



TOMINGLEY

GOLD OPERATIONS PTY LTD

(A wholly owned subsidiary of Alkane Resources Ltd)

ABN 53 149 040 371



Tomingley Gold Extension Project

Surface Water

EIS Technical Report

Part 5

Major Project Application No. PA 09_0155



Prepared by **Jacobs** Jacobs Group (Australia) Pty Limited

December 2021

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Tomingley Gold Mine Expansion Project

Surface Water - EIS Technical Report

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RW Corkery & Co



Tomingley Gold Mine Expansion Project

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Australian Rainfall and Runoff (ARR 2019) outlines several fundamental themes which are also particularly relevant to this Study:

- All models are coarse simplifications of very complex processes. No model can therefore be perfect, and no model can represent all of the important processes accurately.
- Model accuracy and reliability will always be limited by the accuracy of the terrain and other input data.
- Model accuracy and reliability will always be limited by the reliability / uncertainty of the inflow data.
- No model is 'correct' therefore the results require interpretation.
- A model developed for a specific purpose is probably unsuitable for another purpose without modification, adjustment, and recalibration. The responsibility must always remain with the modeller to determine whether the model is suitable for a given problem.
- Recognition that no two flood events behave in exactly the same manner.
- Design floods are a best estimate of an "average" flood for their probability of occurrence.

The interpretation of results and other presentations in this report should be done with an appreciation of any limitations in their accuracy, as noted above.

Executive Summary

Tomingley Gold Operations Pty Ltd (the Applicant), owns and operates Tomingley Gold Operations (TGO), an active gold mine, located immediately to the south of the village of Tomingley approximately 50 km southwest of Dubbo in central-western NSW.

The Applicant is proposing additional or modified TGO operations, and an extension of open cut and underground mining at the San Antonio and Roswell Deposits (SAR) approximately 2 km south of TGO. Collectively, TGO and SAR are referred to as the Tomingley Gold Extension Project (TGE).

The Project has been classified as a "State Significant Development" under Schedule 1 (7(a)) of the State Environmental Planning Policy (State and Regional Development) 2011. As a result, the application for development consent is made under Division 4.7 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). This report has been prepared on behalf of the Applicant to support the Environmental Impact Statement (EIS) and responds to the Secretary's Environmental Assessment Requirements (SEARs) for surface water.

The water assessment for the construction, operation and decommissioning of the Project has been prepared based on existing preliminary design information and a review and analysis of available data, aerial photography, topography, database searches, relevant literature, background reports, and applicable legislation, policies and guidelines.

The desktop review revealed that the SAR Infrastructure Area and surrounds was generally flat with only some minor surface water features present. Two key waterways were identified within the vicinity of the project, including Bulldog Creek which is located within the SAR Infrastructure Area, and Gundong Creek which is located immediately adjacent to the SAR Infrastructure Area. Both creeks were determined to be minimally sensitive to hydrological and water quality impacts based on the identified characteristics of the waterways.

Upon review of the project design and construction methodology, potential impacts during construction were determined to be related to mobilisation of sediment and contaminants to downstream receivers by stormwater runoff. During construction, the following potential impacts were identified if no mitigation measures were implemented:

- Erosion of soils and subsequent sedimentation of waterways;
- Reduced water quality from elevated turbidity, nutrients and heavy metal contaminants;
- Migration of litter off-site; and
- Contamination from accidental leaks or spills of chemicals and fuels.

These potential impacts are considered highly unlikely to occur and would be managed through implementation of proposed erosion and sediment controls and other identified management measures. No construction discharges are proposed and water collected in the water management system would be re-used on-site.

During operation, the proposed surface water management system is anticipated to contain all runoff generated from the Project which would then be re-used on-site for mining-related purposes. Potential impacts are therefore considered to be limited to when the water management system fails and uncontrolled runoff flows to downstream receivers as a result of a major flood event.

The realigned Newell Highway would achieve a 1% AEP flood immunity during the operational phase of the project which is a substantial improvement on the existing Highway which achieves a less than 20% AEP flood immunity. Scour protection for the culvert outlets has been designed based on velocities from the hydraulic model. The scour protection minimises the risk of scouring, erosion and sedimentation.

Hydraulic behaviour downstream of the Newell Highway has changed due to the higher road level of the proposed Newell Highway and new flow paths created by the proposed transverse culverts under the Highway.

The peak flow would be reduced compared to the existing case whilst the overall duration of flooding would be longer. The total volume of water arriving at downstream properties would reduce by 2.9%. The landuses that would experience an increase in flood depth would exclusively be agricultural or grazing land. Four sheds and potentially one house (subject to confirmation of floor level) was identified to experience a reduction in flood depth (i.e. a net flood benefit) as a result of the proposed design.

Decommissioning activities present a low risk. Significant alteration of the hydrological regime is not expected as the proposed final landform has been designed to ensure runoff and flow paths are similar to original conditions and almost identical to that during the operational phase.

Overall, on the basis of the assessment of the existing data, surrounding environment, the design of the Project, and on the basis that recommended safeguards and management measures are implemented, the assessment concludes that there would be minimal impacts to the surface water. As such, water quality and flooding objectives for downstream receivers are likely to be met and the functionality, long-term viability of their aquatic ecosystems would be maintained.

Glossary

The following terms and acronyms are used within this document.

Table 1-1: Terms and Acronyms used in this Report

Term or Acronym	Description
AHD	Australian Height Datum
Annual exceedance probability (AEP)	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. For example, the 1% AEP flood would have a 1% chance of occurring in any given year.
ANZECC/ARMCANZ	National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality
ARF	Areal Reduction Factor
ARR 2019	Australian Rainfall and Runoff Guidelines – 2019 Edition
Blue Book	Managing Urban Stormwater: Soils and Construction
BoM	Bureau of Meteorology
CC	Climate change
DAWE	Department of Agriculture, Water and the Environment
DEM	Digital Elevation Model
Design Case	Hydraulic modelling case with Project in place
DPI	Department of Primary Industries (former)
DPIE	Department of Planning, Industry and Environment
DTM	Digital terrain model
EIS	Environmental Impact Statement
ELVIS	<u>Elevation Information System - Elevation and Depth – Foundation Spatial Data available from http://elevation.fsdf.org.au/</u>
EP&A Act	Environmental Planning and Assessment Act 1979
EPA	Environmental Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPLs	Environmental protection licences
Existing Case	Hydraulic modelling case pre- Project
FFA	Flood frequency analysis
FM Act	Fisheries Management Act
FRP	Filterable Reactive Phosphorus
GIS	Geographical Information System
HPC	Heavily Parallelised Compute used by TUFLOW
IFD	Intensity-Frequency-Duration
KFH	Key Fish Habitat
LGA	Local Government Area
LiDAR	Light Detection and Ranging
MNES	Matters of National Environmental Significance
Mtpa	Million tonnes per annum
NHRMC	Guidelines for Managing Risks in Recreational Water
NOx	Oxidised Nitrogen
NSW	New South Wales
NWQMS	National Water Quality Management Strategy

Term or Acronym	Description
PMF	Probable Maximum Flood
POEO Act	Protection of the Environment Operations Act
QA	Quaternary Alluvium
RAFTS	RAFTS (xrafts) is a runoff routing model that is used for hydrologic and hydraulic analysis of storm water drainage and conveyance systems.
RCBC	Reinforced Concrete Box Culvert
RCP	Representative concentration pathways
RCP	Reinforced Concrete Pipe (in the context of pipe materials)
RCP (Climate Change)	Representative Concentration Pathway (in the context of Climate Change scenarios)
RFFE	A computer based Regional Flood Frequency Estimation model developed at the Western Sydney University for Australian Rainfall and Runoff project.
ROM	Run of Mine
SAR	San Antonio and Roswell Deposits
SAR Infrastructure Area	See Section 2.1.1 .
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
SRD	State and Regional Development
SRTM	Shuttle Radar Topography Mission
SSD	State Significant Development
SW/FR	Slightly Weathered and Fresh Rock
TA	Tertiary Alluvium
TGEP	Tomingley Gold Extension Project
TGO	Tomingley Gold Operations
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled one dimensional and two-dimensional hydraulic solutions using a powerful and robust computation.
WAL	Water Access Licence
Water Quality Objectives	WQOs
WQ	Water Quality
WSP	Water Sharing Plan

1. Introduction

1.1 Project background

Tomingley Gold Operations Pty Ltd (the Applicant), a subsidiary company of Alkane Resources Ltd, owns and operates Tomingley Gold Operations (TGO), an active gold mine, located immediately to the south of the town of Tomingley approximately 50 km southwest of Dubbo in central-western NSW (**Figure 1-1**).

The Applicant is proposing additional or modified TGO operations, plus extension of open cut and underground mining, at the San Antonio and Roswell Deposits (SAR) approximately 2 km south of TGO, hereafter referred to as SAR. Collectively, TGO and SAR are referred to as the Tomingley Gold Extension Project (TGEP or the Project). The project is further described in **Section 2**.

The Project has been classified as a "State Significant Development" under Schedule 1 (7(a)) of the State Environmental Planning Policy (State and Regional Development) 2011. As a result, the application for development consent is made under Division 4.7 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

1.2 Purpose of this document

Jacobs Australia Pty Ltd (Jacobs) has been commissioned by RW Corkery & Co, on behalf of the Applicant, to prepare a Surface Water Impact Assessment for the Project's Environmental Impact Statement (EIS). The scope of Jacobs' assessment is as follows:

- Establishment of existing surface water conditions
- Development of hydrologic and hydraulic model of the site for the flood impact assessment
- Water quality impact assessment

The following elements were **excluded** from Jacobs' scope of works:

- Stormwater Management Plan
- Erosion and Sediment Control Plan
- Site Water Balance Assessment

This surface water assessment is intended to address the Secretary's Environmental Assessment Requirements (SEARs) in relation to surface water quantity and quality components within the Jacobs' scope of works (refer to **Section 1.3**). The report identifies baseline environmental conditions in the vicinity of the proposed works and includes an assessment of potential impacts to surface water during construction, operation and decommissioning of the Project.

