APPENDIX D

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

HYDRO ENGINEERING & CONSULTING PTY LTD

REPORT

Tahmoor South Amended Project
Surface Water Baseline Assessment

Prepared for: Tahmoor Coal Pty Ltd

38a Nash Street
Rosalie QLD 4064
p (07) 3367 2388

PO Box 1575
Carindale QLD 4152
www.hecons.com
ABN 11 247 282 058

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1.0 INTRODUCTION

Hydro Engineering & Consulting Pty Ltd (HEC) was commissioned by Tahmoor Coal Pty Limited (Tahmoor Coal) to complete a Surface Water Assessment for the Tahmoor South Project (the Project). The Surface Water Assessment formed a 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 was 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 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. The water balance model was developed to simulate the water management system supply reliability, the adequacy of the current licensed discharge to Tea Tree Hollow to manage release of water from the mine site and to assess the risk of site overflow 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 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 Project Area which has been revised to address key issues raised in submissions relating to the EIS, as described below. The assessment has been revised to incorporate additional baseline data for the Project following submission of the EIS.

1.1 BACKGROUND AND OVERVIEW

Tahmoor Coal is seeking development consent for the continuation of mining at the 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.

In accordance with the requirements of the EP&A Act, the *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation) and the Secretary's Environmental Assessment Requirements (SEARs), an EIS was prepared to assess the potential environmental, economic and social impacts of the Project. The EIS for the Project was placed on public exhibition by the Department of Planning, Industry and Environment (DPIE) (formerly the Department of Planning and Environment [DPE]) from 23 January 2019 to 5 March 2019.

Key issues raised in submissions included concerns relating to the proposed extent of longwall mining, the magnitude of subsidence impacts and the extent of vegetation clearing required for the expansion of the reject emplacement area (REA). In response to these and other issues raised in Government agency, local Council, stakeholder and community submissions, and as a result of ongoing mine planning, several amendments have been made to the proposed development, so as to also further reduce the predicted environmental impacts of the Project.

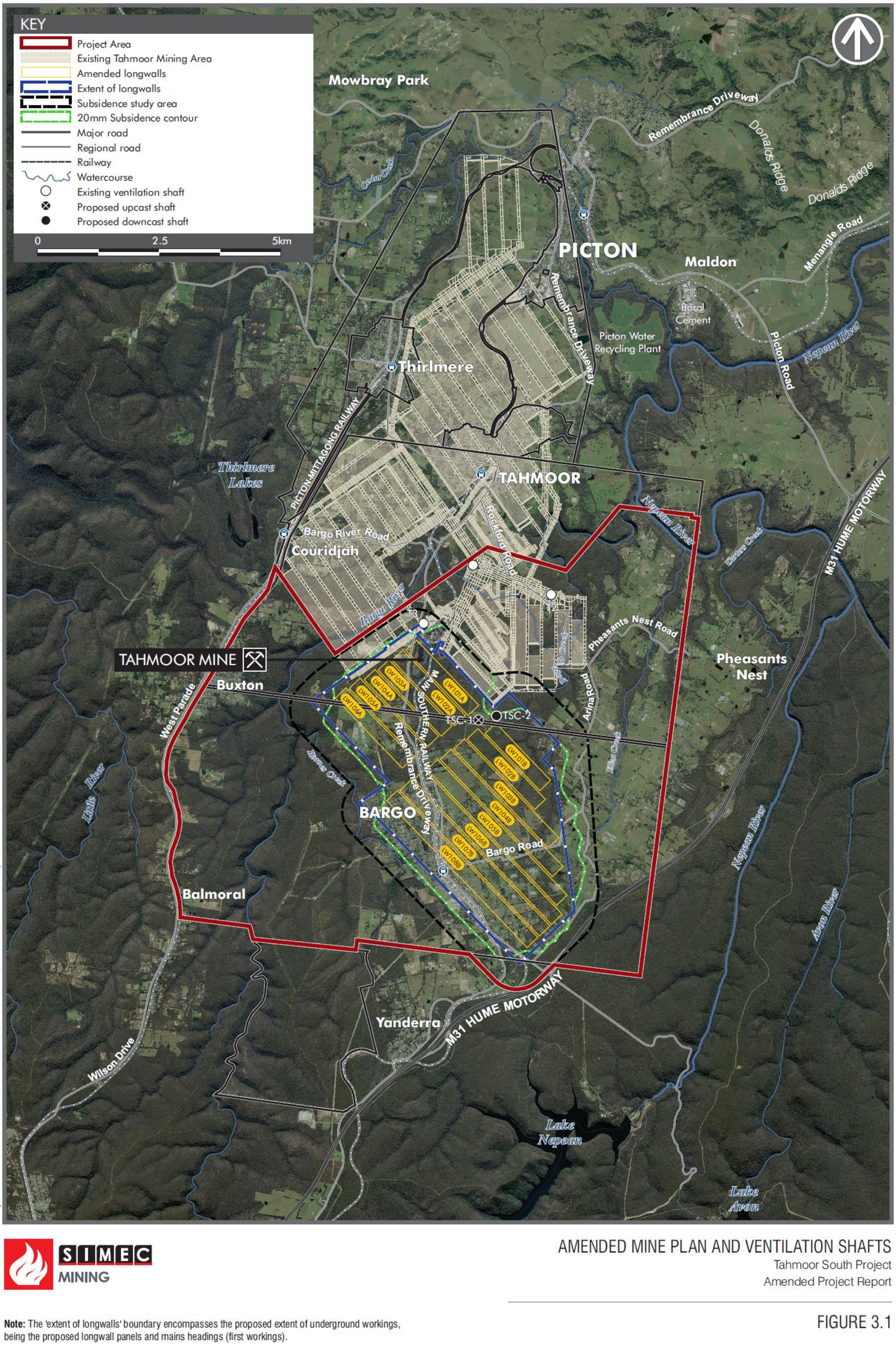

Figure 1 Locality Plan and Project Layout

The key amendments to the Project since public exhibition of the EIS are:

- A revised mine plan, including:
  - an amended longwall panel layout and the removal of LW109;
  - a reduction in the height of extraction within the longwall panels from up to 2.85 metres (m) to up to 2.6 m; and
  - a reduction in the proposed longwall width, from up to 305 m to approximately 285 m.
- A reduction in the total amount of Run-of-Mine (ROM) coal to be extracted over the Project life, from approximately 48 million tonnes (Mt) to approximately 43 Mt of ROM coal, comprising;
  - 30 Mt of coking coal product (reduced from 35 Mt);
  - 2 Mt of thermal coal product (reduced from 3.5 Mt)
- A revised extended REA; including:
  - a reduction in the additional capacity required to accommodate the Project;
  - a reduction in the REA extension footprint, from 43 ha to 11 ha;
  - an increase in the final height of the REA (from RL 305 m to RL 310 m).
- Confirmation of the location and footprint of ancillary infrastructure associated with the ventilation shaft sites (e.g. the power connection easement for ventilation shaft site TSC1); and
- A continuation of the use of the existing upcast shaft (T2); although, operation will reduce from two fans during Tahmoor North operations to one fan once the new ventilation shafts and fans (TSC1 and TSC2) are in operation in Tahmoor South.

No amendments have been made to other key aspects of the Project as presented in the EIS for which development consent is sought, such as the proposed annual coal extraction rate, mining method, traffic movements and employee numbers. A detailed description of the amended development is provided in the Amendment Report (AECOM, 2020).

1.2 PURPOSE OF REPORT

This BA has been revised to incorporate additional baseline data assessed for the Project following submission of the EIS. The report has also been revised to address key issues raised in the EIS submissions pertaining to the baseline hydrology and water quality characteristics of the proposed Project Area. In this way, it serves as an update to the Surface Water Baseline Study (HEC, 2018a, Appendix J of the Tahmoor South Project EIS). Section 8.0 presents a summary of key changes presented in this BA in comparison with the EIS assessment.

1.3 AMENDED PROJECT

The Amended Project would use longwall mining to extract coal from the Bulli seam within the bounds of Consolidated Coal Lease 716 (CCL716) and CCL747. Coal extraction of up to four (4) million tonnes of ROM coal per annum is proposed as part of the development with extraction of up to 43 Mt of ROM coal over the life of the Project. The project would produce approximately:

- 30 Mt coking coal product;
- 2 Mt thermal coal product; and
- 12 Mt of rejects.

These approximate market mix volumes include moisture and are therefore an estimate only. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing coal handling and processing plant (CHPP) and coal clearance facilities and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla and Newcastle (from time to time) for Australian and international markets. Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers via road.

The amended development would use the existing surface infrastructure at the Tahmoor Mine surface facilities area. Some upgrades are proposed to facilitate the extension.

The amended development also incorporates the planning for rehabilitation and mine closure once mining ceases.

In summary, the key components of the amended development comprise:

- Longwall mining in the Central Domain;
- Mine development including underground development, vent shaft construction, pre-gas drainage and service connection;
- Upgrades to the existing surface facilities area including:
  - Upgrades to the CHPP;
  - Expansion of the existing REA;
  - Additional mobile plant for coal handling;
  - Additions to the existing bathhouses and associated access ways; and
  - Upgrades to onsite and offsite service infrastructure, including electrical;
- Rail transport of product coal to Port Kembla and Newcastle (from time to time);
- Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers via road;
- Mine closure and rehabilitation; and
- Environmental management.

1.4 STUDY REQUIREMENTS

The Project EIS was 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. This BA report has been revised to address key issues raised in the EIS submissions pertaining to the BA submitted as a component of the EIS.

1.4.1 Secretary's Environmental Assessment Requirements

The Surface Water Assessment is guided by the 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 requirements are outlined in Table 1, including where they were addressed in Surface Water Assessment reports submitted as part of the EIS.

The Surface Water Assessment also took 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 were 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	BA 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.	BA Report Sections 5 to 8
	b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.	BA 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.	BA 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.	BA 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	BA Report Sections 5.2 & 5.3 & HydroSimulations (2018) BA Report Section 1.4 & 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	BA 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. • Spatial, temporal and seasonal trends in streamflow and/or standing water levels. • Spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals and metalloids and radionuclides). • Current stressors on watercourses, including impacts from any currently approved projects.	Gippel (2013) BA Report Sections 5.1, 5.3 & 7 BA Report Section 8 BA 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.	BA 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.	BA 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	BA 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. • Impacts associated with surface water diversions. • Impacts to water quality, including consideration of mixing zones. • 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 7 Not relevant SWIA Report Section 10 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.	BA 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.	BA 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.	BA 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.	BA 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.	BA 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.	BA 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) BA 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.	BA 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).	BA 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.	BA 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.	BA 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).	BA 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.

Following preparation of the preliminary environmental assessment (PEA) for the Project (AECOM, 2012a), the proposed mine plan for the Project was 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.

1.4.2 EIS Submissions

The submissions from government agencies that are relevant to the BA and the section of the report which addresses the submissions are summarised in Table 3.

Table 3 EIS Submissions – Surface Water Baseline Assessment

Agency	Submission	How / Where Addressed
Department of Industry (NSW Department of Industry Lands and Water Division)	Clarification and validation of the surface water modelling undertaken for the EIS is required, with respect to the modelling approach used particularly when predicting changes to low baseflows. Clarification and validation of the surface water modelling undertaken for the EIS is required, including the following: a) The Australian Water Balance Model (AWBM) models used in the Surface Water Baseline Study should be reviewed and validated. b) Metrics should be provided from the model validation to identify the uncertainty in the AWBM models with specific reference to the *Guidelines for rainfall-runoff modelling: Towards best practice model application*.	Section 5.0 presents the revised catchment modelling undertaken for Dog Trap Creek Downstream, Eliza Creek and Bargo River Upstream. The models have been re-calibrated using additional streamflow data collected since submission of the EIS. Section 5.0 provides additional discussion on the approach to model development and calibration. Statistical metrics are presented in Table 14, Section 5.0 illustrating the model 'goodness-of-fit' in accordance with the *Guidelines for rainfall-runoff modelling: Towards best practice model application*. Table 36 presents a comparison of the statistical metrics for the previous model calibration compared with the updated model calibration.
NSW Environment Protection Authority (EPA)	Water quality data from various ambient sites have been assessed against ANZECC (2000) guideline trigger levels for the protection of Aquatic Ecosystems, however, a range of analytes have not been assigned guideline values (e.g. interim values from Volume 2 of ANZECC (2000) or by referencing international literature). The purpose of site-specific trigger values in Tables 19 to Table 30 is also unclear. The ANZECC (2000) site specific trigger value methodology is used to modify the default trigger values based on high quality reference sites, e.g. use of slightly-disturbed site (sic) to derive trigger values for a slightly to moderately disturbed level of protection.	Section 7.0 presents a summary of the water quality monitoring data for various sites within the Project Area and surrounding region which has been updated to include data recorded since submission of the EIS. Where possible, the water quality data has been compared with the ANZECC (2000) guideline trigger levels for the protection of Aquatic Ecosystems in accordance with the perceived principal beneficial uses of the surface water resources in the area. Site-specific trigger values (SSTVs) have been developed for all analytes to provide a baseline against which to compare future monitored water quality in order to assess if an impact may be occurring. As described in Section 7.0, it is intended that the SSTVs will be incorporated into water quality Trigger Action Response Plans (TARPs) for sites downstream of the Project Area.

Table 1 (Cont.) EIS Submissions – Surface Water Baseline Assessment

Agency	Submission	How / Where Addressed

NSW Environment Protection Authority (EPA)	The EPA recommends that the Department of Planning and Environment request the following be completed:
	…
	• for site discharges, monitoring should occur initially for a full range of potential pollutants during controlled discharges and managed overflows. This discharge monitoring should include:
	  o a full suite of metals
	  o sulfate, total dissolved solids and electrical conductivity, major ions
	  o total suspended solids and turbidity
	  o any residual settling agent risks (flocculants or coagulants)
	  o volume and frequency of controlled discharges and frequency of managed overflows.
		Section 7.1 provides details of water quality monitoring for site discharges and summarises the monitored water quality data for releases to LDP1 and for site water storages which release to Licenced Overflow Points (LOPs).

Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC)	Water quality monitoring during 2012- 2015 found that water from all impacted and reference sites exceeded multiple water quality parameters when compared to ANZG (2018) guidelines for aquatic ecosystem protection. Although increased salinity, metals and barium precipitate identified downstream of the wastewater discharge sites are attributed to mine water, explanations are not provided for the observed exceedances of national and site-specific guideline values across most sites. More recent monitoring data should be used to confirm that the contaminant concentrations have been reduced with improvements to the Waste Water Treatment Plant (WWTP).	Section 7.0 presents a summary of the water quality monitoring data for various sites within the Project Area and surrounding region which has been updated to include data recorded since submission of the EIS. A comparison with the LDP 1 release water quality is also presented. The reduction in constituent concentrations following improvements to the WWTP has been discussed in Section 7.0. The natural and anthropogenic nature of the baseline water quality has also been discussed.
	An effective monitoring program needs to justify the selection of reference, baseline and impacted sites. This is especially critical for sampling water quality because water from the reference sites exceeded multiple water quality parameters when compared to the ANZG (2018) guidelines for aquatic ecosystem protection. Sometimes, the same sites have been used inconsistently. For example, sites serving as controls for water discharge also served as impact sites for mine subsidence. This inconsistency needs justification…	Justification for the selection of reference, baseline and impact sites is presented in Section 4.2 and Section 7.0. Control / reference sites are independent of impact sites. Baseline / impact sites have been selected to enable comparison of water quality before, during and after project development.

2.0 SCOPE OF BASELINE ASSESSMENT REPORT

This report provides a summary of the available streamflow and water quality data of the Project Area and surrounding region. Outcomes comprise the characterisation of the surface water resources which could be affected by the Amended 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.

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.

The baseline datasets used to characterise the streamflow and water quality characteristics of the Project Area and surrounding region have been updated since submission of the EIS. Table 4 provides a summary of the updated datasets which have been used to inform the revised BA (this report).

Table 4 Summary of Updated Baseline Datasets

Dataset	Location	Dataset Presented in EIS	Updated Dataset
Baseline Flow Monitoring			
300010a	Bargo River Upstream Bargo	4/5/2008 – 16/9/2013	4/5/2008 - present
300011a	Bargo River Downstream Rockford Road Bridge	4/7/2007 – 16/9/2013	4/7/2007 – present
300061	Bargo River	5/3/2012 – 19/8/2013	5/3/2012 – present
300062	Hornes Creek	16/2/2012 – 16/9/2013	16/2/2012 – present
300063	Dog Trap Creek Downstream	29/2/2012 – 9/8/2013	29/2/2012 – present
300064	Dog Trap Creek Upstream	3/3/2012 – 10/8/2013	3/3/2012 – 1/12/2015
300056	Tea Tree Hollow	8/2/2010 – 10/9/2013	8/2/2010 – present
300075	Cow Creek	13/2/2013 – 30/8/2013	13/2/2013 – 30/8/2013
300076	Carters Creek	23/11/2012 – 17/9/2013	23/11/2012 – 1/12/2015 20/2/2019 – present
300073	Eliza Creek	1/11/2012 – 17/9/2013	1/11/2012 – present
SILO Data Drill		1/1/1889 – 31/12/2017	1/1/1889 - present
Surface Water Quality Monitoring		30/5/2012 – 17/6/2015	30/5/2012 – 17/6/2015 18/2/2019 – present*
LDP1 Discharge Water Quality Monitoring		N/A	10/3/2010 – present
LOP Discharge Water Quality Monitoring		N/A	10/10/2014 - present

* excludes Site 20, Site 21 and Site 24

[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/

3.0 PROJECT AREA CLIMATE

3.1 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 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 5 to Table 7 below.

Table 5 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 6 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 7 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

3.2 RAINFALL

Regional rainfall monitoring stations in the vicinity of the Tahmoor Mine area have varying periods of record (Table 8). The Buxton and Picton stations are the closest BoM stations with long term records without significant gaps in the data record.

Table 8 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 Area from the SILO Data Drill are summarised in Table 9. 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 9 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.

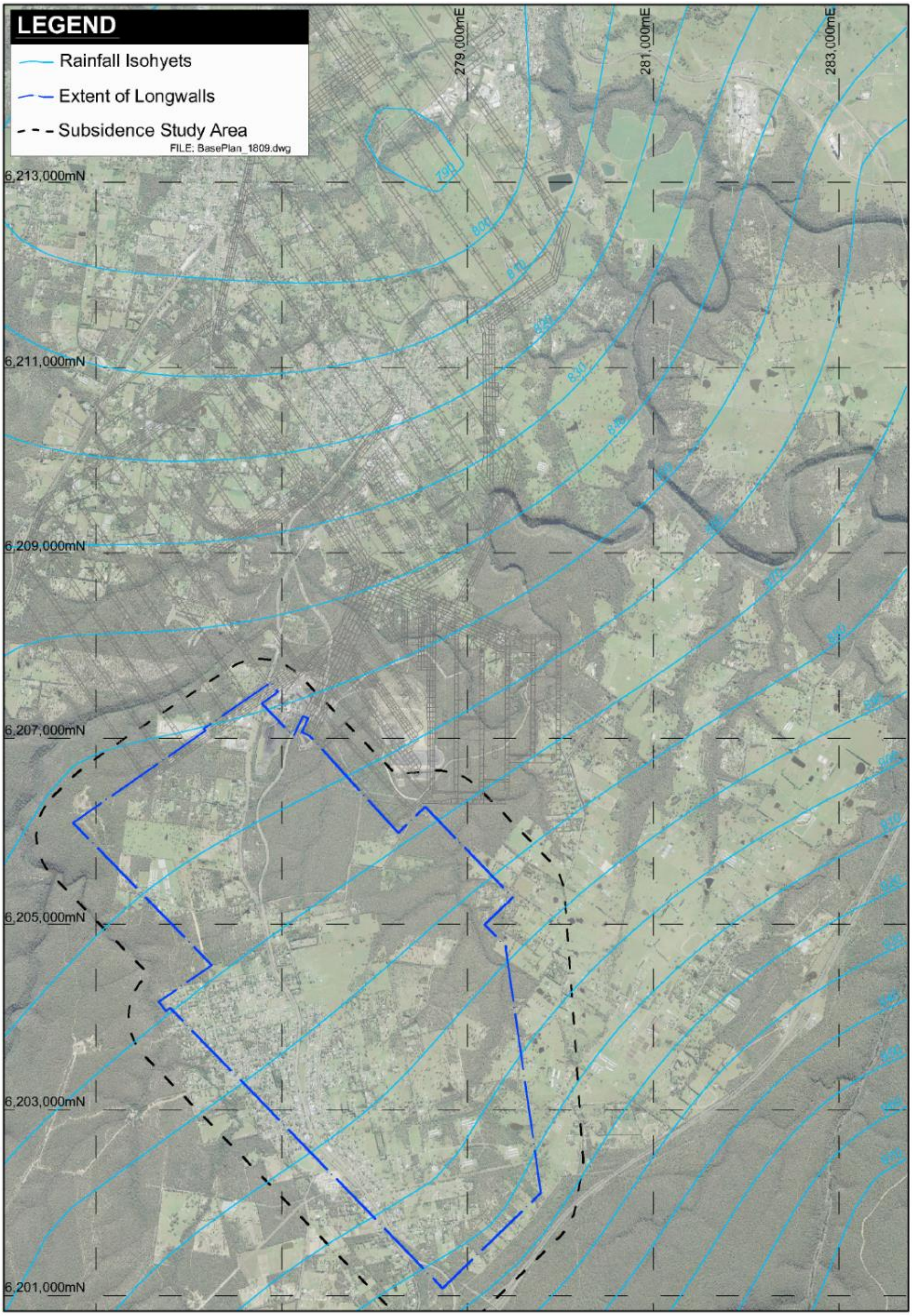

Figure 2 Average Annual Rainfall Isohyets Tahmoor Mine Site Area

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.

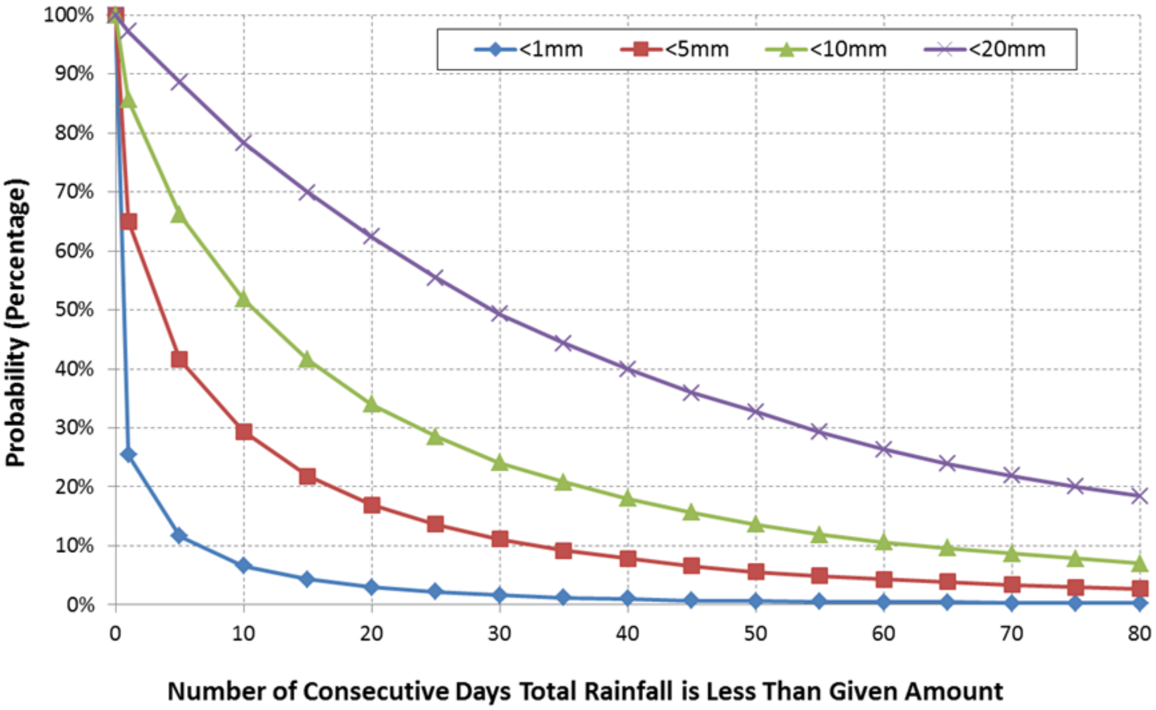

Figure 3 Low Rainfall Persistence Characteristics – Tahmoor South Project Area

3.3 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 10 along with the average monthly rainfall derived from the nearest Data Drill point.

[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 10 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.

4.0 CATCHMENTS AND DRAINAGE

4.1 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 from its mouth in Broken Bay on the northern side of the Sydney Metropolitan area.

4.2 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

[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.

reaches of Tea Tree Hollow and Dog Trap Creek have previously been affected by mining-induced subsidence associated with the Tahmoor Mine. The catchment boundaries of the creeks overlying the proposed longwall mining areas are shown in Figure 5.

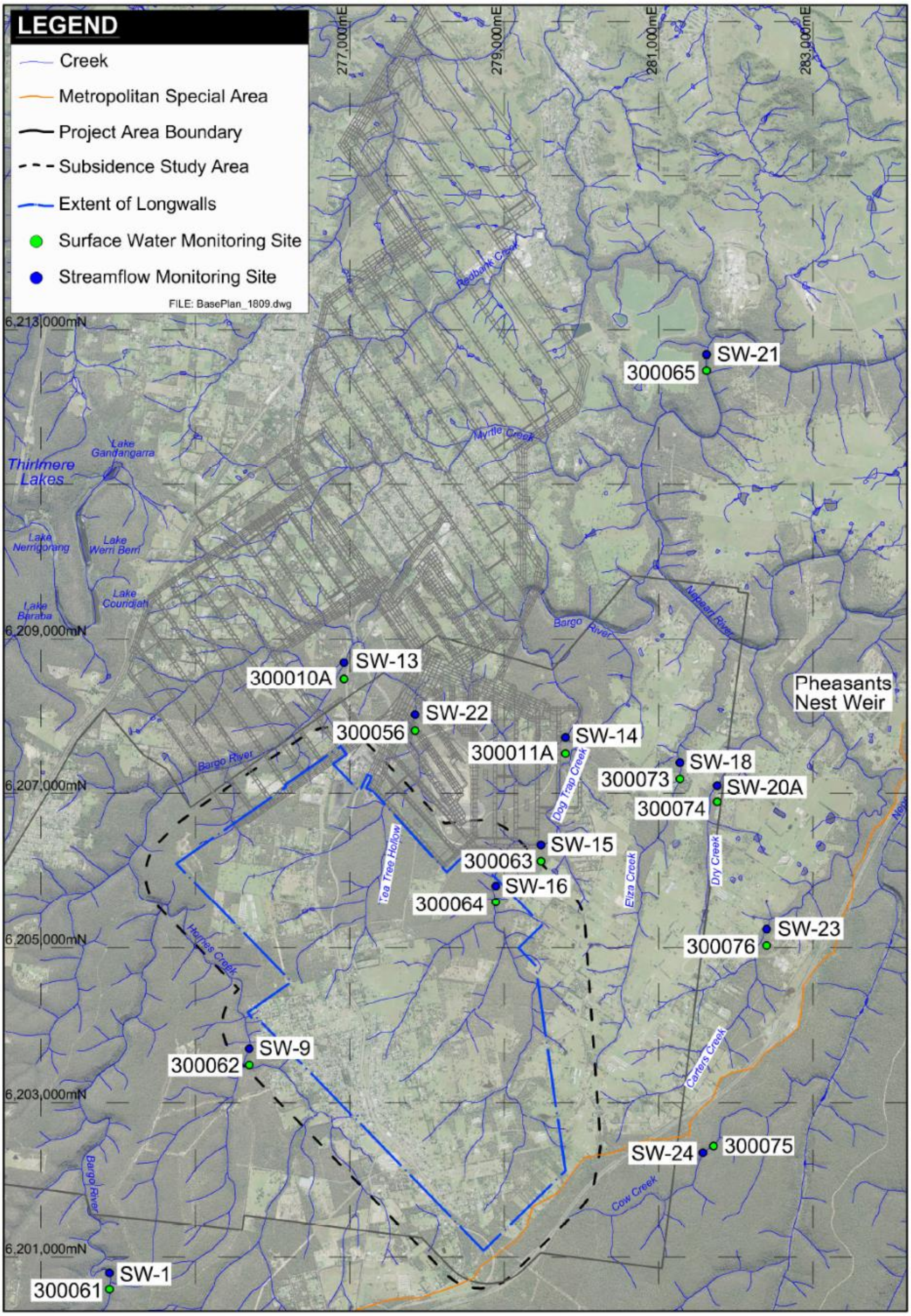

Figure 4 Project Area Drainages and Surface Water Monitoring Sites

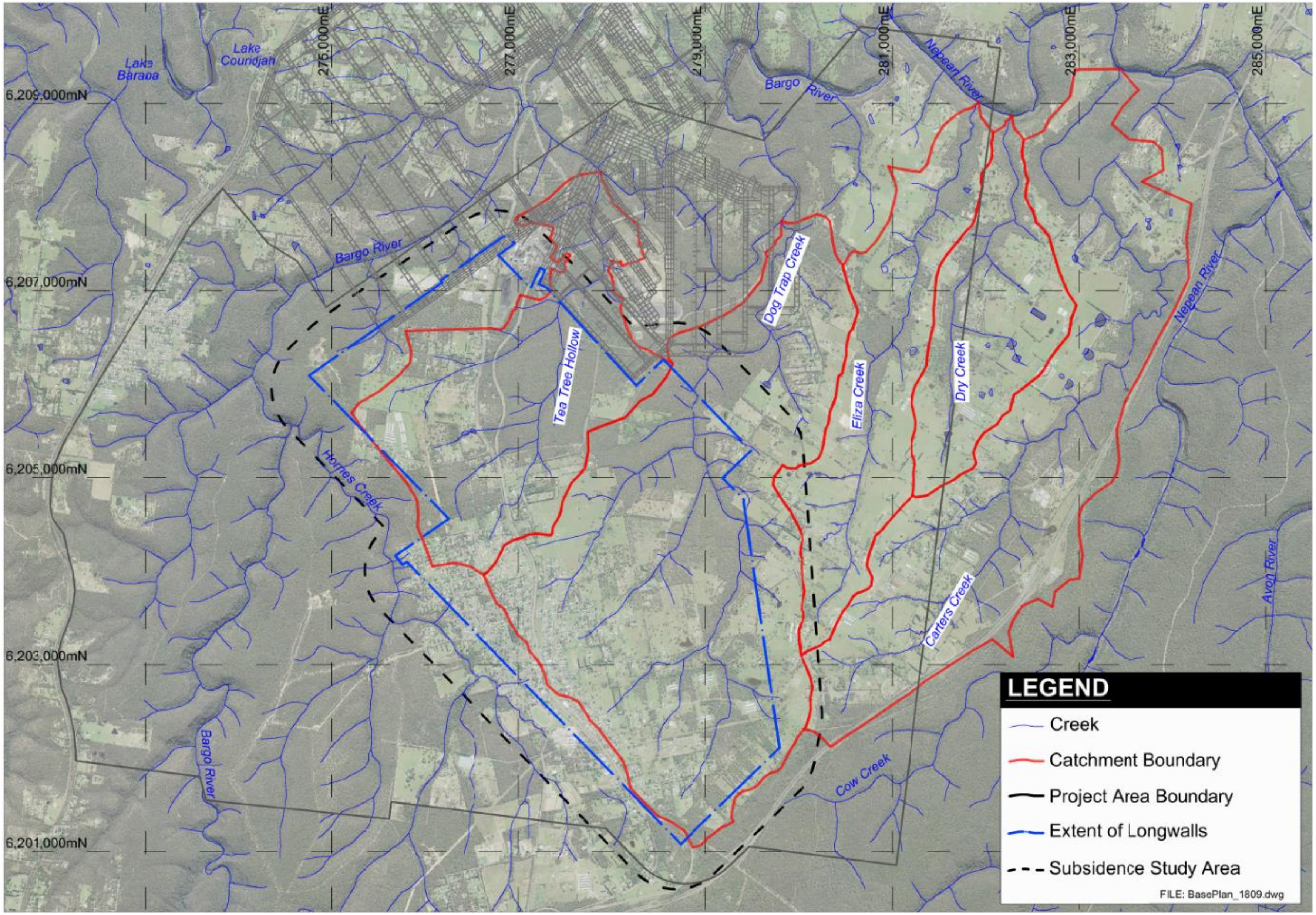

Figure 5 Project Area Creek Catchment Boundaries

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 ratings[5] 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 5.0 and Section 7.0 below. In terms of locations, the sites were either categorised as (AECOM, 2012b):

Control / Reference site: a site which is to provide control / reference 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.

Site selection was undertaken in accordance with ANZECC (2000). As the Project is located within a modified ecosystem i.e. urban, agricultural, industrial and resource development has been undertaken previously in the catchment area, the 'best available' reference sites have been adopted. The sites, listed and categorised in Table 11, enable water quality reference conditions to be developed for control and baseline sites against which water quality data collected at impact sites can be assessed following project commencement.

[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 11 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

4.2.1 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. Water quality monitoring of Hornes Creek was recommenced in February 2019 with samples collected at approximately monthly intervals to present.

4.2.2 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 of Tea Tree Hollow

[6] Strahler stream order classification scheme

was recommenced in February 2019 with samples collected at approximately monthly intervals to present.

4.2.3 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. Water quality monitoring was recommenced in March 2019 with sampling at approximately monthly intervals undertaken to present.

4.2.4 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. Water quality monitoring was recommenced in February 2019 with monthly sampling undertaken to present.

4.2.5 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. Water quality monitoring was recommenced on Carters Creek in February 2019 with monthly sampling undertaken to present.

4.2.6 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. Water quality monitoring of Dry Creek has not been recommenced because the catchment of the creek is outside the proposed amended development subsidence study area.

4.2.7 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. Water quality monitoring of Cow Creek has not been recommenced because the catchment of the creek is substantially outside the proposed amended development subsidence study area.

4.3 BASELINE STREAMFLOW DATA

Details of gauging stations on Project Area streams established by Tahmoor Coal are summarised in Table 12 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).

Table 12 Summary of Baseline Flow Monitoring Stations

Gauging Station Number	Name	Catchment Area (km^2)	Period of Water Level Records
300010a	Bargo River Upstream Bargo	93.1	4/5/2008 - present
300011a	Bargo River Downstream Rockford Road Bridge	108.5	4/7/2007 – present
300061	Bargo River	42.2	5/3/2012 – present
300062	Hornes Creek	16.5	16/2/2012 – present
300063	Dog Trap Creek Downstream	11.3	29/2/2012 – present
300064*	Dog Trap Creek Upstream	9.7	3/3/2012 – 1/12/2015
300056	Tea Tree Hollow	6.7	8/2/2010 – present
300075	Cow Creek	4.5	13/2/2013 – 30/8/2013
300076	Carters Creek	4.8	23/11/2012 – 1/12/2015 20/2/2019 – present
300073	Eliza Creek	3.6	1/11/2012 – present

* Dog Trap Creek Upstream (300064) was reinstalled in 2019 at a site immediately downstream of the former location and (renamed GS 300064A)

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.

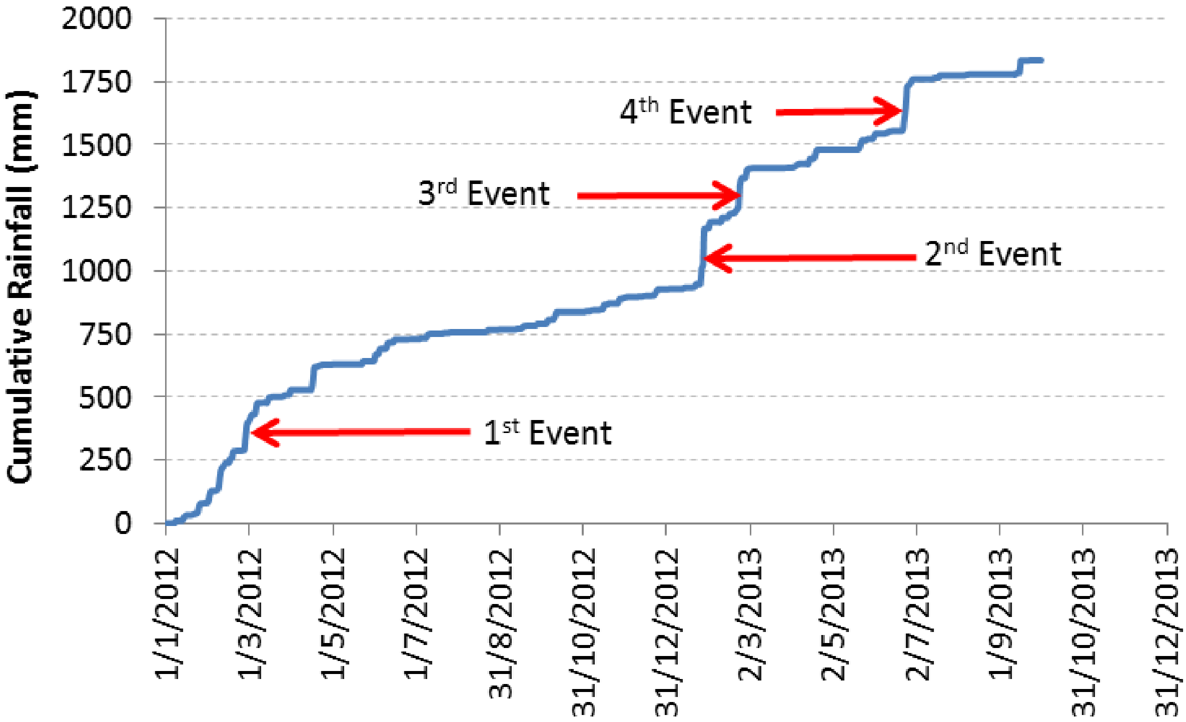

Figure 6 Cumulative Rainfall 2012 to 2013

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.

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

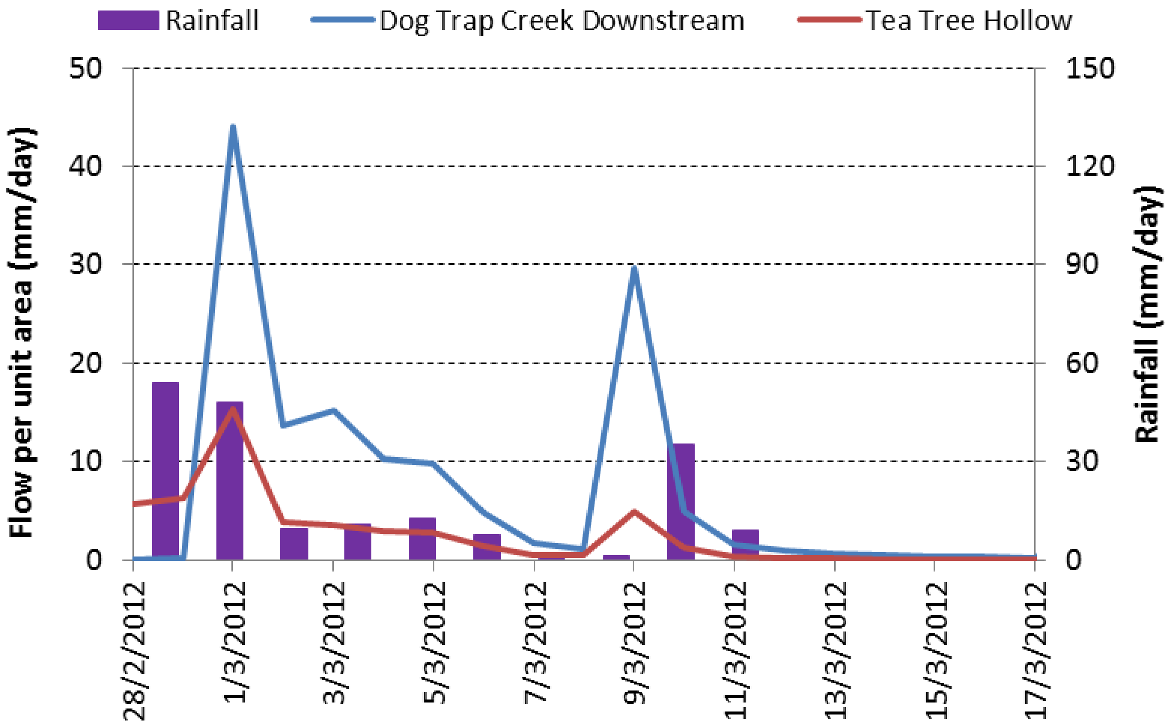

Figure 7 Streamflow Response to 28th February to 12th March 2012 Rainfall Event

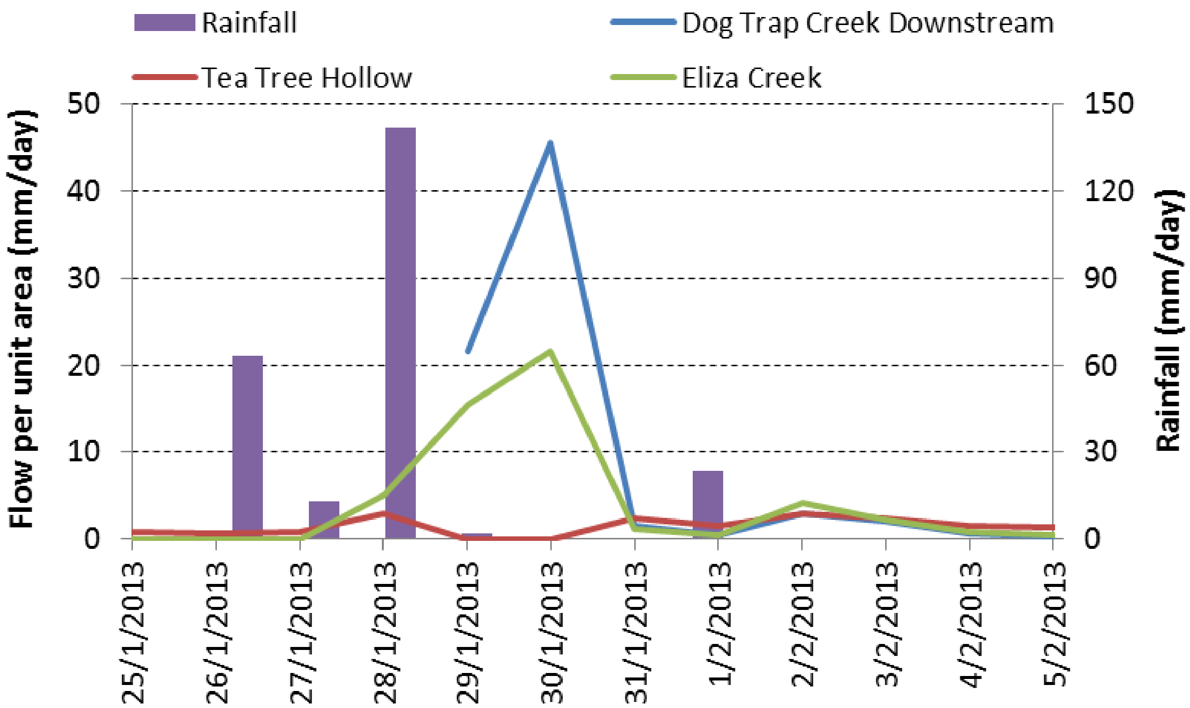

Figure 8 Streamflow Response to 28th January to 1st February 2013 Rainfall Event

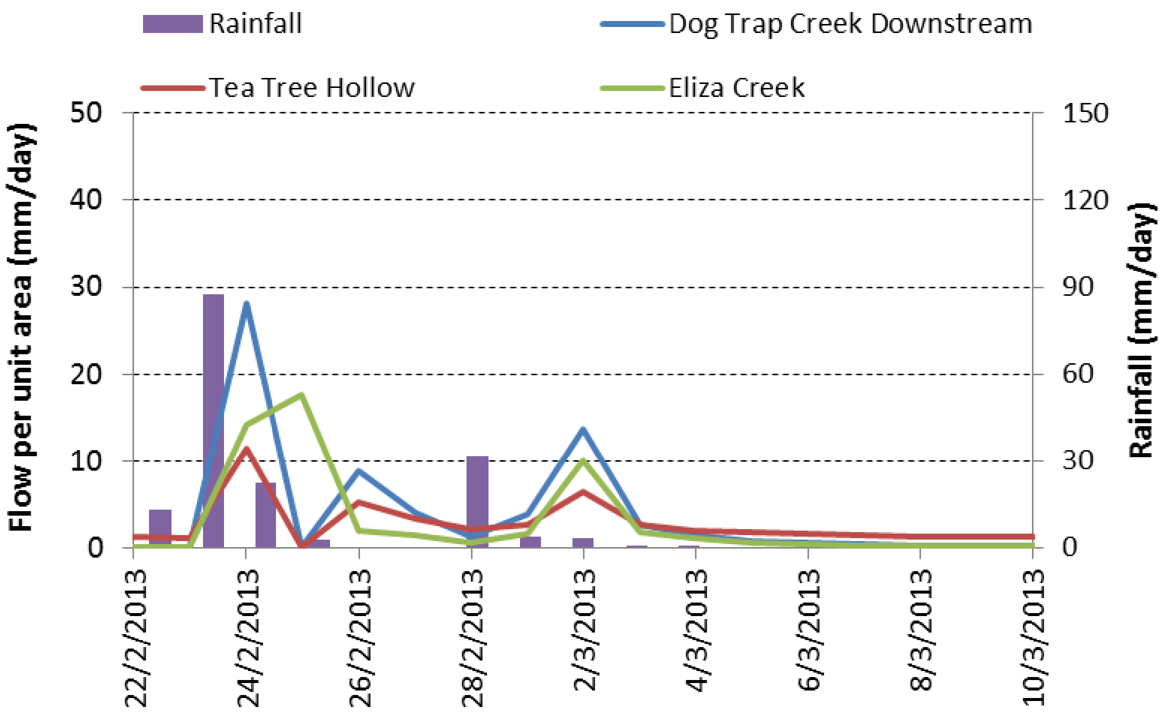

Figure 9 Streamflow Response to 23rd February to 4th March 2013 Rainfall Event

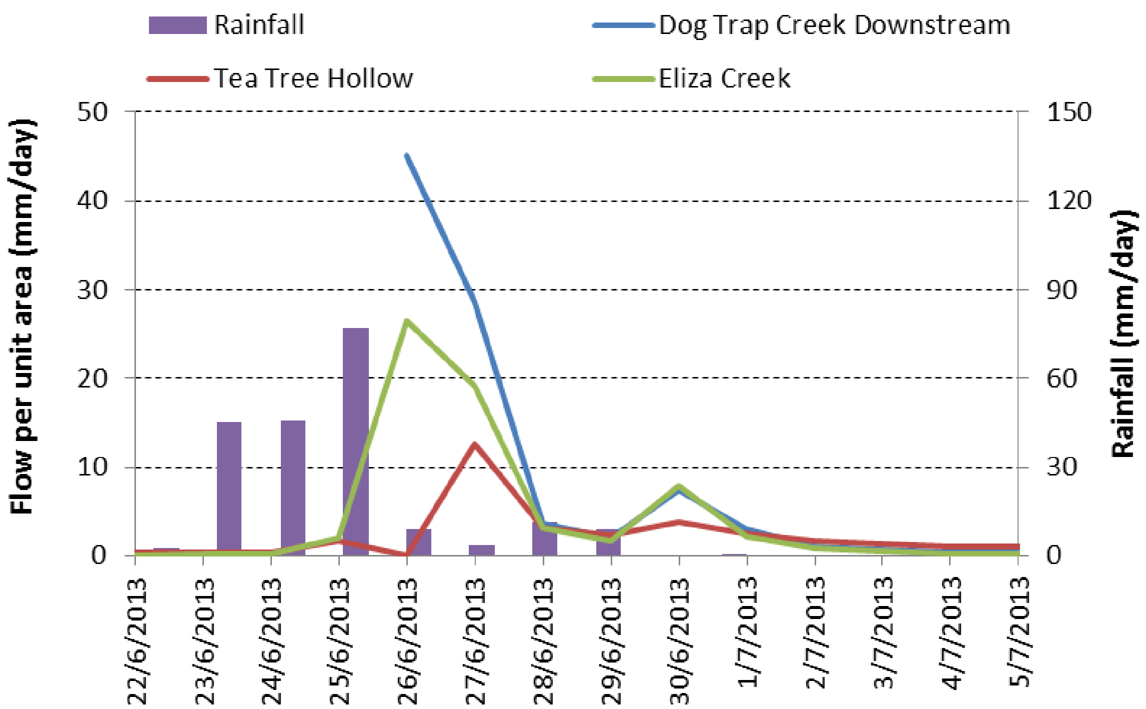

Figure 10 Streamflow Response to 25th June 2013 to 1st July 2013 Rainfall Event

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 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.

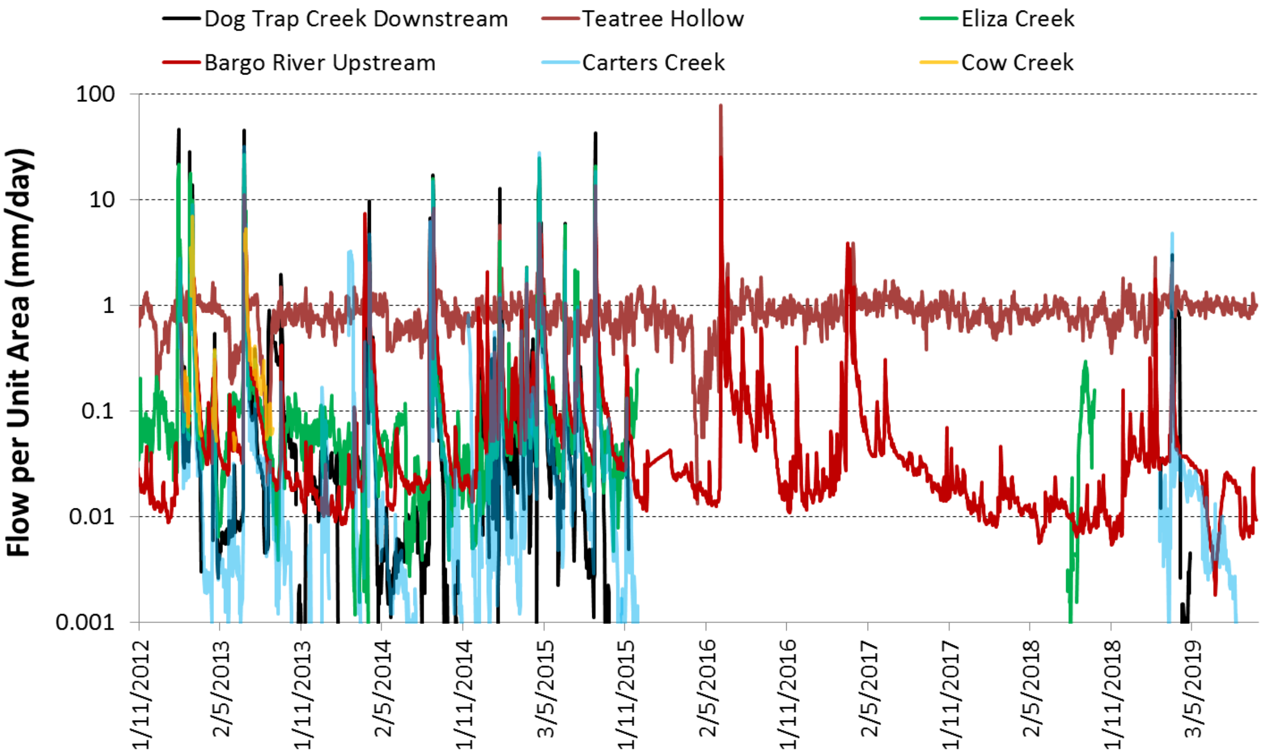

Figure 11 Recorded Streamflow Hydrographs – Project Area

5.0 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. For the Bargo River, streamflow gauging during high flows is not possible and therefore stream rating curves have been extrapolated for high flows. Consequently, the model accuracy at high flows may be limited.

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 modelling of Carters Creek, however, Carters Creek has broadly similar hydrological characteristics to that of Dog Trap Creek. As such, this has enabled the streamflow characteristics to be assessed using the results produced from the Dog Trap Creek catchment model.

As reported in Vaze et al. (2011), long data sets are required when undertaking model calibration in order to adequately represent climatic variability. As such, the available streamflow records have been used for model calibration only at this stage, with model validation to be undertaken once additional streamflow records are available.

Recorded data was available for Dog Trap Creek Downstream between March 2012 and December 2015 and for February 2019 to present. As such, the AWBM was calibrated for the period March 2012 to December 2015. Recorded data was available for Eliza Creek between December 2015 and July 2018 and for February 2019 to present. As such, the Eliza Creek AWBM was calibrated for the period December 2015 and July 2018. For both Dog Trap Creek Downstream and Eliza Creek, data which has been recorded from February 2019 will be used for model validation once sufficient records are available (at least one year of continuous data is required). The Bargo River Upstream AWBM was calibrated for the full period of available data from March 2012 to September 2019 and the flow duration curve and statistical methods derived for the equivalent period.

It should be noted that no recorded rainfall data was available from within the catchments of Dog Trap and Eliza Creek. Daily rainfall and evaporation data for the three catchments' models were obtained from the SILO Data Drill[8] for locations as close as possible to each catchment's centroid. For Dog Trap Creek the SILO daily rainfall data was averaged with data from the Tahmoor pit top weather station which is located just outside the catchment.

[8] https://www.longpaddock.qld.gov.au/silo/

The plots and metrics provided in the following sections were identified from the eWater CRC *Guidelines for Rainfall-Runoff Modelling: Towards Best Practice Model Application* (Vaze et al., 2011) as assessment techniques and measures for calibration and validation of hydrological models.

5.1 DOG TRAP CREEK DOWNSTREAM (GS 300063)

The AWBM simulated and monitored flow for Dog Trap Creek Downstream are shown in Figure 12.

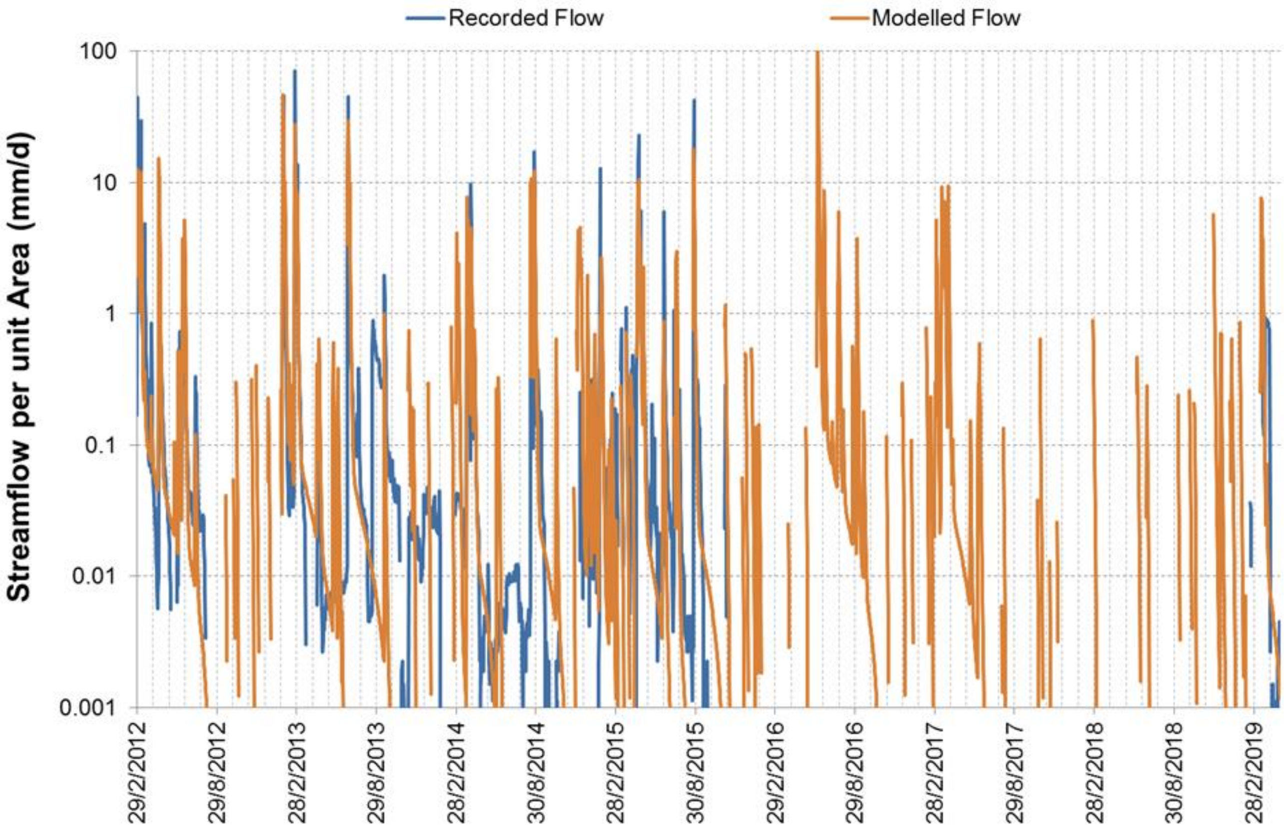

Figure 12 Recorded and Modelled Flows - Dog Trap Creek Downstream (GS 300063)

Figure 12 illustrates that the match between modelled and recorded flows for Dog Trap Creek Downstream is reasonable with the general trend in flows well replicated by the model. There was a period between August 2012 and January 2013 when no flows were recorded. Similar behaviour was also observed at the upstream Dog Trap Creek gauging station 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 may have been loss of data at the Dog Trap Creek gauging stations or there may be some flow diversion or underflow at these locations. Tahmoor longwall 11, adjacent to GS 300063 on Dog Trap Creek, was mined in 1993.

The match between modelled and recorded flows can also be assessed by comparing the flow duration curves of recorded and modelled flows – refer Figure 13 which has been compiled for the calibration period excepting the period of no flow between August 2012 and January 2013.

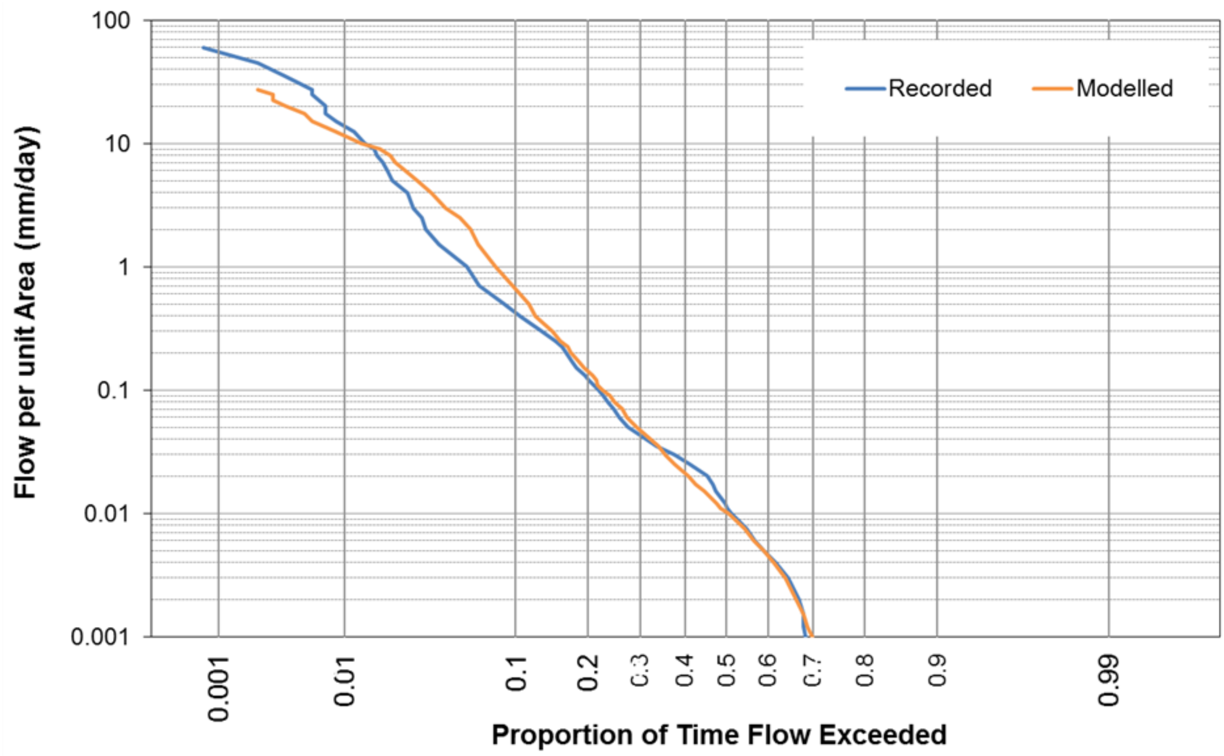

Figure 13 Modelled and Recorded Flow Duration Curves - Dog Trap Creek Downstream (GS 300063)

Figure 13 illustrates that low flows are well replicated by the model. There is a slight overestimation of medium modelled flows (flows which are exceeded 3% to 15% of the time) and an underestimation of high flows (flows which are exceeded 0.1% to 1% of the time) in comparison with recorded flows. Further metrics of model fit are given in Section 5.4.

5.2 ELIZA CREEK (GS 300073)

The AWBM simulated and monitored flow for Eliza Creek are shown in Figure 14.

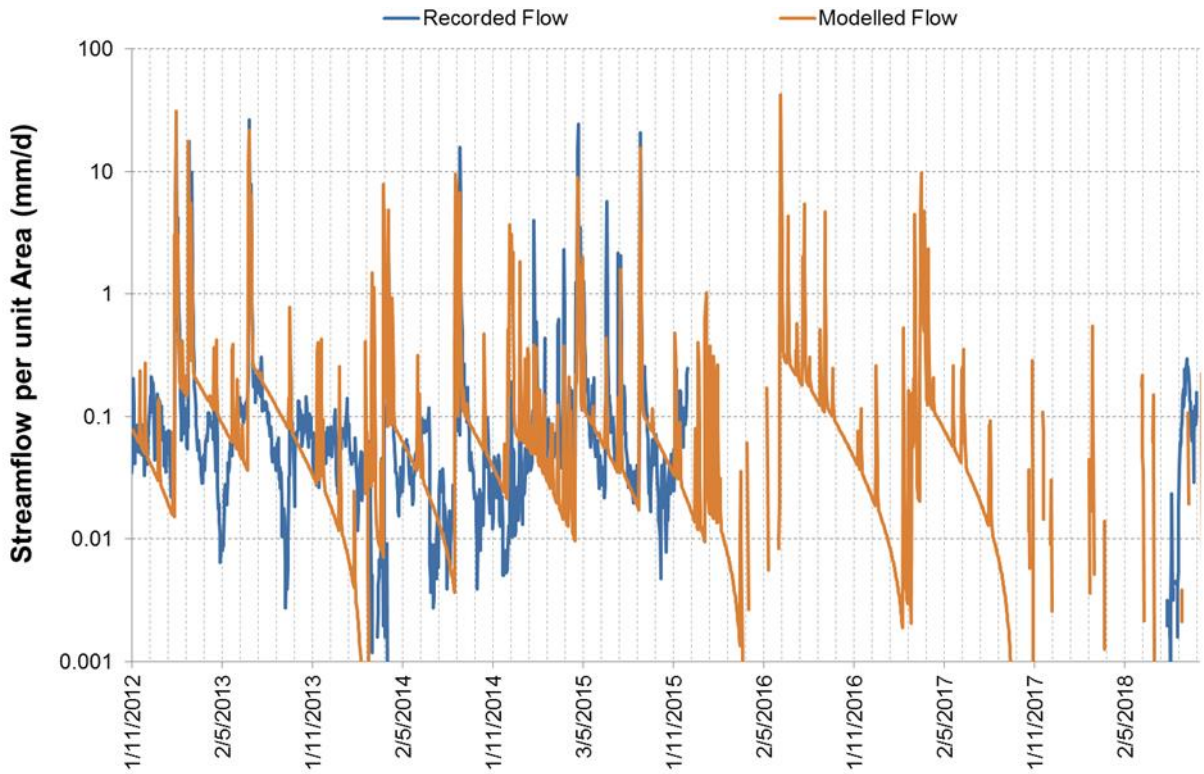

Figure 14 Recorded and Modelled Flows - Eliza Creek (GS 300073)

Figure 14 illustrates that the general trend in streamflow rates for Eliza Creek is reasonably well replicated by the AWBM, however, there are some periods in which low flows are over or under-estimated.

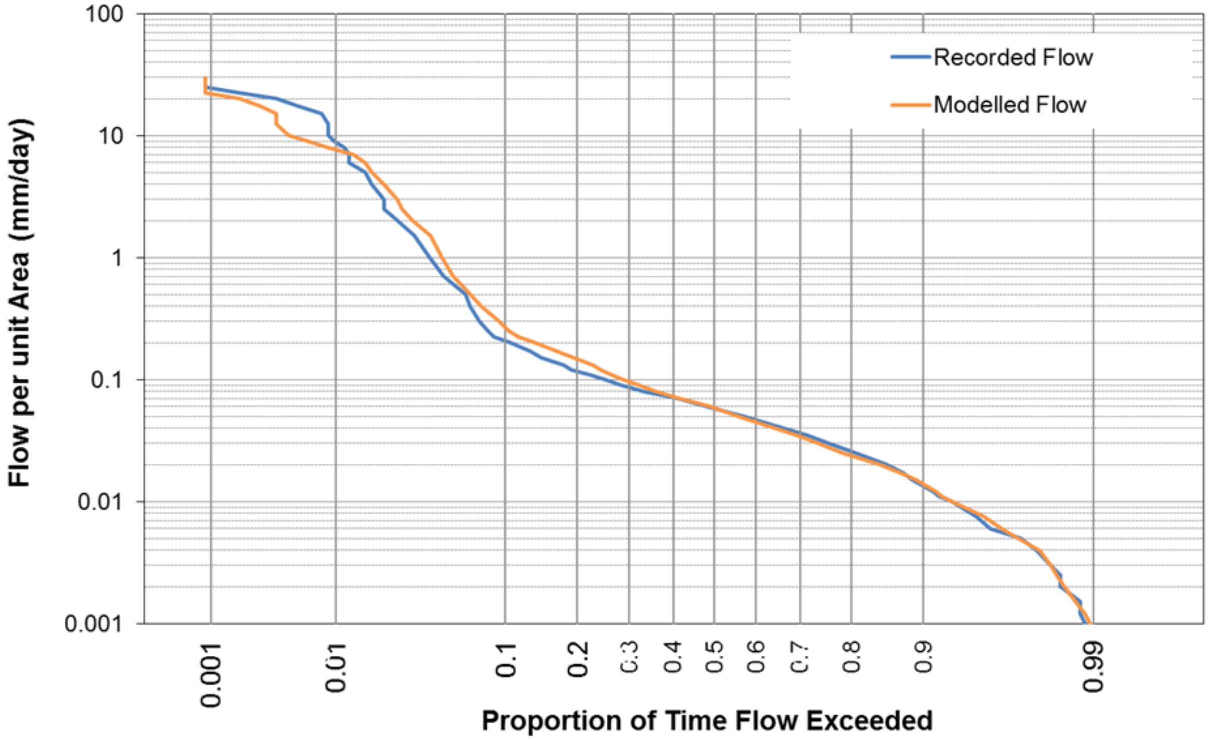

Figure 15 Modelled and Recorded Flow Duration Curves - Eliza Creek (GS 300073)

The flow duration curve (Figure 15) illustrates that, overall, the AWBM is simulating a representative proportion of low flow periods. There is a very slight overestimation of medium modelled flows and a slight underestimation of high flows (flows which are exceeded 0.1% to 1% of the time) in comparison with recorded flows. Further metrics of model fit are given in Section 5.4.

5.3 BARGO RIVER UPSTREAM (GS 300010A)

The AWBM simulated and monitored flow for the Bargo River Upstream are shown in Figure 16.

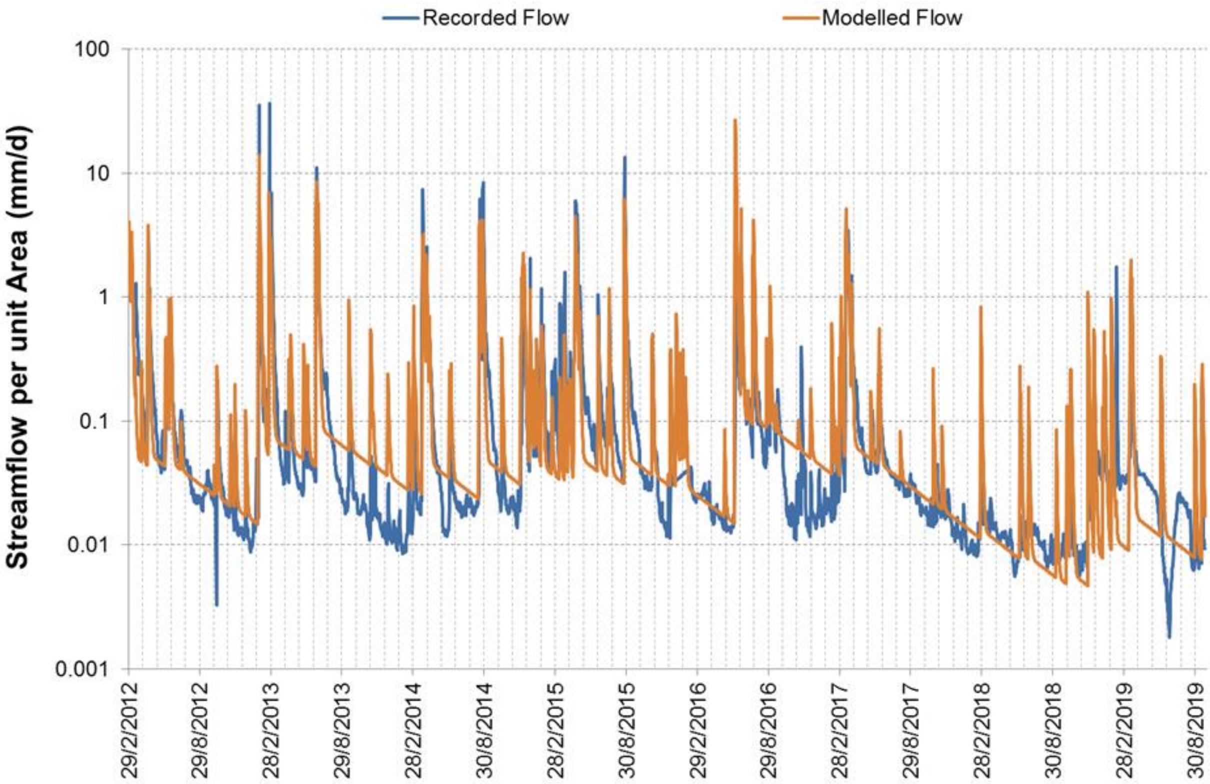

Figure 16 Recorded and Modelled Flows Bargo River Upstream (GS 300010a)

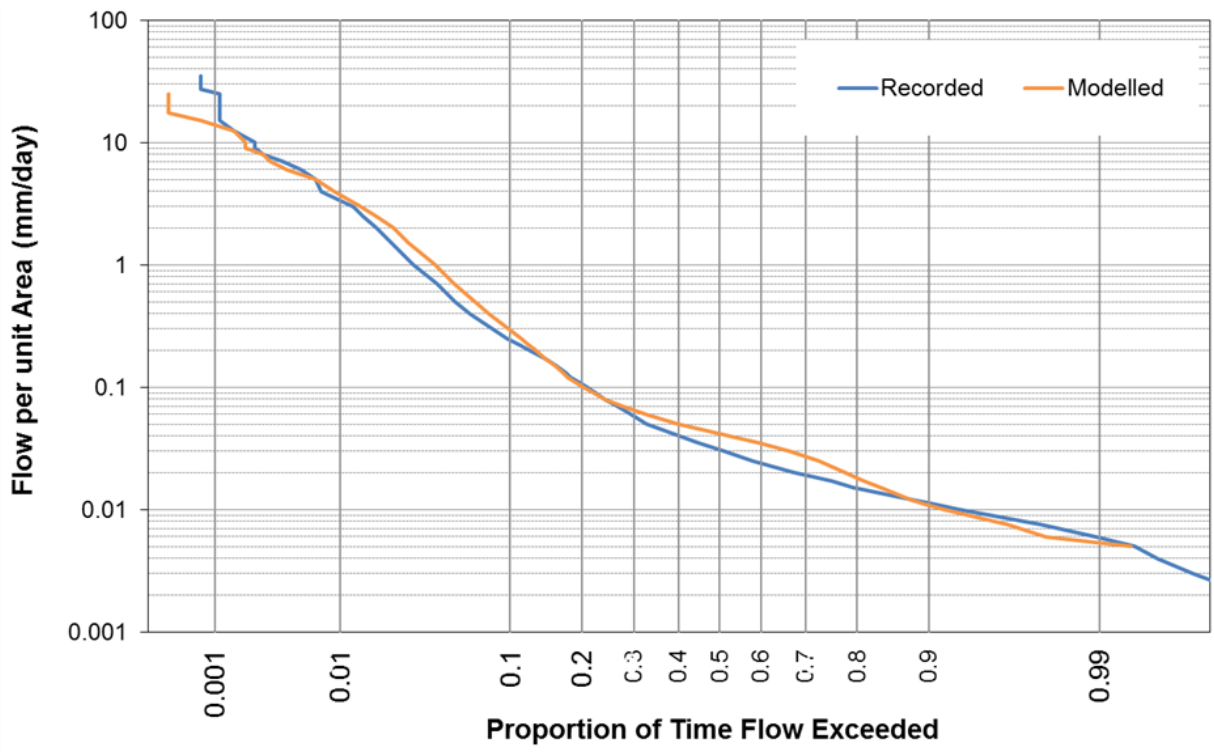

Figure 17 Modelled and Recorded Flow Duration Curves - Bargo River Upstream (GS 300010a)

Figure 16 illustrates that the general trend in streamflow rates for Bargo River Upstream is well replicated by the AWBM, although very low flow periods appear to be slightly over-estimated as evidenced by the flow duration curve (Figure 17). Because the streamflow rating for high flows is extrapolated, there is some variation in recorded and modelled high flow rates.

5.4 DISCUSSION

Results of catchment modelling suggest that there may be a non-negligible 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 many 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 13 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 13 Comparison of AWBM Baseflow Indices and Baseflow Recession Rates

Stream	Baseflow Index	Baseflow Recession Constant
Dog Trap Creek	0.025	0.97
Eliza Creek	0.2	0.985
Bargo River Upstream	0.157	0.995

Table 14 summarises statistical parameters of model fit which have been identified from and calculated in accordance with Vaze et al. (2011).

Table 14 AWBM Statistical Metrics

Stream/Gauging Station	Ratio of Model to Recorded Streamflow	Coefficient of Determination on Monthly Flows (r^2)	Nash Sutcliffe Coefficient of Efficiency on Monthly Flows
Dog Trap Creek (GS 300063)	97.3%	0.77	0.77
Eliza Creek (GS 300073)	97.2%	0.76	0.76
Bargo River Upstream (GS 300010a)	105%	0.72	0.62

Vaze et al. (2011) suggest that modelled and recorded streamflow volumes should match to within 5%. As shown in Table 14, modelled to recorded streamflow volumes match to within 2.7% for Dog Trap Creek, 2.8% for Eliza Creek and 5% for Bargo River Upstream.

The Nash Sutcliffe coefficient of efficiency (NSE) is indicative of the predictive power or accuracy of the hydrological model. Moriasi et al. (2007) suggest that a NSE on monthly streamflows of $0.75 < NSE < 1.0$ is a very good performance rating, $0.65 < NSE < 0.75$ is good and $0.5 < NSE < 0.65$ is satisfactory. Based on the metrics presented in Table 14, the NSE for Dog Trap Creek and Eliza Creek indicate a very good performance rating between recorded and modelled flows while a satisfactory performance rating has been achieved for Bargo River Upstream.

The coefficient of determination on monthly flows (r^2) quantifies the degree of correlation between recorded and modelled streamflow rates and is representative of the proportion of variance in the recorded data which is able to be replicated or explained by the model. The r^2 values in Table 14 indicate that the Dog Trap Creek model explains 77% of the variability in the recorded data, the Eliza Creek model explains 76% and the Bargo River Upstream model explains 72%. Values of r^2 greater than 0.5 are generally considered acceptable (Moriasi et al., 2007).

6.0 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 10^{th} 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 consecutive 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 using the calibrated models described in Section 5.0 above. The models were run over for a 131 year period of SILO Data Drill climatic data to produce estimates of the corresponding flows that would have occurred under these climatic conditions.

6.1 ELIZA CREEK FLOW CHARACTERISTICS

The baseline flow characteristics for Eliza Creek are presented in Table 15 and Figure 18 and Figure 19 below.

Table 15 Baseline Flow Statistics – Eliza Creek at (GS 300073)

Statistic	Value
Mean Daily Flow (ML/day)	1.46
Median Daily Flow (ML/day)	0.15
Average Annual Yield (% Rainfall)	14
Base Flow Index	0.20
Flow Variability	9.5

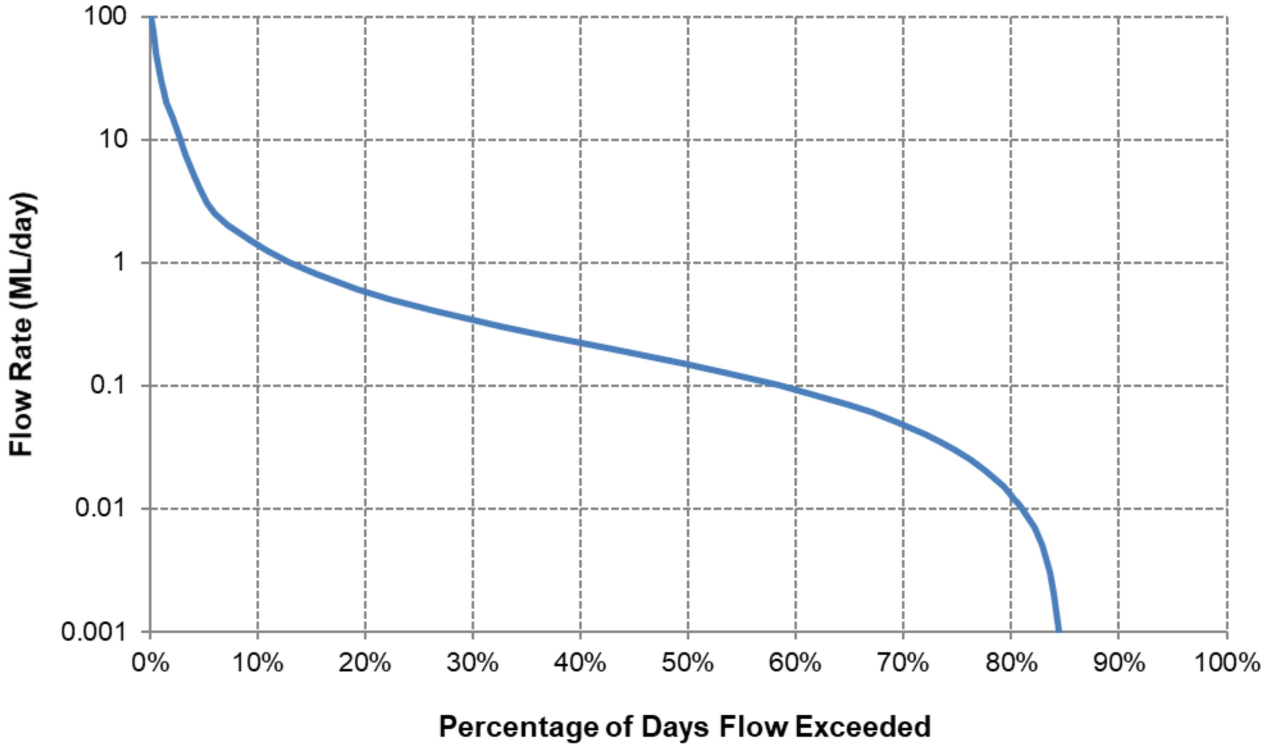

Figure 18 Daily Flow Duration Curve – Eliza Creek at GS 300073

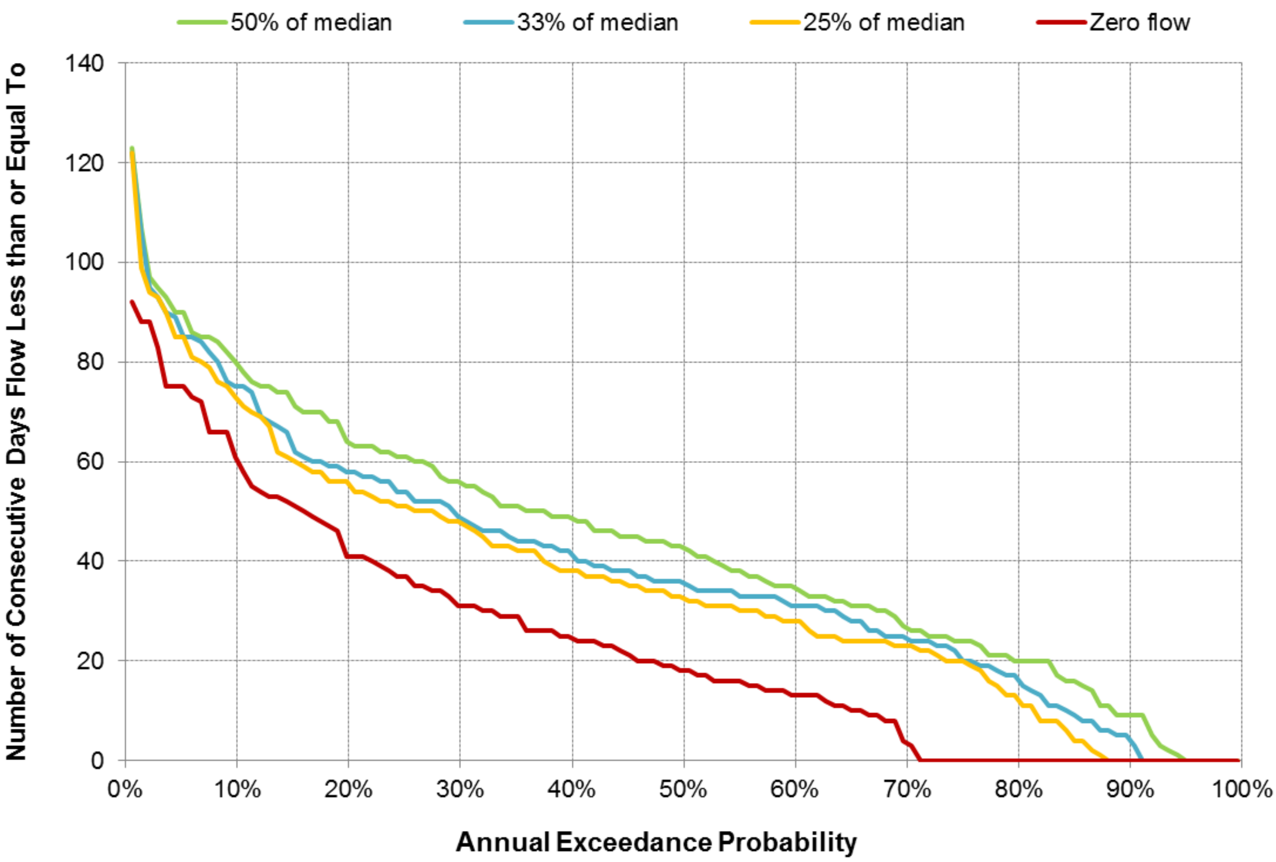

Figure 19 Low Flow Duration Exceedance Characteristics - Eliza Creek at GS 300073

6.2 DOG TRAP CREEK FLOW CHARACTERISTICS

The baseline flow characteristics of Dog Trap Creek (Downstream) as calculated from the catchment model run using a 131 year period of the SILO Data Drill are presented in Table 16, Figure 20 and Figure 21 below.

Table 16 Baseline Flow Statistics – Dog Trap Creek Downstream (GS 300063)

Statistic	Value
Mean Daily Flow (ML/day)	7.76
Median Daily Flow (ML/day)	0.09
Average Annual Yield (% Rainfall)	76
Base Flow Index	0.03
Flow Variability	81.2

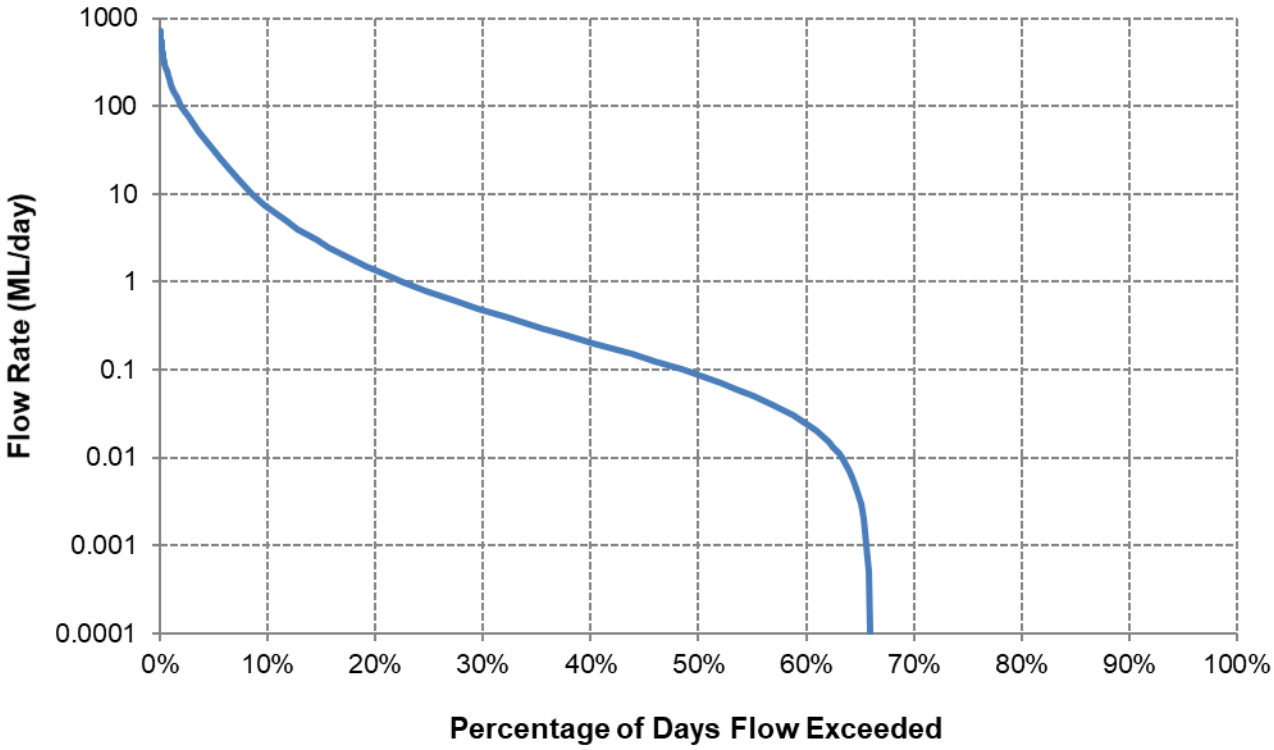

Figure 20 Daily Flow Duration Curve – Dog Trap Creek Downstream (GS 300063)

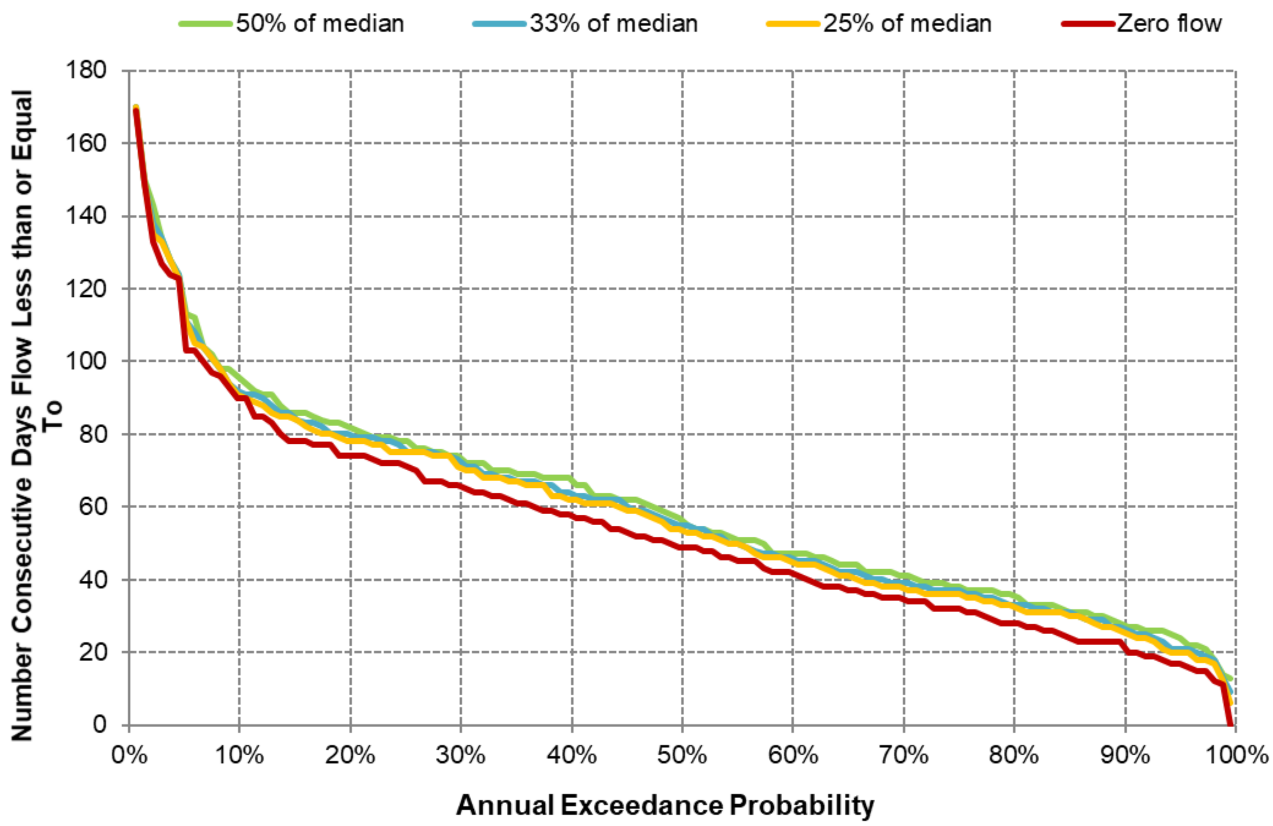

Figure 21 Low Flow Duration Exceedance Characteristics - Dog Trap Creek Downstream (GS 300063)

6.3 BARGO RIVER UPSTREAM FLOW CHARACTERISTICS

The baseline flow characteristics of the Bargo River Upstream as calculated from the catchment model run using a 131 year period of the SILO Data Drill are presented in Table 17, Figure 22 and Figure 23 below.

Table 17 Baseline Flow Statistics – Bargo River Upstream (GS 300010a)

Statistic	Value
Mean Daily Flow (ML/day)	30.1
Median Daily Flow (ML/day)	4.14
Average Annual Yield (% Rainfall)	12%
Base Flow Index	0.16
Flow Variability	8.8

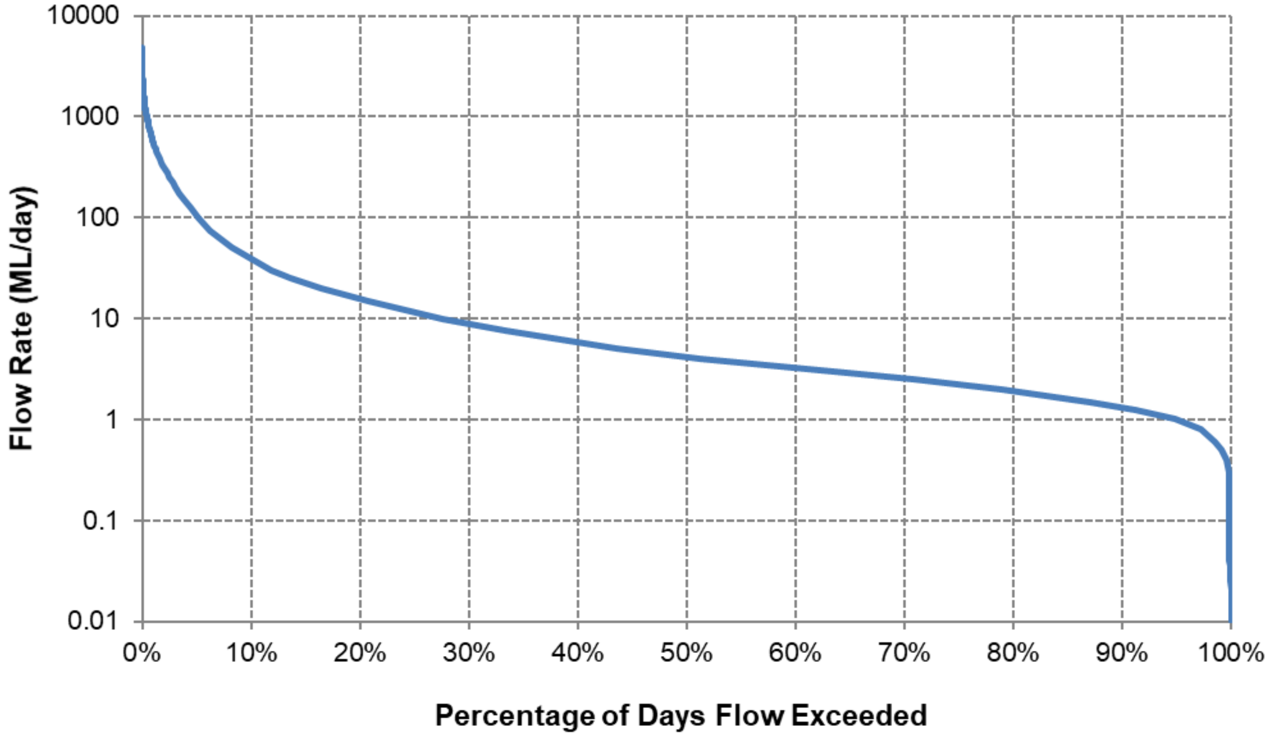

Figure 22 Daily Flow Duration Curve – Bargo River Upstream (GS 300010a)

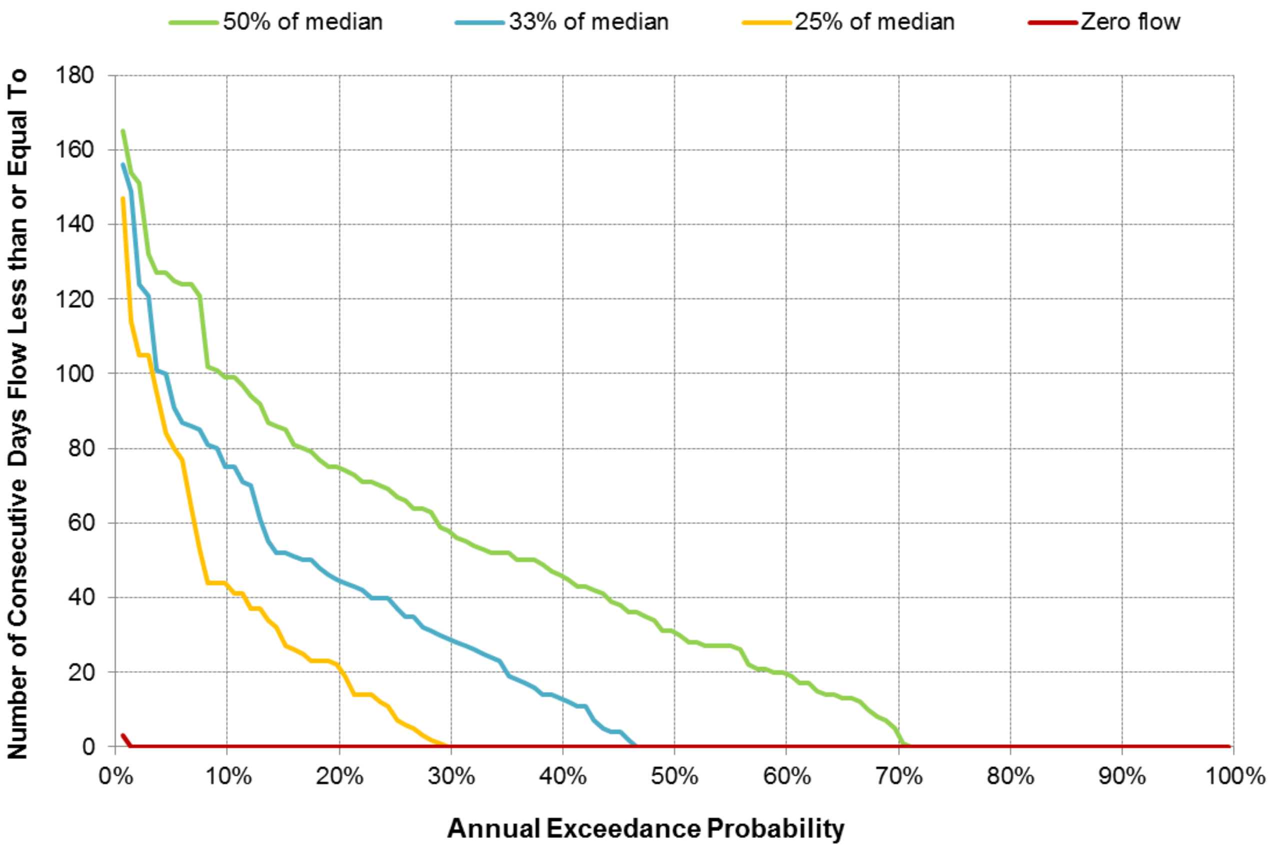

Figure 23 Low Flow Duration Exceedance Characteristics –- Bargo River Upstream (GS 300010a)

6.4 TEA TREE HOLLOW FLOW CHARACTERISTICS

The baseline low flow characteristics of Tea Tree Hollow have been estimated assuming a constant release rate of 3.9 ML/day based on the average daily release rate from the Tahmoor Mine in 2018 (SIMEC, 2019). 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 18. The modelled flow duration curve is shown in Figure 24.

Table 18 Baseline Flow Statistics –Tea Tree Hollow (GS 300056)

Statistic	Value
Mean Daily Flow (ML/day)	6.7
Median Daily Flow (ML/day)	4.2
Flow Variability	0.6

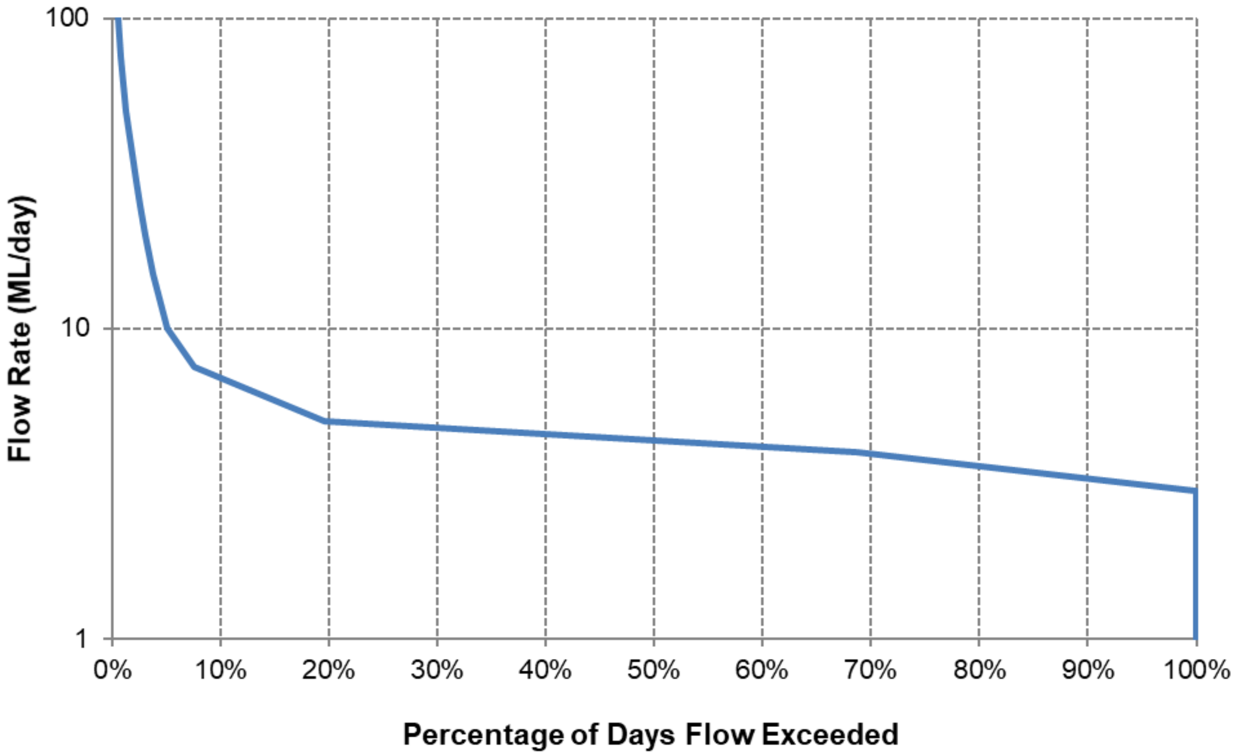

Figure 24 Daily Flow Duration Curve – Tea Tree Hollow at GS 300056 Downstream of Tahmoor Mine Release

6.5 CARTERS CREEK FLOW CHARACTERISTICS

The monitored flow data for Carters Creek has exhibited broadly similar hydrological behaviour during periods of low flow as Dog Trap Creek – refer Figure 25. As such, 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.

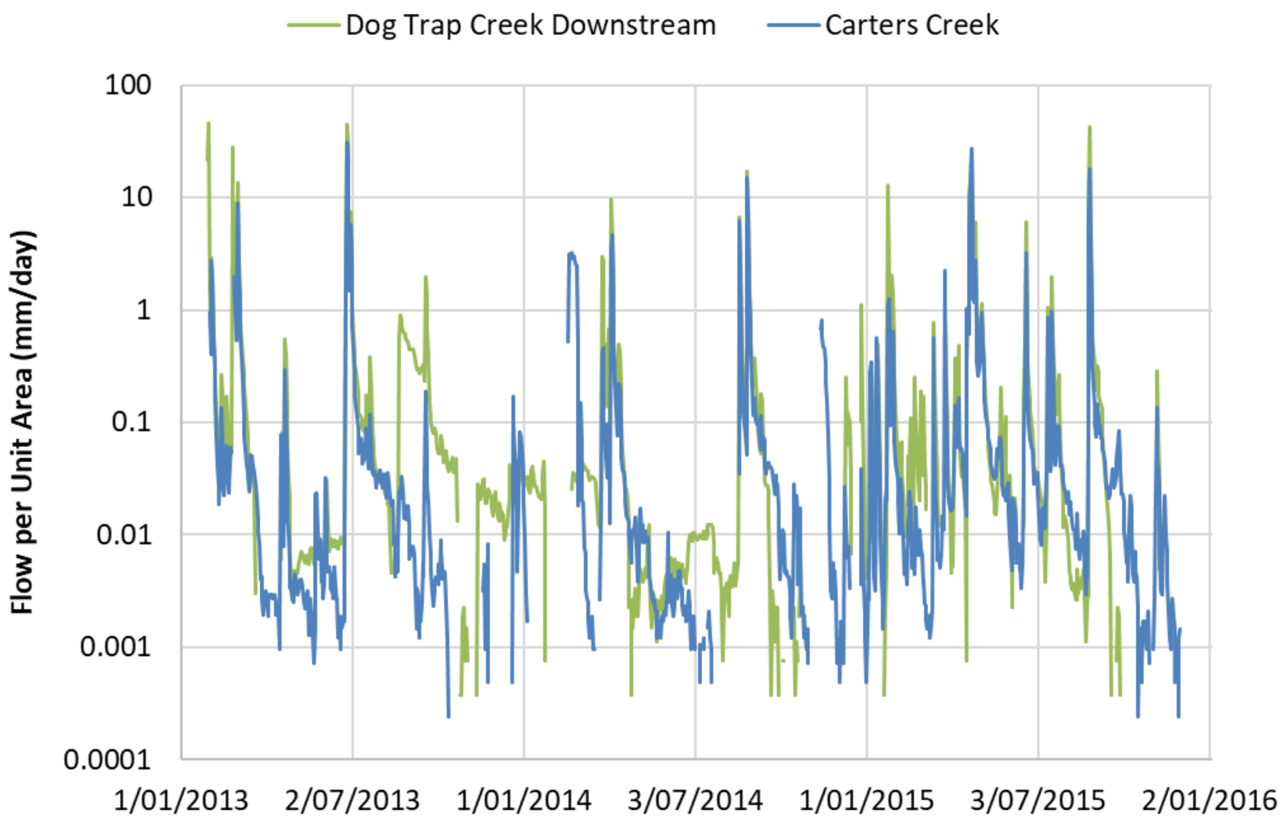

Figure 25 Comparative Recorded Flows - Carters and Dog Trap Creeks

The baseline flow characteristics of Carters Creek as calculated from the catchment model run using a 131 year period of the SILO Data Drill are presented in Table 19 and Figure 26 below.

Table 19 Baseline Flow Statistics – Carters Creek (300076)

Statistic	Value
Mean Daily Flow (ML/day)	3.3
Median Daily Flow (ML/day)	0.04
Average Annual Yield (% Rainfall)	24
Base Flow Index	0.03
Flow Variability	81.2

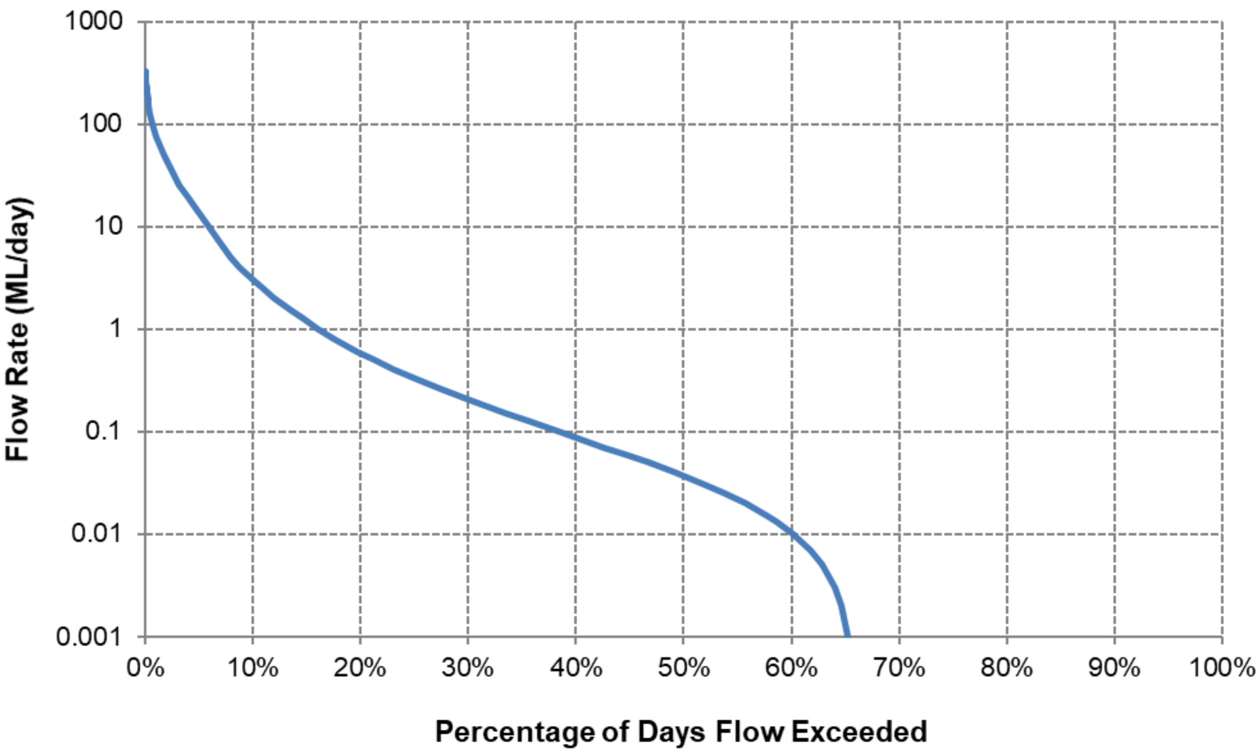

Figure 26 Daily Flow Duration Curve – Carters Creek (GS 300076)

6.6 COW CREEK FLOW CHARACTERISTICS

The monitored flow data for Cow Creek has exhibited broadly similar hydrological behaviour during periods of low flow as Eliza Creek – refer Figure 27. As such, 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.

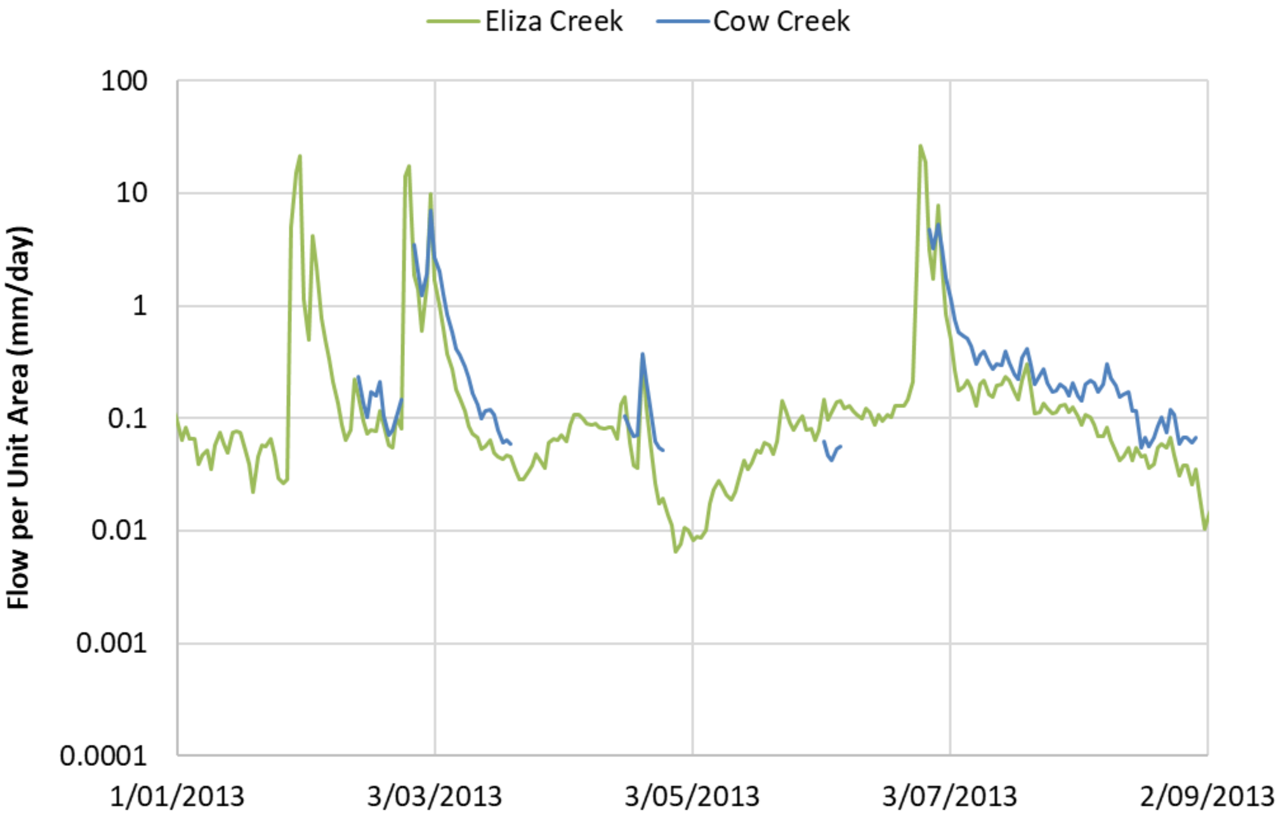

Figure 27 Comparative Recorded Flows - Cow and Eliza Creeks

The baseline flow characteristics of Cow Creek as calculated from the catchment model run using a 131 year period of the SILO Data Drill are presented in Table 20 and Figure 28 below.

