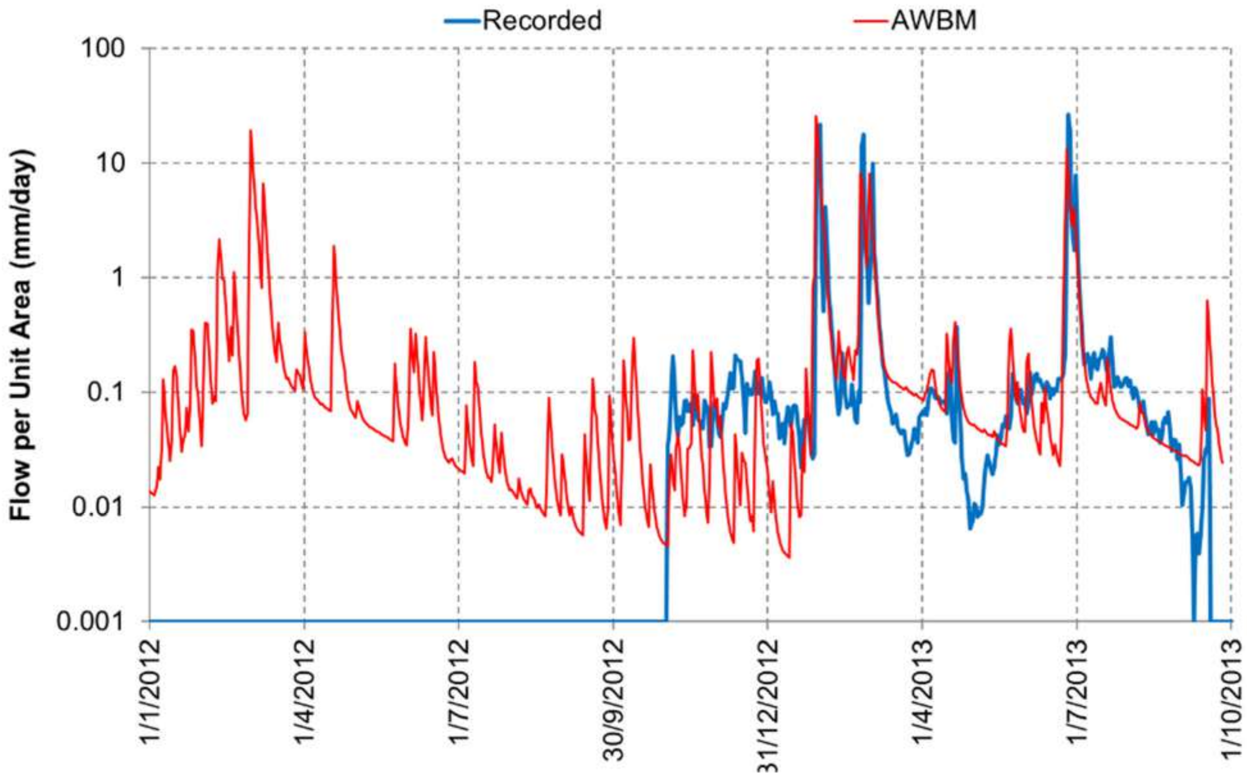

Figure 14 Recorded and Modelled Flows - Eliza Creek (GS 300073)

Again the overall model match between AWBM and recorded data is considered fairly close. Recorded flow is thought to be erroneous during the period between 2nd November 2012 and 28th January 2013. The recorded flow during this period indicates regular and erratic spikes without any "normal" recessionary behaviour and may be due to blockage of the level sensor or the control of the gauging station. After this period the match between recorded and modelled flow is generally close. The flow duration plot (plotted so as to ignore erroneous flows), shows a good fit to recorded flows – refer Figure 15. All three AWBM surface stores overflowed during the calibration period, indicating that the period includes a representative range of flow rates.

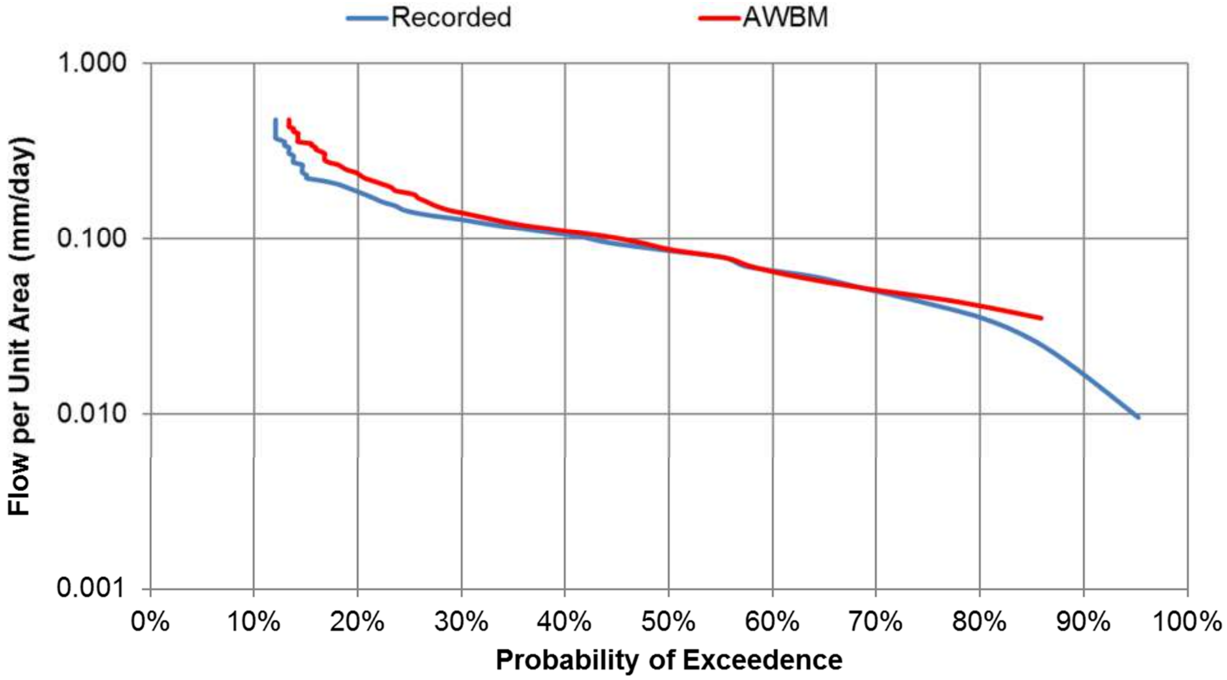

Figure 15 Modelled and Recorded Flow Duration Curves - Eliza Creek (GS 300073)

6.3 BARGO RIVER UPSTREAM (GS 300010A)

The gauging station on the Bargo River upstream was commissioned in May 2008 and operated through until December 2009 when the station was closed. The station was re-opened in February 2012. An AWBM has been calibrated to monitored flows – over both the 2008-2009 and 2012-2013 periods - refer Figure 16. It should be noted that limitations on high flow ratings have prevented calculation of high flows in monitored data and therefore the model accuracy at high flows may be limited.

The model match between AWBM and recorded flow over the initial (2008 to 2009) period is considered to be poor. The match for the latter (2012 – 2013) period by comparison is considered good. The flow duration curves for recorded and modelled flows over the two periods are shown in Figure 17.

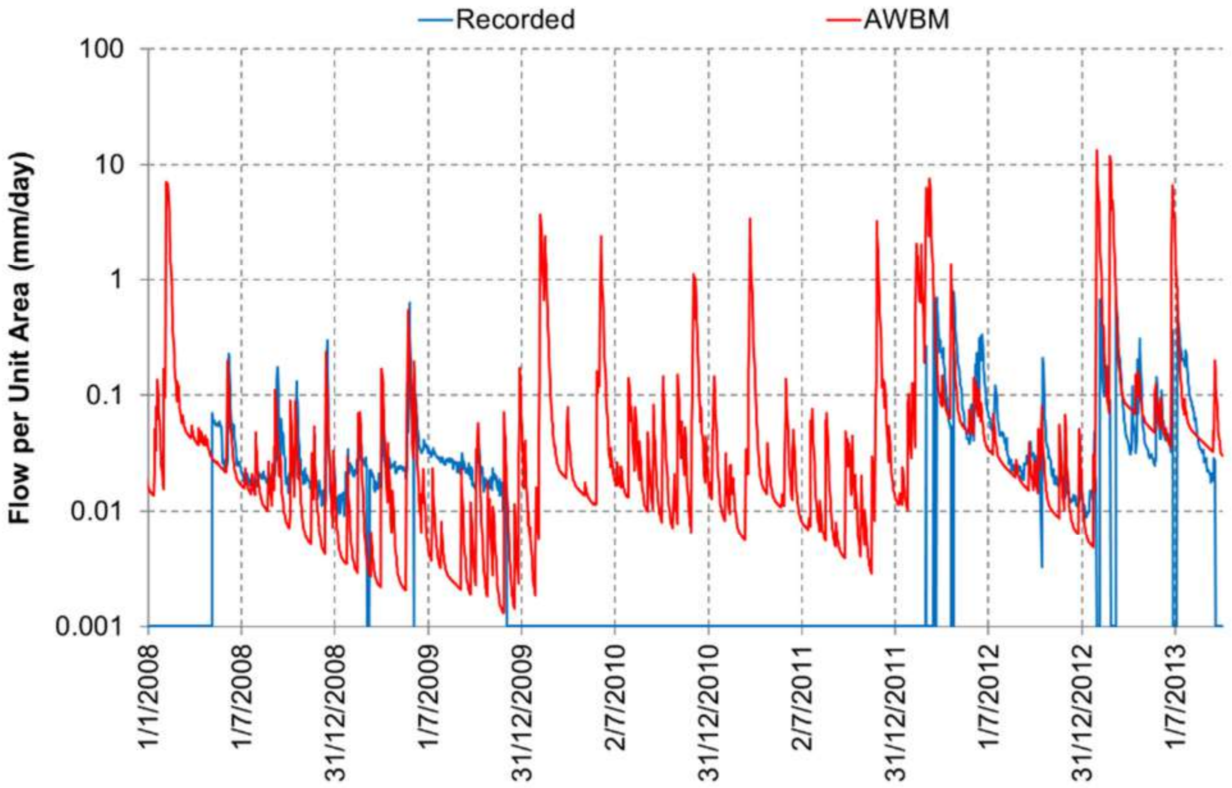

Figure 16 Recorded and Modelled Flows Bargo River Upstream (GS 300010a)

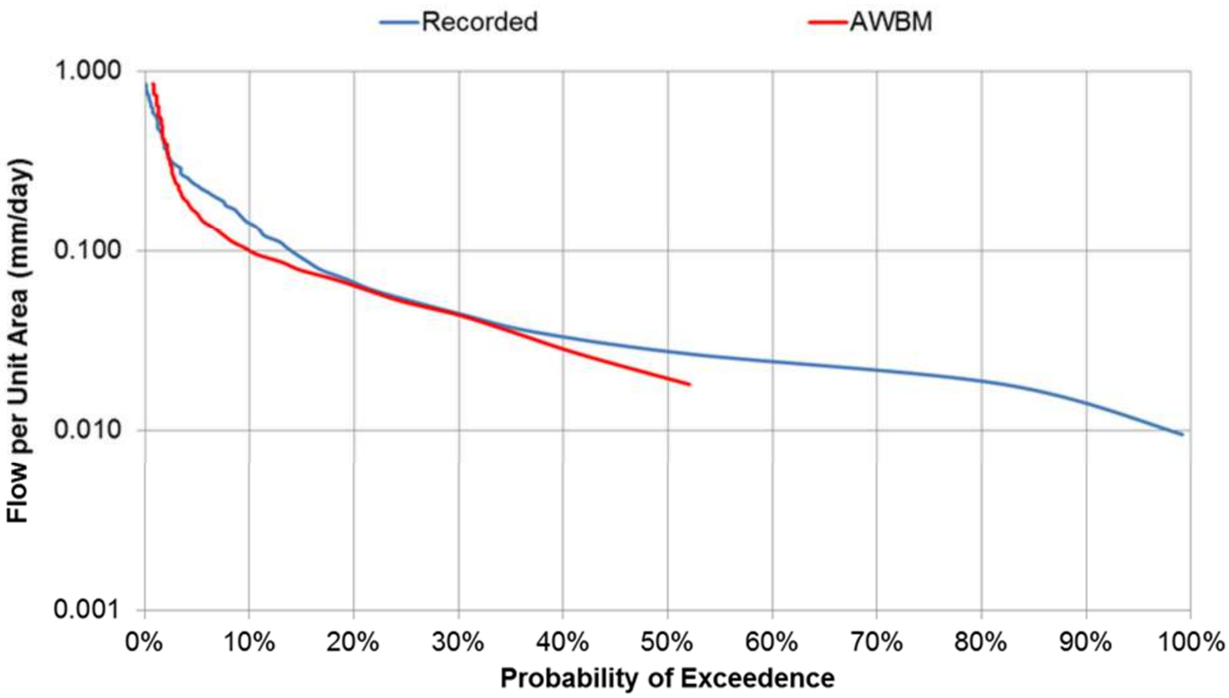

Figure 17 Modelled and Recorded Flow Duration Curves - Bargo River Upstream (GS 300010a)

6.4 CARTERS AND COW CREEKS

The monitored flow data for Cow Creek appears to have similar hydrological behaviour during periods of low flow as Eliza Creek – refer Figure 18. These catchments are considered to be hydrologically similar and it is considered that reasonable estimates of flow statistics for Cow Creek can be obtained using the Eliza Creek catchment model adjusted for differences in catchment area.

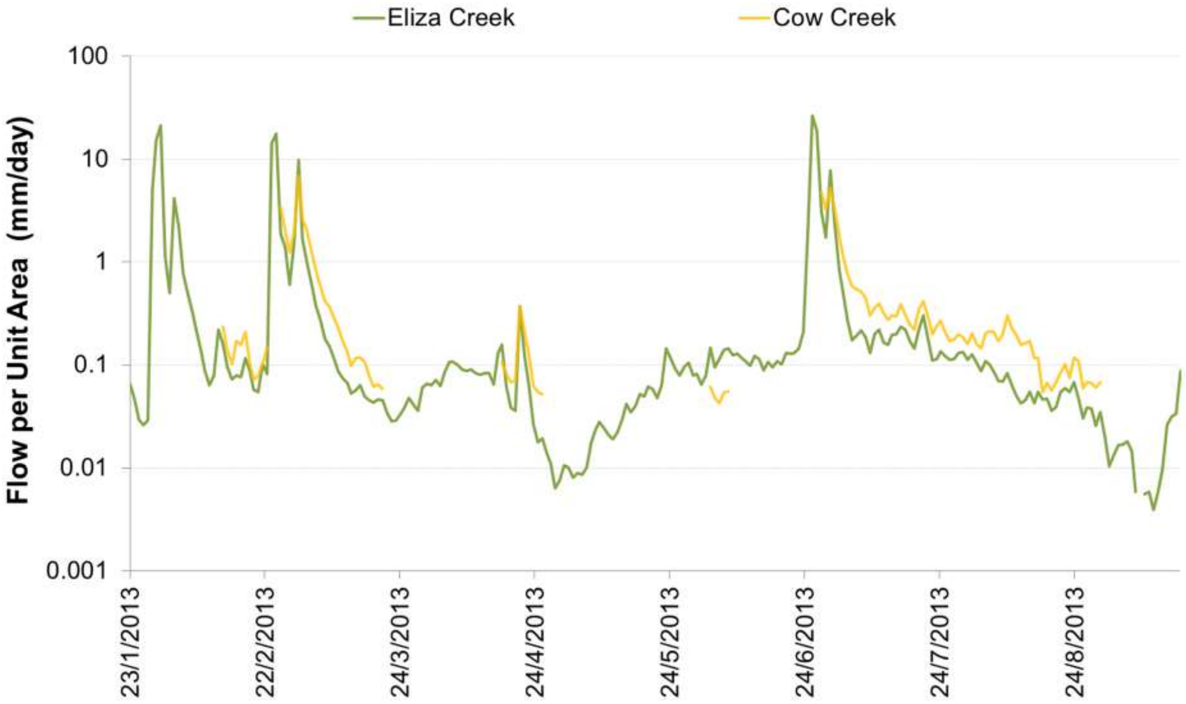

Figure 18 Comparative Recorded Flows - Cow and Eliza Creek

The monitored flow data for Carters Creek has exhibited similar hydrological behaviour during periods of low flow as Dog Trap Creek – refer Figure 19. These catchments are considered to be hydrologically similar and it is considered that reasonable estimates of flow statistics for Carters Creek can be obtained using the Dog Trap Creek catchment model adjusted for differences in catchment area.

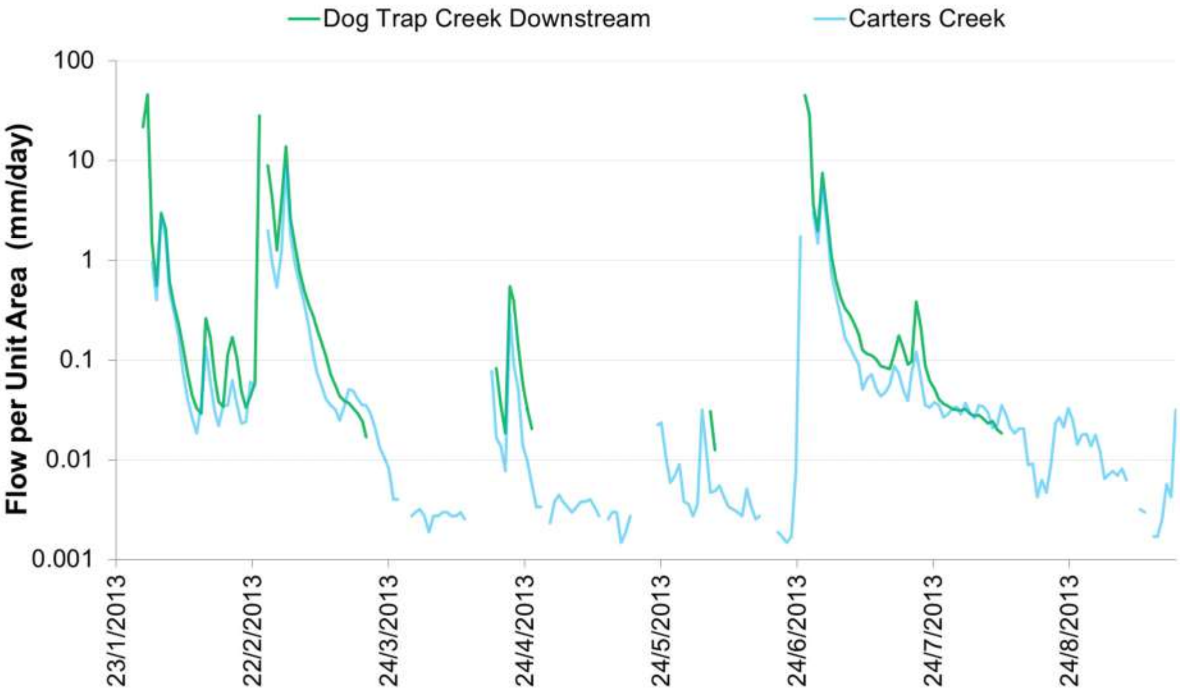

Figure 19 Comparative Recorded Flows - Carters and Dog Trap Creeks

6.5 DISCUSSION

Results of catchment modelling suggest that there may be a transmission loss in the Dog Trap Creek catchment and perhaps in Eliza Creek. The principal model parameters which affect low flow and recessionary flow are the Baseflow Index (which determines the volume of modelled flow derived from groundwater inflow sources to the stream as a proportion of the total flow) and the Baseflow Recession Constant which dictates the rate that groundwater sourced streamflow recedes during drying periods. The Baseflow Index varies between 0 (where there is no baseflow contribution) to 1 where flow is totally derived from groundwater sources. A Baseflow Index of zero typically occurs in arid areas of Australia and low values of the Baseflow Index (i.e. less than 0.15) are common in Australian streams. High values (greater than 0.5) typically occur in high rainfall, mountainous catchments such as the wet tropics of far north Queensland. The Baseflow Recession Constant (also a number between 0 and 1) typically varies between 0.99 (for streams which recede slowly) and 0.9 for rapidly receding streams. The Baseflow Indices and Baseflow Recession Constants obtained from the above AWBM calibrations are summarised in Table 11 below. These values show that baseflow makes a significantly lower contribution to flow in Dog Trap Creek than in Eliza Creek or the Bargo River Upstream.

Table 11 Comparison of AWBM Baseflow Indices and Baseflow Recession Rates

Stream	Baseflow Index	Baseflow Recession Constant
Dog Trap Creek	0.045	0.98
Eliza Creek	0.1	0.98
Bargo River Upstream	0.1	0.99

7.0 CATCHMENT RUNOFF AND STREAMFLOW

Streamflow is typically highly variable over time and information on average flows provides only a limited understanding of the flows characteristics of a stream. There are various methods or metrics for describing streamflow characteristics of a catchment. The following streamflow and runoff descriptors have been used following recommendations from a published study of characterization methods for flow in streams in eastern Australia (Growns and Marsh, 2000). Given that the potential effects of longwall mining on streamflow are predominantly related to loss of flow and changes to low flow persistence, streamflow descriptors of particular relevance to low flow related ecological impact assessment have been used.

1. Mean annual flow (ML/year)
2. Median daily flow (ML/day)
3. Average Annual Yield (% of Average Annual Catchment Rainfall)
4. Baseflow Index defined as the ratio of Baseflow Volume to Total Flow Volume
5. Flow Variability defined as (Q_{10} – Q_{90})/Median daily flow

   Where the 10th percentile flow value is labelled Q_{90} and is the flow that is equalled or exceeded 90% of the time. Q_{10} is the flow that is equalled or exceeded 10% of the time.
6. Average Daily Flow Duration Curve is a plot of percentile values against discharge values. It is calculated using daily flows over the entire period and shows the percentage of time during which flows exceed a given magnitude.
7. Low Flow Spells Analysis. This comprises identifying periods when flow is below threshold values. The low flow threshold levels used were 0, 1/2, 1/3, and 1/4 times the median daily flow. The duration of events that flow was below threshold values was calculated for each year and the distribution of these was plotted as exceedance probability plots.

These statistics have been calculated for long periods of simulated streamflow data generated using the calibrated models described in Section 6.0 above. The models were run over a long period of SILO Data Drill climatic data to produce estimates of the corresponding flows that would have occurred under these climatic conditions.

7.1 ELIZA CREEK FLOW CHARACTERISTICS

The baseline flow characteristics for Eliza Creek as calculated from the catchment model run using a 124 year period of the SILO Data Drill are presented in Table 12 and Figure 20 and Figure 21 below.

Table 12 Baseline Flow Statistics – Eliza Creek at (GS 300073)

Statistic	Value
Mean Daily Flow (ML/day)	0.95
Median Daily Flow (ML/day)	0.14
Average Annual Yield (% Rainfall)	11
Base Flow Index	0.1
Flow Variability	6.8

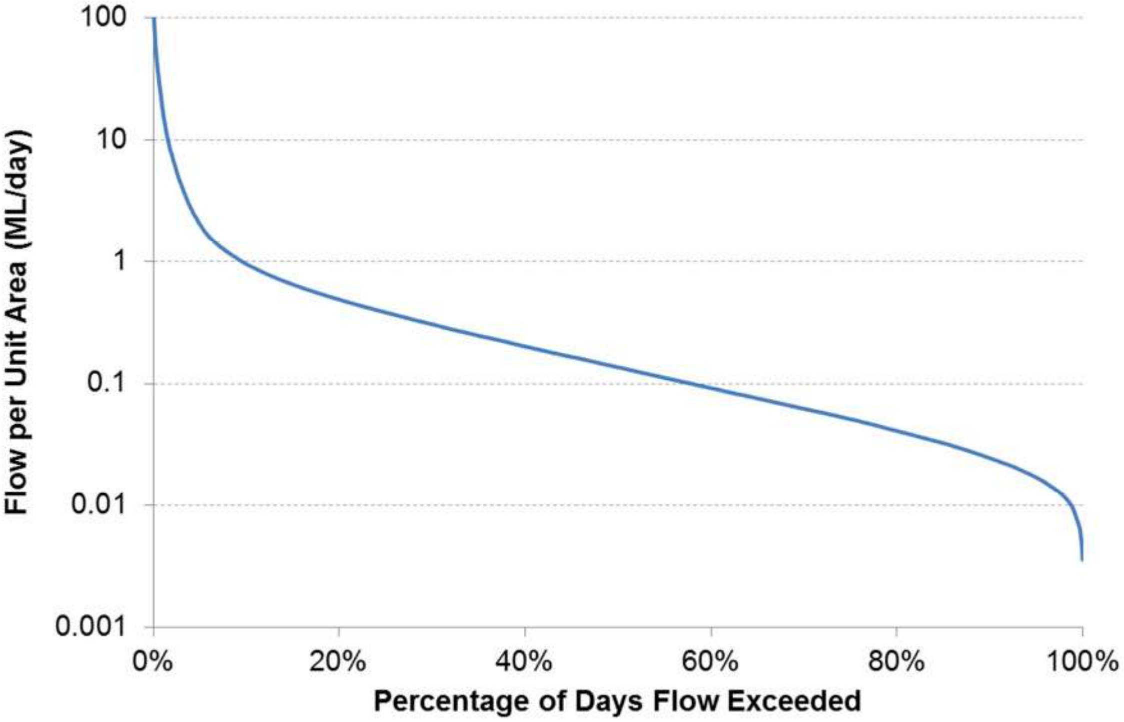

Figure 20 Average Daily Flow Duration Curve – Eliza Creek at GS 300073

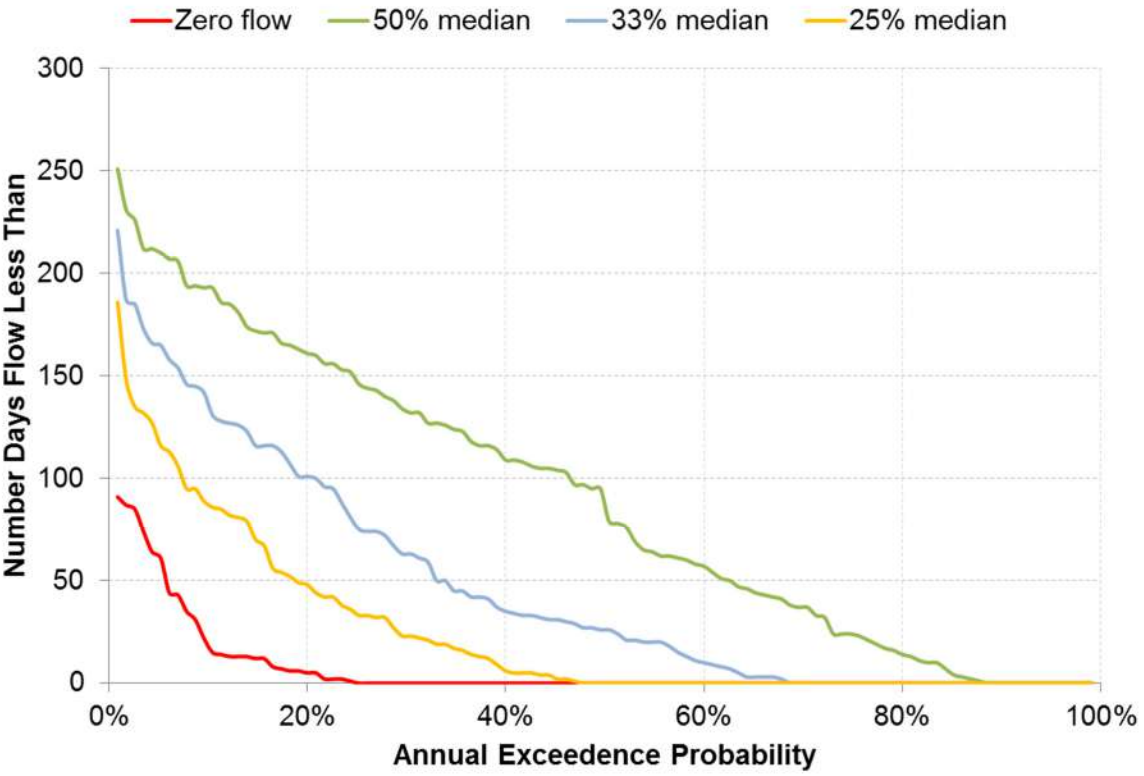

Figure 21 Low Flow Duration Exceedance Characteristics - Eliza Creek at GS 300073

7.2 DOG TRAP CREEK FLOW CHARACTERISTICS

The baseline flow characteristics of Dog Trap Creek (Downstream) as calculated from the catchment model run using a 124 year period of the SILO Data Drill are presented in Table 13, Figure 22 and Figure 23 below.

Table 13 Baseline Flow Statistics – Dog Trap Creek Downstream (GS 300063)

Statistic	Value
Mean Daily Flow (ML/day)	4.95
Median Daily Flow (ML/day)	0.2
Average Annual Yield (% Rainfall)	18
Base Flow Index	0.1
Flow Variability	44.2

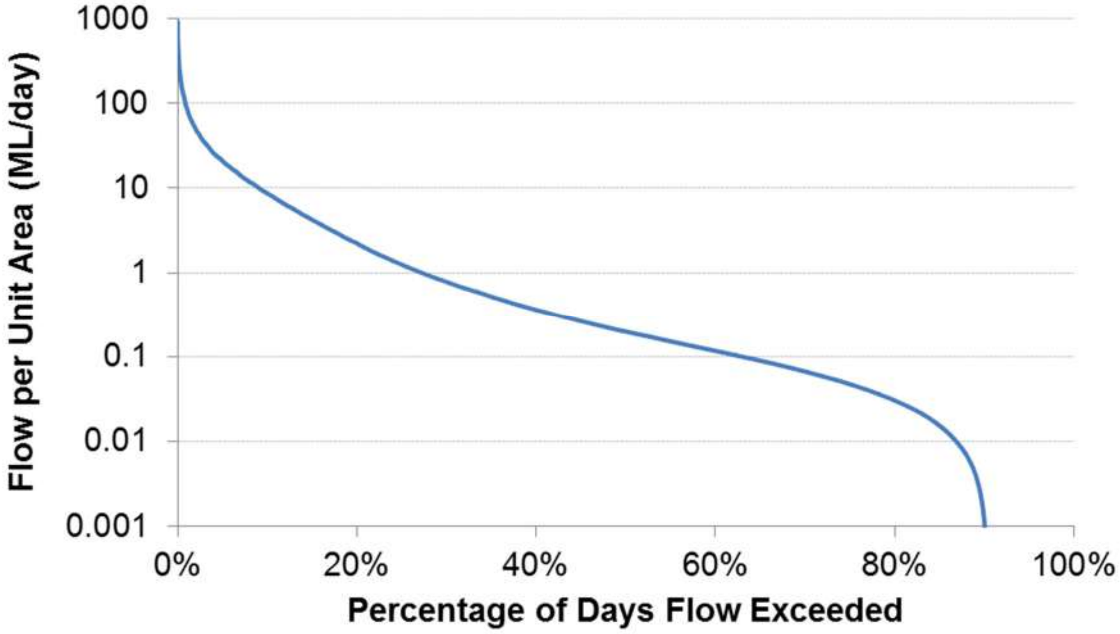

Figure 22 Average Daily Flow Duration Curve – Dog Trap Creek Downstream (GS 300063)

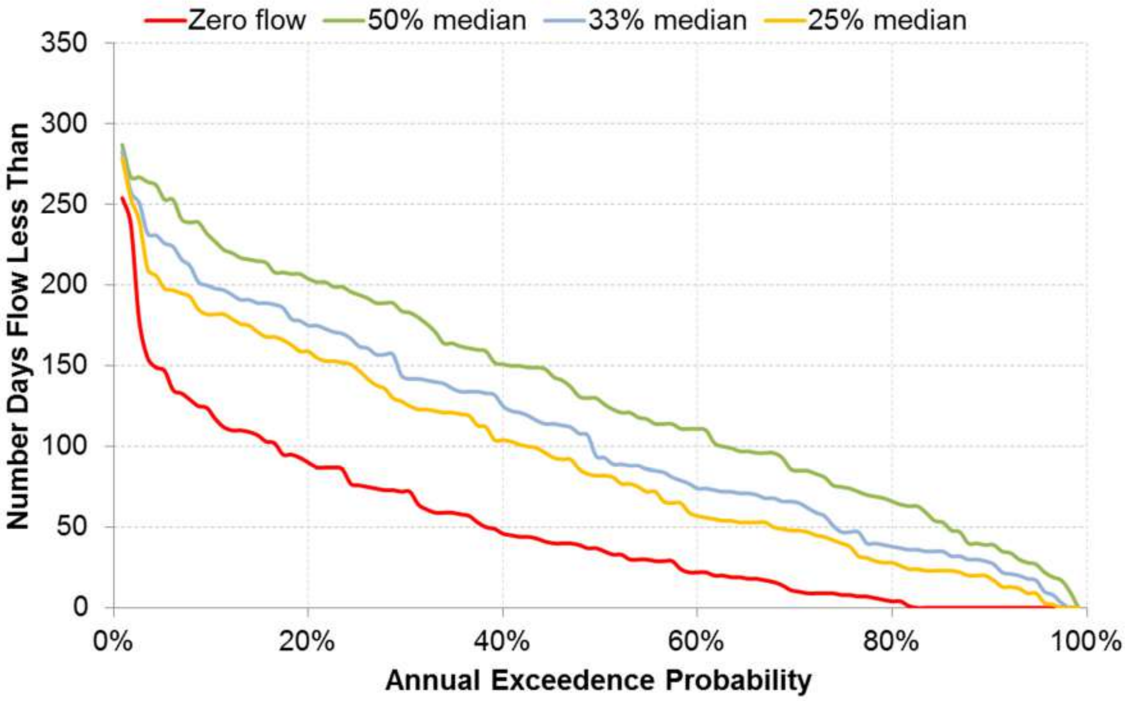

Figure 23 Low Flow Duration Exceedance Characteristics - Dog Trap Creek Downstream (GS 300063)

7.3 BARGO RIVER UPSTREAM FLOW CHARACTERISTICS

The baseline flow characteristics of the Bargo River Upstream as calculated from the catchment model run using a 124 year period of the SILO Data Drill are presented in Table 14, Figure 24 and Figure 25 below.

Table 14 Baseline Flow Statistics – Bargo River Upstream Bargo (GS 300010a)

Statistic	Value
Mean Daily Flow (ML/day)	23.9
Median Daily Flow (ML/day)	2.6
Average Annual Yield (% Rainfall)	11
Base Flow Index	0.1
Flow Variability	5.8

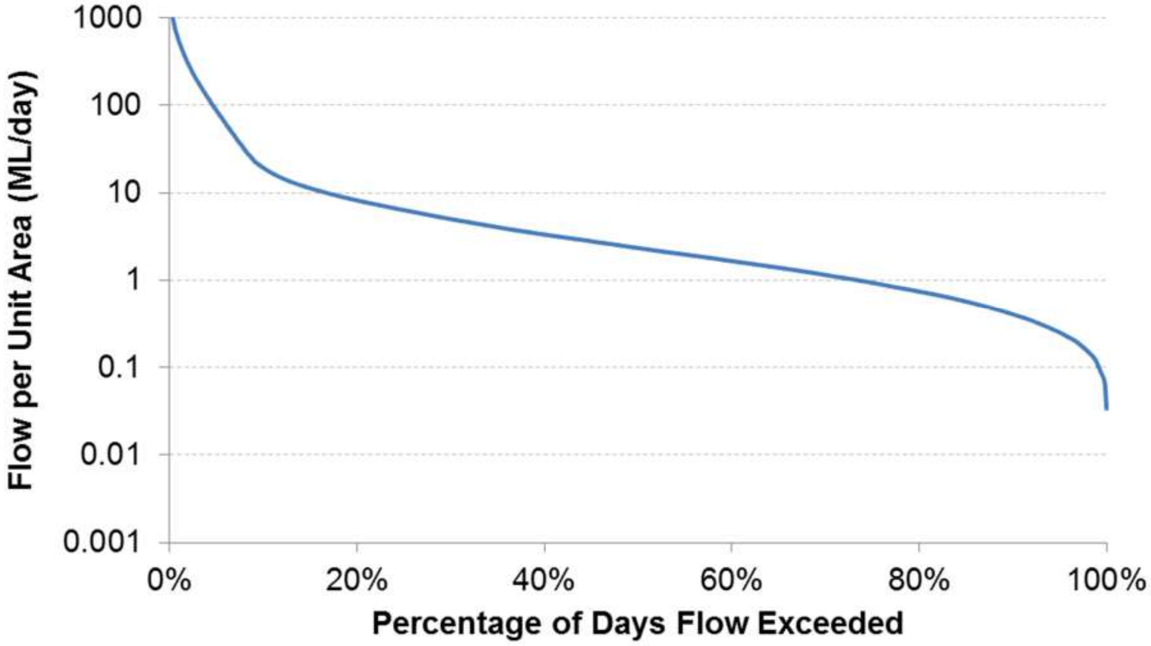

Figure 24 Average Daily Flow Duration Curve – Bargo River Upstream Bargo (GS 300010a)

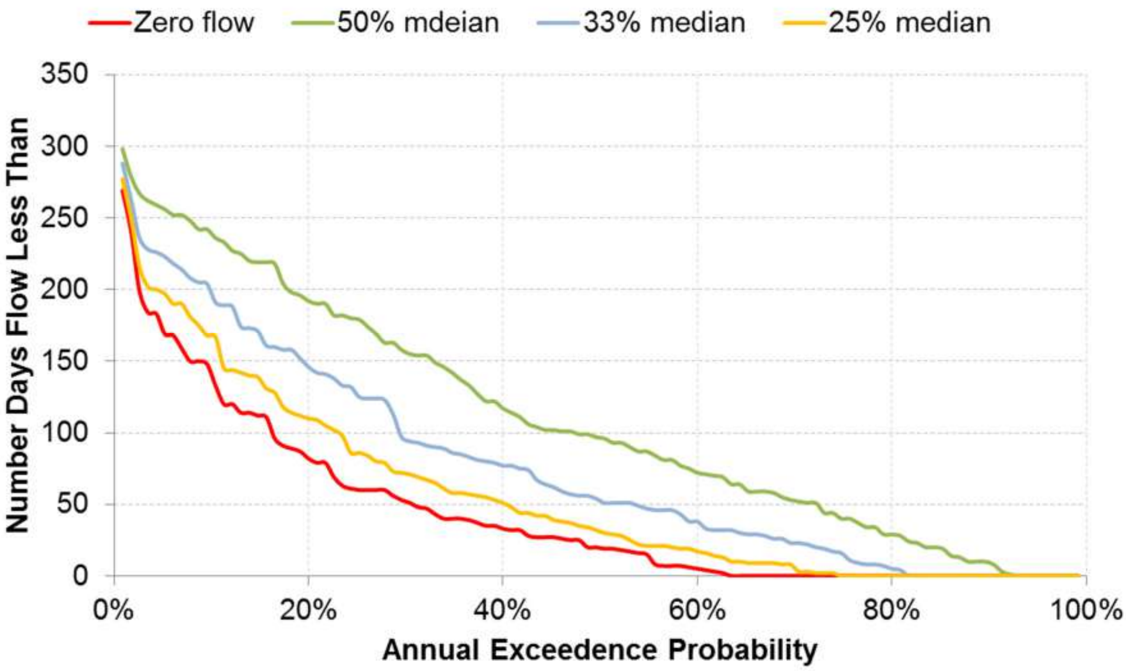

Figure 25 Low Flow Duration Exceedance Characteristics –- Bargo River Upstream Bargo (GS 300010a)

7.4 TEA TREE HOLLOW FLOW CHARACTERISTICS

The baseline low flow characteristics of Tea Tree Hollow have been estimated assuming a constant release rate of 5.3 ML/day from the Tahmoor Mine. Flow generated from the upslope catchment has been based on the Eliza Creek catchment model. The high minimum flow maintained by controlled release completely dominates low flow statistics. The relevant modelled flow statistics of Tea Tree Hollow downstream of are summarised in Table 15. The modelled flow duration curve is shown in Figure 26.

Table 15 Baseline Flow Statistics –Tea Tree Hollow (GS 300056)

Statistic	Value
Mean Daily Flow (ML/day)	6.3
Median Daily Flow (ML/day)	5.3
Flow Variability	Approx. 0

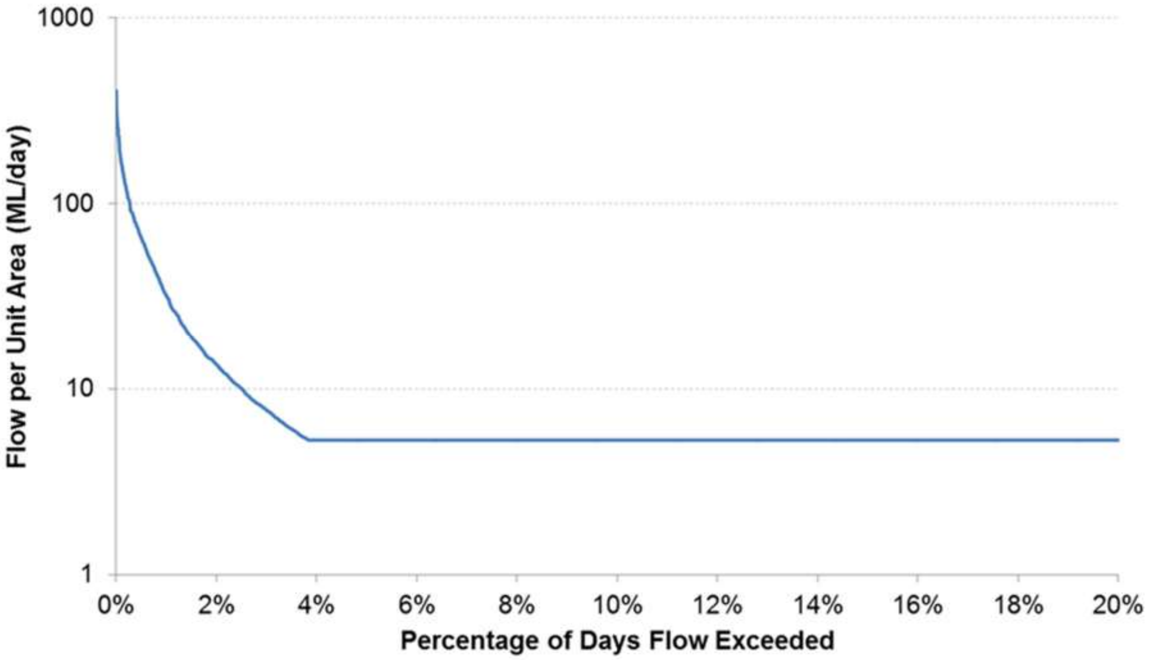

Figure 26 Average Daily Flow Duration Curve – Tea Tree Hollow at GS 300056 Downstream of Tahmoor Mine Release

7.5 CARTERS CREEK FLOW CHARACTERISTICS

The baseline flow characteristics of Carters Creek have been assessed assuming hydrological similarly with Dog Trap Creek. The characteristics presented below (Table 16) are the same as those calculated from the Dog Trap Creek catchment model factored on the basis of catchment area. The modelled flow duration curve for Carters Creek is shown in Figure 27.

Table 16 Baseline Flow Statistics – Carters Creek (GS 300076)

Statistic	Value
Mean Daily Flow (ML/day)	0.44
Median Daily Flow (ML/day)	0.084
Average Annual Yield (% Rainfall)	18
Base Flow Index	0.1
Flow Variability	44.2

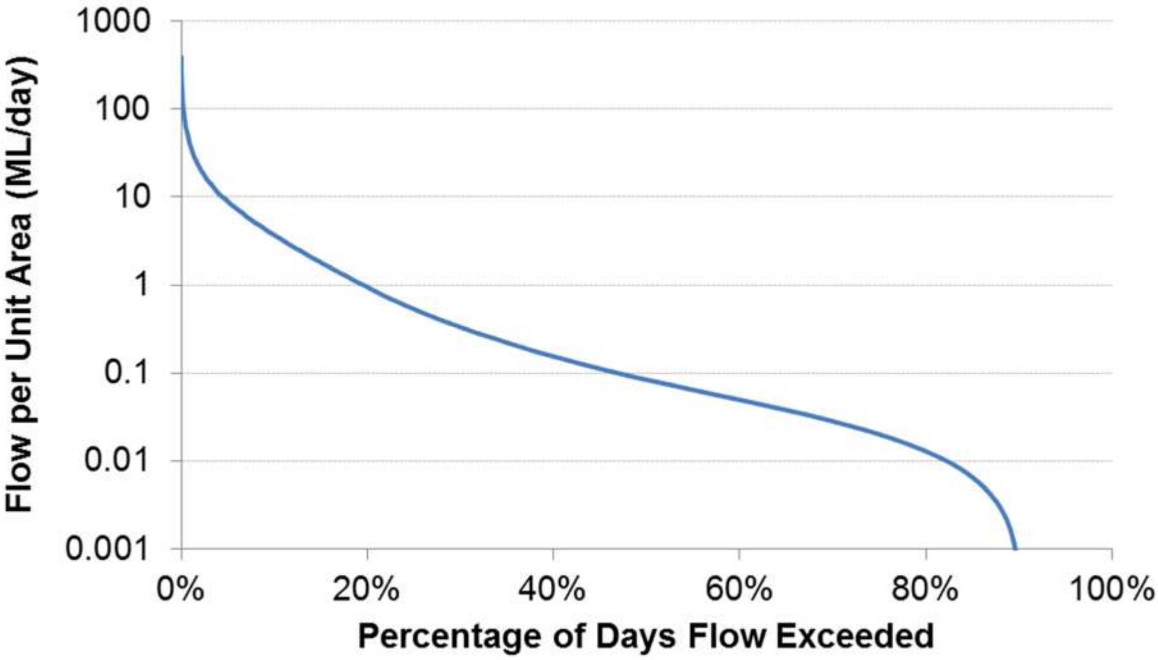

Figure 27 Average Daily Flow Duration Curve – Carters Creek (GS 300076)

7.6 COW CREEK FLOW CHARACTERISTICS

The baseline flow characteristics of Cow Creek have been assessed assuming hydrological similarly with Eliza Creek. The characteristics presented below (Table 17) are the same as those calculated from the Eliza Creek catchment model – factored on the basis of catchment area. The modelled flow duration curve for Cow Creek is shown in Figure 28.

Table 17 Baseline Flow Statistics – Cow Creek (GS 300075)

Statistic	Value
Mean Daily Flow (ML/day)	1.19
Median Daily Flow (ML/day)	0.2
Average Annual Yield (% Rainfall)	11
Base Flow Index	0.1
Flow Variability	6.8

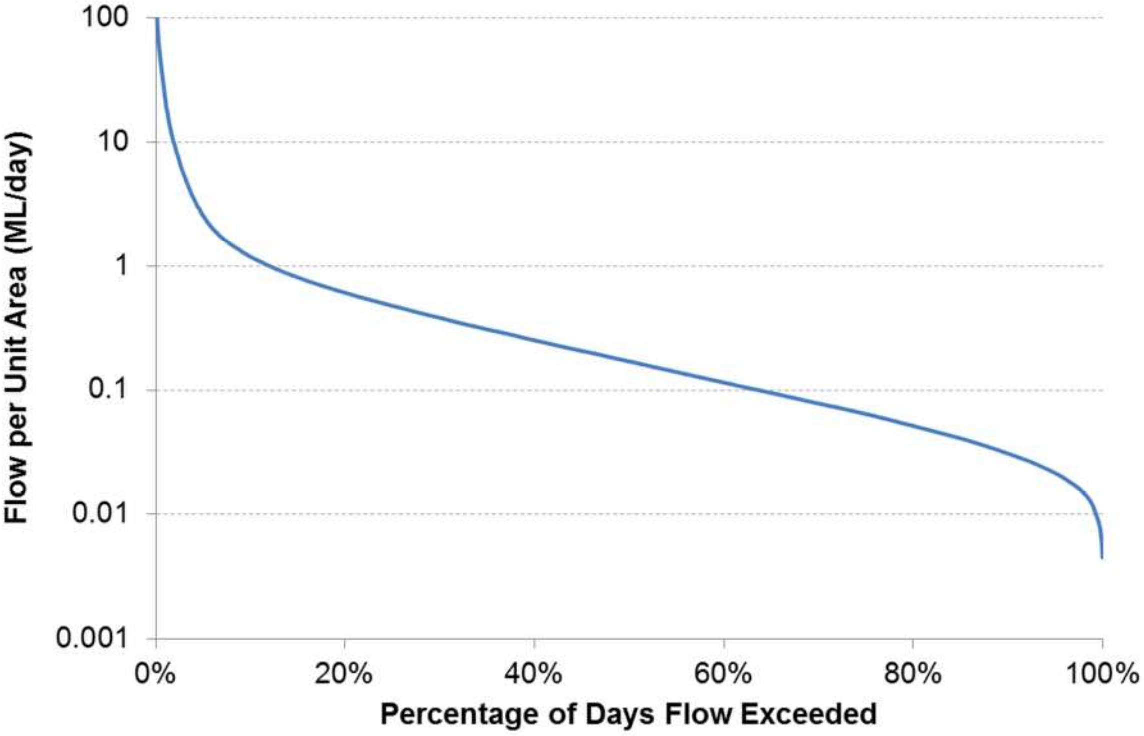

Figure 28 Average Daily Flow Duration Curve – Cow Creek (GS 300075)

8.0 STREAMFLOW WATER QUALITY

Water quality monitoring has been conducted at or at sites adjacent to all baseline flow gauging station sites in the Project Area. The baseline water quality data has been assessed against ANZECC (2000) guideline trigger levels for the protection Aquatic Ecosystems and Recreational Uses in accordance with the perceived principal beneficial uses of the surface water resources in the area. The guideline trigger levels used in the assessment are summarised in Table 18 below.

Water Quality Objectives (WQOs) have been adopted for all NSW catchments by the NSW government consistent with the ANZECC (2000) guidelines. At the time the WQOs were approved, the Healthy Rivers Commission (HRC) had completed a public inquiry into the Hawkesbury-Nepean system. The HRC recommended water quality objectives in its Final Report (HRC, 1998) which have been adopted by the NSW Government. The report recommended that the ANZECC (2000) guideline values be adopted as suitable WQOs for the Hawkesbury-Nepean River catchment, with the exception of nutrients and chlorophyll-a.

Table 18 Water Quality Triggers used in Baseline Water Quality Assessment

Parameter	ANZECC Guidelines		
	Aquatic Ecosystems (95%ile level of species protection)	Upland Rivers (NSW)	Recreational Use
Aluminium (µg/L)	-	-	200
Aluminium (µg/L) pH > 6.5	55	-	-
Arsenic (µg/L)	-	-	50
Arsenic (µg/L) (As III)	24	-	-
Barium (µg/L)	-	-	1,000
Cadmium (µg/L)	0.2	-	5
Chromium (µg/L)	-	-	50
Copper (µg/L)	1.4	-	1,000
Iron (µg/L)	-	-	300
Lead (µg/L)	3.4	-	50
Mercury (µg/L)	0.6	-	1
Selenium (µg/L)	11	-	10
Sodium (mg/L)	-	-	300
Sulphate (mg/L)	-	-	400
Zinc (µg/L)	8	-	5,000
pH (pH units)	6.5-8	-	6.5-8.5
EC (µS/cm) and TDS (g/L)	-	EC 350	TDS 1,000
Turbidity (NTU)	-	2-25	-
Chloride (mg/L)	-	-	400
$CaCO_3$ (mg/L) Hardness	-	-	500

Data collected from the commencement of monitoring in September 2012 to June 2015 are summarised in a series of tables below (refer Table 19 to Table 30). Note when laboratory results have been recorded at below the limit of detection the result has been analysed assuming the concentration was equal to the limit of detection. In cases where values have been recorded at below the limit of detection minimum concentrations have been reported as zero. Median values which exceeded the guideline trigger values for protection of aquatic ecosystems have been highlighted. Site specific trigger values have been derived from the monitored data as the 80th percentile of monitored values (as well as the 20th percentile for pH) and are included in the Tables.

Table 19 Water Quality Summary – Bargo River at SW-1

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	29	0	14	7	11	-	0
Sulphate (mg/L)	29	0	19	3	5.4	-	0
Chloride (mg/L)	29	22	65	45	54	-	0
Calcium (mg/L)	29	0	4	2	3	-	-
Magnesium (mg/L)	29	2	7	4	6	-	-
Sodium (mg/L)	29	14	28	21	23	-	0
Potassium (mg/L)	29	0	4	2	2	-	-
Aluminium (mg/L)	29	0.02	0.82	0.06	0.14	15	5
Arsenic (mg/L)	29	0	0.001	0.001	0.001	0	0
Barium (mg/L)	29	0.008	0.052	0.013	0.0226	-	0
Cadmium (mg/L)	29	0	0.031	0.0001	0.005	7	6
Chromium (mg/L)	29	0	0.001	0.001	0.001	-	0
Copper (mg/L)	26	0	0.001	0.001	0.001	0	0
Lead (mg/L)	29	0	0.001	0.001	0.001	0	0
Selenium (mg/L)	29	0	0.02	0.01	0.01	1	1
Zinc (mg/L)	29	0	0.143	0.005	0.0104	14	0
Iron (mg/L)	29	0	6.15	0.81	1.17	-	27
Mercury (mg/L)	21	0	0.0001	0.0001	0.0001	0	0
pH	28	5.9	8.8	7	6.4, 7.7	13	-
Turbidity (NTU)	28	0	24.5	4.6	10.6	0	0
EC (µS/cm)	28	104	236	159	193	0	-

There was one exceedance of the aquatic ecosystem and recreational guidelines for selenium, fourteen exceedances of the aquatic ecosystem guideline value for zinc and all but two samples exceeded the guideline trigger value for recreational use for iron at Bargo River Upstream SW-1. The recreational guideline value for iron relates to aesthetic considerations and taste and does not relate to health. There have also been exceedances of both the aquatic ecosystem guideline trigger and the recreational guideline for aluminium. There were seven exceedances of the aquatic ecosystem guideline trigger for cadmium and pH fell outside the aquatic ecosystem guideline range thirteen times. All other parameters except selenium and zinc were below guideline trigger values.

Table 20 Water Quality Summary – Hornes Creek at SW-9

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	39	0	116	21	29	-	0
Sulphate (mg/L)	39	2	29	10	12	-	0
Chloride (mg/L)	39	16	250	72	116	-	0
Calcium (mg/L)	39	3	9	5	7.4	-	-
Magnesium (mg/L)	39	2	17	6	9.4	-	-
Sodium (mg/L)	39	13	96	42	61.8	-	0
Potassium (mg/L)	39	0	5	3	4	-	-
Aluminium (mg/L)	39	0	1.94	0.12	0.556	30	17
Arsenic (mg/L)	39	0	0.01	0.001	0.001	0	0
Barium (mg/L)	39	0.017	0.34	0.039	0.1116	-	0
Cadmium (mg/L)	39	0	0.245	0.0001	0.0001	5	4
Chromium (mg/L)	39	0	0.002	0.001	0.001	-	0
Copper (mg/L)	36	0	0.032	0.001	0.002	8	0
Lead (mg/L)	39	0	0.003	0.001	0.001	0	0
Selenium (mg/L)	39	0	0.023	0.002	0.01	4	4
Zinc (mg/L)	39	0.007	0.109	0.033	0.04	37	0
Iron (mg/L)	39	0	19.2	0.05	6.03	-	16
Mercury (mg/L)	31	0	0.0001	0.0001	0.0001	0	0
pH	39	4.7	9.2	6.7	6.2, 7.3	16	-
Turbidity (NTU)	39	0	113	11.1	35.8	5	1
EC (µS/cm)	39	31	938	296	431	0	-

All but two of the samples collected from Hornes Creek at SW-9 exceeded the guideline trigger value for protection of aquatic ecosystems for zinc. There were five exceedances of the guideline trigger value for protection of aquatic ecosystems for cadmium and eight for copper. There were sixteen exceedances of the iron guideline trigger value for recreational use. There were sixteen exceedances of the aquatic ecosystem guideline trigger range for pH and five exceedances of the turbidity guideline trigger value. There have also been exceedances of both the aquatic ecosystem and recreational use guideline triggers for aluminium and selenium. The median concentration of aluminium and zinc exceeded the guideline trigger values for protection of aquatic ecosystems.

Table 21 Water Quality Summary – SW-13 Bargo River at Upstream Bargo

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	37	0	10	6	8	-	0
Sulphate (mg/L)	37	2	14	5	6	-	0
Chloride (mg/L)	37	21	74	50	64	-	0
Calcium (mg/L)	37	0	4	3	3	-	-
Magnesium (mg/L)	37	0	8	4	6	-	-
Sodium (mg/L)	37	12	38	26	31	-	0
Potassium (mg/L)	37	0	5	2	3	-	-
Aluminium (mg/L)	37	0	3	0.12	0.588	23	14
Arsenic (mg/L)	37	0	6	0.001	0.001	1	1
Barium (mg/L)	37	0.01	32	0.021	0.029	-	1
Cadmium (mg/L)	37	0	0.026	0.0001	0.0001	6	6
Chromium (mg/L)	37	0	0.003	0.001	0.001	-	0
Copper (mg/L)	34	0	0.003	0.001	0.001	5	0
Lead (mg/L)	37	0	0.02	0.001	0.001	1	0
Selenium (mg/L)	37	0	0.01	0.002	0.01	0	0
Zinc (mg/L)	37	0	0.048	0.015	0.0228	35	0
Iron (mg/L)	37	0	13.4	0.05	1.25	-	15
Mercury (mg/L)	29	0	0.002	0.0001	0.0001	0	1
pH	37	3.73	26.6	7	6.6, 7.5	11	-
Turbidity (NTU)	36	0	46.2	8.4	14.6	0	0
EC (µS/cm)	37	19	320	187	243	0	-

The water quality results for the Bargo River at Upstream (SW-13) are generally similar to those obtained for the Bargo River at SW-1. All but two of the samples collected at the Bargo River Upstream exceeded the zinc guideline trigger for protection of aquatic ecosystems. There were fifteen exceedances of the iron guideline trigger for recreational use and one for barium. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium, arsenic and cadmium. The median concentrations of aluminium and zinc exceeded the guideline trigger values for protection of aquatic ecosystems.

Table 22 Water Quality Summary – SW-14 Bargo River Downstream Rockford Road Bridge

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	36	21	822	500	596	-	18
Sulphate (mg/L)	36	0	23	10	13	-	0
Chloride (mg/L)	36	21	90	67	77	-	0
Calcium (mg/L)	36	0	16	10	13	-	-
Magnesium (mg/L)	36	0	14	8.5	12	-	-
Sodium (mg/L)	36	19	407	283	348	-	17
Potassium (mg/L)	36	2	27	17	21	-	-
Aluminium (mg/L)	36	0.03	1.3	0.145	0.29	32	13
Arsenic (mg/L)	36	0	0.086	0.039	0.059	20	13
Barium (mg/L)	36	0.07	4.56	1.22	2.48	-	23
Cadmium (mg/L)	36	0	2.66	0.0001	0.0001	6	6
Chromium (mg/L)	36	0	0.002	0.001	0.001	-	0
Copper (mg/L)	33	0	0.012	0.001	0.0038	14	0
Lead (mg/L)	36	0	0.007	0.001	0.002	4	0
Selenium (mg/L)	36	0	0.097	0.016	0.046	21	21
Zinc (mg/L)	36	0.008	0.754	0.0665	0.399	35	0
Iron (mg/L)	36	0	7.74	0.06	0.4	-	8
Mercury (mg/L)	28	0	0.0001	0.0001	0.0001	0	0
pH	36	3.69	9.7	8.6	8.2, 8.9	31	-
Turbidity (NTU)	35	0	39.5	8.4	16.1	0	0
EC (µS/cm)	36	1.47	1660	867	1371	0	-

The concentrations of bicarbonate and sodium at the Bargo River at Rockford Bridge – SW-14, were noticeably higher than at the upstream sites on the Bargo River (i.e. at SW-1 and SW-13). It is presumed that this reflects the effects of licensed releases from LDP1 at the Tahmoor pit top via Tea Tree Hollow. All but one of the samples collected exceeded the guideline trigger for protection of aquatic ecosystems for zinc. There were twelve exceedances of the guideline trigger for protection of aquatic ecosystems for arsenic, six for copper and four for lead. There were eighteen exceedances of the guideline trigger for recreational use for bicarbonate, seventeen for sodium, and twenty three for barium. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium, arsenic and selenium. The median concentrations of aluminium, arsenic, selenium, zinc and pH have exceeded the guideline trigger values for protection of aquatic ecosystems.

Table 23 Water Quality Summary – SW-15 Dog Trap Creek (Downstream)

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	25	0	65	24	30	-	0
Sulphate (mg/L)	25	2	30	14	18	-	0
Chloride (mg/L)	25	25	210	46	56	-	0
Calcium (mg/L)	25	4	16	6	7	-	-
Magnesium (mg/L)	25	2	17	5	6.2	-	-
Sodium (mg/L)	25	12	91	28	31	-	0
Potassium (mg/L)	25	0	12	7	7	-	-
Aluminium (mg/L)	25	0.06	1.86	0.45	0.776	25	23
Arsenic (mg/L)	25	0	0.01	0.001	0.001	0	0
Barium (mg/L)	25	0.016	0.244	0.02	0.0334	-	0
Cadmium (mg/L)	25	0	0.019	0.0001	0.0001	1	1
Chromium (mg/L)	25	0	0.002	0.001	0.001	-	0
Copper (mg/L)	22	0	0.004	0.001	0.002	6	0
Lead (mg/L)	25	0	0.002	0.001	0.001	0	0
Selenium (mg/L)	25	0	0.01	0.001	0.01	0	0
Zinc (mg/L)	25	0.007	0.187	0.068	0.0838	22	0
Iron (mg/L)	25	0	32.4	0.05	0.494	-	7
Mercury (mg/L)	20	0	0.0001	0.0001	0.0001	0	0
pH	23	6.4	8.5	7.1	6.9, 7.5	2	-
Turbidity (NTU)	20	5.1	106	10.5	18.6	1	1
EC (µS/cm)	20	132	322	236	249	0	-

At the Dog Trap Creek Downstream (SW-15) there have been twenty two exceedances of the aquatic ecosystem guideline trigger for zinc and six for copper. There have been seven exceedances of the iron guideline trigger value for recreational use. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium. The median concentrations of aluminium and zinc have exceeded the guideline trigger values for both protection of aquatic ecosystems and recreational use. All other parameters were within guideline trigger values.

Table 24 Water Quality Summary – SW-16 Dog Trap Creek (Upstream)

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	34	0	88	32	37	-	0
Sulphate (mg/L)	34	0	27	15	21	-	0
Chloride (mg/L)	34	26	210	52	67	-	0
Calcium (mg/L)	34	4	23	7	10	-	-
Magnesium (mg/L)	34	3	17	6	8.4	-	-
Sodium (mg/L)	34	13	91	33	37	-	0
Potassium (mg/L)	34	0	12	8	9	-	-
Aluminium (mg/L)	34	0.06	1.07	0.385	0.624	34	32
Arsenic (mg/L)	34	0	0.003	0.001	0.001	0	0
Barium (mg/L)	34	0.02	0.244	0.025	0.0336	-	0
Cadmium (mg/L)	34	0	0.03	0.0001	0.0001	3	3
Chromium (mg/L)	34	0	0.005	0.001	0.001	-	0
Copper (mg/L)	31	0	0.005	0.001	0.002	9	0
Lead (mg/L)	34	0	0.002	0.001	0.001	0	0
Selenium (mg/L)	34	0	0.01	0.001	0.0054	0	0
Zinc (mg/L)	34	0.007	0.221	0.0875	0.1082	31	0
Iron (mg/L)	34	0	32.4	0.05	0.508	-	9
Mercury (mg/L)	26	0	0.0001	0.0001	0.0001	0	0
pH	34	6.3	9.6	7.1	6.9, 7.5	5	-
Turbidity (NTU)	33	2.6	65	10.6	23.2	2	0
EC (µS/cm)	34	31	1,077.2	285	329	0	-

Water quality at the Dog Trap Creek upstream site (SW-16) was generally similar to the downstream site – refer Table 23. There have been thirty one exceedances of the aquatic ecosystem trigger value for zinc and seven for copper. There have been nine exceedances of the iron guideline trigger value for recreational use. There have also been exceedances of both the aquatic ecosystem and recreational use trigger guideline values for aluminium. The median concentrations of aluminium and zinc have both exceeded the guideline trigger values for protection of aquatic ecosystems. All other parameters were below guideline trigger values.

Table 25 Water Quality Summary – SW-18 Eliza Creek

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	34	11	47	26	38	-	0
Sulphate (mg/L)	34	12	80	24	28	-	0
Chloride (mg/L)	34	21	457	325	387	-	4
Calcium (mg/L)	34	4	39	14	17	-	-
Magnesium (mg/L)	34	3	46	35	41	-	-
Sodium (mg/L)	34	13	205	149	178	-	0
Potassium (mg/L)	34	5	10	6	7	-	-
Aluminium (mg/L)	34	0	3.29	0.02	0.758	13	12
Arsenic (mg/L)	34	0	0.002	0.001	0.001	0	0
Barium (mg/L)	34	0.026	0.175	0.113	0.1494	-	0
Cadmium (mg/L)	34	0	0.179	0.0001	0.03006	7	7
Chromium (mg/L)	34	0	0.003	0.001	0.001	-	0
Copper (mg/L)	34	0	0.031	0.0015	0.0182	17	0
Lead (mg/L)	34	0	0.034	0.001	0.001	4	0
Selenium (mg/L)	34	0	0.022	0.01	0.018	10	10
Zinc (mg/L)	34	0.01	0.33	0.0245	0.0656	34	0
Iron (mg/L)	34	0	10.7	3.64	8.754	-	29
Mercury (mg/L)	31	0	0.0001	0.0001	0.0001	0	0
pH	35	5.8	9.2	6.7	6.3, 7.5	14	-
Turbidity (NTU)	35	12.5	284	33.5	57	14	2
EC (µS/cm)	35	1.228	1360	965	1300	0	-

At the Eliza Creek monitoring site (SW-18), there have been thirty four exceedances of the aquatic ecosystem guideline trigger value for zinc, four for lead and seventeen for copper. There have been exceedances of the recreational guideline value for chloride and iron. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium. The median concentrations of copper and zinc have exceeded the guideline trigger values for protection of aquatic ecosystems. All other parameters' median values were below the guideline trigger values. Compared to the other monitoring sites, the concentrations of sodium and chloride in Eliza Creek have been elevated.

Table 26 Water Quality Summary – SW-20A Dry Creek

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	27	9	42	12	15	-	0
Sulphate (mg/L)	27	0	11	3	5	-	0
Chloride (mg/L)	27	35	134	66	84	-	0
Calcium (mg/L)	27	2	6	3	3	-	-
Magnesium (mg/L)	27	4	15	8	9	-	-
Sodium (mg/L)	27	15	54	37	39	-	0
Potassium (mg/L)	27	6	10	7	8	-	-
Aluminium (mg/L)	27	0.14	4.06	0.27	0.698	27	18
Arsenic (mg/L)	27	0	0.004	0.001	0.001	0	0
Barium (mg/L)	27	0.015	0.083	0.023	0.0332	-	0
Cadmium (mg/L)	27	0	0.022	0.0001	0.0001	2	2
Chromium (mg/L)	27	0	0.003	0.001	0.001	-	0
Copper (mg/L)	27	0	0.005	0.001	0.0028	9	0
Lead (mg/L)	27	0	0.01	0.001	0.001	2	0
Selenium (mg/L)	27	0	0.004	0.001	0.001	0	0
Zinc (mg/L)	27	0.01	0.18	0.056	0.0648	27	0
Iron (mg/L)	27	0	6.16	0.05	0.05	-	4
Mercury (mg/L)	24	0	0.0001	0.0001	0.0001	0	0
pH	28	3.7	9.4	6.9	6.5, 7.8	9	-
Turbidity (NTU)	28	6	262	15.5	26.8	4	1
EC (µS/cm)	28	154.5	442	269	304	0	-

At the Dry Creek monitoring site (SW-20A), there have been twenty seven exceedances of the aquatic ecosystem guideline trigger value for zinc, two for lead and nine for copper. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium. The median concentrations of aluminium and zinc both exceeded the guideline trigger values for protection of aquatic ecosystems. All other parameters were below guideline trigger values.

Table 27 Water Quality Summary – SW-21 Nepean River at Maldon Weir

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	30	9	161	49	94	-	0
Sulphate (mg/L)	30	3	6	4	5	-	0
Chloride (mg/L)	30	17	66	25	32	-	0
Calcium (mg/L)	30	0	4	2.5	3.2	-	-
Magnesium (mg/L)	30	0	8	3	4	-	-
Sodium (mg/L)	30	12	83	31	49	-	0
Potassium (mg/L)	30	0	6	2	4	-	-
Aluminium (mg/L)	30	0.02	8.25	0.145	0.288	23	11
Arsenic (mg/L)	30	0	0.03	0.002	0.0032	1	0
Barium (mg/L)	30	0.021	0.52	0.0995	0.248	-	0
Cadmium (mg/L)	30	0	0.303	0.0001	0.00014	6	5
Chromium (mg/L)	30	0	0.008	0.001	0.001	-	0
Copper (mg/L)	27	0	0.003	0.001	0.002	8	0
Lead (mg/L)	30	0	0.017	0.001	0.001	4	0
Selenium (mg/L)	30	0	0.021	0.003	0.008	1	1
Zinc (mg/L)	30	0.01	0.75	0.0385	0.076	30	0
Iron (mg/L)	30	0	0.63	0.05	0.184	-	4
Mercury (mg/L)	24	0	0.0001	0.0001	0.0001	0	0
pH	32	6.6	9.3	7.7	7.1, 8.2	10	-
Turbidity (NTU)	31	1.5	65.6	10.3	18.7	1	0
EC (µS/cm)	32	23	448	161	257	0	-

At the Maldon Weir on the Nepean River (SW-21) there have been thirty exceedances of the aquatic ecosystem guideline trigger value for zinc, one for selenium, four for lead, six for cadmium, one for arsenic and eight for copper. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium. The median concentrations of aluminium and zinc both exceeded the guideline trigger values for the protection of aquatic ecosystems. All other parameters were within the guideline trigger values except for pH and turbidity.

Table 28 Water Quality Summary – SW-22 Tea Tree Hollow

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	26	591	1160	841	955	-	26
Sulphate (mg/L)	26	9	40	16	25	-	0
Chloride (mg/L)	26	53	97	76	84	-	0
Calcium (mg/L)	26	5	28	18	21	-	-
Magnesium (mg/L)	26	9	21	15	17	-	-
Sodium (mg/L)	26	293	651	474	533	-	25
Potassium (mg/L)	26	24	40	28	31	-	-
Aluminium (mg/L)	26	0.03	0.7	0.14	0.25	23	6
Arsenic (mg/L)	26	0.039	0.154	0.0805	0.106	26	23
Barium (mg/L)	26	0.608	6.47	3.52	4.59	-	19
Cadmium (mg/L)	26	0	4.7	0.0001	2.68	7	7
Chromium (mg/L)	26	0	0.003	0.001	0.001	-	0
Copper (mg/L)	26	0	0.023	0.003	0.007	20	0
Lead (mg/L)	26	0	0.015	0.002	0.006	8	0
Selenium (mg/L)	26	0.039	0.111	0.070	0.083	26	26
Zinc (mg/L)	26	0.01	1.12	0.776	0.868	26	0
Iron (mg/L)	26	0	0.45	0.075	0.1	-	1
Mercury (mg/L)	21	0	0.0001	0.0001	0.0001	0	0
pH	28	8.2	10.8	8.7	8.6, 9.1	28	-
Turbidity (NTU)	28	2	118	21.3	41.6	4	2
EC (µS/cm)	28	159	2460	1875	2097	5	-

At the Tea Tree Hollow monitoring site (SW-22), which is downstream of the Tahmoor Mine licenced discharge point LDP 1, there have been twenty six exceedances of the aquatic ecosystem guideline trigger value for zinc, twenty six for selenium, eight for lead, twenty six for arsenic and twenty for copper. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium, arsenic and selenium. The median concentrations of aluminium, arsenic, copper, selenium, pH and zinc exceeded the guideline trigger values or ranges for protection of aquatic ecosystems. Compared to the other monitoring sites the concentrations of sodium and bicarbonate have been elevated.

Table 29 Water Quality Summary – SW-23 Carters Creek

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	29	5	138	38	62	-	0
Sulphate (mg/L)	29	0	57	19	27	-	0
Chloride (mg/L)	29	10	132	70	100	-	0
Calcium (mg/L)	29	0	18	10	14.8	-	-
Magnesium (mg/L)	29	0	21	11	15.4	-	-
Sodium (mg/L)	29	11	63	40	57	-	0
Potassium (mg/L)	29	0	28	16	21.4	-	-
Aluminium (mg/L)	29	0.07	1.15	0.32	0.706	29	19
Arsenic (mg/L)	29	0	0.011	0.001	0.001	0	0
Barium (mg/L)	29	0.005	0.099	0.044	0.0672	-	0
Cadmium (mg/L)	29	0	0.032	0.0001	0.0001	1	1
Chromium (mg/L)	29	0	0.002	0.001	0.001	-	0
Copper (mg/L)	29	0	0.003	0.001	0.002	9	0
Lead (mg/L)	29	0	0.002	0.001	0.001	0	0
Selenium (mg/L)	29	0	0.0025	0.001	0.002	0	0
Zinc (mg/L)	29	0.01	0.188	0.104	0.142	29	0
Iron (mg/L)	29	0	3.65	0.05	0.05	-	3
Mercury (mg/L)	25	0	0.0001	0.0001	0.0001	0	0
pH	31	3.7	10	7.3	6.9, 7.9	5	-
Turbidity (NTU)	31	6.4	123	16.5	30.3	3	1
EC (µS/cm)	31	155	637	413	529	0	-

At the Carters Creek monitoring site (SW-23) there have been twenty nine exceedances of the aquatic ecosystem trigger for zinc and nine for copper. There have also been exceedances of both the aquatic ecosystem and recreational use triggers for aluminium, pH, turbidity and cadmium. The median concentrations of aluminium and zinc exceeded the trigger values for protection of aquatic ecosystems. All other parameters were below guideline trigger values.

Table 30 Water Quality Summary – SW-24 Cow Creek

Parameter	No. of Samples	Minimum	Maximum	Median	Site Specific Trigger Values (20%ile, 80%ile)	Number Exceeding	
						ANZECC Aquatic Ecosystems Guideline Value	ANZECC Recreational Use Guideline Value
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	25	4	51	6	7.2	-	0
Sulphate (mg/L)	25	0	12	5	8	-	0
Chloride (mg/L)	25	16	85	26	29	-	0
Calcium (mg/L)	25	0	11	1	1	-	-
Magnesium (mg/L)	25	0	11	2	2	-	-
Sodium (mg/L)	25	12	45	16	17.2	-	0
Potassium (mg/L)	25	0	12	2	3.2	-	-
Aluminium (mg/L)	25	0.18	2.07	0.555	0.82	20	19
Arsenic (mg/L)	25	0	0.001	0.001	0.001	0	0
Barium (mg/L)	25	0.003	0.04	0.006	0.0128	-	0
Cadmium (mg/L)	25	0	0.01	0.0001	0.0001	2	2
Chromium (mg/L)	25	0	0.002	0.001	0.001	-	0
Copper (mg/L)	25	0	0.003	0.001	0.001	3	0
Lead (mg/L)	25	0	0.002	0.001	0.001	0	0
Selenium (mg/L)	25	0	0.005	0.001	0.001	0	0
Zinc (mg/L)	25	0.01	0.099	0.013	0.0142	20	0
Iron (mg/L)	25	0	2.02	0.05	0.05	-	3
Mercury (mg/L)	25	0	0.0001	0.0001	0.0001	0	0
pH	27	6.1	8.9	6.8	6.3, 8	10	-
Turbidity (NTU)	27	5.6	40.6	12.7	20.2	0	0
EC (µS/cm)	27	70	204	109	112	0	-

At the Cow Creek monitoring site (SW-24) there have been twenty exceedances of the aquatic ecosystem guideline trigger value for zinc and three for copper. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium, cadmium and pH. The median concentrations of aluminium and zinc have exceeded the guideline trigger values for protection of aquatic ecosystems. All other parameters were below guideline trigger values.

The time history of key water quality indicators recorded in samples collected at the Tea Tree Hollow, Dog Trap Creek (downstream) and Eliza Creek monitoring sites are provided as a series of plots below – refer Figure 29 to Figure 36. These illustrate the variability of water quality in watercourses that span the majority of the Project Area. The following specific observations have been made in relation to these plots:

1. Electrical conductivity (an indication of salinity) has been significantly higher and more variable at the Eliza Creek monitoring site than at other sites.
2. pH values have been within or close to the ANZECC guideline range (6.5 to 8.5) - at all three monitoring sites. Relatively higher values have been recorded at Tea Tree Hollow and relatively lower values have been recorded at the Eliza Creek monitoring site.
3. Turbidity has been consistently relatively low at the Dog Trap Creek monitoring site. Relatively elevated levels have been recorded at the Eliza Creek monitoring site.
4. Sulphate has been consistently low at Tea Tree Hollow and higher and more variable at the Dog Trap and Eliza Creek monitoring sites.
5. Aluminium concentrations have been highly variable at all three monitoring sites.
6. Arsenic concentrations have been low at the Dog Trap and Eliza Creek monitoring sites but occasionally elevated and highly variable at the Tea Tree Hollow monitoring site.
7. Iron concentrations have been low at the Tea Tree Hollow and Eliza Creek monitoring sites and occasionally elevated at the Dog Trap Creek monitoring site.
8. Manganese concentrations have been highly variable but uncorrelated between monitoring sites. More persistent elevated concentrations have been recorded at the Eliza Creek monitoring site.