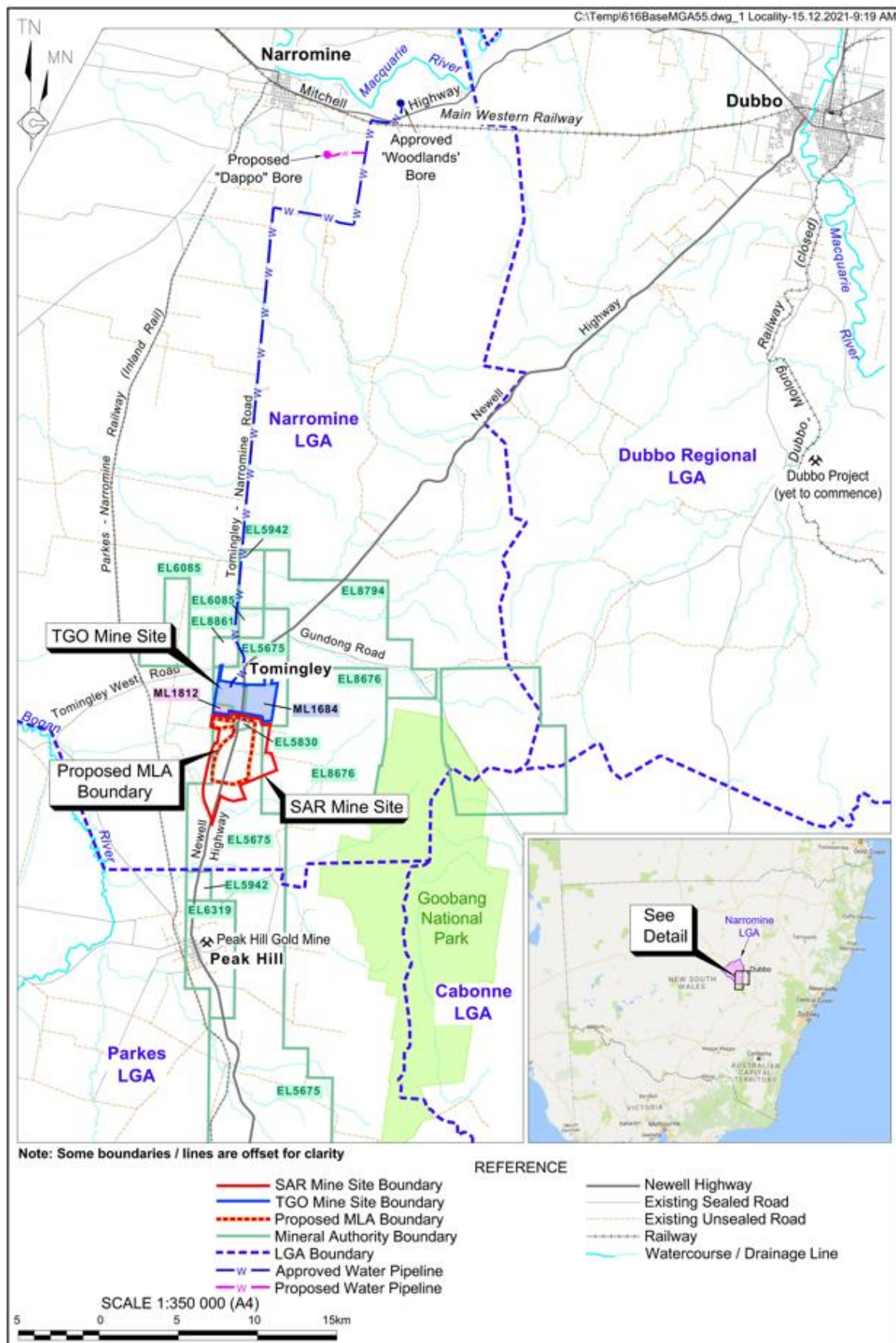


Figure 1-1 Locality Plan and Mineral Authorities

1.3 SEARs

On 22nd July 2021, the Applicant was issued SEARs in relation to the Project. SEARs relevant to surface water are summarised in **Table 1-1**.

Table 1-1: SEARs – Surface Water

Summarised or Paraphrased Water specific SEARs	See Report Section
<i>The EIS must address the following specific issues with the level of assessment of likely impacts proportionate to the significance of, or degree, of impact on, the issue, within the context of the project location and the surrounding environment and having regard to applicable NSW Government policies and guidelines, including:</i>	
an assessment of the likely impacts of the development on the quantity and quality of surface, and groundwater resources, having regard to the <i>NSW Aquifer Interference Policy</i>;	Water quality impacts are discussed in Section 6 and flood impacts are discussed in Section 7 . Groundwater impacts are detailed in the Groundwater Technical Report.
an assessment of the hydrological characteristics of the site and downstream;	Existing environment outlined in Section 5 , hydrological characteristics described Section 5.3 .
an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure and systems and other water users, including impacts to water supply from dams, and riparian and licensed water users;	Water quality impacts are discussed in Section 6 and flood impacts are discussed in Section 7 . Groundwater impacts are detailed in the Groundwater Technical Report.
demonstration that water for the construction and operation of the development, for the life of the project, can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant <i>Water Sharing Plan (WSP)</i>, and include an assessment of the current market depth where water entitlement is required to be purchased;	Discussed in Section 3.2 .
a description of the measures proposed, including monitoring activities and methodologies, to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo;	Recommended mitigation measures outlined in Section 8 .
a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts;	Project description provided in Section 2.2 and other recommended mitigation measures outlined in Section 8 .
Demonstrate how the proposal will: - Protect Water Quality Objectives in receiving waters, where they are being achieved; and - Contribute towards achievement of the Water Quality Objectives, where they are not being achieved.	Discussed in Section 6.4 .
an assessment of the potential flooding impacts of the project;	Provided in Section 7.1.4 .

ENVIRONMENTAL PLANNING INSTRUMENTS, POLICIES, GUIDELINES AND PLANS	
Consider relevant government policies, including: - Water Sharing Plans - NSW State Rivers and Estuary Policy (DPI Water) - NSW Water Quality and River Flow Objectives - National Water Quality Management Strategy: Australian Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ) - National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ) - National Water Quality Management Strategy: Guidelines for Sewerage Systems – Effluent Management (ARMCANZ/ANZECC) - National Water Quality Management Strategy: Guidelines for Sewerage Systems – Use of Reclaimed Water (ARMCANZ/ANZECC) - Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (EPA) - Managing Urban Stormwater: Soils & Construction (Landcom) and associated Volume 2E: Mines and Quarries (DECC) - Managing Urban Stormwater: Treatment Techniques (EPA) - Managing Urban Stormwater: Source Control (EPA) - Technical Guidelines: Bunding & Spill Management (EPA) - A Rehabilitation Manual for Australian Streams (LWRRDC and CRCCH) - NSW Guidelines for Controlled Activities (NOW) - Floodplain Development Manual (OEH) - Floodplain Risk Management Guideline (OEH)	Described in Section 3, and applied throughout the assessment.

1.4 Report structure

The report structure is as follows:

- **Section 1** provides the Project background and purpose of the report;
- **Section 2** describes the Project;
- **Section 3** describes the relevant legislation and policies applicable to the assessment;
- **Section 4** outlines the surface water assessment methodology;
- **Section 5** describes the existing conditions of surface water resources within and surrounding the SAR Infrastructure Area;
- **Section 6** describes the potential Water Quality impacts of the Project;
- **Section 7** describes the potential Flooding impacts of the Project;
- **Section 8** outlines recommended environmental safeguards and mitigation measures to be implemented during construction and operation to protect surface water and groundwater resources; and,
- **Section 9** presents the assessment conclusions.
- **Annexure A** presents the applicable Water Quality Guidelines (ANZG, 2018)
- **Annexure B** presents the hydrology and hydraulics technical report and detail on the flooding assessment

2. Project description

2.1 Project overview

The Project comprises two components as follows:

- Approved TGO mining operations (**Figure 2-1**). These activities are undertaken in accordance with development consent MP 09_0155. The approved activities would continue under any new development consent, with MP 09_0155 to be surrendered following receipt of the new development consent and all required approvals for the Project. The approved activities include the following.
 - Extraction of ore and waste rock from four open cuts, with underground mining beneath three of those open cuts.
 - Construction of three out-of-pit waste rock emplacements and one in-pit emplacement.
 - Construction and use of various haul roads, a run-of-mine (ROM) pad and associated stockpiles.
 - Construction and use of a Processing Plant to process up to 1.5 million tonnes per annum (Mtpa).
 - Construction and use of two residue storage facilities comprising Residue Storage Facility 1 (to Stage 9 or a maximum elevation of 286.5m AHD) and Residue Storage Facility 2 (to Stage 2 or a maximum elevation of 272m AHD).
 - Construction and use of ancillary infrastructure.
- The proposed SAR operations and additional or modified TGO operations, including the following (**Figure 2-1** and **Figure 2-2**).
 - Realigned Newell Highway and Kyalite Road and associated intersections with Back Tomingley West Road and McNivens Lane and Kyalite Road overpass.
 - The SAR Open Cut and Underground Mine.
 - Construction of two waste rock emplacements, namely the Caloma and SAR Waste Rock Emplacement and backfilling of the associated open cuts.
 - The SAR Amenity Bund, Haul Road and Services Road between the SAR Open Cut and the Caloma 2 Open Cut.
 - Processing of ore from the SAR deposits using the approved Processing Plant at a maximum rate of 1.75Mtpa.
 - Increased capacity for Residue Storage Facility 2, from Stage 2 to Stage 9, with a maximum elevation of 286m AHD.
 - Associated surface and underground activities and infrastructure.

In addition, the Project would include an extension of the approved mine life, likely from 31 December 2025 to 31 December 2032.