Table 20 Baseline Flow Statistics – Cow Creek (300075)

Statistic	Value
Mean Daily Flow (ML/day)	1.85
Median Daily Flow (ML/day)	0.19
Average Annual Yield (% Rainfall)	17
Base Flow Index	0.20
Flow Variability	9.5

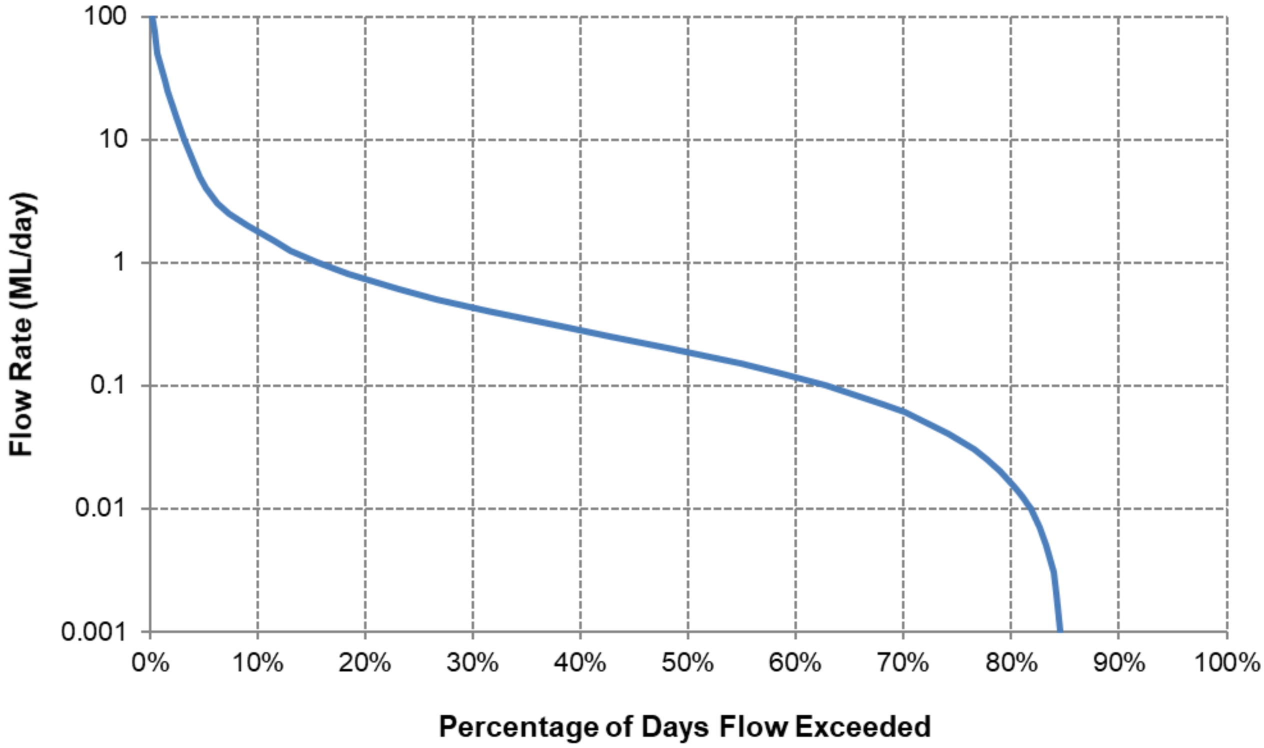

Figure 28 Daily Flow Duration Curve – Cow Creek (GS 300075)

7.0 BASELINE WATER QUALITY DATA

Water quality monitoring has been conducted at or at sites adjacent to all baseline flow gauging station sites in the Project Area. Additionally, water quality monitoring has been undertaken at Licenced Discharge Point (LDP) 1 and at site water storages which discharge to a Licenced Overflow Point (LOP).

For comparative purposes and to provide an indication of baseline conditions, the baseline water quality data has been compared with the ANZECC (2000) and ANZG (2018) default guideline trigger levels for the protection of aquatic ecosystems and recreational use in accordance with the perceived principal beneficial uses of the surface water resources in the area. The default guideline trigger values used in the assessment are summarised in Table 21.

The recreational guideline values are based on the *Australian Drinking Water Guidelines* (NHMRC, 2011) which are derived assuming the consumption of 2 Litres (L) per day. The *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008) state that, when applying the values to recreational water exposure, consumption of 100-200 millilitres (mL) per day should be taken into consideration, as opposed to 2 L per day for which the drinking water guideline values have been derived. The values presented in Table 21 for recreational use are based on the consumption of 2 L per day and are therefore highly conservative.

Table 21 Water Quality Triggers used in Baseline Water Quality Assessment

Parameter	ANZECC (2000) & ANZG (2018) Water Quality 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
Escherichia coli (CFU/100 mL)	150		

* Electrical conductivity – a measure of salinity

7.1 LICENCED RELEASE WATER QUALITY DATA

Under EPL 1389, discharge to Tea Tree Hollow is licenced at the following four locations (SIMEC, 2019):

- 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.

Water quality monitoring has been undertaken each month since March 2010 at LDP1, since April 2017 at dam S9 and since April 2015 at dam S4 and S8. An extensive range of constituents have been monitored including:

- a full suite of metals (dissolved and total);
- physicochemical parameters;
- nutrients;
- oil and grease; and
- *Escherichia coli* and flagellates.

The wider suite of constituents is monitored annually, while specific constituents of interest are monitored monthly.

Table 22 presents a summary of the water quality data in comparison with the default water quality trigger values presented in Table 21 and the water quality limits for LDP1. Where 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. For constituents which do not have a limit under EPL 1389 and the median value exceeds the lowest default water quality trigger value, the value has been shaded.

Table 22 LDP1 Water Quality Summary

Constituent	ANZECC(2000) & ANZG (2018) Default Guideline Value			LDP1 Limit	LDP1			
	95%ile level of species protection	Upland rivers	Recreational Use		No. of Samples	Minimum	Median	Maximum
pH	6.5 - 8	-	6.5 - 8.5	6.5 - 9	58	8	8.5	9
Turbidity (NTU)	-	2 - 25	100	150	58	0.6	4.8	33.6
EC (µS/cm)	-	30 - 350	1,000	2,600	58	1,420	2,025	2,400
Oil & Grease (mg/L)	-	-	-	10	58	5	5	5
Escherichia coli (CFU/100 mL)	-	-	1,000*	-	57	1	48	1,700
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	-	-	500	-	5	823	994	1,020
Sulphate as SO_4 (mg/L)	-	-	400	-	5	10	11	17
Chloride (mg/L)	-	-	400	-	57	51	78	123
Calcium - Dissolved (mg/L)	-	-	-	-	57	7	23	44
Magnesium (mg/L)	-	-	-	-	57	7	14	22
Sodium (mg/L)	-	-	300	-	57	367	452	655
Potassium (mg/L)	-	-	-	-	57	18	25	34
Aluminium - Total (mg/L)	0.055	-	0.2	-	2	0.03	0.07	0.11
Arsenic - Total (mg/L)	0.024	-	0.05	0.2	58	0.012	0.05	0.146
Barium - Total (mg/L)	-	-	1.0	-	57	1.66	4.43	6.44
Cadmium - Total (mg/L)	0.0002	-	0.005	-	5	0.0001	0.0001	0.0001
Chromium - Total (mg/L)		-	0.05	-	5	0.001	0.001	0.001
Copper - Total (mg/L)	0.0014	-	1.0	-	7	0.001	0.003	0.005
Iron - Total (mg/L)		-	0.3	-	57	0.05	0.14	1.59
Lead - Total (mg/L)	0.0034	-	0.05	-	5	0.001	0.001	0.003
Manganese - Total (mg/L)	1.9	-	-	-	7	0.017	0.038	0.076
Mercury - Total (mg/L)	0.0006	-	0.001	-	5	0.0001	0.0001	0.0001
Nickel - Total (mg/L)	0.011	-	-	0.2	58	0.043	0.063	0.084
Selenium - Total (mg/L)	0.011	-	0.01	-	5	0.01	0.01	0.01
Zinc - Total (mg/L)	0.008	-	5.0	0.3	58	0.03	0.06	0.24

* Median bacterial content for secondary contact in fresh and marine waters

Table 22 illustrates that the water quality limits specified in EPL 1389 have not been exceeded at LDP1. The median concentration of sodium, barium and bicarbonate alkalinity exceeded the default guideline trigger value for recreational use while the median concentration of aluminium and copper exceeded the default guideline trigger value for the 95% level of species protection.

Table 26 presents a summary of the water quality data in comparison with the ANZECC (2000) aquatic ecosystem (95% level of species protection and NSW upland rivers) and recreational default guideline trigger values. For comparative purposes, the water quality limits for LDP1 are also presented however these limits do not apply to the LOPs.

Where the median value for each LOP exceeds the ANZECC (2000) aquatic ecosystem default guideline trigger value, the value has been shaded. It should be noted that water quality data is monitored on a monthly basis whereas the monitoring of overflow volumes is event based. Therefore, the water quality data summarised below is not necessarily indicative of the water quality during overflow periods. Table 3, Section 2.4, of the Water Management Strategy and Site Water Balance (HEC, 2020b) presents the LOP overflow volumes for 2014 to 2018.

Table 23 LOP Water Quality Summary

Constituent	ANZECC (2000) Default Guideline Trigger Value			LDP1 Limit	LOP3				LOP4				LOP5			
	95%ile level of species protection	Upland rivers	Recreational Use		No. of Samples	Minimum	Median	Maximum	No. of Samples	Minimum	Median	Maximum	No. of Samples	Minimum	Median	Maximum
pH Unit (pH Unit)	6.5 - 8	-	6.5 - 8.5	6.5 - 9	31	7.1	8.4	9.0	56	8.2	9.0	9.7	57	6.7	7.3	8.5
Turbidity (NTU)	-	2 - 25	100	150	31	1.7	12.5	454.0	56	2.5	16.5	1,340	57	0.5	3.8	157.0
Electrical Conductivity (µS/cm)	-	30 - 350	1,000	2,600	31	166	1,680	2330	56	504	1,830	2,460	57	311	1,740	2,150
Dissolved Oxygen (mg/L)	-	-	-	-	3	7.9	9.9	9.9	5	7.4	8.5	9.9	5	5.5	5.7	8.0
Dissolved Oxygen (% saturation)	-	90-110	-	-	2	98	100	102	4	86	107	122	4	60	64	104
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	-	-	500	-	3	823	933	947	5	565	804	946	6	874	989	1,100
Ammonia as N (mg/L)	-	-	-	-	3	0.16	0.18	0.48	5	0.01	0.15	0.18	5	0.08	0.18	0.75
Total Nitrogen as N (mg/L)	0.25	-	-	-	3	0.30	0.70	2.30	5	0.80	2.60	7.10	5	0.30	0.90	9.40
Total Phosphorus as P (mg/L)	0.02	-	-	-	3	0.01	0.01	0.01	5	0.01	0.03	0.58	5	0.01	0.01	0.02
Total Suspended Solids (mg/L)	-	-	-	-	31	5.0	10.0	174.0	56	5.0	14.0	480.0	57	5.0	5.0	54.0
Oil & Grease (mg/L)	-	-	-	10	31	5.0	5.0	8.0	56	5.0	5.0	9.0	57	5.0	5.0	7.0
Escherichia coli (CFU/100mL)	-	-	150	-	16	1	150	4,300	36	11	175	2,000	22	1	34	880
Chloride (mg/L)	-	-	400	-	30	9.0	17.5	43.0	55	13.0	33.0	74.0	55	8.0	14.0	37.0
Fluoride (mg/L)	-	-	-	-	3	0.20	0.20	0.20	4	0.20	0.30	0.30	5	0.20	0.20	0.30
Sulphate as SO_4 (mg/L)	-	-	400	-	3	16	20	21	5	1	11	19	6	12	21	30

Table 23 (Continued) LOP Water Quality Summary

Constituent	ANZECC (2000) Default Guideline Trigger Value		LDP1 Limit	LOP3				LOP4				LOP5			
	95%ile level of species protection	Recreational Use		No. of Samples	Minimum	Median	Maximum	No. of Samples	Minimum	Median	Maximum	No. of Samples	Minimum	Median	Maximum
Aluminium - Total (mg/L)	0.055	0.2	-	-	-	-	-	2	0.22	0.93	1.64	3	0.03	0.05	2.07
Arsenic - Total (mg/L)	0.024	0.05	0.2	31	0.001	0.002	0.01	56	0.001	0.01	0.09	57	0.001	0.001	0.00
Barium - Total (mg/L)	-	1	-	30	0.2	0.7	2.3	55	0.1	1.7	4.1	56	0.5	0.8	2.5
Boron - Total (mg/L)	0.37	1	-	3	0.06	0.06	0.07	5	0.05	0.05	0.07	5	0.05	0.06	0.07
Cadmium - Total (mg/L)	0.0002	0.005	-	3	0.0001	0.0001	0.0001	5	0.0001	0.0001	0.0001	6	0.0001	0.0001	59
Calcium - Dissolved (mg/L)	-	-	-	30	5.0	26.5	55.0	55	4.0	12.0	35.0	55	10.0	57.0	76.0
Chromium - Total (mg/L)	-	0.05	-	3	0.001	0.001	0.001	5	0.001	0.001	0.003	5	0.001	0.001	0.001
Cobalt - Total (mg/L)	-		-	3	0.001	0.001	0.001	5	0.001	0.001	0.004	5	0.001	0.001	0.001
Copper - Total (mg/L)	0.0014	1	-	3	0.001	0.001	0.006	7	0.001	0.002	0.004	8	0.001	0.001	0.003
Cyanide - Total (mg/L)	-	-	-	3	0.004	0.004	0.004	5	0.004	0.004	0.004	5	0.004	0.004	0.004
Iron - Total (mg/L)	-	0.3	-	30	0.06	0.42	2.18	55	0.05	0.10	4.68	56	0.05	0.28	1.37
Lead - Total (mg/L)	0.0034	0.05	-	3	0.001	0.001	0.001	5	0.001	0.001	0.002	5	0.001	0.001	0.001
Manganese - Total (mg/L)	1.9	-	-	3	0.01	0.01	0.01	7	0.00	0.01	0.02	8	0.01	0.04	0.14
Mercury - Total (mg/L)	0.0006	0.001	-	3	0.0001	0.0001	0.0001	5	0.0001	0.0001	0.0001	5	0.0001	0.0001	0.0001
Nickel - Total (mg/L)	0.011	-	0.2	31	0.00	0.02	0.03	56	0.00	0.02	0.06	57	0.01	0.02	0.03
Selenium - Total (mg/L)	0.011	0.01	-	3	0.01	0.01	0.01	5	0.01	0.01	0.01	5	0.01	0.01	0.01
Silver - Total (mg/L)	-	-	-	3	0.001	0.001	0.001	5	0.001	0.001	0.001	5	0.001	0.001	0.001
Zinc - Total (mg/L)	0.008	5	0.3	31	0.005	0.005	0.031	56	0.005	0.005	0.050	57	0.005	0.005	0.218

Table 23 shows that the median pH value recorded at LOP3 and LOP4 exceeded the ANZECC (2000) default guideline trigger value for aquatic ecosystems however was less than or equivalent to the LDP1 discharge limit. The median electrical conductivity values and nickel concentrations recorded at LOP3, LOP4 and LOP5 exceeded the default guideline trigger value for aquatic ecosystems however were less than the LDP1 discharge limit. Median concentrations of total nitrogen recorded at each LOP exceeded the default guideline trigger value for aquatic ecosystems, while the median concentration for total phosphorus, aluminium and copper also exceeded the guideline value at LOP4.

7.2 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 derivation of appropriate water quality guideline trigger values for each site has been undertaken in accordance with the ANZECC (2000) Guidelines and the revised Water Quality Guidelines (ANZG, 2018) which are progressively superseding the ANZECC (2000) Guidelines. The "reference-site data" approach detailed in the ANZG (2018) was used to assess baseline water quality conditions and develop site specific trigger values for which to assess potential water quality impacts against. The ANZG (2018) states that, for modified ecosystems, 'best available' reference sites should be adopted for providing reference conditions. If the water quality monitored at the assessment or impact site following Project development departs in a meaningful way from the reference condition, then the site is assessed to be affected in some way.

As the Project is located within a modified ecosystem i.e. urban, agricultural, industrial and resource development has been undertaken previously in the catchment area, the 'best available' reference sites have been adopted. The sites, listed in Table 11 of Section 4.2, enable water quality reference conditions to be developed for control and baseline sites. Site specific trigger values (SSTVs) have been derived from the monitored data as the 80th percentile of monitored values where sufficient monitored data are available to derive this statistic (a minimum of ten records).

The aim of the SSTVs is to provide a baseline against which to compare future monitored water quality in order to assess if an impact may be occurring. The measured data following each monitoring event, in addition to the annual median of measured data, will be compared with the SSTVs. Should an exceedance be identified, this will lead to the gathering of additional information or further investigation to determine whether an impact has occurred and if there is a risk to the environment. It is intended that the SSTVs will be incorporated into water quality Trigger Action Response Plans (TARPs) for sites downstream of the Project Area.

Data collected from the commencement of monitoring in September 2012 to September 2019 are summarised in a series of tables below (refer Table 24 to Table 35). 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.

Table 24 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)	37	1	14	7	11	-	0
Sulphate (mg/L)	37	1	19	3	5	-	0
Chloride (mg/L)	37	22	65	46	53.8	-	0
Calcium (mg/L)	37	1	4	3	3	-	-
Magnesium (mg/L)	37	2	7	5	6	-	-
Sodium (mg/L)	37	14	28	22	24	-	0
Potassium (mg/L)	37	1	4	2	2	-	-
Aluminium (mg/L)	37	0.01	0.82	0.05	0.10	17	5
Arsenic (mg/L)	37	0.001	0.001	0.001	0.001	0	0
Barium (mg/L)	37	0.008	0.052	0.013	0.018	-	0
Cadmium (mg/L)	29	0.0001	0.031	0.0001	0.005	7	6
Chromium (mg/L)	29	0.0001	0.001	0.001	0.001	-	0
Copper (mg/L)	34	0.001	0.001	0.001	0.001	0	0
Lead (mg/L)	37	0.001	0.002	0.001	0.001	0	0
Selenium (mg/L)	37	0.001	0.02	0.01	0.01	1	1
Zinc (mg/L)	37	0.001	0.143	0.005	0.01	13	0
Iron (mg/L)	37	0.15	6.15	0.80	1.12	-	32
Mercury (mg/L)	21	0.0001	0.0001	0.0001	0.0001	0	0
pH	36	5.87	8.84	6.96	6.44, 7.63	14	9
Turbidity (NTU)	28	0	24.5	4.6	10.6	0	0
EC (µS/cm)	36	104	236	168	197	0	0

There was one exceedance of the aquatic ecosystem and recreational default guideline trigger values for selenium, thirteen exceedances of the aquatic ecosystem default guideline trigger value for zinc and all but five samples exceeded the default 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 and the recreational guideline default trigger value for aluminium. There were seven exceedances of the aquatic ecosystem default guideline trigger for cadmium and pH fell outside the aquatic ecosystem guideline range fourteen times. All other parameters were below default guideline trigger values.

Table 25 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)	45	1	116	17	29	-	0
Sulphate (mg/L)	45	2	29	8	12	-	0
Chloride (mg/L)	45	16	250	80	172	-	0
Calcium (mg/L)	45	3	9	5	7	-	-
Magnesium (mg/L)	45	2	17	7	13.2	-	-
Sodium (mg/L)	45	13	96	45	70.8	-	0
Potassium (mg/L)	45	1	5	3	4	-	-
Aluminium (mg/L)	45	0.01	1.94	0.08	0.46	33	17
Arsenic (mg/L)	45	0.001	0.01	0.001	0.001	0	0
Barium (mg/L)	45	0.017	0.34	0.042	0.189	-	0
Cadmium (mg/L)	39	0.0001	0.245	0.0001	0.0001	5	4
Chromium (mg/L)	39	0.0001	0.002	0.001	0.001	-	0
Copper (mg/L)	42	0.001	0.032	0.001	0.001	8	0
Lead (mg/L)	45	0.001	0.003	0.001	0.001	0	0
Selenium (mg/L)	45	0.001	0.1	0.01	0.013	9	9
Zinc (mg/L)	45	0.005	0.172	0.016	0.05	35	0
Iron (mg/L)	37	0.87	25.8	2.18	9.5	-	37
Mercury (mg/L)	31	0.0001	0.0001	0.0001	0.0001	0	0
pH	45	4.02	9.21	6.64	5.7, 7.1	22	21
Turbidity (NTU)	39	0	113	11.1	35.8	10	1
EC (µS/cm)	45	31	938	321	666	21	0

Of the up to forty-five samples collected from Hornes Creek at SW-9, thirty-five exceeded the default guideline trigger value for protection of aquatic ecosystems for zinc. There were five exceedances of the default guideline trigger value for protection of aquatic ecosystems for cadmium and eight for copper. There were thirty-seven exceedances of the iron default guideline trigger value for recreational use. There were twenty-two exceedances of the aquatic ecosystem default guideline trigger range for pH (with pH both above and below the respective upper and lower guideline values), five exceedances of the turbidity guideline trigger value and twenty-one exceedances of the EC default guideline trigger value. There have also been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium and selenium. The median concentrations of aluminium and zinc exceeded the default guideline trigger values for protection of aquatic ecosystems.

Table 26 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)	43	1	10	6	8.6	-	0
Sulphate (mg/L)	43	2	14	5	6	-	0
Chloride (mg/L)	43	21	74	50	62.6	-	0
Calcium (mg/L)	43	1	4	3	3.6	-	-
Magnesium (mg/L)	43	1	8	5	6	-	-
Sodium (mg/L)	43	12	38	26	30	-	0
Potassium (mg/L)	43	1	5	2	3	-	-
Aluminium (mg/L)	43	0.01	1.03	0.08	0.44	23	13
Arsenic (mg/L)	43	0.001	0.006	0.001	0.001	0	0
Barium (mg/L)	43	0.01	0.088	0.02	0.028	-	0
Cadmium (mg/L)	36	0.0001	0.026	0.0001	0.0001	6	6
Chromium (mg/L)	36	0.001	0.003	0.001	0.001	-	0
Copper (mg/L)	40	0.001	0.004	0.001	0.001	6	0
Lead (mg/L)	43	0.001	0.002	0.001	0.001	0	0
Selenium (mg/L)	43	0.001	0.032	0.01	0.0148	9	9
Zinc (mg/L)	43	0.005	0.05	0.01	0.0444	29	0
Iron (mg/L)	35	0.01	3.28	1.1	1.83	-	27
Mercury (mg/L)	28	0.0001	0.0001	0.0001	0.0001	0	0
pH	42	3.73	10.1	7	6.6, 7.488	11	10
Turbidity (NTU)	35	0	46.2	8.5	14.78	4	0
EC (µS/cm)	43	19	320	189	241.6	0	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. Twenty-nine of the samples collected at the Bargo River Upstream exceeded the zinc default guideline trigger value for protection of aquatic ecosystems. There were twenty-seven exceedances of the iron default guideline trigger value for recreational use and one for barium. There have also been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium and cadmium. The median concentrations of aluminium and zinc exceeded the default guideline default trigger values for protection of aquatic ecosystems. Both pH and turbidity have also exceeded default guideline trigger values for protection of aquatic ecosystems, with the pH value both above and below the respective upper and lower guideline trigger values.

Table 27 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)	43	21	822	460	595.2	-	19
Sulphate (mg/L)	43	1	23	11	15	-	0
Chloride (mg/L)	43	21	90	67	75.6	-	0
Calcium (mg/L)	43	1	17	11	13	-	-
Magnesium (mg/L)	43	1	14	10	12	-	-
Sodium (mg/L)	43	19	407	264	340.8	-	18
Potassium (mg/L)	43	2	27	16	21	-	-
Aluminium (mg/L)	43	0.03	1.3	0.14	0.256	35	13
Arsenic (mg/L)	43	0.001	0.086	0.024	0.058	20	13
Barium (mg/L)	43	0.07	4.56	1.24	2.46	-	29
Cadmium (mg/L)	36	0.0001	2.66	0.0001	0.0001	6	6
Chromium (mg/L)	36	0.001	0.002	0.001	0.001	-	0
Copper (mg/L)	40	0.001	0.012	0.001	0.002	15	0
Lead (mg/L)	43	0.001	0.007	0.001	0.002	4	0
Selenium (mg/L)	43	0.001	0.563	0.01	0.07	14	14
Zinc (mg/L)	43	0.007	0.11	0.035	0.052	40	0
Iron (mg/L)	35	0.01	1.61	0.39	0.79	-	18
Mercury (mg/L)	28	0.0001	0.0001	0.0001	0.0001	0	0
pH	43	3.69	9.7	8.63	8.19, 8.90	38	30
Turbidity (NTU)	35	0	39.5	8.4	16.1	2	0
EC (µS/cm)	43	1.47	1730	1053	1396	35	23

The concentrations of bicarbonate, sodium and barium at the Bargo River at Rockford Bridge – SW-14 were notably higher than at the upstream sites on the Bargo River (i.e. at SW-1 and SW-13). There were nineteen exceedances of the default guideline trigger value for recreational use for bicarbonate, eighteen for sodium and twenty-nine for barium. There were also twenty exceedances of the default guideline trigger value for protection of aquatic ecosystems for arsenic. It is inferred that this reflects the effects of licensed releases from LDP1 at the Tahmoor pit top via Tea Tree Hollow. However, it should be noted that the concentration of arsenic released at LDP1 has greatly declined since improvements have been made to the WWTP (refer Figure 34 below). Consequently, the arsenic concentrations monitored at SW-14 in 2019 did not exceed the default guideline trigger value for protection of aquatic ecosystems.

All but three of the samples collected at SW-14 exceeded the default guideline trigger value for protection of aquatic ecosystems for zinc. There were fifteen exceedances of the default guideline trigger value for protection of aquatic ecosystems for copper and four for lead. Exceedances of both zinc and copper were also recorded at control site SW-19 (Table 25). There have also been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium and selenium; exceedances for which have also been recorded at control site SW-1 (Table 24) and site SW-19 (Table 25). The median concentrations of aluminium, zinc and pH have exceeded the default guideline trigger values for protection of aquatic ecosystems. The recorded pH values have been both above and below the respective upper and lower default guideline trigger values and the EC values have been above the default guideline trigger value for thirty-five of the forty-three samples. Exceedances of these parameters have also been recorded at control site SW-19 (Table 25).

Table 28 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)	30	1	65	27	32.4	-	0
Sulphate (mg/L)	30	2	30	14.5	18.2	-	0
Chloride (mg/L)	30	25	210	46	54.4	-	0
Calcium (mg/L)	30	4	16	6	8.2	-	-
Magnesium (mg/L)	30	2	17	6	8	-	-
Sodium (mg/L)	30	12	91	28	32.2	-	0
Potassium (mg/L)	30	1	12	7	8	-	-
Aluminium (mg/L)	30	0.03	1.86	0.39	0.71	27	24
Arsenic (mg/L)	30	0.001	0.01	0.001	0.001	0	0
Barium (mg/L)	30	0.016	0.244	0.02	0.028	-	0
Cadmium (mg/L)	25	0.0001	0.019	0.0001	0.0001	1	1
Chromium (mg/L)	25	0.001	0.002	0.001	0.001	-	0
Copper (mg/L)	27	0.001	0.004	0.001	0.002	7	0
Lead (mg/L)	30	0.001	0.002	0.001	0.001	0	0
Selenium (mg/L)	29	0.01	0.082	0.01	0.019	6	6
Zinc (mg/L)	29	0.005	0.05	0.009	0.05	15	0
Iron (mg/L)	24	0.01	1.91	0.47	0.99	-	18
Mercury (mg/L)	20	0.0001	0.0001	0.0001	0.0001	0	0
pH	28	6.38	8.46	7.14	6.9, 7.5	2	1
Turbidity (NTU)	20	5.1	106	10.45	18.64	2	1
EC (µS/cm)	25	132	327	236	267.2	0	0

At Dog Trap Creek Downstream (SW-15) there have been fifteen exceedances of the aquatic ecosystem default guideline trigger value for zinc and seven for copper. There have been eighteen exceedances of the iron default guideline trigger value for recreational use. There have also been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium, cadmium, selenium and turbidity. The median concentrations of aluminium and zinc have exceeded the default guideline trigger values for both protection of aquatic ecosystems and recreational use. Both pH and turbidity have also exceeded default guideline trigger values for protection of aquatic ecosystems, with the pH value both above and below the respective upper and lower default guideline trigger values.

Table 29 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)	37	1	88	31	36	-	0
Sulphate (mg/L)	37	1	27	15	21	-	0
Chloride (mg/L)	37	26	210	51	64.8	-	0
Calcium (mg/L)	37	4	23	7	10	-	-
Magnesium (mg/L)	37	3	17	6	8.8	-	-
Sodium (mg/L)	37	13	91	32	37	-	0
Potassium (mg/L)	37	1	12	8	9	-	-
Aluminium (mg/L)	37	0.06	1.07	0.35	0.568	37	32
Arsenic (mg/L)	37	0.001	0.003	0.001	0.001	0	0
Barium (mg/L)	37	0.017	0.244	0.024	0.032	-	0
Cadmium (mg/L)	34	0.0001	0.03	0.0001	0.0001	3	3
Chromium (mg/L)	34	0.001	0.005	0.001	0.001	-	0
Copper (mg/L)	34	0.001	0.005	0.001	0.002	9	0
Lead (mg/L)	37	0.001	0.002	0.001	0.001	0	0
Selenium (mg/L)	37	0.001	0.082	0.01	0.01	6	6
Zinc (mg/L)	37	0.005	0.05	0.007	0.017	15	0
Iron (mg/L)	32	0.01	24.8	0.475	0.928	-	24
Mercury (mg/L)	26	0.0001	0.0001	0.0001	0.0001	0	0
pH	37	6.31	9.6	7.11	6.9, 7.52	5	3
Turbidity (NTU)	33	2.6	65	10.6	23.2	6	0
EC (µS/cm)	37	31	1077	284	329.8	6	1

Water quality at the Dog Trap Creek upstream site (SW-16) was generally similar to the downstream site – refer Table 28. There have been fifteen exceedances of the aquatic ecosystem default guideline trigger value for zinc and nine for copper. There have been twenty-four exceedances of the iron default guideline trigger value for recreational use. There have also been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium, cadmium and selenium. The median concentration of aluminium exceeded the default guideline trigger value for protection of aquatic ecosystems. The pH, turbidity and EC values have also exceeded default guideline trigger values for protection of aquatic ecosystems, with the pH value both above and below the respective upper and lower guideline values.

Table 30 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)	41	9	47	24	36	-	0
Sulphate (mg/L)	41	12	80	23	28	-	0
Chloride (mg/L)	41	21	457	339	395	-	6
Calcium (mg/L)	41	4	39	13	17	-	-
Magnesium (mg/L)	41	3	46	37	41	-	-
Sodium (mg/L)	41	13	205	155	173	-	0
Potassium (mg/L)	41	4	19	6	7	-	-
Aluminium (mg/L)	41	0.01	3.29	0.02	0.47	14	12
Arsenic (mg/L)	41	0.0002	0.002	0.001	0.001	0	0
Barium (mg/L)	41	0.026	0.175	0.123	0.154	-	0
Cadmium (mg/L)	34	0.0001	0.179	0.0001	0.03006	7	7
Chromium (mg/L)	34	0.001	0.003	0.001	0.001	-	0
Copper (mg/L)	41	0.001	0.031	0.001	0.012	18	0
Lead (mg/L)	41	0.001	0.034	0.001	0.001	4	0
Selenium (mg/L)	41	0.001	0.021	0.01	0.01	6	6
Zinc (mg/L)	41	0.01	0.33	0.022	0.038	41	0
Iron (mg/L)	41	0.05	10.7	3.64	8.65	-	37
Mercury (mg/L)	31	0.0001	0.0001	0.0001	0.0001	0	0
pH	42	5.81	9.2	6.76	6.33, 7.26	14	12
Turbidity (NTU)	35	12.5	284	33.5	57	25	2
EC (µS/cm)	42	1.228	1440	1112	1313	36	24

At the Eliza Creek monitoring site (SW-18), there have been forty-one exceedances of the aquatic ecosystem default guideline trigger value for zinc, four for lead and eighteen for copper. There have been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium, cadmium, selenium and turbidity. The recreational default guideline trigger values for chloride, iron, turbidity and EC have been exceeded while the aquatic ecosystem pH value has been both above and below the respective upper and lower default guideline trigger values. The median concentration of zinc has exceeded the default guideline trigger values for protection of aquatic ecosystems. All other parameters' median values were below the default guideline trigger values. Compared to the other monitoring sites, the concentrations of sodium and chloride in Eliza Creek have been elevated.

Table 31 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	1	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	0.0005	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	0.0001	0.022	0.0001	0.0001	2	2
Chromium (mg/L)	27	0.001	0.003	0.001	0.001	-	0
Copper (mg/L)	27	0.001	0.005	0.001	0.0028	9	0
Lead (mg/L)	27	0.001	0.01	0.001	0.001	2	0
Selenium (mg/L)	27	0.001	0.01	0.01	0.01	0	0
Zinc (mg/L)	27	0.005	0.22	0.01	0.0178	19	0
Iron (mg/L)	27	0.26	14.9	0.76	1.488	-	25
Mercury (mg/L)	24	0.0001	0.0001	0.0001	0.0001	0	0
pH	28	3.67	9.43	6.91	6.506, 7.79	9	6
Turbidity (NTU)	28	6	262	15.45	26.76	7	1
EC (µS/cm)	28	154.5	442	269	304.2	2	0

At the Dry Creek monitoring site (SW-20A), there have been nineteen exceedances of the aquatic ecosystem default guideline trigger value for zinc, two for lead, nine for copper and nine for pH (with pH both above and below the respective upper and lower default guideline trigger values). There have also been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium, cadmium, turbidity and EC. There have been twenty-five exceedances of the recreational use default guideline trigger value for iron. The median concentrations of aluminium and zinc have exceeded the default guideline trigger values for protection of aquatic ecosystems.

Table 32 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)	31	9	161	52	93	-	0
Sulphate (mg/L)	31	3	6	4	5	-	0
Chloride (mg/L)	31	17	66	25	32	-	0
Calcium (mg/L)	31	1	4	3	3	-	-
Magnesium (mg/L)	31	1	8	3	4	-	-
Sodium (mg/L)	31	12	83	31	49	-	0
Potassium (mg/L)	31	1	6	2	4	-	-
Aluminium (mg/L)	31	0.02	8.25	0.14	0.26	24	11
Arsenic (mg/L)	31	0.001	0.03	0.002	0.003	1	0
Barium (mg/L)	31	0.021	0.52	0.101	0.246	-	0
Cadmium (mg/L)	31	0.0001	0.303	0.0001	0.0001	6	5
Chromium (mg/L)	31	0.001	0.008	0.001	0.001	-	0
Copper (mg/L)	28	0.001	0.003	0.001	0.002	8	0
Lead (mg/L)	31	0.001	0.017	0.001	0.001	4	0
Selenium (mg/L)	31	0.001	0.01	0.01	0.01	0	0
Zinc (mg/L)	31	0.005	0.158	0.01	0.011	18	0
Iron (mg/L)	31	0.11	24.4	0.41	0.63	-	24
Mercury (mg/L)	25	0.0001	0.0001	0.0001	0.0001	0	0
pH	32	6.58	9.34	7.71	7.11, 8.19	10	2
Turbidity (NTU)	31	1.5	65.6	10.3	18.7	4	0
EC (µS/cm)	32	23	448	161.05	257.4	2	0

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

Table 33 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)	31	591	1160	829	945	-	31
Sulphate (mg/L)	31	9	40	18	25	-	0
Chloride (mg/L)	31	53	105	78	89	-	0
Calcium (mg/L)	31	5	28	18	22	-	-
Magnesium (mg/L)	31	9	21	15	16	-	-
Sodium (mg/L)	31	293	651	468	523	-	30
Potassium (mg/L)	31	22	40	27	30	-	-
Aluminium (mg/L)	31	0.03	0.7	0.12	0.2	27	6
Arsenic (mg/L)	31	0.023	0.154	0.075	0.106	30	23
Barium (mg/L)	31	0.608	6.47	3.38	4.19	-	24
Cadmium (mg/L)	26	0.0001	4.7	0.0001	2.68	7	7
Chromium (mg/L)	26	0.001	0.003	0.001	0.001	-	0
Copper (mg/L)	31	0.001	0.023	0.002	0.005	22	0
Lead (mg/L)	31	0.001	0.015	0.002	0.005	8	0
Selenium (mg/L)	31	0.01	0.111	0.01	0.039	7	7
Zinc (mg/L)	31	0.01	0.316	0.064	0.095	31	0
Iron (mg/L)	31	0.05	0.45	0.13	0.25	-	2
Mercury (mg/L)	21	0.0001	0.0001	0.0001	0.0001	0	0
pH	33	8.16	10.8	8.64	8.57, 9.0	33	29
Turbidity (NTU)	33	2	118	18.6	39.78	12	2
EC (µS/cm)	33	159	2460	1880	2034.8	32	31

At the Tea Tree Hollow monitoring site (SW-22), which is downstream of the Tahmoor Mine licenced discharge point LDP 1, the aquatic ecosystem default guideline trigger range for pH was exceeded in all samples, the default guideline trigger value for zinc was exceeded in all samples, while there were seven exceedances for selenium, eight for lead, thirty (of thirty-one) for arsenic, twenty-two for copper, twenty-seven for aluminium, twelve for turbidity and all but one sample exceeded the default guideline trigger value for EC. The median concentrations of aluminium, arsenic, copper, pH and zinc exceeded the default guideline trigger values or ranges for protection of aquatic ecosystems. Compared to the other monitoring sites the concentrations of sodium, barium and bicarbonate have been elevated. The median concentrations of aluminium, arsenic, copper, pH and zinc have exceeded the default guideline trigger value or range for the protection of aquatic ecosystems.

Table 34 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)	36	5	139	43.5	69	-	0
Sulphate (mg/L)	36	1	135	23	40	-	0
Chloride (mg/L)	36	10	257	71.5	110	-	0
Calcium (mg/L)	36	1	53	11	18	-	-
Magnesium (mg/L)	36	1	33	12	18	-	-
Sodium (mg/L)	36	11	101	41	60	-	0
Potassium (mg/L)	36	1	94	17	24	-	-
Aluminium (mg/L)	36	0.01	1.15	0.23	0.65	32	19
Arsenic (mg/L)	36	0.001	0.011	0.001	0.001	0	0
Barium (mg/L)	36	0.005	0.099	0.0425	0.065	-	0
Cadmium (mg/L)	29	0.0001	0.032	0.0001	0.0001	1	1
Chromium (mg/L)	29	0.001	0.002	0.001	0.001	-	0
Copper (mg/L)	36	0.001	0.005	0.001	0.002	11	0
Lead (mg/L)	36	0.001	0.002	0.001	0.001	0	0
Selenium (mg/L)	36	0.001	0.01	0.01	0.01	0	0
Zinc (mg/L)	36	0.005	0.23	0.01	0.014	24	0
Iron (mg/L)	36	0.06	10.9	0.815	1.3	-	33
Mercury (mg/L)	25	0.0001	0.0001	0.0001	0.0001	0	0
pH	38	3.74	10	7.355	6.95, 7.83	5	2
Turbidity (NTU)	31	6.4	123	16.5	30.3	8	1
EC (µS/cm)	38	155	1360	429	587	25	4

At the Carters Creek monitoring site (SW-23) there have been twenty-four (of thirty-six) exceedances of the aquatic ecosystem default guideline trigger value for zinc and eleven for copper. There have also been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium, pH (with pH both above and below the respective upper and lower default guideline trigger values), turbidity, EC (twenty-five of thirty-eight) and cadmium. The median concentrations of aluminium and zinc exceeded the default guideline trigger values for protection of aquatic ecosystems.

Table 35 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)	21	4	51	6	8	-	0
Sulphate (mg/L)	21	1	12	5	8	-	0
Chloride (mg/L)	21	16	85	26	29	-	0
Calcium (mg/L)	21	1	11	1	1	-	-
Magnesium (mg/L)	21	1	11	2	2	-	-
Sodium (mg/L)	21	12	45	16	17	-	0
Potassium (mg/L)	21	1	12	2	3	-	-
Aluminium (mg/L)	21	0.18	2.07	0.54	0.82	21	20
Arsenic (mg/L)	21	0.0003	0.001	0.001	0.001	0	0
Barium (mg/L)	21	0.003	0.04	0.006	0.012	-	0
Cadmium (mg/L)	21	0.0001	0.01	0.0001	0.0001	2	2
Chromium (mg/L)	21	0.001	0.002	0.001	0.001	-	0
Copper (mg/L)	21	0.001	0.003	0.001	0.001	3	0
Lead (mg/L)	21	0.001	0.002	0.001	0.001	0	0
Selenium (mg/L)	21	0.001	0.01	0.01	0.01	0	0
Zinc (mg/L)	21	0.005	0.019	0.01	0.014	12	0
Iron (mg/L)	21	0.33	2.07	0.49	0.8	-	21
Mercury (mg/L)	21	0.0001	0.0001	0.0001	0.0001	0	0
pH	22	6.07	8.92	6.775	6.316, 7.954	10	8
Turbidity (NTU)	22	5.6	40.6	12.7	20.22	4	0
EC (µS/cm)	22	70	204	109	112	0	0

At the Cow Creek monitoring site (SW-24) there have been twelve exceedances of the aquatic ecosystem default guideline trigger value for zinc and three for copper. There have also been exceedances of both the aquatic ecosystem and recreational use default guideline trigger values for aluminium, cadmium and pH (with pH both above and below the respective upper and lower guideline values). The median concentrations of aluminium and zinc have exceeded the default guideline trigger values for protection of aquatic ecosystems.

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 in comparison with the key water quality indicators for LDP 1 – refer Figure 29 to Figure 36. These illustrate the variability of water quality in watercourses that span the majority of the Project Area. Results for Tea Tree Hollow are likely affected by licensed discharge from LDP1. The following specific observations have been made in relation to these plots and the above tables:

1. Concentrations of aluminium, cadmium, copper, selenium, zinc and iron and pH values in excess or outside the range of the ANZECC aquatic ecosystem and recreational use guidelines have been recorded at the majority of sites within the vicinity of the Project Area, including control and baseline sites. This suggests that the elevated concentrations of these constituents are typical to the surface water systems within the region.
2. Median concentrations of bicarbonate, sodium, arsenic, barium, zinc and electrical conductivity (EC) were notably higher at sites downstream of LDP 1 (SW-22 on Tea Tree Hollow and SW-14 on Bargo River at Rockford Bridge) in comparison with control and baseline sites. This reflects the effects of licensed releases from LDP 1 at the Tahmoor pit top via Tea Tree Hollow based on review of the water quality records at LDP 1.
3. The concentration of arsenic released at LDP1 has greatly declined since improvements have been made to the WWTP (refer Figure 34 below). Consequently, the arsenic concentrations monitored at SW-14 on Bargo River at Rockford Bridge in 2019 did not exceed the default guideline trigger value for protection of aquatic ecosystems.
4. The median concentration of arsenic exceeded the ANZECC aquatic ecosystem default guideline trigger value at LDP 1 and SW-22, though it was equal to the guideline value at SW-14 (further downstream on the Bargo River at Rockford Bridge). The median concentration of barium exceeded the ANZECC recreational use default guideline trigger value at LDP 1, SW-22 and SW-14, although the median concentration at SW-14 was notably lower (1.24 mg/L) than at SW-22 (3.38 mg/L). The median concentration of zinc exceeded the ANZECC aquatic ecosystem default guideline trigger value at LDP 1, SW-22 and SW-14, although the median concentration at SW-14 was notably lower (0.036 mg/L) than at SW-22 (0.064 mg/L). The median EC exceeded the ANZECC default guideline trigger value for NSW upland rivers at LDP 1, SW-22 and SW-14, although the median value at SW-14 was notably lower (1,053 µS/cm) than at SW-22 (1,880 µS/cm).
5. EC has typically been higher at the Tea Tree Hollow monitoring site than other sites. EC values at the Eliza Creek monitoring site have typically been more variable.
6. pH values have been within or close to the ANZECC default guideline trigger value range (6.5 to 8) at Eliza Creek and Dog Trap Creek monitoring sites. Relatively higher values have been recorded in Tea Tree Hollow and relatively lower values have been recorded at the Eliza Creek monitoring site.
7. Turbidity was relatively low at the Dog Trap Creek site during the monitoring period. Relatively elevated levels have been recorded at the Eliza Creek monitoring site. Turbidity was relatively low and less variable at the Tea Tree Hollow monitoring site during the 2019 monitoring period in comparison with the 2012 to 2015 monitoring period.
8. Sulphate concentrations have been consistently low at Tea Tree Hollow and higher and more variable at the Dog Trap and Eliza Creek monitoring sites.
9. Total aluminium concentrations were variable at all three monitoring sites between 2012 and 2015, though have been relatively low and less variable based on 2019 records.
10. Total arsenic concentrations have been low at the Dog Trap and Eliza Creek monitoring sites though occasionally elevated and highly variable at the Tea Tree Hollow monitoring site

between 2012 and 2015. Since early 2019, the arsenic concentrations recorded in Tea Tree Hollow have been less than 0.05 mg/L.

11. Total iron concentrations have been consistently low at the Tea Tree Hollow monitoring site (<1 mg/L) and low at the Dog Trap Creek monitoring site (<2 mg/L), though were elevated and highly variable at the Eliza Creek monitoring site between 2012 and 2015.
12. Total manganese concentrations have been highly variable with time and between monitoring sites. More persistent elevated concentrations have been recorded at the Eliza Creek monitoring site, while low concentrations have been recorded at the Tea Tree Hollow and Dog Trap Creek monitoring sites since early 2019.
13. Total nickel concentrations have been typically low at Eliza Creek and Dog Trap Creek monitoring sites with higher and more variable concentrations recorded in Tee Tree Hollow.
14. Total zinc concentrations have ranged between the limit of detection and 0.05 mg/L at the Dog Trap Creek monitoring site, while zinc concentrations recorded at the Eliza Creek and Tea Tree Hollow sites have been typically higher and more variable.

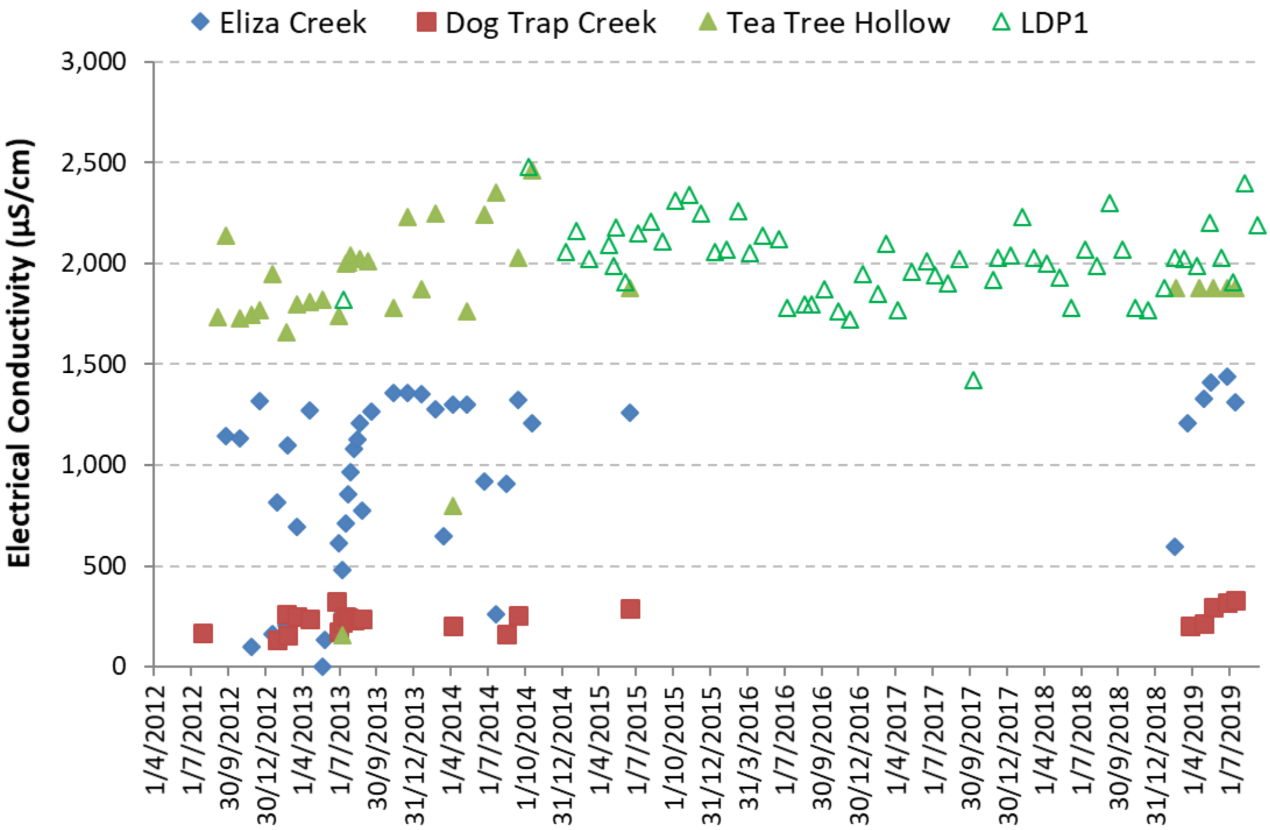

Figure 29 Monitoring Results for Electrical Conductivity

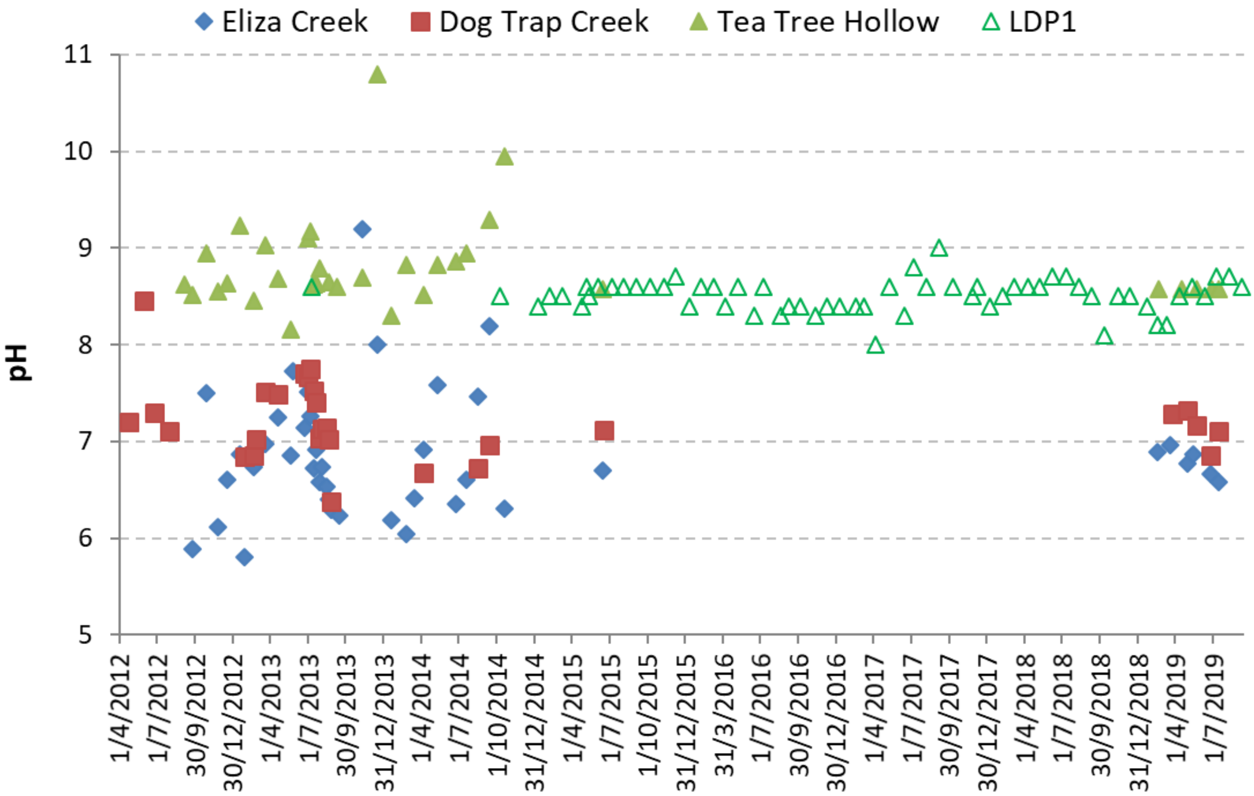

Figure 30 Monitoring Results for pH

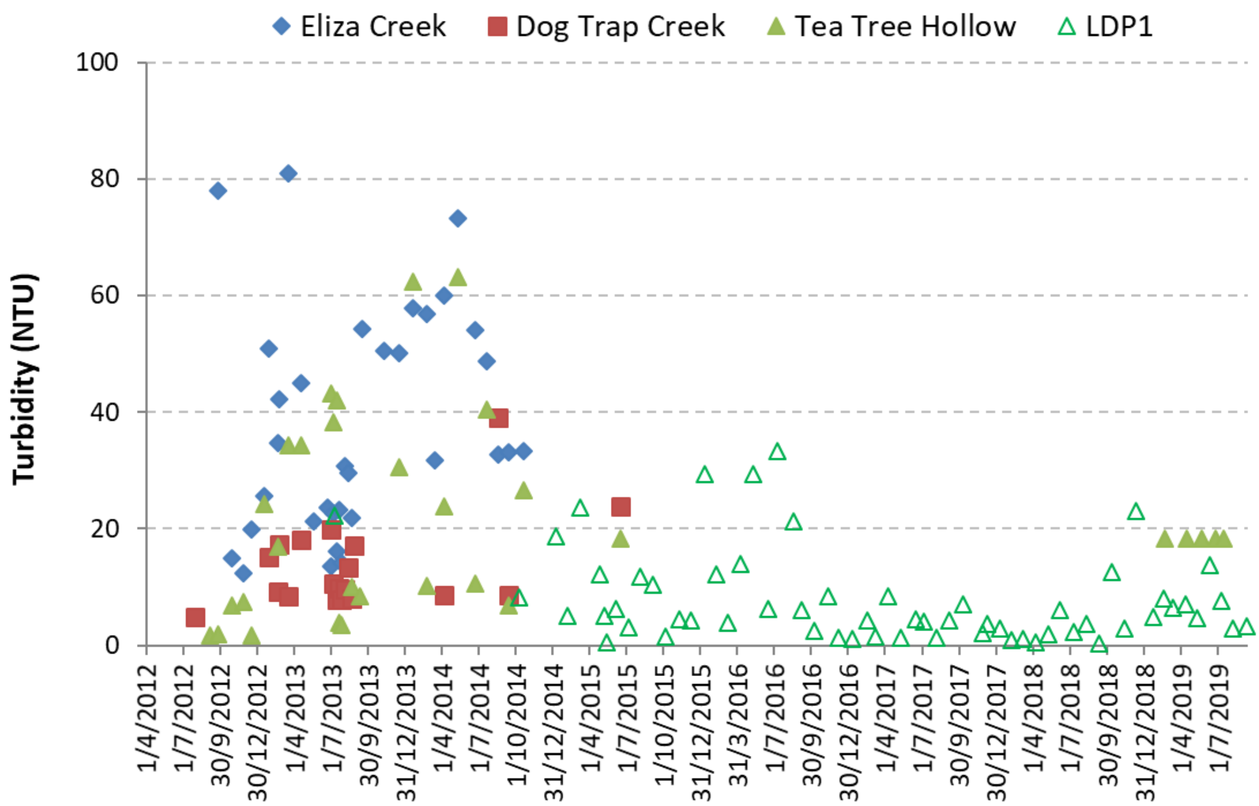

Figure 31 Monitoring Results for Turbidity

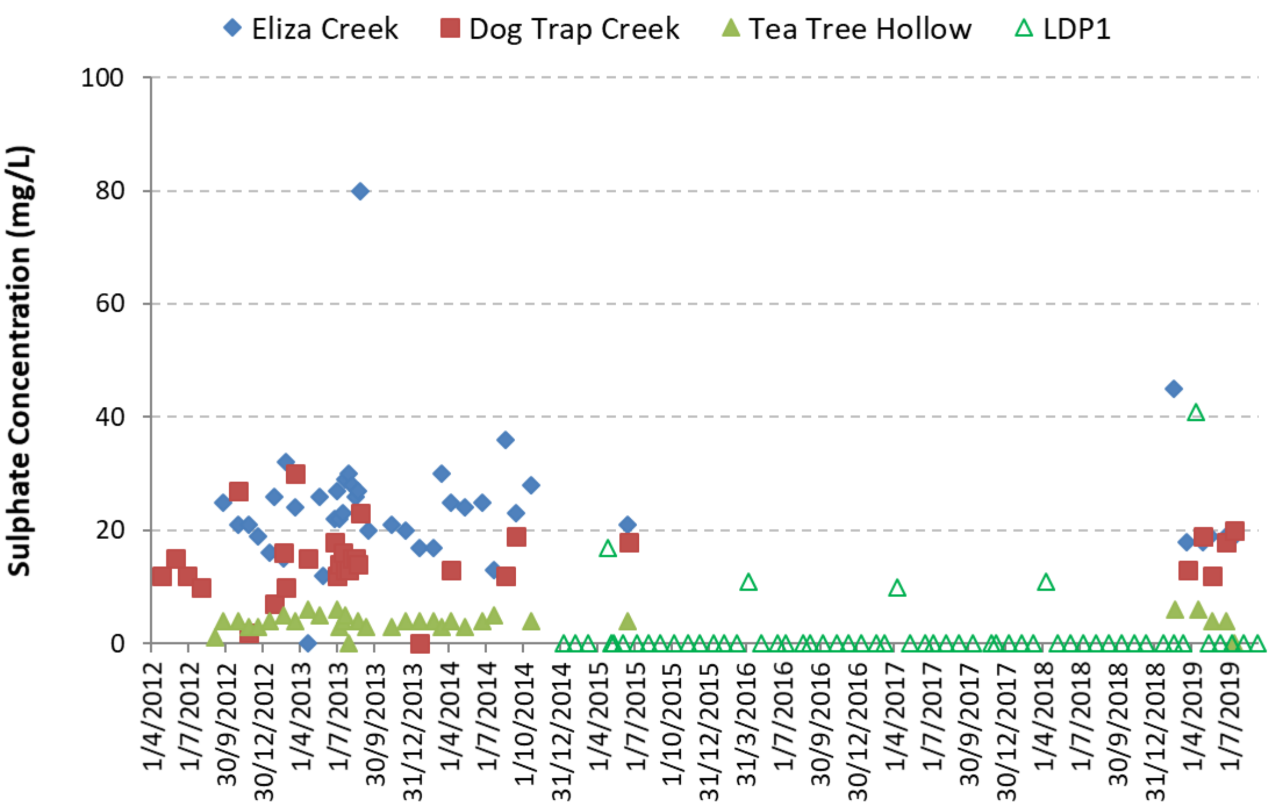

Figure 32 Monitoring Results for Sulphate

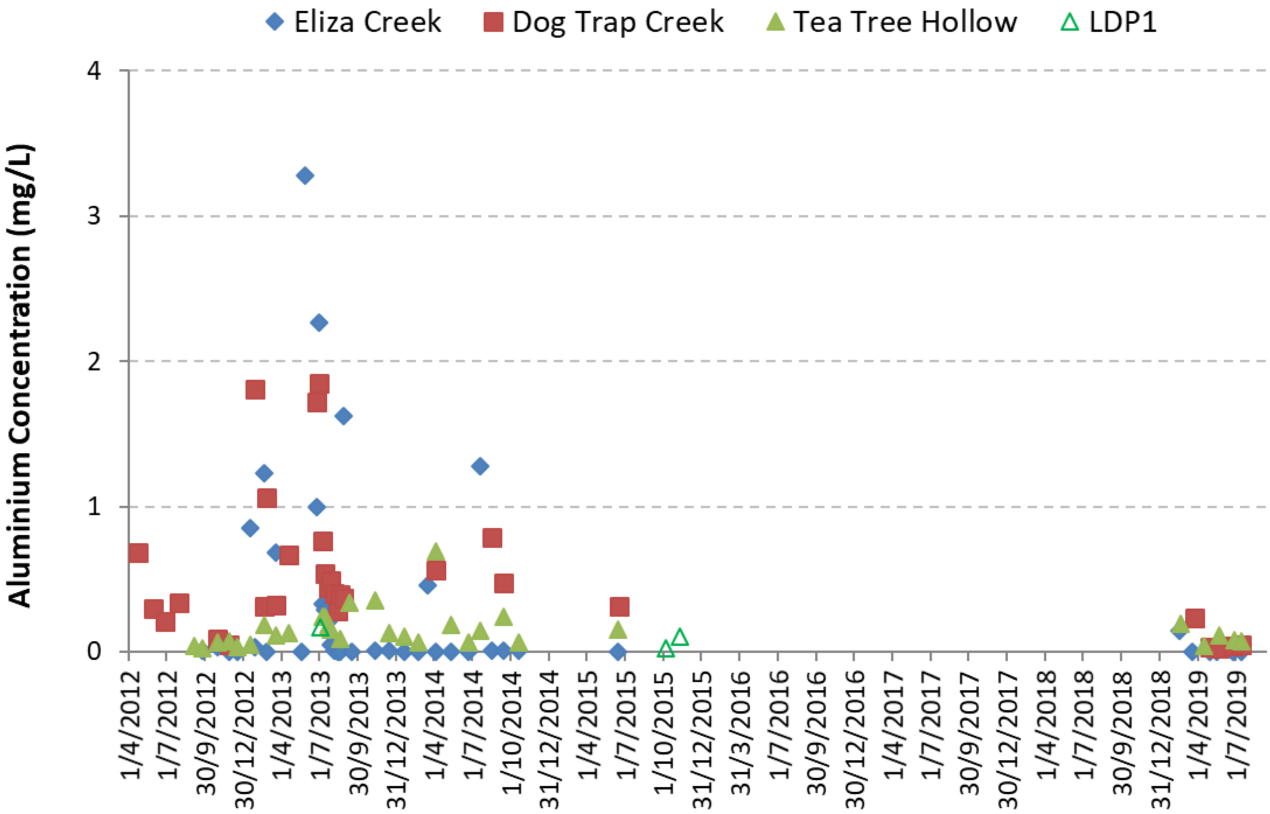

Figure 33 Monitoring Results for Total Aluminium

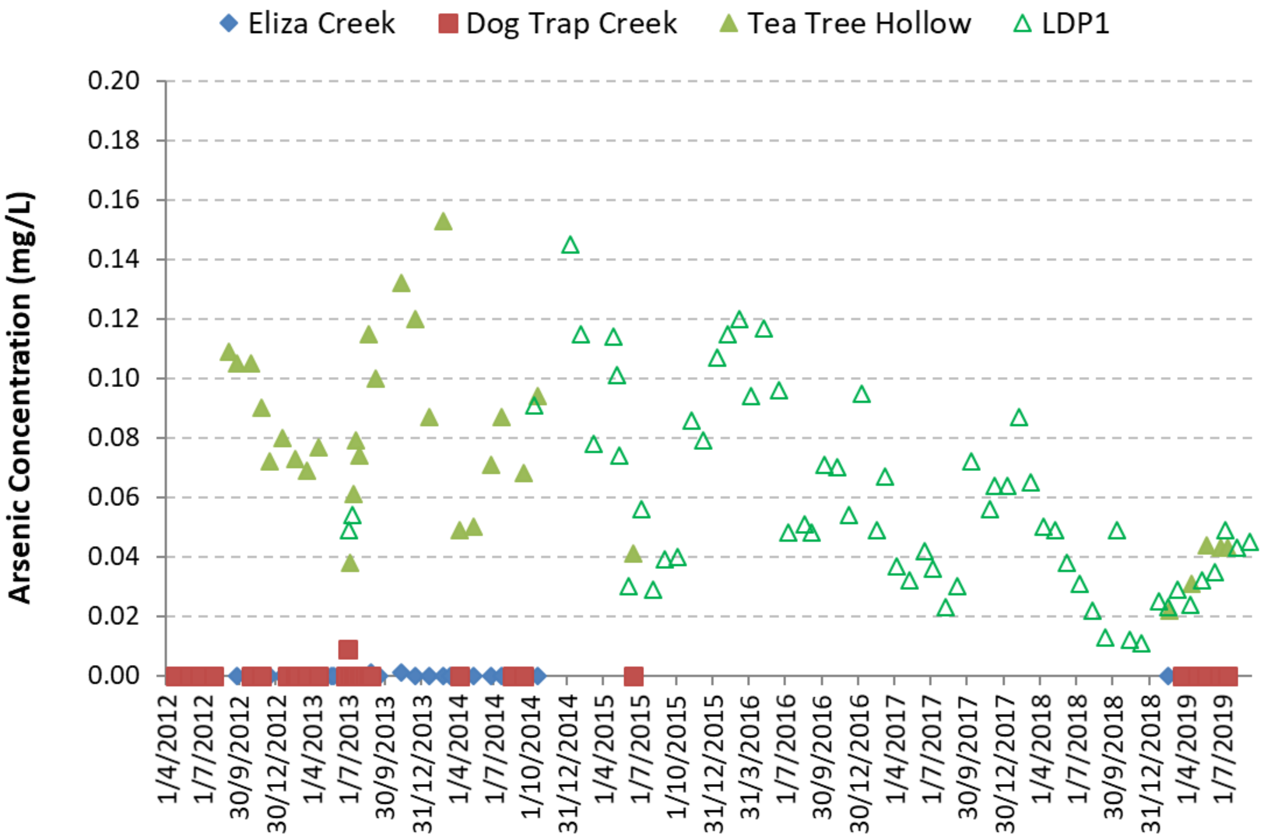

Figure 34 Monitoring Results for Total Arsenic

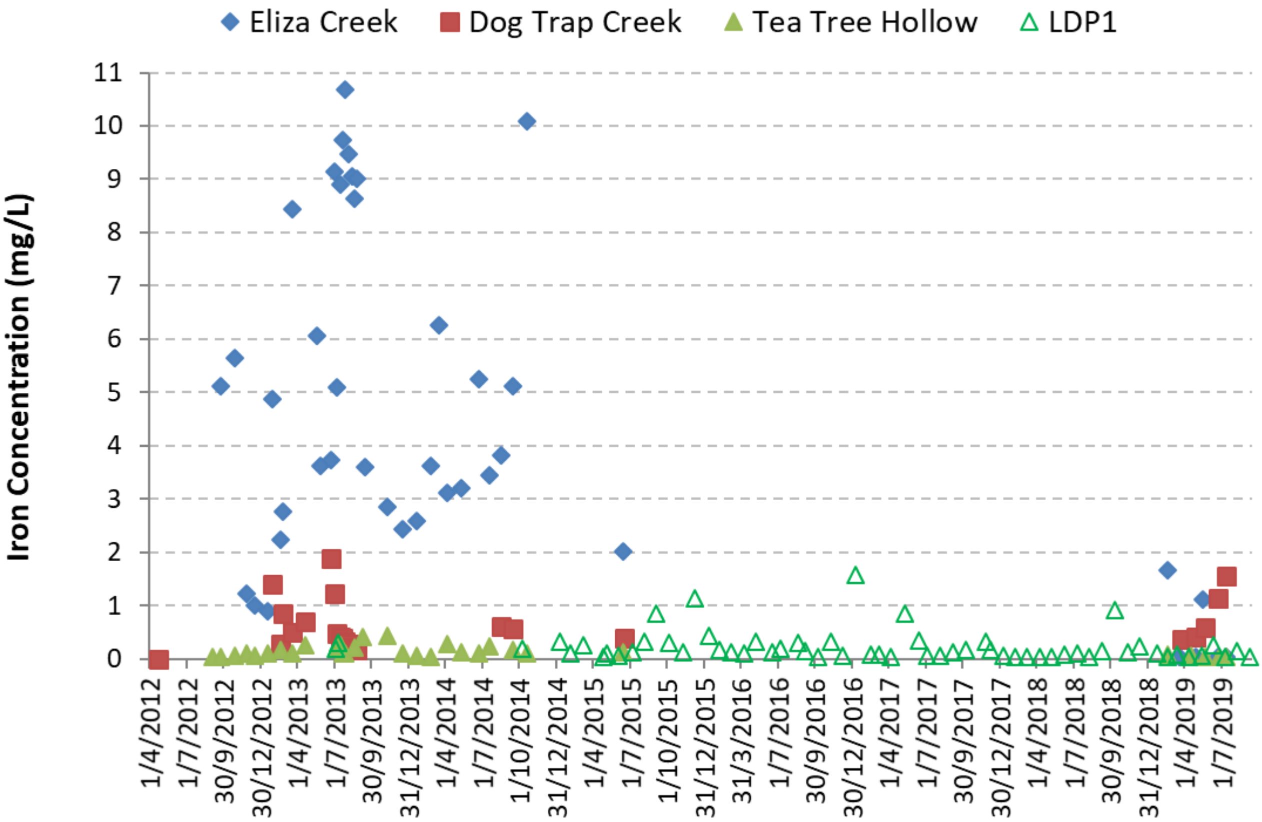

Figure 35 Monitoring Results for Total Iron

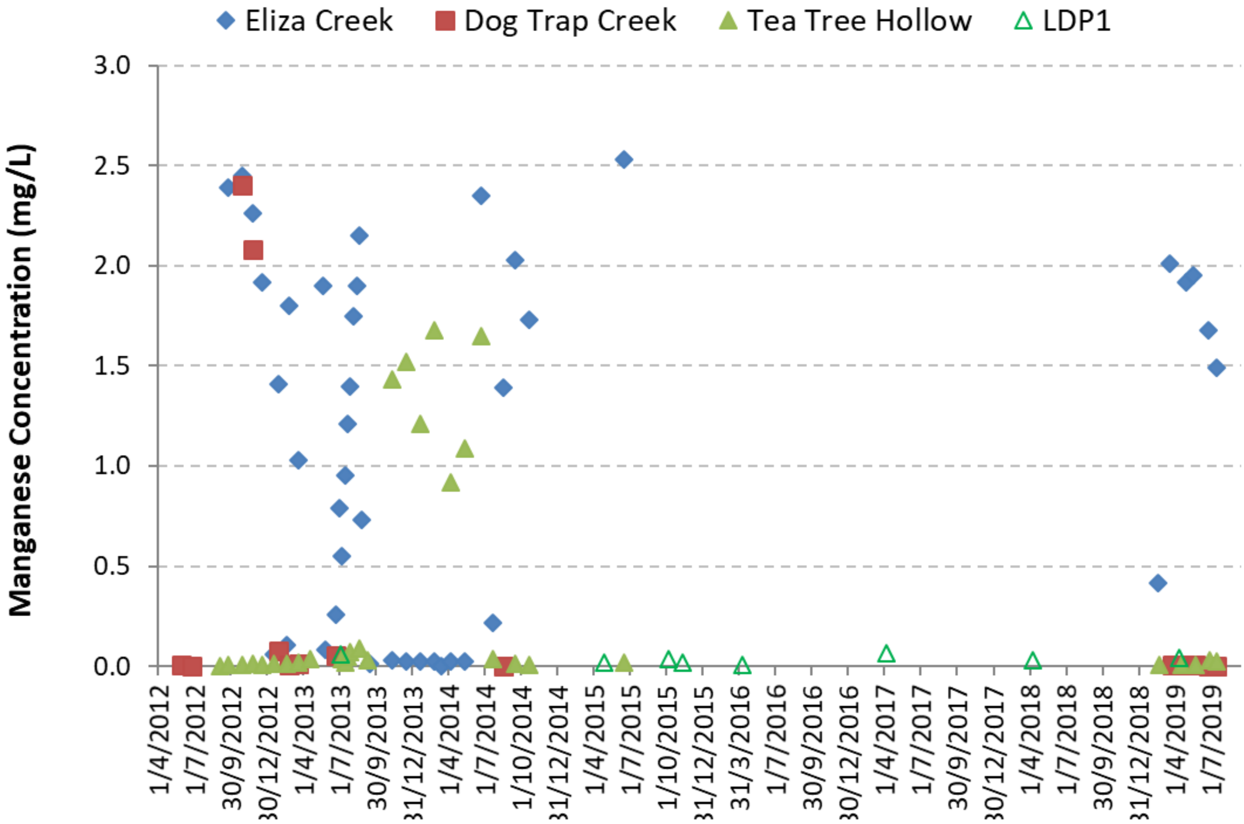

Figure 36 Monitoring Results for Total Manganese

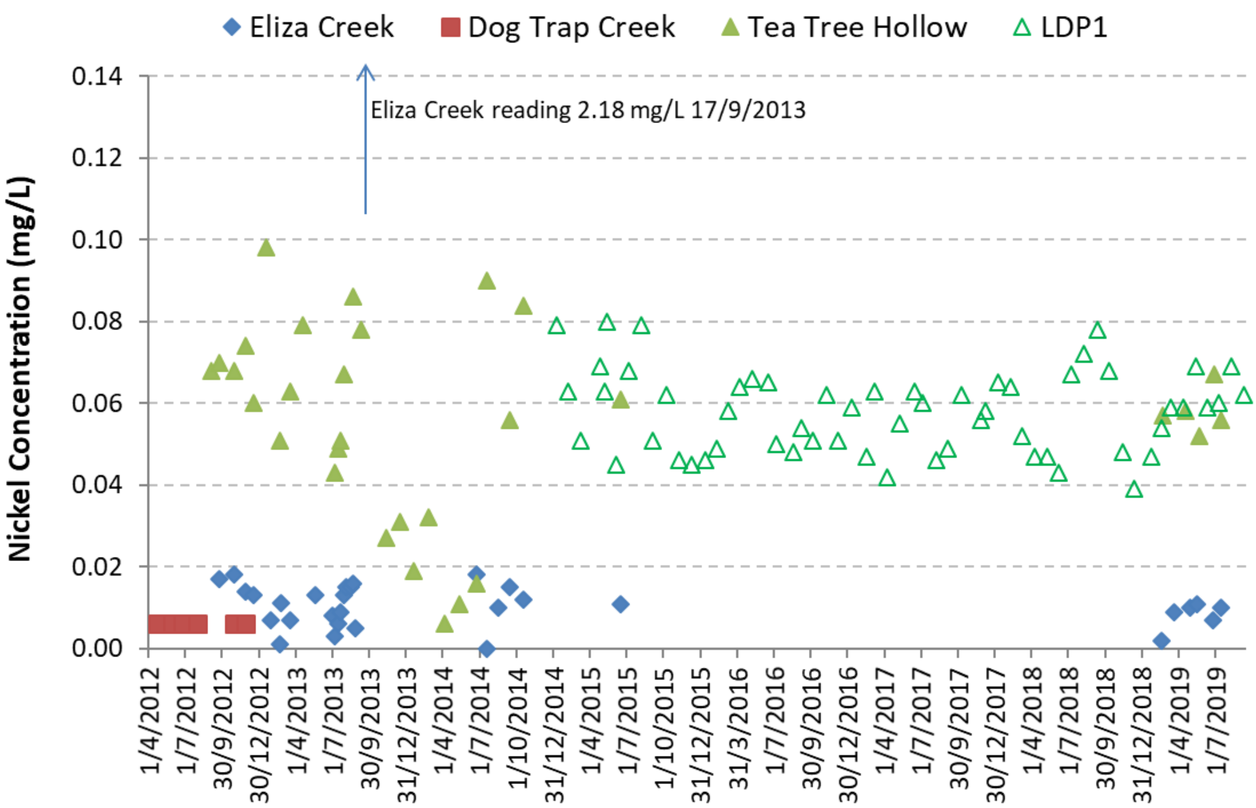

Figure 37 Monitoring Results for Total Nickel

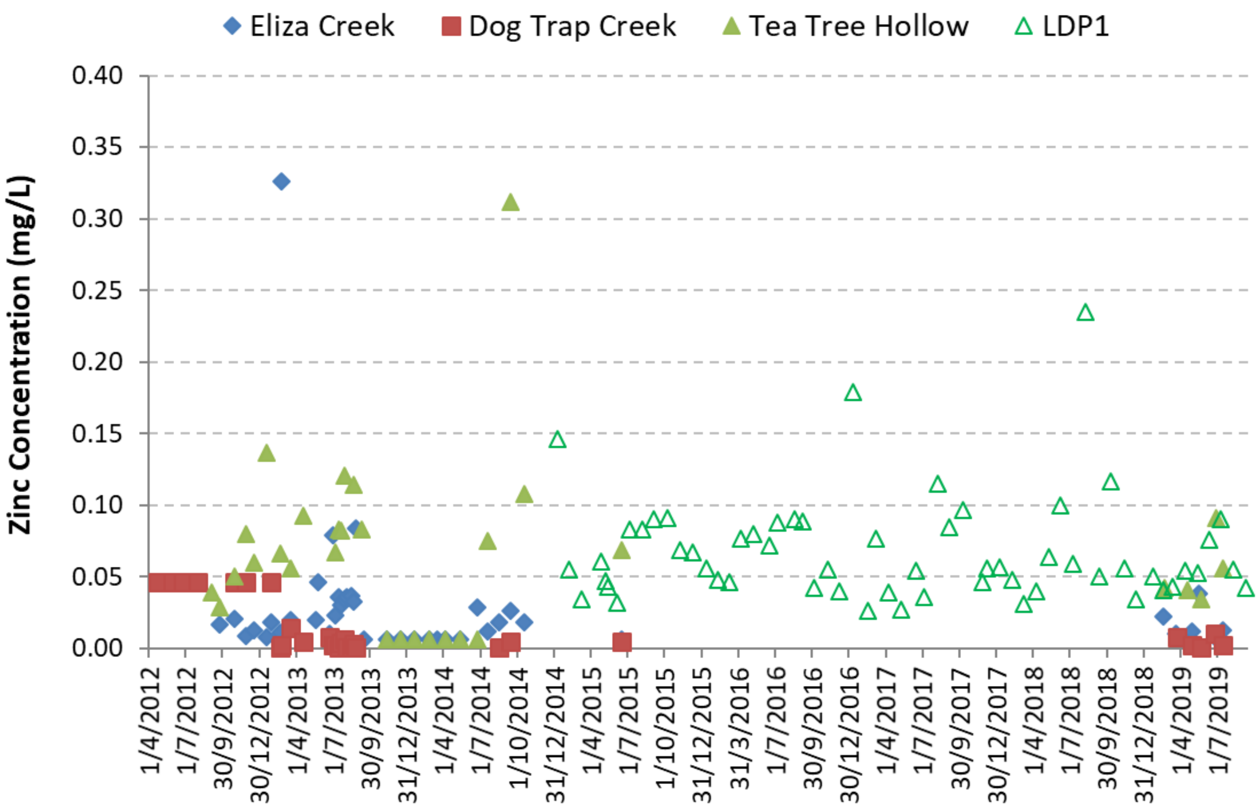

Figure 38 Monitoring Results for Total Zinc

8.0 SUMMARY OF KEY CHANGES TO ASSESSMENT OUTCOMES

This BA has been revised to incorporate additional baseline data assessed for the Amended Project following submission of the EIS. The report has also been revised to address key issues raised in the EIS submissions pertaining to the baseline hydrology and water quality characteristics of the proposed Project Area. In this way, it serves as an update to the Surface Water Baseline Assessment. The key changes relate predominately to the collation and analysis of additional streamflow monitoring and water quality monitoring data for the Project Area and Surrounding Region.

8.1 CATCHMENT MODELLING AND STREAMFLOW ANALYSIS

As detailed in Section 5.0, the catchment models for Dog Trap Creek, Eliza Creek and Bargo River Upstream were recalibrated with additional streamflow data monitored between 2015 and 2019. Table 36 presents a comparison of the statistical metrics for the previous calibration and the revised calibration incorporating additional streamflow monitoring data.

Table 36 AWBM Statistical Metrics

Stream/Gauging Station	Ratio of Model to Recorded Streamflow		Coefficient of Determination on Monthly Flows (r^2)		Nash Sutcliffe Coefficient of Efficiency on Monthly Flows	
	Revised	Previous	Revised	Previous	Revised	Previous
Dog Trap Creek (GS 300063)	97.3%	143%	0.77	0.86*	0.77	0.69*
Eliza Creek (GS 300073)	97.2%	86.5%	0.76	0.91**	0.76	0.78**
Bargo River Upstream (GS 300010a)	105%	91.4%	0.72	0.66	0.62	0.51

* Based on only 6 months with complete data

** Based on only 7 months with complete data

The results in Table 36 illustrate improvements to the model calibration due to incorporation of the additional streamflow monitoring data. The ratio of model to recorded streamflow has vastly improved and is now less than 5% difference as recommended by Vaze et al. (2011). Although the coefficient of determination on monthly flows was higher for the previous Dog Trap Creek and Eliza Creek models, the analysis was based on a dataset with only six months of complete data and as such was likely to be inadequately capturing seasonal variation.

The recalibrated models have enabled improved estimations of the baseflow indices and baseflow recession rates for each catchment. The baseflow index and baseflow recession rates have reduced for Dog Trap Creek and increased for Eliza Creek and Bargo River Upstream from the previous model calibrations. As such, the recalibrated models provide for increased confidence in the simulated streamflow for each catchment, specifically in the simulation of low flows and baseflow recession.

8.2 WATER QUALITY MONITORING

The following summarises the comparative findings of the water quality data presented in the BA for the EIS and the updated data presented in the Amended Project BA (this report):

- the water quality summary for Bargo River (SW-1), Hornes Creek (SW-9) and Bargo River at Upstream Bargo (SW-13) were generally consistent for the EIS BA and the Amended Project BA;
- the median concentrations of aluminium, arsenic, selenium and zinc have reduced from the previous BA, with the reduction in arsenic concentration indicative of improvements to the water quality released at LDP1 (refer Figure 34);
- the water quality summary for Dog Trap Creek Downstream (SW-15) and Dog Trap Creek Upstream (SW-16) were generally consistent for the EIS BA and the Amended Project BA;
- the water quality summary for Eliza Creek (SW-18), Dry Creek (SW-20A) and Nepean River at Maldon Weir (SW-21) were generally consistent for the EIS BA and the Amended Project BA;
- the median concentrations of aluminium, arsenic, selenium and zinc recorded at Tea Tree Hollow (SW-22) have reduced from the previous BA, with the reduction in arsenic concentration indicative of improvements to the water quality released at LDP1 (refer Figure 34); and
- the median concentrations of aluminium and zinc recorded at Carters Creek (SW-23) have reduced from the EIS BA; and
- the median concentration of iron recorded at all sites except Bargo River (SW-1) and Eliza Creek (SW-18) have increased from the EIS BA.

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HYDRO ENGINEERING
& CONSULTING PTY LTD

REPORT

Tahmoor South Amended Project Water Management System and Site Water Balance

Prepared for: Tahmoor Coal Pty Ltd

38a Nash Street
Rosalie QLD 4064
p (07) 3367 2388

PO Box 1575
Carindale QLD 4152
www.hecons.com
ABN 11 247 282 058

Revision	Description	Author	Reviewer	Approved	Date
1	Draft report following EIS submissions	DNF / CAW	TSM / Tahmoor Coal	TSM	20 Nov 2019
2	Final	DNF / CAW	TSM	TSM	8 Dec 2019
3	Final following submission	DNF / CAW	TSM	TSM	12 Feb 2020

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1.0 INTRODUCTION

Hydro Engineering & Consulting Pty Ltd (HEC) was commissioned by Tahmoor Coal Pty Limited (Tahmoor Coal) to complete a Surface Water Assessment for the Tahmoor South Project (the Project). The Surface Water Assessment formed a 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 was 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 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. The water balance model was developed to simulate the water management system supply reliability, the adequacy of the current licensed discharge to Tea Tree Hollow to manage release of water from the mine site and to assess the risk of site overflow 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 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

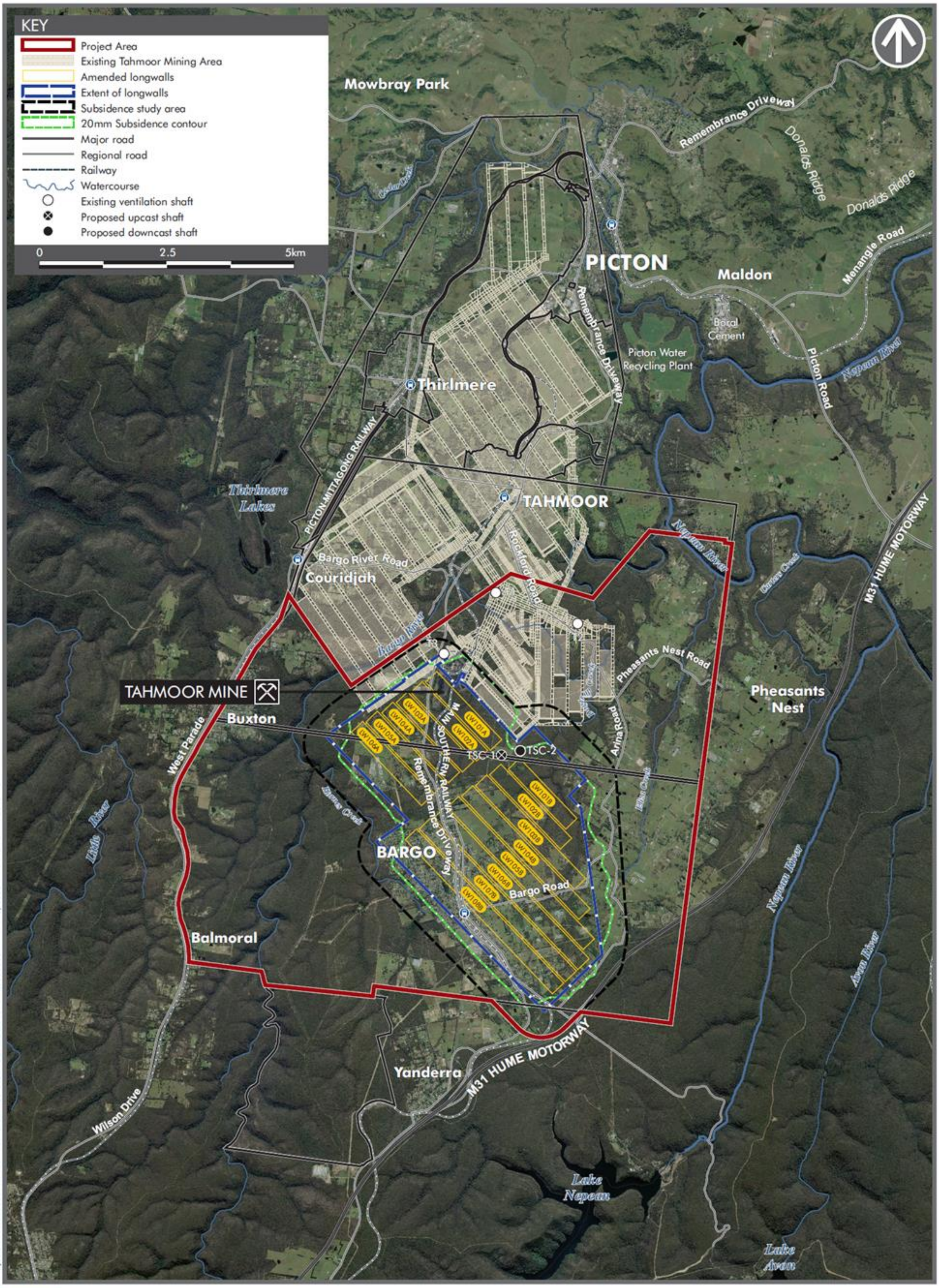
This report details the Water Management System and Site Water Balance for the Project Area which has been revised to address key issues raised in submissions relating to the EIS, as described below. The report describes the existing water management system, the proposed changes to site water management as a result of the Amended 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 is seeking development consent 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.

In accordance with the requirements of the EP&A Act, the *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation) and the Secretary's Environmental Assessment Requirements (SEARs), an EIS was prepared to assess the potential environmental, economic and social impacts of the Project. The EIS for the Project was placed on public exhibition by the Department of Planning, Industry and Environment (DPIE) (formerly the Department of Planning and Environment [DPE]) from 23 January 2019 to 5 March 2019.

Key issues raised in submissions included concerns relating to the proposed extent of longwall mining, the magnitude of subsidence impacts and the extent of vegetation clearing required for the expansion of the reject emplacement area (REA).



SIMEC MINING

AMENDED MINE PLAN AND VENTILATION SHAFTS
Tahmoor South Project
Amended Project Report

FIGURE 3.1

Note: The 'extent of longwalls' boundary encompasses the proposed extent of underground workings, being the proposed longwall panels and mains headings (first workings).

Figure 1 Locality Plan and Project Layout

In response to these and other issues raised in Government agency, local Council, stakeholder and community submissions, and as a result of ongoing mine planning, several amendments have been made to the proposed development, so as to also further reduce the predicted environmental impacts of the Tahmoor South Project.

The key amendments to the Project since public exhibition of the EIS are:

- A revised mine plan, including:
  - an amended longwall panel layout and the removal of LW109;
  - a reduction in the height of extraction within the longwall panels from up to 2.85 metres (m) to up to 2.6 m; and
  - a reduction in the proposed longwall width, from up to 305 m to approximately 285 m.
- A reduction in the total amount of Run-of-Mine (ROM) coal to be extracted over the Project life, from approximately 48 million tonnes (Mt) to approximately 43 Mt of ROM coal, comprising;
  - 30 Mt of coking coal product (reduced from 35 Mt);
  - 2 Mt of thermal coal product (reduced from 3.5 Mt)
- A revised extended REA; including:
  - a reduction in the additional capacity required to accommodate the Project;
  - a reduction in the REA extension footprint, from 43 ha to 11 ha;
  - an increase in the final height of the REA (from RL 305 m to RL 310 m).
- Confirmation of the location and footprint of ancillary infrastructure associated with the ventilation shaft sites (e.g. the power connection easement for ventilation shaft site TSC1); and
- A continuation of the use of the existing upcast shaft (T2); although, operation will reduce from two fans during Tahmoor North operations to one fan once the new ventilation shafts and fans (TSC1 and TSC2) are in operation in Tahmoor South.

No amendments have been made to other key aspects of the Project as presented in the EIS for which development consent is sought, such as the proposed annual coal extraction rate, mining method, traffic movements and employee numbers. A detailed description of the amended development is provided in the Amendment Report (AECOM, 2020).

1.2 PURPOSE OF REPORT

This WMS & SWB has been prepared to detail the proposed changes to site water management required to support the Amended Project and to present the results from the water balance model simulation of the proposed water management system over the Project life. The assessment considers and outlines the differences in impacts compared to the original project as presented in the EIS. In this way, it serves as an update to the Tahmoor South EIS Water Management System and Site Water Balance (HEC, 2018c) (Appendix J of the Tahmoor South EIS). Section 7.0 presents a summary of key changes presented in this WMS & SWB in comparison with the EIS assessment.

1.3 AMENDED PROJECT

The Amended Project would use longwall mining to extract coal from the Bulli seam within the bounds of CCL716 and CCL747. Coal extraction of up to four (4) million tonnes of ROM coal per annum is proposed as part of the development with extraction of up to 43 Mt of ROM coal over the life of the Project. The project would produce approximately:

- 30 Mt coking coal product;
- 2 Mt thermal coal product; and
- 12 Mt of rejects.

These approximate market mix volumes include moisture and are therefore an estimate only. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing CHPP and coal clearance facilities and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla and Newcastle (from time to time) for Australian and international markets. Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers via road.

The amended development would use the existing surface infrastructure at the Tahmoor Mine surface facilities area. Some upgrades are proposed to facilitate the extension.

The amended development also incorporates the planning for rehabilitation and mine closure once mining ceases.

In summary, the key components of the amended development comprise:

- Longwall mining in an area known as the Central Domain;
- Mine development including underground development, vent shaft construction, pre-gas drainage and service connection;
- Upgrades to the existing surface facilities area including:
  - Upgrades to the CHPP;
  - Expansion of the existing REA;
  - Additional mobile plant for coal handling;
  - Additions to the existing bathhouses and associated access ways; and
  - Upgrades to onsite and offsite service infrastructure, including electrical;
- Rail transport of product coal to Port Kembla and Newcastle (from time to time);
- Up to 200,000 tonnes per annum of either product coal or reject material proposed to be transported to customers via road;
- Mine closure and rehabilitation; and
- Environmental management.

1.4 STUDY REQUIREMENTS

The Project EIS was 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. This SWIA report has been revised to assess the potential impacts of the Amended Project on local and regional surface water resources and to address key issues raised in the EIS submissions pertaining to the SWIA submitted as a component of the EIS.

1.4.1 Secretary's Environmental Assessment Requirements

The Surface Water Assessment is guided by the 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 Surface Water Baseline Assessment (HEC, 2020a) 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 exclude 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.

1.4.2 EIS Submissions

The agency and community submissions specific to the WMS & SWB are summarised in Table 1 and the section of this report in which the submissions are addressed are provided.

Table 1 EIS Submissions – Water Management System and Site Water Balance

Agency	Submission	How / Where Addressed
NSW Environment Protection Authority (EPA)	It is unclear if there are any managed overflows of mine water from licensed discharge point (LDP) 1, e.g. flows above pumping rates/timing of pumping to underground storage. This should be clarified and if necessary, the frequency, volume and potential impacts assessed in the EIS. The EIS indicates drainage from the product coal stockpile area into retention dams S2 and S3 where wastewater 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 licensed overflow point (LOP) 4. The potential impact of this discharge is not assessed in the EIS and its sizing and frequency of overflow is not clear. If pollutants other than clean sediments are present, then sizing and overflow frequency in accordance with the Managing Urban Stormwater (Blue Book) Volume 2E may not be adequate. <u>Controlled discharges from sediment basins</u> It appears that there are no controlled discharges from the Reject Emplacement Area (REA). It is unclear how storage capacity of basins in this area are restored in the required management period so that subsequent rainfall events are adequately captured and settled, e.g. it is noted that Dam S4 is pumped to Dam M3, however the management periods for these dams is unclear. This information may have been included in a PRP report, however, it is not available for assessment in the EIS. <u>Flocculants</u> The potential impact of sediment settling agents are not assessed in the EIS. It is the responsibility of licence holders to ensure their licence regulates the discharge of all pollutants that pose a risk of non-trivial harm. <u>Managed overflows</u> Managed overflows are assumed to be consistent with the requirements of the Blue Book Volume 2E, however a specific managed overflow assessment is not provided. While overflows are likely to be diluted, the overflow frequency from the Blue Book relates to 'clean' sediment, i.e. that does not contain elevated levels of other pollutants.	The current discharge/overflow volumes to LDP1 are specified in Section 2.5. The predicted discharge/overflow volumes to LDP1 for the Amended Project are discussed in Section 6.3. The management of sediment dams is discussed in Section 2.4. The current discharge/overflow volumes to the LOPs are specified in Section 2.4. The predicted discharge/overflow volumes to the LOPs for the Amended Project are discussed in Section 6.3. The BA report (HEC, 2020a) summarises the discharge water quality to LDP1 and LOP 3, 4 and 5. The SWIA report (HEC, 2020d) discusses the potential changes in water quality to LDP1 based on the predicted discharge volumes summarised in Section 6.3. The sediment settling agent is specified in Section 2.0, with details provided of the settling agent composition.

Table 1 (Cont.) EIS Submissions – Water Management System and Site Water Balance

<table>
<tr><th>Agency</th><th>Submission</th><th>How / Where Addressed</th></tr>
<tr><td rowspan="2">NSW Environment Protection Authority (EPA)</td><td>The EPA recommends that the Department of Planning and Environment request the following be completed:
the potential for any managed overflows from LDP 1 is clarified and if necessary the frequency, volume and potential impacts assessed in the EIS
further information is provided on the methods for returning sediment basin capacities based on design management periods set out in Blue Book Volume 2E
the potential impact of sediment settling agents in discharges from the site are assessed
for site discharges, monitoring should occur initially for a full range of potential pollutants during controlled discharges and managed overflows. This discharge monitoring should include:
a full suite of metals
sulfate, total dissolved solids and electrical conductivity, major ions
total suspended solids and turbidity
any residual settling agent risks (flocculants or coagulants)
volume and frequency of controlled discharges and frequency of managed overflows.
This initial monitoring should occur until it is demonstrated that mitigation measures are effective (e.g. measures may include placement of inert material on the outer surfaces of the waste rock emplacement.) Subject to initial results, a reduced suite of key indicators may be able to be developed, however, periodic monitoring of a wider suite of analytes may be required.</td><td>The current discharge/overflow volumes to LDP1 are specified in Section 2.5. The predicted discharge/overflow volumes to LDP1 for the Amended Project are discussed in Section 6.3.

The management of sediment dams is discussed in Section 2.4. The current discharge/overflow volumes to the LOPs are specified in Section 2.4. The predicted discharge/overflow volumes to the LOPs for the Amended Project are discussed in Section 6.3.

The BA report (HEC, 2020a) details the water quality monitoring undertaken for licenced releases and provides a summary of the discharge water quality to LDP1 and LOP 3, 4 and 5.

The SWIA report (HEC, 2020d) discusses the potential changes in water quality to LDP1 based on the predicted discharge volumes summarised in Section 6.3.

The sediment settling agent is specified in Section 2.0, with details provided of the settling agent composition.</td></tr>
<tr><td>Section 4.5 of Appendix J states that "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."
The potential impact of the proposed sewage discharge is not assessed in the EIS and details of the upgrade are not provided, including potential impacts on downstream aquatic ecosystems and water users, e.g. recognised swimming sites. The practical measures that could be taken to prevent, control, abate or mitigate that pollution are not considered, including reuse of effluent onsite.</td><td>Per Section 3.6, the upgraded Sewage Treatment Plant (STP) is proposed to have a peak capacity of 61 kL/day which represents a small percentage of outflow to LDP1 (less than 2% of the average historical release). The upgraded STP will be designed and constructed to produce effluent of a suitable quality to enable discharge via LDP1 or to be used in the future for irrigation of the REA. Discharge to LDP1 would continue to occur in accordance with EPL 1389. Water quality monitoring for a range of constituents, including faecal coliforms, would continue to be undertaken in accordance with the water monitoring program for LDP1.</td></tr>
</table>

Table 1 (Cont.) EIS Submissions – Water Management System and Site Water Balance

Agency	Submission	How / Where Addressed
Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC)	The proponent intends to increase water storage capacity by construction of additional sediment dams and storage of excess water in the goaf. Overflow from sediment dams is proposed to be released into the Bargo River and Tea Tree Hollow. There are no volumetric limits in place for the release of overflow water, although conditions are prescribed for the existing mine. Potential impacts to the surface water receiving environment from overflow discharges are not considered. Condition of the current receiving environment and the extent to which it is impacted by existing activities are not adequately discussed and require information from a more robust monitoring program.	The BA report (HEC, 2020a) summarises the current receiving environment and licensed release water quality. The current discharge/overflow volumes to LDP1 are specified in Section 2.5. The predicted discharge/overflow volumes to LDP1 for the Amended Project are discussed in Section 6.3. The current discharge/overflow volumes to the LOPs are specified in Section 2.4. The predicted discharge/overflow volumes to the LOPs for the Amended Project are discussed in Section 6.3. The SWIA report (HEC, 2020d) discusses the potential changes in water quality to LDP1 based on the predicted discharge volumes summarised in Section 6.3.
	If it is intended to store the waste water from coal washing and groundwater from dewatering activities in the goafed areas, the IESC considers further information is needed on the underground storage proposal. This should include: a) further information on the water quality of the water being stored underground with a full risk assessment of the potential contamination caused by untreated water leaking into the groundwater (potential impacts to the receiving environment); b) assurance that the lack of water storage does not lead to releases of untreated water into Tea Tree Hollow and the Bargo River…	The underground water storage proposal has been modified such that mine dewatering from Tahmoor South will be transferred directly to the proposed Tahmoor North underground storage, rather than from dam M3. As such, potential impacts to groundwater quality are unlikely (refer HEC [2020d]). As discussed in Section 6.4, the stored water volume of the goafed area is predicted to reach capacity by 2033 based on the median model forecast result and by mid-2032 based on the 95th percentile model result. In order to maintain treatment of water to be discharged via LDP 1, the capacity of the Water Treatment Plant may need to be upgraded prior to 2032.

Table 1 (Cont.) EIS Submissions – Water Management System and Site Water Balance

Agency	Submission	How / Where Addressed
Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC)	Potential impacts to surface and groundwater quality from the proposed project could occur through impacts associated with water discharges, water storage and mining-induced ground movements. To mitigate these potential impacts, the IESC considers that the Proponent's existing operation facilities would be improved by ensuring: a. the WWTP is operating as intended to mitigate metal concentrations in water prior to discharge. There is no evidence in the EIS that the WWTP is achieving the required water quality objectives since its 2014 upgrade as no recent data has been provided. It is also noted that no water quality data is provided for LPO3, LPO4, and LPO5; and b. the water treatment system has the capacity to store and treat contaminated mine water during storm events or during periods of high groundwater inflows. The IESC considers that if the additional water balance work finds a high risk of untreated water discharges, additional storage capacity should be installed so that untreated water is not released or allowed to overflow to Tea Tree Hollow or the Bargo River.	Section 2.1 discusses the proposed upgraded WWTP which is intended to achieve the required water quality objectives. Section 3.0 summarises the proposed water management system for the Amended Project which has been conceptually designed to ensure appropriate treatment of site runoff prior to release to Tea Tree Hollow and the Bargo River. Two additional sediment ponds are proposed to manage runoff from the REA and have been conceptually designed in accordance with DECC (2008) [Blue Book Volume 2E], as stated in Section 3.2. As part of the Amended Project, it is proposed to develop an underground storage within goafed areas of the Tahmoor North underground mine into which mine dewatering from Tahmoor South underground would be pumped when there is insufficient capacity to treat the mine dewatering through the upgraded WWTP. The proposed underground water storage is discussed in Section 3.4, while Section 6.4 presents the predicted timing and volume of underground water storage.

2.0 EXISTING WATER MANAGEMENT SYSTEM

The water management system at the existing Tahmoor Coal Mine comprises 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 releases to be made from the mine site to Tea Tree Hollow 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. Table 2 provides a summary of the Tahmoor Colliery water storages, with further details and locations provided in the sections to follow.

Table 2 Tahmoor Colliery Existing Water Storages

Water Storage	Capacity	Details
M1	1.8 ML	The ROM Stockpile area drains to M1, M2, M3 and M4. Groundwater dewatering from the underground is pumped to M1 and is ultimately treated through the Waste Water Treatment Plant (WWTP) via M3. The predominant inflow to dam M4 is treated water from the WWTP, with dam M4 also receiving overflow from dam M3. Clarified water from M3/M4 is reused within the site, either at the washery or for dust suppression at the stockpiles. Overflow from M4 is released at LDP1.
M2	0.5 ML	
M3	9.0 ML	
M4	8.0 ML	
M5	3.0 ML	Stormwater from No.2 Shaft site area is directed to M5 which overflows to M6.
M6	4.5 ML	
S2 / S3	8.3 ML	Stockpile dams S2 / S3 are used to supply water for dust suppression with excess water directed to S4.
S4	36.9 ML	Dam S4 pumps to dam M3. Excess water in Dam S4 can overflow to LOP4.
S5	0.5 ML	Temporary Reject Material Storage area silt trap - discharges to dam S6.
S6	1.5 ML	Temporary Reject Material Storage area dam which discharges to dam S9.
S7a	12.0 ML	REA dams designed to act as retention basins with releases directed to dam S8 & S10.
S7b	1.0 ML	
S7	41.5 ML	Main storage for catchment runoff from the REA with releases directed to Dam S9.
S8 / S10	0.5 ML	Dam S8 and S10 discharge to dam S9 and can overflow via LOP5.
S9	0.35 ML	Dam S9 pumps to dam S4 and can overflow via LOP3.

Source: CH2M Hill (2008) and SIMEC (2019)

2.1 PIT TOP AREA

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

[1] Environment Protection Authority – NSW, Licence 1389, version date: 13-Aug-2018.

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

The coagulant used is Magnasol® 572 which is a low molecular weight, highly cationic coagulant (BASF, 2015). Magnasol 572 is comprised of 98% polyaluminium chloride (PAC) and 2% quaternary ammonium cationic organic polymer of 8% nitrogen content (EcoEngineers, 2012). As such, Magnasol 572 may contribute to aluminium in discharge waters dependent on the volume used.

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 with the fine rejects 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. The binding agent PetroTac® is used to control dust emissions and suspended sediment in runoff from the Pit Top area. PetroTac is a non-toxic, non-hazardous, environmentally sensitive dust suppressant (SynTech Products Corporation, 2005).

A Gas Drainage Plant and 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. The product coal stockpile area drains to dams S2 and S3. Water overflows from these storages into the larger dam S4 from where water is automatically dosed with a coagulant 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.

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 and 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 was a requirement to enhance treatment of water prior to release via Pollution Reduction Program 22 which involved 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 (V): 0.013 mg/L
- Arsenic (III): 0.024 mg/L

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

The WWTP has had continued performance issues and as a result, Tahmoor Coal has been exploring alternative approaches to meeting the discharge water quality requirements (Tahmoor Coal, 2019). Tahmoor Coal have issued a specification for design and construction of an upgraded WWTP to treat water prior to discharge. The specified WWTP target water quality is to meet the 95th percentile ANZECC default guideline trigger values for the protection of aquatic ecosystems (ANZG, 2018). The specific targets are as follows:

- pH: 6.5-9
- Electrical Conductivity: <500 μS/cm
- Suspended Solids: <30 mg/L
- Turbidity: <150 NTU
- Oil and grease: <10 mg/L
- Iron: <0.7 mg/L
- Manganese: <1.9 mg/L
- Nickel: <0.011 mg/L
- Zinc: <0.008 mg/L
- Arsenic (V): <13 μg/L
- Arsenic (III): <24 μg/L

2.2 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. 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.

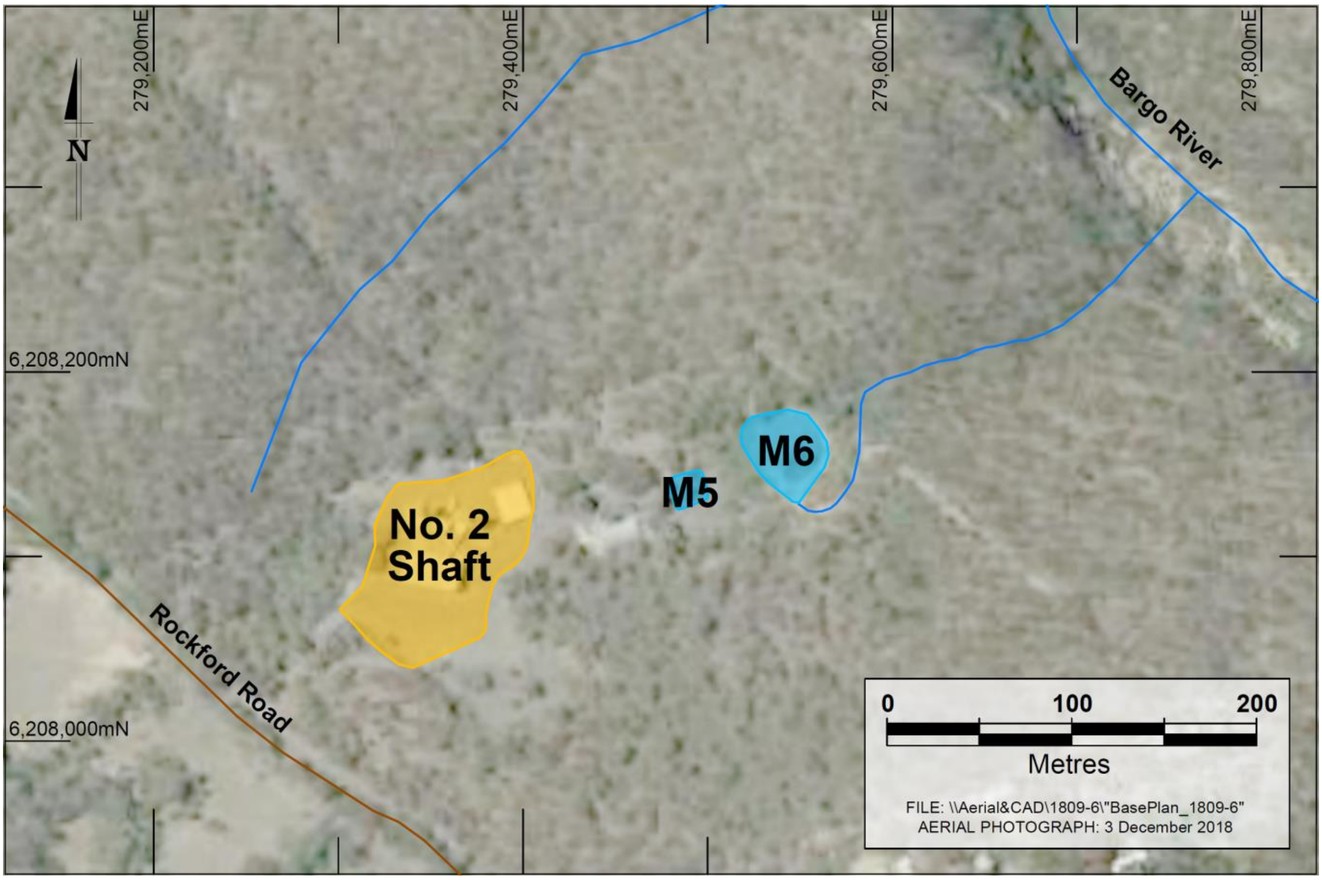


Figure 3 Layout of Vent Shaft No. 2 Area and Water Management Infrastructure

2.3 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 with Magnasol 572. Water from dam S4 is pumped to mine water dam M3 or, during wet weather, discharges to Tea Tree Hollow via LOP4. The REA is also currently served by LOP3 for overflow from dam S9 and LOP5 for overflow from dam S8 – refer Figure 4. A schematic representation of the existing water management system is shown in Figure 5.