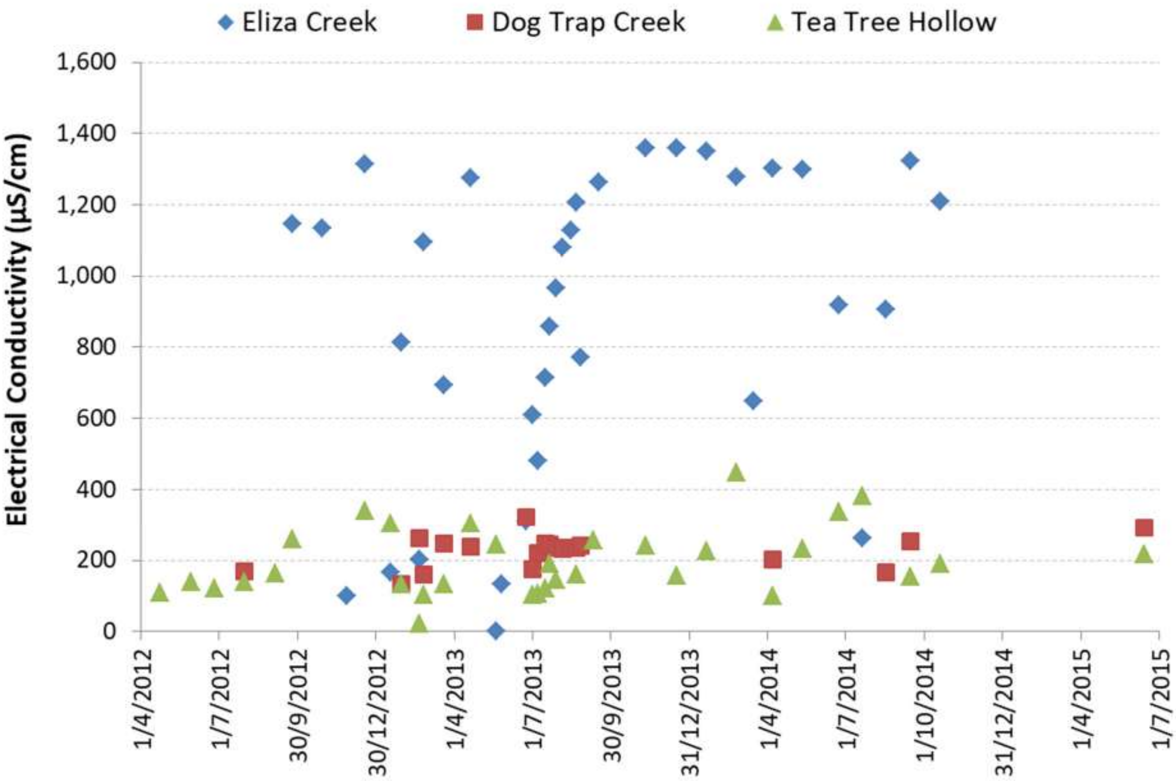

Figure 29 Monitoring Results for Electrical Conductivity

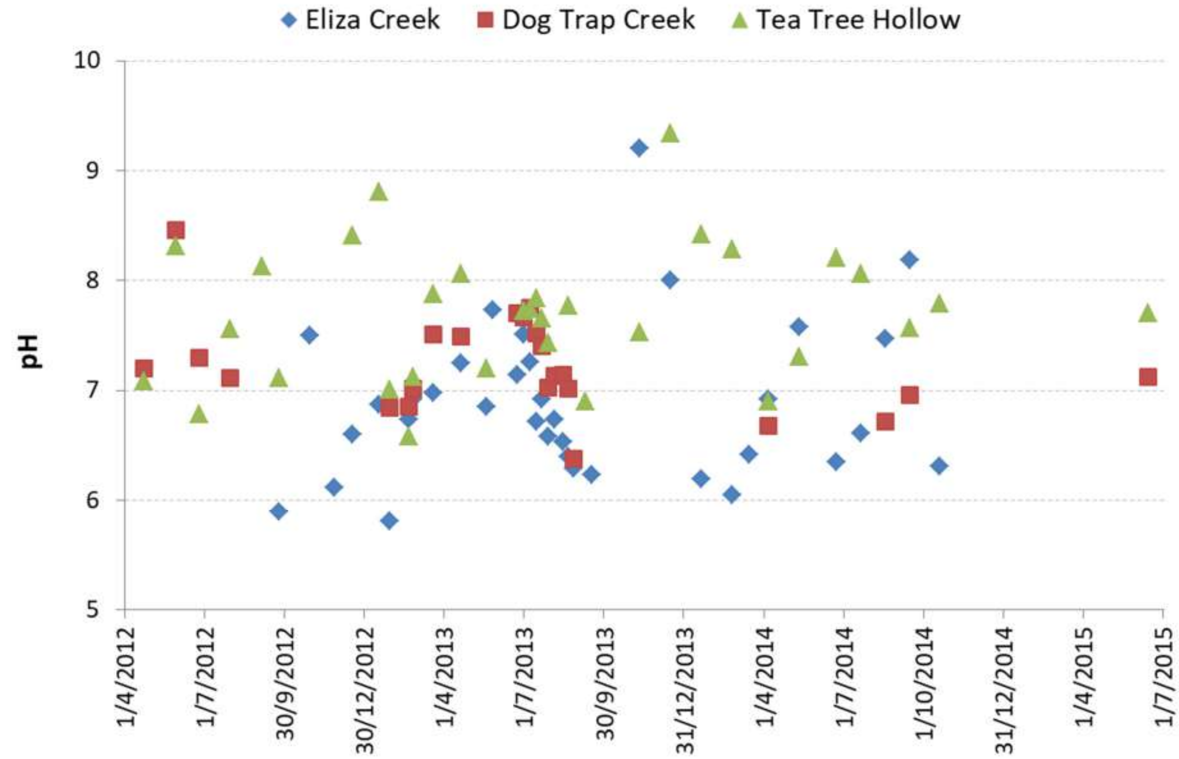

Figure 30 Monitoring Results for pH

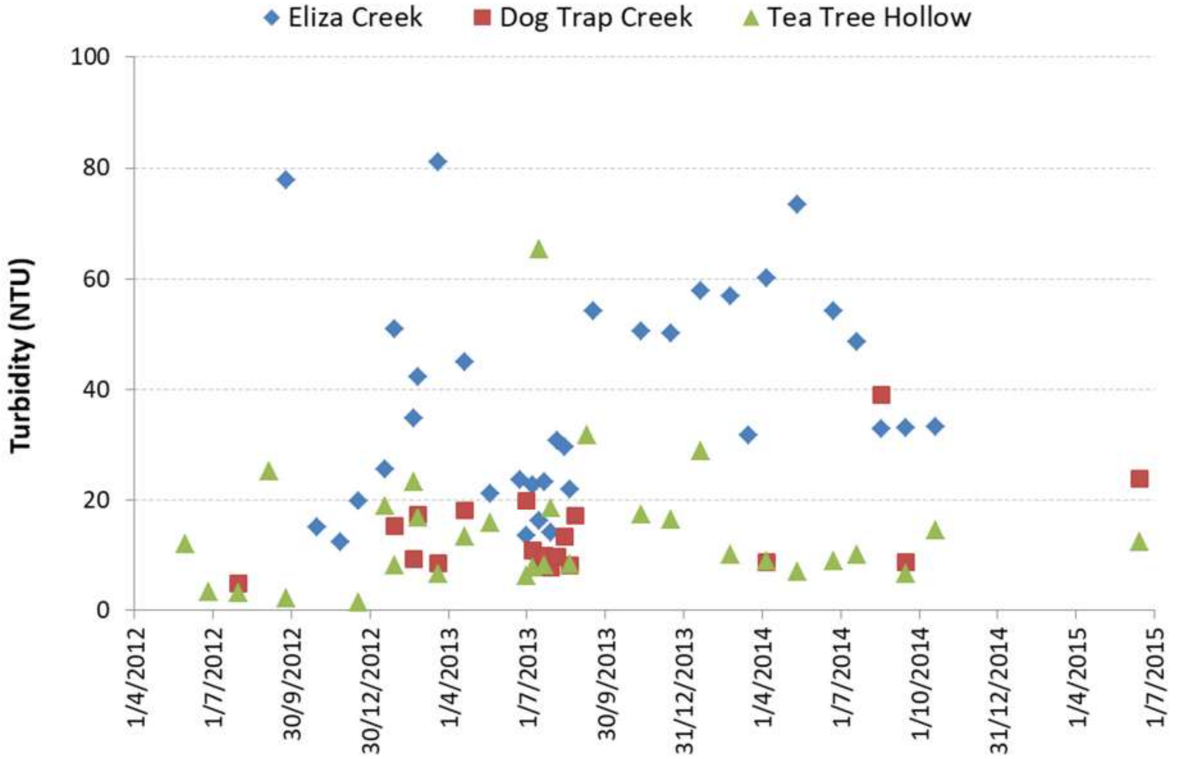

Figure 31 Monitoring Results for Turbidity

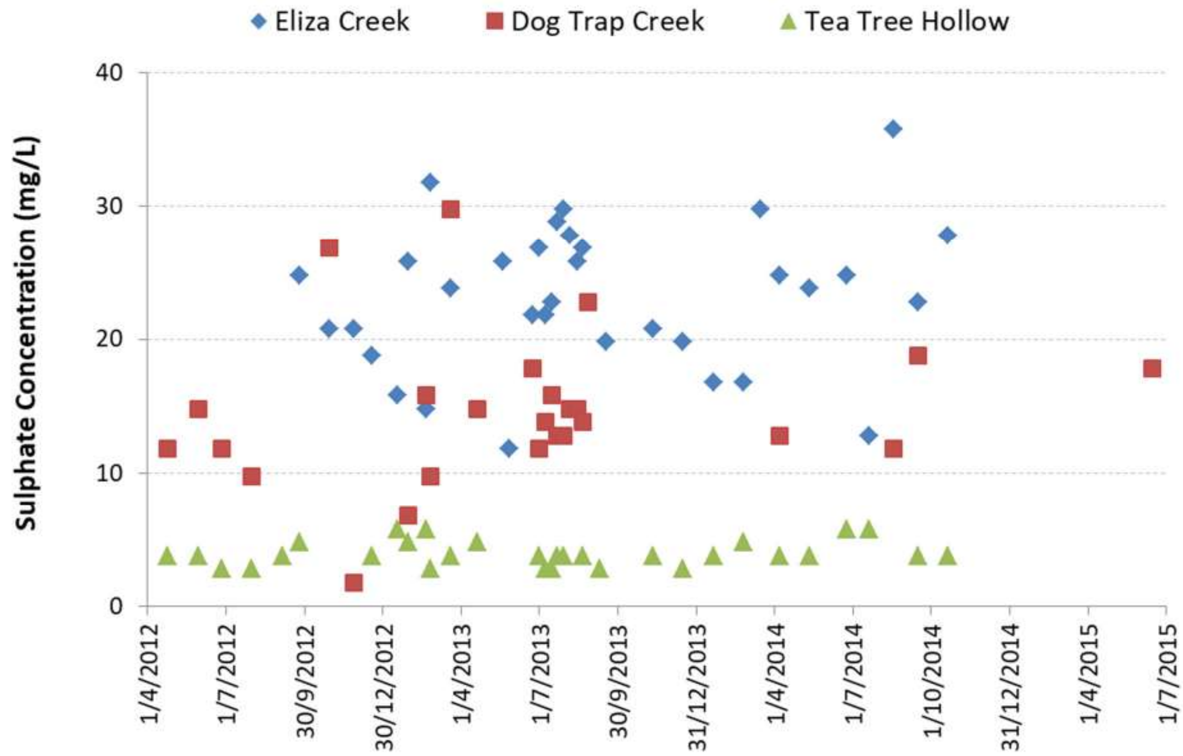

Figure 32 Monitoring Results for Sulphate

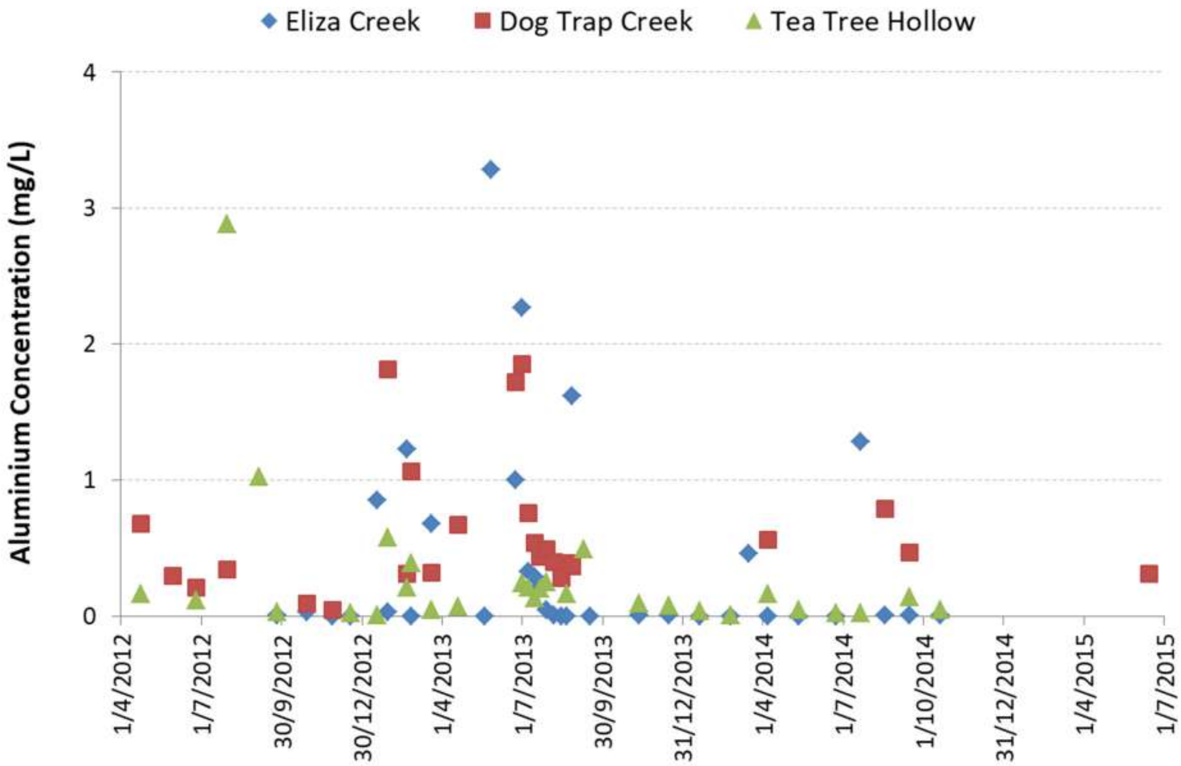

Figure 33 Monitoring Results for Aluminium

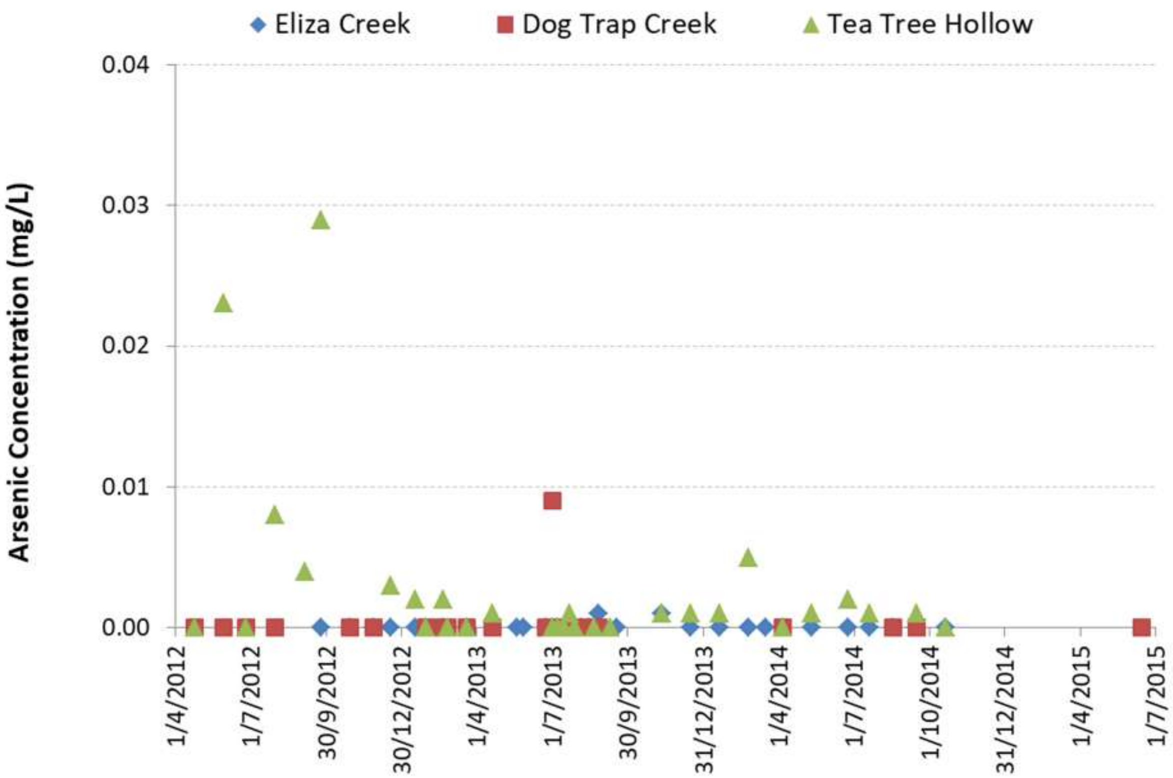

Figure 34 Monitoring Results for Arsenic

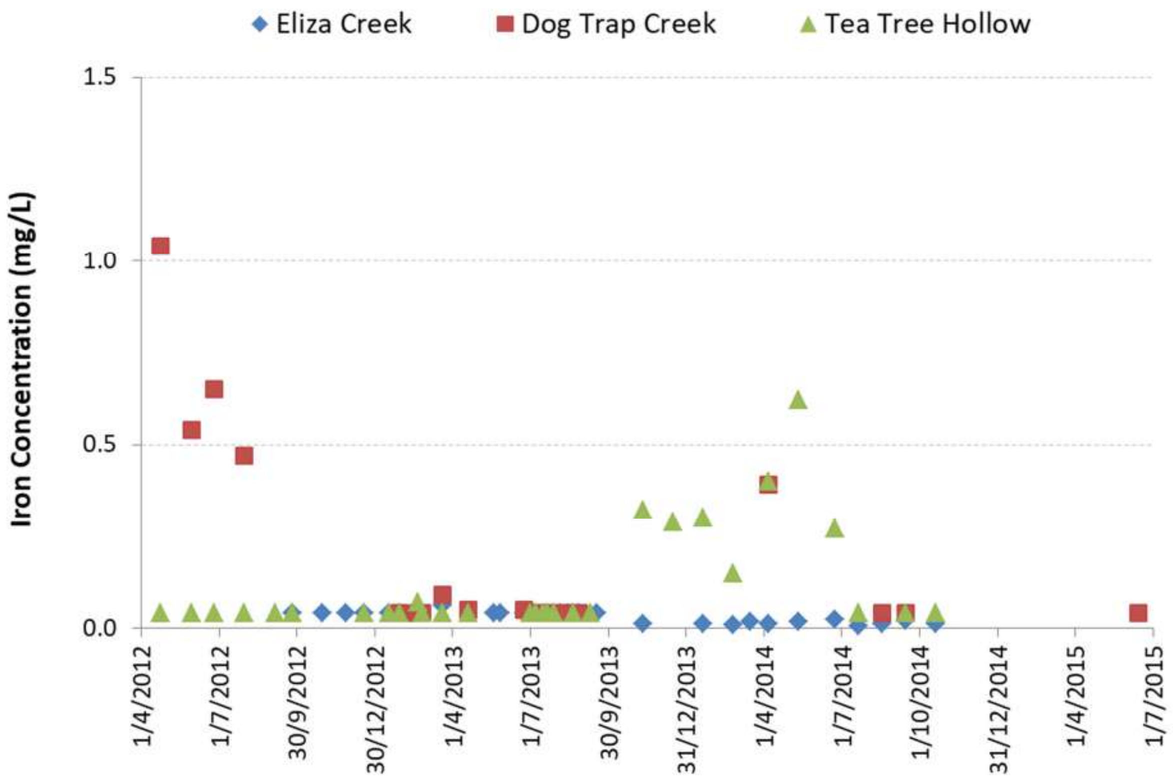

Figure 35 Monitoring Results for Iron

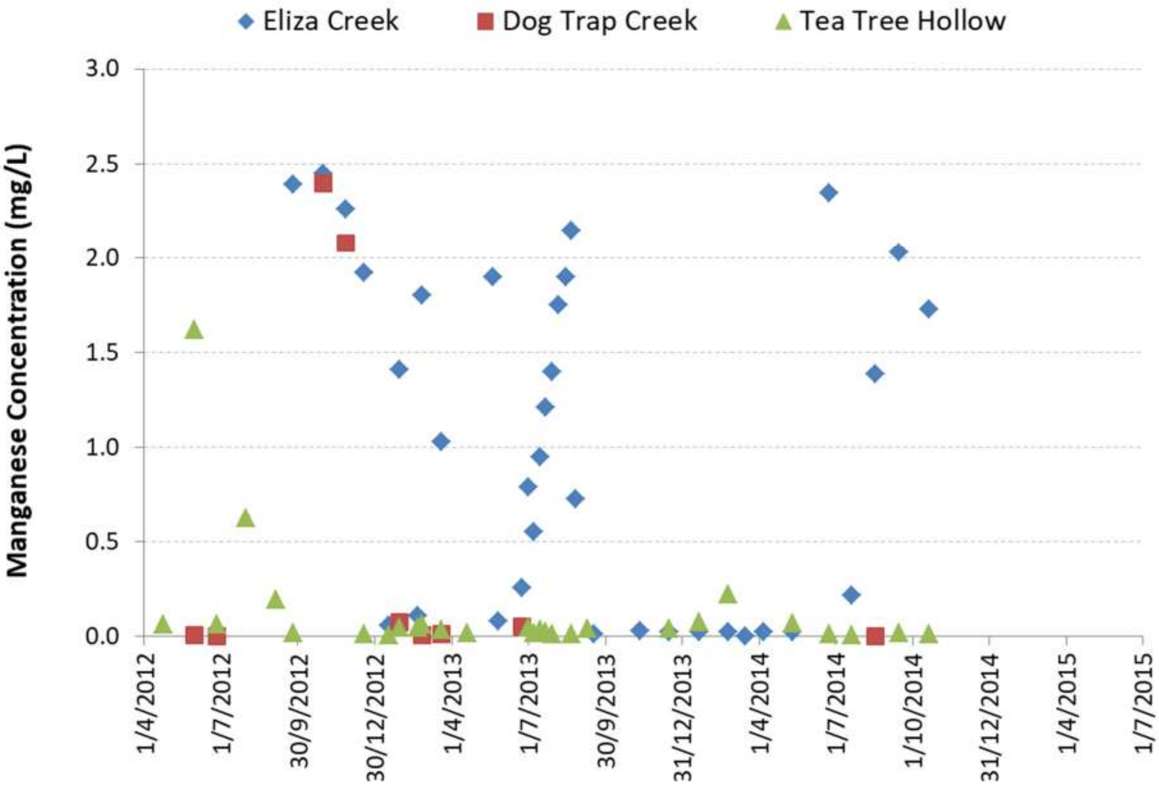

Figure 36 Monitoring Results for Manganese

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REPORT

Tahmoor South EIS
Flood Study

Prepared for: Tahmoor Coal Pty Ltd

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Revision	Description	Author	Reviewer	Approved	Date
1	Draft	TSM / CAW	TSM	TSM	2 Nov 2018
2	Final	TSM / CAW	Tahmoor Coal, AECOM	TSM	16 Nov 2018

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1.0 INTRODUCTION

Hydro Engineering & Consulting Pty Ltd (HEC) has been commissioned by Tahmoor Coal Pty Limited (Tahmoor Coal) to complete a surface water assessment for the Tahmoor South Project (the Project). The purpose of this assessment is to complete the surface water assessment component of the Environmental Impact Statement (EIS) for the Project under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Surface Water Assessment has been undertaken in four parts.

- Baseline Assessment (BA) Report which documents the available baseline and background information and analysis of the climate, hydrology and water quality characteristics of local and regional water resources of relevance to the Tahmoor South Project.
- Water Management System and Site Water Balance Report (WMS/SWB) which describes the existing water management system, the proposed changes to site water management and the results of a water balance model simulation of the proposed water management system over the Project life including water supply reliability, the adequacy of the current discharge licence to Tea Tree Hollow to manage disposal of water during periods/circumstances when excesses are predicted and the risk of overflows under a wide range of climatic conditions which could occur during the Project life.
- Flood Study (FS) comprising an assessment of the effects of the Tahmoor South Project on flooding in overlying watercourses and their floodplains.
- Surface Water Impact Assessment (SWIA) Report which contains a detailed qualitative and quantitative assessment of the potential impacts which are either predicted to occur or could occur from the Project - including the effect of predicted subsidence on natural stream features, potential effects to catchment yield, flow diversion and stream water quality

This report details the Flood Study Assessment for the Tahmoor South Project Area.

1.1 BACKGROUND AND OVERVIEW

Tahmoor Coal owns and operates the Tahmoor Mine, an underground coal mine approximately 80 kilometres (km) south-west of Sydney, in the Southern Coalfields of NSW. Tahmoor Coal produces up to three million tonnes per annum of product coal from its existing operations at the Tahmoor Mine, and undertakes underground mining under existing development consents, licences and the conditions of relevant mining leases.

Tahmoor Coal is seeking approval for the Tahmoor South Project, being the extension of underground coal mining at Tahmoor Mine, to the south and east of the existing Tahmoor Mine surface facilities area. The proposed development would continue to be accessed via the existing surface facilities at Tahmoor Mine, located between the towns of Tahmoor and Bargo.

The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2035. The proposal would enable mining to be undertaken within the southern portion of Tahmoor Coal’s existing lease areas and for operations and employment of the current workforce to continue for a further 13 years.

The proposed development would extend mining at Tahmoor Mine within the Project Area, using longwall methods, with the continued use of ancillary infrastructure at the existing Tahmoor Mine surface facilities area. The Project Area is adjacent and to the south of the Existing Tahmoor Approved Mining Area. It also overlaps a small area of the Existing Tahmoor Approved Mining Area comprising the surface facilities area, historical workings and other existing mine infrastructure.

1.2 PROPOSED DEVELOPMENT

The proposed development will use longwall mining to extract coal from the Bulli seam within the bounds of CCL 716 and CCL 747. Coal extraction of up to 4 Mtpa ROM is proposed as part of the development. Once the coal has been extracted and brought to the surface, it will be processed at Tahmoor Mine's existing Coal Handling and Preparation Plant (CHPP) and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla for export to the international market.

The key components of the proposed development comprise:

- Mine development including underground redevelopment, ventilation shaft construction, pre-gas drainage and service connection;
- Longwall mining in the Project Area;
- Upgrades to the existing surface facilities area including:
    - upgrades to the CHPP;
    - expansion of the existing reject emplacement area (REA);
    - relocation of the rejects bin and extension of the rejects conveyor;
    - additional mobile plant for coal handling;
    - additions to the existing bathhouses, stores and associated access ways;
    - upgrades to onsite and offsite service infrastructure, including electrical supply;
- Rail transport of product coal to Port Kembla, and Newcastle (from time to time);
- Mine closure and rehabilitation; and
- Environmental management.

1.3 STUDY REQUIREMENTS

The Tahmoor South Project EIS has been prepared in accordance with Division 4.1, Part 4 of the EP&A Act which ensures that the potential environmental effects of a proposal are properly assessed and considered in the decision-making process.

The Surface Water Assessment is guided by the Secretary's Environmental Assessment Requirements (SEARs) for SSD 17_8445, including the amendment dated 14 February 2018 to incorporate the requirements of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Detailed agency comments have also been addressed in this and other component reports including comments from the NSW Environment Protection Authority (EPA), NSW Office of Environment & Heritage (OEH) and WaterNSW. The BA Report contains a summary of these requirements including where they have been addressed.

It is noted that since the preparation of the preliminary environmental assessment (PEA) for the Project (AECOM, 2012), the proposed mine plan for Tahmoor South has been amended to preclude mining and related subsidence within the Sydney Drinking Water Catchment, that is, within the catchment of Cow Creek, a tributary of the Nepean River upstream of Pheasant's Nest Weir. It is therefore concluded that there would be no surface water related impacts resulting from the Project on these catchments – refer also SWIA Report Section 14.

2.0 PROJECT DESCRIPTION

2.1 OVERVIEW

Tahmoor Coal is seeking approval for the continuation of mining at Tahmoor Mine, extending underground operations and associated infrastructure south within the Bargo area and to the east within the Pheasants Nest area (refer Figure 1). The proposed development seeks to extend the life of underground mining at Tahmoor Mine for an additional 13 years until approximately 2035.

The proposed development will use longwall mining to extract coal from the Bulli seam within the bounds of CCL716 and CCL747. Coal extraction of up to 4 million tonnes of run-of-mine (ROM) coal per annum is proposed as part of the development with extraction of up to 37 Mt of ROM coal over the life of the Project.

The proposed Project would utilise the existing surface infrastructure at the Tahmoor Mine surface facilities area, with some upgrades proposed to facilitate the extension. The proposed Project also incorporates the planning for rehabilitation and mine closure once mining ceases.

2.2 UNDERGROUND MINING OPERATIONS

2.2.1 Mining Area

Tahmoor Coal holds CCL 747 and CCL 716. The Project proposes to mine coal from the Bulli seam at a depth of between approximately 375 m and 430 m below ground level. The proposed mining area is bounded by known geological fault zones.

During the mine planning process, a constraints analysis, risk assessment and preliminary fieldwork were undertaken to identify sensitive natural surface features (such as waterways, cliffs, and Aboriginal heritage sites) and to develop Risk Management Zones (RMZs). Subsequent to the risk assessment the proposed longwall layout was modified to minimise significant subsidence impacts to these natural features.

The longwalls would be orientated in a south-east/north-west direction and would be located within the Bargo area. The longwall layout would continue to be refined during the detailed design phase of the proposed development. However, the maximum extent of longwall mining for the proposed development would be as depicted on Figure 1.

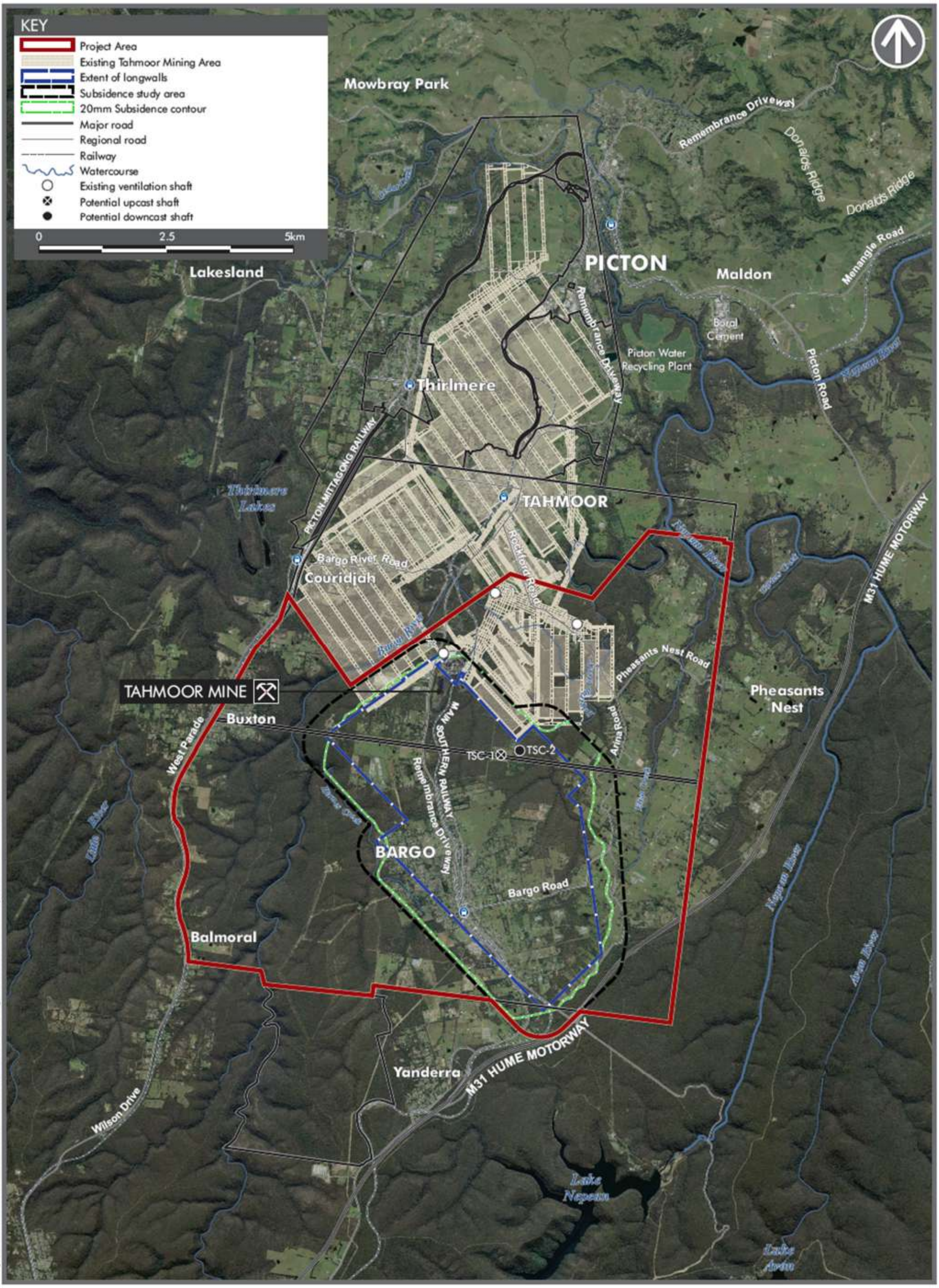

Figure 1 Locality Plan and Project Layout

As part of the proposed development, subsidence predictions have been undertaken for residential, commercial and business structures, public infrastructure such as pools and public amenities, utility services such as water and gas mains, and other associated infrastructure. These predictions and potential impacts would be captured within a subsidence management plan (SMP) prior to longwall mining for the proposed development and would incorporate the management measures identified herein.

2.2.2 Mine Development

To enable the continuation of mining to occur sequentially with the current mining operations in Tahmoor North, which are scheduled for completion in approximately 2022, the Project's development works need to commence in approximately 2019. Pre-development activities include:

- recovery of existing underground development roadways;
- redevelopment of the underground pit bottom;
- pre-gas drainage;
- longwall development including establishment of gate roads;
- installation of electrical, water and gas management networks; and
- the purchase and installation of equipment.

An additional 50 to 175 personnel would be required for the Project's development works, which may occur concurrently with the ongoing mining operations at Tahmoor North. Additional site amenities, including bath houses and additional onsite car parks would be required to accommodate the increased workforce during the transition period from mining operations at Tahmoor North and the Project's development works.

During this transition period, other site infrastructure required for longwall mining at the Project would be constructed. Specifically, this would include construction of new mine ventilation shafts, construction of a hardstand area for longwall machinery set up and upgrades to the CHPP.

2.2.3 Mine Ventilation

The proposed development would utilise the existing mine's ventilation system, including the existing three ventilation shafts, being one upcast (T2) and two downcast shafts (T1 and T3). Additionally, the proposed development would require the construction of two ventilation shafts to provide a reliable and adequate supply of ventilation air to personnel in the mine. The two additional vent shafts proposed for the Project are:

- TSC1: an upcast ventilation shaft that will be located on Tahmoor Coal's Charlies Point Road property; and
- TSC2: a downcast ventilation shaft that will be located on Crown Land adjacent to Tahmoor Coal's Charlies Point Road property.

The construction of the ventilation shafts would require the disturbance of an area of between four to six hectares in area at each location. Access to TSC1 and TSC2 would be from the existing road network.

The construction of each of the proposed ventilation shafts would involve the following:

- Construction of internal roads to allow access for construction and operational maintenance vehicles.
- Establishment of the construction site to allow sufficient space for stockpiling of shaft liners for TSC1 and TSC2, temporary spoil emplacement for TSC2, water management, storage

and safe movement on-site during construction activities. Establishment of the ventilation shaft site would involve:

- Installation of environmental controls such as silt fences, fencing with lockable gates, as well as display of signage relating to restricted entry.
- Clearing of vegetation and stripping of topsoil. Topsoil would be temporarily stockpiled for rehabilitation post construction.
- Excavation and construction of a temporary hardstand area for operation of drilling equipment. The hardstand area would be determined by the size and number of liner pieces to be manufactured and excavated to a depth of approximately 0.2 m. The temporary hardstand areas would include:
    - approximately 2,000m² of road base surrounding the site compound area and drill rig slab for site facilities;
    - approximately 2,000m² for laydown areas and a 4,500m² levelled hardstand area for storage of the ventilation shaft liners;
    - a stable access way between the liner storage area and the shaft to facilitate transport of the cured liner segments on purpose built trailers; and
    - a concrete pad 20 m by 15 m is to be constructed around the top of the shaft as a foundation for the drill rig and to provide a clean work area.
- Connection of 66 kV electrical power and establishment of electrical substations at ventilation shaft sites.
- Sinking of the shaft using blind boring methods (or similar method), and lining of the shafts using a composite concrete and steel liner (or similar method).
- Construction of fan buildings and installation of ventilation fans. The upcast shaft site fan building would also incorporate a fan outlet stack, approximately 30 m high, to control odour discharge from the mine.

Runoff from site TSC1 would report to storages within the existing pit top water management system. Site TSC2 would incorporate water treatment sedimentation controls, with the settled water from the ventilation shaft being pumped via overland pipeline to a final sedimentation pond on the surface facilities area for further treatment and discharge though LDP1. Alternatively water may be discharged via a new licensed discharge point, which would require a variation to EPL 1389.

2.2.4 Gas Drainage Operations

Coal mines need to control underground gas concentration levels to below safe limits so that miners are able to work in a safe environment and mining operations can be undertaken as efficiently as possible.

The coal seams within the Southern Coalfield are generally known to be gassy, with methane and carbon dioxide released from the goaf during mining. Gas in the underground workings would be managed by a series of gas drainage operations including:

- pre-gas drainage, whereby gas would be extracted from the coal seam prior to longwall mining;
- post-gas drainage, whereby gas would be extracted from the goaf; and
- gas extraction via the mine ventilation system, which would occur throughout mining.

Gas management would continue to use the existing infrastructure, including the Tahmoor Mine Gas Plant, Gas Plant Vent and Flare Plant, as well as the WCMG Power Plant when it is available. Some components of the existing gas management infrastructure may need to be upgraded throughout the life of the proposed development

2.2.5 Pre-Gas Drainage

The purpose of pre-gas drainage is to reduce gas volumes in the coal seams prior to mining, with the Bulli, Wongawilli and Balgownie seams targeted for pre-gas drainage at Tahmoor Mine. Pre-gas drainage of the gas levels in the seams is required to facilitate the timely commencement and progression of mining as well as to reduce the demands on the mine ventilation system for the purpose of gas dilution during operations.

Pre-gas drainage activities are mainly undertaken underground, via drilling and drainage from the roadways developed for longwall panels. Underground pre-gas drainage works at Tahmoor Mine would drain gas following development of the mine roadways and prior to longwall development. Gas would be drawn from the coal seam by vacuum and piped to the Gas Plant at the surface facilities area via the underground pipe network. Underground gas drainage of the coal seam would continue ahead of longwall development for the life of mining.

Surface pre-gas drainage works are proposed for the eastern portion of the Project Area. Extracted gas would be brought to the surface and transferred via a pipeline to the existing gas plant at the Tahmoor Mine. To enable gas to be released from the seam during pre-gas drainage, the coal seam would be dewatered via horizontal drilling within the seam. The drained water would be collected on the surface and transferred to the existing water management system at the surface facilities area via an overland pipeline or truck.

Two Surface to Inseam (SIS) drilling sites and gas well sites are proposed, subject to the final detailed design of the development mains. SIS drilling and gas well sites are subject to obtaining land access agreements and therefore flexibility is required for the location of these works. The gas collection pipeline is proposed to be constructed within a trench alongside the public roadway and potential exists for alternative locations.

Gas from the coal seam would be drained using pumps, collected at the surface and piped to the existing Gas Plant at the Tahmoor Mine surface facilities area to be used in the WCMG Power Plant or Gas Fare Plant.

2.2.6 Post Gas Drainage

Post-gas drainage would be required as strata relaxation caused by the retreating underground longwall face would liberate volumes of gas into the mine workings from the underlying Wongawilli seam and from overlying strata, released due to fracturing of the goaf. To capture this gas during the proposed development, cross-measure boreholes are proposed to be drilled from the mine workings into the Wongawilli seam. These boreholes would be designed to collect the gas at its source or to intercept gas before it migrates into the mine workings. At the conclusion of mining from each panel, the panel would be sealed and gas drawn from the sealed areas as part of the post-gas drainage operations. The gas collected from the in-seam and cross-measure boreholes would be drawn by vacuum via the underground pipe network to the Gas Plant located at the surface facilities area.

2.2.7 Gas in Ventilation

The ventilation system would deliver fresh air into the mine from the existing and proposed downcast vent shafts and would extract stale air from the mine via the existing and proposed upcast vent shafts

(refer Section 2.2.3). Similar to the existing operations, the ventilation system would carry the remaining diluted gases out of the mine via the upcast mine vent shafts.

2.2.8 Mining Method and Equipment

Underground mining would be undertaken via main roadway and longwall development using continuous miners. Longwall development refers to the mining of a series of roadways (gate roads) and cut-throughs, to form pillars of coal that would support the overlying strata during the extraction of coal. Longwalls would be up to 305 m wide. The gate roads would be approximately 5.2 m wide and approximately 3 m high.

Coal would be cut from the coal face by the longwall shearer, loaded onto the armoured face conveyor and transported to the surface facilities area via a series of underground conveyors. The longwall would retreat as coal is mined and the overlying rock strata would collapse into the void left by the coal extraction, forming the goaf.

A new hardstand area would be constructed adjacent to the existing southern coal stockpile at the surface facilities area to cater for the delivery and assemblage of mining equipment and the storage of equipment.

Tahmoor Coal would continue to investigate improved or alternate mining methods and technology throughout the life of the proposed development. Improved methods would be utilised where available to allow for the efficient and economically viable extraction of the coal resource. Tahmoor Coal would ensure that the resulting environmental and social impacts of improved or alternate methods are consistent with those predicted in this EIS

2.2.9 Mine Access

The proposed development would use the existing infrastructure at Tahmoor Mine for employee and material access to the mine. Access to the mine would be via the existing Tahmoor Mine surface facilities area, the existing drift, and men and materials travel lift installed within the T3 downcast shaft. The T3 vertical men and material travel lift has a capacity for 70 persons and approximately 12 tonnes of materials.

2.2.10 Coal Production

Tahmoor Coal is a shareholder of Port Kembla Coal Terminal and has contractual arrangements in place for coal export associated with the proposed output from the Project.

The proposed development would transport product coal from Tahmoor Mine to Port Kembla, via the existing mine rail load out, rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway.

Tahmoor Mine currently has four allocated train paths per day from ARTC for the rail network between the Tahmoor Mine and Port Kembla. This current allocation is equivalent to the transport of approximately four million tonnes of product coal per annum and is sufficient for the life of the Tahmoor South Project. A rail transport study has been undertaken for the proposed development, which indicates that the existing rail capacity would be sufficient for the proposed transport of product coal to Port Kembla under the proposed development, and no increase in rail capacity between Tahmoor Mine and Port Kembla would be required. As such, existing rail infrastructure and the number of allowable train movements would remain unchanged

2.3 SURFACE FACILITIES AREA

The existing surface facilities and infrastructure at the Tahmoor Mine surface facilities area, operating within surface CCL 716 and Mining Lease 1642, would be utilised for the proposed development.

Upgrades to some aspects of the surface facilities area would be required and are associated with the increase in annual coal production for the proposed development. Upgrades to existing surface infrastructure would be undertaken within the area of the existing Tahmoor Mine surface lease (Mining Lease 1642) and additional surface lease areas required for the proposed development. The proposed upgrades are described in the following sub-sections.

2.3.1 Coal Handling and Preparation Plant

The existing CHPP would be utilised for the proposed development. The existing CHPP would be upgraded including the installation of:

- a new coarse rejects screen,
- additional belt press filter capacity, and
- an increase in thickener capacity.

The existing ROM stockpile area would continue to be utilised by the proposed development. During peak production ROM coal may be trucked from the ROM stockpile to the coal product stockpiles and re-trucked back to the ROM stockpile when required. Reject material generated from the coal washing process at the CHPP would be transported to the expanded REA via the existing reject conveyor to the reject bin for disposal, then transported by haul truck to the REA.

2.3.2 Rejects Management

The existing REA would be expanded onto adjacent areas to accommodate the reject material associated with the proposed development. The expansion area is anticipated to cover up to an additional 43 hectares, providing an additional emplacement capacity of approximately 12 Mt for the rejects generated during the operation of the proposed development.

Construction and maintenance of new internal haul roads would be required to cater for the REA expansion.

The stormwater management system and infrastructure at the existing REA would be augmented with the construction of additional sedimentation dams, drains and pumping station. These are described in the WMS/SWB Report.

2.3.3 Plant and Equipment

The proposed development would utilise existing plant and equipment at the surface facilities area and would also require additional mobile plant for coal material handling at the surface facilities area. The proposed additional plant would include:

- a secondary bulldozer at the product coal stockpile.
- additional ancillary equipment such as trucks, cranes and forklifts for use around the surface facilities area to manage product and equipment stores.

2.3.4 Hours of Operation

The proposed development, including construction activities, would to operate 24 hours a day, seven days per week, consistent with the working hours of the current operations at the Tahmoor Mine.

3.0 SCOPE OF FLOOD STUDY

Subsidence associated with longwall mining has the potential to affect flood prone areas as a result of changes in slope and cross section geometry of watercourses and their floodplains. This flood study has assessed the effects of subsidence on flooding of land in the Study Area during 50%, 10%, 1% (1:100), 0.5% (1:200), 0.2% (1:500) Annual Exceedance Probability (AEP) flood events and a Probable Maximum Flood (PMF) event.

The flood study has comprised hydrologic and hydraulic modelling to predict flood levels for flood events up to the PMF level in areas affected by mine subsidence before and after mining. The flood study report documents where flooding risks have changed as a result of subsidence.

In urbanised areas such as the township of Bargo, which lies within the western margins of the Study Area, subsidence has the potential to affect piped stormwater drainage systems, kerb and gutters and culverts as well as overland flow paths including roads and open channel drains. The likely effects of subsidence on surface stormwater management infrastructure in the urban areas of the Bargo township have also been assessed.

4.0 STUDY AREA

The main drainage features in the Study Area are shown on Figure 2 below. The western and southern parts of the Study Area consist of gently undulating flats, on which the township of Bargo has been established.

The portion of the Project Area underlain by the proposed longwall panels is predominantly drained by Tea Tree Hollow and Dog Trap Creek which both flow northward to the Bargo River. A small area on the south-western side of the Project Area is drained by headwater tributaries of Hornes Creek which flows into the Bargo River at Picton Weir on the western side of the Study Area upstream of the Tea Tree Hollow confluence.

The eastern portion of the Project Area is predominantly drained by Eliza Creek which flows generally north-eastward to the Nepean River.

Local creeks commence as relatively flat, ill-defined channels in the gently undulating upland plateau areas. Further downstream, the drainage lines descend into the incised valleys and the rugged landscape of the deeply dissected Hawkesbury Sandstone. Watercourses in these lower sections are characterised by steep, confined channels. Geomorphological mapping (Gippel, 2013) have described the upper reaches of Tea Tree Hollow and Dog Trap Creek as being relatively low energy, sediment source zones. Further downstream, the incised channels are described as being relatively higher energy systems than headwater streams with very limited sediment storage (Gippel, 2013).

The upper reaches of the drainages in the Study Area are potentially more susceptible to flood inundation due to the flatter terrain and low capacity drainage channels in these areas. The effect of culverts and other constructed constrictions in the more urbanised upland areas is to also increase the extent of flooding in these areas. Flooding in the lower reaches is confined by the steep, incised channel geometry.

The potential effects of the Project on flooding have been investigated by undertaking a comparative flood study of watercourses in the pre-subsidence and the predicted post-subsidence topography. Results from the flood study are presented for the following AEP and hydraulic conditions:

1. Flood extent maps: 10%, 1%, 0.5%, 0.2% AEP flood events and PMF events as required by the Project SEARs (refer BA Report) and for the 50% AEP – representing a significant but relatively common flood event.
2. Flood Planning Level maps (1% AEP maps plus 0.5m free board).
3. Flood Prone Land maps (PMF flood extent maps).

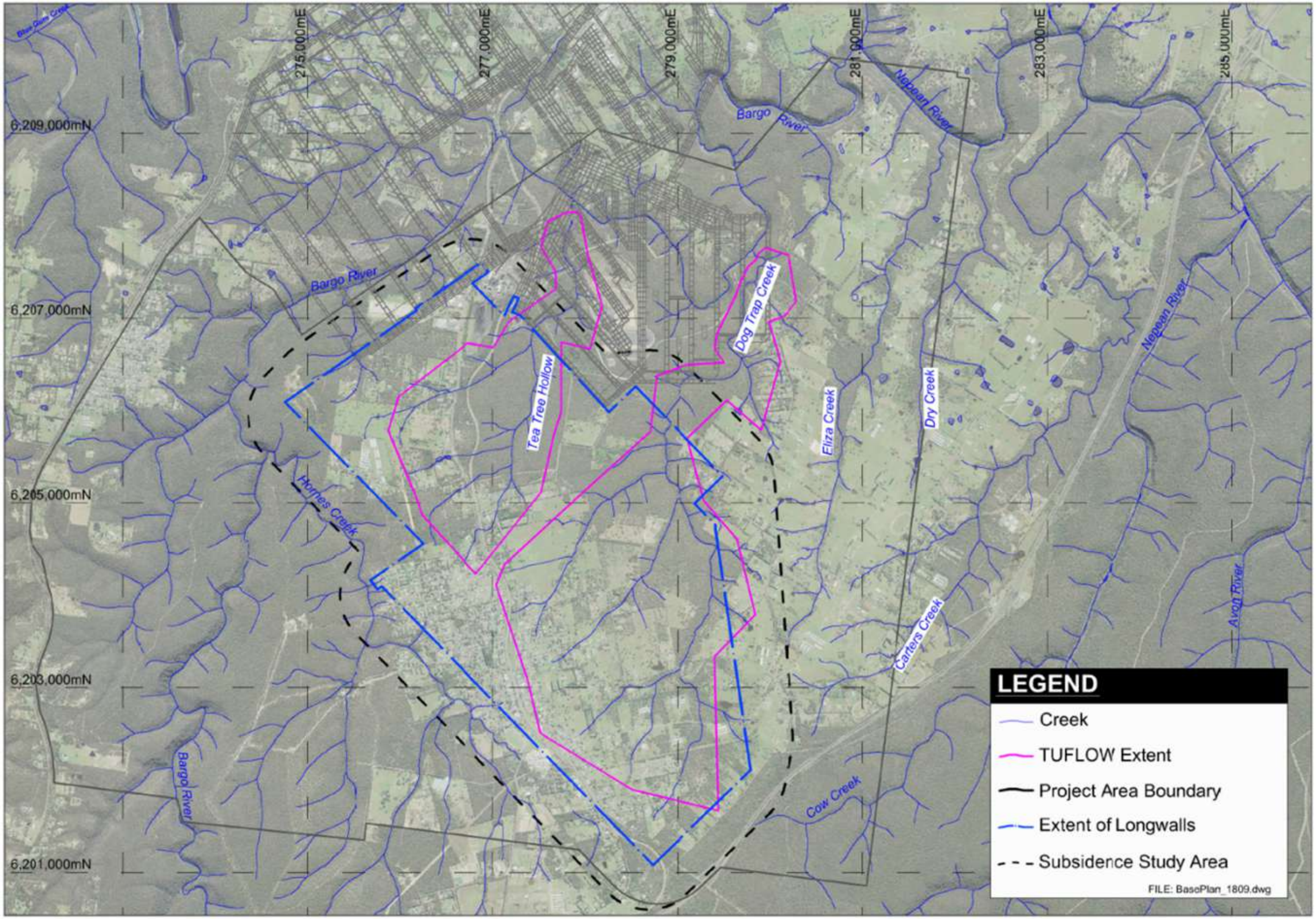

Figure 2 Project Area Layout, Surface Drainages and Hydraulic Model Extents

5.0 HYDROLOGICAL MODELLING OF LOCAL DRAINAGES

Flood hydrographs for the assessed flood events were generated using the rainfall routing model RORB (Laurenson, et al, 2010) which is a commonly used and well established model for generating flood hydrographs from design rainfall. The design rainfall data were estimated using the procedures as described in the 2016 version of Australian Rainfall and Runoff - ARR 2016 (Ball et al, 2016). Design rainfall intensity-frequency-duration data are summarised in Table 1. Design PMP rainfall data are summarised in Table 2.

Table 1 Design Rainfall Intensity-Frequency-Duration Data

Duration	Design Rainfall* (mm) for Given Annual Exceedance Probability										
	63.2%	50%	20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%
1 min	1.92	2.18	3.06	3.72	4.4	5.39	6.2				
2 min	3.22	3.63	4.99	5.98	7	8.51	9.75				
3 min	4.45	5.03	6.94	8.35	9.8	11.9	13.7				
4 min	5.55	6.29	8.74	10.5	12.4	15.1	17.4				
5 min	6.53	7.41	10.4	12.5	14.8	18.1	20.7				
10 min	10.2	11.6	16.3	19.9	23.6	29	33.4				
15 min	12.6	14.4	20.3	24.7	29.4	36	41.5				
30 min	17.2	19.5	27.3	33.2	39.3	48.1	55.4				
1 hr	22.3	25.2	35.1	42.3	49.8	60.5	69.3				
2 hr	28.5	32.3	44.7	53.6	62.8	75.7	86.2				
3 hr	33.1	37.6	52.1	62.4	72.9	87.6	99.4				
6 hr	43.1	49.2	69.1	83.2	97.3	116	131				
12 hr	56.3	65	93.3	113	134	160	180				
1 day	72.5	84.4	124	152	182	218	246	264	295	318	342
2 day	89.3	104	155	194	234	282	319	355	405	445	484
3 day	98.3	115	171	214	259	313	354	399	458	504	553
4 day	104	121	180	225	273	329	373	421	484	534	589
5 day	108	126	187	232	280	338	383	433	498	549	607
6 day	111	130	191	237	285	343	388	437	504	555	614
7 day	114	133	195	241	288	346	391	437	505	555	614

* Source: http://www.bom.gov.au/water/designRainfalls/revised-ifd/?design=rare&sdday=true&coordinate_type=dd&latitude=34.25&longitude=150.6&user_label=Tahmoor&values=depths&update=&year=2013

Table 2 Design Probable Maximum Precipitation

Duration	Design Rainfall (mm) for Given Modelled Catchment	
	Dog Trap Creek	Tea Tree Hollow
15 min	144	153
20 min	166	176
25 min	188	199
30 min	211	222
45 min	266	280
1 hr	315	330
1.5 hr	403	422
2 hr	466	490
2.5 hr	521	546
3 hr	563	591
4 hr	645	678
4.5 hr	676	712
5 hr	709	747
6 hr	754	792
9 hr	860	910
12 hr	950	1000
18 hr	1050	1100
1 day	1110	1140
1.5 day	1240	1270
2 day	1310	1340
3 day	1370	1400
4 day	1420	1450

RORB models were established for Dog Trap Creek and Tea Tree Hollow as these creek catchments will be underlain by the proposed longwall panels. RORB simulates flood hydrographs generated from rainfall events over a catchment using a logical network of sub-catchments which are defined from topographical mapping of the catchment and its drainage network. The pattern of rainfall corresponding to the flood event is input to the model. Rainfall excess (i.e. that component of incident rainfall which becomes direct runoff during the flood event) is calculated using a rainfall loss model with loss parameters provided by the user. The model rainfall excess is routed through a series of model conceptual storages which represent the storage effects of runoff moving across the catchment and through its drainage channel network. The "capacity" of the conceptual model storages is determined by global storage parameters (i.e. storage coefficient and storage exponent). The model conceptual storages are distributed through the model network according to the distribution of contributing catchment area and/or channel length that each conceptual storage represents.

The key model parameters used in the rainfall routing models are summarised in Table 3 and Table 4. The parameters were estimated following procedures as recommended in ARR 2016. No model calibration was undertaken.

Table 3 Summary of RORB Rainfall Routing Model Parameters

Catchment	Storage Coefficient (k_c)	Storage Exponent (m)
Dog Trap Creek	3.93	0.8
Tea Tree Hollow	2.82	0.8

Table 4 RORB Loss Parameters

Design AEP	Initial Loss (mm)	Continuous Loss (mm)
50%	25	2.5
10%	20	2.5
1%	10	2.5
0.5%	5	2
0.2%	0	2
PMF	0	1

The RORB models were simulated with rainfall patterns as recommended in ARR 2016 derived (for a given AEP and catchment area) using differing rainfall durations to find the duration which gave the largest peak flow. The hydrographs with this critical duration and peak flow rates were used in the subsequent hydraulic modelling (refer Section 6.0).

The peak discharge rates obtained from the RORB modelling at the downstream end of each modelled catchment are summarized in Table 5.

Table 5 Modelled Peak Flood Discharges at Catchment Outlets

Catchment	Catchment Outlet Peak Flow Rates (m^3/s)					
	50%	10%	1%	0.5%	0.2%	PMF
Dog Trap Creek at Bargo River Confluence	18.8	49.7	93.9	121.9	159.0	751.0
Tea Tree Hollow at Bargo River Confluence	10.0	27.1	53.4	71.5	93.8	450.5

6.0 HYDRAULIC MODELLING OF LOCAL DRAINAGES

The hydraulic modelling to estimate areas that would be affected (i.e. inundated) as a result of flooding was undertaken using the 2 dimensional hydrodynamic model TUFLOW^{TM}. TUFLOW (BMT WBM, 2010) is an accepted 2 dimensional numerical, finite difference model which simulates the hydraulic conditions throughout the modelled watercourse by solving the free surface flow equations of momentum and conservation. The pre and post-subsidence topography (digital terrain model - DTM) used in the modelling was supplied by Tahmoor Coal. It is understood that the pre-subsidence DTM was obtained from a LiDAR survey, while the post-subsidence topography was based on predictions by Mine Subsidence Engineering Consultants Pty Ltd (MSEC) – specialist subsidence consultants. The DTM had a vertical and horizontal resolution/accuracy of +/- 0.1m and +/- 0.2m respectively. The model was set up using a 3 m by 3 m horizontal grid. Separate models were developed for Dog Trap Creek and Tea Tree Hollow. Longitudinal sections along the four modelled creeks are shown in Figure 3 indicating both pre and post-subsidence topography. The extent of the modelled areas is indicated on Figure 2.

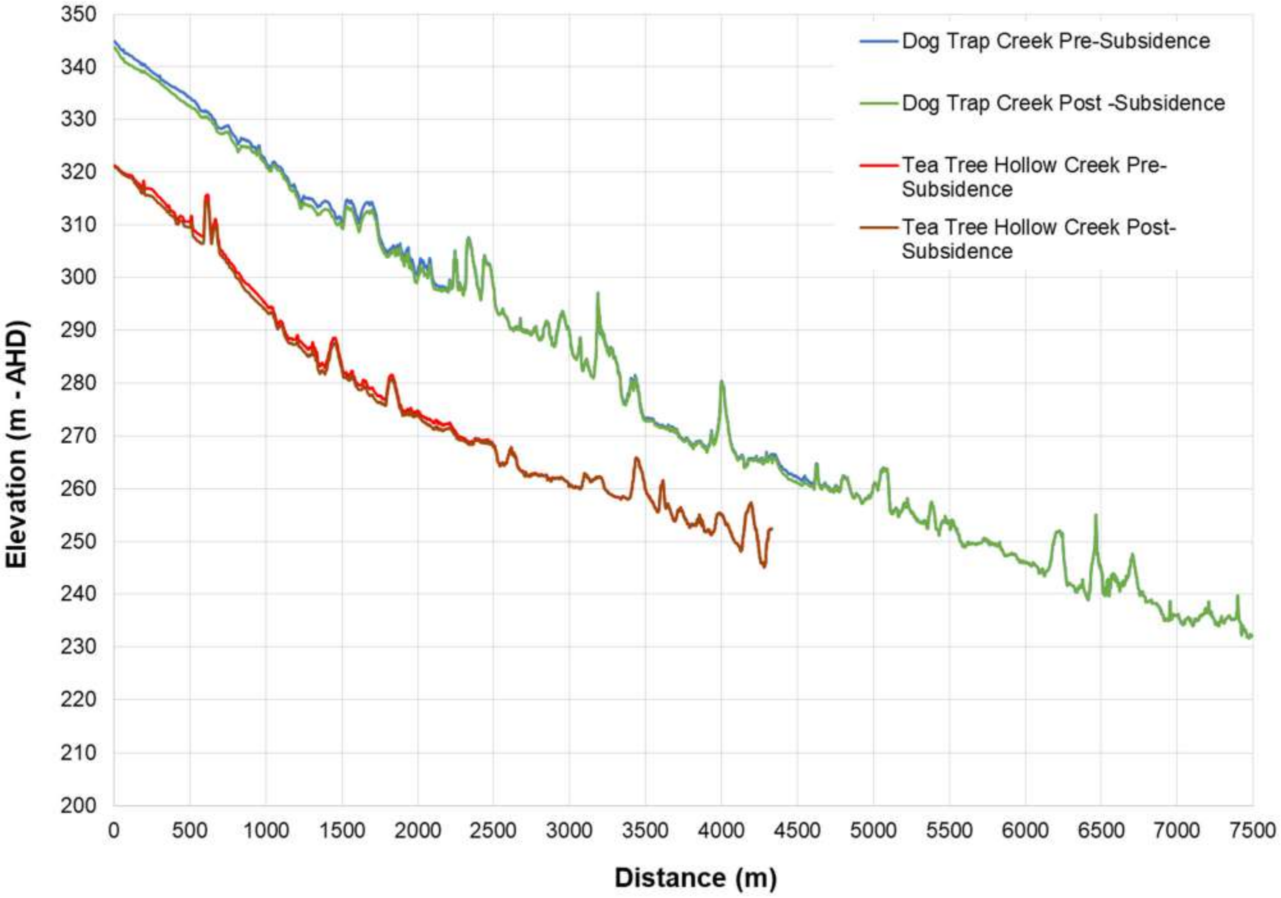

Figure 3 Modelled Stream Longitudinal Sections

There is currently insufficient data to calibrate the flood models. Selection of Manning's 'n' friction factors, which are used in the model to simulate energy loss due to friction, were selected based on site observations and by matching conditions evident in photographs from the geomorphic photograph data base developed by Gippel (2013) during field surveys with published guidelines (e.g. Barnes, 1967). For the main creek channels 'n' values varied between 0.03 and 0.06, with the majority of areas assigned a value of 0.05. In overbank areas a value of 0.03 was used. Whilst the resulting models are un-calibrated they are considered sufficiently accurate to quantify the effects of subsidence on flooding – being the difference between model runs conducted using the pre and post subsidence topography.

Areas inundated during the passage of the assessed flood events were output from the model and are shown as a series of figures that follow. The figures depict the maximum areas inundated during the passage of the design AEP hydrographs under existing (pre-subsidence) conditions and the additional areas that would be inundated in the post-subsidence topography. There were some areas which would be inundated under existing conditions which would not be post-subsidence during the same flood event. These areas were found to be relatively small and have not been shown. Areas inundated under post-subsidence conditions are highlighted in red and areas inundated under pre-subsidence conditions shown in blue. By overlaying the pre-subsidence model results (shown in blue) on the post-subsidence model results (shown in red) reveals additional inundation as red areas and the limits of areas that would be currently inundated in the blue outline. The flood inundation maps for the 50% AEP and 1% AEP events are shown in **Error! Reference source not found.** to Figure 9, with discussion of results in the following sub-sections. These represent results for significant but relatively common flood events and very large, relatively rare flood events. The flood inundation maps for the 10%, 0.5%, 0.2% AEP and PMF are provided in Appendix A.

6.1 DOG TRAP CREEK – 1% AEP EVENT

Results of the hydraulic model runs for Dog Trap Creek have been spilt into the northern and southern parts of the creek to improve clarity. Figure 4 below depicts the simulated maximum areas inundated during passage of the 1% AEP event in the southern (upstream) part of the Dog Trap Creek catchment.

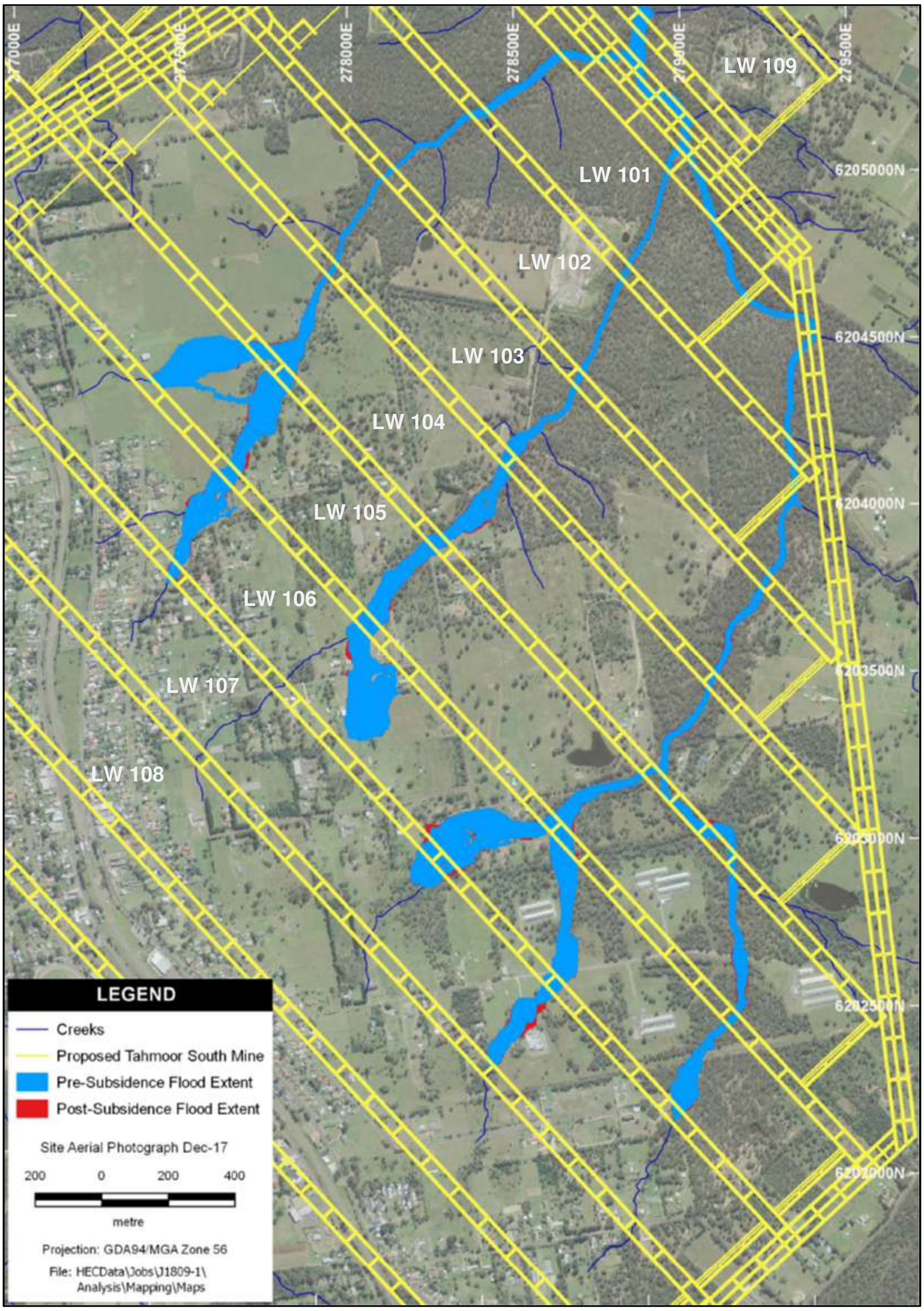

Figure 4 Extent of Predicted 1% AEP Flooding – Southern (upstream) Dog Trap Creek

Significant overbank and fringing floodplain areas are predicted to be inundated during the passage of the 1% AEP flood event in the eastern outskirts of the Bargo township and the adjacent rural and semi-rural areas – under both existing and post-subsidence conditions. Further downstream inundation is limited to the main channel areas of Dog Trap Creek. The predicted effects of subsidence on increasing flood inundation (red on the figure) are limited to small areas in the upstream on the edges of the floodplains overlying longwalls 106 and 107. These increases in flood inundation are close to the resolution of the model i.e. +/- 3m.

Figure 5 depicts the simulated maximum areas inundated during passage of the 1% AEP event in the northern (downstream) half of the Dog Trap Creek catchment. Flooding in the downstream reaches of Dog Trap Creek is contained within the main channel. The hydraulic model predicts that there would be no detectable increase or new areas that would be inundated during this event as a result of subsidence changes to surface topography.

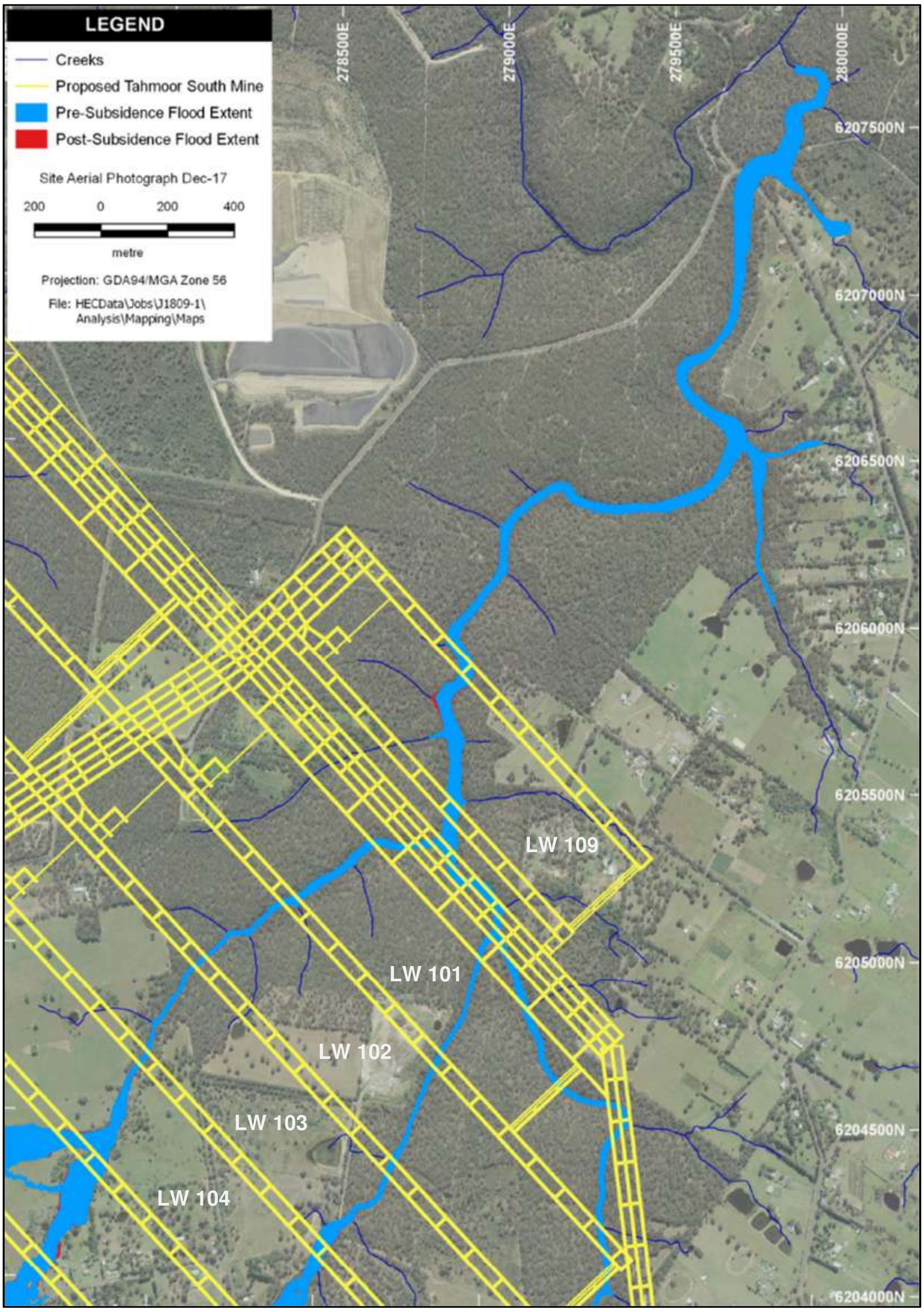

Figure 5 Extent of Predicted 1% AEP Flooding – Northern (downstream) Dog Trap Creek

6.2 DOG TRAP CREEK – 50% AEP EVENT

Figure 6 depicts the simulated maximum areas inundated during passage of the 50% AEP event in the southern (upstream) half of the Dog Trap Creek catchment. As expected, the area of inundation is significantly less extensive than would be inundated during the larger, 1% AEP event. Increases in the area that would be inundated by this event as a result of subsidence (shown by the red shaded areas in the figure) are located in the same floodplain areas as were predicted to be affected by subsidence under the larger 1% AEP flood event (refer Figure 4).

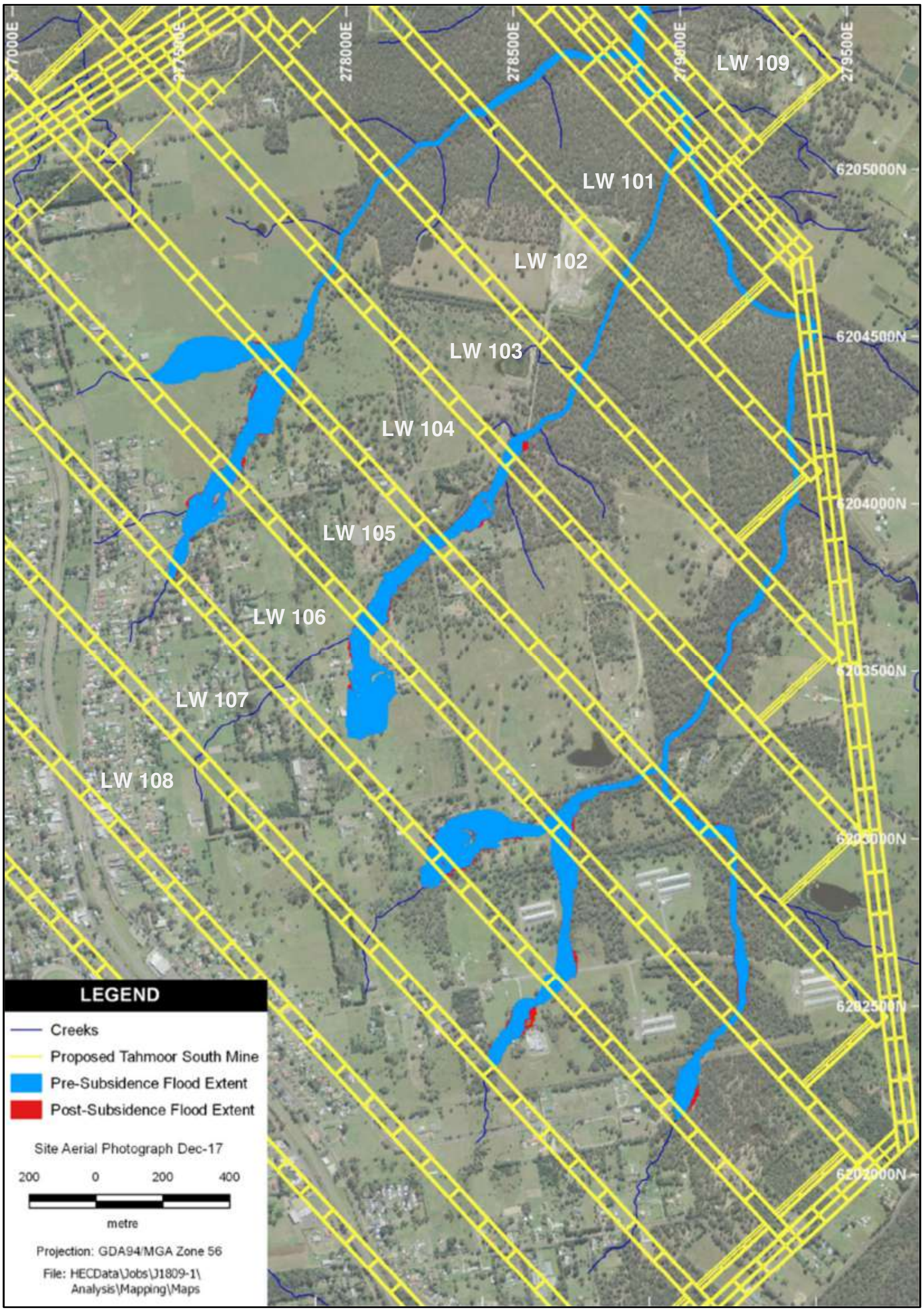

Figure 6 Extent of Predicted 50% AEP Flooding – Southern (upstream) Dog Trap Creek

Figure 7 depicts the simulated maximum areas inundated during passage of the 50% AEP event in the northern (downstream) part of the Dog Trap Creek catchment. As with the 1% AEP event, flooding is modelled as being well contained within the main channel. The hydraulic model predictions are for no detectable increase or new areas that would be inundated during this event as a result of subsidence-related changes to surface topography

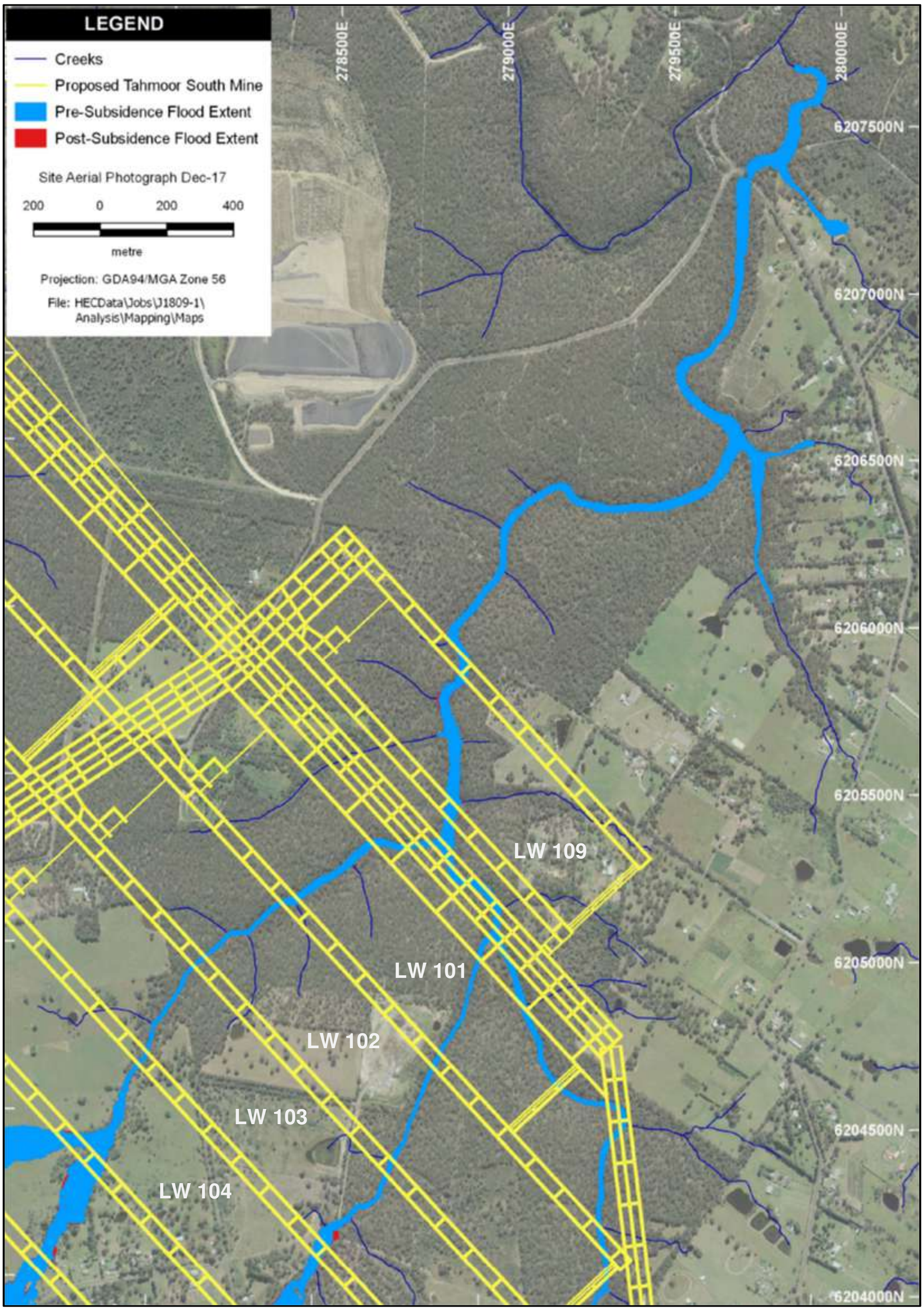

Figure 7 Extent of Predicted 50% AEP Flooding – Northern (downstream) Dog Trap Creek

6.3 TEA TREE HOLLOW – 1% AEP EVENT

Figure 8 below depicts the simulated maximum areas inundated during passage of the 1% AEP event in the southern (upstream) portion of the Tea Tree Hollow catchment.

The hydraulic model predicts that significant overbank flooding would occur under existing conditions in areas upstream of the culverts beneath Remembrance Drive and the corridor between Remembrance Drive and the railway embankment. There is also a section of Remembrance Drive which is predicted to be inundated during the passage of the 1% AEP flood event. Further downstream inundation is limited to the main channel areas.

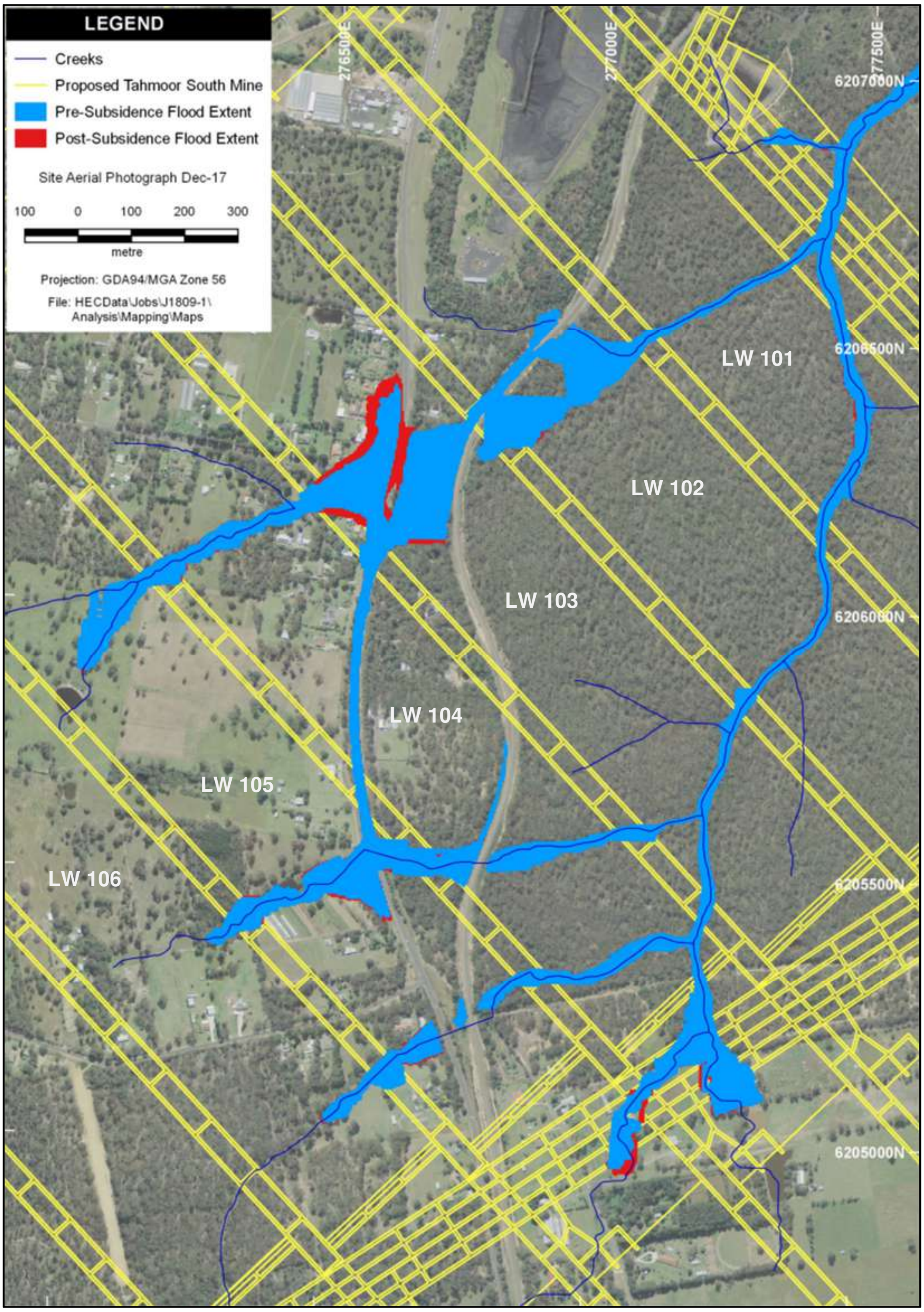

Figure 8 Extent of Predicted 1% AEP Flooding – Southern (upstream) Tea Tree Hollow

The hydraulic model predicts that the effects of subsidence would increase areas subject to flood inundation (red shading in Figure 8) on the western side of Remembrance Drive. The largest increase is on the western side of Remembrance Drive overlying longwall 103. Drainage enhancement works, including provision of additional drainage culverts or pipes under Remembrance Drive, are recommended to reduce the impacts associated with the predicted increased flood inundation in this location.

Figure 9 depicts the simulated maximum areas inundated during passage of the 1% AEP event in the northern (downstream) part of the Tea Tree Hollow catchment.

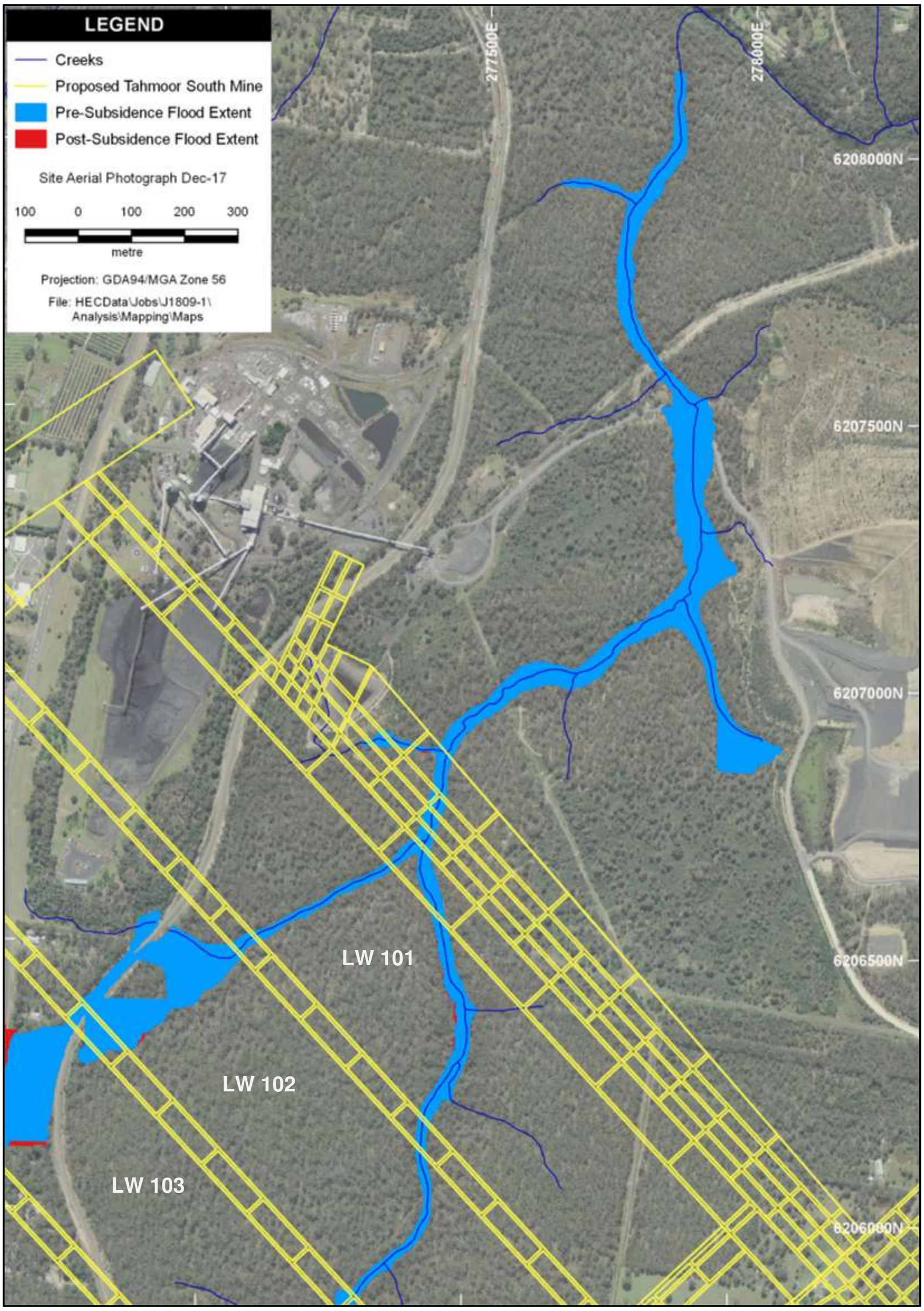

Figure 9 Extent of Predicted 1% AEP Flooding – Northern (downstream) Tea Tree Hollow

Predicted flooding in these sections of the creek is well contained within the main channel. There is no detectable increase in predicted flood inundation during this event as a result of subsidence changes to surface topography.

6.4 TEA TREE HOLLOW – 50% AEP EVENT

Figure 10 depicts the simulated maximum areas inundated during passage of the 50% AEP event in the southern (upstream) part of the Tea Tree Hollow catchment. As with the 1% AEP event significant overbank flooding is predicted in areas upstream of the culverts beneath Remembrance Drive and the corridor between Remembrance Drive and the railway embankment.

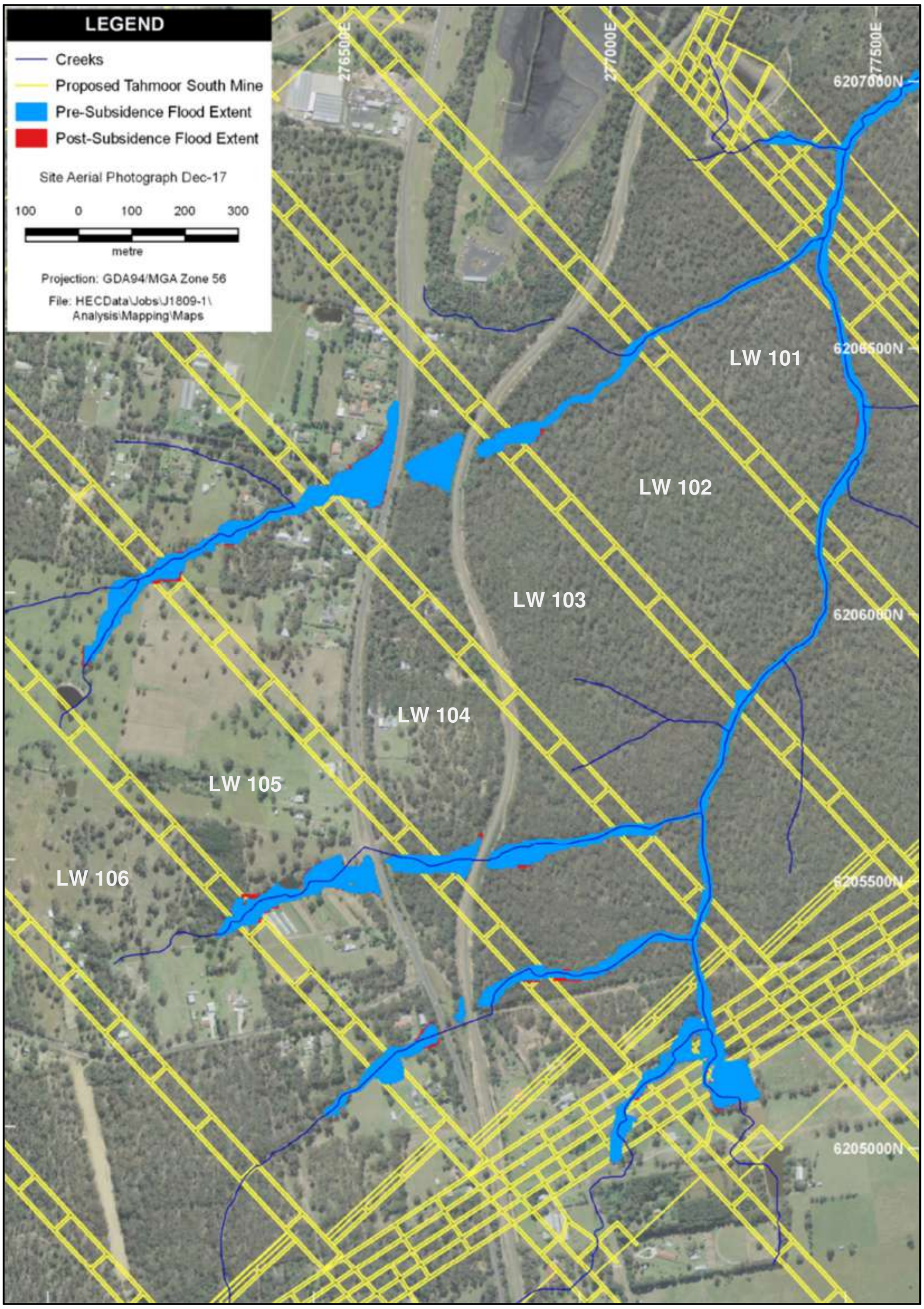

Figure 10 Extent of Predicted 50% AEP Flooding – Southern (Upstream) Tea Tree Hollow

The predicted effects of subsidence on increasing flood inundation (red shading in Figure 10) are minor and at the limit of the model resolution.

Figure 11 depicts the simulated maximum areas inundated during passage of the 50% AEP event in the northern (downstream) part of the Tea Tree Hollow catchment.

As with the 1% AEP event, predicted flooding in these sections of the creek is well contained within the main channel. There is no detectable increase in predicted flood inundation during this event as a result of subsidence changes to surface topography.