2.1.1 Project Area Definition for the Surface Water Assessment

This surface water assessment is limited to assessment of proposed design features which alter the existing landscape and thus have the potential to alter pre-existing flow paths and impact the hydrologic regime. These design features include all features which require bulk earthworks within the SAR Mine Site boundary (including the SAR open cut, waste rock emplacements, amenity bund, inundation bund, stockpiles, administration area), as well as the haul road, Kyalite Road, Newell Highway and Back Tomingley West Road realignments. Together, these areas of focus have been referred to as the 'SAR Infrastructure Area' in this report.

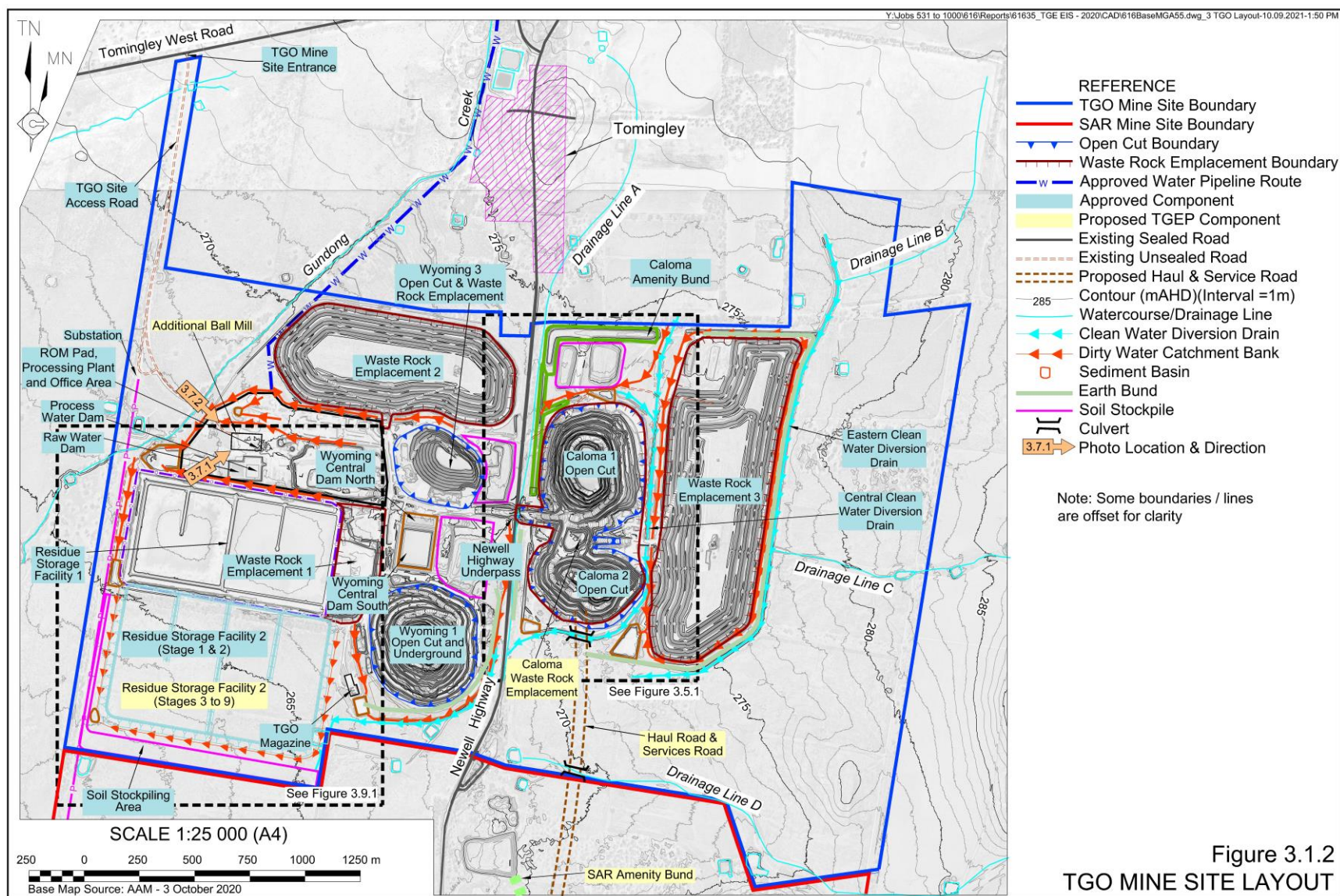


Figure 3.1.2
TGO MINE SITE LAYOUT

Figure 2-1 TGO mine site layout (Source: RW Corkery & Co, 2021)

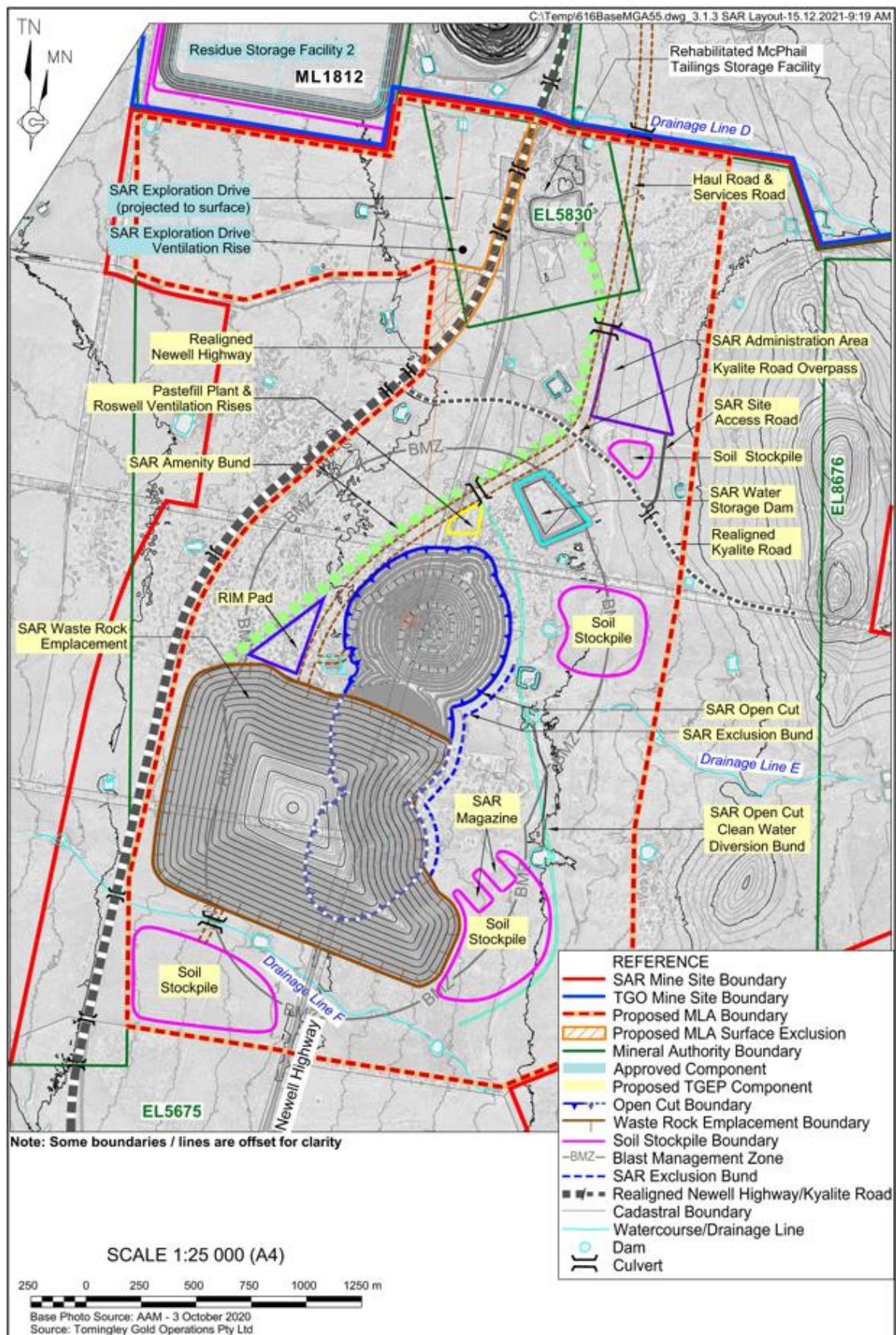


Figure 2-2 SAR Mine Site layout (Source: RW Corkery & Co, 2021)

2.2 Project description

2.2.1 Site establishment

Site establishment activities would include the following:

- Key boundaries and locations would be marked on the ground and recorded on relevant site construction plans and documents.
- Existing infrastructure within the disturbance area, including communication lines, powerlines, fences, buildings and sheds would be progressively demolished and/or relocated.
- Additional services required for the Project, including powerlines, communication lines and pipelines would be established.
- Suitable fences, including warning signs, would be established to separate active mining areas from areas that would continue to be used for agricultural purposes.
- Construction laydown and equipment parking area, as well as office/amenity buildings would be established.
- Vegetation clearing followed by stripping and stockpiling of soil would be undertaken.
- Borrow pits would be established within the footprint of the Waste Rock Emplacement and/or SAR Open Cut for the supply of construction materials.
- Construction of the Haul Road, Services Road, Amenity Bund, Administration Area, internal site roads, hard stands, explosives magazines, water storages and other site infrastructure.

2.2.2 Road realignments

The Project would require realignment of the following public roads:

- Newell Highway and intersections with Kyalite Road, McNivens Lane and Back Tomingley West Road.
- Kyalite Road, including an overpass over the Haul Road and Services Road.

The current alignment of the Newell Highway is within the proposed SAR Open Cut. The Applicant proposes to realign the Highway approximately 1km to the west. The proposed realigned Highway would be constructed on a like-for-like basis to the standard required by Transport for NSW. The realigned section of the Highway is proposed to incorporate flood protection for a 5% Annual Exceedance Probability (AEP) rainfall event.