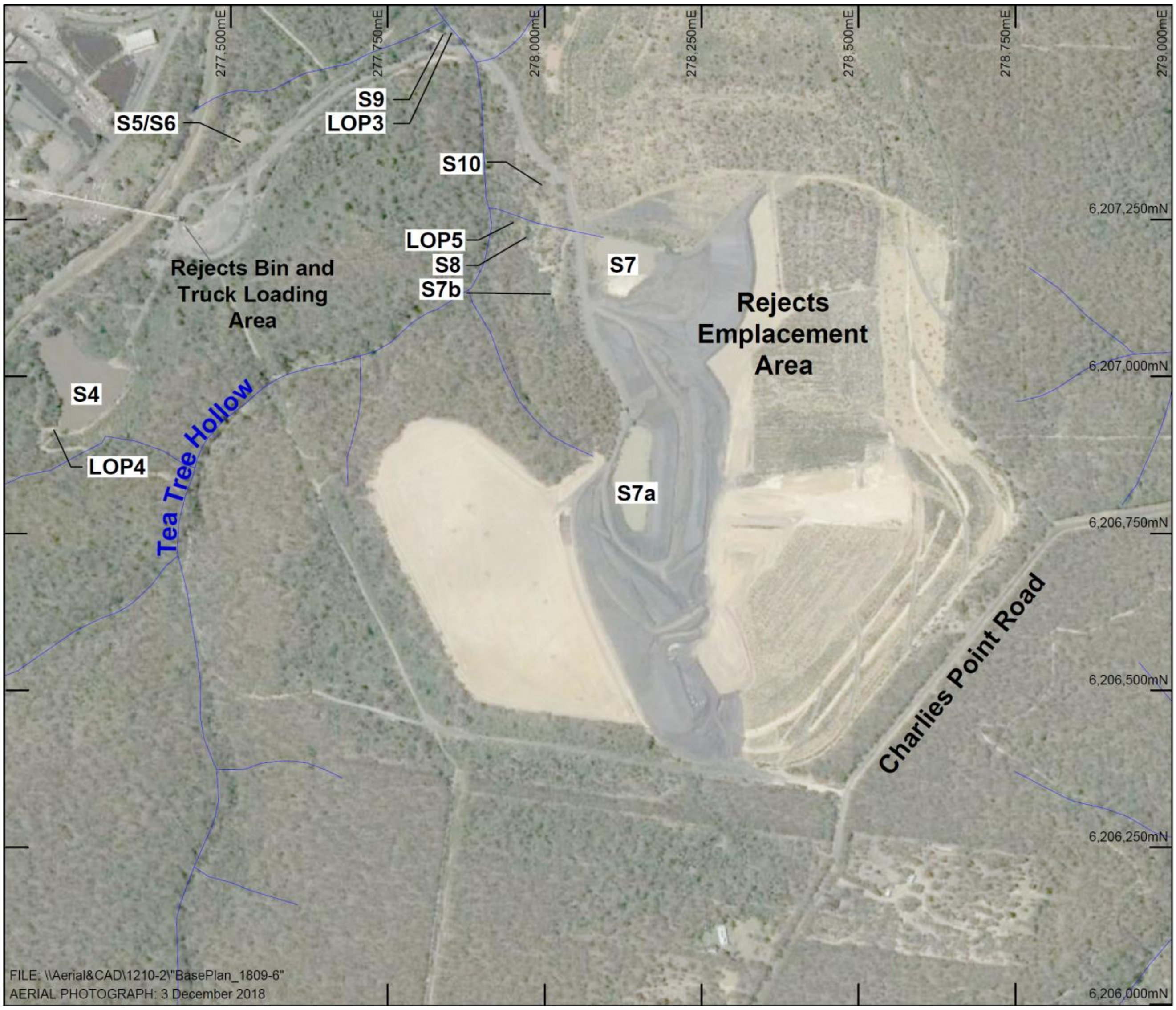


Figure 4 Layout of Reject Emplacement Area and Water Management Infrastructure

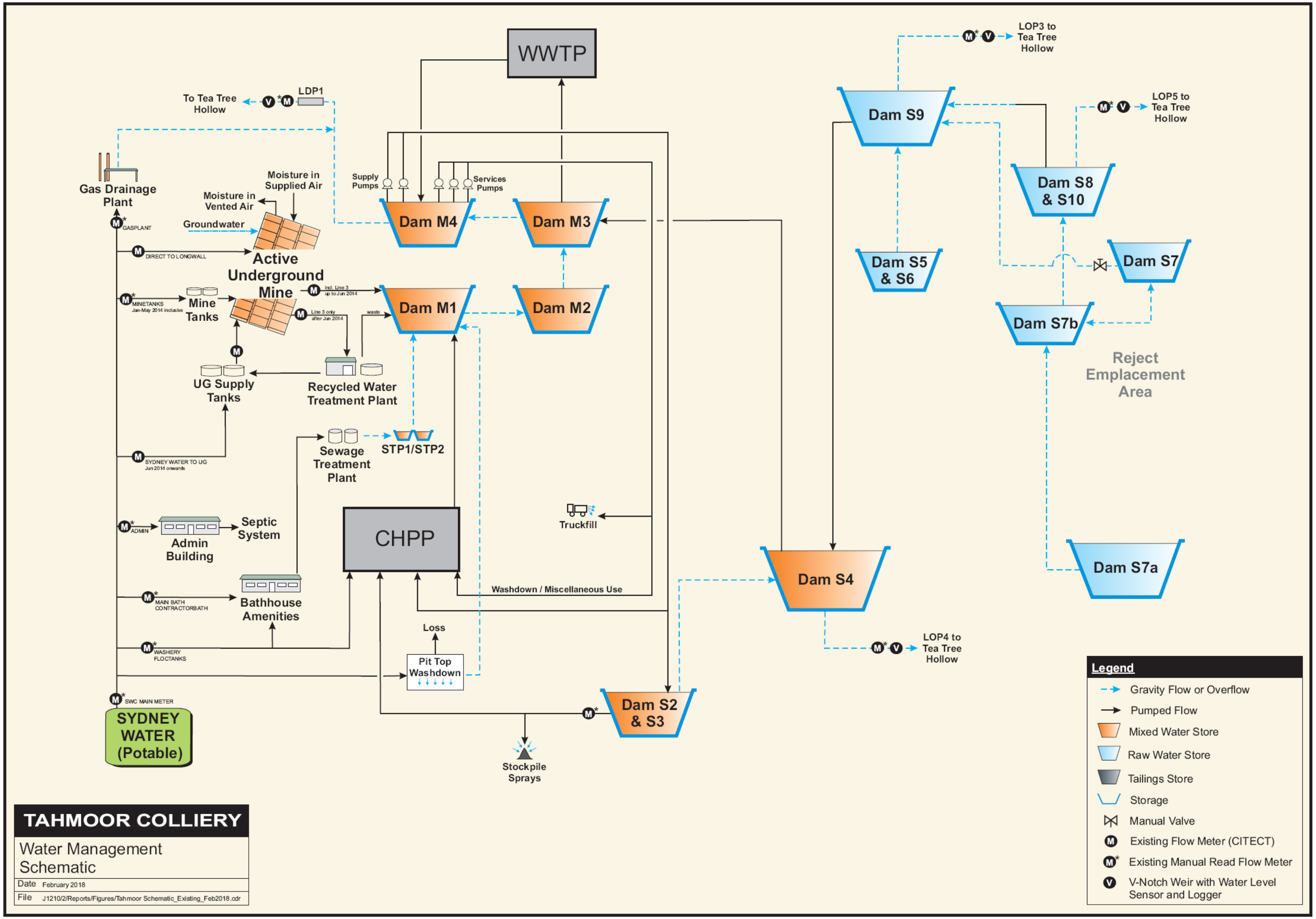


Figure 5 Schematic of Existing Water Management System

2.4 EXISTING SEDIMENT AND EROSION CONTROL

Erosion and sediment control at the REA is managed via a documented sediment and erosion control plan (Xstrata Coal, 2011). Sediment basins have been designed and are managed generally in accordance with the *Managing Urban Stormwater (Blue Book) Volume 2E* (DECC, 2008). There are no volumetric or water quality limits for the LOPs specified in EPL 1389, though overflow volume and water quality monitoring of the dams is undertaken by Tahmoor Coal. Table 2 presents the total monitored overflow volume discharged via each LOP between 2014 and 2018.

Table 2 LOP Overflow Volumes

Year	Overflow Volume (ML)		
	LOP3	LOP4	LOP5
2014	51.6	23.7	2.3
2015	2.4	32.8	1.6
2016	113.3	70.0	3.8
2017	0.0	27.0	0.8
2018	9.7	0.0	0.1

Table 2 illustrates that overflow to the LOPs has typically been low though peaked in 2016.

2.5 EXISTING ENVIRONMENT PROTECTION LICENCE – WATER MANAGEMENT CONDITIONS

Discharge to LDP1 occurs via a drain located within Mining Lease (ML) 1642 downstream from the mine water final treatment dam (dam M4 – refer Figure 2). The predominant inflow to dam M4 is treated water from the WWTP, with dam M4 also receiving overflow from dam M3. Dam M3 receives overflow from dam M2, while dam M2 receives overflow from dam M1. Dam M1 receives underground dewatering, with dam M3 supplying the WWTP. Water is sourced from dam M4 for on-site use. The catchment area of these dams (including dam M4) is small and overflow only occurs in periods of intense rainfall. The volumetric discharge limit from LDP1 per EPL 1389 is 15.5 ML/day. 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". On average, discharge to LDP1 was approximately 4.7 ML/d in 2016, 4.9 ML/d in 2017 and 3.9 ML/d in 2018 (SIMEC, 2019).

3.0 PROPOSED TAHMOOR SOUTH PROJECT WATER MANAGEMENT UPGRADES

The proposed Amended Project water management system will be based on the existing water management system, with most aspects to 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;
- Upgrade 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;
- Upgrade of the WWTP; 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.

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.

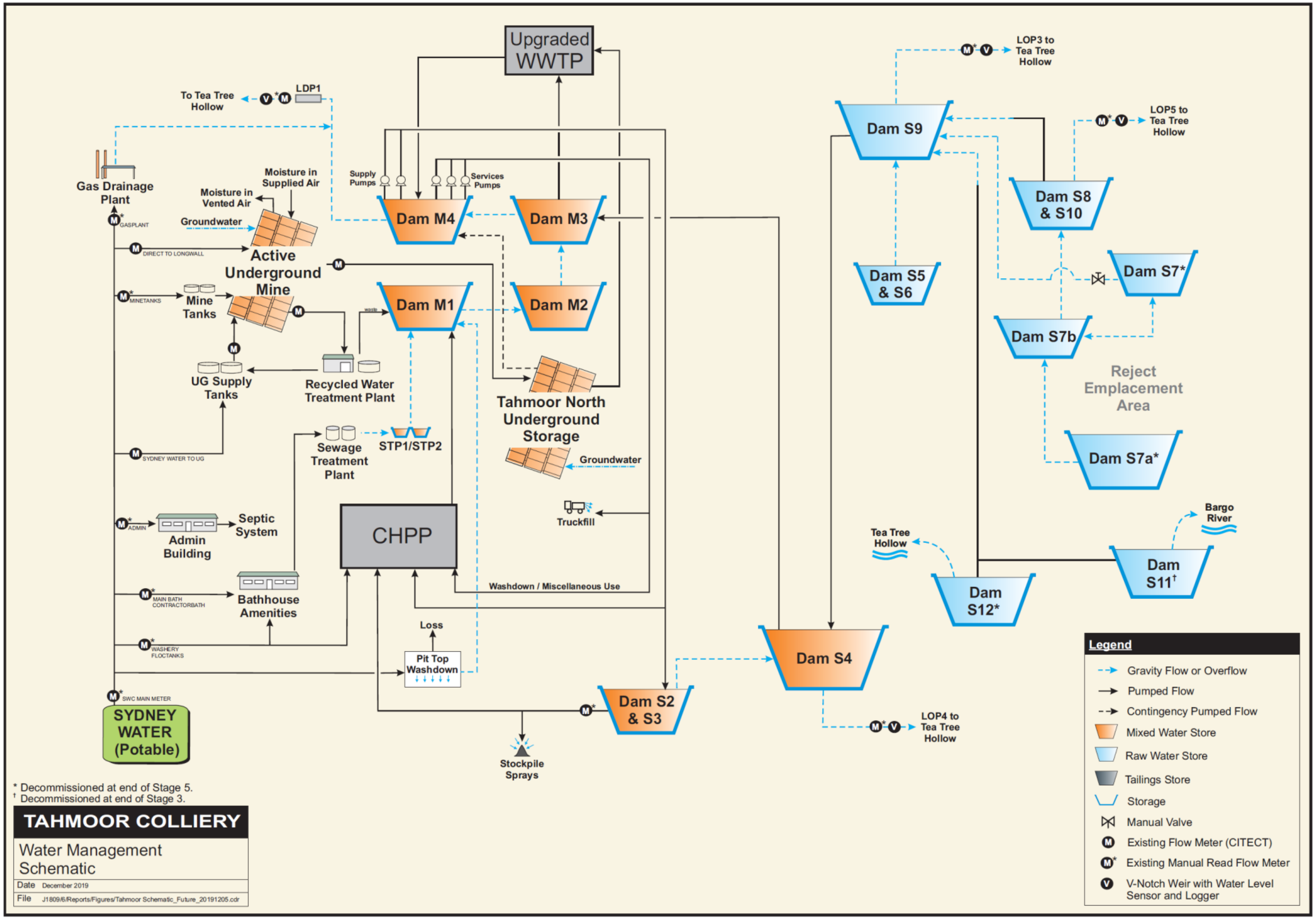


Figure 6 Schematic of Project Water Management System

3.1 REA EXPANSION

The disposal of CHPP reject over the remaining Project life would necessitate development of additional emplacement areas and extension of the height of existing emplacement areas. The REA is proposed to be developed in six stages over the remaining Project life as illustrated in Figure 7 to Figure 12. As with the current REA, drainage (runoff and seepage) from the REA would be directed to a series of sediment dams. 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. 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 illustrated in Figure 7 to Figure 12 and summarised as follows:

- The existing sediment dams external to the REA are to be retained until Stage 6.
- Additional drop structures and collection drains are to be constructed for each stage of the REA to direct runoff to dam S7 and S7a.
- Dam S11 is to be commissioned at the end of Stage 3 to manage runoff from the REA during Stage 4 to Stage 6.
- Dam S12 is to be commissioned at the end of Stage 5 to manage runoff from the REA during Stage 6.
- Dam S7 and S7a are to be decommissioned at the end of Stage 5 and covered with rejects within the extended REA.
- Water in dam S11 and S12 would be pumped to an open drain leading to S9.
- Any overflow from dam S11 would report to the Bargo River via the proposed diversion drain, while 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 by Australian Mine Design & Development (2019) and on the assumption that completed areas would be progressively rehabilitated – a process which involves shaping, placement of topsoil layers and vegetation. It has been assumed that once vegetation on rehabilitated areas of the REA has reached a stable condition (assumed to be three 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 segregating runoff from rehabilitated areas and runoff from adjacent active or partially rehabilitated areas.

3.2 PROPOSED SEDIMENT PONDS

The conceptual design of the proposed sediment dams, S11 and S12, has been undertaken in accordance with the Landcom (2004) and DECC (2008) guidelines as follows:

- Type F sediment retention basin;
- Sediment dams to be in place for more than three years;
- A sensitive receiving environment and therefore capacity to be adequate to capture runoff from a 95th percentile 5-day duration rainfall event of 66.3 mm (Camden 5-day rainfall depth in Table 6.3a of Landcom, 2004 – Camden was selected as the closest location to the Tahmoor Mine with available data as presented in Table 6.3a of Landcom, 2004);
- A volumetric runoff coefficient of 0.79 assuming soil hydrologic group D (Table F2 of Landcom [2004]) and a rainfall depth of 66.3 mm to calculate settling zone capacity; and
- Allowance for sediment storage zone capacity equal to 50% of the above calculated settling zone capacity.

The catchment areas of the sediment dams are shown on Figure 10 to Figure 12. The sediment dams have been conceptually sized by adopting a nominal 3 m depth and 1 vertical (V):2.5 horizontal (H) excavated side slopes. A summary of estimated catchment areas, resulting total capacity and storage surface area of each sediment dam is provided in Table 3.

Table 3 Summary of Proposed Sediment Dams

Sediment Dam	Stage/s Required	Estimated Maximum Catchment Area (ha)	Settling Zone Volume (ML)	Sediment Zone Volume (ML)	Minimum Required Volume (ML)	Surface Area at Minimum Required Volume (ha)	Pump Rate (L/s)
S11	4 to 6	23.3	12.2	6.1	18.3	0.8	30
S12	6	41.9	22.0	11.0	33.0	1.3	60

The sediment dams will be equipped with a pump to transfer water an open drain leading to S9. The pump rate, as specified in Table 3, has been selected based on the requirement that the sediment dams can be emptied within 5 days of filling, as per Landcom (2004).

3.3 POLLUTION REDUCTION PROGRAMS

A series of Pollution Reduction Programs (PRPs) have been implemented on site since 2005. There are currently two active programs relating to site water management. Stage 3 of PRP 22 involves the development and commissioning of the upgraded WWTP to improve the quality of mine water released from LDP1 (refer Section 2.1). PRP 26 involves an aquatic health assessment in Tea Tree Hollow and the Bargo River to assess the effects of the mine water discharge through LDP1. PRP 26 is to be completed within 9 months of completion of PRP 22.

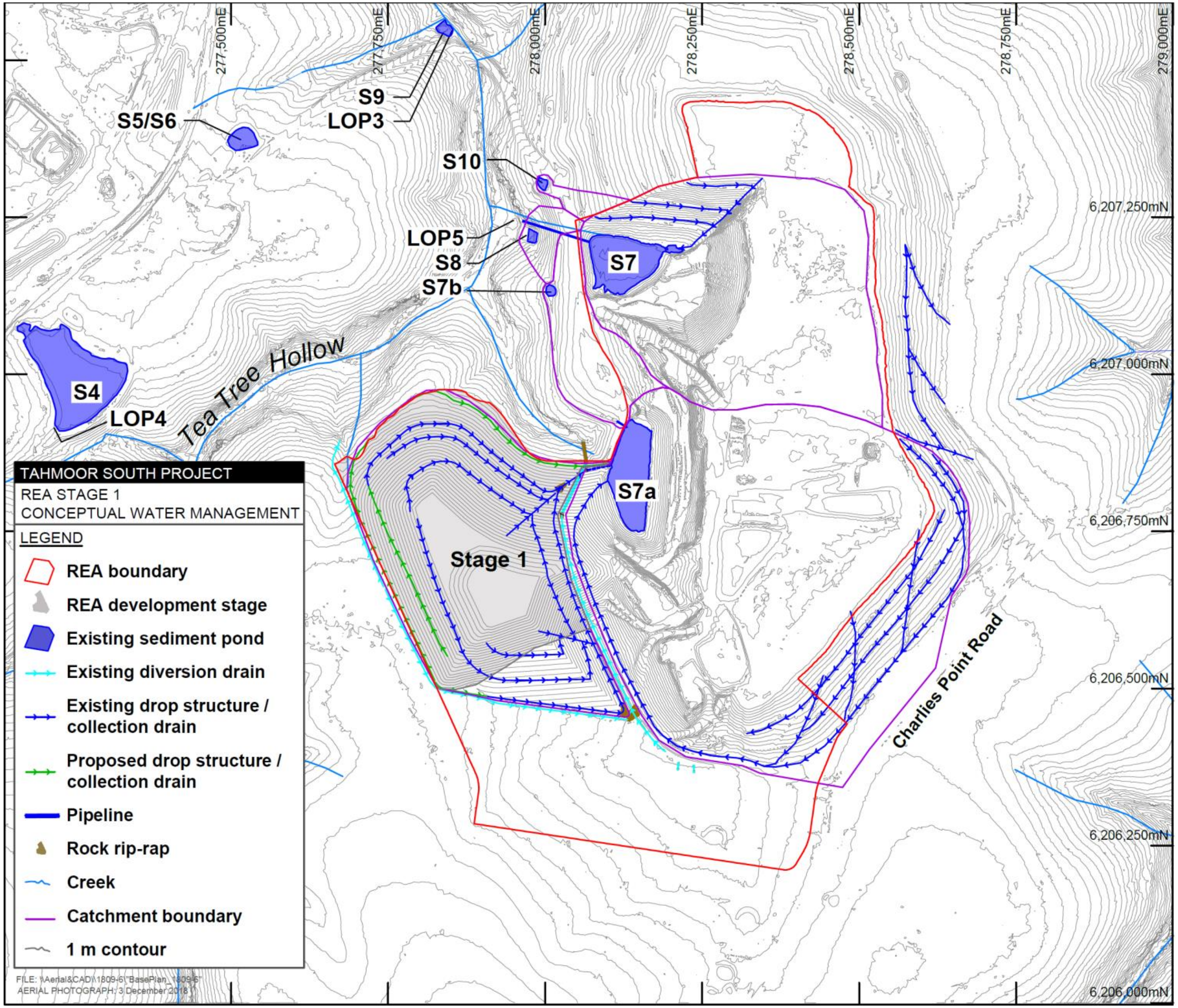


Figure 7 REA Stage 1 Conceptual Water Management System

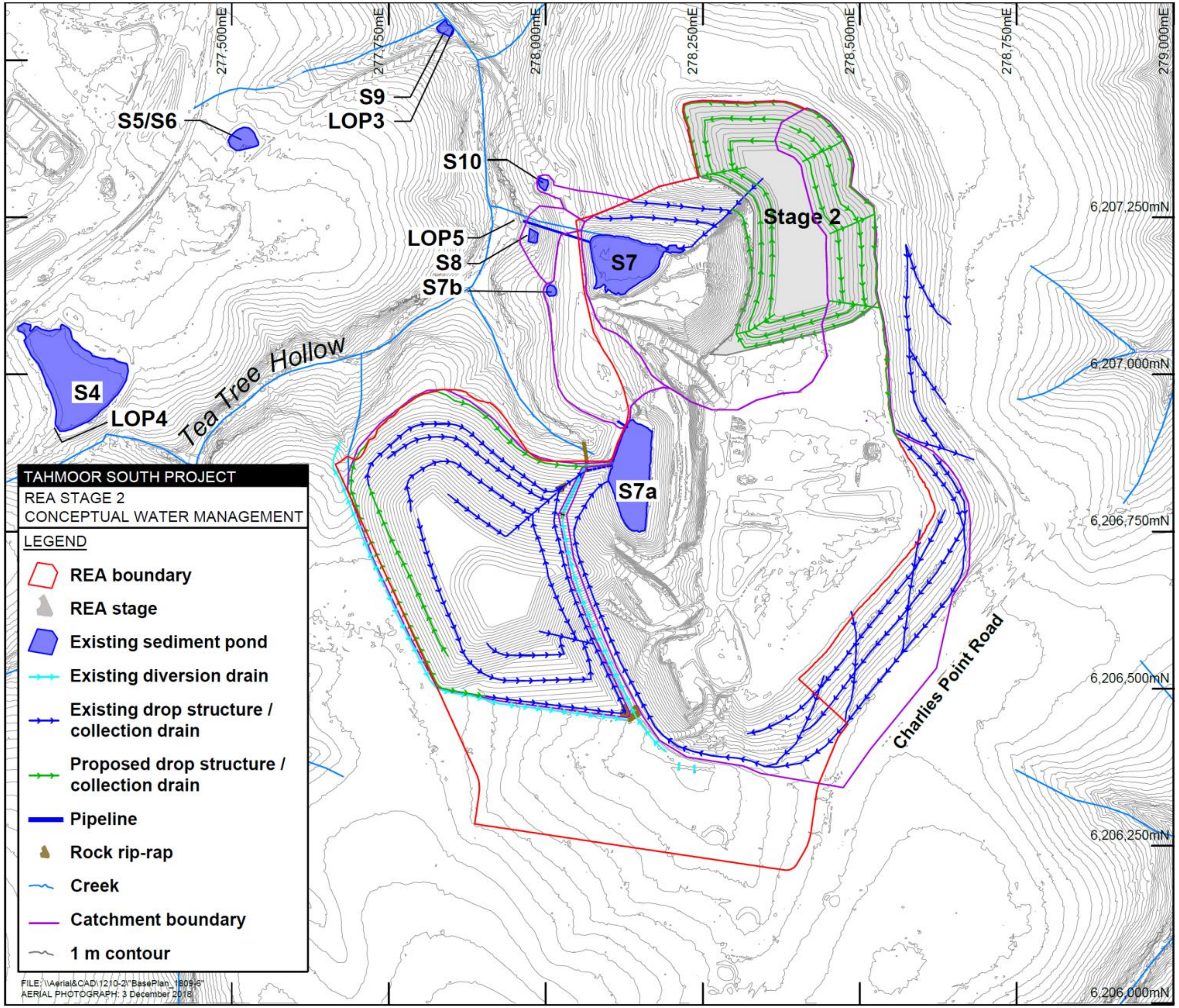


Figure 8 REA Stage 2 Conceptual Water Management System

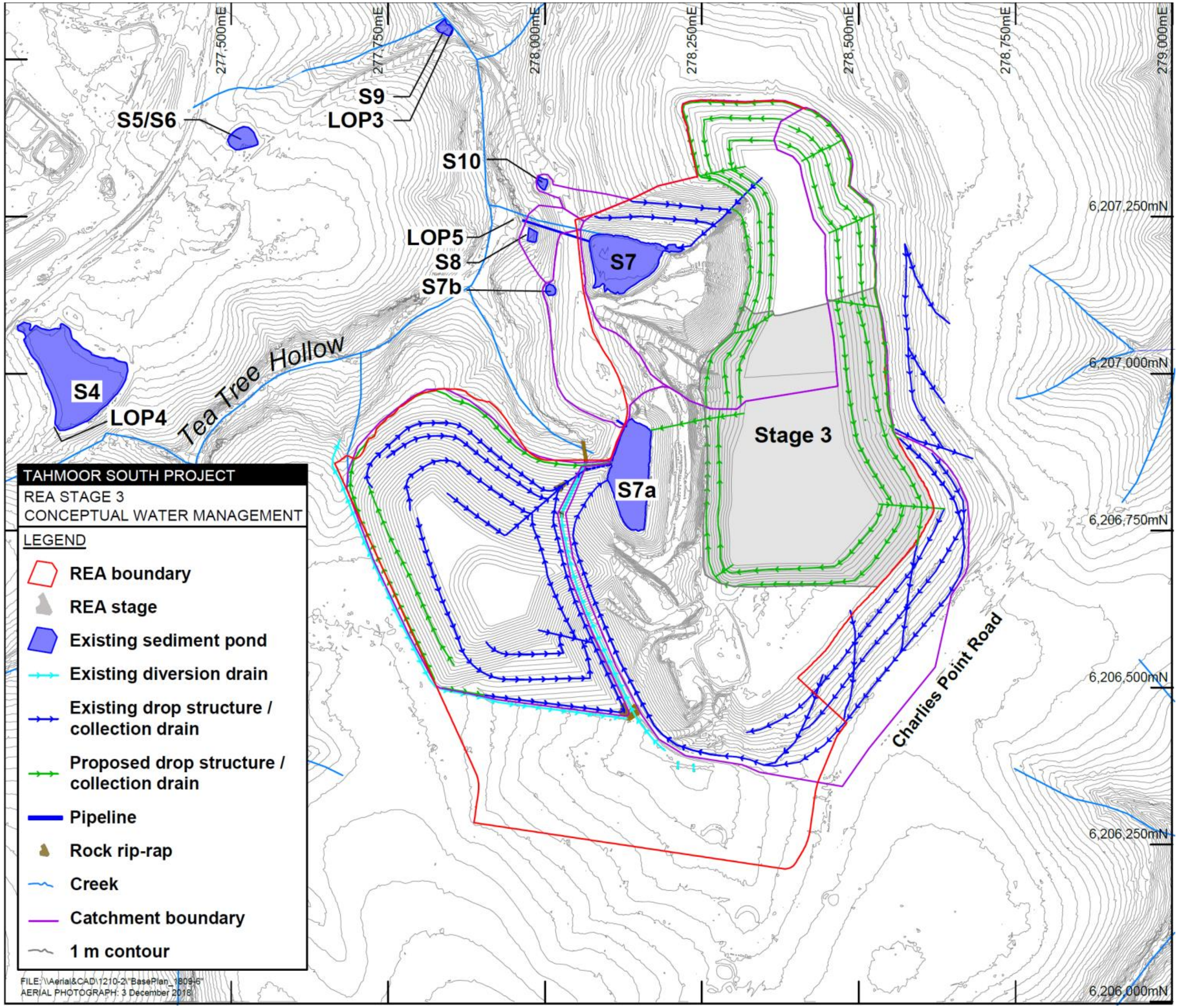


Figure 9 REA Stage 3 Conceptual Water Management System

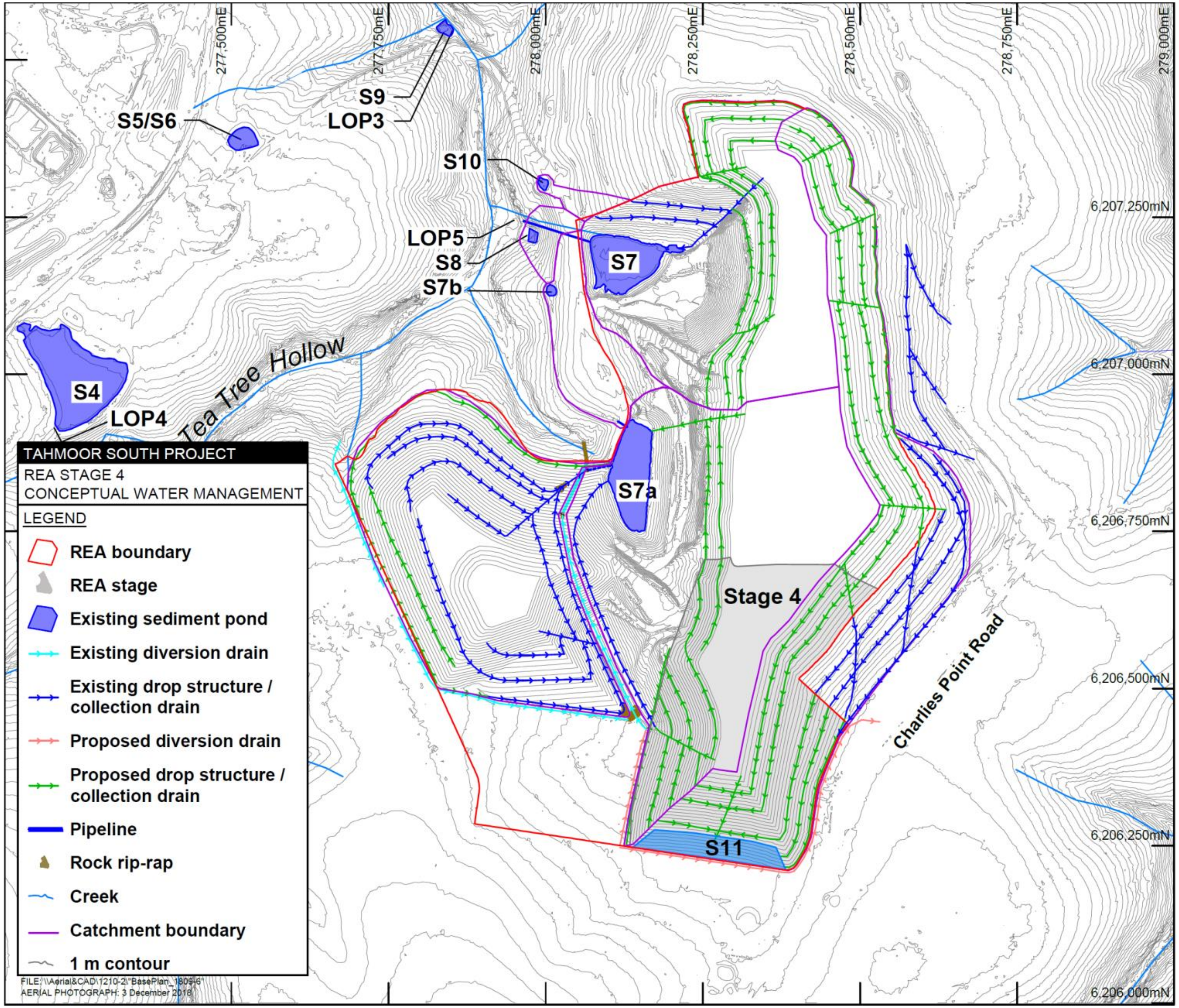


Figure 10 REA Stage 4 Conceptual Water Management System

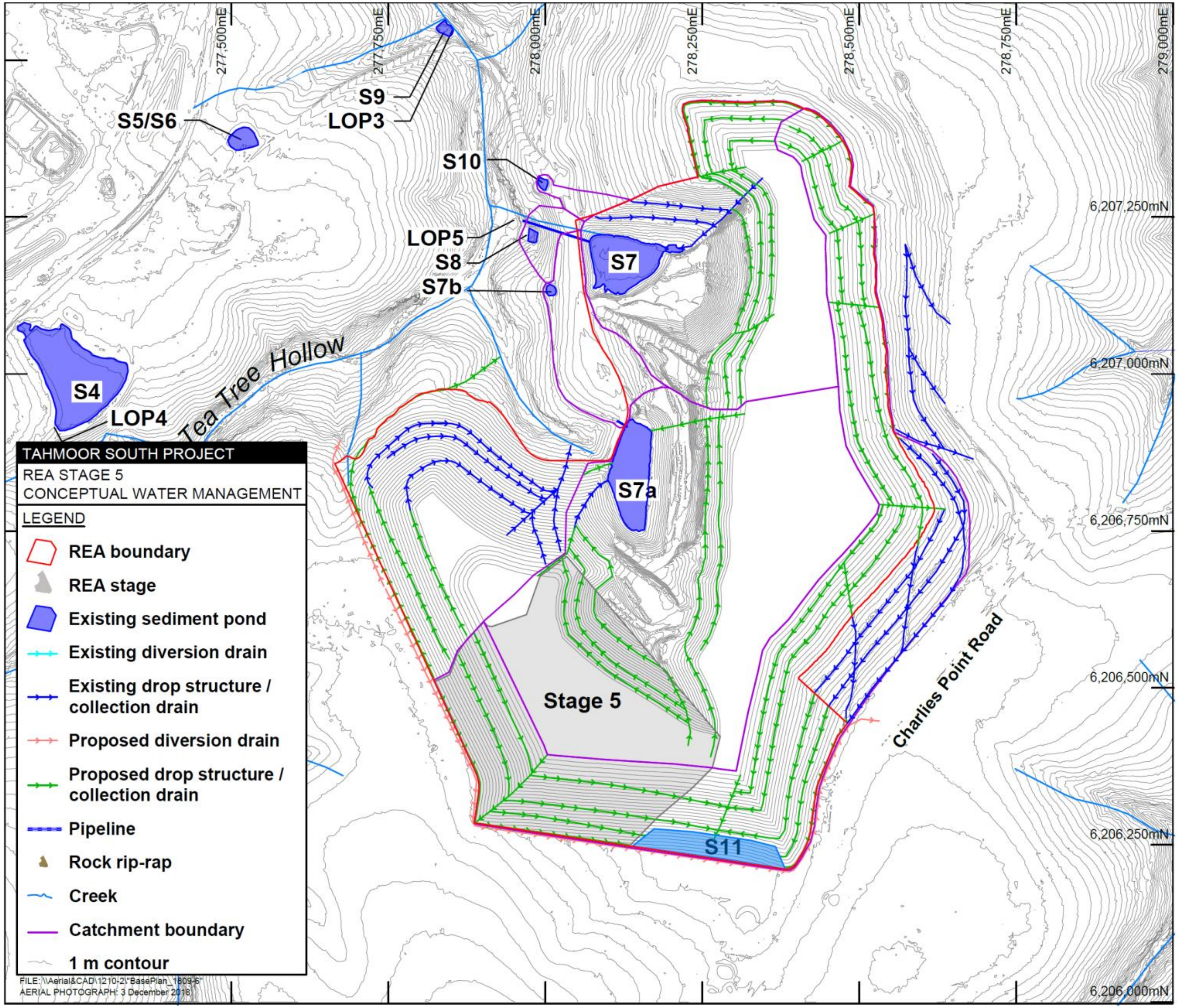


Figure 11 REA Stage 5 Conceptual Water Management System

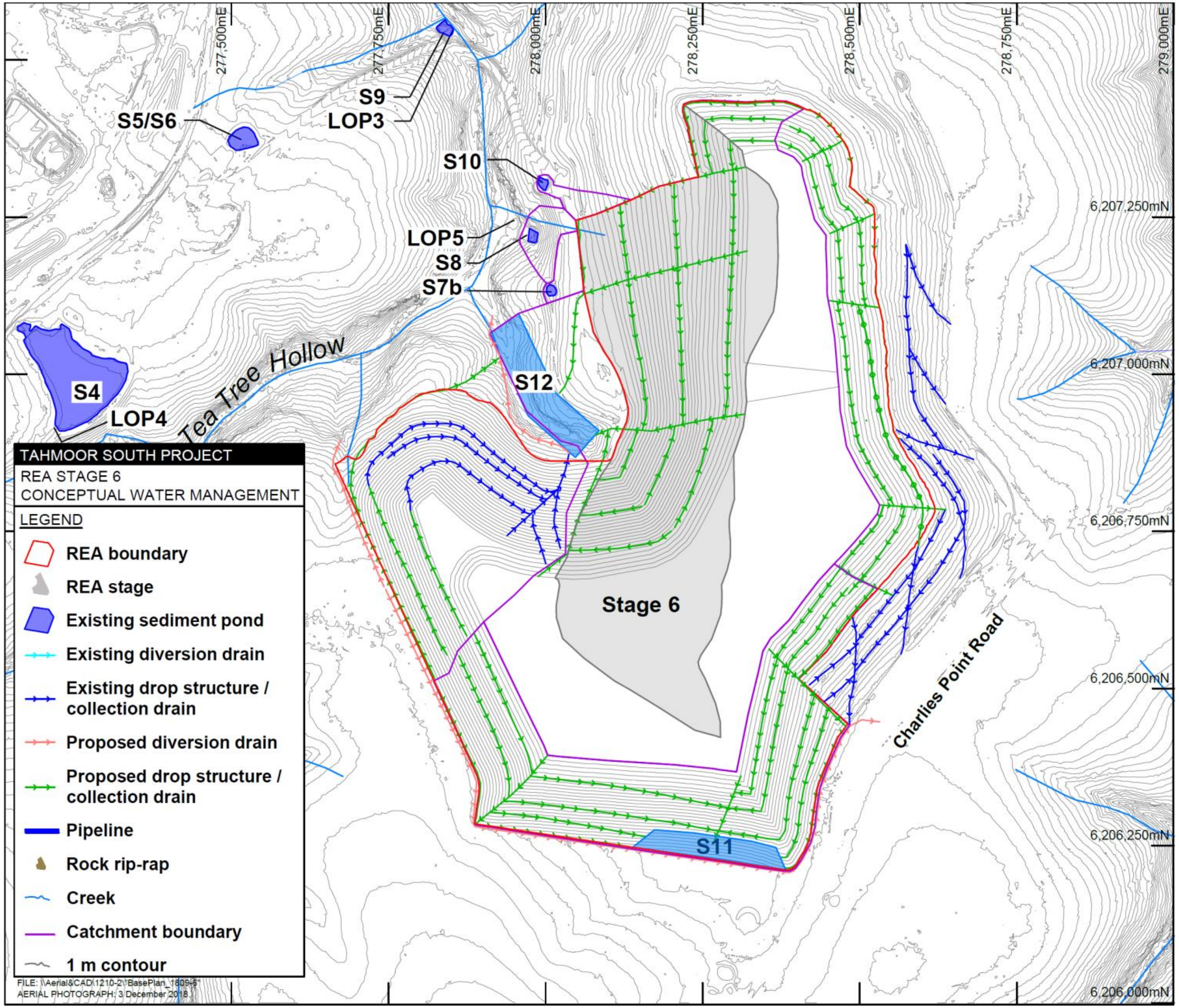


Figure 12 REA Stage 6 Conceptual Water Management System

3.4 UNDERGROUND WATER STORAGE

The current WWTP capacity of 6 ML/day is to be retained for the proposed upgraded WWTP. Forecast groundwater modelling for the Project (HydroSimulations, 2020) has indicated that Project underground inflows may at times exceed 6 ML/day. In addition to underground dewatering, water recovered from the pit top area and REA which is pumped to mine water dam M3 (i.e. rainfall runoff from these areas) will also report to the upgraded WWTP (refer Figure 6). Therefore, there may be times when the capacity of the upgraded WWTP is exceeded. As part of the Amended Project, it is proposed to develop an underground storage within goafed areas of the Tahmoor North underground into which mine dewatering from the Tahmoor South underground would be pumped. At times of lower inflow, water could be recovered from the underground storage, treated within the upgraded 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 4,752 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.

3.5 VENTILATION SHAFTS

The Project will continue to use the existing ventilation system and shafts as outlined in Section 2.2. Two additional ventilation shafts are proposed to be constructed as part of the Amended Project. 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 13.

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.

3.6 SEWAGE TREATMENT PLANT UPGRADE

An upgrade is proposed at the pit top STP to treat sewage on site for additional bathhouses. The upgraded STP is proposed to have a peak capacity of 61 kL/day (Cardno, 2019). The STP will be designed and constructed to produce effluent of a suitable quality to enable discharge via LDP1 or to be used in the future for irrigation of the REA. The treated water quality to be achieved at the discharge outlet is presented in Table 4.

Table 4 Upgraded STP Treated Water Quality

Parameters	Treated Water Quality	
	50^{th} Percentile	90^{th} Percentile
Biological Oxygen Demand (mg/L)	5	10
Total Suspended Solids (mg/L)	10	15
Total Nitrogen (mg/L)	6	1
Ammonia (mg/L)	1	2
Total Phosphorus (mg/L)	0.3	0.5
pH	6.5-8.5	6.5-8.5
Oil and grease (mg/L)	-	5
Escherichia Coli (CFU/100 mL)	-	200

* Source: Cardno (2019)

In accordance with the requirements of the *Australian Guidelines for Water Recycling* (NHMRC, 2006), the upgraded STP will achieve a validated 1 log virus removal.

Discharge to LDP1 would continue to occur in accordance with EPL 1389. Water quality monitoring for a range of constituents, including faecal coliforms, would continue to be undertaken in accordance with the existing water monitoring program for LDP1.

Figure 13 Proposed Project Conceptual Ventilation Shaft Layout

4.0 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 and Amended Project life (i.e. from 2020 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. The model operates on a sub-daily time step and simulates the water balance behaviour of all the storages and storage linkages shown in Figure 5 and Figure 6.

4.1 CLIMATIC DATA USED IN SIMULATIONS

A long sequence of historical climate data (rainfall and evaporation) was obtained from the SILO Data Drill[2] for use in the model. The Data Drill comprised daily rainfall and evaporation for the period from 1889 to 2018 inclusive. The model was run using one hundred and thirty (130) possible 16-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 1889 to 1905, the second sequence comprising 1890 to 1906, the third sequence comprising 1891 to 1907 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.

4.2 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 have been cleared of vegetation and topsoil stripped in preparation for reject disposal);
4. Active reject disposal areas;
5. Partially rehabilitated reject disposal areas – rehabilitated areas for which vegetation has become partially established;
6. Fully rehabilitated reject disposal areas; and
7. Coal stockpile areas.

The identification of sub-catchment areas was based on the most recent aerial photograph and an indication of the future progression of the REA.

2 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 (Jeffrey, 2001).

For the natural sub-catchment type, model parameters were derived from an AWBM calibrated to approximately reproduce flows in a nearby gauged watercourse[3]. Parameters for other sub-catchment types were set based on experience with similar projects and adjusted as part of calibration (refer Section 5.0).

4.3 PROJECT AREA CATCHMENTS

The Project catchments in the pit top area reporting to each storage are summarised in Table 5. These catchments are not expected to change over the planned Project life.

Table 5 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 6. 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 three-year period to establish a revegetated cover.

Table 6 Pit Top Area REA Catchments

Date Commencing	Stage	Sub-Catchment Areas (ha)								
		Hardstand	Natural (undisturbed)	Cleared and Stripped	Active rejects disposal	Covered rejects	Partially rehabilitated	Fully rehabilitated	Stockpiles	TOTAL
Jan 2020	Existing	3.5	4.1	13.2	13.9	5.3	13.2	8.4	0.0	61.6
Jul 2020	1	3.5	4.1	14.2	13.9	5.3	13.2	8.4	0.0	62.6
Jul 2023	2	3.5	4.1	8.3	26.1	5.3	9.4	9.3	0.0	66.1
Jul 2024	3	3.5	4.1	2.0	35.2	1.3	15.4	4.6	0.0	66.1
Jul 2026	4	3.9	2.5	10.1	35.2	1.3	11.2	4.8	0.0	68.9
Jul 2029	5	3.6	2.5	8.3	28.9	0.0	16.9	4.8	0.0	65.0
Jul 2033	6	3.2	3.0	2.2	18.5	10.4	6.7	12.5	0.0	56.5

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

4.4 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[4].

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% (w/w)
- Product coal: 7.79% (w/w)
- Combined rejects (on conveyor): 11% (w/w)

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 7.

Table 7 Annual Coal Processing and Make-Up Water Demand Schedule

Date	Bulk ROM (Mt)*	Product (Mt)†	CHPP Make-Up Demand (ML)
Jan 2020	2.9	2.0	69
July 2020	2.6	1.8	58
July 2021	2.2	1.5	52
July 2022	1.2	0.7	31
July 2023	3.6	2.3	87
July 2024	3.0	2.0	71
July 2025	3.3	2.5	71
July 2026	3.3	2.6	69
July 2027	3.4	2.8	70
July 2028	3.4	2.7	71
July 2029	3.3	2.7	66
July 2030	3.2	2.6	67
July 2031	3.6	3.0	72
July 2032	3.2	2.7	65
July 2033	3.0	2.4	65
July 2034	3.3	2.1	81
July 2035	1.9	1.3	42
Total	**50.3**	**37.8**	**1,109**

* At ROM moisture

† At Product moisture

[4] 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 constraints – e.g. supply to flocculant tanks and washery potable supply. These demand rates have been based on recent average monitored use supplied by Tahmoor Coal with future variations proportioned according to forecast ROM Coal tonnages.

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 and haul roads and 73 ML/annum for coal stockpile areas.

4.5 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). Underground water (groundwater inflow plus water supplied from the surface for underground use) from Tahmoor South, in excess of the upgraded WWTP capacity, will be pumped to the Tahmoor North underground for storage (refer Section 3.4). For the purposes of the model simulation, it was assumed that the underground storage was available at the start of the simulation period.

Predictions of future groundwater inflow to the Tahmoor North and Tahmoor South underground mining operations and to the proposed underground water storage were provided by HydroSimulations (2020). The predicted groundwater inflow rates are plotted in Figure 14.

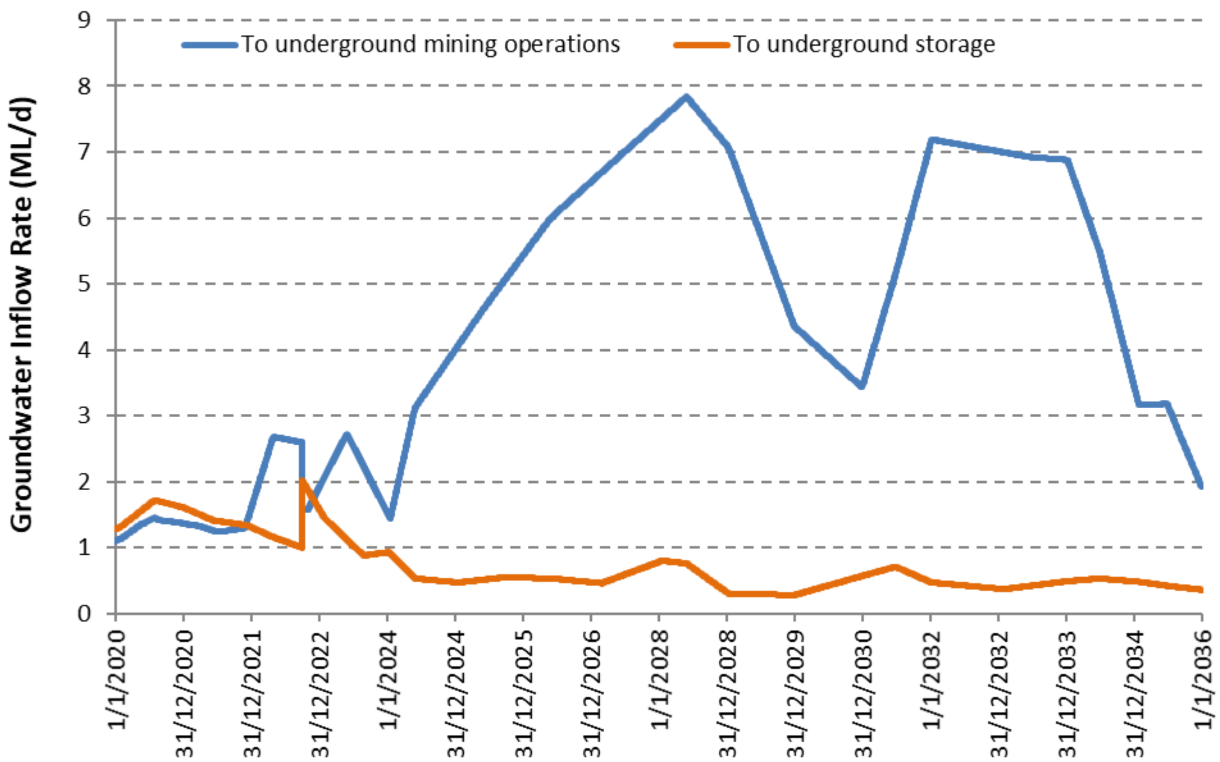


Figure 14 Predicted Groundwater Inflow Rates (HydroSimulations, 2020)

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.

4.6 WATER MANAGEMENT STORAGES

Details of the existing and proposed water management storages provided by Tahmoor Coal are summarised in Table 8.

Table 8 Summary of Water Management Storages

Storage	Capacity (ML)	Surface Area at Capacity (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	0.48	Existing pit top sediment and water retention dam to be retained
M4	8.0	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 and replaced by S12 at the end of Stage 5
S7a	12.0	1.42	Existing sediment dam to be decommissioned and replaced by S12 at the end of Stage 5
S7b	1.0	0.06	Existing sediment dam to be retained
S8 and S10	0.5	0.04	Existing sediment dams to be retained
S9	0.4	0.40	Existing sediment and transfer dam to be retained
S11	18.3	0.76	Proposed REA sedimentation dam to be commissioned at the end of Stage 3
S12	33.0	1.30	Proposed REA sedimentation dam to be commissioned at the end of Stage 5
Underground Water Storage	4,752	n/a	Assumed commissioned at the start of the Project

4.7 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 9.

Table 9 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 or S4 above 95% capacity	60 L/s
S4	M3	S4 above 90% capacity and M3 below 80% capacity	S4 below 90% capacity or M3 above 80% capacity	50 L/s
S11	S9	S9 below 70% capacity and S11 above 10% capacity	S9 above 70% capacity or S11 below 10% capacity	30 L/s
S12	S9	S9 below 70% capacity and S12 above 10% capacity	S9 above 70% capacity or S12 below 10% capacity	60 L/s
Underground Water Storage	Upgraded WWTP and M4	Upgraded WWTP inflow rate less than 6 ML/day	Upgraded WWTP inflow rate equal to or greater than 6 ML/day	6 ML/day minus Upgraded WWTP inflow rate

4.8 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 (9 ML/annum)
    b. Pit top washdown (136 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 4.5)
    f. CHPP make-up water (refer Section 4.4)
3. Underground mine water extraction including groundwater inflow based on groundwater inflow predictions produced by HydroSimulations (2020)
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 4.4)
4. Water discharged to the environment (via LDP1, LOPs and proposed S11 and S12)
5. Water losses during truck washdown and other facilities water use (15 ML/annum based on estimated 10% loss of current wash down use)

5.0 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 15 to Figure 18.

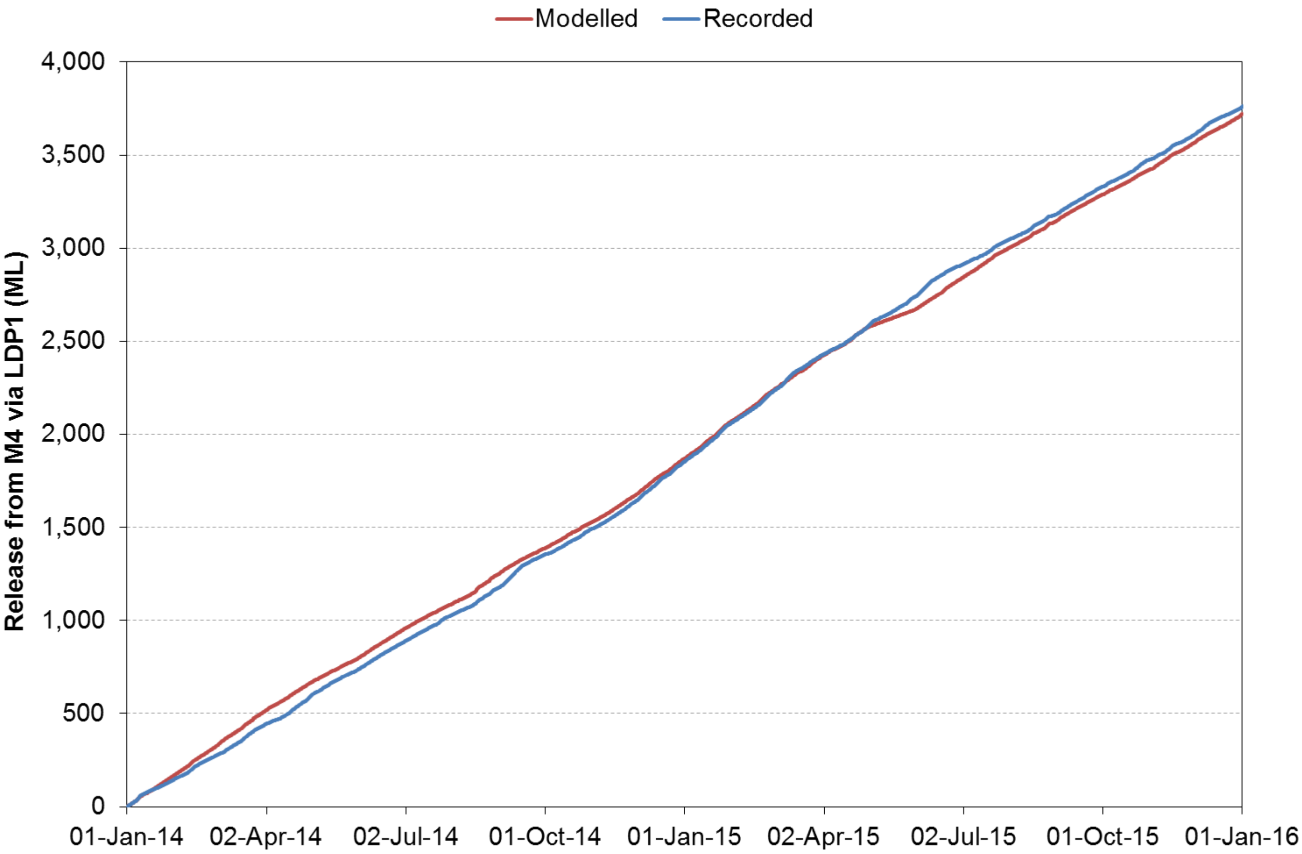


Figure 15 Modelled Versus Recorded Cumulative Release from M4 via LDP1

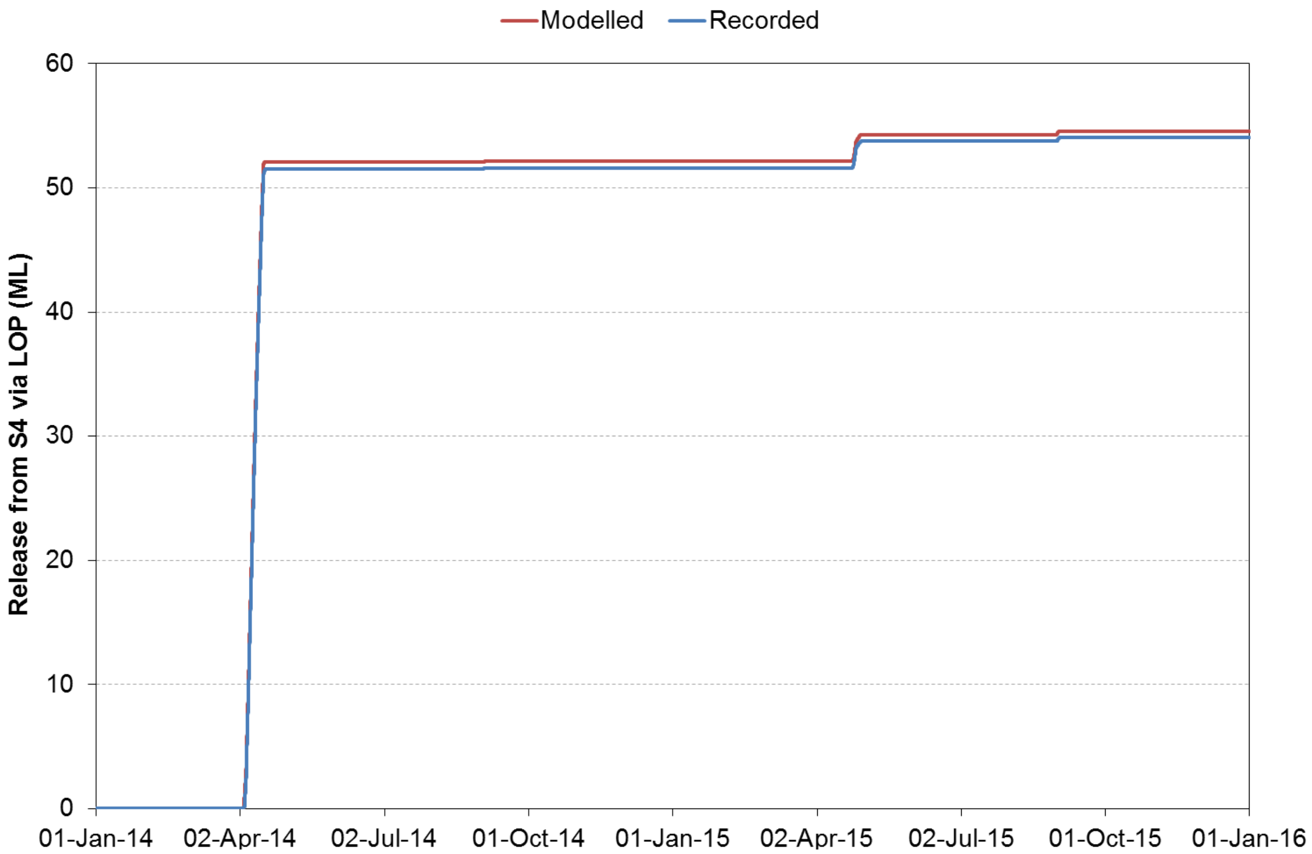


Figure 16 Modelled Versus Recorded Cumulative Release from S4 via LOP

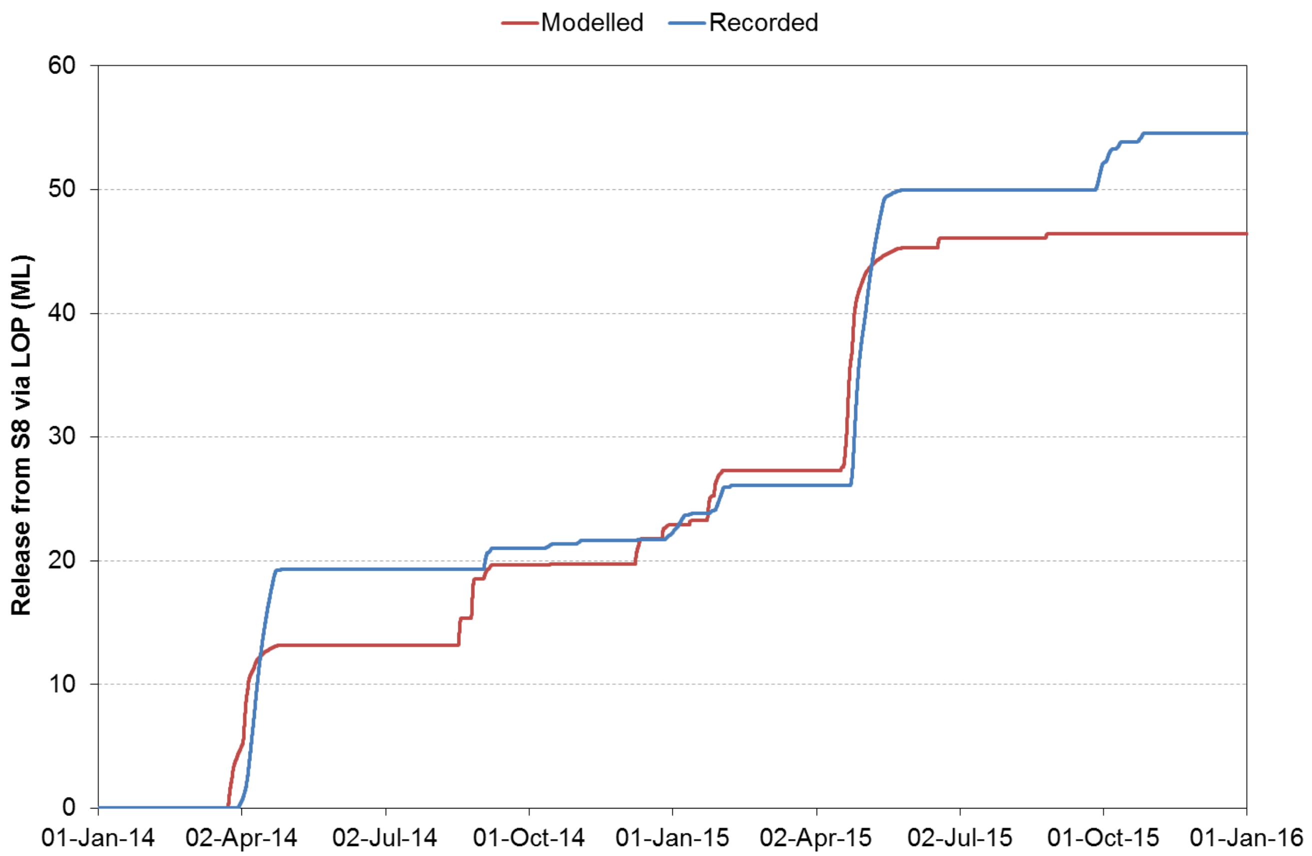


Figure 17 Modelled Versus Recorded Cumulative Release from S8 via LOP

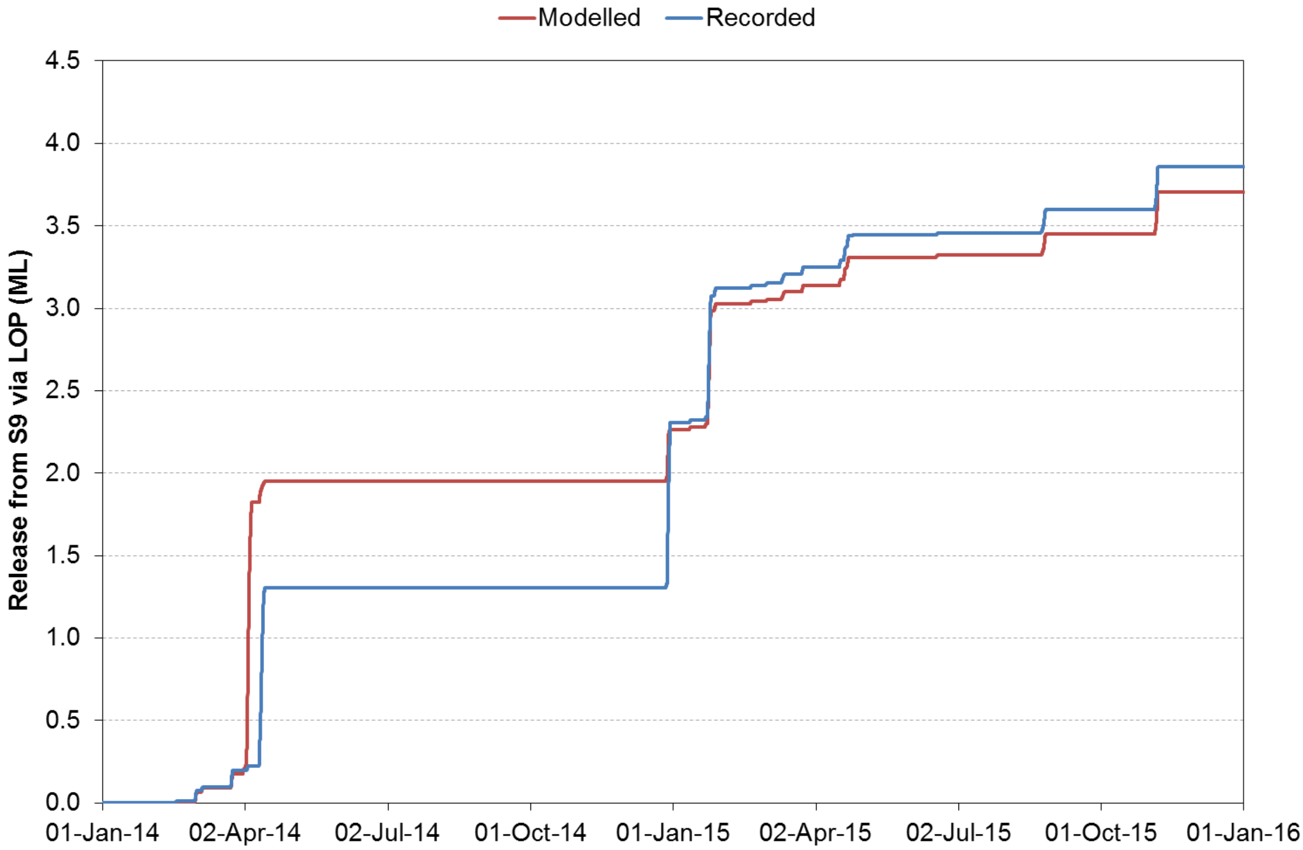


Figure 18 Modelled Versus Recorded Cumulative Release from S9 via LOP

Figure 15 to Figure 18 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 10.

Table 10 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

6.0 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 the conditions of EPL 1389.

6.1 AVERAGE SIMULATED SYSTEM ANNUAL INFLOWS AND OUTFLOWS

The simulated average annual total system inflows and outflows over the Amended Project life are summarised in Table 11. The results have been averaged over the full model simulation period of 16 years.

Table 11 Simulated Average Water Balance Results

Description	Volume (ML/annum)	% of Total Inflows or Outflows
Inflows		
Rainfall Runoff	366	13%
Sydney Water Supply	480	17%
Groundwater Inflow to Underground Mine	1,916	66%
Ventilation Moisture (In)	136	5%
Total Inflows	**2,897**	
Outflows		
Evaporation	63	2%
Discharge via LDP1	2,030	77%
Release via LOPs, S11 and S12	120	5%
CHPP Make-Up Water Supply	81	3%
Haul Road Dust Suppression	11	<1%
Stockpile Sprays (Dust Suppression)	73	1%
Pit Top Washdown Water	14	3%
Ventilation Moisture (Out)	254	10%
Total Outflows	**2,645**	

The excess of inflow over outflow in Table 11 indicates a net increase in stored water over the Amended Project life – refer Section 6.4. 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 4.5).

6.2 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 19 shows the simulated demand for potable water from the Sydney Water supply. The forecast annual average of 480 ML (refer Table 11) is within the range of recorded annual volumes for 2014 to 2018 (ranging from 403 ML to 549 ML).

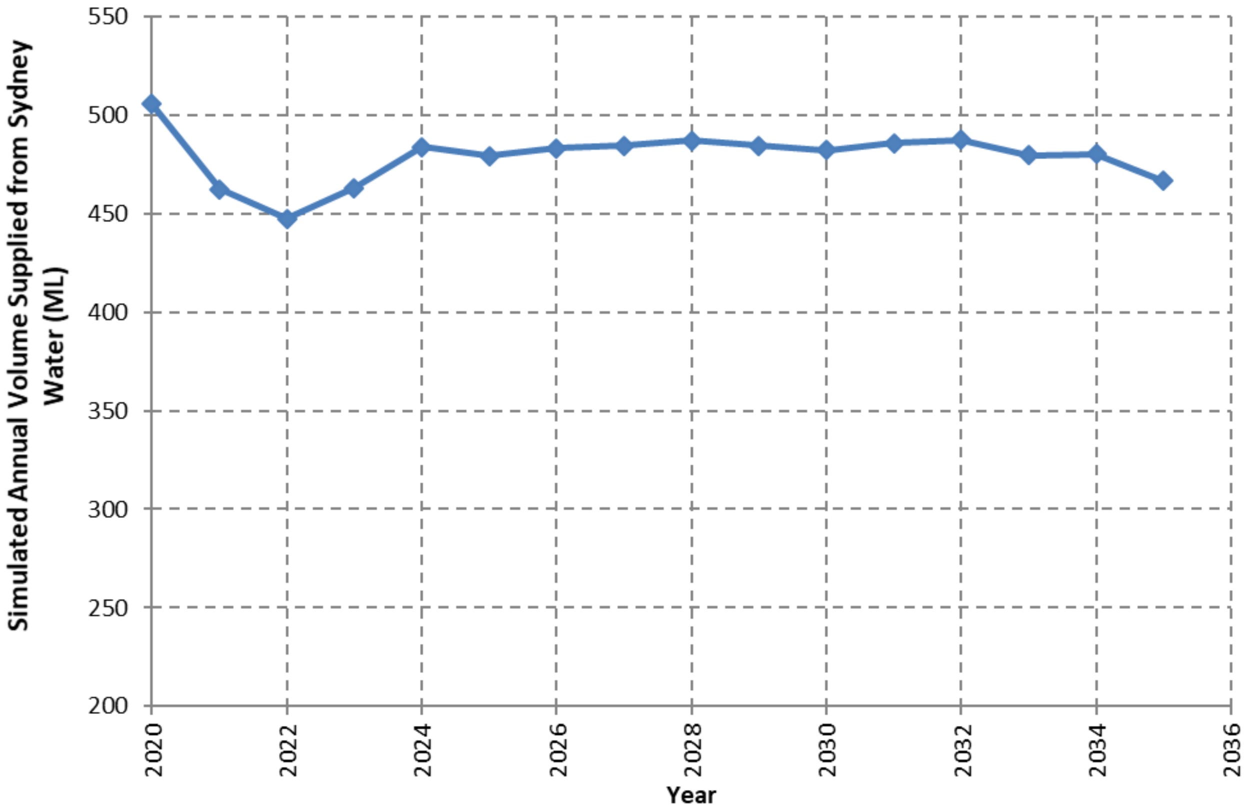


Figure 19 Simulated Annual Water Demand from Sydney Water

6.3 CONTROLLED RELEASES AND STORAGE OVERFLOWS

Simulated volumes of water discharged via LDP1 over the Project life are shown in Figure 20. The 5th percentile and 95th percentile results represent the range of predicted total annual volumes 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 130 simulated sequences. It should be noted that the results presented in Figure 20 are for each independent year and do not necessarily represent a sequence of results for the full simulation period (16 years).

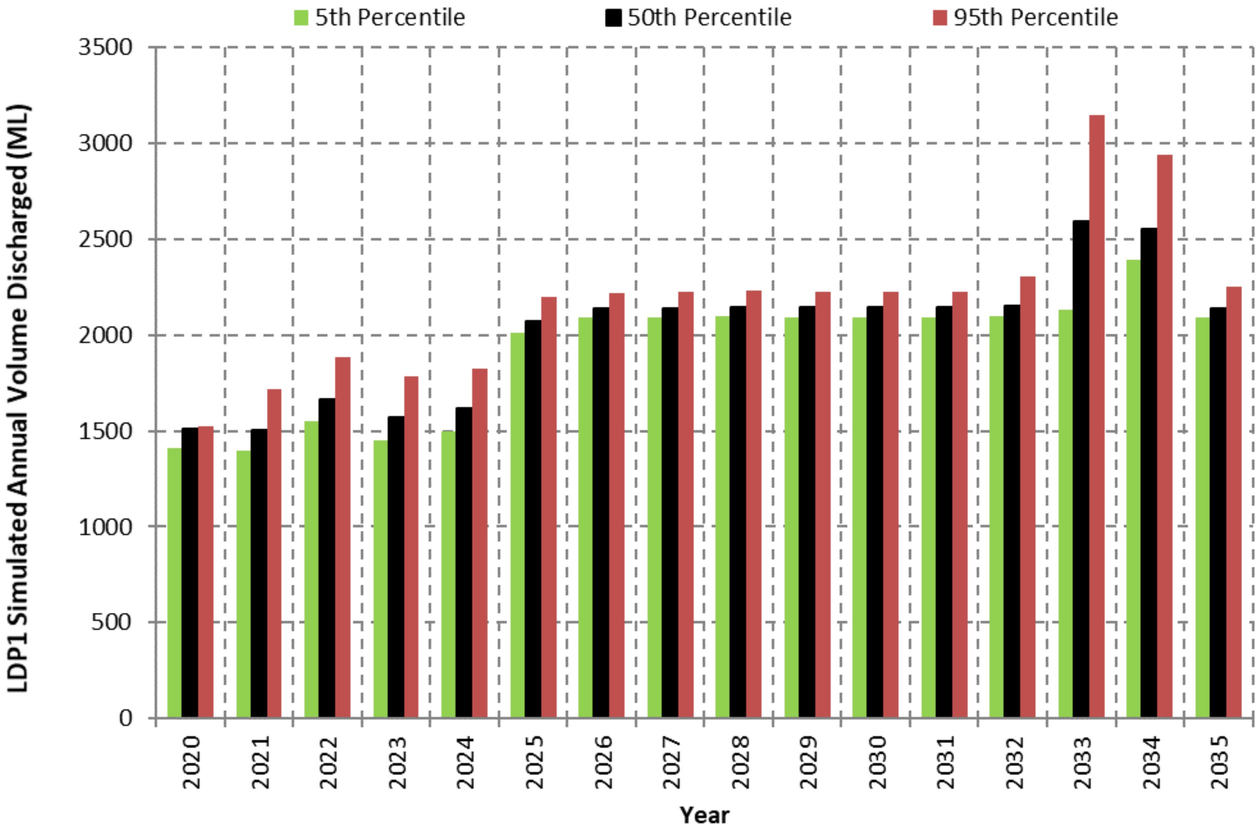


Figure 20 Simulated Annual Exceedance Statistics for Release via LDP1 to Tea Tree Hollow

Figure 20 illustrates that release via LDP1 to Tea Tree Hollow is predicted to peak in 2033 at 3,148 ML based on the 95th percentile result and 2,595 ML based on the median result. On average, based on the results for the full simulation period (16 years) and all 130 realizations, release to LDP1 is predicted at 2,029 ML/annum.

Figure 21 shows annual exceedance statistics for simulated overflow releases to Tea Tree Hollow via the LOP3, LOP4 and LOP5. It should be noted that the results presented in Figure 21 are for each independent year and do not necessarily represent a sequence of results for the full simulation period (16 years).

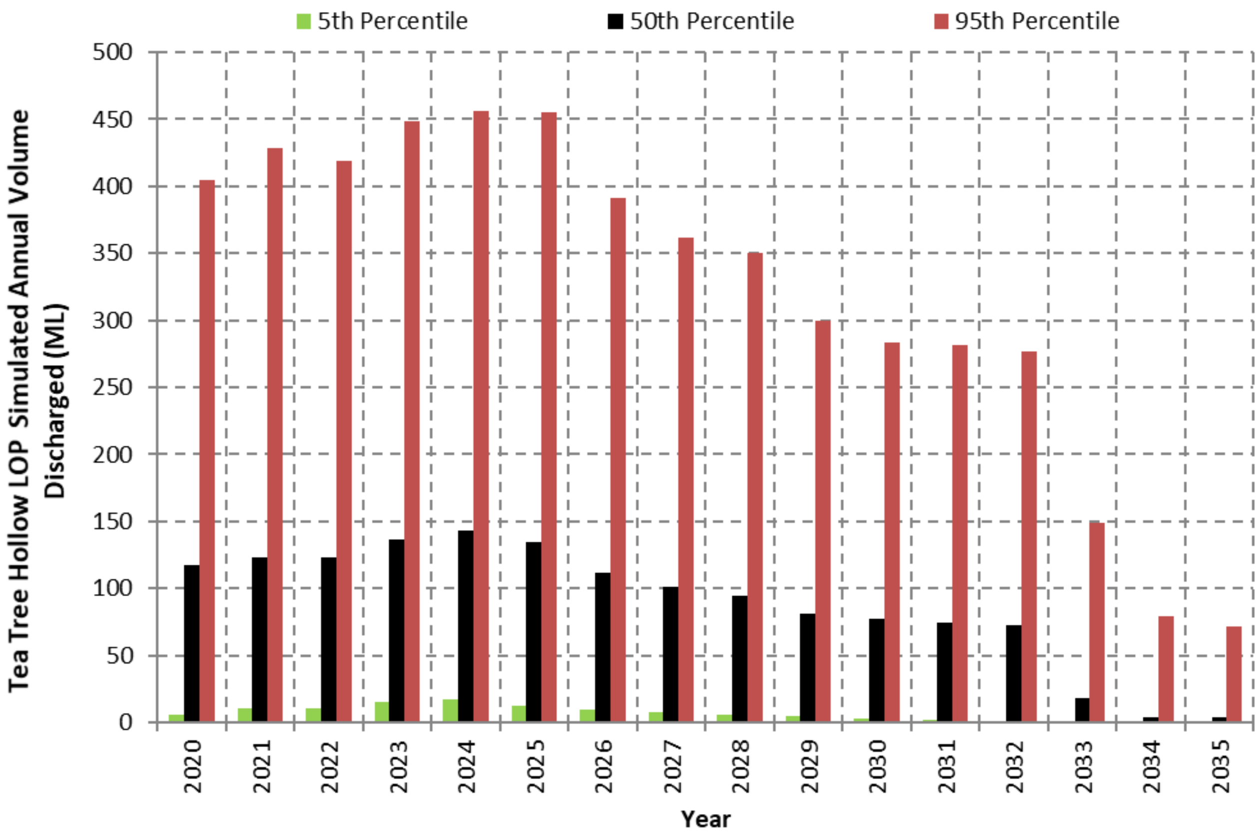


Figure 21 Simulated Annual Exceedance Statistics for Release via LOPs to Tea Tree Hollow

Simulated overflows to Tea Tree Hollow via the LOPs are predicted to peak in 2024 at 144 ML based on the median result and 456 ML for the 95th percentile results. For the 95th percentile results, simulated overflows varied from 405 ML in 2020, to 456 ML in 2024 and 72 ML in 2035. The reduction in predicted overflow from 2024 to 2035 is indicative of changes to the REA catchment areas, including rehabilitation of portions of the REA and subsequent redirection of the surface runoff off-site. On average, based on the results for the full simulation period (16 years) and all 130 realizations, release to the LOPs is predicted at 115 ML/annum.

Figure 22 shows the simulated annual exceedance statistics for releases from dam S11 to the Bargo River. The results presented in Figure 22 represent a sequence of results for the full simulation period (16 years).

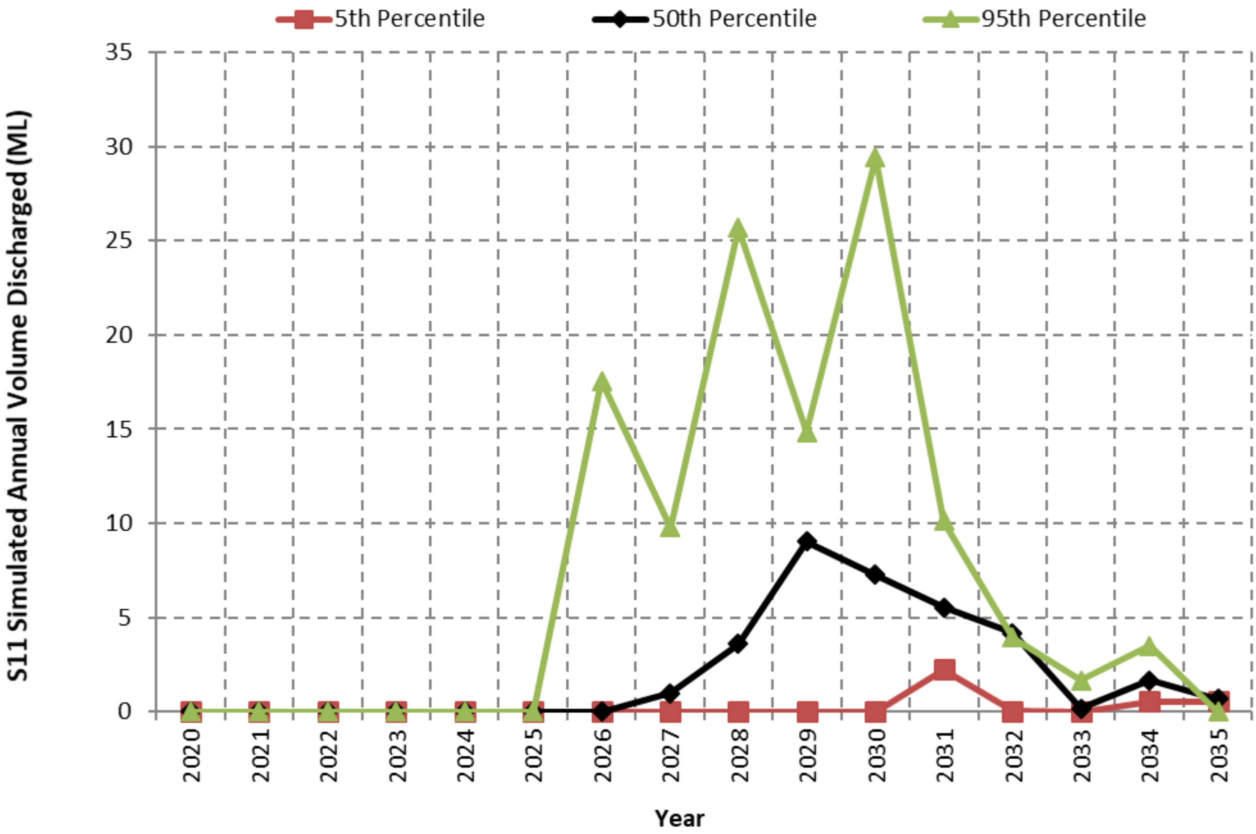


Figure 22 Simulated Annual Exceedance Statistics for Release from S11 to the Bargo River

Figure 22 illustrates that simulated overflows from dam S11 would be relatively low with a maximum of 10 ML/annum predicted based on the median results. Based on the 95th percentile results, overflows of up to 29 ML/annum are predicted.

Figure 23 shows the simulated annual exceedance statistics for releases from dam S12 to Tea Tree Hollow. The results presented in Figure 23 represent a sequence of results for the full simulation period (16 years).

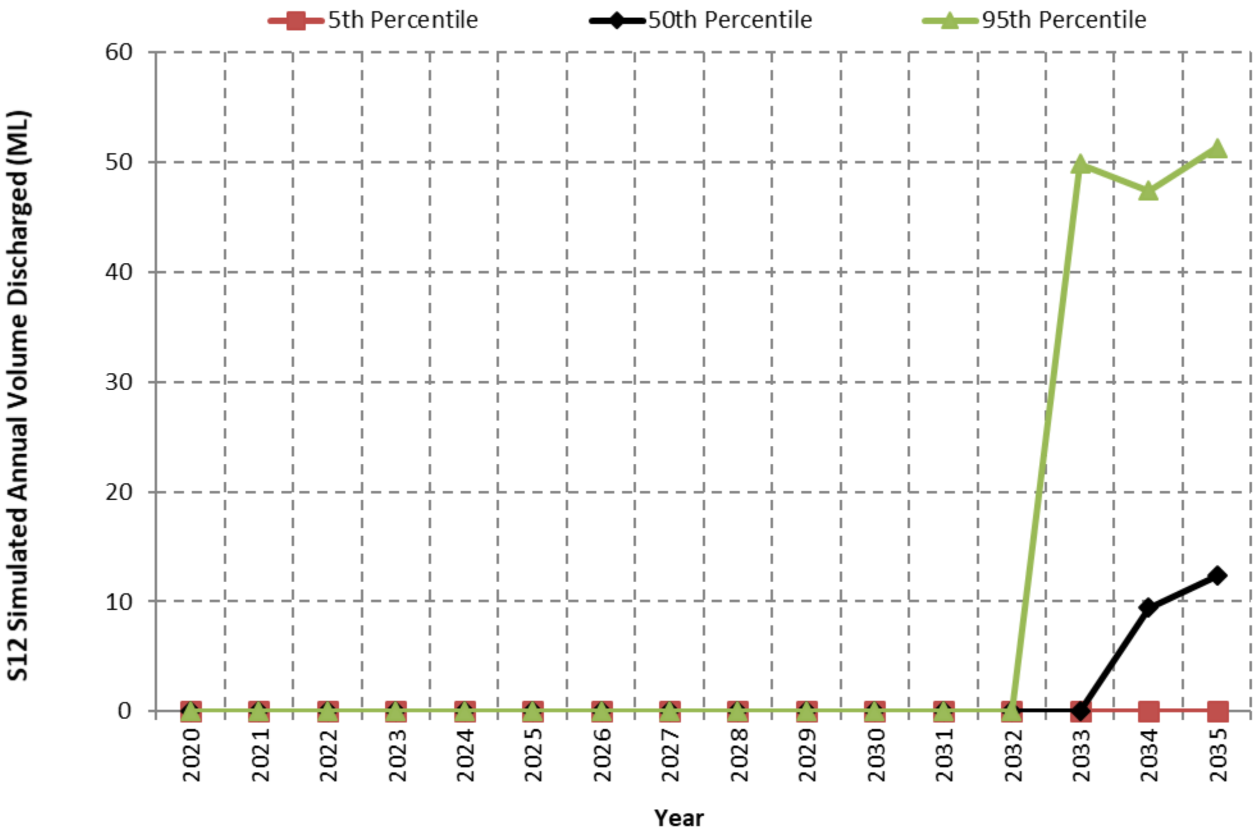


Figure 23 Simulated Annual Exceedance Statistics for Release from S12 to Tea Tree Hollow

Figure 23 illustrates that simulated overflows from dam S12 would only occur in the last three years of the Project and would be relatively low, with a maximum of 12 ML/annum predicted based on the median results. Based on the 95^{th} percentile results, overflows of up to 51 ML/annum are predicted.

6.4 STORED WATER VOLUME IN UNDERGROUND WATER STORAGE

The simulated performance of the water management system described in Sections 6.1 to 6.3 assumes a 4,752 ML capacity underground water storage and a 6 ML/d capacity upgraded WWTP (refer Section 3.4). The simulated volume of water stored in the underground water storage is shown in Figure 24.

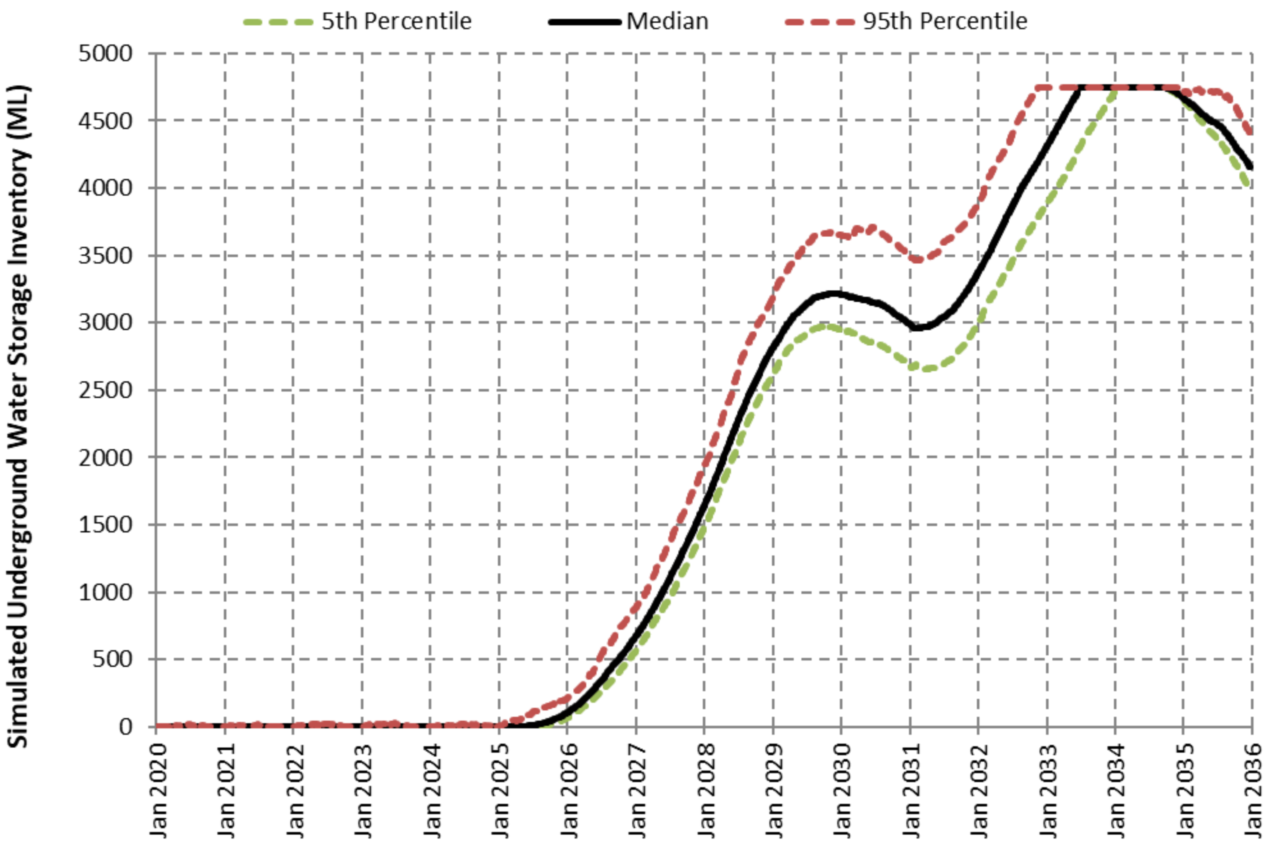


Figure 24 Simulated Underground Water Storage Volume – with 6 ML/d WWTP

Figure 24 indicates that the stored water volume is predicted to increase from 2025 and is likely to near the storage capacity by 2033 based on the median model results. The 95th percentile results indicate that the stored water volume may reach the storage capacity by mid-2032. The key driver of this result is the predicted underground groundwater inflow rates (refer Figure 14). Once the underground storage capacity is reached, mine dewatering in excess of the treatment capacity would discharge to LDP1. Note that Figure 20 indicates an increase in median and 95th percentile annual discharge volumes from approximately 2032 onwards.

In order to maintain treatment of water to be discharged via LDP1, the capacity of the proposed upgraded WWTP may need to be increased. Additional simulations were undertaken with increased upgraded WWTP capacities of 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 capacities of the upgraded WWTP is shown in Figure 25.

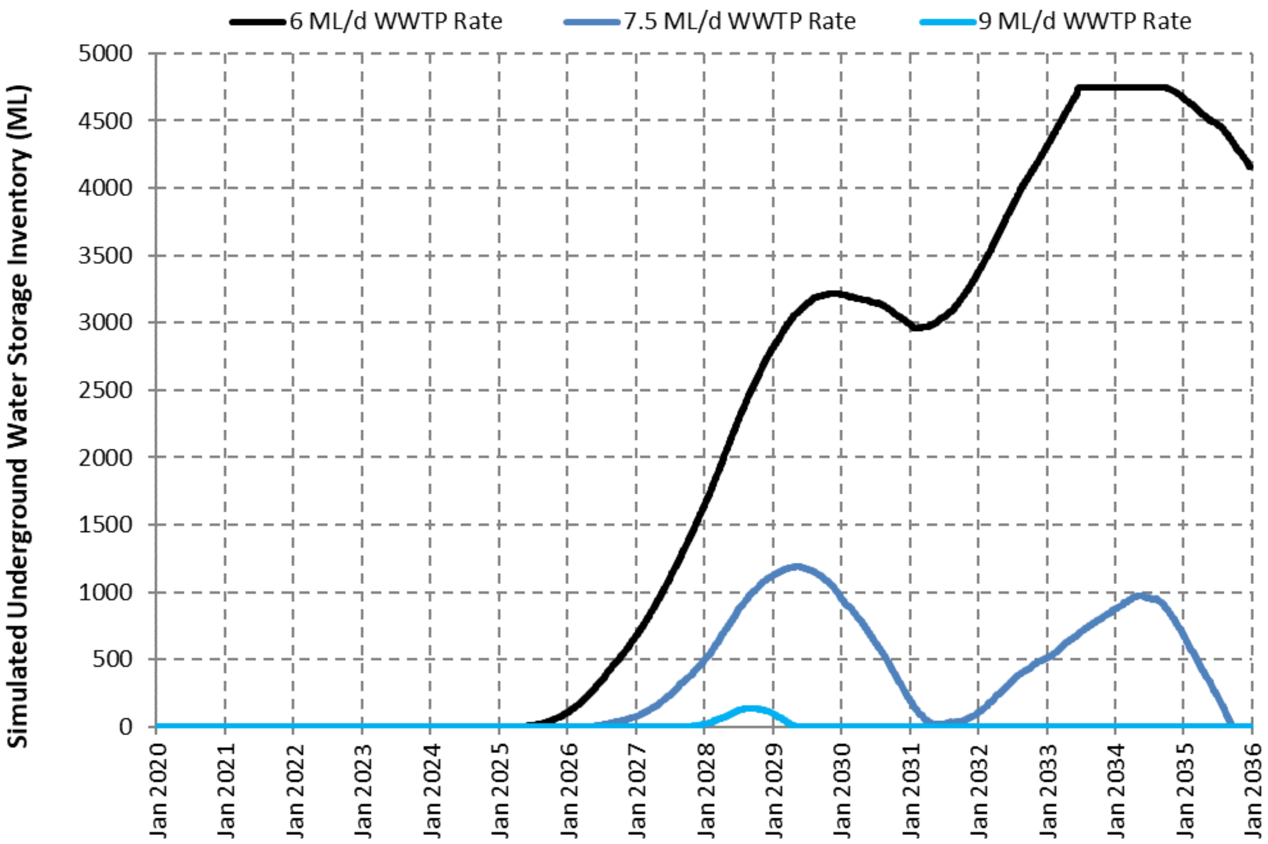


Figure 25 Simulated Median Underground Water Storage Volume – with Differing RO WWTP Capacities

The above model results indicate that a WWTP capacity increase of 1.5 to 3 ML/day is predicted to be sufficient to reduce the volume of water required to be stored underground. Assuming development of the Project commences in 2020, an upgraded WWTP capacity of 6 ML/d (in combination with the underground water storage) is predicted to be adequate until 2032, following which an increase in capacity is likely to be required. The capacity of the upgraded WWTP will be reassessed prior to 2032 dependent on actual groundwater inflow and climatic conditions experienced at the mine.

6.5 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 17% of system inflows.
2. On-going controlled releases of treated water to Tea Tree Hollow via LDP1 of approximately 2,029 ML/annum on average will be required 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 456 ML.
4. Based on the 95th percentile model result, a peak annual overflow from dam S11 to Bargo River of 29 ML/annum was predicted.

5. Based on the 95th percentile results, a peak annual overflow from dam S12 to Tea Tree Hollow of 51 ML/annum was predicted.
6. The 6 ML/day capacity upgraded WWTP in combination with a 4,752 ML capacity underground water storage is predicted to provide sufficient capacity to ensure continued treatment of water discharged via LDP1 until 2032, assuming mining commences in 2020. Thereafter an upgraded WWTP capacity increase of between 1.5 to 3 ML/day is likely to be required, dependent on actual groundwater inflow and climatic conditions experienced at the mine.

7.0 SUMMARY OF KEY CHANGES TO ASSESSMENT OUTCOMES

This Water Management System and Site Water Balance has been prepared to detail the proposed changes to site water management required to support the Amended Project and to present the results from the water balance model simulation of the proposed water management system over the Project life. The report has also been revised to address key issues raised in the EIS submissions pertaining to the Water Management System and Site Water Balance. In this way, it serves as an update to the Tahmoor South EIS Water Management System and Site Water Balance (HEC, 2018c).

The following summarises the key changes to the assessment outcomes for the Amended Project as compared to the assessment undertaken for the EIS:

- Groundwater inflow to the underground mine is predicted to average 1,916 ML/annum based on the Amended Project in comparison with an estimated 1,693 ML predicted for the EIS;
- Discharge via LDP1 is predicted to average 2,029 ML/annum based on the Amended Project in comparison with an estimated 1,693 ML predicted for the EIS;
- Discharge via the LOPs to Tea Tree Hollow is predicted to average 115 ML/annum based on the Amended Project in comparison with an estimated 58 ML/annum predicted for the EIS;
- The simulated annual release to Bargo River from dam S11 is predicted to peak at 29 ML/annum based on the 95th percentile results for the Amended Project as opposed to a predicted 116 ML/annum presented in the EIS;
- The simulated annual release to Tea Tree Hollow from dam S12 is predicted to peak at 51 ML/annum based on the 95th percentile results for the Amended Project (release from dam S12 was reported in the EIS as a component of the total estimate of discharge via the LOPs);
- The underground water storage is predicted to increase from 2025 and is likely to reach the storage capacity by 2033 based on the median model results for the Amended Project. The 95th percentile results indicate that the stored water volume may reach the storage capacity by mid-2032 for the Amended Project. The EIS predictions identified that the underground water storage was likely to near the storage capacity by 2034 based on the median model results and by the end of 2033 based on the 95th percentile results; and
- Assuming development the Project commences in 2020, an upgraded WWTP capacity increase of between 1.5 to 3 ML/day is likely to be required prior by 2032 for the Amended Project, dependent on actual groundwater inflow and climatic conditions experienced at the mine.

8.0 REFERENCES

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HYDRO ENGINEERING & CONSULTING PTY LTD

REPORT

Tahmoor South Amended Project Flood Study

Prepared for: Tahmoor Coal Pty Ltd

38a Nash Street
Rosalie QLD 4064
p (07) 3367 2388

PO Box 1575
Carindale QLD 4152
www.hecons.com
ABN 11 247 282 058

Revision	Description	Author	Reviewer	Approved	Date
1	Revised report following EIS submissions	TSM / CAW	Tahmoor Coal, EMM	TSM	11 Nov 2019
2	Draft	TSM / CAW	Tahmoor Coal, EMM	TSM	8 Dec 2019
3	Final	TSM / CAW	Tahmoor Coal, EMM	TSM	9 Jan 2020
4	Final following submission	TSM / CAW	Tahmoor Coal, EMM	TSM	12 Feb 2020

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1.0 INTRODUCTION

Hydro Engineering & Consulting Pty Ltd (HEC) was commissioned by Tahmoor Coal Pty Limited (Tahmoor Coal) to complete a Surface Water Assessment for the Tahmoor South Project (the Project). The Surface Water Assessment formed a 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 was undertaken in four parts:

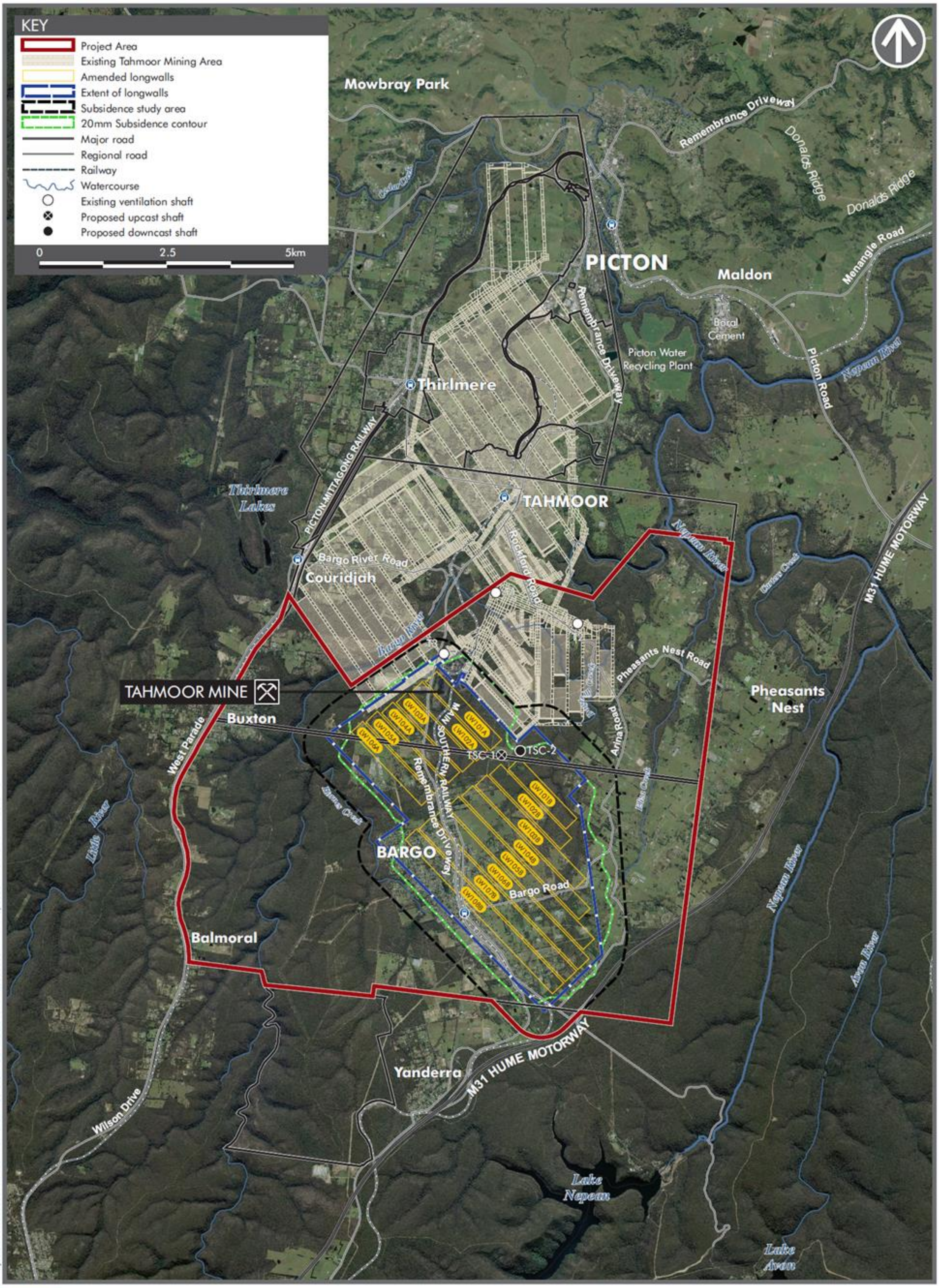
- Baseline Assessment (BA) Report which documents the available baseline and background information and analysis of the climate, hydrology and water quality characteristics of local and regional water resources of relevance to the Project.
- Water Management System and Site Water Balance Report (WMS & 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. The water balance model was developed to simulate the water management system supply reliability, the adequacy of the current licensed discharge to Tea Tree Hollow to manage release of water from the mine site and to assess the risk of site overflow 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 Project on flooding in overlying watercourses and 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 Flood Study for the Project Area which has been revised to address key issues raised in submissions relating to the EIS, as described below. The report summarises the results of an assessment of the potential impacts of the Amended Project on flooding in overlying watercourses and floodplains.

1.1 BACKGROUND AND OVERVIEW

Tahmoor Coal is seeking development consent for the continuation of mining at the 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.

In accordance with the requirements of the EP&A Act, the *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation) and the Secretary's Environmental Assessment Requirements (SEARs), an EIS was prepared to assess the potential environmental, economic and social impacts of the Project. The EIS for the Project was placed on public exhibition by the Department of Planning, Industry and Environment (DPIE) (formerly the Department of Planning and Environment [DPE]) from 23 January 2019 to 5 March 2019.



SIMEC MINING

AMENDED MINE PLAN AND VENTILATION SHAFTS
Tahmoor South Project
Amended Project Report

Note: The 'extent of longwalls' boundary encompasses the proposed extent of underground workings, being the proposed longwall panels and mains headings (first workings).

Figure 1 Locality Plan and Project Layout

Key issues raised in submissions included concerns relating to the proposed extent of longwall mining, the magnitude of subsidence impacts and the extent of vegetation clearing required for the expansion of the reject emplacement area (REA). In response to these and other issues raised in Government agency, local Council, stakeholder and community submissions, and as a result of ongoing mine planning, several amendments have been made to the proposed development, so as to also further reduce the predicted environmental impacts of the Project.

The key amendments to the Project since public exhibition of the EIS are:

- A revised mine plan, including:
  - an amended longwall panel layout and the removal of LW109;
  - a reduction in the height of extraction within the longwall panels from up to 2.85 metres (m) to up to 2.6 m; and
  - a reduction in the proposed longwall width, from up to 305 m to approximately 285 m.
- A reduction in the total amount of Run-of-Mine (ROM) coal to be extracted over the Project life, from approximately 48 million tonnes (Mt) to approximately 43 Mt of ROM coal, comprising;
  - 30 Mt of coking coal product (reduced from 35 Mt);
  - 2 Mt of thermal coal product (reduced from 3.5 Mt)
- A revised extended REA; including:
  - a reduction in the additional capacity required to accommodate the Project;
  - a reduction in the REA extension footprint, from 43 ha to 11 ha;
  - an increase in the final height of the REA (from RL 305 m to RL 310 m).
- Confirmation of the location and footprint of ancillary infrastructure associated with the ventilation shaft sites (e.g. the power connection easement for ventilation shaft site TSC1); and
- A continuation of the use of the existing upcast shaft (T2); although, operation will reduce from two fans during Tahmoor North operations to one fan once the new ventilation shafts and fans (TSC1 and TSC2) are in operation in Tahmoor South.

No amendments have been made to other key aspects of the Project as presented in the EIS for which development consent is sought, such as the proposed annual coal extraction rate, mining method, traffic movements and employee numbers. A detailed description of the amended development is provided in the Amendment Report (AECOM, 2020).

1.2 PURPOSE OF REPORT

This FS has been prepared to assess the impacts of the Amended Project on flooding of land in the Project Area and potential impacts to overland flow paths in the urban areas of the Bargo Township. The assessment considers and outlines the differences in impacts compared to the Project as presented in the EIS. In this way, it serves as an update to the Tahmoor South EIS Flood Study (HEC, 2018c) (Appendix J of the Tahmoor South EIS). Section 8.0 presents a summary of key changes presented in this FS in comparison with the EIS assessment.

1.3 AMENDED PROJECT

The Amended Project would use longwall mining to extract coal from the Bulli seam within the bounds of CCL716 and CCL747. Coal extraction of up to four (4) million tonnes of ROM coal per annum is proposed as part of the development with extraction of up to 43 Mt of ROM coal over the life of the Amended Project. The project would produce approximately:

- 30 Mt coking coal product;
- 2 Mt thermal coal product; and
- 12 Mt of rejects.

These approximate market mix volumes include moisture and are therefore an estimate only. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing coal handling and processing plant (CHPP) and coal clearance facilities and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla and Newcastle (from time to time) for Australian and international markets. Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers via road.

The amended development would use the existing surface infrastructure at the Tahmoor Mine surface facilities area. Some upgrades are proposed to facilitate the extension.

The amended development also incorporates the planning for rehabilitation and mine closure once mining ceases.

In summary, the key components of the amended development comprise:

- Longwall mining in the Central Domain;
- Mine development including underground development, vent shaft construction, pre-gas drainage and service connection;
    - Upgrades to the existing surface facilities area including:
    - Upgrades to the CHPP;
    - Expansion of the existing REA;
    - Additional mobile plant for coal handling;
    - Additions to the existing bathhouses and associated access ways; and
    - Upgrades to onsite and offsite service infrastructure, including electrical;
- Rail transport of product coal to Port Kembla and Newcastle (from time to time);
- Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers via road;
- Mine closure and rehabilitation; and
- Environmental management.

1.4 STUDY REQUIREMENTS

The Project EIS was 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 report has been revised to assess impacts of the Amended Project on flooding of land in the Project Area and to address key issues raised in the EIS submissions pertaining to the FS submitted as a component of the EIS.

1.4.1 Secretary's Environmental Assessment Requirements

The Surface Water Assessment is guided by the 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 Surface Water Baseline Assessment (HEC, 2020a) 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 the Project has been amended to exclude 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.

1.4.2 EIS Submissions

The submissions from government agencies that are relevant to the FS and the section of the report which addresses the submissions are summarised in Table 1.

Table 1 EIS Submissions – Surface Water Baseline Assessment

Agency	Submission	How / Where Addressed
Office of Environment and Heritage	Assessment of flood characteristics across the range of flood events as recommended in OEH's suggested SEARs.	Flood modelling has been undertaken for 50%, 10%, 1% 0.5%, 0.2% AEP peak flows and PMF, as detailed in Section 5.0. For each peak flow, modelling has been undertaken for existing conditions and with predicted Project subsidence. Table 1 of the Surface Water Baseline Assessment lists the relevant report and section in which the OEH SEARs have been addressed.
	The report indicates utilising a RORB hydrologic model and a TUFLOW hydraulic model for the flood assessment. These models can provide adequate information on flooding behaviour. However, the report has only depicted the extent of flooding for pre and post development conditions, which is considered inadequate to satisfy the project's SEARs. The SEARs required the proponent to address flooding behaviour in the vicinity of the project which includes information on flood characteristics for pre and post development scenarios (i.e. extent, depth, velocity, hydraulic and hazard categories etc).	Flooding has been characterised across the full range of events (50%, 10%, 1%, 0.5%, 0.2% and PMF), as detailed in Section 5.0. Velocity and bed shear have been assessed for the 50% AEP only as this is representative of channel forming events (refer HEC [2020d]). Lower AEP events are not considered representative. The change in flood extent as a result of the Project has been assessed for all events (Section 5.0 and Appendix A). Changes are predicted to be very limited ("...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"). Due to the very limited changes, an emergency response plan is not considered justified. SEARs OEH recommendations have been addressed in the BA report (HEC, 2020a).
	Accordingly, to satisfy the SEARs, it is prudent to address flooding characteristics for the full range of floods in order to: - determine the impact of the project on flooding behaviour; - determine the impact of flooding on the project; - address the risk to people and infrastructure associated with various flood events; - address the impacts on existing downstream areas for the full range of flooding. - prepare an emergency response plan to ensure risk to personnel and damages to infrastructure during larger flood events is minimised and managed. The plan would include a flood evacuation strategy to ensure that safe evacuation from the site can be achieved.	