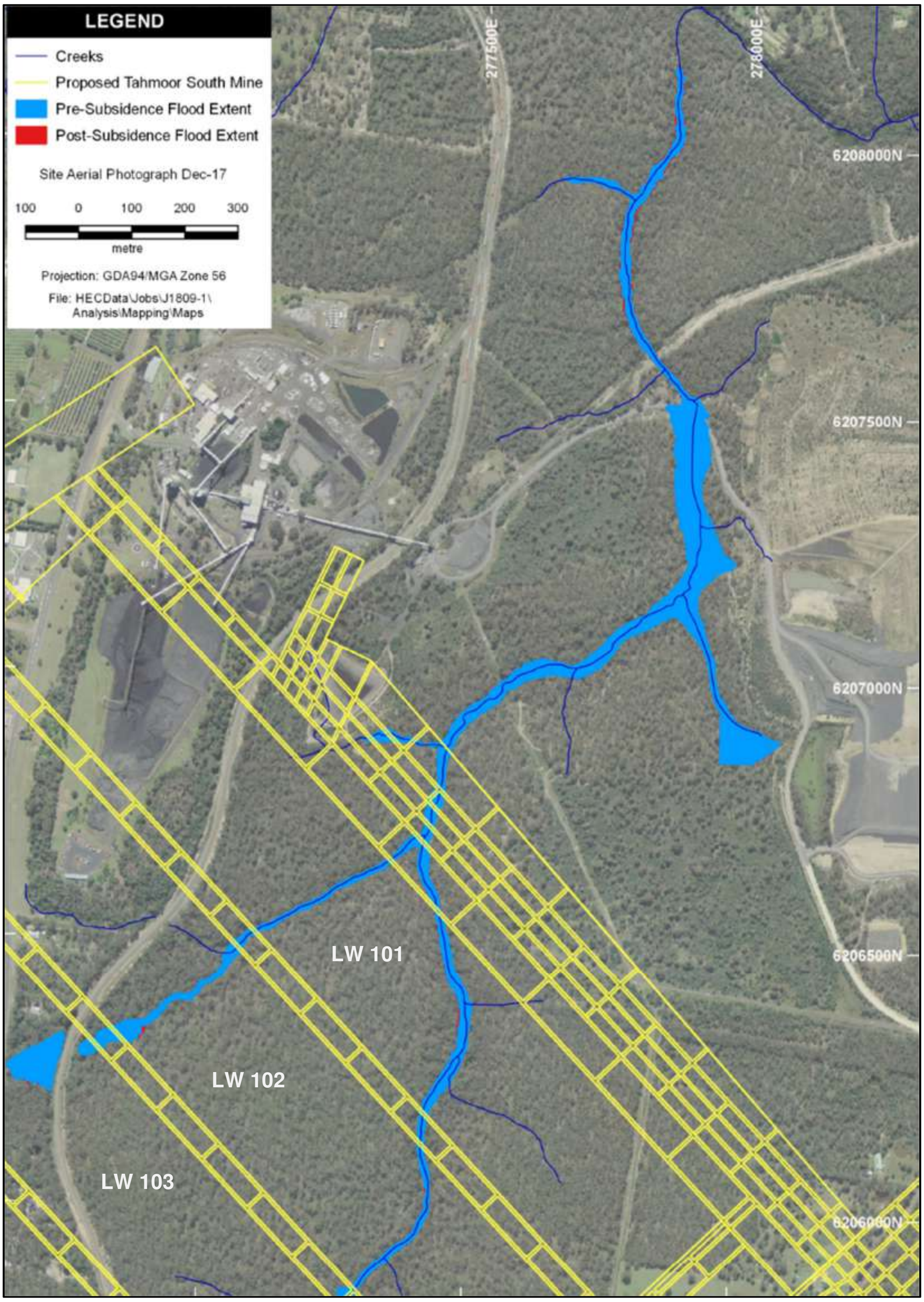

Figure 11 Extent of Predicted 50% AEP Flooding – Northern (Downstream) Tea Tree Hollow

6.5 FLOODPLAIN MAPPING

The following features have been mapped in line with the NSW Floodplain Development Manual (NSW Government, 2005):

- Flood prone land;
- Floodways;
- Flood planning area.

Flood prone land is defined as land susceptible to flooding during a PMF event (NSW Government, 2005). PMF flood extent maps are included in Appendix A.

Floodway areas are defined as areas where significant discharge occurs during floods and are often aligned with naturally defined channels (NSW Government, 2005). This has been interpreted as being effective bankfull flow. For the purposes of this study and in the context of the creeks in the vicinity of the Project, this has been assumed to be approximately the 10% AEP flood level. Flood extent maps for the 10% AEP flood are included in Appendix A.

Flood planning areas are assumed to be approximately equivalent to the 1% AEP flood extent. Flood extent maps for the 1% AEP flood are included in Appendix A.

7.0 OVERLAND FLOW PATHS IN BARGO TOWNSHIP

Longwalls 106, 107 and 108 would be mined under the township of Bargo. The township of Bargo lies on a local topographic ridgeline which separates the Hornes Creek catchment to the west and south from the Tea Tree Hollow and Dog Trap Creek catchments to the north and east.

Mine subsidence has the potential to damage existing stormwater infrastructure, which has been assessed by MSEC (2018). MSEC (2018) propose that any subsidence impacts to the stormwater infrastructure would be managed via the Subsidence Management Plan (SMP) process. Under this process, subsidence damage to stormwater infrastructure would be rehabilitated and rectified by Tahmoor Coal or Subsidence Advisory NSW under the compensation provisions of the *Coal Mine Subsidence Compensation Act 2017*.

During intense rainfall, stormwater would also drain via overland flow paths comprising natural and constructed depressions in the surface topography. The objective of this assessment has been to identify where predicted subsidence topography is likely to increase local flooding in existing overland flow paths in the Bargo township. This has been achieved by identifying where overland flow paths intersect the gate roads between longwall panels, which would form relatively elevated areas in the post subsidence topography and as a consequence may increase flooding.

The layout of proposed longwalls in relation to the Bargo Township is shown in Figure 12 below together with the overland flow paths which overlie the proposed gate roads.

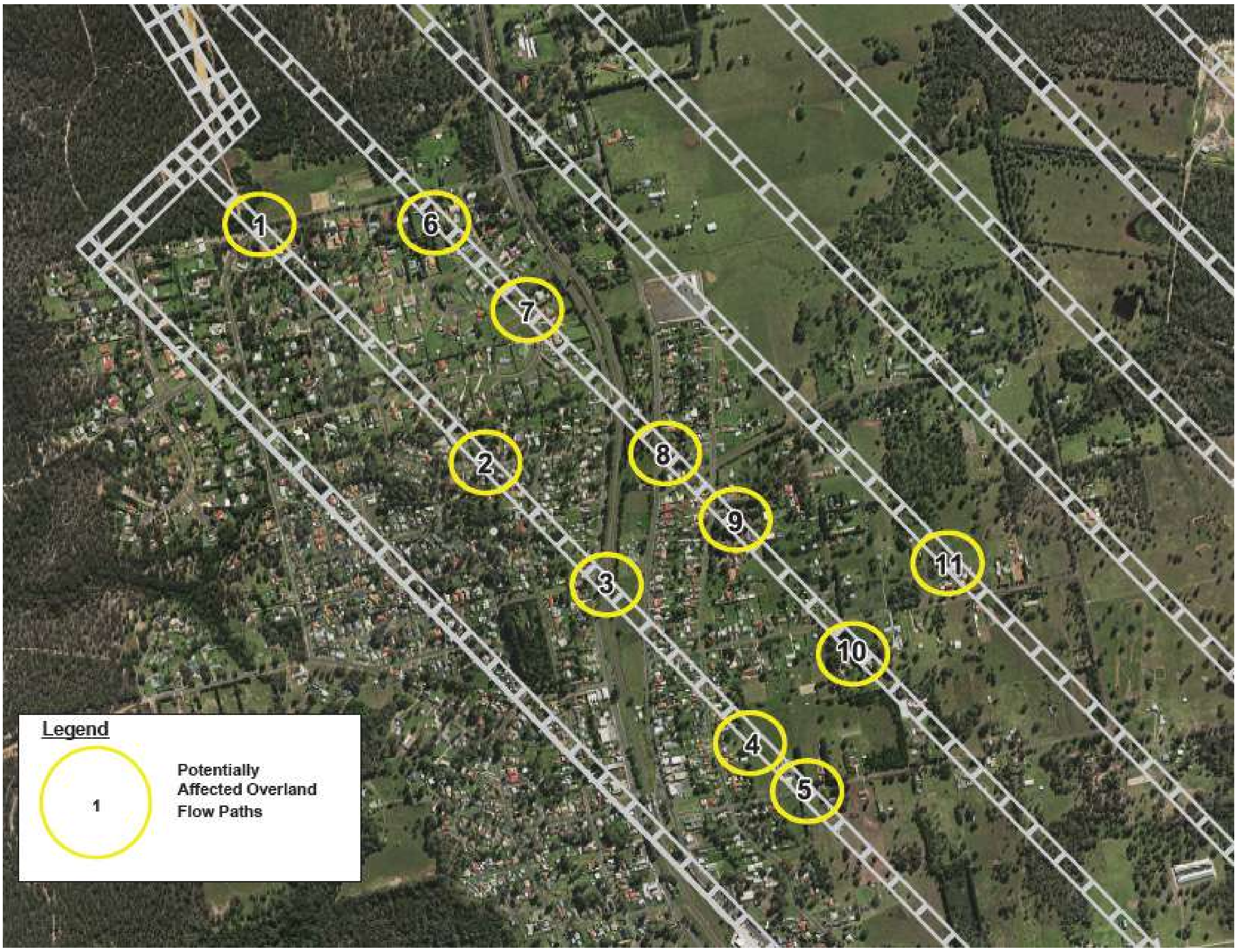

Figure 12 Proposed Longwall Panel Layout – Bargo Township and Potentially Affected Overland Flow Paths

The predicted subsidence movements could lead to changes in overland flow paths in the locations identified as 1 to 10 in Figure 12. The probable effect to flooding of land in these areas has been assessed qualitatively and is summarised below.

7.1 OVERLAND FLOW PATH 1 – WELLERS ROAD

There is an existing overland flow path on the northern side of Wellers Road in an area overlying the proposed gate road between longwalls 107 and 108, as outlined on – refer Figure 12 and Figure 13. Figure 13 shows an aerial photograph image of the area. The area comprises a timbered area on the northern side of Wellers Road where overland flow follows a natural depression. The catchment upstream of this location is estimated to be about 20 ha. The average slope of overland flow path upslope of the gate road in this area would reduce from about 2.8% to 2.2% due to predicted subsidence. This change in slope would result in about a 10% increase in normal flow depth which is a small change and similar to the effect natural changes in vegetation, such as length of grass, would have on flow depth. It is considered unlikely the reduced gradient would pose any significant risk of increased flooding outside the immediate timbered area.

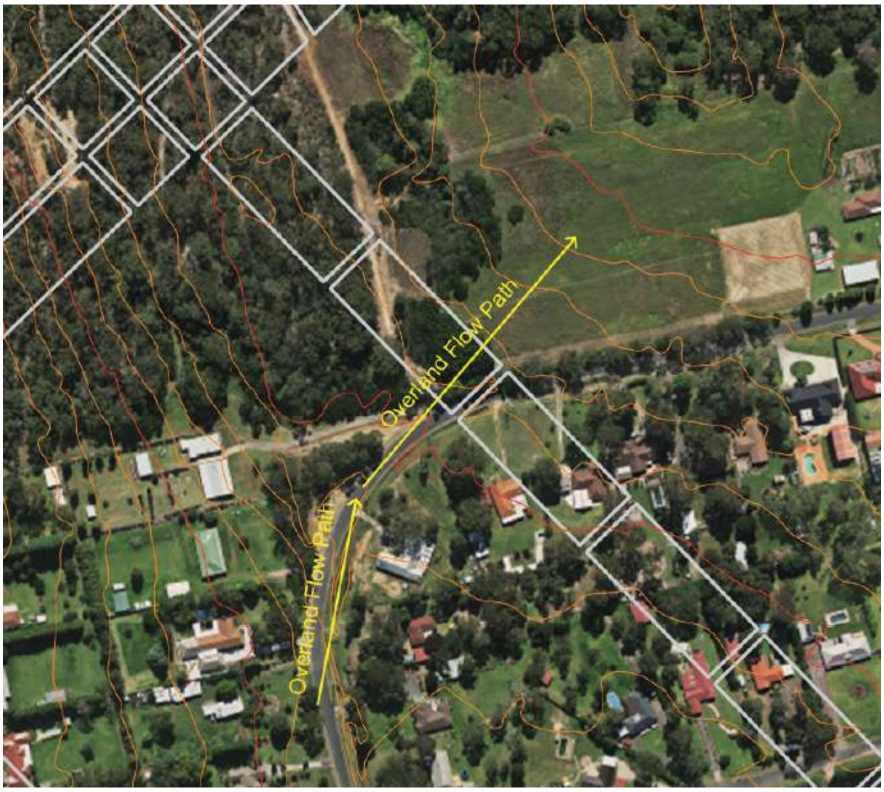

Figure 13 Overland Flow Path North of Wellers Road

7.2 OVERLAND FLOW PATH 2 – HAMBRIDGE ROAD

There is an existing overland flow path south of Hambridge Road in an overland flow path which crosses Hambridge Road and then follows a drainage easement on the Northern side of Hambridge Road as outlined in Figure 14. This area abuts the proposed gate road between longwalls 107 and 108. An aerial photograph of the area is shown in Figure 14. The catchment upstream of this location is about 2.3 ha.

The small upslope catchment means that the risk of significant overland flow and flooding at this location is low. The average slope of the overland flow path upslope of the gate road in this area would reduce from about 5.6% to 5.4% as a result of the predicted subsidence. This change in slope would result in about a 2% increase in normal flow depth which is considered to be negligible.

Figure 14 Overland Flow Path South of Hambridge Road

7.3 OVERLAND FLOW PATH 3 – REMEMBRANCE DRIVE

There is an existing overland flow path west of Remembrance Drive and east of Radnor Road which abuts the proposed gate road between longwalls 107 and 108 as outlined in Figure 15. The catchment upstream of this location is about 3.7 ha. The small upslope catchment area means that the risk of significant overland flow and flooding at this location is low. The average slope of the overland flow path upslope of the gate road in this area would reduce from about 8.9% to 8.8% as a result of the predicted subsidence. This change in slope would result in about a 2.3% increase in normal flow depth which is considered to be negligible.

Figure 15 Overland Flow Path West of Remembrance Drive

7.4 OVERLAND FLOW PATH 4 – HAWTHORNE ROAD

There is an existing overland flow path east of Hawthorne Road which abuts the proposed gate road between longwalls 107 and 108 as outlined in Figure 16. The area comprises a flat grassed open area. The catchment upstream of this location is about 12 ha. The average slope of the overland flow path upslope of the gate road in this area would reduce from about 3.3% to 3.1% as a result of the predicted subsidence. This change in slope would result in about a 3.6% increase in normal flow depth which is very small and less than changes associated with normal changes in vegetation. It is considered unlikely there would be any significant risk of increased flooding outside the immediate open area as a result of the predicted subsidence.

Figure 16 Overland Flow Path East of Hawthorne Road

7.5 OVERLAND FLOW PATH 5 – BARGO ROAD

There is an existing overland flow path north of Bargo Road and east of Hawthorne Road which abuts the proposed gate road between longwalls 107 and 108 as outlined in Figure 17. The area comprises a grassed and lightly timbered open area. The upslope catchment at this location is about 4.6 ha. The small catchment means that the risk of significant overland flow and flooding at this location is low. The average slope of the overland flow path upslope of the gate road in this area would reduce from about 3.2% to 3% as a result of the predicted subsidence. This change in slope would result in about a 4% increase in normal flow depth which is very small and less than changes associated with normal changes in vegetation. It is considered unlikely there would be any significant risk of increased flooding outside the open area.

Figure 17 Overland Flow Path North of Bargo Road

7.6 OVERLAND FLOW PATH 6 – WELLERS ROAD AND HOGANS DRIVE

There is an existing overland flow path south of Wellers Road and west of Hogans Drive which abuts the proposed gate road between longwalls 106 and 107 as outlined in Figure 18. The area comprises a timbered undeveloped area. The upslope catchment at this this location is about 10.8 ha. The average slope of the overland flow path upslope of the gate road in this area would reduce from about 2.6% to 2.2% as a result of the predicted subsidence. This change in slope would result in about a 7.4% increase in normal flow depth which is a small compared to the effect natural changes in vegetation, such as length of grass, would have on flow depth. It is considered unlikely there would be any significant risk of increased flooding outside the open timbered area.

Figure 18 Overland Flow Path South of Wellers Road

7.7 OVERLAND FLOW PATH 7 – HOGANS DRIVE

There is an existing overland flow path east of Hogans Drive which abuts the proposed gate road between longwalls 106 and 107 as outlined on Figure 19. The area comprises an open undeveloped parcel of land. The upslope catchment at this location is about 15 ha. The average slope of overland flow path upslope of the gate road in this area would reduce from about 4.8% to 4.3% as a result of the predicted subsidence. This change in slope would result in about a 5% increase in normal flow depth which is small. Given the extensive open area and relatively elevated level of the surround land it is considered that there would not be any significant increased risk of flooding outside the open area.

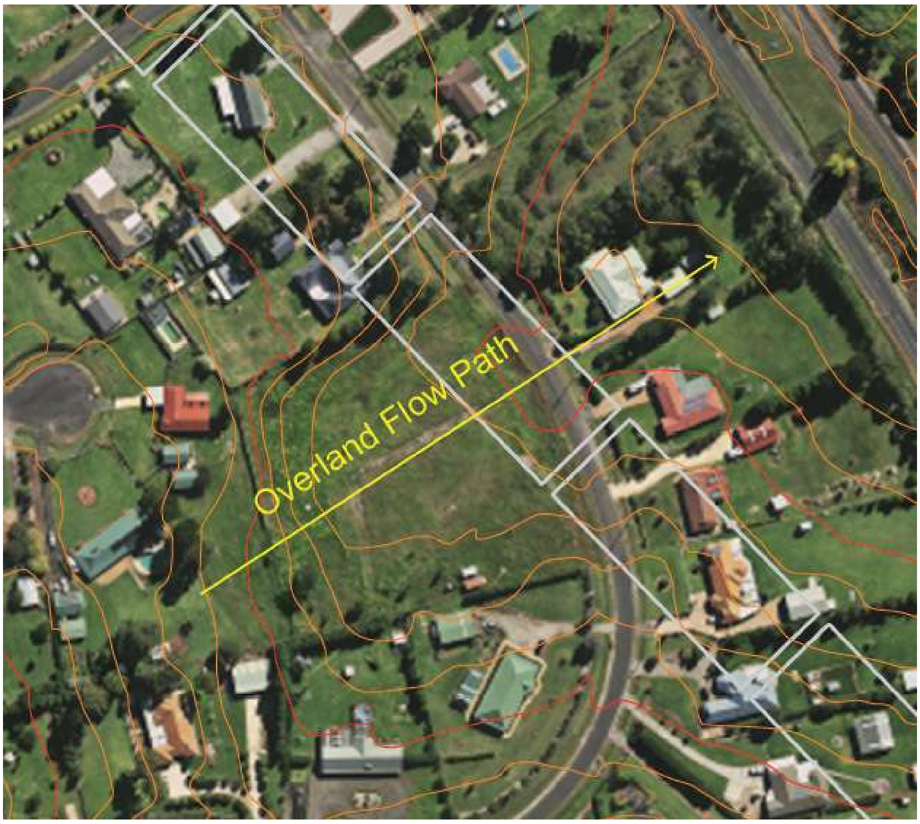

Figure 19 Overland Flow Path East of Hogans Drive

7.8 OVERLAND FLOW PATH 8 – GREAT SOUTHERN ROAD

There is an existing overland flow path in a large open area between the railway line and Great Southern Road which abuts the proposed gate road between longwalls 106 and 107 as outlined in Figure 20. The area comprises an open undeveloped parcel of land. The upslope catchment at this location is about 15.6 ha. The average slope of overland flow path upslope of the gate road in this area would reduce from about 4.4% to 3.9% as a result of the predicted subsidence. This change in slope would result in about a 5.5% increase in normal flow depth which is small. It is considered that the reduced gradient would not pose any significant risk of increased flooding outside this area.

Figure 20 Overland Flow Path Between Railway and Great Southern Road

7.9 OVERLAND FLOW PATH 9 – HAWTHORNE ROAD

There is an existing overland flow path in a large open area east of Hawthorne Road which abuts the proposed gate road between longwalls 106 and 107 as outlined in Figure 21. The area comprises timbered undeveloped land. The upslope catchment at this location is about 10.3 ha. The average slope of overland flow path upslope of the gate road in this area would reduce from about 3% to 2.5% as a result of the predicted subsidence. This change in slope would result in about an 8% increase in normal flow depth which is small and comparable to the effect of natural changes to vegetation on flow depth. It is considered that the reduced gradient is unlikely to pose any significant risk of increased flooding outside the open area.

Figure 21 Overland Flow Path East of Hawthorne Road

7.10 OVERLAND FLOW PATH 10 – DYMOND ROAD AND WATTLE STREET

There is an existing overland flow path in a large open area south of the Dymond Road/Wattle Street intersection which abuts the proposed gate road between longwalls 106 and 107 as outlined in Figure 22. The area comprises an undeveloped, timbered area upstream of an existing farm dam. The upslope catchment at this location is about 29.4 ha. The average slope of the overland flow path upslope of the gate road in this area would reduce from about 1.6% to 1% as a result of the predicted subsidence. This change in slope would result in about a 19% increase in normal flow depth. It is considered likely this change could affect flooding in the immediate open area but that it is unlikely to significantly increase flooding within the surrounding developed areas.

Figure 22 Overland Flow Path South of the Dymond Road/Wattle Street Intersection

7.11 OVERLAND FLOW PATH 11 – DYMOND ROAD

There is an existing overland flow path in a large open area on the northern side of Dymond Road which abuts the proposed gate road between longwalls 105 and 106 as outlined in Figure 23. The area comprises an undeveloped, timbered area with a farm dam in the flow path upslope of the gate road. The upslope catchment at this location is about 45 ha. The average slope of the overland flow path upslope of the gate road in this area would reduce from about 2.5% to 2.1% as a result of the predicted subsidence. This change in slope would result in about a 7.8% increase in normal flow depth which is small. It is considered that the reduced gradient would not pose any significant risk of increased flooding outside this immediate area.

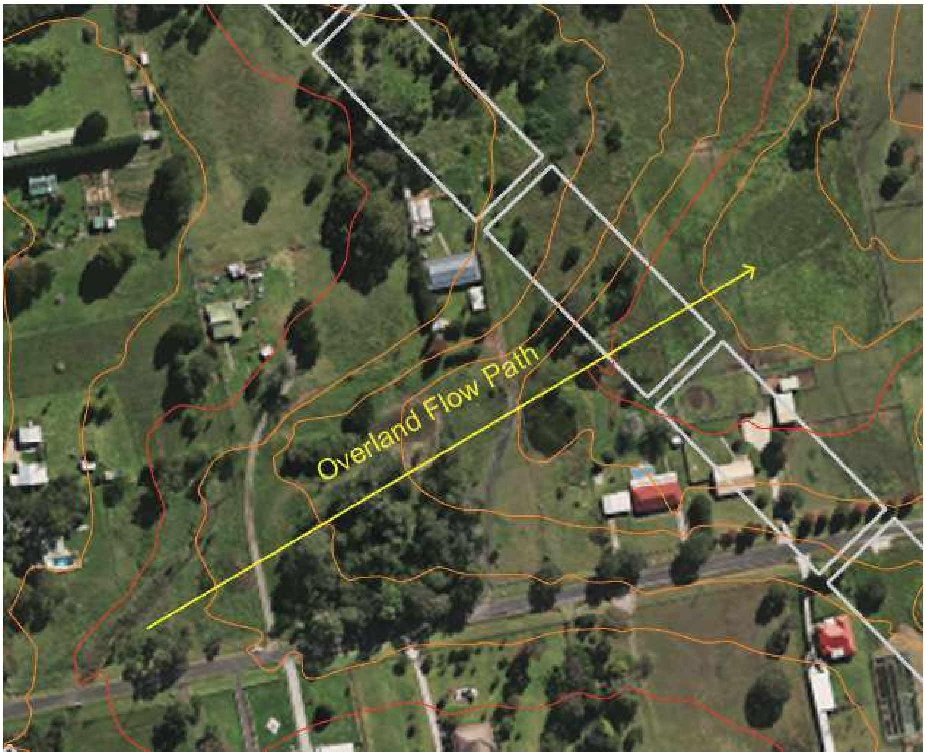

Figure 23 Overland Flow Path North of Dymond Road

8.0 SUMMARY AND RECOMMENDATION

The drainage lines in the Project Area are naturally more susceptible to flood inundation due to the flatter terrain and low capacity primary channels in these areas. The effect of culverts and other constructed constrictions in the more urbanised upland areas also increase the extent of flooding in these areas. In contrast flooding in the lower reaches is confined by the naturally steep, incised channel geometry in these areas.

Results of modelling indicate that predicted subsidence would result in some localised minor changes to flooding in creeks in the Project Area for events up to the 1% AEP level. These simulated changes include both increases and decreases in the inundation area. The largest increases in flood inundation were predicted using the hydraulic model to occur in mostly undeveloped, open areas the upper reaches of Dog Trap Creek.

The hydraulic model predictions are also for an increase in flood inundation upstream of the Remembrance Drive culvert crossing of Tea Tree Hollow near Caloola Road which could impact an urbanised area in the Bargo township. This could however be mitigated by increasing the capacity of the culverts at this location. Suitable upgrades to the road and rail culverts at this location are recommended following subsidence.

Mine subsidence also has the potential to cause some damage to existing stormwater infrastructure, which has been assessed by MSEC (2018). MSEC (2018), propose that any subsidence impacts to stormwater infrastructure would be managed via the Subsidence Management Plan process. Subsidence damage to stormwater infrastructure would be rehabilitated and rectified by Tahmoor Coal or the Mines Subsidence Board under the compensation provisions of the *Mine Subsidence Compensation Act, 1961*. An assessment of changes to overland flow paths associated with subsidence in the Bargo township area show that the predicted subsidence induced tilts are small relative to the natural gradients along potential overland flow paths and that any changes to flow along these features is likely to be imperceptible.

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APPENDIX A

Flood Extent Maps

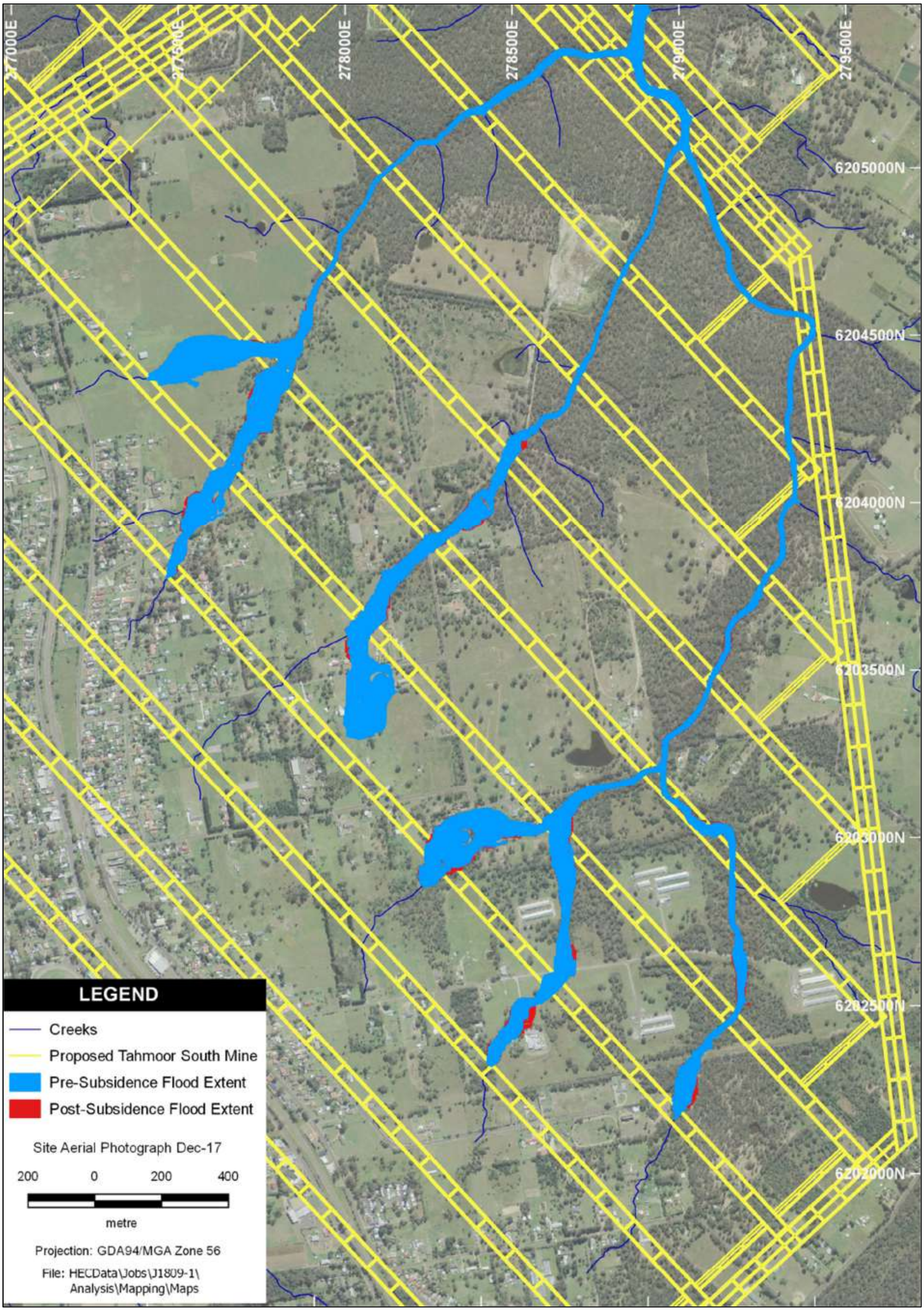

Figure A1: Extent of Predicted 10% AEP Flooding, Southern Part (upstream) - Dog Trap Creek

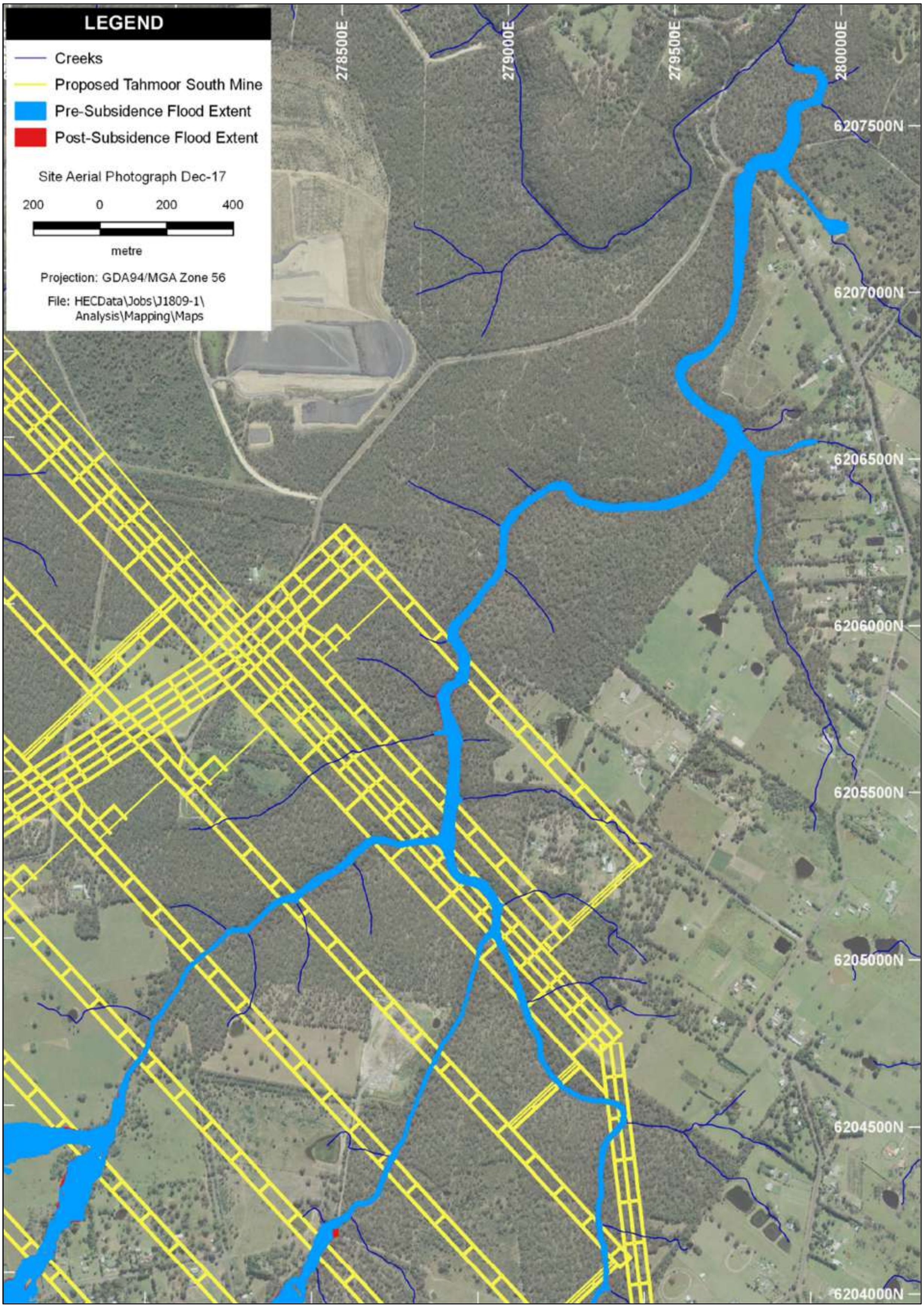

Figure A2: Extent of Predicted 10% AEP Flooding, Northern Part (downstream) - Dog Trap Creek

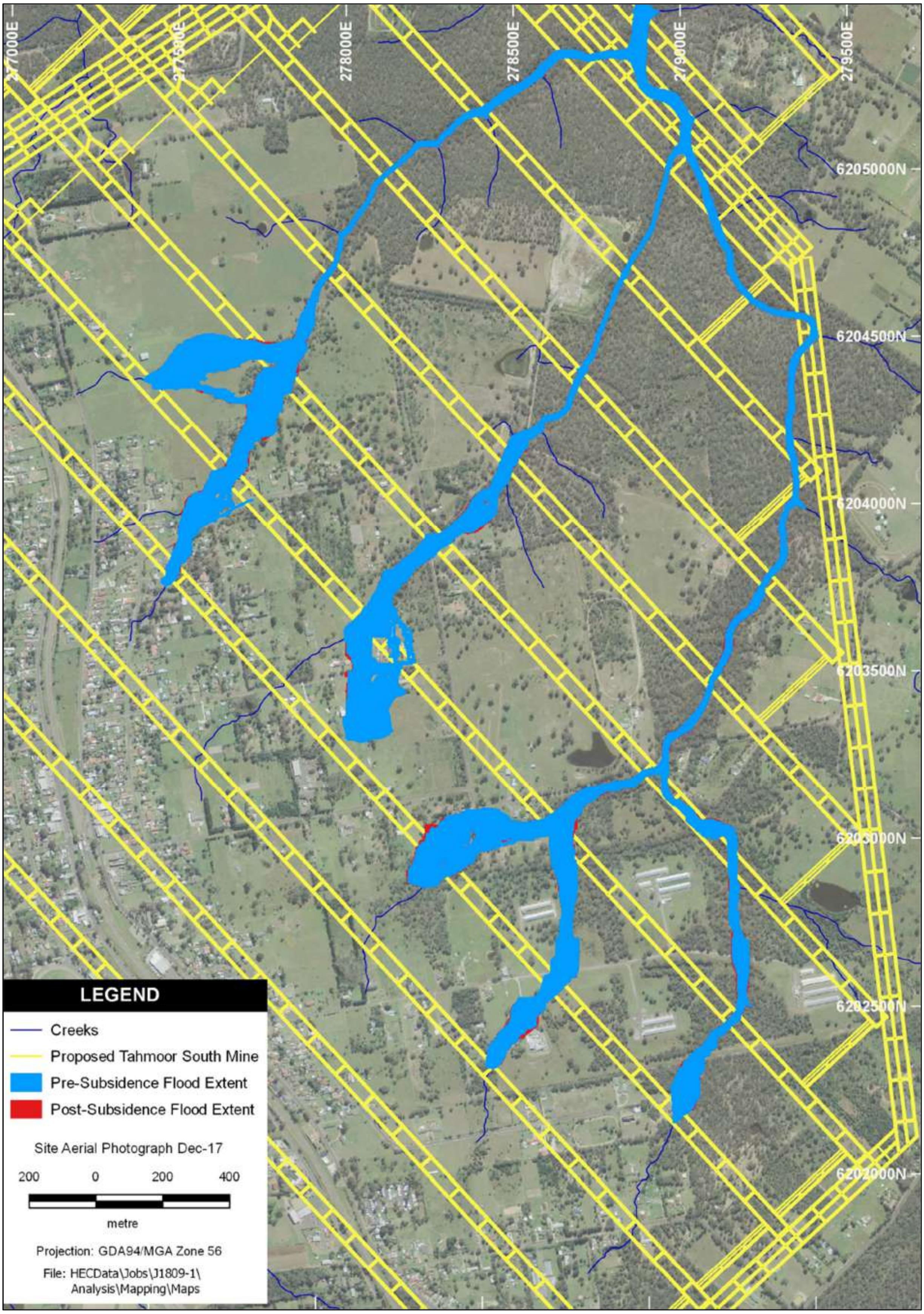

Figure A3: Extent of Predicted 0.5% AEP Flooding, Southern Part (upstream) - Dog Trap Creek

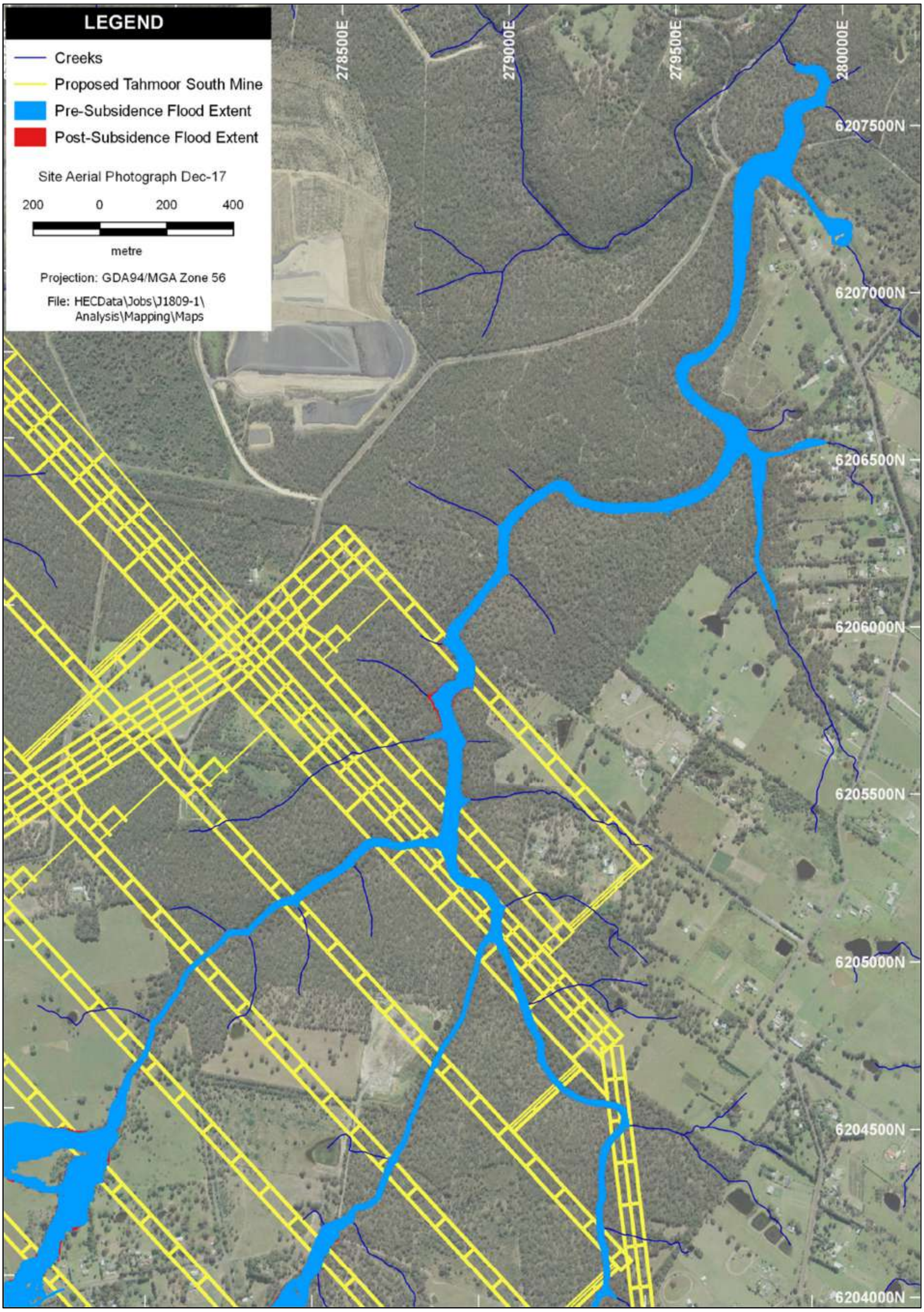

Figure A4: Extent of Predicted 0.5% AEP Flooding, Northern Part (downstream) - Dog Trap Creek

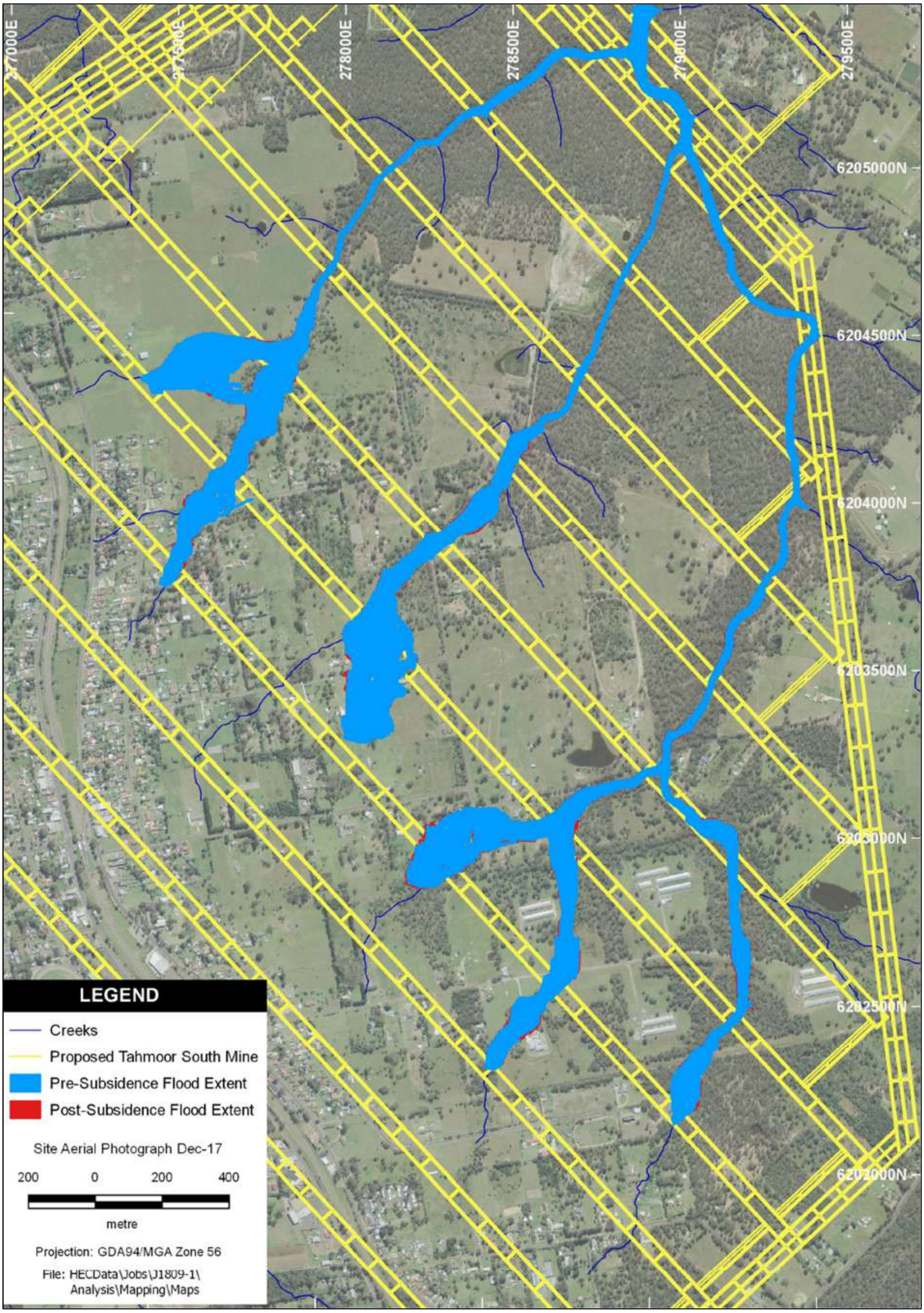

Figure A5: Extent of Predicted 0.2% AEP Flooding, Southern Part (upstream) - Dog Trap Creek

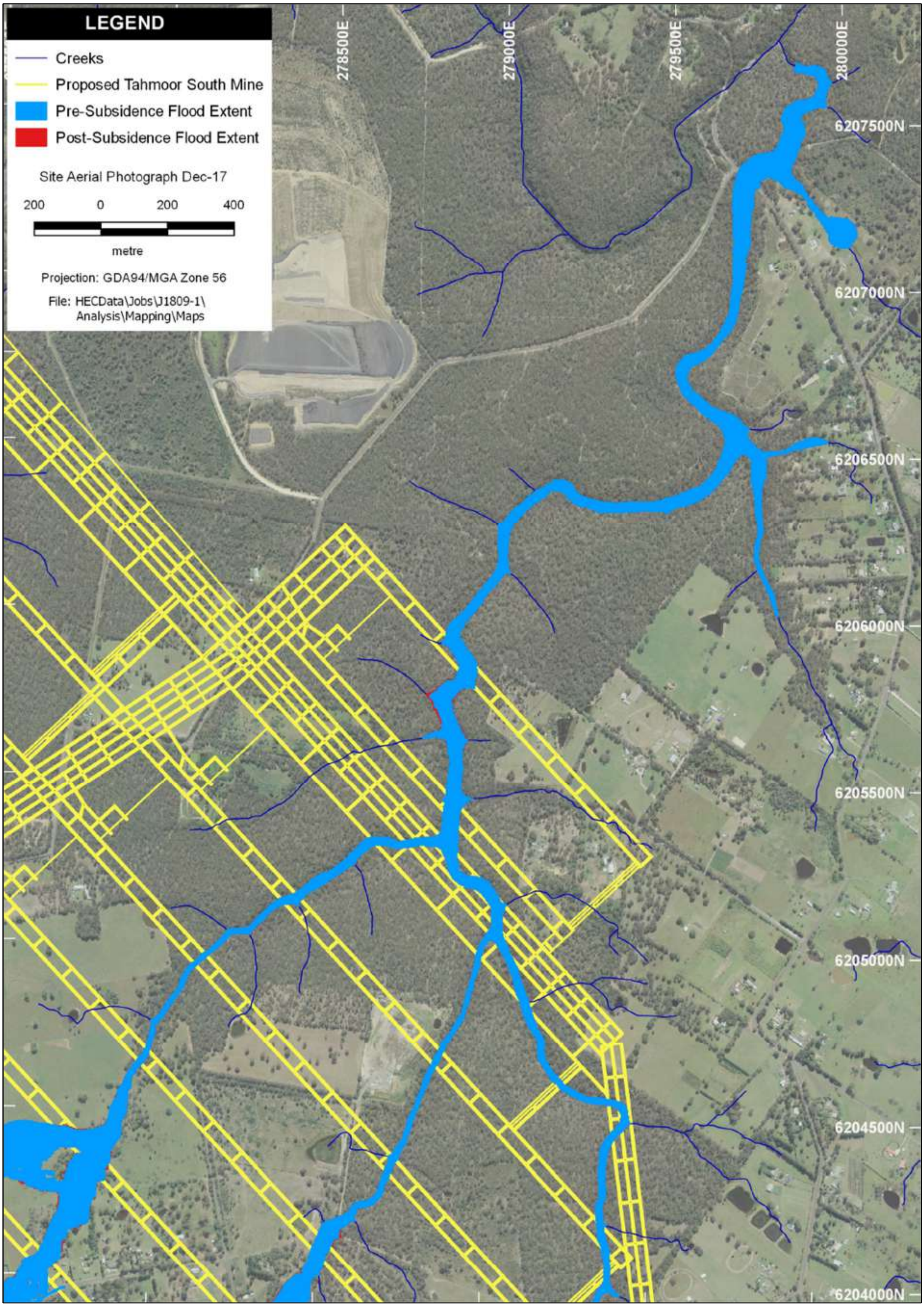

Figure A24: Extent of Predicted 0.2% AEP Flooding, Northern Part (downstream) - Dog Trap Creek

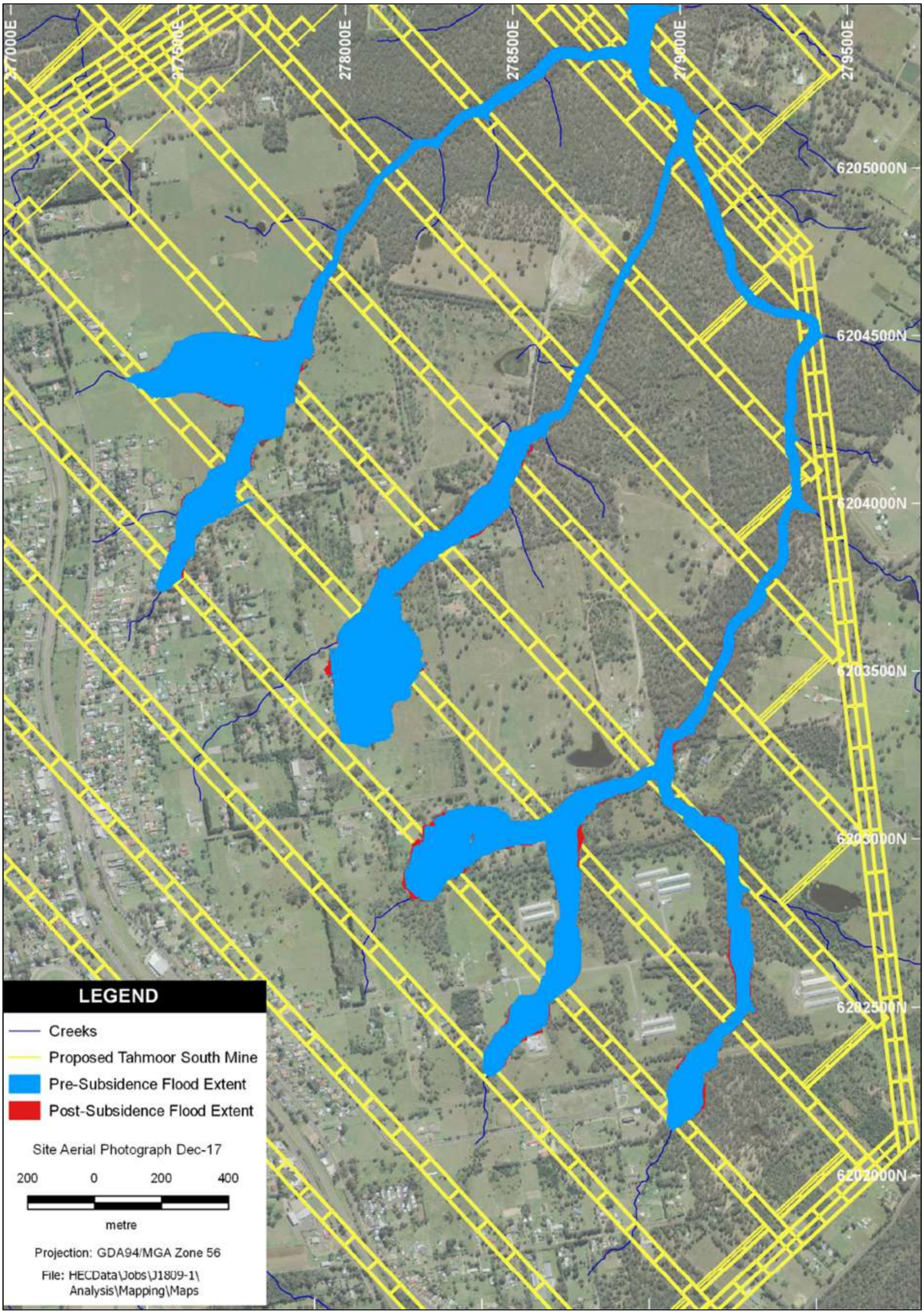

Figure A7: Extent of Predicted PMF Event Flooding, Southern Part (upstream) - Dog Trap Creek

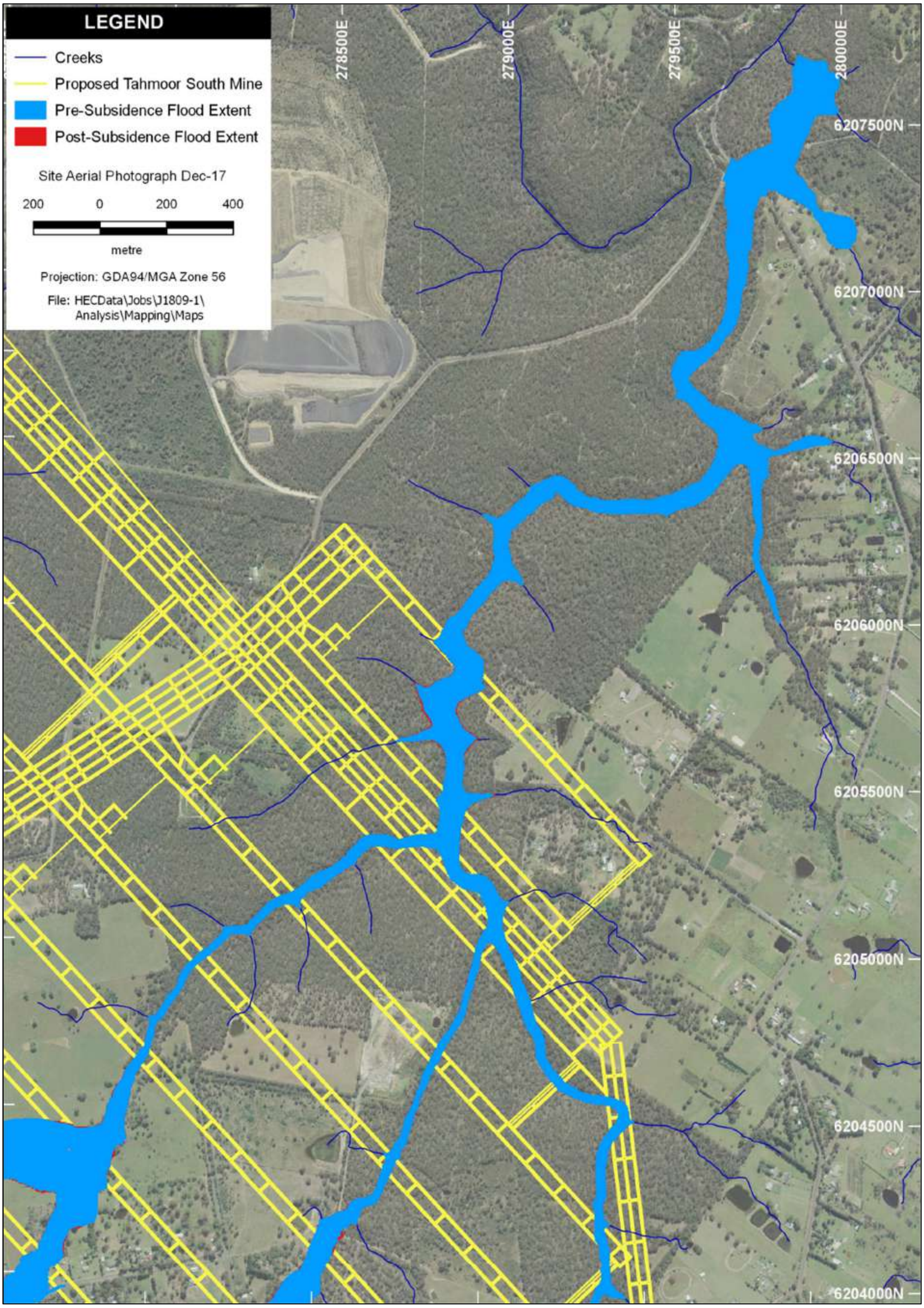

Figure A8: Extent of Predicted PMF Event Flooding, Northern Part (downstream) - Dog Trap Creek

APPENDIX A: TEA TREE HOLLOW

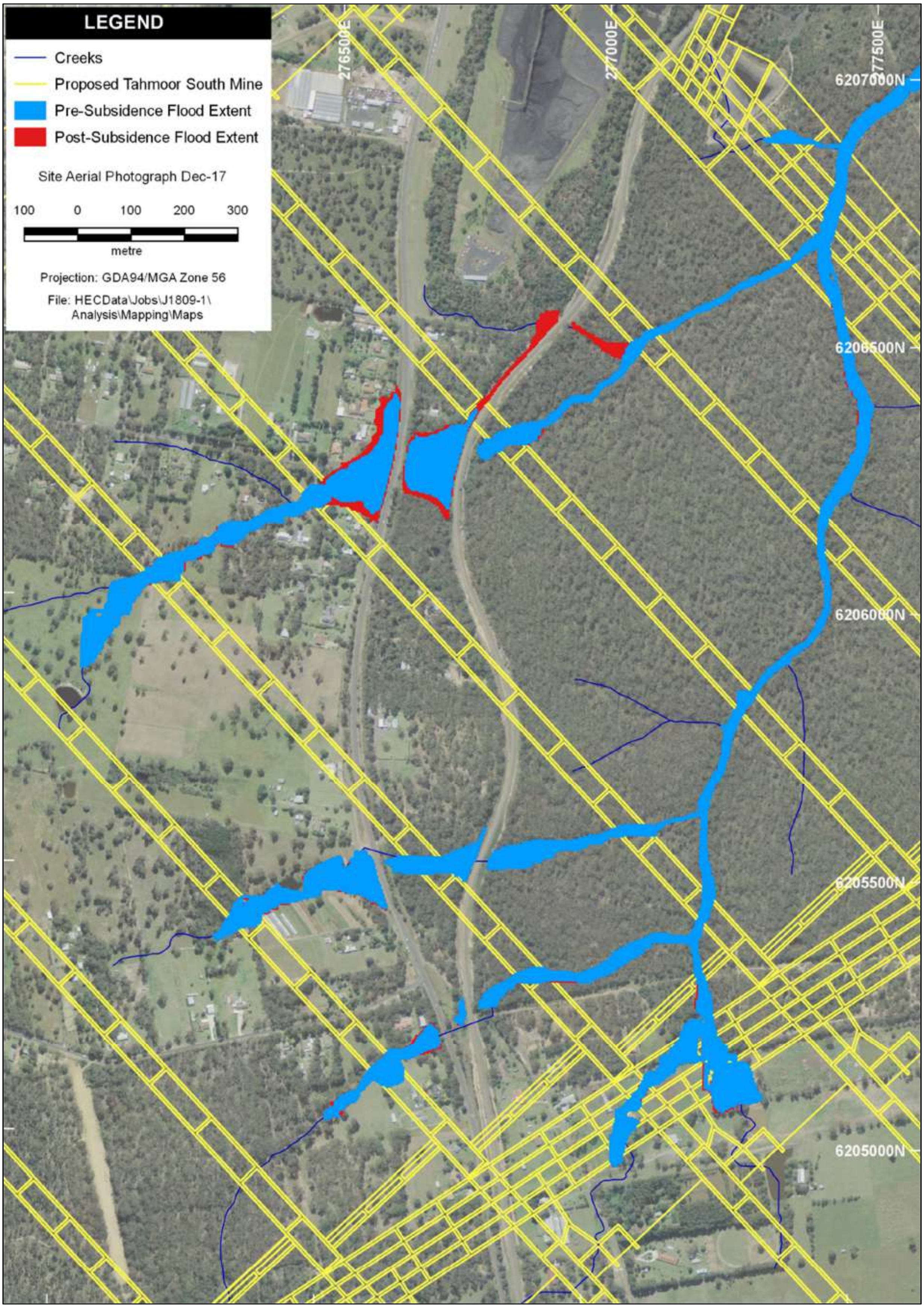

Figure A9: Extent of Predicted 10% AEP Flooding, Southern Part (upstream) – Tea Tree Hollow

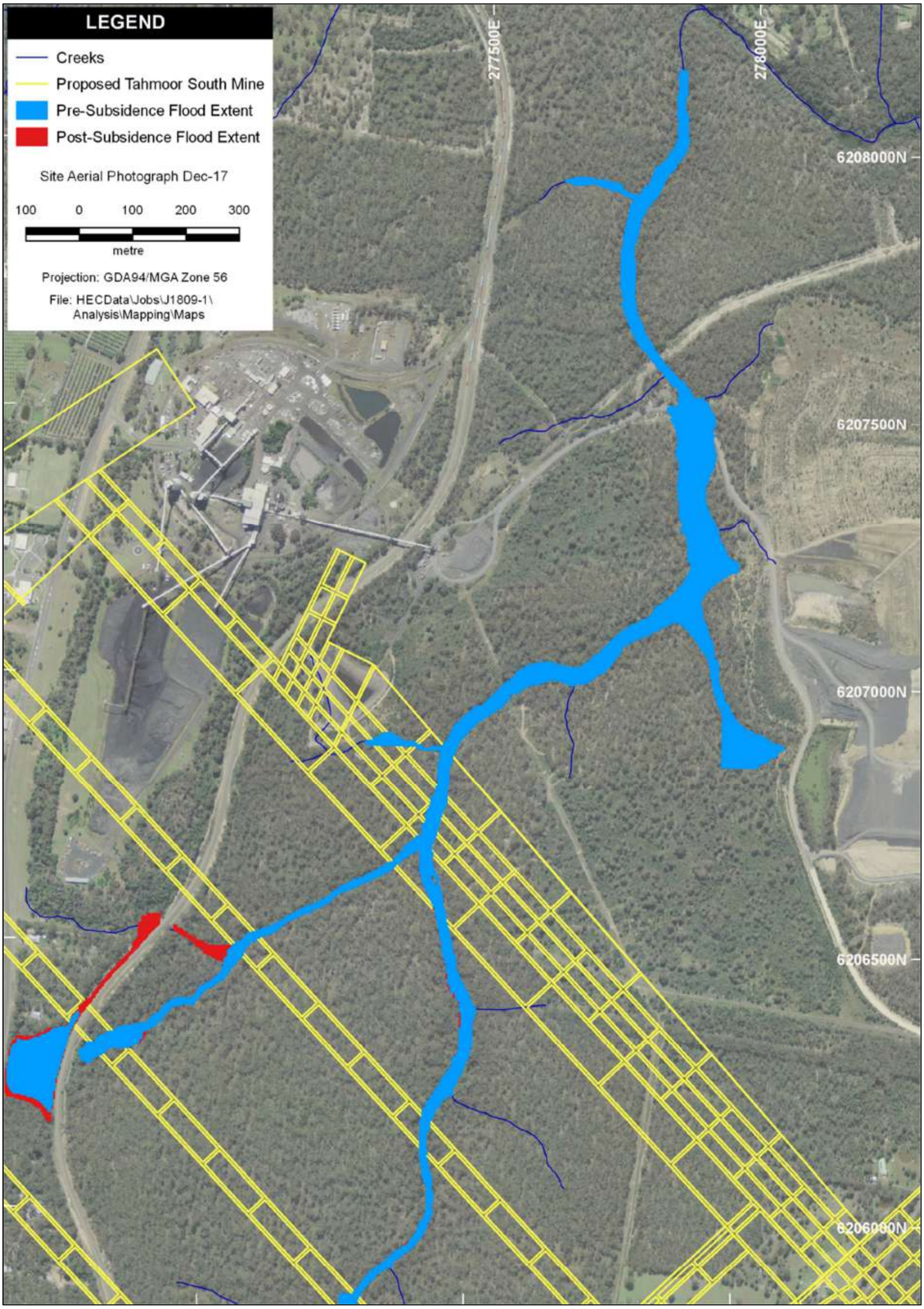

Figure A25: Extent of Predicted 10% AEP Flooding, Northern Part (downstream) – Tea Tree Hollow

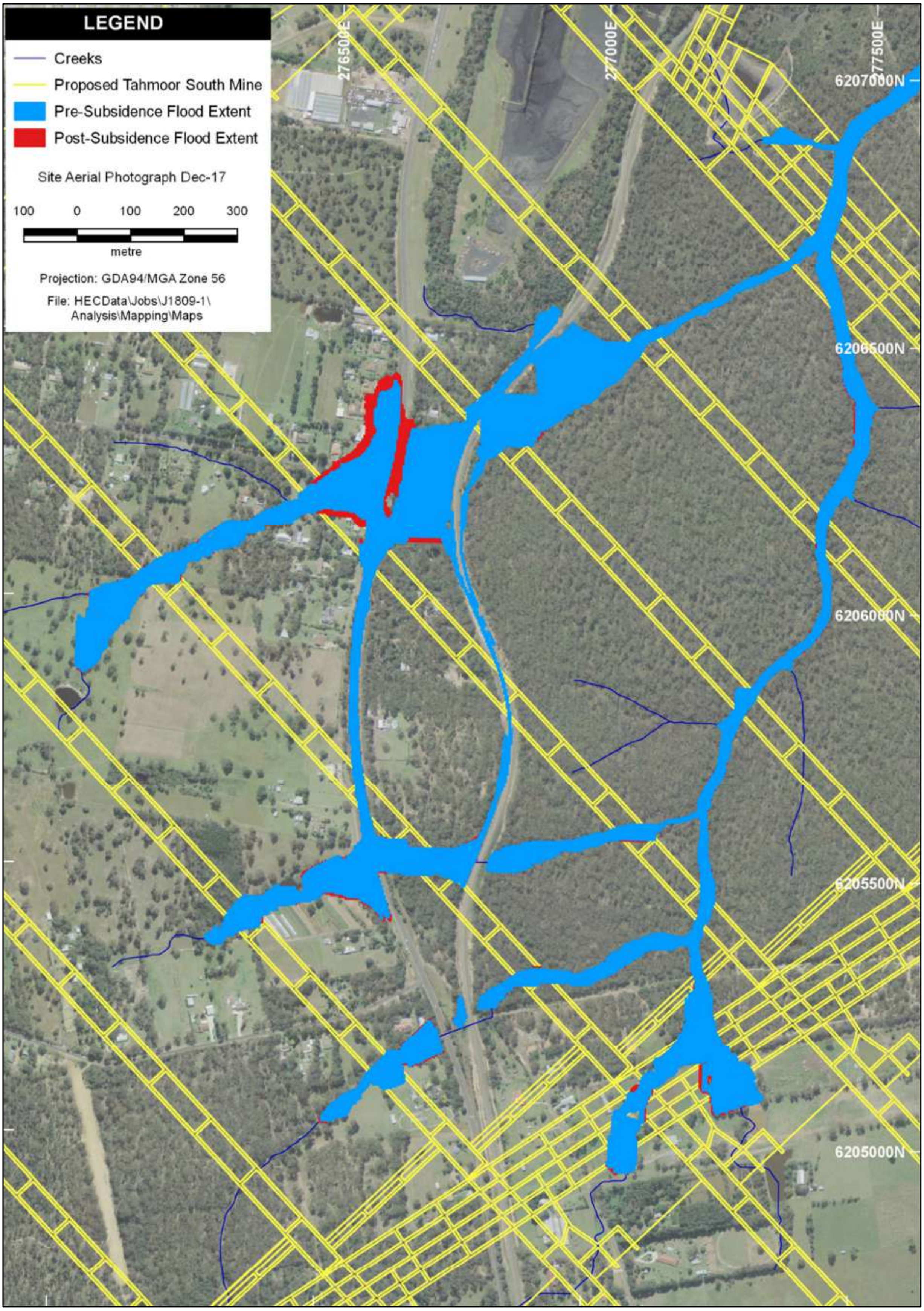

Figure A11: Extent of Predicted 0.5% AEP Flooding, Southern Part (upstream) – Tea Tree Hollow

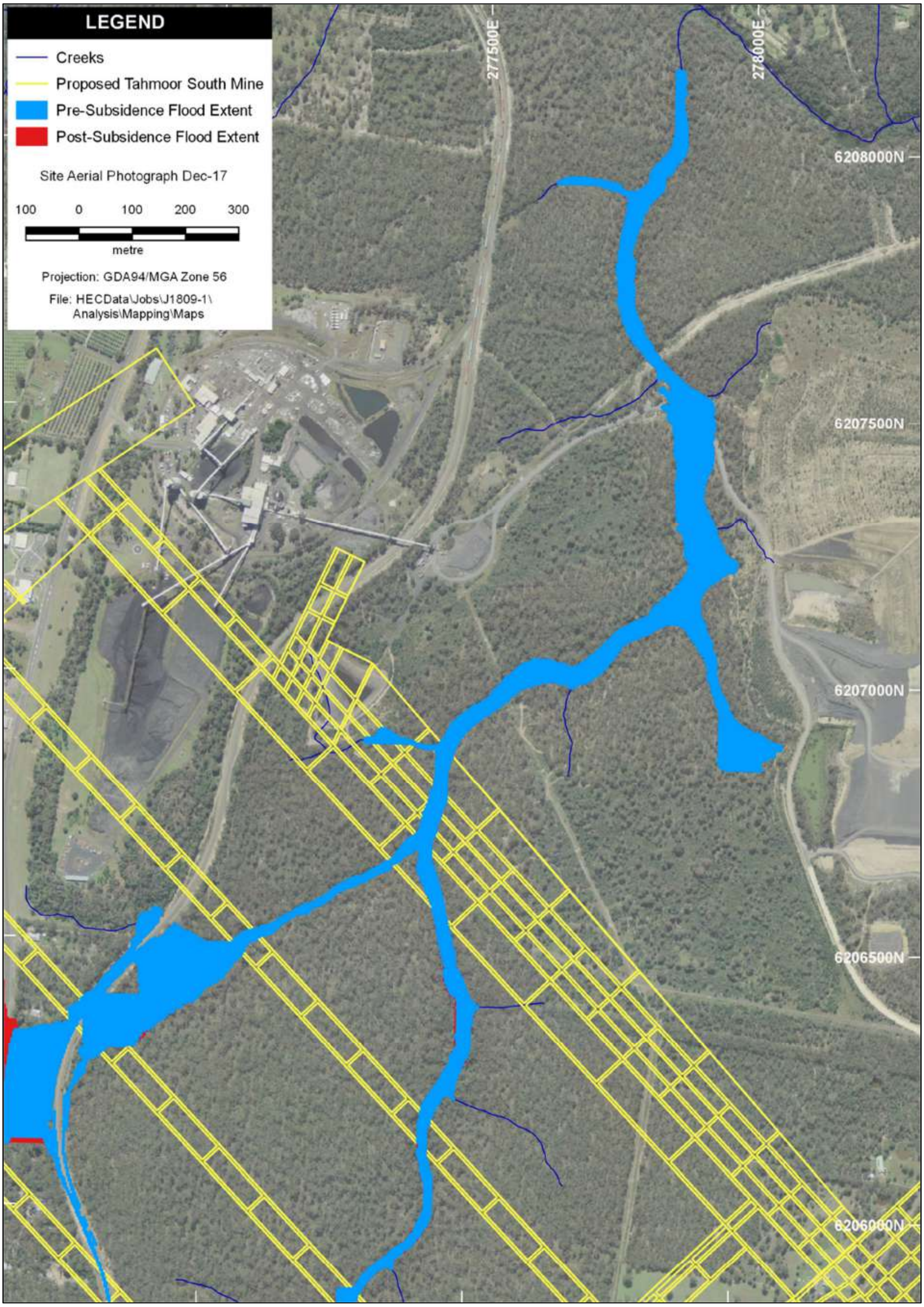

Figure A12: Extent of Predicted 0.5% AEP Flooding, Northern Part (downstream) – Tea Tree Hollow

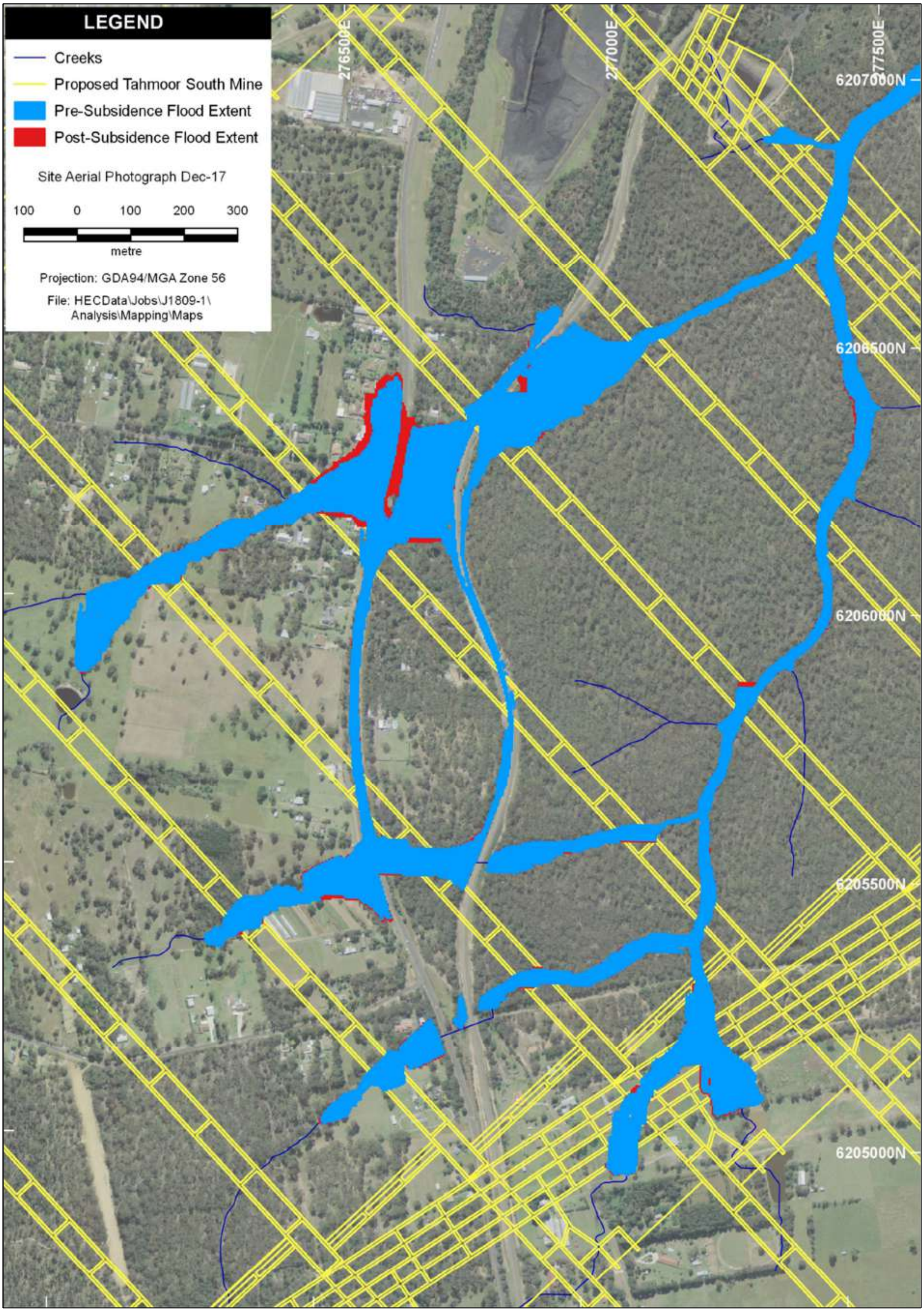

Figure A13: Extent of Predicted 0.2% AEP Flooding, Southern Part (upstream) – Tea Tree Hollow

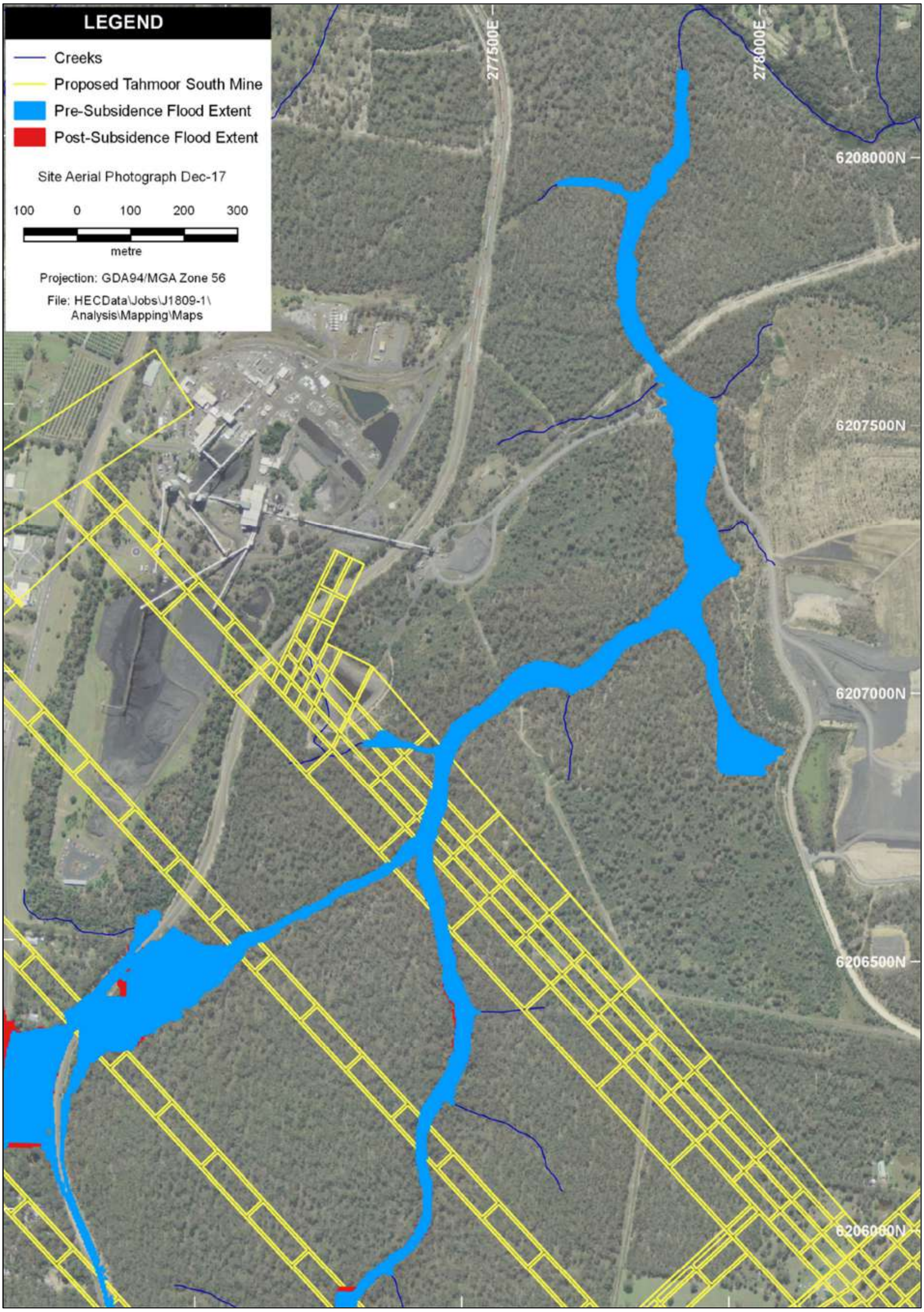

Figure A14: Extent of Predicted 0.2% AEP Flooding, Northern Part (downstream) – Tea Tree Hollow

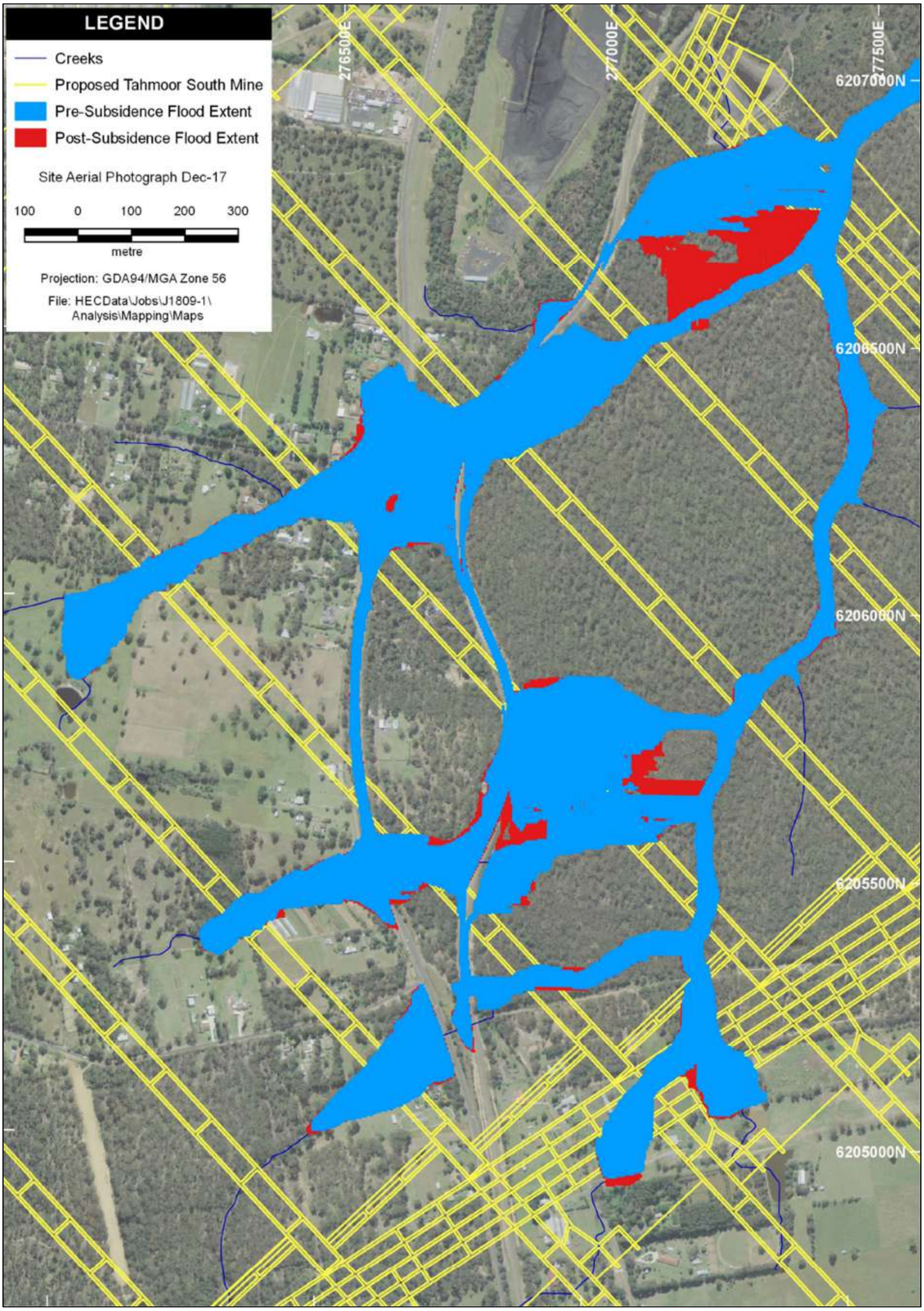

Figure A15: Extent of Predicted PMF Flooding, Southern Part (upstream) – Tea Tree Hollow

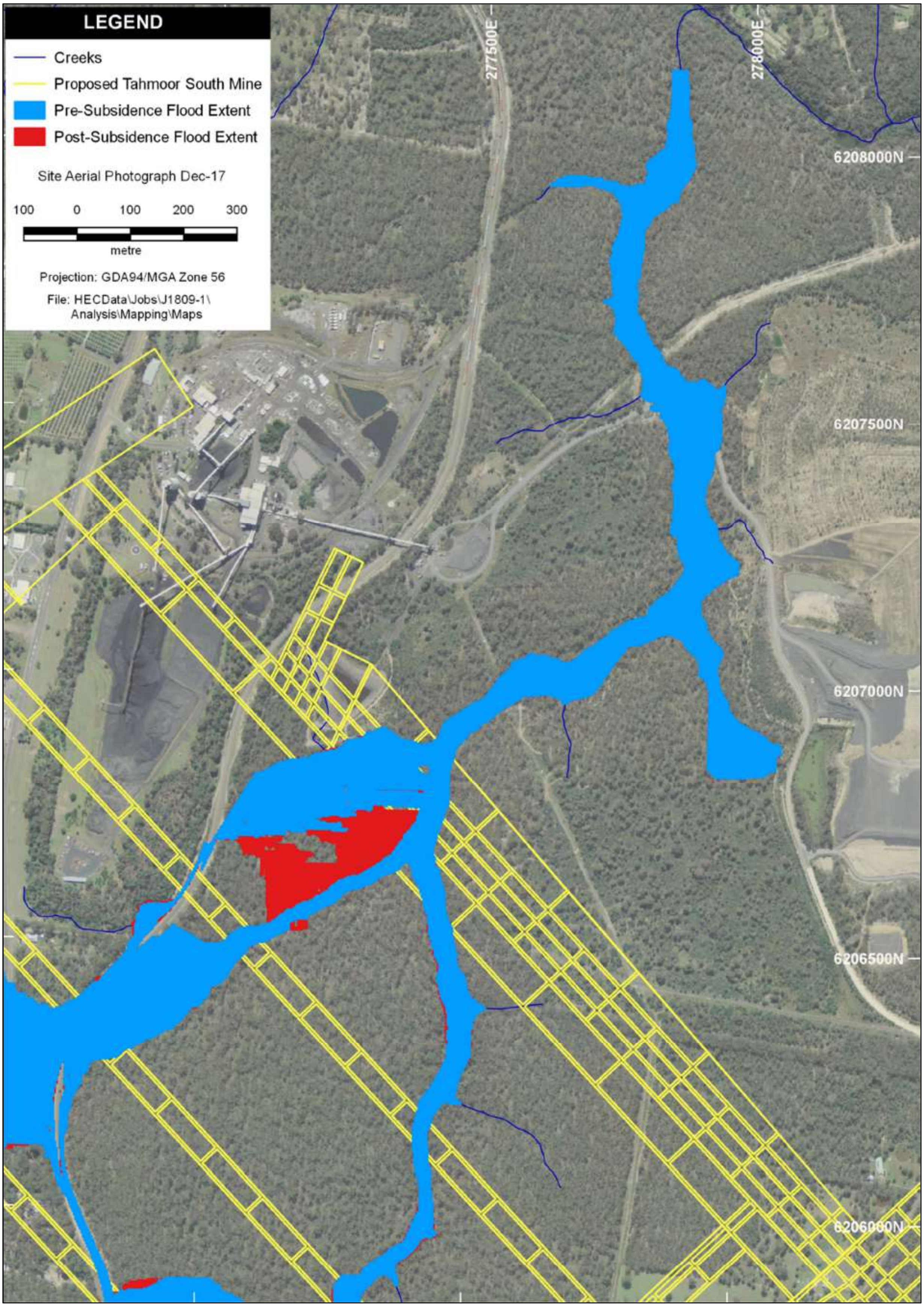

Figure A16: Extent of Predicted PMF Flooding, Northern Part (downstream) – Tea Tree Hollow

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REPORT

Tahmoor South EIS
Water Management System and Site Water Balance

Prepared for: Tahmoor Coal Pty Ltd

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Revision	Description	Author	Reviewer	Approved	Date
1	Draft	DNF / CAW	TSM	TSM	23 Oct 2018
2	Second draft	DNF / CAW	Tahmoor Coal, AECOM	TSM	1 Nov 2018
3	Final	DNF / CAW	-	TSM	16 Nov 2018

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1.0 INTRODUCTION

Hydro Engineering & Consulting Pty Ltd (HEC) has been commissioned by Tahmoor Coal Pty Limited (Tahmoor Coal) to complete a surface water assessment for the Tahmoor South Project (the Project). The purpose of this assessment is to complete the surface water assessment component of the Environmental Impact Statement (EIS) for the Project under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Surface Water Assessment has been undertaken in four parts.