Kyalite Road is also within the footprint of the SAR Open Cut. As a result, it would additionally be realigned to the north and would include an overpass over the Haul Road and Services Roads. The realigned road would be sealed from the intersection with Newell Highway to a point 30m east of the intersection with the SAR Site Access Road. The realigned road would be constructed to the standard required by Narromine Shire Council.

2.2.3 Proposed extension to mining activities

The mining activities would include elements of the following operations. Further detail on the mining activities can be found in the EIS report.

- Open Cut mining
- Underground mining
- Waste rock management

2.2.4 Water management

Surface water diversion structures would be constructed during the initial site establishment phase of the Project. The surface water diversions would be designed to convey water at non-erosive velocities. An Inundation Bund

would be constructed to the east of the SAR Open Cut to provide protection from extreme rainfall events (up to the 0.1% AEP event). Details of the Design features can be seen in **Figure 2-2**.

Culverts would be installed under the relocated Newell Highway, Haul Road and Services Road and gaps would be left in the SAR Amenity Bund for flow conveyance purposes (see Figure 2-4 for the conceptual Amenity Bund design). Where existing culverts under the section of the Newell Highway to be decommissioned are inadequate, sections of the road would be removed. Where it is practicable to do so, the existing Newell Highway and transverse culverts have been retained. The locations where the existing Newell Highway is to be retained is shown in **Figure 2-3**.

Potentially sediment-laden or dirty water would be retained within the disturbed section of the Mine Site and would be used for mining-related purposes. Dirty water would be prevented from being discharged from site. Further details on this would be available in the Site Stormwater Management Plan (not prepared by Jacobs).

Water removed from the underground workings would be pumped to a surface storage facility and would be used for mining-related purposes. Mine water would be prevented from being discharged from site. Further details on this would be available in the Site Stormwater Management Plan (not prepared by Jacobs).

The current water supply for TGO is drawn from groundwater sources including the Woodlands Borefield located approximately 35 km north of the TGO Mine Site in the Lower Macquarie alluvial aquifer. Groundwater extraction from the borefield for the purpose of mineral ore processing is permitted under WAL20270 with an annual extraction limit of 1,000 ML.

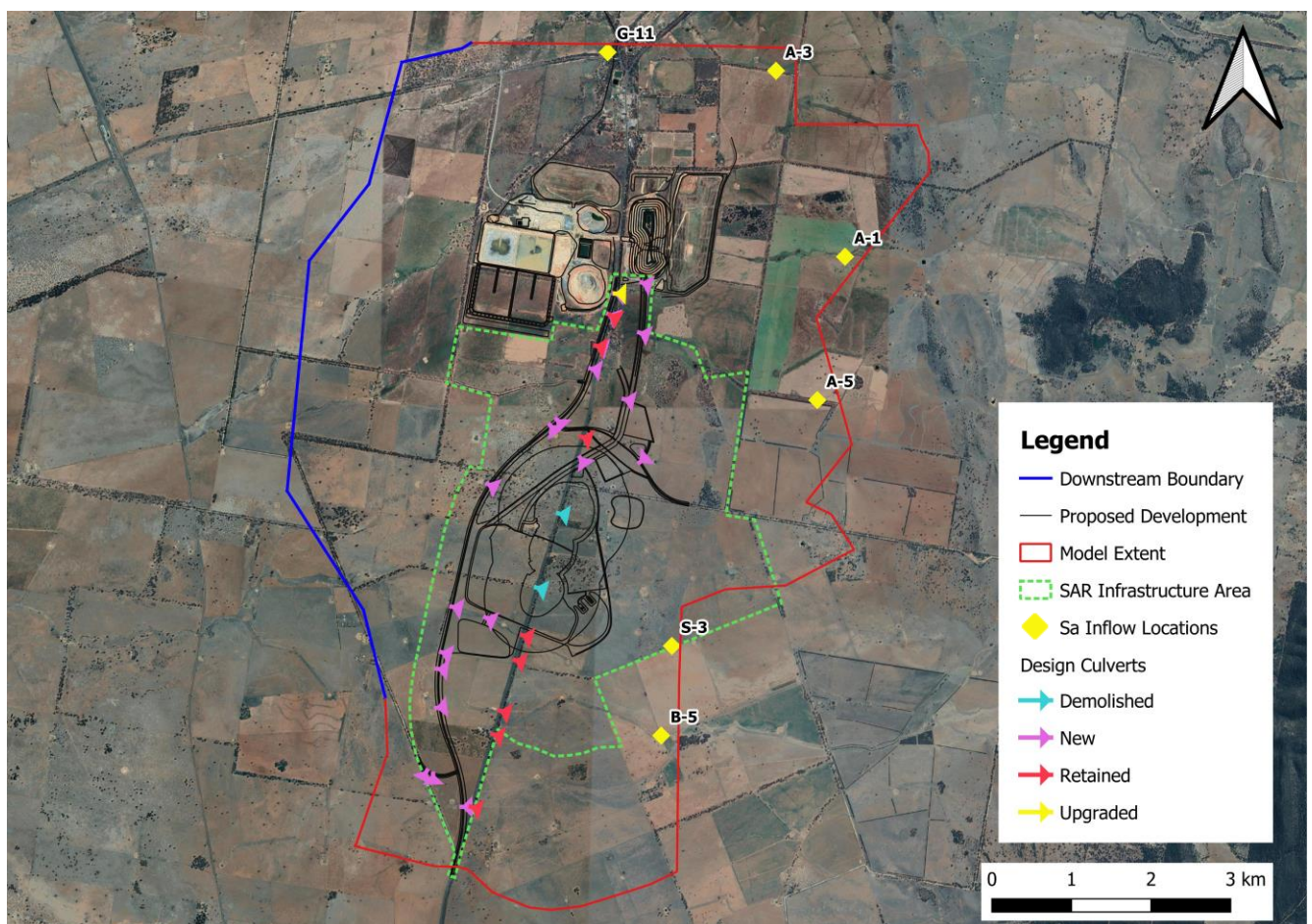


Figure 2-3: SAR Mine Site - Hydraulic model schematisation

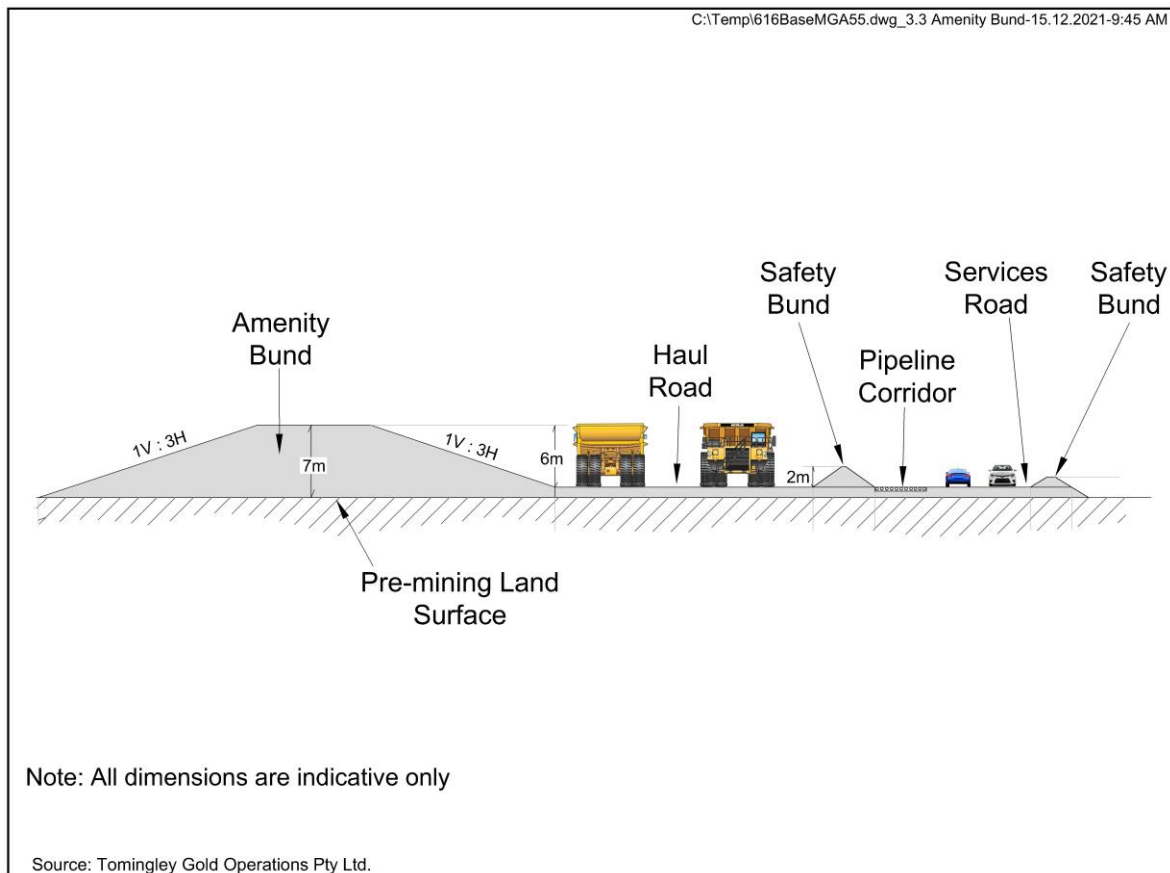


Figure 2-4: Amenity Bund Concept Drawing

2.2.5 Final landform, land use, rehabilitation and mine closure

The approved and proposed final landform would include the following:

- Two bunded and fenced final voids, namely the approved and existing Wyoming 1 Open Cut and a proposed void within the northern section of the SAR Open Cut.
- Three fully backfilled open cuts, namely the approved Wyoming 3 and proposed Caloma 1 and Caloma 2 Open Cuts, as well as the southern and central sections of the SAR Open Cut.
- Four shaped and rehabilitated Waste Rock Emplacements, namely the approved and existing WRE2 and WRE3 and the proposed Caloma and SAR Waste Rock Emplacements.
- A capped, shaped and revegetated RSF1 and RSF2.
- Water management structures.
- The realigned Newell Highway and Kyalite Road would be retained. The Haul Road overpass on Kyalite Road would be removed or retained in consultation with Narromine Shire Council.