Table 1 (Cont.) EIS Submissions – Surface Water Baseline Assessment

Agency	Submission	How / Where Addressed
Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC)	The IESC has some confidence in assessment of the relative impacts on the flood risks estimated by the modelling, and agree that the likely impacts on flooding risk due to mining activities is low. However, the degree of confidence regarding the absolute estimates of the flood risks is low because the configuration of the adopted flood model was based solely on regional information without calibration, and no information is provided on some of the key modelling assumptions (e.g. whether the flood estimates were derived using deterministic or ensemble rainfall patterns). Accordingly, it is suggested that the results of this modelling be reviewed if further analysis of the uncertainty in mining-induced ground movements indicate the relative impacts on surface water resources may be greater than that currently estimated. Surface water resources identified within the predicted area of subsidence include water quality and aquatic habitats in Tea Tree Hollow, Dog Trap Creek and their tributaries, as well as riparian corridors including potentially groundwater-dependent vegetation.	Calibration of the flood modelling was not possible due to a lack of recorded significant flood levels for Tee Tree Hollow and Dog Trap Creek. As stated in Section 5.0, 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 2019 version of *Australian Rainfall and Runoff* - ARR 2019 (Ball et al, 2019). Modelling was undertaken for eight design rainfall events – 0.2%, 0.5%, 1%, 10%, 50% AEP and the probable maximum flood (PMF). In line with the ARR 2019 guidelines, there are 10 'ensemble' temporal patterns applicable to each design rainfall event, with separate patterns for different durations. Different temporal patterns apply within each of four (AEP) categories of severity. For each AEP and duration, the RORB model was run using the ten temporal patterns for the range of applicable event durations. For each duration, the modelled hydrograph which produced the closest peak flow to the median peak flow (of 10) at the downstream boundary of the catchment was selected as the hydrograph for that duration. For each AEP, the rainfall duration which gave the highest peak flow rate (i.e. the 'critical duration') was selected for use in subsequent hydraulic modelling. This process was repeated for all design AEPs.

2.0 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 Subsidence 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 Subsidence 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 overland flow paths in the urban areas of the Bargo Township have been assessed.

3.0 STUDY AREA

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

The portion of the Subsidence Study 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 Subsidence Study Area is drained by headwater tributaries of Hornes Creek which flows into the Bargo River at Picton Weir on the western side of the Subsidence Study Area upstream of the Tea Tree Hollow confluence.

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 Subsidence 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 Amended 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).

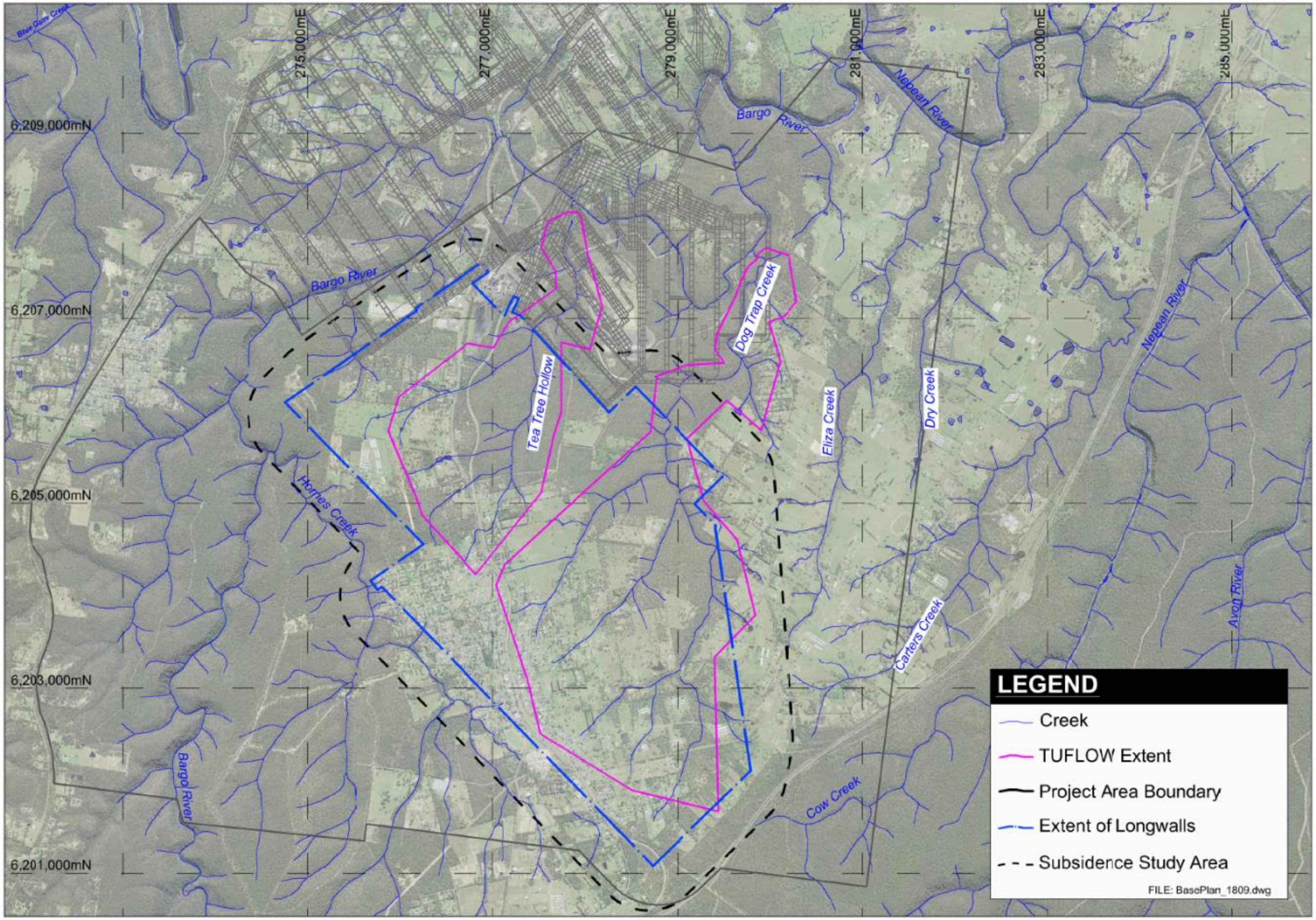


Figure 2 **Project Area Layout, Surface Drainages and Hydraulic Model Extents**

4.0 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 described in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (ARR) (Ball et al, 2019). Modelling was undertaken for eight design rainfall events – 0.2%, 0.5%, 1%, 10%, 50% AEP and the probable maximum flood (PMF). In line with the ARR 2019 guidelines, there are 10 'ensemble' temporal patterns applicable to each design rainfall event, with separate patterns for different durations. Different temporal patterns apply within each of four (AEP) categories of severity. For each AEP and duration, the RORB model was run using the ten temporal patterns for the range of applicable event durations. For each duration, the modelled hydrograph which produced the closest peak flow to the median peak flow (of 10) at the downstream boundary of the catchment was selected as the hydrograph for that duration. For each AEP, the rainfall duration which gave the highest peak flow rate (i.e. the 'critical duration') was selected for use in subsequent hydraulic modelling. This process was repeated for all design AEPs.

Design rainfall intensity-frequency-duration data are summarised in Table 2. Design PMP rainfall data are summarised in Table 3.

Table 2 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 3 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 4 and Table 5. The parameters were estimated following procedures as recommended in ARR 2019. No model calibration was undertaken because no recorded significant flood level data was available.

Table 4 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 5 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 5.0).

The peak discharge rates obtained from the RORB modelling at the downstream end of each modelled catchment are summarized in Table 6.

Table 6 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

5.0 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™. 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. Models were developed for Dog Trap Creek and Tea Tree Hollow and encompassed the extent shown in Figure 2.

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 subsidence predictions were revised following submission of the EIS to assess the potential impacts of the Amended Project (MSEC, 2020). The DTM had a vertical and horizontal resolution/accuracy of +/- 0.1m and +/- 0.2m respectively. The model was developed using a 3 m by 3 m horizontal grid. Separate longitudinal sections along the four modelled creeks are shown in Figure 3 indicating both pre and post-subsidence topography.

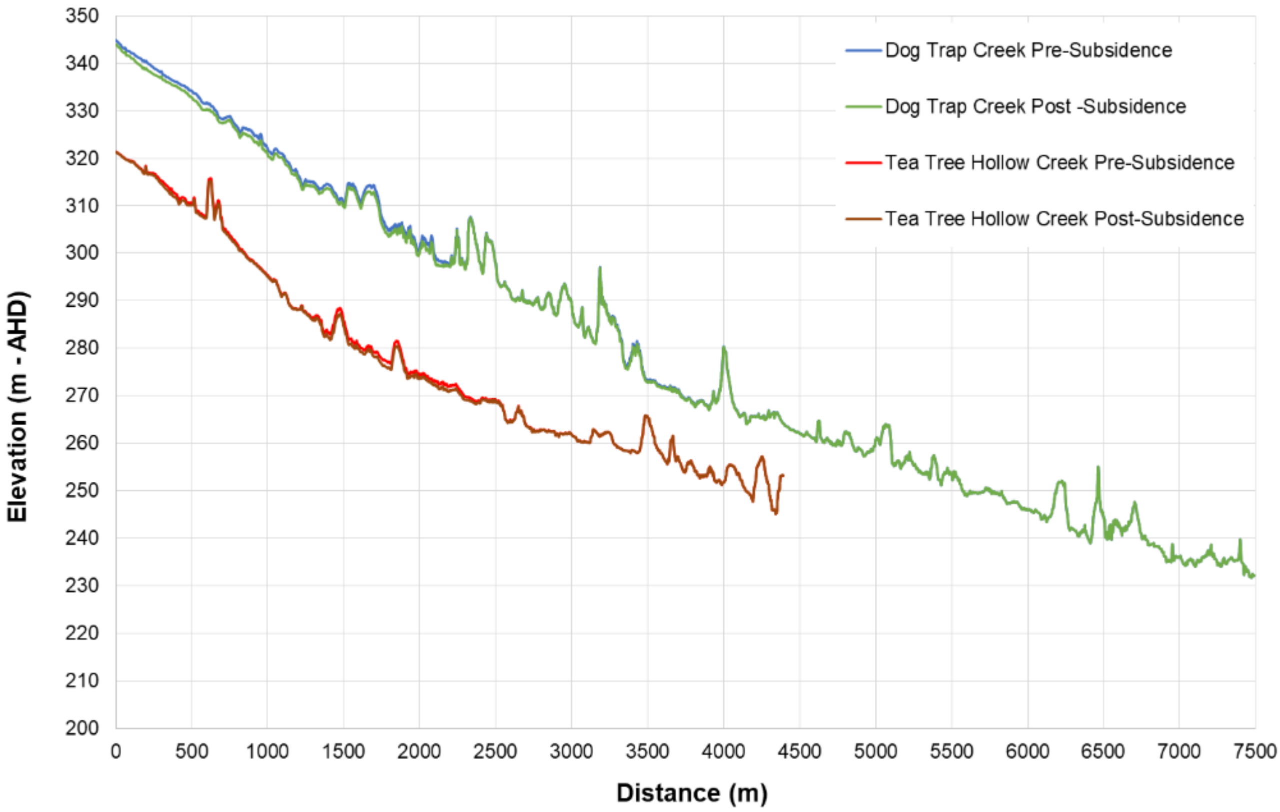


Figure 3 Modelled Stream Longitudinal Sections

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.

A comprehensive flood modelling study has not been undertaken previously for Dog Trap Creek and Tea Tree Hollow and limited flood information is available for these surface water systems. As such, there is currently insufficient data to calibrate the flood models.

Areas inundated during the passage of the assessed flood events were output from the model and are shown as a series of figures in the sections 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 based on the post-subsidence topography. In some locations, areas that are currently inundated during specific flood events have the potential to be less inundated based on the post-subsidence topography. These areas were found to be relatively small and have not been illustrated on the flood inundation figures. The flood inundation maps for the 50% AEP and 1% AEP events are shown in Figure 4 to Figure 11, with discussion of results in the following sub-sections. These represent results for significant but relatively common flood events and for 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.

5.1 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 for improved 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.

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 104B to 107B. 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.

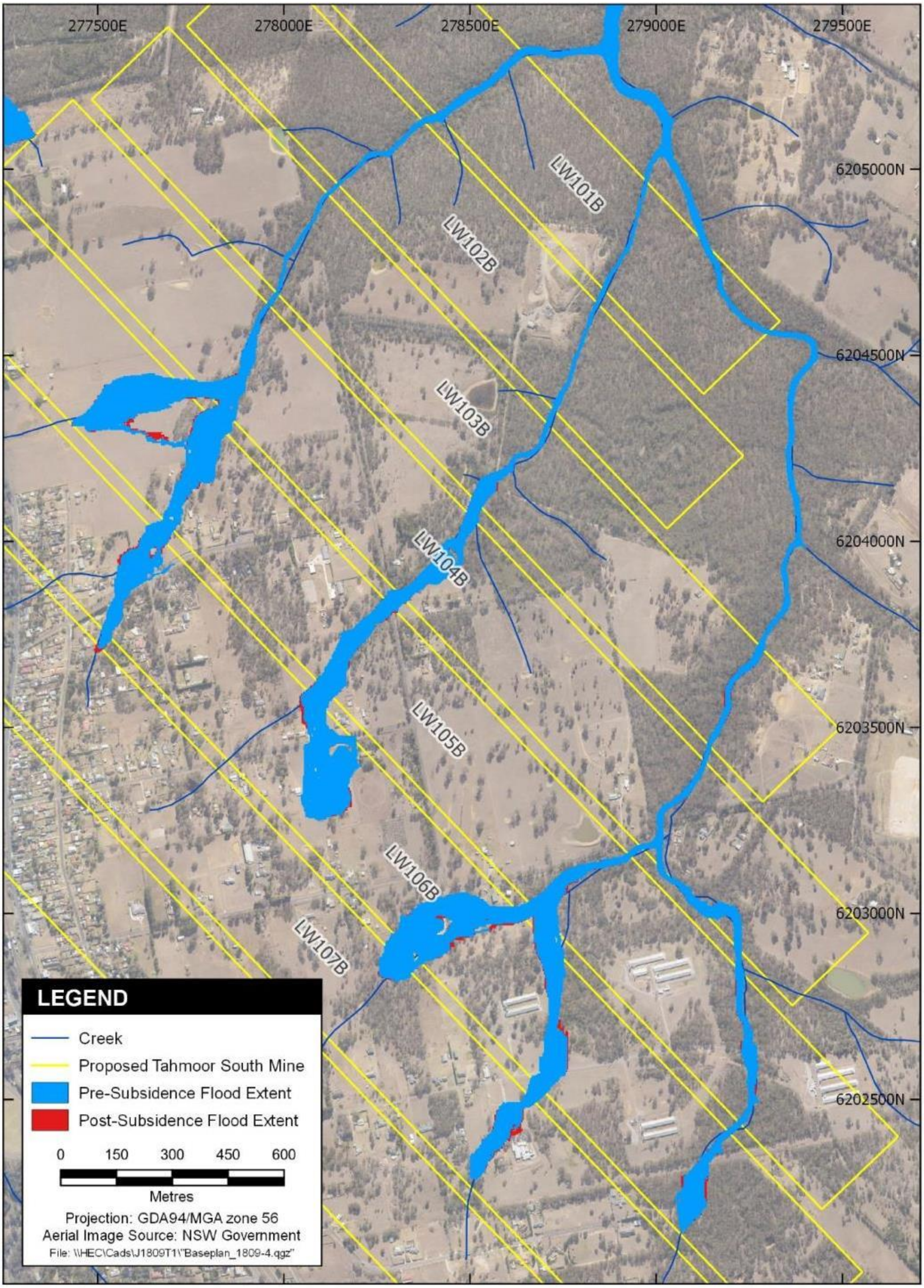


Figure 4 Extent of Predicted 1% AEP Flooding – Southern (upstream) Dog Trap Creek

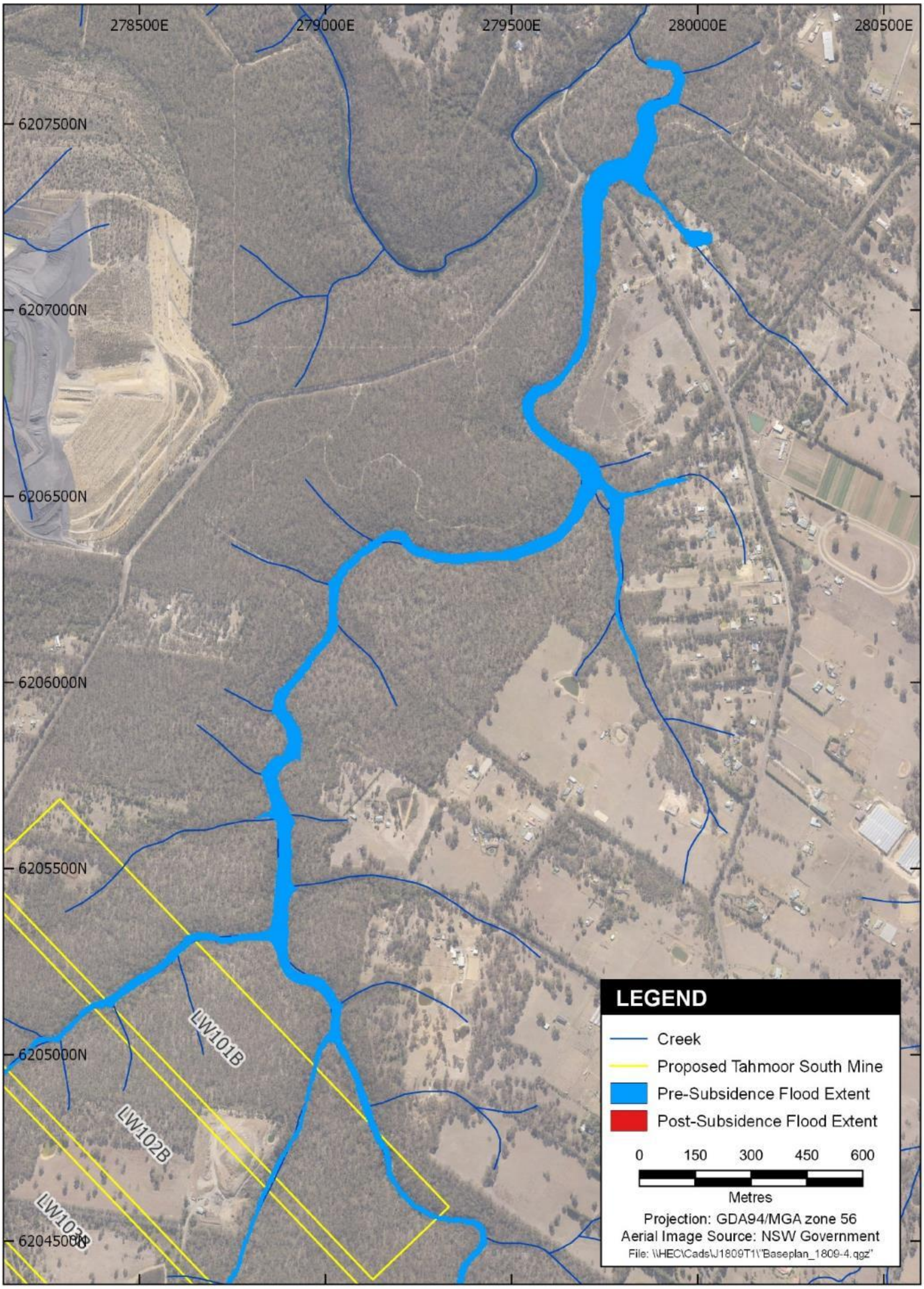


Figure 5 Extent of Predicted 1% AEP Flooding – Northern (downstream) Dog Trap Creek

5.2 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 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 indicate no detectable increase or new areas that would be inundated during this event as a result of subsidence-related changes to surface topography.

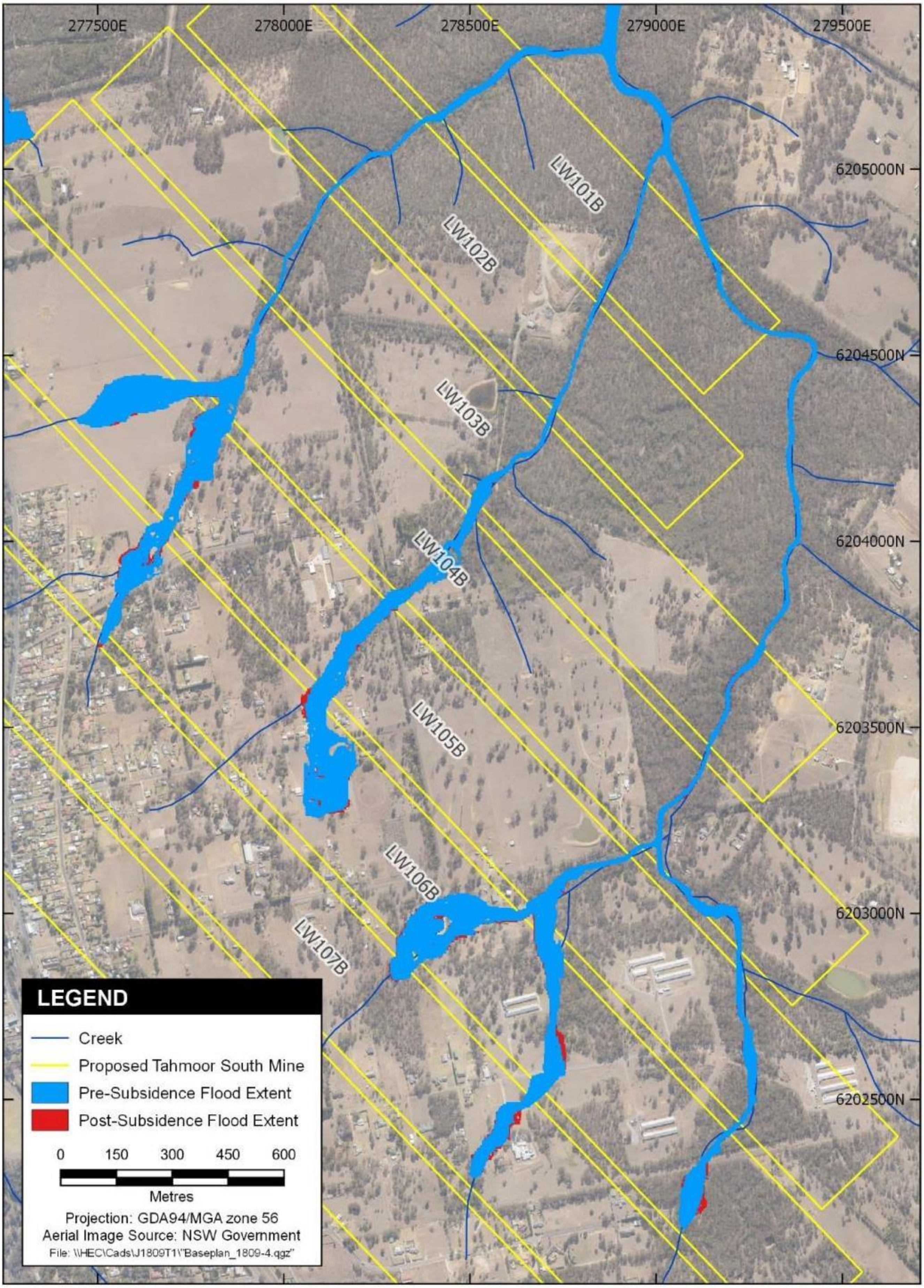


Figure 6 Extent of Predicted 50% AEP Flooding – Southern (upstream) Dog Trap Creek

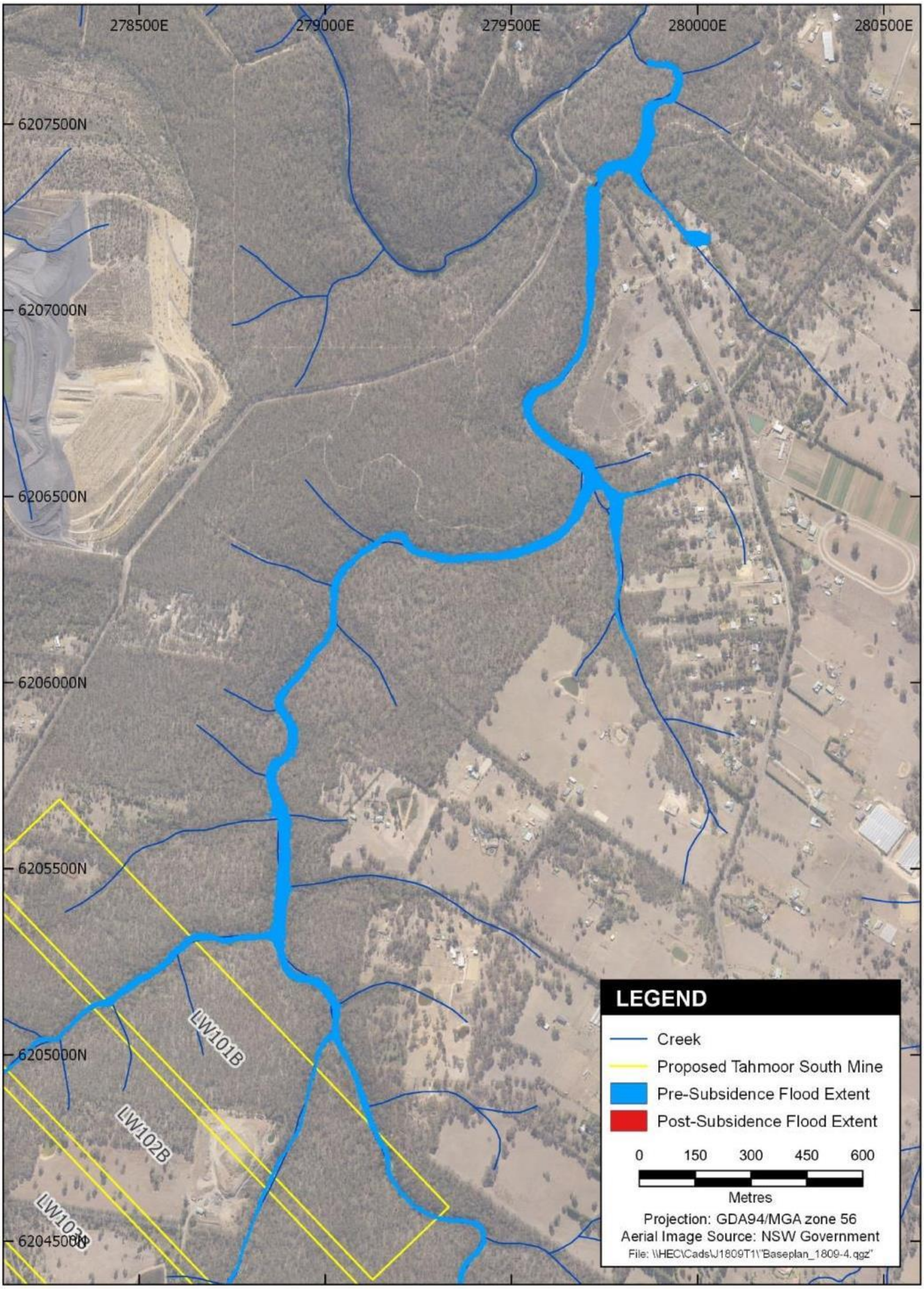


Figure 7 Extent of Predicted 50% AEP Flooding – Northern (downstream) Dog Trap Creek

5.3 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.

The hydraulic model predicts that the effects of subsidence would result in an increase in 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 103A. 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. 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.

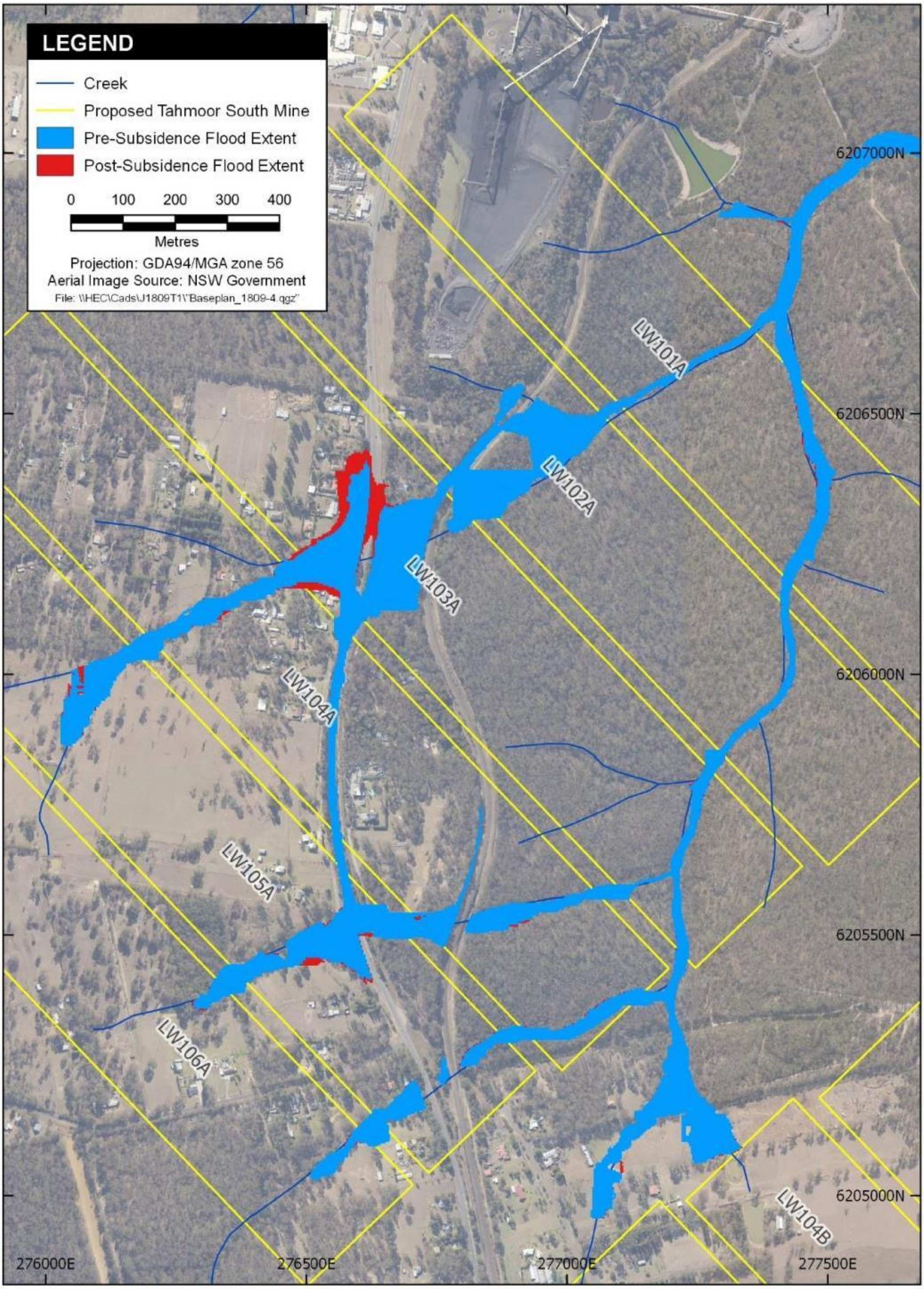


Figure 8 Extent of Predicted 1% AEP Flooding – Southern (upstream) Tea Tree Hollow

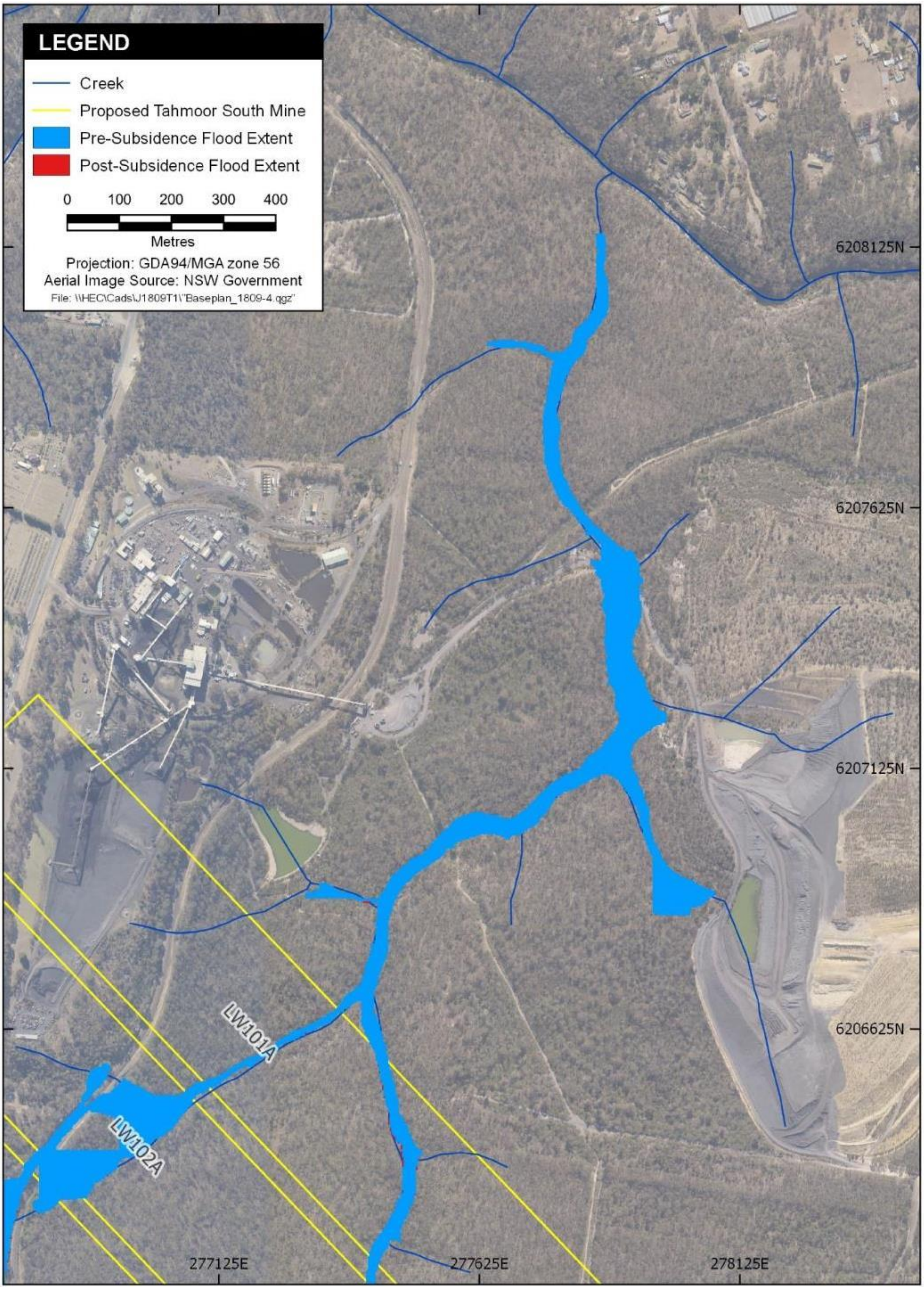


Figure 9 Extent of Predicted 1% AEP Flooding – Northern (downstream) Tea Tree Hollow

5.4 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. 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.

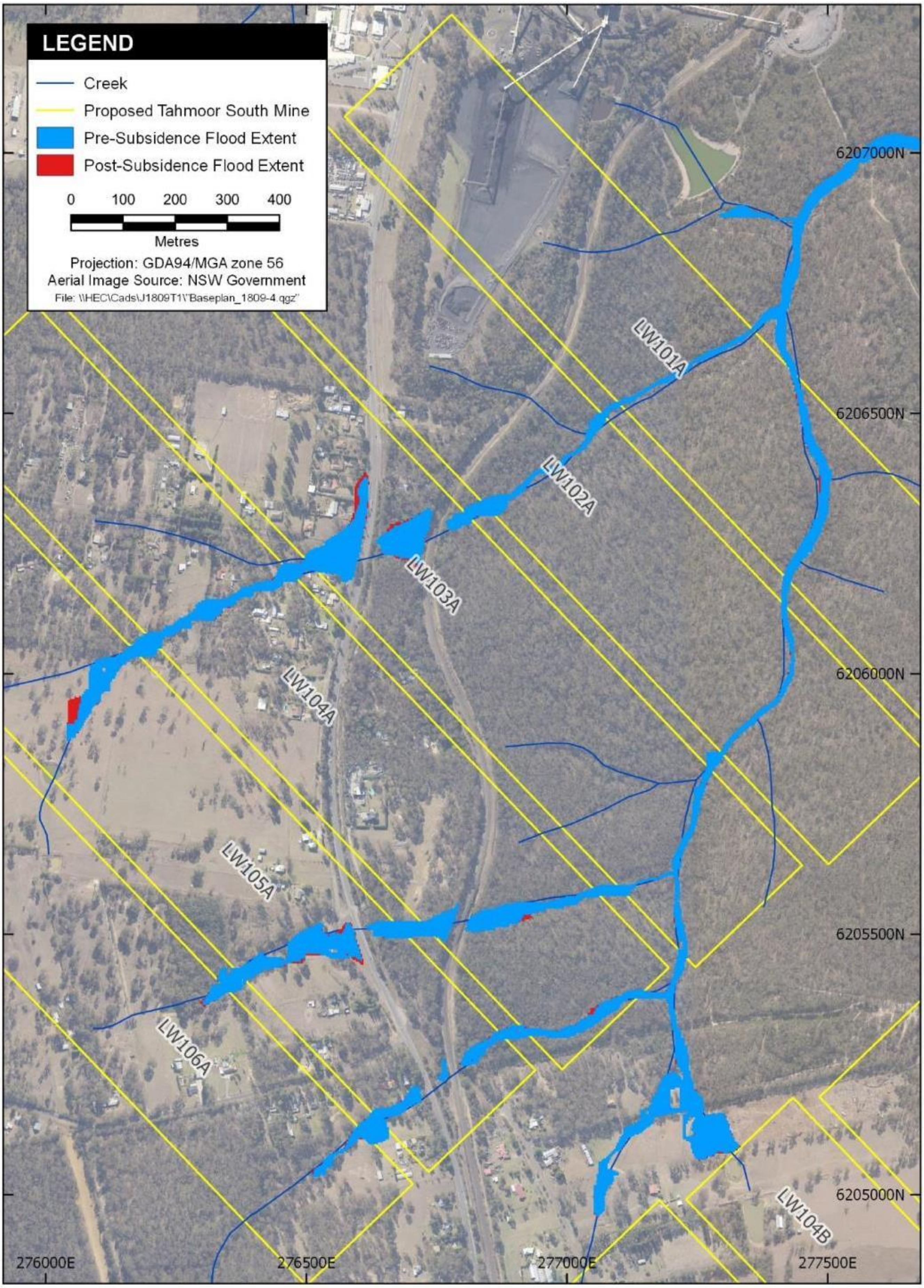


Figure 10 Extent of Predicted 50% AEP Flooding – Southern (Upstream) Tea Tree Hollow

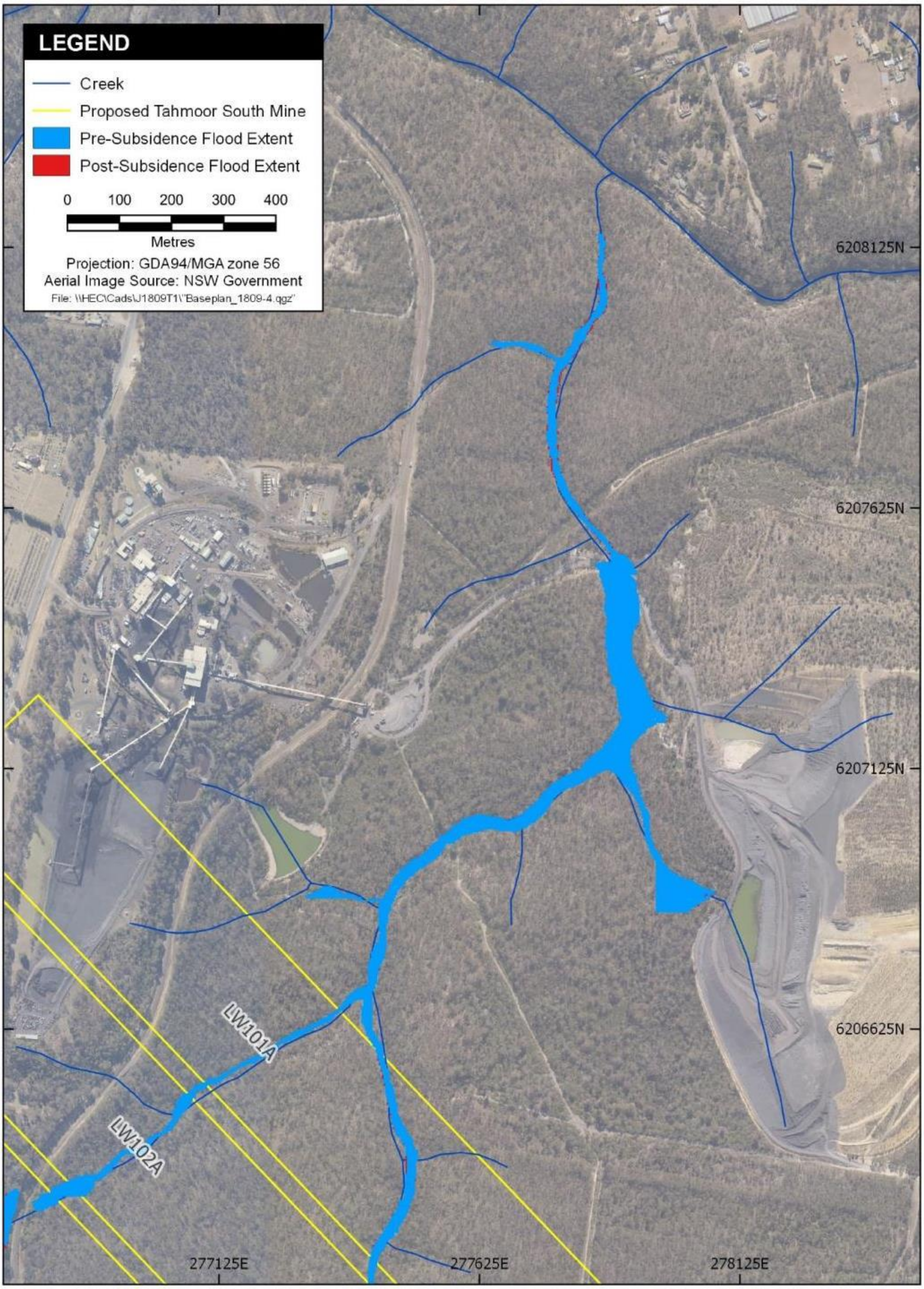


Figure 11 Extent of Predicted 50% AEP Flooding – Northern (Downstream) Tea Tree Hollow

5.5 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 Amended 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.

6.0 OVERLAND FLOW PATHS IN BARGO TOWNSHIP

Longwalls 106B, 107B and 108B would be mined under the Bargo Township. 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 including the trunk drainage system. MSEC (2020) recommended that any subsidence impacts to the stormwater infrastructure be managed via the Subsidence Management Plan (SMP) process. Under this process, subsidence damage to stormwater infrastructure would be rectified by Tahmoor Coal or Subsidence Advisory NSW under the compensation provisions of the *Coal Mine Subsidence Compensation Act 2017.*

Stormwater would also drain via overland flow paths comprising natural and constructed depressions in the surface topography. Overland flow paths would carry runoff draining to the entry points in the trunk drainage system and flow in excess of the trunk drainage system capacity during major storm events. The objective of this assessment has been to identify where predicted post-subsidence topography would be likely to exacerbate local flooding in existing overland flow paths in the Bargo Township area. This has been achieved by identifying where overland flow paths cross over proposed gate roads between longwall panels. Because gate road areas would form relatively elevated areas in the post-subsidence topography overland flow paths upslope of the gate roads may experience increased inundation.

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. The locations where existing overland flow paths could be adversely affected by subsidence are shown as numbered circles 1 to 17 in Figure 12. The probable effect on flooding of land in these areas has been assessed qualitatively and is summarised below.

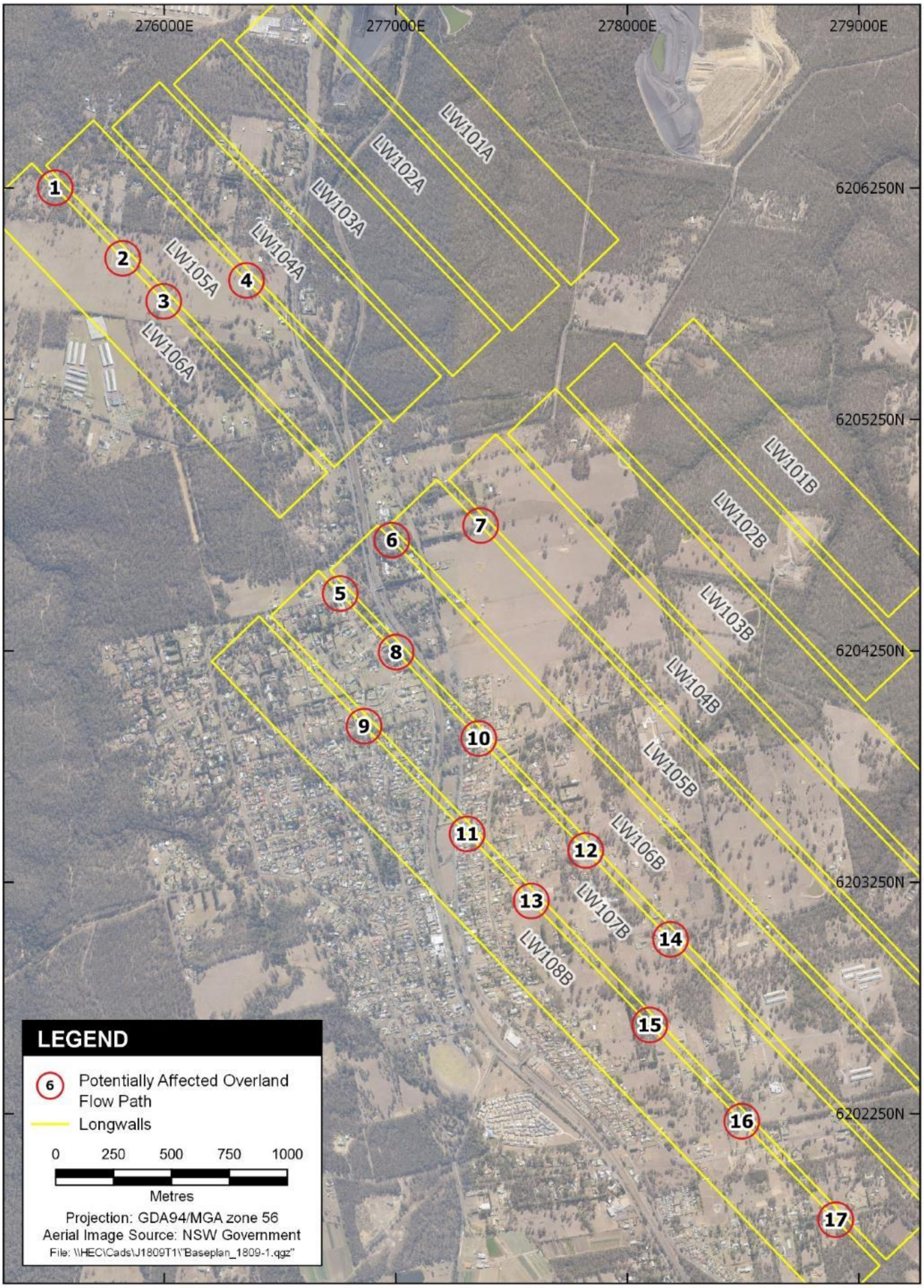


Figure 12 Proposed Longwall Panel Layout – Bargo Township and Potentially Affected Overland Flow Paths

6.1 OVERLAND FLOW PATH 1 – NORTHERN SIDE OF BARGO TOWNSHIP

Three overland flow paths were identified on the northern side of Bargo overlying the proposed gate road between longwalls 105A and 106A and one overlying the proposed gate road between longwalls 104A and 105A – refer Figure 12. Figure 13 shows an aerial photograph image of the most northerly overland flow path (i.e. overland flow path 1), between longwalls 105A and 106A. The area comprises timbered terrain where overland flow would follow a steep, incised natural creek line. There is no predicted ponding upslope of the gate road as a result of subsidence. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 5.5% to 5.2% due to predicted subsidence. It is considered unlikely the slightly reduced gradient would have any observable effect on flow depth in the creek line.

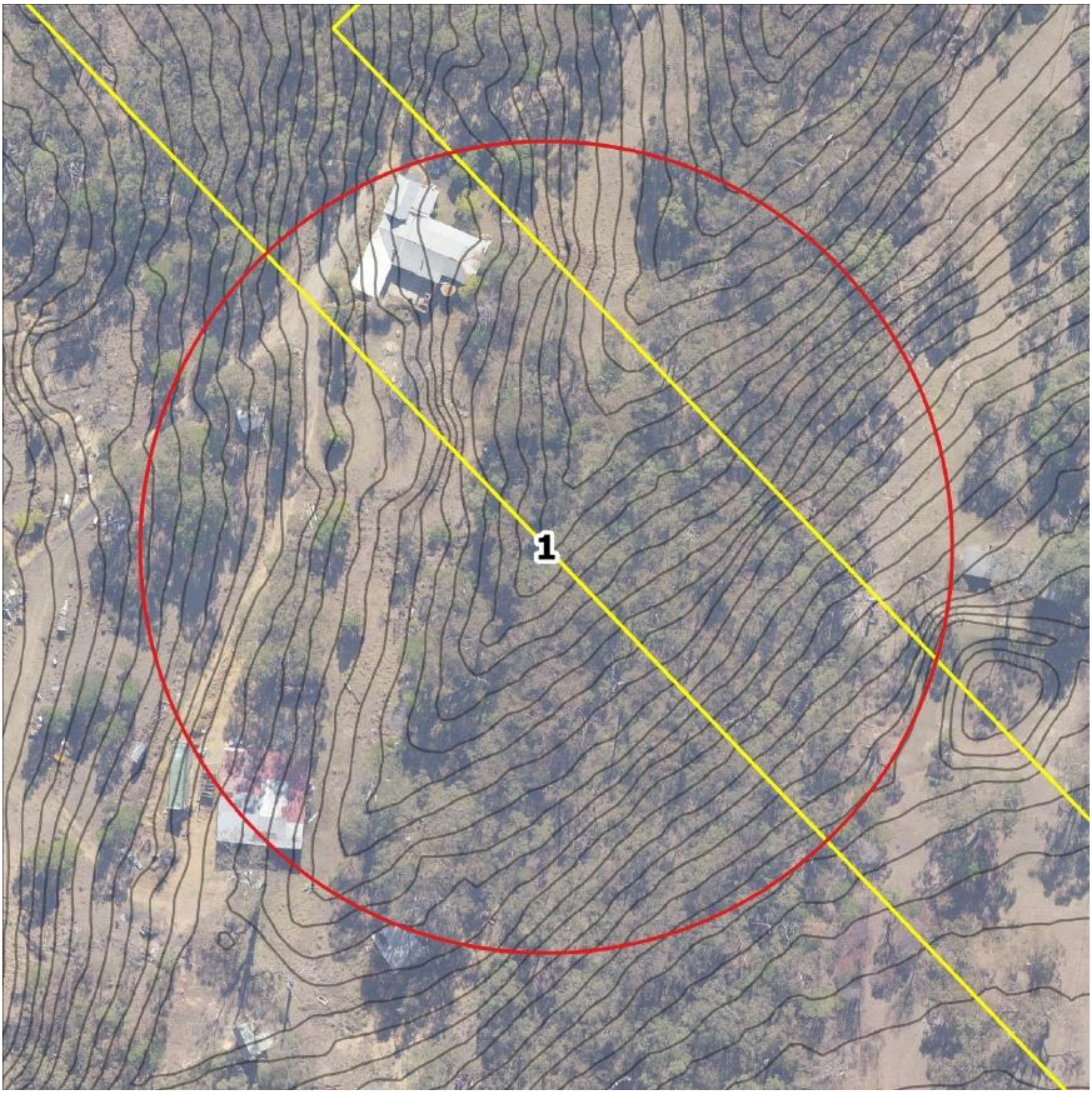


Figure 13 Overland Flow Path 1 - North of Bargo Township

6.2 OVERLAND FLOW PATH 2 – NORTHERN SIDE OF BARGO TOWNSHIP

Figure 14 shows an aerial photograph image of overland flow path 2 on the northern side of Bargo between longwalls 105A and 106A. The area comprises an open grassed paddock were overland flow would follow a depression downstream of a small farm dam overflow. There is no predicted ponding as a result of subsidence. The average slope of the overland flow path upslope of the gate road would reduce from approximately 3.5% to 3.3% due to predicted subsidence. It is considered unlikely that this slight reduction in gradient would pose any significant risk of increased flooding outside the existing overland flow path area.

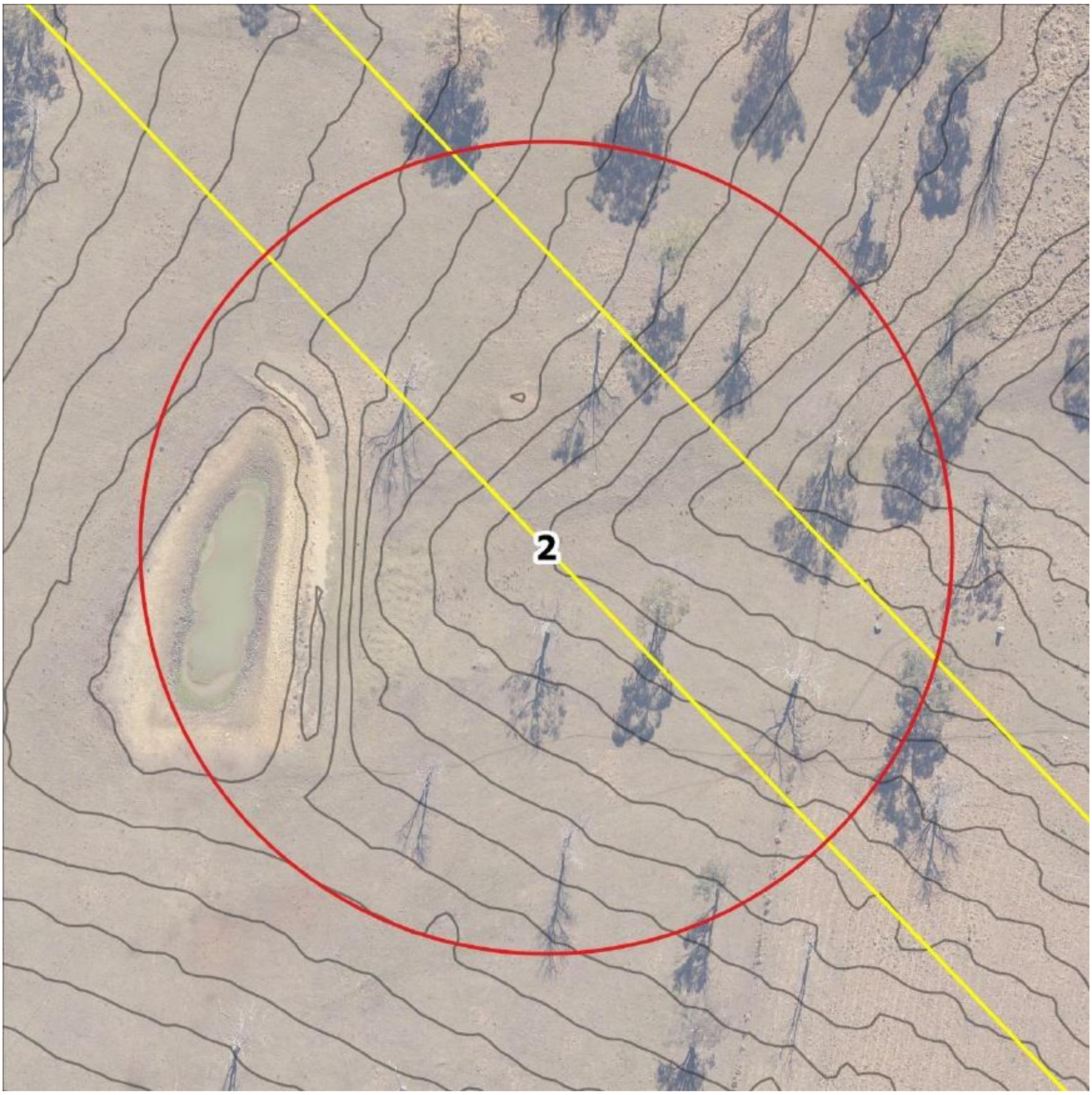


Figure 14 Overland Flow Path 2 – Northern Side of Bargo Township

7.3 OVERLAND FLOW PATH 3 – NORTHERN SIDE OF BARGO TOWNSHIP

Figure 15 shows an aerial photograph image of overland flow path 3. The site is located on the northern side of Bargo between longwalls 105A and 106A. The area comprises an open grassed paddock area where overland flow would follow a shallow swale which flows into a small farm dam. There is no predicted ponding as a result of subsidence. The average slope of the overland flow path upslope of the gate road would reduce from approximately 4.1% to 3.9% due to predicted subsidence. It is considered unlikely the slightly reduced gradient would pose any significant risk of increased flooding outside the swale.

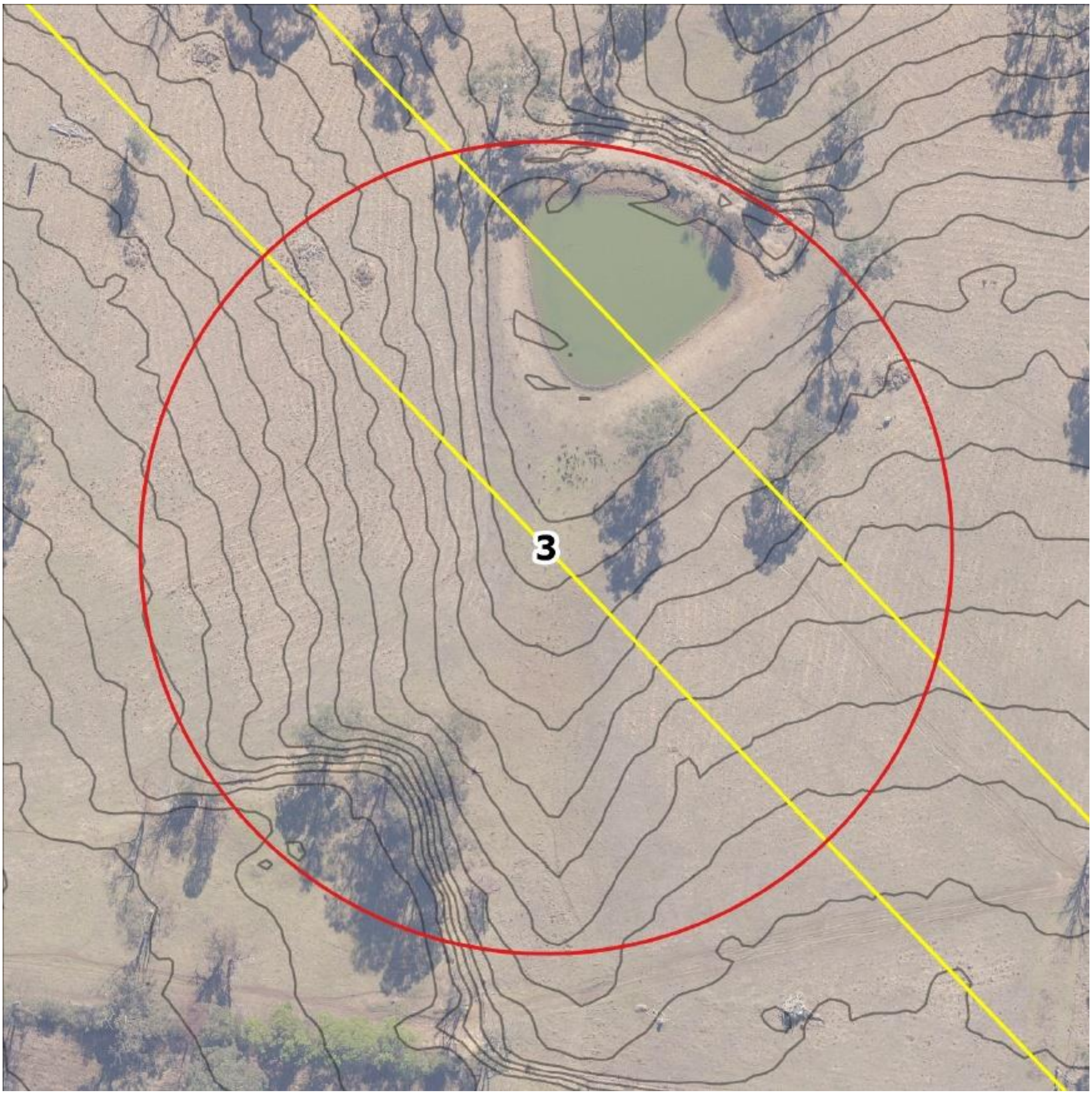


Figure 15 Overland Flow Path 3 –Northern Side of Bargo Township

7.4 OVERLAND FLOW PATH 4 – NORTHERN SIDE OF BARGO TOWNSHIP

Figure 16 shows an aerial photograph image of overland flow path 4. The site is located on the northern side of Bargo between longwalls 104A and 105A. The area comprises an open grassed paddock were overland flow would follow an ill-defined flow path upslope of a residential area. There is no predicted ponding as a result of subsidence. The average slope of the overland flow path upslope of the gate road in this area would reduce from about 4.0% to 3.7% due to predicted subsidence. It is considered unlikely the slightly reduced gradient would increase flooding outside the overland flow path area.

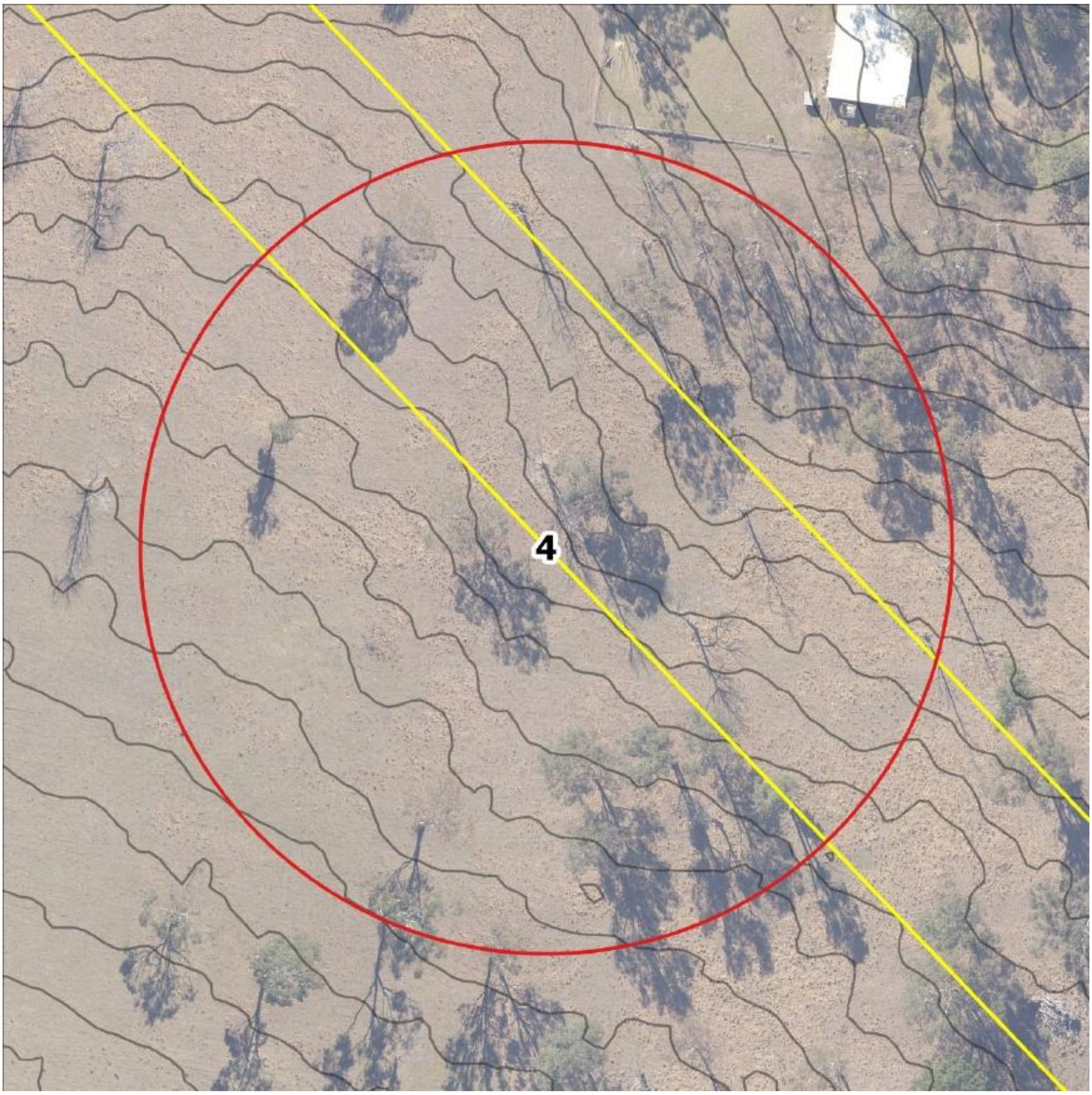


Figure 16 Overland Flow Path 4 East of Hawthorne Road

7.5 OVERLAND FLOW PATH 5 – NORTHERN SIDE OF WELLERS ROAD

Overland flow path 5 is located on the northern side of Wellers Road, in an area overlying the proposed gate road between longwalls 106B and 107B. Figure 17 shows an aerial photograph image of the area. The area comprises open space between two residential buildings on the southern side of Wellers Road and a timbered informal drainage line on the northern side of Wellers Road. The catchment upstream of this location is estimated to be about 17.6 ha. The average slope of the overland flow path upslope of the gate road would reduce from approximately 2.8% to 2.4% due to predicted subsidence. There is no ponding within the overland flow path as a result of subsidence and it is considered unlikely the reduced gradient would pose a risk of significant increased flooding within the existing overland flow path area.

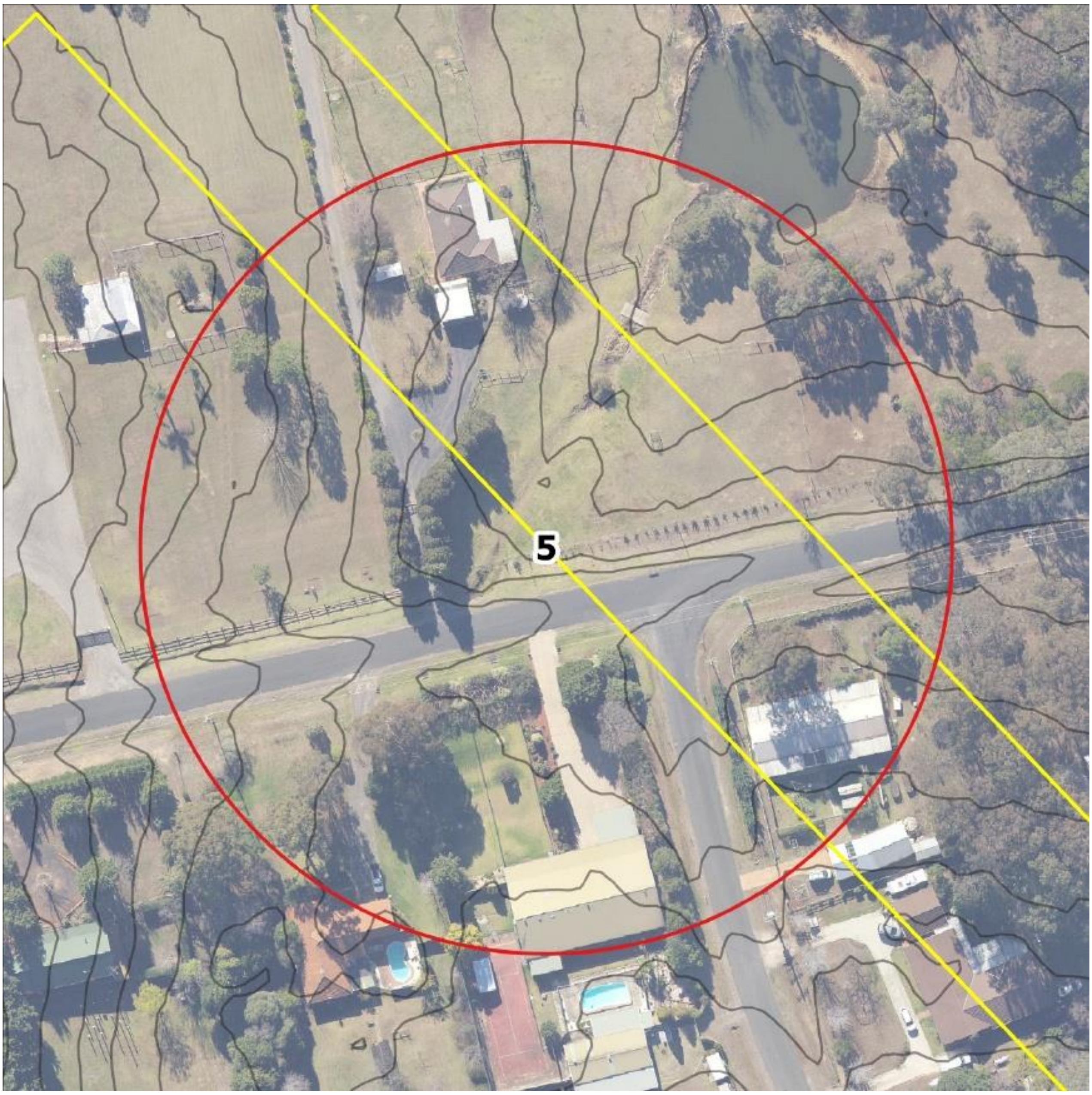


Figure 17 Overland Flow Path 5 – Northern Side of Wellers Road

7.6 OVERLAND FLOW PATH 6 – WESTERN SIDE OF GREAT SOUTHERN ROAD

Figure 18 shows an aerial photograph image of overland flow path 6 on the western side of Great Southern Road. The overland flow path overlies the proposed gate road between longwalls 105B and 106B. The area comprises an open, partially timbered drainage corridor where overland flow would follow a natural depression. There is no predicted ponding as a result of subsidence. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 3.3% to 3.2% due to predicted subsidence. It is considered unlikely the slightly reduced gradient would pose a significant risk of increased flooding outside the existing drainage corridor

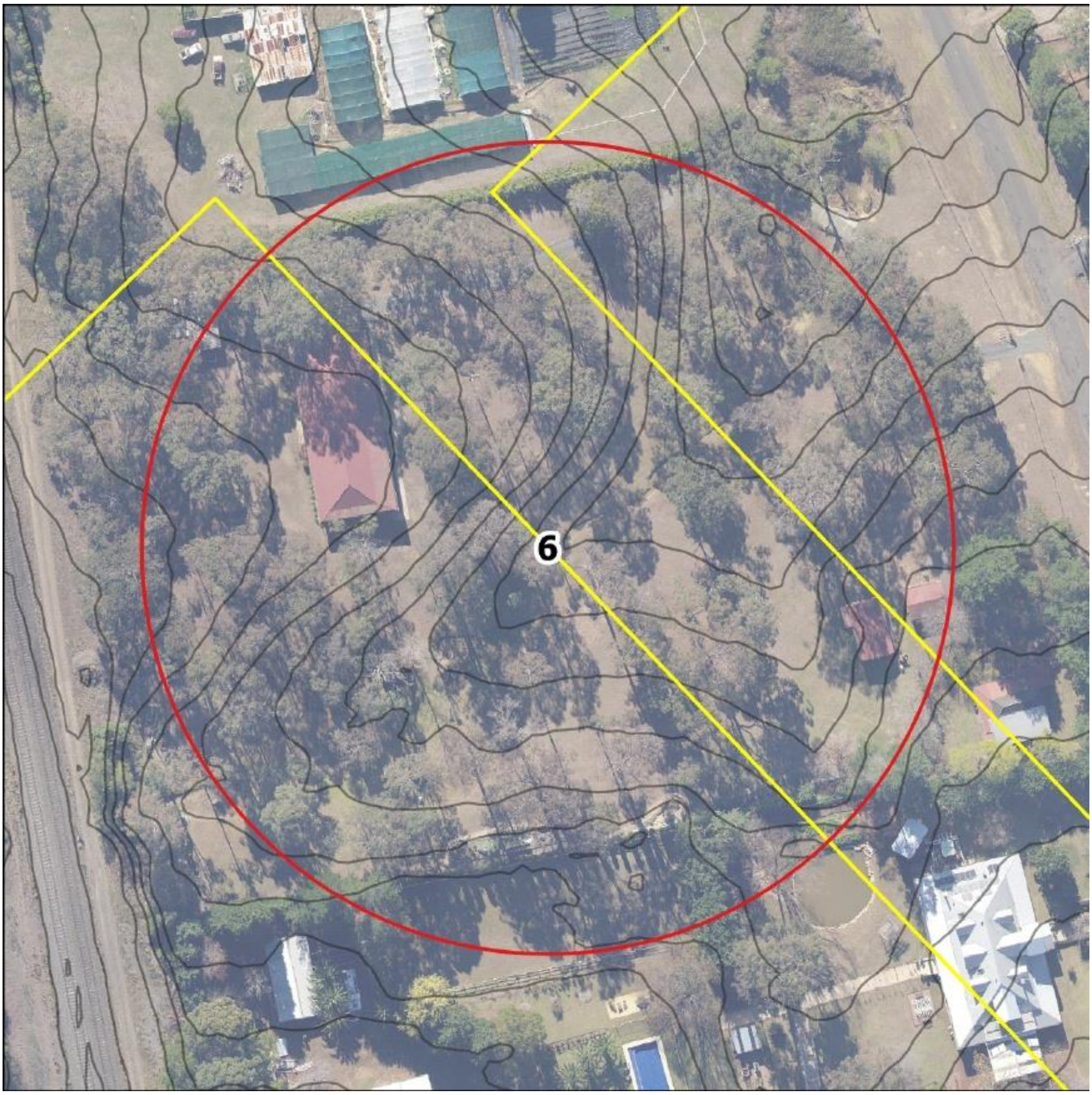


Figure 18 Overland Flow Path 6 – West of the Great Southern Road

7.7 OVERLAND FLOW PATH 7 – EAST OF THE GREAT SOUTHERN ROAD

Figure 19 shows an aerial photograph image of overland flow path 7 which is located on the eastern side of Great Southern Road. The overland flow path overlies the proposed gate road between longwalls 104B and 105B. The area comprises an open grassed paddock and an established tree break where overland flow would follow a natural depression. There is no predicted ponding as a result of subsidence. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 2.4 % to 2.2% due to predicted subsidence. It is considered unlikely the slightly reduced gradient would pose a significant risk of increased flooding outside the overland flow path area.

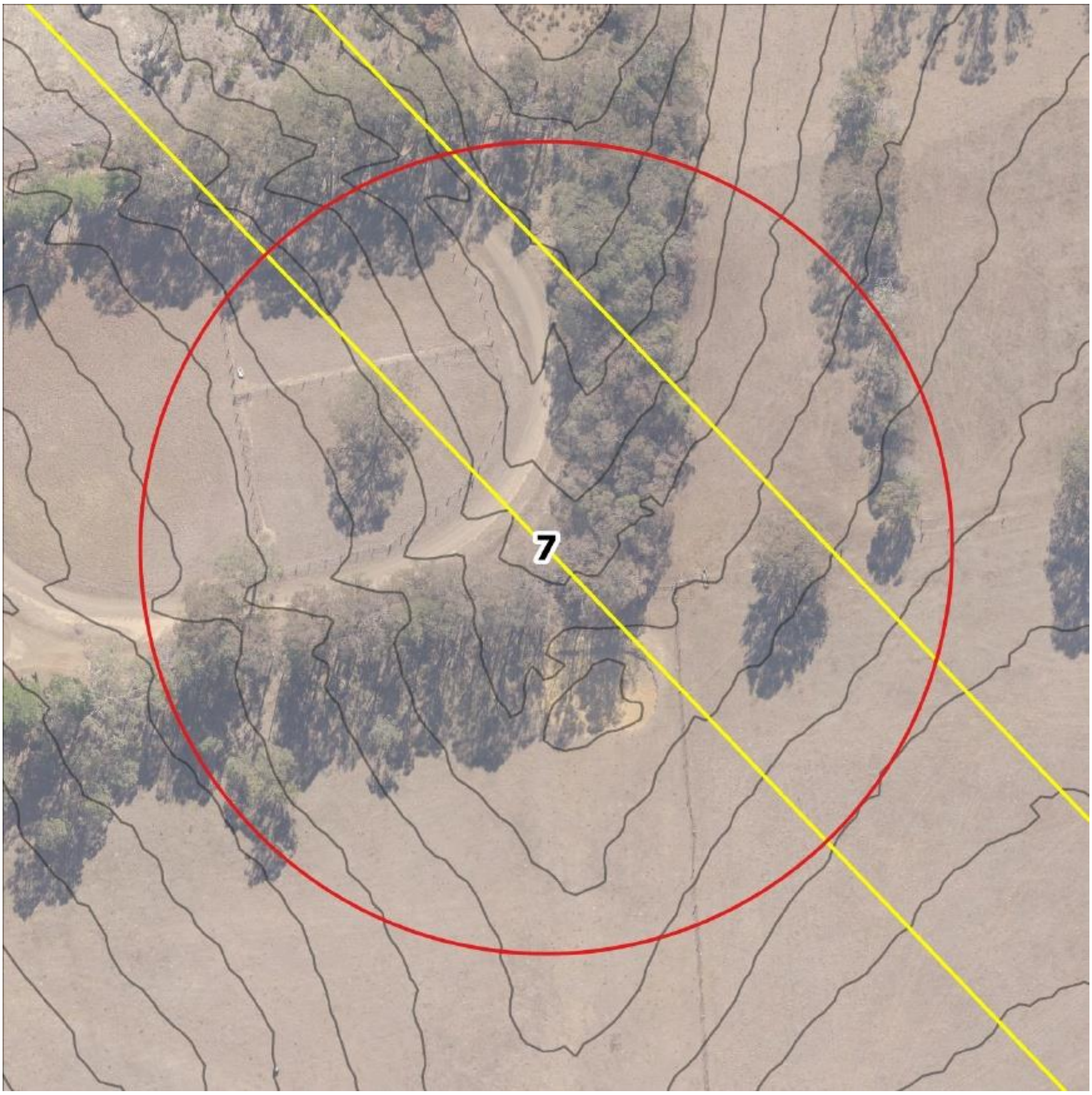


Figure 19 Overland Flow Path 7 East of Great Southern Road

7.8 OVERLAND FLOW PATH 8 – BETWEEN HOGANS DRIVE AND REMEMBRANCE DRIVE

Overland flow path 8 comprises a drainage corridor between two housing allotments on Hogans Drive. The drainage corridor overlies the proposed gate road between longwalls 106B and 107B – refer Figure 20. The area comprises an open, vegetated swale. There is no ponding predicted to occur as a result of subsidence. The average slope of overland flow path upslope of the gate road in this area would reduce from approximately 4.1% to 3.8% as a result of the predicted subsidence. It is considered that the slightly reduced gradient would not pose a risk of significant increased flooding outside the drainage corridor.

Figure 20 Overland Flow Path 8 Between Hogans Drive and Remembrance Drive

7.9 OVERLAND FLOW PATH 9 – BETWEEN SCOT STREET AND HOGANS DRIVE

Overland flow path 9 comprises a drainage corridor located in an open relatively steep confined swale on Hogans Drive upslope of a residential building. The swale overlies the proposed gate road between longwalls 107B and 108B – refer Figure 21. The catchment area contributing to this overland flow path is estimated to be some 4.8 ha. There is no ponding predicted to occur as a result of subsidence. The average slope of overland flow path upslope of the gate road in this area would reduce from approximately 5.4% to 5.1% as a result of the predicted subsidence. It is considered that the slightly reduced gradient would not pose a significant risk of increased flooding within or outside the swale.

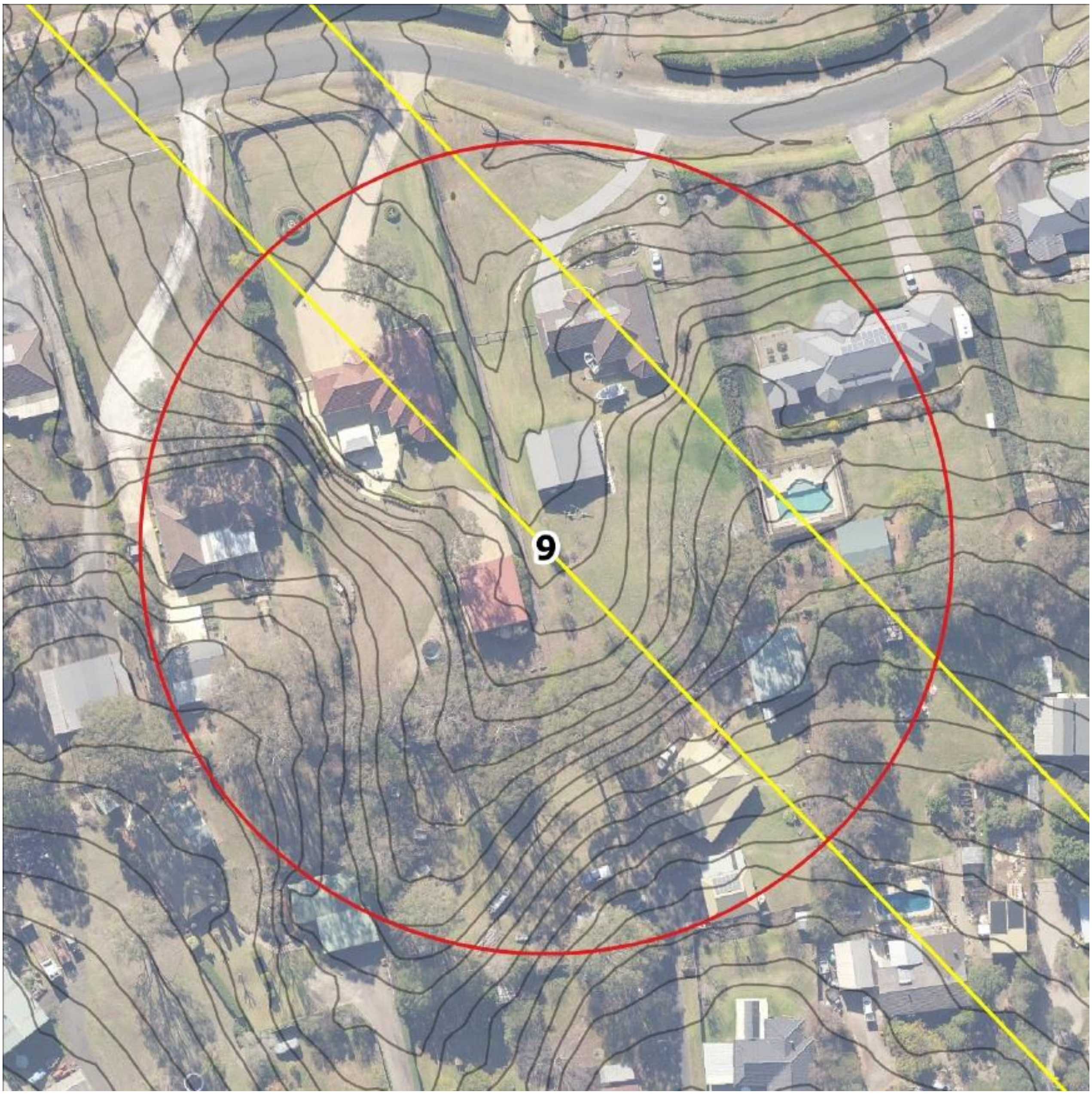


Figure 21 Overland Flow Path 9 – Between Scots Street and Hogans Drive

7.10 OVERLAND FLOW PATH 10 – BETWEEN GREAT SOUTHERN ROAD AND HAWTHORNE ROAD

There is an existing ill-defined overland flow path which passes through two housing allotments fronting Hawthorne Road. The overland flow path, which overlies the proposed gate road between longwalls 106B and 107B, has a surface catchment of some 4.5 ha. There is no ponding predicted to occur along the overland flow path as a result of subsidence. The average slope of overland flow path upslope of the gate road in this area would reduce from approximately 2.9% to 2.6% as a result of the predicted subsidence. It is considered that the reduced gradient would not pose a risk of significant increased flooding within the overland flow path area.

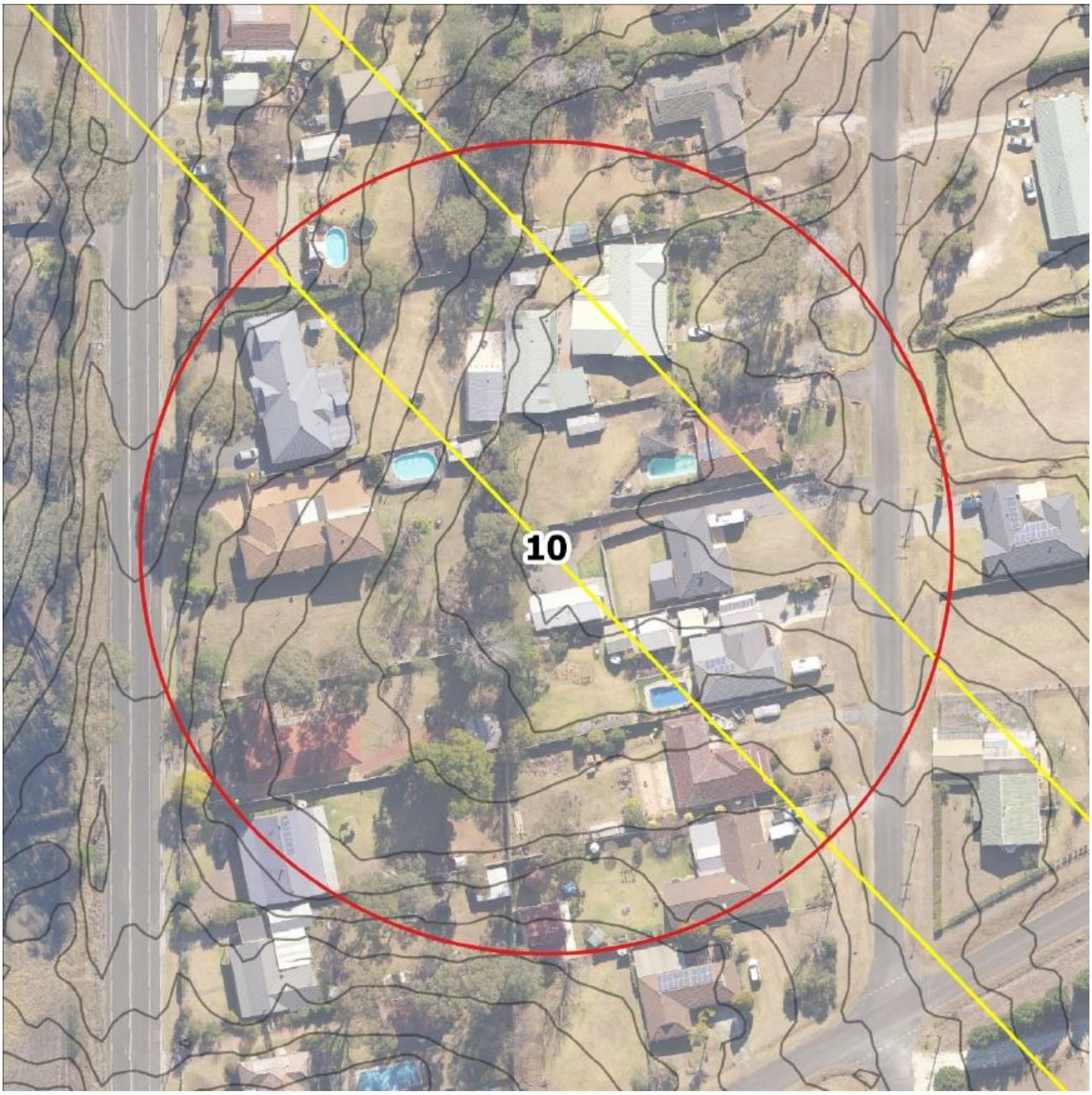


Figure 22 Overland Flow Path 10 Between Great Southern Road and Hawthorne Road

7.11 OVERLAND FLOW PATH 11 – BETWEEN GREAT SOUTH ROAD AND HAWTHORNE DRIVE

Overland flow path 11 passes through two housing allotments located between Hawthorne Road and Great Southern Road. The overland flow path overlies the proposed gate road between longwalls 107B and 108B - refer Figure 23. There is no ponding predicted to occur along the overland flow path as a result of subsidence. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 4.1% to 3.9% as a result of the predicted subsidence. It is considered that the slightly reduced gradient would not pose a significant risk of increased flooding within the overland flow path area.

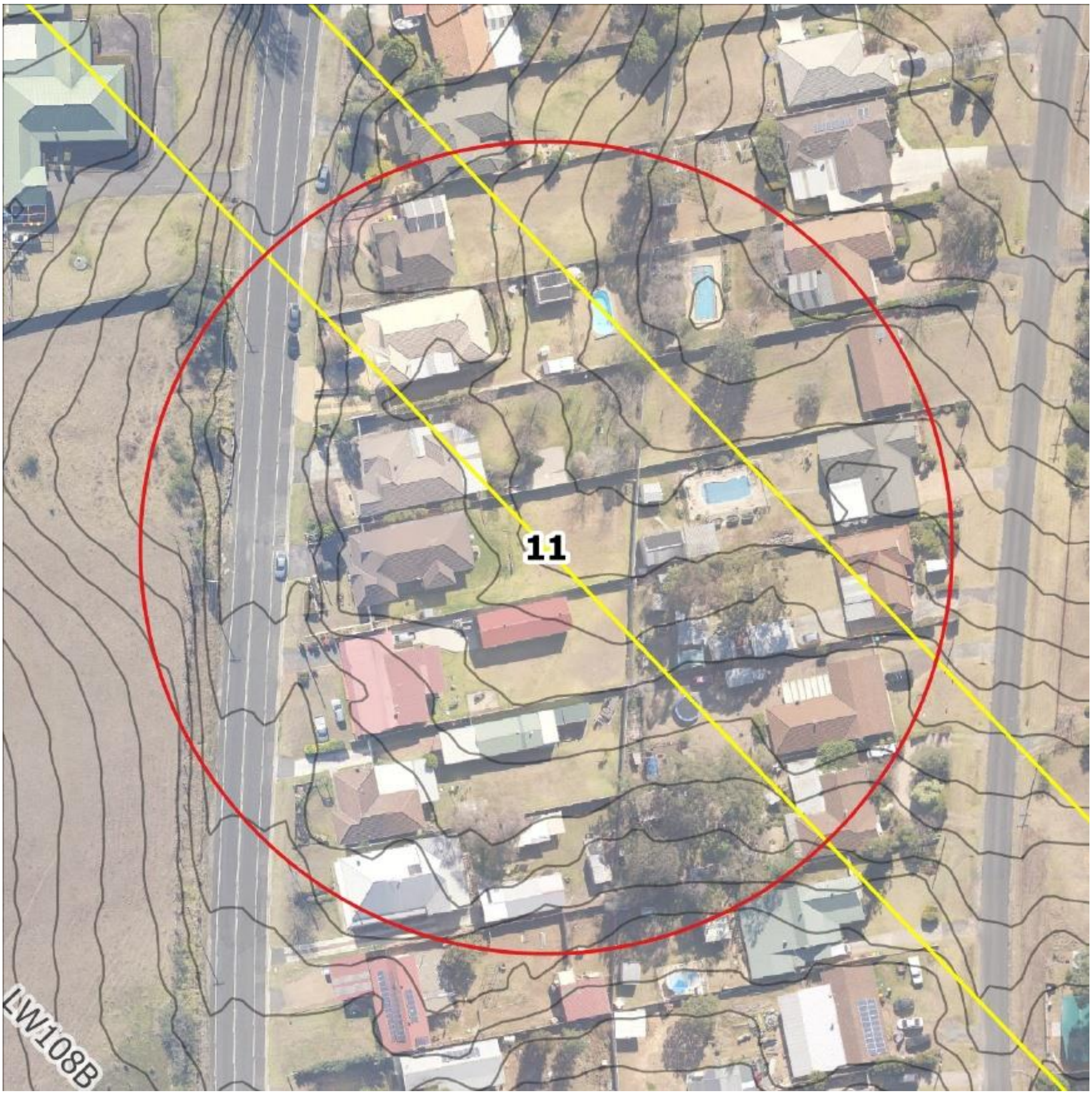


Figure 23 Overland Flow Path 11 - Between Great South Road and Hawthorne Drive

7.12 OVERLAND FLOW PATH 12 – DYMOND STREET

Overland flow path 12 comprises a small channel within a large open area on the northern side of Dymond Road which overlies the proposed gate road between longwalls 106B and 107B – refer Figure 24. The area comprises an undeveloped, partially timbered area with a farm dam in the flow path upslope of the gate road. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 2.5 % to 2.1 % as a result of the predicted subsidence. Subsidence would not cause surface ponding in this area and it is considered that the reduced gradient would not pose a significant risk of increased flooding outside the overland flow path area.

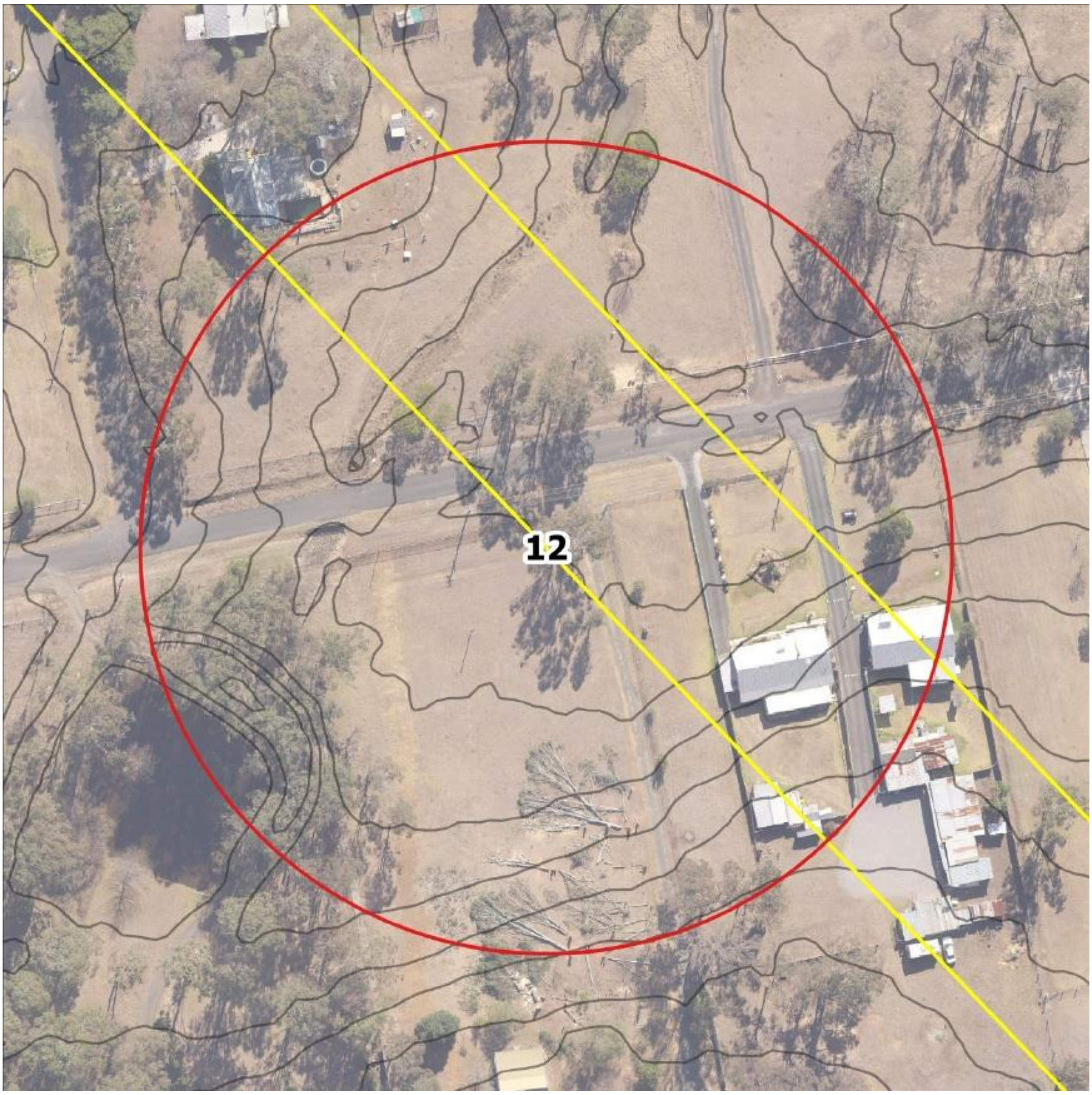


Figure 24 Overland Flow Path 12 – Dymond Street

7.13 OVERLAND FLOW PATH 13 – EAST OF HAWTHORNE ROAD

Overland flow path 13 comprises a shallow swale within in a large open area on the east of Hawthorne Road and south of Dymond Road – refer Figure 25. The overland flow path overlies the proposed gate road between longwalls 107B and 108B. The area comprises an undeveloped, sparsely timbered paddock upslope of the gate road. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 2.6 % to 2.3 % as a result of the predicted subsidence. Subsidence would not cause ponding of the surface in this area and it is considered that the reduced gradient would not pose any significant risk of increased flooding outside the open area.

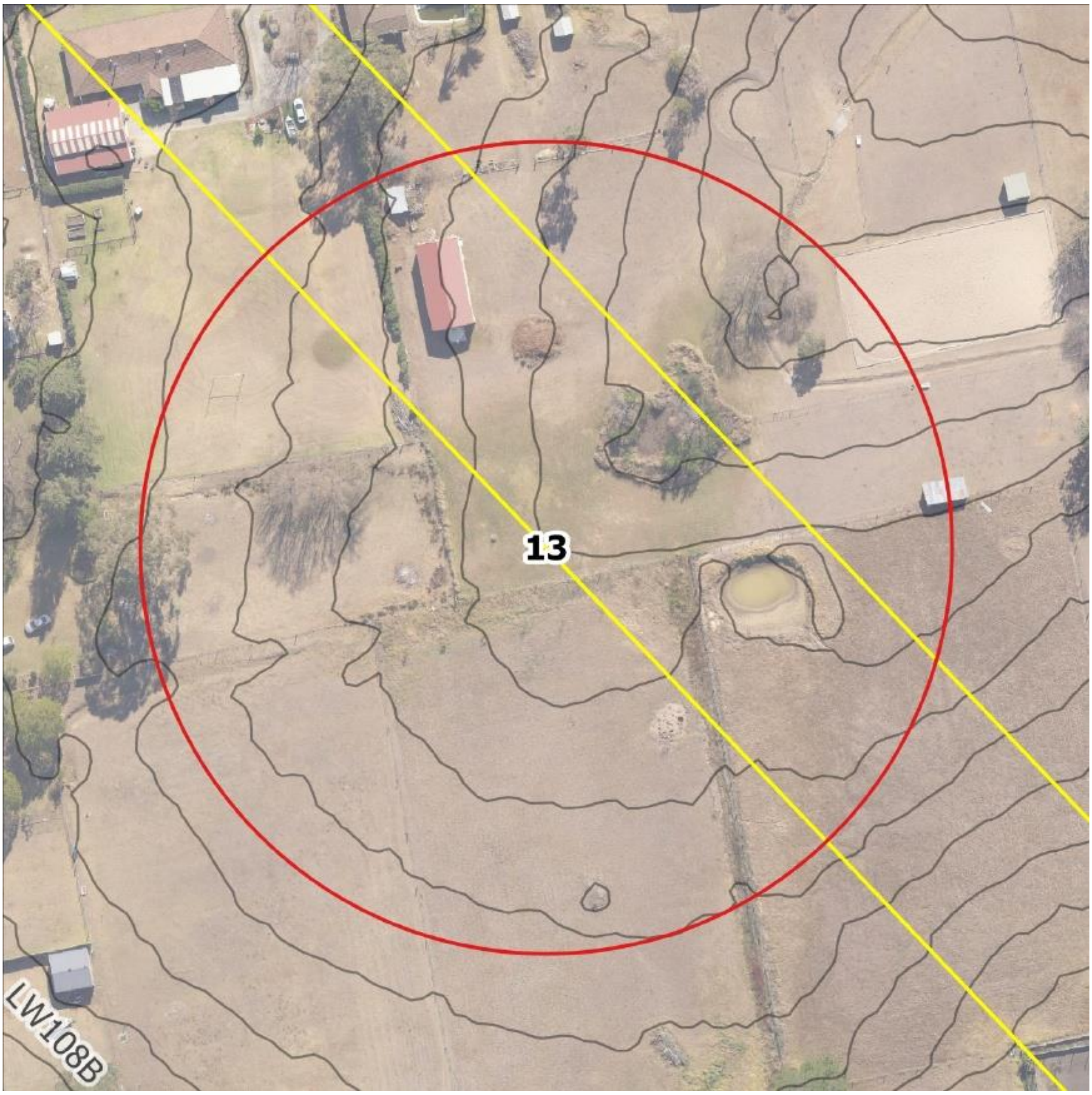


Figure 25 Overland Flow Path 13 – East of Hawthorne Road

7.14 OVERLAND FLOW PATH 14 – BARGO ROAD

Overland flow path 14 comprises in a large low-lying, open area between two buildings on the southern side of Bargo Road. The area overlies the proposed gate road between longwalls 106B and 107B – refer Figure 26. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 2.2 % to 1.9 % as a result of the predicted subsidence. Subsidence would not cause ponding of the surface in this area and it is considered that the reduced gradient would not pose a significant risk of increased flooding outside the open area.

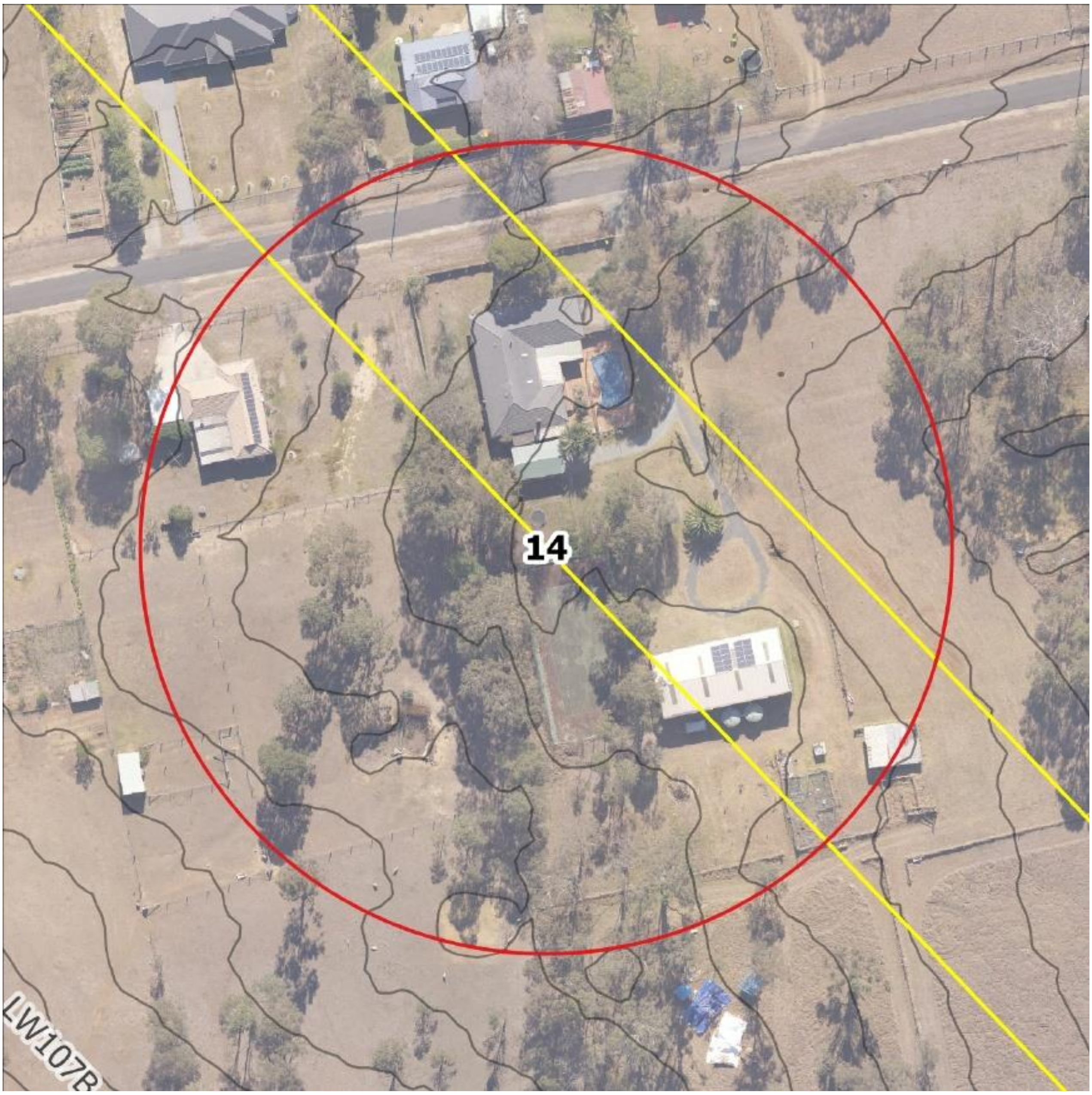


Figure 26 Overland Flow Path 14 – Bargo Road

7.15 OVERLAND FLOW PATH 15 – JOHNSTON ROAD

Overland flow path 15 comprises a small swale within in an open area on the northern side of Johnston Road which overlies the proposed gate road between longwalls 107B and 108B. The area comprises a mix of grassed and timbered areas. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 5.3 % to 5.0 % as a result of the predicted subsidence. Subsidence would not cause ponding of the surface in this area and it is considered that the reduced gradient would not pose any significant risk of increased flooding.

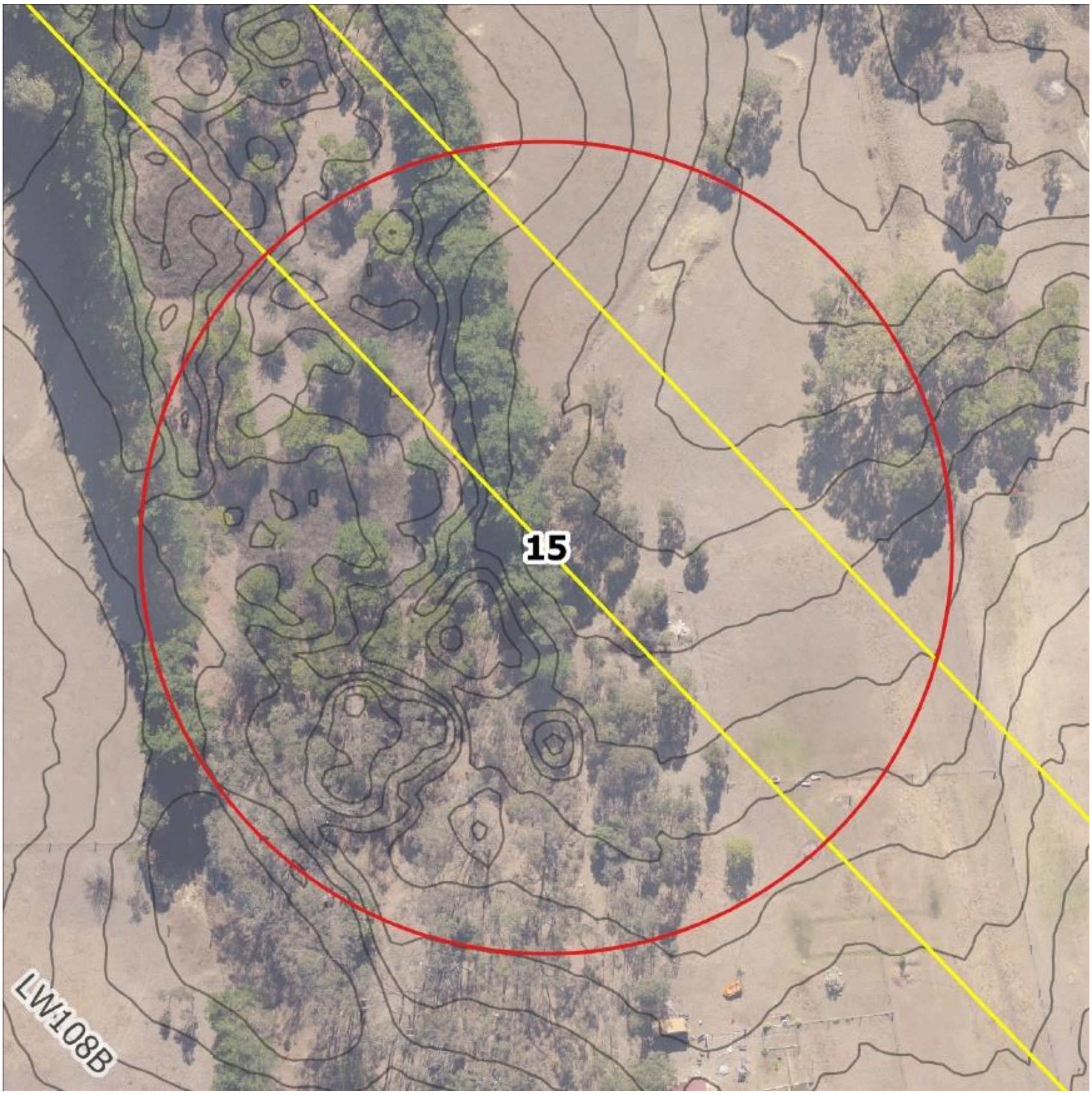


Figure 27 Overland Flow Path 15 –Johnston Road

7.16 OVERLAND FLOW PATH 16 – NORTH OF HAWTHORNE ROAD

Overland flow path 16 comprises a shallow swale in a large open area on the northern side of Hawthorne Road which overlies the proposed gate road between longwalls 107B and 108B. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 2.3 % to 2.1 % as a result of the predicted subsidence. Subsidence would not cause ponding of the surface in this area and it is considered that the slightly reduced gradient would not pose a significant risk of increased flooding outside the open area.