- Baseline Assessment (BA) Report which documents the available baseline and background information and analysis of the climate, hydrology and water quality characteristics of local and regional water resources of relevance to the Tahmoor South Project.
- Water Management System and Site Water Balance Report (WMS/SWB) which describes the existing water management system, the proposed changes to site water management and the results of a water balance model simulation of the proposed water management system over the Project life including water supply reliability, the adequacy of the current discharge licence to Tea Tree Hollow to manage disposal of water during periods/circumstances when excesses are predicted and the risk of overflows under a wide range of climatic conditions which could occur during the Project life.
- Flood Study (FS) comprising an assessment of the effects of the Tahmoor South Project on flooding in overlying watercourses and their floodplains.
- Surface Water Impact Assessment Report (SWIA) which contains a detailed qualitative and quantitative assessment of the potential impacts which are either predicted to occur or could occur from the Project - including the effect of predicted subsidence on natural stream features, potential effects to catchment yield, flow diversion and stream water quality

This report details the Water Management System and Site Water Balance for the Tahmoor South Project Area. It describes the existing water management system, the proposed changes to site water management as a result of the Project and the results from the water balance model simulation of the proposed water management system over the Project life.

1.1 BACKGROUND AND OVERVIEW

Tahmoor Coal owns and operates the Tahmoor Mine, an underground coal mine approximately 80 kilometres (km) south-west of Sydney, in the Southern Coalfields of NSW. Tahmoor Coal produces up to three million tonnes per annum of product coal from its existing operations at the Tahmoor Mine, and undertakes underground mining under existing development consents, licences and the conditions of relevant mining leases.

Tahmoor Coal is seeking approval for the Tahmoor South Project, being the extension of underground coal mining at Tahmoor Mine, to the south and east of the existing Tahmoor Mine surface facilities area. The proposed development would continue to be accessed via the existing surface facilities at Tahmoor Mine, located between the towns of Tahmoor and Bargo.

The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2035. The proposal would enable mining to be undertaken within the southern portion of Tahmoor Coal's existing lease areas and for operations and employment of the current workforce to continue for a further 13 years.

The proposed development would extend mining at Tahmoor Mine within the Project Area, using longwall methods, with the continued use of ancillary infrastructure at the existing Tahmoor Mine surface facilities area. The Project Area is adjacent and to the south of the Existing Tahmoor Approved Mining Area. It also overlaps a small area of the Existing Tahmoor Approved Mining Area comprising the surface facilities area, historical workings and other existing mine infrastructure.

1.2 PROPOSED DEVELOPMENT

The proposed development would use longwall mining to extract coal from the Bulli seam within the bounds of CCL 716 and CCL 747. Coal extraction of up to 4 Mtpa ROM is proposed as part of the development. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing Coal Handling and Preparation Plant (CHPP) and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla for export to the international market.

The key components of the proposed development comprise:

- Mine development including underground redevelopment, ventilation shaft construction, pre-gas drainage and service connection;
- Longwall mining in the Project Area;
- Upgrades to the existing surface facilities area including:
    - upgrades to the CHPP;
    - expansion of the existing reject emplacement area (REA);
    - relocation of the rejects bin and extension of the rejects conveyor;
    - additional mobile plant for coal handling;
    - additions to the existing bathhouses, stores and associated access ways;
    - upgrades to onsite and offsite service infrastructure, including electrical supply;
- Rail transport of product coal to Port Kembla, and Newcastle (from time to time);
- Mine closure and rehabilitation; and
- Environmental management.

1.3 STUDY REQUIREMENTS

The Tahmoor South Project EIS has been prepared in accordance with Division 4.1, Part 4 of the EP&A Act which ensures that the potential environmental effects of a proposal are properly assessed and considered in the decision-making process.

The Surface Water Assessment is guided by the Secretary's Environmental Assessment Requirements (SEARs) for SSD 17_8445, including the amendment dated 14 February 2018 to incorporate the requirements of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Detailed agency comments have also been addressed in this and other component reports including comments from the NSW Environment Protection Authority (EPA), NSW Office of Environment & Heritage (OEH) and WaterNSW. The BA Report contains a summary of these requirements including where they have been addressed.

It is noted that since the preparation of the preliminary environmental assessment (PEA) for the Project (AECOM, 2012), the proposed mine plan for Tahmoor South has been amended to preclude mining and related subsidence within the Sydney Drinking Water Catchment, that is, within the catchment of Cow Creek, a tributary of the Nepean River upstream of Pheasant's Nest Weir. It is therefore concluded that there would be no surface water related impacts resulting from the Project on these catchments – refer also SWIA Report Section 14.

2.0 PROJECT DESCRIPTION

2.1 OVERVIEW

Tahmoor Coal is seeking approval for the continuation of mining at Tahmoor Mine, extending underground operations and associated infrastructure south within the Bargo area (refer Figure 1). The proposed development seeks to extend the life of underground mining at Tahmoor Mine for an additional 13 years until approximately 2035.

The proposed development will use longwall mining to extract coal from the Bulli seam within the bounds of CCL716 and CCL747. Coal extraction of up to 4 million tonnes of run-of-mine (ROM) coal per annum is proposed as part of the development with extraction of up to 37 Mt of ROM coal over the life of the Project.

The proposed Project would utilise the existing surface infrastructure at the Tahmoor Mine surface facilities area, with some upgrades proposed to facilitate the extension. The proposed Project also incorporates the planning for rehabilitation and mine closure once mining ceases.

2.2 UNDERGROUND MINING OPERATIONS

2.2.1 Mining Area

Tahmoor Coal holds CCL 747 and CCL 716. The Project proposes to mine coal from the Bulli seam at a depth of between approximately 375 m and 430 m below ground level. The proposed mining area is bounded by known geological fault zones.

During the mine planning process, a constraints analysis, risk assessment and preliminary fieldwork were undertaken to identify sensitive natural surface features (such as waterways, cliffs, and Aboriginal heritage sites) and to develop Risk Management Zones (RMZs). Subsequent to the risk assessment the proposed longwall layout was modified to minimise significant subsidence impacts to these natural features.

The longwalls would be orientated in a south-east/north-west direction and would be located within the Bargo area. The longwall layout would continue to be refined during the detailed design phase of the proposed development. However, the maximum extent of longwall mining for the proposed development would be as depicted on Figure 1.

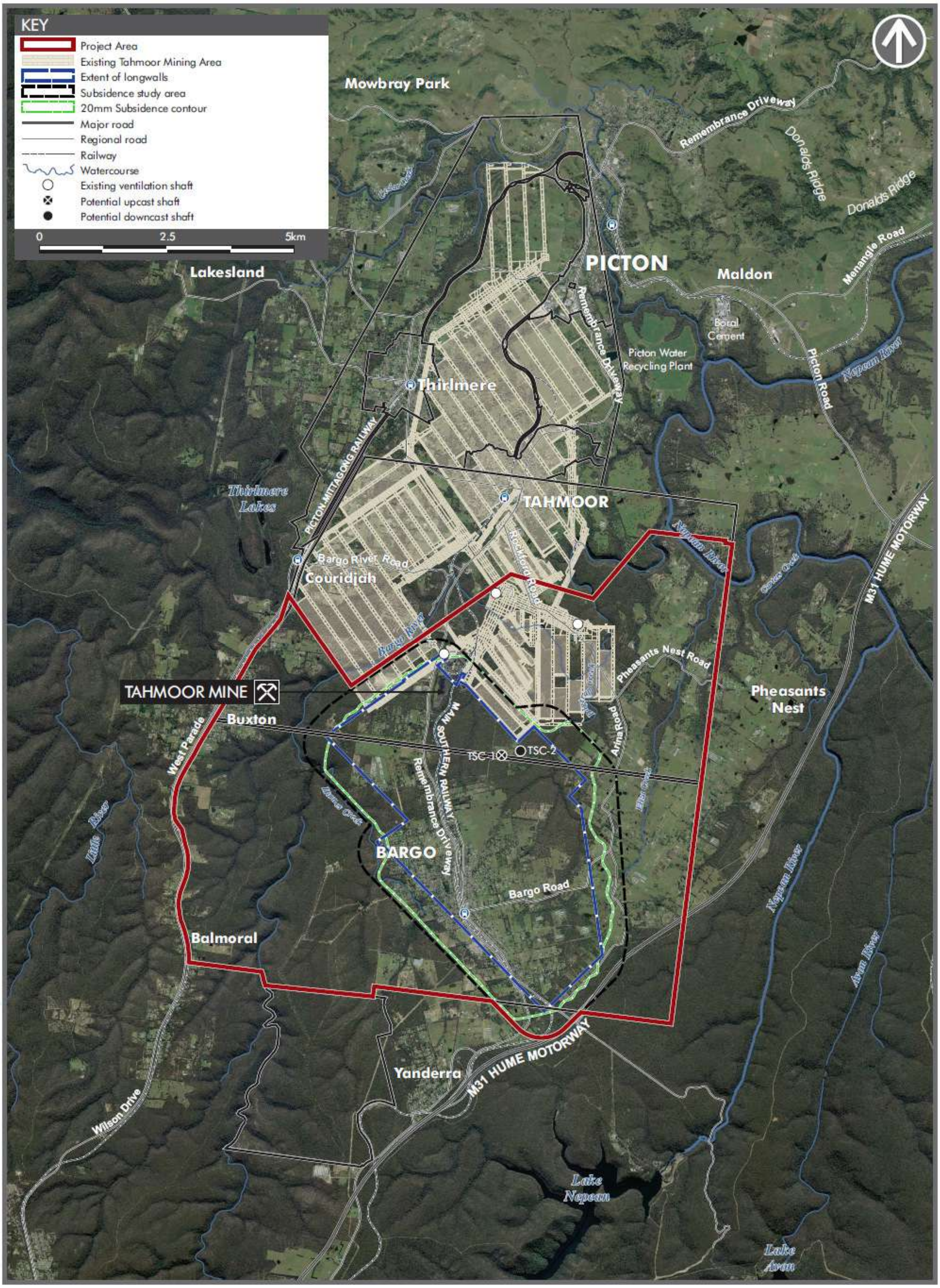

Figure 1 Locality Plan and Project Layout

As part of the proposed development, subsidence predictions have been undertaken for residential, commercial and business structures, public infrastructure such as pools and public amenities, utility services such as water and gas mains, and other associated infrastructure. These predictions and potential impacts would be captured within a subsidence management plan (SMP) prior to longwall mining for the proposed development and would incorporate the management measures identified herein.

2.2.2 Mine Development

To enable the continuation of mining to occur sequentially with the current mining operations in Tahmoor North, which are scheduled for completion in approximately 2022, the Project's development works need to commence in approximately 2019. Pre-development activities include:

- recovery of existing underground development roadways;
- redevelopment of the underground pit bottom;
- pre-gas drainage;
- longwall development including establishment of gate roads;
- installation of electrical, water and gas management networks; and
- the purchase and installation of equipment.

An additional 50 to 175 personnel would be required for the Project's development works, which may occur concurrently with the ongoing mining operations at Tahmoor North. Additional site amenities, including bath houses and additional onsite car parks would be required to accommodate the increased workforce during the transition period from mining operations at Tahmoor North and the Project's development works.

During this transition period, other site infrastructure required for longwall mining at the Project would be constructed. Specifically, this would include construction of new mine ventilation shafts, construction of a hardstand area for longwall machinery set up and upgrades to the CHPP.

2.2.3 Mine Ventilation

The proposed development would utilise the existing mine's ventilation system, including the existing three ventilation shafts, being one upcast (T2) and two downcast shafts (T1 and T3). Additionally, the proposed development would require the construction of two ventilation shafts to provide a reliable and adequate supply of ventilation air to personnel in the mine. The two additional vent shafts proposed for the Project are:

- TSC1: an upcast ventilation shaft that will be located on Tahmoor Coal's Charlies Point Road property; and
- TSC2: a downcast ventilation shaft that will be located on Crown Land adjacent to Tahmoor Coal's Charlies Point Road property.

The proposed locations of the ventilation shafts are shown on Figure 1.

The construction of the ventilation shafts would require the disturbance of an area of between four to six hectares at each location. Access to TSC1 and TSC2 would be from the existing road network.

Construction and operational water management for these sites is described in Section 4.4.

2.2.4 Gas Drainage Operations

Coal mines need to control underground gas concentration levels to below safe limits so that miners are able to work in a safe environment and mining operations can be undertaken as efficiently as possible.

The coal seams within the Southern Coalfield are generally known to be gassy, with methane and carbon dioxide released from the goaf during mining. Gas in the underground workings would be managed by a series of gas drainage operations including:

- pre-gas drainage, whereby gas would be extracted from the coal seam prior to longwall mining;
- post-gas drainage, whereby gas would be extracted from the goaf; and
- gas extraction via the mine ventilation system, which would occur throughout mining.

Gas management would continue to use the existing infrastructure, including the Tahmoor Mine Gas Plant, Gas Plant Vent and Flare Plant, as well as the WCMG Power Plant when it is available. Some components of the existing gas management infrastructure may need to be upgraded throughout the life of the proposed development

2.2.5 Pre-Gas Drainage

The purpose of pre-gas drainage is to reduce gas volumes in the coal seams prior to mining, with the Bulli, Wongawilli and Balgownie seams targeted for pre-gas drainage at Tahmoor Mine. Pre-gas drainage of the gas levels in the seams is required to facilitate the timely commencement and progression of mining as well as to reduce the demands on the mine ventilation system for the purpose of gas dilution during operations.

Pre-gas drainage activities are mainly undertaken underground, via drilling and drainage from the roadways developed for longwall panels. Underground pre-gas drainage works at Tahmoor Mine would drain gas following development of the mine roadways and prior to longwall development. Gas would be drawn from the coal seam by vacuum and piped to the Gas Plant at the surface facilities area via the underground pipe network. Underground gas drainage of the coal seam would continue ahead of longwall development for the life of mining.

Surface pre-gas drainage works are proposed for the eastern portion of the Tahmoor South Mine area. Extracted gas would be brought to the surface and transferred via a pipeline to the existing gas plant at the Tahmoor Mine. To enable gas to be released from the seam during pre-gas drainage, the coal seam would be dewatered via horizontal drilling within the seam. The drained water would be collected on the surface and transferred to the existing water management system at the surface facilities area via an overland pipeline or truck.

Two Surface to Inseam (SIS) drilling sites and gas well sites are proposed, subject to the final detailed design of the development mains. SIS drilling and gas well sites are subject to obtaining land access agreements and therefore flexibility is required for the location of these works. The gas collection pipeline is proposed to be constructed within a trench alongside the public roadway and potential exists for alternative locations.

Gas from the coal seam would be drained using pumps, collected at the surface and piped to the existing Gas Plant at the Tahmoor Mine surface facilities area to be used in the WCMG Power Plant or Gas Fare Plant.

2.2.6 Post-Gas Drainage

Post-gas drainage would be required as strata relaxation caused by the retreating underground longwall face would liberate volumes of gas into the mine workings from the underlying Wongawilli seam and from overlying strata, released due to fracturing of the goaf. To capture this gas during the proposed development, cross-measure boreholes are proposed to be drilled from the mine workings into the Wongawilli seam. These boreholes would be designed to collect the gas at its source or to intercept gas before it migrates into the mine workings. At the conclusion of mining from each panel, the panel would be sealed and gas drawn from the sealed areas as part of the post-gas drainage operations. The gas collected from the in-seam and cross-measure boreholes would be drawn by vacuum via the underground pipe network to the Gas Plant located at the surface facilities area.

2.2.7 Gas in Ventilation

The ventilation system would deliver fresh air into the mine from the existing and proposed downcast vent shafts and would extract stale air from the mine via the existing and proposed upcast vent shafts (refer Section 2.2.3). Similar to the existing operations, the ventilation system would carry the remaining diluted gases out of the mine via the upcast mine vent shafts.

2.2.8 Mining Method and Equipment

Underground mining would be undertaken via main roadway and longwall development using continuous miners. Longwall development refers to the mining of a series of roadways (gate roads) and cut-throughs, to form pillars of coal that would support the overlying strata during the extraction of coal. Longwalls would be up to 305 m wide. The gate roads would be approximately 5.2 m wide and approximately 3 m high.

Coal would be cut from the coal face by the longwall shearer, loaded onto the armoured face conveyor and transported to the surface facilities area via a series of underground conveyors. The longwall would retreat as coal is mined and the overlying rock strata would collapse into the void left by the coal extraction, forming the goaf.

A new hardstand area would be constructed adjacent to the existing southern coal stockpile at the surface facilities area to cater for the delivery and assemblage of mining equipment and the storage of equipment.

Tahmoor Coal would continue to investigate improved or alternate mining methods and technology throughout the life of the proposed development. Improved methods would be utilised where available to allow for the efficient and economically viable extraction of the coal resource. Tahmoor Coal would ensure that the resulting environmental and social impacts of improved or alternate methods are consistent with those predicted in this EIS

2.2.9 Mine Access

The proposed development would use the existing infrastructure at Tahmoor Mine for employee and material access to the mine. Access to the Tahmoor South Mine would be via the existing Tahmoor Mine surface facilities area, the existing drift and men and materials travel lift installed within the T3 downcast shaft. The T3 vertical men and material travel lift has a capacity for 70 persons and approximately 12 tonnes of materials.

2.2.10 Coal Production

Tahmoor Coal is a shareholder of Port Kembla Coal Terminal and has contractual arrangements in place for coal export associated with the proposed output from the Project.

The proposed development would transport product coal from Tahmoor Mine to Port Kembla, via the existing mine rail load out, rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway.

Tahmoor Mine currently has four allocated train paths per day from ARTC for the rail network between the Tahmoor Mine and Port Kembla. This current allocation is equivalent to the transport of approximately four million tonnes of product coal per annum and is sufficient for the life of the Tahmoor South Project. A rail transport study has been undertaken for the proposed development, which indicates that the existing rail capacity would be sufficient for the proposed transport of product coal to Port Kembla under the proposed development, and no increase in rail capacity between Tahmoor Mine and Port Kembla would be required. As such, existing rail infrastructure and the number of allowable train movements would remain unchanged

2.3 SURFACE FACILITIES AREA

The existing surface facilities and infrastructure at the Tahmoor Mine surface facilities area, operating within surface CCL 716 and Mining Lease 1642, would be utilised for the proposed development.

Upgrades to some aspects of the surface facilities area would be required and are associated with the increase in annual coal production for the proposed development. Upgrades to existing surface infrastructure would be undertaken within the existing Tahmoor Mine surface lease area (Mining Lease 1642) and additional surface lease areas required for the proposed development. The proposed upgrades are described in the following sub-sections.

2.3.1 Coal Handling and Preparation Plant

The existing CHPP would be utilised for the proposed development. The existing CHPP would be upgraded including the installation of:

- a new coarse rejects screen,
- additional belt press filter capacity, and
- an increase in thickener capacity.

The existing ROM stockpile area would continue to be utilised by the proposed development. During peak production ROM coal may be trucked from the ROM stockpile to the coal product stockpiles and re-trucked back to the ROM stockpile when required. Reject material generated from the coal washing process at the CHPP would be transported to the expanded REA via the existing reject conveyor to the reject bin for disposal, then transported by haul truck to the REA.

2.3.2 Rejects Management

The existing REA would be expanded onto adjacent areas to accommodate the reject material associated with the proposed development. The expansion area is anticipated to cover up to an additional 43 hectares, providing an additional emplacement capacity of approximately 12 Mt for the rejects generated during the operation of the proposed development.

Construction and maintenance of new internal haul roads would be required to cater for the REA expansion.

The stormwater management system and infrastructure at the existing REA would be augmented with the construction of additional sedimentation dams, drains and pumping station.

2.3.3 Plant and Equipment

The proposed development would utilise existing plant and equipment at the surface facilities area and would also require additional mobile plant for coal material handling at the surface facilities area. The proposed additional plant would include:

- a secondary bulldozer at the product coal stockpile.
- additional ancillary equipment such as trucks, cranes and forklifts for use around the surface facilities area to manage product and equipment stores.

2.3.4 Hours of Operation

The proposed development, including construction activities, would to operate 24 hours a day, seven days per week, consistent with the working hours of the current operations at the Tahmoor Mine.

3.0 EXISTING WATER MANAGEMENT SYSTEM

The water management system at the existing Tahmoor Coal Mine comprises the combined infrastructure and management measures which are employed to manage water on the site and the movement of water onto and off the site. There is currently one licensed discharge point (LDP1) and three licensed overflow points (LOP3, LOP4 and LOP5) which have been authorised for controlled and uncontrolled releases (respectively) to be made from the mine site at specified locations and specified conditions under Environment Protection Licence (EPL) 1389 issued to Tahmoor Coal[1]. Details of the LDP and LOPs are provided in Section 3.5.

The existing site water management system is documented in the site water management plan and is described below.

3.1 PIT TOP AREA

The pit top area is predominantly located within the rail loop – refer Figure 2. The pit top encompasses the main surface operations including the CHPP, workshop, warehouse, storage yard areas and sediment dams M1, M2, M3 & M4 – refer Figure 2. The dams are interconnected such that dam M1 flows into M2 and M2 flows into M3 and finally M3 flows into M4. The pit top area dams are dosed with coagulant to enhance sediment settling and improve discharge water quality.

The CHPP incorporates screening and cyclone circuits to remove overburden and inter-burden rock fragments. The CHPP also separates the coal into coking and thermal products. Coal wash reject material is produced as a waste stream from the CHPP. The fine rejects are dewatered in the CHPP using a belt filter press prior to being combined with coarse rejects. This material is conveyed to a transit area on the eastern side of the rail loop prior to being trucked and placed in the REA.

Runoff from the workshop area and waste oil tank/storage area reports to an oil water separator. Treated water from the separator reports to dam M1, while the recovered waste oil is transferred to an above ground waste oil tank prior to disposal off site. Runoff from the remaining pit top area, including the ROM coal stockpile area and the CHPP, drains to dams M2, M3 and M4. Excess water in M4 is discharged to Tea Tree Hollow via LDP1. A binding agent “PetroTac” is used to control dust emissions and suspended sediment in runoff from the Pit Top area.

The Gas Drainage Plant and Envirogen Power Station are located adjacent to the mine pit top area – refer Figure 2. Drainage from this area reports to a surface drain on the outside of the rail loop which discharges to Tea Tree Hollow via LDP1.

Drainage from the product coal stockpile area drains into retention dams S2 and S3. Water overflows from these storages and flows into the larger retention dam S4 from where water is automatically dosed with a flocculant prior to discharge to Tea Tree Hollow via LOP4.

A package sewage treatment plant, located near dam M1, is used to treat sewage from the mine production offices, mine bathhouses and the CHPP. Treated effluent from the sewage treatment plant is discharged into two maturation ponds which overflow to dam M1. A separate septic treatment system is used to treat sewage from the demountable offices located on site.

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[1] Environment Protection Authority – NSW, Licence 1389, version date: 20-Nov-2017.

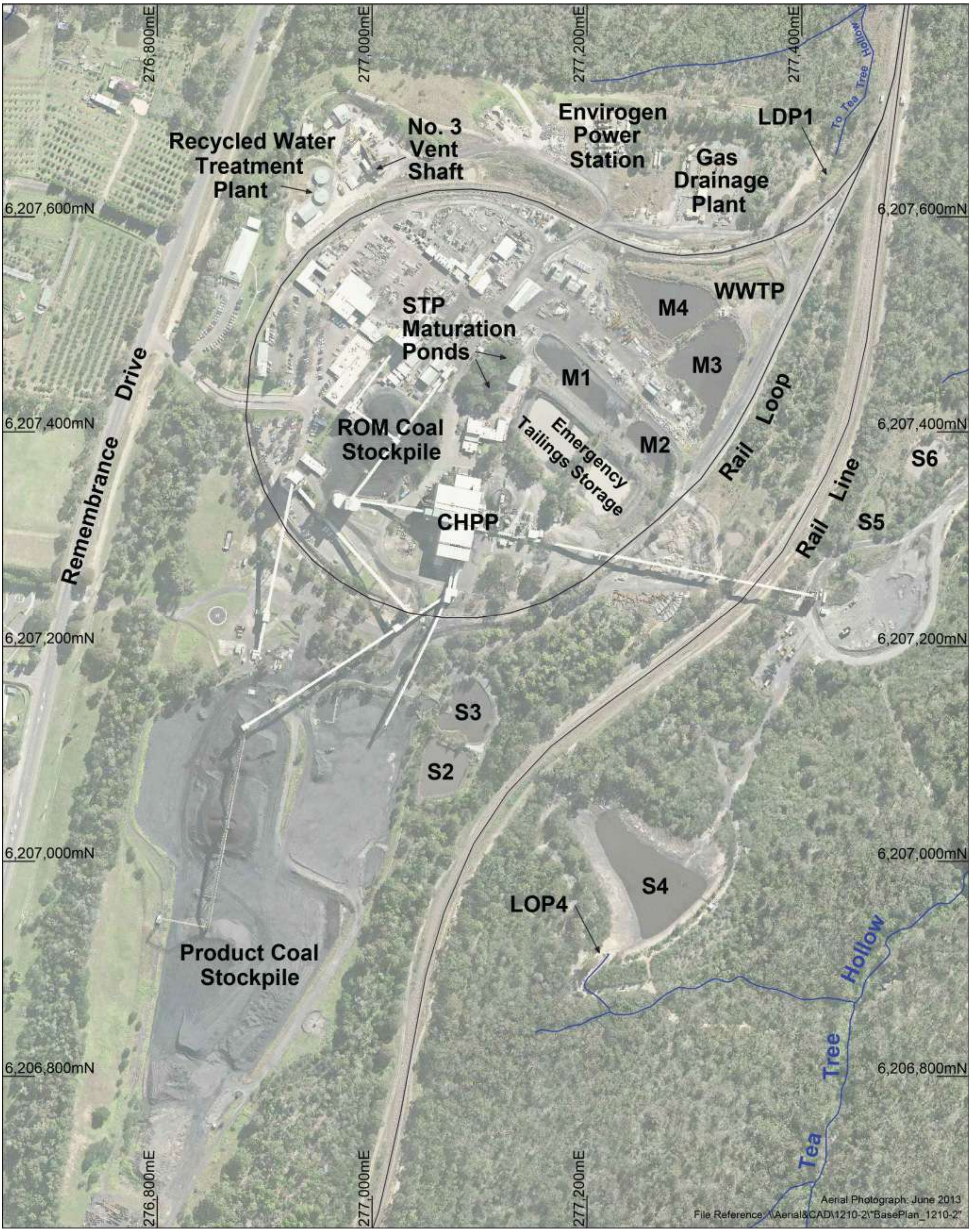

Figure 2 Layout of Existing Pit Top Area and Water Management Infrastructure

Water required in the CHPP is supplied (recycled) from dam M4. A small additional raw water demand for pump glands, flocculation and reagent dosing is supplied by Sydney Water. Water in M4 is also pumped to a truckfill point near the REA for dust suppression on the haul road to the REA and on the REA itself. Water for dust suppression on the product coal stockpile area is drawn from dams S2/S3.

The underground mining operation currently uses approximately 1.2 ML/day of water. Approximately 1 ML/day of this is used for dust suppression on the coal face, for drilling, wash down and other miscellaneous uses underground. The remaining 0.2 ML/day is potable water used in the longwall machine and is supplied by Sydney Water. A Recycled Water Treatment Plant was constructed in an area adjacent to the rail loop in 2012 to treat a proportion of the water recovered from the underground mine and to recycle it back underground for non-potable uses. Recovered water in excess of the non-potable underground demand (currently about 3 ML/day) is directed to dam M1. The Recycled Water Treatment Plant has an operational capacity to produce 1 ML/day.

The majority of excess water discharge from site occurs via LDP1. As part of EPL 1389, there is a requirement to enhance treatment of water prior to release via Pollution Reduction Program 22 which involves the development and commissioning of a waste water treatment plant (WWTP) to reduce the concentrations of arsenic, nickel and zinc in mine water released from LDP1. The WWTP was constructed in June 2015 to treat up to 6 ML/d of mine water drawn from sediment dam M3. The treatment objectives were to reduce the metals concentrations to the following maximum levels:

- Arsenic: 0.013 mg/L
- Nickel: 0.011 mg/L
- Zinc: 0.008 mg/L

Work has commenced on modifications to the WWTP and these are scheduled for completion in November 2018.

3.2 VENTILATION SHAFTS

There are three ventilation shafts servicing the underground mining operations. No. 1 Shaft is located on Stratford Road, Tahmoor and is considered to be a clean water catchment devoid of potential surface water contaminants. Stormwater runoff from the No. 1 Ventilation Shaft area drains to the Bargo River[2]. No. 2 Shaft is located on Rockford Road, Tahmoor (refer Figure 3). The No.2 Shaft is the main up-cast ventilation fan. Runoff from the surface area around the No.2 Ventilation Shaft drains via a surface drain to sediment dams M5 and M6 for settling. These storages overflow to the Bargo River. The No.3 ventilation shaft site is located adjacent to the mine pit top (refer Figure 2). Drainage from the area around the No.3 Shaft site reports to a series of sediment dams. Overflow from these structures is discharged to Tea Tree Hollow via LDP1[3].

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[2] Xstrata/Glencore "Soil and Water Management Plan" (EMS MGP 005), February 2012.

[3] Ibid

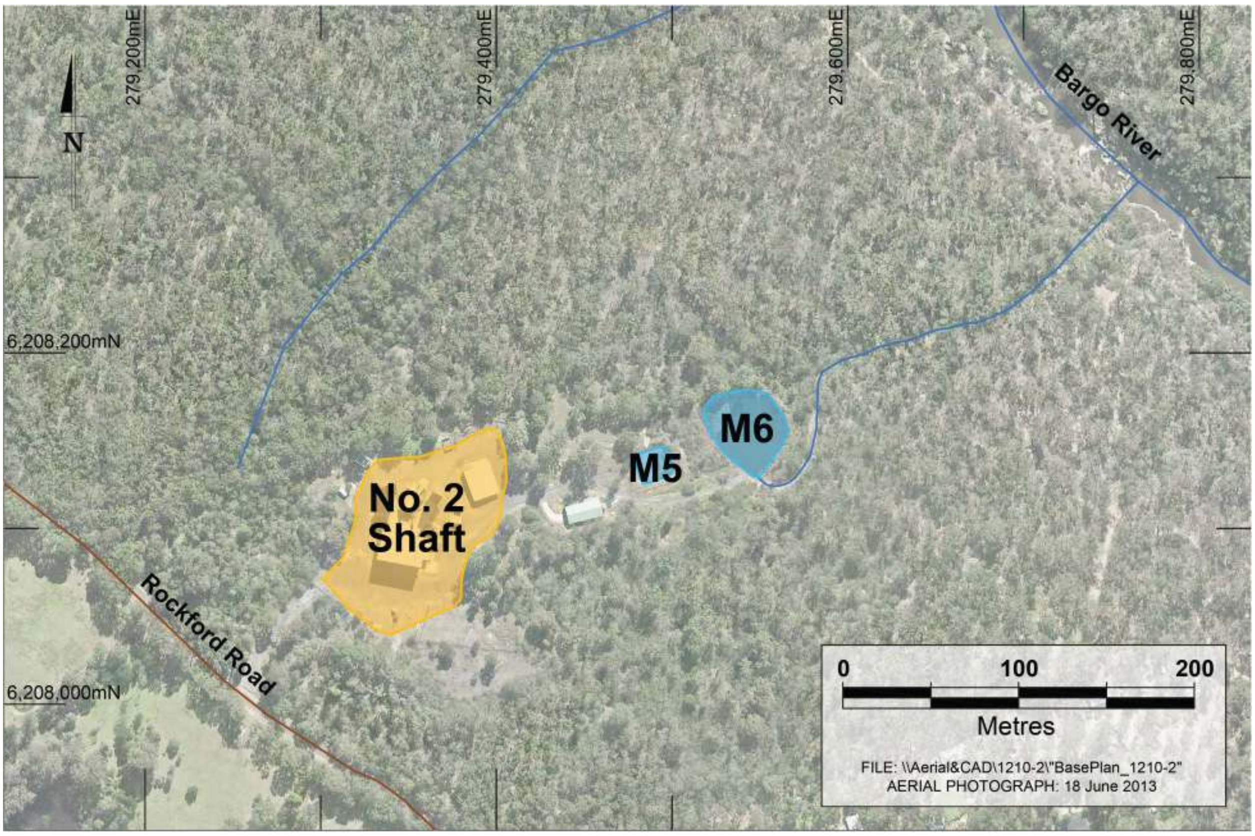
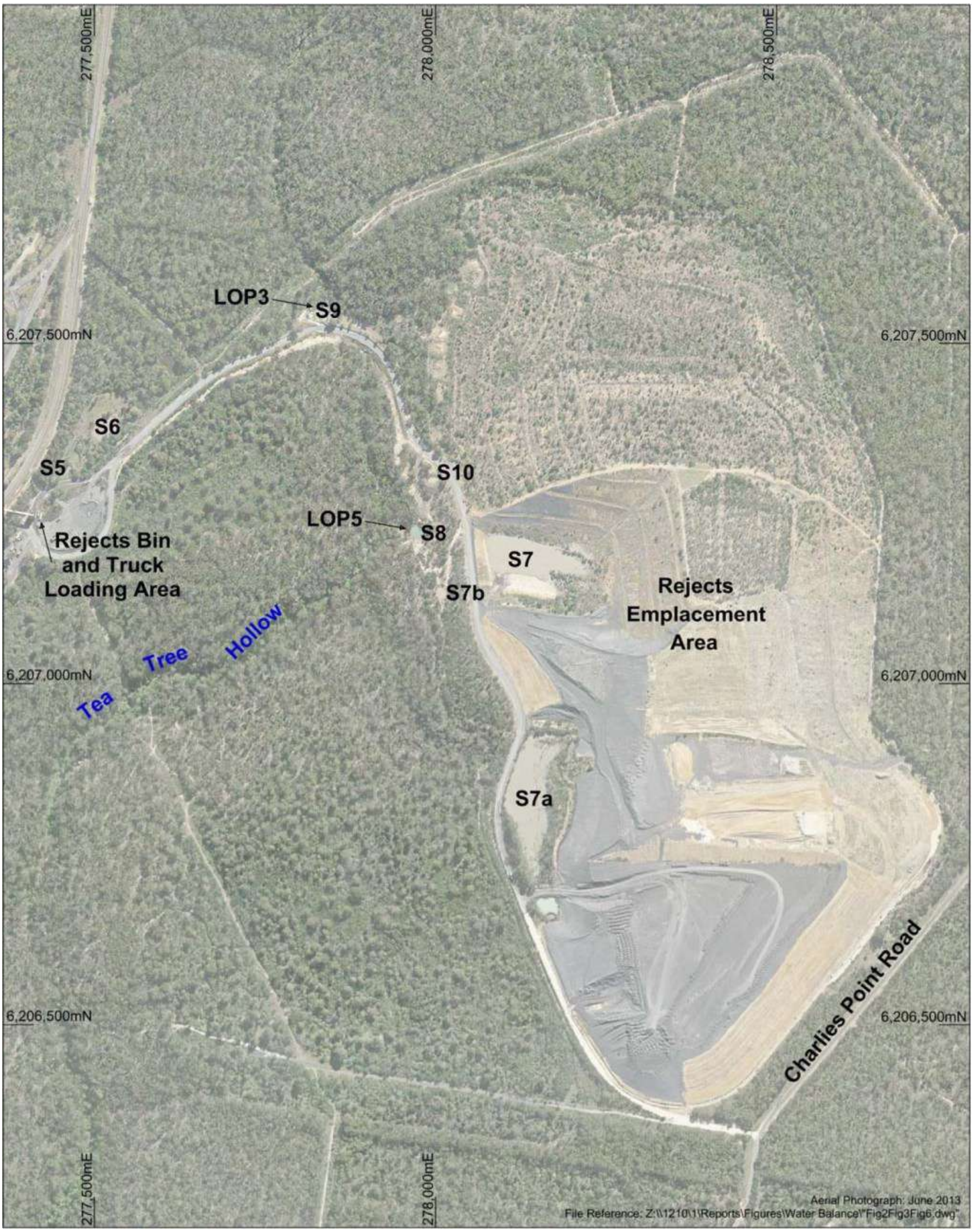


Figure 3 Layout of Vent Shaft No. 2 Area and Water Management Infrastructure

3.3 REJECT EMPLACEMENT AREA

Rejects from the CHPP comprise dewatered fines and coarse reject. These reject streams are mixed and transported via conveyor to a bin and loading area prior to placement in the REA which is located some 1.5 km east of the pit top area – refer Figure 4. The REA stormwater management system comprises a network of collection drains and sedimentation retention dams (S5, S6, S7, S7a, S7b, S8, S9 and S10 – refer Figure 4). Drainage water which collects in these storages is pumped to dam S4 for automatic coagulant (flocculant) dosing. Water from dam S4 is pumped to Sediment Dam M3 or, during wet weather, discharges to Tea Tree Hollow via LOP4. The REA is also currently served by an LOP for overflow from dam S9 and an LOP for overflow from dam S8 – refer Figure 4.

A schematic representation of the existing water management system is shown in Figure 5.



Aerial Photograph: June 2013
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Figure 4 Layout of Reject Emplacement Area and Water Management Infrastructure

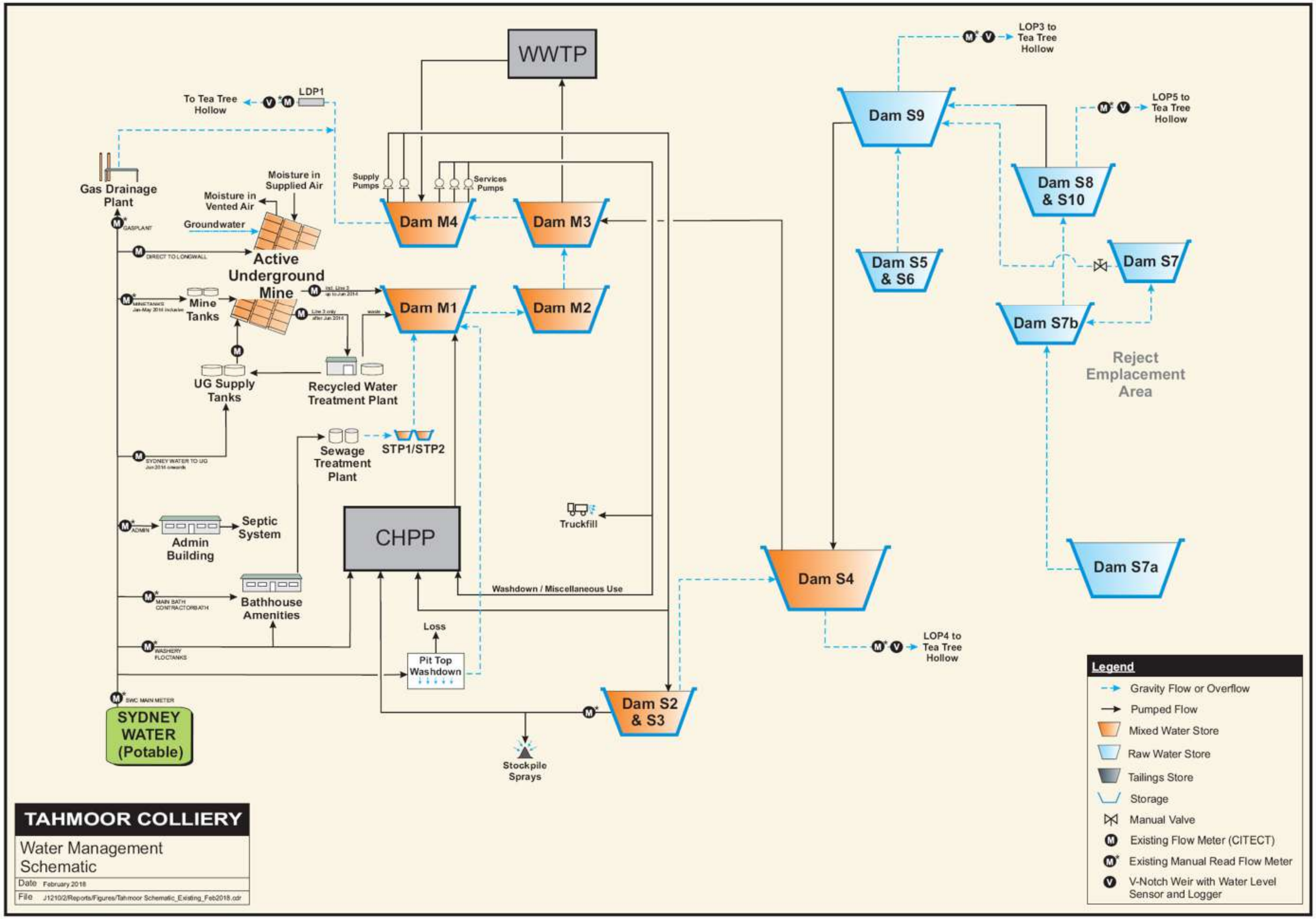

Figure 5 Schematic of Existing Water Management System

3.4 EXISTING SEDIMENT AND EROSION CONTROL

Erosion and sediment control at the REA site is managed via a formal sediment and erosion control plan (ESCP). The existing ESCP[4] has been compiled in accordance with the current guidelines[5].

3.5 EXISTING ENVIRONMENT PROTECTION LICENCE – WATER MANAGEMENT CONDITIONS

Under EPL 1389, discharge to waters is licenced at the following four locations (points) – refer Glencore (2017):

- LDP1 Main mine water discharge from drain downstream of dam M4.
- LOP3 Overflow from the REA dam S9.
- LOP4 Overflow from the REA dam S4.
- LOP5 Overflow from the REA dam S8.

The volumetric discharge limit from LDP1 is 15.5 ML/day, while there are no volumetric limits for the LOPs. The EPL also permits wet weather release in excess of this limit, defined to be when there has been in excess of 10 mm of rainfall in a 24 hour period at the premises - “provided all practical measures are taken to minimise additional pollution caused by wet weather”[6].

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[4] Xstrata Coal Tahmoor Colliery “Erosion & Sediment Control Plan (ESCP) Refuse Emplacement Area Stages 15 & 16”, November 2011

[5] Managing Urban Storm Water (Landcom, 2004) including Volume 2E Mines and Quarries (DECCW, 2008)

[6] Environment Protection Authority – NSW, Licence 1389, version date: 20-Nov-2017.

4.0 PROPOSED TAHMOOR SOUTH PROJECT WATER MANAGEMENT UPGRADES

The proposed Project water management system will be based on the existing water management system and most aspects will remain unchanged. As part of the development of the Project the following changes are proposed to the existing water management system:

- Development and expansion of the stormwater drainage management and runoff control for the planned staged expansion of the REA;
- Upgrading of water supply and water reticulation infrastructure needed to handle increased coal throughput and coal handling facilities;
- Changes to underground mine water supply and mine dewatering reticulation needed to service the Tahmoor South operations; and
- Development of an underground storage within goafed areas of the Tahmoor North underground, in order to store water pumped from sediment dam M3 that is in excess of the WWTP capacity.

Two additional ventilation shafts are proposed as part of the Project.

A schematic representation of the proposed water management system for the combined existing Tahmoor North and the proposed Tahmoor South operations is shown in Figure 6.

The catchment areas contributing to the water management system comprise the pit top area which lies within and immediately adjacent to the rail loop, the catchments around the ventilation shafts and the REA catchments. The only catchments which are predicted to change in the pit top area over the remaining expanded Project life are the REA catchments.

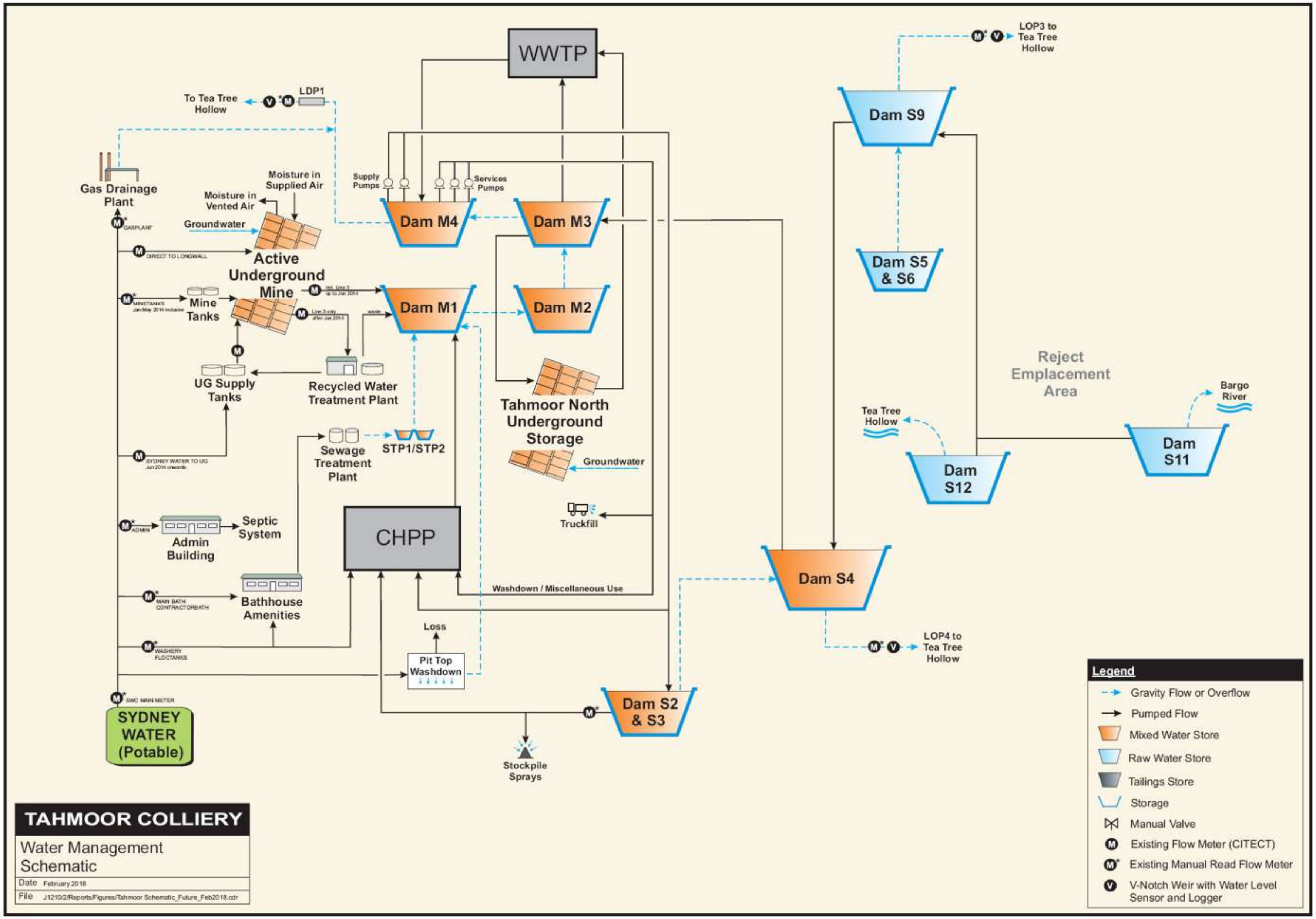

Figure 6 Schematic of Project Water Management System

4.1 REA EXPANSION

The disposal of CHPP reject over the remaining Project life would necessitate development of additional emplacement areas. These areas would be continuous with the existing REA landform and result in expansion to the south and west – refer Figure 7. The REA would continue to be developed in three main areas: Area 1A, Area 2 and Area 1B with approximate timing as shown in Figure 7. Completed areas would be progressively rehabilitated – a process which involves shaping, placement of topsoil layers and vegetation.

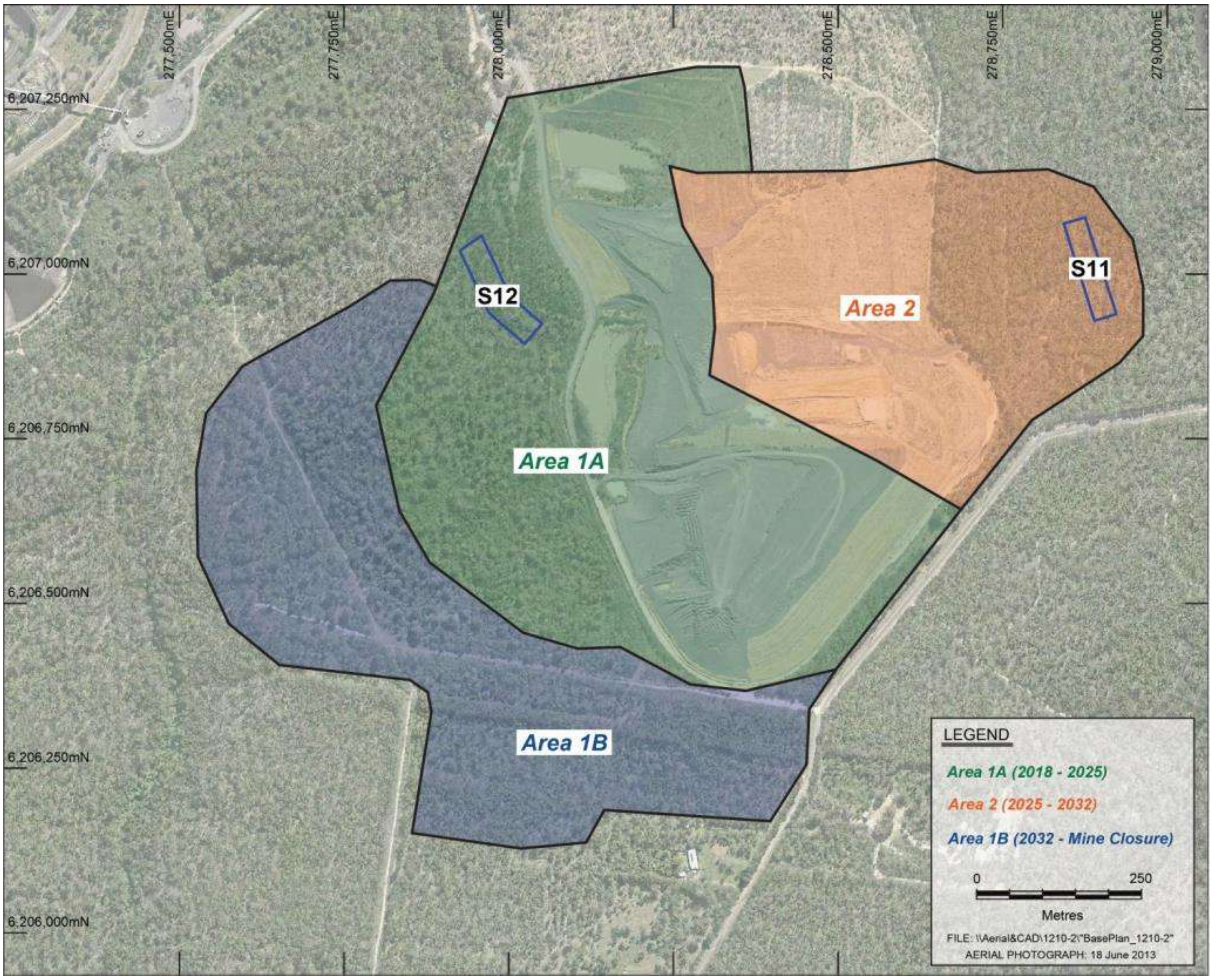

Figure 7 Assumed Rejects Emplacement Area Development

A water and soil management plan has been developed for the proposed REA expansion as part of the REA expansion design[7]. As with the current REA, drainage (runoff and seepage) from the REA would be directed to a series of sediment dams. Currently water which accumulates in these structures is transferred by a combination of pumping and gravity to S9. Water in S9 is then pumped to M3 via S4. Water is ultimately released from M4 via LDP1. Changes to the REA water management system would consist of the addition of two new sediment dams (S11 and S12) designed to collect runoff from the REA expansion as well as some changes to the management of the existing sediment dams. Dam S12 would replace existing dams S7, S7A, S7B, S8 and S10. The likely timing for the commissioning of dams S11 and S12, as well as the other associated changes to the existing water management system, are described below:

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[7] "Tahmoor Reject Emplacement Area Expansion Water Management Plan", SKM, February 2013.

1. Dam S11 and S12 would be constructed and commissioned at the start of the Project. Dam S7, S7a, S7b, S8, and S10 would be decommissioned and either covered with rejects within the expanded REA or left to overflow passively to Tea Tree Hollow.
2. Water in dam S11 would be pumped to an open drain leading to S9.
3. Any overflow from dam S11 would report to the Bargo River.
4. Water which accumulates in S12 would also be transferred to S9 via an open drain[8].
5. Any overflow from dam S12 would report to Tea Tree Hollow.

Changes to the REA catchment over the remaining Project life have been inferred from the design plans compiled by SKM[9] and on the assumption that rehabilitation of completed areas would be undertaken progressively over the remaining expanded Project life as is practical. It has also been assumed that once vegetation on rehabilitated areas of the REA has reached a stable condition (assumed to be two years), runoff from these areas would be suitable for release off site and would not need to be retained within the water management system. The extent and timing of these changes in status would depend on the practicality of separating runoff from rehabilitated areas from runoff from adjacent active or partially rehabilitated areas.

4.2 POLLUTION REDUCTION PROGRAMS

A series of Pollution Reduction Programs (PRPs) have been implemented on site since 2005. There are currently 2 remaining programs relating to site water management to be completed. PRP 22 involves the development and commissioning of the WWTP to reduce the concentrations of arsenic, nickel and zinc in mine water released from LDP1 (refer Section 3.1). PRP 26 involves an aquatic health assessment in Tea Tree Hollow and the Bargo River following recommissioning of the WWTP to determine any changes to aquatic health. This is required to occur nine months following WWTP recommissioning.

4.3 UNDERGROUND WATER STORAGE

The WWTP has a design capacity of 6 ML/day. Forecast groundwater modelling for the Project (HydroSimulations, pers. comm, 17/10/2018) has indicated that Project underground inflows may at times exceed 6 ML/day. In terms of inflow to the WWTP, there is in addition water recovered from the pit top area and REA which is pumped to sediment dam M3 (i.e. rainfall runoff from these areas) – refer Figure 6. Therefore there may be times when the capacity of the WWTP is exceeded. As part of the Project, it is proposed to develop an underground storage within goafed areas of the Tahmoor North underground into which water would be pumped from sediment dam M3 at times when inflow to dam M3 exceeded the WWTP capacity. At times of lower inflow, water could be recovered from the underground storage, treated within the WWTP and released via LDP1. The underground storage would be formed within the void space of the mined longwall panels up to and including LW30. A storage capacity of 4,751 ML has been estimated within this area. Water would be pumped into and out of the storage via the existing drift and no new surface infrastructure is envisaged outside the pit top area.

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[8] "Tahmoor Rejects Emplacement Area Expansion Water and Soil Management", SKM November 2013

[9] SKM "Reject Emplacement Area Drawings NW00243-ECC-DG-0003(D), NW00243-ECC-DG-0003(D), NW00243-ECC-DG-0004(D), NW00243-ECC-DG-0013(D), NW00243-ECC-DG-0014(D), NW00243-ECC-DG-0015(D), NW00243-ECC-DG-0016(D) and NW00243-ECC-DG-0017(D)", October 2013.

4.4 VENTILATION SHAFTS

The Project will continue to use the existing ventilation system and shafts as outlined in Section 3.2. Two additional ventilation shafts are proposed as part of the Project as outlined in Section 2.2.3.

The construction of the ventilation shafts will require the disturbance of an area of approximately four to six hectares at each location. A conceptual construction and operational site layout for the additional two proposed ventilation shafts is shown in Figure 8.

The construction of each of the proposed ventilation shafts would involve the following:

- Construction of internal roads to allow access for construction and operational maintenance vehicles.
- Establishment of the construction site to allow sufficient space for stockpiling of shaft liners for TSC1 and TSC2, temporary spoil emplacement for TSC2, water management, storage and safe movement on-site during construction activities. Establishment of the ventilation shaft site would involve:
    - Installation of environmental controls such as silt fences, fencing with lockable gates, as well as display of signage relating to restricted entry.
    - Clearing of vegetation and stripping of topsoil. Topsoil would be temporarily stockpiled for rehabilitation post construction.
    - Excavation and construction of a temporary hardstand area for operation of drilling equipment. The hardstand footprint would be determined by the size and number of liner pieces to be manufactured and excavated to a depth of approximately 0.2 m. The temporary hardstand areas would include:
        - approximately 2,000m² of road base surrounding the site compound area and drill rig slab for site facilities;
        - approximately 2,000m² for laydown areas and a 4,500m² levelled hardstand area for storage of the ventilation shaft liners;
        - a stable access way between the liner storage area and the shaft to facilitate transport of the cured liner segments on purpose built trailers; and
        - a concrete pad 20 m by 15 m is to be constructed around the top of the shaft as a foundation for the drill rig and to provide a clean work area.
    - Connection of 66 kV electrical power and establishment of electrical substations at ventilation shaft sites.
    - Sinking of the shaft using blind boring methods (or similar method), and lining of the shafts using a composite concrete and steel liner (or similar method).
    - Construction of fan buildings and installation of ventilation fans. The upcast shaft site fan would also incorporate a fan outlet stack, approximately 30 m high, to control odour discharge from the mine.

Runoff from site TSC1 would report to storages within the existing pit top water management system. Site TSC2 would incorporate water treatment sedimentation controls, with the settled water from the ventilation shaft being pumped via overland pipeline to a final sedimentation pond on the surface facilities area for further treatment and discharge though LDP1. Alternatively water may be discharged via a new licensed discharge point, which would require a variation to EPL 1389.

Figure 8 Proposed Project Conceptual Ventilation Shaft Layout

4.5 SEWAGE TREATMENT PLANT UPGRADE

A sewage water treatment plant upgrade is proposed at the pit top to treat sewage on site for additional proposed bathhouses. The discharged effluent would be treated by the upgrade plant and would flow into two maturation ponds, which flow through to and are discharged via LDP1. Water quality tests would be carried out periodically on the water discharging from LDP1 to test for any elevated levels of faecal coliforms.

5.0 WATER BALANCE SIMULATION MODELLING

A water balance model of the Tahmoor water management system has been developed to simulate the management of water over the remaining Tahmoor North life and Project life (i.e. from 2018 to 2035). The model simulates the water balance of all water management storages, the generation of runoff from rainfall over mine surface facility catchments, recovery of water from underground mining operations and supply of water to meet the demands of the CHPP, the underground mine and for dust suppression. The model has been developed using the GoldSim® simulation package. It operates on a sub-daily time step and simulates the water balance behaviour of all the storages shown in Figure 5 and Figure 6 together with the storage linkages shown.

5.1 CLIMATIC DATA USED IN SIMULATIONS

A long sequence of historical climate data (rainfall and evaporation) was obtained from the SILO Data Drill[10] for use in the model. The Data Drill comprised daily rainfall and evaporation for the period from 1889 to 2016 inclusive. The model was run using one hundred and twenty eight (128) possible 18-year climatic sequences formed using the available climatic record. The climatic sequences were formed by "moving" along the climatic record one year at a time with the first sequence comprising the first 18 years in the record. The second sequence comprised years 2 to 19 in the record, the third comprised years 3 to 20 and so on. The start and end of the historical record was 'linked' so that additional sequences, including years from both the beginning and end of the record, were combined to generate additional climate sequences. The results from all climate sequences were used to generate water storage volume estimates and other relevant water balance statistics. This method effectively includes all recorded historical climatic events in the water balance model, including high, low and median rainfall periods.

5.2 RAINFALL RUNOFF MODELLING

Rainfall runoff in the water balance simulation model is simulated using the Australian Water Balance Model or AWBM (Boughton, 2004). The AWBM is a nationally-recognised, catchment-scale water balance model that estimates streamflow from rainfall and evaporation.

For the purposes of hydrological modelling, catchment areas were split into the following seven different sub-catchment types:

1. Hardstand areas - including roads , paved areas, buildings and storage areas;
2. Natural (areas undisturbed by mining or reject placement activities);
3. Cleared and stripped areas in the REA (i.e. natural areas that had been cleared of vegetation and had topsoil stripped in preparation reject disposal);
4. Active reject disposal areas;
5. Partially rehabilitated reject disposal areas – rehabilitated areas on which vegetation has become partially established;
6. Fully rehabilitated reject disposal areas; and
7. Coal stockpile areas.

The identification of sub-catchment areas was undertaken with the aid of an aerial photograph and an indication of the future progression of the REA.

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[10] The Data Drill is a system which provides synthetic data sets for a specified point by interpolation between surrounding point records held by the Bureau of Meteorology. It is based on Jeffrey *et al*. (2001).

For the natural sub-catchment type, model parameters were derived from an AWBM calibrated to approximately reproduce flows in a nearby gauged watercourse[11]. Parameters for other sub-catchment types were set based on experience with similar projects and adjusted as part of calibration (refer Section 6.0).

5.3 PROJECT AREA CATCHMENTS

The Project catchments in the pit top area reporting to each storage are summarised in Table 1. These catchments would not change over the planned Project life.

Table 1 Pit Top Area Storage Catchments

Storage	Catchment Area (ha)			
	Hardstand	Natural (undisturbed)	Coal Stockpile	TOTAL
M1	0.44	0.00	0.00	0.44
M2	5.46	1.74	0.30	7.51
M3	0.84	0.00	0.00	0.84
M4	2.90	0.24	0.47	3.61
S2 and S3	1.49	6.00	7.40	14.90
S4	2.14	6.02	0.00	8.16
S5 and S6	2.49	1.89	0.26	4.64

The inferred progression of REA catchments adopted in the water balance modelling is summarised in Table 2. During the Project, the REA catchment and sub-catchment areas change with 'active' rejects disposal areas diminishing, fully rehabilitated areas increasing and partially rehabilitated areas peaking towards the end of the Project life before decreasing. To derive these areas, it was assumed that, following completion of rejects placement in a given area, a one year period would be required to regrade and cover the rejects, followed by a two year period to establish a revegetated cover. In the forecast model, the AWBM parameters for each sub-catchment type were kept constant for the Project life (using calibrated values - refer Section 6.0) – only the sub-catchment areas changed as given in Table 2.

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[11] Redbank Creek flow measured at the gauging station at monitoring site RC11 (GS300048) from December 2009 to March 2013.

Table 2 Pit Top Area REA Catchments

Year	Hard-stand	Natural (un-disturbed)	Cleared and Stripped	Active rejects disposal	Covered rejects	Partially rehabil-itated	Fully rehabil-itated	Stock-piles	TOTAL
2018	25.21	38.26	1.13	31.27	7.47	16.32	6.13	8.44	134.24
2019	24.53	29.78	1.05	45.23	5.25	14.38	5.58	8.44	134.24
2020	24.27	28.61	0.96	63.57	4.80	15.16	5.03	8.44	150.84
2021-2024	24.14	28.03	0.92	44.97	4.58	14.78	4.75	8.44	130.61
2025	24.14	25.29	0.92	54.68	2.30	10.30	4.55	8.44	130.61
2026	24.14	22.53	0.92	64.41	0.01	5.82	4.35	8.44	130.61
2027-2031	24.14	22.52	0.92	64.44	0.00	5.80	4.35	8.44	130.61
2032	24.14	35.34	0.92	14.77	0.00	74.22	4.35	8.44	162.17
2033	24.14	22.56	0.92	27.38	0.00	42.68	36.06	8.44	162.17
2034	24.14	22.52	0.92	27.41	0.00	10.77	67.97	8.44	162.17
2035-2039	23.58	22.52	0.92	27.41	0.00	6.53	6.30	8.44	95.70

5.4 WATER DEMAND

The CHPP is a major water user at Tahmoor Colliery; however a significant proportion of the water used is internally recycled via the use of a tailings belt filter press. Make-up water is required to replace residual water exported with the combined process tailings and coarse reject material, moisture in product coal plus minor incidental losses such as wash down, water used in pipe flushing during shut downs and other ancillary uses. The first priority for CHPP make-up water is recycled water from dam M4. Sydney Water is used as the second priority source of water to satisfy any un-met make-up water demand[12].

The CHPP make-up water demand has been calculated based on forecast tonnages and the following moisture contents (as advised by Tahmoor Coal):

- Run-of-mine (CHPP feed) coal: 6.33%
- Product coal: 7.79%
- Combined rejects (on conveyor): 11%

The proposed annual run-of-mine (ROM) coal production, product and calculated CHPP make-up water demands over the remaining expanded Project life are summarised in Table 3.

---

[12] There are also some processes in the CHPP which require potable grade water which cannot be satisfied using water from M4 due to water quality limitations – supply to flocculant tanks and washery potable supply. These have been based on recent average monitored use supplied by Tahmoor Coal with future variation in proportion to forecast ROM Coal tonnages.

Table 3 Coal Processing and Make-Up Water Demand Schedule

Year	Bulk ROM (Mt)*	Product (Mt)†	CHPP Make-Up Demand (ML)
2018	2.60	2.08	52.8
2019	2.60	2.07	54.6
2020	3.02	2.21	67.9
2021	3.74	2.44	91.2
2022	4.99	3.43	117.5
2023	3.83	2.51	93.3
2024	2.75	2.05	61.1
2025	2.68	2.08	57.6
2026	2.67	2.10	56.7
2027	2.70	2.18	56.0
2028	2.66	2.08	57.0
2029	2.88	2.21	62.2
2030	2.60	2.13	53.2
2031	2.44	1.86	53.3
2032	2.82	2.31	57.8
2033	2.54	1.60	63.3
2034	2.22	1.44	54.3
2035	1.12	0.74	27.0
Total	**50.86**	**37.52**	**1,137**

* At ROM moisture

† At Product moisture

Water is also used for dust suppression on the REA, internal haul roads and for suppression of dust emissions from coal stockpiles. Whilst the overall area of the REA will increase, Tahmoor Coal expects that with progressive rehabilitation, there will not be any significant increase in dust suppression water demand. The advised demand for dust suppression water is 11 ML/annum for the REA/haul roads and 73 ML/annum for coal stockpile areas.

5.5 MINE DEWATERING AND UNDERGROUND MINE WATER DEMAND

The water demand for the underground mining operations has been estimated as a constant value based on long-term average monitored use. Water recovered from underground mining operations is treated in the Recycled Water Treatment Plant at the surface. A portion of the treated water is reused for underground mining purposes with the remainder pumped to dam M1. A demand rate of 1.13 ML/d has been assumed for underground mining operations, with 0.62 ML/d sourced from the Recycled Water Treatment Plant and the remainder from Sydney Water (based on long-term average monitored use). Excess underground water (groundwater inflow) is directed to dam M1.

Predictions of future groundwater inflow to the Tahmoor North and Project underground mining operations and the proposed underground water storage (refer Section 4.3) have been made by HydroSimulations (pers. comm, 17/10/2018). The predicted groundwater inflow rates are plotted in Figure 9.

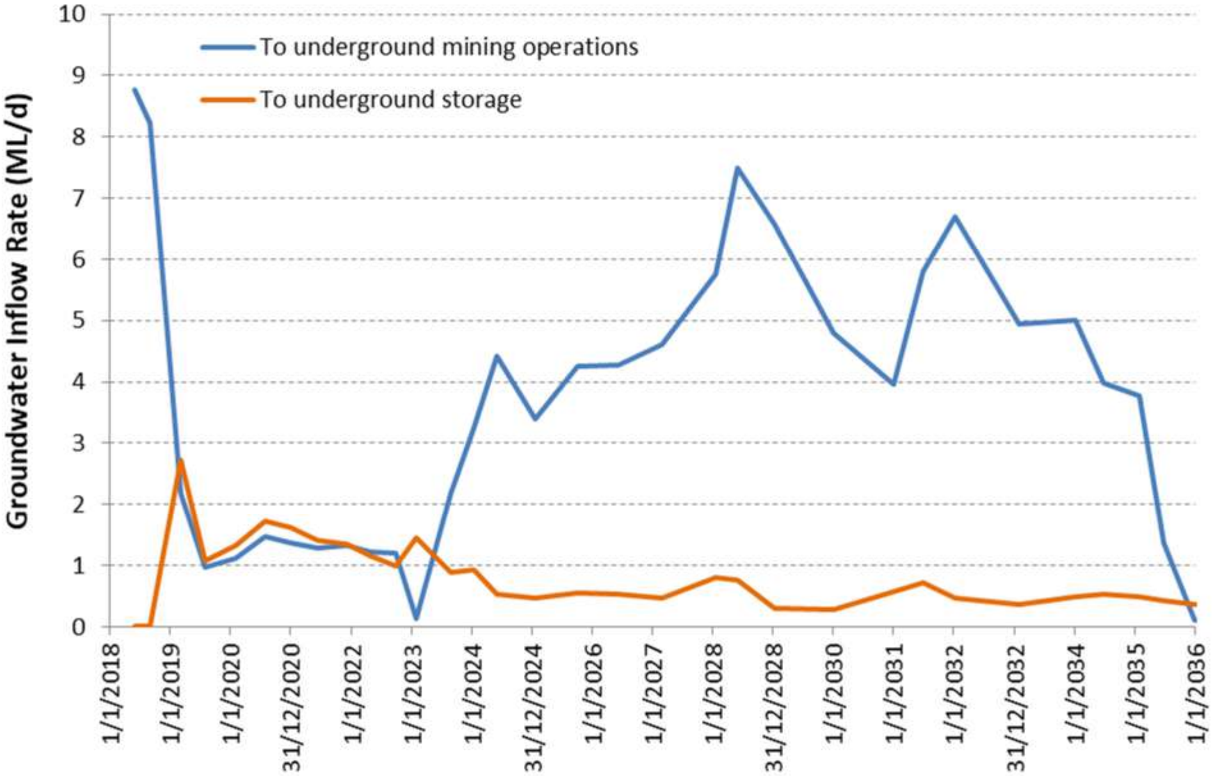

Figure 9 Predicted Groundwater Inflow Rates (HydroSimulations, pers. comm, 17/10/2018)

Moisture in ventilation air entering and leaving the underground mining operations is simulated based on a long-term average value calculated from air flow and temperature data supplied by Tahmoor Coal. Values of 0.37 ML/d and 0.7 ML/d were calculated for inflow and outflow respectively.

5.6 WATER MANAGEMENT STORAGES

Details of the existing and proposed water management storages provided by Tahmoor Coal are summarised in Table 4.

Table 4 **Summary of Water Management Storages**

Storage	Capacity (ML)	Maximum Surface Area (ha)	Function and Active Life
M1	1.8	0.28	Existing pit top sediment and water retention dam to be retained
M2	0.5	0.09	Existing pit top sediment and water retention dam to be retained
M3	9	0.48	Existing pit top sediment and water retention dam to be retained
M4	8	0.44	Existing pit top sediment and water retention dam to be retained
S2 and S3	8.3	0.36	Existing product coal stockpile sedimentation dam to be retained
S4	36.9	1.42	Collection dam for transfer to M1 to be retained
S5 and S6	2.5	0.11	Existing sediment and transfer dams to be retained
S7	11.3	0.94	Existing sediment dam to be decommissioned by and replaced by S12 at the start of the Project
S7a	12	1.42	Existing sediment dam to be decommissioned by and replaced by S12 at the start of the Project
S7b	1	0.06	Existing sediment dam to be decommissioned by and replaced by S12 at the start of the Project
S8 and S10	0.47	0.04	Existing sediment dams to be decommissioned and replaced by S12 at the start of the Project
S9	0.4	0.4	Existing sediment and transfer dam to be retained
S11	3	1.32	Proposed REA sedimentation dam. To be commissioned at the start of the Project
S12	4	1.32	Proposed REA sedimentation dam to be commissioned at the start of the Project
Underground Water Storage	4,751	n/a	Assumed commissioned at the start of the Project (1 Jan 2019)

5.7 PROTOCOLS FOR WATER TRANSFERS

Protocols for water transfers between storages provided by Tahmoor Coal and used in water balance model simulations are summarised in Table 5.

Table 5 Summary of Inter-Storage Water Transfer Protocols

Source	Destination	Pump Start Trigger	Pump Stop Trigger	Flow Rate
S7	S9	S9 below 70% capacity	S9 above 70% capacity	By gravity estimated 4.4 L/s
S8	S9	S9 below 35% capacity	S9 above 35% capacity	5 L/s
S9	S4	S9 above 10% capacity	S9 below 5% capacity orS4 above 95% capacity	60 L/s
S4	M3	S4 above 80% capacity	S4 below 20% capacity	50 L/s
S11	S9	S11 above 25% capacity	S11 below 5% capacity	10 L/s
S12	S9	S12 above 25% capacity	S12 below 5% capacity	10 L/s
M3	Underground Water Storage	M3 above capacity and Underground Water Storage below capacity[†]	M3 below capacity[†]	Not pump limited[†]
Underground Water Storage	WWTP and M4	WWTP inflow rate less than 6 ML/day	WWTP inflow rate equal to or greater than 6 ML/day	6 ML/day minus WWTP inflow rate

* Prior to S12 being constructed, S11 will be pumped to S9 via an existing drain

[†] M3 is simulated as effectively overflowing to the underground water storage

5.8 WATER MANAGEMENT SYSTEM INFLOWS AND OUTFLOWS

The overall water management system inflows comprise (refer Figure 6):

1. Rainfall runoff
2. Sydney Water supply (based on information provided by Tahmoor Coal)
    a. CHPP flocculation (12 ML/annum)
    b. Pit top washdown (146 ML/annum)
    c. Surface amenities (such as bathhouse and admin area use) (21 ML/annum
    d. Gas Drainage Plant (10 ML/annum)
    e. Underground mine demand (0.51 ML/d - refer Section 5.5)
    f. CHPP make-up water (refer Section 5.4)
3. Underground mine water extraction including groundwater inflow based on groundwater inflow predictions produced by HydroSimulations (pers. comm, 17/10/2018)
4. Moisture entering the underground mine via the ventilation system (refer Section 5.5).

The overall system outflows from the water balance comprise:

1. Evaporation from water storages
2. Moisture exiting the mine via the ventilation system (refer Section 5.5)
3. Haul road and stockpile dust suppression (84 ML/annum - refer Section 5.4)
4. Water discharged to the environment (via LDP1 and LOPs)
5. Water losses during truck washdown and other facilities water use (15 ML/annum based on estimated 10% loss of current wash down use)

6.0 MODEL CALIBRATION

Model calibration was undertaken using a two year period of recorded data for 2014 and 2015 to attempt to match recorded and simulated release from the four historical release points on site (from M4, S4, S8 and S9). The following data was used in model calibration:

- Recorded daily site rainfall;
- Daily pan evaporation data sourced from the SILO Data Drill for the period of calibration;
- Site water storage catchment and sub-catchment areas estimated from contour plans and aerial photography;
- Estimates of initial water storage volumes;
- Assuming zero accumulation of water in the Underground Workings, groundwater inflow was calculated using the water balance;
- Recorded monthly CHPP feed, rejects and product tonnes as well as moisture contents of these streams;
- Recorded Sydney Water supplies; and
- Recorded release volumes from the four release points.

As part of calibration, AWBM parameters for sub-catchments were adjusted iteratively to improve the match between modelled and recorded release volumes. Comparisons of modelled versus recorded cumulative release volumes from each of the four release points over the calibration period are given in Figure 10 to Figure 13.

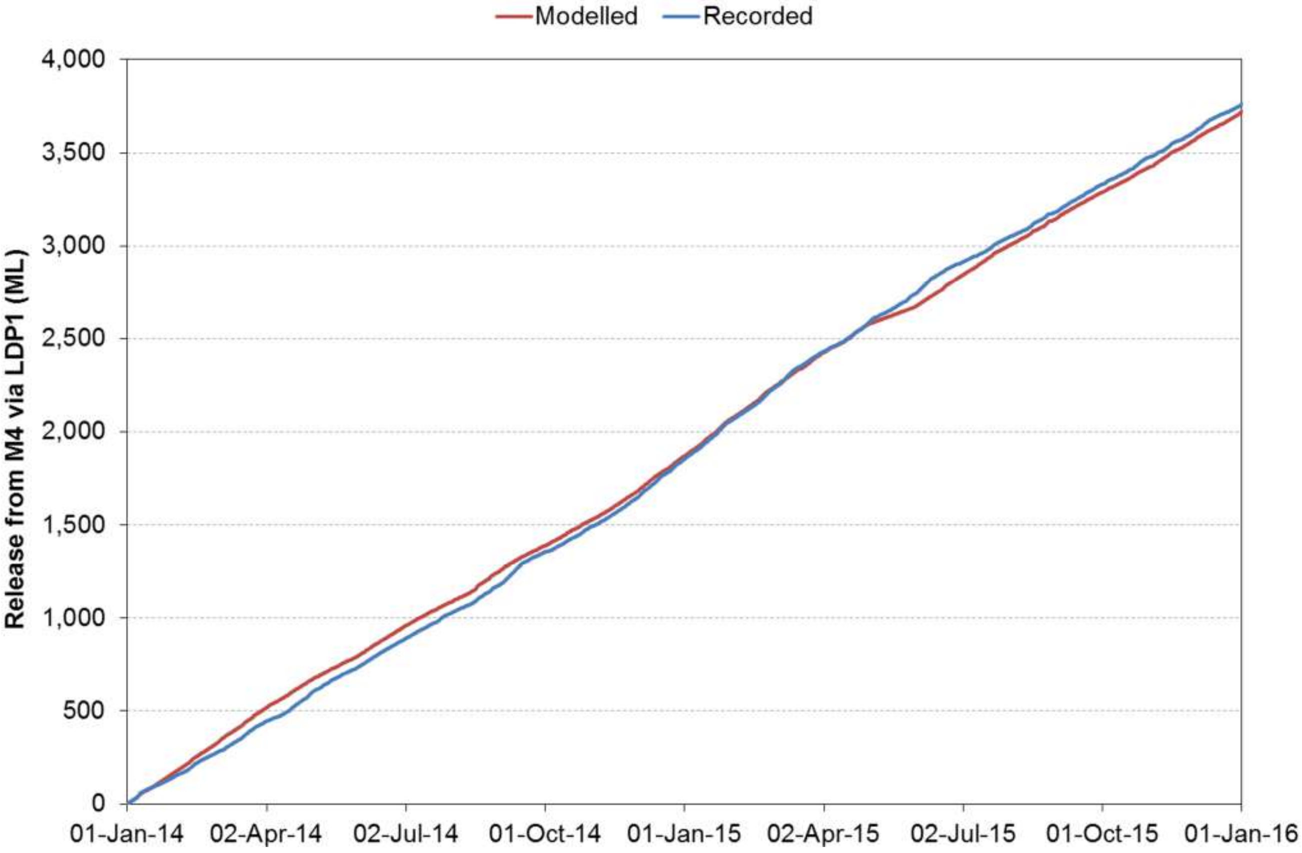

Figure 10 Modelled Versus Recorded Cumulative Release from M4 via LDP1

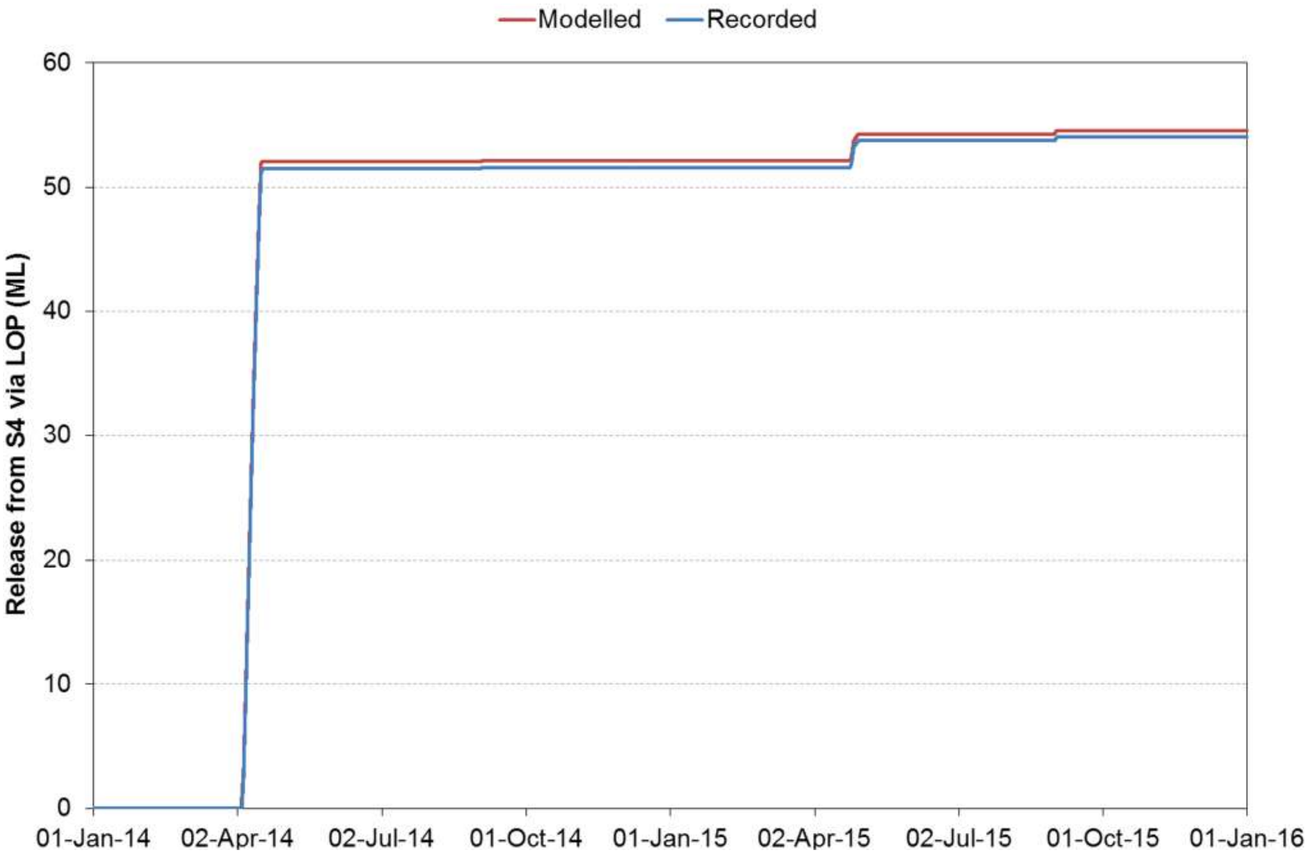

Figure 11 Modelled Versus Recorded Cumulative Release from S4 via LOP

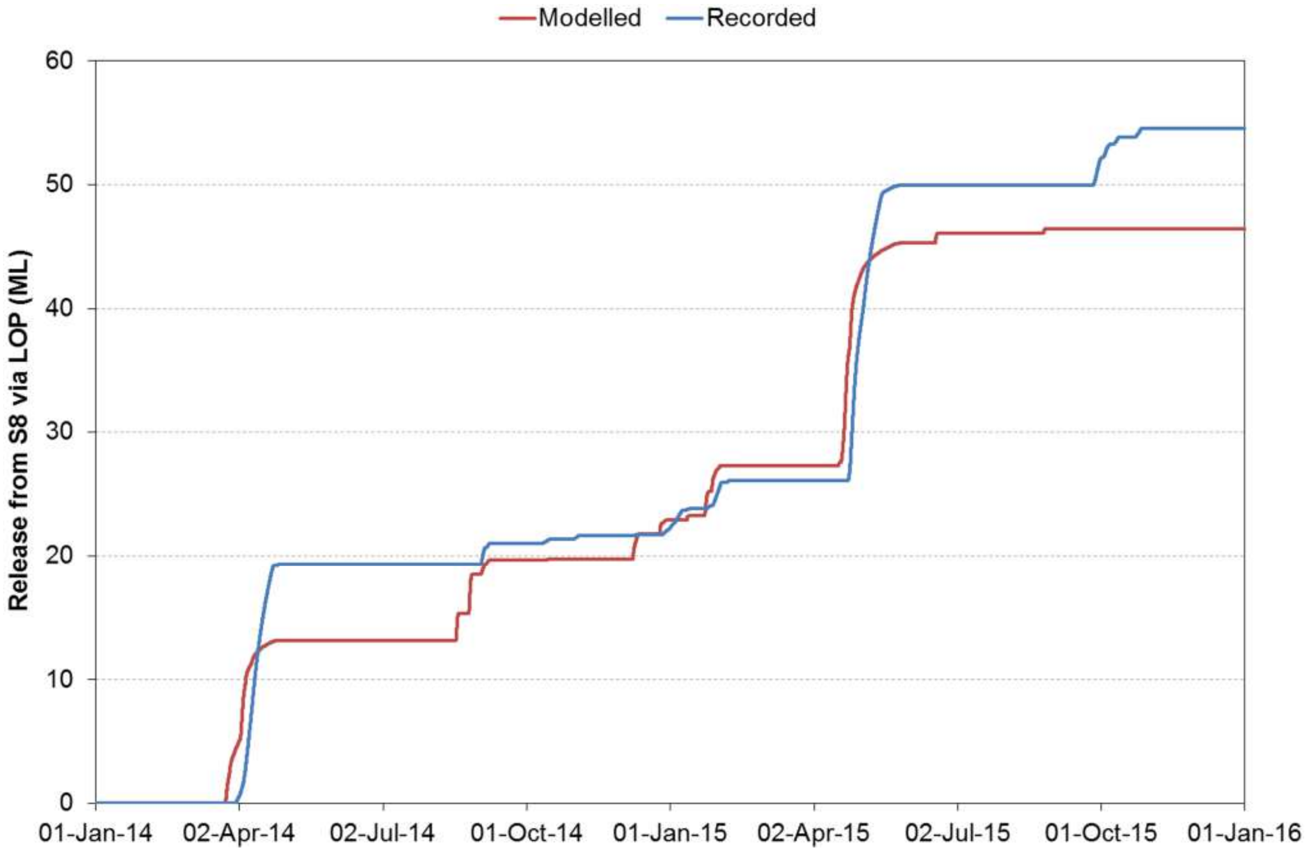

Figure 12 Modelled Versus Recorded Cumulative Release from S8 via LOP

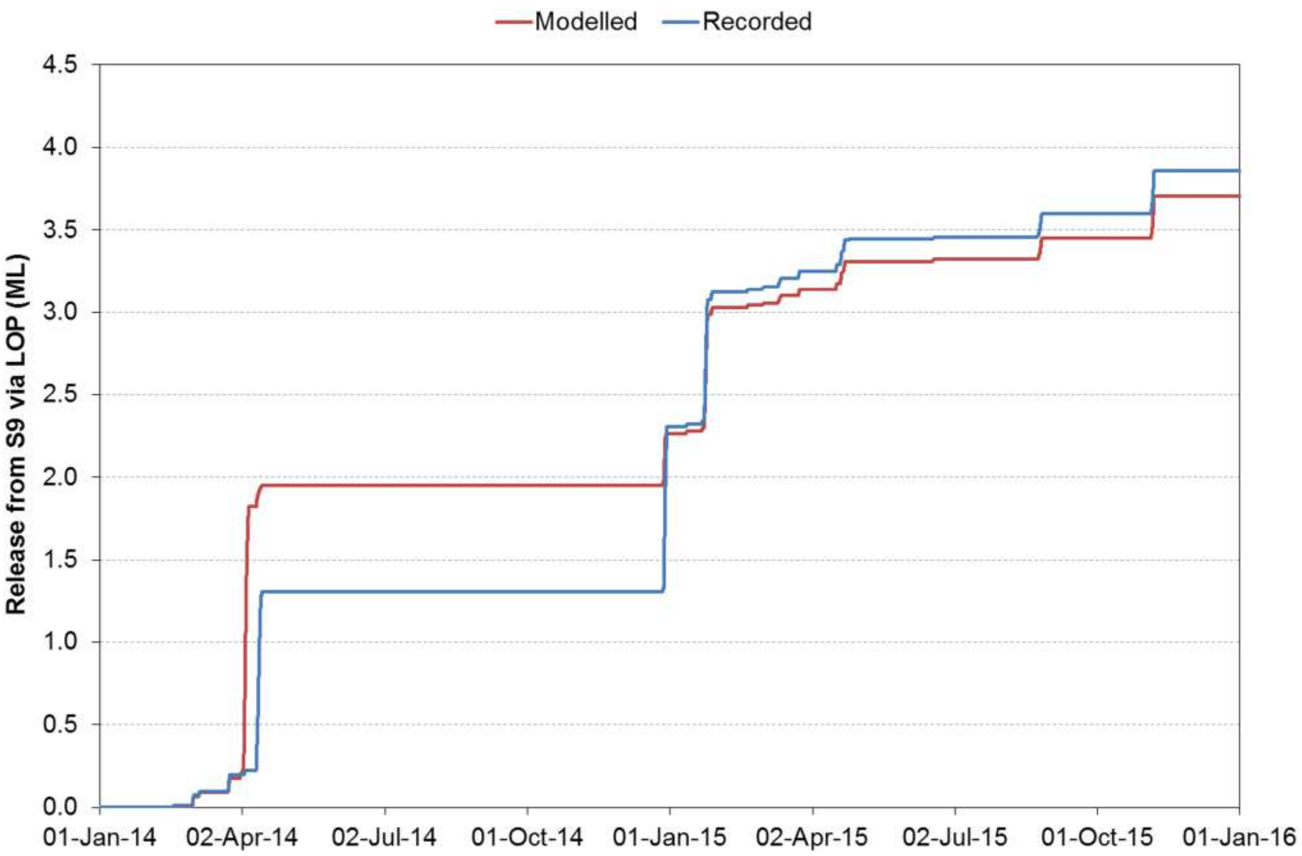

Figure 13 Modelled Versus Recorded Cumulative Release from S9 via LOP

Figure 10 to Figure 13 indicate a good match between modelled and recorded release via the release points over the calibration period. The largest cumulative release volume (by far) is from LDP1 and the modelled cumulative volume is within approximately 1% of the recorded volume.