All infrastructure not required for the final land use would be removed or reduced in size, indicatively including the following:

- The Amenity Bund and Haul Road would be removed. The Services Road would be reduced in size to facilitate ongoing management of the land post-mining.
- The SAR Administration Area would be largely removed, with those structures suitable for the final land use retained. This may include sheds and limited hardstand areas.
- The Processing Plant, TGO Administration building and associated infrastructure would be removed.

- The magazines, RIM Pad, Pastefill Plant and other infrastructure would all be removed.
- All entrances to the underground workings would be sealed.

The final land use would comprise a mixture of agriculture and nature conservation.

Rehabilitation would be undertaken progressively, with the outer face of the SAR Waste Rock Emplacement rehabilitated as each lift is established, on an indicatively annual cycle throughout the life of the Project. Rehabilitation of other sections of the Project Site would be undertaken at the end of mine life. A Rehabilitation Management Plan describing the proposed rehabilitation operations and providing detailed completion criteria would be prepared in accordance with the guidelines relevant at that time.

Following completion of all rehabilitation operations and confirmation that the relevant completion criteria have been achieved, the Applicant would relinquish the Mining Leases.

3. Legislation and policy framework

This section provides consideration of the legislative and policy framework for the surface water assessment.

3.1 Commonwealth legislation

3.1.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) aims to protect Matters of National Environmental Significance (MNES). Under the EPBC Act, where an action has potential to have a significant impact on a MNES, the proposal is referred to the Commonwealth Department of Agriculture, Water and the Environment (DAWE). The referral process involves a decision on whether or not the proposal is a 'controlled action'. When a proposal is declared a controlled action, approval from the Minister for the Environment is required. This Project includes no controlled activity.

3.2 State legislation

3.2.1 Environmental Planning and Assessment Act 1979 and Environmental Planning and Assessment Regulation 2000

The *Environmental Planning and Assessment Act 1979* (EP&A Act) and the *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation) provide the framework for development assessment in NSW. The EP&A Act and the EP&A Regulation include provisions to ensure that the potential environmental impacts of a development are considered in the decision-making process prior to proceeding to construction.

The Project is declared State Significant Development (SSD) under the *State Environmental Planning Policy (State and Regional Development) 2011* (SEPP SRD) and an Environmental Impact Statement (EIS) has been prepared under Division 4.7 of the EP&A Act. The SEARs have been issued and this report considers those requirements as relevant to surface water resources (refer to **Section 1.3**).

Section 4.41 of the EP&A Act states that particular licences, permits and approvals such as a water management work approval under section 90, or an activity approval under section 91 of the *Water Management Act 2000* (WM Act) do not apply to a SSD project.

3.2.2 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (NSW) (POEO Act) is administered by the Environmental Protection Authority (EPA). The POEO Act regulates air and water pollution, noise control and waste management. The Act contains pollution controls and requirements for granting environmental protection licences (EPLs) for scheduled activities under Schedule 1, which includes mining for minerals, as well as for unscheduled activities or prescribed matters (as listed in Schedule 5 of the *Protection of the Environment Operations (General) Regulation 2009*) that cover the discharge of water that may cause pollution.

Under the POEO Act, there is a legal responsibility to ensure that runoff leaving a site meets an agreed water quality standard, including water being discharged from construction sediment ponds after storm events.

During construction of the Project, the construction contractor will be required to obtain an EPL for the duration of the construction phase. Should discharges to the waterways be required during construction, erosion and sediment controls associated with the construction of the Project will be designed to achieve licenced water quality standards outlined in the EPL.

Alkane Resources will require an EPL for the operation of the proposed mine operations. The licence would stipulate specific monitoring (i.e. parameters, locations etc.) to monitor environmental performance of the project. Permanent drainage infrastructure will be designed and managed in accordance with EPL licence conditions.

3.2.3 Water Act 1912, Water Management Act 2000 and Water Management (General) Regulation 2011

The *Water Act 1912* and the *Water Management Act 2000* (WM Act) are the two key pieces of legislation for the management of water in NSW and contain provisions for the licensing of water access and use. The *Water Act 1912* is being progressively phased out and replaced by the WM Act. Further to this, the *Water Management Amendment Act 2014* (WM Amendment Act) changes some sections of the WM Act including planning, licensing and compliance.

The aims of the WM Act are to provide for the sustainable and integrated management of the State's water sources for the benefit of both present and future generations. The WM Act implicitly recognises the need to allocate and provide water for the environmental health of rivers and groundwater systems, while also providing license holders with more secure access to water and greater opportunities to trade water through the separation of water licenses from land. The WM Act enables the State's water resources to be managed under water sharing plans, which establish the rules for the sharing of water in a particular water source between water users and the environment, and rules for the trading of water in a particular water source. Ordinarily, if an activity leads to a take from a groundwater or surface water source covered by a WSP, then an approval and / or licence is required. In general, the WM Act requires:

- a Water Access Licence (WAL) to take water;
- a water supply works approval to construct a work; and
- a water use approval to use the water.

With regards to surface water, the Project resides in the Upper Bogan River Water Source of the Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012. In relation to the Upper Bogan River Water Source, the NSW Water Register (Water NSW, 2021a) indicates this surface water source has 27 WALs and a total share component of 1,849 units/ML. The register indicates that the volume of water made available to all the WALs is 1,849 ML.

It is noted that, as the Project is considered to be a SSD under Section 4.41 of the EP&A Act, the authorisation provided by a water use approval under Section 89 of the WM Act, a water management work approval under Section 90 of the WM Act or an activity approval under Section 91 WM Act are not required. Rather, this authorisation is provided by a development consent.

Thus, if the Project's surface water extraction is assessed and approved as part of the SSD proposal, only a WAL would be required. However, as no new surface water is expected to be taken from site, a WAL for surface water would not be required.

3.2.4 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) provides for the protection of threatened fish and marine vegetation and is administered by NSW Fisheries within the Department of Planning Industry and Environment (Regions, Industry, Agriculture & Resources). The FM Act aims to conserve, develop and share fishery resources and conserve marine species, habitats and diversity.

Waterways within the footprint area have been categorised with regards to NSW Fisheries key fish habitat mapping and threatened species distribution mapping (refer to **Section 5.3.1** for further detail). No threatened species have been mapped within the waterways in the water quality and flood study areas.

3.3 Relevant policies and guidelines

The following policies, guidelines and plans also have relevance to the Project

3.3.1 State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 amended 2013

The *State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007* (NSW), amended in 2013, was made under the *Environmental Planning and Assessment Act 1979* (NSW). The policy sets the requirements for permissible development, and considers the requirements for development applications and the gateway process for approvals. The policy allows for the proper management and development of mineral extractive resources whilst promoting ecologically sustainable development.

3.3.2 National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) (Australian Government, 2018) was formulated with the objective of achieving sustainable use of the nation's water resources by protecting and enhancing water quality whilst maintaining economic and social development.

The NWQMS contains guidelines for setting water quality objectives to sustain current or likely future environmental values for water resources. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018) (referred to herein as the ANZG (2018) Water Quality Guidelines) are part of the NWQMS and are described in **Section 3.3.3**. The ANZG (2018) Water Quality Guidelines superseded Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000a).

Other guidelines which form part of the NWQMS include Guidelines for Sewerage Systems – Effluent Management (ANZECC/ARMCANZ, 1997) and Use of Reclaimed Water (ANZECC/ARMCANZ, 2000b).

3.3.3 Australian and New Zealand Water Quality Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Environment and Conservation Council (ANZECC/ARMCANZ) published *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000c) to provide benchmarks against which to assess the existing water quality of waterways. The guidelines were updated in 2018 to incorporate new science and knowledge developed over the past 20 years (ANZG, 2018), and several parameters have again been updated in 2021. The ANZG (2018) Water Quality Guidelines are an online resource which incorporates the Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000a) and Guideline for Sewage Systems (ANZECC/ARMCANZ, 1997; ANZECC/ARMCANZ, 2000b).

The ANZG (2018) Water Quality Guidelines have been applied with guidance from the *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (DEC, 2006) booklet to understand the current health of the waterways in the study area and the ability to support nominated water quality objectives, particularly the protection of aquatic ecosystems. The ANZG (2018) Water Quality Guidelines provide default guideline values which have been considered when describing the existing water quality and key indicators of concern. However, many of the guideline values are still in a draft form. Currently, physical and chemical stressors for aquatic ecosystems for the Southeast Coast (the geographic region relevant to this Project) have not yet been completely updated.

The ANZG (2018) Water Quality Guidelines are not intended to directly apply to contaminant concentrations in industrial discharges or stormwater quality (unless stormwater systems are regarded as having relevant community value). They have been derived to apply to the ambient waters that receive effluent or stormwater discharges and protect the water quality objectives they support.

The ANZG (2018) Water Quality Guidelines do not contain default guideline values for physico-chemical indicators relevant to the Project. The water quality targets relevant to the Project are set out in the Murray-Darling Basin Plan, the Murray-Darling Basin Agreement and the ANZG (2018) Water Quality Guidelines.

3.3.4 Guidelines for Managing Risks in Recreational Waters

The *Guidelines for Managing Risks in Recreational Water* (NHRMC, 2008) aim to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters.

The guidelines provide recommended values for indicators that may pose a risk to human health. These indicators are relevant for waterways that are used for recreational activities but have the potential to be polluted. These guidelines are applicable to this assessment because waterways in proximity of the Project Site have been nominated as the environmental values of 'Primary contact recreation' and 'Secondary contact recreation'. This is further detailed in **Section 4.2.2**.