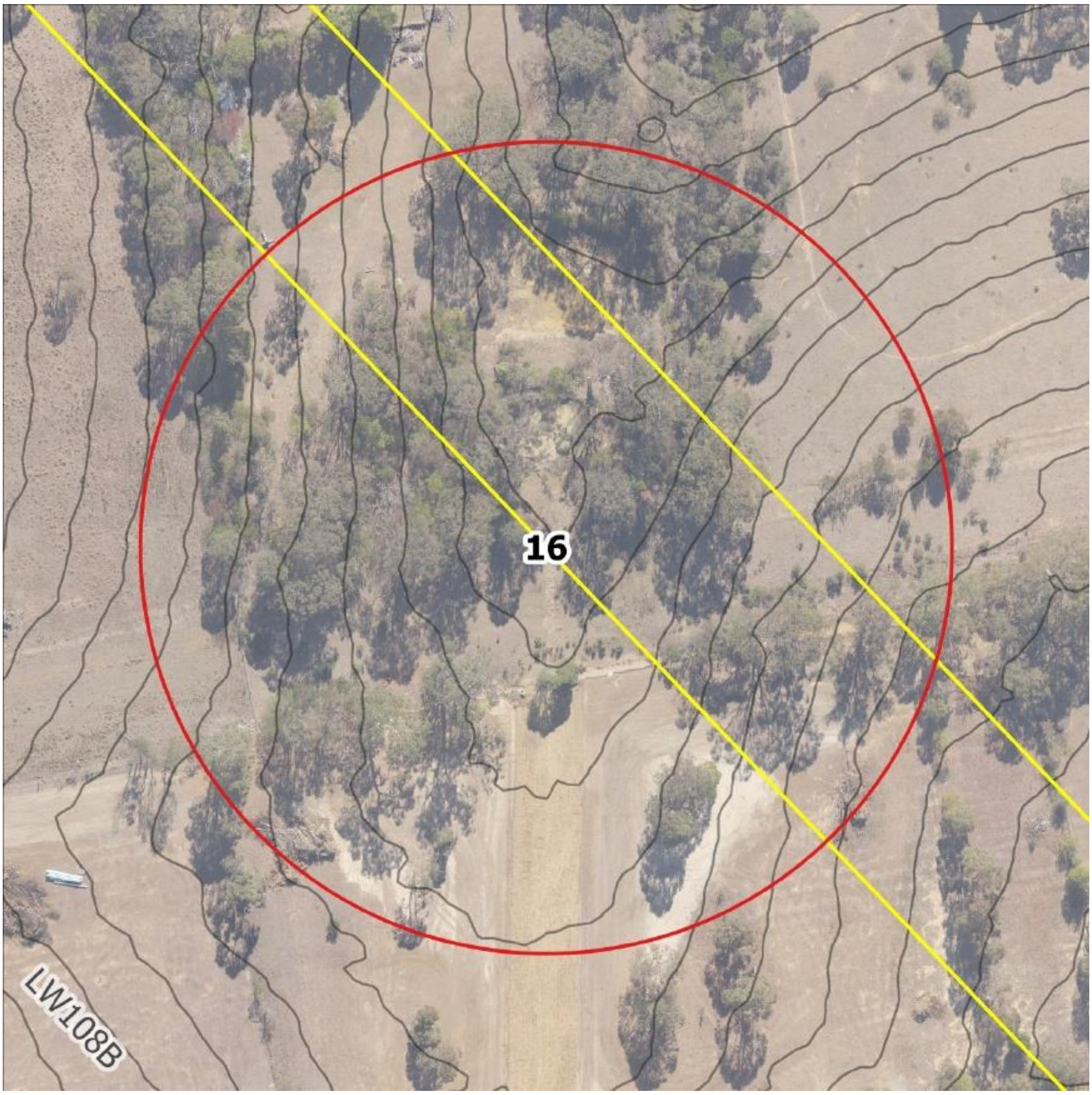


Figure 28 Overland Flow Path 16 –North of Hawthorne Road

7.17 OVERLAND FLOW PATH 17 – SOUTH OF RESERVOIR ROAD

Overland flow path 17 comprises a low-lying open upslope of several houses on the southern side of Reservoir Road which overlies the proposed gate road between longwalls 107B and 108B. The area comprises a minor drainage corridor in the headwaters of Dog Trap Creek. The average slope of the overland flow path upslope of the gate road in this area would reduce from approximately 2.5 % to 2.1 % as a result of the predicted subsidence. Subsidence would not cause ponding of the surface in this area and it is considered that the reduced gradient would not pose a significant risk of increased flooding outside this open area.

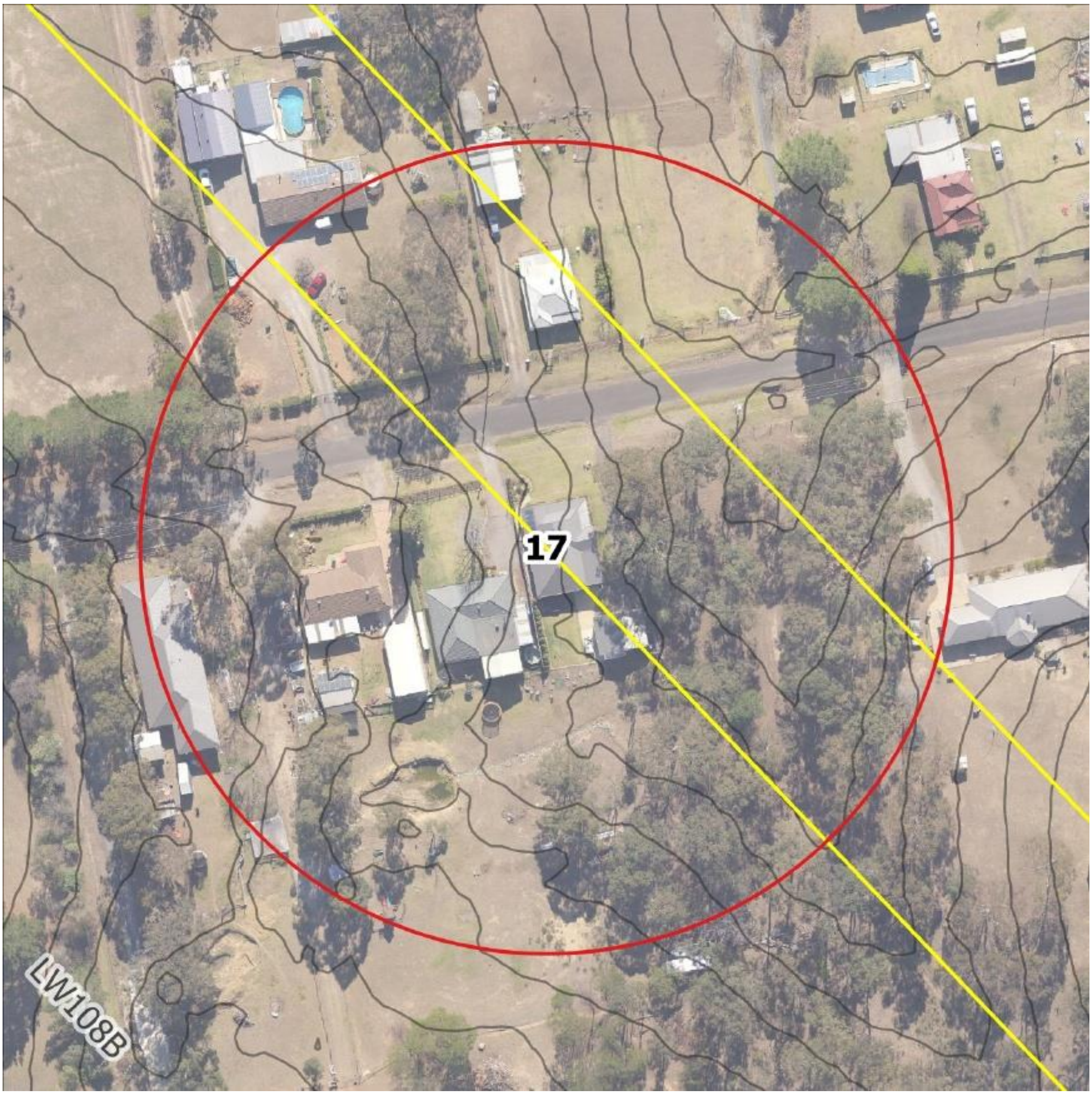


Figure 29 Overland Flow Path 17 –South of Reservoir Road

7.0 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 (2020). MSEC (2020) 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.

8.0 SUMMARY OF KEY CHANGES TO ASSESSMENT OUTCOMES

This Flood Study has been prepared to assess the impacts of the Amended Project on flooding of land in the Subsidence Study Area and potential impacts to overland flow paths in the urban areas of the Bargo Township. The differences in impacts compared with the original assessment presented in the EIS are summarised as follows:

- The predicted effects of subsidence on increasing flood inundation associated with Dog Trap Creek are limited to small areas in the upstream reaches on the edges of the floodplains overlying longwalls 104B to 107B. The predicted extent of post-subsidence inundation associated with the Amended Project is similar to that presented in the original assessment for both the 1% AEP and 50% AEP.
- The hydraulic model predicts that the effects of subsidence would result in an increase in areas subject to flood inundation on the western side of Remembrance Drive during a 1% AEP flood event in Tea Tree Hollow. The largest increase is on the western side of Remembrance Drive overlying longwall 103A. The predicted effects of subsidence on increasing flood inundation during a 50% AEP in Tea Tree Hollow are minor and at the limit of the model resolution. The predicted extent of post-subsidence inundation associated with the Amended Project is similar to that presented in the original assessment for both the 1% AEP and 50% AEP.
- The average slope of overland flow paths within the Bargo Township is predicted to reduce as a result of the predicted subsidence associated with the Amended Project. The qualitative assessment of impacts to overland flow paths indicates that the predicted subsidence is unlikely to result in ponding within the overland flow paths and it is considered unlikely that the predicted reduced gradients would pose a risk of significant increased flooding within the existing overland flow path areas.
- The predicted subsidence associated with the Amended Project is expected to have less impact on flow depth within overland flow paths than predicted for the original assessment.

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APPENDIX A – FLOOD EXTENT MAPS

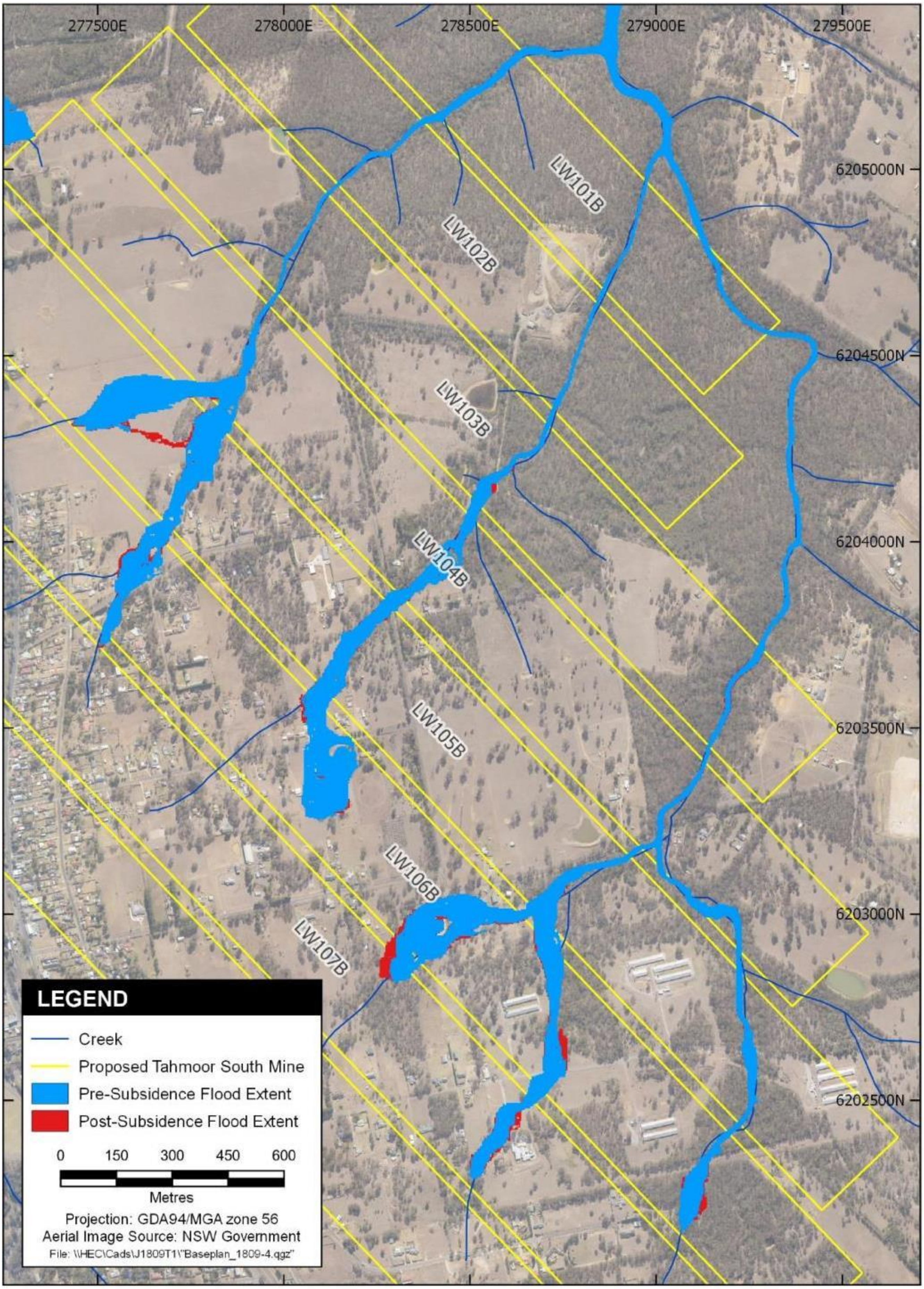

Figure A1: Extent of Predicted 10% AEP Flooding, Southern (upstream) - Dog Trap Creek

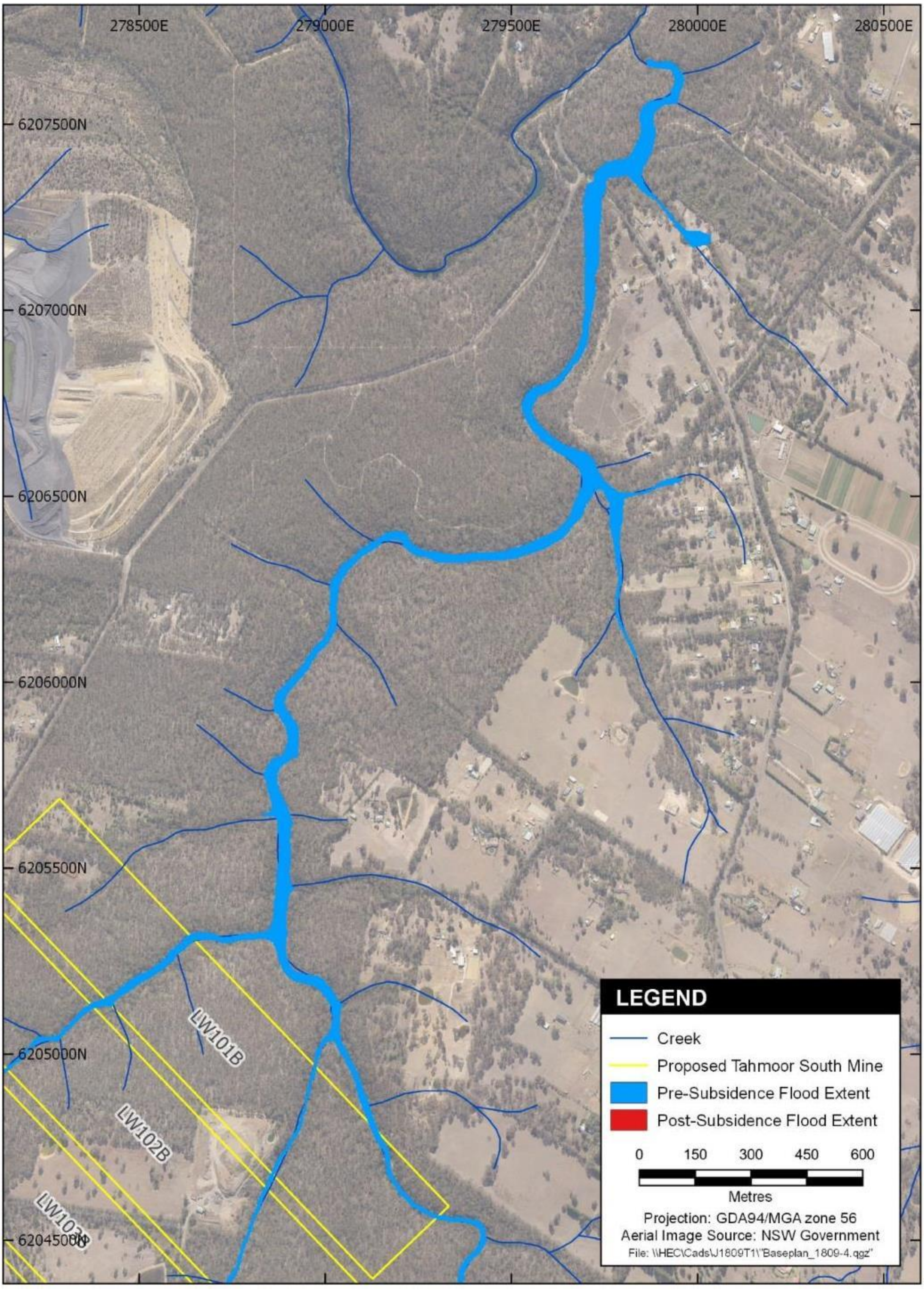

Figure A2: Extent of Predicted 10% AEP Flooding, Northern (downstream) - Dog Trap Creek

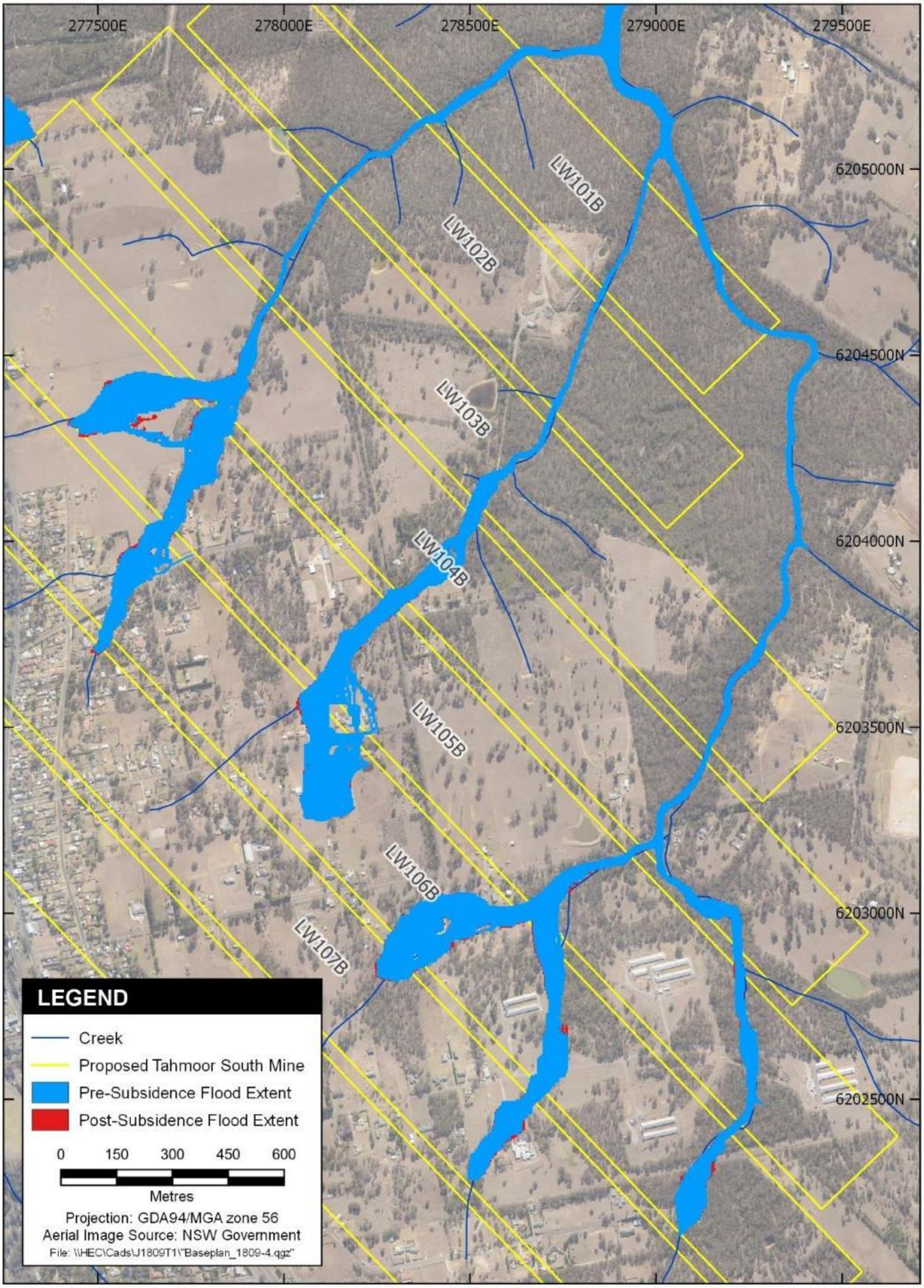

Figure A3: Extent of Predicted 0.5% AEP Flooding, Southern (upstream) - Dog Trap Creek

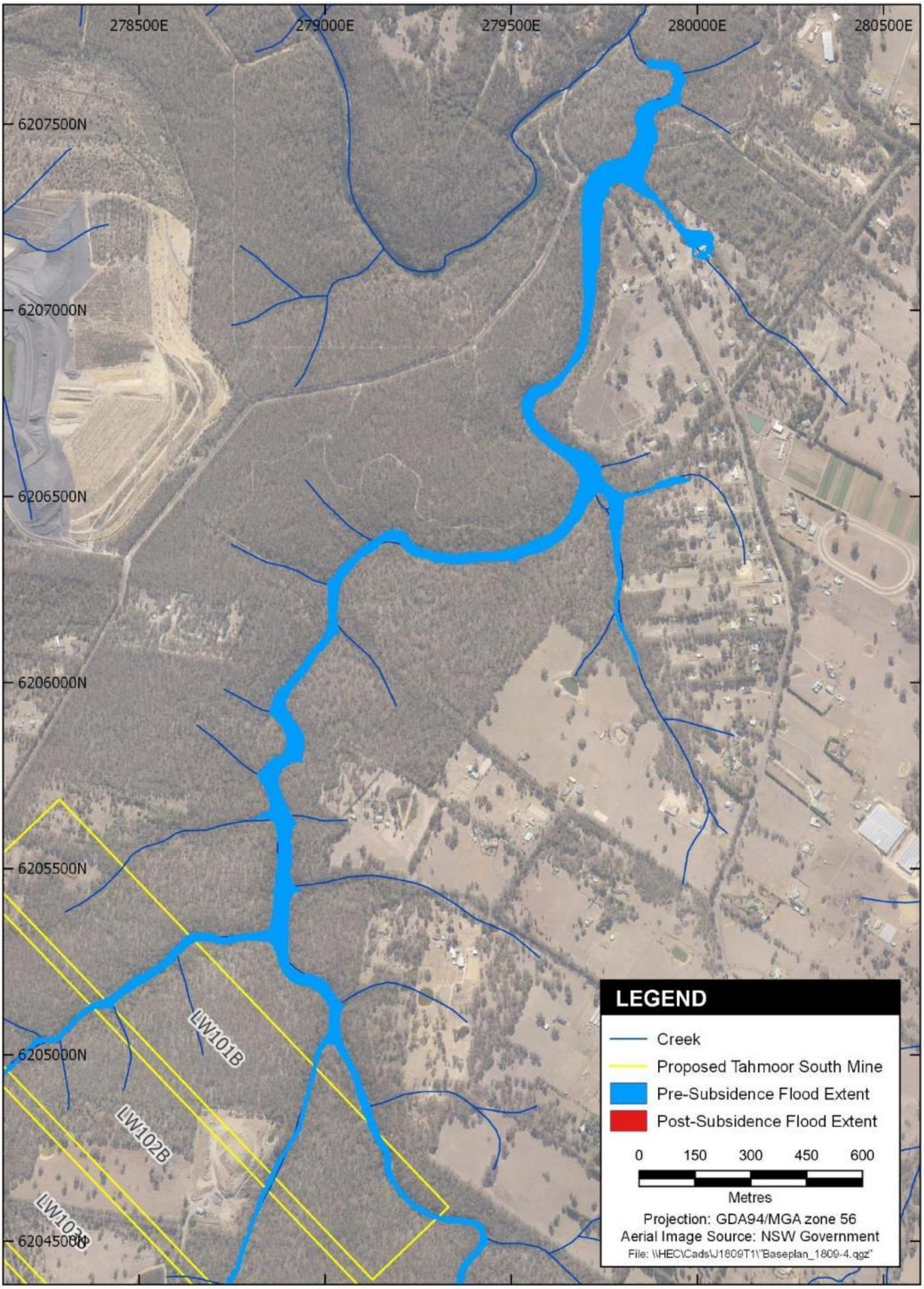

Figure A4: Extent of Predicted 0.5% AEP Flooding, Northern (downstream) - Dog Trap Creek

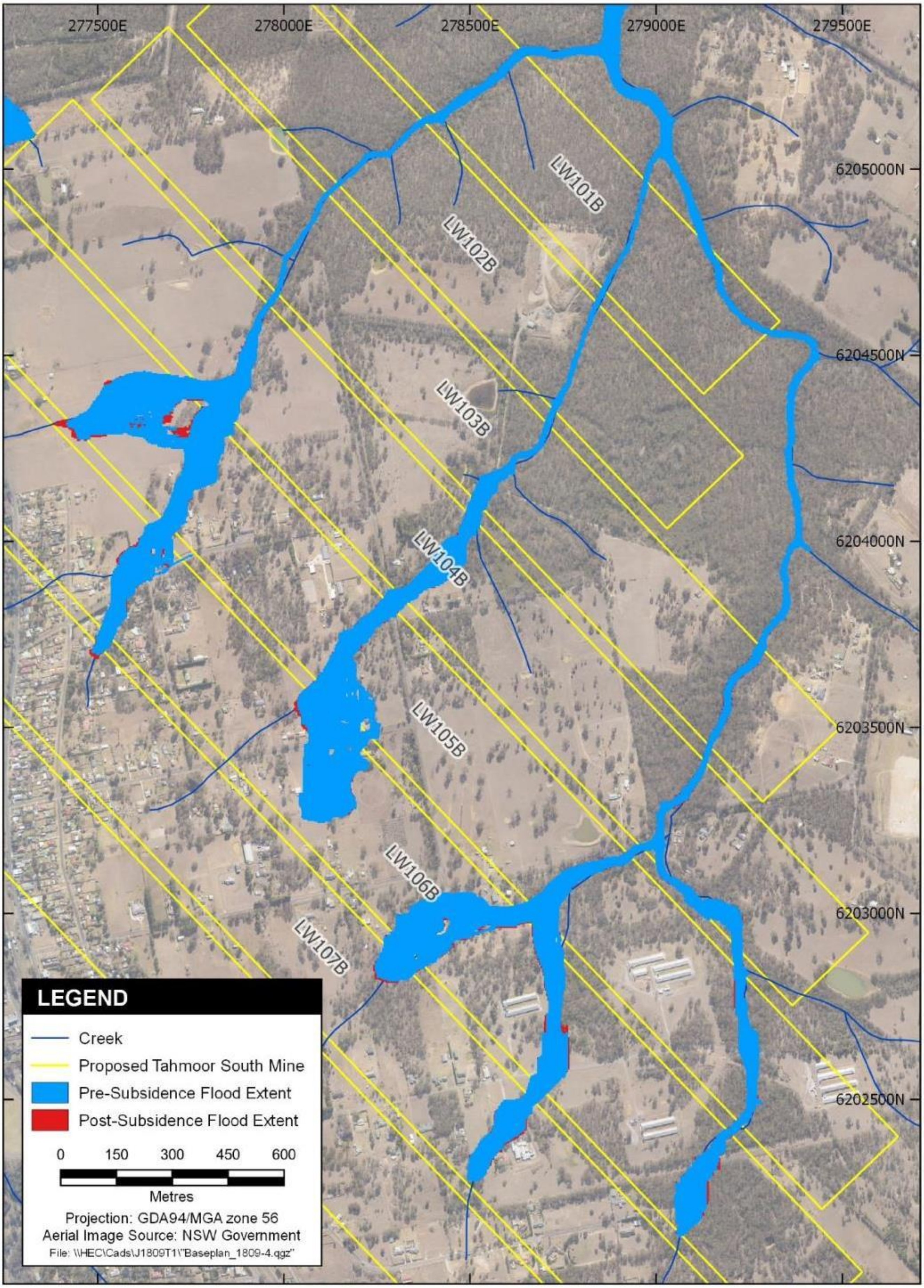

Figure A5: Extent of Predicted 0.2% AEP Flooding, Southern (upstream) - Dog Trap Creek

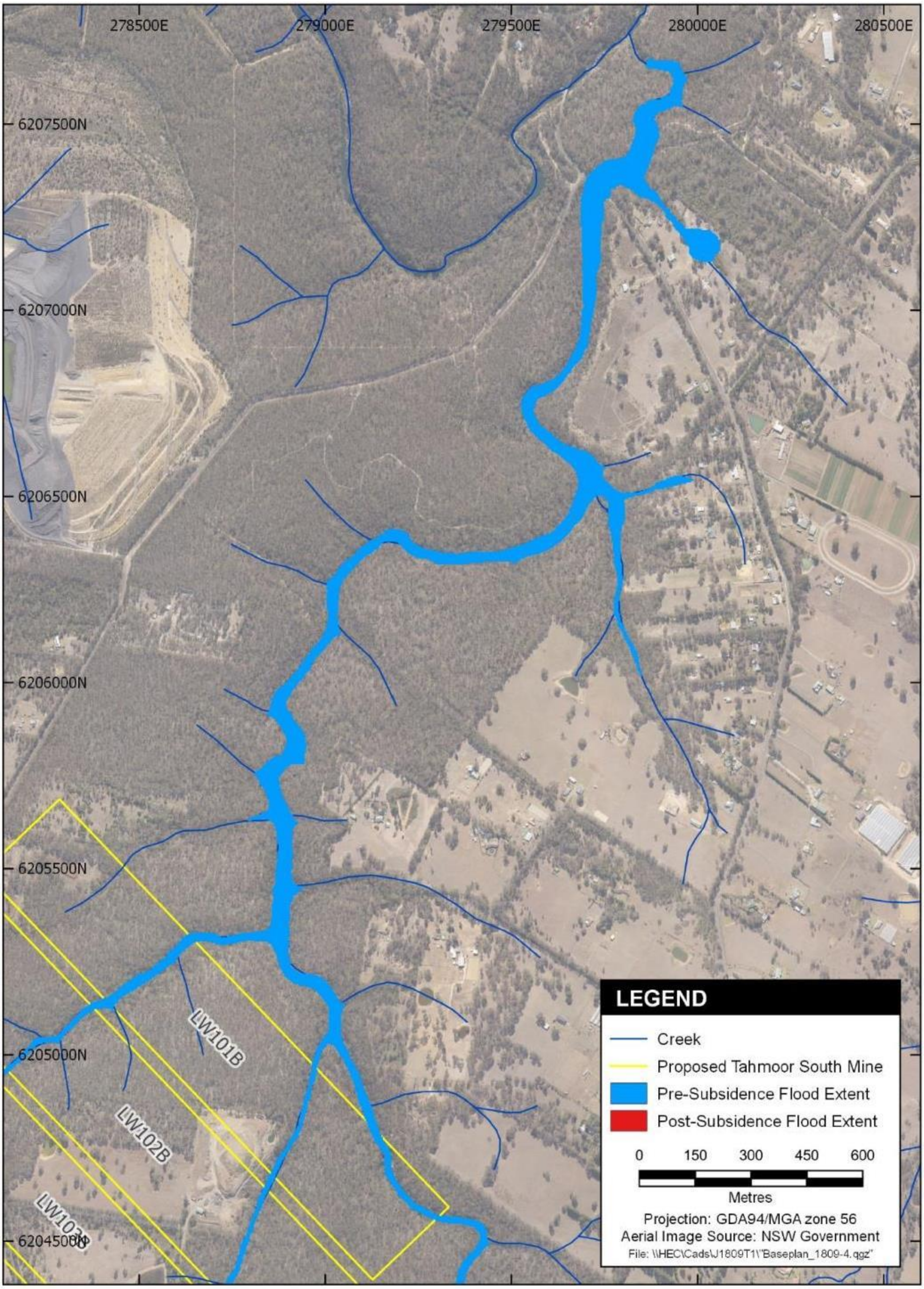

Figure A6: Extent of Predicted 0.2% AEP Flooding, Northern (downstream) - Dog Trap Creek

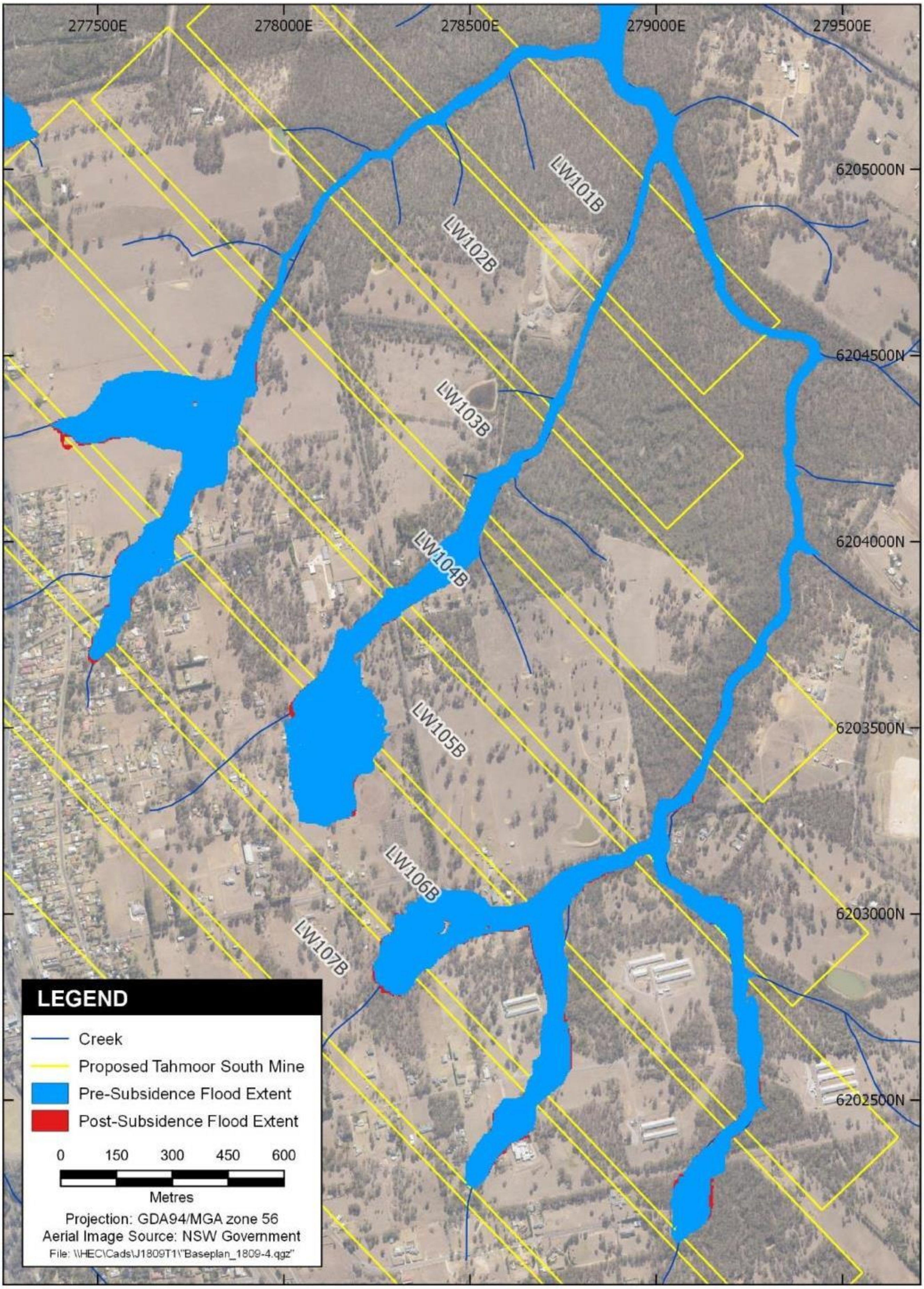

Figure A7: Extent of Predicted PMF Event Flooding, Southern (upstream) - Dog Trap Creek

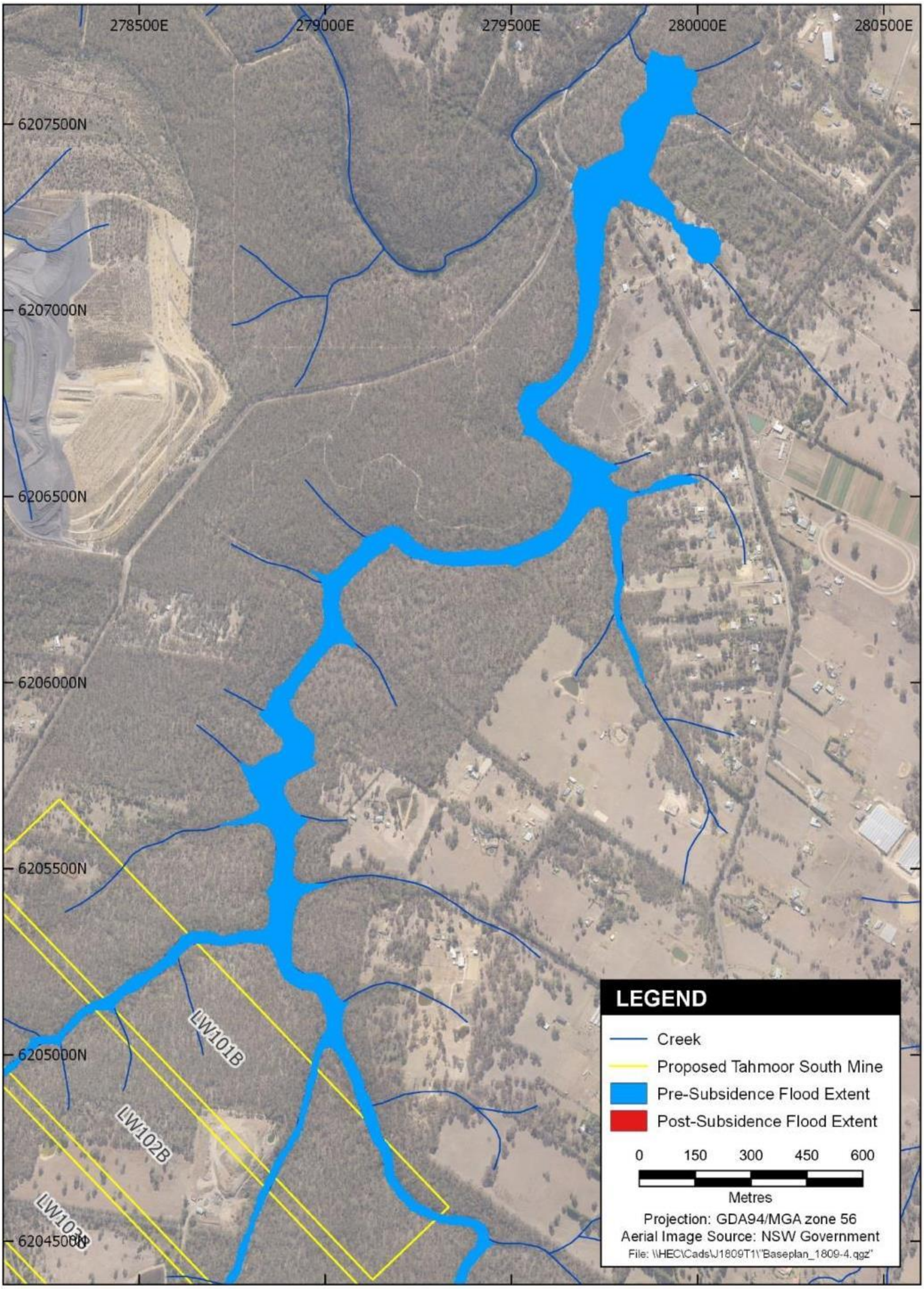

Figure A8: Extent of Predicted PMF Event Flooding, Northern (downstream) - Dog Trap Creek

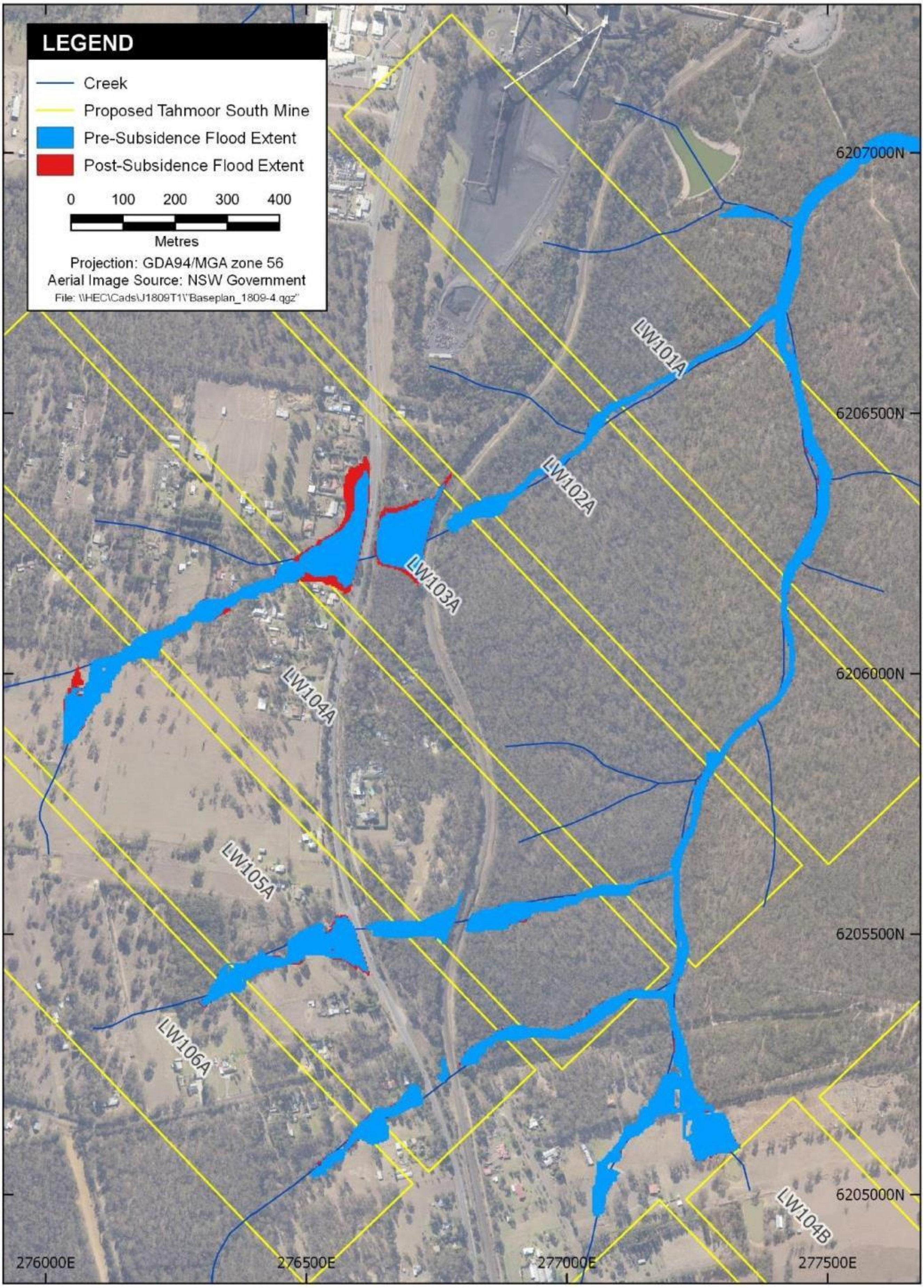

Figure A9: Extent of Predicted 10% AEP Flooding, Southern (upstream) – Tea Tree Hollow

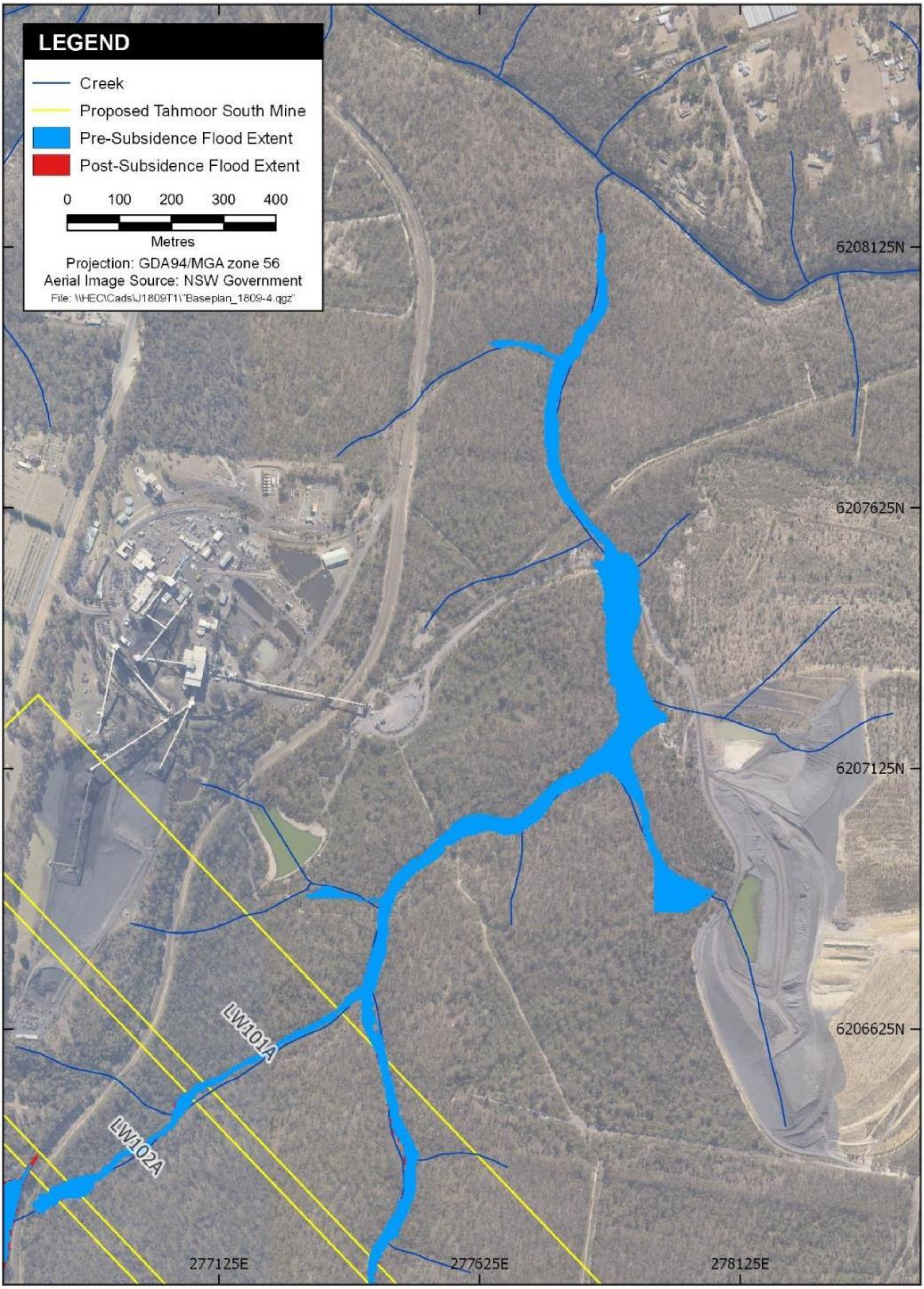

Figure A10: Extent of Predicted 10% AEP Event Flooding, Northern (downstream) - Dog Trap Creek

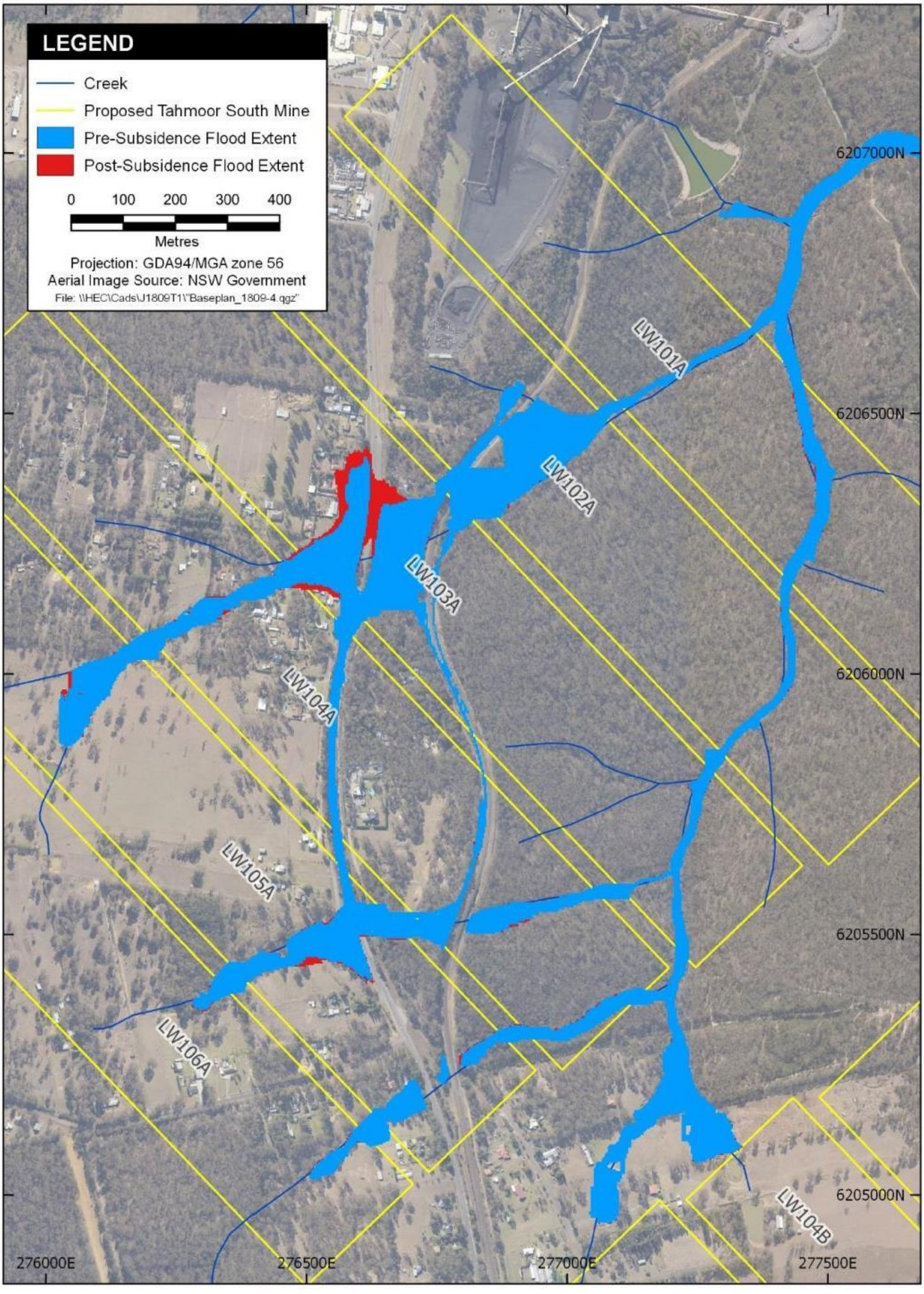

Figure A11: Extent of Predicted 0.5% AEP Flooding, Southern (upstream) – Tea Tree Hollow

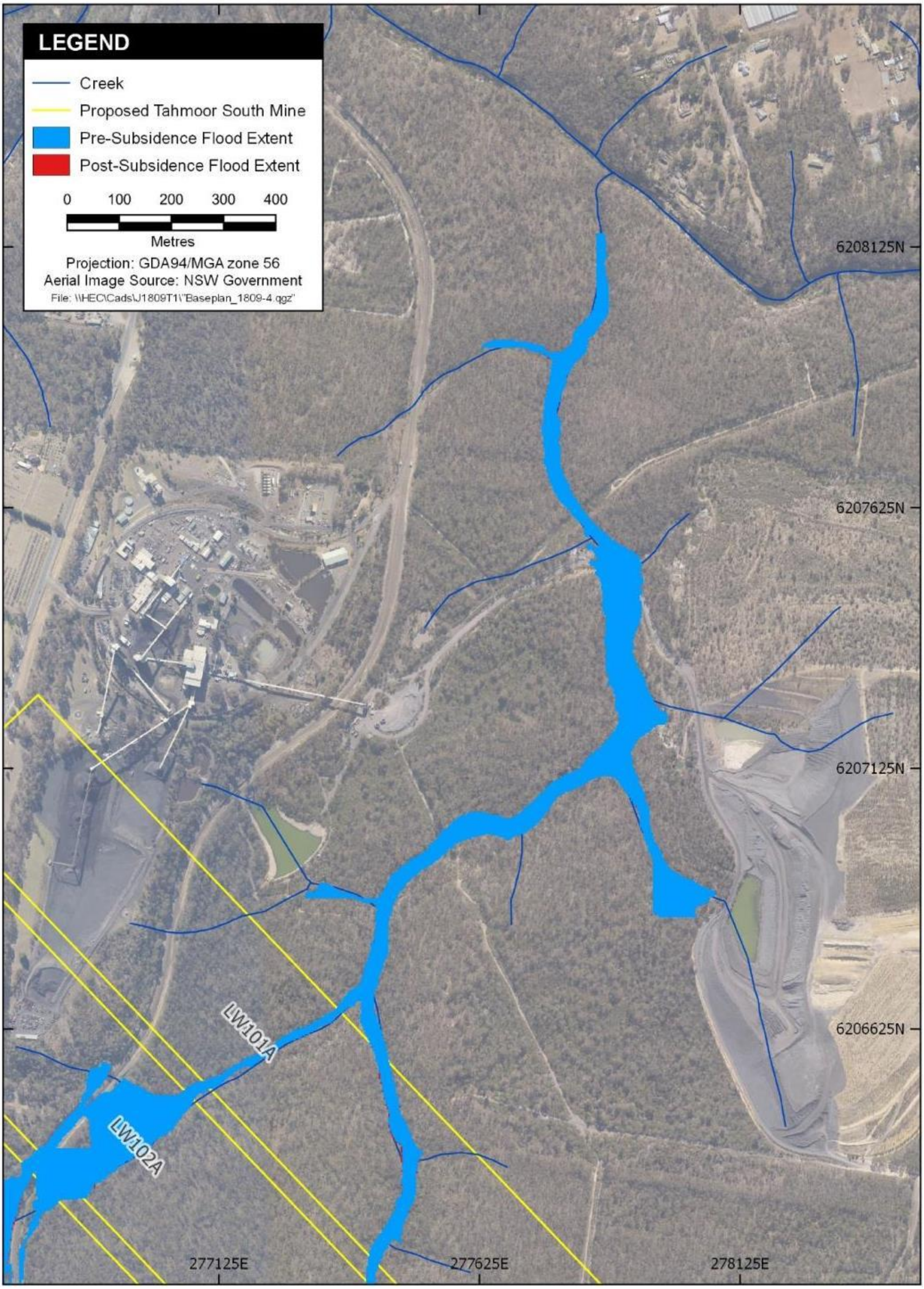

Figure A12: Extent of Predicted 0.5% AEP Flooding, Northern (downstream) – Tea Tree Hollow

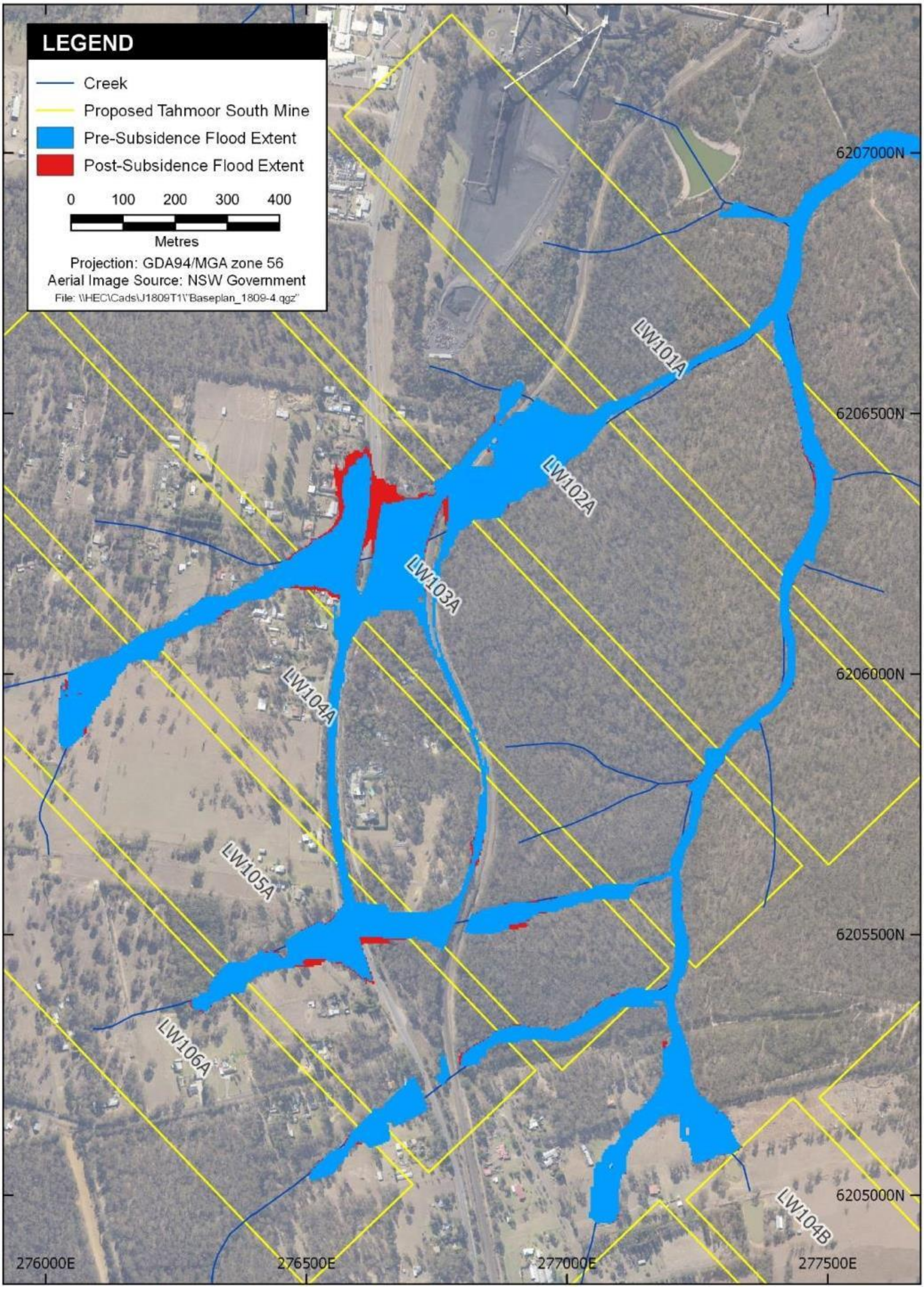

Figure A13: Extent of Predicted 0.2% AEP Flooding, Southern (upstream) – Tea Tree Hollow

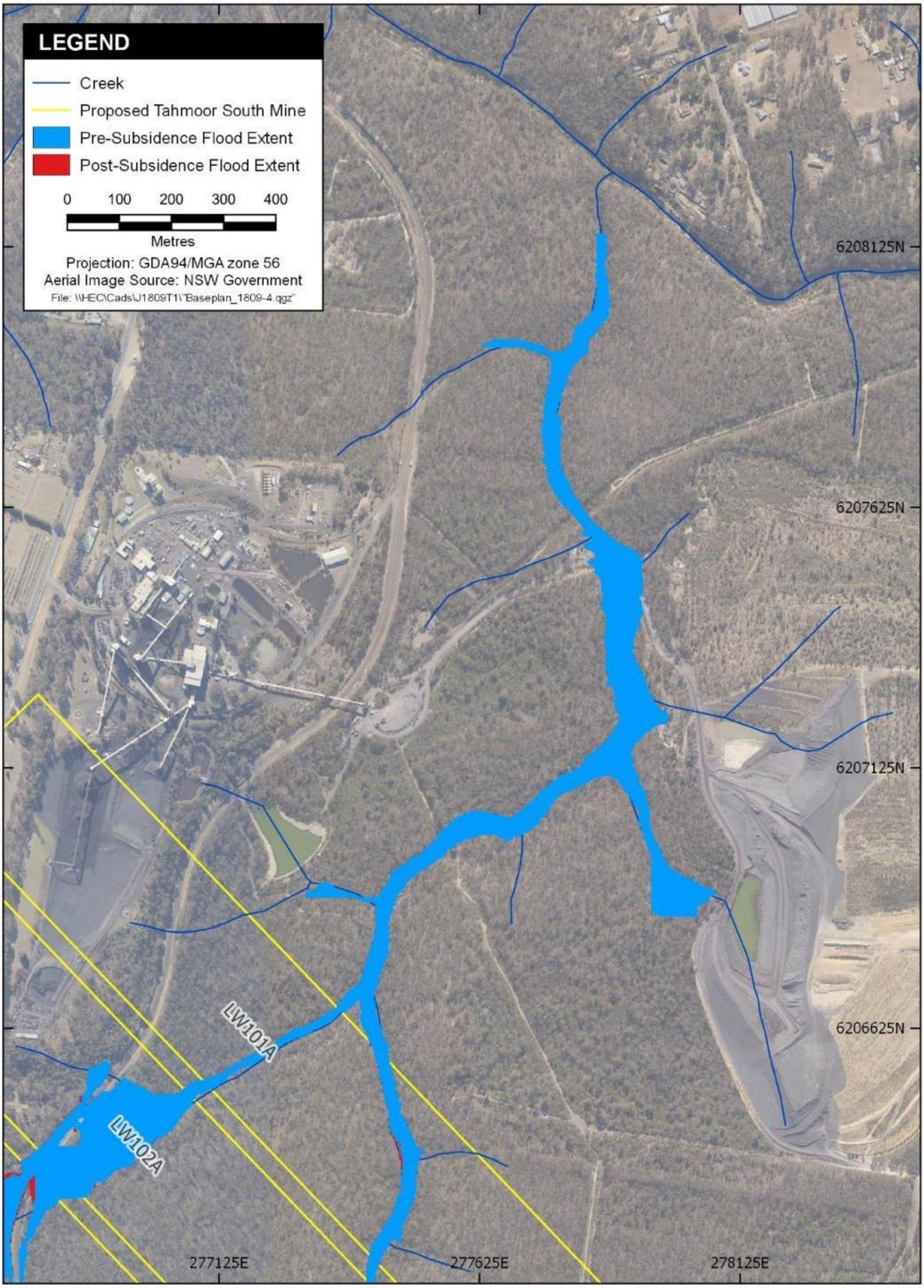

Figure A14: Extent of Predicted 0.2% AEP Flooding, Northern (downstream) – Tea Tree Hollow

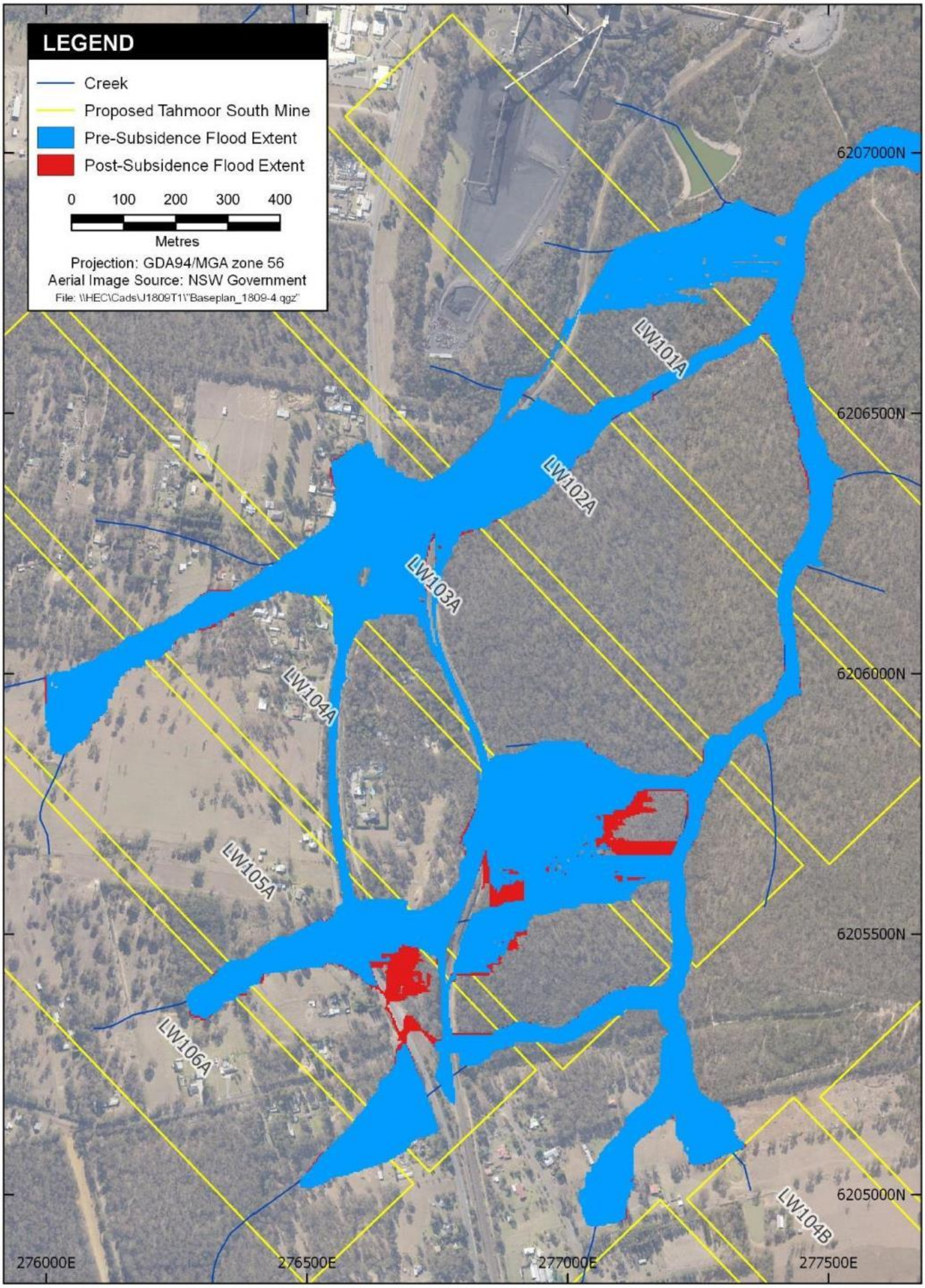

Figure A15: Extent of Predicted PMF Flooding, Southern (upstream) – Tea Tree Hollow

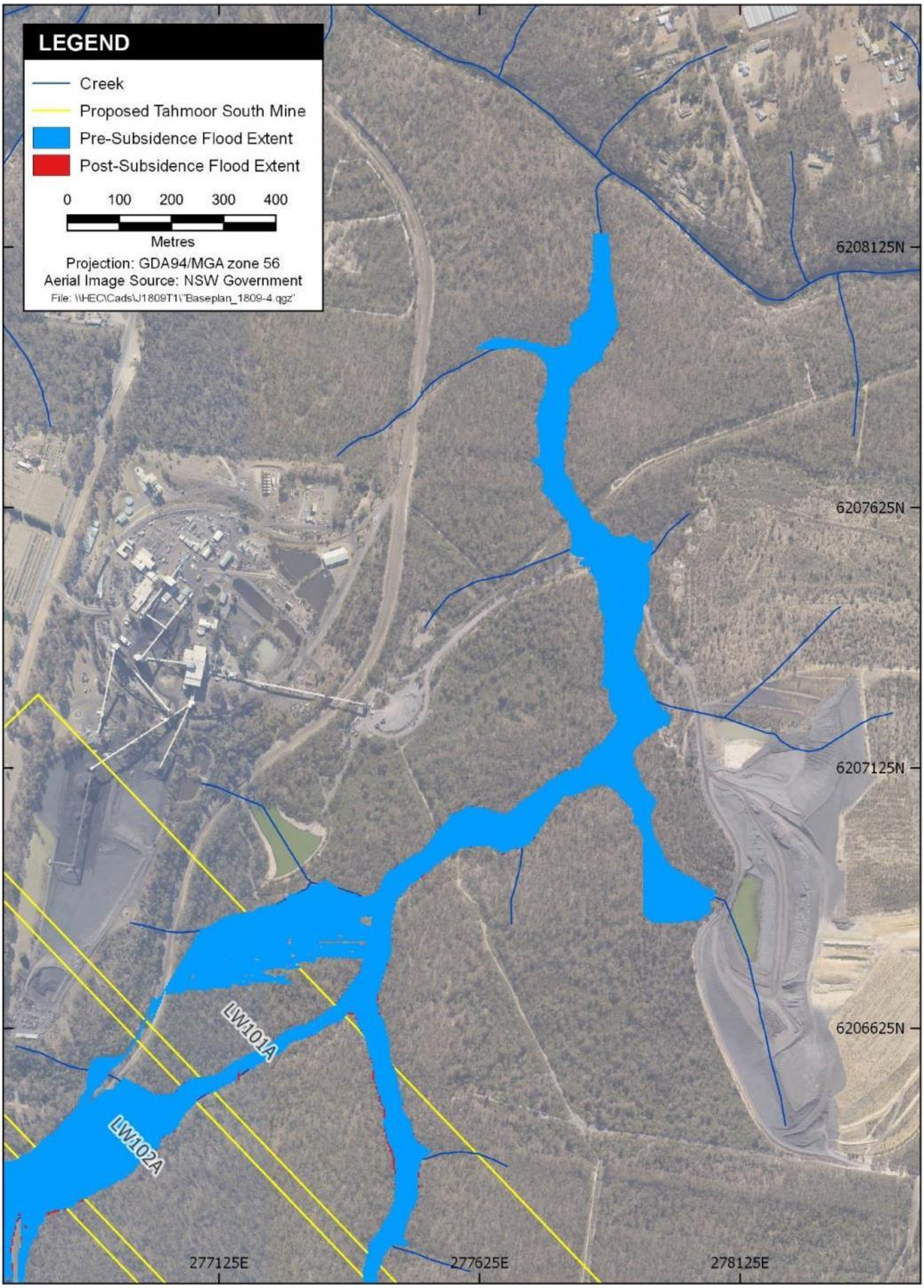

Figure A16: Extent of Predicted PMF Flooding, Northern (downstream) – Tea Tree Hollow

HYDRO ENGINEERING & CONSULTING PTY LTD

REPORT

Tahmoor South Amended Project Surface Water Impact Assessment

Prepared for: Tahmoor Coal Pty Ltd

38a Nash Street
Rosalie QLD 4064
p (07) 3367 2388

PO Box 1575
Carindale QLD 4152
www.hecons.com
ABN 11 247 282 058

Revision	Description	Author	Reviewer	Approved	Date
1	Revised report following EIS submission	TSM / CAW	Tahmoor Coal	TSM	25 Nov 2019
2	Draft	TSM / CAW	Tahmoor Coal	TSM	8 Dec 2019
3	Second Draft	TSM / CAW	Tahmoor Coal	TSM	13 Dec 2019
4	Final	TSM / CAW	Tahmoor Coal	TSM	9 Jan 2020
5	Final following submission	TSM / CAW	Tahmoor Coal	TSM	12 Feb 2020

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1.0 INTRODUCTION

Hydro Engineering & Consulting Pty Ltd (HEC) was commissioned by Tahmoor Coal Pty Limited (Tahmoor Coal) to complete a Surface Water Assessment for the Tahmoor South Project (the Project). The Surface Water Assessment formed a 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 was undertaken in four parts:

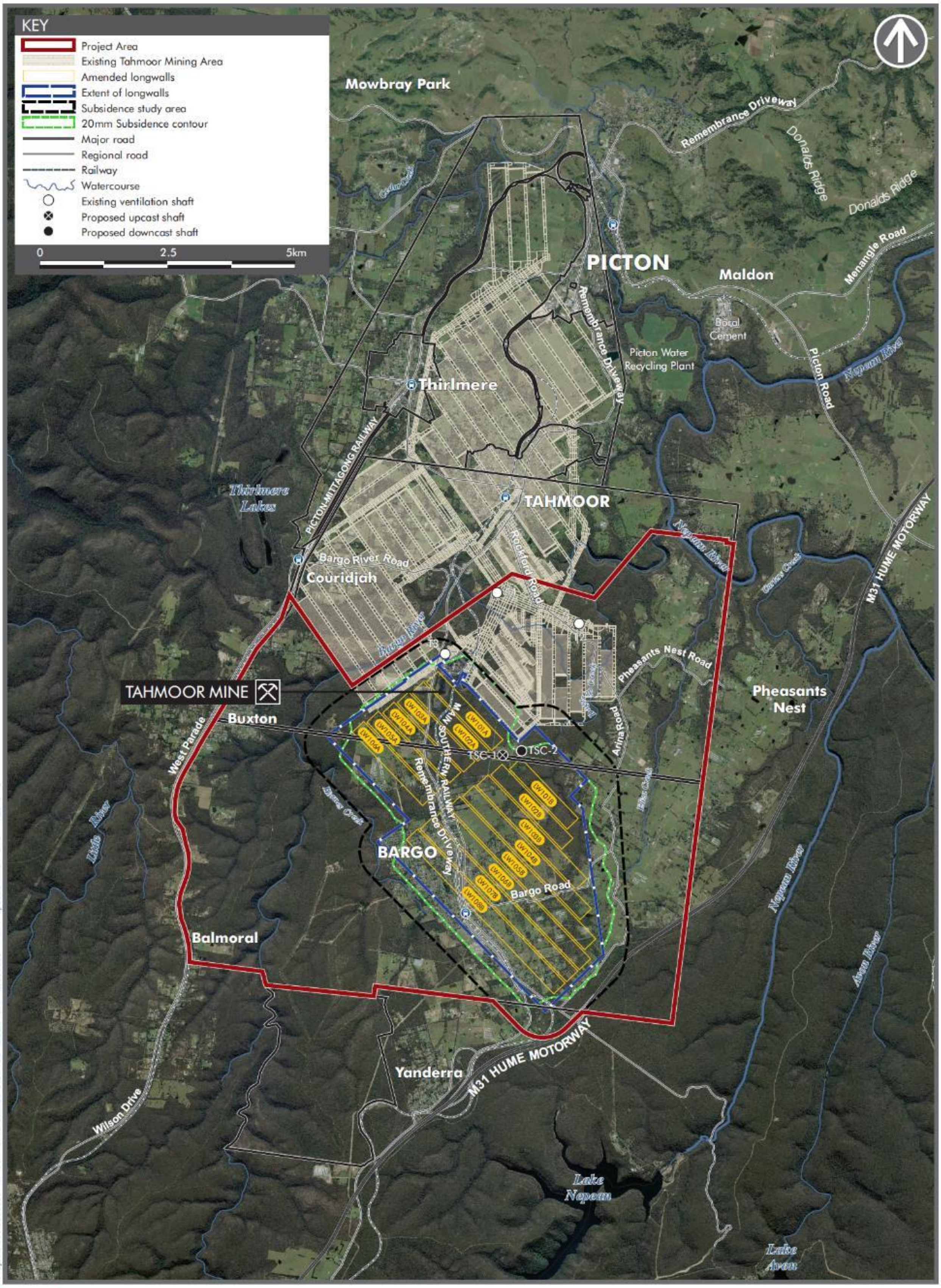
- Baseline Assessment (BA) Report which documents the available baseline and background information and analysis of the climate, hydrology and water quality characteristics of local and regional water resources of relevance to the Project.
- Water Management System and Site Water Balance Report (WMS & 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. The water balance model was developed to simulate the water management system supply reliability, the adequacy of the current licensed discharge to Tea Tree Hollow to manage release of water from the mine site and to assess the risk of site overflow 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 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 Project Area which has been revised to address key issues raised in submissions relating to the EIS, as described below. The report summarises the results of an assessment of the potential impacts of the Amended Project 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 is seeking development consent for the continuation of mining at the 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.

In accordance with the requirements of the EP&A Act, the *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation) and the Secretary's Environmental Assessment Requirements (SEARs), an EIS was prepared to assess the potential environmental, economic and social impacts of the Project. The EIS for the Project was placed on public exhibition by the Department of Planning, Industry and Environment (DPIE) (formerly the Department of Planning and Environment [DPE]) from 23 January 2019 to 5 March 2019.



Note: The 'extent of longwalls' boundary encompasses the proposed extent of underground workings, being the proposed longwall panels and mains headings (first workings).

Figure 1 Locality Plan and Project Layout

Key issues raised in submissions included concerns relating to the proposed extent of longwall mining, the magnitude of subsidence impacts and the extent of vegetation clearing required for the expansion of the reject emplacement area (REA). In response to these and other issues raised in Government agency, local Council, stakeholder and community submissions, and as a result of ongoing mine planning, several amendments have been made to the proposed development, so as to also further reduce the predicted environmental impacts of the Project.

The key amendments to the Project since public exhibition of the EIS are:

- A revised mine plan, including:
  - an amended longwall panel layout and the removal of LW109;
  - a reduction in the height of extraction within the longwall panels from up to 2.85 metres (m) to up to 2.6 m; and
  - a reduction in the proposed longwall width, from up to 305 m to approximately 285 m.
- A reduction in the total amount of Run-of-Mine (ROM) coal to be extracted over the Project life, from approximately 48 million tonnes (Mt) to approximately 43 Mt of ROM coal, comprising;
  - 30 Mt of coking coal product (reduced from 35 Mt);
  - 2 Mt of thermal coal product (reduced from 3.5 Mt)
- A revised extended REA; including:
  - a reduction in the additional capacity required to accommodate the Project;
  - a reduction in the REA extension footprint, from 43 ha to 11 ha;
  - an increase in the final height of the REA (from RL 305 m to RL 310 m).
- Confirmation of the location and footprint of ancillary infrastructure associated with the ventilation shaft sites (e.g. the power connection easement for ventilation shaft site TSC1); and
- A continuation of the use of the existing upcast shaft (T2); although, operation will reduce from two fans during Tahmoor North operations to one fan once the new ventilation shafts and fans (TSC1 and TSC2) are in operation in Tahmoor South.

No amendments have been made to other key aspects of the Project as presented in the EIS for which development consent is sought, such as the proposed annual coal extraction rate, mining method, traffic movements and employee numbers. A detailed description of the amended development is provided in the Amendment Report (AECOM, 2020).

1.2 PURPOSE OF REPORT

This SWIA has been revised to assess the potential impacts of the Amended Project on local and regional surface water regimes and surface water quality. The report has also been revised to address key issues raised in the EIS submissions pertaining to the surface water impact assessment for the Project. In this way, it serves as an update to the Surface Water Impact Assessment (HEC, 2018d, Appendix J of the Tahmoor South Project EIS). Section 13.0 presents a summary of key changes presented in this SWIA in comparison with the EIS assessment.

1.3 AMENDED PROJECT

The Amended Project would use longwall mining to extract coal from the Bulli seam within the bounds of Consolidated Coal Lease 716 (CCL716) and CCL747. Coal extraction of up to four (4) million tonnes of ROM coal per annum is proposed as part of the development with extraction of up to 43 Mt of ROM coal over the life of the Project. The project would produce approximately:

- 30 Mt coking coal product;
- 2 Mt thermal coal product; and
- 12 Mt of rejects.
- 2 Mt thermal coal product; and
- 12 Mt of rejects.

These approximate market mix volumes include moisture and are therefore estimates only. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing coal handling and processing plant (CHPP) and coal clearance facilities and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla and Newcastle (from time to time) for Australian and international markets. Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers via road.

The amended development would use the existing surface infrastructure at the Tahmoor Mine surface facilities area. Some upgrades are proposed to facilitate the extension. The amended development also incorporates the planning for rehabilitation and mine closure once mining ceases.

In summary, the key components of the amended development comprise:

- Longwall mining in the Central Domain;
- Mine development including underground development, vent shaft construction, pre-gas drainage and service connection;
    - Upgrades to the existing surface facilities area including:
    - Upgrades to the CHPP;
    - Expansion of the existing REA;
    - Additional mobile plant for coal handling;
    - Additions to the existing bathhouses and associated access ways; and
    - Upgrades to onsite and offsite service infrastructure, including electrical;
- Rail transport of product coal to Port Kembla and Newcastle (from time to time);
- Up to 200,000 tonnes per annum of either product coal or reject material is proposed to be transported to customers via road;
- Mine closure and rehabilitation; and
- Environmental management.

1.4 STUDY REQUIREMENTS

The Project EIS was 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. This SWIA report has been revised to assess the potential impacts of the Amended Project on local and regional surface water resources and to address key issues raised in the EIS submissions pertaining to the SWIA submitted as a component of the EIS.

1.4.1 Secretary's Environmental Assessment Requirements

The Surface Water Assessment is guided by the 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 (HEC, 2020a) 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 the Project has been amended to exclude 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.

1.4.2 EIS Submissions

The submissions from government agencies that are relevant to the SWIA and the section of the report which addresses the submissions are summarised in Table 1.

Table 1 EIS Submissions – Surface Water Impact Assessment

Agency	Submission	How / Where Addressed
Department of Industry (NSW Department of Industry Lands and Water Division)	Expansion of the existing surface water monitoring network should be undertaken to improve monitoring of stream flow and pool water levels. Expansion of the existing surface water monitoring network should be undertaken to achieve the following. a) Support the reinstatement of surface stream flow monitoring gauges as well as enhancing the reliability of recorded low flows. b) Address the number of pool water level monitoring sites as there are too few. Three in Dog Trap Creek and Two in Tea Tree Hollow are insufficient to detect changes across the project area. c) Review the proposed number of pool water level monitoring sites and increase them to at least six pools per creek and have water level loggers installed. d) River flow monitoring should be implemented as soon as possible and persist throughout the life of the mine and include 5 years of post-project monitoring to assess the long-term impacts.	Streamflow monitoring has recommenced on Hornes Creek, Dog Trap Creek Eliza Creek and Carters Creek in order to expand baseline data (up to the period of mining within these catchments) and assess impact to flows post mining. Additional pool water level monitoring sites have been, or are proposed to be, implemented in surface water systems within and adjacent to the Project area (refer Section 12.0). The BA report (HEC, 2020a) summarises the baseline surface water flow and water quality monitoring for the Project area and surrounding region.
Office of Environment and Heritage	A large number of Remediation Plans are currently being developed for streams affected by mining in the Southern Coalfields, however, they usually lack any objective measures to assess the success of any remediation applied. In all cases, it is highly uncertain that remediation will be a success or that flows and pool holding capacities will be restored. There is no objective scientific or peer—reviewed evidence that impacted areas above longwall mining operations have self—remediated as suggested in the EIS. Under such circumstances, avoidance is the only effective solution to maintaining the social and environmental values of 3rd order and above streams as highly significant features in the landscape. Given the high environmental and associated social/cultural values of Dog Trap Creek in particular, it is recommended that LW101, LW104 & LW103 are reduced to avoid directly under the 3rd order sections of Dog Trap Creek or within its angle of draw. Consideration should also be given to redesigning LW109 so as not to impact the 3rd order sections of Dog Trap Creek.	Section 12.5 addresses the implementation of remediation measures for Tahmoor South should subsidence induced fracturing occur in pools / streams within the Subsidence Study Area.

Table 1 (Cont.) EIS Submissions – Surface Water Impact Assessment

Agency	Submission	How / Where Addressed
Office of Environment and Heritage	Tahmoor Colliery currently discharges waste mine water to Teatree Hollow, a tributary of the Bargo River, under EPL 1389. The quality of the discharge is however poor and represents a significant point source of pollution to the Bargo River. This discharge dominates flow in the Bargo River; potentially due in large part to the fracturing and water diversions from previous mining underneath the Bargo River. Relative to other sites, the LDP1 discharge is high in levels of bicarbonate alkalinity, sodium, calcium, magnesium, potassium, arsenic, barium, selenium and zinc. The electrical conductivity of the discharge is also high and the pH alkaline. Many of the contaminants are being discharged at levels that exceed the ANZECC guidelines including a number of contaminants (eg bicarbonate, barium) which are not specifically included on EPL1389. … The impacts from the discharge are transferred downstream into the Bargo River and for approximately 5-6km downstream until the Bargo River joins the Nepean River. If the mine expansion is approved there is a need to review EPL1389 and address issues surrounding contaminants above ANZECC guidelines, toxicity of the discharge and the amount of salt being discharged into an important freshwater river.	Section 9.1 discusses the proposal to commission an upgraded Wastewater Treatment Plant (WWTP) to reduce the concentrations of constituents discharged via LDP1. The specified upgraded WWTP target water quality is to meet the 95th percentile ANZECC (ANZG 2018) Guideline values. Specific targets are: - pH 6.5-9 - Electrical Conductivity <500µS/cm - Suspended Solids <30mg/L - Turbidity <150NTU - Oil and grease <10mg/L - Iron <0.7mg/L - Manganese <1.9mg/L - Nickel <0.011mg/L - Zinc <0.008mg/L - Arsenic (V) <13µg/L - Arsenic (III) <24µg/L The BA report (HEC, 2020a) provides a summary of the water quality discharge via LDP1 and at surface water monitoring locations downstream of the release point, including the Bargo River.
Office of Environment and Heritage	Likely impacts of the Tahmoor South proposal can be assessed by considering the impacts associated with previous mining at Tahmoor Colliery, as well as other sites in the Southern Coalfields. Since the depth of cover at Tahmoor South is shallower than at Tahmoor North and panel widths have been increased, the risk of surface impacts are potentially increased further for the Tahmoor South longwalls. Much of the detail in the EIS appears somewhat dated (often over 4-5 years old) and does not adequately consider the more recent impacts of mining LW29-32 in the Tahmoor North area of operations. The cumulative impacts of past longwalls at Tahmoor Colliery have had significant impacts on the Bargo River, Myrtle Creek and Redbank Creek. Mining has now drained approximately 2.8km of Redbank Creek, caused extensive iron staining and emptying of the weir pool on Redbank Creek. It is highly unlikely that these impacts will ever be successfully restored, despite the current requirement to remediate Redbank Creek. …	The review of subsidence impacts to surface water systems within the vicinity of Tahmoor Mine and in the Southern Coalfields has been updated to incorporate recent findings (refer Section 5.0). The surface water flow and water quality impacts to Redbank Creek have been specifically addressed in Section 5.2. These assessments have also been revised to incorporate recent monitoring data.

Table 1 (Cont.) EIS Submissions – Surface Water Impact Assessment

Agency	Submission	How / Where Addressed
Wollondilly Council	The re-emergence downstream of water drained from watercourses as a result of mined induced fracturing. The Research Study by Dr Ian Wright on Redbank Creek involved the analysis of water considered to be such re-emergence. The high level of pollutant readings at this locality detailed in the research study attached to this submission highlight the potential for significant impacts to waterway health.	Surface water quality impacts in Redbank Creek as a result of mining activities are detailed in Section 5.2.2.
EPA NSW	Overall the EIS does not adequately assess the potential water quality impacts of discharges via Licence Discharge Point (LDP) 1. The EPA's EIS Requirements for the Project (letter dated 24/04/17, DOC 17/269642—01), include the following: 1. 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. 2. The EIS should integrate the results of the aquatic health study in the Bargo River (PRP 23) as well as previous aquatic studies undertaken by the mine. An assessment should also be made of the possible increase in groundwater make and changes in quality from the new Tahmoor South area and whether additional treatment capacity will be needed. These two requirements have not been adequately addressed in the EIS. An impact assessment for controlled surface water discharges of mine water (with potentially elevated levels of salinity, metals or other pollutant impacts) is not included in the EIS for LDP 1. The EIS discharge assessment is limited to referring to past and current PRPs related to the existing development and provision of water quality data and discussion for an ambient site downstream of the discharge. The status of PRP investigations and any further assessment related to the new proposal also should be integrated into the development assessment process.	The BA report (HEC, 2020a) provides a summary of the water quality discharge via LDP1 and at surface water monitoring locations downstream of the release point, including Bargo River. Section 9.1 discusses the proposal to commission an upgraded WWTP to reduce the concentrations of constituents discharged via LDP1. The predicted increase in releases to LDP1 and Licensed Overflow Points (LOPs) and from the proposed sediment dams S11 and S12 as a result of the Amended Project are discussed in the WMS & SWB report (HEC, 2020b). The potential impacts to water quality are discussed in Section 9.1.

Table 1 (Cont.) EIS Submissions – Surface Water Impact Assessment

Agency	Submission	How / Where Addressed
EPA NSW	The EIS refers to PRP 23 that did not recommend any changes to existing discharge licence limits to electrical conductivity/salinity. This assessment is not incorporated in the EIS. The additional tonnes of salt that will be discharged to the river system over the life of the new proposal and its fate downstream were not assessed in PRP 23. Reference to the findings of a prior PRP does not provide a contemporary assessment of the potential impact of the ongoing saline discharge related to the proposed development and does not consider: • any current or emerging issues with salinity, including new research • additional salinity loads from extending the mining period and increasing discharge volumes • any potential changes to the salinity or related impacts. …	Section 9.1 discusses the proposal to commission an upgraded WWTP to reduce the concentrations of parameters discharged via LDP1. The specified upgraded WWTP target water quality is to meet the 95th percentile ANZECC (ANZG 2018) Guideline values. Specific targets are: - pH 6.5-9 - Electrical Conductivity <500µS/cm - Suspended Solids <30mg/L - Turbidity <150NTU - Oil and grease <10mg/L - Iron <0.7mg/L - Manganese <1.9mg/L - Nickel <0.011mg/L - Zinc <0.008mg/L - Arsenic (V) <13µg/L - Arsenic (III) <24µg/L
EPA NSW	The EIS does not provide an adequate characterisation of the discharge or assessment of the potential for pollutants other than salinity and selected metals to be present in discharges, e.g. Coal seams. The potential for increases in pH downstream of the discharge is not assessed. Potential levels of methane in mine water discharges are also not assessed, however, the EIS states that methane is not likely to be a significant issue.	The updated assessment of Redbank Creek water quality (refer Section 5.2.2) indicates that mining in the Redbank Creek catchment has not affected pH levels in the creek to any significant extent. Gas emissions have not been observed in streams or pools above mining at the Tahmoor Mine to date. As such, it is not anticipated that increases in pH or gas emissions will occur as a result of the Project. Section 9.1 discusses the proposal to commission an upgraded WWTP to reduce the concentrations of constituents discharged via LDP1. The predicted increase in releases to LDP1 and LOPs, and from the proposed sediment dams S11 and S12, as a result of the Amended Project are discussed in the WMS & SWB (HEC, 2020b). The potential impacts to water quality are discussed in Section 9.1.

Table 1 (Cont.) EIS Submissions – Surface Water Impact Assessment

Agency	Submission	How / Where Addressed
EPA NSW	EPA recommends that the Department of Planning and Environment request the following be completed: • a surface water quality discharge assessment for LDP1 be provided on contaminants and salinity and salinity—related risks based on current scientific knowledge, including pH, metals, salinity loads, toxicity of various specific ions and potential ionic mix related risks; • relevant information from the PRP process that can inform the impact assessment is included and, where appropriate, updated in the EIS; … It is also recommended that any water quality assessment separates: 1. discharge trigger values or criteria (which should be based on guideline values for slightly to moderately disturbed aquatic ecosystems or site—specific trigger values from slightly modified reference sites selected and sampled in accordance with the Australian Water Quality Guidelines); and 2. trigger values or criteria that may be used to assess ambient water quality differences upstream and downstream of the development. In this case site-specific trigger values from some sites (that are not based on Australian Water Quality Guideline reference site requirements) may be used to compare upstream water quality to downstream water quality using appropriate statistical comparisons. These upstream waters, however, if degraded, do not provide a basis for deriving site—specific discharge criteria. …	The BA report (HEC, 2020a) provides a summary of the water quality discharged via LDP1 and at surface water monitoring locations downstream of the release point, including Bargo River. Details of the derivation of site-specific trigger values for baseline and impact sites are also provided in the BA report (HEC, 2020a). Section 9.1 discusses the proposal to commission an upgraded WWTP to reduce the concentrations of constituents discharged via LDP1.
Commonwealth IESC	To assist in providing more confidence in impact predictions, further investigations and monitoring (as discussed in paragraphs 37 - 39), supported by the further analysis of existing data should be focused on quantifying losses of surface water into near-surface fracture zones and the possibility of partial or complete returns of these flows to surface water at some point and time to support GDEs.	Section 5.2.1 presents an assessment of the impact of subsidence on streamflow in Redbank Creek following mining at Tahmoor North.

Table 1 (Cont.) EIS Submissions – Surface Water Impact Assessment

Agency	Submission	How / Where Addressed
Commonwealth IESC	The deficiencies in the groundwater modelling of potential impacts to surface water systems affect the predictions of reductions in stream flow (especially during low-flow periods) and pool persistence in the surface water assessment (EIS, Appendix J). …	The groundwater modelling has been revised by HydroSimulations (2020). Updated baseflow reduction predictions for the Project and cumulatively have been incorporated in the revised assessment of potential impacts to streamflow (refer Section 6.3 and Section 10.0).
	To conclude that mining activities have had little impact on streamflows, the proponent has used the Australian Water Balance Model (AWBM). However, the use of simple visual comparisons of modelled versus observed flow behaviour is not compelling as the simulations are influenced by limitations in model calibration that could impact on different components of the flow regime. More defensible insights could be drawn by undertaking a trend analysis on the differences between model simulations and observed flows over time (i.e. by analysing the modelled residuals), but without such evidence it is not possible to have confidence in the current conclusions.	An assessment of mining induced impacts to streamflow in Redbank Creek is provided in Section 5.2.1. The model parameters have been revised in order to improve the model fit during the earlier period of available recorded data (Dec 2009 to the end of 2012 – up to the end of mining of longwall 26). The improved model fit provides greater confidence in the model outcomes which indicate that mining activities have had little impact on streamflow in Redbank Creek downstream of the subsidence area.
	It is noted in the EIS (Appendix I, p. 49) that surface cracking can result in subsurface flow and, where flow re-emerges downstream, water quality is affected. This change in water quality is not assessed further in the EIS. The proponent should use existing data from Tahmoor North to provide an assessment of the likely impacts of this process on water quality and the implications for ecosystems dependent on this water.	Monitoring data from the existing Tahmoor Coal Mine has been used to provide an updated assessment of the water quality impacts to Redbank Creek due to mining. The revised assessment is provided in Section 5.2.2.
	If it is intended to store the waste water from coal washing and groundwater from dewatering activities in the goafed areas, the IESC considers further information is needed on the underground storage proposal. This should include: a) further information on the water quality of the water being stored underground with a full risk assessment of the potential contamination caused by untreated water leaking into the groundwater (potential impacts to the receiving environment); b) assurance that the lack of water storage does not lead to releases of untreated water into Tea Tree Hollow and the Bargo River.	The underground water storage proposal has been modified such that mine dewatering from Tahmoor South will be transferred directly to the proposed Tahmoor North underground storage, rather than from dam M3. As such, potential impacts to groundwater quality are unlikely (refer Section 9.2). The potential lack of water storage has been assessed in the WMS & SWB (HEC, 2020b) and recommendations made for increasing the capacity of the upgraded WWTP in the future if required.

Table 1 (Cont.) EIS Submissions – Surface Water Impact Assessment

Agency	Submission	How / Where Addressed
Commonwealth IESC	The proponent states that cracks will naturally remediate through sediment infilling. However, the creek beds in this area are mainly bedrock or rock bars where suitably fine sediment is unlikely to collect. Moreover, much of the sediment is sandy and infilled cracks would retain some permeability. Although the proponent indicates that grouting may be employed, the IESC is unaware of any successful deployment of this method at a large scale (e.g. along a creek line) in a natural system that has been verified by appropriate stream gauge data over both the short and long term. The proponent has not provided detailed and independently peer-reviewed evidence that streambed subsidence impacts can be remediated.	Recent monitored streamflow behaviour (Section 5.2.1) suggests that natural 'healing' behaviour may have occurred at site R11 on Redbank Creek. Although the catchment surface geology is predominately sandstone, there is fine grained topsoil present throughout the catchment which will generate fine sediment and contribute to sealing cracks, as summarised in Section 6.2. Section 12.5 addresses the implementation of remediation measures for the Project should subsidence induced fracturing occur in pools / streams within the Project area.
Nation Trust	The Subsidence report clearly identifies that there will be subsidence impacts to the land within Wirrimbirra Sanctuary. Amongst other impacts, it predicts that a ground cracking and movement may drain the existing natural watercourse through the property. As an intermittent watercourse, it is suggested that any loss of flow (or mineralised ground water contamination, the other `likely' adverse impact) will not have a substantive impact, as the surrounding flora and fauna is adapted to intermittent water supplies. The Trust suggests that this is naive and wrong-headed, as clearly, the local ecology is more highly dependent upon the intermittent flows and any loss of flow is likely to have an increased impact, not a lesser one	The potential impacts to the tributary of Tea Tree Hollow and the pools within this tributary are addressed in Section 6.6.

2.0 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 in the BA report (HEC, 2020a). The following is a brief summary intended to form a background to the surface water impact assessment. The surface water systems within the Project Area are shown in Figure 2.

2.1 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 kilometres (km) of the river pass through the Bargo River Gorge, which is characterised 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 are shown in Figure 3. 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.

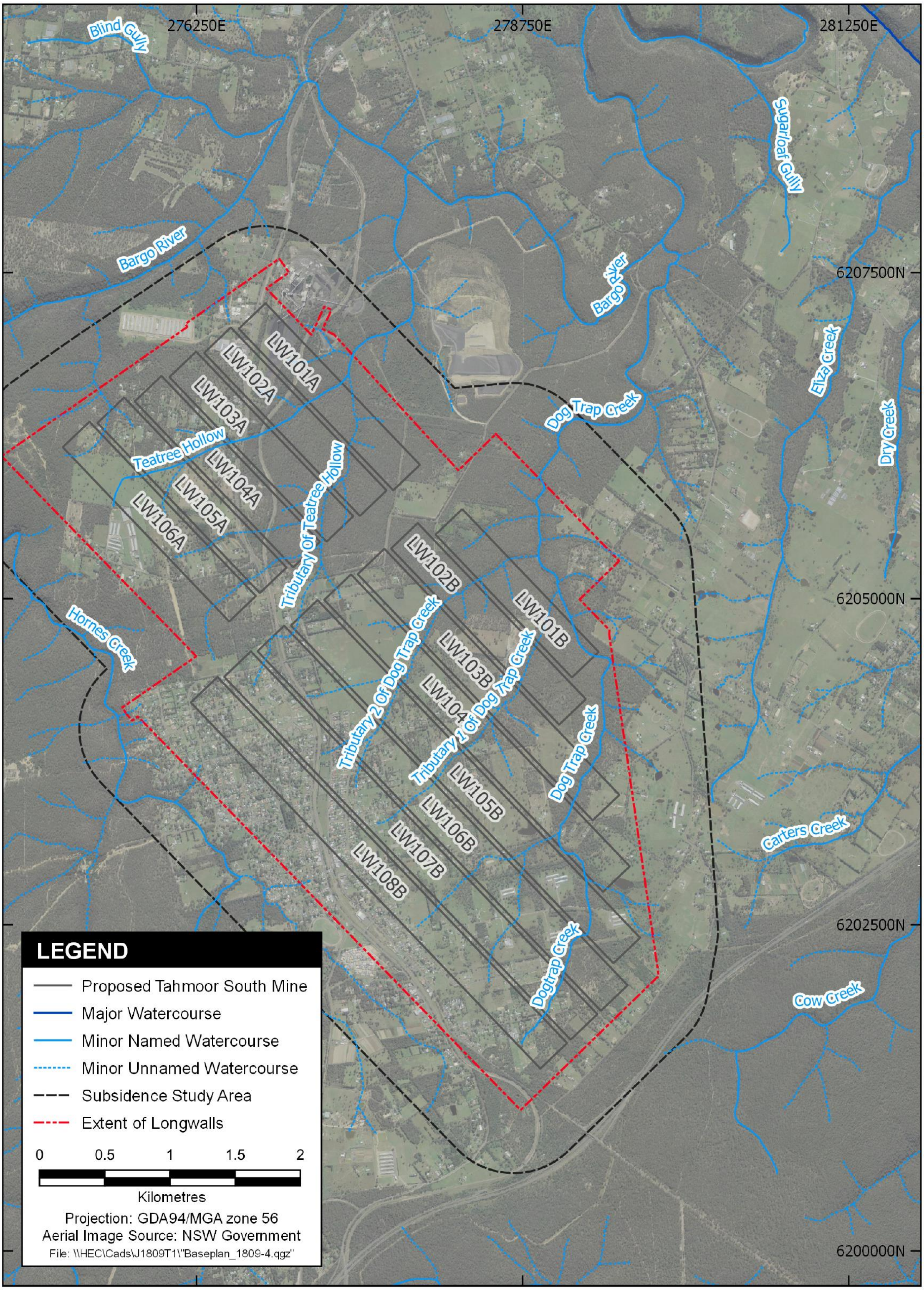


Figure 2 Project Area Streams and Proposed Longwalls

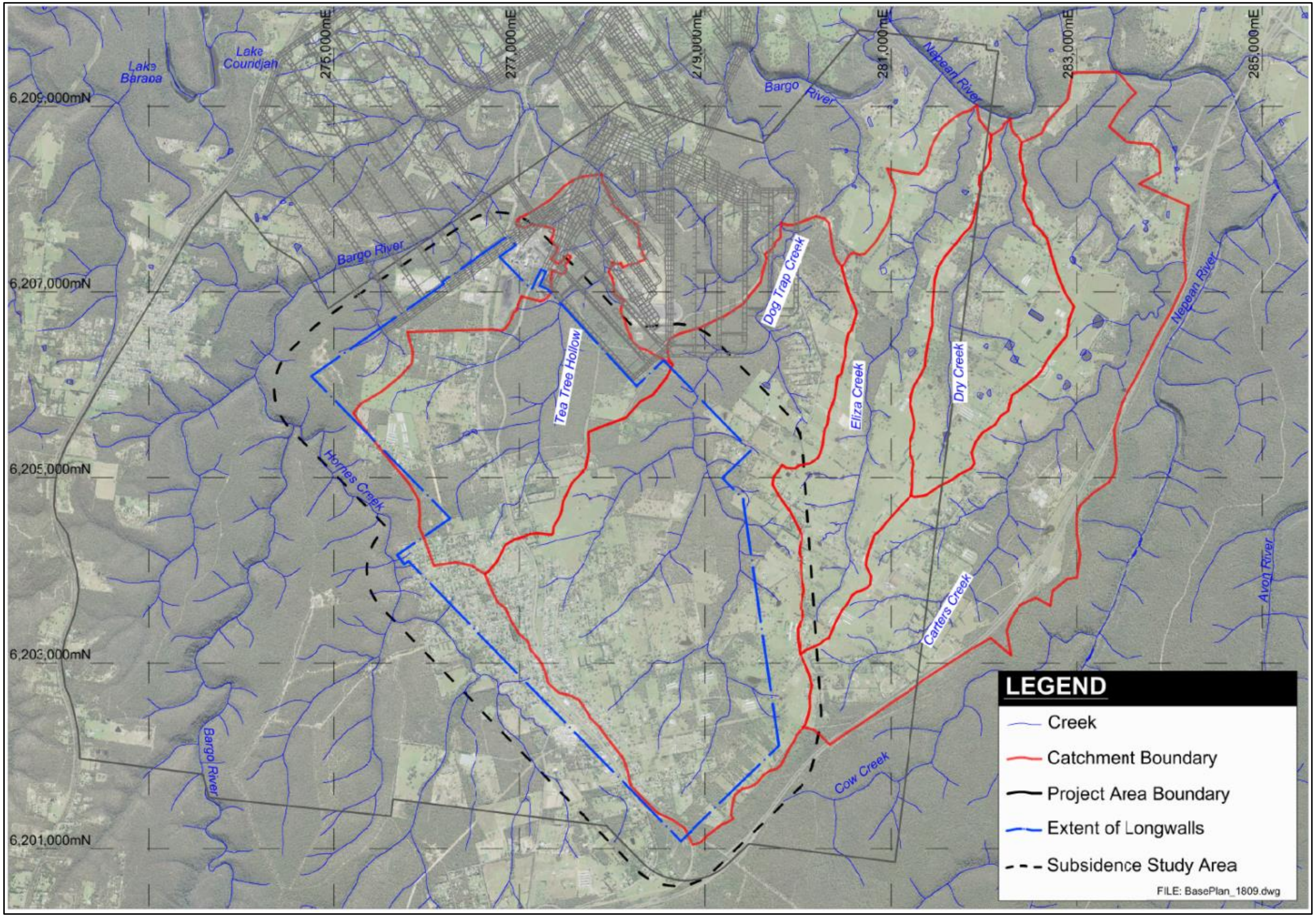


Figure 3 Project Area Streams and Catchments

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.

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 (2020a).

2.1.1 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. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid-2013. Water quality monitoring of Hornes Creek was recommenced in February 2019 with samples collected at approximately monthly intervals to the present time.

2.1.2 Tea Tree Hollow

Tea Tree Hollow is a 3rd order stream overlying the western part of the Project 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.

Under EPL 1389, 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. 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 of Tea Tree Hollow was recommenced in February 2019 with samples collected at approximately monthly intervals to present.

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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

2.1.3 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. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid-2013. Water quality monitoring was recommenced in March 2019 with sampling at approximately monthly intervals undertaken to present.

2.1.4 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.

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. Water quality monitoring was recommenced in February 2019 with monthly sampling undertaken to present.

2.1.5 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. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid-2013. Water quality monitoring of Cow Creek has not been recommenced as the catchment of the creek is substantially outside the proposed Amended Project subsidence study area.

2.1.6 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. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid-2013. Water quality monitoring of Dry Creek has not been recommenced because the catchment of the creek is outside the proposed amended development subsidence study area.

2.1.7 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 3^{rd} 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. Water quality sampling was undertaken typically on an approximate monthly interval, with a period of more intensive (approximately weekly) monitoring during mid-2013. Water quality monitoring was recommenced on Carters Creek in February 2019 with monthly sampling undertaken to present.

2.2 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 50). 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 7.0).

3.0 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 (2020). 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.

3.1 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. 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. The shallow fracture network is referred to as an "upper zone of disconnected-cracking" in HydroSimulations (2020) – i.e. which is disconnected from the longwall mining. MSEC (2020) indicate that any flow redirected through this shallow fracture network is unlikely to divert into deeper strata or the mine itself.
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 6.0 and Section 0.

3.2 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 8.0.

3.3 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 9.0.

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

4.0 PREDICTED SUBSIDENCE IMPACTS TO WATERCOURSES IN PROJECT AREA

4.1 GENERAL

A detailed description of the longwall mining process and the consequential subsidence movements at the overlying ground surface are provided in MSEC (2020). 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, 2020). The mechanisms that cause fracturing and the expected fracturing at the Tahmoor Mine are also described in detail in MSEC (2020) and reference should be made 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 5.0).

The following specific predictions of subsidence related impacts to watercourses in the Project Area have been summarised from MSEC (2020).

4.2 PREDICTED SUBSIDENCE IMPACTS TO THE BARGO RIVER

The Bargo River is located at a minimum distance of 690 m from the closest proposed longwall panel (LW102A). The maximum predicted subsidence, upsidence and closure for the Bargo River, resulting from the extraction of the proposed longwalls, is less than 20mm (MSEC, 2020). As such, MSEC (2020) have predicted that it is unlikely that secondary extraction from the Project proposed longwalls would have any adverse impacts on the Bargo River.

4.3 PREDICTED SUBSIDENCE IMPACTS TO LOCAL STREAMS

The location of the streams within the Subsidence Study Area are shown in Figure 2. A summary of the major streams within the Subsidence Study Area is provided in Table 2.

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

Table 2 Streams within the Subsidence Study Area (MSEC, 2020)

Watercourse	Strahler Stream Order	Description
Dog Trap Creek	3rd Order	Located directly above the proposed LW101B and LW103B to LW108B, with a total length of 2.8 km directly mined beneath*. LW12 and LW14 have been previously mined beneath a 1 km reach downstream of LW101B.
Hornes Creek	4th Order	Not directly mined beneath, located outside the extent of longwalls and 540 metres south-west of proposed amended LW108B.
Tea Tree Hollow	3rd Order	Located directly above the proposed LW101A to LW106A, with a total length of 2.1 km directly mined beneath. LW1 and LW2 have been previously mined beneath a 0.5 km reach downstream of LW101A.
Tributary 1 to Dog Trap Creek	2nd Order	Located directly above the proposed LW101B to LW108B, with a total length of 2.6 km directly mined beneath.
Tributary 2 to Dog Trap Creek	2nd Order	Located directly above the proposed LW101B to LW107B, with a total length of 2.4 km directly mined beneath.
Tributary to Tea Tree Hollow	3rd Order	Located directly above the proposed LW101A to LW103A, and LW105B to LW106B, with a total length of 2.1 km directly mined beneath.

* Includes longwalls and chain pillars

The maximum predicted values of total subsidence, upsidence and closure for local watercourses from the MSEC (2020) are reproduced in Table 3 below. The profiles of predicted subsidence, upsidence and valley closure along the affected reaches of local streams within the Subsidence Study Area compiled by MSEC (2020) are provided in Appendix A.

Table 3 Maximum Predicted Total Subsidence, Upsidence and Closure for Local Watercourses (MSEC, 2020)

Watercourse	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Dog Trap Creek*	1,550*	575*	425*
Hornes Creek	20	20	20
Tea Tree Hollow*	1,350*	375*	250*
Tributary 1 to Dog Trap Creek	1,600	750	750
Tributary 2 to Dog Trap Creek	1,575	525	450
Tributary to Tea Tree Hollow	1,250	400	350

* 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 natural grade along the stream reaches overlying the proposed longwalls varies between 5 mm/m (0.5%) and 50 mm/m (5%) (MSEC, 2020). MSEC (2020) have predicted a maximum increase in grade in Dog Trap Creek of 8 mm/m and a maximum decrease in grade of 10 mm/m. For Hornes Creek, the predicted maximum increase and decrease in grade is less than 0.5 mm/m while for Tea Tree Hollow, the maximum increase in grade is predicted as 8 mm/d and the maximum decrease in grade is predicted as 7.5 mm/m (MSEC, 2020).

There is a predicted reversal of grade along a naturally flat section of Dog Trap Creek, upstream of the tailgate of Longwall 103B and as such there is increased potential for ponding of up to 0.2 m depth and 150 m upstream of this location (MSEC, 2020). For the remainder of stream reaches overlying the proposed longwalls, there could be localised areas which could experience small increases in the levels of ponding, where the predicted maximum tilts occur in locations where the natural gradients are low (MSEC, 2020). As the predicted changes in grade are typically less than 10 mm/m, any localised changes in ponding are expected to be minor (MSEC, 2020).