The AWBM parameters derived from the calibration are provided in Table 6.

Table 6 Calibrated AWBM Parameters

Parameter	Sub-Catchment Type						
	Hardstand	Natural Surface	Pre-Strip	Co-Disposed Rejects	Partially Rehabilitated Rejects	Rehabilitated Rejects	Stockpiles
C_1 (mm)	5	6	5	5	8	6	5
C_2 (mm)	-	85	20	50	60	75	50
C_3 (mm)	-	180	-	-	90	160	-
A_1	1	0.072	0.1	0.15	0.072	0.072	0.1
A_2	-	0.650	0.9	0.85	0.650	0.650	0.9
A_3	-	0.278	-	-	0.278	0.278	-
K_s (d^{-1})	0.1	0.2	0.1	0.2	0.2	0.2	0.1
BFI	0	0.12	0	0.5	0.5	0.5	0.9
K_b (d^{-1})	0.96	0.95	0.96	0.95	0.95	0.95	0.98

7.0 SIMULATED PERFORMANCE OF WATER MANGEMENT SYSTEM

The predicted performance of the water management system and its capacity to meet design objectives over the remaining expanded Project life has been assessed by analysing results from the water management simulation model which incorporates a range of climatic conditions. Results of the simulation model runs are presented below for the following water management system performance measures:

1. The average water balance which provides an overall (i.e. high level) understanding of the magnitude of different components of the water balance.
2. Water supply efficiency - the capacity of the water management system to satisfy the various water demands from recycling and reuse of water on site.
3. Capacity to contain water on site and capacity to manage off-site releases within conditions of the EPL.

7.1 AVERAGE SIMULATED SYSTEM ANNUAL INFLOWS AND OUTFLOWS

The simulated average annual total system inflows and outflows over the expanded Project life are summarised in Table 7.

Table 7 Simulated Average Water Balance Results (Averaged over Project Life)

Description	ML/annum	% of Total Inflows or Outflows
Inflows		
Rainfall Runoff	373	14%
Sydney Water Supply	485	18%
Groundwater Inflow to Underground Mine	1,693	63%
Ventilation Moisture (In)	136	5%
Total Inflows	**2,687**	
Outflows		
Evaporation	56	2%
Discharge via LDP1	2,135	82%
Discharge via LOPs	58	2%
CHPP Make-Up Water Supply	76	3%
Haul Road Dust Suppression	11	<1%
Stockpile Sprays (Dust Suppression)	26	1%
Pit Top Washdown Water	14	1%
Ventilation Moisture (Out)	224	9%
Total Outflows	**2,600**	

The excess of inflow over outflow in Table 7 indicates a net increase in stored water over the Project life – refer Section 7.4.

Water recovered from underground mining operations, treated in the Recycled Water Treatment Plant and then recycled to the underground mine averaged 226 ML/annum. This amounts to 55% of the estimated underground mine water demand (refer Section 5.5).

7.2 WATER SUPPLY EFFICIENCY AND SITE WATER REUSE

A key component of the water management system performance is its capacity to provide a reliable secure water supply. The capacity of the proposed water management system to achieve this requirement would normally be assessed by tracking simulated water supply shortfalls for the different water supply requirements. It has however been inherently assumed in the simulation modelling that there would be no restrictions on supply of water from the Sydney Water supply and hence no shortfalls. The objective of water supply management at Tahmoor is to minimise the need to source water from Sydney Water and the assessment of the water supply performance has therefore focused on its capacity to satisfy water demand using on-site supply resources as a priority.

Figure 14 shows the simulated demand for potable water from the Sydney Water supply. The forecast annual average of 484 ML (refer Table 7) is within the range of recorded annual volumes sourced for the last five years (ranging from 403 ML to 549 ML).

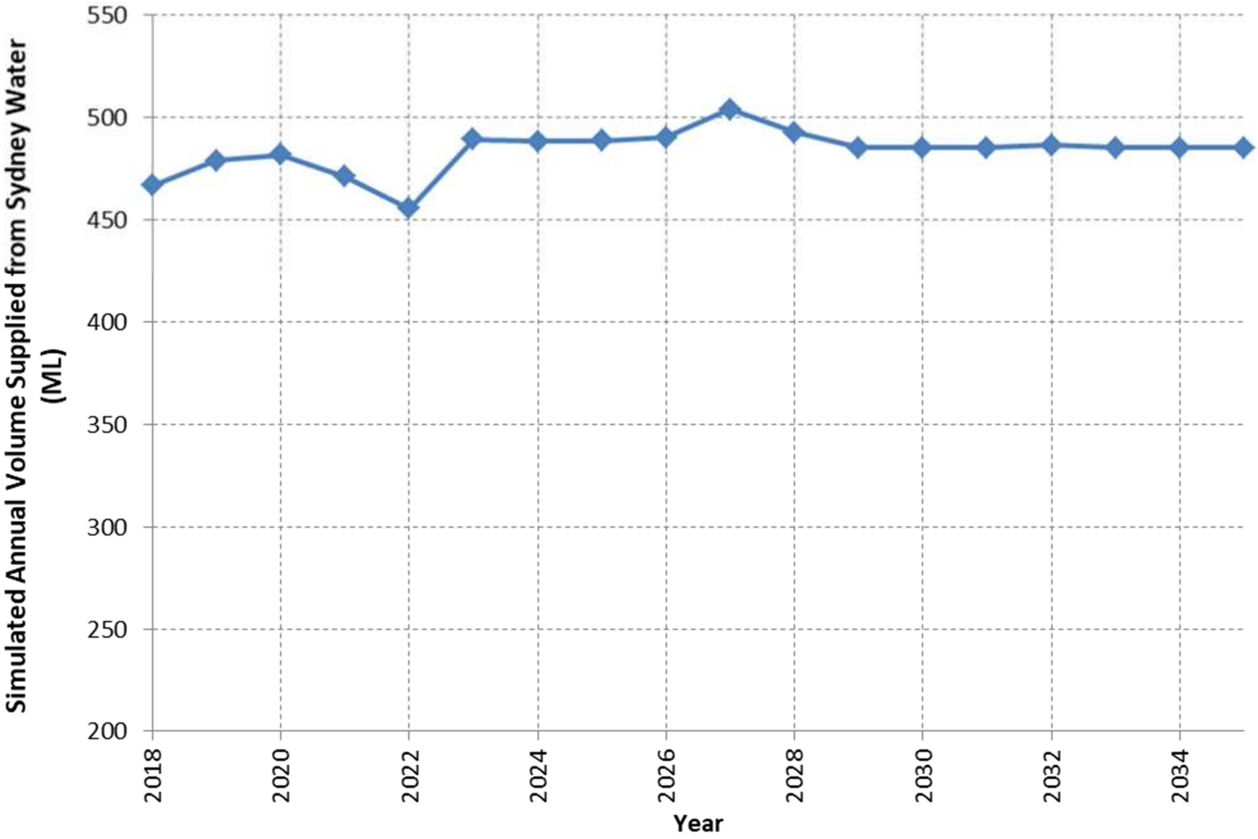

Figure 14 Simulated Annual Water Demand from Sydney Water

7.3 CONTROLLED RELEASES AND STORAGE OVERFLOWS

Simulated volumes of water discharged via LDP1 over the Project life are shown in Figure 15. The 5th percentile and 95th percentile plots in Figure 15 indicate predicted total water volume ranges within which the predicted total volume could vary, within these risk or confidence limits/levels (derived from an analysis of results from all realizations modelled). These plots have been calculated on an annual basis using results of all 128 simulated sequences. For example the 95th percentile simulated discharge in 2032 was 2,760 ML. In the same year, modelling predicted that in 50 % of climatic sequences discharge of 2,222 ML or less would occur.

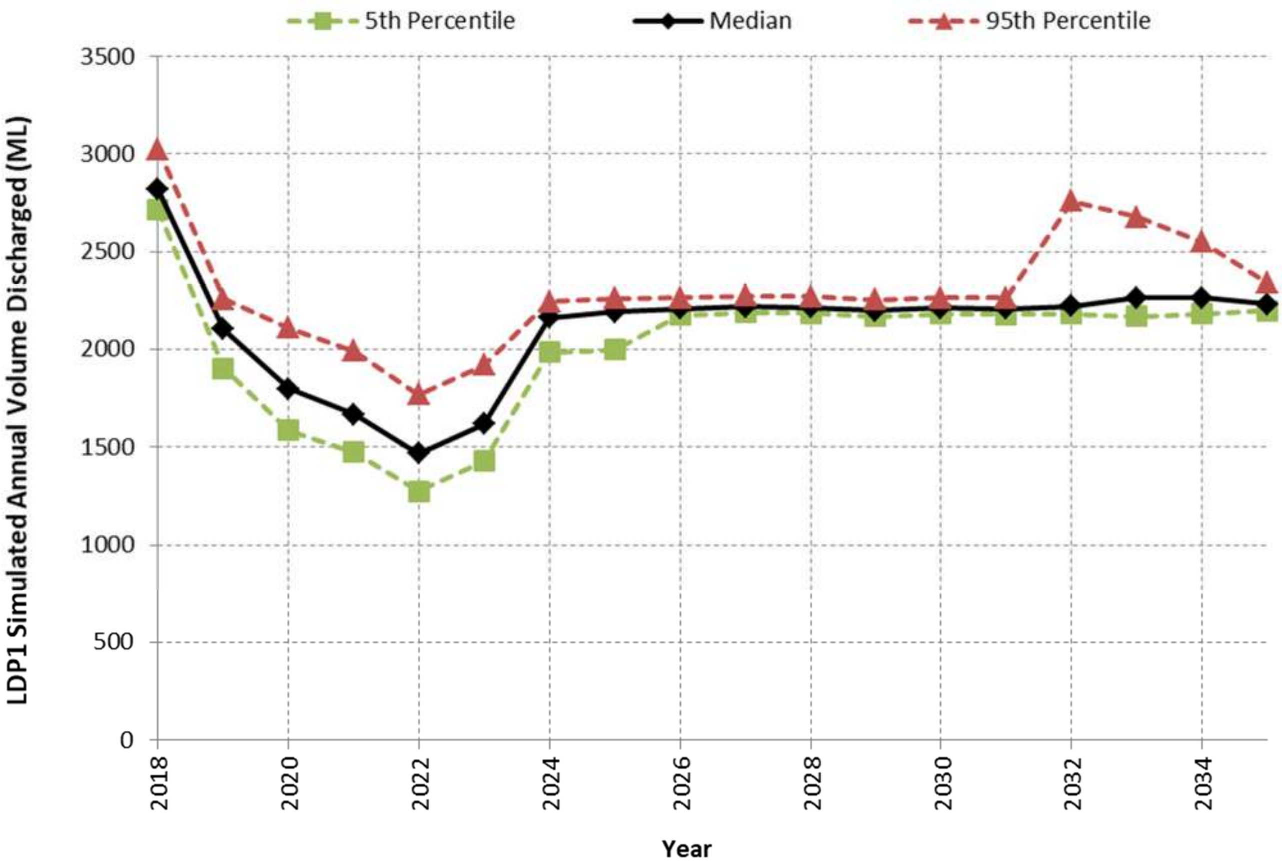

Figure 15 Simulated Annual Exceedance Statistics for Release via LDP1 to Tea Tree Hollow

Figure 16 shows annual exceedance statistics for simulated overflow releases to Tea Tree Hollow via the LOPs.

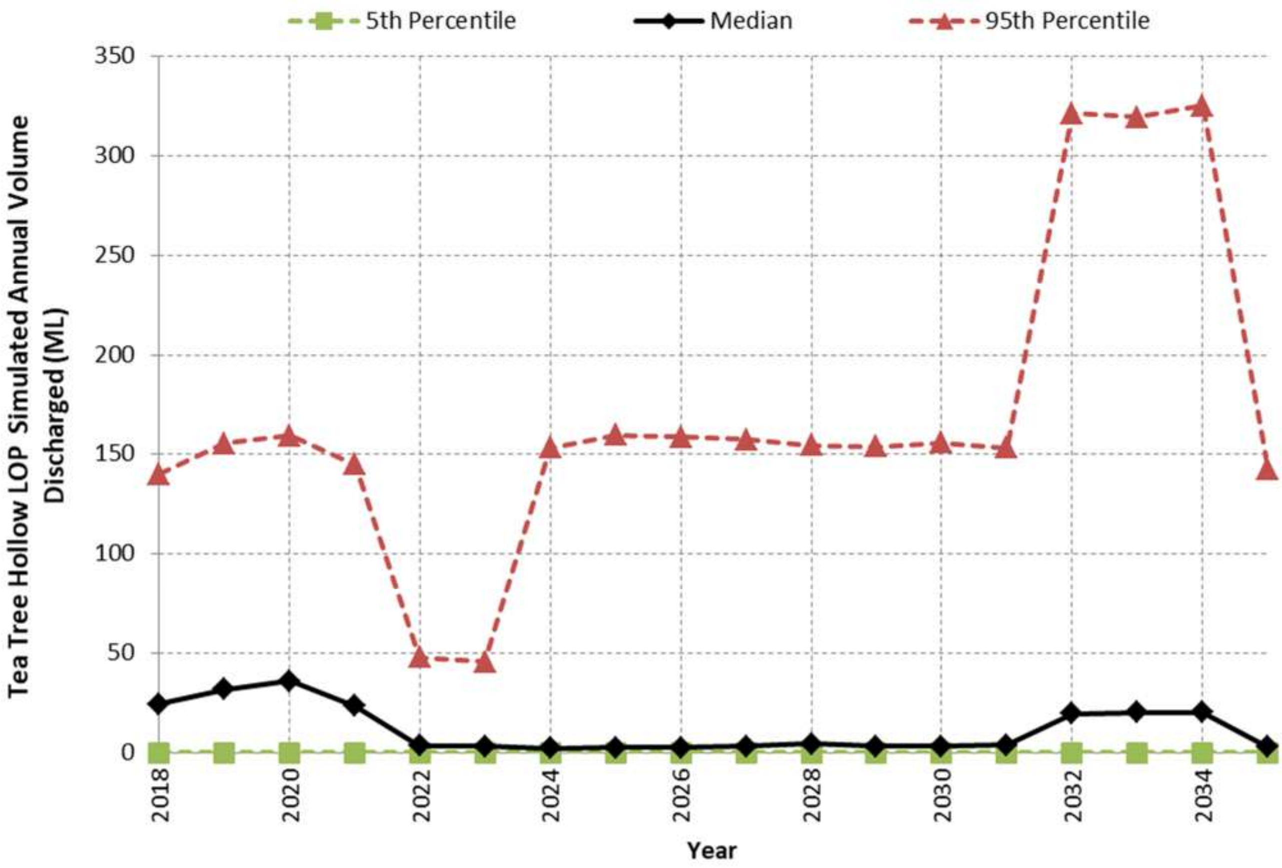

Figure 16 Simulated Annual Exceedance Statistics for Release via LOPs to Tea Tree Hollow

Simulated overflows at the median level are relatively small with a maximum of 36 ML in 2020. Under higher rainfall conditions, reflected in the 95th percentile plot, simulated overflows varied from 46 ML in 2023 to 325 ML in 2034. These results show that climate variability is likely to have a significant bearing on overflow. Changes to REA catchments (i.e. development of additional emplacement areas and progressive rehabilitation) would affect the likelihood and magnitude of overflows.

Figure 17 shows the simulated annual exceedance statistics for releases from the LOP from dam S11 to the Bargo River. Simulated overflows from dam S11 would be relatively rare with negligible releases simulated in 50 % of simulated climatic scenarios. Under higher rainfall climatic conditions, as reflected in the 95th percentile plot, overflows up to about 116 ML/annum were simulated.

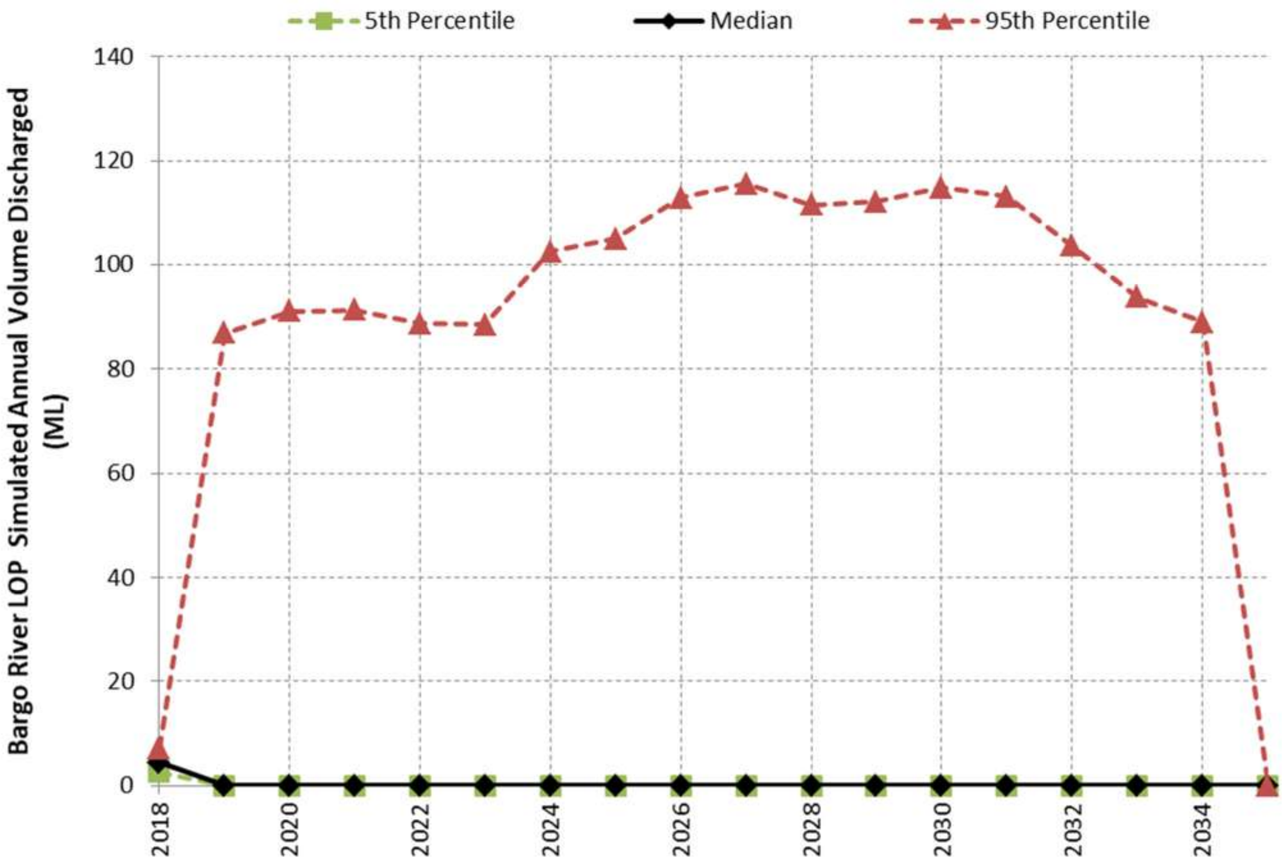

Figure 17 Simulated Annual Exceedance Statistics for Release from S11 to the Bargo River

7.4 STORED WATER VOLUME IN UNDERGROUND WATER STORAGE

The simulated performance of the water management system described in Sections 7.1 to 7.3 assumes a 4,751 ML capacity underground water storage and a 6 ML/d capacity WWTP (refer Section 4.3). The simulated volume of water stored in the underground water storage is shown in Figure 18.

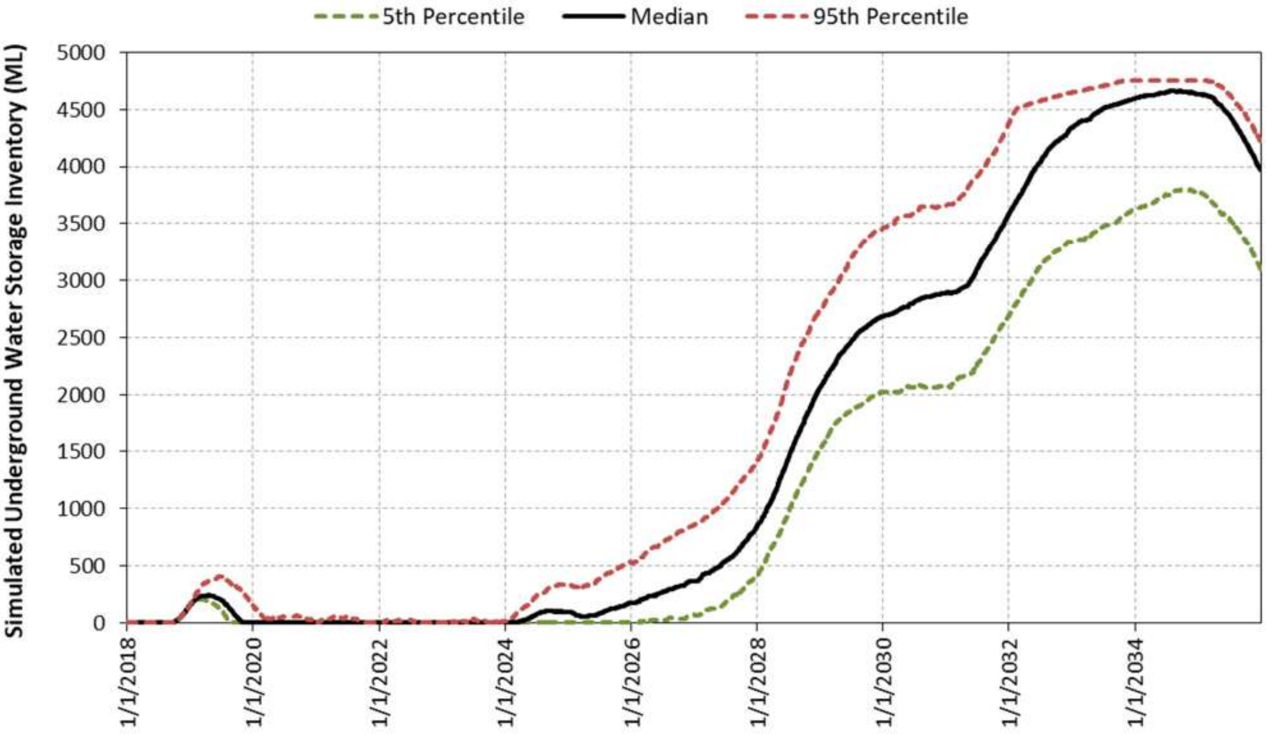

Figure 18 Simulated Underground Water Storage Volume – with 6 ML/d WWTP

Figure 18 indicates that the stored water volume is predicted to increase during the middle years of the Project life and is likely to near the storage capacity by 2034 based on the model outputs for median climatic conditions. Under 95th percentile climatic conditions, the stored water volume is predicted to reach the storage capacity by the end of 2033. The key driver of this result is the predicted underground groundwater inflow rates (refer Figure 9). Once the underground storage capacity is reached, water in excess of the WWTP capacity would not be able to be transferred to the underground water storage and would need to be transferred to M4 and hence LDP1. Note that Figure 15 indicates an increase in median and 95th percentile annual discharge volumes from approximately 2031 onwards.

In order to maintain treatment of water to be discharged via LDP1, the capacity of the WWTP may need to be upgraded at some stage. Additional simulations were undertaken with increased WWTP capacities: 7.5 ML/d and 9 ML/d. The resulting simulated median volume of water stored in the underground water storage for the three different WWTP rates is shown in Figure 19.

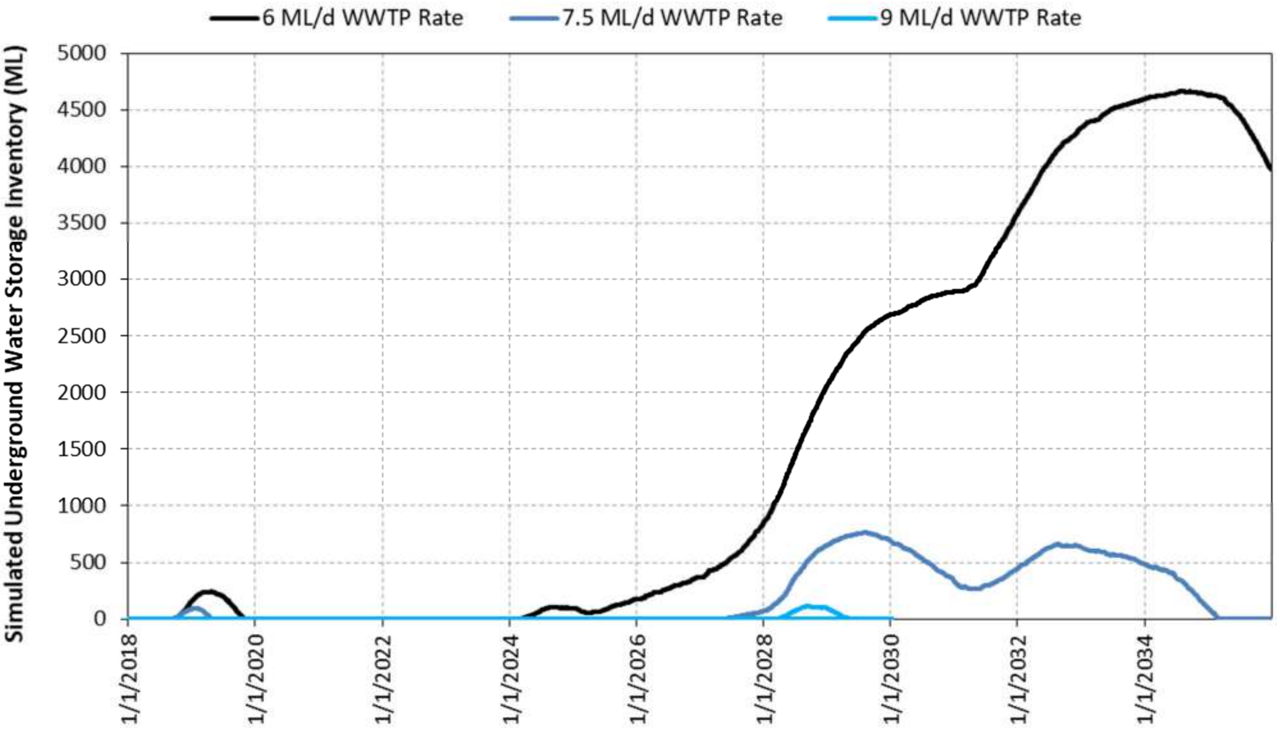

Figure 19 Simulated Median Underground Water Storage Volume – with Differing WWTP Capacities

The above model results indicate that a WWTP capacity upgrade of 1.5 to 3 ML/day should be adequate to control the build-up of water in the underground water storage. Modelling indicates that the existing WWTP (in combination with the underground water storage) should be adequate for a number of years – at least until 2031 – following which an upgrade is likely to be required. The exact capacity of the upgrade would be determined during the Project life depending on actual conditions experienced.

7.5 SUMMARY

In summary the predicted outcomes of the expanded Project life water balance model indicate the following.

1. A high level of water supply efficiency is maintained by on site recycling with 55% of underground mine water demand met by water recycled from the mine. Maintenance of supply from Sydney water is however required to meet specific water supply requirements. On average water supplied by Sydney Water accounted for 18% of system inflows.
2. The need for on-going controlled releases of treated water to Tea Tree Hollow via licensed discharge point LDP1 of approximately 2,200 ML/annum for much of the Project life.
3. Overflows to Tea Tree Hollow from LOPs are predicted during higher rainfall climatic conditions. The maximum 95th percentile annual simulated overflow from all Tea Tree Hollow licensed overflow points was 325 ML.
4. Small overflows were also simulated from the dam S11 LOP to the Bargo River during higher rainfall climatic conditions. The maximum 95th percentile simulated annual overflow from dam S11 was 116 ML/annum.

5. The recommissioned 6 ML/day capacity WWTP in combination with a 4,751 ML capacity underground water storage should be adequate to ensure continued treatment of water discharged via LDP1 at least until 2031. Thereafter a WWTP capacity upgrade of between 1.5 to 3 ML/day is likely to be required, depending on actual conditions experienced. The WWTP is easily scalable to 9 ML/day.

8.0 REFERENCES

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REPORT

Tahmoor South Project

Surface Water Impact Assessment

Prepared for: Tahmoor Coal Pty Ltd

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2	Final	TSM / CAW	Tahmoor Coal, AECOM	TSM	16 Nov 2018
3	Final - Revised	TSM / CAW	Tahmoor Coal, AECOM	TSM	20 Dec 2018

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APPENDICES

1.0 INTRODUCTION

Hydro Engineering & Consulting Pty Ltd (HEC) has been commissioned by Tahmoor Coal Pty Limited (Tahmoor Coal) to complete a surface water assessment for the Tahmoor South Project (the Project). The purpose of this assessment is to complete the surface water assessment component of the Environmental Impact Statement (EIS) for the Project under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Surface Water Assessment has been undertaken in four parts.

- Baseline Assessment (BA) Report which documents the available baseline and background information and analysis of the climate, hydrology and water quality characteristics of local and regional water resources of relevance to the Tahmoor South Project.
- Water Management System and Site Water Balance Report (WMS/SWB) which describes the existing water management system, the proposed changes to site water management and the results of a water balance model simulation of the proposed water management system over the Project life including water supply reliability, the adequacy of the current discharge licence to Tea Tree Hollow to manage disposal of water during periods/circumstances when excesses are predicted and the risk overflows under a wide range of climatic conditions which could occur during the Project life.
- Flood Study (FS) comprising an assessment of the effects of the Tahmoor South Project on flooding in overlying watercourses and their floodplains.
- Surface Water Impact Assessment Report (SWIA) which contains a detailed qualitative and quantitative assessment of the potential impacts which are either predicted to occur or could occur from the Project - including the effect of predicted subsidence on natural stream features, potential effects to catchment yield, flow diversion and stream water quality.

This report details the Surface Water Impact Assessment for the Tahmoor South Project Area. This report summarises the results of an assessment of the effects of subsidence on local and regional surface water regimes and surface water quality. Results from the assessment have been used to recommend mitigation measures to reduce the effects of subsidence on the flow, water quality and stability of overlying watercourses. Recommendations are also made for ongoing monitoring.

1.1 BACKGROUND AND OVERVIEW

Tahmoor Coal owns and operates the Tahmoor Mine, an underground coal mine approximately 80 kilometres (km) south-west of Sydney, in the Southern Coalfields of NSW. Tahmoor Coal produces up to three million tonnes per annum of product coal from its existing operations at the Tahmoor Mine, and undertakes underground mining under existing development consents, licences and the conditions of relevant mining leases.

Tahmoor Coal is seeking approval for the Tahmoor South Project, being the extension of underground coal mining at Tahmoor Mine, to the south and east of the existing Tahmoor Mine surface facilities area. The proposed development would continue to be accessed via the existing surface facilities at Tahmoor Mine, located between the towns of Tahmoor and Bargo.

The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2035. The proposal would enable mining to be undertaken within the southern portion of Tahmoor Coal's existing lease areas and for operations and employment of the current workforce to continue for a further 13 years.

The proposed development would extend mining at Tahmoor Mine within the Project Area, using longwall methods, with the continued use of ancillary infrastructure at the existing Tahmoor Mine surface facilities area. The Project Area is adjacent and to the south of the Existing Tahmoor Approved Mining Area. It also overlaps a small area of the Existing Tahmoor Approved Mining Area comprising the surface facilities area, historical workings and other existing mine infrastructure.

1.2 PROPOSED DEVELOPMENT

The proposed development would use longwall mining to extract coal from the Bulli seam within the bounds of CCL 716 and CCL 747. Coal extraction of up to 4 Mtpa ROM is proposed as part of the development. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing Coal Handling and Preparation Plant (CHPP) and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla for export to the international market.

The key components of the proposed development comprise:

- Mine development including underground redevelopment, ventilation shaft construction, pre-gas drainage and service connection;
- Longwall mining in the Project Area;
- Upgrades to the existing surface facilities area including:
  - upgrades to the CHPP;
  - expansion of the existing reject emplacement area (REA);
  - relocation of the rejects bin and extension of the rejects conveyor;
  - additional mobile plant for coal handling;
  - additions to the existing bathhouses, stores and associated access ways;
  - upgrades to onsite and offsite service infrastructure, including electrical supply;
- Rail transport of product coal to Port Kembla, and Newcastle (from time to time);
- Mine closure and rehabilitation; and
- Environmental management.

1.3 STUDY REQUIREMENTS

The Tahmoor South Project EIS has been prepared in accordance with Division 4.1, Part 4 of the EP&A Act which ensures that the potential environmental effects of a proposal are properly assessed and considered in the decision-making process.

The Surface Water Assessment is guided by the Secretary's Environmental Assessment Requirements (SEARs) for SSD 17_8445, including the amendment dated 14 February 2018 to incorporate the requirements of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Detailed agency comments have also been addressed in this and other component reports including comments from the NSW Environment Protection Authority (EPA), NSW Office of Environment & Heritage (OEH) and WaterNSW. The BA Report contains a summary of these requirements including where they have been addressed.

It is noted that since the preparation of the preliminary environmental assessment (PEA) for the Project (AECOM, 2012), the proposed mine plan for Tahmoor South has been amended to preclude mining and related subsidence within the Sydney Drinking Water Catchment, that is, within the catchment of Cow Creek, a tributary of the Nepean River upstream of Pheasants Nest Weir. It is therefore concluded that there would be no surface water related impacts resulting from the Project on these catchments – refer also Section 13.0.

2.0 PROJECT DESCRIPTION

2.1 OVERVIEW

Tahmoor Coal is seeking approval for the continuation of mining at Tahmoor Mine, extending underground operations and associated infrastructure south within the Bargo area and to the east within the Pheasants Nest area (refer Figure 1). The proposed development seeks to extend the life of underground mining at Tahmoor Mine for an additional 13 years until approximately 2035.

The proposed development will use longwall mining to extract coal from the Bulli seam within the bounds of CCL716 and CCL747. Coal extraction of up to 4 million tonnes of run-of-mine (ROM) coal per annum is proposed as part of the development with extraction of up to 37 Mt of ROM coal over the life of the Project.

The proposed Project would utilise the existing surface infrastructure at the Tahmoor Mine surface facilities area, with some upgrades proposed to facilitate the extension. The proposed Project also incorporates the planning for rehabilitation and mine closure once mining ceases.

2.2 UNDERGROUND MINING OPERATIONS

2.2.1 Mining Area

Tahmoor Coal holds CCL 747 and CCL 716. The Project proposes to mine coal from the Bulli seam at a depth of between approximately 375 m and 430 m below ground level. The proposed mining area is bounded by known geological fault zones.

During the mine planning process, a constraints analysis, risk assessment and preliminary fieldwork were undertaken to identify sensitive natural surface features (such as waterways, cliffs, and Aboriginal heritage sites) and to develop Risk Management Zones (RMZs). Subsequent to the risk assessment the proposed longwall layout was modified to minimise significant subsidence impacts to these natural features. The underground extent of the mine proposed on Figure 1 represents this configuration.

The longwalls would be orientated in a south-east/north-west direction and would be located within the Bargo area. The longwall layout would continue to be refined during the detailed design phase of the proposed development. However, the maximum extent of longwall mining for the proposed development would be as depicted on Figure 1.

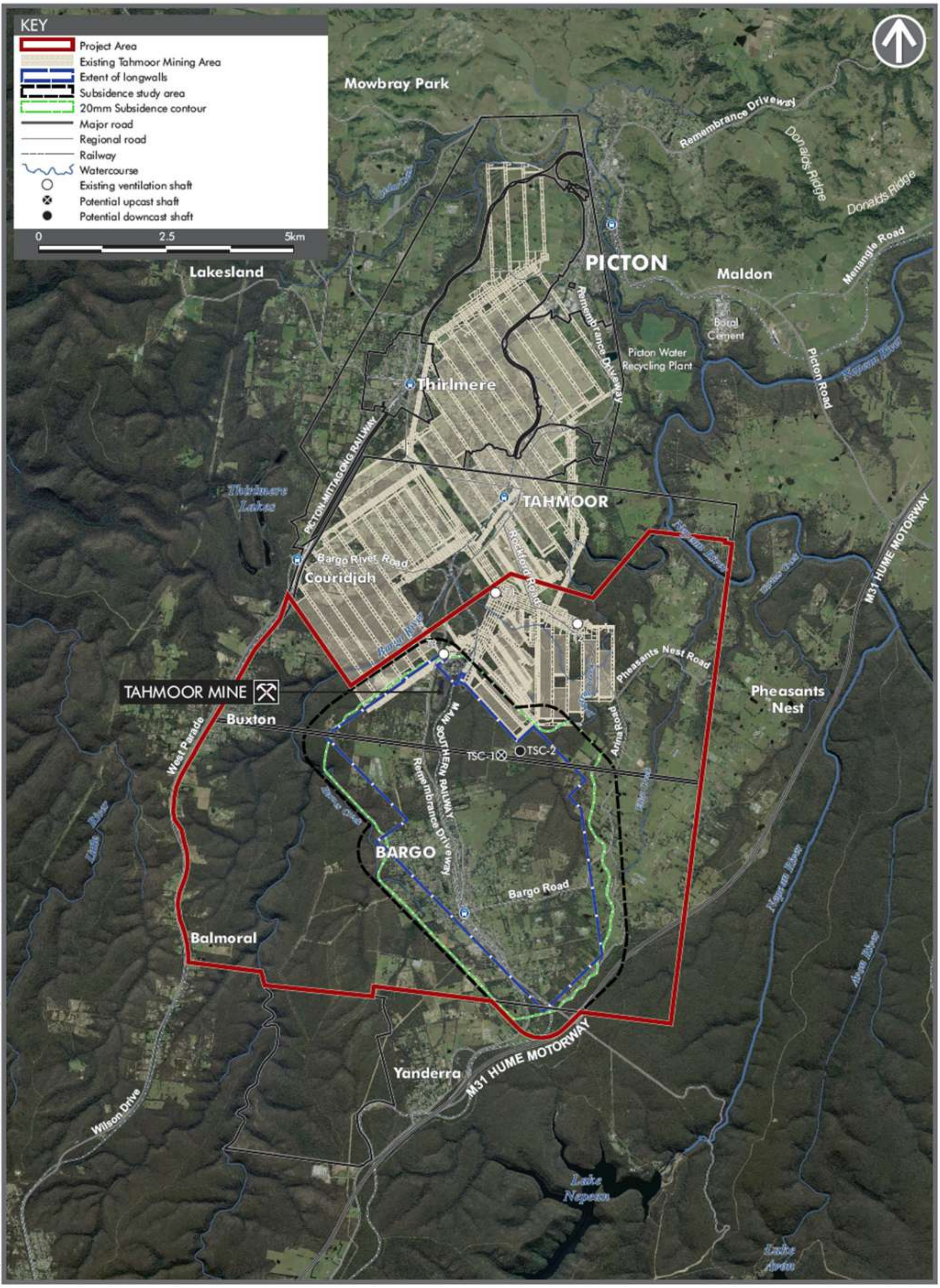

Figure 1 Locality Plan and Project Layout

As part of the proposed development, subsidence predictions have been undertaken for residential, commercial and business structures, public infrastructure such as pools and public amenities, utility services such as water and gas mains, and other associated infrastructure. These predictions and potential impacts would be captured within a subsidence management plan (SMP) prior to longwall mining for the proposed development and would incorporate the management measures identified herein.

2.2.2 Mine Development

To enable the continuation of mining to occur sequentially with the current mining operations in Tahmoor North, which are scheduled for completion in approximately 2022, the Project's development works need to commence in approximately 2019. Pre-development activities include:

- recovery of existing underground development roadways;
- redevelopment of the underground pit bottom;
- pre-gas drainage;
- longwall development including establishment of gate roads;
- installation of electrical, water and gas management networks; and
- the purchase and installation of equipment.

An additional 50 to 175 personnel would be required for the Project's development works, which may occur concurrently with the ongoing mining operations at Tahmoor North. Additional site amenities, including bath houses and additional onsite car parks would be required to accommodate the increased workforce during the transition period from mining operations at Tahmoor North and the Project's development works.

During this transition period, other site infrastructure required for longwall mining at the Project would be constructed. Specifically, this would include construction of new mine ventilation shafts, construction of a hardstand area for longwall machinery set up and upgrades to the CHPP.

2.2.3 Mine Ventilation

The proposed development would utilise the existing mine's ventilation system, including the existing three ventilation shafts, being one upcast (T2) and two downcast shafts (T1 and T3). Additionally, the proposed development would require the construction of two ventilation shafts to provide a reliable and adequate supply of ventilation air to personnel in the mine. The two additional vent shafts proposed for the Project are:

- TSC1: an upcast ventilation shaft that will be located on Tahmoor Coal's Charlies Point Road property; and
- TSC2: a downcast ventilation shaft that will be located on Crown Land adjacent to Tahmoor Coal's Charlies Point Road property.

The construction of the ventilation shafts would require the disturbance of an area of between four to six hectares in area at each location. Access to TSC1 and TSC2 would be from the existing road network.

The construction of each of the proposed ventilation shafts would involve the following:

- Construction of internal roads to allow access for construction and operational maintenance vehicles.
- Establishment of the construction site to allow sufficient space for stockpiling of shaft liners for TSC1 and TSC2, temporary spoil emplacement for TSC2, water management, storage

and safe movement on-site during construction activities. Establishment of the ventilation shaft site would involve:

- Installation of environmental controls such as silt fences, fencing with lockable gates, as well as display of signage relating to restricted entry.
- Clearing of vegetation and stripping of topsoil. Topsoil would be temporarily stockpiled for rehabilitation post construction.
- Excavation and construction of a temporary hardstand area for operation of drilling equipment. The hardstand area would be determined by the size and number of liner pieces to be manufactured and excavated to a depth of approximately 0.2 m. The temporary hardstand areas would include:
    - approximately 2,000 m^2 of road base surrounding the site compound area and drill rig slab for site facilities;
    - approximately 2,000 m^2 for laydown areas and a 4,500 m^2 levelled hardstand area for storage of the ventilation shaft liners;
    - a stable access way between the liner storage area and the shaft to facilitate transport of the cured liner segments on purpose built trailers; and
    - a concrete pad 20 m by 15 m is to be constructed around the top of the shaft as a foundation for the drill rig and to provide a clean work area.
- Connection of 66 kV electrical power and establishment of electrical substations at ventilation shaft sites.
- Sinking of the shaft using blind boring methods (or similar method), and lining of the shafts using a composite concrete and steel liner (or similar method).
- Construction of fan buildings and installation of ventilation fans. The upcast shaft site fan building would also incorporate a fan outlet stack, approximately 30 m high, to control odour discharge from the mine.

Runoff from site TSC1 would report to storages within the existing pit top water management system. Site TSC2 would incorporate water treatment sedimentation controls, with the settled water from the ventilation shaft being pumped via overland pipeline to a final sedimentation pond on the surface facilities area for further treatment and discharge though LDP1. Alternatively water may be discharged via a new licensed discharge point, which would require a variation to EPL 1389.

2.2.4 Gas Drainage Operations

Coal mines need to control underground gas concentration levels to below safe limits so that miners are able to work in a safe environment and mining operations can be undertaken as efficiently as possible.

The coal seams within the Southern Coalfield are generally known to be gassy, with methane and carbon dioxide released from the goaf during mining. Gas in the underground workings would be managed by a series of gas drainage operations including:

- pre-gas drainage, whereby gas would be extracted from the coal seam prior to longwall mining;
- post-gas drainage, whereby gas would be extracted from the goaf; and
- gas extraction via the mine ventilation system, which would occur throughout mining.

Gas management would continue to use the existing infrastructure, including the Tahmoor Mine Gas Plant, Gas Plant Vent and Flare Plant, as well as the WCMG Power Plant when it is available. Some components of the existing gas management infrastructure may need to be upgraded throughout the life of the proposed development

2.2.5 Pre-Gas Drainage

The purpose of pre-gas drainage is to reduce gas volumes in the coal seams prior to mining, with the Bulli, Wongawilli and Balgownie seams targeted for pre-gas drainage at Tahmoor Mine. Pre-gas drainage of the gas levels in the seams is required to facilitate the timely commencement and progression of mining as well as to reduce the demands on the mine ventilation system for the purpose of gas dilution during operations.

Pre-gas drainage activities are mainly undertaken underground, via drilling and drainage from the roadways developed for longwall panels. Underground pre-gas drainage works at Tahmoor Mine would drain gas following development of the mine roadways and prior to longwall development. Gas would be drawn from the coal seam by vacuum and piped to the Gas Plant at the surface facilities area via the underground pipe network. Underground gas drainage of the coal seam would continue ahead of longwall development for the life of mining.

Surface pre-gas drainage works are proposed for the eastern portion of the Project Area. Extracted gas would be brought to the surface and transferred via a pipeline to the existing gas plant at the Tahmoor Mine. To enable gas to be released from the seam during pre-gas drainage, the coal seam would be dewatered via horizontal drilling within the seam. The drained water would be collected on the surface and transferred to the existing water management system at the surface facilities area via an overland pipeline or truck.

Two Surface to Inseam (SIS) drilling sites and gas well sites are proposed, subject to the final detailed design of the development mains. SIS drilling and gas well sites are subject to obtaining land access agreements and therefore flexibility is required for the location of these works. The gas collection pipeline is proposed to be constructed within a trench alongside the public roadway and potential exists for alternative locations.

Gas from the coal seam would be drained using pumps, collected at the surface and piped to the existing Gas Plant at the Tahmoor Mine surface facilities area to be used in the WCMG Power Plant or Gas Fare Plant.

2.2.6 Post-Gas Drainage

Post-gas drainage would be required as strata relaxation caused by the retreating underground longwall face would liberate volumes of gas into the mine workings from the underlying Wongawilli seam and from overlying strata, released due to fracturing of the goaf. To capture this gas during the proposed development, cross-measure boreholes are proposed to be drilled from the mine workings into the Wongawilli seam. These boreholes would be designed to collect the gas at its source or to intercept gas before it migrates into the mine workings. At the conclusion of mining from each panel, the panel would be sealed and gas drawn from the sealed areas as part of the post-gas drainage operations. The gas collected from the in-seam and cross-measure boreholes would be drawn by vacuum via the underground pipe network to the Gas Plant located at the surface facilities area.

2.2.7 Gas in Ventilation

The ventilation system would deliver fresh air into the mine from the existing and proposed downcast vent shafts and would extract stale air from the mine via the existing and proposed upcast vent shafts

(refer Section 2.2.3). Similar to the existing operations, the ventilation system would carry the remaining diluted gases out of the mine via the upcast mine vent shafts.

2.2.8 Mining Method and Equipment

Underground mining would be undertaken via main roadway and longwall development using continuous miners. Longwall development refers to the mining of a series of roadways (gate roads) and cut-throughs, to form pillars of coal that would support the overlying strata during the extraction of coal. Longwalls would be up to 305 m wide. The gate roads would be approximately 5.2 m wide and approximately 3 m high.

Coal would be cut from the coal face by the longwall shearer, loaded onto the armoured face conveyor and transported to the surface facilities area via a series of underground conveyors. The longwall would retreat as coal is mined and the overlying rock strata would collapse into the void left by the coal extraction, forming the goaf.

A new hardstand area would be constructed adjacent to the existing southern coal stockpile at the surface facilities area to cater for the delivery and assemblage of mining equipment and the storage of equipment.

Tahmoor Coal would continue to investigate improved or alternate mining methods and technology throughout the life of the proposed development. Improved methods would be utilised where available to allow for the efficient and economically viable extraction of the coal resource. Tahmoor Coal would ensure that the resulting environmental and social impacts of improved or alternate methods are consistent with those predicted in this EIS.

2.2.9 Mine Access

The proposed development would use the existing infrastructure at Tahmoor Mine for employee and material access to the mine. Access to the mine would be via the existing Tahmoor Mine surface facilities area, the existing drift, and men and materials travel lift installed within the T3 downcast shaft. The T3 vertical men and material travel lift has a capacity for 70 persons and approximately 12 tonnes of materials.

2.2.10 Coal Production

Tahmoor Coal is a shareholder of Port Kembla Coal Terminal and has contractual arrangements in place for coal export associated with the proposed output from the Project.

The proposed development would transport product coal from Tahmoor Mine to Port Kembla, via the existing mine rail load out, rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway.

Tahmoor Mine currently has four allocated train paths per day from ARTC for the rail network between the Tahmoor Mine and Port Kembla. This current allocation is equivalent to the transport of approximately four million tonnes of product coal per annum and is sufficient for the life of the Tahmoor South Project. A rail transport study has been undertaken for the proposed development, which indicates that the existing rail capacity would be sufficient for the proposed transport of product coal to Port Kembla under the proposed development, and no increase in rail capacity between Tahmoor Mine and Port Kembla would be required. As such, existing rail infrastructure and the number of allowable train movements would remain unchanged

2.3 SURFACE FACILITIES AREA

The existing surface facilities and infrastructure at the Tahmoor Mine surface facilities area, operating within surface CCL 716 and Mining Lease 1642, would be utilised for the proposed development.

Upgrades to some aspects of the surface facilities area would be required and are associated with the increase in annual coal production for the proposed development. Upgrades to existing surface infrastructure would be undertaken within the area of the existing Tahmoor Mine surface lease (Mining Lease 1642) and additional surface lease areas required for the proposed development. The proposed upgrades are described in the following sub-sections.

2.3.1 Coal Handling and Preparation Plant

The existing CHPP would be utilised for the proposed development. The existing CHPP would be upgraded including the installation of:

- a new coarse rejects screen,
- additional belt press filter capacity, and
- an increase in thickener capacity.

The existing ROM stockpile area would continue to be utilised by the proposed development. During peak production ROM coal may be trucked from the ROM stockpile to the coal product stockpiles and re-trucked back to the ROM stockpile when required. Reject material generated from the coal washing process at the CHPP would be transported to the expanded REA via the existing reject conveyor to the reject bin for disposal, and then transported by haul truck to the REA.

2.3.2 Rejects Management

The existing REA would be expanded onto adjacent areas to accommodate the reject material associated with the proposed development. The expansion area is anticipated to cover up to an additional 43 hectares, providing an additional emplacement capacity of approximately 12 Mt for the rejects generated during the operation of the proposed development.

Construction and maintenance of new internal haul roads would be required to cater for the REA expansion.

The stormwater management system and infrastructure at the existing REA would be augmented with the construction of additional sedimentation dams, drains and pumping station. These are described in the WMS/SWB Report.

2.3.3 Plant and Equipment

The proposed development would utilise existing plant and equipment at the surface facilities area and would also require additional mobile plant for coal material handling at the surface facilities area. The proposed additional plant would include:

- a secondary bulldozer at the product coal stockpile.
- additional ancillary equipment such as trucks, cranes and forklifts for use around the surface facilities area to manage product and equipment stores.

2.3.4 Hours of Operation

The proposed development, including construction activities, would to operate 24 hours a day, seven days per week, consistent with the working hours of the current operations at the Tahmoor Mine.

3.0 OVERVIEW OF SURFACE WATER RESOURCES IN STUDY AREA

A detailed description of the baseline characteristics of surface water resources in the Study Area is provided the Baseline Hydrology Report. The following is a brief summary intended to form a background to the surface water assessment.

3.1 CATCHMENTS AND DRAINAGE

The existing Tahmoor Mine and the Project Area are located within the Bargo River catchment. From its headwaters near the townships of Hill Top and Yerrinbool, the Bargo River flows in a generally north-easterly direction through incised valleys and gorges to its confluence with the Nepean River, near the Pheasants Nest Weir. The lower 4 km of the river pass through the Bargo River Gorge, which is characterized by steep rock faces up to 110 m high. The river consists of a sequence of pools, glides and rock bars across sandstone bedrock, with occasional boulder fields and cobblestone riffles. The Bargo River drains a total catchment of some 130 square kilometres (km^2) at its confluence with the Nepean River.

The Bargo River has intermittent flow in its upstream reaches. In its upper reaches flows are, to some degree, regulated by the Picton Weir, which is approximately 14 km upstream of the Nepean River confluence. Downstream of the Tahmoor Mine pit top (i.e. downstream of the Tea Tree Hollow confluence) flow is perennial due to persistent discharges from Tahmoor Mine. The Bargo River flows into the Nepean River 9 km downstream of the Tea Tree Hollow confluence.

The Nepean River rises in the Great Dividing Range to the west of the Project Area. Its headwaters also lie in the coastal ranges to the east of the Project Area. Flows in the upper reaches of the Nepean River are highly regulated by the Upper Nepean Water Supply Scheme, operated by WaterNSW, which incorporates four major water supply dams on the Cataract, Cordeaux, Avon and Nepean Rivers. The Nepean Dam is situated approximately 18 km upstream of the Bargo River confluence. Flows in the Nepean River near and downstream of the Project Area are not part of a WaterNSW Drinking Water Catchment Area.

Further downstream, the Nepean River has been extensively modified by the construction of a series of in-stream weirs which have created a series of pondages - the closest to the Project Area being the Maldon Weir. Ponding behind the Maldon Weir does not affect water levels as far upstream as the Project Area.

The Nepean River flows into the Warragamba River near the Wallacia River, downstream of which it is referred to as the Hawkesbury-Nepean River. The Hawkesbury- Nepean catchment is one of the largest coastal catchments in NSW with an area of some 21,400 km^2 at its mouth in Broken Bay on the northern side of the Sydney Metropolitan area.

The Project Area catchments and associated monitoring sites are shown in Figure 2. Topography in the Project Area is varied, ranging from gently undulating plateau, ridges and low hills in the upland areas, to a rugged landscape of deeply dissected valleys and gorges in Hawkesbury Sandstone. The upland areas, including Bargo Township, are drained by headwater streams of Hornes Creek, Tea Tree Hollow, Dog Trap Creek and Eliza Creek. The lower reaches of Tea Tree Hollow, Dog Trap Creek and the Bargo River have, to varying degrees, experienced subsidence-related effects due to mining operations at the existing Tahmoor Mine.

The Project Area is predominantly drained by Tea Tree Hollow and Dog Trap Creek which flow generally north and eastward toward the Bargo River. A small area on the south western side of the proposed longwall panel extent is drained by headwater tributaries of Hornes Creek which flows into the Bargo River at Picton Weir.

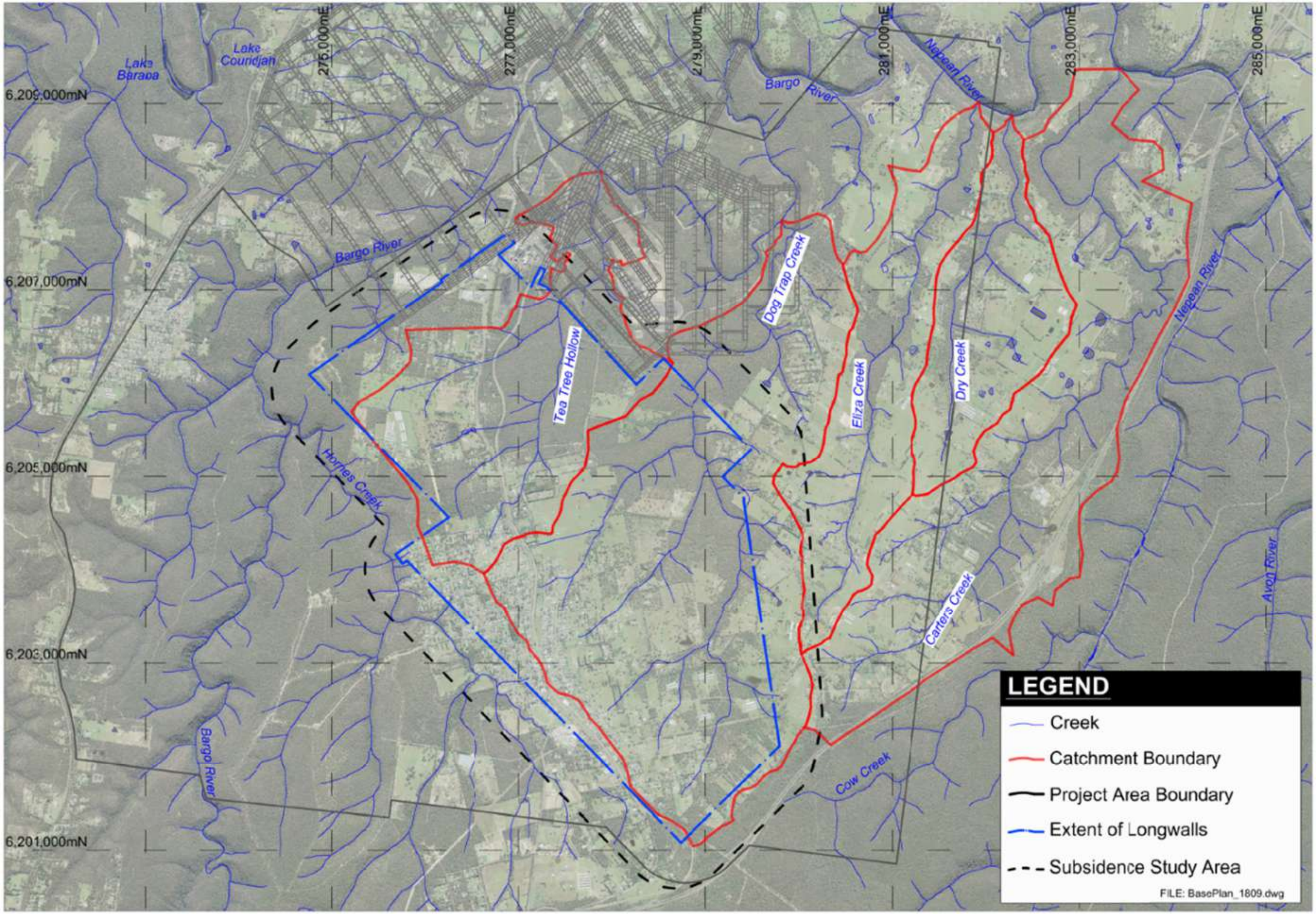

Figure 2 Project Area Streams and Catchments

The eastern portion of the Project Area is predominantly drained by Eliza Creek which flows generally northward to the Nepean River. A small part of the eastern portion of the Project Area is also drained by Carters Creek which flows north-eastward to the Nepean River. Cow Creek, which is within the Metropolitan Special Area, lies to the east of the Project Area and is a tributary of the Nepean River upstream of Pheasants Nest Weir.

A summary of the hydrological characteristics of these drainages is provided below. Tahmoor Coal established gauging stations on each of these creeks at various times as indicated below and have undertaken a flow gauging program to develop flow ratings[1] for each station. A baseline water quality monitoring program has also been undertaken at each gauging station. Results of this monitoring are summarized in HEC (2018a).

3.1.1 Hornes Creek

Hornes Creek is a 4th order stream[2] with a total catchment of 19.5 km^2, some 3% of which lies within the Project Area. Creek flows are likely to be affected by stormwater runoff from the southern part of the township of Bargo.

Tahmoor Coal established a streamflow gauging station on Hornes Creek in February 2012 and undertook water quality sampling between May 2012 and June 2015.

3.1.2 Tea Tree Hollow

Tea Tree Hollow is a 3rd order stream which drains the portion of the Project Area overlying the western part of the Tahmoor South mine area. Tea Tree Hollow flows from its headwaters in the northern part of the Bargo Township, through the Project Area and past the existing Tahmoor pit top and REA to the Bargo River. In total, it drains a total area of some 6.8 km^2. Tea Tree Hollow comprises two main tributary arms which join upstream of the Tahmoor REA.

Licensed discharges from the Tahmoor mine pit top enter Tea Tree Hollow at LDP1 some 800 m upstream of the confluence with the Bargo River.

Tahmoor Coal established a streamflow gauging station on Tea Tree Hollow in February 2010 and undertook water quality sampling between September 2012 and June 2015.

3.1.3 Dog Trap Creek

Dog Trap Creek is a 3rd order stream which drains the portion of the Project Area overlying the eastern part of the Tahmoor South mine area. The catchment rises along a low ridge line which runs through the centre of the Bargo Township. It drains a total area of 13.6 km^2 at its confluence with the Bargo River. The upper reaches of Dog Trap Creek comprise three main tributaries.

Tahmoor Coal established two gauging stations on Dog Trap Creek in February - March 2012 and undertook water quality sampling at two sites between April 2012 and June 2015.

3.1.4 Eliza Creek

Eliza Creek drains much of the eastern portion of the Project Area. Mining is not proposed within the catchment of Eliza Creek. The catchment rises along a low ridge line to the south of the Project Area. The creek is a 2nd order stream and drains a total area of 4.9 km^2 at its confluence with the Bargo River.

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[1] Flow rating is a calibration relationship specific to each gauging station site which enables flow rate to be derived from recorded water level at that particular site location. A period of time is required following station establishment to develop a rating relationship.

[2] Strahler stream order classification scheme

Tahmoor Coal established a gauging station on Eliza Creek in October 2012 and undertook water quality sampling between September 2012 and June 2015.

3.1.5 Cow Creek

The upper reaches of Cow Creek drain a small area on the south-eastern side of the Project Area. The catchment rises along a low ridge line on the eastern side of the Project Area approximately coincident with the Hume Highway. The creek is a 3rd order stream at the Project Area boundary. It drains a total area of 10.1 km^2 at its confluence with the Nepean River, some 18% of which is within the Project Area.

Tahmoor Coal established a gauging station in February 2013 and undertook water quality sampling on Cow Creek between February 2013 and June 2015.

3.1.6 Dry Creek

The upper reaches of Dry Creek drain a small area on the eastern side of the Project Area. The catchment rises along low ridge line on the eastern side of the Project Area. The creek comprises a 1st order stream at the Project longwall boundary. It drains a total area of 3.6 km^2 at its confluence with the Nepean River.

Tahmoor Coal established a gauging station on Dry Creek in January 2013 and undertook water quality sampling between September 2012 and June 2015.

3.1.7 Carters Creek

The upper reaches of Carters Creek drain a small area on the south-eastern side of the Project area. Mining is not proposed within the catchment of Carters Creek. The catchment rises along low ridge line on the eastern side of the Project Area. The creek comprises a 3rd order stream at the Project longwall boundary. It drains a total area of 6.4 km^2 at its confluence with the Nepean River, some 35% of which is within the Project Area.

Tahmoor Coal established a gauging station on Carters Creek in October 2013 and undertook water quality sampling between September 2012 and June 2015.

3.2 THIRLMERE LAKES

The Thirlmere Lakes lie to the west of the existing Tahmoor Mine, in the upper reaches of Blue Gum Creek, which ultimately flows to Lake Burragorang (Warragamba Dam) – Sydney's main water supply storage. The Thirlmere Lakes lie within the Thirlmere Lakes National Park which is part of the Greater Blue Mountains World Heritage Area. The Lakes are a series of five interconnected Lakes (in order from most upstream to downstream): Gandangarra, Werri Berri, Couridjah, Baraba and Nerrigorang (refer Figure 28). The nearest Tahmoor Mine longwall panels to the Thirlmere Lakes were mined between 1996 and 2002 and were located approximately 600 m from Lake Couridjah.

The Project is significantly further from the Thirlmere Lakes than the Tahmoor Mine. This assessment has considered the potential impact of the Project on the Thirlmere Lakes (refer Section 8.0).

4.0 IDENTIFICATION OF AND APPROACH TO THE ASSESSMENT OF SURFACE WATER IMPACTS

The following potential impacts to surface water from the Project have been identified based on consideration of the proposed Project, experience with historical longwall mining at Tahmoor and other similar longwall mining operations in the Southern Coalfields and the subsidence assessment compiled by MSEC (2018). Some (or possibly all) of these effects may occur in Tea Tree Hollow and Dog Trap Creek reek as these are directly mined under by longwall methods and subsequently impacted by subsidence. They are less likely to occur in streams that are not directly mined under or are on the edge of planned longwall mining areas.

Potential impacts to surface waters can be divided into three principal types:

1. impacts to flow rate or the quantity of flow;
2. changes to the hydraulic characteristics and associated impacts to the physical stability of the watercourses; and
3. impacts to the water quality characteristics of watercourses.

These potential impacts and the mechanisms or causes of them are given in the sub-sections below in relation to the Project.

4.1 POTENTIAL IMPACTS TO FLOW RATE OR QUANTITY OF WATER IN WATERCOURSES

1. Reduced flow due to excision of catchment runoff from areas associated with expansion of the REA. Potential impacts to Tea Tree Hollow and Bargo River.
2. Reduced runoff and loss of surface flow due to the subsidence induced shallow (tensile) fracture network and flow capture/diversion resulting in loss of a proportion of low flows and the diversion of this water downstream via the underground fracture network. The shallow fracture network is referred to as an “upper zone of disconnected-cracking” in HydroSimulations (2018a) – i.e. which is disconnected from the longwall mining. MSEC (2018) indicate that any flow redirected through this shallow fracture network would not divert into deeper strata or the mine itself. Associated impacts include reduced frequency of pools overflowing, lower pool water levels and periodic loss of interconnection between pools during dry weather. Potential impacts to Tea Tree Hollow, Dog Trap Creek and Hornes Creek and possible “flow-on” effects to downstream watercourses.
3. Reduced flow due to baseflow reduction as a result of increased groundwater discharge or reduced groundwater discharge. Potential impacts to Tea Tree Hollow, Dog Trap Creek and Hornes Creek and possible effects on Thirlmere Lakes.
4. Reduced flow due to creation of subsidence depressions and associated trapping/containment of runoff. Potential impacts to Tea Tree Hollow, Dog Trap Creek and Hornes Creek and possible “flow-on” effects to downstream watercourses.
5. Increased flow due to increases in controlled discharge and/or overflows from water management system. Potential impacts to Tea Tree Hollow and Bargo River.
6. Increased flow due to enhanced groundwater baseflow created by subsidence enhanced fracturing and delamination of bedding planes which result in enhanced surface-groundwater interactions - e.g. emergence of (ferruginous) springs. Potential impacts to Tea Tree Hollow and Dog Trap Creek.

Predicted impacts to flow rate and quantity of water are addressed in Section 7.0 and Section 8.0.

4.2 POTENTIAL IMPACTS TO HYDRAULIC FLOW CHARACTERISTICS AND STABILITY OF WATERCOURSES

1. Changes in flow velocity and bed shear stresses due to subsidence induced changes to the shape and profile of watercourses. Potential impacts to Tea Tree Hollow and Dog Trap Creek.
2. Reduced stability of bed and banks due to subsidence induced fracturing. Potential impacts to Tea Tree Hollow and Dog Trap Creek.
3. Reduced stability of bed and banks due to loss of riparian vegetation from lower soil moisture availability as a result of subsidence induced fracturing. Potential impacts to Tea Tree Hollow and Dog Trap Creek.
4. Changes to flooding and flood regimes due to the effects of subsidence on the geometry of watercourses. Potential impacts to Tea Tree Hollow and Dog Trap Creek.

Predicted impacts to flow characteristics and stability or watercourses area addressed in Section 9.0.

4.3 POTENTIAL IMPACTS TO SURFACE WATER QUALITY OF WATERCOURSES

1. Discharge or spill of contaminants from mine infrastructure areas to watercourses. Potential impacts to Tea Tree Hollow and downstream watercourses.
2. Liberation of contaminants from subsidence induced fracturing in watercourses causing localised and transient increases in iron concentrations and other constituents due to flushing of freshly exposed fractures in the sandstone rocks which contain variable levels of mineralisation. Potential impacts to Tea Tree Hollow and Dog Trap Creek and downstream watercourses.
3. Changes to the chemical composition of surface flows due to either increased or decreased groundwater fed baseflow contribution to watercourses. Creation and/or enhancement of existing iron-rich groundwater springs; Potential impacts to Tea Tree Hollow and Dog Trap Creek and downstream watercourses.
4. Drainage of strata gas[3] and expression to the surface through surface water.

Predicted impacts to surface water quality are addressed in Section 10.0.

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[3] Release of methane rich gases from overburden sequences.

5.0 PREDICTED SUBSIDENCE IMPACTS TO WATERCOURSES IN PROJECT AREA

5.1 GENERAL

A detailed description of the longwall mining process and the consequential subsidence movements at the overlying ground surface are provided in MSEC (2018). Subsidence can result in fracturing of strata overlying the mining operations including surface near surface fracturing. The shallow fracture network may cause diversion of surface flow downstream but would not divert into deeper strata or the mine itself (MSEC, 2018). The mechanisms that cause fracturing and the expected fracturing at Tahmoor are also described in detail in MSEC (2018) and the reader is referred to relevant sections of that report.

Past experience shows where subsidence and, in particular, valley closure and upsidence occur in watercourses which is sufficient to cause fracturing of rock-bars and development of dilation cracking along the prominent drainage lines, the following hydrological effects are likely to occur:

- capture of a proportion of low flows and the diversion of this water downstream via the created underground fracture network;
- re-emergence of surface flow downstream of the affected area;
- reduced frequency of pools overflowing and lower pool water levels during dry weather;
- reduced and periodic loss of interconnection between pools during dry weather;
- localised and transient increases in iron concentration and other minerals due to flushing from freshly exposed fractures in the sandstone rocks which contain variable mineralisation;
- creation and/or enhancement of existing iron rich springs; and
- drainage of strata gas[4].

Past experience at the Tahmoor Mine in the upper headwater creeks including Myrtle and Redbank Creeks, is that impacts include localised and relatively isolated cracking of bed sediments; creation of transient and permanent pools in subsidence depressions and/or alteration to existing pools and small scale bed and bank scour due to local increases in bed and bank slope (refer Section 6.0).

The following specific predictions of subsidence related impacts to watercourses in the Project Area have been summarised from MSEC (2018).

5.2 PREDICTED SUBSIDENCE IMPACTS TO THE BARGO RIVER

The maximum predicted subsidence, upsidence and closure for the Bargo River, resulting from the extraction of the proposed longwalls, is less than 20mm (MSEC, 2018).

The Bargo River is located at a distance of 975 m from the closest proposed longwall panel. At this distance MSEC (2018) considered that the river would not experience measurable subsidence or upsidence movements. MSEC (2018) findings indicate that it is unlikely flow rates or water quality in the Bargo River would be affected by subsidence associated with the Project.

5.3 PREDICTED SUBSIDENCE IMPACTS TO LOCAL STREAMS

A summary of the maximum predicted values of total subsidence, upsidence and closure for local watercourses from the MSEC (2018) are reproduced in Table 1 below.

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[4] Release of methane rich gases from overburden sequences.

Table 1 Maximum Predicted Total Subsidence, Upsidence and Closure for Local Watercourses (MSEC, 2018)

Watercourse	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Dog Trap Creek*	1,850*	550*	425*
Hornes Creek	50	30	50
Tea Tree Hollow*	1,400*	400*	275*

* Note: downstream sections of Dog Trap Creek and Tea Tree Hollow have been previously mined beneath. The maximum predicted parameters provided in the above table include those resulting from the extraction of these earlier longwalls.

The predicted changes in stream bed grade are typically less than 1%. As such, MSEC (2018) expected that any localised changes in ponding would be minor. The predicted maximum increase in stream bed grade is 1.2%, which is relatively small compared to the natural gradients and, as such, MSEC (2018) predicted that the potential for increased scouring would be insignificant.

Where the longwalls mine directly beneath the streams, MSEC (2018) considered that it is likely dilation cracking would occur along the stream bed and that diversion of water from the stream beds into the dilated strata would occur. Partial or complete diversion of surface water and drainage of pools may occur at locations and times where the rate of flow diversion is greater than the rate of incoming surface water.

Based on the previous experience of mining beneath streams at the Tahmoor Mine, it is likely that fracturing and surface flow diversions would occur in the sandstone bedrock along the streams, particularly for streams that are located directly above the proposed longwalls. In some of these locations, MSEC (2018) expected that the fracturing could impact the holding capacity of the standing pools, particularly those located directly above the proposed longwalls. It is unlikely, however, that there would be any net loss of water from the catchments. Experience has also shown that, over time, pools tend to recover naturally due to sealing by deposited fine sediment (Tahmoor Colliery, 2004, Centennial Tahmoor, 2005, Centennial Coal, 2006, Centennial Coal, 2007. Xstrata Coal, 2008).

MSEC (2018) considered that it is likely that gas emissions would occur as a result of the mining of the Project longwalls. Gas is sometimes released into rivers and streams as these areas form topographical low points in the landscape. Where these gas releases occur into the water column there is insufficient time for any significant amount of gas to dissolve into the water and the majority of the gas is released into the atmosphere. MSEC (2013) considered that it unlikely that gas release would have an adverse impact on water quality.

The profiles of predicted subsidence, upsidence and valley closure along the affected reaches of local streams within the Project Area compiled by MSEC (2018) are provided in Appendix A.

The main channel of Cow Creek is located approximately 1 km from the nearest Project longwall. MSEC (pers. comm. 22/10/2018) report that, at this distance, the maximum predicted subsidence, upsidence and valley closure are less than 20 mm. Accordingly, the potential for localised impacts on Cow Creek such as fracturing and surface water flow diversion are extremely low.

6.0 REVIEW OF PAST SUBSIDENCE IMPACTS TO FLOW AND WATER QUALITY

Underground longwall mining has been conducted at the Tahmoor mine since 1987. Mining of longwall panels 22 to 27 has resulted in subsidence in Myrtle and Redbank Creeks which are small tributaries of the Nepean River. Monitoring of flows and water quality in these tributaries prior to and during the mining phase has provided a data set which can be used to quantify the effect of subsidence from longwall mining on these creeks. Given the similarity in scale and form of these watercourses to the watercourses overlying the Project Area, examination of the past effects of mining on these creeks provides a basis for assessing the potential impacts to watercourses within the Project Area (i.e. Tea Tree Hollow and Dog Trap Creek).

There have also been a significant number of watercourses in the Southern Coalfields more generally which have been affected by subsidence from longwall mining. The reported impacts to these streams also provide a useful reference for assessing the potential impacts of mining at Tahmoor South on surface water resources.

6.1 SUBSIDENCE IMPACTS TO MYRTLE AND REDBANK CREEK

The locations of Tahmoor North longwalls 20 to 27 in relation to Redbank Creek and the location of flow and water quality monitoring sites are shown in Figure 3. The start and completion dates for these longwalls are given in Table 2 below.

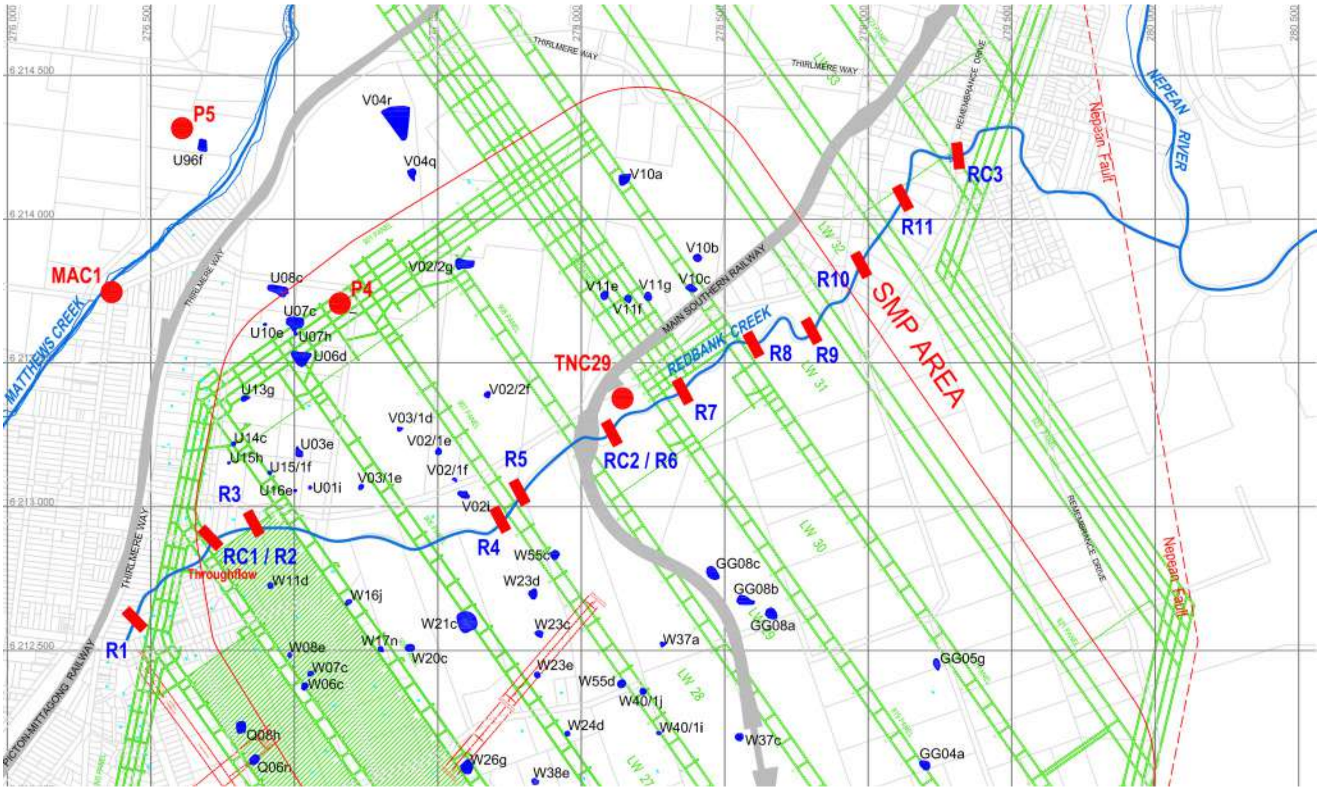

Figure 3 Monitoring Sites and Longwall Mining Beneath Redbank Creek (Geoterra, 2011)

Table 2 Summary of Past Longwall Mining in the Redbank Creek Catchment

Longwall	Start Date	End Date
22**	7 June 2004	28 June 2005
23A**	12 September 2005	26 February 2006
23B**	20 March 2006	27 August 2006
24B**	11 September 2006	2006 April 2007
24A*	15 November 2007	19 July 2008
25	22 August 2008	21 February 2011
26	30 March 2011	15 October 2012
27	8 November 2012	22 March 2014

*This longwall did not undermine Myrtle or Redbank Creeks

**This longwall was in the catchment but did not undermine Redbank Creek

Observations of subsidence impacts to Myrtle and Redbank Creeks associated with longwalls 22 to 26 have been reported in previous “End of Panel” reports. Longwalls 22 to 26 were all 283 m wide. Coal seam thickness varied from 1.8 to 2.2m and cover (i.e. depth from top of seam to surface) varied from 395 m to 440 m. Maximum measured vertical subsidence was 1,240 mm and maximum valley closure measured in Redbank Creek was 160 mm as a result of longwall 26.

The following key observations and conclusions were reached based on field observations and the available data provided in these reports.

The report compiled following completion of longwall 23B (Geoterra, 2007) concluded that mining had not resulted in any observable effects to streamflow or water quality in Myrtle Creek as a result of subsidence effects. Minor cracking of rock in the bed of Myrtle Creek was observed over longwall 22 along with a crack in soils in the banks of the creek overlying longwall 23B (Geoterra, 2007). A ferruginous seep was reported in Redbank Creek prior to the creek being undermined.

Following completion of longwall 25, four cracks was reported in the bed of Myrtle Creek overlying longwalls 22, 23B and 25 (Geoterra, 2011). Longwall 25 undermined a section of Redbank Creek near the northern end of the panel. Sub-surface underflow was also reported in a 6 m long section of Redbank Creek overlying longwall 25. The observed through-flow was reported to be in the absence of observable bed cracking. There was no change to streamflow or water quality at the flow monitoring sites in either Myrtle or Redbank Creeks as a result of mining longwall 25 (Geoterra, 2011).

Following completion of longwall 26 it was reported GeoTerra (2013) that there had been no adverse effects reported to streamflow, water quality or to bed and bank stability in Myrtle Creek. Subsidence had resulted in cracking of the streambed and through-flow in isolated sections of Redbank Creek including a pool in overlying longwall 25. GeoTerra (2013) reported that overall, there had been no adverse effect on stream bed stability, stream bank stability or water quality in Redbank Creek during the monitoring period.

The following subsidence effects on Redbank Creek were reported following completion of longwall 26 (GeoTerra, 2013). The location of the observations in relation to mined longwalls 25, 26 and 27 are shown in Figure 4.

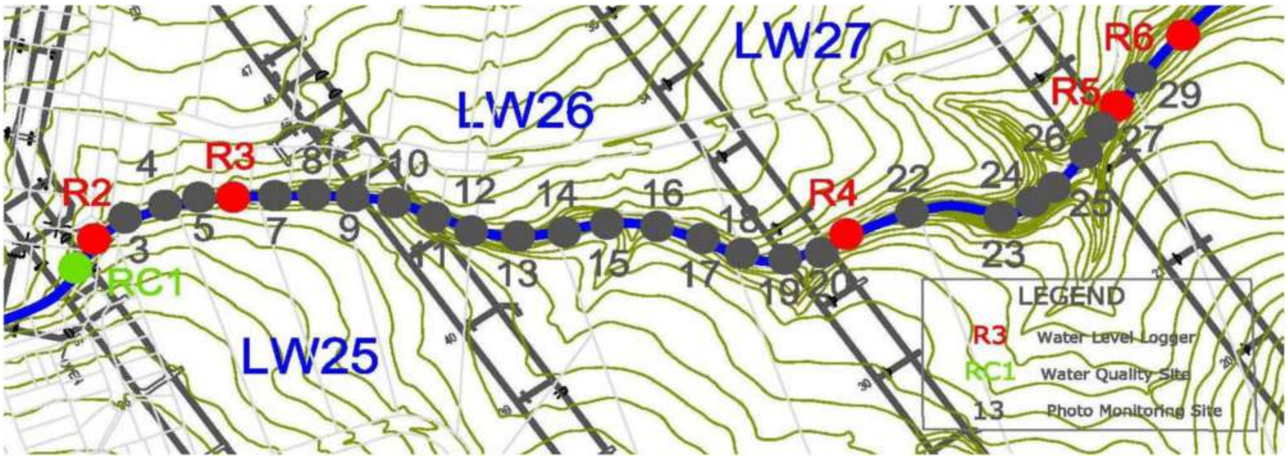

Figure 4 Location of Subsidence Observations in Redbank Creek (Geoterra, 2013)

The reported subsidence effects on Redbank Creek due to extraction of longwall 26 are shown in photographs contained in GeoTerra (2013) which have been reproduced in Appendix B.

Monitoring of flow and water quality in Redbank and Myrtle Creeks is ongoing. The collected data provides a basis for quantifying the possible impacts of subsidence. Commencement of flow monitoring in Myrtle Creek post-dates the commencement of longwall mining beneath the watercourse. The significant urban influences in this creek also confound the analysis of both flow and water quality data. In comparison flow data is available for Redbank Creek some 12 months prior to longwall 25 undermining Redbank Creek. Redbank Creek is also less affected by urban influence and for these reasons provides a clearer basis for a quantitative investigation of the effects of past subsidence on flow and water quality that is of relevance to the Project.

6.2 ASSESSMENT OF FLOW AND WATER QUALITY DATA FOR MYRTLE AND REDBANK CREEKS

Redbank Creek overlies the western end of longwall 25 as a small channel with an incised bed 1 m to 2 m deep which evolves into a channel up to 3 m deep and 10 m wide downstream of longwall 26 (Geoterra, 2013). The headwaters of Redbank Creek lie within the residential area of the town of Thirlmere, with housing and road development significantly affecting the banks of the creek. Over longwalls 25 and 26, the creek flows out of the main residential area and through the urban fringe of Thirlmere. Surface water quality and streamflow monitoring sites on Redbank Creek are shown in Figure 5.