3.3.5 NSW Water Quality and River Flow Objectives

The NSW Water Quality Objectives (WQOs) (DECCW, 2006) are the agreed long-term goals for NSW's surface water, as determined by the then Department of the Environment, Climate Change and Water (now Department of Planning, Industry and Environment). They set out:

- The community's values and uses (ie. healthy aquatic ecosystem, water suitable for recreation or drinking water etc) for our waterways (rivers, creeks, lakes and estuaries); and
- A range of water quality indicators to assess whether the current condition of the waterway supports these values and uses.

The WQOs identify environmental values for NSW waters and the ANZG (2018) guidelines provide the technical guidelines to assess the water quality needed to protect these values.

The Project Site falls within the "Macquarie-Bogan River" catchment (DECCW, 2006). The waterways within this section of the catchment have been categorised as "uncontrolled streams", which are described as streams and waterbodies that are not in estuaries or other categories. The flow pattern in these streams may have been altered in some way through land-use change and extraction. Many of these streams flow into the regulated river sections, and so changes to their flow regime will affect downstream flows

Environmental values (DECCW, 2006) that have been nominated for uncontrolled streams are detailed in **Section 4.2.2**. Associated default guideline values (ANZG, 2018) applicable to the environmental values are provided in Annexure A.

3.3.6 Murray Darling Basin Plan

The Murray Darling Basin Plan (MDBA, 2012) provides a coordinated approach to managing Basin water resources across Queensland, NSW, ACT, Victoria and South Australia. In NSW, the plan came into effect following the signing of Inter-governmental and National Partnership Agreements in 2014. As lead agency, DPIE (water) is working across government with Biodiversity and Conservation Division and Department of Primary Industries (Fisheries) and other agencies to implement the plan.

3.3.7 Water Quality Management Plan for the Macquarie Castlereagh Watercourse Resource Plan

Under the Murray Darling Basin Plan, there is a requirement to develop water quality management plans for each water resource plan area within the Murray-Darling Basin with the purpose of providing a framework to protect, enhance and restore water quality that is suitable for a range of outcomes. The Macquarie-Castlereagh water quality management plan (DoI, 2018) identifies relevant water quality objectives for the Macquarie-Castlereagh watercourse and the water quality targets required to achieve these objectives.

3.3.8 Managing Urban Stormwater guidance documents

Managing Urban Stormwater: Soils and Construction, commonly referred to as the 'Blue Book', outlines the basic principles for stormwater management during construction. Volume 1 (Landcom, 2004) provides guidance on design and construction of sediment and erosion control measures to protect downstream water quality, thereby improving the health, ecology and amenity of rivers and streams. Volume 2E: Mines and Quarries (DECC, 2008) provides guidance for reducing impacts of land disturbance activities on waterways by better management of soil erosion and sediment control on and around mines and quarries.

Other components of the Managing Urban Stormwater guidance document package which are applicable to the operational phase of this Project are *Managing Urban Stormwater: Treatment Techniques* (EPA, 1997), which contains a range of techniques for treating runoff from urban areas, and *Managing Urban Stormwater: Source Control* (EPA, 1998), which provides guidance for a range of source control techniques that can be adopted to minimise impacts on the stormwater environment.

3.3.9 NSW Flood Prone Land Policy

The NSW Flood Prone Land Policy is produced within section 1.1 of the *Floodplain Development Manual* (DIPNR, 2005). The manual highlights the requirements consistent with the *Water Act 1912* to manage the risks resulting from natural hazards in order to reduce the impact of flooding on individual owners and occupiers of flood-prone property and to reduce private and public losses resulting from floods. The manual "*promotes the use of a merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable*".

3.3.10 Flood Planning Guideline

On 31 January 2007 the NSW Planning Minister announced a guideline for development control on floodplains (the "Flood Planning Guideline"). An overview of the Flood Planning Guideline and associated changes to the *EP&A Act and Environmental Planning and Assessment Regulation 2000* (EP&A Regulation) was issued by the then Department of Planning in a Planning Circular dated 31 January 2007 (Reference PS 07-003). The Flood Planning Guideline issued by the Minister in effect relates to a package of directions and changes to the EPA Act, EP&A Regulation and *Floodplain Development Manual* (DIPNR, 2005).

This Flood Planning Guideline confirms that unless there are "exceptional circumstances", councils are to adopt the 100 year flood (ie 1% AEP flood) as the flood planning level for residential development, with the exception of some sensitive forms of residential development such as seniors living housing. The Flood Planning Guideline does provide that controls on residential development above the 100 year flood may be imposed subject to an "exceptional circumstance" justification being agreed to by the Department of Natural Resources and the Department of Planning (both now incorporated into the Department of Planning, Industry and Environment (DPIE)) prior to the exhibition of a draft local environmental plan or draft development control plan.

DPIE are currently proposing to provide an updated Flood Prone Land Package to provide land use planning advice to councils, however this has not yet been implemented at the time of finalising this report.

Local environmental plans (LEPs) are the principal planning controls for local councils, summarising permissible land uses throughout the local government area (LGA). The Project is located within the Narromine Shire LGA.

The LEPs include a clause on flood planning. The objectives of this clause are to:

- Minimise the flood risk to life and property associated with the use of land.
- Allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change.
- To avoid significant adverse impacts on flood behaviour and the environment.

The flood planning clause applies to:

- Land identified as "flood planning area" on the Flood Planning Map.
- Other land at or below the flood planning level which is defined as the level of a 1:100 average recurrent interval (ie 1% AEP) flood event plus 0.5 metres freeboard.

The flood planning clause identifies that development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

- Is compatible with the flood hazard of the land.
- Is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties.

- Incorporates appropriate measures to manage risk to life from flood.
- Is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.
- Is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

No flood overlay for the SAR Infrastructure Area was found on the Narromine LEP online portal. While the provisions of these LEPs does not apply to State Significant projects, such as the proposal, the relevant matters have been considered in this assessment.

3.3.11 NSW Climate Change Policy Framework

The NSW Climate Change Policy Framework (OEH, 2016) summarises how the NSW Government intends to support the reduction of emissions to reduce the effects of climate change, and measures to adapt to the risks associated with climate change.

One of the policy directions is to reduce risks and damage to public and private assets in NSW arising from climate change. This has been considered in the design and assessment of the SAR Infrastructure Area by considering the projected climate for the year 2090 when carrying out the flood modelling (refer **Section 7.1.6**).

3.4 Guidelines

3.4.1 Australian Rainfall and Runoff

Australian Rainfall and Runoff (Ball et al., 2019) (ARR 2019) is a national guideline for the estimation of design flood characteristics in Australia. The approaches presented in ARR 2019 are essential for policy decisions and projects involving:

- Flood impact assessments
- Infrastructure such as roads, rail, bridges, dams and stormwater systems
- Flood management plans for urban and rural communities
- Flood warnings and flood emergency management
- Estimation of extreme flood levels

Reference was made to ARR 2019 in developing the methodological framework for assessing potential impacts of the proposal on hydrology, flooding and water quality.

3.4.2 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia

Australian Disaster Resilience Handbook 7, Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (Australian Institute for Disaster Resilience, 2017) provides guidance on best practice in flood risk management in Australia. This handbook aims to encourage practice that works towards the vision that *floodplains are strategically managed for the sustainable long-term benefit of the community and the environment, and to improve community resilience to floods*.

The handbook promotes the consideration and management of flood impacts to existing and future development within the community and it aims to improve community flood resilience using a broad risk management hierarchy of avoidance, minimisation and mitigation to:

- Limit the health, social and financial costs of occupying the floodplain
- Increase the sustainable benefits of using the floodplain
- Improve or maintain floodplain ecosystems dependent on flood inundation

The handbook emphasises the need for understanding flood behaviour so that the full range of flood risk to the community can be understood, effectively communicated and, where practical and justifiable, mitigated. The

handbook facilitates informed decisions on the management of this risk, and economic investment in development and infrastructure on the floodplain.

4. Methodology

The methodology for assessment of potential surface water quality, hydrology and flooding impacts arising from the Project is outlined in the following sections and has broadly included:

- Desktop assessment, including review and analysis of existing surface water information to understand the existing environment and identify potential waterway-specific risks;
- A qualitative assessment of the quality of pollutants that may be introduced during construction and operation, and the impact that this may have on surface water quality (with reference to the ANZG (2018) Water Quality Guidelines) and on applicable environment values as identified in the DECCW (2006) *NSW Water Quality and River Flow Objectives*;
- Development of a hydrologic (RAFTS) and hydraulic (TUFLOW) model to assess the flooding impacts. Technical details of the model setup and analysis can be found in the *“Hydrologic and Hydraulic Technical Report”* (see Annexure B); and
- Recommendations for appropriate treatment measures to mitigate the impacts of construction, operation and decommissioning on surface water, including outlining water quality controls.

4.1 Water Quality and Flood study Areas

In general, the water quality and flood study areas for the surface water assessment is the area directly affected by the Project and any additional areas likely to be indirectly affected by the Project. The surface water assessment has been split into two components, the water quality assessment and the flooding assessment. The water quality assessment and flooding assessment have a slightly different water quality and flood study areas as described in **Section 4.1.1** and **Section 4.1.2**, respectively.

4.1.1 Water Quality

For the water quality assessment, the water quality study area (referred to herein as the WQ study area) generally comprises the construction and operational footprints, the entire upstream catchment that drains onto the Mine Site and the downstream catchment to the confluence of Gundong Creek and Bulldog Creek. The WQ study area is depicted in Figure 4-1.

Due to the anthropogenic activities that have been historically undertaken at the Project Site and surrounds, waterways within the WQ study area have been classified as ‘slightly to moderately disturbed ecosystems’, which is defined as ‘Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity’ (ANZG, 2018).

4.1.2 Flooding

For the flooding and hydrology assessment, the flood study area (referred to herein as the flood study area), includes the entire upstream catchment, the Project Site and downstream floodplain to the end of the hydraulic model. The flood study area is depicted in Figure 4-1.