Where the longwalls mine directly beneath the streams, MSEC (2020) considered that fracturing may result in surface water flow diversion. Partial or complete diversion of surface water and loss of water from pools may occur at locations and times where the rate of flow diversion is greater than the rate of incoming surface water and where substantial fracturing occurs. However, it is unlikely that there would be any net loss of flow from the catchment as any redirected flow would not be diverted into deeper strata or the mine, rather would reappear in the surface water system further downstream (MSEC, 2020).

Gippel (2013) reports that, while the channel beds are predominately exposed bedrock, sand, gravel, cobble and mud were also commonly found in the creek beds throughout the Project Area. Where such loose materials occur, there is potential for the fractures to be filled with finer material during flow events subsequent to fracturing, thereby reducing the rate of flow through the fractures (MSEC, 2020). At other mines within the Southern Coalfields, there have been reports of pools naturally recovering over time due to the sealing of fractures by deposited fine sediment (Tahmoor Colliery, 2004, Centennial Tahmoor, 2005, Centennial Coal, 2006, Centennial Coal, 2007. Xstrata Coal, 2008).

MSEC (2020) 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. Potential gas emissions may result in small, isolated areas of vegetation dieback as observed at other mines within the Southern Coalfields. However, strata gas discharge into private bores in the Project area has not occurred and no vegetation impacts have been observed or reported to date (SIMEC, 2019).

The main channel of Cow Creek is located approximately 1 km from the nearest Project longwall. MSEC (2020) 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.

5.0 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 31 has resulted in subsidence in Myrtle Creek and Redbank Creek 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 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.

5.1 SUBSIDENCE IMPACTS TO MYRTLE AND REDBANK CREEK

The locations of Tahmoor North longwalls in relation to Redbank Creek and Myrtle Creek, and the Redbank Creek monitoring locations, are shown in Figure 4. The start and completion dates for these longwalls are given in Table 4 below.

Table 4 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
28	24 April 2014	1 May 2015
29	29 May 2015	3 April 2016
30	20 June 2016	28 May 2017
31	29 June 2017	17 August 2018

*This longwall did not undermine Myrtle Creek or Redbank Creek

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

Observations of subsidence impacts to Myrtle Creek and Redbank Creek associated with LW22 to LW30 have been reported in Tahmoor Coal End of Panel reports. LW22 to LW31 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 500 m. Maximum measured vertical subsidence was 1,240 mm and maximum valley closure measured in Redbank Creek was 179 mm.

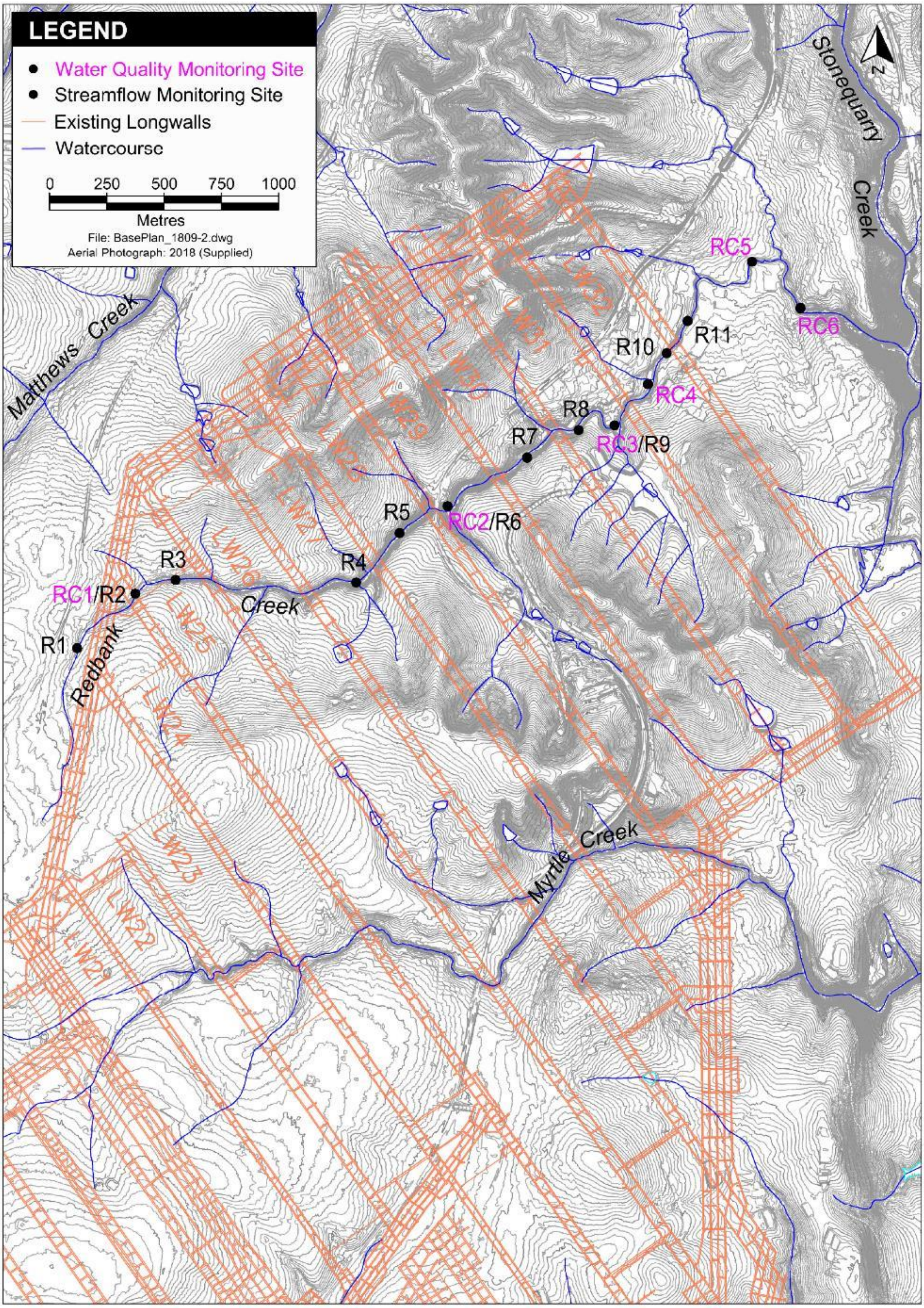


Figure 4 Longwall Mining Beneath Redbank Creek and Myrtle Creek

Following completion of LW23B, 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 LW22 along with a crack in soils in the banks of the creek overlying LW23B (Geoterra, 2007). A ferruginous seep was reported in Redbank Creek prior to the creek being undermined.

Following completion of LW25, four cracks were reported in the bed of Myrtle Creek overlying LW22, LW23B and LW25 (Geoterra, 2011). LW25 undermined a section of Redbank Creek near the northern end of the panel and sub-surface underflow (diversion) was reported in a 6 m long section of exposed sandstone in Redbank Creek overlying the longwall. The flow diversion was reported to be in the absence of observable bed cracking (SIMEC, 2019). There was no change to streamflow or water quality at flow monitoring sites in Myrtle Creek or Redbank Creek further downstream as a result of mining of LW25 and no generation of ferruginous seepage was observed (Geoterra, 2014 and SIMEC, 2019).

Following completion of LW26, GeoTerra (2012) reported that there had been no adverse effects reported to streamflow, water quality or to bed and bank stability in Myrtle Creek. Subsidence resulted in cracking of the streambed and underflow in isolated sections of Redbank Creek including a pool overlying LW25. Pool desiccation was observed in clay incised sections of the creek containing cobbles. GeoTerra (2014) reported that overall, there was no adverse effect on stream bed stability, stream bank stability or water quality in Redbank Creek during the monitoring period. While localised flow diversion was observed at some sites in Redbank Creek, no overall loss of streamflow was reported (SIMEC, 2019).

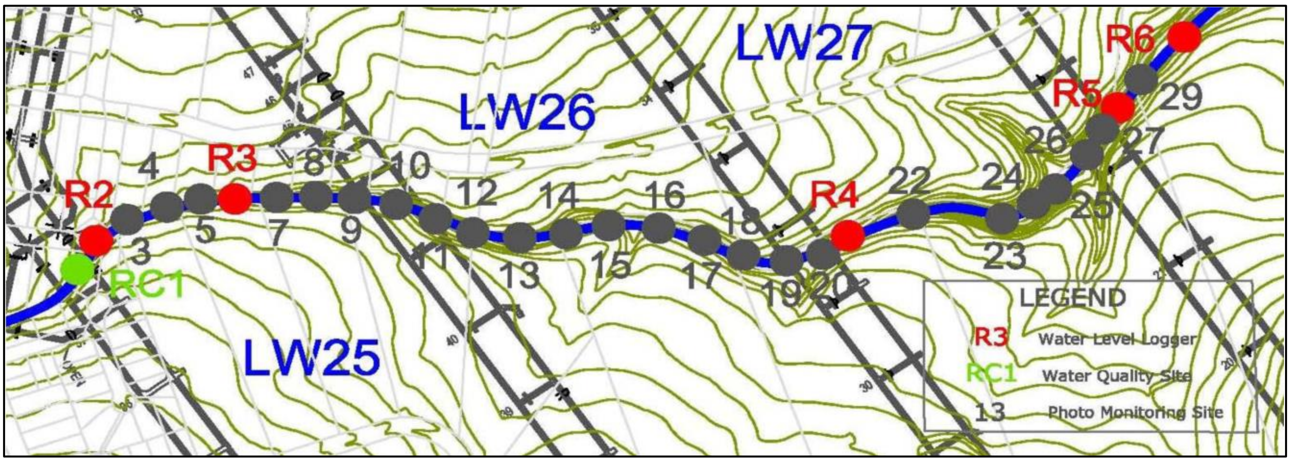


Figure 5 Location of Subsidence Observations in Redbank Creek (Geoterra, 2013)

The reported subsidence effects on Redbank Creek due to extraction of LW26 are shown in photographs contained in GeoTerra (2012) which have been reproduced in Appendix B.

Following mining of LW27, cracking was observed at sites along Redbank Creek and pools were observed to drain at times of low flow, though diverted flow was observed to re-emerge downstream of LW27. Increased salinity was recorded downstream of the subsidence zone and elevated levels of iron, manganese, zinc and nickel were recorded during the mining of LW27.

During mining of LW28, LW29 and LW30, additional subsidence effects were observed. Cracking was observed at sites along Redbank Creek and pools were observed to drain at times of low flow, though diverted flow was observed to re-emerge downstream of each longwall. Increased salinity was recorded downstream of the subsidence zone and elevated levels of iron, manganese, zinc and nickel were also recorded (SIMEC, 2019). Gas emissions have not been observed in streams or pools above mining at the Tahmoor Mine (Tahmoor Colliery, 2013).

No direct evidence of dam wall or floor cracking was observed following mining of LW25 to LW28. Associated adverse water level, water storage or water quality effects were not observed during site investigations, however, complaints were made by three landowners with respect to loss of water holding capacity in dams following mining of LW26 (GeoTerra, 2014).

Monitoring of flow and water quality in Redbank Creek and Myrtle Creek 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 LW25 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.

5.2 ASSESSMENT OF FLOW AND WATER QUALITY DATA FOR REDBANK CREEK

Redbank Creek overlies the western end of LW25 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 LW25 and LW26, 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 4.

5.2.1 Assessment of Streamflow – Redbank Creek

Streamflow gauging stations have been established at 11 sites on Redbank Creek – refer Figure 4. 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 – located approximately 300 m downstream of LW32.

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.

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 a 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 summarised in Table 5 below. Parameters for R11 indicated with a "*" in Table 5 have been altered slightly from those given in HEC (2018) in order to improve the model fit during the earlier period of available recorded data (Dec 2009 to the end of 2012 – up to the end of mining of LW26). Daily rainfall data used in the model was obtained as the average of recorded data at the Tahmoor Coal pit top weather station, the Picton Bureau of Meteorology rainfall gauge (Station 68052) and the WaterNSW Lakesland rainfall gauge (Station 568295)[5]. No rainfall data was available from within the Redbank Creek catchment. Daily evaporation data was sourced from the SILO Data Drill[6] for a location close to the Redbank Creek catchment[7].

Table 5 AWBM Parameters - Redbank Creek Catchment

AWBM Parameter	Description of Parameter Effect	R4	R11
A1	Proportion of catchment contributing to AWBM surface storage 1	0.15	0.2*
A2	Proportion of catchment contributing to AWBM surface storage 2	0.5	0.4*
A3	Proportion of catchment contributing to AWBM surface storage 3	0.35	0.4*
C1 (mm)	Capacity of AWBM surface storage 1	1	3*
C2 (mm)	Capacity of AWBM surface storage 2	100	120
C3 (mm)	Capacity of AWBM surface storage 3	160	160
K_S	Surface flow recession rate constant	0.25	0.25
BFI	Proportion of rainfall excess reporting to baseflow store	0.08	0.12
K_B	Baseflow recession rate constant	0.85	0.87*
T_L (mm/day)	Transmission loss rate	0.0015	0.0013*

The modelled and recorded flow hydrographs and flow frequency duration plots for site R4 for the periods of mining of LW25 and LW26 are shown in Figure 6 to Figure 9 below. These are substantially unchanged from HEC (2018d).

Figure 10 below shows the modelled and recorded flow hydrographs for site R4 for the periods of mining of LW27 to LW 32.

[5] Data from the WaterNSW station was only used from July 2013 onwards because prior to this date the recorded data differed significantly from the record at the other two stations.

[6] 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/

[7] https://www.longpaddock.qld.gov.au/silo/point-data/ for 34 12'S 150 36'E.

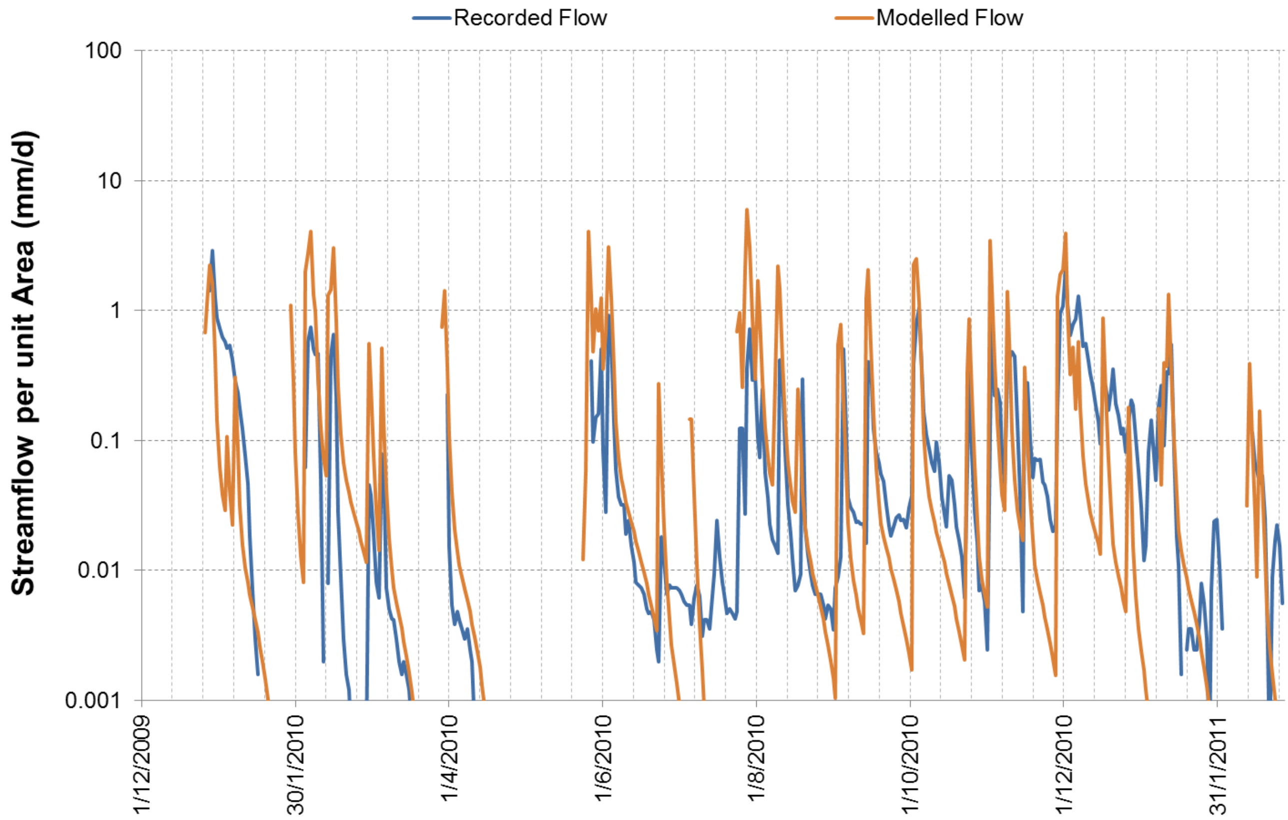


Figure 6 Streamflow – Redbank Creek Site R4 during Mining of LW25

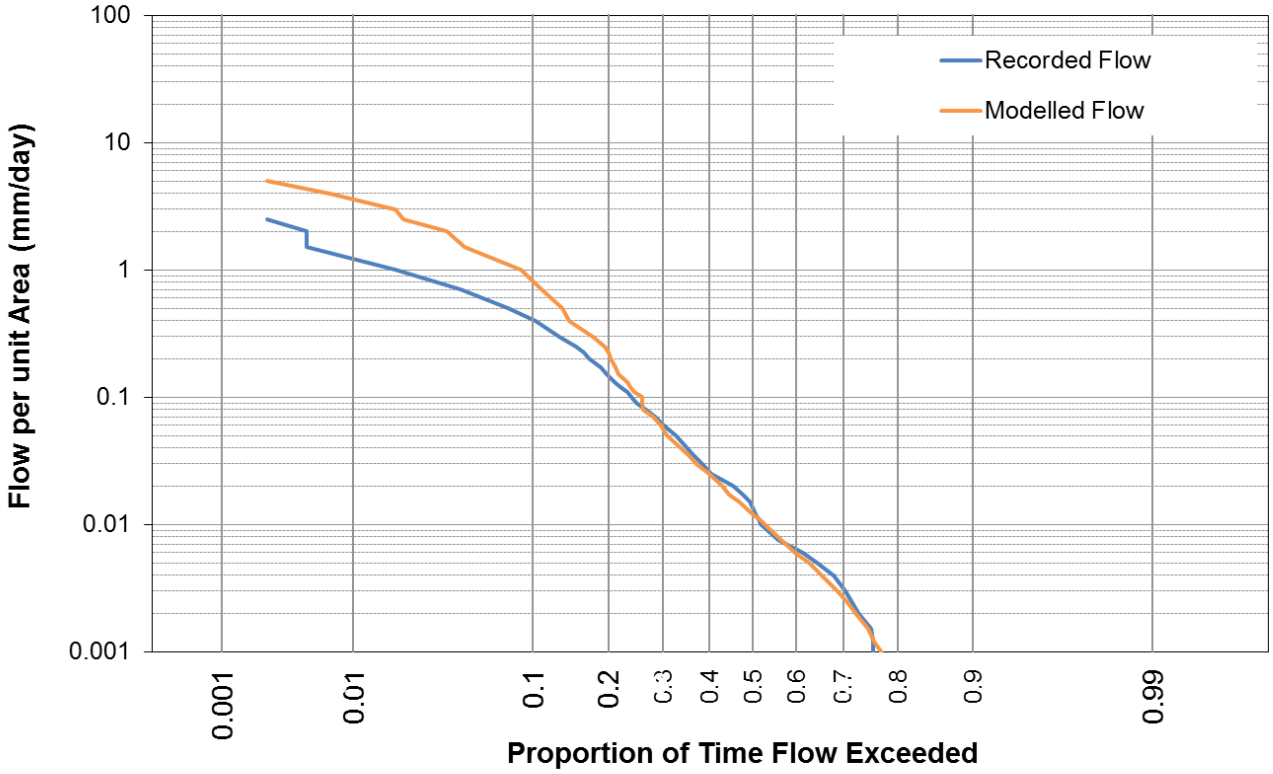


Figure 7 Flow Frequency Duration Plots – Redbank Creek Site R4 during Mining of LW25

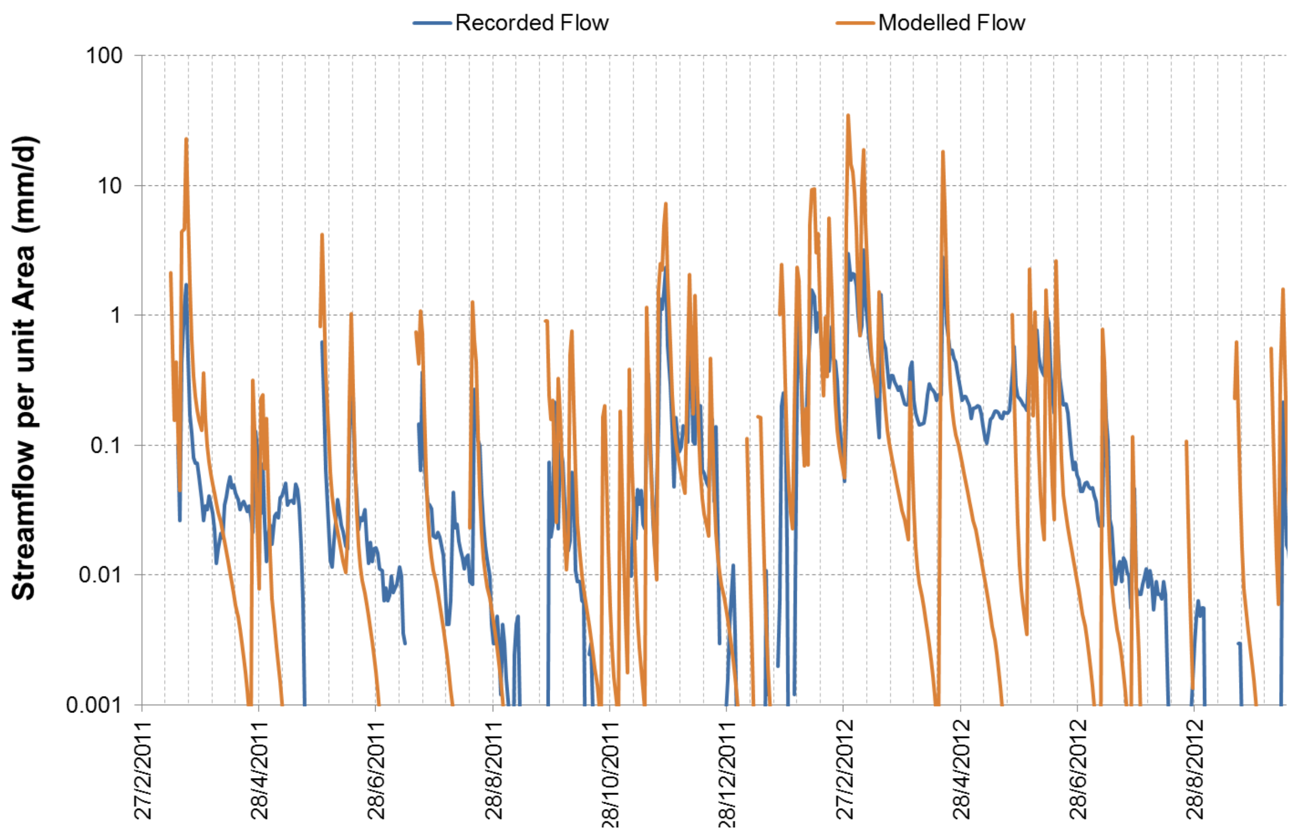


Figure 8 Streamflow – Redbank Creek Site R4 during Mining of LW26

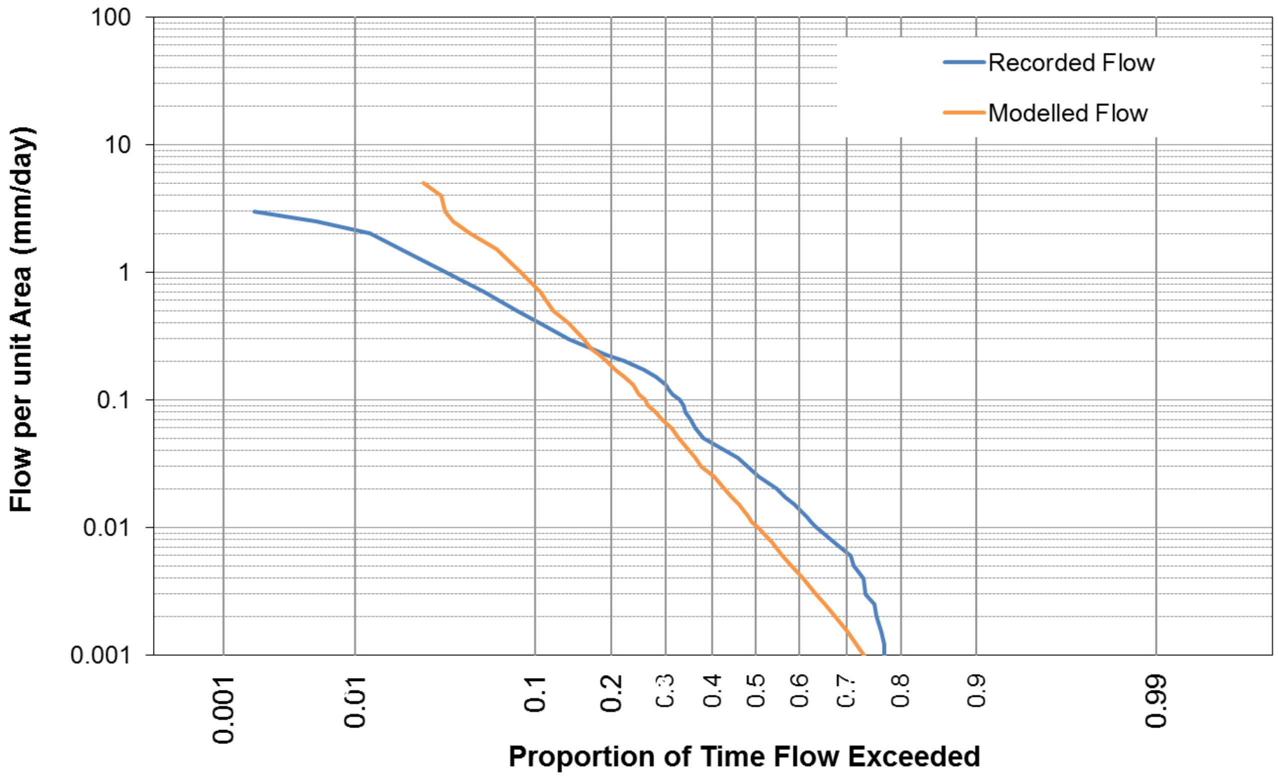


Figure 9 Flow Frequency Duration Plots – Redbank Creek Site R4 during Mining of LW26

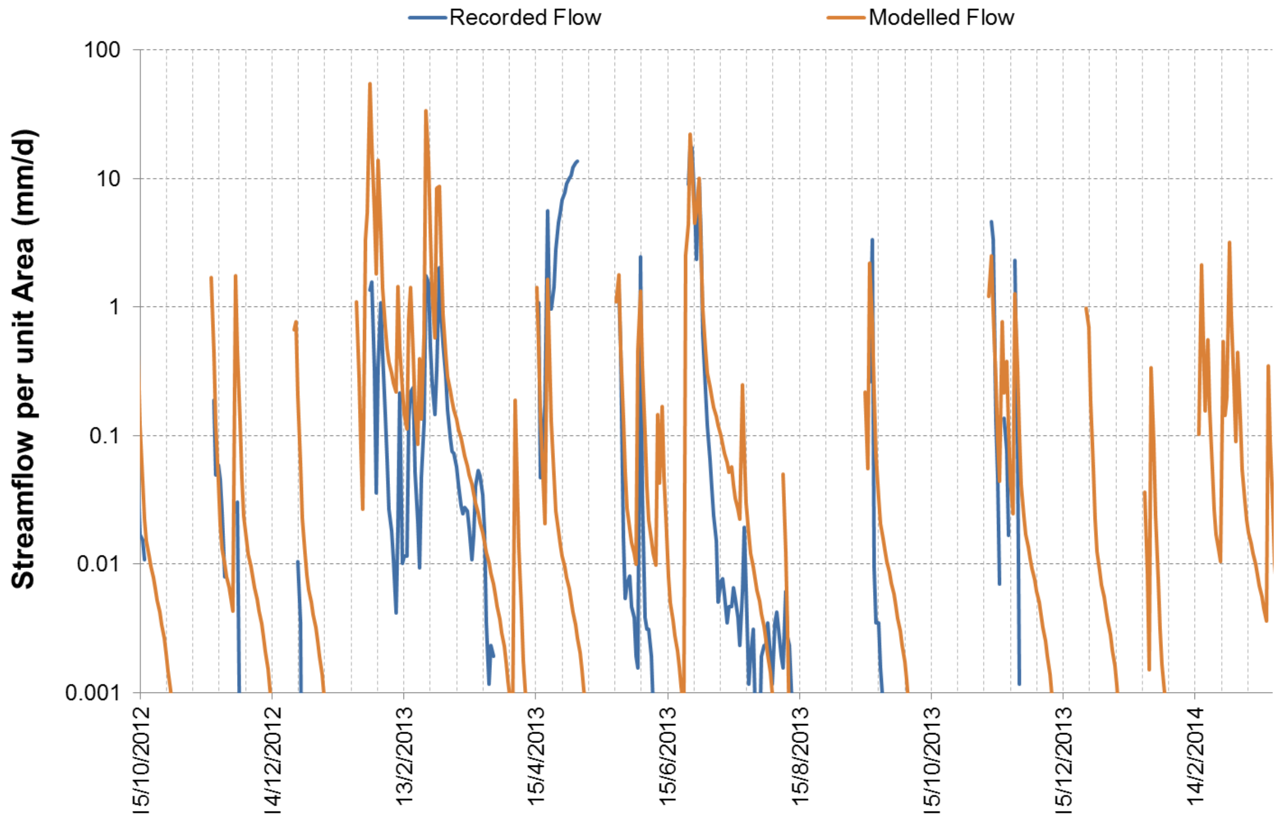


Figure 10 Streamflow – Redbank Creek Site R4 during Mining of LW27

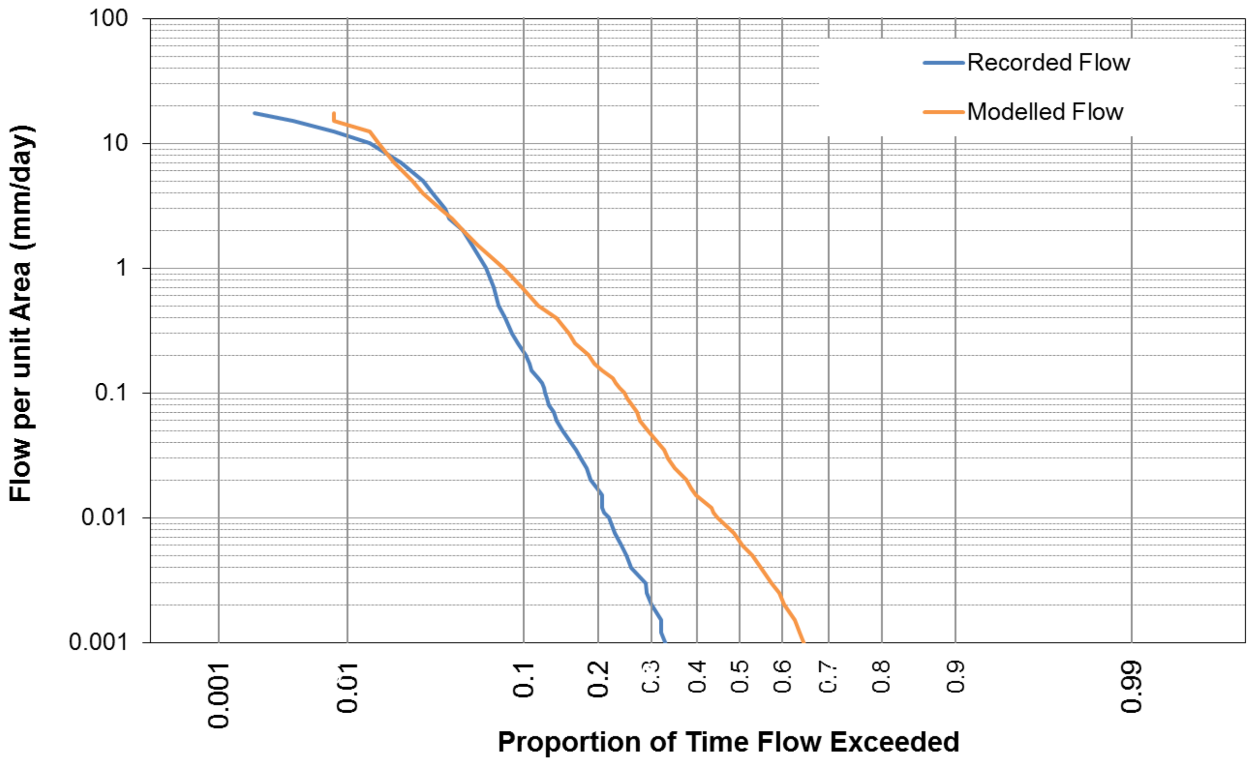


Figure 11 Flow Frequency Duration Plots – Redbank Creek Site R4 during Mining of LW27

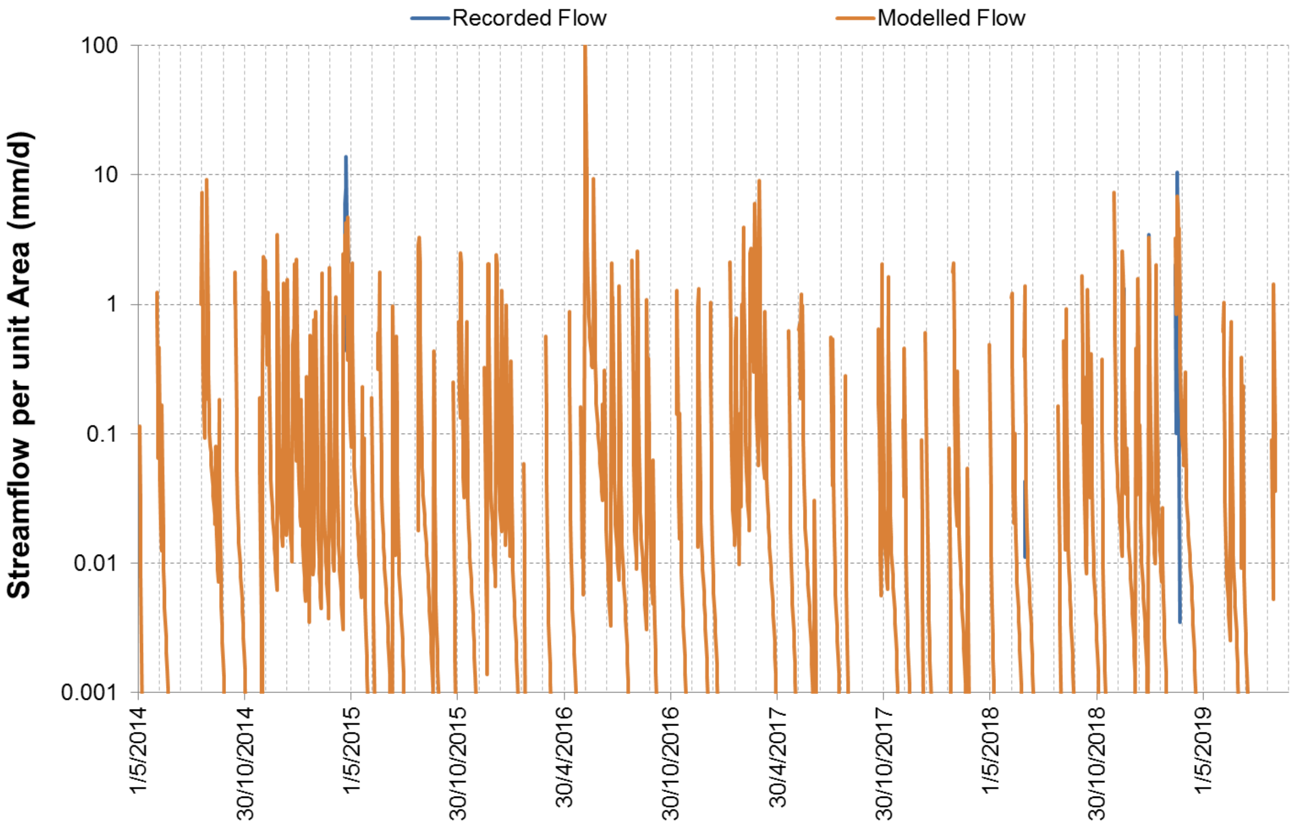


Figure 12 Streamflow – Redbank Creek Site R4 during Mining of LW28 to LW32

It is apparent from Figure 6 to Figure 12 that there has been a change in the flow behaviour at site R4 with time, likely associated with longwall mining beneath the site. It seems likely that the control for the streamflow gauging station has been affected.

The modelled and recorded flow hydrographs and flow frequency duration plots for site R11 for the periods of mining of LW25 to LW32 are shown in Figure 13 to Figure 28.

During the mining of LW25 and LW26, most of the time, recorded low flows were well reproduced by the model (Figure 13 to Figure 16). Model calibration occurred using data from this period and the model fit to recorded daily data is considered good with a coefficient of determination of 0.94. Recorded flow is ephemeral, with flow ceasing for periods in between rainfall events.

During the mining of LW27 in early 2013 (Figure 17) there is a clear change evident in the recorded flow behaviour at site R11. From this time on, flow is more persistent, with zero flow recorded rarely. The flow frequency duration plots show a long ‘tail’, suggesting a much greater prevalence of baseflow. This behaviour persists for more than 4 years until the period of mining of LW31 in late 2017 (refer Figure 25). From that time, recorded flow at site R11 returns to more of an ephemeral nature, albeit with some additional baseflow (refer Figure 28) compared with conditions prior to mining of LW27.

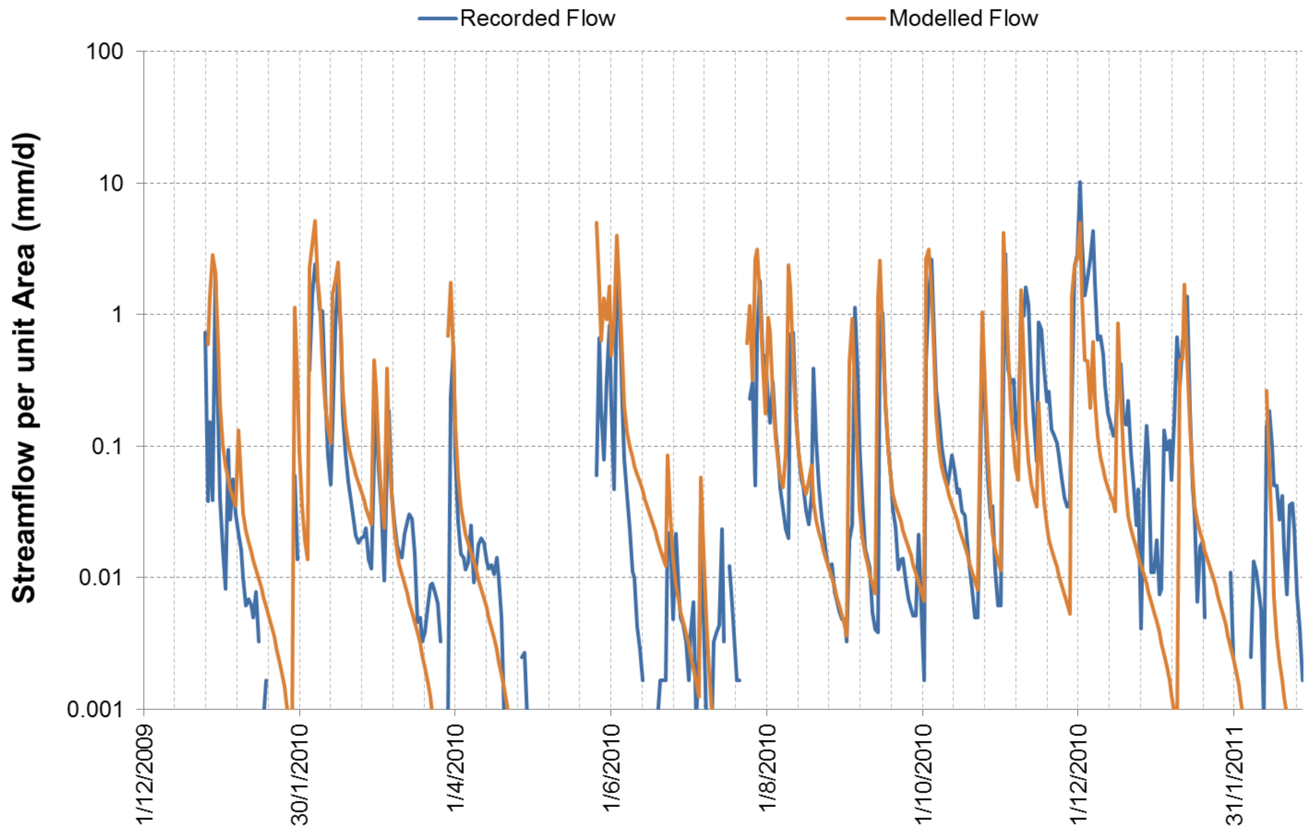


Figure 13 Streamflow – Redbank Creek Site R11 during Mining of LW25

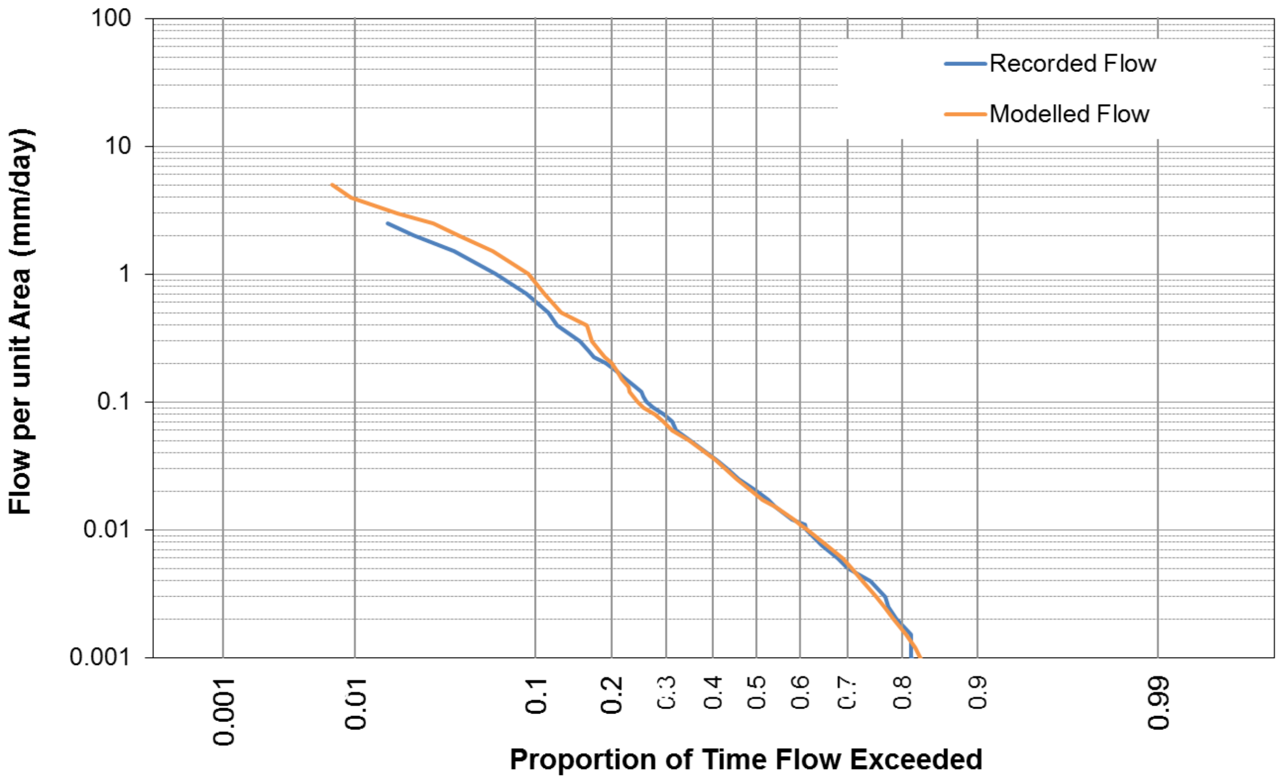


Figure 14 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW25

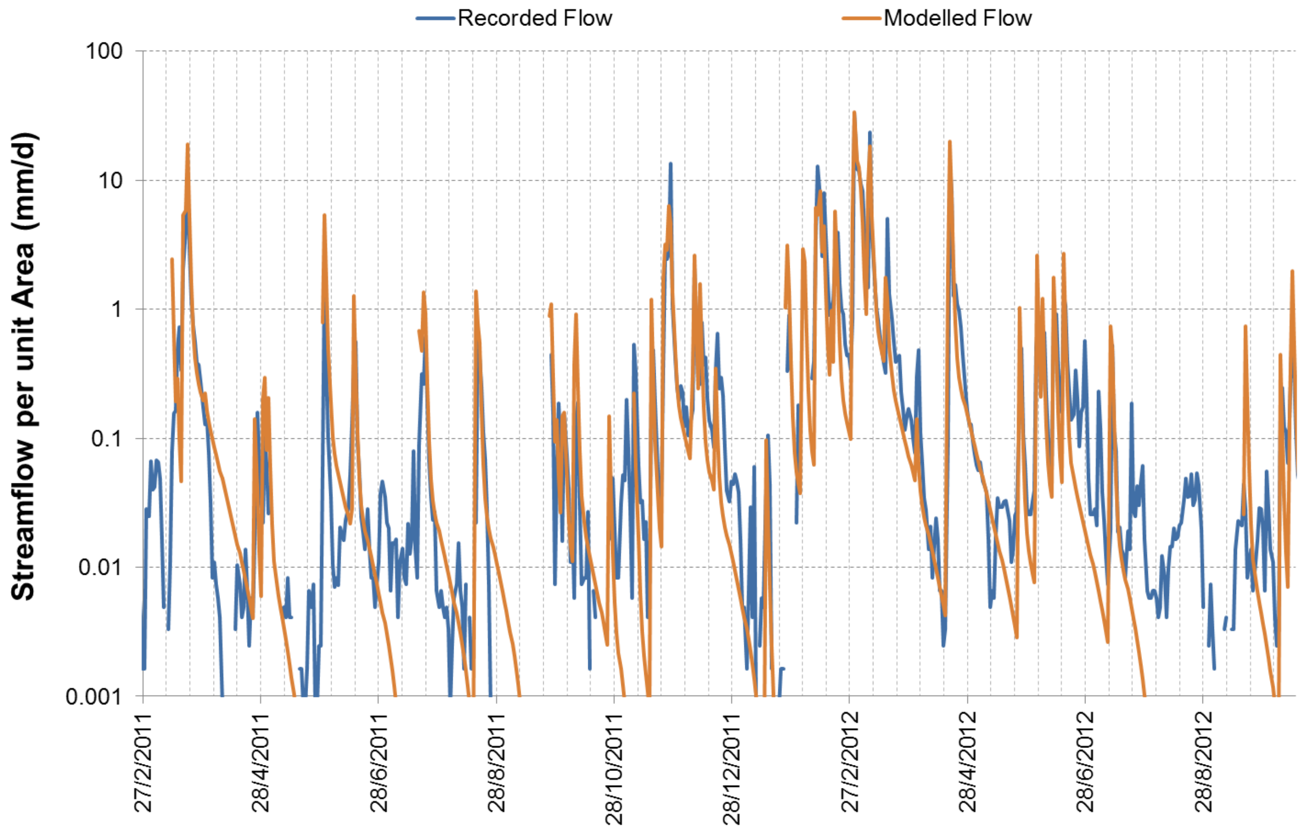


Figure 15 Streamflow – Redbank Creek Site R11 during Mining of LW26

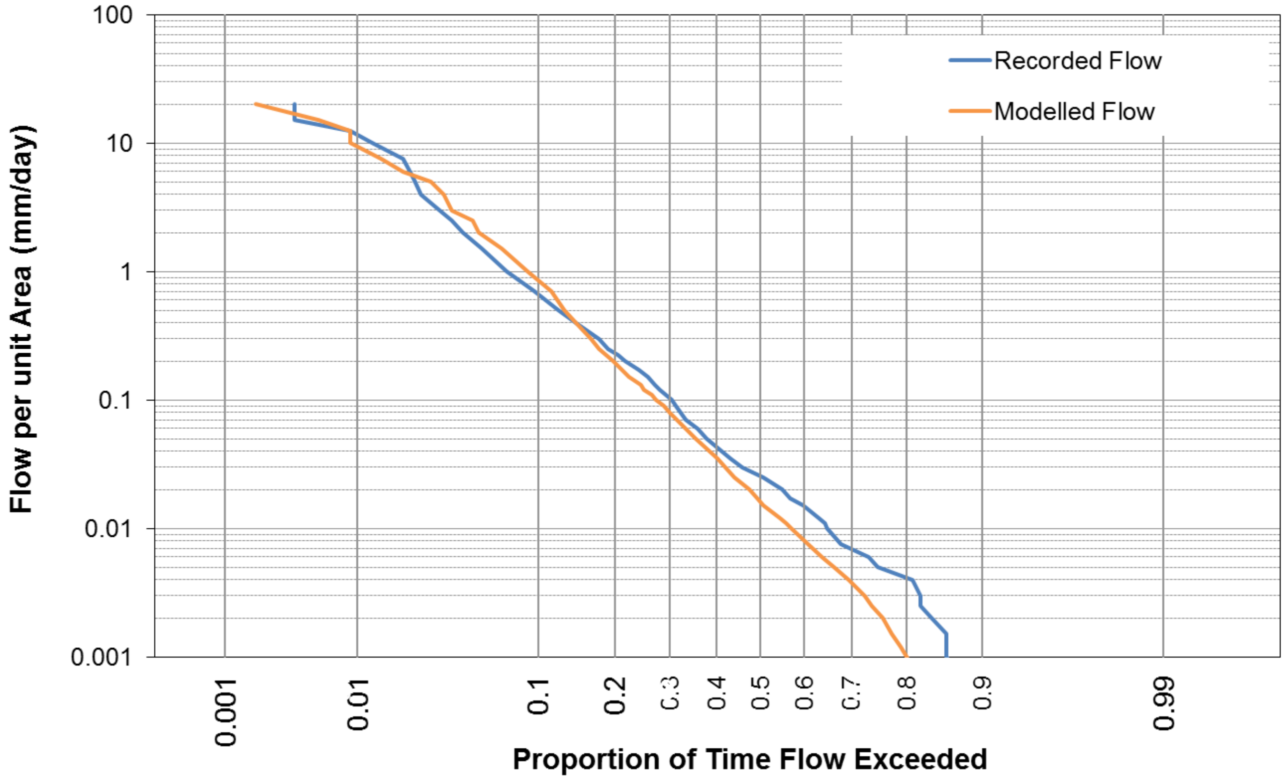


Figure 16 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW26

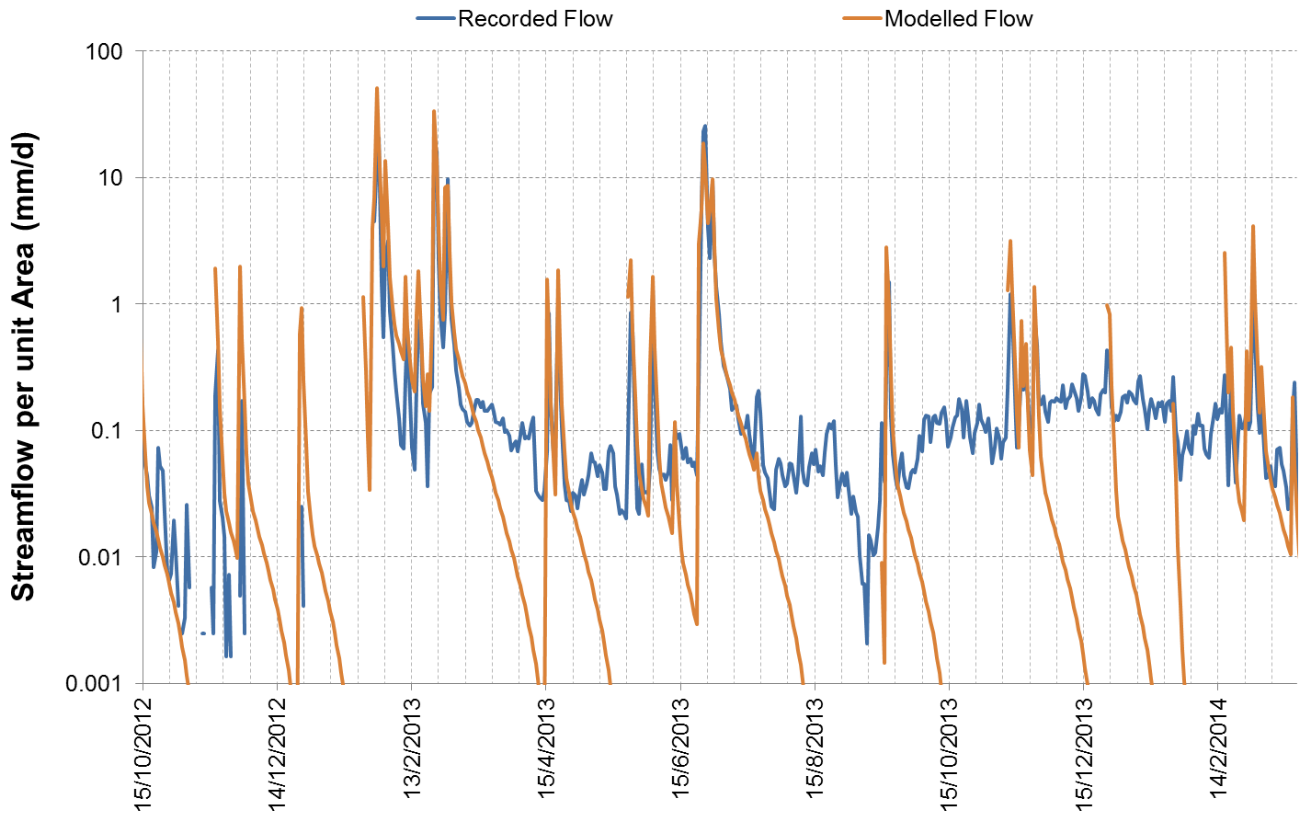


Figure 17 Streamflow – Redbank Creek Site R11 during Mining of LW27

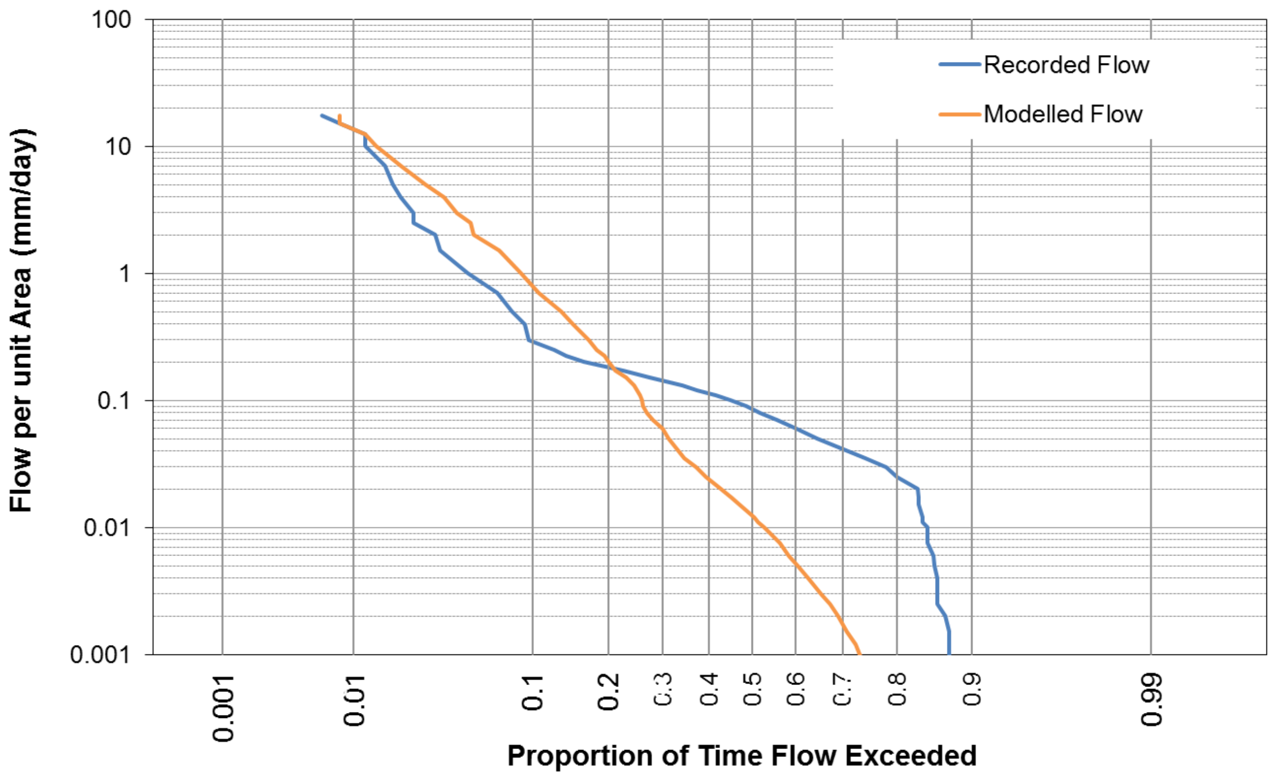


Figure 18 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW27

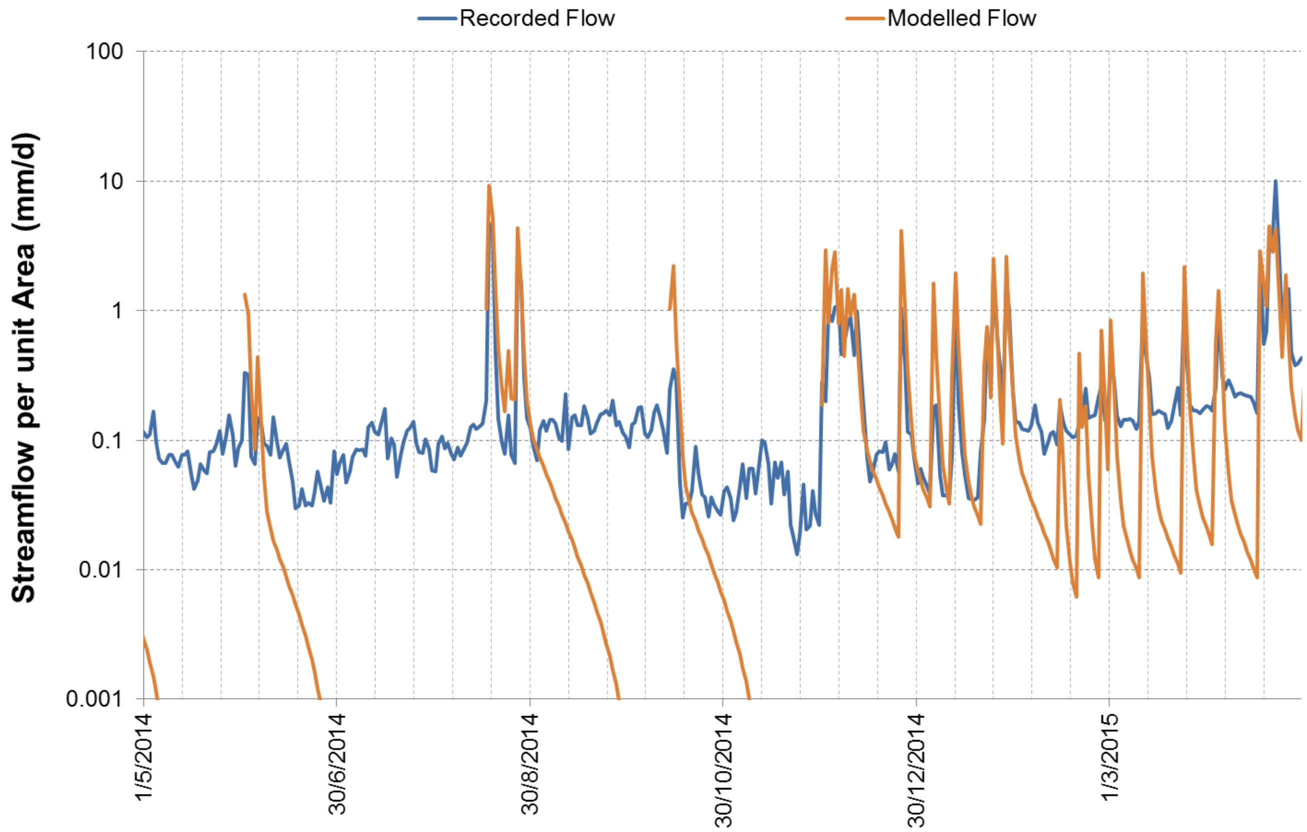


Figure 19 Streamflow – Redbank Creek Site R11 during Mining of LW28

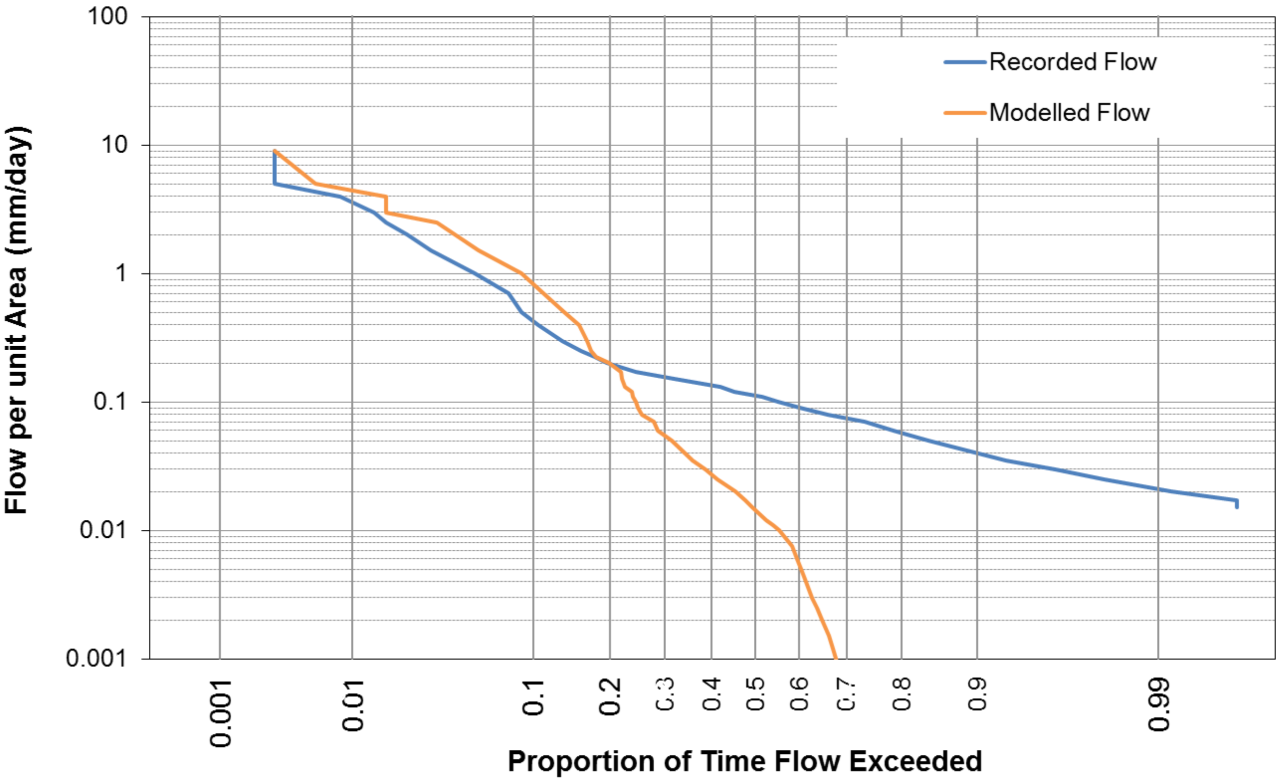


Figure 20 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW28

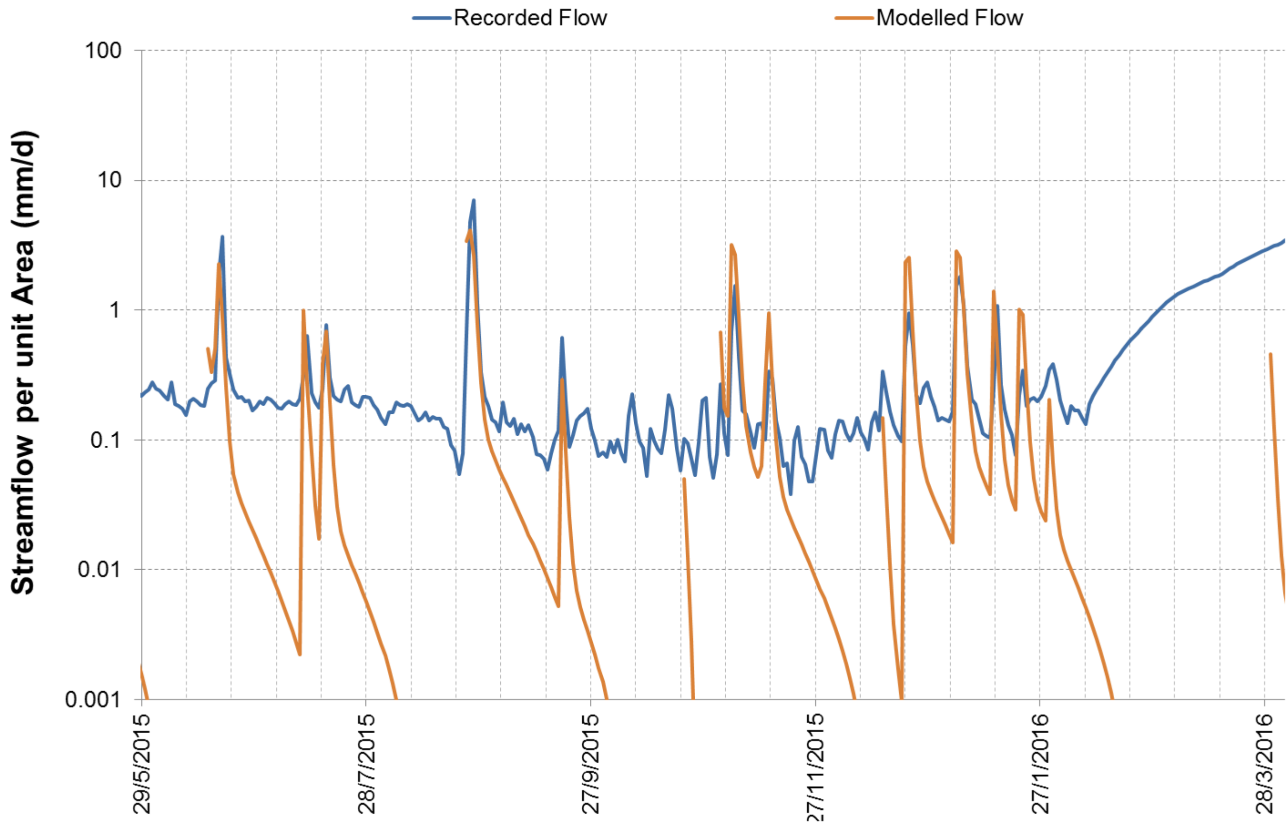


Figure 21 Streamflow – Redbank Creek Site R11 during Mining of LW29

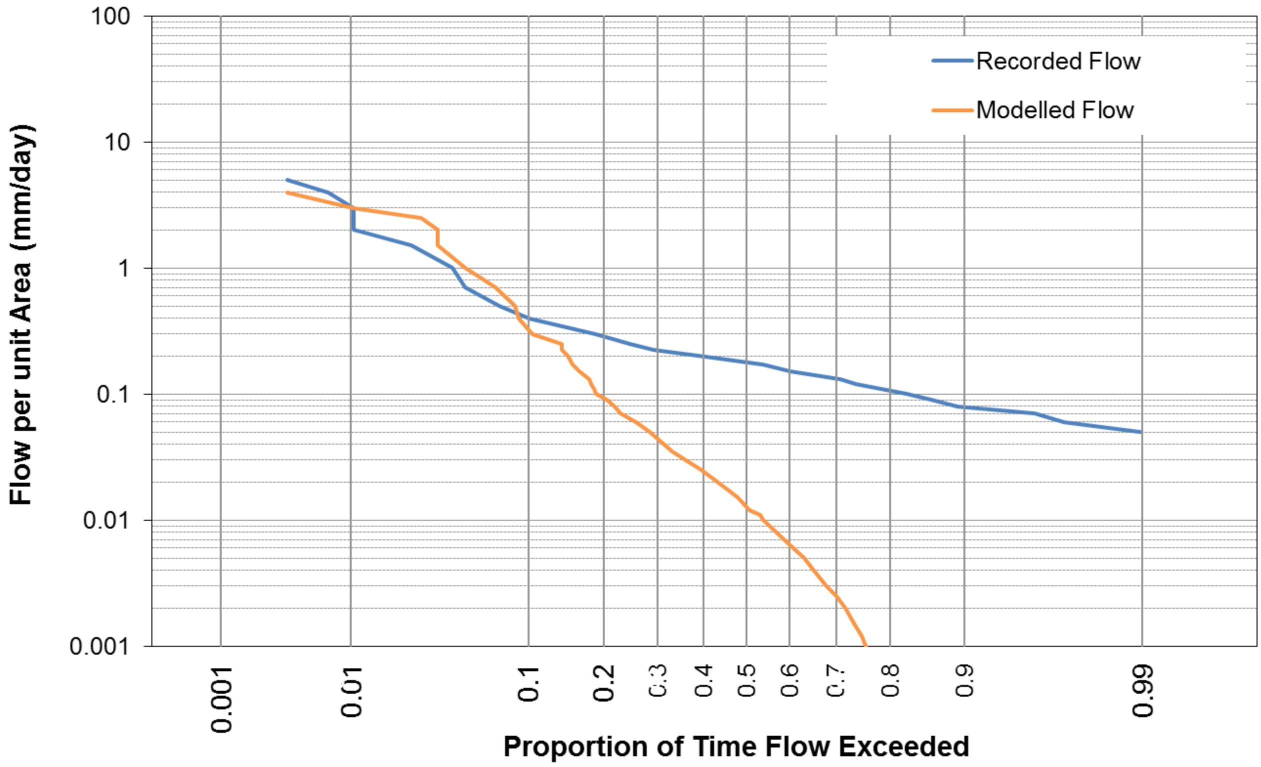


Figure 22 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW29

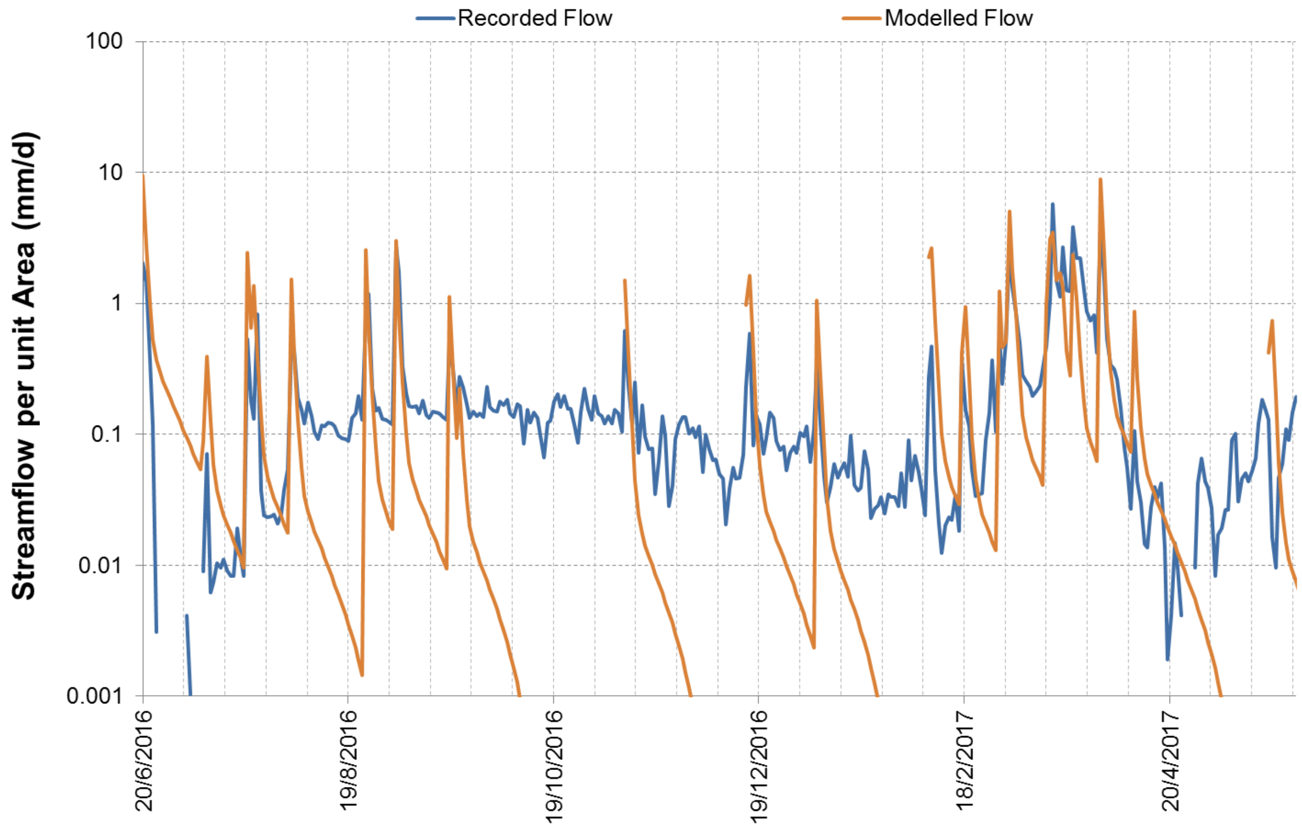


Figure 23 Streamflow – Redbank Creek Site R11 during Mining of LW30

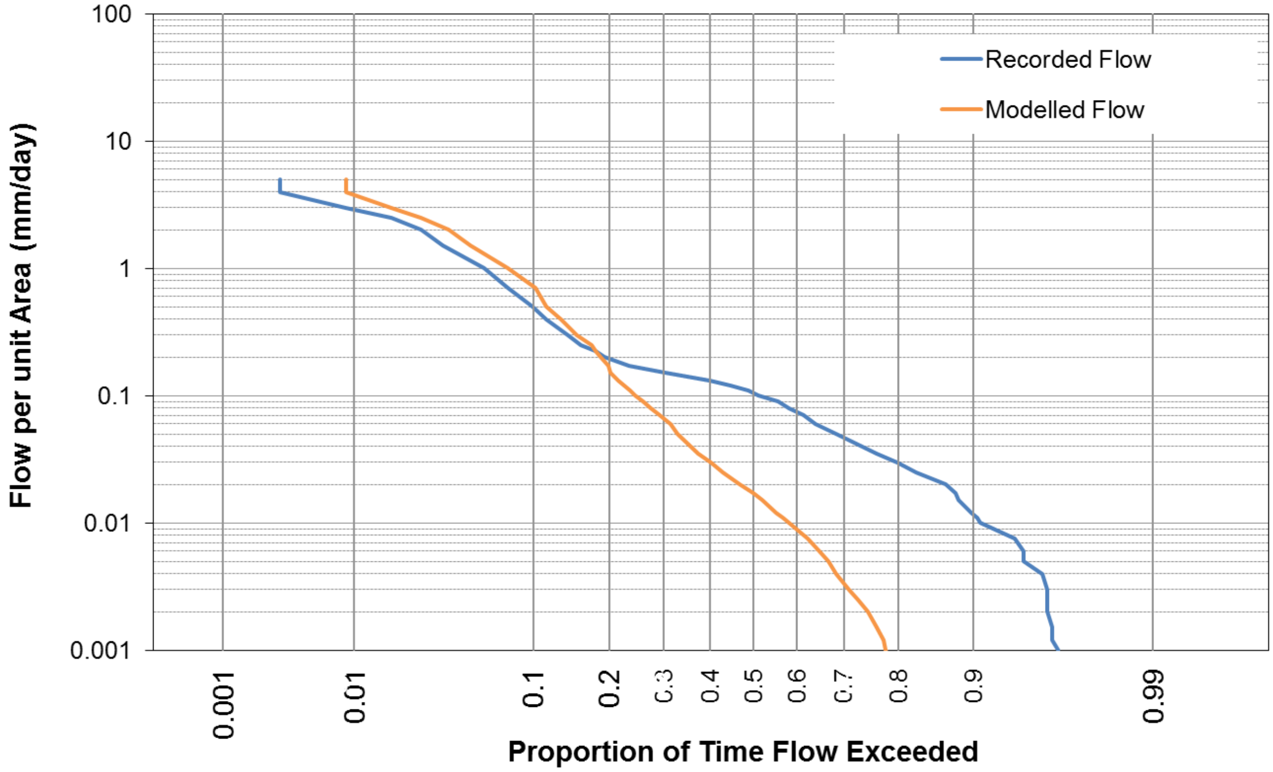


Figure 24 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW30

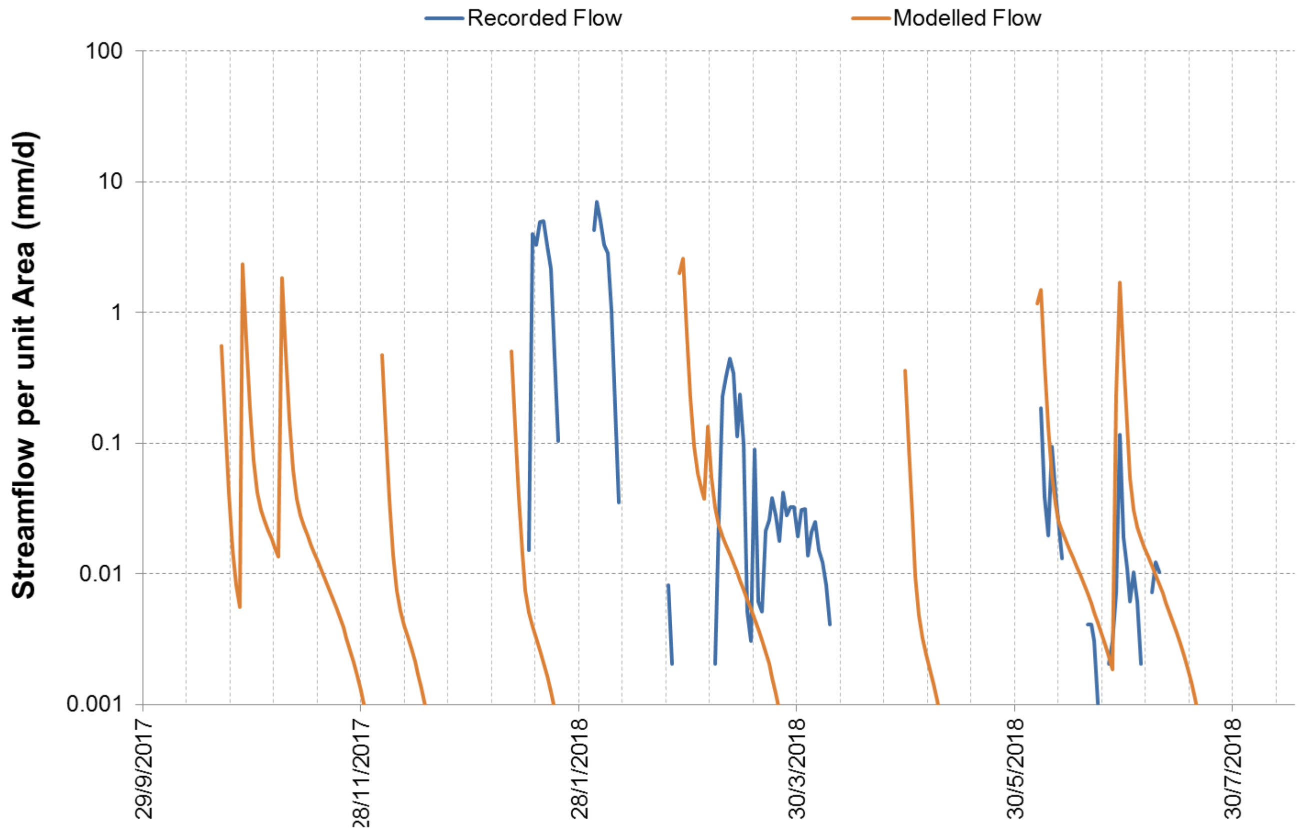


Figure 25 Streamflow – Redbank Creek Site R11 during Mining of LW31

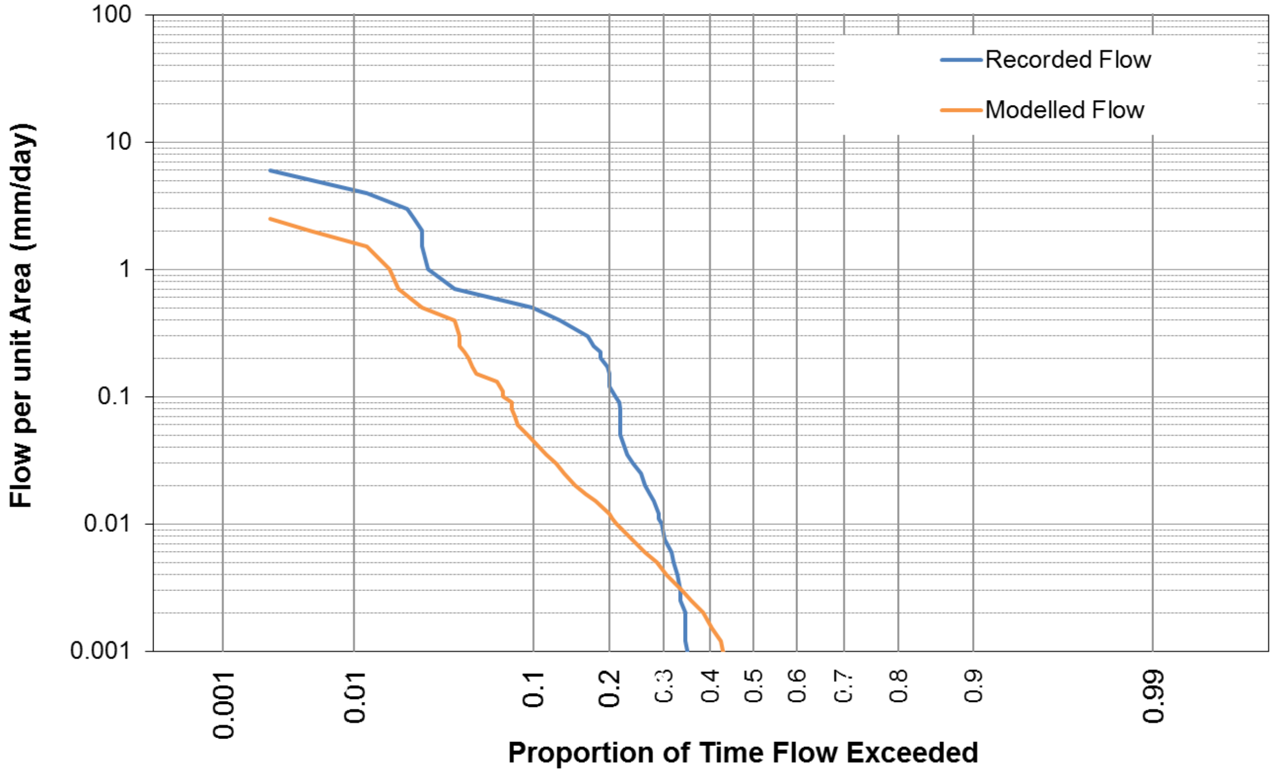


Figure 26 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW31

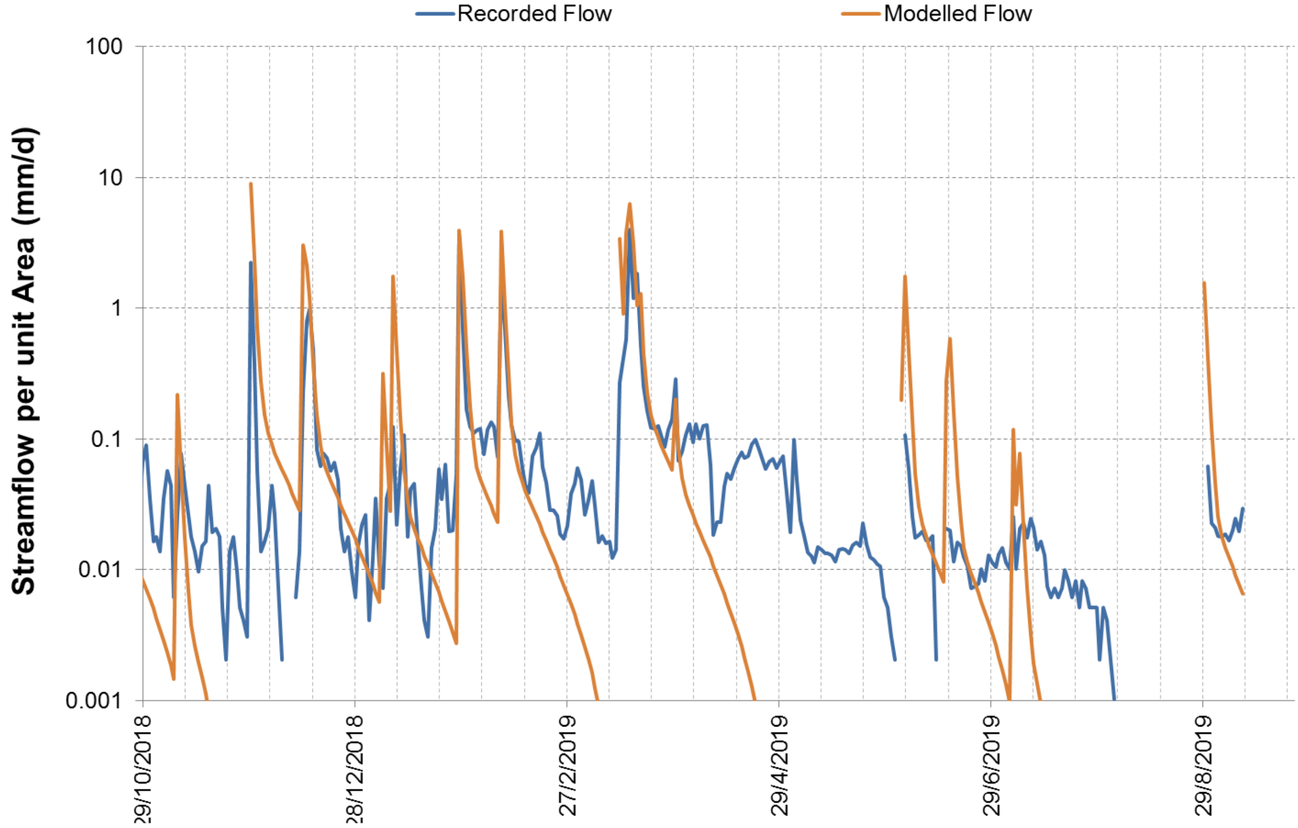


Figure 27 Streamflow – Redbank Creek Site R11 during Mining of LW32

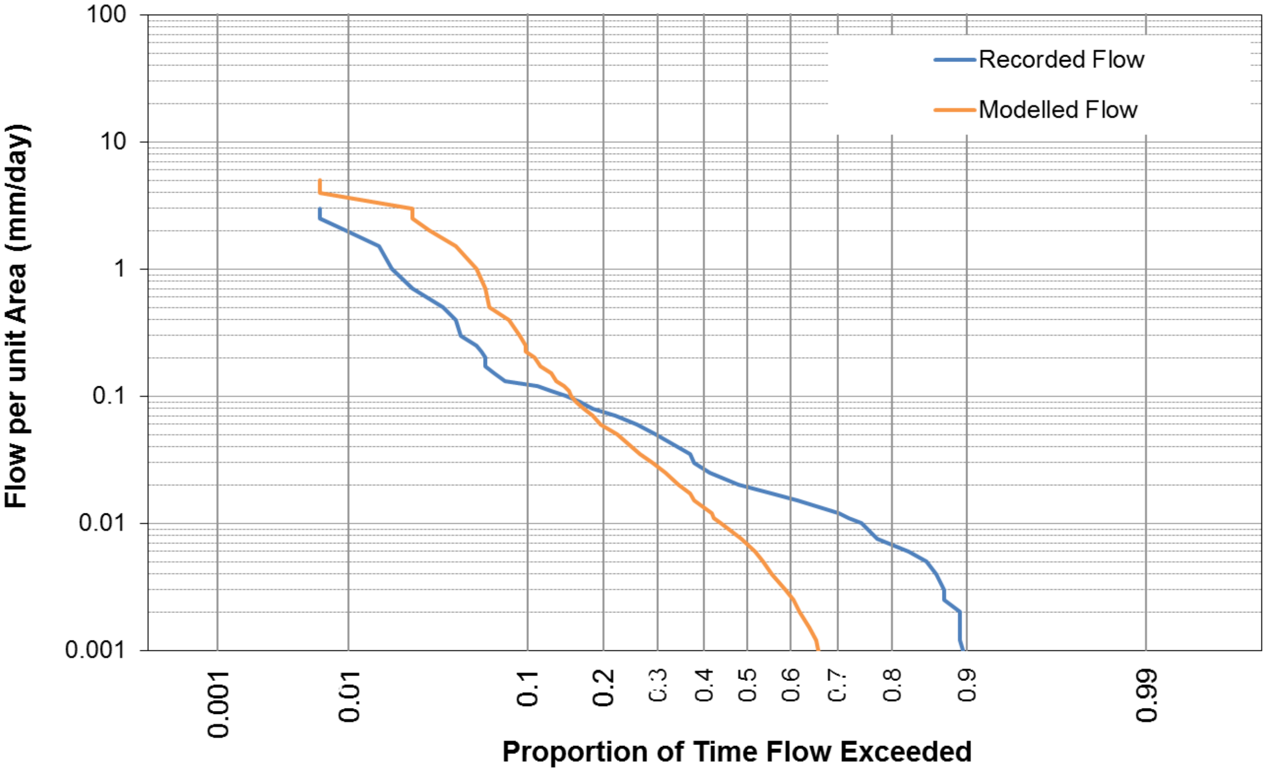


Figure 28 Flow Frequency Duration Plots – Redbank Creek Site R11 during Mining of LW32

The flow record at site R11 suggests a change in the flow regime from the mining of LW27, with greater prevalence of baseflow. This is considered likely associated with subsidence-induced fracturing causing underflow and delayed drainage of flow reporting to the downstream site R11. A second change in the flow regime is apparent, from the period during the mining of LW31, with the prevalence of baseflow diminishing and ephemeral flow prevailing. Possible causes of this second change include:

1. Natural 'healing' of subsidence induced fracturing reducing the prevalence of underflow and delayed drainage.
2. Closure of subsidence cracking within the previously mined area due to the mining of additional longwalls.
3. Subsidence-induced fracturing affecting the flow control (rock bar) at site R11, causing flow to leak through the flow control.

With regard to the latter possible cause, it is noted that site R11 is approximately 120 m beyond the predicted 20 mm subsidence limit for LW31 and the change in flow regime was first evident during mining of LW31. Site R11 is within the 50 mm predicted subsidence contour for LW32 however field observations by Tahmoor Coal personnel and consultants indicate that there has been no evidence of subsidence impacts (fracturing or reduction of flow) at site R11 and downstream. Therefore it seems more likely that the more recent change to a more ephemeral flow regime may be related to natural 'healing' behaviour and/or closure of subsidence cracking due to the mining of additional longwalls. Additional catchment specific research would need to be undertaken to better understand the cause of this behaviour.

5.2.2 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 to August 2019 were assessed for water quality sampling sites RC1 (upstream), RC2 (mid) and RC5 (downstream) – refer Figure 4. Note that water quality sampling site RC5 is located downstream of the limit of subsidence effects associated with the most downstream longwall panel (LW32) and would therefore likely be downstream of flow re-emergence.

Recorded concentrations of key water quality indicators for this period are shown below in Figure 29 to Figure 35. The following observations are apparent from a visual assessment of the data.

1. <u>Recorded electrical conductivity</u> (EC - a measure of salinity) increased at the downstream site RC5 following the mining of LW26, reaching a peak during the mining of LW 27 and LW28. Thereafter EC levels at RC5 have fallen. During the mining of LW32, EC levels at RC5 were close to those recorded prior to the mining of LW25. Recorded EC at RC2 likewise peaked during the mining of LW27 and LW28, however there were also elevated EC readings at RC2 prior to LW25. These higher salinity levels at RC2 appear to be unrelated to mining and possibly relate to pre-existing groundwater inflows (e.g. ferruginous springs). Monitoring of water quality at RC2 has only been possible on two occasions since the mining of LW29 and these have indicated EC levels also near to the lower bound of records prior to LW25. There has been no obvious change to EC at the upstream site RC1.

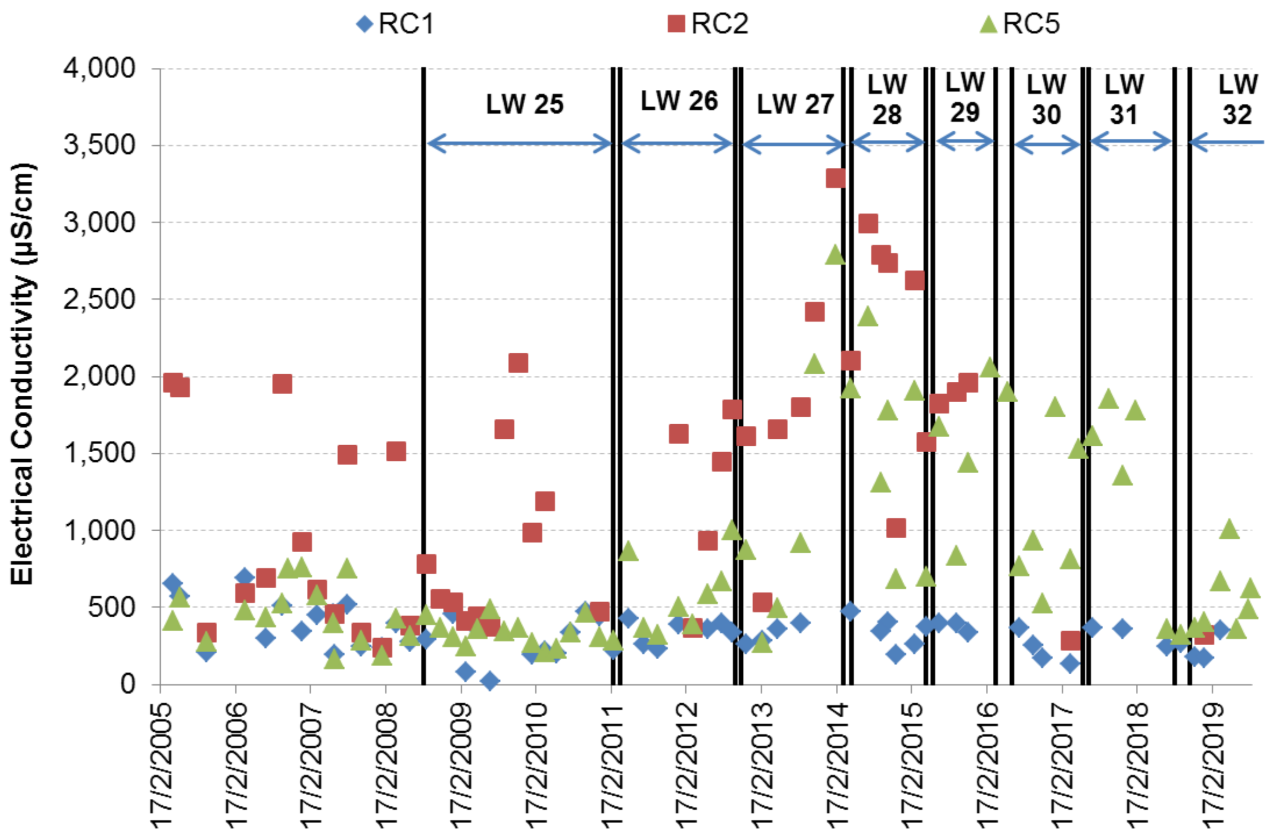


Figure 29 Recorded Electrical Conductivity (field) – Redbank Creek

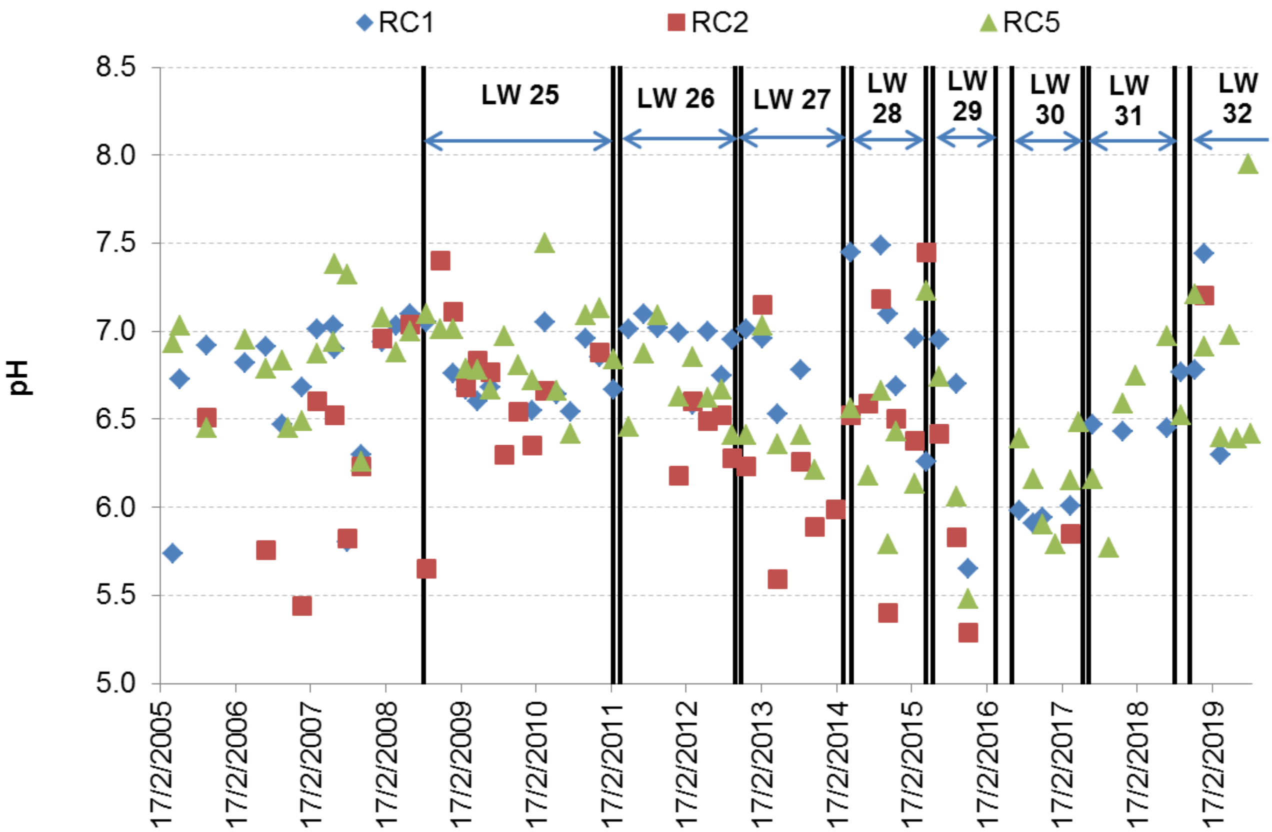


Figure 30 Recorded pH (field) – Redbank Creek

2. Recorded pH has been relatively consistent over the entire period and relatively consistent between the three sites, with a slight decrease evident since late 2015 to mid 2017 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.

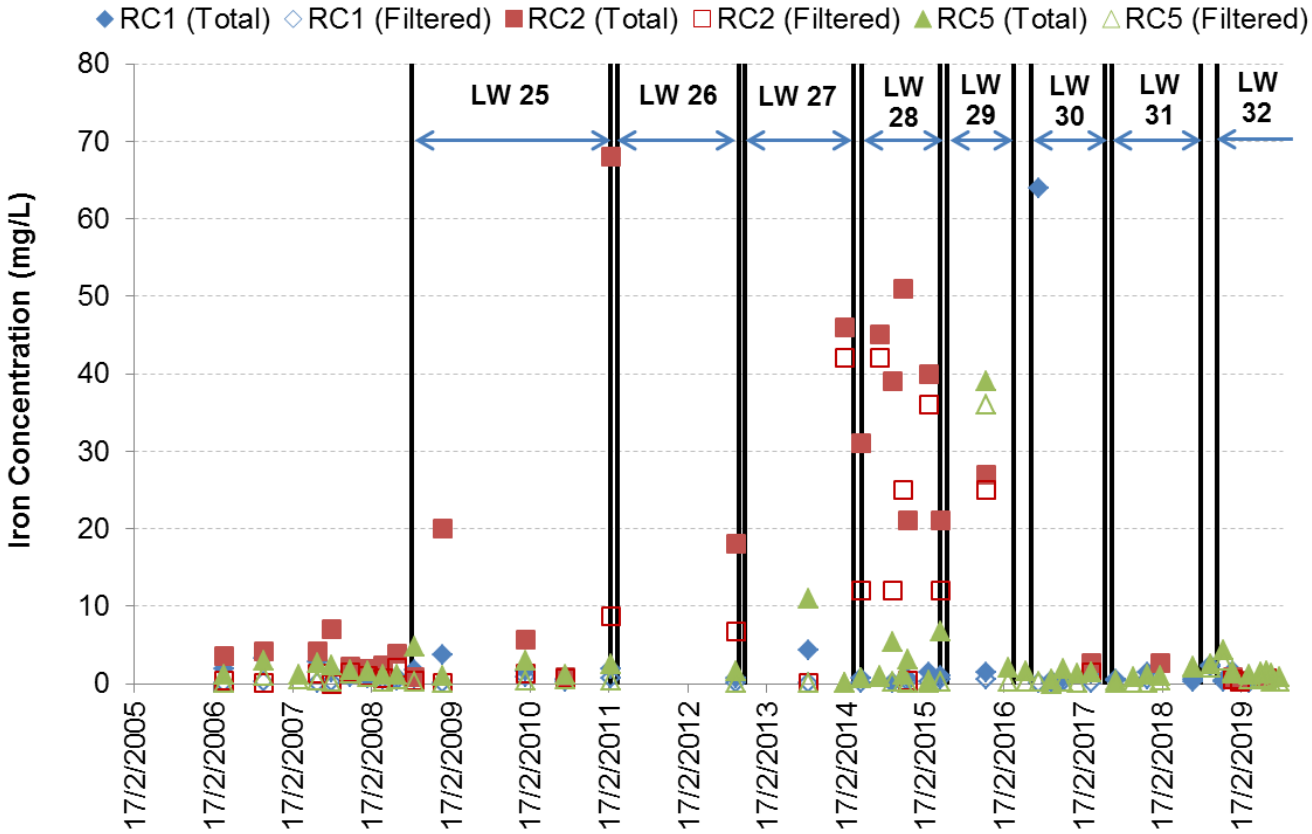


Figure 31 Recorded Iron Concentration – Redbank Creek

3. There was a significant rise in iron concentrations at site RC2 predominantly during mining of LW27, LW28 and LW29 (which were closest to RC2), with 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 LW25 (March 2011) although again 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. Recorded iron concentrations at RC5 have been low since mining of LW29. 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.

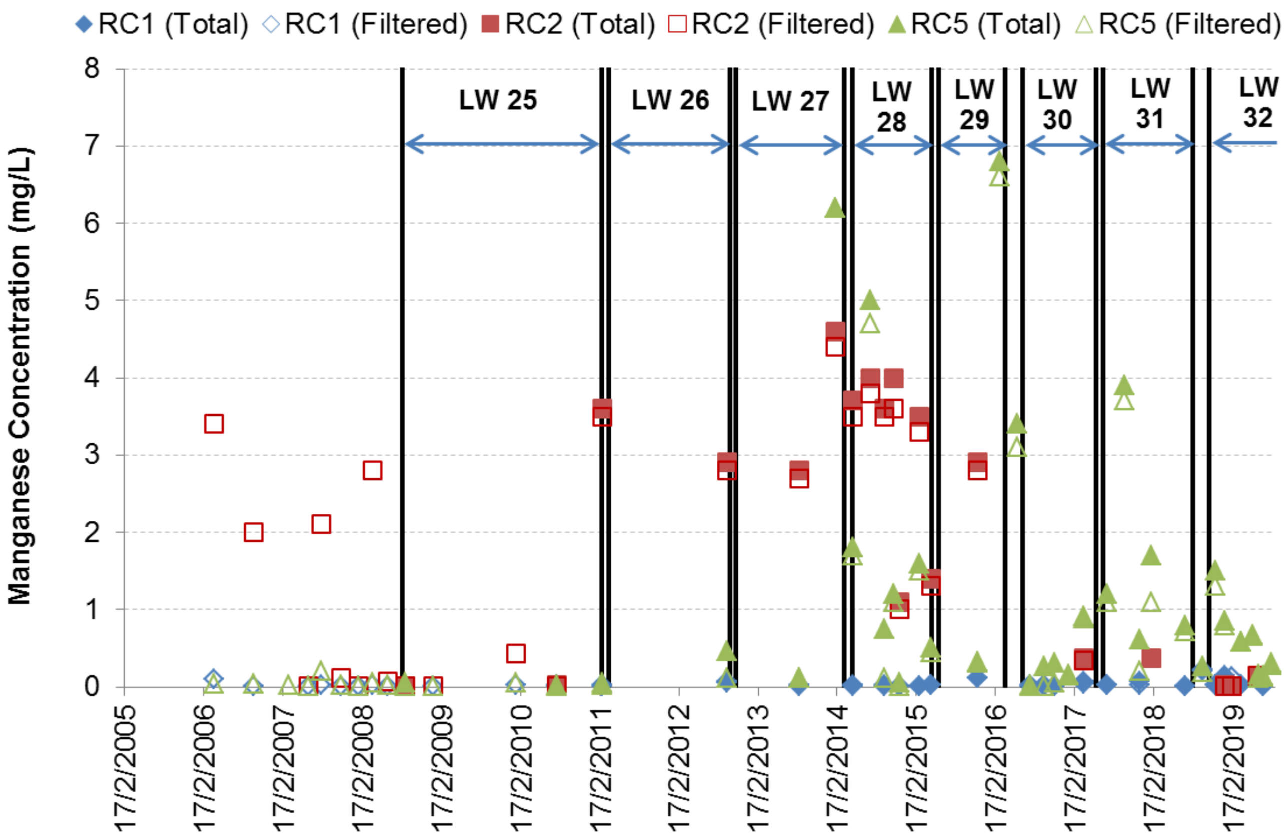


Figure 32 Recorded Manganese Concentration – Redbank Creek

4. Relatively high manganese concentrations have been recorded at site RC2 (up to 4.6 mg/L total) and RC5 (up to 6.6 mg/L). At RC2 these occurred during mining of LW25 to LW29, while at RC5 these were most notable between mining of LW27 to LW31. 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 LW31. The elevated manganese concentrations at site RC2 may be, at least in part, unrelated to mining of LW25 to LW29 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. It appears likely that increased manganese concentrations at site RC5 are related to mining, although concentrations have diminished with time.

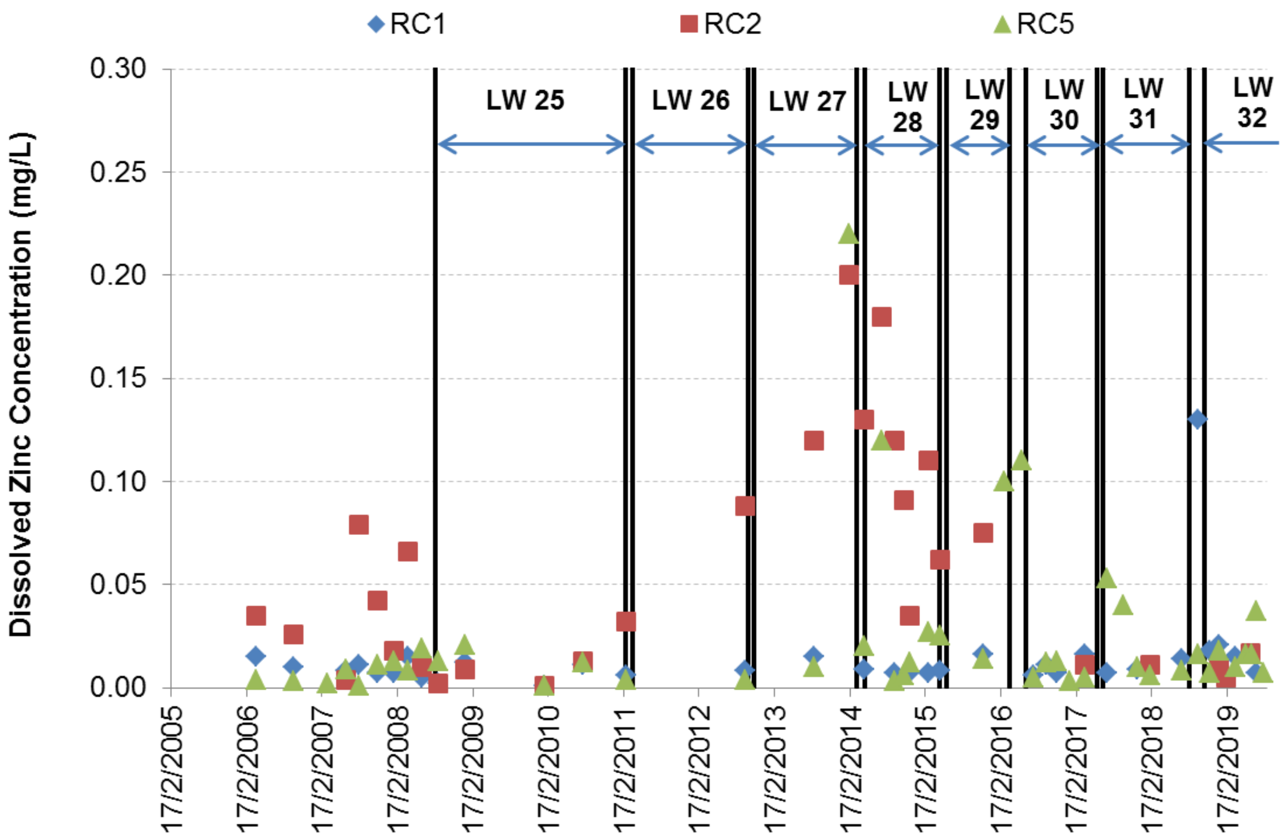


Figure 33 Recorded Dissolved Zinc Concentration – Redbank Creek

5. Recorded zinc concentrations (filtered only available) have also been relatively elevated at site RC2 compared to the other sites, with concentrations rising further during mining of LW26 to LW29. Elevated concentrations were recorded at downstream site RC5 during and following mining of LW27 to LW29, however concentrations have diminished in recent times. Concentrations at upstream site RC1 have remained relatively low with the exception of a "spike" in the recorded data of 0.13 mg/L in September 2018. The pattern in recorded zinc concentrations 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, although this has decreased with time.