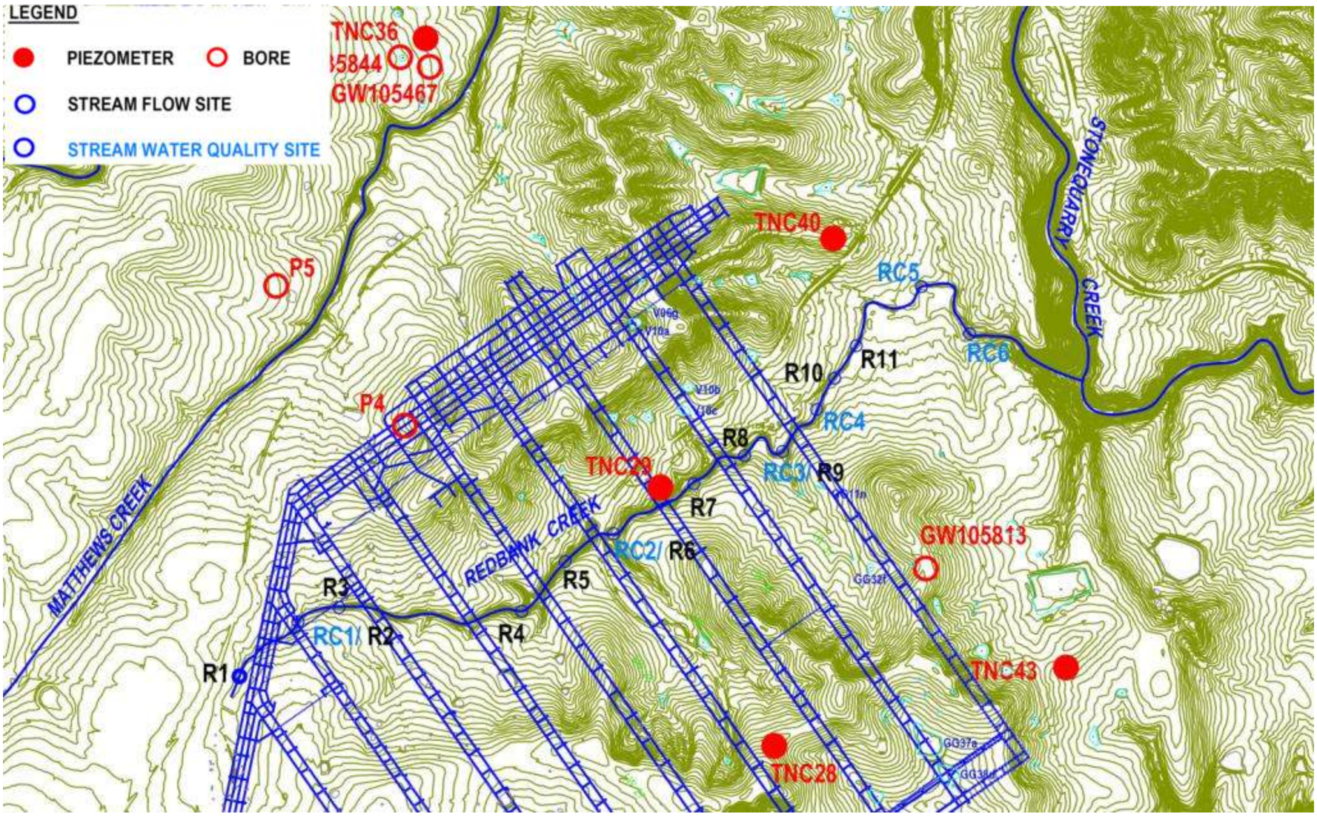

Figure 5 Monitoring Sites – Redbank Creek (supplied by GeoTerra)

6.2.1 Assessment of Surface Water Quality – Redbank Creek

Water quality monitoring has been conducted by routine sampling and laboratory analyses. Results for the period February 2005 July 2017 were assessed for water quality sampling sites RC1 (upstream), RC2 (mid) and RC5 (downstream) - refer Figure 5. Recorded concentrations of key water quality indicators for this period are shown below in Figure 6 to Figure 11. The concurrence of mining of longwalls 25 to 30 is also shown. The following observations are apparent from a visual assessment of the data.

1. Recorded electrical conductivity (EC - a measure of salinity) has increased at the downstream site RC5 during and following the mining of longwalls 26 onwards, while EC increased at the mid-stream site RC2 during and following the mining of longwalls 25 to 29, with the maximum value recorded at both sites near the end of longwall 27 mining. However there were also elevated EC readings at RC2 prior to longwall 25. These higher salinity levels appear to be unrelated to mining and possibly relate to pre-existing groundwater inflows (ferruginous springs) reported in Redbank Creek (GeoTerra, 2013). There has been no obvious change to EC at the upstream site RC1. EC values at RC2 and RC5 have trended somewhat lower following mining of longwall 28.
2. Measured pH has been relatively consistent over the entire period and relatively consistent between the three sites, with a slight decrease observed since late 2015 at all three sites (i.e. including RC1 – upstream). This suggests that longwall mining in the Redbank Creek catchment has not affected pH levels in the creek to any significant extent.

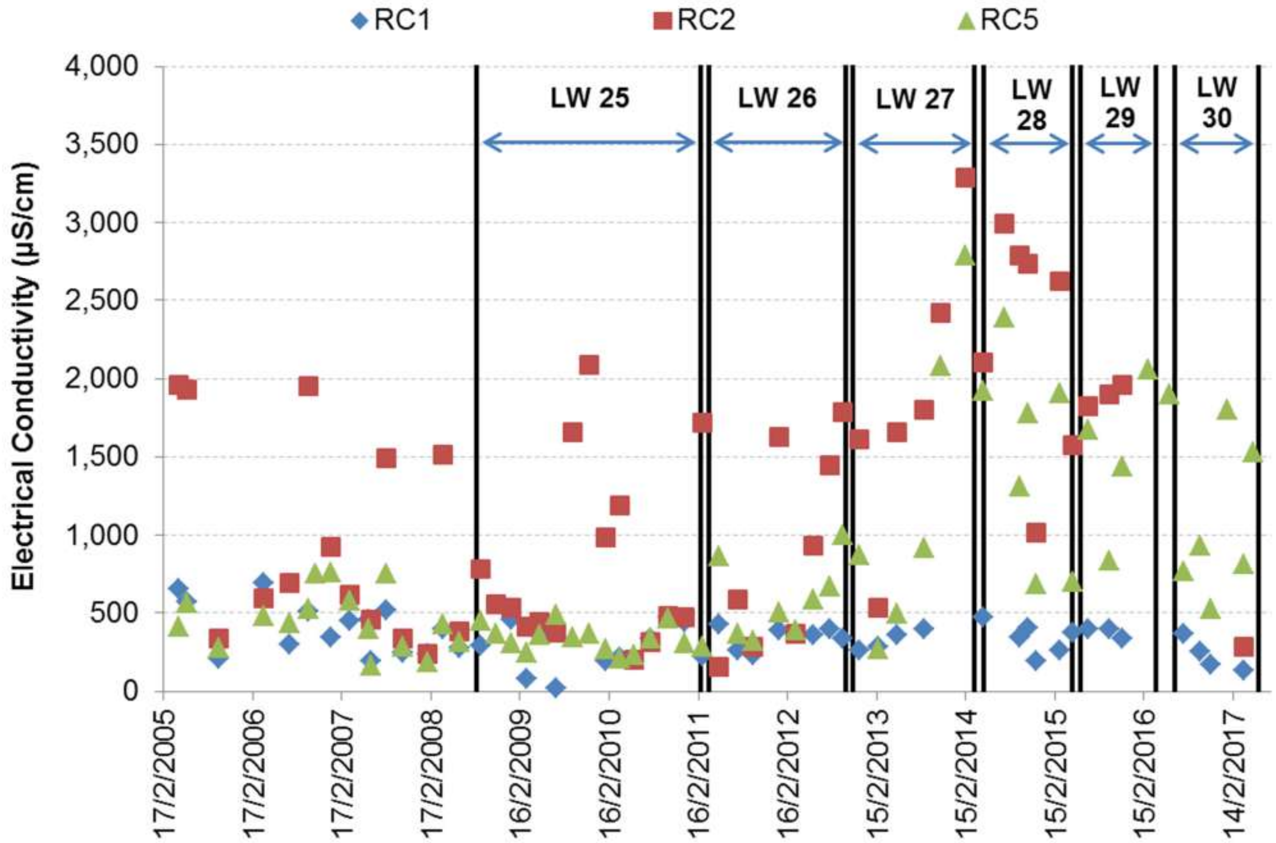

Figure 6 Recorded Electrical Conductivity (field) – Redbank Creek

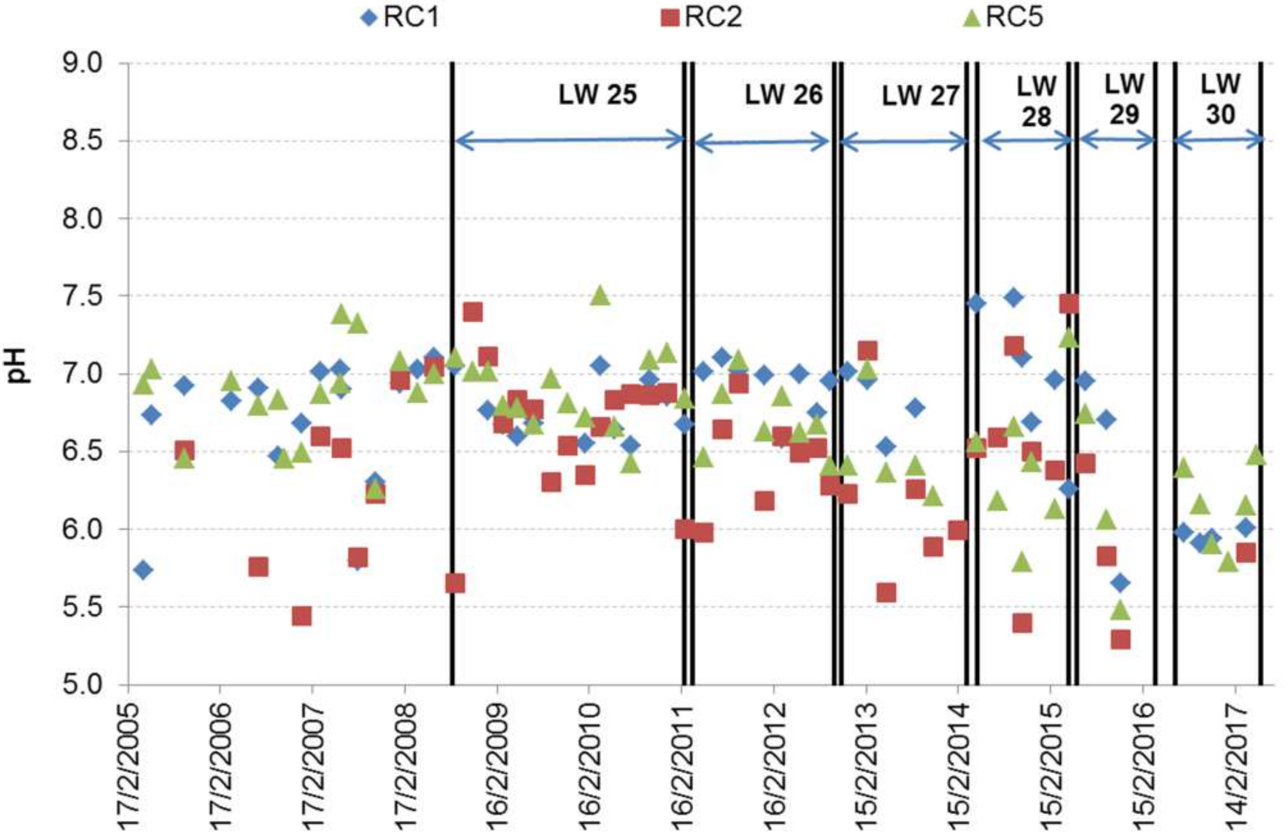

Figure 7 Recorded pH (field) – Redbank Creek

3. There was a significant rise in iron concentrations at site RC2 predominantly during and following mining of longwalls 27 and 28 (which were closest to RC2) and one elevated reading at downstream site RC5. A peak “spike” in the recorded data at RC2 of 68 mg/L (total) occurred near the end of mining of longwall 25 (March 2011) although the dissolved concentration did not rise at that time. Reported iron concentrations have generally been low at site RC1 (upstream) with the exception of a spike of 64 mg/L (total) in July 2016 – there was no parallel spike in the dissolved concentration or other recorded metals (refer Figure 9 and Figure 10). Recorded iron concentrations at RC5 have been low since mining of longwall 29. The reported pattern of iron concentrations suggest that longwall mining and the reported cracking of bedrock has resulted in periodic increases in iron. The absence of a similar pattern of elevated concentrations at either the upstream site (RC1) or the downstream site (RC5) suggests that the effects were localized.

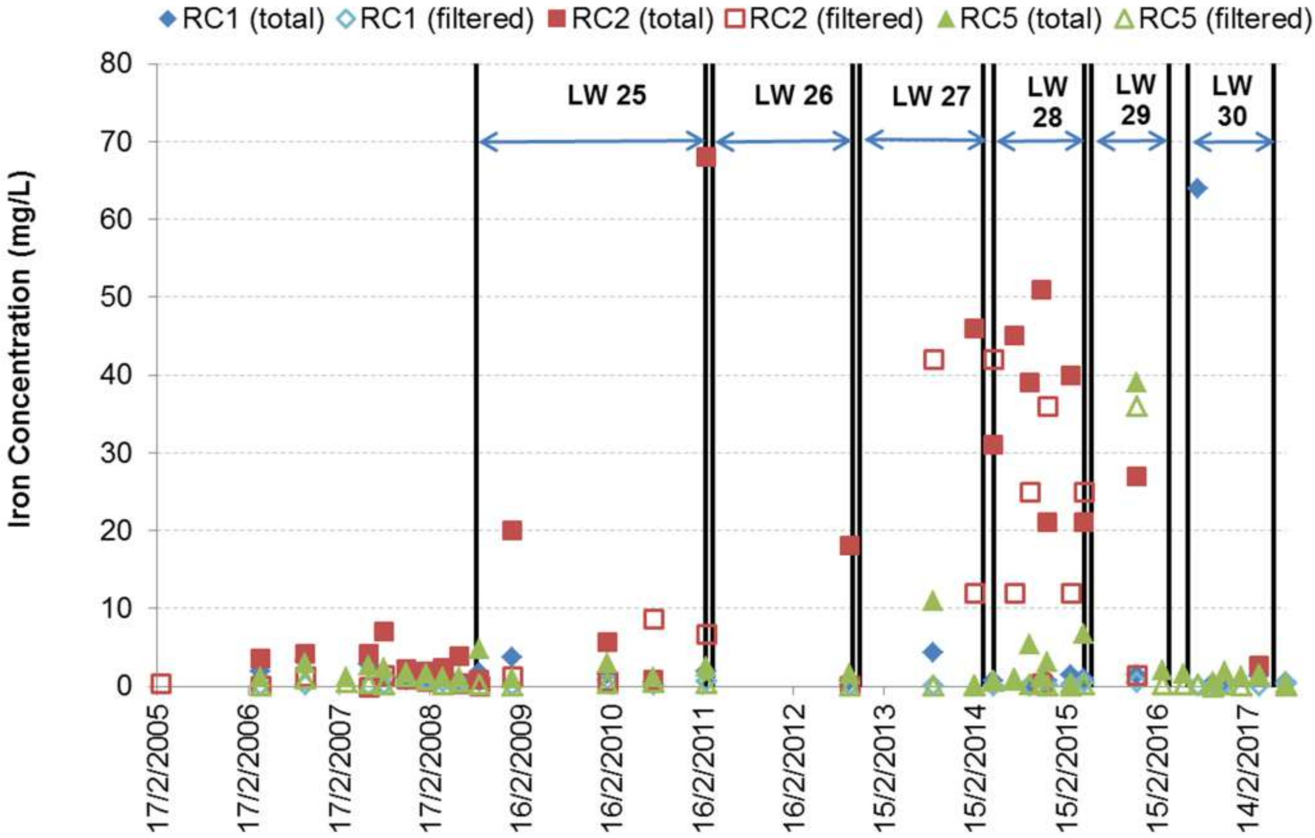

Figure 8 Recorded Iron Concentration – Redbank Creek

4. Relatively high manganese concentrations have been reported at site RC2 (up to 4.6 mg/L total) and RC5 (up to 6.6 mg/L). At RC2 these occurred during or following longwalls 25 to 29, while at RC5 these were most notable between longwalls 27 to 29. Elevated concentrations were also recorded on four occasions at RC2 before longwall mining, although only filtered samples were analysed. Manganese concentrations at site RC1 (upstream) have been relatively low for the full period of data, as have concentrations at site RC5 (downstream) since the completion of longwall 29. The elevated manganese concentrations at site RC2 may be unrelated to mining of longwalls 25 to 29 and possibly relate to pre-existing groundwater inflows (ferruginous springs) reported in Redbank Creek which may also be responsible for the periodic elevated EC and zinc concentrations reported at this site.

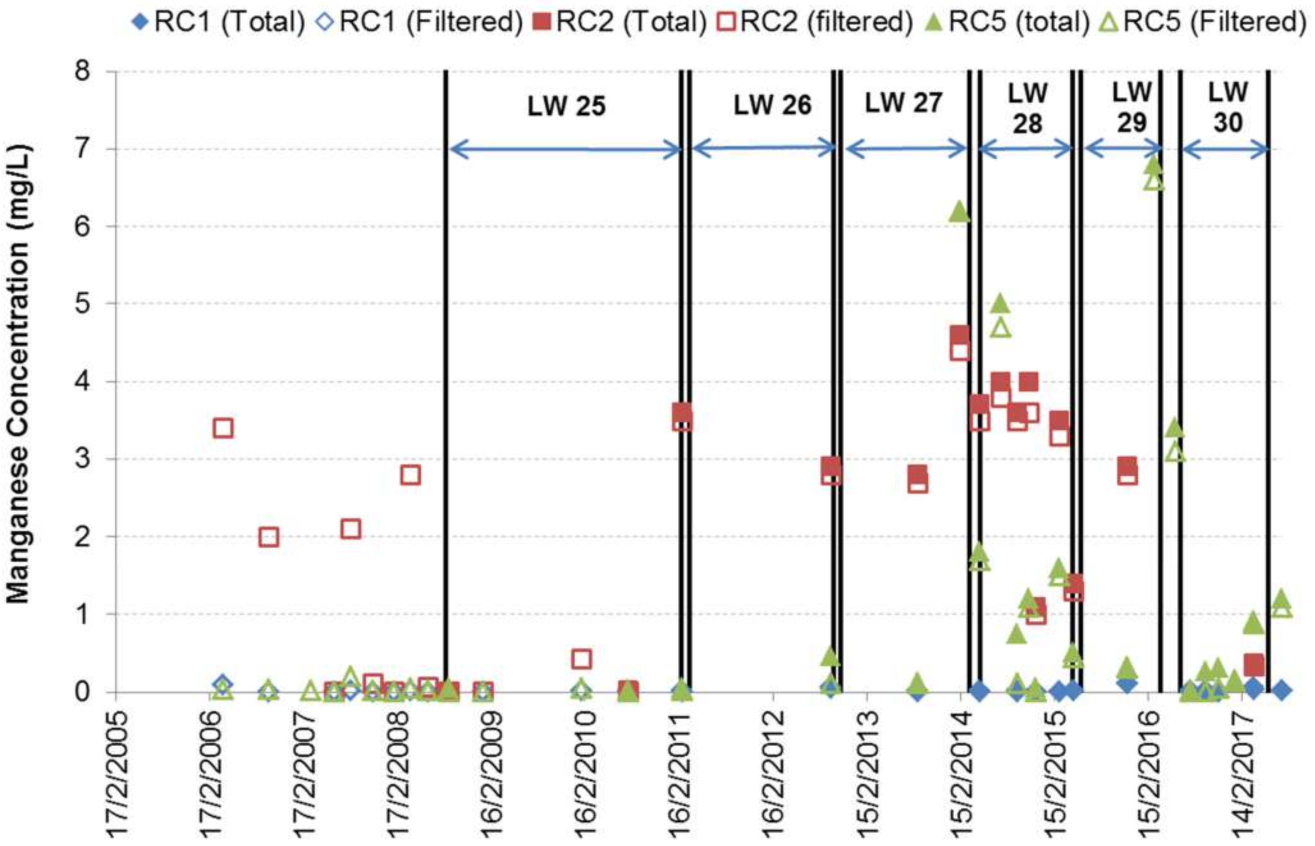

Figure 9 Recorded Manganese Concentration – Redbank Creek

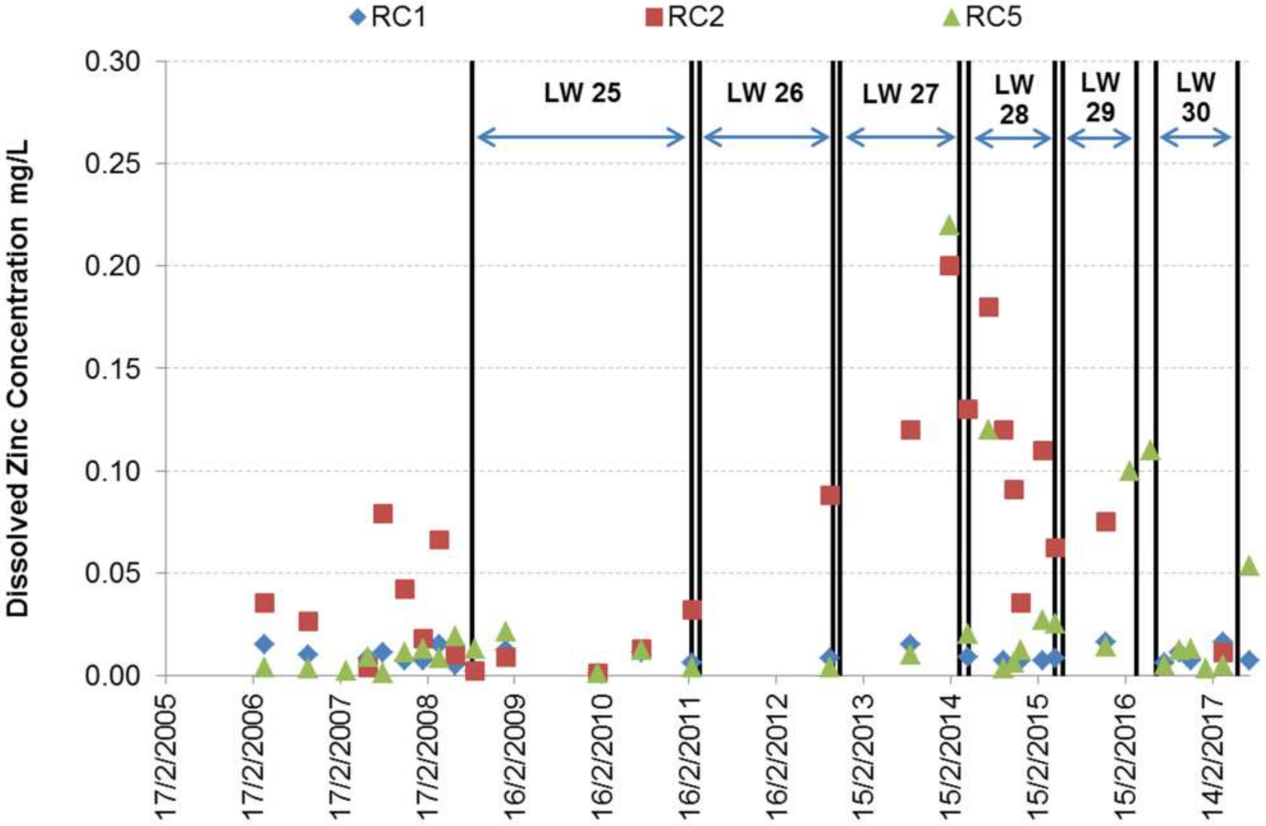

Figure 10 Recorded Dissolved Zinc Concentration – Redbank Creek

5. Reported zinc concentrations (filtered only available) have also been relatively elevated at site RC2 compared to the other sites, with concentrations rising further during and following mining of longwalls 26 to 29. Elevated concentrations were recorded at downstream site RC5 during and following mining of longwalls 27 to 30. Concentrations at upstream site RC1 have remained relatively low. This pattern is similar to the pattern evident in iron concentrations and suggests that longwall mining and the reported cracking of bedrock has resulted in periodic increases in zinc concentrations.

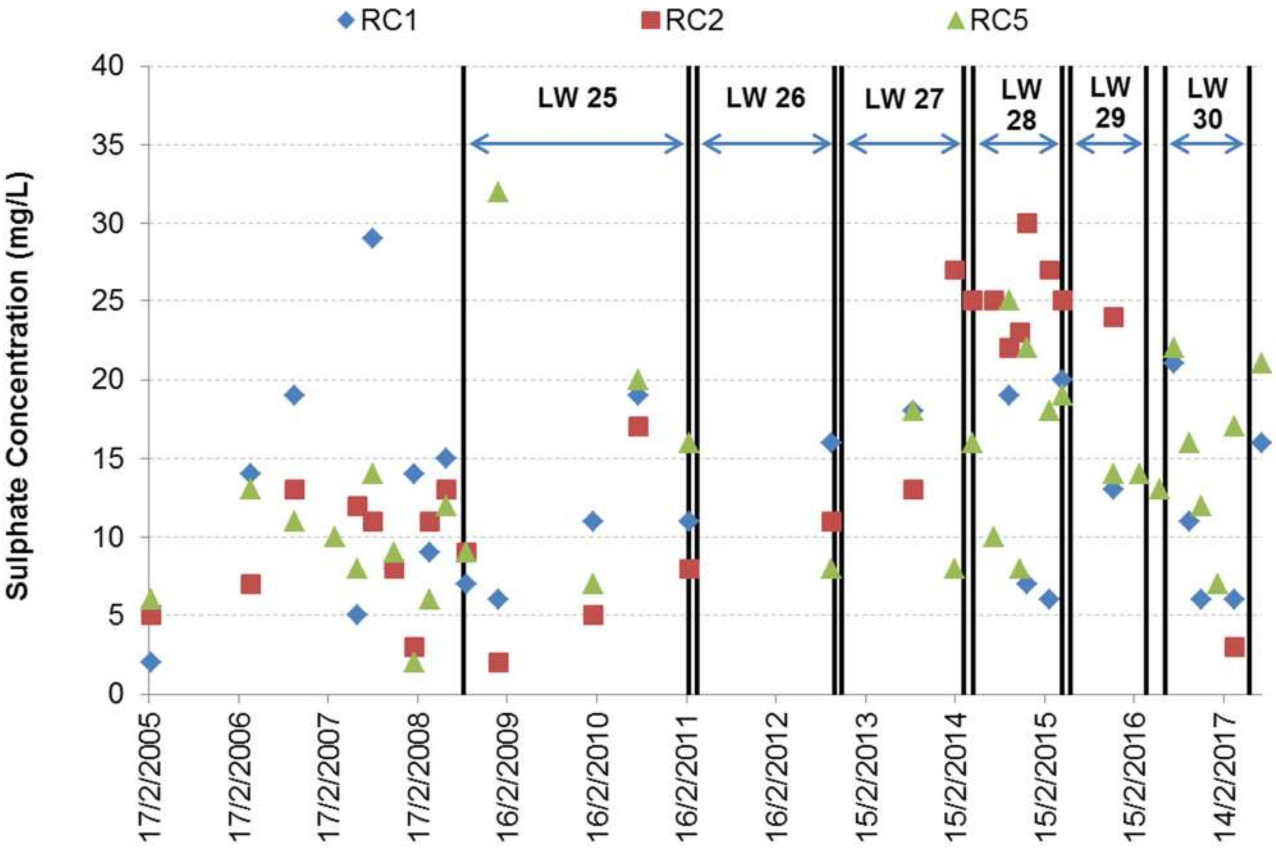

Figure 11 Sulphate Concentration – Redbank Creek

6. Sulphate concentrations have been relatively consistent between sites over the period of available data, although the data indicate a slight increase at RC2 near the end of mining of longwall 27 to the mining of longwall 29.

6.2.2 Assessment of Streamflow – Redbank Creek

Streamflow gauging stations have been established at 11 sites on Redbank Creek – refer Figure 5. Rating curves needed to convert the recorded water levels at these sites to flow rate have been established for low flows at sites R4 and R7. A more complete rating relationship has been established for site R11.

Sites R4 and R11 have been used in this assessment. Site R4 has a reliable low flow rating and is within the potentially affected reaches of Redbank Creek. Site R11 is the site which is furthest downstream of the potential impacts of longwall mining and has the most reliable rating. The potential effects of subsidence on streamflow would affect low flows. If longwall mining in the Redbank Creek catchment has had a measurable effect on flows it would be detectable as a change to low flows and low flow recessionary behaviour. It has been observed at other locations where surface flows are lost to subsidence induced subsurface fracture systems that the subsurface flow "reappears" at the surface further downstream (Gilbert & Associates, 2008). These observations suggest that at these sites the localised impacts do not affect the overall catchment yield.

The flow record at site R4 provides the opportunity to assess whether there has been a detectable change in low flow and low flow recessionary behaviour in Redbank Creek in the reach immediately overlying longwall 27 (mined from November 2012 to March 2014) and some 500m downstream of longwall 26 (mined from March 2011 to October 2012). By contrast the flow record at site R11 provides the opportunity to assess whether there has been a detectable change in flows in Redbank Creek at a location which is some two kilometres downstream of longwall 26.

Because flow in natural watercourses is highly variable in response to climatic events, it is difficult to assess whether low flow behaviour is changing over time by examining a flow record in isolation. What is required is some means of assessing whether, given the climatic conditions, the catchment response has changed over time. This has been achieved by using a fitted catchment flow model to provide a time invariant predictor of flows. Comparing modelled to recorded flow over time provides the opportunity to assess, in a systematic way, whether low flow is changing over time and whether this change indicates an increased loss of flow.

The flow model used was the Australian Water Balance Model (AWBM) (Boughton, 2004), which is a nationally recognised catchment-scale water balance model for simulating surface runoff and baseflow processes on gauged and un-gauged catchments. Model parameters affecting surface water runoff were selected to be similar at both locations with parameters affecting baseflow and transmission loss being varied to obtain fits to low flows and low flow recession. The model parameters used in the assessment of flows at R4 and R11 are summarized in Table 3 below.

Table 3 AWBM Parameters - Redbank Creek Catchment

AWBM Parameter	Description of Parameter Effect	R4	R11
A1	Proportion of catchment contributing to surface runoff with low storage	0.15	0.15
A2	Proportion of catchment contributing to surface runoff with moderate storage	0.5	0.5
A3	Proportion of catchment contributing to surface runoff with large storage	0.35	0.35
C1 (mm)	Surface runoff from low storage areas	1	1
C2 (mm)	Surface runoff from moderate storage areas	100	100
C3 (mm)	Surface runoff from large storage areas	160	160
K_S	Surface flow recession rate	0.25	0.25
BFI	Amount of baseflow generated	0.8	0.12
K_B	Baseflow recession rate	0.85	0.85
T_L (mm/day)	Transmission loss rate	0.0015	0.0003

6.2.2.1 Analysis of Flows at Redbank Creek Site R4

The streamflow record at site R4 has been converted to flow per unit area (expressed as ML/day per km^2 or mm/day) and plotted on a logarithmic scale to accentuate low flows. The plot of recorded and modelled flows is shown on Figure 12 when mining was occurring in longwall 25[5].

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[5] Note that longwall 25 commenced prior to commencement of streamflow monitoring data collection at monitoring site R4 and site R11.

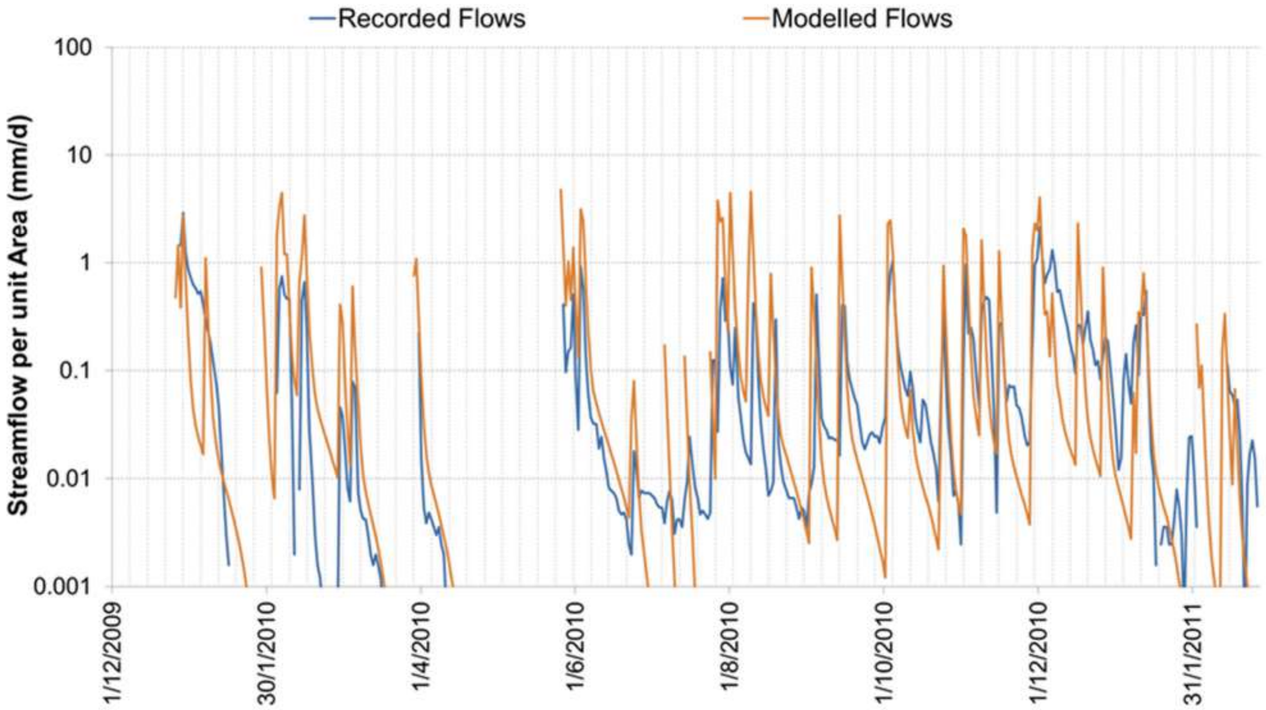

Figure 12 **Streamflow – Redbank Creek Site R4 during Mining of Longwall 25**

Whilst there are periods when recorded low flows are less than modelled (most notably between February and April 2010) and when low flow recession has been recorded at faster rates (most notably between February and April 2010), there have also been periods when modelled low flows are less than recorded. The model fit to recorded low flows is considered to be fair. A comparison of the flow duration frequency plot for observed and modelled flows over this period (refer Figure 13) shows that the model somewhat over-predicts the frequency of very low flows, which is conservative from a low flow assessment perspective.

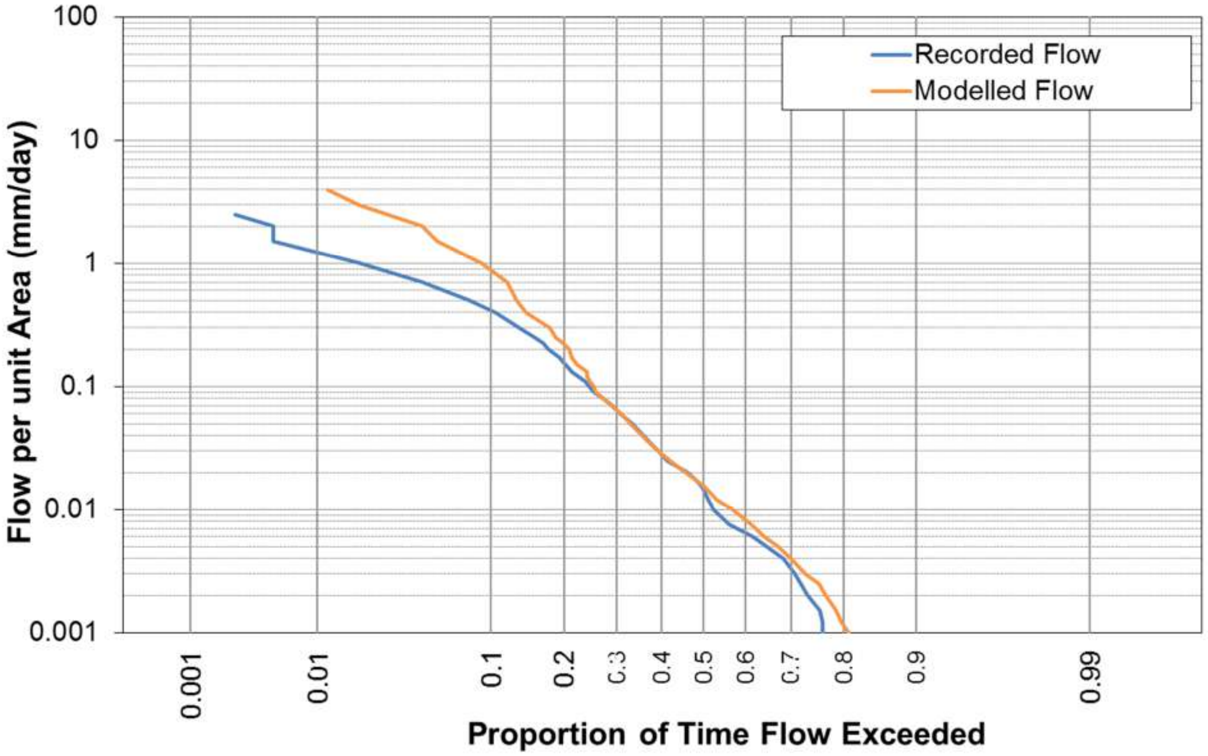

Figure 13 **Flow Frequency Duration Plots – Redbank Creek Site R4 during Mining of Longwall 25**

Figure 14 shows the comparison between recorded and modelled flows during the period that longwall 26 was being mined.

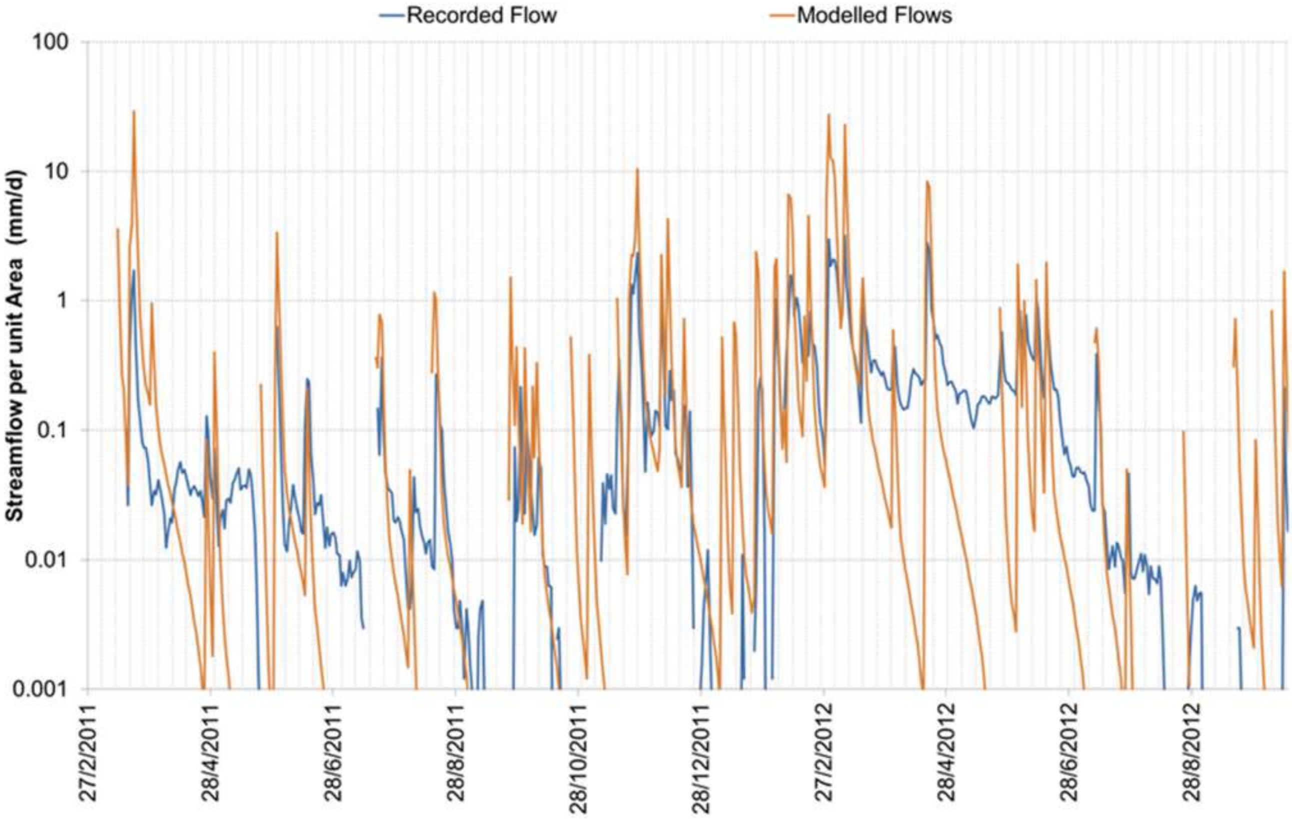

Figure 14 Streamflow – Redbank Creek Site R4 during Mining of Longwall 26

Over this period there were also periods when recorded low flows were less than modelled and where low flow recession rates were faster than those predicted by the model – predominantly in the period December 2011 to February 2012. Most of the time however, the model can be seen to be under-predicting low recessionary flows. Again the model fit to recorded low flows is considered to be fair over this period. A comparison of the flow duration frequency plot for observed and modelled flows over this period (refer Figure 15) shows that the model predicts the frequency of very low flows reasonably well.

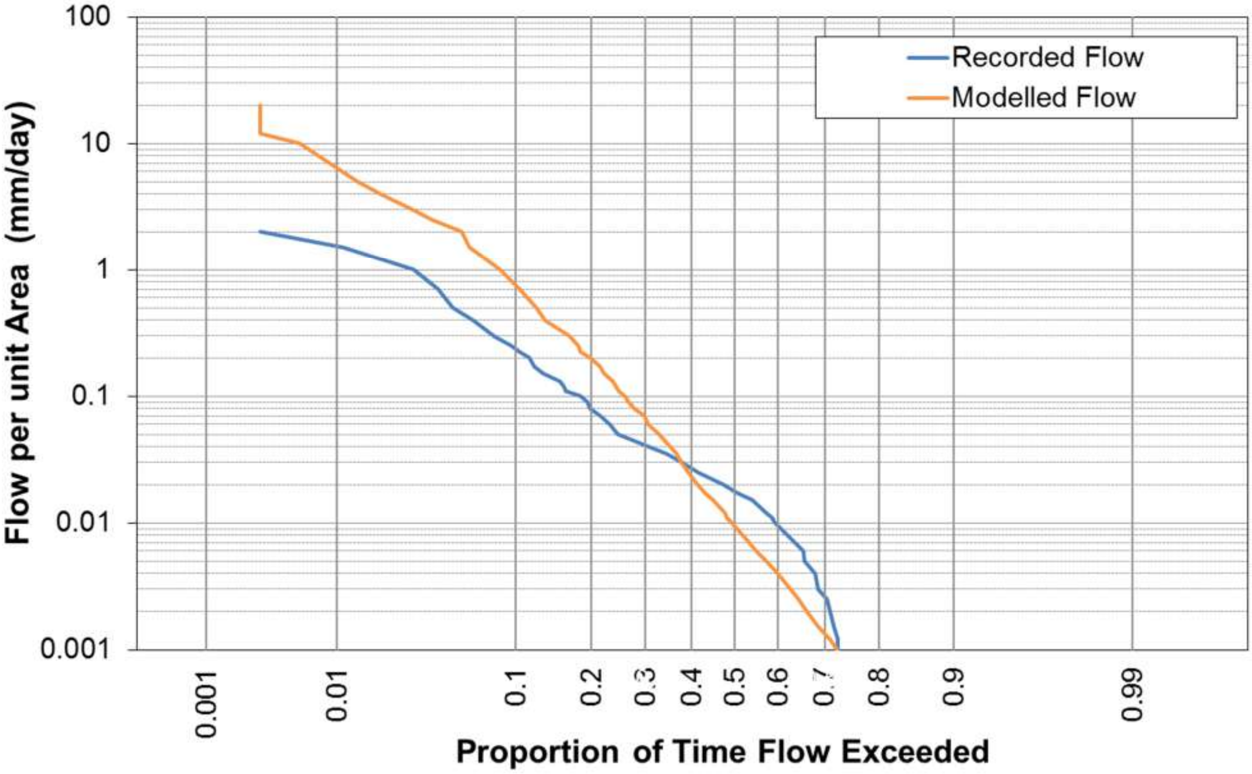

Figure 15 Flow Frequency Duration Plots – Redbank Creek Site R4 during Mining of Longwall 26

Figure 16 shows the comparison between available recorded and modelled flows at site R4 during the period that longwall 27 was being mined[6].

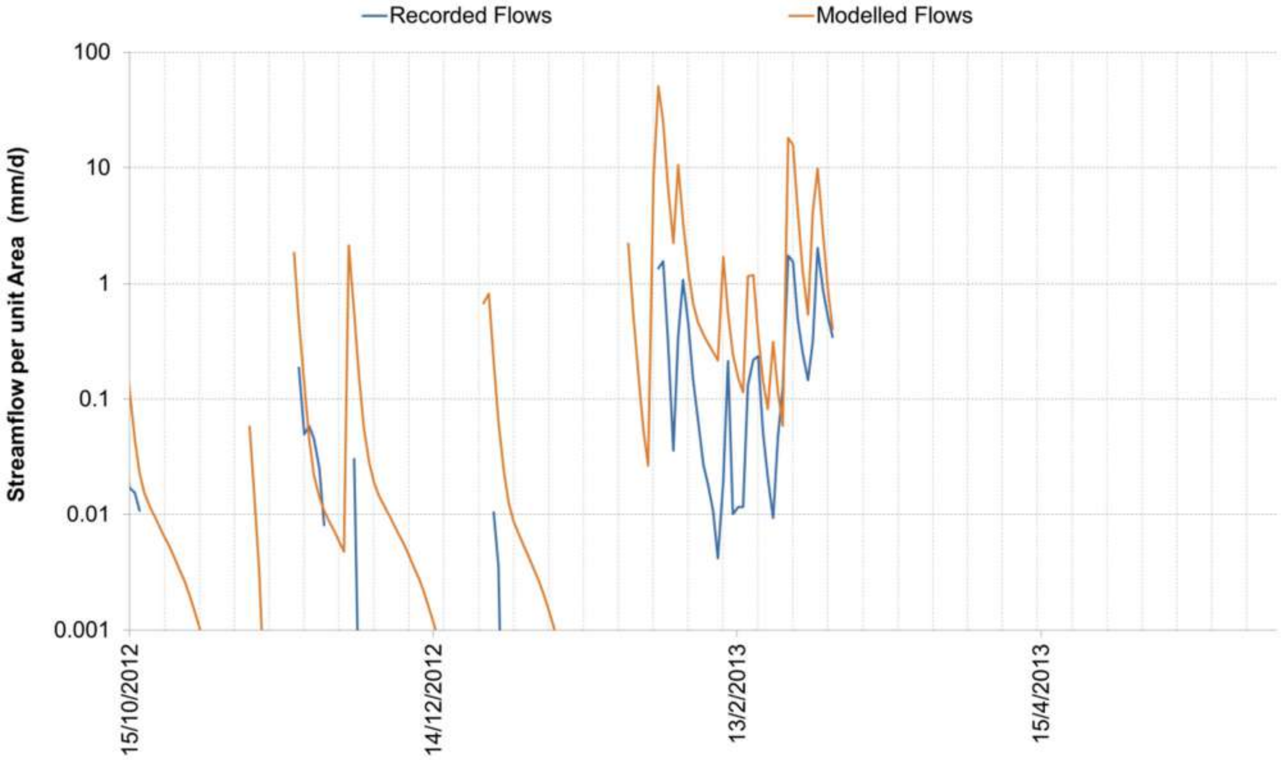

Figure 16 Streamflow – Redbank Creek Site R4 during Mining of Longwall 27

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[6] Note the available streamflow monitoring data does not cover the period of mining of longwall 27 which was ongoing at the time this analysis was conducted.

The streamflow data plotted in Figure 16 comprises a relatively short period of record including very low flows and periods of no flow from mid October 2012 until January 2013. Over this period the model over-predicts low flows. A possible interpretation is that there could have been a reduction in low flows at site R4 related to longwall mining which was not previously apparent, when mining of longwalls 25 and 26 occurred. However, it is difficult to distinguish possible mining-related effects on low flows from other effects (e.g. catchment change) in this semi-urbanised catchment.

6.2.2.2 Analysis of Flows at Redbank Creek Site R11

Recorded and modelled flows at site R11 on Redbank Creek over the period that mining of longwall 25 was being undertaken are shown in Figure 17 below.

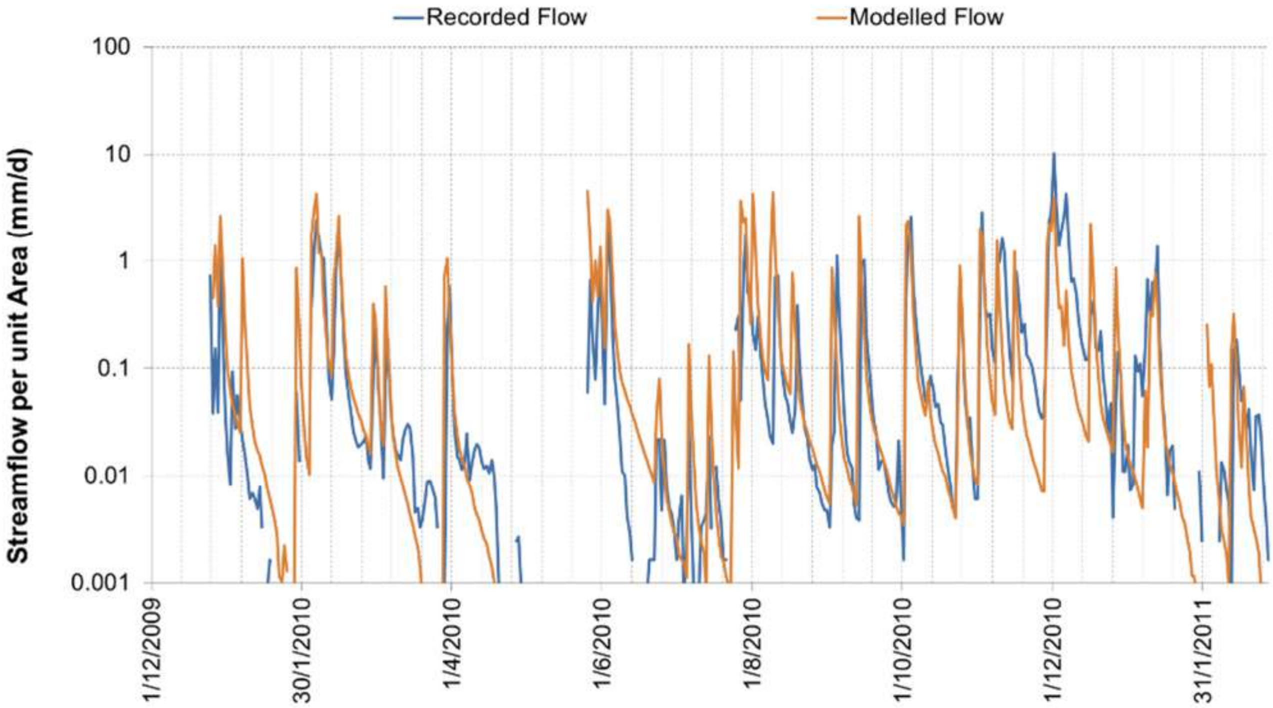

Figure 17 Streamflow – Redbank Creek Site R11 during Mining of Longwall 25

While there are some periods where the recorded low flows are less than modelled and when low flow recession has been recorded at faster rates (most notably in June 2010), most of the time, recorded low flows have been well reproduced by the model. The model fit to recorded flows is considered to be good. A comparison of the flow duration frequency plot for observed and modelled flows over this period (refer Figure 18) shows that the model provides a good fit but is slightly over-predicting the frequency of very low flows.

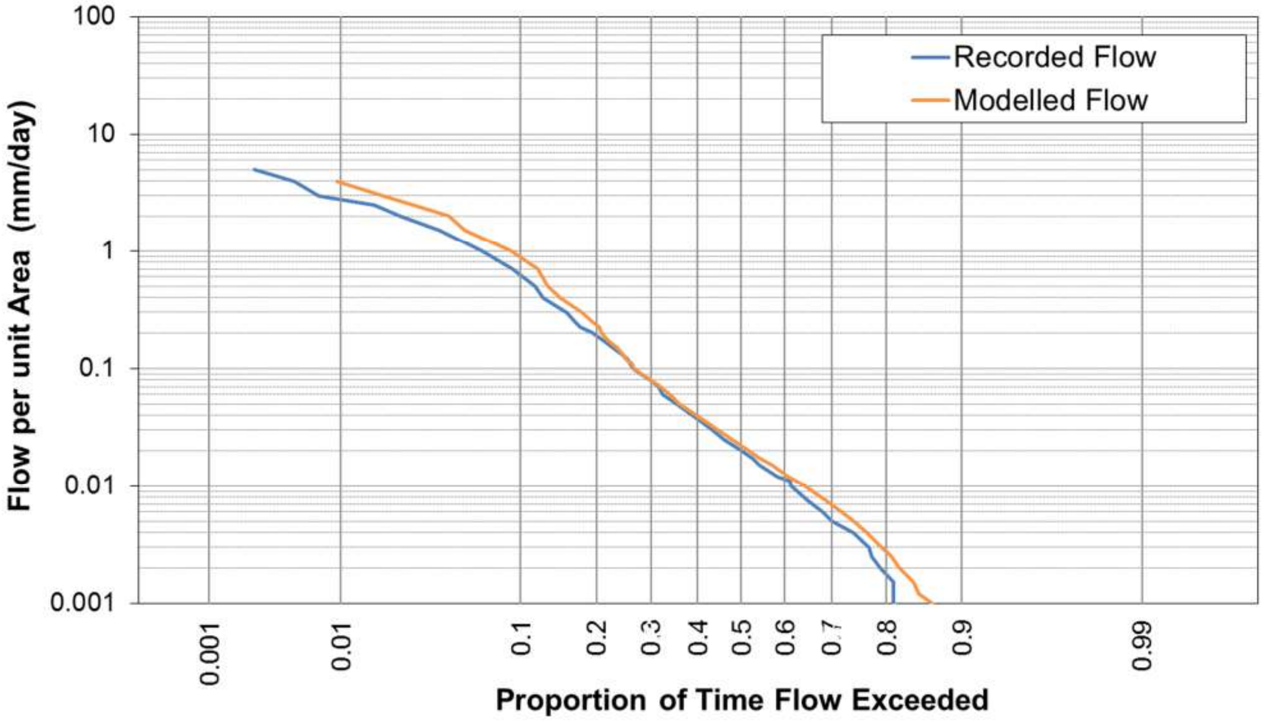

Figure 18 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of Longwall 25

Recorded and modelled flows at site R11 on Redbank Creek over the period that mining of longwall 26 was being undertaken are shown in Figure 19 below.

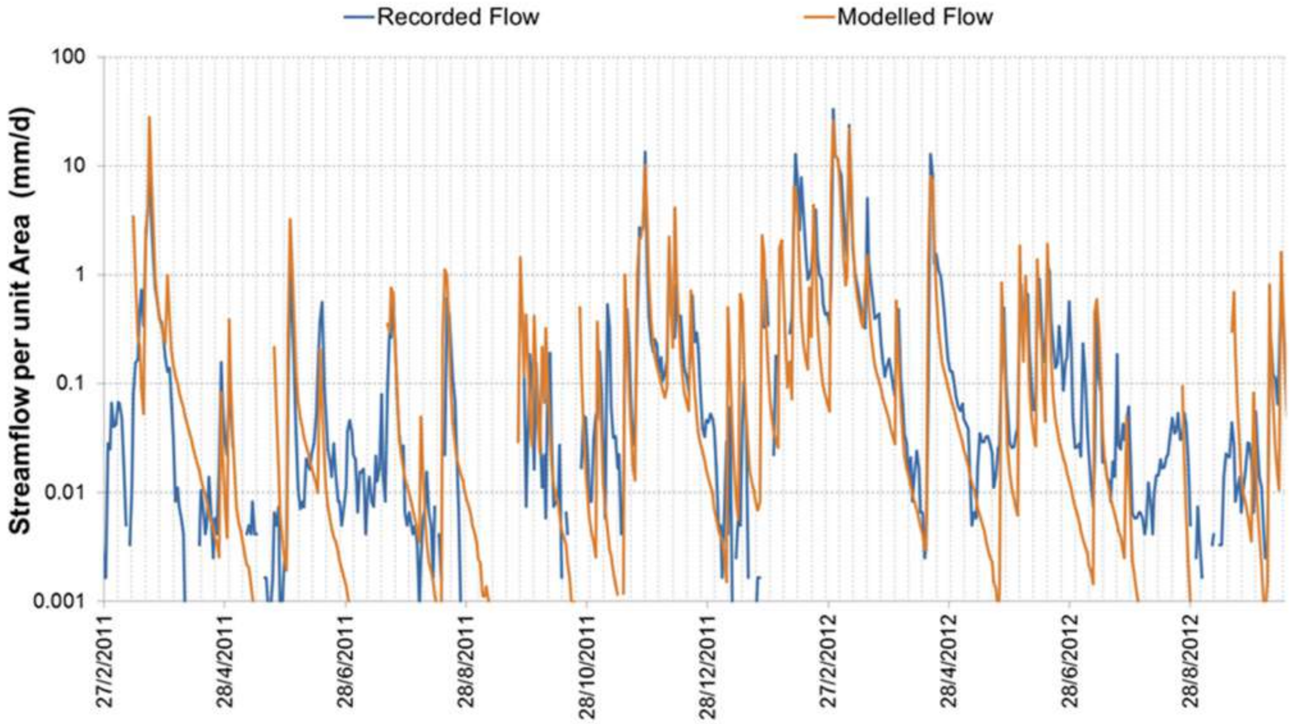

Figure 19 Streamflow – Redbank Creek Site R11 during Mining of Longwall 26

The model fit to recorded flows over this period is considered to be good. There are some instances however when the recorded low flows were less than modelled and where recorded low flow recession rates were faster than modelled recession rates -most notably at the start of the period in

February 2011 through to early April 2011. Most of the time however, recorded low flows have been well reproduced by the model. This is demonstrated by the flow duration frequency plots for observed and modelled flows over this period (refer Figure 20).

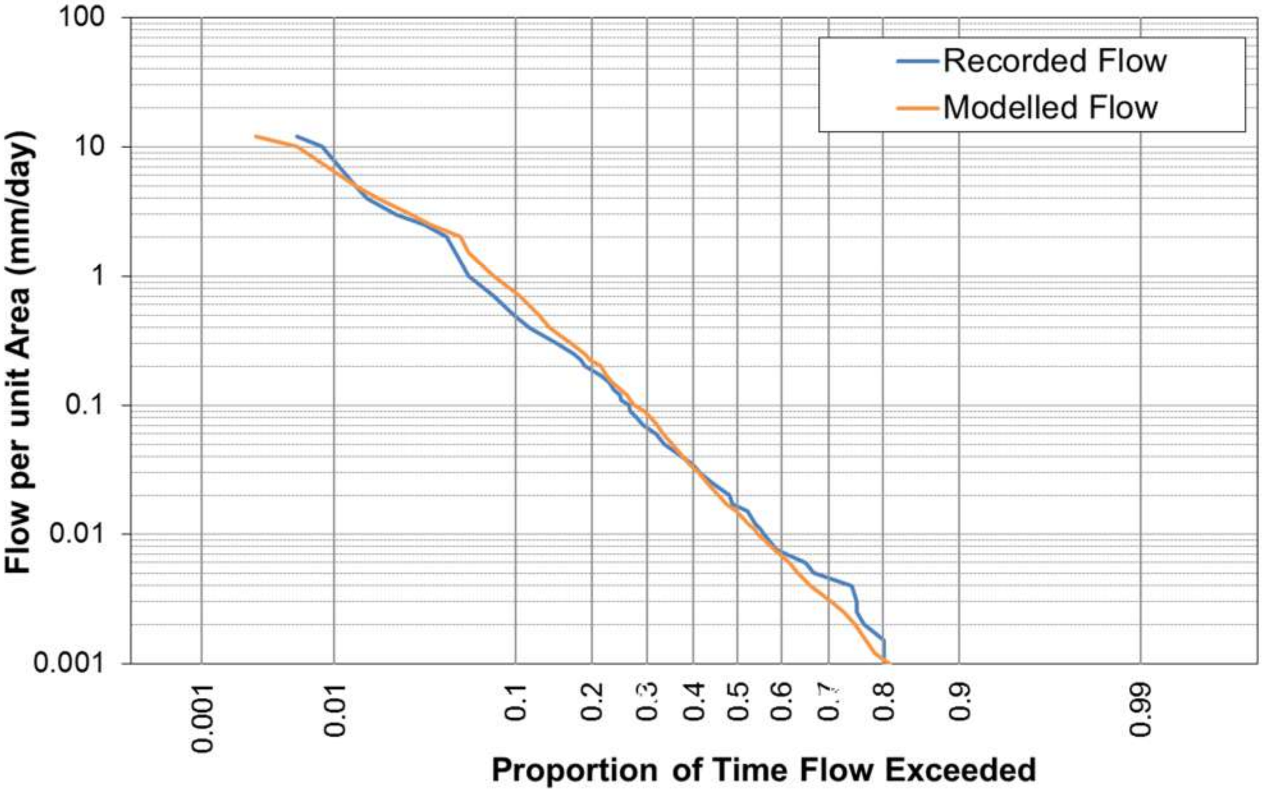

Figure 20 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of Longwall 26

Figure 21 shows the comparison between available recorded and modelled flows at site R11 during the period that longwall 27 was being mined.

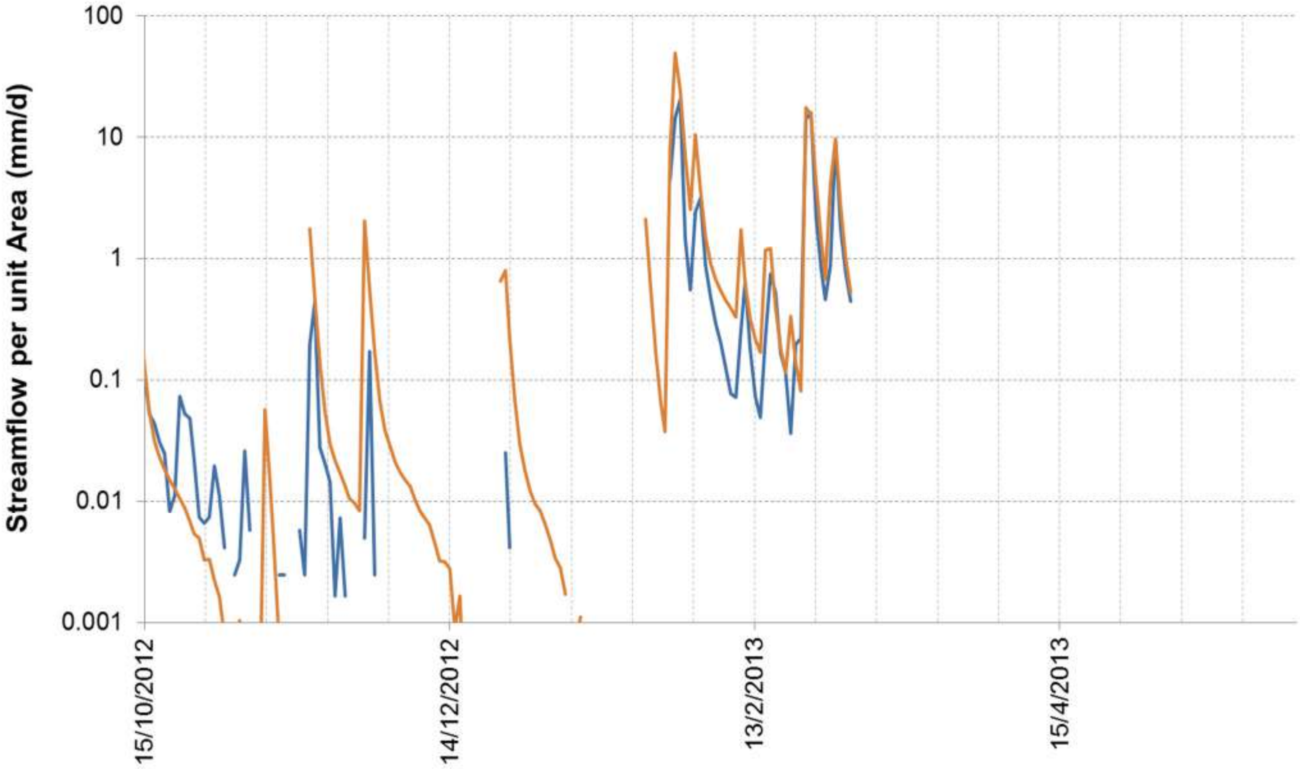

Figure 21 Streamflow – Redbank Creek Site R11 during Mining of Longwall 27

The fit between modelled and recorded flows is fair over this relatively short period. There are periods of that the model over-predicts and under-predicts recorded low flows. There is however no indication that recorded flow has systematically departed from model predictions. Compared to the recorded flows at site R4 over this period there is no real evidence that flow, and in particular low flow, reduced at site R11 over this period. If there has been a reduction of flow at site R4 there is no evidence that it has affected flows downstream at site R11.

6.2.2.2 Conclusions from Redbank Creek Flow Analysis

Examination of the flow record from monitoring site R4 and monitoring site R11 on Redbank Creek from December 2009 to March 2013 suggest that mining of longwalls 25, 26 and 27 within the Redbank Creek catchments, including mining directly beneath Redbank Creek itself, has not affected flows and low flows at site R11 downstream. There is some evidence that flows at site R4 may have been reduced during the period of low flow recorded between October 2012 and January 2013.

6.3 SUMMARY OF PREVIOUS IMPACTS ON FLOW AND WATER QUALITY IN STREAMS IN THE SOUTHERN COALFIELDS

6.3.1 Reported Impacts to Flow

Waratah Rivulet overlies the longwall mining operations at the Metropolitan Coal Mine near Helensburgh. Waratah Rivulet flows into the Woronora Reservoir – a Sydney water supply storage. Low flows in Waratah Rivulet have been observed to flow via subsurface fracture networks resulting in loss of pool water levels and drying up of sections of the watercourse during periods of low flows. A section of Waratah Rivulet was directly undermined by longwalls 10, 11 and 12. Longwall 10 was 140 m wide and longwalls 11 and 12 were 163 m wide. Analysis of recorded flows at a downstream gauging station on Waratah Rivulet (located downstream of longwall mining) however indicating that whilst there was localized impact, there was no net affect to catchment yield (Gilbert & Associates, 2008). These conclusions were supported by a water balance of the Woronora Reservoir over the period 1977 to 2008 which incorporated 18 years between 1977 and the commencement of longwall mining in the catchment in 1995. This analysis indicated dam inflows were readily matched by predictions of a catchment model over the entire period - i.e. there were no discernible changes to catchment inflows due to longwall mining post-1995.

Stokes Creek overlies longwall mining which has taken place at the West Cliff Colliery, near Appin. A hydrological analysis was undertaken of the effects of longwall mining conducted beneath Stokes Creek (Gilbert & Associates, 2009) between July 1990 and March 1999. Stokes Creek flows into O'Hares Creek downstream of the limits of historical longwall mining. There has been no longwall mining in O'Hares Creek upstream of the Stokes Creek confluence. Monitored flow data was available for four gauging stations in the Stokes/O'Hares Creek catchment for the analysis. Data at three stations (two on Stokes Creek and one on O'Hares Creek) pre-dated longwall mining. The gauging stations on Stokes Creek had been closed in 1987 prior to the commencement of longwall mining in 1990. The remaining gauging station on O'Hares Creek (GS213200 O'Hares Creek at Wedderburn), located downstream of the Stokes Creek confluence, has been in operation since 1978. Comparative analysis of this data showed at recorded flows at all stations were consistent and that there had been no change to the flow characteristics, and relevantly to the low flow characteristics, prior to and after the commencement of longwall mining.

6.3.2 Reported Impacts to Stream Water Quality

Analysis of water quality data collected on Waratah Rivulet (Gilbert & Associates, 2008) showed water quality both within and downstream of reaches affected by subsidence was generally good with most water quality indicators being low relative to the default triggers for protection of aquatic ecosystems published by ANZECC (2000). The effects of subsidence were however evident as localized and transient spikes in iron, manganese and aluminium which could be linked in time to subsidence induced fracturing of the stream bed.

Assessments of subsidence impacts have been conducted by Illawarra Coal Holdings Pty Ltd (ICHPL) on all recent (post 2005) longwall mining operations at their West Cliff, Dendrobium, Eloura, Tower and Appin Collieries. The following summary has been compiled from information published in the Bulli Seam EIS (Gilbert & Associates, 2009).

Appin longwall 701, which was mined between October 2007 and May 2008, came within about 190 m (in plan location) of the Nepean River at its closest point. Two iron release zones were reported during mining which resulted in visible iron stains – one in the Nepean River and one in Elladale Creek – an adjacent tributary. The iron stain in Elladale Creek was believed to have been related to a reactivation (additional movement) of a previously goafed area. Four gas release zones were also observed in the Nepean River and one in Elladale Creek.

Mining of longwalls 31 and 32 at West Cliff Colliery came within about 30 m (in plan) of the Georges River. The observed and monitored effects on water quality in the Georges River during and following completion of these longwalls is summarised as follows:

1. A small localised and isolated spike in manganese concentration (0.32 mg/L) was detected during mining of Longwall Panel 31a. The manganese concentration in the spike was however low compared to default ANZECC (2000) concentrations for the protection of aquatic ecosystems. The spike may not have been as a result of mining.
2. Nine minor observations of gas release were detected along the Georges River during mining of LW32.
3. Two small iron stains were observed during and following completion of Longwall Panel 32.

The Cataract River was undermined by longwalls 3 to 16 of the Tower Colliery underground operations between March 1990 and April 1999. Reported impacts on the Cataract River include:

1. reduced dissolved oxygen concentration;
2. increased turbidity;
3. strata gas emissions which declined in magnitude and intensity over the monitored period;
4. increased electrical conductivity (salinity); and
5. minor pH fluctuations.

Appin Colliery longwalls 301 and 302 were mined close to but not directly beneath the Cataract River between October 2006 and September 2007. Reported impacts included gas releases and observations of iron staining along the adjacent reach of the Cataract River. Results of paired water quality sampling upstream and downstream of the area adjacent the longwall panel were unable to provide any clear evidence of water quality effects. Water quality in this reach of Cataract River was dominated by periods of variable and at times significant releases of water from the upstream Cataract Dam during the monitoring period.

Similar effects were noted from observations and monitoring during mining of Appin Colliery longwall 405 which was mined close to the Cataract River between February 2002 and April 2003.

Stokes Creek was undermined by West Cliff Colliery longwalls 17 to 24 between 1990 and 1999. The longwall panels resulted in some 3.3km of Stokes Creek being directly undermined. Stream condition mapping and photographic reconnaissance of Stokes Creek in the reach affected by longwalls 17 to 24 in 2008 revealed iron staining and flocs in pools - refer photographs reproduced below.

Typical Iron Flocs and Pool – Stokes Creek in Reach Previously Undermined:

Typical Iron Staining in Boulder-field – Stokes Creek in Area Undermined by Longwall Mining:

Mallaty Creek was undermined by West Cliff Colliery longwalls 32 and 33 between February 2007 and June 2008. Monitoring revealed minor iron staining which was attributed to a groundwater spring possibly associated with subsidence movements. Extensive water quality monitoring along Mallaty Creek prior to mining confirmed the presence of a saline spring within the reach which was subsequently undermined by longwall 32. During mining there was a localised and temporary increase in pH which was attributed to subsidence effects on the spring. There were no other water quality effects that were attributed to subsidence effects.

Mining of longwalls 3 and 4 at Dendrobium Mine occurred between March 2007 and October 2008. The panels are located within 250m (in plan) at the closest point to the shoreline of the Cordeaux Reservoir. It was concluded from the analysis of water quality data that there were localised spikes in aluminium and iron recorded in one creek which could be attributable to the effects of subsidence induced cracking. The peak concentrations measured were however low compared to relevant ANZECC (2000) Guidelines and were not above levels in other creeks in the area.

Longwall mining under Kembla Creek and several of its tributaries was conducted in 2007. It was reported that there were no changes in water quality that could be related to mining effects. Minor fracturing and pool water loss was however reported in tributary streams.

The headwaters of Wongawilli Creek and Native Dog Creek were undermined by Elouera Colliery Longwall Panels 1 to 6 between 1993 and 2001. An intense and widespread fire in December 2001 had a major impact on vegetation in the area and resulted in erosion and redistribution of sediment in local drainages following subsequent intense rainfall events. Water quality monitoring revealed relatively low pH and dissolved oxygen concentrations and elevated metals (aluminium and zinc) in Native Dog and Wongawilli Creeks. These effects were attributed to longwall mining beneath these creeks and to the effects of drought. It was inferred from the data that these effects were ameliorating with time – having peaked in March/April 2003.

7.0 PREDICTION OF IMPACTS TO THE QUANTITY OF FLOW IN TAHMOOR SOUTH AREA WATERCOURSES

7.1 REDUCED FLOWS DUE TO CATCHMENT EXCISION

The proposed REA expansion would involve an increase in the total area of 43 ha, bringing the total REA area to 137 ha. Operations at the REA involve disposal of dewatered coal reject in defined cells. Once reject disposal operations are completed in one cell, it is shaped, covered, revegetated and stabilized whilst disposal operations continue in the next cell. Drainage from the REA is collected in a series of perimeter drains and sediment dams. Water in these areas is diverted to the pit top area for reuse in the pit top recycled water supply. The 70 ha area represents approximately 0.5% of the catchment area of the Bargo River at its confluence with the Nepean River.

Recycled water is also sourced from runoff from the pit top catchments (including the REA) and water recovered from the underground mining operations. Recycled water is returned for reuse underground. Water recovered from mining operations in excess of the recycling plant capacity is diverted to M2, treated in a waste water treatment plant (refer Section 10.1) before being discharged to Tea Tree Hollow via Licensed Discharge Point 1 (LDP1). The net reduction in dry weather flow in Tea Tree Hollow will therefore be equal to the decrease in mine water make. The minimum groundwater recovery rate (during the Project) predicted by HydroSimulations (2018b) is about 3.3 ML/day (down from the current 4 ML/day) however this is predicted to occur for the first half of 2024 only. The average predicted groundwater recovery rate for the Project period is 4.9 ML/day (HydroSimulations, 2018b). Allowing for an ongoing 1 ML/day treatment and recycling that would imply a transient reduction in flows in Tea Tree Hollow below LDP1 averaging 0.1 ML/d and up to 1.7 ML/day. This would be offset by recent revisions to the REA water management system which sees additional pumping capacity to transfer water from the REA Sediment Dams for treatment in the waste water treatment plant and release via LDP1 (refer HEC, 2018b). It is anticipated that, on average, there may be a slight increase in flow to Tea Tree Hollow due to slight increases in mine inflow from groundwater and the expanded REA catchment, that are proposed to be discharged within the current limits of LDP1.

7.2 LOSS OF FLOW TO SUBSIDENCE INDUCED FRACTURING – UNDERFLOW

Non-conventional subsidence movements have been observed in many steep sided valleys in the Southern Coalfields whereby the valley sides move inward toward the watercourse (known as valley closure) and buckling and upward movement of strata occurs in the valley floor (known as upsidence). Upsidence often results in the creation of a shallow, subsurface fracture network which extends along the floor of the valley over the subsidence affected length of the valley. An upsidence induced subsurface fracture network will typically have a high capacity to transport flow and, depending on the degree of interconnection of the fracture system and its connection with the bed, there can be significant diversion of surface flow beneath the surface in reaches affected by upsidence. As the fracture network approaches the downstream limit of upsidence the fracturing reduces progressively forcing flow back to the surface.

The impacts of localised diversion of surface flow in upsidence induced subsurface fracture network, include loss of water holding capacity of pools, reduced frequency of pools overflowing and periodic loss of interconnection between pools during dry weather within the affected reach. Potentially these sorts of impacts could occur in Tea Tree Hollow and Dog Trap Creek as a result of the Project.

It is currently not possible to predict the precise locations where diversion of surface flow due to upsidence induced fracturing will occur or to predict the flow capacity of the subsurface fracture networks which could form. Past experience however provides a valuable guide. Analysis of past observations of valley closure and upsidence due to non-conventional subsidence by MSEC (2007) indicates that some of the main factors are:

1. The pre-existing level of in-situ horizontal stresses that exist in the valley floor strata.
2. The depth and shape of the valley.
3. The geomorphology of the stream – the presence of rock bars and perennial pools, the presence and mobility of alluvium.
4. The geological characteristics of the valley including the strength, bedding, jointing and fracturing characteristics of the near surface rocks.

Diversion of surface flows is thought to occur predominantly via pools where the fractures intersect the bed of permanent pools creating a permanent head and supply of water to ‘feed’ the fracture system. MSEC (2013) have developed a preliminary relationship between measured valley closure and the proportion of rock bar controlled pools that have been observed to lose flow holding capacity due to upsidence induced fracturing and bedding plane separation. This relationship, which is reproduced as Figure 22 below, suggests that about 10% of rock bar pools would be affected in valleys which experience valley closure of 200 mm, increasing to 50% of rock bar controlled pools which experience valley closure of 500 mm. Very few rock bar pools have been affected where valley closure is less than 100 mm. Most (95%) of rock bar controlled pools have been affected where valley closure has exceeded 800 mm.

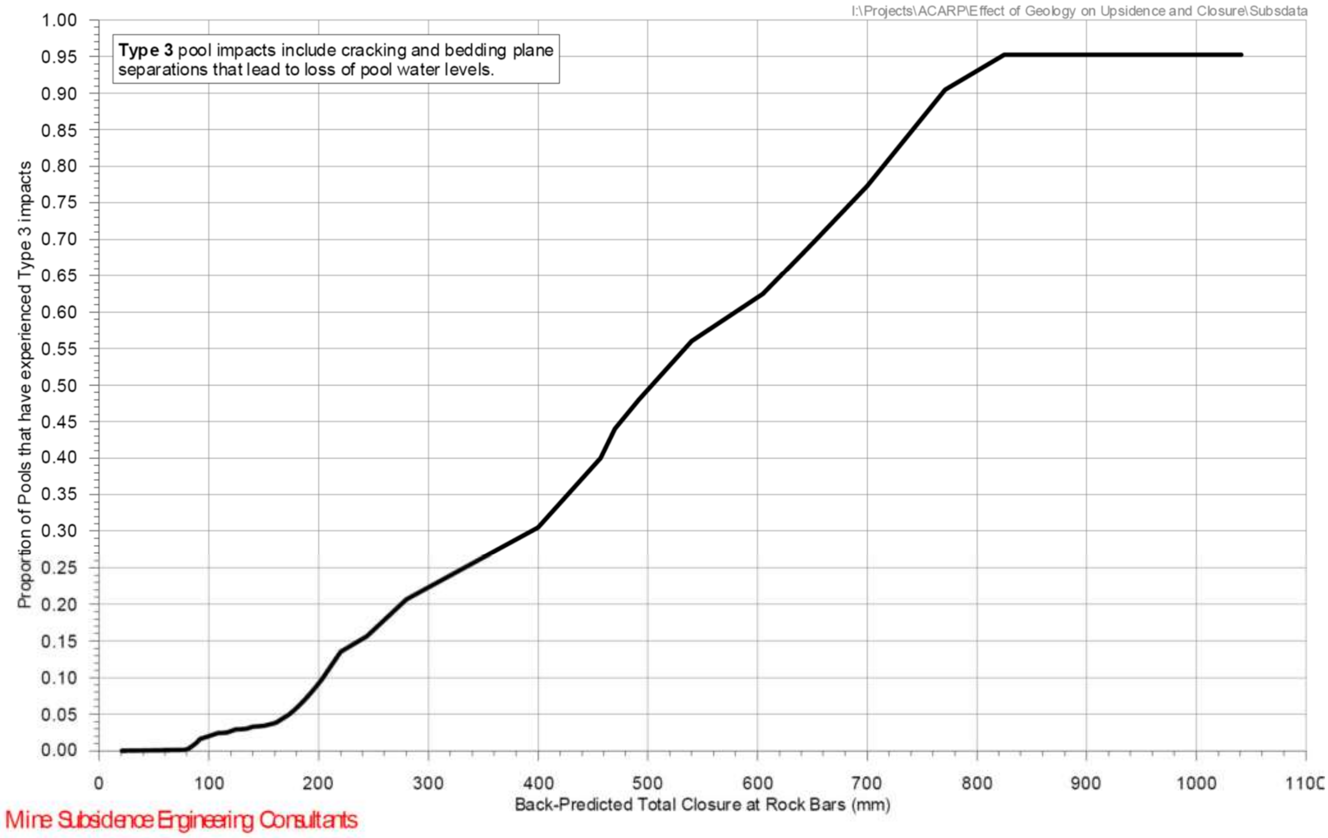

Figure 22 Preliminary Relationship Between Valley Closure and Loss of Pool Water Holding Capacity (after MSEC, 2013)

The following qualitative descriptors have been derived from this preliminary relationship for use in the impact assessment for pools in the Project Area watercourses.

- The risk of loss of water holding capacity in rock bar controlled pools is negligible where the predicted valley closure is less than 100 mm.

- There is a low chance of flow loss occurring in rock bar controlled pools where predicted valley closure is between 100 and 280 mm.
- There is a moderate chance of flow loss occurring in rock bar controlled pools where predicted valley closure is between 280 and 500 mm.
- There is a high chance of flow loss occurring in rock bar controlled pools where predicted valley closure is between 500 and 700 mm.
- There is a very high chance of flow loss occurring in rock bar controlled pools where predicted valley closure is greater than 700 mm becoming almost certain when valley closure predictions exceed 800 mm.

Valley closure predictions for watercourses overlying the Project Area longwalls have been provided by MSEC (2018) in a series of figures which are reproduced in Appendix A. The maximum predicted (MSEC, 2018) valley closure and upsidence in local streams are summarised in Table 1.

The distribution of predicted closure categories along Tea Tree Hollow and Dog Trap Creek is shown in Figure 23 and Figure 24 below including the location of mapped pools.

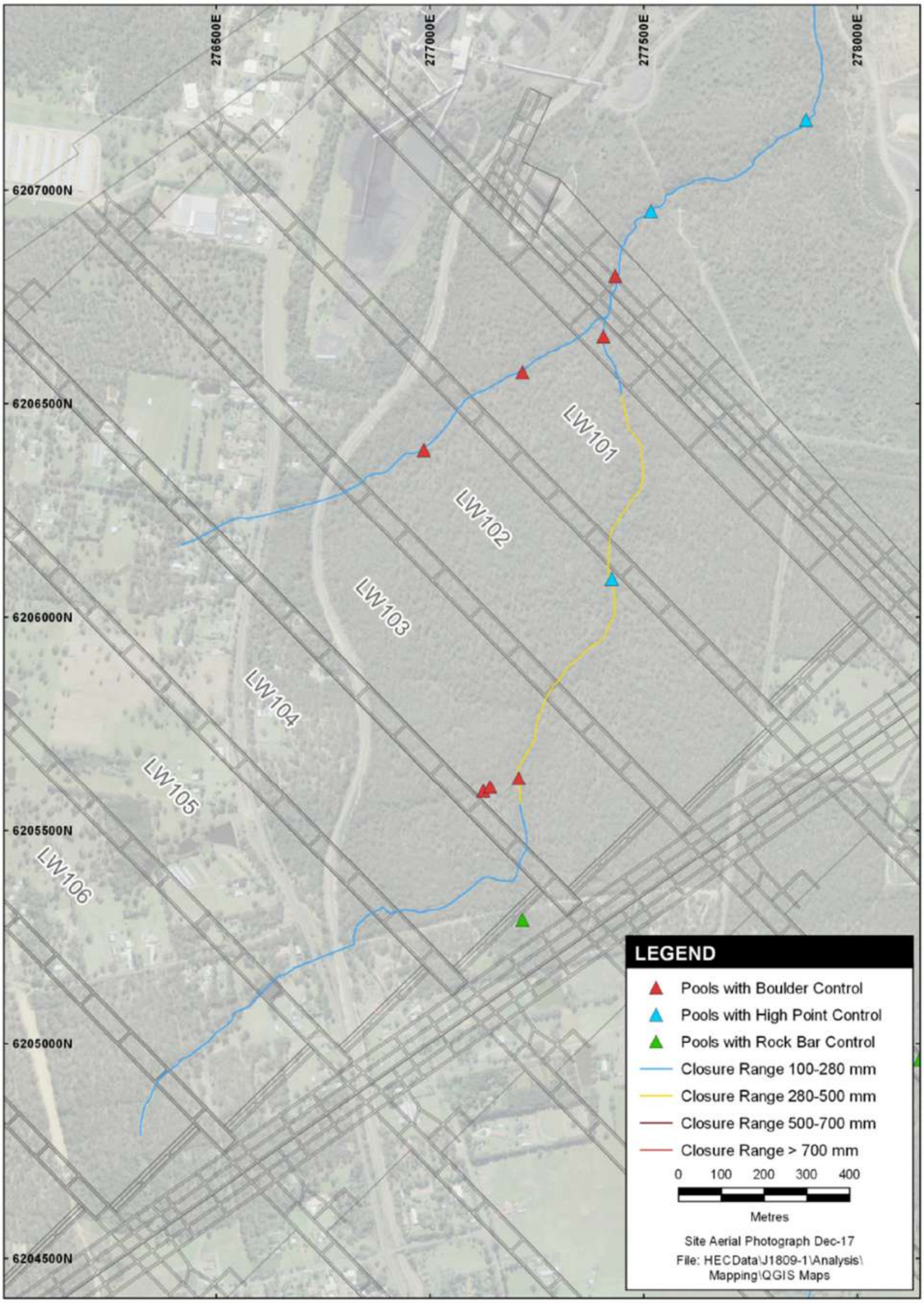

Figure 23 Qualitative Risk to Pools in Tea Tree Hollow

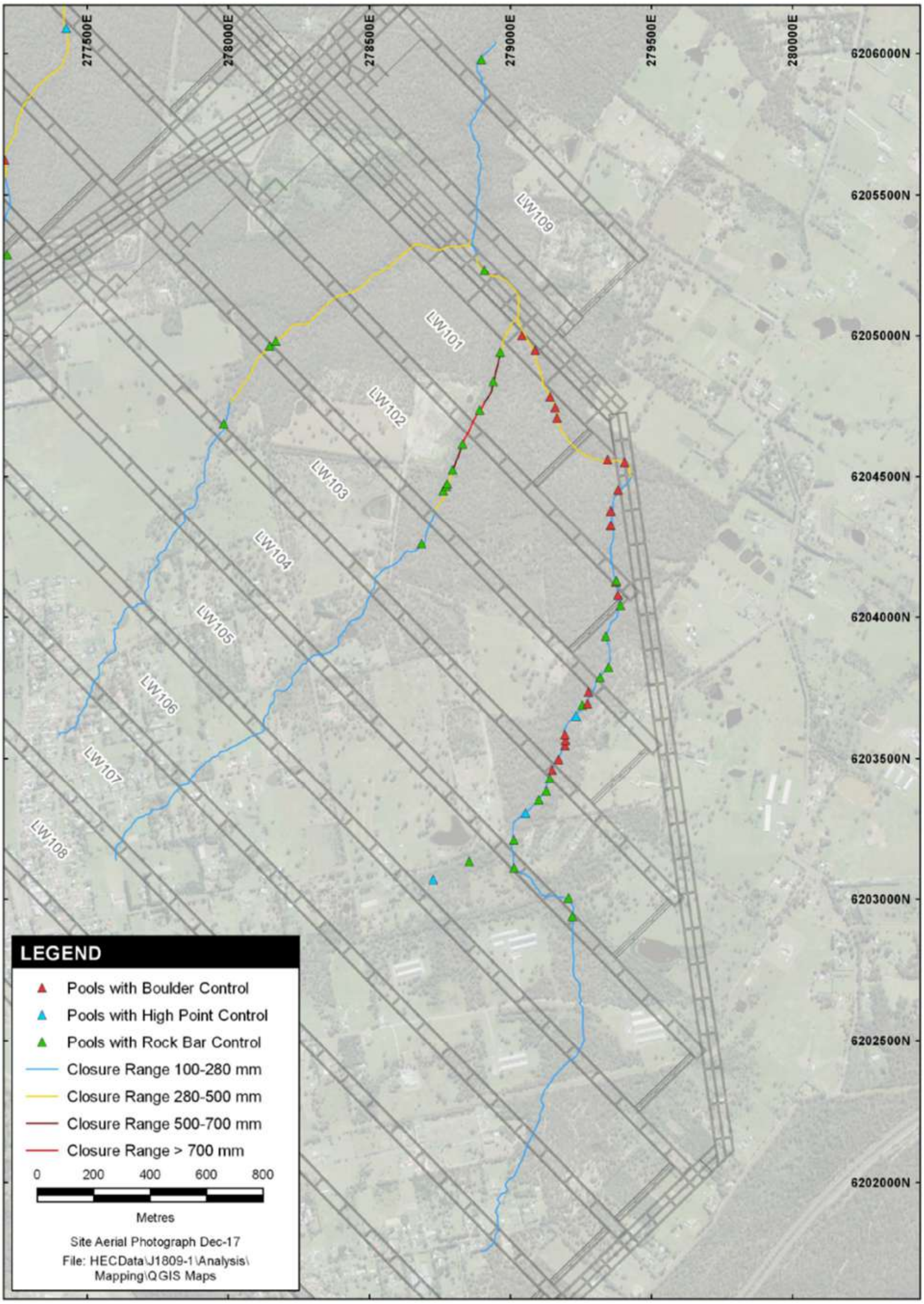

Figure 24 Qualitative Risk to Pools in Dog Trap Creek

There were 14 pools mapped in Tea Tree Hollow. Most pools are located in areas where there is a low risk of impact to water holding capacity. Two pools are however located in an area of moderate risk of impact to flow holding capacity. The largest number of pools (in excess to 70), were mapped on Dog Trap Creek. Of these some 14 are located in areas of either moderate or high risk of loss of water holding capacity.