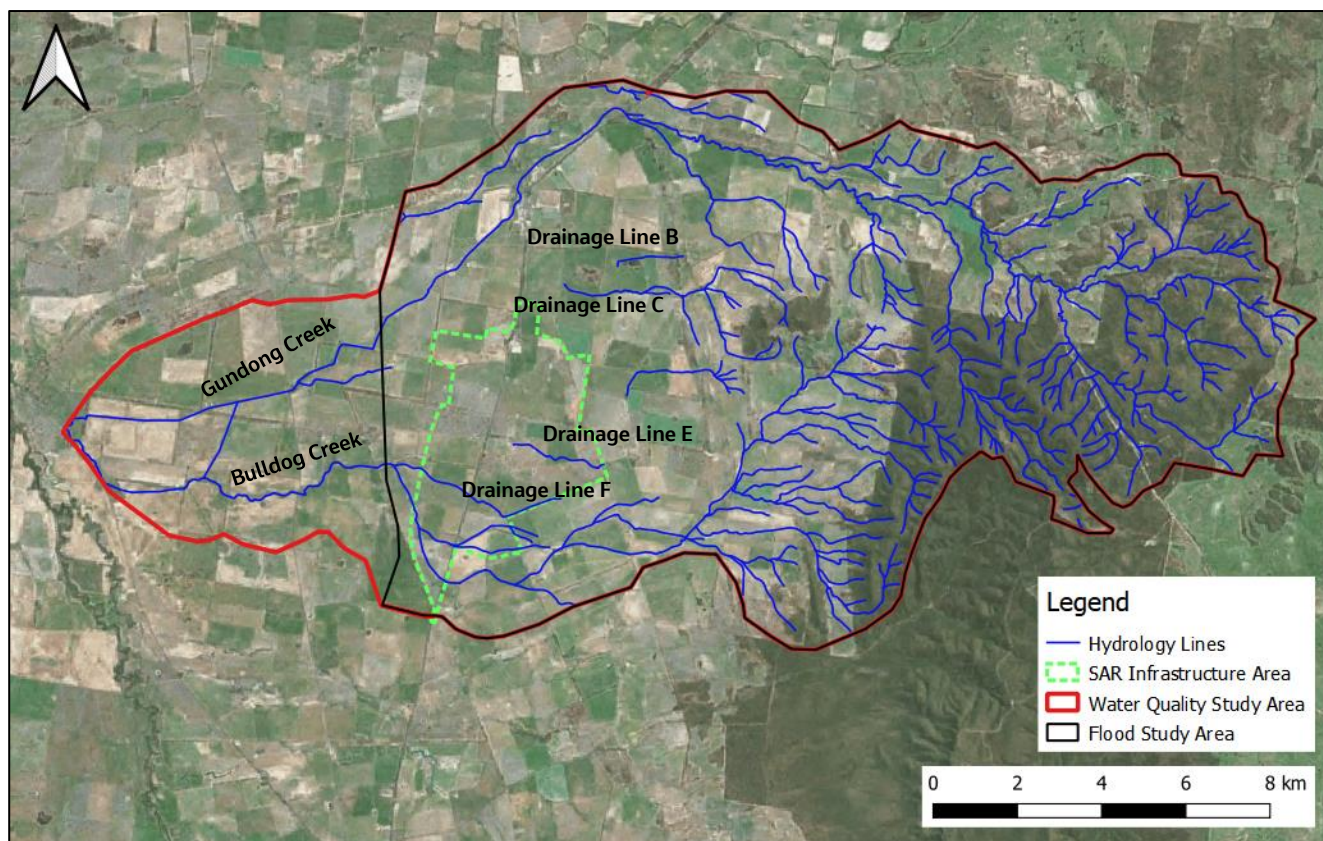


Figure 4-1: Surface water assessment study areas

4.2 Desktop assessment

4.2.1 Desktop review

The desktop assessment involved a review of existing surface water conditions across the flood study and water quality study areas to assess the likely and potential impacts of the Project on surface water quality, flooding and hydrology during construction, operation and decommissioning. The review of information has included a review of relevant literature, water quality and flow data, background information on land use and details of the proposed design, operation and decommissioning of the Project. Information sources included:

- Climate data (BOM, 2021b);
- Australian Rainfall and Runoff (Ball, *et al*, 2019);
- Catchments in the Murray-Darling Basin – Macquarie-Castlereagh snapshot (MDBA, 2021);
- Macquarie-Bogon River catchment snapshot (DPI, 2021b);
- NSW Fisheries Spatial Data Portal (DPIE, 2021a);
- Groundwater Dependent Ecosystem (GDE) online atlas (BOM, 2021a)
- NSW Planning Portal (DPIE, 2021c);
- Geological mapping (Krynen *et al*, 1990)

- NSW soil and land information database “eSpade” (DPIE, 2021d);
- Tomingley Gold Extension Project (TGEP) Geotechnical report (WSP, 2021);
- TGEP Scoping Report (RWC, 2021);
- Water management schematics (RWC, 2021);
- NSW Geographic Information; and,
- Water quality data for relevant waterways in the WQ study area (Alkane Resources).

4.2.2 Environmental Values

As described in **Section 3.3.5**, waterways in the water quality and flood study areas are categorised as “uncontrolled streams”. DECCW (2006) nominates the following environmental values for protection of uncontrolled streams:

- **Protection of aquatic ecosystems:** Aquatic ecosystems comprise the animals, plants and micro-organisms that live in water and the physical and chemical environment in which they interact. Aquatic ecosystems have historically been impacted upon by multiple pressures including changes in flow regime, modification and destruction of key habitats, development and poor water quality. Water quality parameters can be divided into those that have a direct toxic effect on organisms and animals (toxicants) and those that indirectly affect ecosystems causing a problem for a specific environmental value (stressors). Toxicants which are relevant to this assessment are primarily metals/metalloids, while the stressors include nutrients, which consist of nitrogen (total nitrogen (TN), ammonia, oxidised nitrogen (NO_x)) and phosphorus (total phosphorus (TP) and filterable reactive phosphorus (FRP)), turbidity, total suspended solids (TSS), salinity and pH which have the potential to cause degradation of aquatic ecosystems. The DECCW (2006) objectives for aquatic ecosystems are consistent with the agreed national framework for assessing water quality set out in the ANZG (2018) guidelines.
- **Visual amenity:** The aesthetic appearance of a waterbody is an important aspect with respect to visitation and recreation. The water should be free from noticeable pollution, floating debris, oil, scum and other matter. Substances that produce objectionable colour, odour, taste or turbidity and substances and conditions that produce undesirable aquatic life should not be apparent (NHMRC, 2008). The key aesthetic indicators are transparency, odour and colour;
- **Secondary contact recreation:** Secondary contact recreation implies some direct contact with the water would be made but ingestion is unlikely in activities such as boating, fishing and wading. Bacteriological indicators are used to assess the suitability of water for recreation;
- **Primary contact recreation:** Primary contact recreation implies some direct contact with the water would be made during activities such as swimming in which there is a high probability of water being swallowed. Bacteriological indicators, nuisance organisms, algal blooms, pH, temperature, chemical contaminants, surface films, visual clarity and colour are used to assess the suitability of water for recreation;
- **Livestock water supply:** The purpose of the livestock water supply objective is to protect water quality to maximise the production of healthy livestock. Indicators monitored for this objective include algae and blue-green algae, salinity, faecal coliforms and chemical contaminants;
- **Irrigation water supply:** The purpose of the irrigation water supply objective is to protect quality of waters applied to crops and pasture. Indicators monitored for this objective include algae and blue-green algae, salinity, faecal coliforms and heavy metals; and
- **Aquatic food (cooked):** Aquaculture generally involves the production of food for human consumption, and suitable water quality is needed for maintaining viable aquaculture operations. The guidelines primarily relate to toxicant concentrations and reducing the potential for these to accumulate in the tissues of seafood that is likely to be consumed by humans.

Additionally, objectives for streams within the catchment have also been nominated, namely:

- Homestead water supply,

- Drinking water at point of supply – Disinfection only,
- Drinking water at point of supply – Clarification and disinfection, and
- Drinking water at point of supply – Groundwater.

However these do not apply to streams within the water quality and flood study areas as the areas are not included in a drinking water catchment.

As mentioned in **Section 4.1.1**, the Project Site has been classified as 'slightly to moderately disturbed' and therefore ANZG (2018) recommend applying the guidelines for 'slightly to moderately disturbed ecosystems' for physical and chemical stressors and assessing toxicants against the 95% species protection level and 99% species protection level for bioaccumulating toxicants. The guideline values and indicators applicable to the Project Site are provided in Annexure A.

Often in modified environments there is the potential for the current water quality to not meet the existing guidelines and trigger values for protecting nominated environmental values. Irrespective of the current condition of waterways, the Project should not further degrade water quality. As such, the key objective of the Project surface water assessment is to minimise the potential impacts on downstream receiving waters, so that the Project changes the existing water regime by the smallest amount practicable.

4.2.3 Sensitive Receiving Environments

Sensitive receiving environments (SREs) are environments that have a high conservation value or support ecosystems/human uses of water that are particularly sensitive to pollution or degradation of water quality. It is important to identify SREs that are directly impacted by the Project or are located downstream of Project activities so that these values may be adequately protected. SREs within the water quality and flood study areas were identified based on the following considerations:

- Presence of Key Fish Habitat (KFH) based on NSW Fisheries KFH maps (DPIE, 2021a);
- Presence of threatened aquatic species listed under the BC Act and or EPBC Act; or
- Groundwater and surface water dependent vegetation and fauna communities listed under the BC Act (BOM, 2021a)

Determination of SREs is provided in **Section 5.3.1**. For each identified SRE, the sensitivity of the SRE has been defined on a four-point scale from Very Low to High depending on the receptor's surface water features and aquatic values. The scale is defined in **Table 4-1**.