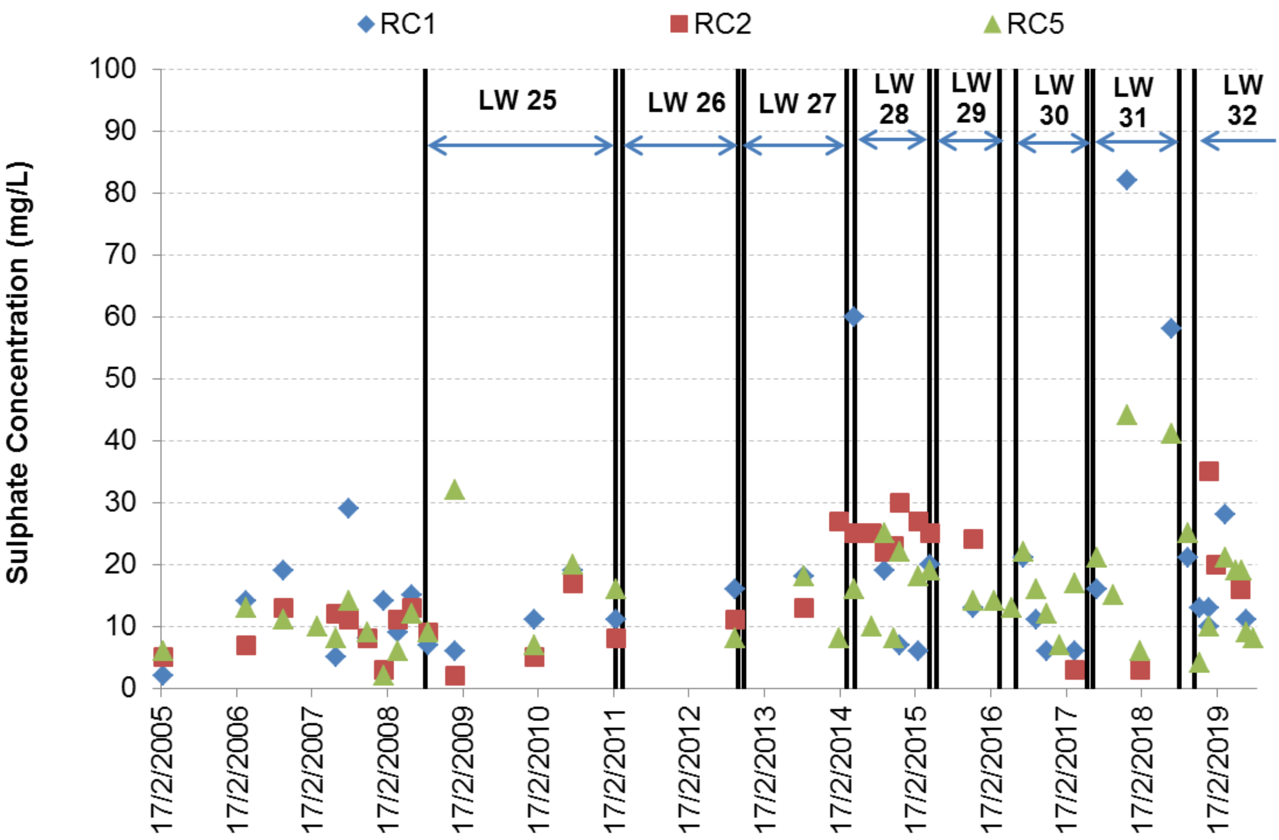


Figure 34 Recorded Sulphate Concentration – Redbank Creek

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 LW27 to the mining of LW29 and a single elevated reading during the mining of LW32 (although LW32 is located well downstream of RC2 and therefore mining of LW32 is unlikely to be the cause of this behaviour). Increased sulphate concentrations were recorded at downstream site RC5 during and shortly following the mining of LW31 but these diminished during mining of LW32.

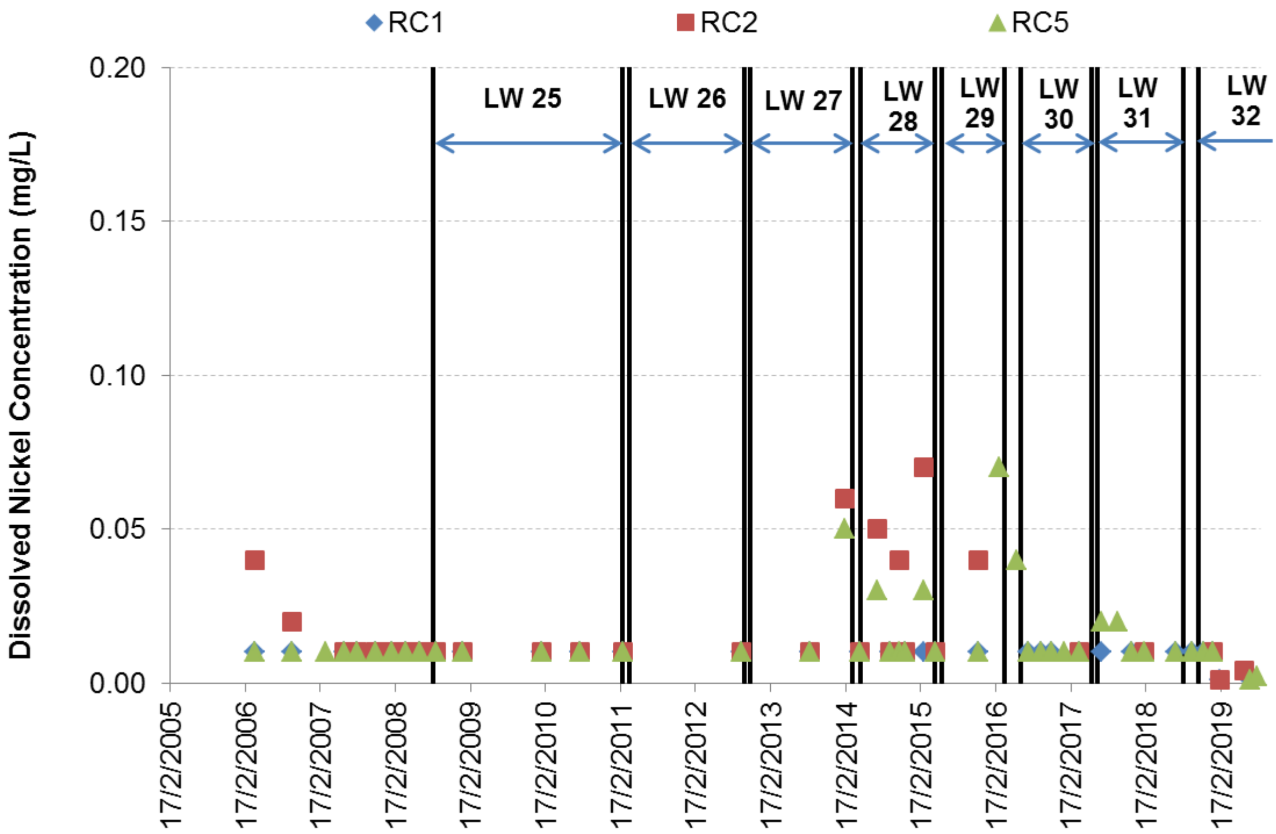


Figure 35 Recorded Dissolved Nickel Concentration – Redbank Creek

7. Recorded <u>dissolved nickel</u> at sites RC2 and RC5 rose during mining of LW27, LW28 and LW29 before subsequently falling back to levels that were recorded prior to mining of LW27 suggesting a temporary increase during mining of those three longwalls. Some elevated nickel concentrations were recorded at RC5 prior to mining of LW25.

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

5.3.1 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 LW10, LW11 and LW12. LW10 was 140 m wide and LW11 and LW12 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 localised impact, there was no net effect 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.

5.3.2 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 localised 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 Operations Project EIS (Gilbert & Associates, 2009).

Appin LW701, 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 LW31 and LW32 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 LW31a. 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 LW 32.

The Cataract River was undermined by LW3 to LW16 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 LW301 and LW302 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 LW405 which was mined close to the Cataract River between February 2002 and April 2003.

Stokes Creek was undermined by West Cliff Colliery LW17 to LW24 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 LW17 to LW24 in 2008 revealed iron staining and flocs in pools - refer photographs reproduced below.

Photo 1 Typical Iron Flocs and Pool – Stokes Creek in Reach Previously Undermined

Photo 2 Typical Iron Staining in Boulder-field – Stokes Creek in Area Undermined by Longwall Mining:

Mallaty Creek was undermined by West Cliff Colliery LW32 and LW33 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 LW32. 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 LW3 and LW4 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 LW1 to LW6 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.

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

6.1 REDUCED FLOWS DUE TO CATCHMENT EXCISION

The proposed REA expansion would involve an increase in the total area of 11.06 ha, bringing the total REA to 106.1 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 stabilised 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. As per HEC (2020b), the maximum catchment area excised for the REA is estimated at 69 ha which 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 (WWTP) before being discharged to Tea Tree Hollow via EPL 1389 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 (2020) is about 2.4 ML/day (down from the current 4 ML/day), predicted to occur for the first half of 2024 only. The average predicted groundwater recovery rate for the Project period is 5.2 ML/day (HydroSimulations, 2020). Allowing for an ongoing 1 ML/day treatment and recycling that would imply a transient change in flows in Tea Tree Hollow below LDP1 averaging between an increase in 0.2 ML/d to a decrease in up to 2.6 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 upgraded WWTP and release via LDP1 (refer HEC, 2020b). 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 (refer Section 6.7).

6.2 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 such 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. A rock bar impact model for the Southern Coalfield was developed by Barbato et al. (2014) and has been used to assess the potential for "Type 3" impacts to surface water systems. The rock bar impact model relates the likelihood of impact on rock bars with the predicted total valley closure along the stream based on the previous longwall mining experience in the Southern Coalfield. A Type 3 impact is defined as *fracturing in a rock bar or upstream pool resulting in reduction in standing water level based on current rainfall and surface water flow.*

The following qualitative descriptors have been derived from the rock bar impact model and applied to the impact assessment for pools for the Project:

- For predicted total closure of less than 210 mm, less than 10% of rock bars or upstream pools are expected to be impacted.
- For predicted total closure between 210 mm and 290 mm, less than 20% of rock bars or upstream pools are expected to be impacted.
- For predicted total closure between 290 mm and 420 mm, less than 30% of rock bars or upstream pools are expected to be impacted.
- For predicted total closure between 420 mm and 475 mm, less than 40% of rock bars or upstream pools are expected to be impacted.

Valley closure predictions for watercourses overlying the Project longwalls have been provided by MSEC (2020) in a series of figures which are reproduced in Appendix A. The maximum predicted (MSEC, 2020) valley closure and upsidence in local streams are summarised in Table 3. The location of mapped pools and distribution of predicted closure categories for each pool along Tea Tree Hollow and Dog Trap Creek is shown in Figure 36 and Figure 37.

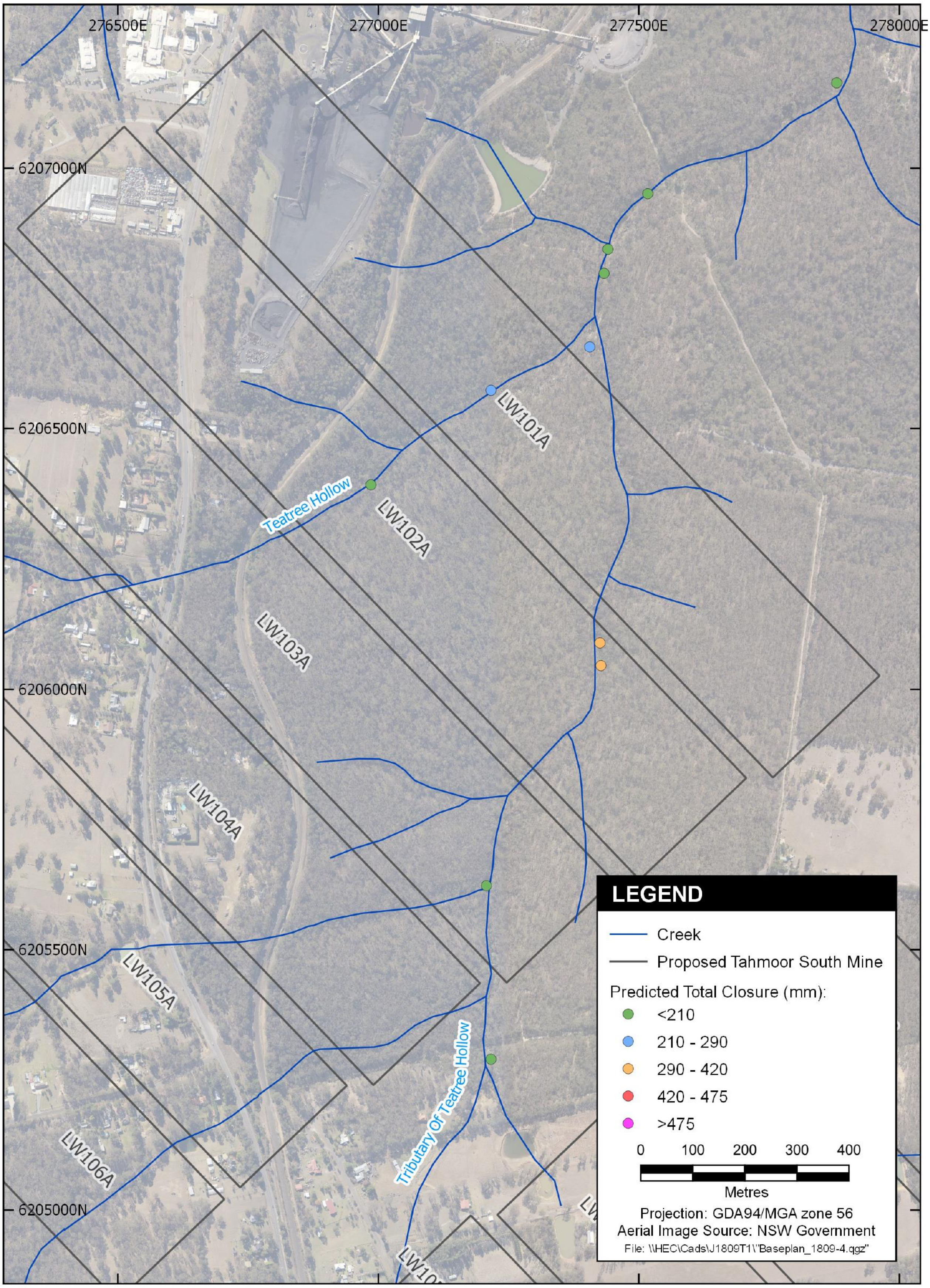


Figure 36 Qualitative Risk to Pools in Tea Tree Hollow

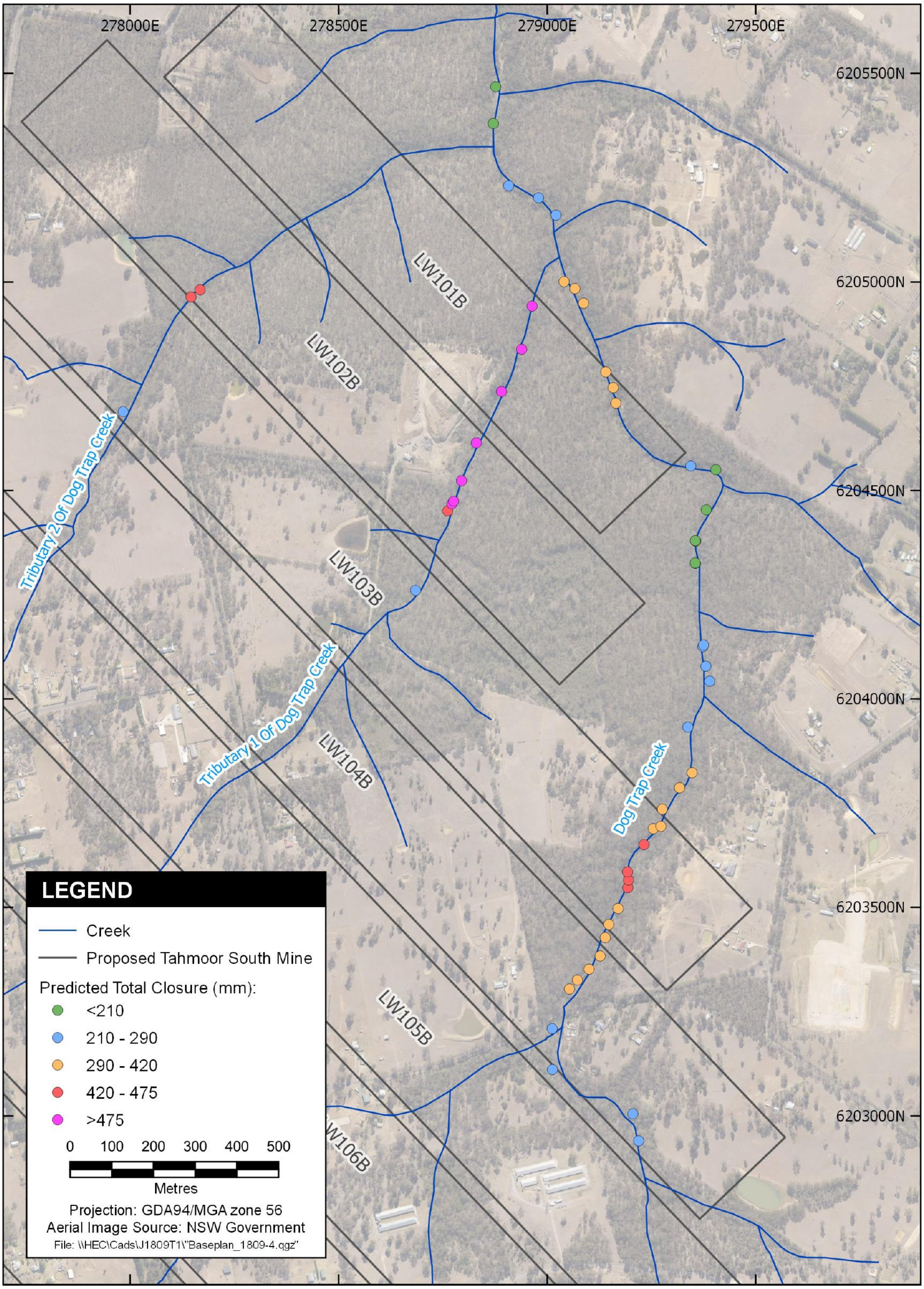


Figure 37 Qualitative Risk to Pools in Dog Trap Creek

There were eight pools mapped in Tea Tree Hollow and five pools mapped on a tributary of Tea Tree Hollow (note that two pools located outside of the Subsidence Study Area are not shown in Figure 36). The total predicted closure for seven of the eight pools mapped in Tea Tree Hollow and for two of the eight pools mapped in the tributary of Tea Tree Hollow, is less than 210 mm, indicating that less than 10% of these pools are expected to be impacted. One pool on Tea Tree Hollow and one pool on the tributary of Tea Tree Hollow are predicted to have a total closure of less than 290 mm, (less than 20% of pools are expected to be impacted). Two pools on the tributary of Tea Tree Hollow have a predicted total closure of 300 and 325 mm respectively. At this total closure prediction, less than 30% of pools are expected to be impacted.

The largest number of pools (in excess to 70), were mapped on Dog Trap Creek. For 40 of these pools, less than 20% of pools are expected to be impacted. For eighteen pools, less than 30% are expected to be impacted and for fourteen pools, less than 50% are expected to be impacted.

6.3 LOSS OF SURFACE FLOWS TO GROUNDWATER (BASEFLOW REDUCTION)

HydroSimulations (2020) 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 (2020) 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 6 below. The mean daily flow and baseflow rate, estimated using AWBM as described in the BA report (HEC, 2020a), is presented in comparison with the predicted maximum baseflow reduction.

Table 6 Summary of Predicted Effect of Maximum Baseflow Reductions on Average Flows

Stream/Site	Mean Daily Flow (ML/d)	Mean Daily Baseflow (ML/d)	Maximum Baseflow Reduction (ML/d)*	Maximum Reduction as % of Mean Daily Flow	Maximum Reduction as % of Mean Daily Baseflow
Bargo River, Site 13	30.1	4.73	0.051	0.17%	1.08%
Tea Tree Hollow, Site 22	6.7	3.90	0.027	0.40%	0.70%
Dog Trap Creek, Site 15	7.8	0.19	0.101	1.30%	51.9%
Eliza Creek, Site 18	1.5	0.29	0.001	0.06%	0.28%
Carters Creek, Site 23	3.3	0.08	0.002	0.05%	1.94%
Cow Creek (catchment extent)	2.6	0.52	0.018	0.69%	3.45%

* Per HydroSimulations (2020).

The maximum predicted reduction in flow is relatively small in terms of mean daily flow but represents a significant percentage (51.9%) of the average estimated baseflow at Dog Trap Creek, a small percentage at Cow Creek, Bargo River and Carters Creek (1.1% to 3.45%) and a low percentage at Tea Tree Hollow and Eliza Creek (less than 1%). The reduction in flow in Tea Tree Hollow would be offset by on-going licensed discharge from LDP1 (refer Section 6.1).

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[8] generated for the existing and maximum impact cases.

Figure 38 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).

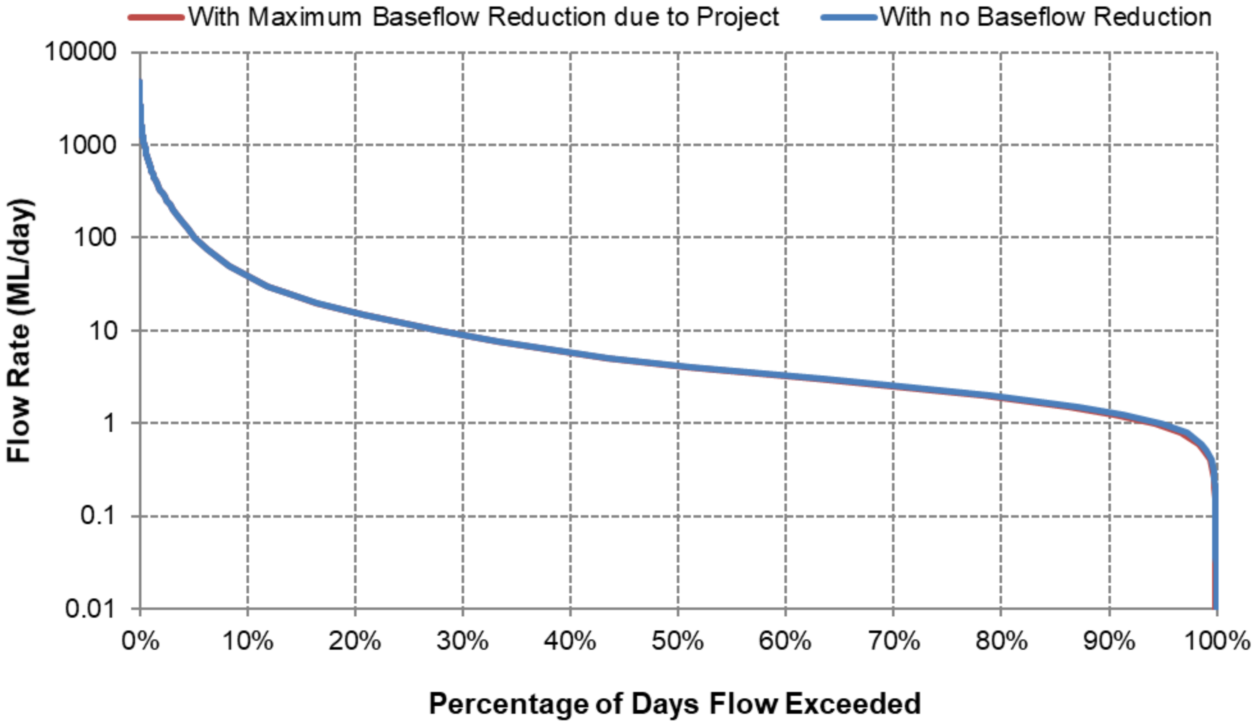


Figure 38 Flow Duration Curve – Bargo River Upstream (GS 300010a) with and without Maximum Baseflow Reduction due to the Project

Figure 38 shows that there is no apparent effect for flows greater than approximately 3 ML/day which occur on about 64% of days. The probability that flow would be greater than 1 ML/day would reduce from 95% to 94% of days. This level of change would be imperceptible and very small compared to natural variability in catchment conditions and is therefore considered to be negligible.

Figure 39 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).

8 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

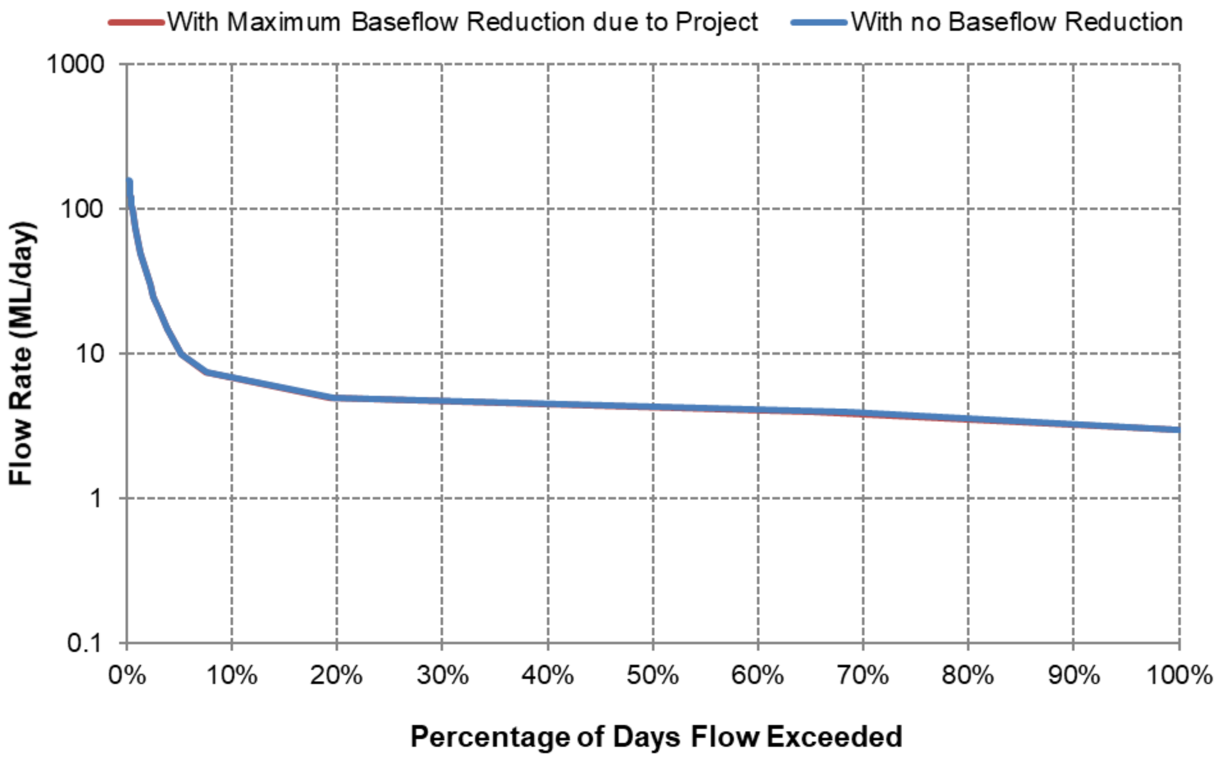


Figure 39 Flow Duration Curve – Tea Tree Hollow (GS 300056) with and without Maximum Baseflow Reduction due to the Project

Due to 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 (refer Section 6.6).

Figure 40 shows the maximum and long-term predicted impact of the baseflow reduction on flows in Dog Trap Creek at the downstream gauging station (GS 300063).

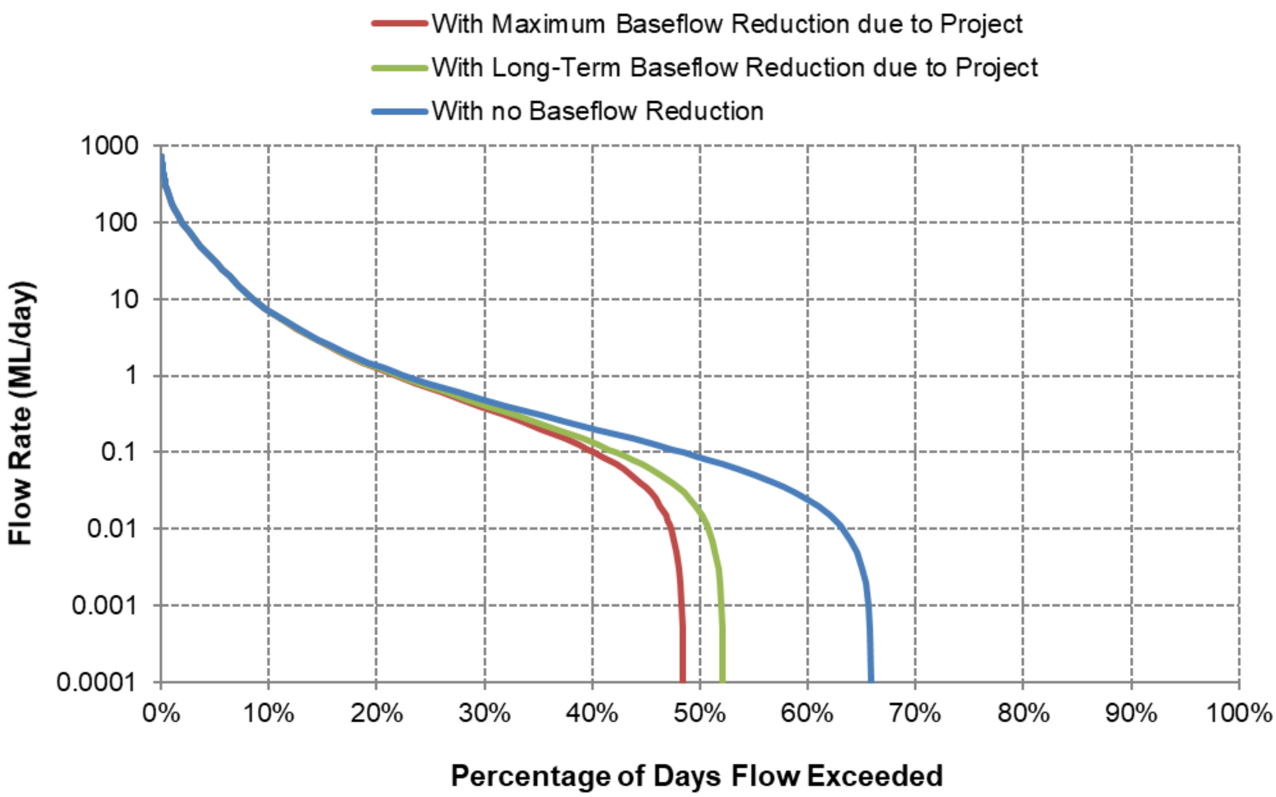


Figure 40 Flow Duration Curve – Dog Trap Creek (GS 300063) with and without Maximum and Long-Term Baseflow Reduction due to the Project

Figure 40 illustrates that there is no apparent effect for flows greater than approximately 1 ML/day. The largest effect is seen on flows below about 0.1 ML/day. The probability that flow would be greater than 0.1 ML/day would reduce from 48% to 40% of days based on the maximum predicted reduction in baseflow. This level of change would be detectable during normal periods of low flow and would likely be distinguishable from natural variability in catchment conditions.

In the long-term (greater than 100 years), the baseflow reduction is predicted to be 0.07 ML/d (HydroSimulations, 2020). The probability that flow would be greater than 0.1 ML/day would reduce from 48% to 42% of days based on the long-term predicted reduction in baseflow. This level of change would be detectable during normal periods of low flow and would likely be distinguishable from natural variability in catchment conditions.

Figure 41 shows the maximum predicted impact of the baseflow reduction due to the Project on flows in Carters Creek at the gauging station (GS 300076).

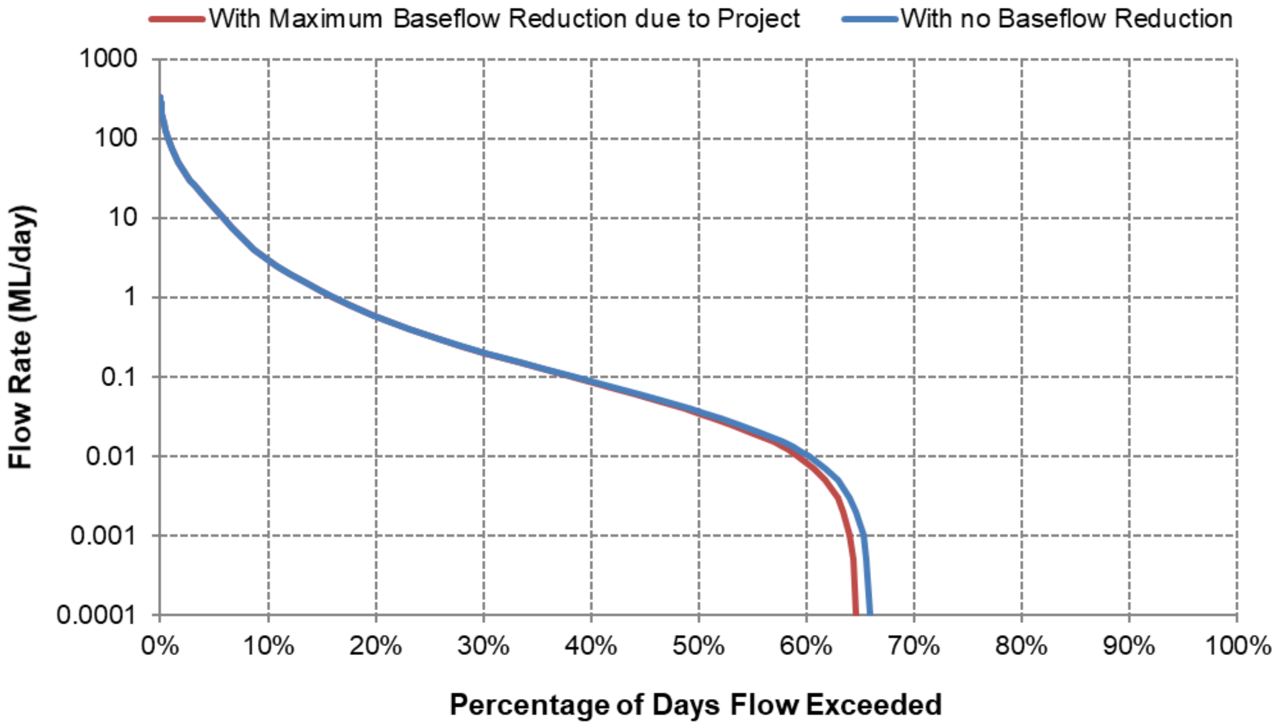


Figure 41 Flow Duration Curve – Carters Creek (GS 300076) with and without Maximum Baseflow Reduction due to the Project

Figure 41 illustrates that there is no apparent effect for flows greater than about 0.1 ML/day. The largest effect is seen on flows below about 0.01 ML/day. The probability that flow would be greater than 0.01 ML/day would reduce from 60% to about 59% of days. This level of change would be low compared to natural variability in catchment conditions.

Figure 42 shows the maximum predicted impact of the baseflow reduction on streamflow in Eliza Creek at the gauging station (GS 300073).

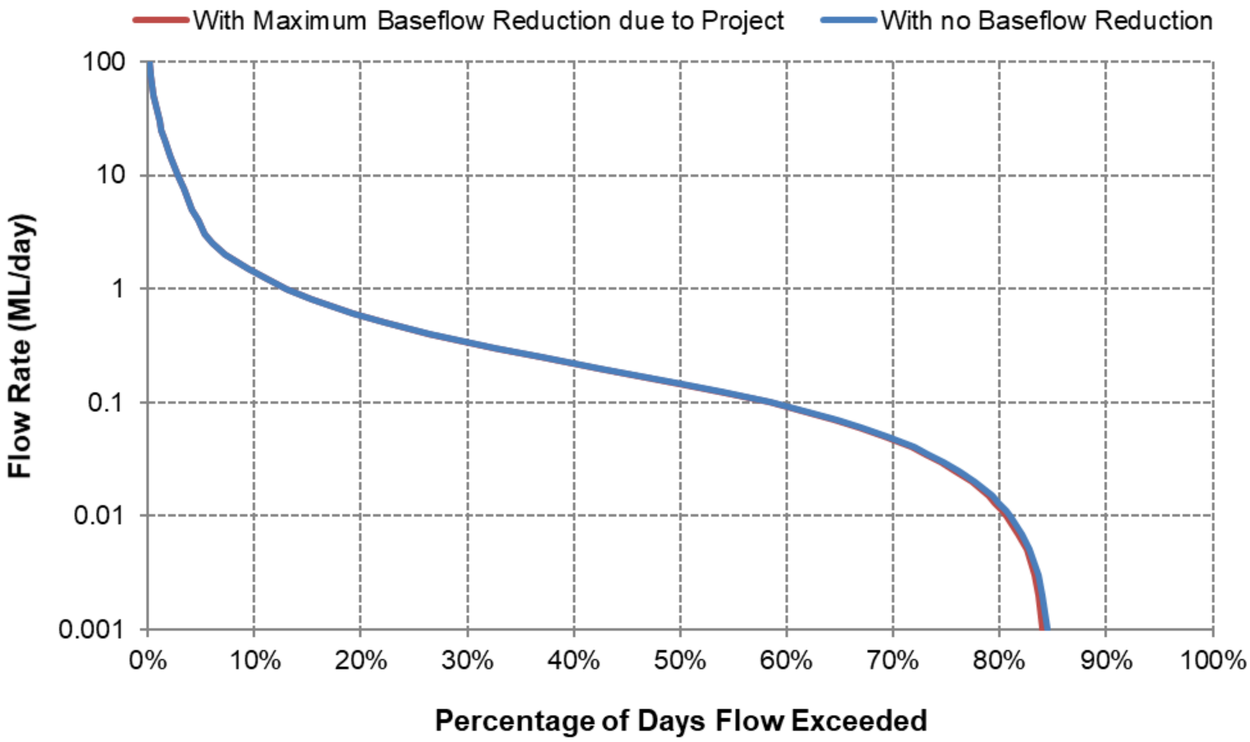


Figure 42 Flow Duration Curve – Eliza Creek (GS 300073) with and without Maximum Baseflow Reduction due to the Project

Figure 42 illustrates that there is no apparent effect for flows greater than about 0.05 ML/day. The largest effect is seen on flows below about 0.02 ML/day. The probability that flow would be greater than 0.02 ML/day would reduce from 78% to about 77% of days. This level of change would be imperceptible and very small compared to natural variability in catchment conditions.

Figure 43 shows the maximum and long-term predicted impact of the baseflow reduction on streamflow in Cow Creek at the gauging station (GS 300075).

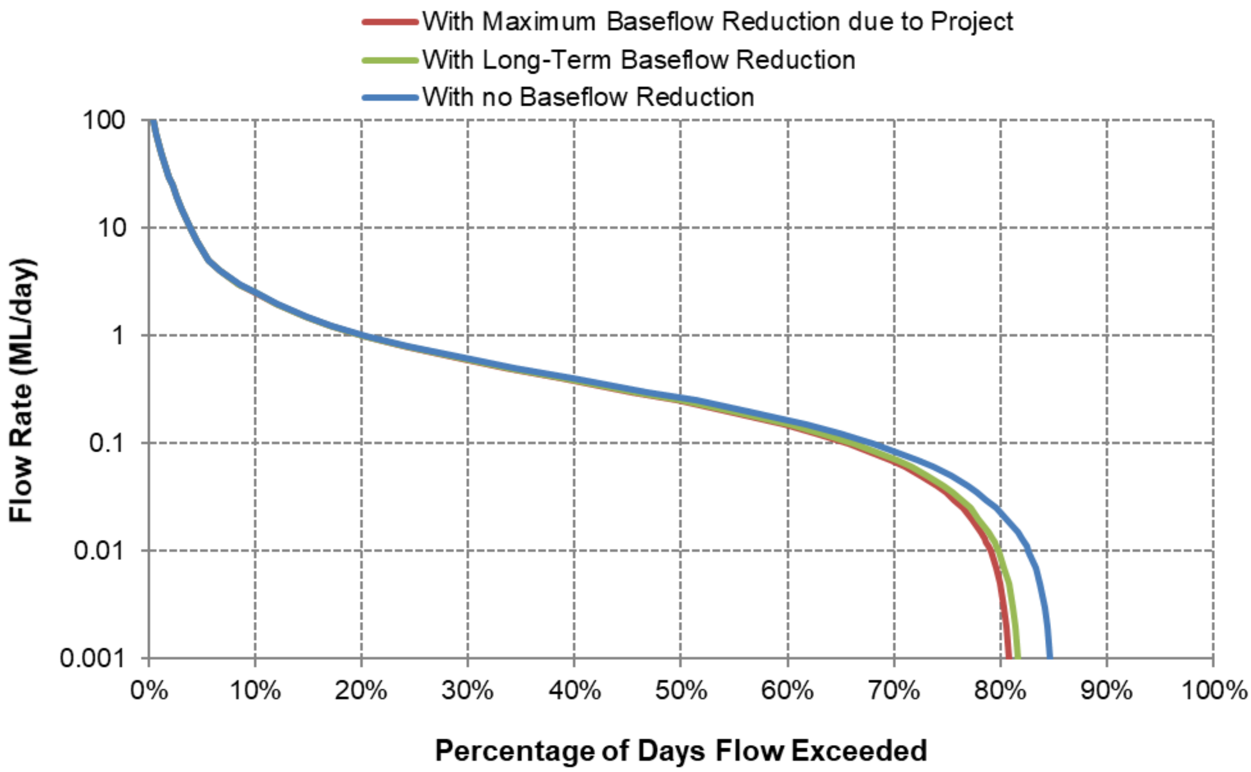


Figure 43 Flow Duration Curve – Cow Creek (Catchment Extent) with and without Maximum and Long-Term Baseflow Reduction due to the Project

Figure 43 illustrates that there is no apparent effect for flows greater than about 0.5 ML/day. The largest effect is seen on flows less than approximately 0.1 ML/day. The probability that flow would be greater than 0.01 ML/day would reduce from 83% to 79% of days based on the maximum predicted baseflow reduction. This level of change may be detectable during normal periods of low flow and distinguishable from natural variability in catchment conditions.

In the long-term (greater than 100 years), the baseflow reduction is predicted to be 0.014 ML/day (HydroSimulations, 2020). The probability that flow would be greater than 0.01 ML/day would reduce from 83% to 80% of days based on the long-term predicted baseflow reduction. This level of change may be detectable during normal periods of low flow and distinguishable from natural variability in catchment conditions.

Although the predicted baseflow reduction in Cow Creek, which is within the Metropolitan Special Area, may be detectable during normal periods of low flow, the combined effects of the Project, consumptive groundwater extraction and the effects of other existing mining projects are predicted to have a negligible impact on Sydney's water supply sources. Section 10.1 presents an assessment of the potential water supply impact in three management zones in the Upper Nepean River water source, namely Pheasants Nest Weir, Stonequarry Creek and Maldon Weir, based on the maximum and long-term predicted baseflow reduction due to the Amended Project and cumulative impacts. The assessment outcomes indicate that the predicted baseflow reductions are likely to have a negligible observable impact on mean daily flow at these locations.

6.4 POTENTIAL IMPACTS TO POOLS IN COW CREEK DUE TO BASEFLOW REDUCTION

The geomorphology assessment undertaken for the Project (Gippel, 2013) identified that a high percentage of the length of Cow Creek comprises of pools. To assess the potential impact of the predicted baseflow reduction on the pools within Cow Creek, a water balance assessment was undertaken for three pools of different lengths corresponding to the minimum, median and maximum of the recorded pool lengths. Table 7 summarises the dimensions of the three pools, as provided by Gippel (2013) – refer Figure 44.

Table 7 Cow Creek Pool Dimensions

Pool	Depth (m)	Width (m)	Length (m)	Estimated Volume (m^3)	Catchment Area (km^2)
CO1-1	0.5	4	5.5	5.5	0.9
CO2-1	1.2	8	17.5	84	2.3
CO3-1	1.1	6.6	80.5	292	4.0

Each pool was modelled independently, with the catchment yield (i.e. runoff plus baseflow) reporting to each pool estimated using the catchment model for Cow Creek detailed in the BA report (HEC, 2020a). Daily rainfall and pan evaporation data for use in the model was sourced from the SILO Data Drill for a location close to the Cow Creek catchment for the full 130 years of available data. Pool storage volume and surface area variation versus depth were estimated from the dimensions given in Table 7. Direct rainfall and evaporation were applied to the water surface area of the pool, with a pan factor[9] adopted to convert pan evaporation to open water evaporation. The maximum predicted baseflow reduction rate (refer Table 6) for the Cow Creek catchment was converted to a rate in ML/day per unit catchment area and applied to the pool catchment area. The reduction in catchment yield was estimated based on the predicted maximum baseflow reduction for the pool catchment.

[9] Monthly pan factors from values given in McMahon et al (2013).

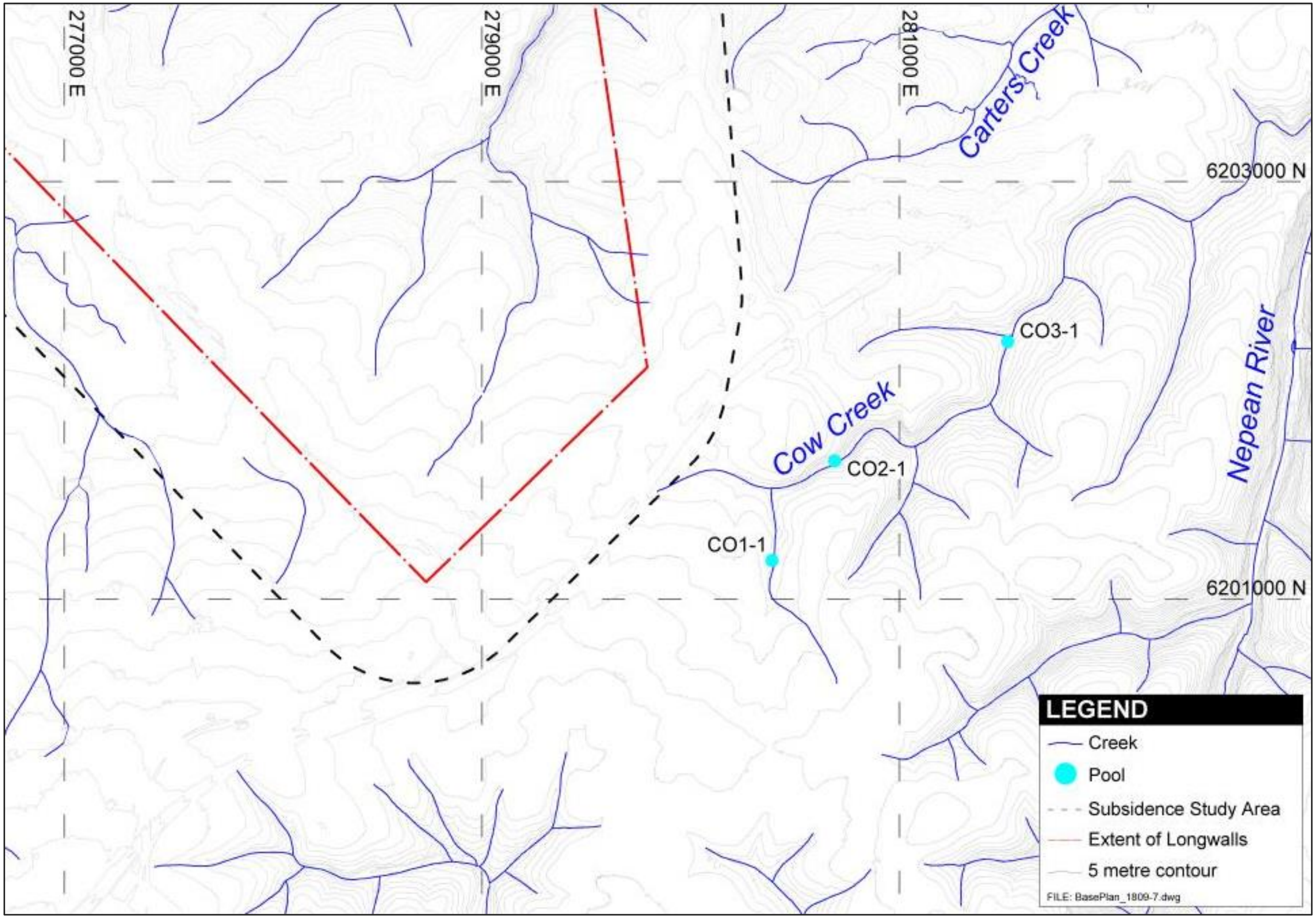


Figure 44 Cow Creek Modelled Pool Locations

Figure 45 presents the percentage of days (for the 130 year modelled period) in which different water levels in pool CO1-1 are predicted to be exceeded at present (with no baseflow reduction) and with the maximum predicted baseflow reduction due to the Project.

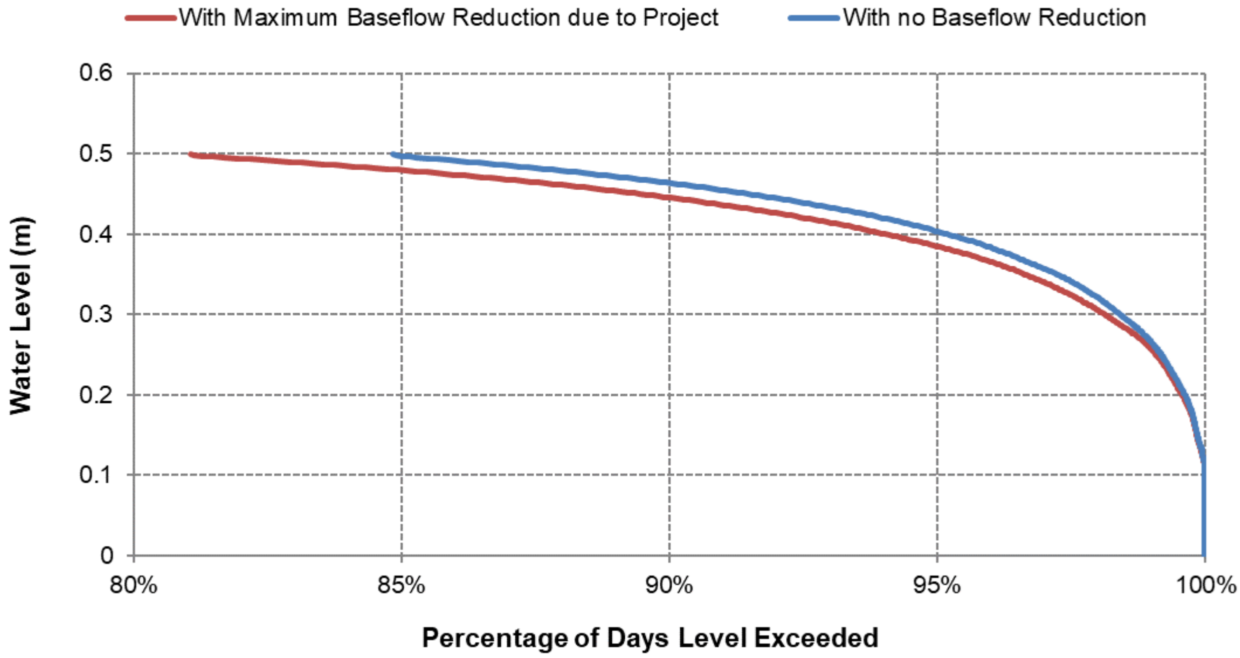


Figure 45 Cow Creek Pool (CO1-1) Predicted Water Level with and without Maximum Baseflow Reduction due to Project

Figure 45 illustrates that CO1-1 pool is predicted to currently be at capacity on more than 85% of days, declining to 81% of days due to the predicted maximum reduction in baseflow. The level of the pool is predicted to currently be greater than 0.27 m on 99% of days, reducing to 0.26 m due to the predicted maximum baseflow reduction. The maximum reduction in pool water level due to the predicted baseflow reduction is estimated to be 0.018 m.

Figure 46 presents the percentage of days (for the 130 year modelled period) in which the different water levels in pool CO2-1 are predicted to be exceeded at present (with no baseflow reduction) and with the maximum predicted baseflow reduction due to the Project.

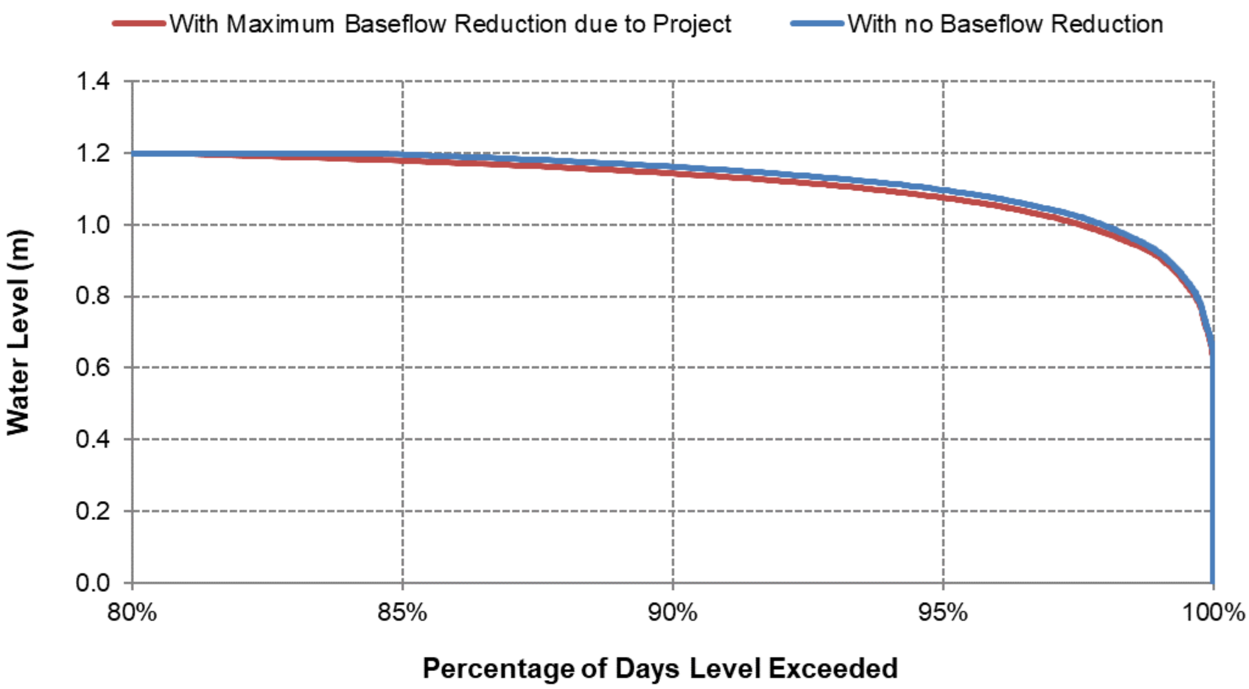


Figure 46 Cow Creek Pool (CO2-1) Predicted Water Level with and without Maximum Baseflow Reduction due to Project

Figure 46 illustrates that CO2-1 pool is predicted to currently be at capacity on more than 85% of days, declining to 81% of days due to the predicted maximum reduction in baseflow. The level of the pool is predicted to currently be greater than 0.71 m for 99% of days, reducing to 0.70 m due to the predicted maximum baseflow reduction. The maximum reduction in pool water level due to the predicted baseflow reduction is estimated at 0.021 m.

Figure 47 presents the percentage of days (for the 130 year modelled period) in which the different water levels in pool CO3-1 are predicted to be exceeded at present (with no baseflow reduction) and with the maximum predicted baseflow reduction due to the Project.

Figure 47 illustrates that CO3-1 pool is predicted to currently be at capacity on more than 83% of days, declining to 79% of days due to the predicted maximum reduction in baseflow. The level of the pool is predicted to currently be greater than 0.62 m for 99% of days, reducing to 0.61 m due to the predicted maximum baseflow reduction. The maximum reduction in pool water level due to the predicted baseflow reduction is estimated at 0.021 m.

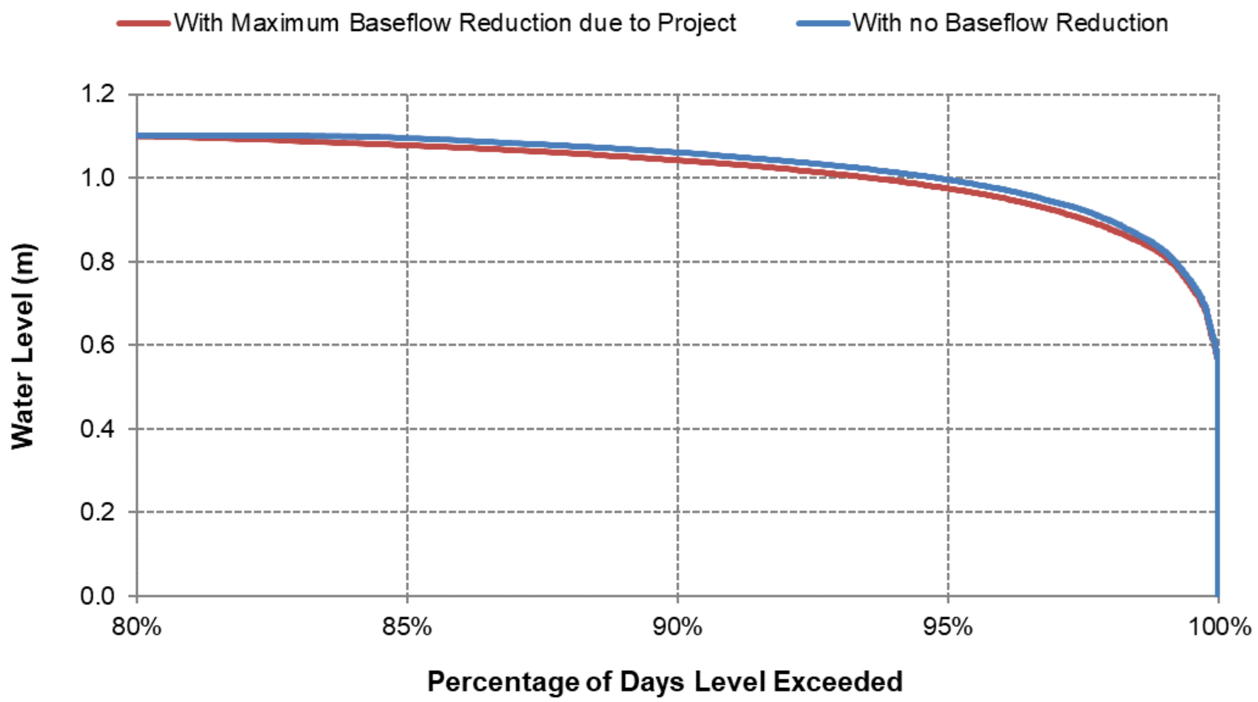


Figure 47 Cow Creek Pool (CO3-1) Predicted Water Level with and without Maximum Baseflow Reduction due to Project

The water balance assessment undertaken for the Cow Creek pools illustrates that the potential impact to pool water level due to the maximum predicted baseflow reduction is likely to be similar for varying pool sizes along Cow Creek. It should be noted that the pools have been modelled independently and the potential reduction in overflow from pool to pool and the effect of this on the pool water balance has not been assessed. Consequently, the assessment outcomes represent independent impacts to each pool as opposed to cumulative impacts along the length of Cow Creek.

Notwithstanding, the assessment outcomes indicate that the impact to pool water level due to the predicted baseflow reduction is likely to be imperceptible in comparison with natural variation in catchment conditions and is therefore considered to be negligible.

6.5 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 is only one location in which subsidence induced depressions may occur. As stated in Section 4.3, there is a predicted reversal of grade along a naturally flat section of Dog Trap Creek, upstream of the tailgate of LW103B, and as such there is increased potential for ponding to 150 m upstream of this location (MSEC, 2020). This may have a minor impact on flows downstream of this location. In the absence of any significant surface ponding created by subsidence, there should be no effect on flows in other local watercourses.

6.6 POTENTIAL IMPACTS TO WIRRIMBIRRA SANCTUARY

The Wirrimbirra Sanctuary is a heritage-listed fauna sanctuary, native plant nursery, education centre and flora sanctuary located within the Subsidence Study Area (refer Figure 48). A tributary of Tea Tree Hollow and a small portion of Tea Tree Hollow flow through the property.

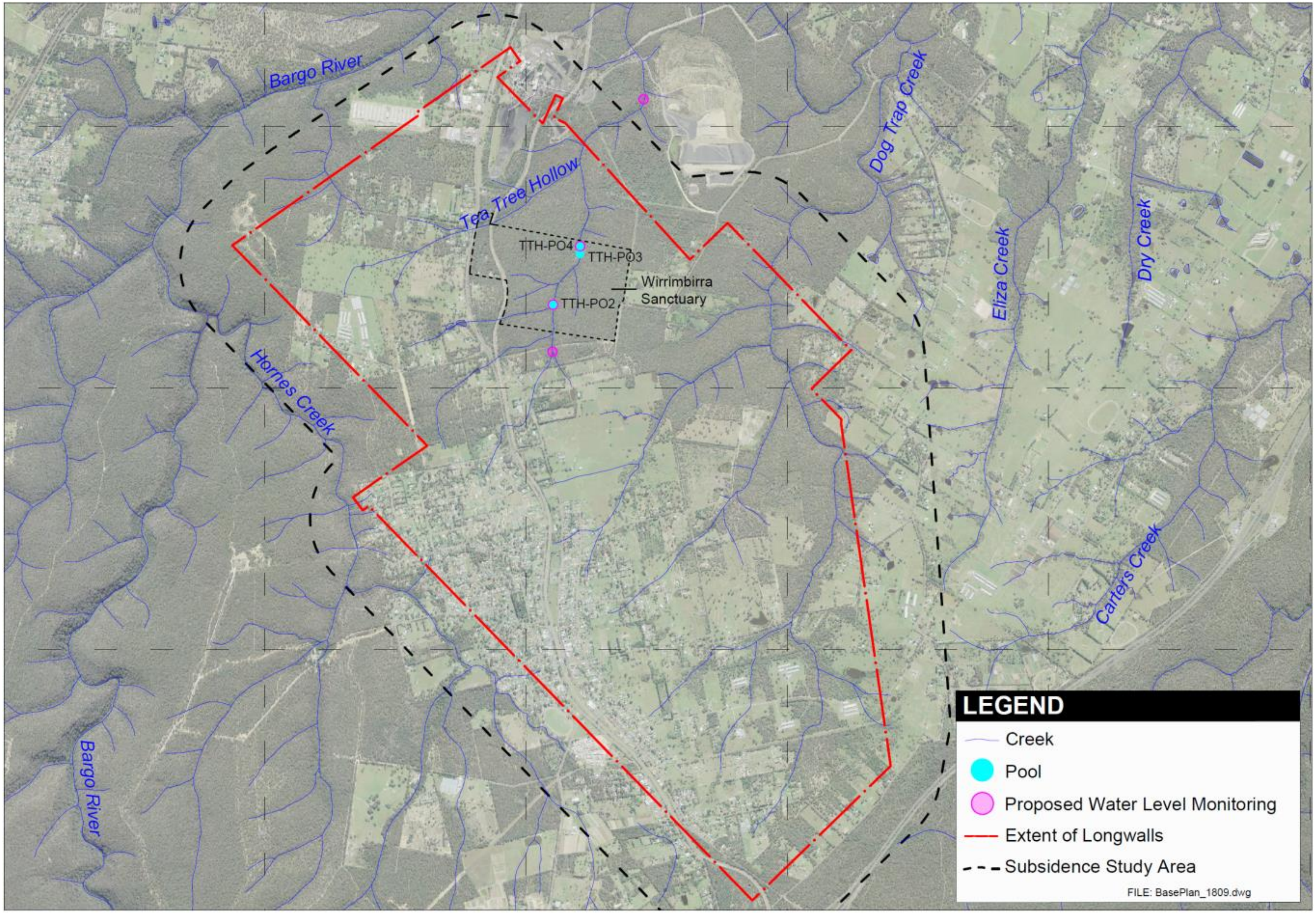


Figure 48 Wirrimbirra Sanctuary and Tea Tree Hollow Tributary Pools

Three pools have been identified on the Tea Tree Hollow tributary within Wirrimbirra Sanctuary – TTH-PO2, TTH-PO3, TTHPO4 as shown in Figure 48. Subsidence predictions for the pools on the Tea Tree Hollow Tributary have been provided by MSEC (2020) and are presented in Table 8.

Table 8 Subsidence Predictions for Tea Tree Hollow Tributary

Pool	Predicted Total Subsidence after all Longwalls (mm)	Predicted Total Upsidence after all Longwalls (mm)	Predicted Total Closure after all Longwalls (mm)
TTH-PO2	950	225	200
TTH-PO3	1000	300	300
TTH-PO4	850	300	325

Based on the rock bar impact model for the Southern Coalfield detailed in Section 6.2, while there is a chance that TTH-PO2 may be impacted if subsidence occurs, it is unlikely as less than 10% of pools are expected to be impacted at this level of predicted total closure. The predicted total closure after all longwalls is 300 mm at TTH-PO3 and 325 mm at TTH-PO4. As such, there is a moderate chance that pools TTH-PO3 or TTH-PO4 may be impacted (30% of rock bars or upstream pools are expected to be impacted at this level of predicted total closure).

HydroSimulations (2020) have predicted a maximum baseflow reduction rate of 0.016 ML/d for Tea Tree Hollow and the tributary of Tea Tree Hollow at the northern boundary of Wirrimbirra Sanctuary. Flow generated from the catchment to this location has been estimated based on the Eliza Creek catchment model (refer HEC, 2020a). The relevant modelled flow statistics of Tea Tree Hollow at Wirrimbirra Sanctuary are summarised in Table 9.

Table 9 Baseline Flow Statistics –Tea Tree Hollow (GS 300056)

Statistic	Value
Mean Daily Flow (ML/d)	1.21
Mean Daily Baseflow (ML/d)	0.24
Maximum Baseflow Reduction (ML/d)	0.016
Maximum Reduction as % of Mean Daily Flow	1.3%
Maximum Reduction as % of Mean Daily Baseflow	6.6%

Figure 49 shows the maximum predicted impact of the predicted baseflow reduction on streamflow in Tea Tree Hollow at the northern boundary of Wirrimibirra Sanctuary.

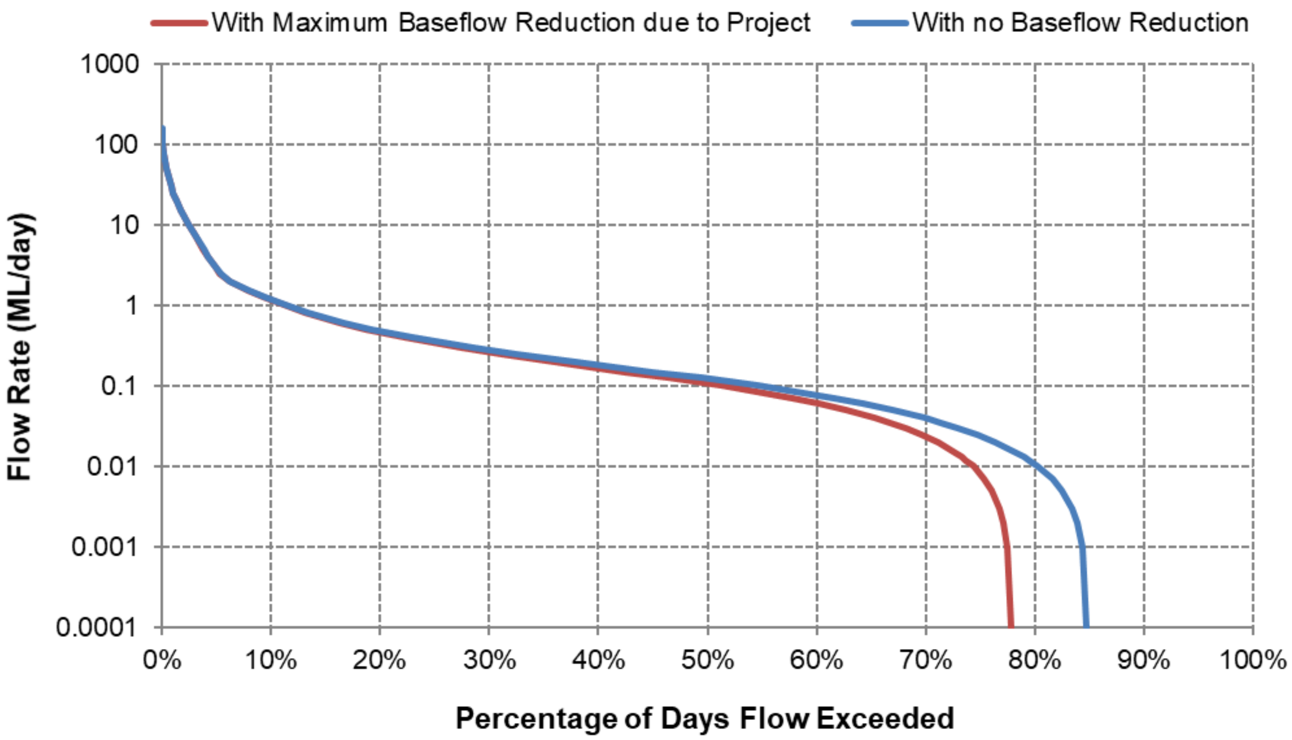


Figure 49 Flow Duration Curve – Tea Tree Hollow Tributary at Wirrimbirra Sanctuary with and without Maximum Baseflow Reduction due to the Project

Figure 49 illustrates that there is no apparent effect for flows greater than about 0.5 ML/day. The largest effect is seen on flows below approximately 0.01 ML/d. The probability that flow would be greater than 0.01 ML/day would reduce from 80% to 74% of days. This level of change may be detectable during normal periods of low flow and distinguishable from natural variability in catchment conditions.

Water level monitoring is proposed to be conducted upstream and downstream of Wirrimbirra Sanctuary and at TTH-PO2 and TTH-PO4, as shown in Figure 48. The proposed pool level monitoring will complement stream flow monitoring undertaken on Tea Tree Hollow downstream of the Wirrimbirra Sanctuary. The monitoring network would enable assessment of any changes in pool water level and streamflow in Tea Tree Hollow as a result of the Project. Should impacts be identified, a Trigger Action Response Plan (TARP) will be implemented comprising management and remediation measures (refer Section 12.5).

6.7 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 currently discharges treated water to Tea Tree Hollow in accordance with EPL 1389. The water balance modelling undertaken for the Amended Project (HEC, 2020b) indicates that discharge via LDP1 is predicted to average 2,029 ML/annum for much of the Amended Project life. This equates to approximately 5.6 ML/day on average for the Amended Project as opposed to 4.6 ML/day predicted for the EIS (HEC, 2018b). The volumetric discharge limit from LDP1 permitted by EPL 1389 is 15.5 ML/day. As such, the discharge via LDP1 predicted for the Amended Project is well below the discharge limit specified in EPL 1389.

Discharge via the LOPs to Tea Tree Hollow is predicted to average 115 ML/annum based on the Amended Project. The simulated annual release to Tea Tree Hollow from proposed dam S12 is predicted to average 13 ML/annum equating to a total predicted average discharge of 128 ML/annum to Tea Tree Hollow due to the Amended Project. This is less than the maximum discharge via the LOPs to Tea Tree Hollow recorded in 2016 of 187 ML/annum.

The simulated annual release to Bargo River from proposed dam S11 is predicted to average 4.5 ML/annum or 0.01 ML/day. Given that the mean daily flow rate in Bargo River at Site 13 is 30.1 ML/day (refer Table 6), an average release rate of 0.01 ML/day represents an inconsequential volume that would likely be indistinguishable from natural variability in catchment conditions.

7.0 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, 2018).

7.1 SURFACE CHARACTERISTICS

The Thirlmere Lakes are a series of five interconnected Lakes (in order from most upstream to downstream): Gandangarra, Werri Berri, Couridjah, Baraba and Nerrigorang (refer Figure 50). 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 50).

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 50).

The Lakes themselves generally comprise dense fringing vegetation around their perimeter (near top water level) with sedges and grasses within the inundation area (refer Photo 3). 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 Photo 4).

Photo 3 Lake Gandangarra Looking West (January 2012)

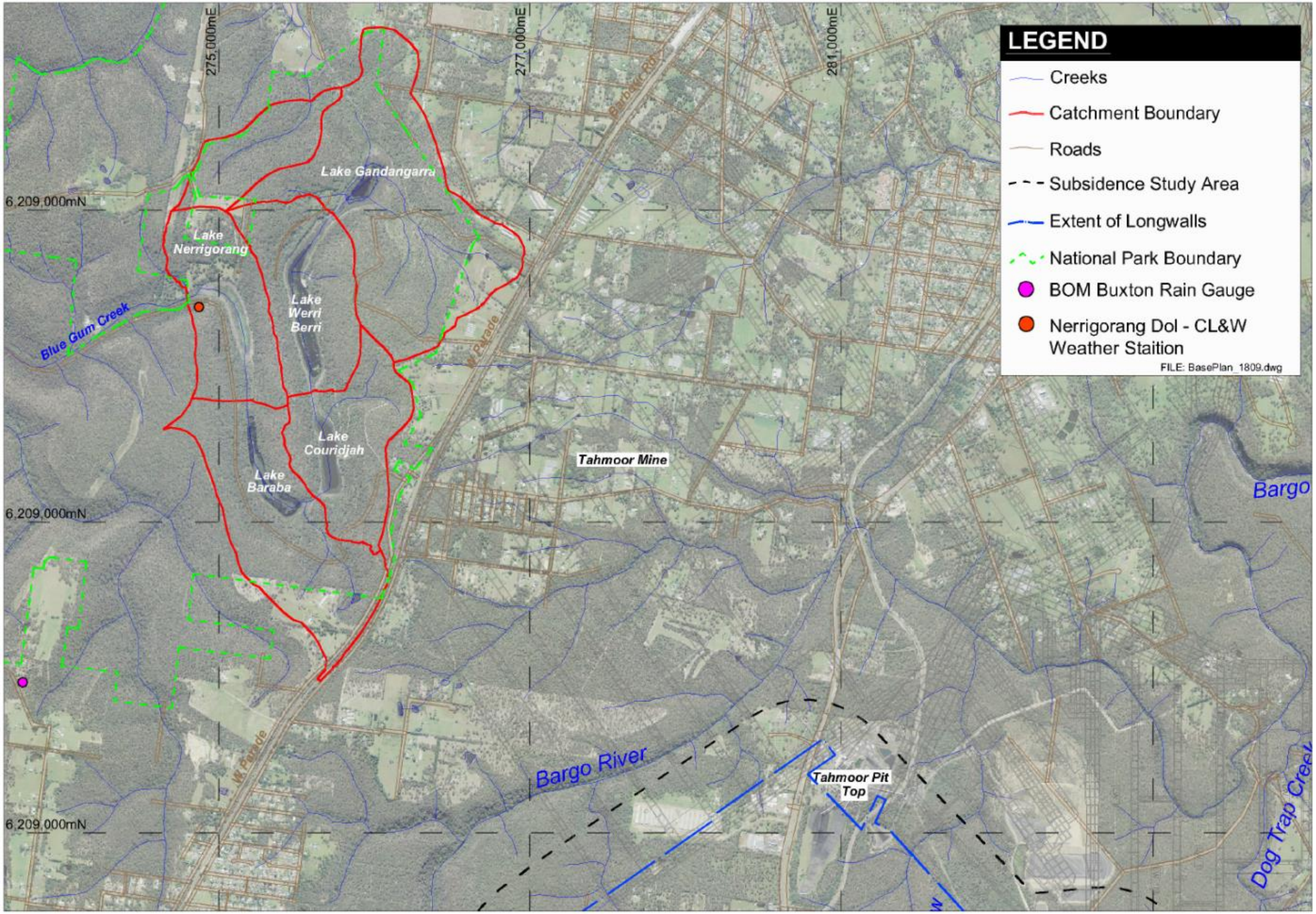


Figure 50 Thirlmere Lakes Area - Plan

Photo 4 Lake Couridjah Looking North (January 2012)

The catchment area of Lake Gandangarra has been estimated as totalling 1.96 km^2 – using 0.5 m interval topographic contours provided by Tahmoor Coal (checked against a 1 m digital elevation model sourced from NSW Government – Spatial Services). The estimated catchment area boundaries of all the lakes are shown in Figure 50. A separate catchment is delineated north of Lake Nerrigorang and west of Lake Gandangarra. This catchment reports to a small dam located on a topographic saddle north of Lake Gandangarra. A site inspection of the small dam was undertaken by Tahmoor Coal and the direction of discharge from this dam was unable to be discerned. On the basis of the available 0.5 m interval topographic contours, it appears most likely that this dam discharges to the south. For the purposes of modelling, the separate catchment was assumed to contribute to Lake Gandangarra (i.e. the dam was assumed to discharge to the south). The individual estimated lake catchment areas are given in[10] Table 10 and shown on Figure 50.

[10] Estimated from topographic contours derived from LiDAR survey undertaken in February 2013.

Table 10 Thirlmere Lakes Catchment Areas

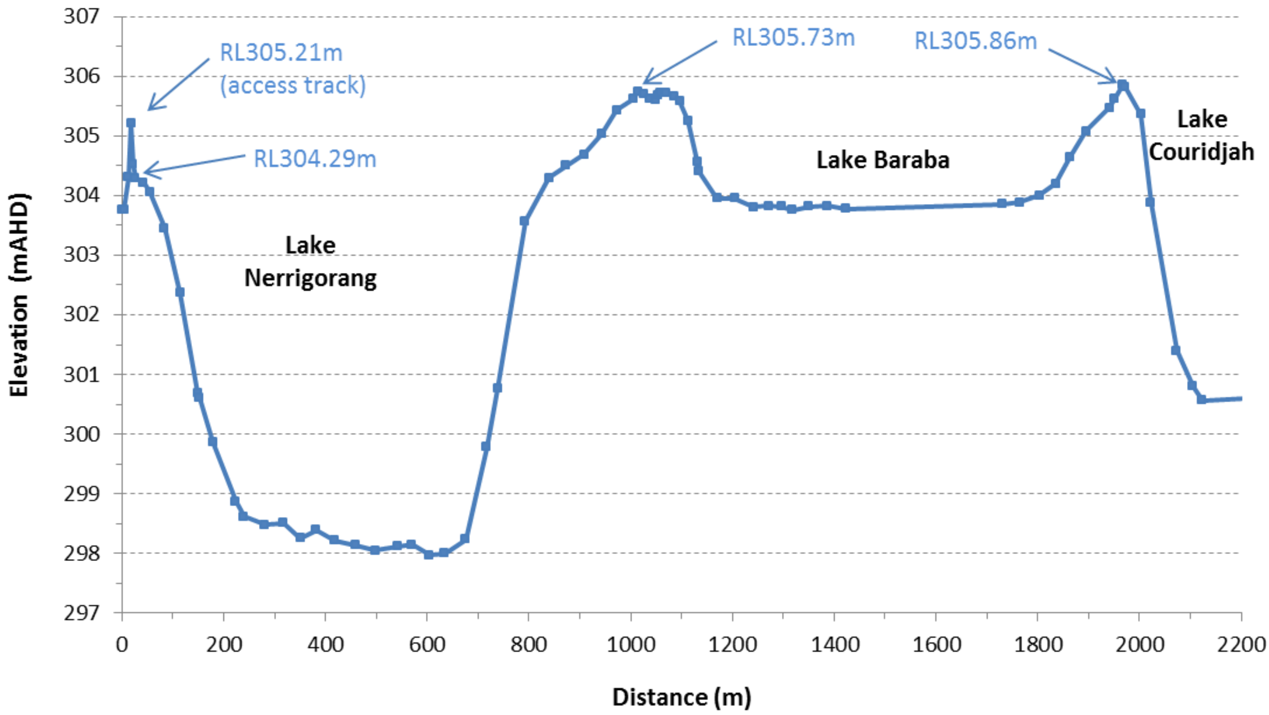
Lake	Catchment Area (km^2)	Lake Full Surface Area (km^2)	Catchment:Surface Area Ratio
Gandangarra	1.96	0.12	16.3
Werri Berri	0.70	0.16	4.4
Couridjah	0.66	0.09	7.3
Baraba	1.03	0.08	12.9
Nerrigorang	0.65	0.08	8.1
TOTAL	5.00	0.53	9.4

Terrestrial surveys of the Lakes were undertaken in 2012 (at a time of low Lake levels – refer Plates 3 and 4) 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 10. 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).

The 2012 survey was unable to determine the lowest lake levels in the most upstream three lakes (i.e. Lakes Gandangarra, Werri Berri and Couridjah) because these lakes contained water and mud at their lowermost points, preventing access for terrestrial survey. This should not significantly affect estimates of lake capacities and water balance behaviour.

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 51. The estimated capacity of the three combined Lakes to their overflow level at 305.86 m AHD is 1,158 ML.

Note that the longitudinal sections do not necessarily show the lowest point in each lake. As outlined above the lowest point in the most upstream three lakes could not be reached, while for Lake Baraba, the surveyed lowest point was located close to the eastern shore line.



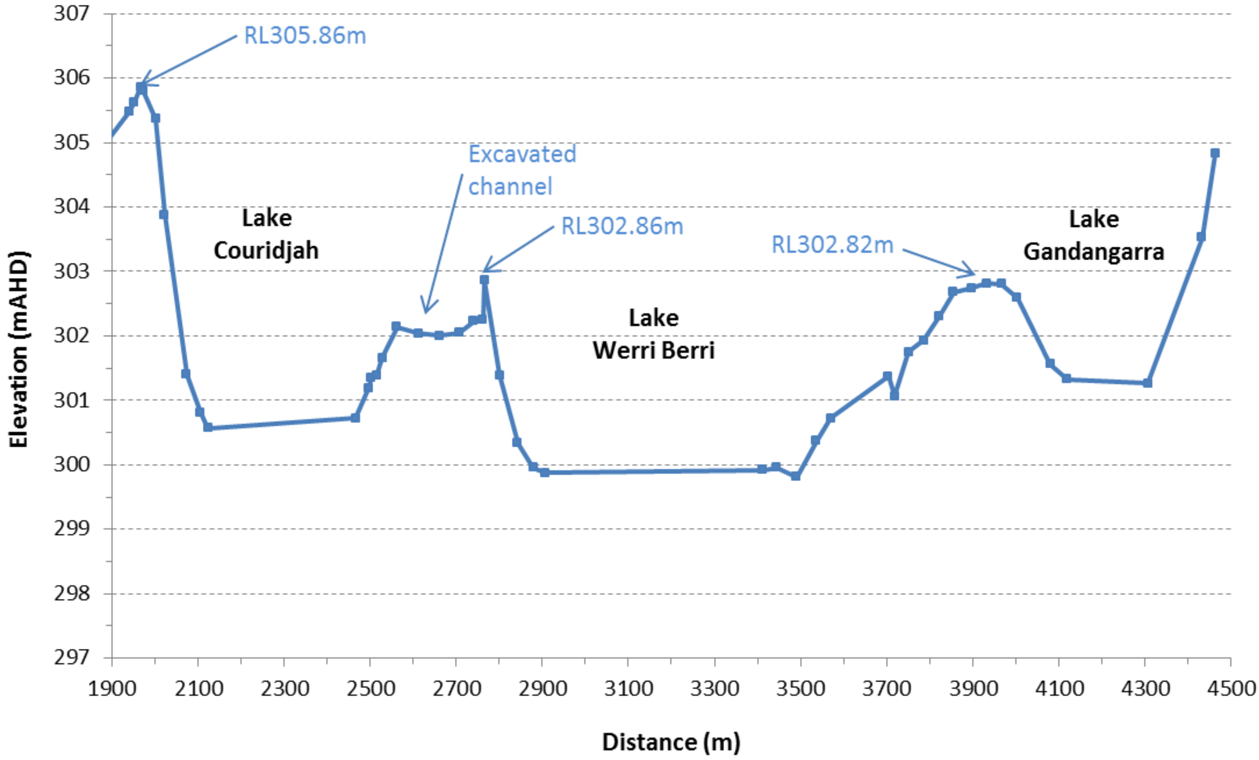


Figure 51 Lake Longitudinal Sections

Lake Baraba has an overflow level just lower than the inflow level from Lake Couridjah (refer Figure 51). 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 51). 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.

7.2 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 (2018) and used to assess the impact of the Project.

7.3 WATER BALANCE MODELLING

7.3.1 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.:

$$\textit{Change in Storage} = \textit{Inflow} - \textit{Outflow}$$

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.

7.3.2 Model Components and Data

7.3.2.1 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 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 50), 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.

7.3.2.2 Catchment Runoff Simulation

Catchment runoff was simulated using the AWBM (refer HEC [2020a]). AWBM parameters were initially estimated from model calibrations for nearby gauged streams and adjusted as part of model calibration (refer Section 7.3.3).

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[11] BoM Station 68166.

7.3.2.3 Lake Storage Characteristics, Evaporation and Evapotranspiration

Surface storage characteristics (Lake level versus volume and area) were derived from the available topographic survey (refer Section 7.1). 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 52, 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 52 shows that the two sets of data are reasonably close. The calculated pan factors were used in the water balance model.

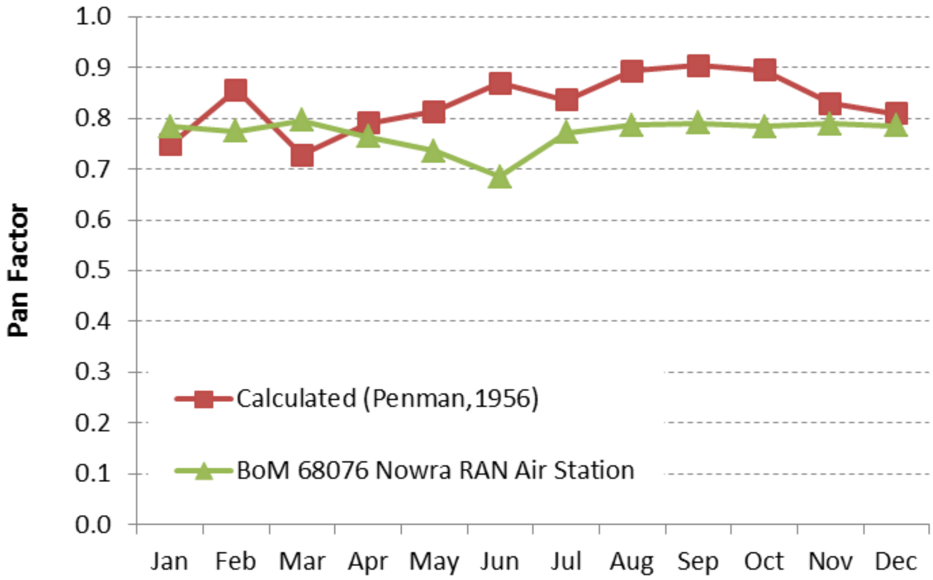

Figure 52 Monthly Evaporation Pan Factors

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 53). Calculation of sub-surface storage volume assumed a porosity of 0.25 for the alluvium (consistent with Pells, 2011).

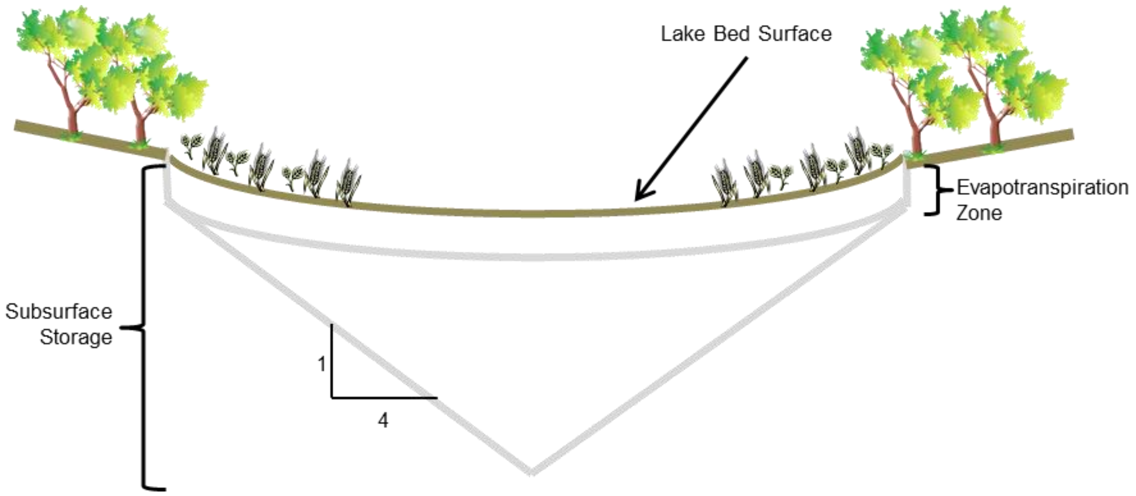

Figure 53 Conceptual Sub-Surface Lake Storage

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 53. 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.

7.3.2.4 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 7.1). 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).

7.3.2.5 Groundwater Recharge from Lakes

Deep groundwater (bedrock) recharge rates from the Lakes were estimated by HydroSimulations (2018) 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 11 and Table 12.

Table 11 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 12 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 (2018) but rather included to improve model calibration.

7.3.2.6 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.

7.3.3 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.

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 54.

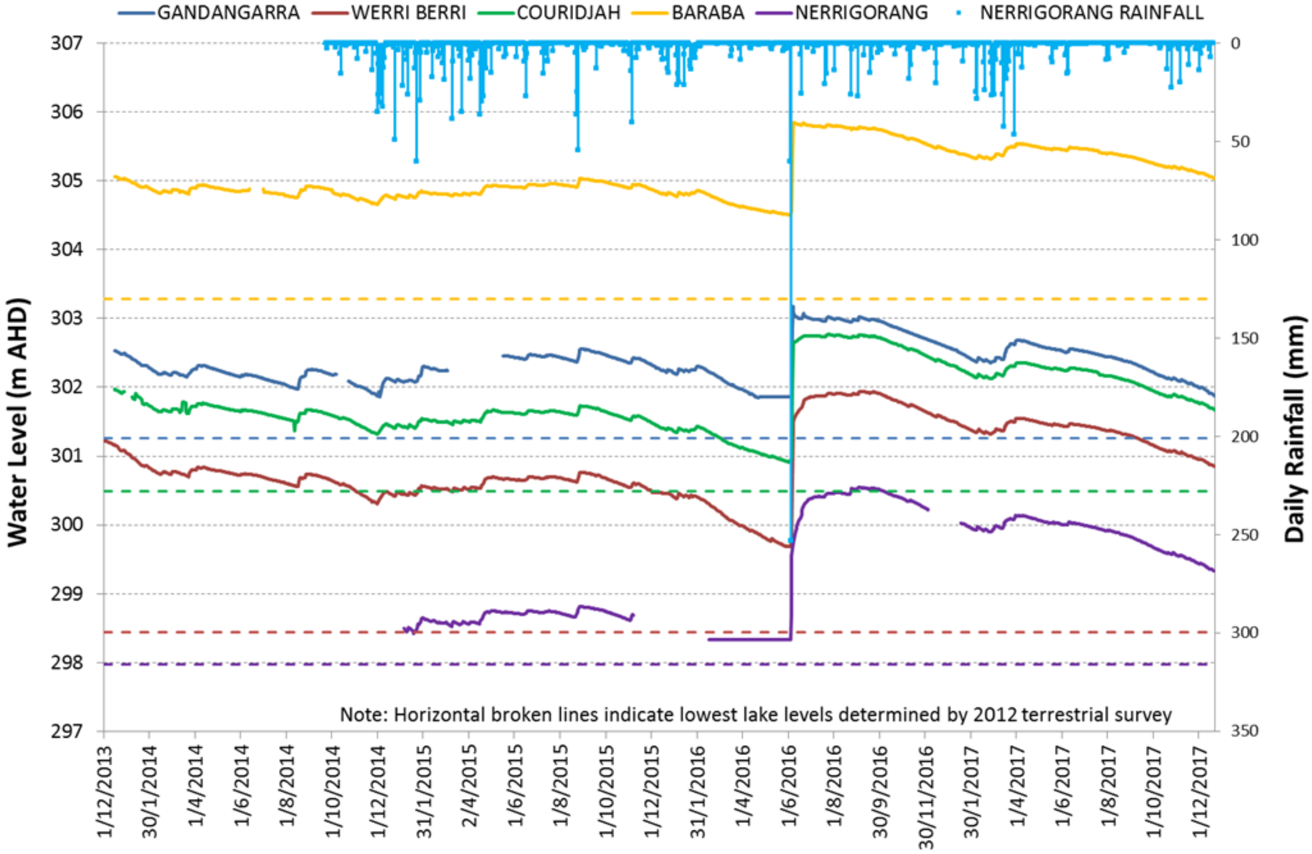

Figure 54 Recorded Lake Water Levels

Also plotted on Figure 54 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 7.3.3) 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 11.

Comparisons between estimated actual Lake water volume (from monitored levels and storage characteristics) and modelled volumes are shown in Figure 55 to Figure 59 for the individual Lakes. A similar plot of the total Lake water volume is given in Figure 60.

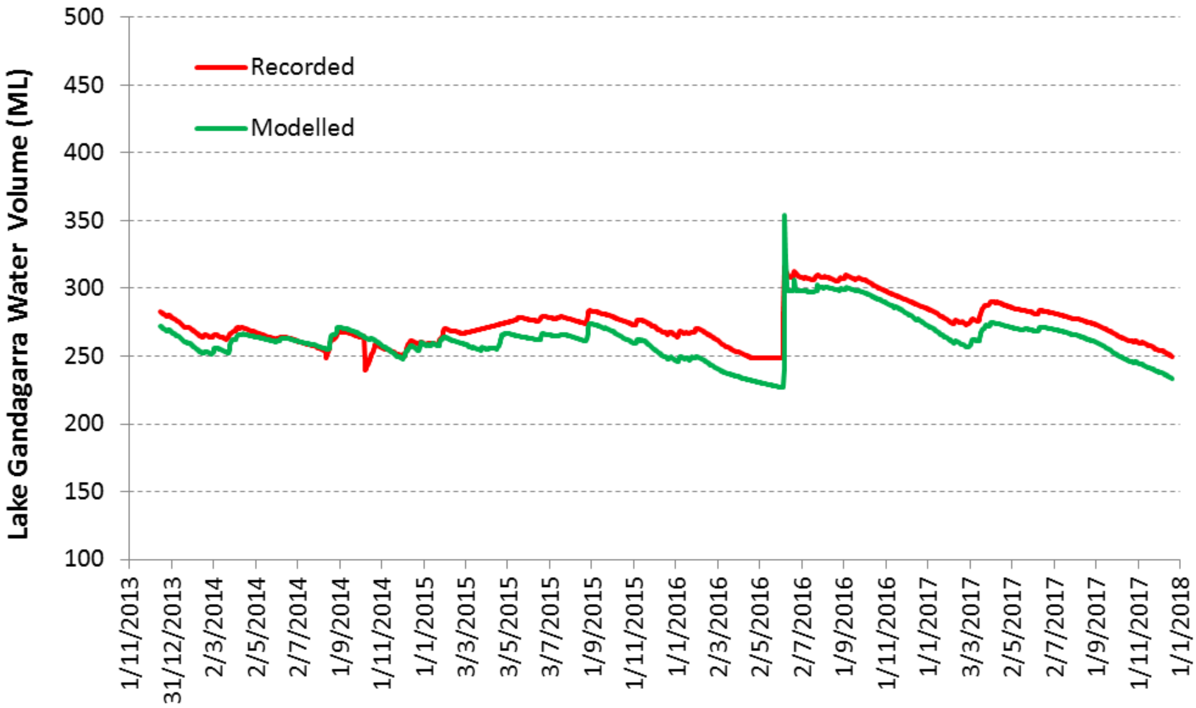

Figure 55 Calibrated Model and Estimated Actual Water Volume – Lake Gandangarra

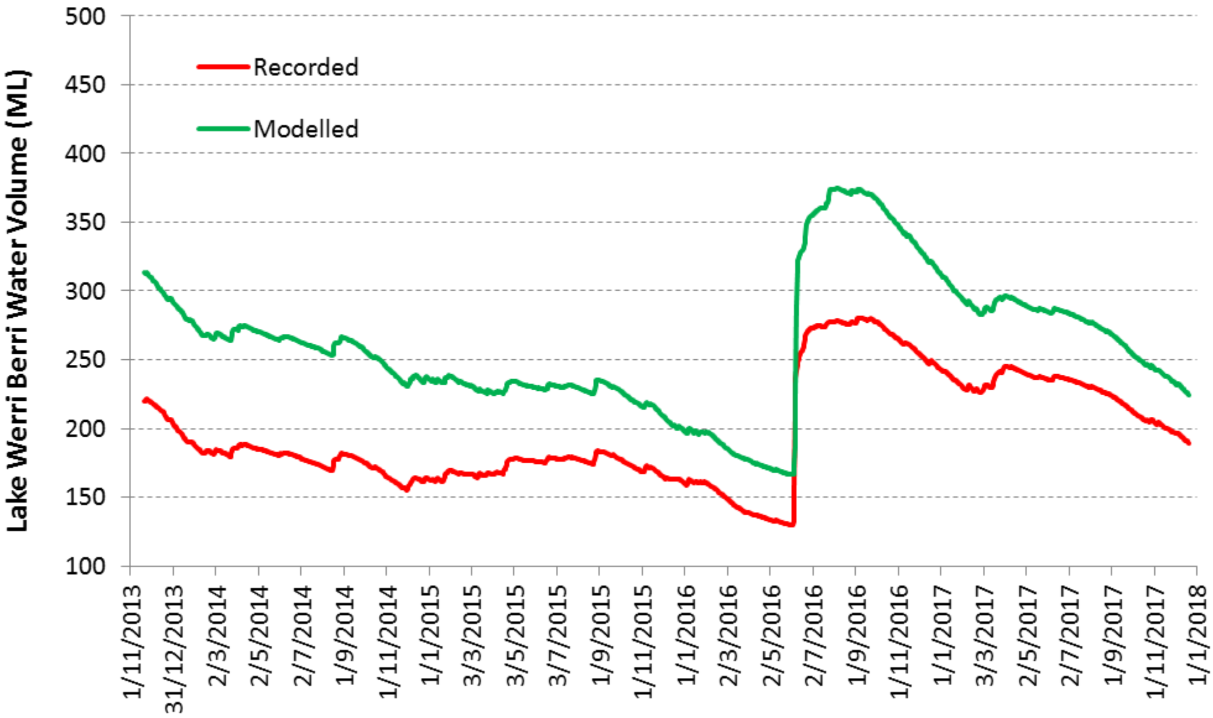

Figure 56 Calibrated Model and Estimated Actual Water Volume – Lake Werri Berri

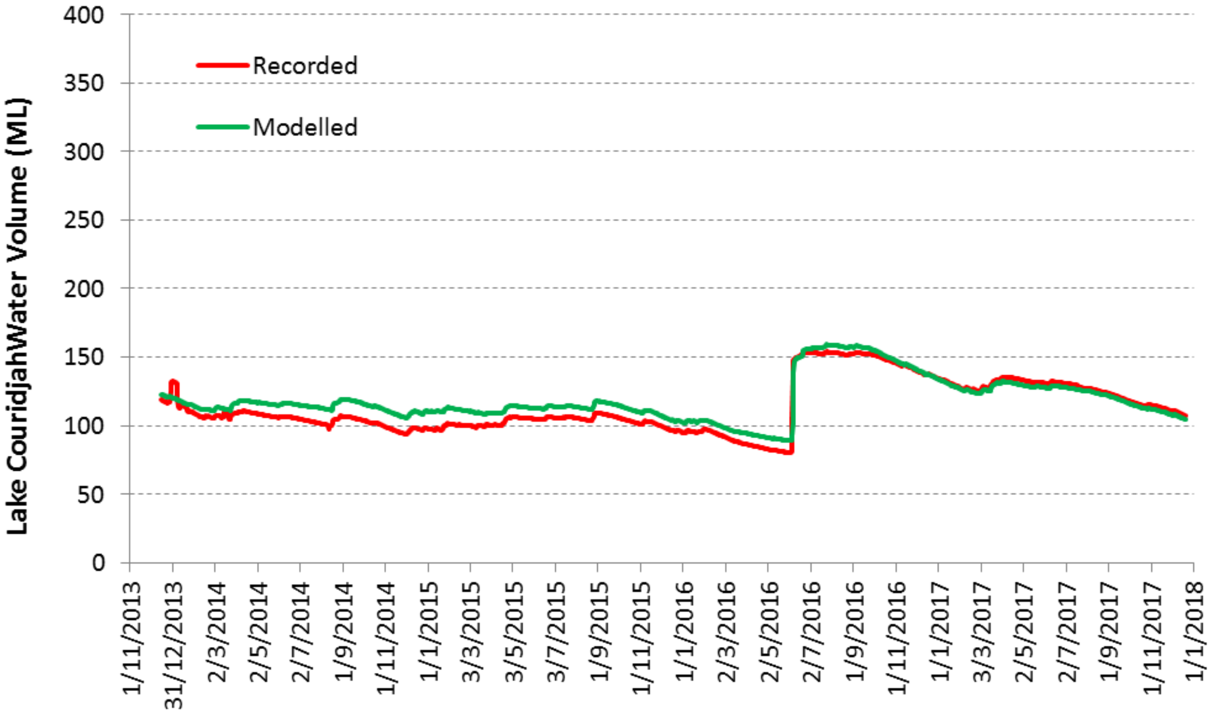

Figure 57 Calibrated Model and Estimated Actual Water Volume – Lake Couridjah

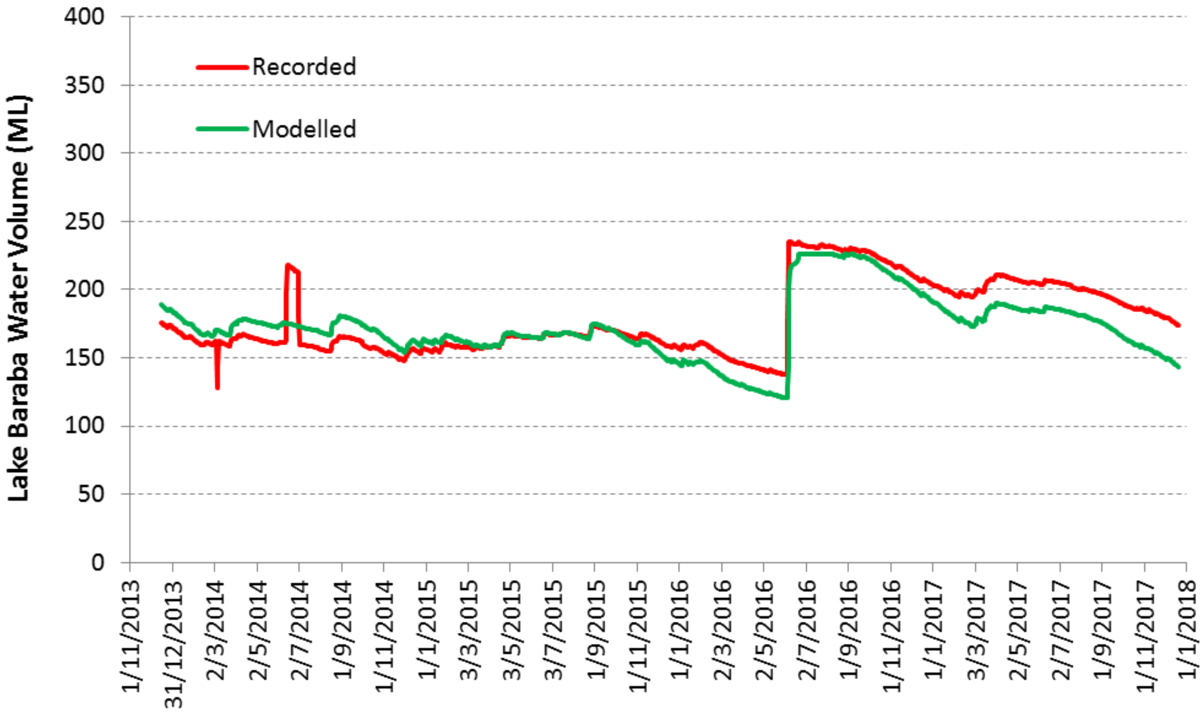

Figure 58 Calibrated Model and Estimated Actual Water Volume – Lake Baraba

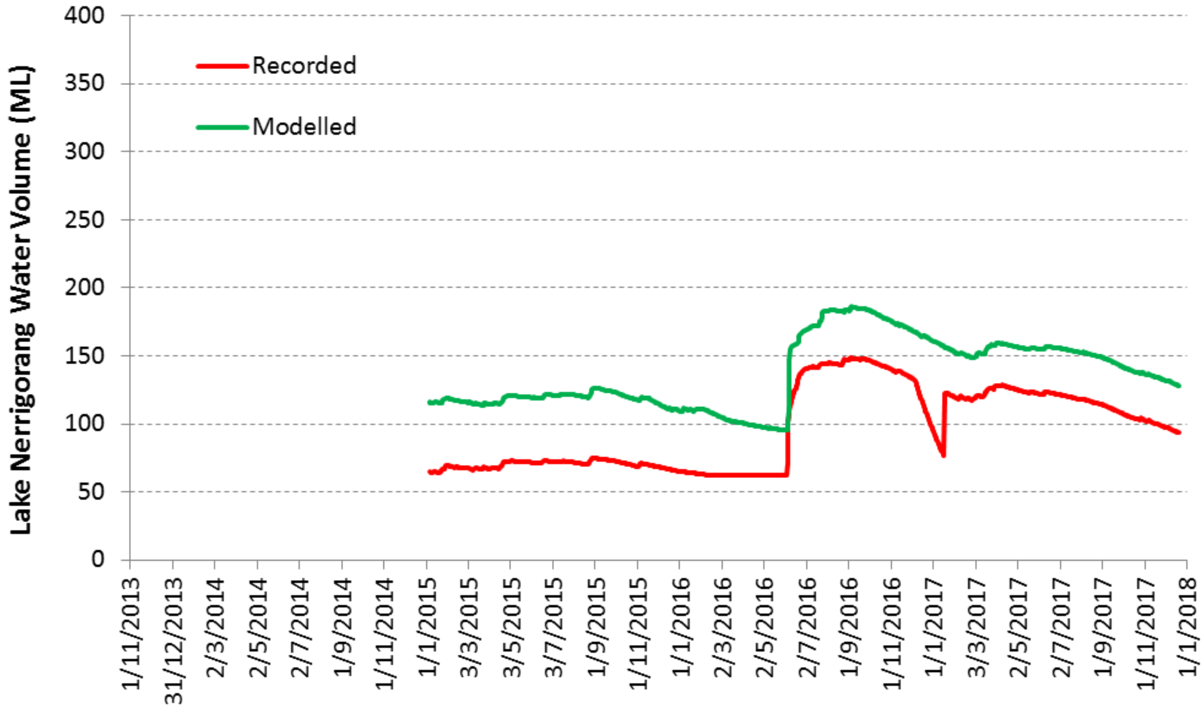

Figure 59 Calibrated Model and Estimated Actual Water Volume – Lake Nerrigorang

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.

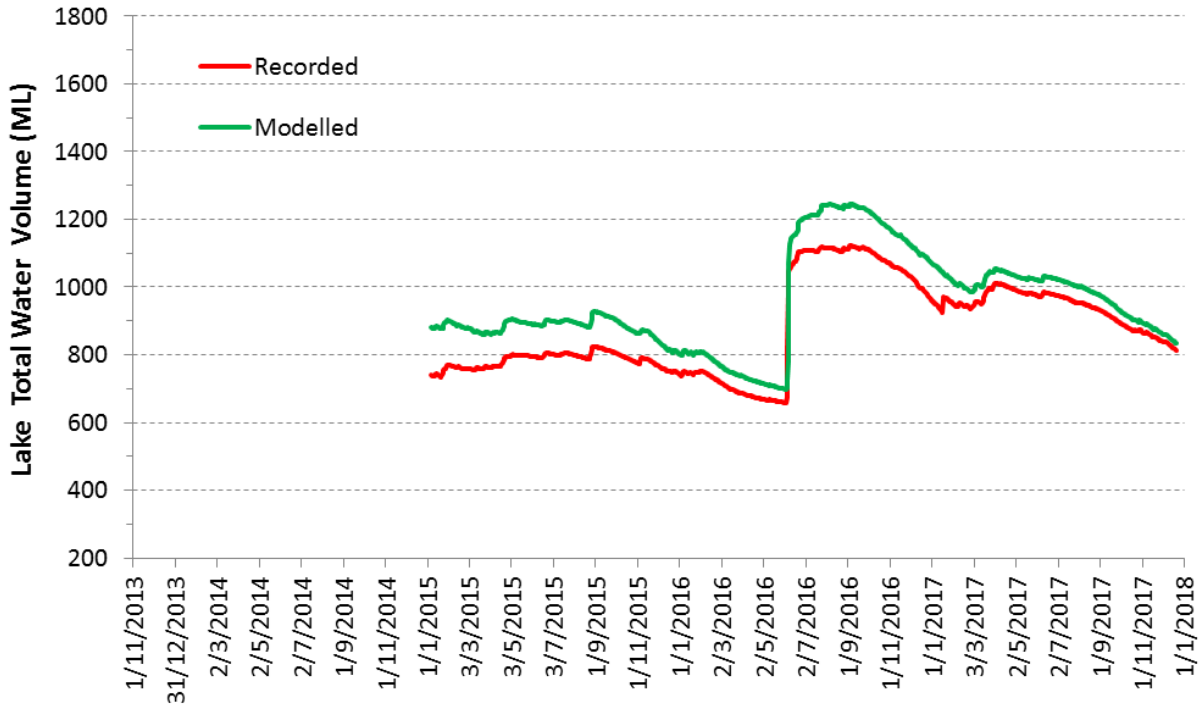

Figure 60 Calibrated Model and Estimated Actual Total Lake Water Volume

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.

7.3.4 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 11 (existing) and Table 12 (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 13.

Table 13 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 (2018) 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.

8.0 PREDICTION OF IMPACTS TO THE HYDRAULICS AND STABILITY OF WATERCOURSES

8.1 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™ (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.

8.1.1 Dog Trap Creek

There are three main arms to Dog Trap Creek in the upper and middle reaches overlying proposed LW101 to LW107 and LW109. The simulated flow velocities for a peak 50% AEP flow for the pre-subsidence condition are shown in Figure 61 and Figure 62. 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 velocities were about 3 m/s peaking at approximately 4.5 m/s in isolated areas.