7.3 LOSS OF SURFACE FLOWS TO GROUNDWATER (BASEFLOW REDUCTION)

HydroSimulations (2018b) describe baseflow reduction as *"…the process of inducing leakage from a creek or river into the aquifer via a downward gradient or weakening an upward gradient from the aquifer into the watercourse and thereby reducing the rate at which baseflow occurs."*

HydroSimulations (2018b) have made predictions of baseflow reductions for local and regional streams. Predictions of maximum baseflow reduction due to the Project at the main monitoring sites are summarized in Table 4 below. The mean daily flow and baseflow rate, estimated using AWBM as described in Section 6 of the Surface Water Baseline Study (HEC, 2018), is presented in comparison with the predicted maximum baseflow reduction.

Table 4 Summary of Predicted Effect of Maximum Baseflow Reductions on Average Flows

Stream/Site	Mean Daily Flow (ML/d)	Mean Daily Baseflow (ML/d)	Maximum Reduction (ML/d)*	Maximum Reduction as % of Mean Daily Flow	Maximum Reduction as % of Mean Daily Baseflow
Bargo River, Site 13	23.9	2.39	0.1	0.4%	4.2%
Tea Tree Hollow, Site 22	6.3	3.5	0.11	1.7%	3.1%
Dog Trap Creek, Site 15	4.95	0.495	0.26	5.3%	52.5%

* Per HydroSimulations (2018b).

The maximum predicted reduction in flow is relatively small in terms of mean daily flow but represents a significant percentage (52.5%) of the average estimated baseflow at Dog Trap Creek and a small to moderate percentage at the Bargo River (4.2%) and Tea Tree Hollow (3.1%). The reduction in flow in Tea Tree Hollow would be offset by on-going licensed discharge from LDP1 (refer Section 7.1).

It is expected that reduction in baseflow would be most noticeable during periods of low flow which would normally be dominated by baseflow. The effect on low flows can be seen by comparing the flow duration curves[7] generated for the existing and maximum impact cases.

Figure 25 shows the maximum impact of the predicted baseflow reduction due to the Project on flows in the Bargo River at the Bargo River Upstream gauging station (GS 300010a). There is negligible apparent effect for flows greater than approximately 1 ML/day which occur on about 70% of days. The largest effect can be seen on flows below about 0.5 ML/day and less. The probability that flow would be greater than 0.1 ML/day would reduce from 99% to 97% of days as a result of the maximum predicted baseflow reduction. This level of change would be imperceptible and very small compared to natural variability in catchment conditions and is therefore considered to be negligible.

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[7] A Flow Duration Curve is a plot of the proportion of time (days) flow is greater than a given flow rate based on a long period of record. In this report it has been calculated using daily flows over the entire modelled period. The flow duration curves produced in this report have been plotted on logarithmic scale to accentuate low flows

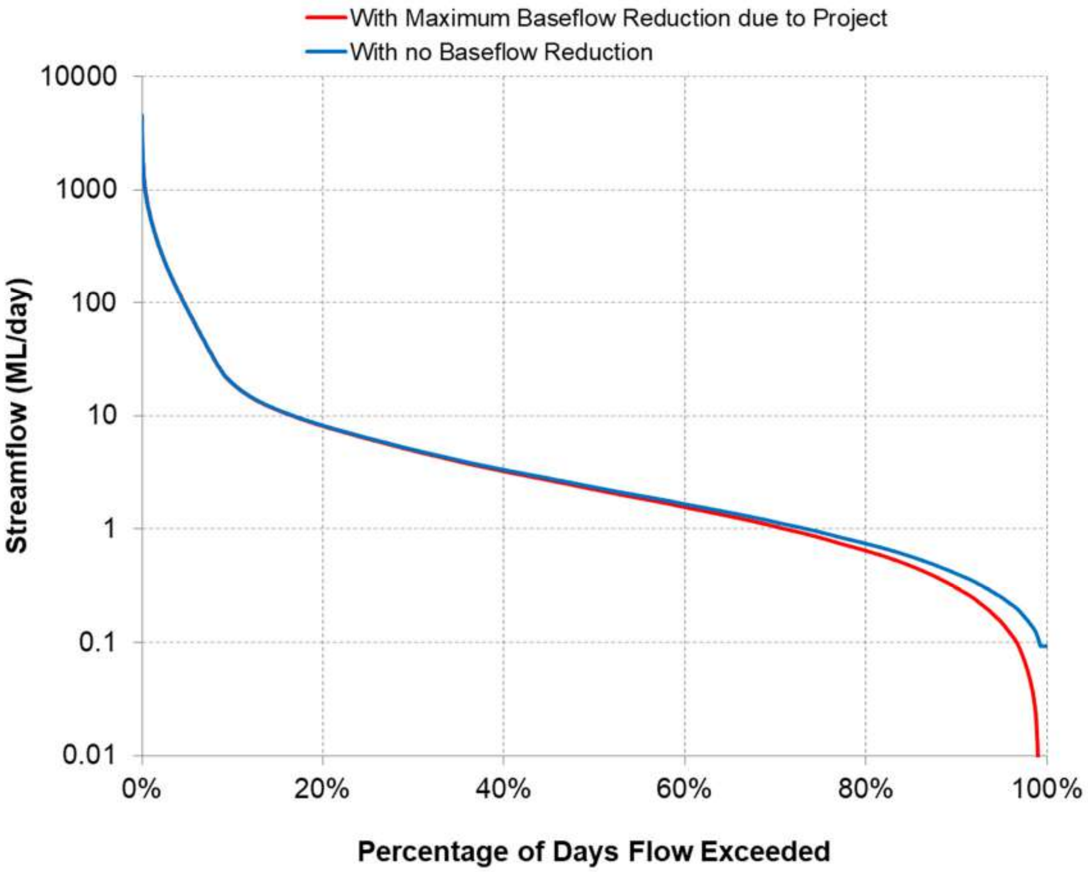

Figure 25 Flow Duration Curve – Bargo River Upstream (GS 300010a) with and without Maximum Baseflow Reduction due to Project

Figure 26 shows the maximum impact of the predicted baseflow reduction due to the Project on flows in Tea Tree Hollow at the gauging station (GS 300056). Because of the effect of the persistent releases from LDP1, the effects of predicted baseflow reduction on Tea Tree Hollow at the gauging station (GS 300056) would be negligible. The effects upstream of the discharge would however potentially have greater effects on low flows. Given the similarity of Tea Tree Hollow catchment to the Dog Trap Creek catchment it is considered likely the effects on low flows would be similar to those described for Dog Trap Creek at GS 300063 below i.e. detectable, significant effects would be likely during normal periods of low flow.

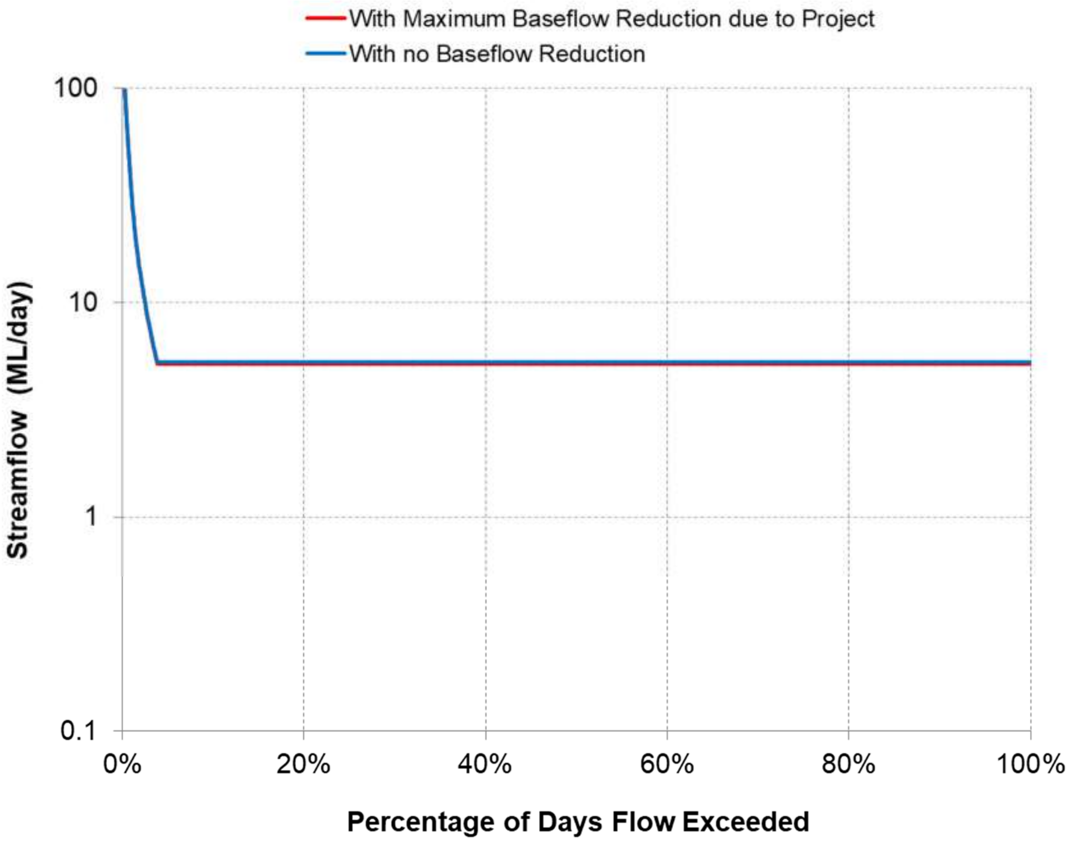

Figure 26 Flow Duration Curve – Tea Tree Hollow (GS 300056) with and without Maximum Baseflow Reduction due to Project

Figure 27 shows the maximum predicted impact of the predicted baseflow reduction on flows in Dog Trap Creek at the downstream gauging station (GS 300063). There is minimal apparent effect for flows greater than about 2 ML/day. The largest effect is seen on flow below about 0.1 ML/day. The probability that flow would be greater than 0.01 ML/day would reduce from 87% to 45% of days. This level of change would be detectable during normal periods of low flow. This level of change would likely be distinguishable from natural variability in catchment conditions and is therefore considered to be significant.

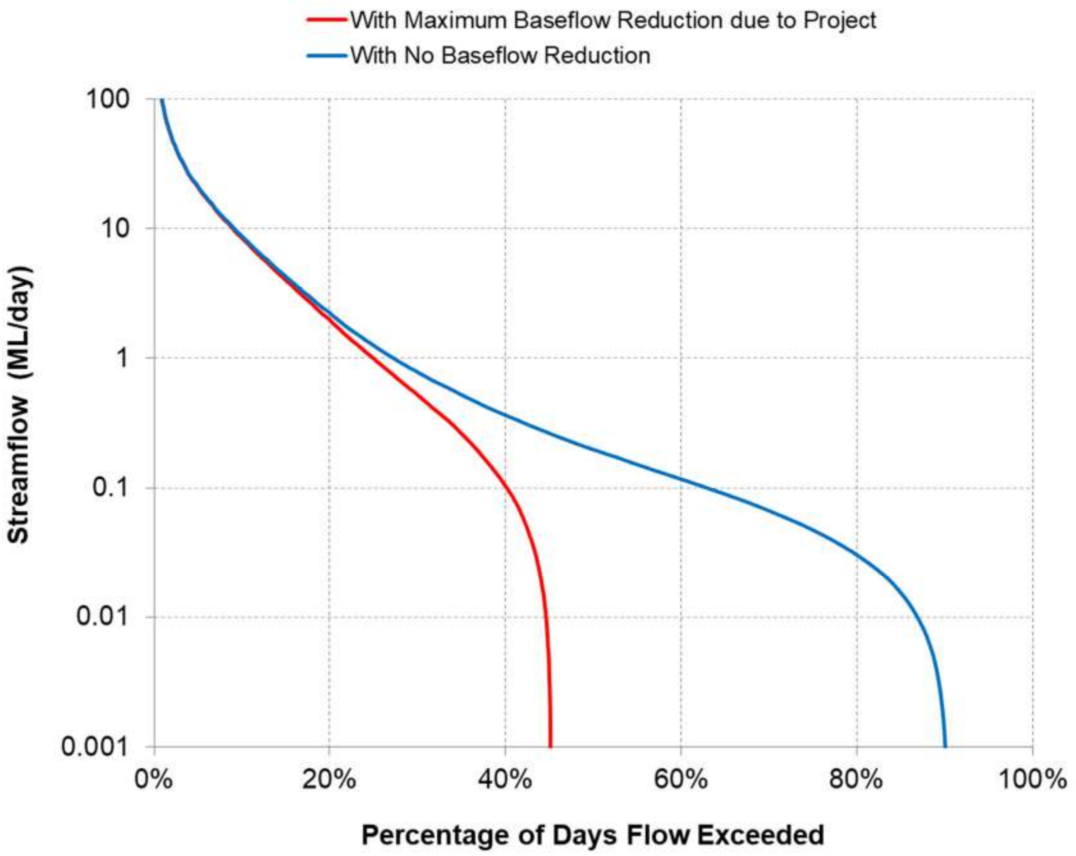

Figure 27 Flow Duration Curve – Dog Trap Creek (GS 300063) with and without Maximum Baseflow Reduction due to Project

7.4 REDUCED FLOWS DUE TO TRAPPING OF RUNOFF IN SUBSIDENCE DEPRESSIONS

The creation of subsidence depressions and associated containment of runoff could reduce flows downstream. There is potential for this sort of impact to affect flows in Tea Tree Hollow, Dog Trap Creek and Hornes Creek with possible "flow-on" effects to downstream watercourses.

An examination of the predicted post-subsidence topography indicates that there are no subsidence induced depressions evident either within watercourses or in their catchments. In the absence of any significant surface ponding created by subsidence there should be no effect on flows in local watercourses.

7.5 INCREASED FLOWS DUE TO CONTROLLED DISCHARGES AND OVERFLOWS FROM WATER MANAGEMENT SYSTEM

Overflows and releases from the water management system could affect flows in Tea Tree Hollow and the Bargo River.

Tahmoor Mine discharges treated water to Tea Tree Hollow under conditions attached to EPL[8] 1389. Results of water balance simulation modelling (HEC, 2018b) indicate that total discharges and overflow from the combined existing Tahmoor North and the proposed Project is unlikely to increase significantly from current levels. Simulated average (mean) discharge and overflow rates are 2,222 ML/annum and 36 ML/annum respectively.

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[8] Environment Protection Authority – NSW, Licence 1389, Version Date: 20-Nov-2017.

8.0 POTENIAL IMPACTS TO THE HYDROLOGY OF THIRLMERE LAKES

A water balance model of the Thirlmere Lakes has been used to assess the likely impacts of the Project on the hydrology of the lakes. The model simulates surface water processes as well as groundwater flux informed by separate groundwater modelling (HydroSimulations, 2018a).

8.1 SURFACE CHARACTERISTICS

The surface geology within the catchment of Thirlmere Lakes is dominated by extensive areas of Hawkesbury Sandstone which outcrop on the valley sides and ridges. In places there is a capping of Wianamatta Shale. The upper valley sides generally comprise a thin sandy soil mantle, while the Lakes themselves are underlain by a significant depth of alluvium (Pells, 2011).

There is significant topographic relief within the Lakes' catchment. Surface elevations vary from approximately 350 m Australian Height Datum (AHD) down to approximately 300 m AHD at the outfall of Lake Nerrigorang (refer Figure 28).

Catchment ground cover primarily comprises undisturbed eucalypt woodlands with some cleared land located along the eastern and north-western boundaries. The majority of the catchment lies within the Thirlmere Lakes National Park, however cleared land at the head of the catchment (east of Lake Gandangarra) and the north-western and southern sides of the catchment is privately owned (refer Figure 28).

The Lakes themselves generally comprise dense fringing vegetation around their perimeter (near top water level) with sedges and grasses within the inundation area (refer Plate 1). The very centres of the upstream three Lakes and, most notably, Lake Couridjah lack vegetation. These areas comprise organic fine silty soils with a propensity to desiccate and crack when drying (refer Plate 2).

Plate 1 – Lake Gandangarra Looking West (January 2012)

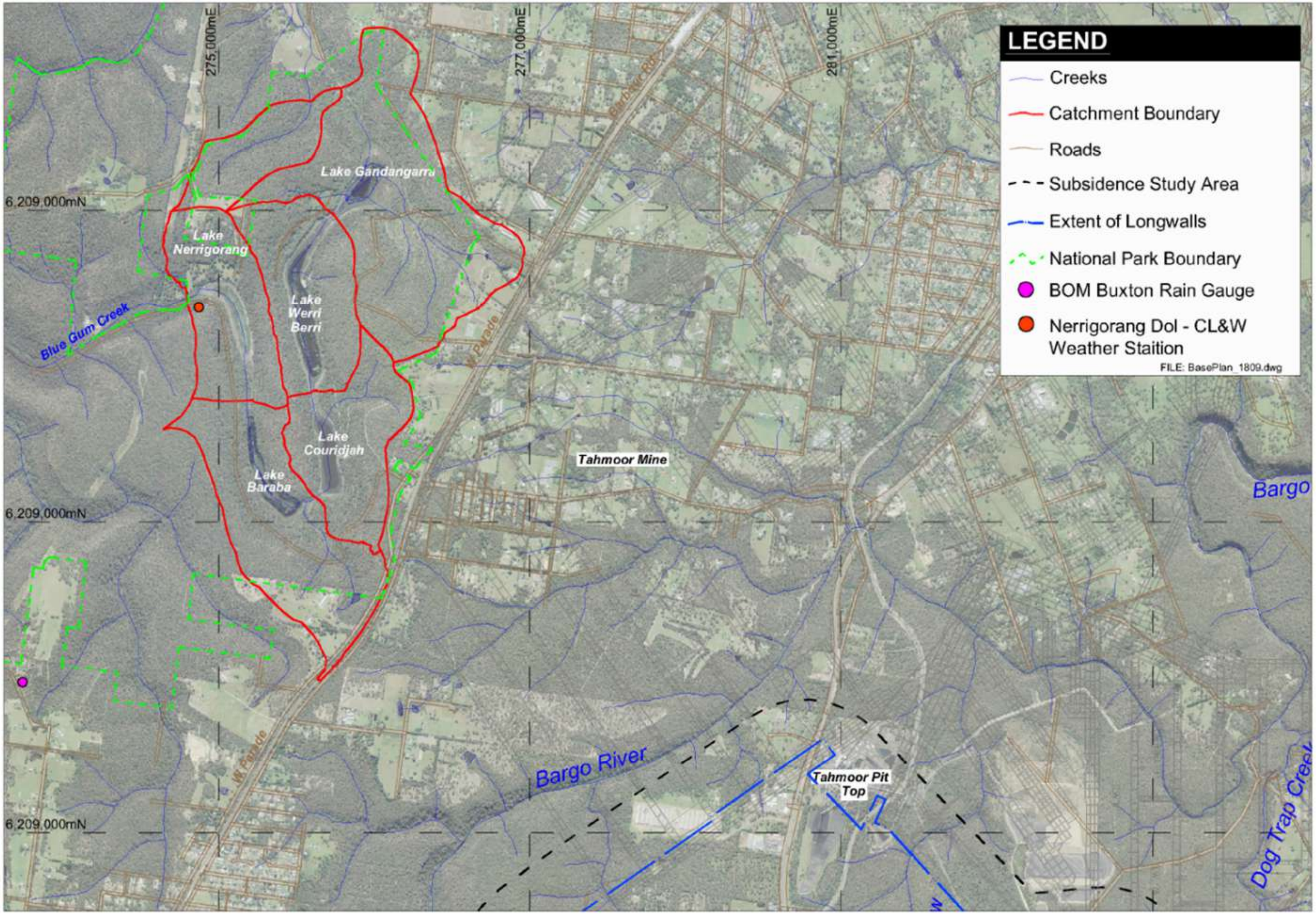

Figure 28 Thirlmere Lakes Area - Plan

Plate 2 – Lake Couridjah Looking North (January 2012)

The catchment of the Lakes in total is estimated at approximately 5 km^2 with the largest portion of the catchment reporting to Lake Gandangarra (39%). The individual estimated lake catchment areas are given in[9] Table 5 and shown on Figure 28.

Table 5 Thirlmere Lakes Catchment Areas

Lake	Catchment Area (km^2)	Lake Full Surface Area (km^2)	Catchment:Surface Area Ratio
Gandangarra	1.96	0.12	16.3
Werri Berri	0.70	0.16	4.4
Couridjah	0.66	0.09	7.3
Baraba	1.03	0.08	12.9
Nerrigorang	0.65	0.08	8.1
TOTAL	5.00	0.53	9.4

Terrestrial surveys of the Lakes were undertaken in 2012 (at a time of low Lake levels – refer Plates 1 and 2) and used together with topographic contours derived from LiDAR survey undertaken in 2013 to estimate the capacities of the Lakes up to their overflow levels. Lake surface areas at their overflow levels are also given in Table 5. The total Lake surface area comprises more than 10% of the catchment. The total catchment area of the Lakes is relatively small and therefore the volume of water in the Lakes varies significantly with climate, with Lake levels historically fluctuating between dry and full conditions (Riley, et al, 2012).

Survey has indicated that the overflow level of Lake Couridjah is higher than both the overflow levels of Lake Werri Berri and Lake Gandangarra. Therefore at higher lake water levels, these three Lakes form one water body. This is shown in the longitudinal sections plotted in Figure 29. The estimated capacity of the three combined Lakes to their overflow level at 305.86 m AHD is 1,158 ML.

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[9] Estimated from topographic contours derived from LiDAR survey undertaken in February 2013.

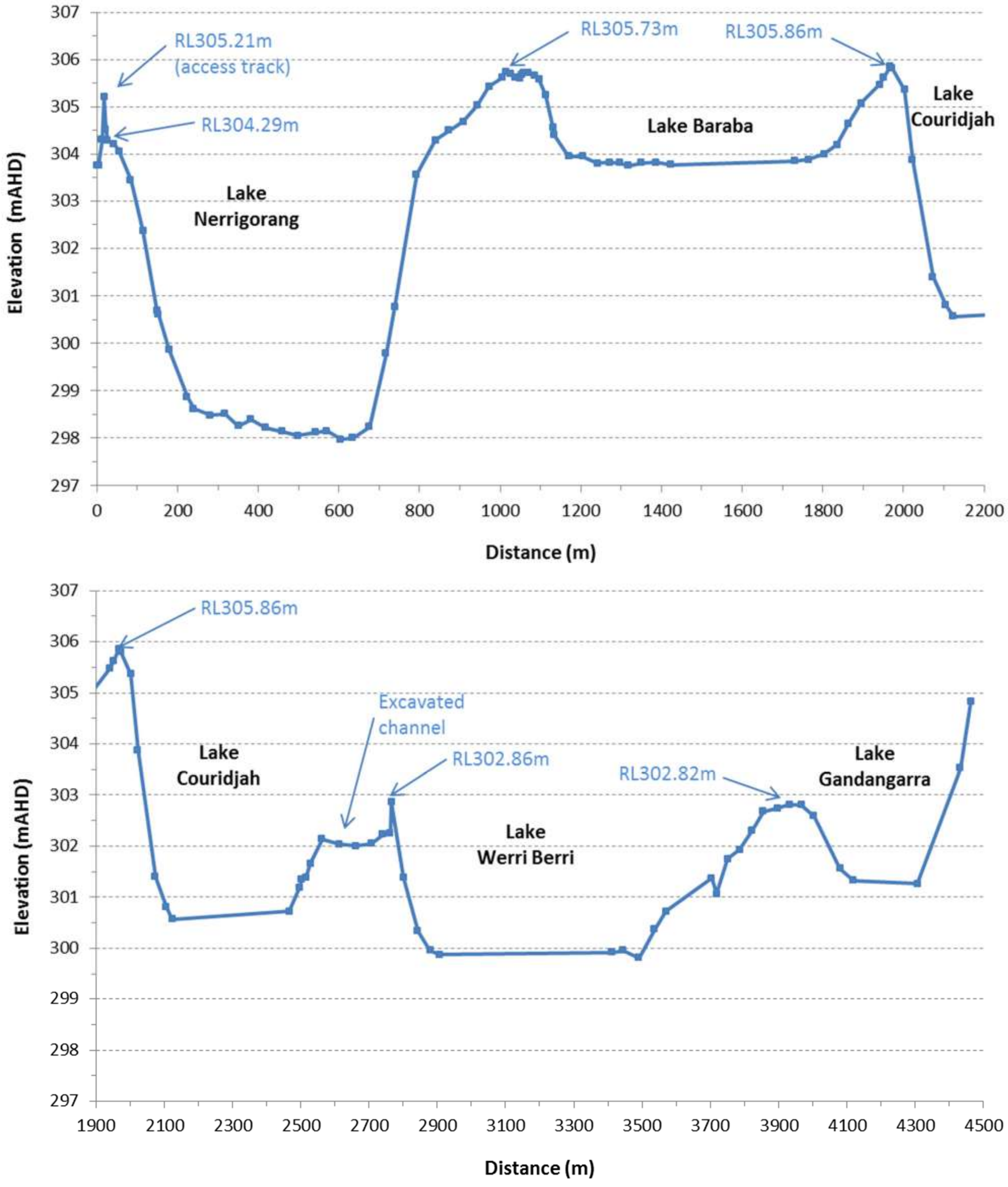

Figure 29 Lake Longitudinal Sections

Lake Baraba has an overflow level just lower than the inflow level from Lake Couridjah (refer Figure 29). The estimated capacity of Lake Baraba is 124 ML.

Lake Nerrigorang appears to form a separate water body from the other Lakes and is also the deepest lake (refer Figure 29). An access track constructed across Blue Gum Creek, near the Lake outfall, appears to control Lake Nerrigorang water levels at present. The nature and permeability of the access track materials is unknown however numerous holes were noted in this embankment during site inspections suggesting possible flow pathways. For the purposes of modelling and this assessment it has been assumed that the Lake Nerrigorang overflow level is located at the base of the access track embankment – a lower level of approximately 304.29 m AHD. The estimated capacity of Lake Nerrigorang to this level is 312 ML.

The total combined estimated capacity of Thirlmere Lakes (Couridjah, Gandangarra, Werri Berri Baraba and Nerrigorang) is 1,594 ML.

8.2 GROUNDWATER

A significant depth (possibly more than 50 m) of alluvium has accumulated below the Lake beds (Pells, 2011). Groundwater within this alluvium forms a perched system above the deeper water table within the bedrock. Alluvial groundwater is connected to the ponded water within the Lakes. When the alluvium is saturated, surface water ponds form within the Lakes. Surface water-groundwater interactions within the Lakes and alluvial systems are an important component of the water balance of the Lakes. Perched groundwater within the alluvium recharges the deeper bedrock water table – i.e. the Lakes are a 'losing' system. A detailed regional groundwater model including the Thirlmere Lakes has been developed by HydroSimulations (2018a) and used to assess the impact of the Project.

8.3 WATER BALANCE MODELLING

8.3.1 Model Objective and Description

A water balance model of the Thirlmere Lakes has been developed in order to simulate the potential impacts of the Project on the behaviour of the Lakes. The water balance model is a daily time-step mass balance model. The model simulates daily changes in the volume of water in each of the Lakes in response to inflows and outflows, i.e.:

Change in Storage = Inflow – Outflow

Where:

> *Inflow* includes direct rainfall, catchment rainfall runoff, seepage from adjoining Lakes and overflows from other Lakes; and
>
> *Outflow* includes evaporation/evapotranspiration from the Lake and fringing vegetated area, seepage to adjoining Lakes, groundwater recharge of the deeper bedrock water table, overflows to other Lakes or Blue Gum Creek and pumped extraction.

8.3.2 Model Components and Data

8.3.2.1 Rainfall and Evaporation Data

A 129 year daily rainfall data set (1889 to 2017 inclusive) was developed for the model by combining data obtained from the SILO Data Drill[10] for a location near to the Thirlmere Lakes with data from the nearest Bureau of Meteorology (BoM) rainfall station – located at Buxton[11] (refer Figure 28), with data available from 1967 onwards. Daily pan evaporation data was also sourced from the SILO Data Drill for the same period as the rainfall data. Model simulations were undertaken for the full period of available climate data.

8.3.2.2 Catchment Runoff Simulation

Catchment runoff was simulated using the AWBM (refer Section 6.2.2). AWBM parameters were initially estimated from model calibrations for nearby gauged streams and adjusted as part of model calibration (refer Section 8.3.3).

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[10] The SILO Data Drill is a system which provides synthetic data sets for a specified point by interpolation between surrounding point records held by the BoM. Refer https://www.longpaddock.qld.gov.au/silo/datadrill/

[11] BoM Station 68166.

8.3.2.3 Lake Storage Characteristics, Evaporation and Evapotranspiration

Surface storage characteristics (Lake level versus volume and area) were derived from the available topographic survey (refer Section 8.1). In the model, on each day, Lake water surface area was calculated from modelled volume using these characteristics. The model calculates water evaporation using pan evaporation data multiplied by a pan factor multiplied by the Lake water area. Pan factors are used to convert evaporation pan data to open water evaporation and are usually less than one (reflecting a higher evaporation rate from a shallow metal evaporation pan than from a deep water body such as a lake). Open water evaporation data can be calculated using the Penman (1956) equation and recorded weather station data. By comparing calculated open water evaporation data to pan evaporation data, pan factors can be calculated.

A weather station has been established next to Lake Nerrigorang by the Department of Industry - Crown Lands and Water Division (CL&W), with daily data available for a three year period from October 2014. The derived average monthly pan factors from this data are plotted in Figure 30, together with monthly pan factors obtained from McMahon et al (2013) for Nowra (the nearest available location at a comparable elevation to the Thirlmere Lakes). Figure 30 shows that the two sets of data are reasonably close. The calculated pan factors were used in the water balance model.

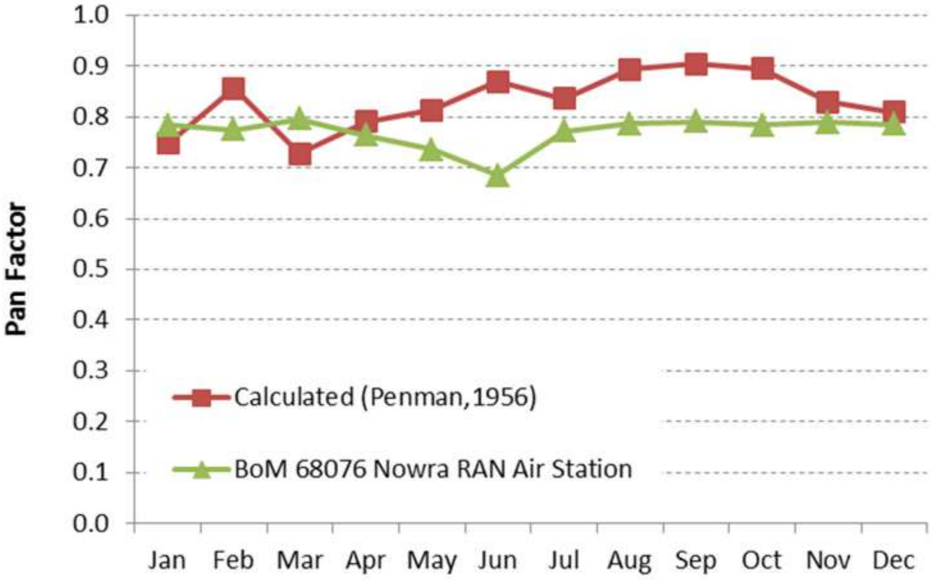

Figure 30 Monthly Evaporation Pan Factors

As well as the capacity of the Lakes to store free (visible) water, additional storage volume exists in the alluvial deposits that exist below the floor of the Lakes. Consistent with Pells (2011), subsurface storage was assumed to extend down from each Lake's shore line (at overflow level) at a slope of 4 horizontal (H):1 vertical (V). This slope was based on the valley characteristics described in Pells (2011) which assumed the alluvium/bedrock interface would follow the surrounding valley slope of 4H:1V (refer Figure 31). Calculation of sub-surface storage volume assumed a porosity of 0.25 for the alluvium (consistent with Pells, 2011).

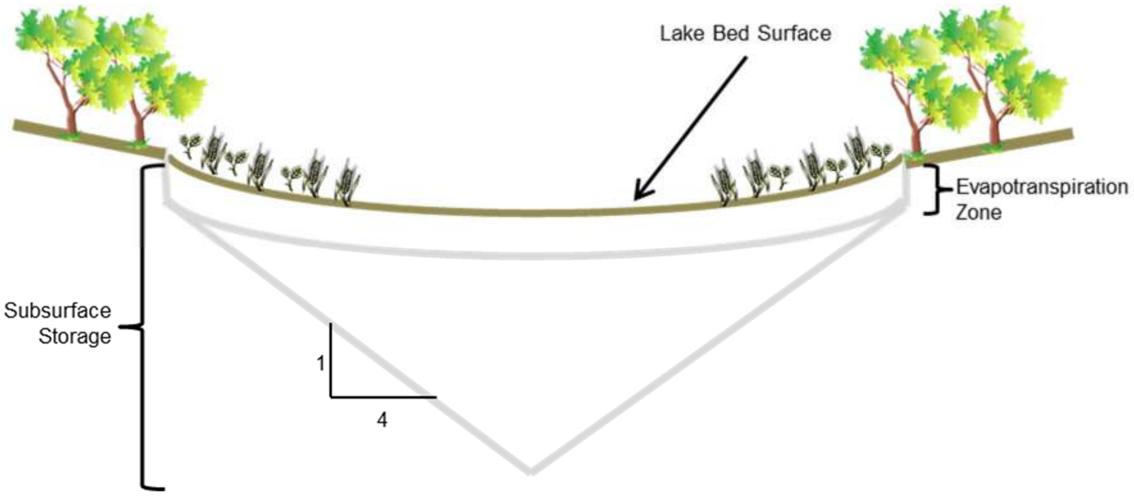

Figure 31 Conceptual Sub-Surface Lake Storage

It was recognised that although the Lakes may at times contain no surface water (and therefore no direct ponded water evaporation would occur), evapotranspiration would occur from fringing and lake bed vegetation as well as from the dark-coloured exposed lake bed material itself. Therefore the sub-surface area subject to evapotranspiration was also calculated. Evapotranspiration was modelled to occur when the water table was within 1 m of the lake surface. The concept is illustrated in Figure 31. A pan factor of 0.85 was used to convert records of daily pan evaporation to an evapotranspiration rate (consistent with the rate used in the AWBM). This number is consistent with published guidelines (FAO, 1998) for average pan factors multiplied by a crop factor for 'reed swamp' vegetation. Lake evapotranspiration was only calculated from lake bed and bank areas (below Lake overflow level) that were within 1 m of the surface and were not inundated by ponded water.

As each Lake fills and overflows to the adjacent Lake evapotranspiration occurs in the linking channels. Evapotranspiration area was estimated using a constant width and the distance between the upstream lake overflow level and the downstream lake water level. Evapotranspiration rate was again calculated as daily pan evaporation multiplied by 0.85.

8.3.2.4 Seepage Between Lakes

Seepage between Lakes was simulated using Darcy's Law, i.e.

$$Q = kiA$$

Where

Q = groundwater flow rate (m^3/s)
k = hydraulic conductivity (m/s)
i = groundwater hydraulic gradient (m/m)
A = cross-sectional area (m^2)

A hydraulic conductivity (*k*) of 5×10^{-6} m/s was assumed for the alluvial material (reported as being sandy clay material – Pells [2011]). The hydraulic gradient (*i*) was calculated from the relative lake water levels and an assumed constant distance between the Lake centroids. The distance between Lake centroids was based on survey data (refer Section 8.1). The cross-sectional area of flow (*A*) was calculated from the simulated water level in the Lake bed alluvium and the assumed 4H:1V alluvium cross-sectional geometry (refer Section 8.3.2.3).

8.3.2.5 Groundwater Recharge from Lakes

Deep groundwater (bedrock) recharge rates from the Lakes were estimated by HydroSimulations (2018a) as a function of lake water level. Recharge rates were estimated for both existing conditions and with the Project (at maximum impact). Recharge rates are summarised in Table 6 and Table 7.

Table 6 Modelled Lake Groundwater Recharge Rates - Existing

Lake Level (mAHD)	Rate (m^3/day)			Lake Level (mAHD)	Rate (m^3/day)	Lake Level (mAHD)	Rate (m^3/day)
	Lake Gandangarra	Lake Werri Berri	Lake Couridjah		Lake Baraba		Lake Nerrigorang
298	11	15	12	303.3	4	298	11
300	17	32	20	304	5	300	10
302	26	78	18	305.2*	6*	301	30
304	119	289	145	306	86	302	77
306	458	632	375			304	276

Table 7 Modelled Lake Groundwater Recharge Rates – With Project

Lake Level (mAHD)	Rate (m^3/day)			Lake Level (mAHD)	Rate (m^3/day)	Lake Level (mAHD)	Rate (m^3/day)
	Lake Gandangarra	Lake Werri Berri	Lake Couridjah		Lake Baraba		Lake Nerrigorang
298	12	17	12	303.3	5	298	14
300	17	34	21	304	6	300	11
302	27	79	19	305.2*	7*	301	31
304	125	302	150	306	87	302	84
306	464	645	381			304	283

* Denotes a line of data not provided by HydroSimulations (2018a) but rather included to improve model calibration.

8.3.2.6 Extraction from Lakes

Extraction from Lake Couridjah occurred during the early to mid 20th century to supply steam trains. Estimated demands were derived from information provided by Mr Ian Sheppard[12]. Estimated demands varied from 130 m^3/week from 1920 to 1931, 60 m^3/week from 1932 to 1948, 50 m^3/week from 1949 to 1957 and 20 m^3/week from 1957 to 1964.

Based on data given in Pells (2011), it appears that water was pumped from Lake Nerrigorang in the 1980s for several weeks by a landholder. Pumps were used for several weeks and reportedly ran 24 hours per day at a rate of 1000 gallons/min (63 L/s). In the model three pumping campaigns were assumed which lasted for six weeks each. However, in the water balance model, water was only pumped if there was water available in the Lake.

8.3.3 Model Calibration

Calibration is the process by which model parameters are modified in order to match recorded system behaviour, thereby improving the ability of the model to simulate the real system.

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[12] Chairman of the Illawarra Division of NSW Rail Transport Museum and former Environment and Community Manager at Tahmoor Colliery.

Continuous records of the water level in Lake Nerrigorang have been maintained since early 2015 and for the remaining Lakes since late 2013 (NSW Government, 2017). Although published data includes both raw recorded depth data and water level (in m AHD), only the former was obtained (daily data) and converted to m AHD using a level survey of the lake water levels undertaken in February 2017, with confirming levels surveyed in February 2018 (i.e. by comparing surveyed levels to recorded levels on the given day). A plot of recorded Lake levels is shown in Figure 32.

Figure 32   Recorded Lake Water Levels

Also plotted on Figure 32 is daily rainfall data from the CL&W weather station at Lake Nerrigorang. This daily record was compared with the BoM record from the Buxton rainfall station and some significant differences found. For example, during the high rainfall event that occurred in early June 2016, 313 mm was recorded at the Lake Nerrigorang weather station, while 345 mm was recorded at the BoM Buxton station. In addition, it was noted that there was a significant stand of trees to the south of the Lake Nerrigorang weather station which can introduce error into the rainfall readings. Therefore it was decided to continue to use the BoM Buxton rainfall station as input to the model.

The recorded Lake water levels were converted to equivalent water volumes using the Lake storage characteristics (refer Section 8.3.3) in order to compare directly to simulated lake volumes. Model catchment rainfall-runoff (AWBM) parameters were then adjusted in an effort to achieve as good a match as possible between modelled volumes and those derived from recorded levels for all the Lakes. Common AWBM parameters were set for all Lake catchment areas. Note that the model simulation commenced in 1889 and therefore initial conditions were immaterial to the calibration.

Additional historical water level information, prior to the establishment of water level monitoring, could be derived from aerial photography of the Lakes. Ideally this may be achieved by overlaying aerial photographs on a contour plan, however most aerial photographs suffer from a degree of distortion, therefore an accurate water level cannot be obtained directly. An alternative is to measure the area of each Lake from the aerial photograph and then use the Lake storage characteristics to obtain an estimated level. However, this is often difficult to achieve because of the heavy fringing vegetation around the Lakes covering the edge of the water, which affects the accuracy of the estimate. Because of the potentially equivocal data that would be produced using aerial photographs, only the recorded Lake water level data has been used for calibration in this study.

Lake groundwater recharge rates were as given in Table 6.

Comparisons between estimated actual Lake water volume (from monitored levels and storage characteristics) and modelled volumes are shown in Figure 33 to Figure 37 for the individual Lakes. A similar plot of the total Lake water volume is given in Figure 38.

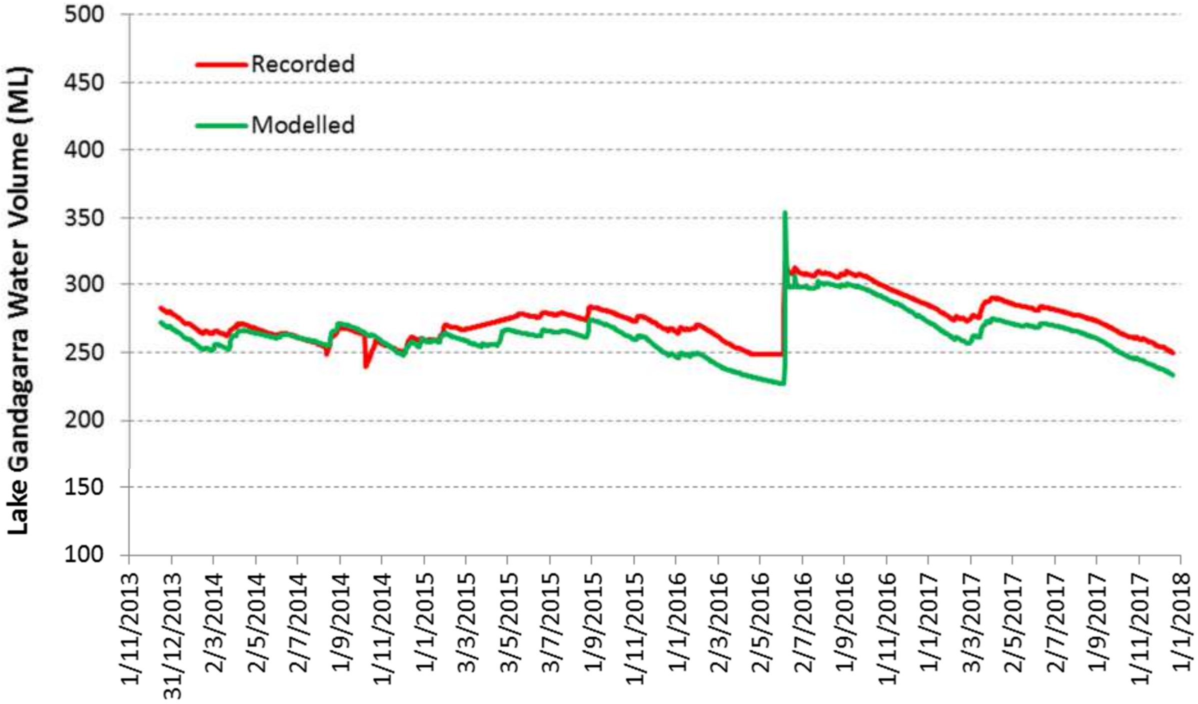

Figure 33 Calibrated Model and Estimated Actual Water Volume – Lake Gandangarra

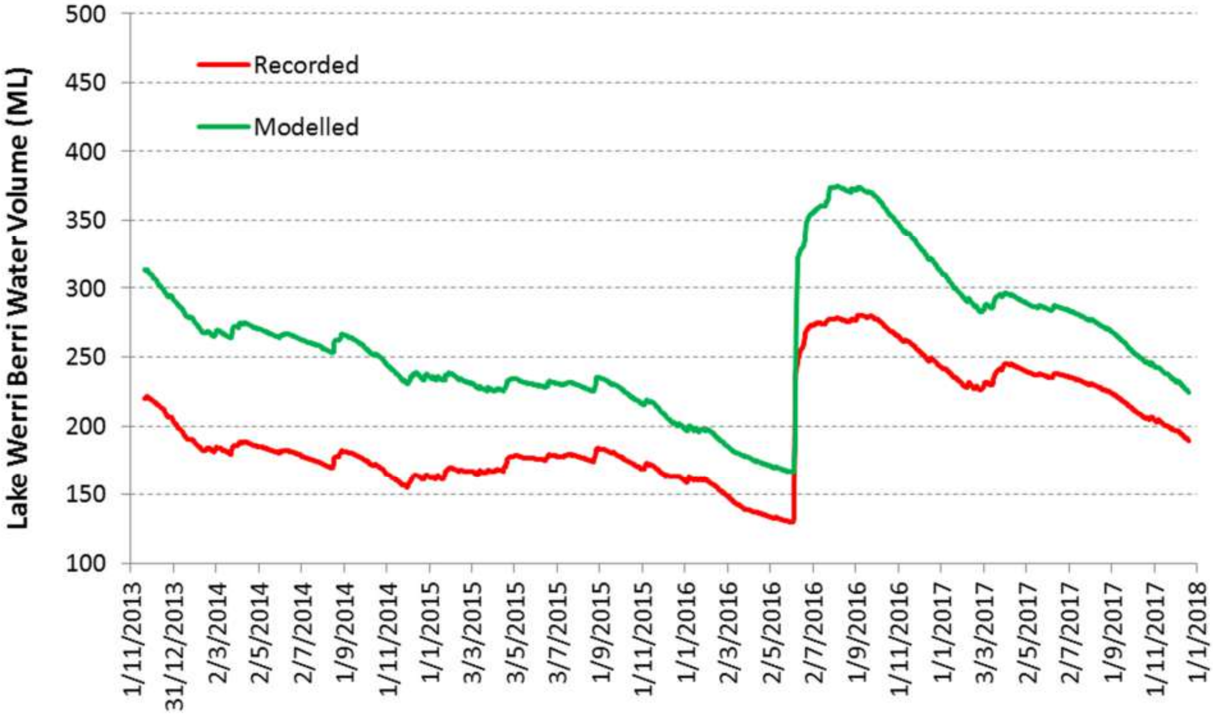

Figure 34 Calibrated Model and Estimated Actual Water Volume – Lake Werri Berri

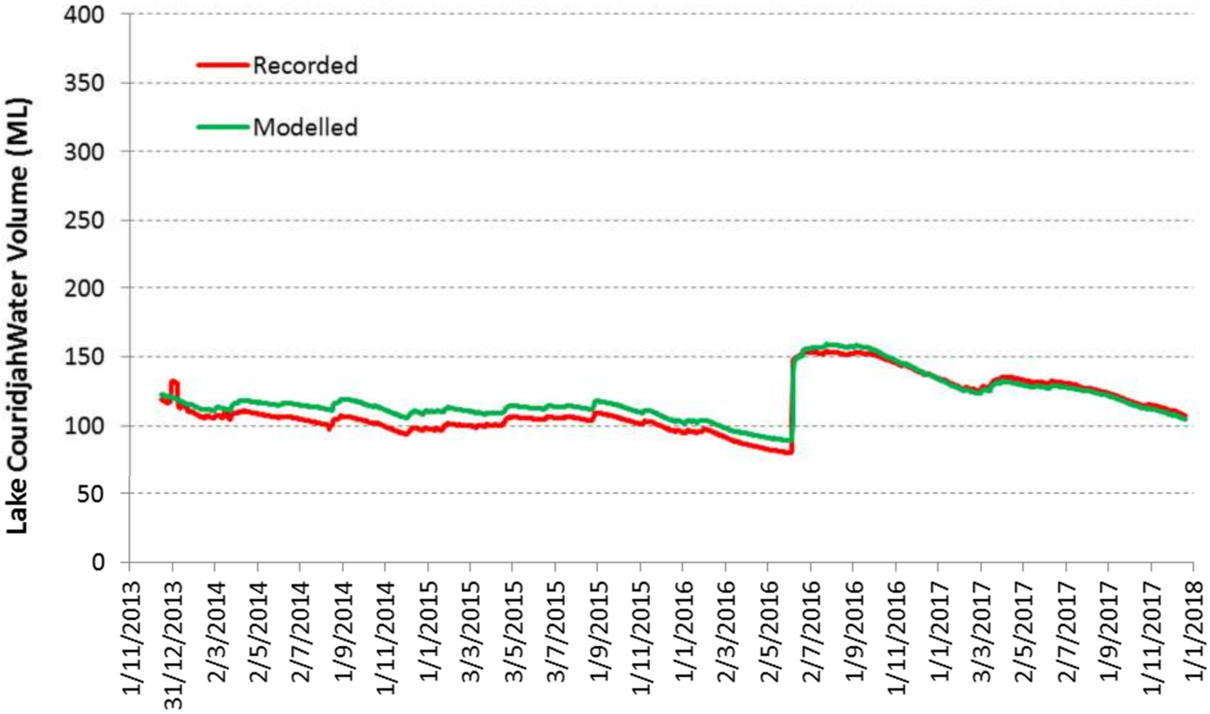

Figure 35 Calibrated Model and Estimated Actual Water Volume – Lake Couridjah

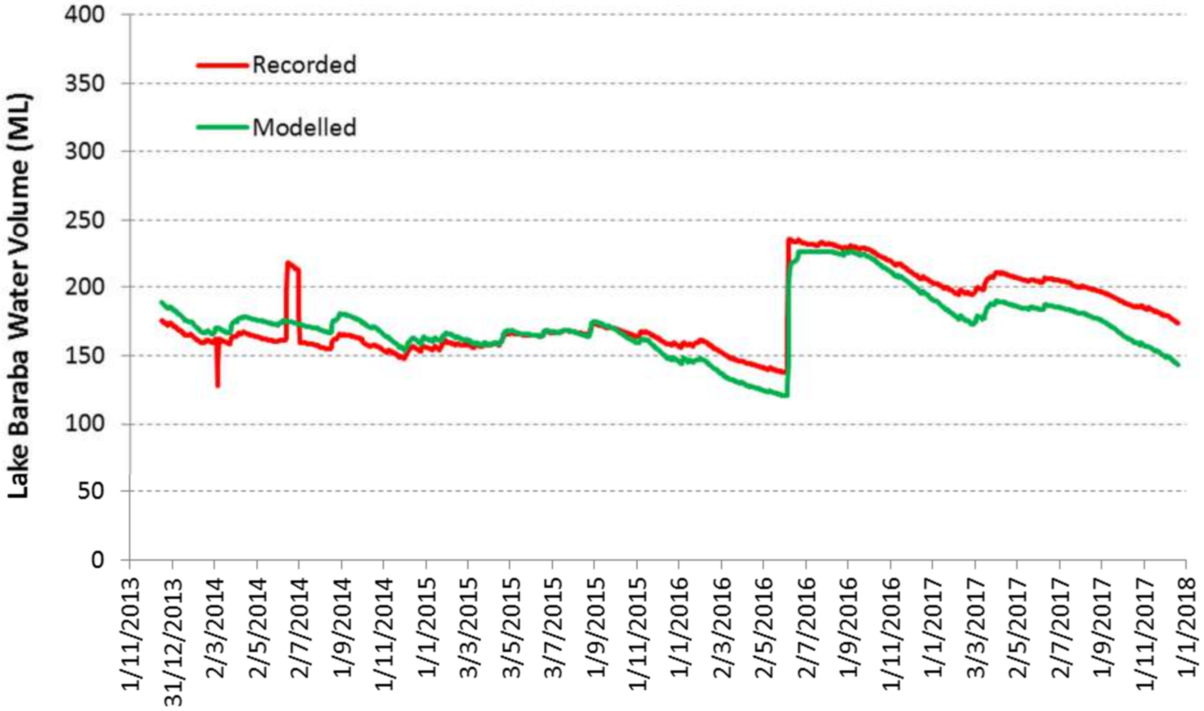

Figure 36 Calibrated Model and Estimated Actual Water Volume – Lake Baraba

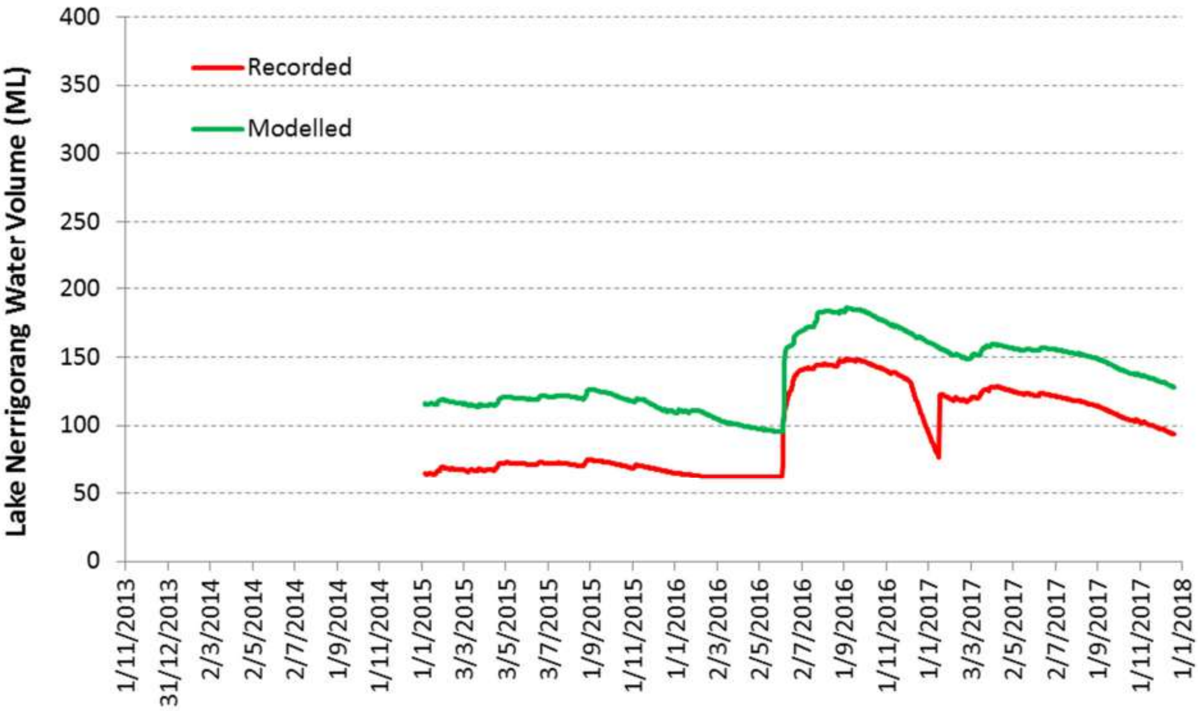

Figure 37 Calibrated Model and Estimated Actual Water Volume – Lake Nerrigorang

There is generally a good replication of Lake water volumes derived from recorded levels for Lakes Gandangarra, Couridjah and Baraba. The modelled volume in Lakes Werri Berri and Nerrigorang appears to be greater than the corresponding volumes derived from recorded levels, although the slope of the Lake Nerrigorang hydrograph is well replicated.

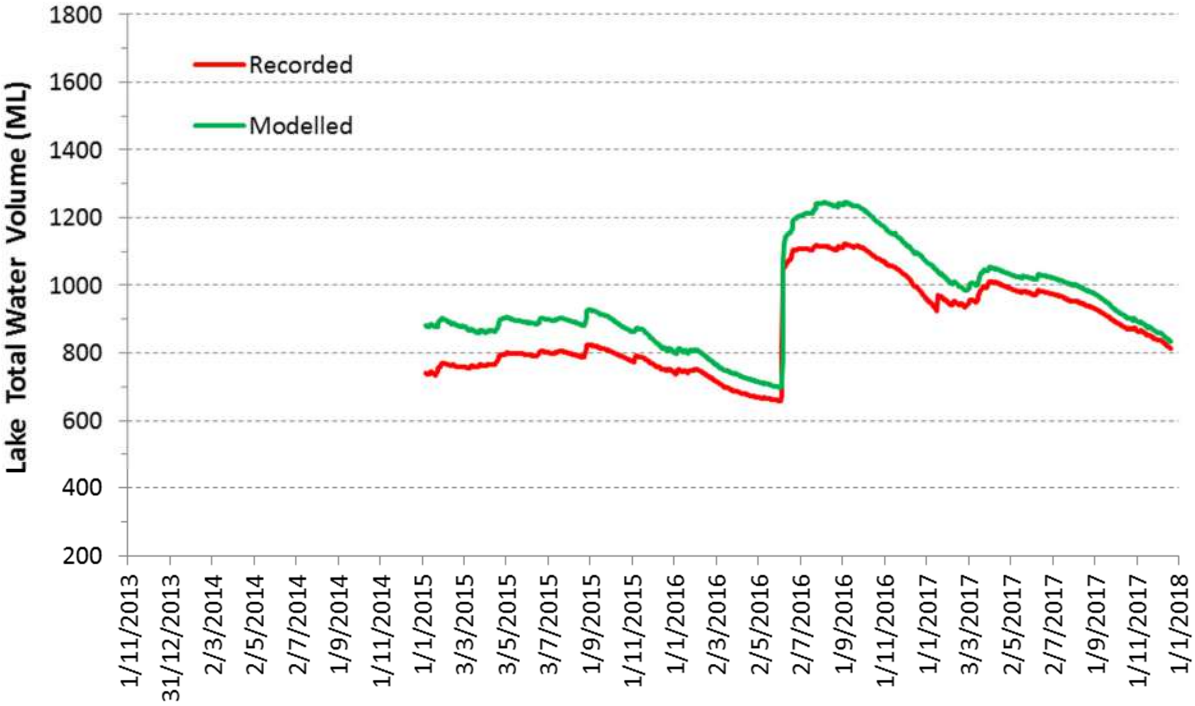

Figure 38 Calibrated Model and Estimated Actual Total Lake Water Volume

Overall the model appears to replicate the total volume derived from recorded levels well, with a coefficient of determination (linear regression coefficient) of 0.95. The estimated effective runoff coefficient (runoff as a proportion of rainfall multiplied by catchment area) for the full 5 km^2 Lake catchment is 12% for the full period modelled. The following may be factors influencing the apparent model mismatch for Lakes Werri Berri and Nerrigorang:

- Mis-representation of the Lake Werri Berri storage characteristics, particularly at low Lake levels (the centre of Lake Werri Berri was not able to be fully accessed during terrestrial survey in 2012);
- Higher groundwater recharge rates than simulated by the groundwater model; and
- On-going pumped extraction from Lake Nerrigorang.

8.3.4 Model Results and Conclusions

The calibrated Lake water balance model was used to assess changes that could occur due to the increase in groundwater recharge that is predicted as a result of the Project. Comparisons were made between model simulations undertaken using the groundwater recharge rates in Table 6 (existing) and Table 7 (with Project). Model simulations were undertaken using the full available 129 years of historical climate data.

Modelled total inflows and outflows for the two simulated cases are summarised in Table 8.

Table 8 Modelled Total (129 Year) Lake Water Balance

Inflow Component	Existing (ML)	With Project (ML)
Direct Rainfall	22,161 (35%)	21,856 (35%)
Catchment Runoff	40,436 (65%)	40,457 (65%)
Total	62,597	62,313
Outflow Component	**Existing (ML)**	**With Project (ML)**
Evaporation & Evapotranspiration	41,675 (65.9%)	41,190 (65.5%)
Groundwater Recharge	14,989 (23.7%)	15,319 (24.3%)
Overflow and Seepage to Blue Gum Creek	5,085 (8.0%)	4,978 (7.9%)
Pumped Extraction	1,446 (2.3%)	1,433 (2.3%)
Total	63,195	62,921

By far the most significant outflow component from the Lakes is to evaporation/evapotranspiration, comprising approximately two-thirds of outflows. Groundwater recharge by contrast comprises approximately a quarter of outflows. The Project will only affect the groundwater recharge component.

There is a modelled 330 ML (or 2.6 ML/year average) increase in groundwater recharge as a result of the Project and a 107 ML (or 0.8 ML/year average) decrease in discharge to Blue Gum Creek (from Lake Nerrigorang). This level of change would be very small compared to natural variability in downstream catchment conditions, and in the context of the potential impacts on inflow to downstream Lake Burragorang (Warragamba Dam), it would be imperceptible.

Modelling predicts that average Lake water levels would decrease by between 0.01 m and 0.06 m. The predicted average number of weeks per decade that the Lakes were without any discernible ponded water increases by between 3 and 5.2 weeks. These levels of change would again be imperceptible and very small compared to natural variability and are therefore considered negligible.

Note that the above impacts assume a constant increase in groundwater recharge from the Lakes. HydroSimulations (2018a) have indicated a gradual recovery in groundwater impacts following completion of mining. Therefore the above changes would decrease with time following the end of mining.

9.0 PREDICTION OF IMPACTS TO THE HYDRAULICS AND STABILITY OF WATERCOURSES

9.1 CHANGES IN FLOW VELOCITY AND BED SHEAR STRESS DUE TO SUBSIDENCE

Subsidence could result in changes to the vertical and horizontal alignment of watercourses. This will in turn result in changes to the hydraulic characteristics of the watercourses and has the potential to change erosion and sediment deposition patterns. The potential effect of predicted subsidence movements on the hydraulic characteristics of overlying watercourses have been assessed using a two dimensional hydraulic model: TUFLOW^{TM} (BMT WBM, 2010). TUFLOW is a numerical, finite difference model which simulates the hydraulic conditions throughout the modelled watercourse by solving the free surface flow equations of momentum and conservation. The pre and post-subsidence topography used in the modelling was supplied by MSEC via Tahmoor Coal Pty Ltd. The digital terrain model had a vertical and horizontal resolution/accuracy of +/- 0.1 m and +/- 0.2 m respectively. The model was set up using a 3 m by 3 m grid. Separate models were developed for Tea Tree Hollow and Dog Trap Creek.

There is currently insufficient data to calibrate the creek hydraulic models. Manning's 'n' friction factors, which are used in the model to simulate energy loss due to friction, were selected based on site observations and by matching conditions evident in photographs from the geomorphic photograph data base developed by Gippel (2013) as part of field surveys and using published guidelines – e.g. USGS (1967). Whilst the resulting models are un-calibrated they are considered sufficiently accurate to quantify the effects of subsidence on the hydraulic conditions and, in particular, to the changes to these conditions attributable to subsidence effects – being the difference between model simulations conducted using the pre and post-subsidence topography.

The hydraulic effects due to subsidence have been assessed via comparisons of predicted flow velocity and bed shear stress. Flow velocity is a basic hydraulic property and an indicator of the energy of the flow. Bed shear stress is the stress or force per unit area which develops at the interface between flowing water and the streambed as a result of the frictional resistance of the bed. It is an indicator of the erosional forces acting on the bed (and inundated parts of the banks). The potential for erosion to occur is a balance between these erosional forces and the erosional resistance of the bed and banks – including the stabilising effects of vegetation.

Flow velocity and bed shear stresses have been assessed for the 50% annual exceedance probability[13] (AEP) flood event which typically considered representative of channel forming event.

Results of modelling are represented as flow maps showing the distribution of the selected attributes by colour differentiation. Maps are presented for both the pre and post-subsidence scenario and the difference between the pre and post subsidence scenarios.

9.1.1 Dog Trap Creek

There are three main arms to Dog Trap Creek in the upper and middle reaches overlying proposed longwalls 101 to 107 and 109. The simulated flow velocities for a peak 50% AEP flow for the pre-subsidence condition are shown in Figure 39 and Figure 40. In general flow velocity is high in Dog Trap Creek due to the relatively steep bed gradient. The lowest velocities occur in the upper reaches where the drainage channel is flatter and the flows are more dispersed. Velocities increase as the creek gradient steepens and becomes more defined further downstream. The highest simulated

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[13] The annual exceedance probability of a nominated flood event is the chance or probability of that flood being equalled or exceeded at least once in any year.

velocities were about 2 m/s peaking at approximately 3.5 m/s in an isolated area over LW 102 and LW 105.

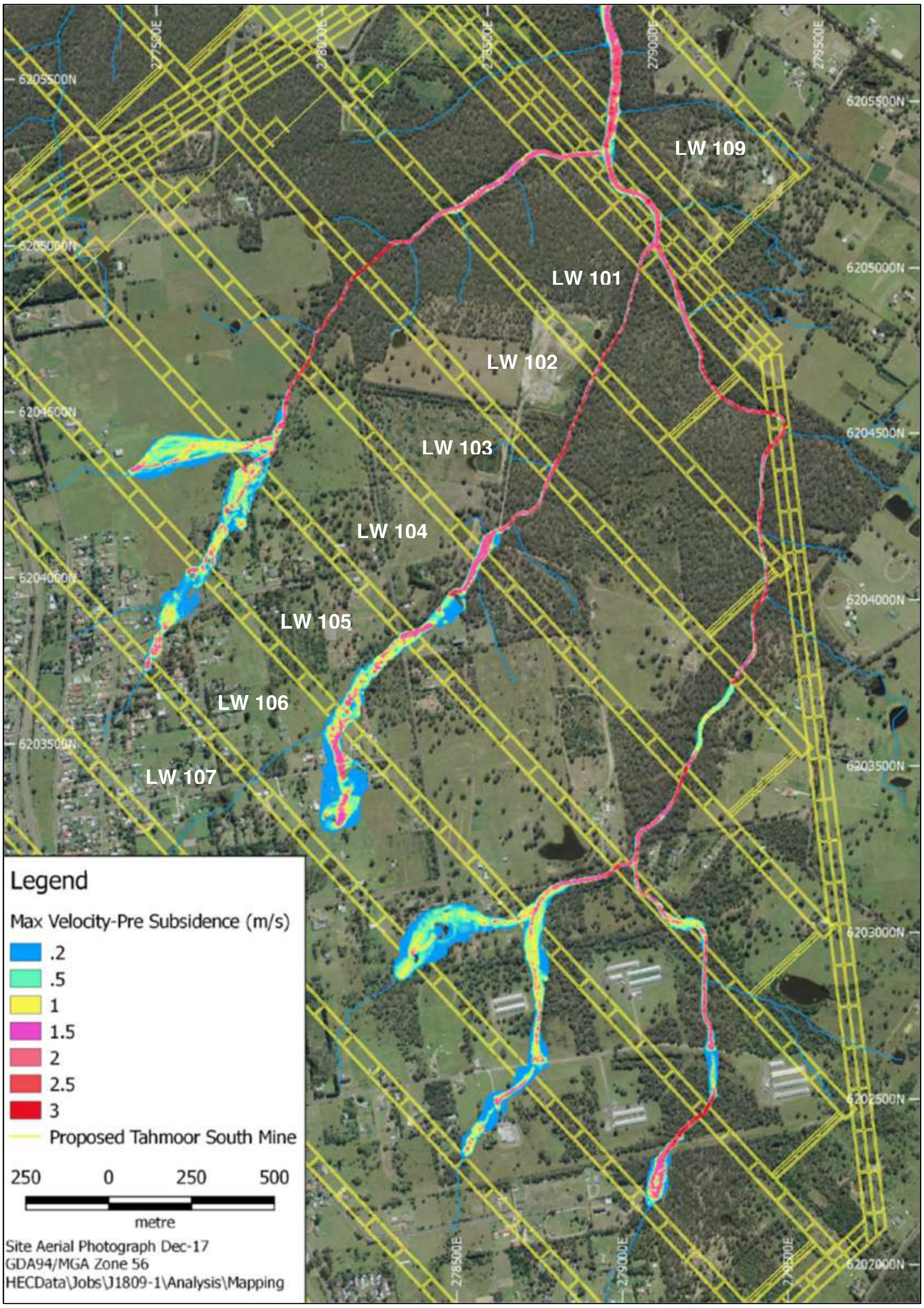

Figure 39 Pre-Subsidence Maximum Flow Velocity – Dog Trap Creek (Upstream) 50% AEP Event

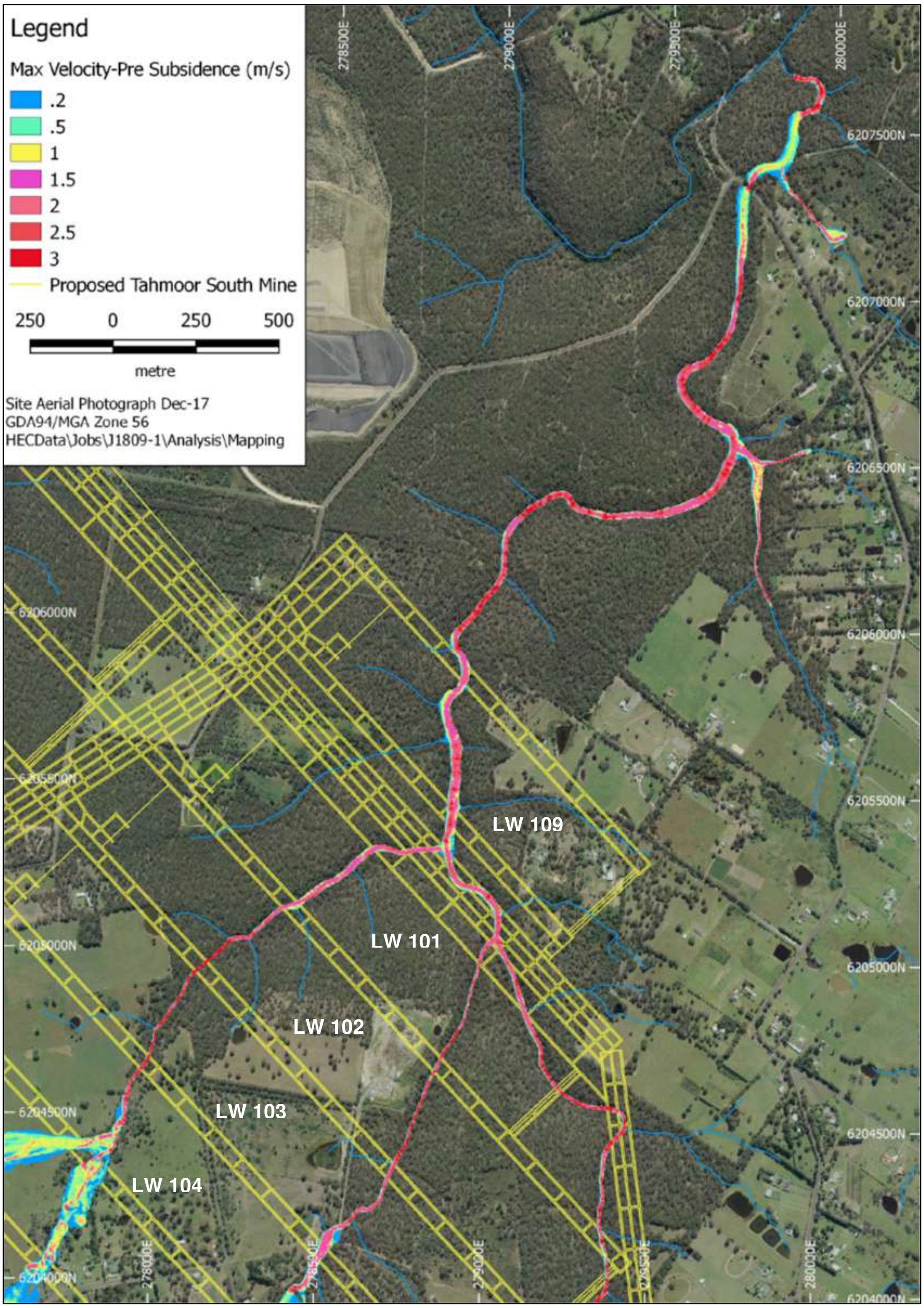

Figure 40 **Pre-Subsidence Maximum Flow Velocity – Dog Trap Creek (Downstream) 50% AEP Event**

Figure 41 and Figure 42 show simulated changes in flow velocity resulting from the effects of subsidence. Peak flow velocity is predicted to decrease in some areas and to increase in other areas. Significant increases in velocity (i.e. between 0.8 and 0.9 m/s) were predicted in isolated sections overlying LW 103 to 106. Relatively smaller increases in velocity (0.25 to 0.3 m/s) were predicted in areas overlying LW 101 to 107 and LW 109

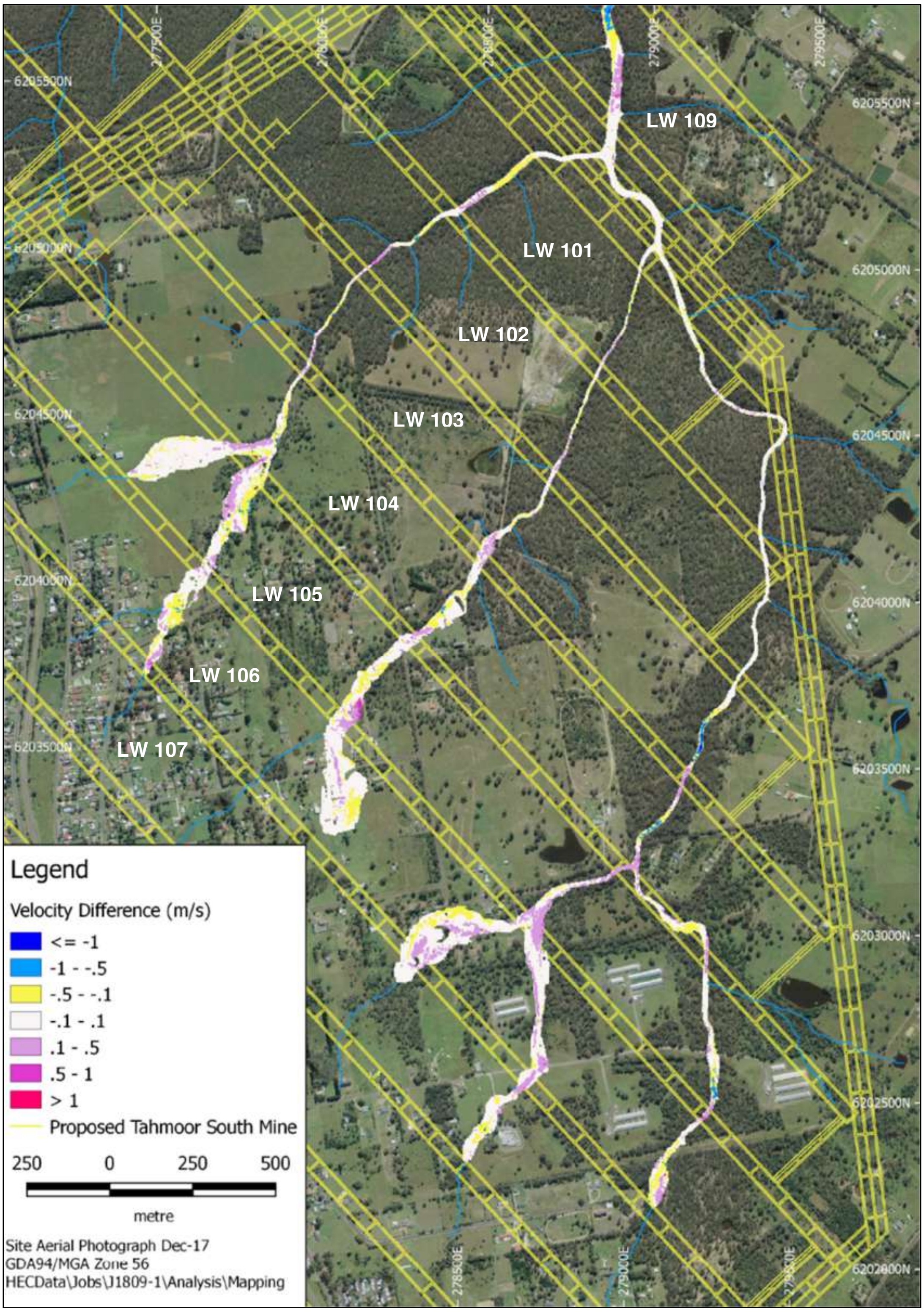

Figure 41 Change in Flow Velocity – Dog Trap Creek (upstream) 50% AEP Event

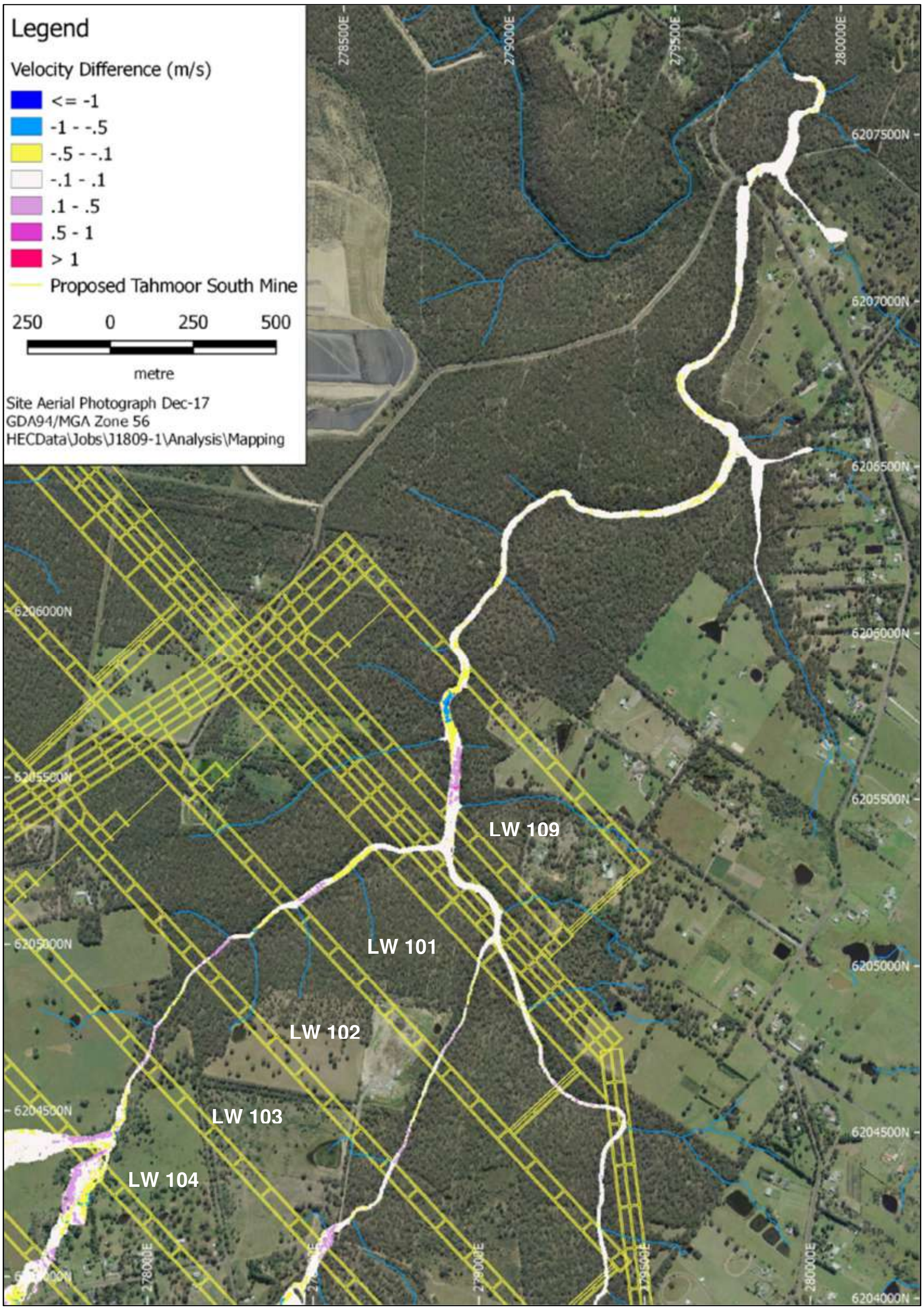

Figure 42 Change in Flow Velocity – Dog Trap Creek (downstream) 50% AEP Event

The simulated bed shear stress distribution under peak 50% AEP flow for the pre-subsidence and post-subsidence scenarios are shown in Figure 43, Figure 44, Figure 45 and Figure 46. The pattern and distribution of bed shear stresses is similar in both scenarios and similar to the distribution of flow velocity. Bed shear stresses are relatively lower in the upper sections of the watercourse and higher further downstream. Areas of notably high bed shear stress were simulated in the reach over LW 101, 102 and LW 103 where simulated bed shear stresses were generally in the range of 20 to 50 Pascals (Pa).