[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.

Figure 63 and Figure 64 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 104B and 106B. Relatively smaller increases in velocity (0.25 to 0.3 m/s) were predicted in areas overlying LW 101B and 105B.

The simulated bed shear stress distribution under peak 50% AEP flow for the pre-subsidence and post-subsidence scenarios are shown in Figure 65, Figure 66, Figure 67 and Figure 68. 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 101B, 102B and LW 104B where simulated bed shear stresses were generally below 50 Pascals (Pa).

The change to bed shear stress evident between the pre-subsidence and post-subsidence scenarios is shown in Figure 69 and Figure 70. 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 more than 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 8.1.3.

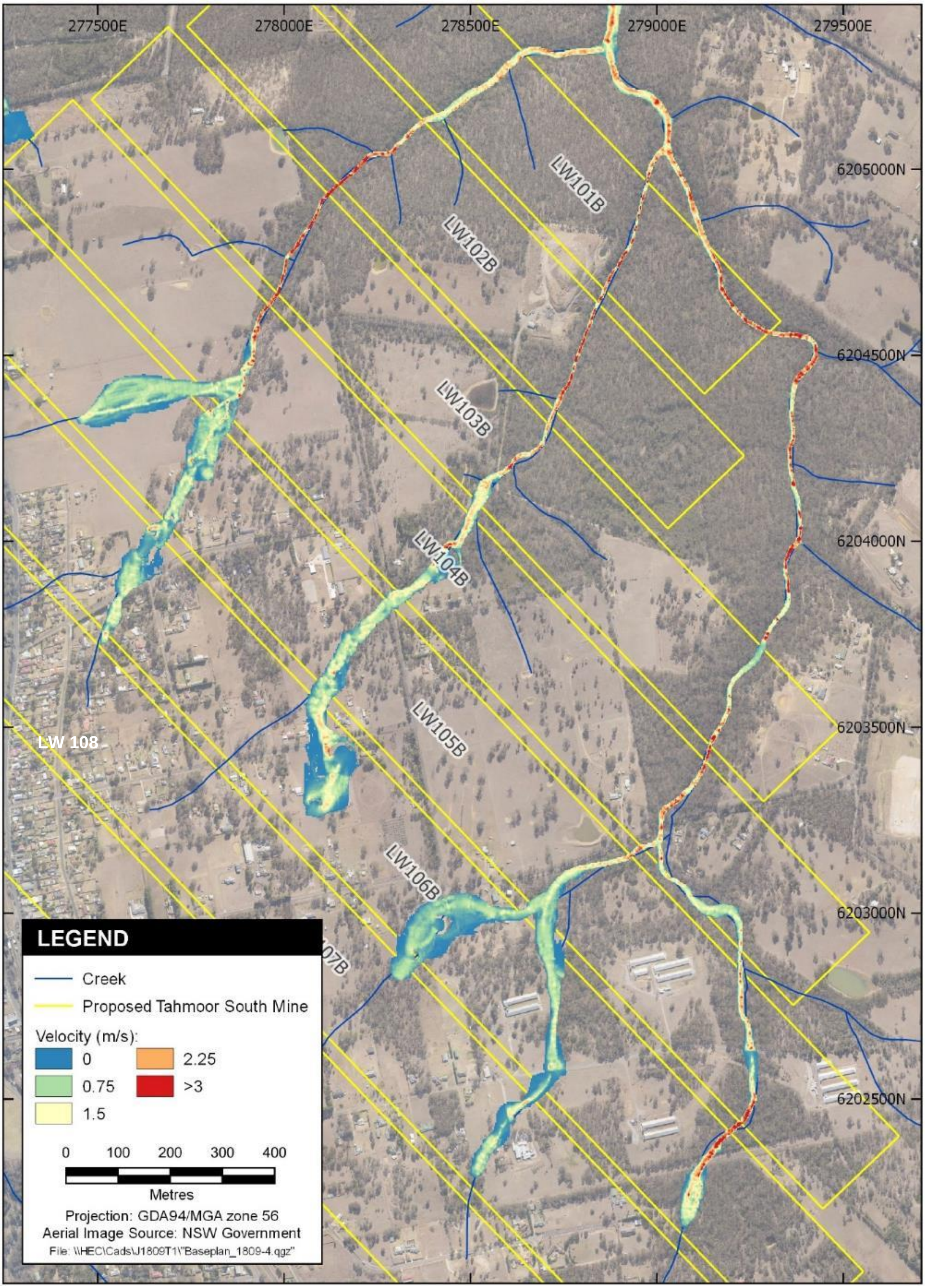

Figure 61 Pre-Subsidence Maximum Flow Velocity – Dog Trap Creek (Upstream) 50% AEP Event

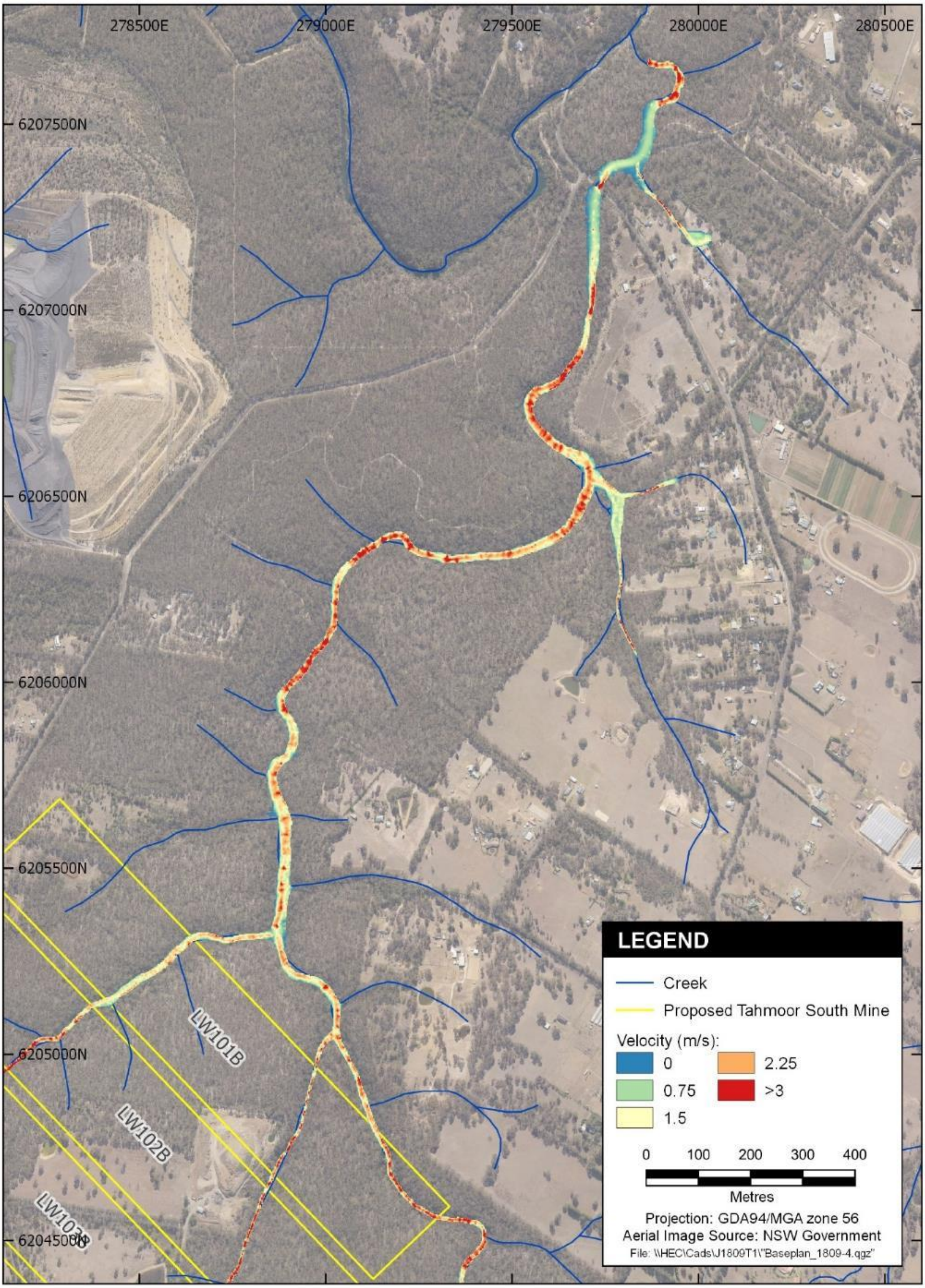

Figure 62 Pre-Subsidence Maximum Flow Velocity – Dog Trap Creek (Downstream) 50% AEP Event

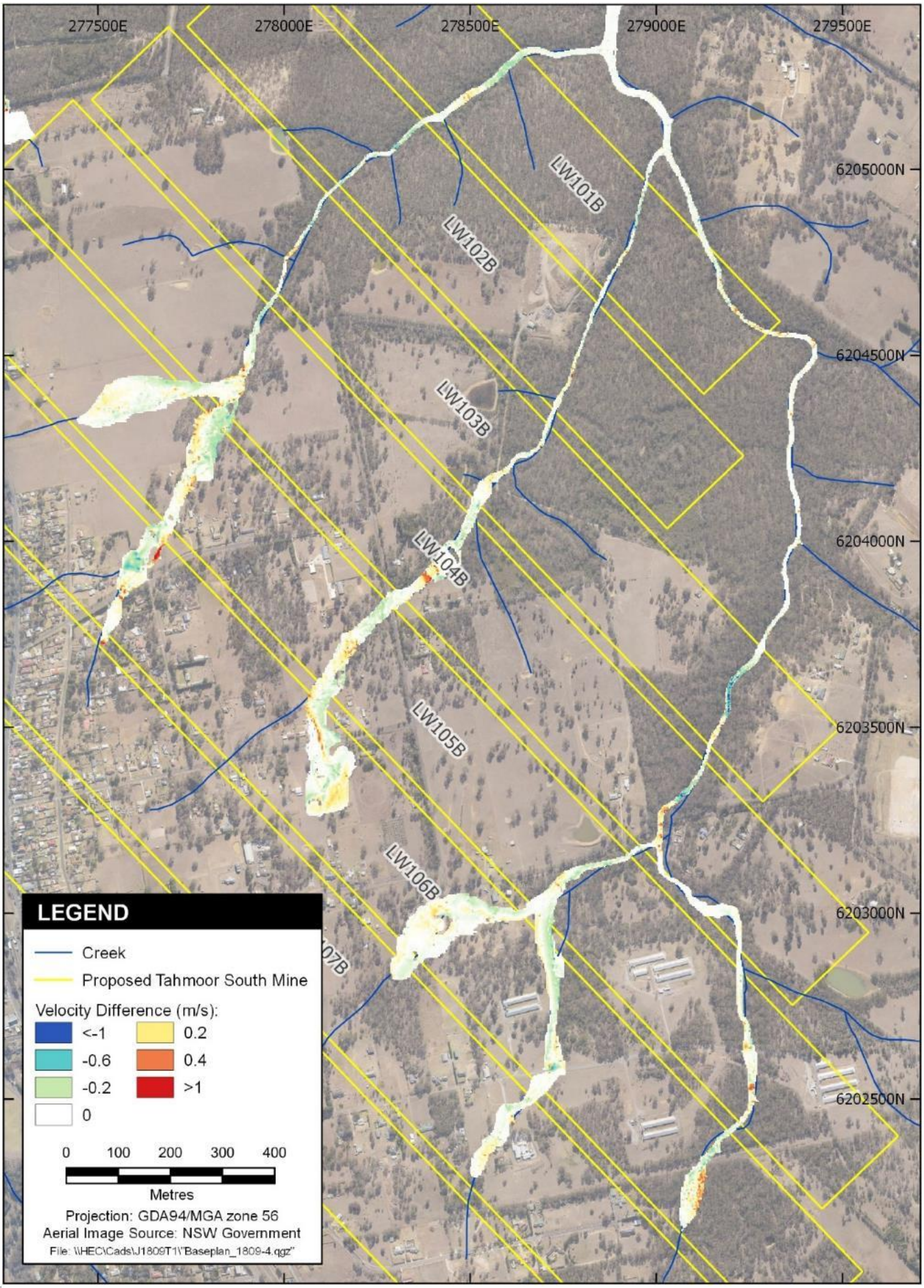

Figure 63 Change in Flow Velocity – Dog Trap Creek (upstream) 50% AEP Event

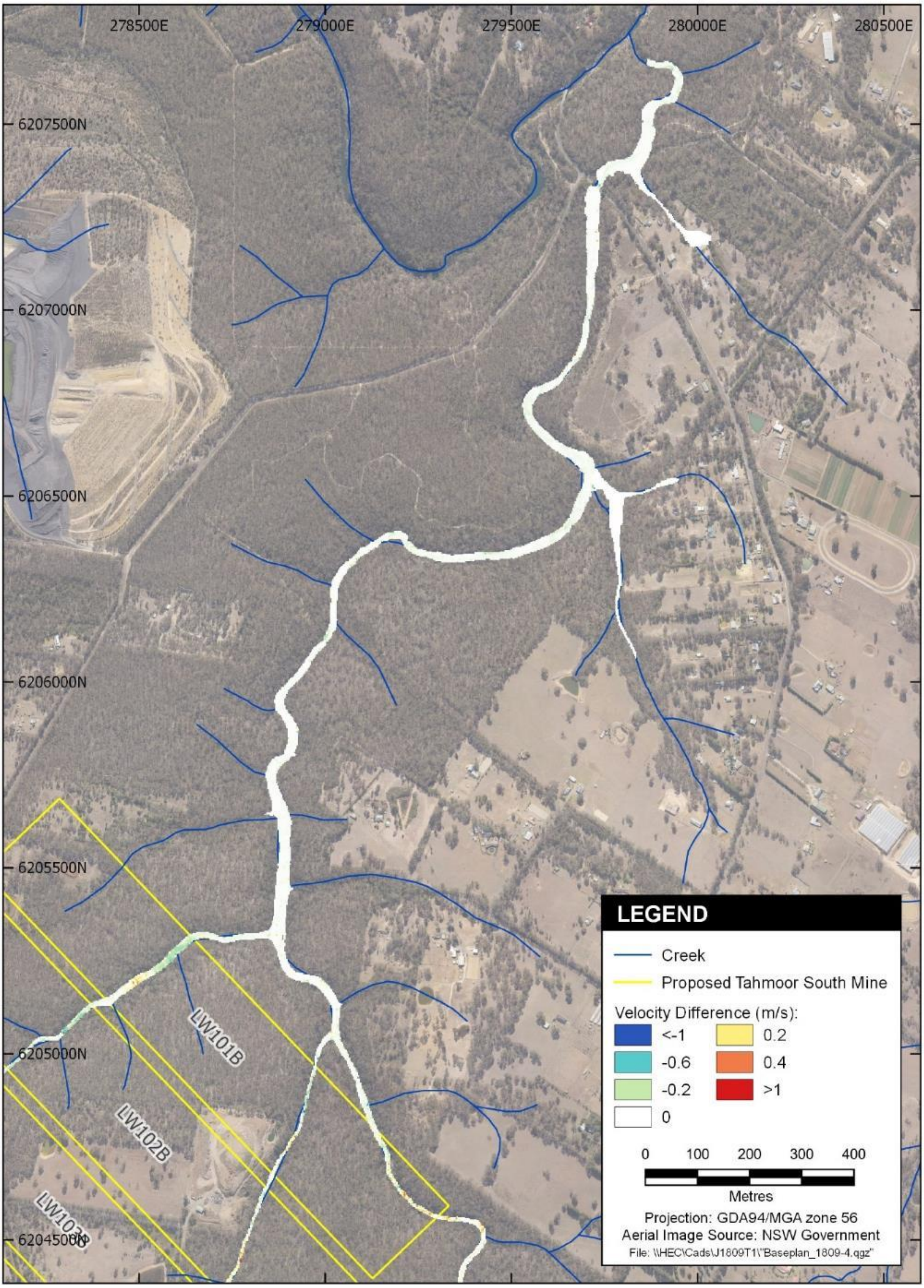

Figure 64 Change in Flow Velocity – Dog Trap Creek (downstream) 50% AEP Event

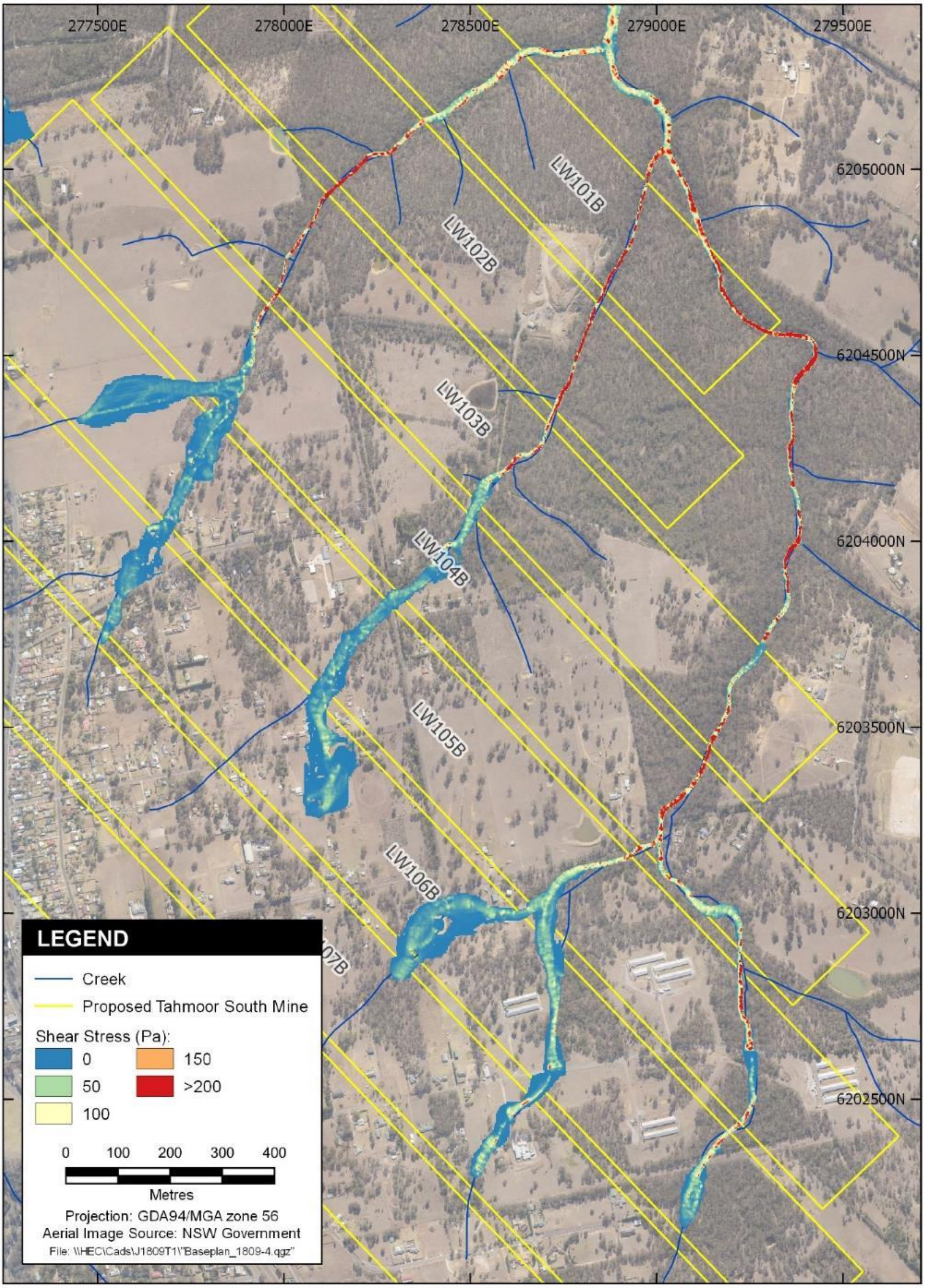

Figure 65 Pre-subsidence Maximum Bed Shear Stress – Dog Trap Creek (upstream) 50% AEP Event

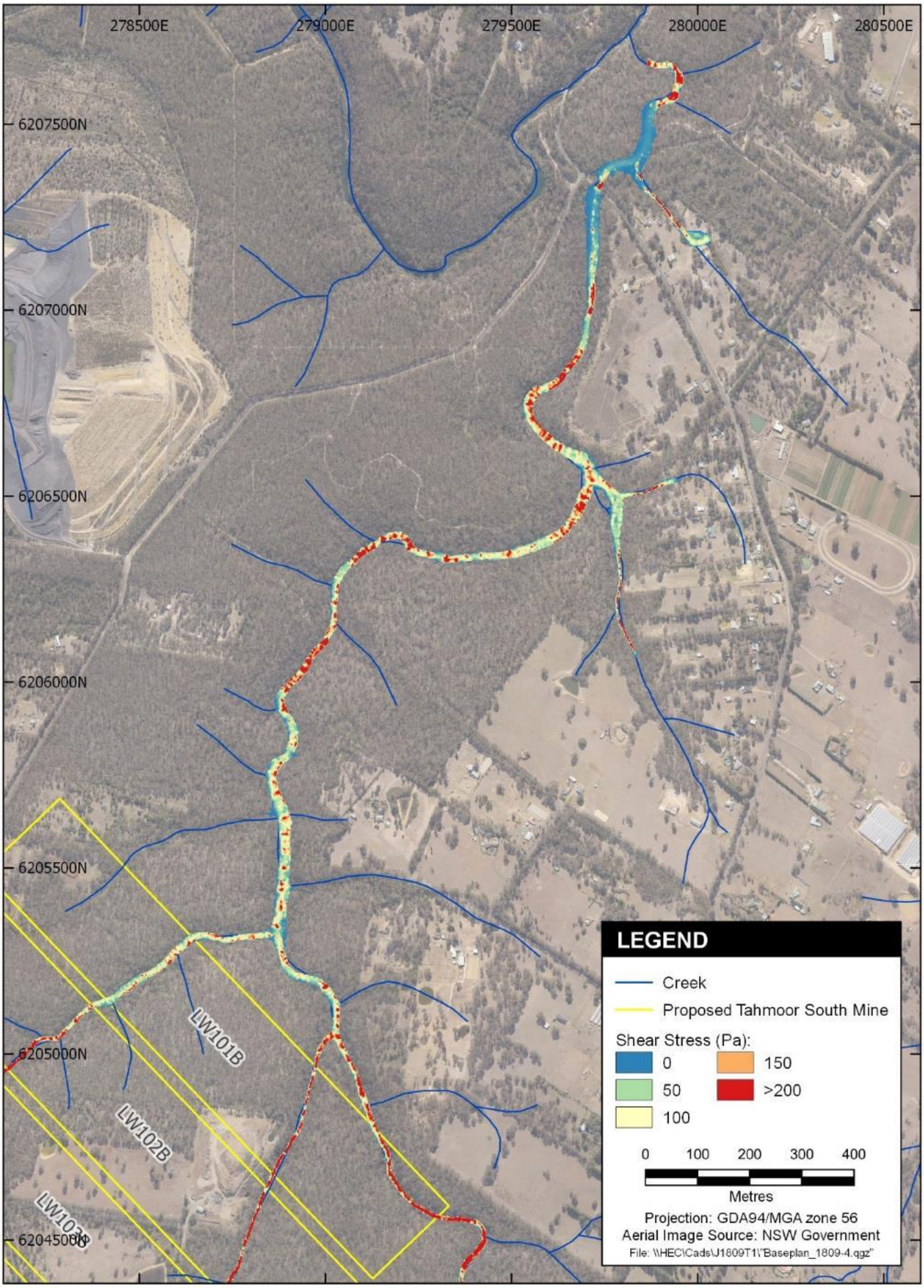

Figure 66 Pre-subsidence Maximum Bed Shear Stress – Dog Trap Creek (downstream) 50% AEP Event

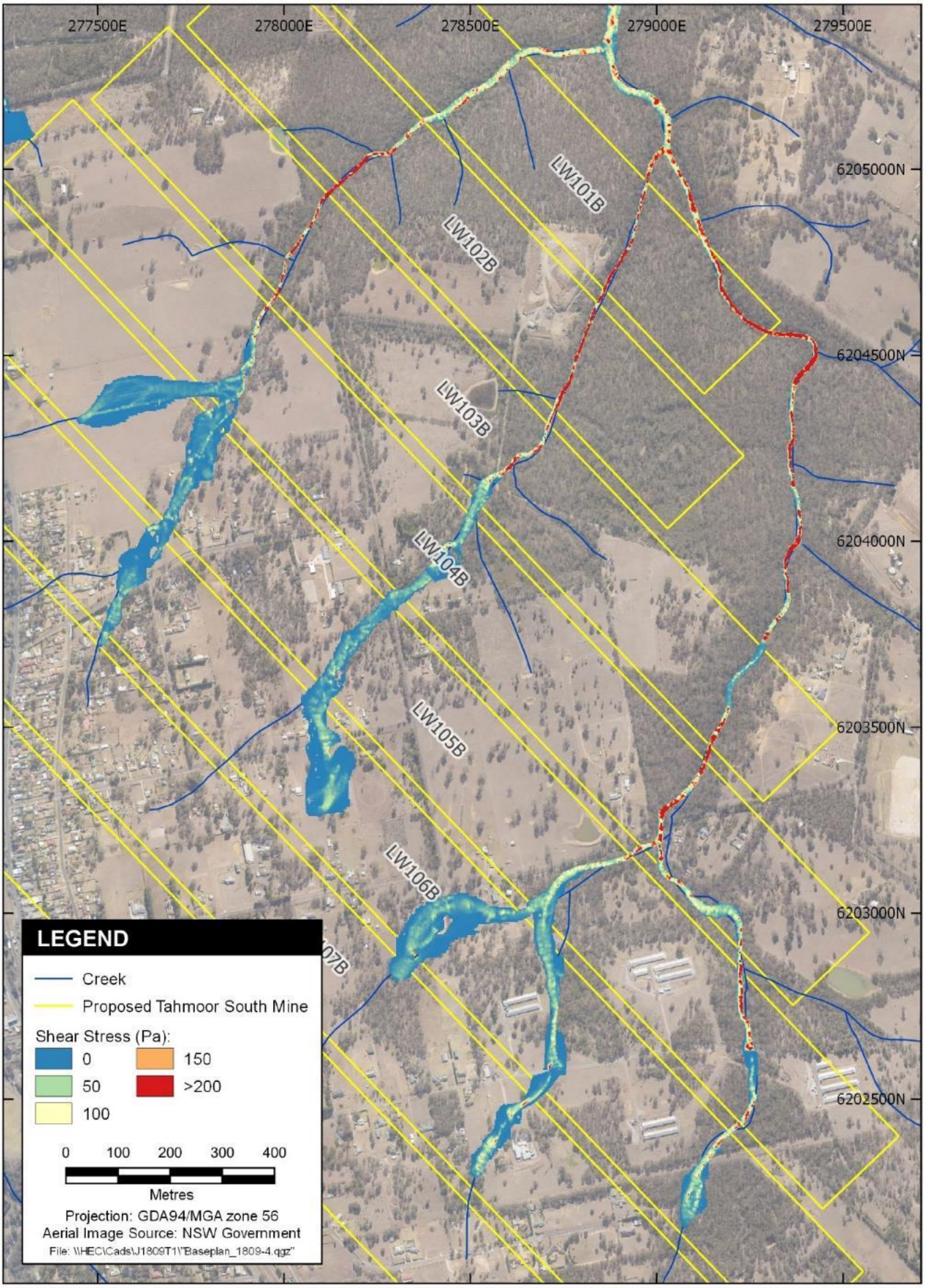

Figure 67 Post-subsidence Maximum Bed Shear Stress – Dog Trap Creek (upstream) 50% AEP Event

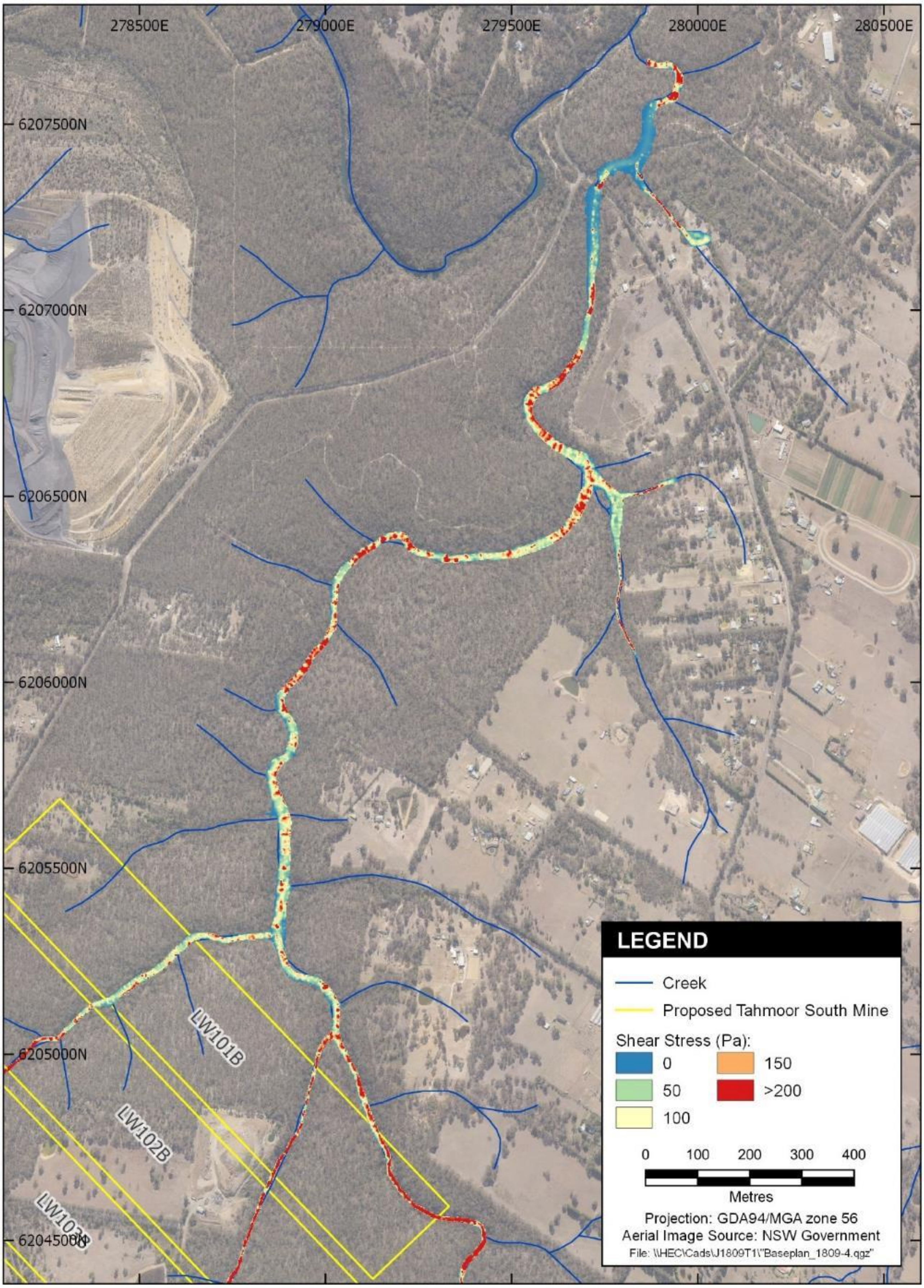

Figure 68 Post-subsidence Maximum Bed Shear Stress – Dog Trap Creek (downstream) 50% AEP Event

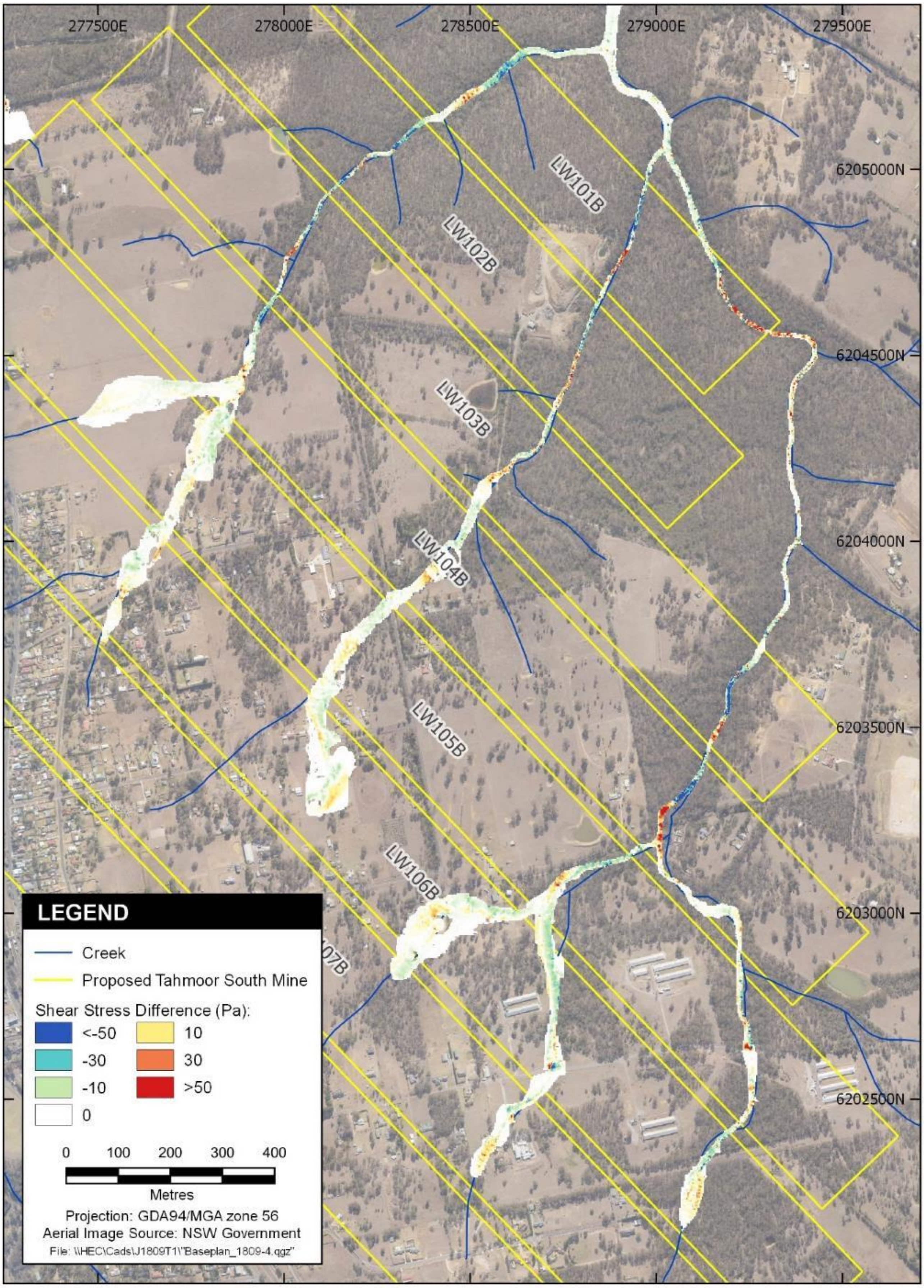

Figure 69 Change in Bed Shear Stress – Dog Trap Creek (upstream) 50% AEP Event

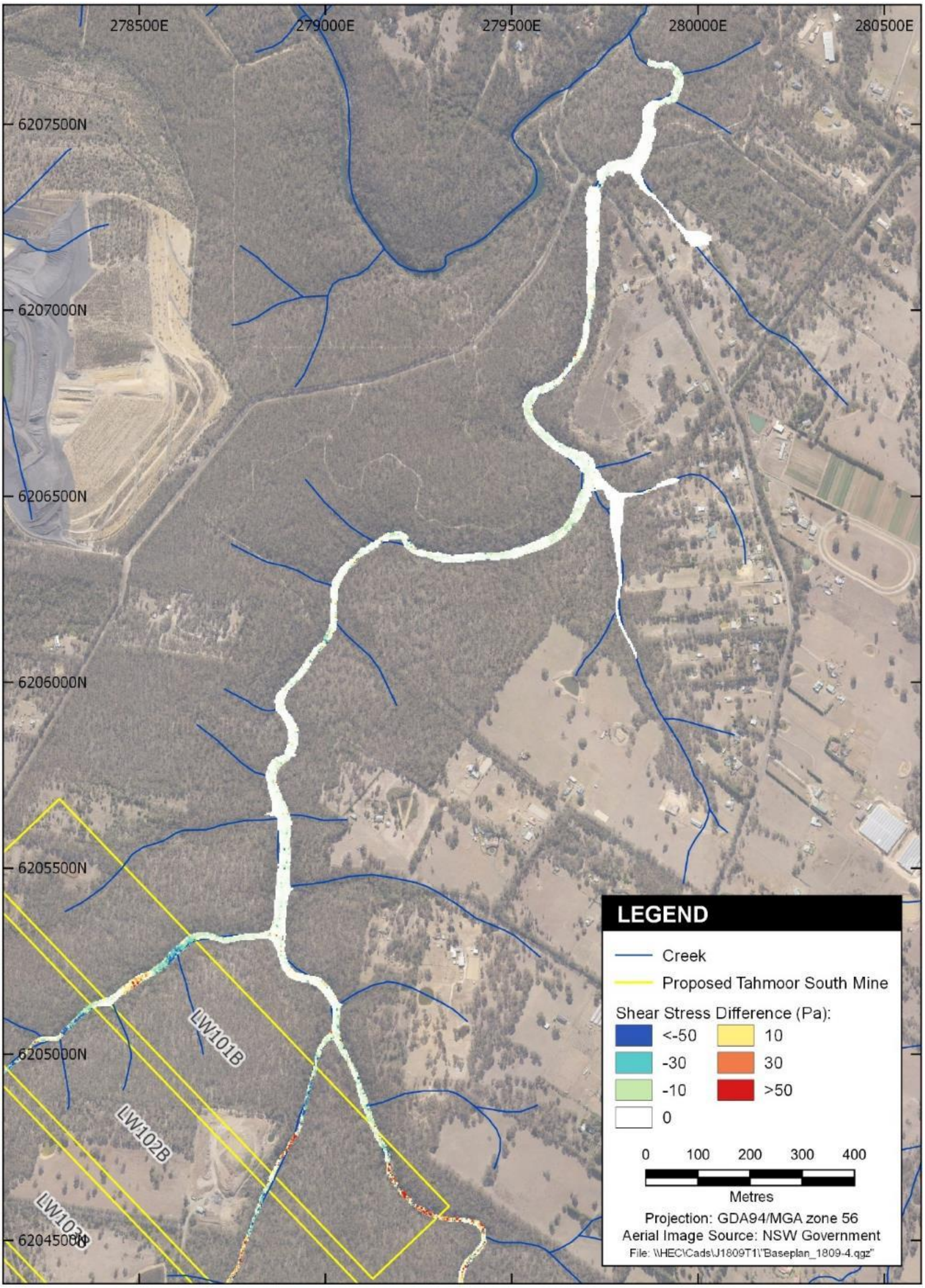

Figure 70 Change in Bed Shear Stress – Dog Trap Creek (downstream) 50% AEP Event

8.1.2 Tea Tree Hollow

There are two main arms to Tea Tree Hollow overlying proposed LW101 to LW105. The simulated flow velocities under peak 50% AEP flow for the pre-subsidence condition are shown in Figure 71. 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 to 2.5 m/s in areas overlying LW 101A to LW 103A.

Figure 72 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 0.7 and 1 m/s) are predicted in isolated sections overlying LW 103A and 105A.

The simulated bed shear stress distribution under peak 50% AEP flow for the pre-subsidence and post-subsidence scenarios are shown in Figure 73 and Figure 74. 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 101A to LW 103A of between 50 and 350 Pa.

The change to bed shear stress between the pre-subsidence and post-subsidence scenarios is shown in Figure 75. The most notable changes were simulated on the south-western sides of LW 102A (30-140 Pa) and 103A (30-70 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 8.1.3.

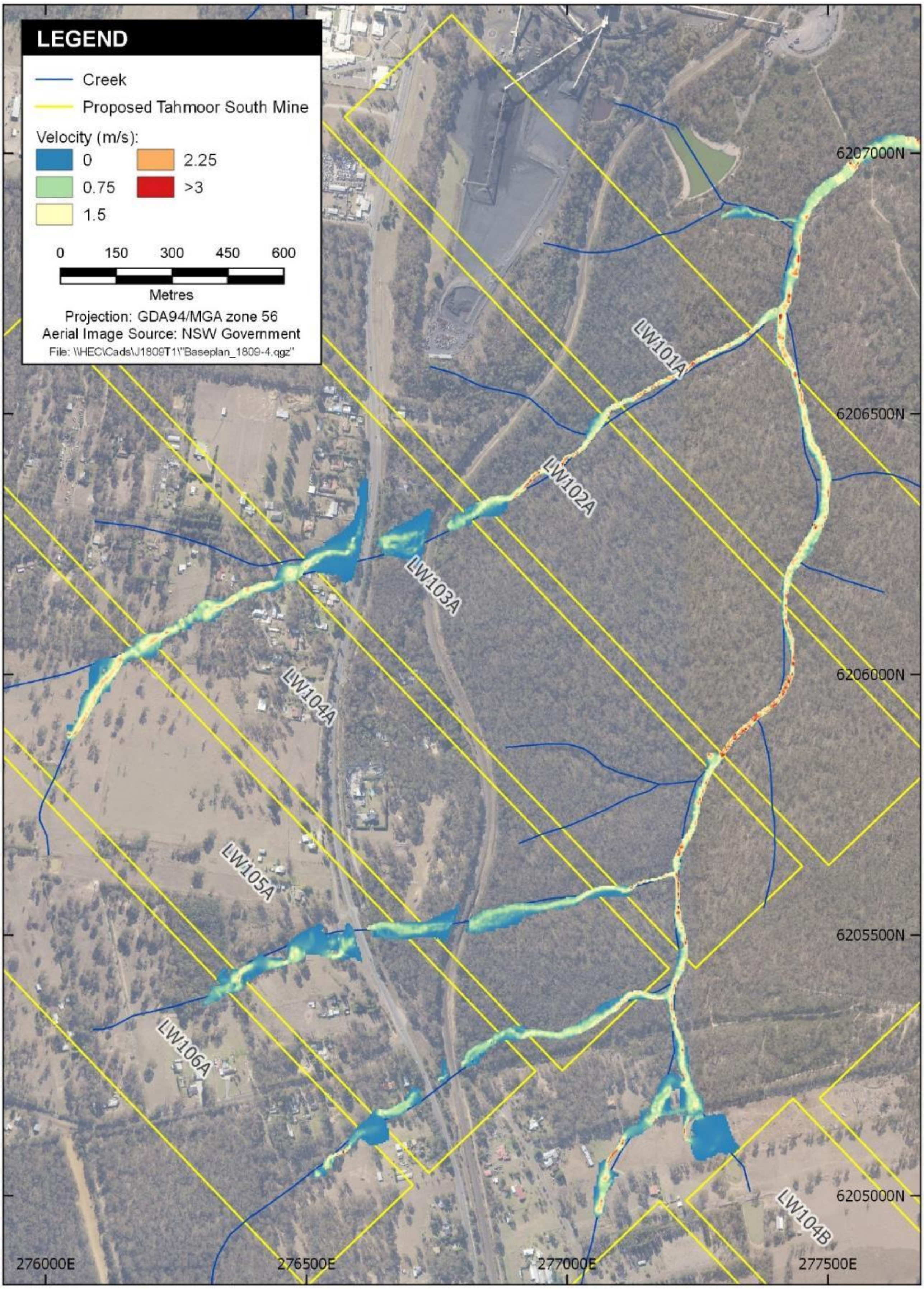

Figure 71 Pre-Subsidence Maximum Flow Velocity –Tea Tree Hollow 50% AEP Event

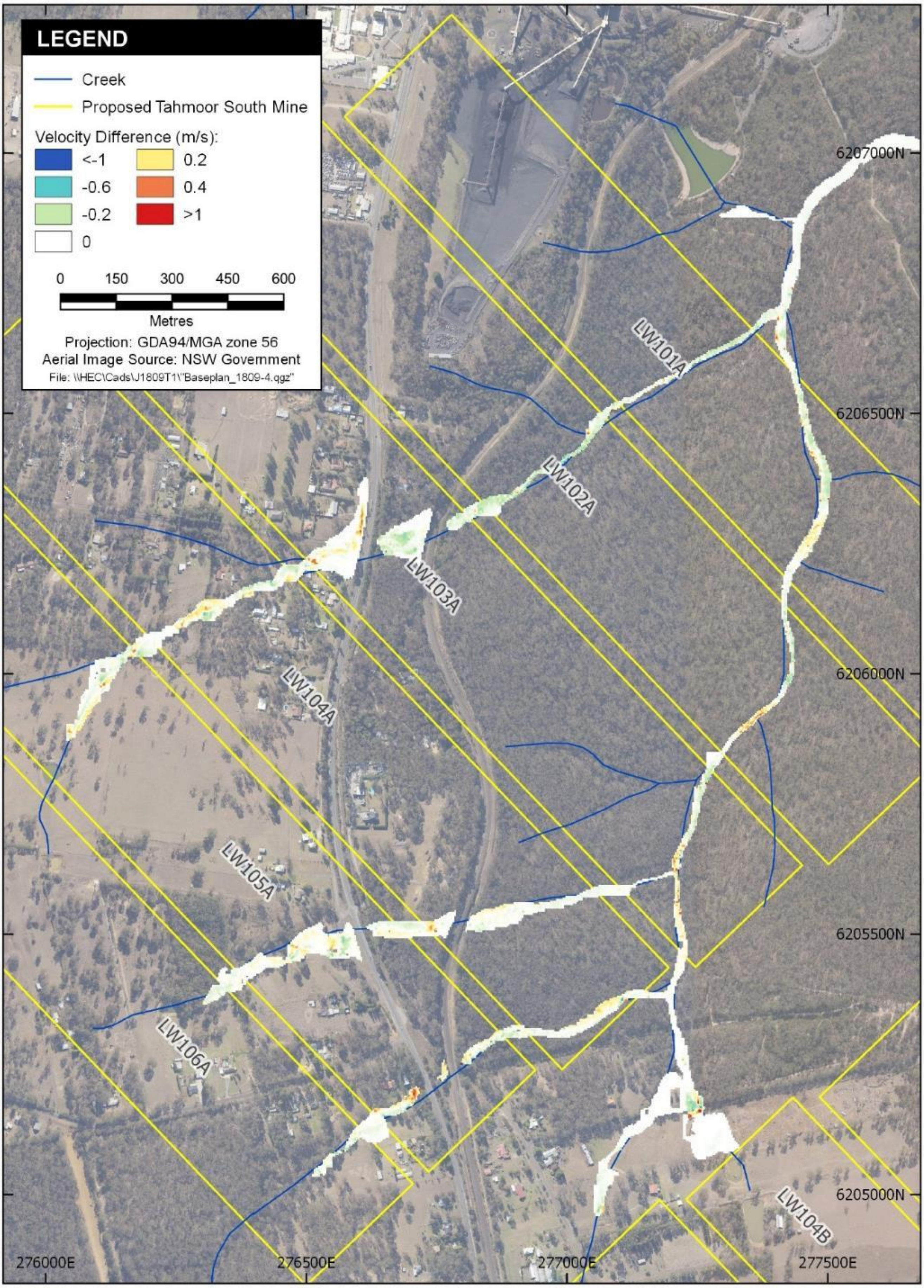

Figure 72 Change in Flow Velocity –Tea Tree Hollow 50% AEP Event

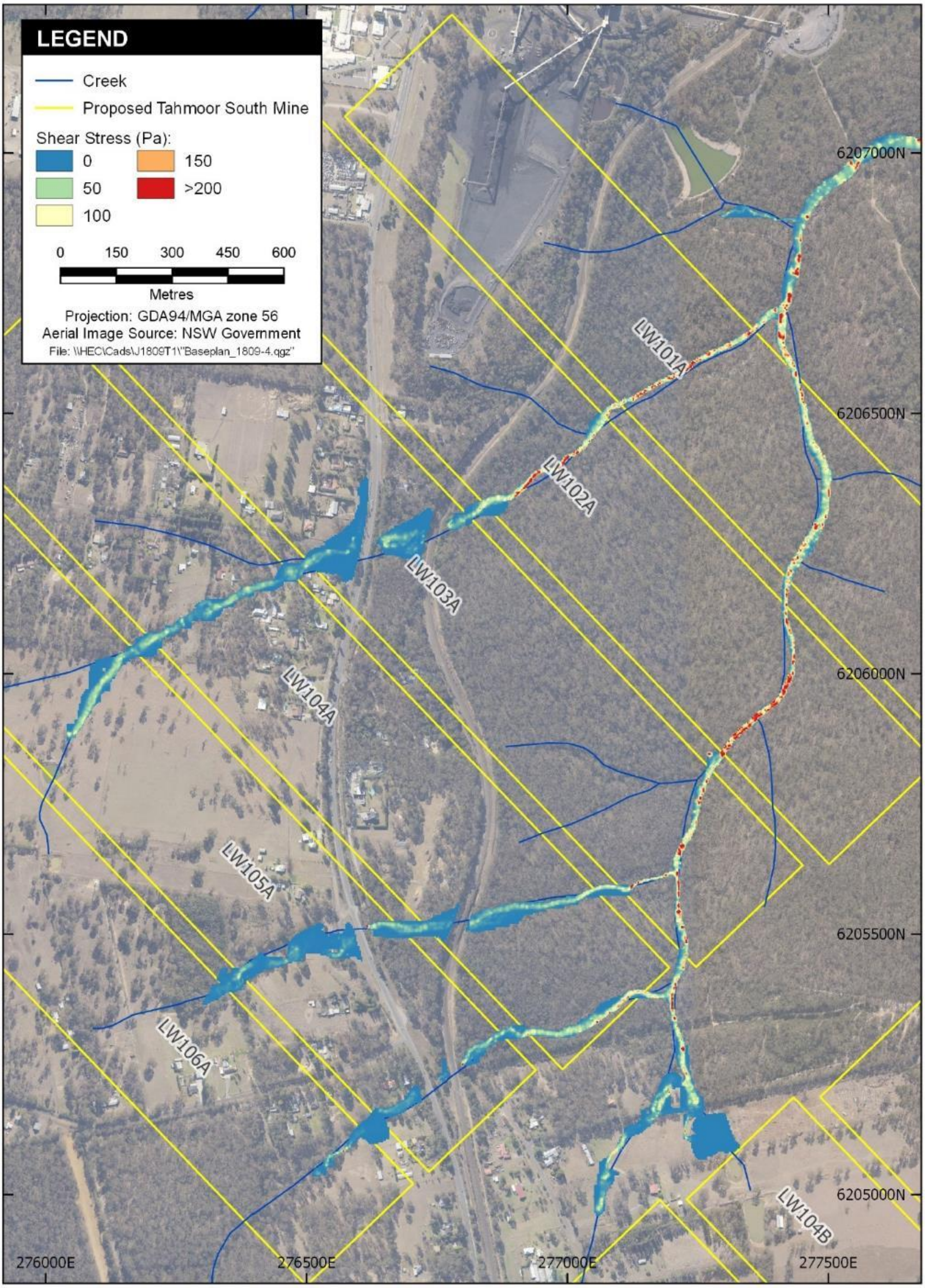

Figure 73 Pre-subsidence Maximum Bed Shear Stress – Tea Tree Hollow 50% AEP Event

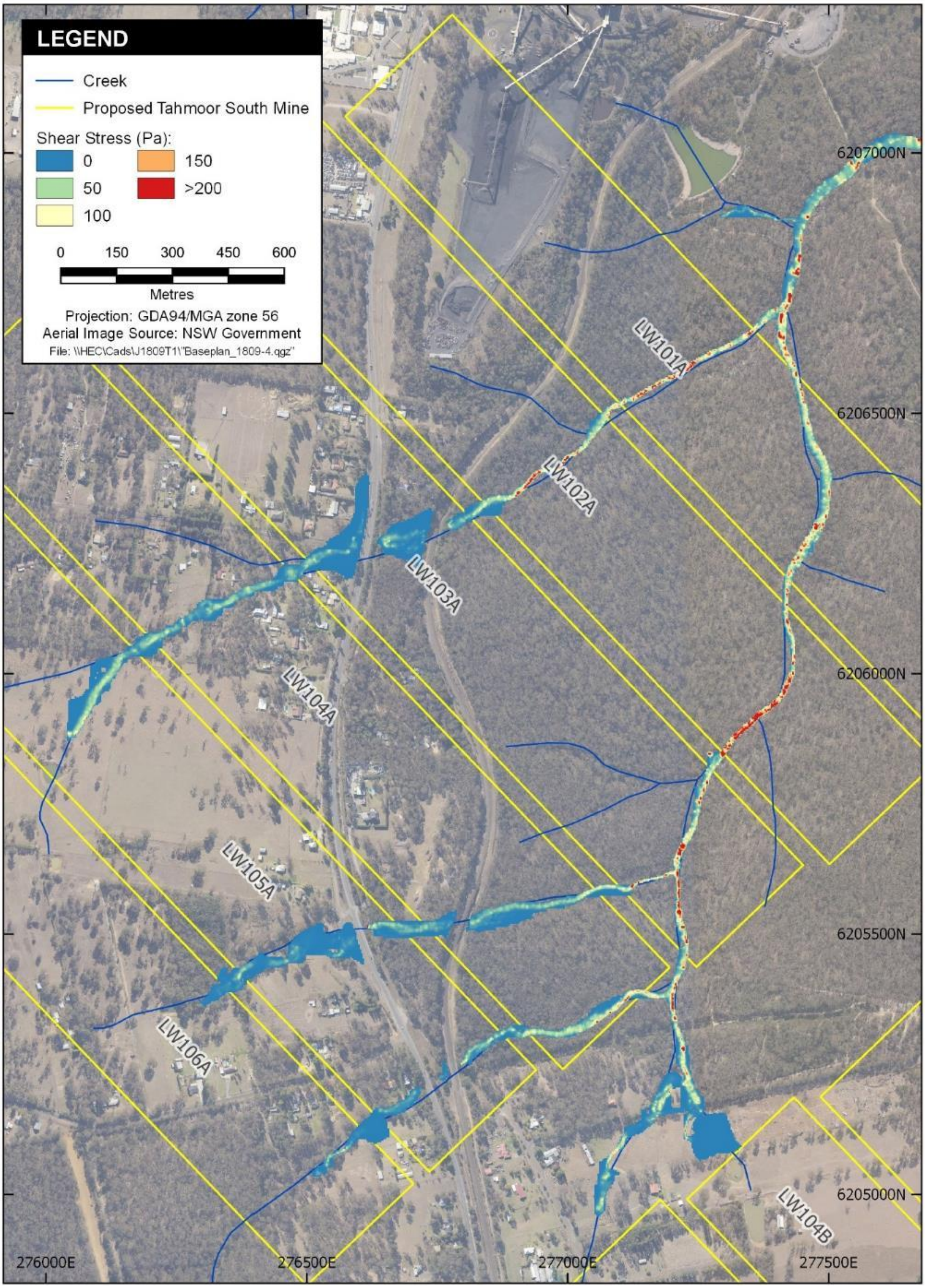

Figure 74 Post-subsidence Maximum Bed Shear Stress – Tea Tree Hollow 50% AEP Event

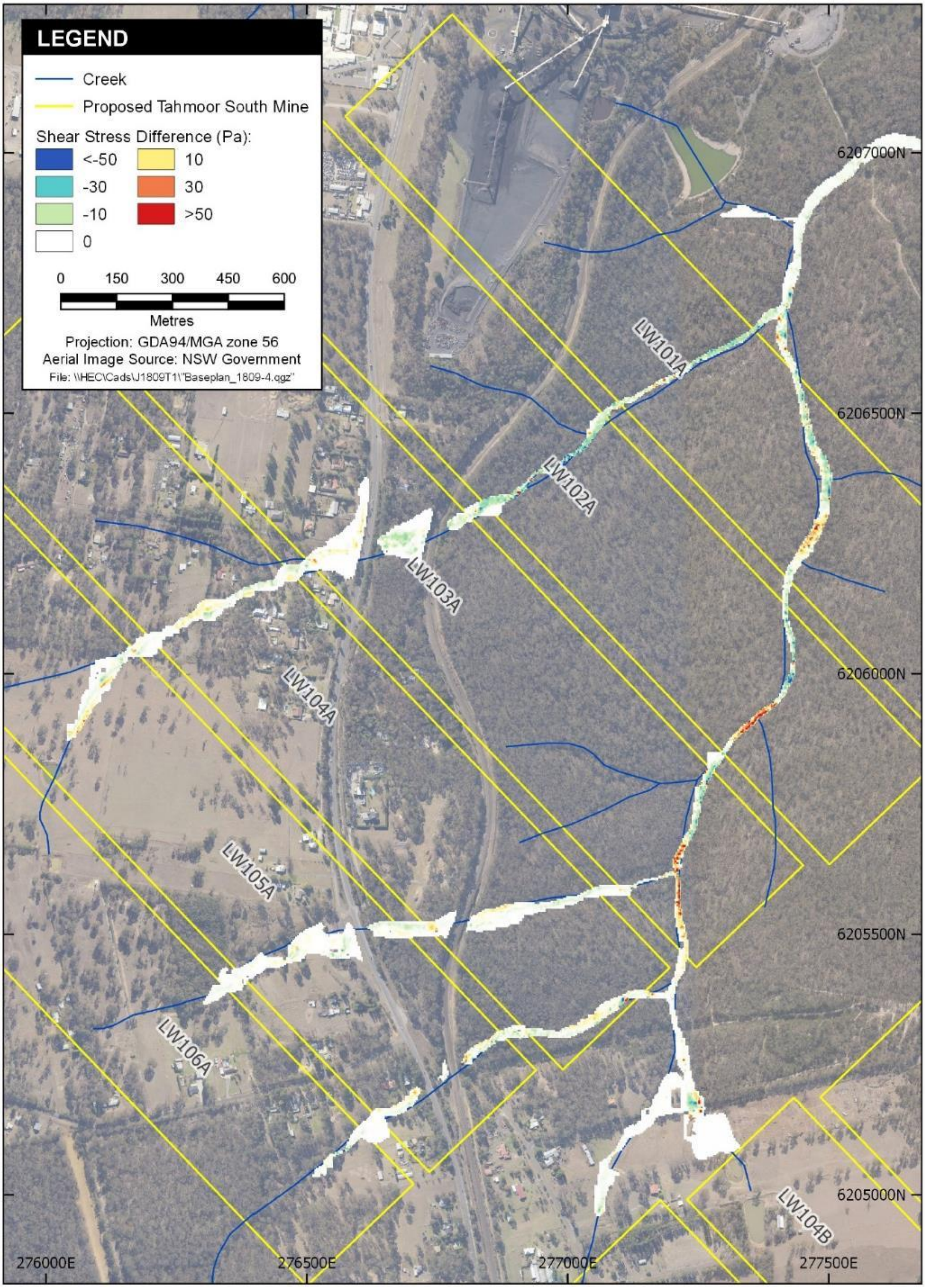

Figure 75 Change in Bed Shear Stress – Tea Tree Hollow 50% AEP Event

8.1.3 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.

8.2 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 and is considered unlikely for the Project. 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.

8.3 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, 2020c and Section 8.0).

9.0 PREDICTION OF IMPACTS TO WATER QUALITY

9.1 RISK AND CONSEQUENCES OF WATER RELEASES FROM PIT TOP AREA

Tahmoor Coal are licensed to release treated water from the water management system in accordance with EPL 1389 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 an upgraded WWTP to reduce the concentrations of constituents released via LDP1. The specified WWTP target water quality is to meet the 95th percentile ANZECC default guideline trigger values for the protection of aquatic ecosystems (ANZG, 2018). The specific targets are as follows:

- pH: 6.5-9
- Electrical Conductivity: <500 µS/cm
- Suspended Solids: <30 mg/L
- Turbidity: <150 NTU
- Oil and grease: <10 mg/L
- Iron: <0.7 mg/L
- Manganese: <1.9 mg/L
- Nickel: <0.011 mg/L
- Zinc: <0.008 mg/L
- Arsenic (V): <13 µg/L
- Arsenic (III): <24 µg/L

The results of predictive modelling (HEC, 2020b) of the water management system over the Amended Project life indicate that release to LDP1 is unlikely to increase above the EPL 1389 volume limits. On the basis of the above, it is expected that the Amended Project would not result in adverse water quality impacts due to releases and overflows from the site water management system.

As stated in Section 6.7, discharge via the LOPs and the proposed dam S12 to Tea Tree Hollow is predicted to be less than the maximum discharge via the LOPs to Tea Tree Hollow recorded in 2016. As such, it is expected that the Amended Project would not result in adverse water quality impacts due to releases and overflows from the site water management system to Tea Tree Hollow.

The simulated annual release to Bargo River from dam S11 is predicted to average 3.7 ML/annum based on the median model results and 11.6 ML/annum based on the 95th percentile model results (HEC, 2020b). A conservative assessment of the potential constituent concentrations in Bargo River due to overflow from dam S11 has been undertaken based on the median water quality records for the Bargo River Upstream and the highest median concentration discharged in overflow to the LOPs. Table 14 presents the estimated constituent concentrations in comparison with the ANZECC (2000) default guideline trigger values for protection of aquatic ecosystems and recreational use.

Table 14 Estimated Water Quality of Bargo River Downstream of Overflow

Constituent	Median Recorded Concentration		Estimated Concentration in Bargo River Downstream of Overflow		ANZECC (2000) Guidelines	
	Bargo River Upstream	Overflow at LOP	Median	95th percentile	95th percentile level of species protection	Recreational use
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	6.0	9.0	6.0	6.0	-	500
Sulfate as SO_4 (mg/L)	5.0	21.0	5.0	5.0	-	400
Chloride (mg/L)	50.5	33.0	50.5	50.5	-	400
Calcium - Dissolved (mg/L)	3.0	57.0	3.0	3.0	-	-
Magnesium - Dissolved (mg/L)	5.0	34.0	5.0	5.0	-	-
Sodium - Dissolved (mg/L)	26.0	425.5	26.2	26.2	-	300
Potassium - Dissolved (mg/L)	2.0	25.0	2.0	2.0	-	-
Aluminium - Total (mg/L)	0.085	0.9	0.085	0.085	0.055	0.2
Arsenic - Total (mg/L)	0.001	0.010	0.001	0.001	0.024	0.05
Barium - Total (mg/L)	0.021	1.7	0.021	0.021	-	1
Cadmium - Total (mg/L)	0.0001	0.0001	0.0001	0.0001	0.0002	-
Chromium - Total (mg/L)	0.001	0.001	0.001	0.001	-	0.05
Copper - Total (mg/L)	0.001	0.002	0.001	0.001	0.001	1
Lead - Total (mg/L)	0.001	0.001	0.001	0.001	0.003	0.050
Selenium - Total (mg/L)	0.010	0.010	0.010	0.010	0.011	0.01
Zinc - Total (mg/L)	0.010	0.005	0.010	0.010	0.008	5
Iron - Total (mg/L)	1.1	0.4	1.1	1.1	-	0.3
Mercury - Total (mg/L)	0.0001	0.0001	0.0001	0.0001	0.0006	0.001
Electrical Conductivity (µS/cm)	189.0	1,830.0	189.8	189.7	350	1,000

Table 13 illustrates that overflow to Bargo River from dam S11 is estimated to result in a very slight increase in the concentration of sodium and electrical conductivity at Bargo River Downstream. The estimated concentration of sodium and electrical conductivity would remain below the ANZECC (2000) and ANZG (2018) default guideline trigger values for protection of aquatic ecosystems and recreational use.

9.2 RISKS TO WATER QUALITY OF UNDERGROUND WATER STORAGE

As described in HEC (2020b), it is proposed to develop an underground storage within goafed areas of the Tahmoor North underground mine into which mine dewatering from the Project would be pumped at times when there is insufficient capacity to treat the dewatering stream through the upgraded WWTP. At times of lower inflow, water could be recovered from the underground storage, treated within the upgraded WWTP and released via LDP1.

The Groundwater Assessment (HydroSimulations, 2020) identified that, based on the groundwater salinity data available, as Project mining progresses, salinity of the mine dewatering stream is unlikely to rise significantly and may potentially fall slightly. Therefore, it is expected that the quality of mine dewatering from Tahmoor South will be similar to that of the groundwater inflow to Tahmoor North. As such, impacts to groundwater quality due to underground storage are unlikely to occur.

9.3 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. These impacts have the potential to affect Tea Tree Hollow, Dog Trap Creek and downstream watercourses. Fracturing of bed rock and upsidence related buckling of stream beds may occur along some sections of these creeks. Based on past experience in the Southern Coalfields, including experience at the existing Tahmoor operation, it is likely that upsidence induced fracturing may lead to releases of aluminium, iron, manganese and zinc. These releases will occur as transient spikes in which would be relatively localised. The extent of impact is expected to be similar to impacts observed in similar streams in the Southern Coalfield – refer discussion on Redbank Creek in Section 5.2.2 and to Stokes, Native Dog and Wongawilli Creeks in Section 5.3.2 and is expected to be transient in nature.

9.4 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 ferruginous springs. These are concentrated (point) inflows and 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 which existed prior to being impacted, it is not expected that these potential impacts would be permanent.

9.5 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, 2020). There have been rare instances of reported vegetation die back (MSEC, 2020).

It has not been reported as an issue at Tahmoor, most likely due to the relative absence of perennial water bodies. It is considered possible that there may 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.

10.0 CUMULATIVE IMPACTS

Cumulative impacts have been described in the mining context Franks et al (2010) as follows:

> *"…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 urbanisation. 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 (2020) 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 - including the existing Tahmoor operation, Appin/Bulli Seam Operations, Dendrobium and Russel Vale / Bellambi / NRE No. 1 - on future baseflow reduction. As with the assessment of the effects of baseflow reduction due to the Project (refer Section 6.3), 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 15 below.

Table 15 Comparison of Maximum Predicted Project and Cumulative Baseflow Reduction Rates on Average Flows in Local Watercourses

	Mean Daily		Maximum Baseflow Reduction due to Project			Maximum Cumulative Baseflow Reduction		
Stream/Site	**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	30.1	4.73	0.051	0.17%	1.08%	0.175	0.58%	3.69%
Tea Tree Hollow, Site 22	6.7	3.90	0.027	0.40%	0.70%	0.088	1.31%	2.25%
Dog Trap Creek, Site 15	7.8	0.19	0.101	1.30%	51.9%	0.133	1.71%	68.53%
Eliza Creek, Site 18	1.5	0.29	0.001	0.06%	0.28%	0.005	0.35%	1.75%
Carters Creek, Site 23	3.3	0.08	0.002	0.05%	1.94%	0.002	0.07%	2.60%
Cow Creek (Catchment Extent)	2.6	0.52	0.018	0.69%	3.45%	0.019	0.71%	3.56%

Table 15 shows that the largest reduction in baseflow as a result of cumulative impacts is predicted to occur at Dog Trap Creek (Site 15) and the Bargo River (Site 13). Figure 76 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).

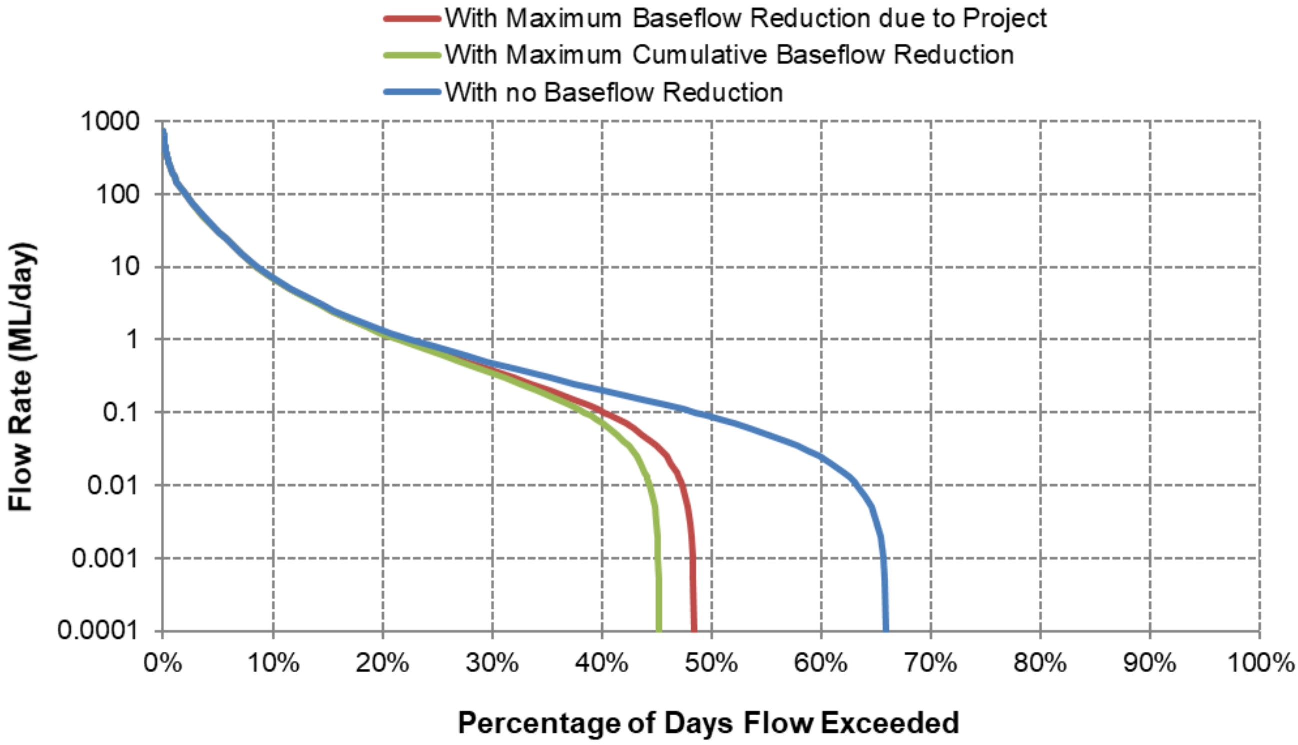

Figure 76 Flow Duration Curve – Dog Trap Creek (GS 300063) - With and Without Maximum Baseflow Reduction

Relative to the maximum predicted effects due to the Project, the maximum cumulative baseflow reduction rates further reduce flows below approximately 1 ML/d. The probability that flow would be greater than 0.1 ML/day would reduce from 48% to 40% of days as a result of the maximum predicted baseflow reduction rates due to the Project and to 38% of days due to the maximum predicted 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.

Figure 77 shows the maximum predicted impact of the predicted baseflow reduction due to the Project and the maximum cumulative baseflow reduction rate on flows in the Bargo River Upstream gauging station (GS 300010a).

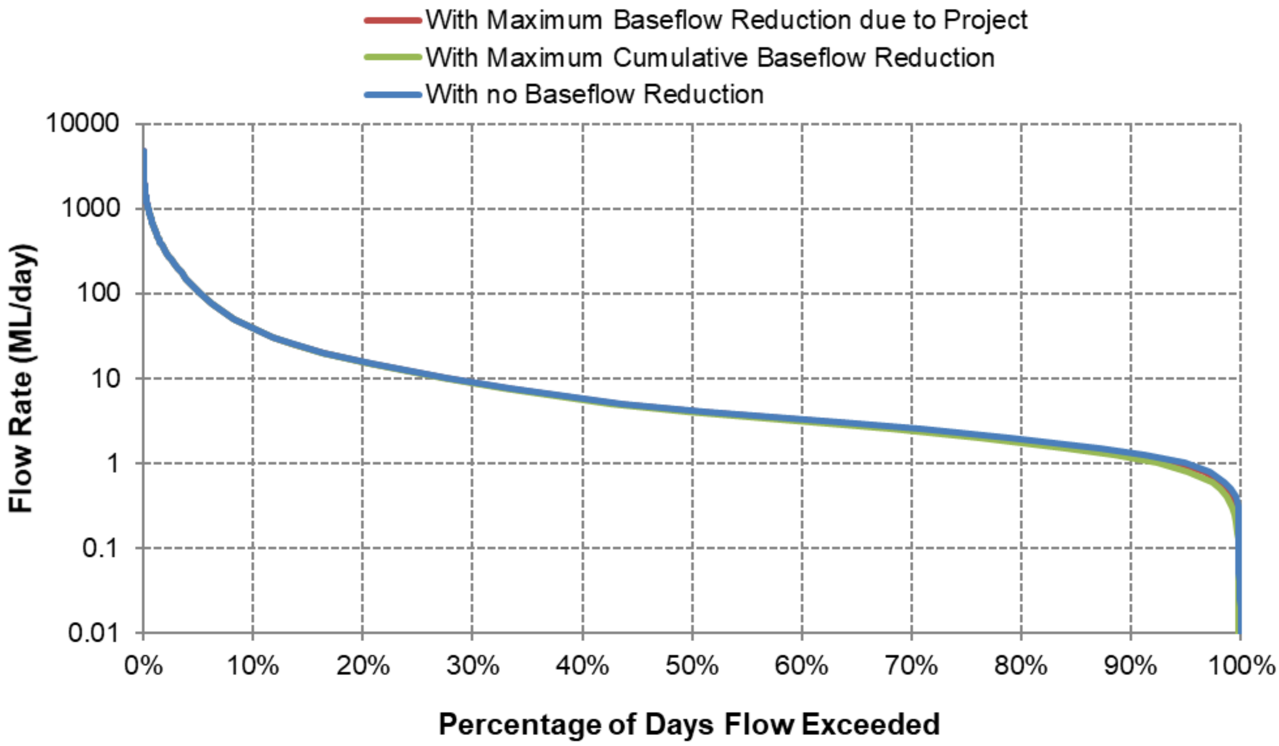

Figure 77 Flow Duration Curve – Bargo River Upstream (GS 300010a) - With and Without Maximum Baseflow Reduction

The probability that flow would be greater than 1 ML/day would reduce from 95% to 94% of days as a result of the maximum predicted baseflow reduction rates due to the Project and to 93% of days based on the predicted maximum cumulative 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.

10.1 WATER SHARING PLAN

WaterNSW 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. Water Sharing Plans (WSPs) have been developed 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 at Picton and Maldon Weir. HydroSimulations (2020) 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 at Picton and Maldon Weir are presented in Table 16 in comparison with the mean daily flow rate at each location.

Table 16 Comparison of Predicted Project and Cumulative Baseflow Reduction Rates on Mean Flows in WSP Management Zones

<table>
<tr><th colspan="3">Stream/Site</th><th>Pheasants Nest Weir</th><th>Stonequarry Creek at Picton</th><th>Maldon Weir</th></tr>
<tr><td colspan="3">Mean Daily Flow (ML/d)</td><td>140.2*</td><td>15.4**</td><td>187.6***</td></tr>
<tr><td rowspan="4">Baseflow Reduction due to Project****</td><td rowspan="2">Maximum</td><td>Baseflow Reduction (ML/d)</td><td>0.014</td><td>0.008</td><td>0.190</td></tr>
<tr><td>% Mean Daily Flow</td><td>0.010%</td><td>0.05%</td><td>0.10%</td></tr>
<tr><td rowspan="2">Long-term</td><td>Baseflow Reduction (ML/d)</td><td>0.011</td><td>0.007</td><td>0.164</td></tr>
<tr><td>% Mean Daily Flow</td><td>0.008%</td><td>0.05%</td><td>0.09%</td></tr>
<tr><td rowspan="4">Cumulative Baseflow Reduction****</td><td rowspan="2">Maximum</td><td>Baseflow Reduction (ML/d)</td><td>0.016</td><td>0.086</td><td>0.499</td></tr>
<tr><td>% Mean Daily Flow</td><td>0.012%</td><td>0.56%</td><td>0.27%</td></tr>
<tr><td rowspan="2">Long-term</td><td>Baseflow Reduction (ML/d)</td><td>0.013</td><td>0.069</td><td>0.426</td></tr>
<tr><td>% Mean Daily Flow</td><td>0.009%</td><td>0.45%</td><td>0.23%</td></tr>
</table>

* Estimated as Maldon Weir mean flow - (Stonequarry Creek mean flow + Bargo SW-14 mean flow) as per HydroSimulations (2018)

** Mean daily flow for January 1990 to November 2019 from WaterNSW (https://realtimedata.waternsw.com.au/)

*** Mean daily flow for January 1990 to October 2008 (Gilbert & Associates, 2009)

**** Per Hydrosimulations (2020)

Table 16 illustrates a predicted maximum reduction in mean daily flow at Pheasants Nest Weir of 0.01% (due to the Project) to 0.012% (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 at Picton, a maximum reduction in mean daily flow of 0.56% is predicted due to cumulative effects, reducing to 0.45% in the long-term. At Maldon Weir, a maximum reduction in mean daily flow of 0.27% is predicted due to cumulative effects, reducing to 0.23% in the long-term. The long-term estimated reduction in mean daily flow is likely to be indiscernible at these locations.

The potential impact on streamflow presented in Table 16 would be mitigated by Tahmoor Coal purchasing sufficient water licences (WALs) for licensable surface water 'take' within the Upper Nepean River water source. A maximum baseflow reduction of 5.1 ML/annum is predicted at Pheasants Nest Weir, 2.9 ML/annum for Stonequarry Creek at Picton and 69.4 ML/annum at Maldon Weir. The total issued share component of unregulated river and domestic and stock water access licences from the Upper Nepean River water source was 15,854 ML in 2018 (WaterNSW, 2019). A maximum predicted reduction of 69.4 ML/annum for the Maldon Weir Management Zone due to the Project surface water 'take' equates to 0.44% of the total issued share component of the Upper Nepean River water source for unregulated river and domestic and stock access.

11.0 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 following definition and criteria for satisfying the neutral or beneficial 'test' are contained in WaterNSW (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.*

As indicated in Section 1.4.1, the proposed mine plan for the Project was amended to exclude mining and related subsidence within the Sydney Drinking Water Catchment. The main channel of Cow Creek, which is within the Metropolitan Special Area, is located approximately 1 km from the nearest Project longwall. MSEC (2020) 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.

As detailed in Section 6.3, HydroSimulations (2020) have estimated a maximum baseflow reduction rate of 0.018 ML/day and a long-term baseflow reduction rate of 0.014 ML/day in Cow Creek due to the Amended Project. A maximum baseflow reduction rate of 0.019 ML/day and a long-term baseflow reduction rate of 0.015 ML/day have been predicted based on cumulative impacts. The estimated level of change to streamflow in Cow Creek, as a result of the predicted baseflow reduction, may be detectable during normal periods of low flow and distinguishable from natural variability in catchment conditions.

Although the above changes are predicted for flow in Cow Creek, the combined effects of the Project, consumptive groundwater extraction and the effects of other existing mining projects are predicted to have a negligible impact on Sydney's water supply sources. As summarised in Section 10.1, a predicted maximum reduction in mean daily flow at Pheasants Nest Weir of 0.01% (due to the Amended Project) to 0.012% (cumulative effect) is predicted. 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 at Picton and Maldon Weir, 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 these locations.

Based on previous experience, in the unlikely event that fracturing were to occur in Cow Creek it is not expected to result in a detectable change to water quality. The predicted impact to streamflow at Pheasants Nest Weir, Stonequarry Creek at Picton and Maldon Weir, as a result of the predicted reduction in baseflow, is immeasurably small and likely to be indiscernible. Based on the above it is concluded that it is unlikely that there would be any identifiable water quality impacts to surface water resources in the Metropolitan Special Area. This is consistent with component (a) of the above definition of a neutral effect on water quality "no identifiable potential impact".

12.0 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].

12.1 BASELINE MONITORING

As stated in the BA report (HEC, 2020a), streamflow monitoring has recommenced on Hornes Creek, Dog Trap Creek, Eliza Creek and Carters Creek in order to expand baseline data (up to the period of mining within these catchments) and assess impacts to flows post mining. Additional water level monitoring sites have also been implemented, or are proposed to be implemented, on Hornes Creek (four additional sites), Dog Trap Creek (four additional sites), Tea Tree Hollow (four additional sites) and Eliza Creek (one additional site). These monitoring sites will provide baseline water level data necessary to enable the assessment of potential impacts to pool water levels as a result of the Project. The Water Management Plan for the Tahmoor mine will be updated to reflect changes to the baseline monitoring program once the Project is approved.

Streamflow gauging activities should be continued to support the development and maintenance of viable gauging station 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 level and water quality monitoring should also be continued.

In order to increase the spatial representation of water quality sites downstream of LDP1, it is recommended that a water quality monitoring site is established on the Bargo River downstream of the confluence with Tea Tree Hollow and upstream of SW14.

12.2 OPERATIONAL MONITORING AND MANAGEMENT

Prior to the commencement of Project longwall mining, it is recommended that an adaptive monitoring and Trigger Action Response Plan (TARP) be developed. It is recommended that the following surface water elements be incorporated into the plan:

- TARPs for water quality exceedances which incorporate both baseline and control monitoring data. Site specific trigger values have been developed in accordance with ANZECC (2000) and ANZG (2018) for baseline sites which may potentially be affected by the Project – refer HEC (2020a).
- TARPs 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.
- TARPs 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.

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 site specific trigger value). Results of

[14] Recommendations related to watercourse stability and geomorphic change are provided by Gippel (2013).

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 7.0).

12.3 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.

12.4 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.

12.5 POTENTIAL REMEDIATION MEASURES

Where subsidence impacts result in pool or stream bed fracturing, pool / stream remediation measures would be implemented in consultation with key Government agencies. Where there is limited ability for fractures to seal naturally, they will be sealed with an appropriate and approved grout. A Corrective Action Management Plan (CMAP) has been developed by Tahmoor Coal for Myrtle Creek and Redbank Creek with pool remediation and rock bar grout curtain wall works proposed. On completion of the Myrtle Creek CMAP Trial Project, outcomes will be assessed to determine the best approach for a future Stage 2 remediation works in Myrtle and Redbank Creek. This will involve a staged approach, with outcomes from each stage being assessed to provide the best approach for the next stage. The purpose of this approach is to provide a strategy of continuous improvement from the staged outcomes. The findings from the staged approach for Myrtle and Redbank Creeks will be applied to develop an effective and appropriate remediation strategy for Tee Tree Hollow and Dog Trap Creek in the event that the streambed or pools are impacted due to the Project.

13.0 SUMMARY OF KEY CHANGES TO ASSESSMENT OUTCOMES

This SWIA has been revised to assess the potential impacts of the Amended Project on local and regional surface water regimes and surface water quality. The report has also been revised to address key issues raised in the EIS submissions pertaining to the surface water impact assessment for the Project. In this way, it serves as an update to the Surface Water Impact Assessment (HEC, 2018, Appendix J of the Tahmoor South Project EIS). The following summarises the key changes to the assessment outcomes for the Amended Project as compared to the assessment undertaken for the EIS:

Assessment of Streamflow - Redbank Creek

The examination of the flow record from monitoring site R4 and monitoring site R11 on Redbank Creek was updated to assess impacts from mining of LW27 to LW31. The flow record from December 2009 to March 2013, assessed for the EIS, identified that mining of LW 25, LW26 and LW27 within the Redbank Creek catchments, including mining directly beneath Redbank Creek itself, had not affected flows and low flows at site R11 downstream. There was some evidence that flows at site R4 may have been reduced during the period of low flow recorded between October 2012 and January 2013.

Assessment of the flow record at site R4, based on updated monitoring data acquired since submission of the EIS, identified that there has been a change in the flow behaviour at site R4 with time, likely associated with longwall mining beneath the site. It seems likely that the control for the streamflow gauging station has been affected at this site.

Assessment of the flow record at site R11, based on updated monitoring data acquired since submission of the EIS, suggests a change in the flow regime from the time of mining of LW27, with greater prevalence of baseflow. This is considered likely associated with subsidence-induced fracturing causing underflow and delayed drainage of flow reporting to site R11. A subsequent second change in the flow regime is apparent, from the period during the mining of LW31, with the prevalence of baseflow diminishing and ephemeral flow prevailing. The more recent change to a more ephemeral flow regime may be related to natural ‘healing’ behaviour and/or closure of subsidence cracking due to the mining of additional longwalls. Additional catchment specific research would need to be undertaken to better understand the cause of this behaviour.

Assessment of Surface Water Quality – Redbank Creek

The surface water quality assessment for Redbank Creek was generally consistent between the assessment submitted for the EIS and the revised assessment detailed in this report. The key outcomes are as follows:

- Recorded electrical conductivity (a measure of salinity) increased at the downstream site RC5 following the mining of LW26, reaching a peak during the mining of LW27 and LW28. Thereafter electrical conductivity levels at RC5 have fallen.
- Longwall mining in the Redbank Creek catchment has not affected pH levels in the creek to any significant extent.
- Periodic and localised pulses of iron, zinc and sulphate concentrations have been recorded at site RC2.
- Relatively high manganese concentrations have been recorded at site RC2 and RC5. The elevated manganese concentrations at site RC2 may be, at least in part, unrelated to mining of LW25 to LW29 and possibly relate to pre-existing groundwater inflows (ferruginous springs)

reported in Redbank Creek. It appears likely that increased manganese concentrations at site RC5 are related to mining, although concentrations have diminished with time.

Loss of Flow to Subsidence Induced Fracturing – Underflow

For the EIS, two pools in Tea Tree Hollow were 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 were located in areas of either moderate or high risk of loss of water holding capacity.

There were eight pools mapped in Tea Tree Hollow and five pools mapped on a tributary of Tea Tree Hollow. The total predicted closure for seven of the eight pools mapped in Tea Tree Hollow and for two of the eight pools mapped in the tributary of Tea Tree Hollow, is less than 210 mm, indicating that less than 10% of these pools are expected to be impacted based on the rock bar impact model developed by Barbato et al. (2014). One pool on Tea Tree Hollow and one pool on the tributary of Tea Tree Hollow are predicted to have a total closure of less than 290 mm (less than 20% of pools are expected to be impacted). Two pools on the tributary of Tea Tree Hollow have a predicted total closure of 300 and 325 mm respectively. At this total closure prediction, less than 30% of pools are expected to be impacted.

For forty pools in Dog Trap Creek and tributaries of Dog Trap Creek, less than 20% of pools are expected to be impacted. For eighteen pools in Dog Trap Creek and tributaries of Dog Trap Creek, less than 30% are expected to be impacted and for fourteen pools, less than 50% are expected to be impacted.

Loss of Surface Flows to Groundwater (Baseflow Reduction)

The baseflow reduction predictions for local and regional streams and subsequent estimated loss of surface flow, presented in the EIS as compared with that assessed for the Amended Project, are summarised as follows:

- The percentage reduction in mean daily flow for Bargo River has reduced from 0.4% to 0.17% due to the Amended Project. For Tea Tree Hollow, the percentage reduction in mean daily flow has reduced from 1.7% to 0.4% while for Dog Trap Creek the percentage reduction in mean daily flow has reduced from 1.7% to 0.4% due to the Amended Project.
- Bargo River Upstream: the level of potential streamflow change would be imperceptible and very small compared to natural variability in catchment conditions and is therefore considered to be negligible (no change between EIS and Amended Project).
- Tea Tree Hollow: due to the persistent releases from LDP1, the effects of predicted baseflow reduction on Tea Tree Hollow at the gauging station (GS 300056) would be negligible (no change between EIS and Amended Project).
- Dog Trap Creek Downstream: the level of potential streamflow change would be detectable during normal periods of low flow. This level of change would likely be distinguishable from natural variability in catchment conditions (no change between EIS and Amended Project).
- Carters Creek: the level of change would be small compared to natural variability in catchment conditions (Carters Creek was not presented in the EIS).
- Eliza Creek: the level of potential streamflow change would be imperceptible and very small compared to natural variability in catchment conditions and is therefore considered to be negligible (Eliza Creek was not presented in the EIS).
- Cow Creek: the level of potential streamflow change may be detectable during normal periods of low flow and distinguishable from natural variability in catchment conditions (Cow Creek was not presented in the EIS).

Changes in Flow Velocity and Bed Shear Stress due to Subsidence

The changes in flow velocity and bed shear stress due to subsidence, presented in the EIS as compared with that assessed for the Amended Project, are summarised as follows:

- Dog Trap Creek:
    - Significant increases in velocity based on subsidence predictions (i.e. between 0.8 and 0.9 m/s) were predicted in isolated sections overlying LW 104B and LW106B. The same magnitude of increase in velocity was predicted for the EIS in isolated sections overlying LW 103 to 106.
    - The changes in bed shear stress due to subsidence predictions 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 more than 50 Pa were predicted. These increases were consistent with those estimated for the EIS.
- Tea Tree Hollow
    - The most significant increases in velocity based on subsidence predictions (i.e. between 0.7 and 1 m/s) are predicted in isolated reaches overlying LW 103A and 105A for the Project. The most significant increases in velocity (i.e. between 0.4 and 0.6 m/s) were predicted in isolated sections overlying LW 104 and LW105 for the EIS.
    - The most notable changes in bed shear stress based on subsidence predictions for the Project were simulated on the south-western sides of LW 102A (30-140 pa) and LW103A (30-70 Pa). The most notable changes estimated for the EIS were simulated on the south-western sides of LW 102 (30-50 pa) and LW101 (10-30 Pa).

Risks and Consequences of Water Releases from Pit Top Area

The results of predicted water balance modelling relating to water releases from the pit top water management system for the Amended Project and associated downstream impacts are summarised as follows:

- The results of predictive modelling (HEC, 2020b) of the water management system over the Amended Project life indicate that release to LDP1 is unlikely to increase above the EPL 1389 volume limits. On this basis, it is expected that the Amended Project would not result in adverse water quality impacts due to releases and overflows from the site water management system.
- Discharge via the LOPs and the proposed dam S12 to Tea Tree Hollow is predicted to be less than the maximum discharge via the LOPs to Tea Tree Hollow recorded in 2016. As such, it is expected that the Amended Project would not result in adverse water quality impacts due to releases and overflows from the site water management system to Tea Tree Hollow.
- Overflow to Bargo River from dam S11 is estimated to result in a very slight increase in the concentration of sodium and total dissolved solids at Bargo River Downstream. The estimated concentration of sodium and total dissolved solids would remain below the ANZECC (2000) default guideline default trigger values for protection of aquatic ecosystems and recreational use.

Cumulative Impacts

The baseflow reduction predictions for local and regional streams as a result of cumulative impacts and subsequent estimated loss of surface flow, presented in the EIS as compared with that assessed for the Amended Project, are summarised as follows

- The percentage reduction in mean daily flow for Bargo River has reduced from 1.3% to 0.6% due to the Amended Project for cumulative impacts. For Tea Tree Hollow, the percentage reduction in mean daily flow has reduced from 2.1% to 1.3% while for Dog Trap Creek the percentage reduction in mean daily flow has reduced from 5.7% to 1.7% due to the Amended Project.
- A maximum reduction in mean daily flow at Pheasants Nest Weir of 0.01% (due to the Amended Project) to 0.012% (cumulative effect) is predicted based on the revised assessment. For the EIS, a maximum reduction in mean daily flow at Pheasants Nest Weir of 0.03% (due to the Amended Project) to 0.36% (cumulative effect) was predicted. The predicted maximum reduction in mean daily flow 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 Amended Project or the cumulative effect, is estimated to have negligible observable impact on the mean daily flow at Pheasants Nest Weir.
- For Stonequarry Creek at Picton, a maximum reduction in mean daily flow of 0.56% is predicted due to cumulative effects, reducing to 0.45% in the long-term (based on the Amended Project). For the EIS, a maximum reduction in mean daily flow of 1.86% was predicted due to cumulative effects, reducing to 0.10% in the long-term. The predicted maximum reduction in mean daily flow represents an immeasurably small and likely indiscernible impact to flows at Stonequarry Creek.
- At Maldon Weir, a maximum reduction in mean daily flow of 0.27% is predicted due to cumulative effects, reducing to 0.23% in the long-term (based on the Amended Project). For the EIS, 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 predicted maximum reduction in mean daily flow represents an immeasurably small and likely indiscernible impact to flows at Maldon Weir.

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APPENDIX A - Profiles of Predicted Subsidence, Upsidence and Valley Closure in Local Streams per MSEC (2020)

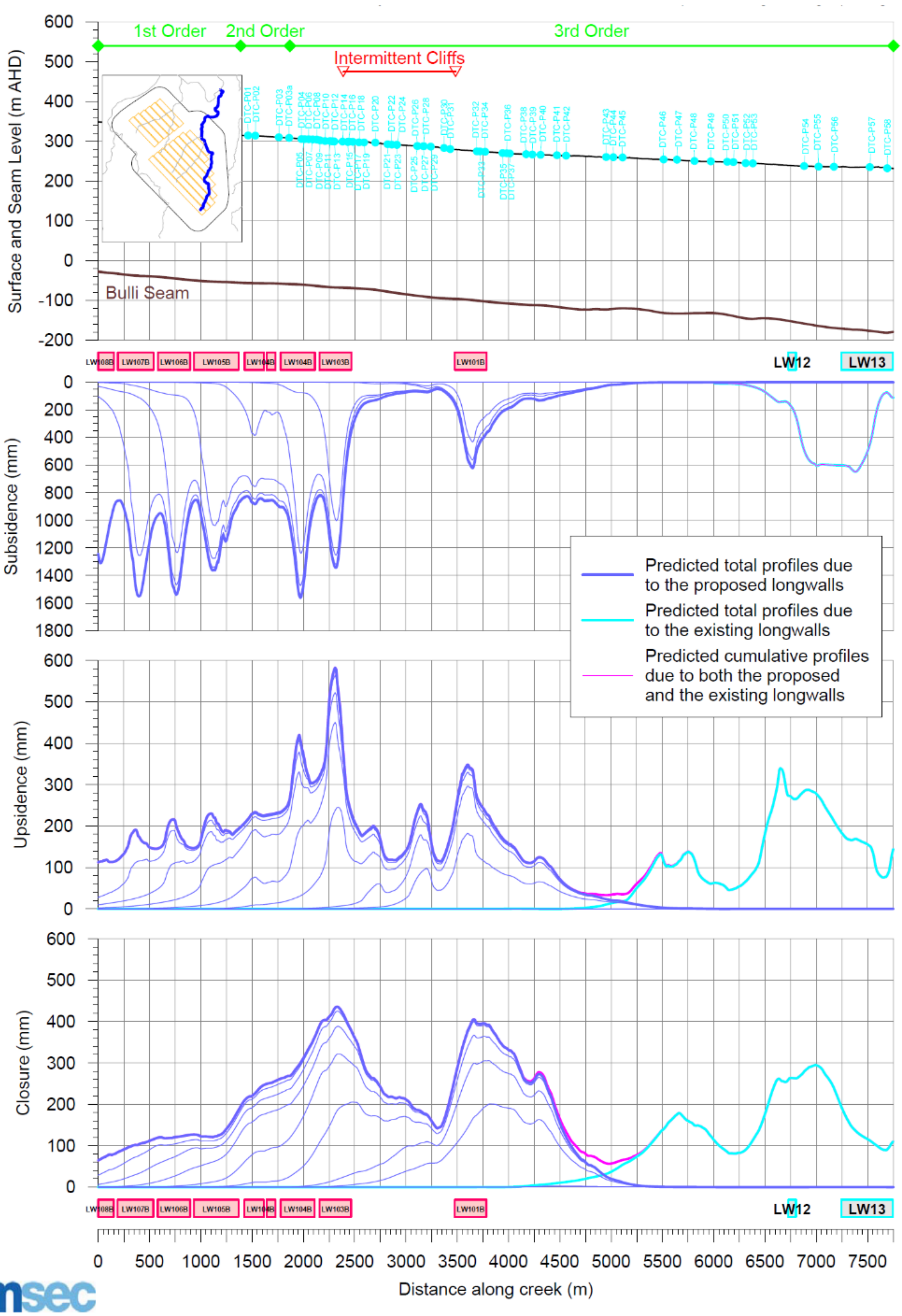

Figure A1 Predicted Subsidence Effects - Dog Trap Creek

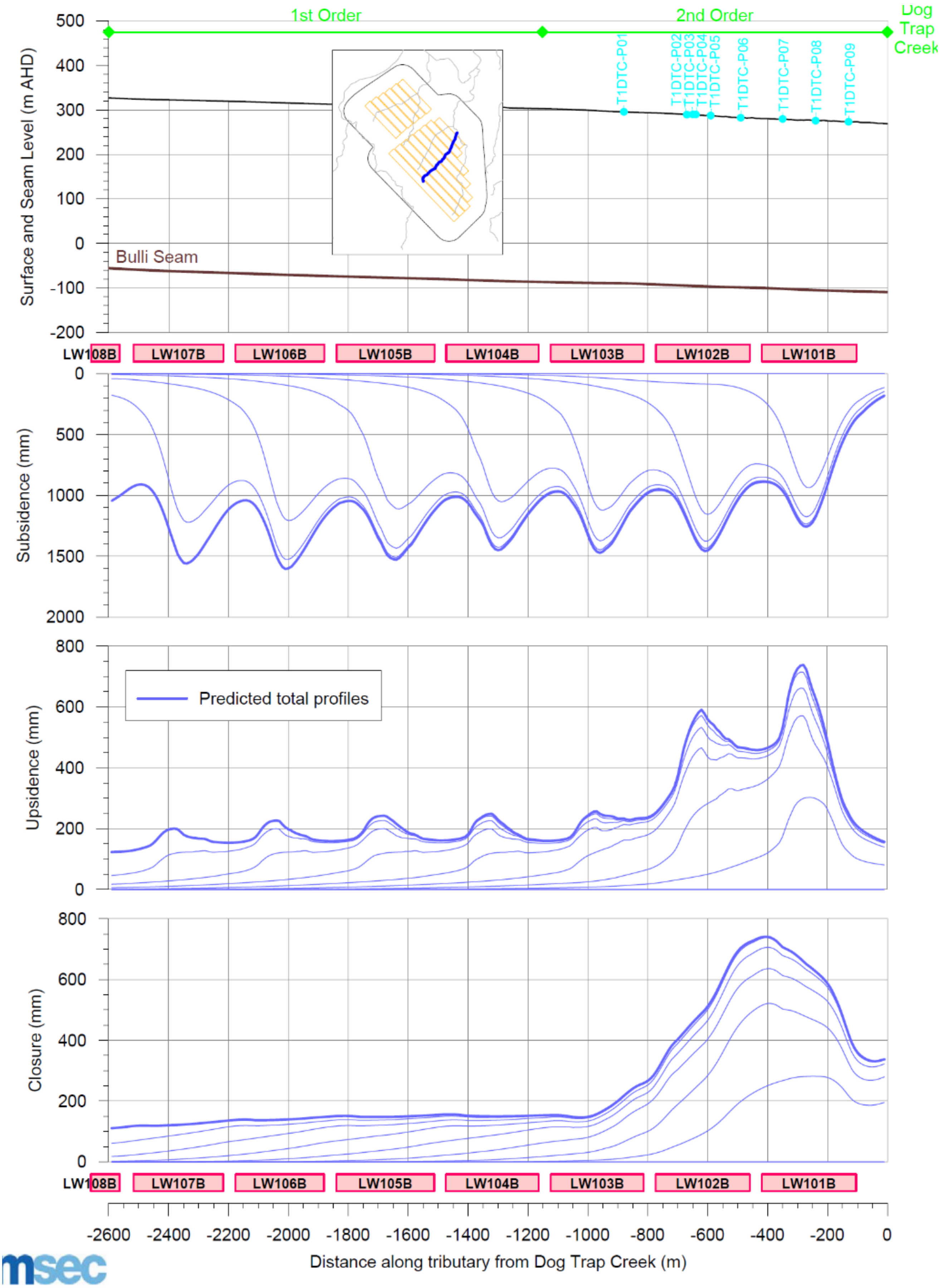

Figure A2 Predicted Subsidence Effects – Tributary 1 of Dog Trap Creek

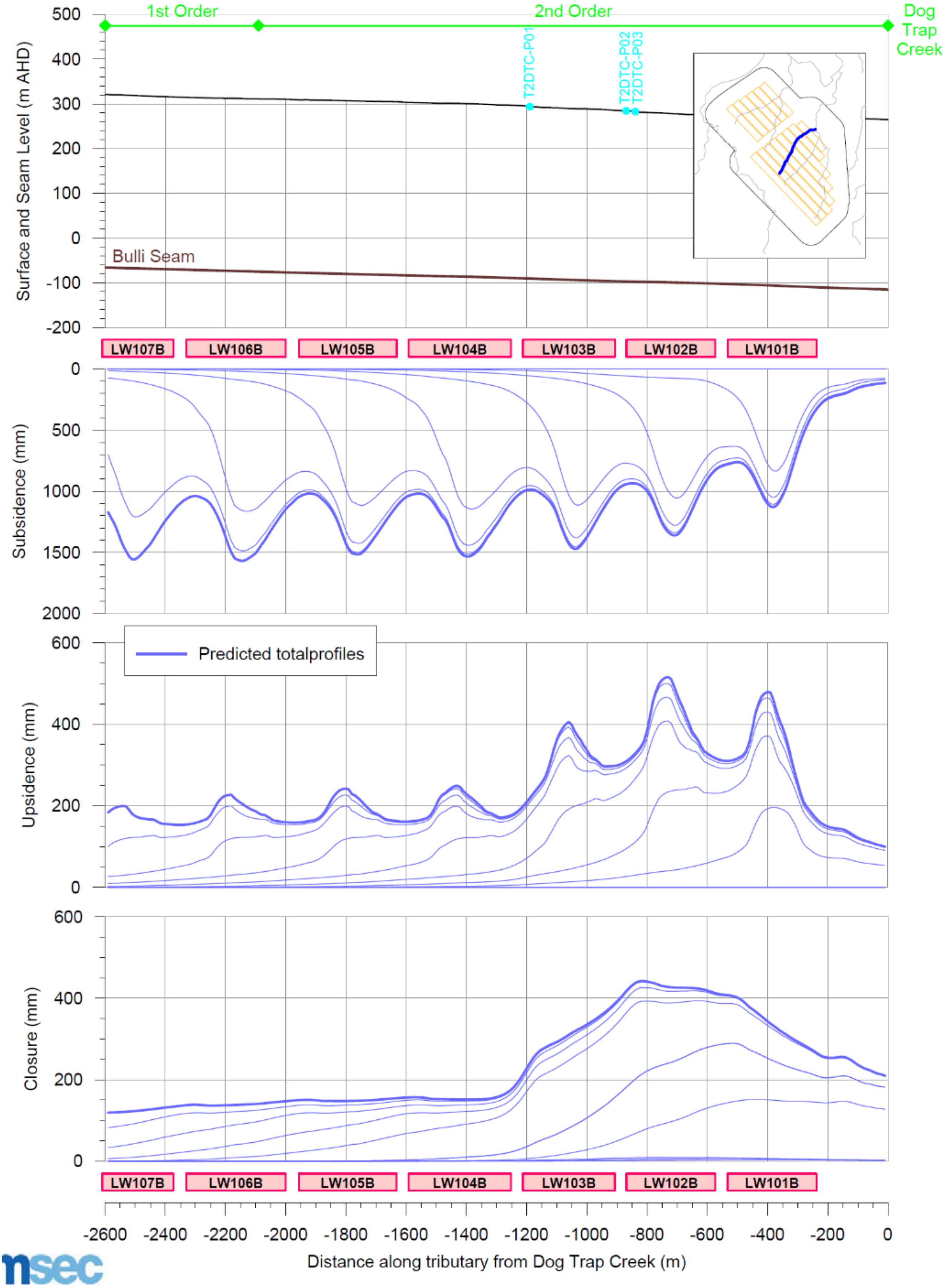

Figure A3 Predicted Subsidence Effects – Tributary 2 of Dog Trap Creek

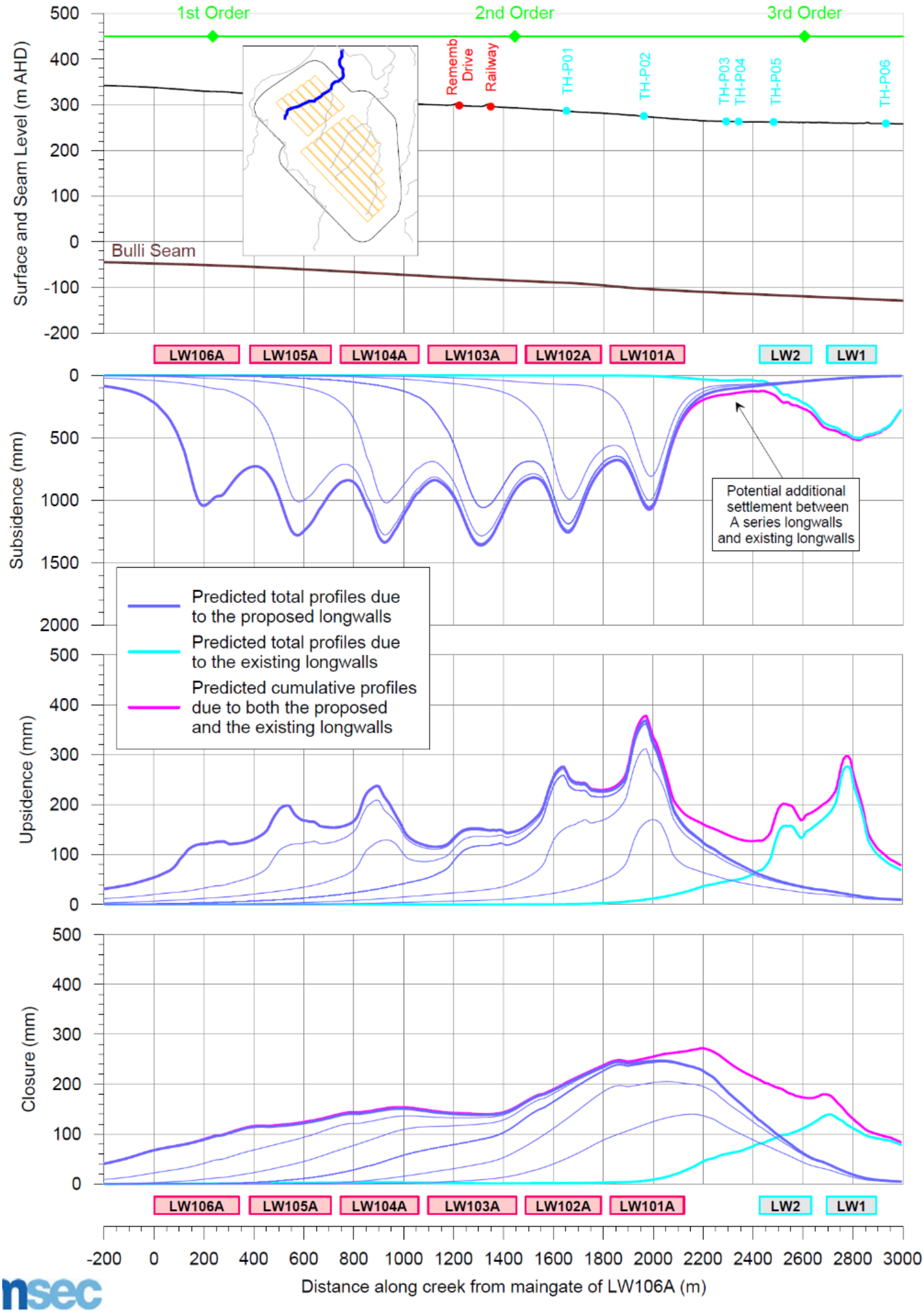

Figure A5 Predicted Subsidence Effects - Tea Tree Hollow

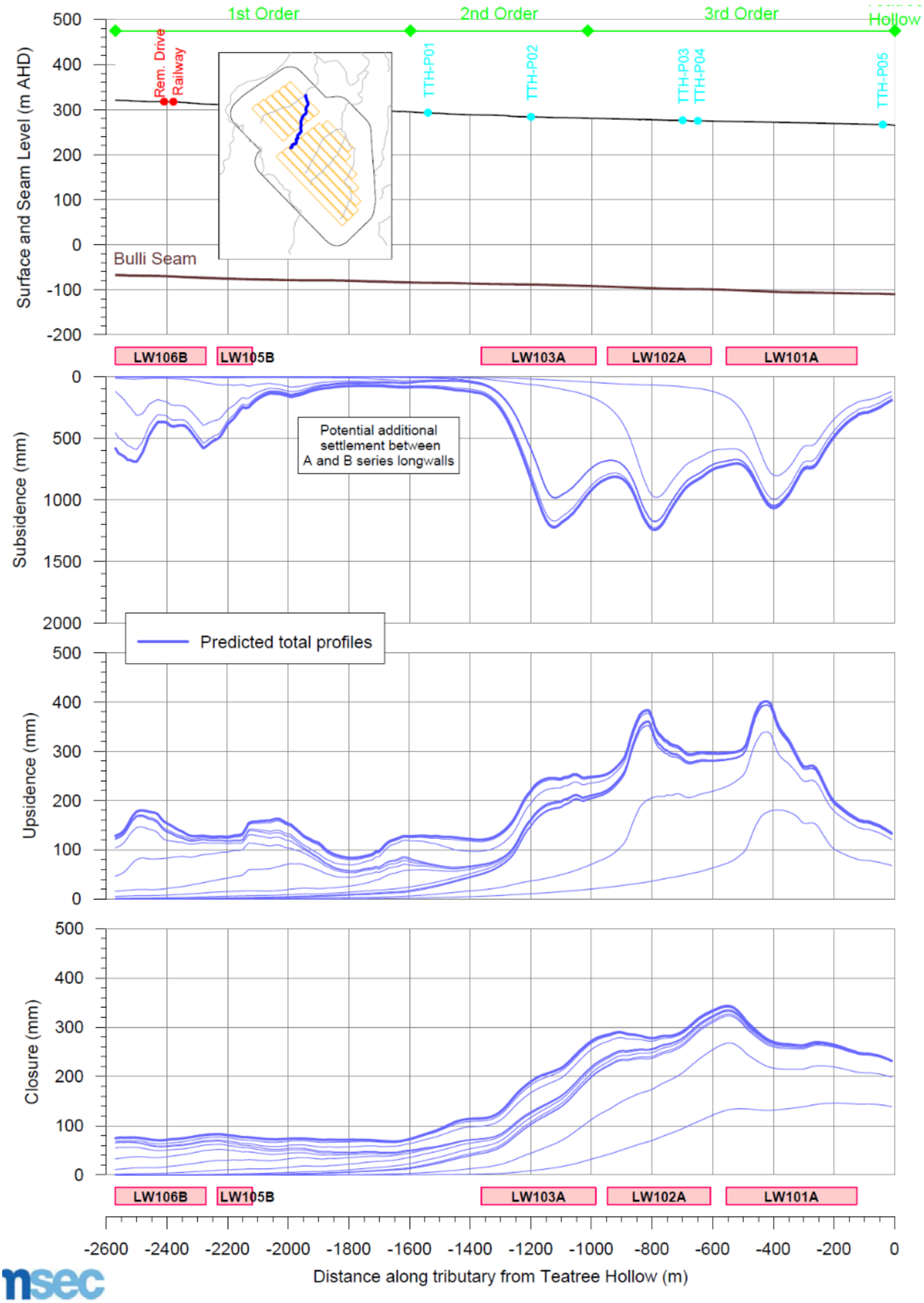

Figure A4 Predicted Subsidence Effects – Tributary of Tea Tree Hollow

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 5) 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 5) 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 5) 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 5) 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.