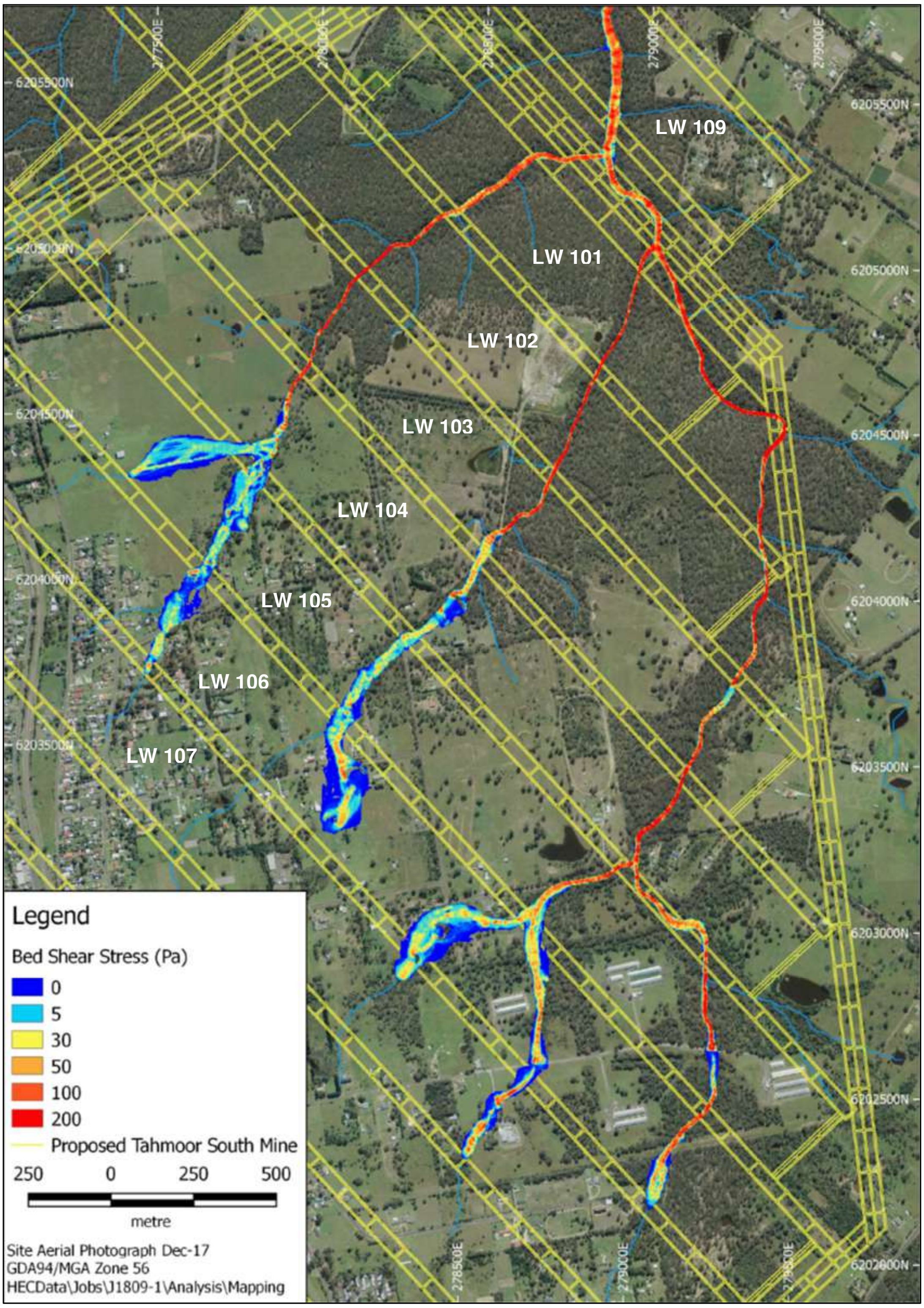

Figure 43 Pre-subsidence Maximum Bed Shear Stress – Dog Trap Creek (upstream) 50% AEP Event

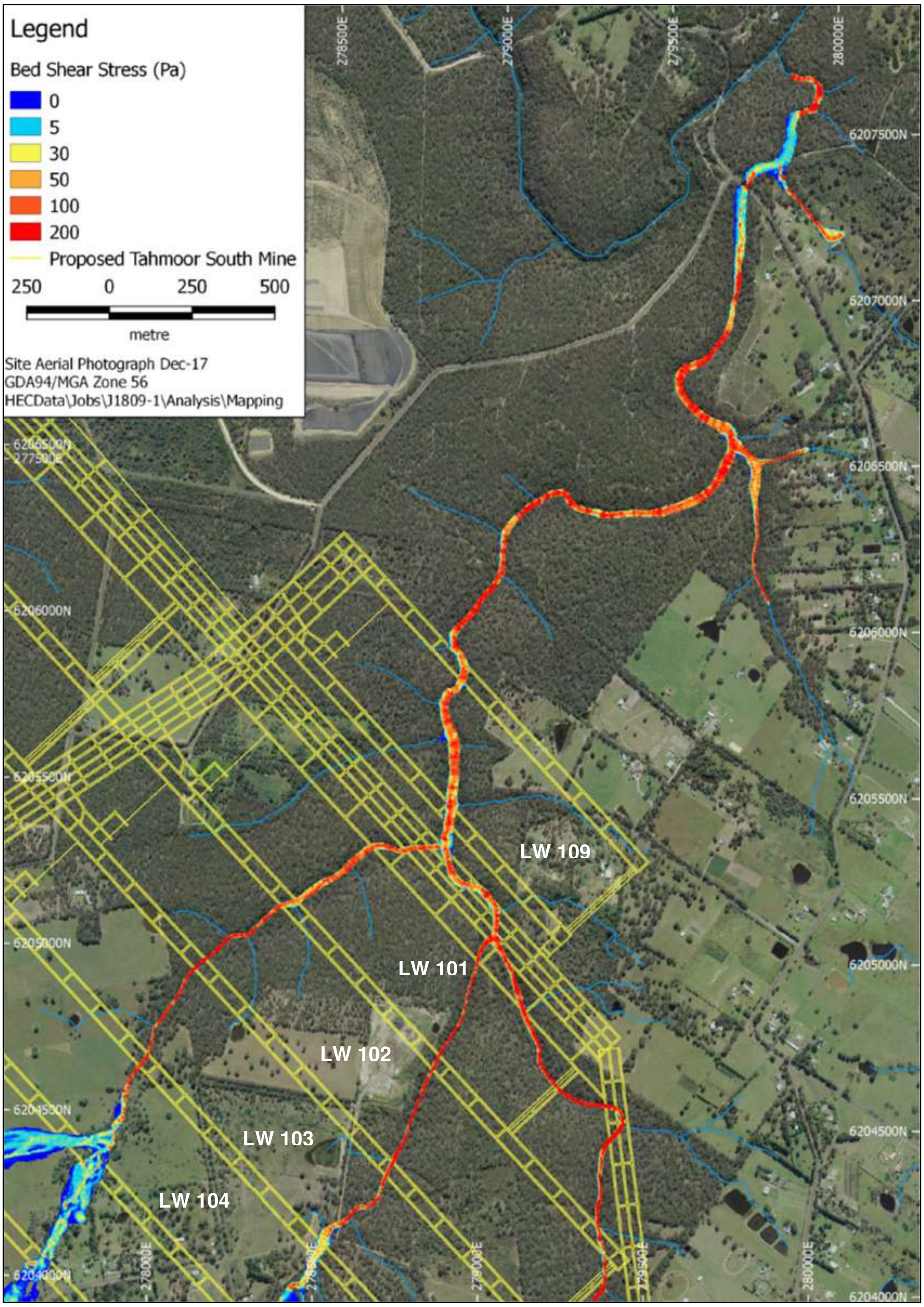

Figure 44 Pre-subsidence Maximum Bed Shear Stress – Dog Trap Creek (downstream) 50% AEP Event

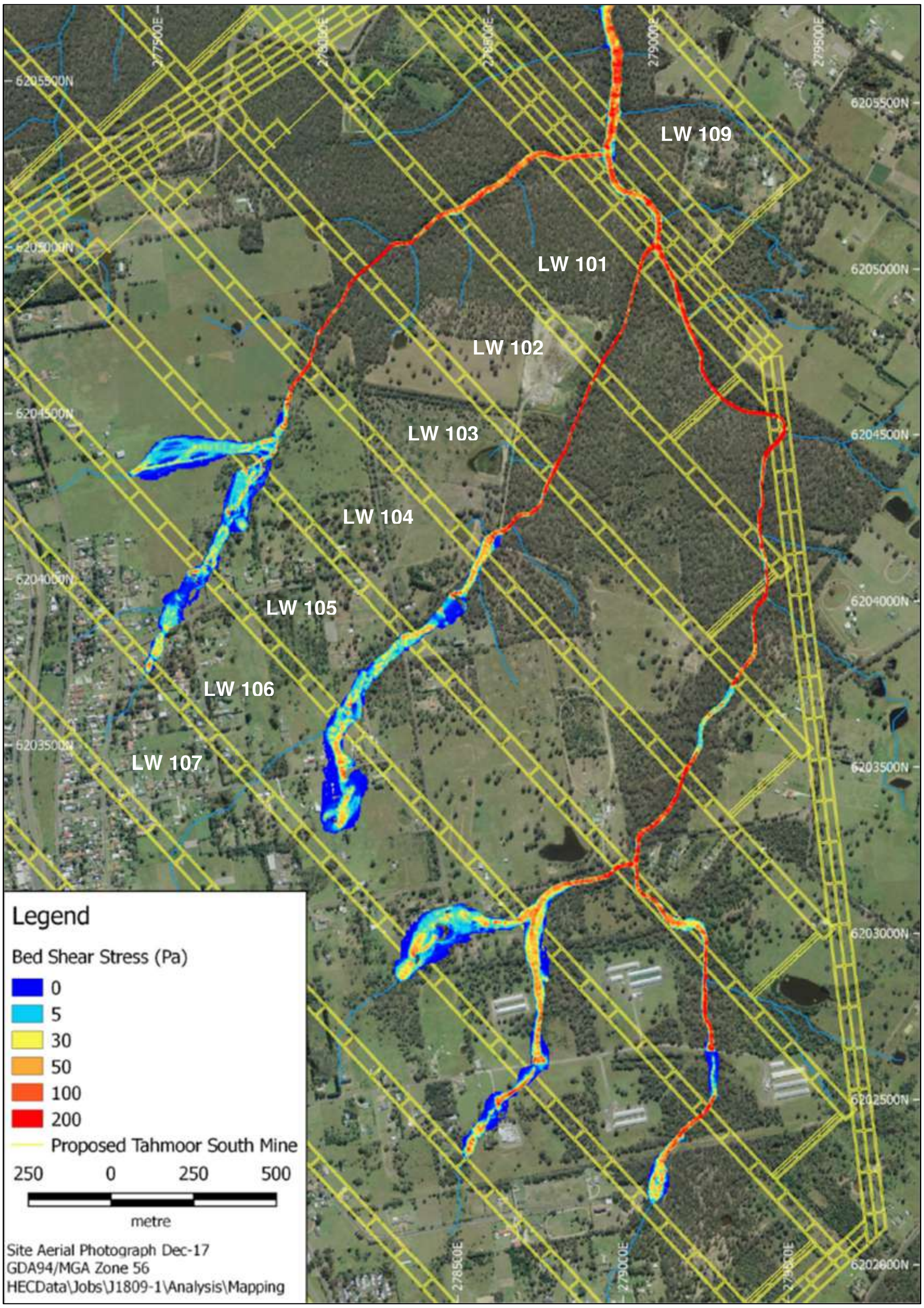

Figure 45 Post-subsidence Maximum Bed Shear Stress – Dog Trap Creek (upstream) 50% AEP Event

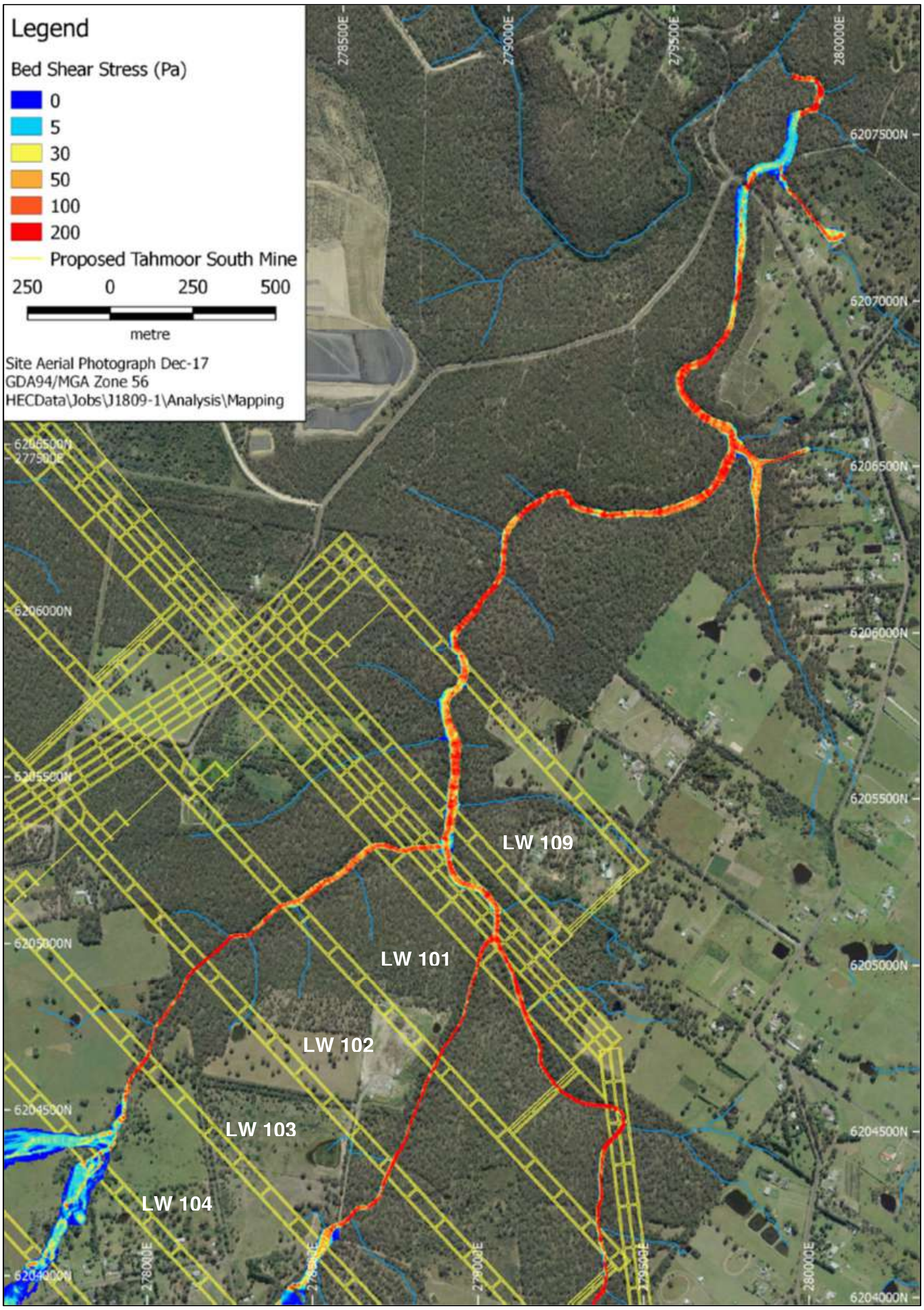

Figure 46 **Post-subsidence Maximum Bed Shear Stress – Dog Trap Creek (downstream) 50% AEP Event**

The change to bed shear stress evident between the pre-subsidence and post-subsidence scenarios is shown in Figure 47 and Figure 48. The changes in bed shear stress were generally small with increases overlying the south-western (upstream) side of longwall panels (where longitudinal bed steepening would occur) of up to generally 30-50 Pa. Small isolated increases of up to 50 Pa were predicted. These have the potential to cause localised increased erosion, depending on the specific nature of the bed materials. Suggested management and mitigation measures are given in Section 9.1.3.

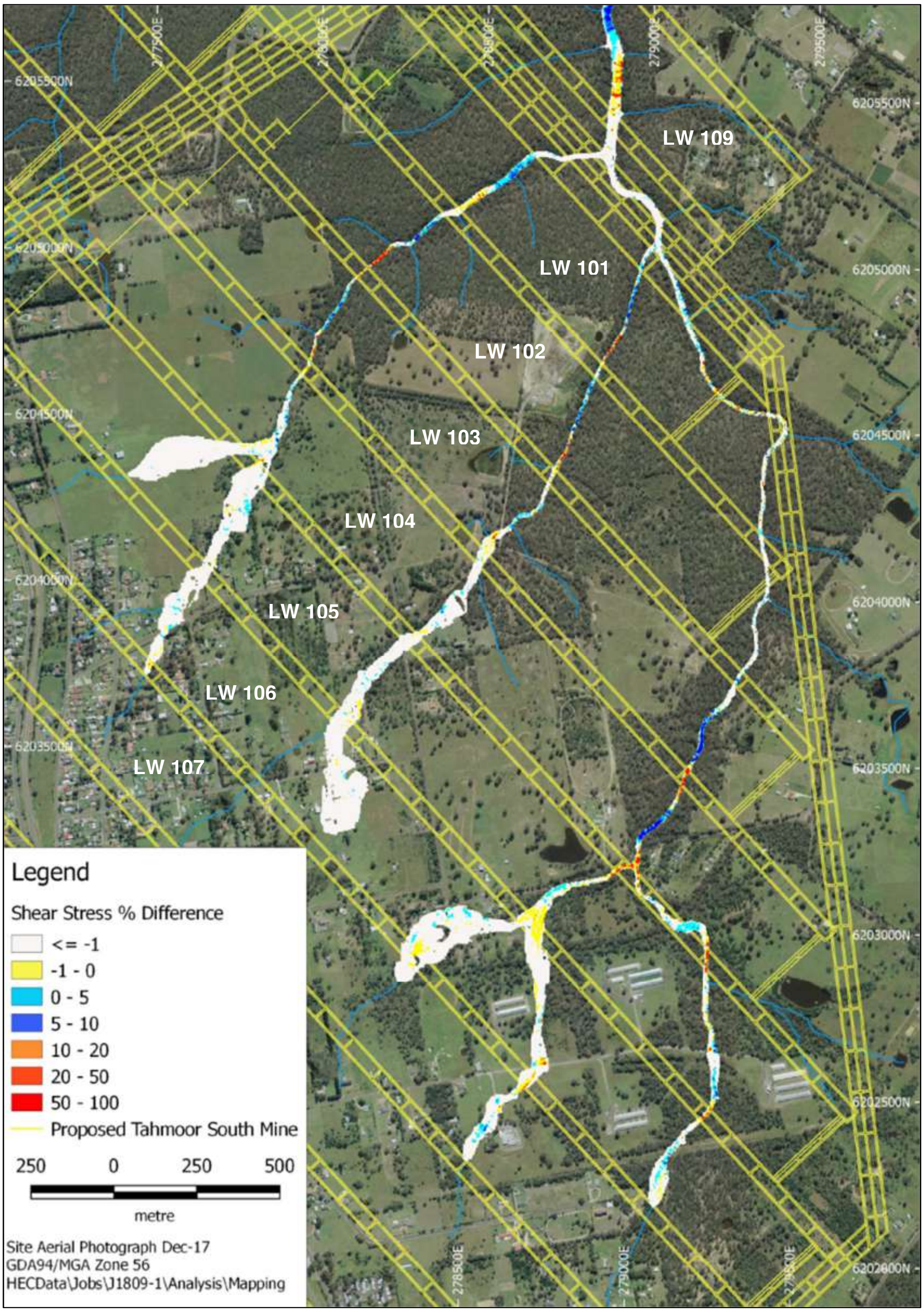

Figure 47 Change in Bed Shear Stress – Dog Trap Creek (upstream) 50% AEP Event

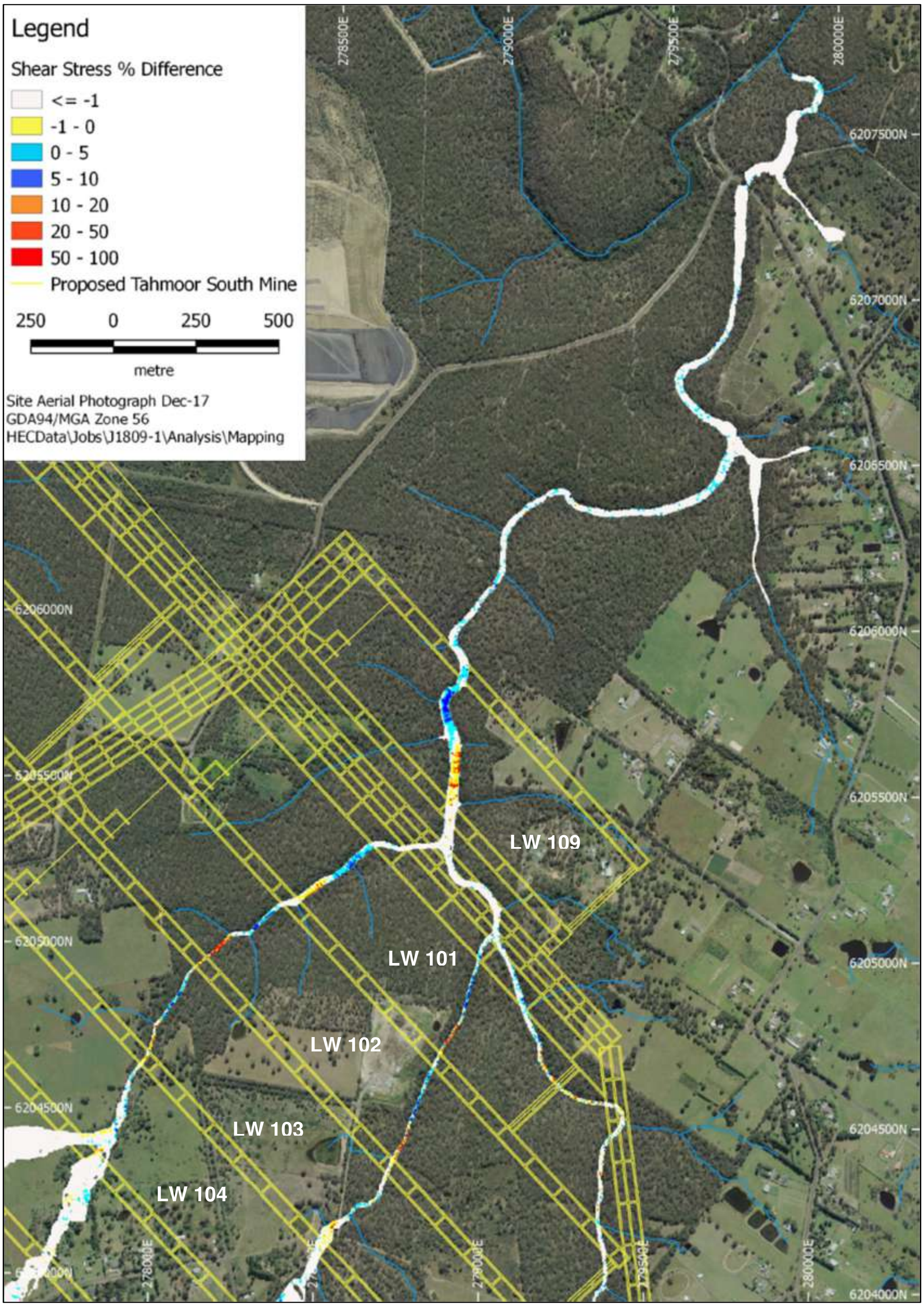

Figure 48 Change in Bed Shear Stress – Dog Trap Creek (downstream) 50% AEP Event

9.1.2 Tea Tree Hollow

There are two main arms to Tea Tree Hollow overlying proposed longwall panels 101 to 105. The simulated flow velocities under peak 50% AEP flow for the pre-subsidence condition are shown in Figure 49. In general flow velocity is high due to the relatively steep bed gradient. The lowest velocities occur in the upper reaches where the drainage channel is flatter and within sections of the creek immediately upstream of main culvert constrictions beneath Remembrance Driveway and the railway line. Velocities are higher downstream of the culvert constrictions and in downstream reaches, which have a steeper bed gradient. The highest simulated velocities reached up 2.5 m/s in areas overlying LW 101, LW 102, LW 103 and LW 105.

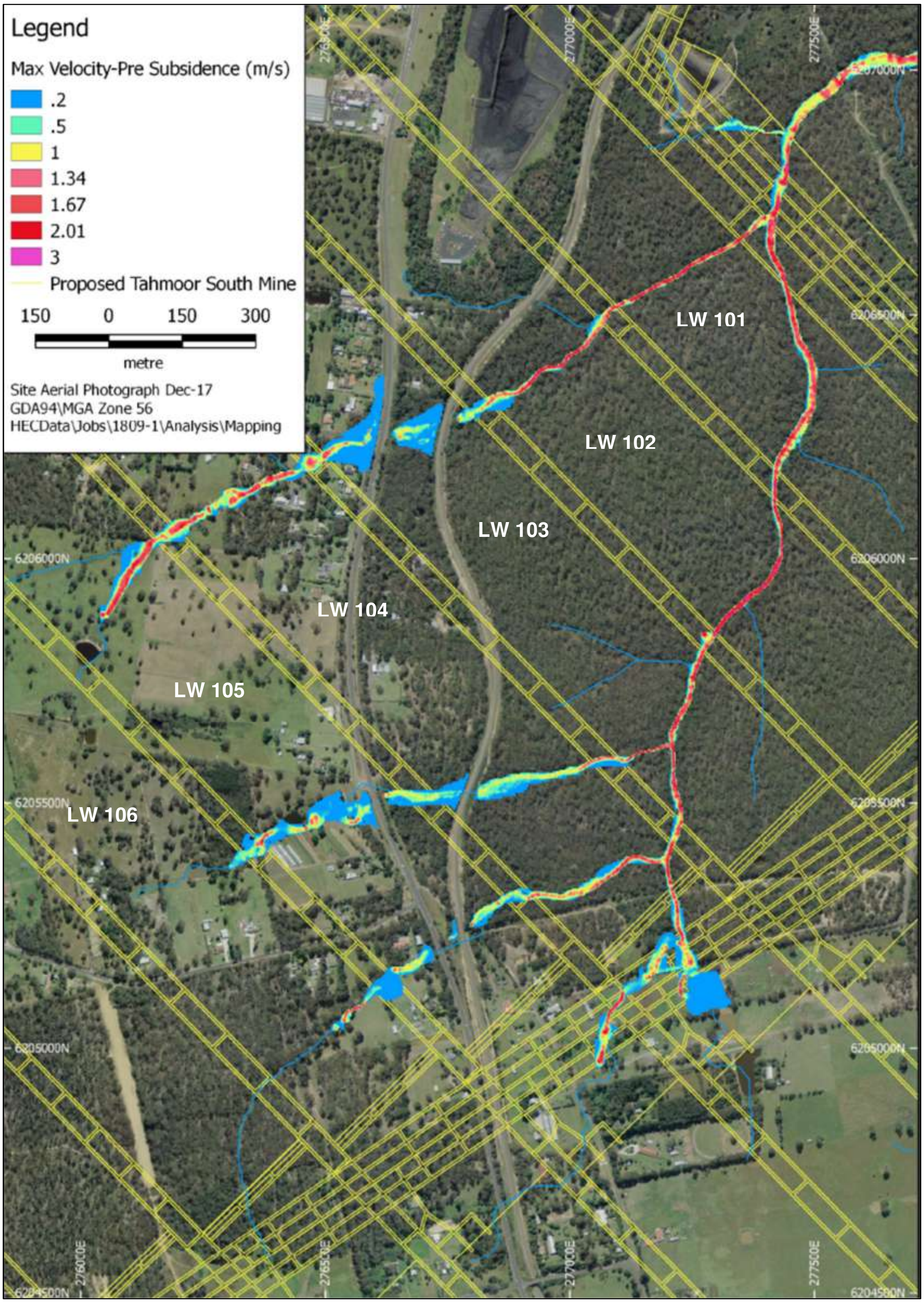

Figure 49 Pre-Subsidence Maximum Flow Velocity –Tea Tree Hollow 50% AEP Event

Figure 50 shows simulated changes in velocity resulting from the effects of subsidence. Peak flow velocity is predicted to decrease in some areas and increase in other areas. The most significant increases in velocity (i.e. between 0.4 and 0.6 m/s) are predicted in isolated sections overlying LW 104 and 105.

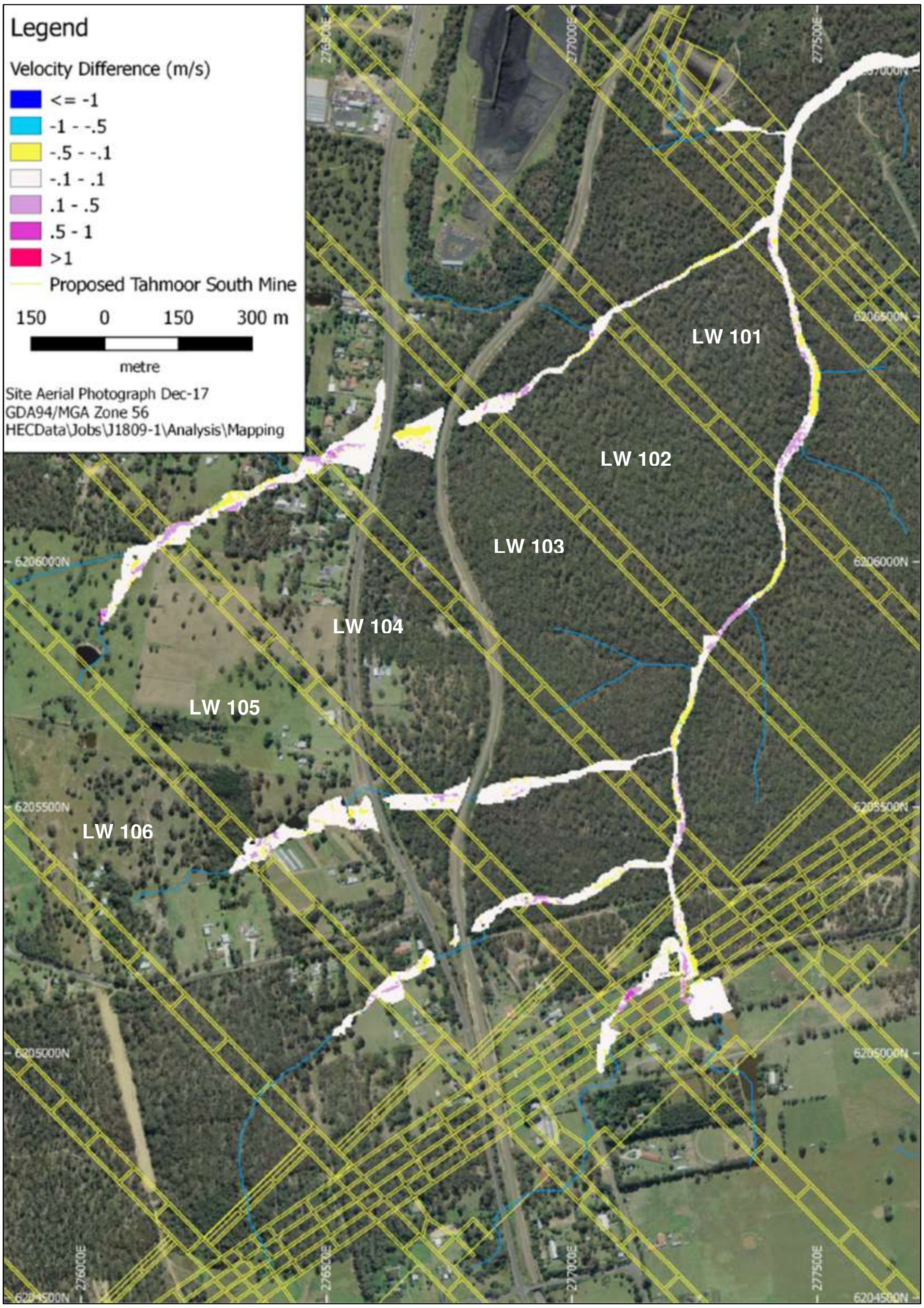

Figure 50 Change in Flow Velocity –Tea Tree Hollow 50% AEP Event

The simulated bed shear stress distribution under peak 50% AEP flow for the pre-subsidence and post-subsidence scenarios are shown in Figure 51 and Figure 52. The pattern and distribution of bed shear stresses is similar in both scenarios. Bed shear stresses are relatively lower in the upper sections of the watercourse and higher further downstream. Areas of notably high bed shear stress occurred over LW 101 to LW 103 of between 50 and 350 Pa.

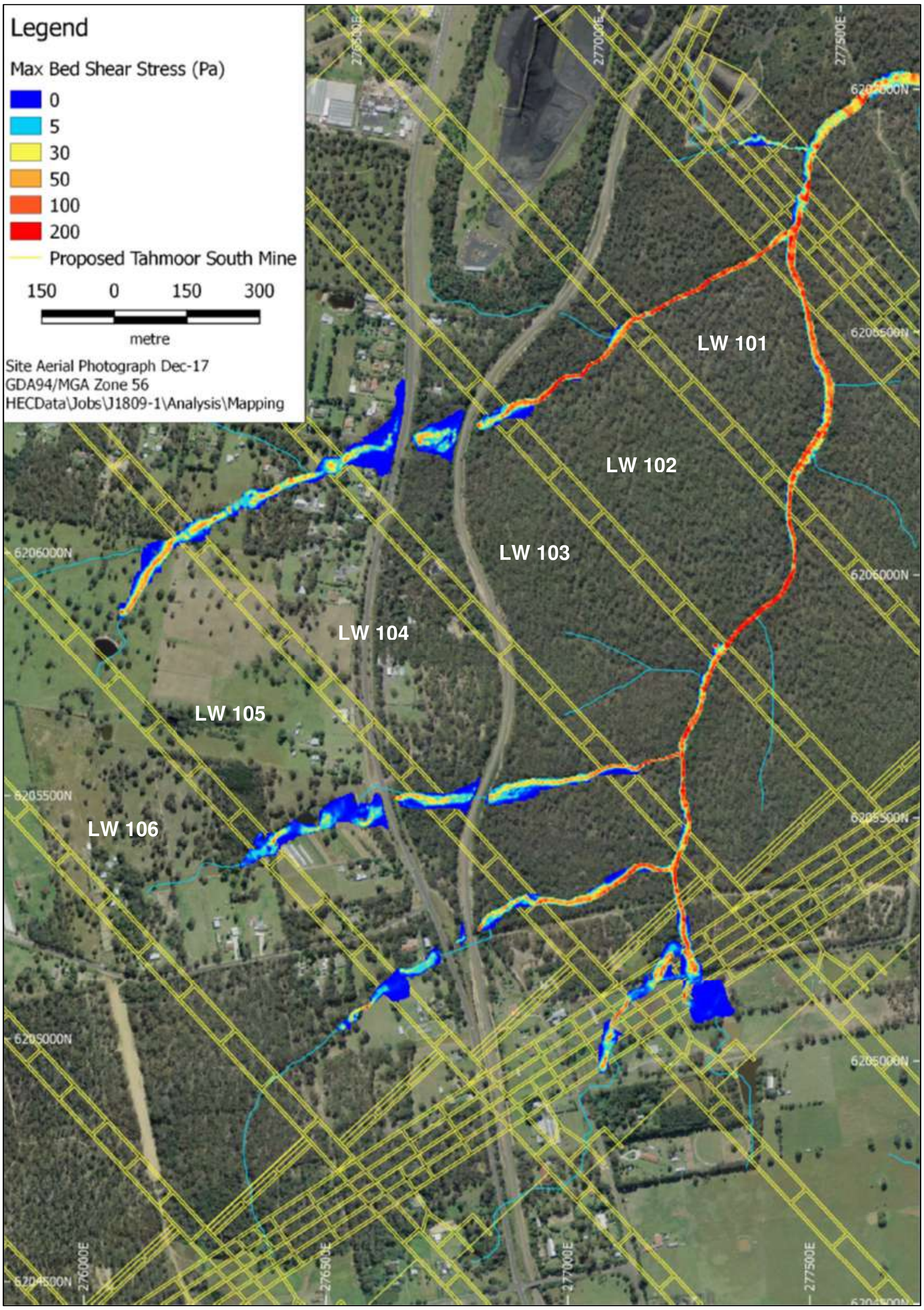

Figure 51 Pre-subsidence Maximum Bed Shear Stress – Tea Tree Hollow 50% AEP Event

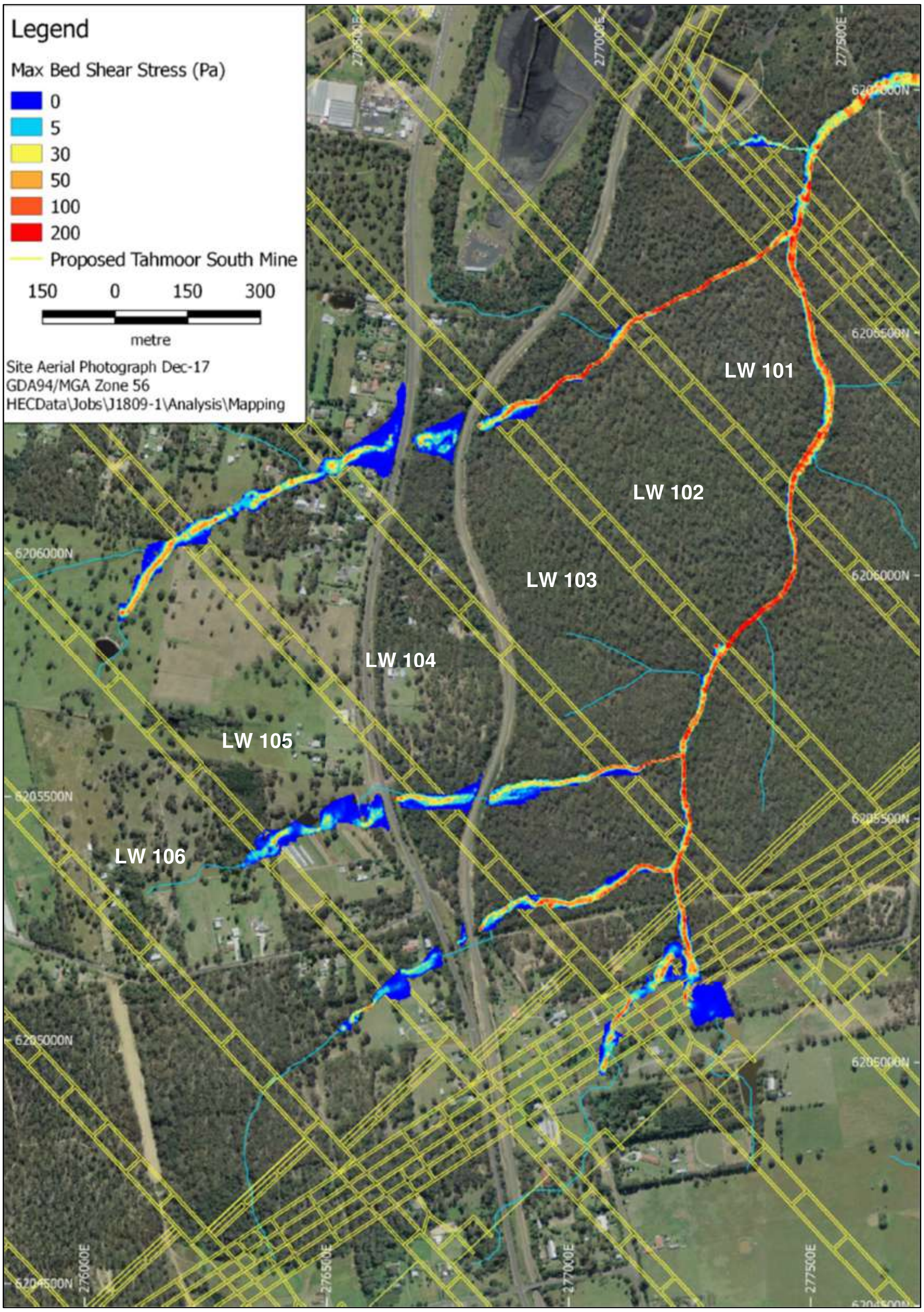

Figure 52 Post-subsidence Maximum Bed Shear Stress – Tea Tree Hollow 50% AEP Event

The change to bed shear stress between the pre-subsidence and post-subsidence scenarios is shown in Figure 53. The most notable changes were simulated on the south-western sides of LW 102 (30-50 pa) and 101 (10-30 Pa). These have the potential to cause localised increased erosion, depending on the specific nature of the bed materials. Suggested management and mitigation measures are given in Section 9.1.3.

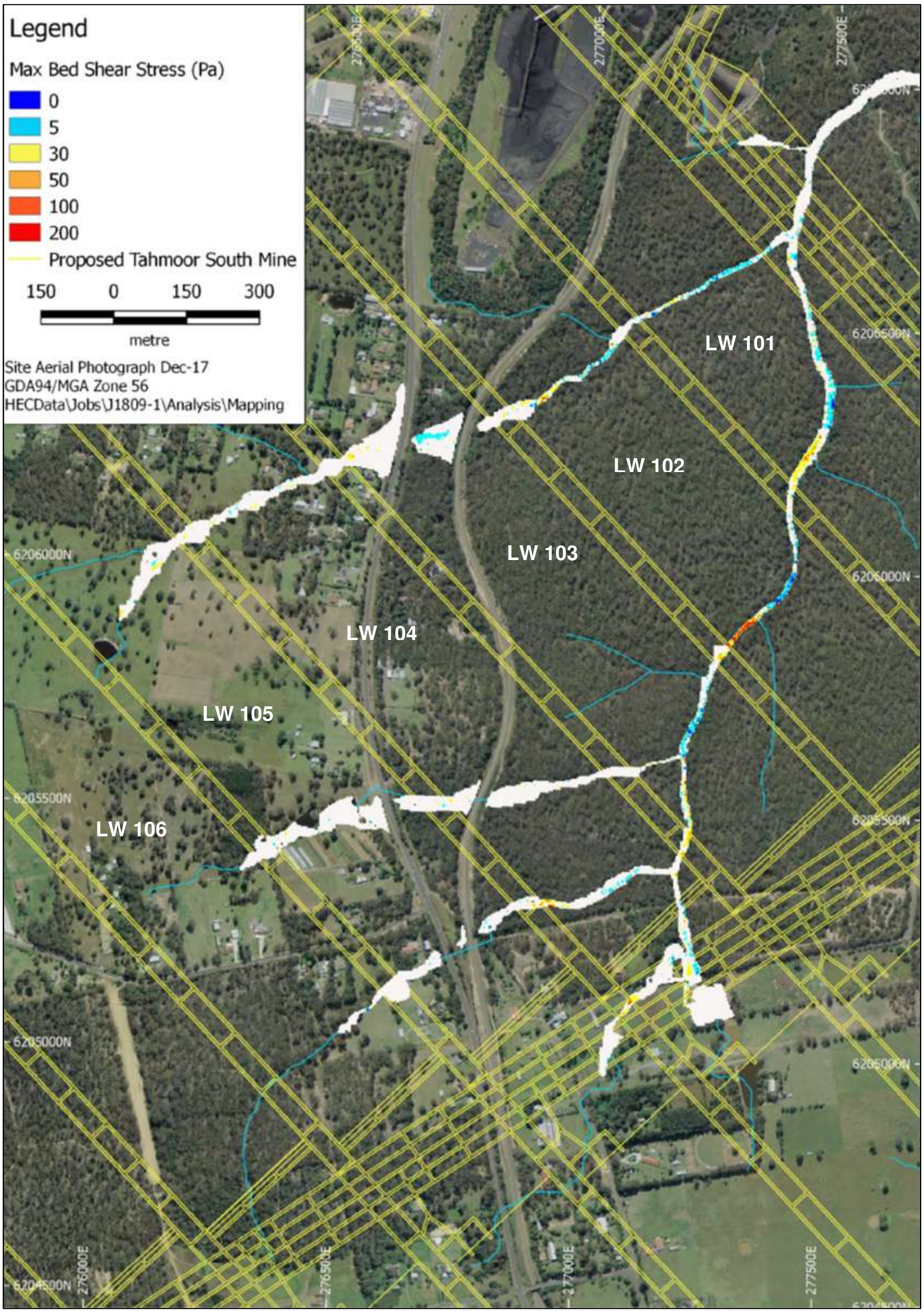

Figure 53 Change in Bed Shear Stress – Tea Tree Hollow 50% AEP Event

9.1.3 Suggested Management and Mitigation Measures

The significance of predicted increases in bed shear stress is dependent on the nature of the stream, specifically its stability and resistance to the predicted increase in shear stress. For example, if the stream is founded in hard durable rock it will likely be more resistant to increases in bed shear stress than it would be if it comprised bare loose sand with no vegetation.

The following management approach is recommended:

1. Inspect and assess the erosional stability/state on vegetation and nature of bed and banks in those areas identified by above modelling as likely to experience significant increase in bed shear - using results of surveys by Gippel (2013).
2. Develop a risk rating (high, medium, low) for each location based on the above.
3. Identify medium and high risk sites where non-invasive preventative measures would be practical (e.g. access control and vegetation enhancement) and implement these, say, 2 years ahead of predicted subsidence.
4. Survey, map and document condition of all medium and high risk areas 12 months ahead of predicted subsidence.
5. Survey, map and document condition at nearby control sites (ratio of 3 control sites for each significant impact site) with similar morphology.
6. Survey high and medium risk sites following significant flow events (e.g. 1 in 2 year AEP events and larger) post-subsidence.
7. In the event of scour /instability which exceeds that observed in the control sites develop a restoration plan specific to the location and the bed and bank material.

9.2 REDUCED STABILITY OF BED AND BANKS DUE TO LOSS OF RIPARIAN VEGETATION

The overall stability of the bed and banks of overlying creeks could be indirectly affected by subsidence induced fracturing and enhanced drainage of groundwater from the banks and bed of creeks leading to loss of riparian vegetation.

This type of impact has generally not been reported in the Southern Coalfields and has not been observed at Tahmoor North to date. It is considered unlikely at Tahmoor South. Observations of riparian vegetation were reported by Gippel (2013) as part of the geomorphological survey and assessment. Gippel (2013) report that, overall, at over 90% of sites where riparian vegetation was surveyed the riparian zone was greater than 50m wide and that it was less than 10m at only 3% of sites. Gippel (2013) also report that the width and continuity of riparian vegetation would not be a significant threat to the stability of riparian vegetation in the Project Area. Gippel (2013) report riparian tree cover tended to be moderate to high in dissected valleys and gorges. Tree cover was in contrast reported as tending to be low in the upland plateau areas which had been largely cleared.

On this basis, it is considered that riparian vegetation associated with streams overlying the Project Area is relatively robust and would be unlikely to be sensitive to any minor change in the moisture level fluctuations associated with the effects of subsidence.

9.3 CHANGES TO FLOODING

A flood study has been conducted to assess the impacts to flooding due to subsidence of watercourses overlying the Project Area. The potential effects of the Project on flooding have been investigated by undertaking a comparative flood study of watercourses using the pre-subsidence and post-subsidence topography (refer HEC, 2018c and Section 9.1).

10.0 PREDICTION OF IMPACTS TO WATER QUALITY

10.1 RISK AND CONSEQUENCES OF WATER RELEASES FROM PIT TOP AREA

Tahmoor Coal are licenced to release treated water from their water management system in accordance with licenced (EPL) release limits. Under the current licence there is also a requirement to enhance treatment of water prior to release via Pollution Reduction Program 22 which involves the development and commissioning of a waste water treatment plant (WWTP) to reduce the concentrations of arsenic, nickel and zinc in mine water released from the consolidated Licensed Discharge Point 1. The WWTP was constructed in June 2015 to treat up to 6 ML/d of mine water. The treatment objectives were to reduce the above metals concentrations to the following maximum concentrations:

- Arsenic: 0.013 mg/L
- Nickel: 0.011 mg/L
- Zinc: 0.008 mg/L

The results of predictive modelling (HEC, 2018b) of the water management system over the remaining mine life indicate that total discharges from the pit top of the combined existing Tahmoor operation and the proposed Project are unlikely to increase above current LDP1 volume limits. On the basis of the above, it is expected that the Project would not result in adverse water quality impacts due to releases and overflows from the site water management system.

Whilst not anticipated, accidental spills could also occur which could result in transient impacts to water quality. The risk of these occurring is not likely to increase as a result of the Project and would be managed as part of the site environmental management system.

10.2 LIBERATION AND FLUSHING OF CONTAMINANTS FROM SUBSIDENCE FRACTURING OF SURFACE ROCKS

Liberation of contaminants can occur from subsidence induced fracturing in watercourses, causing localised and transient increases in iron concentrations and other constituents due to flushing of freshly exposed fractures in the sandstone rocks which contain iron and other mineralisation. This sort of impact has the potential to affect Tea Tree Hollow, Dog Trap Creek and downstream watercourses. Fracturing of bed rock is predicted to occur and upsidence related buckling of stream beds is predicted along some sections of these creeks. Based on past experience in the Southern Coalfields, including experience at the existing Tahmoor operation, it is expected that upsidence induced fracturing may lead to releases of aluminium, iron, manganese and zinc. It is likely these will be seen as transient spikes in the concentration of these and possibly other metals which would be relatively localised. The extent of these impacts is expected to be similar to impacts observed in similar streams in the Southern Coalfield – refer discussion on Redbank Creek in Section 6.2.1 and to Stokes, Native Dog and Wongawilli Creeks in Section 6.3.2 and is expected to be transient in nature.

10.3 CHANGES TO CHEMICAL CHARACTERISTICS OF SURFACE FLOW DUE TO CHANGES IN BASEFLOW

One of the effects of longwall subsidence on watercourses commonly reported is the emergence of what are referred to as ferruginous springs. These are concentrated (point) inflows have a distinctive orange to red/brown colouration caused by enhanced groundwater inflows and oxidation of iron commonly present in shallow groundwater in the area. This is often accompanied by iron flocs, staining of the bed, increased turbidity and the build-up of iron rich slimes. Changes can also occur to the chemical composition of surface flows due to either increased or decreased groundwater fed baseflow contribution to watercourses.

These sorts of water quality impacts have the potential to affect Tea Tree Hollow, Dog Trap Creek and downstream watercourses. Historically these impacts have generally been found to be temporary and over time have reduced. Although there have been known cases where these impacts have taken longer than anticipated to return back to similar conditions prior being impacted, it is not expected that these potential impacts would be permanent.

10.4 CONTAMINATION OF SURFACE WATERS BY GAS DRAINAGE

Drainage of strata gas and expression to the surface through surface water has occurred to varying degrees in the Southern Coalfields. It is most readily detectable in permanent slow moving pools. Studies of the phenomena have shown that the gas flow does not affect the quality of surface waters that it drains through, due to the very low solubility of methane and the short residence time in the water column (MSEC, 2018). There have been rare instances of reported vegetation die back (MSEC, 2009).

It has not been reported as an issue at Tahmoor, most likely due to the relative absence of perennial water bodies. It is considered likely there would be enhanced strata gas emissions generated as a result of the Project and that some of these may be visible as bubbling in more persistent pools in overlying watercourses.

11.0 RECOMMENDED MONITORING, MITIGATION AND MANAGEMENT

Management and mitigation measures will be critically dependent on appropriate monitoring. The following monitoring recommendations are made in relation to assessing the performance of the water management system as it relates to surface water[14].

11.1 BASELINE MONITORING

The network of streamflow monitoring (gauging stations) and water quality monitoring sites used for baseline monitoring (refer HEC, 2018a) should be reinstated. An additional gauging station should be installed on Tea Tree Hollow at a suitable location downstream of the predicted subsidence impact zone and upstream of the licensed discharge points. The station should be established at least 2 years prior to commencement of longwall mining in the Project Area.

Stream gauging activities should be continued to support the development and maintenance of viable ratings and the generation of reliable continuous flow data at all stations. It is recommended that the gauging stations on Dog Trap Creek – downstream and the recommended new gauging station on Tea Tree Hollow be established with enhanced low flow control weirs in order to reliably record low flows. Routine water quality monitoring should also be continued.

It is recommended that a continuous pool water level monitoring network be established. The network should be established at least two years prior to commencement of longwall mining and include the following sites:

- *Dog Trap Creek*: two large, rock bar controlled pools and one boulder controlled pool within sections of the creek with predicted moderate to high risk of loss of water holding capacity. Water level monitoring should also be established in a fourth similarly sized, rock bar controlled pool downstream of the predicted subsidence impact zone as a control site.
- *Tea Tree Hollow*: two large pools within sections of the creek with moderate or higher risk of loss of water holding capacity and one pool downstream of the predicted subsidence impact zone as a control site.

11.2 OPERATIONAL MONITORING AND MANAGEMENT

Prior to the commencement of longwall mining in each domain, it is recommended that an adaptive monitoring and trigger action response plan should be developed. It is recommended that the following surface water elements be incorporated into the plan:

- Action response triggers for water quality exceedances based on recommended approaches in ANZECC (2000) and in particular schemes which incorporate both baseline and control monitoring data. Trigger values have been developed for baseline monitoring on streams potentially affected by the Project – refer HEC (2018a).
- Action response trigger for unexpected flow loss based on analysis of baseline (i.e. pre-subsidence) streamflow data, post-subsidence streamflow data and contemporaneous data from control sites. Catchment flow modelling should also be used in the analysis.
- Action response trigger for unexpected loss of pool water holding capacity based on analysis of baseline (i.e. pre-subsidence) pool water level data, post-subsidence pool water level data and contemporaneous data from control pool sites. Pool water balance modelling should also be used in the analysis particularly during unusual climatic/hydrological conditions.

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[14] Recommendations related to watercourse stability and geomorphic change are provided by Gippel (2013).

When longwall mining is within 200 m of any watercourse it is recommended that weekly inspections, photographic reconnaissance and field based water quality monitoring should be undertaken in that watercourse(s) at sites upstream and downstream of the potentially affected area. Water quality samples should be collected and analysed monthly and increased to weekly if field monitoring results indicate a change from background (e.g. exceedance of the 80th percentile value). Results of monitoring should be analysed in relation to action response triggers on a monthly basis when longwall mining is within 200 m of a watercourse.

It is recommended that the pit top water management system performance should be assessed annually against its predicted performance range. This would entail monitoring the climatic conditions on site, the main water transfers, including off site discharges and changes in stored water volumes. The performance of the water management system should be assessed by comparing the monitored water balance with water balance model predictions. Revision to the water management plan should be undertaken if the performance review indicates the water management system has, or is likely to be, unable to meet its regulatory performance requirements. The water management plan revision should document the measures to be implemented and their effectiveness in meeting regulatory requirements.

It is recommended that the water balance model of the Thirlmere Lakes be updated and recalibrated prior to the commencement of the Project and be used to update the predictions made herein (refer Section 8.0).

11.3 POST MINING MONITORING AND MANAGEMENT

It is recommended that monitoring of streamflow, pool water levels and water quality continue for two years following cessation of longwall subsidence related movement in a watercourse or following completion of any stream/pool remediation. Monitoring data should be reviewed at annual intervals over this period. Reviews should involve assessment against long term performance objectives which should be based on the pre-mine baseline conditions or an approved departure from these.

11.4 POTENTIAL CONTINGENCY MEASURES

Potential contingency measures in the event of unforeseen impacts or impacts in excess of those predicted would include:

- the conduct of additional monitoring (e.g. increase in monitoring frequency or additional sampling) to inform the proposed contingency measures;
- the implementation of stream remediation measures to reduce the extent and effect of subsidence fracturing;
- the implementation of revegetation measures to remediate impacts of vegetation loss due to subsidence;
- the provision of a suitable offset(s) to compensate for the reduction in the quantity of water resources/flow; or
- the implementation of adaptive management measures – e.g. reducing the thickness of the coal seam extracted, narrowing of the longwall panels and/or increasing the setback of the longwalls from the affected area.

12.0 CUMULATIVE IMPACTS

Cumulative impacts have been described in the mining context Franks et al (2010) as:

> *"…arise from compounding activities of a single operation or multiple mining and processing operations, as well as the aggregation and interaction of mining impacts with other past, current and future activities that may not be related to mining."*

In the context of surface water resources potentially impacted by the Project there has been significant past development in both the immediate and downstream catchment areas which, if taken from European settlement, include widespread agricultural development and urbanization. There has also been significant development of the surface water resources themselves - including regulation and extraction of water from local and regional surface water resources and diffuse and point discharge of "wastewater" to local and regional streams. There is no monitored data to enable quantification of the effects of historical developments on the flow and water quality characteristics of the Project Area surface water resources. The effects of past development are however inevitably incorporated into the baseline descriptions of surface water resources developed for the Project which are based on contemporary monitoring.

HydroSimulations (2018b) have assessed cumulative impacts to baseflow reductions due to the combined effects of the Project, consumptive groundwater extraction and the effects of other existing mining projects - principally the existing Tahmoor operation - on future baseflow reduction. As with the assessment of the effects of baseflow reduction due to the Project (refer Section 7.3), the effects on flows are small relative to average flow and would be most notable at low flows. The predicted maximum cumulative baseflow reduction rates compared to the maximum predicted baseflow reduction rates due to the Project are summarised in Table 9 below.

Table 9 Comparison of Maximum Predicted Project and Cumulative Baseflow Reduction Rates on Average Flows in Local Watercourses

Stream/Site	Mean Daily		Maximum Baseflow Reduction due to Project			Maximum Cumulative Baseflow Reduction		
	Flow (ML/d)	Baseflow (ML/d)	Max Reduction (ML/d)	% Mean Daily Flow	% Mean Daily Baseflow	Max Reduction (ML/d)	% Mean Daily Flow	% Mean Daily Baseflow
Bargo River, Site 13	23.9	2.39	0.1	0.4%	4.2%	0.3	1.3%	12.6%
Tea Tree Hollow, Site 22	6.3	3.5	0.11	1.7%	3.1%	0.13	2.1%	3.7%
Dog Trap Creek, Site 15	4.95	0.495	0.26	5.3%	52.5%	0.28	5.7%	56.6%

In general the predicted maximum cumulative baseflow reduction rates are similar to the maximum baseflow reduction rates due to the Project which are discussed in detail in Section 7.3. The largest predicted increases in baseflow reduction rates are at Dog Trap Creek at Site 15 and the Bargo River at Site 13.

Figure 54 shows the maximum predicted impact of the predicted baseflow reductions due to the Project and the maximum cumulative baseflow reduction rates in flows in Dog Trap Creek at the downstream gauging station (GS 300063). Relative to the maximum predicted effects due to the Project, the maximum cumulative baseflow reduction rates further reduce low flows slightly which can be seen as the difference between the green and red lines on Figure 54. The probability that flow would be greater than 0.01 ML/day would reduce from 87% to 45% of days as a result of the maximum predicted baseflow reduction rates due to the Project and 43% of days under maximum cumulative baseflow reduction. This level of change would be detectable during normal periods of low flow and would likely be distinguishable from natural variability in catchment conditions. It is therefore considered to be significant.

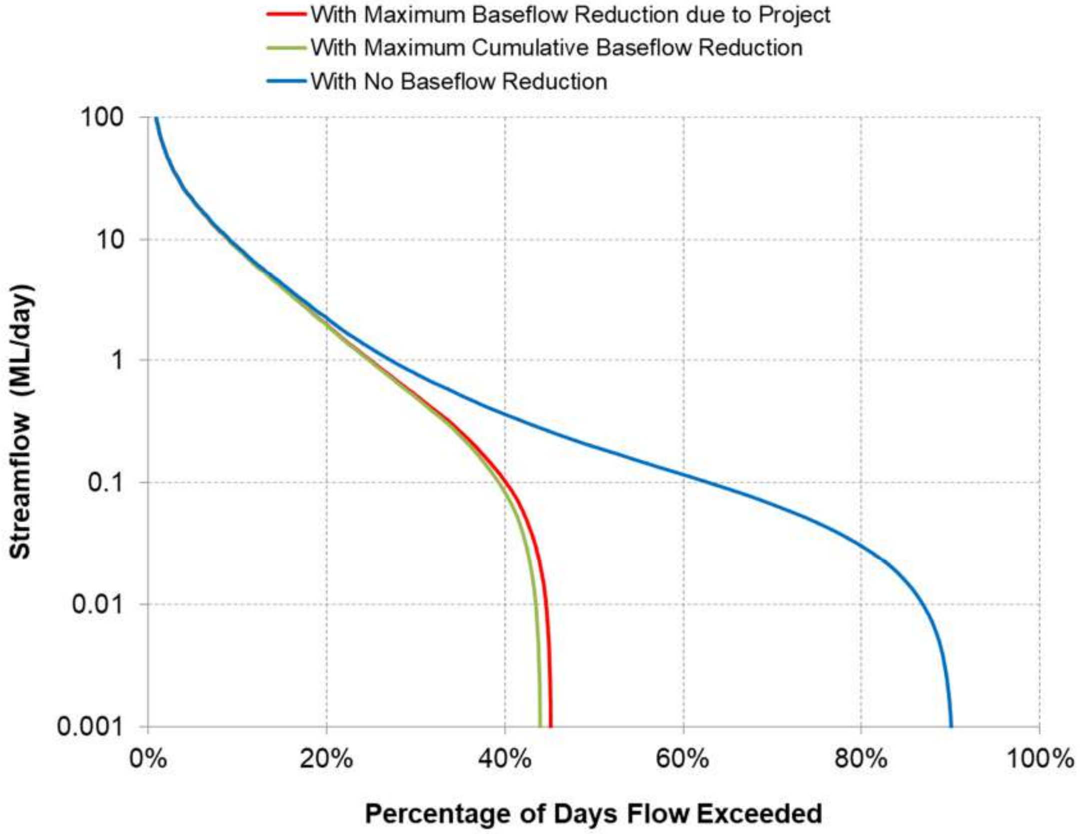

Figure 54 Flow Duration Curve – Dog Trap Creek (GS 300063) - With and Without Maximum Baseflow Reduction Rates

Figure 55 shows the maximum predicted impact of the predicted baseflow reductions due to the Project and the maximum cumulative baseflow reduction rates on flows in the Bargo River Upstream gauging station (GS 300010a). Relative to the maximum predicted effects due to the Project, the maximum cumulative baseflow reduction rates further reduce low flows which can be seen as the difference between the green and red lines on Figure 55. The probability that flow would be greater than 0.1 ML/day would reduce from 99% to 97% of days as a result of the maximum predicted baseflow reduction rates due to the Project and 90% of days under predicted maximum cumulative baseflow reduction. This level of change would be detectable during normal periods of low flow and would likely be distinguishable from natural variability in catchment conditions. It is therefore considered to be significant.

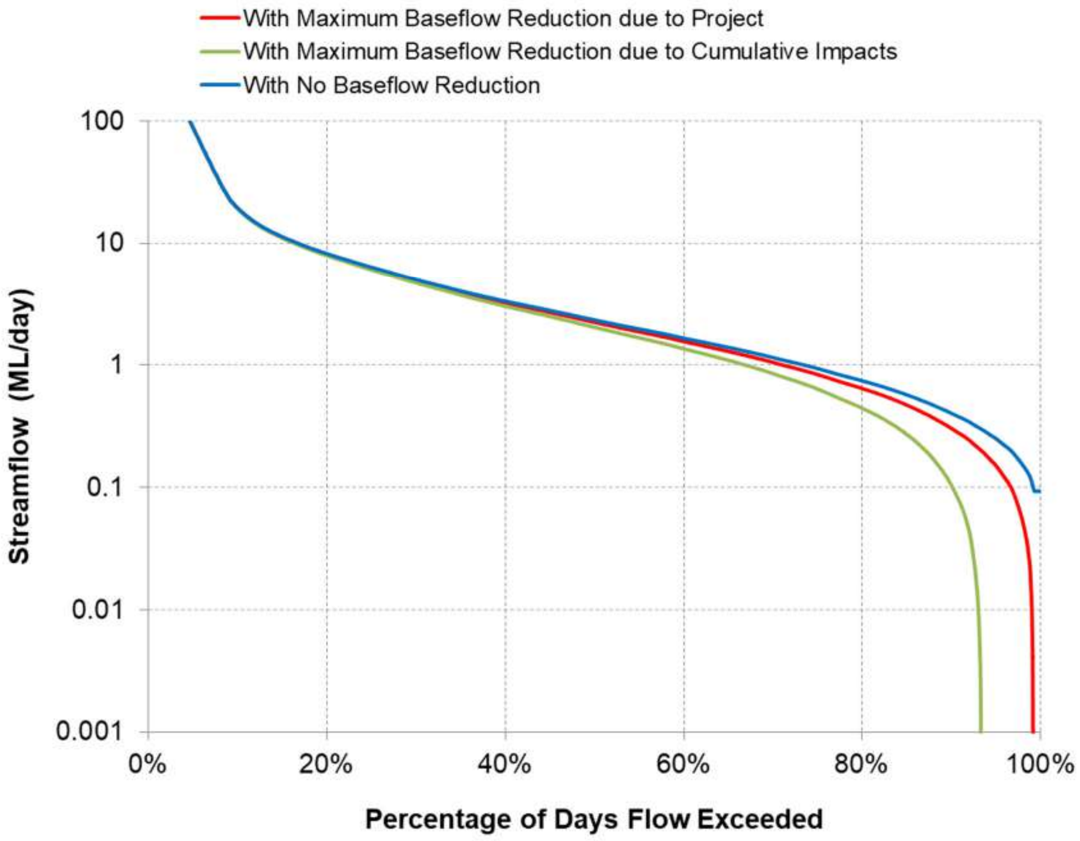

Figure 55 Flow Duration Curve – Bargo River Upstream (GS 300010a) - With and Without Maximum Baseflow Reduction Rates

12.1 WATER SHARING PLAN

The NSW Department of Industry – Water (DI - Water) implements water regulation according to the Water Management Act 2000. A primary objective is the sustainable management and use of water resources, balancing environmental, social and economic considerations. DI - Water has developed Water Sharing Plans (WSPs) for much of the State and these establish rules for sharing and trading water between the environment, town water supplies, basic landholder rights and commercial uses. The Project is located within the Upper Nepean River water source which is regulated by the Water Sharing Plan for Greater Metropolitan Region Unregulated River Water Sources (the WSP).

The Project will involve continued use of water for coal processing within the existing facilities at Tahmoor and for control of dust emission from the REA. The water used in these operations is sourced from the underground operations and from water captured within the existing site water management system – principally at the coal handling and REA areas. Some water is also supplied under agreement with Sydney Water. None of these activities involve extraction of water or water sharing from sources covered by the WSP.

The combined effects of the Project, consumptive groundwater extraction and the effects of other existing mining projects may result in a reduction in baseflow in three management zones in the Upper Nepean River water source, namely Pheasants Nest Weir, Stonequarry Creek and Maldon Weir. HydroSimulations (2018b) have estimated the maximum and long-term baseflow reduction rates as a result of the Project and the baseflow reduction rates due to the cumulative effects of the Project, consumptive groundwater extraction and the effects of other existing mining projects. The baseflow reductions rates for Pheasants Nest Weir, Stonequarry Creek and Maldon Weir are presented in Table 10 in comparison with the mean daily flow rate at each location.

Table 10 Comparison of Predicted Project and Cumulative Baseflow Reduction Rates on Mean Flows in WSP Management Zones

Stream/Site			Pheasants Nest Weir	Stonequarry Creek	Maldon Weir
Mean Daily Flow (ML/d)			140.2*	15.6**	187.6***
Baseflow Reduction due to Project****	Maximum	Baseflow Reduction (ML/d)	0.04	0.06	0.6
		% Mean Daily Flow	0.03%	0.38%	0.32%
	Long-term	Baseflow Reduction (ML/d)	<0.0001	0.007	0.209
		% Mean Daily Flow	0.00%	0.04%	0.11%
Cumulative Baseflow Reduction****	Maximum	Baseflow Reduction (ML/d)	0.5	0.29	1.3
		% Mean Daily Flow	0.36%	1.86%	0.69%
	Long-term	Baseflow Reduction (ML/d)	<0.0001	0.015	0.291
		% Mean Daily Flow	0.00%	0.10%	0.16%

* Estimated as Maldon Weir mean flow - (Stonequarry Creek mean flow + Bargo SW-14 mean flow) as per HydroSimulations (2018b)
** Mean daily flow for January 1990 to December 2016 from WaterNSW (https://realtimedata.waternsw.com.au/)
*** Mean daily flow for January 1990 to October 2008 (Gilbert & Associates, 2009)
**** Per Hydrosimulations (2018b)

Table 10 illustrates a predicted maximum reduction in mean daily flow at Pheasants Nest Weir of 0.03% (due to the Project) to 0.36% (cumulative effect). This represents an immeasurably small and likely indiscernible impact to flows at Pheasants Nest Weir. In the long-term, the reduction in baseflow, either due to the Project or the cumulative effect, is estimated to have negligible observable impact on mean daily flow at Pheasants Nest Weir.

For Stonequarry Creek, a maximum reduction in mean daily flow of 1.86% is predicted due to cumulative effects, reducing to 0.10% in the long-term. At Maldon Weir, a maximum reduction in mean daily flow of 0.69% is predicted due to cumulative effects, reducing to 0.16% in the long-term. The long-term estimated reduction in mean daily flow is likely to be indiscernible at these locations.

13.0 NEUTRAL OR BENEFICIAL EFFECTS

Under the State Environmental Planning Policy (Sydney Drinking Water Catchment) 2011 all development in the Sydney drinking water catchment is required to demonstrate a neutral or beneficial effect on water quality. The Project would involve mining adjacent to but not beneath the Metropolitan Special Area. The main channel of Cow Creek is located approximately 1 km from the nearest Project longwall. MSEC (pers. comm. 22/10/2018) report that, at this distance, the maximum predicted subsidence, upsidence and valley closure are less than 20 mm. Accordingly, the potential for localised impacts on Cow Creek such as fracturing and surface water flow diversion are extremely low.

NSW Water (2015) has published guidelines for assessing compliance with the neutral or beneficial effect of development on water quality. The following definition and criteria for satisfying the neutral or beneficial 'test' are contained in NSW Water (2015).

> "A neutral or beneficial effect on water quality is satisfied if the development:
>
> (a) has no identifiable potential impact on water quality, or
>
> (b) will contain any water quality impact on the development site and prevent it from reaching any watercourse, water-body or drainage depression on the site, or
>
> (c) will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority. "

Based on the above it is concluded that it is extremely unlikely that there could be any identifiable water quality impacts to flow in Cow Creek because longwall mining is sufficiently remote from the creek that the potential for fracturing is extremely low. In the unlikely event that fracturing were to occur, it would not in our opinion and based on our experience, result in a detectable change to water quality in Cow Creek. This is consistent with component (a) of the above definition of a neutral effect on water quality "no identifiable potential impact".

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APPENDIX A

Profiles of Predicted Subsidence, Upsidence and Valley Closure in Local Streams per MSEC (2018)

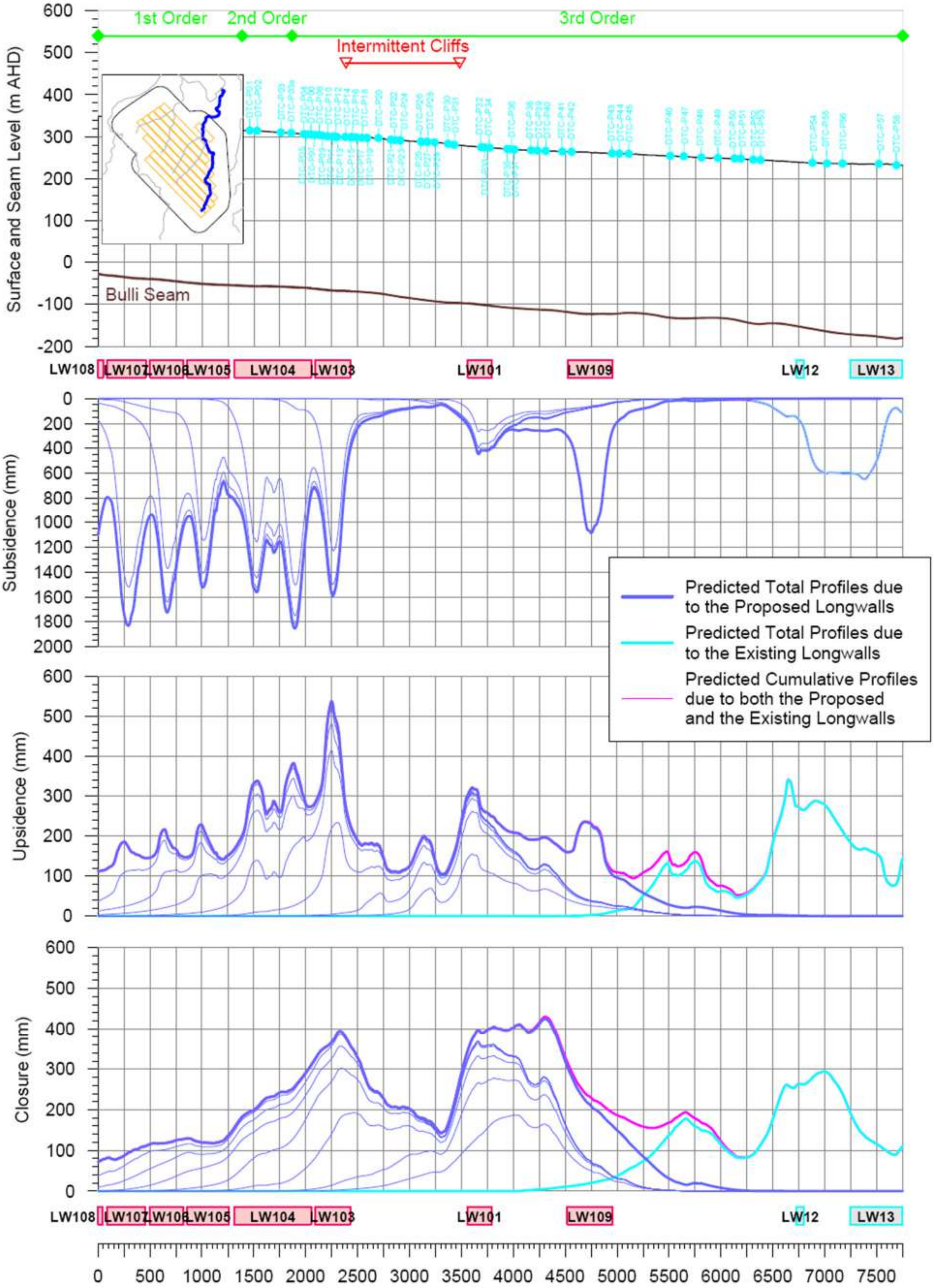

Figure A1 Predicted Subsidence Effects - Main (Southern) Arm Dog Trap Creek

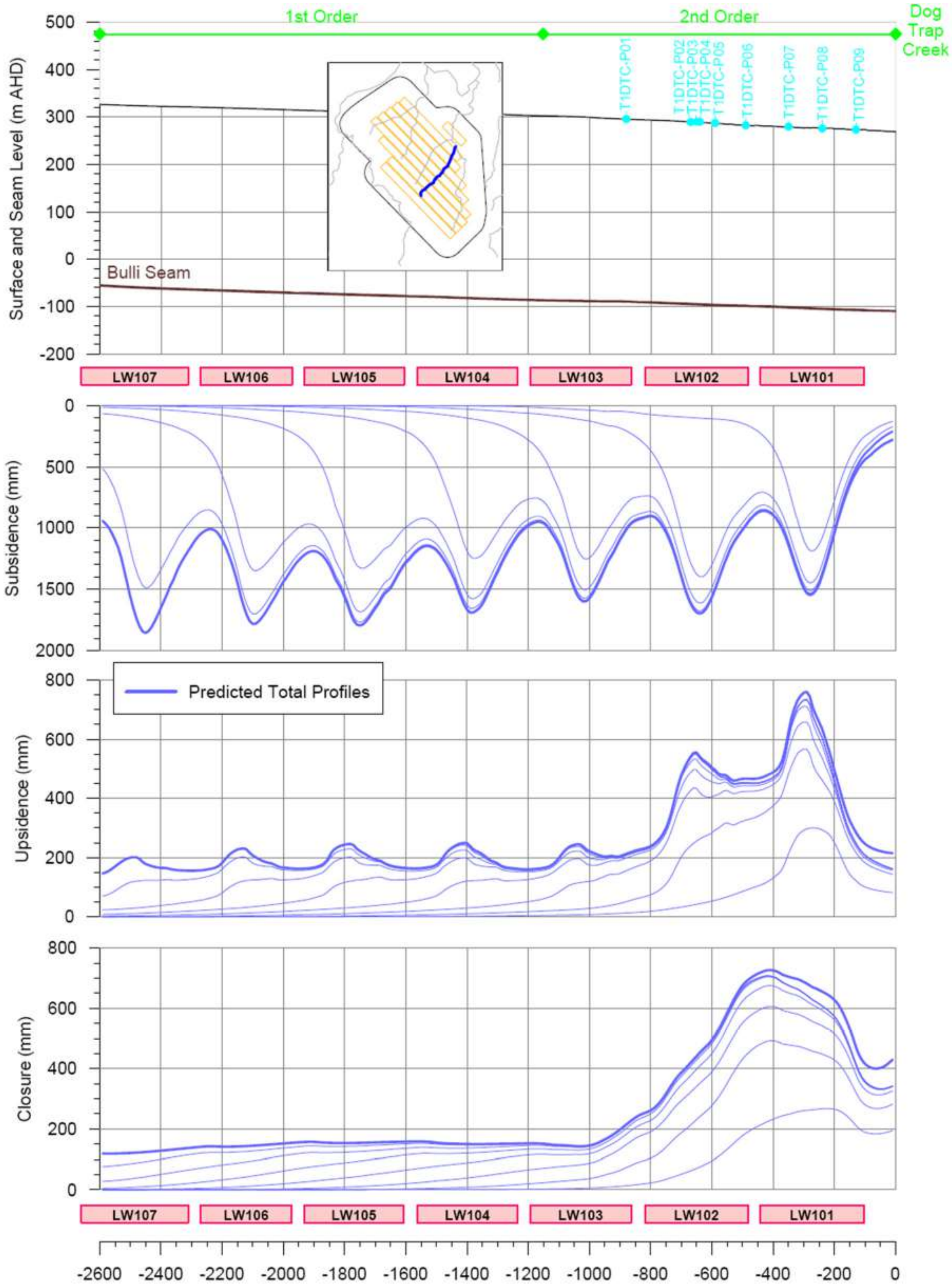

Figure A2 Predicted Subsidence Effects - Central Arm of Dog Trap Creek

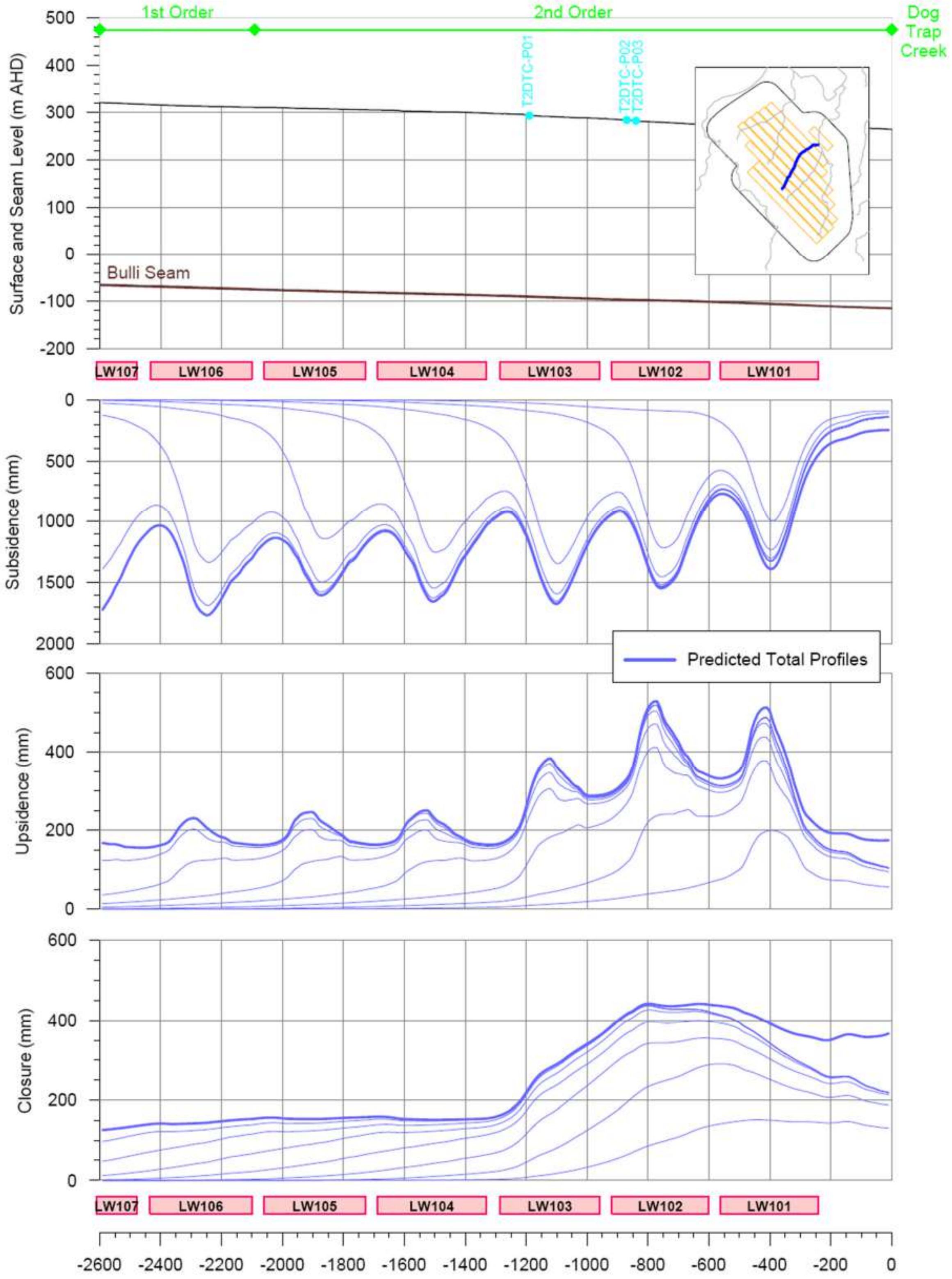

Figure A3 Predicted Subsidence Effects - Northern Arm of Dog Trap Creek

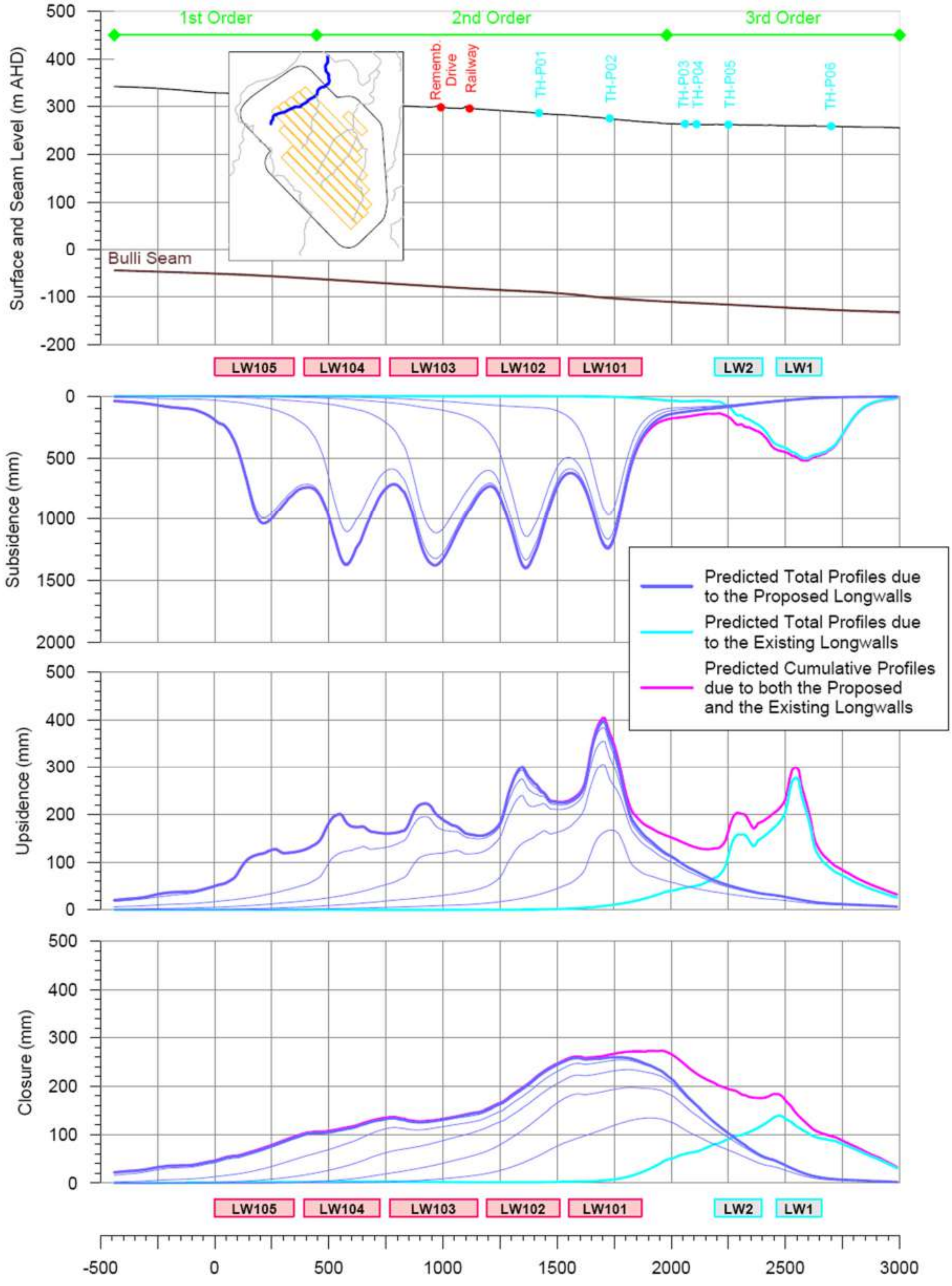

Figure A4 Predicted Subsidence Effects - Northern Arm of Tea Tree Hollow

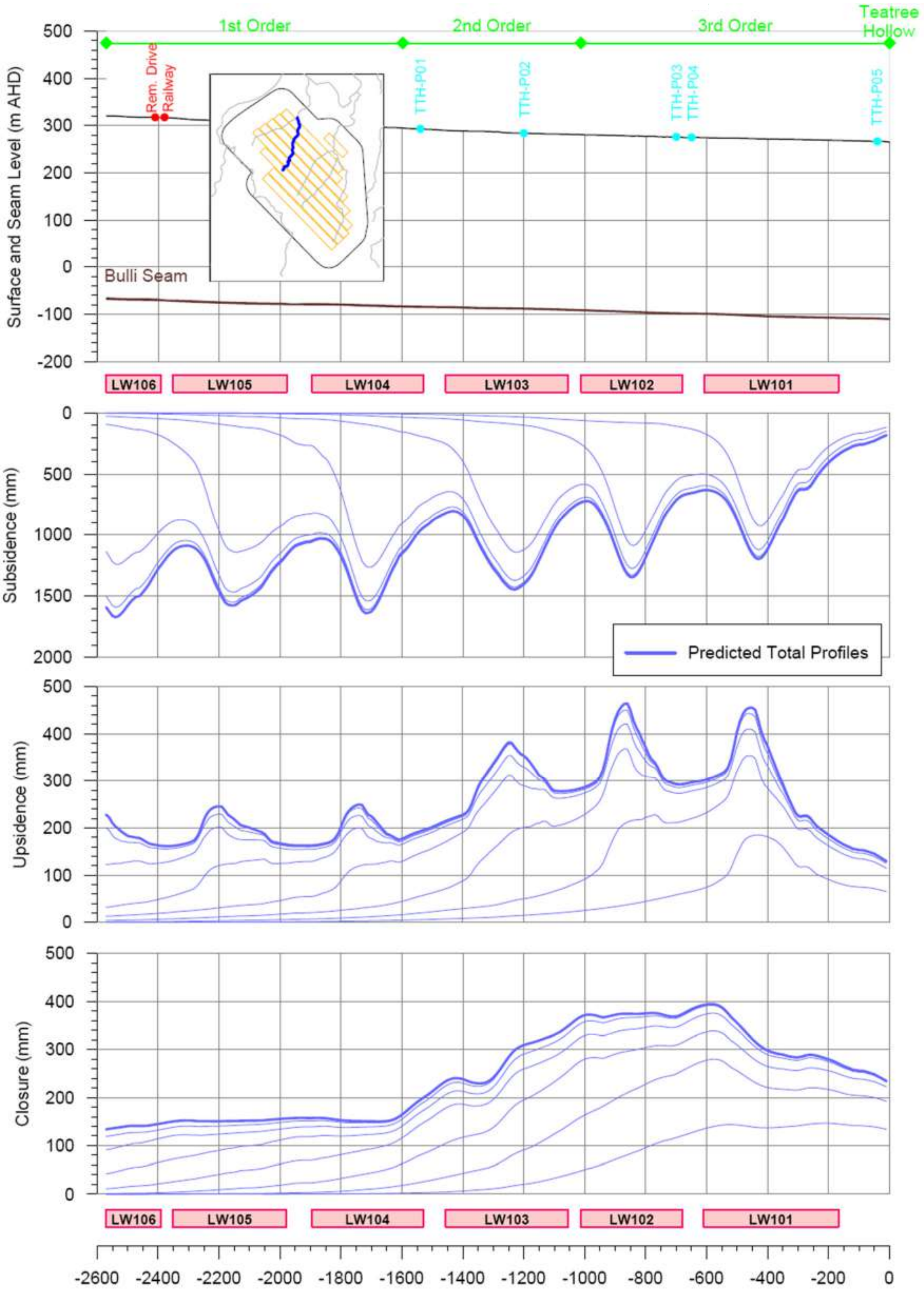

Figure A5 Predicted Subsidence Effects - Southern Arm of Tea Tree Hollow

APPENDIX B

Redbank Creek Subsidence Area Photographs

Observations of Redbank Creek Sites Overlying Longwall 25

The photographs below were taken at Photo Monitoring Sites 5, 6, 8 and 10 (refer Figure 4) and show pool desiccation in a clay-incised section of the creek that contained cobbles and limited exposed sandstone rock-bars.

Observations of Redbank Creek Sites Overlying Longwall 26

The photographs below were taken at Photo Monitoring Site 12 (refer Figure 4) and show sandstone streambed cracking. It was reported that there were no obvious effects on pool holding capacity.

Observations of Redbank Creek Sites Overlying Longwall 27

The photographs below were taken at Photo Monitoring Site 23 (refer Figure 4) and show sandstone rock bar cracking, with reduced surface flow over the rock bar. There were no observed effects on downstream pool holding capacity.

The photographs below were taken at Photo Monitoring Site 26 (refer Figure 4) and show cracking of a sandstone rock bar, with reduced surface flow over the rock bar, although there was no observed effect on downstream pool holding capacity.