Table 4-1. Sensitivity of Water Resource Receptor

Sensitivity	Description	Indicators
High	Attribute has a high quality and rarity on regional or national scale	Water suitable for potable use Supports pristine ecosystems including water dependent MNES Supports EPBC listed, FM listed and BC listed aquatic species Contains freshwater aquatic habitat features in good condition Attributes of water system are unique to the region Water level highly responsive to change in water level
Medium	Attribute has a high quality and rarity on a local scale	Water quality suitable for agricultural or stock use Water supports slightly disturbed ecosystems Contains freshwater aquatic habitat features in good condition Attributes of the water system are locally unique but have few regional equivalent.
Low	Attribute has a medium quality and rarity on local scale	Water quality suitable for aquaculture or industrial use Water supports moderately to very disturbed ecosystems Contains freshwater aquatic habitat features in poor condition

Sensitivity	Description	Indicators
		Attributes of the water system are common on a local, regional and national basis and therefore have local equivalents
Very Low	Attribute has a low quality and rarity on local scale	Water quality unsuitable for any practical use System completely resilient to change Does not contain substantial aquatic habitat

4.2.4 Data Analysis and Modelling

4.2.4.1 Existing water quality data analysis

Water quality data summarised in this report was supplied by Alkane Resources. Water quality monitoring is undertaken at a number of sites within and surrounding the TGO Mine Site as a requirement EPL 20169. Only water quality data collected within the waterways Gundong Creek and Bulldog Creek (ie not sediment basins) were analysed in this assessment. It should be noted that due to the intermittent flow in these waterways that a consistent dataset of monthly monitoring was not available.

4.2.4.2 Flood and hydraulic modelling

A hydrologic RAFTS model was developed to assess the flows for catchments contributing to the Project Site. The model was validated to the Regional Flood Frequency Analysis (RFFE).

A hydraulic TUFLOW model using a combination of rain-on-grid for the TGEP area and RAFTS inflows for external catchments was constructed. The model was used to assess the flood level and change in hydraulic regime between the existing and design cases. The hydraulic model was constructed based on LiDAR data flown in 2020. The following events were simulated:

- 20% AEP
- 10% AEP
- 5% AEP
- 5% AEP with Climate Change
- 2% AEP
- 1% AEP
- 0.1% AEP

Further technical details on the hydrologic and hydraulic model build and assessment are documented in the *"Hydrology and Hydraulics Technical Report"* (Annexure B of this report).

4.2.5 Impact Assessment

The following sections outline the methodology for assessing surface water impacts of construction, operation and decommissioning of the Project. The results of the water quality impact assessment are presented in **Section 6** and the results of the flooding impact assessment are presented in **Section 7**.

4.2.5.1 Identification of impacts

An important component of the assessment is to identify potential impacts associated with surface water on the Project Site. Identified impacts can then be managed or mitigated during design.

4.2.5.2 Impact assessment

An impact assessment was completed to assess the significance of potential impacts associated with the Project on surface water resources. The impact assessment process has considered the following factors:

- Whether or not the Newell Highway achieves a 5% AEP immunity;

- Whether or not transverse culverts under the realigned Newell Highway achieve a velocity of less than 3 m/s in the 5% AEP;
- Whether or not there are sensitive landuses outside the Alkane Controlled Land and potential impacts on these land;
- Whether or not receptors are present and if so, how sensitive they are to the potential impacts (based on the assigned SRE sensitivity classification, refer **Section 4.2.3**)
- The magnitude (or consequence) of the potential impact were it to occur (based on its scale, intensity, timing, duration and frequency). Each potential impact is assigned a consequence rating on a four-point scale from Negligible to High as described in **Table 4-2**.
- Sensitivity and magnitude (or consequence) ratings are then combined to derive a significance rating for each combination of receptor and potential impact. Significance ratings are assigned on a five-point scale from Insignificant to Severe. **Table 4-3** presents the criteria used to rank the overall significance of impact. The criteria are designed to identify whether a significant effect may occur through a qualitative assessment. A description of the adopted definition of significance is presented in **Table 4-4**.

Table 4-2 Magnitude of Potential Impact

Magnitude	Description	Example
Severe	Results in loss of attribute	Irreversible or persistent high-severity impact likely No recovery within foreseeable future Impacts are at a regional, national or international scale Impact would result in significant departure from Federal or State policy or guidance
Moderate	Results in impact on integrity of attribute or loss of part of attribute	Moderate severity impacts likely to persist over time or high-severity impacts that have a short duration only, with rapid recovery upon activity completion Impact extends across regional areas Impact would result in departure from Federal or State policy or guidance
Minor	Results in some measurable changes in attributes quality or vulnerability	Low severity impacts are likely to persist over time, or moderate-severity impacts are likely to have a short duration only, with rapid recovery when the activity is completed Impact extends beyond the area of activity or footprint. Impact would result in minor departure from Federal or State policy or guidance
Negligible	Results in an impact on attribute but of insignificant change to quality or vulnerability	Low severity and short-term impacts restricted to the immediate area of activity or footprint No medium or long-term impacts on receptors Impact would result in insignificant departure from Federal or State policy or guidance

Table 4-3. Significance of predicted effect

Magnitude of Adverse Impact	Sensitivity of the Receptor			
	High	Medium	Low	Very Low
High	Severe	Major	Moderate	Minor
Moderate	Major	Moderate	Moderate	Minor
Minor	Moderate	Moderate	Minor	Insignificant
Negligible	Minor	Minor	Insignificant	Insignificant
^a Table Notes				

Table 4-4 Description of significance levels

Significance level	Description of significance
Severe or Major significance	Significant impact with high likelihood of impact to a rare environmental value on a regional or national scale designated. Impact results in irreversible or persistent high severity impact on the quantity, quality or availability of surface or ground water with little or no chance of recovery in the foreseeable future.
Moderate significance	The environmental value which has a medium quality and rarity on a local scale would be degraded by the impact of moderate severity with impacts persisting over time, or as a result of a short-term impact that recovers immediately upon completion of the activity. The impact may extend over regional scale or across multiple aquifer units.
Minor significance	The environmental value, which has moderate quality and rarity on a local scale, will be affected by a low severity impact. Impacts are likely to be of short duration and to have rapid recovery when the activity is completed.
Insignificance	An insignificant impact exists to an environmental value. The impact is of low severity and restricted to the immediate area of activity. There are no medium- or long-term impacts and recovery is rapid.

4.2.5.3 Identification of mitigation and management measures

Mitigation, management and monitoring measures are considered to reduce the magnitude of the potential impact to have less significance, and ultimately be deemed acceptable. Measures are typically applied where impacts are considered to be unacceptable. The objective of assigning such measures is to reduce the severity of the potential impact to the extent that the overall residual significance of the event becomes insignificant. It is noted that mitigation measures for flooding is already part of the adopted design, and the adopted design has been adopted because it does not cause unacceptable impacts.

Monitoring confirms whether impacts are as predicted or whether further management or mitigation may be required to manage the impact. Mitigation and management measures, including monitoring procedures are described in **Section 8**.

5. Existing Environment

5.1 Catchment overview

5.1.1 Macquarie-Bogan catchment

Broadly, the Project is located in the Macquarie-Bogan catchment in central-west New South Wales. The overall catchment spans an area of approximately 74,800 km² and is bound to the north by the Castlereagh River catchment, to the west by the Barwon-Darling River catchment, to the east by the Hawkesbury-Nepean River catchment and to the south by the Lachlan River catchment. Variable elevations occur across the Macquarie-Bogan catchment ranging from 1,300 mAHD in the mountains south of Bathurst, to less than 100 mAHD on the western floodplains. The catchment encompasses the regional centres of Dubbo, Bathurst and Orange as well as the Macquarie and Bogan Rivers, which flow north-west to the Barwon River as shown in **Figure 5-1**. Both rivers are regulated by Windermere and Burrendong dams and are major sources of both town and agricultural water and support the Ramsar listed Macquarie Marshes located in the western reaches of the catchment between Dubbo and Brewarrina.

The Macquarie River discharges from the Great Dividing Range flowing through Bathurst and Dubbo before traversing the lower plains. The River consists of small dams constructed along its tributaries in order to supply town water. However, the Burrendong Dam near Wellington is the main source of water storage within the catchment (MDBA, 2021).

The Bogan River originates in the Harvey Ranges and flows North West through Nyngan before discharging to the Barwon River (MDBA, 2021). Agriculture is the primary land use within the catchment, which is largely dominated by livestock grazing (DPIE, 2021b).

5.1.2 Sub-catchment

More locally, the Project falls within a sub-catchment which encompasses the ephemeral Gundong and Bulldog Creeks as well as several minor, unnamed tributaries of these streams. The sub-catchment has an area of approximately 247km² to the confluence of Gundong and Bulldog Creeks, forming only a minor portion of the overall Macquarie-Bogan catchment. The sub-catchment is denoted as the "Water Quality Study Area" in **Figure 4-1**.

The sub-catchment drains east to west toward the Bogan River which is located approximately 10 to 12km to the southwest of the Project Site. In this locality, the Bogan River itself is also ephemeral, flowing only after large or sustained rainfall events. Both Gundong Creek and Bulldog Creek rise on the western flanks of the Harveys Range and are fourth (Bulldog Creek) and fifth (Gundong Creek) order drainages as they cross the Newell Highway.

In general, the sub-catchment in close proximity to the SAR Infrastructure Area is characterised as a mostly cleared, flat floodplain area however the upper catchment has steeper topography and is heavily forested within the Goobong National Park (Harveys Range). Gundong Creek and Bulldog Creek are the main channels in the catchment, although they only flow occasionally and have minimal or no channel definition. Minor, upstream tributaries have more well-defined channel reaches. Major sources influencing water quality in the sub-catchment near the SAR Infrastructure Area are related to land uses on the floodplain including cropping, grazing, gold mining activities and the small township of Tomingley to the north (refer to **Section 5.1.4** for further details on surrounding land uses and zoning).

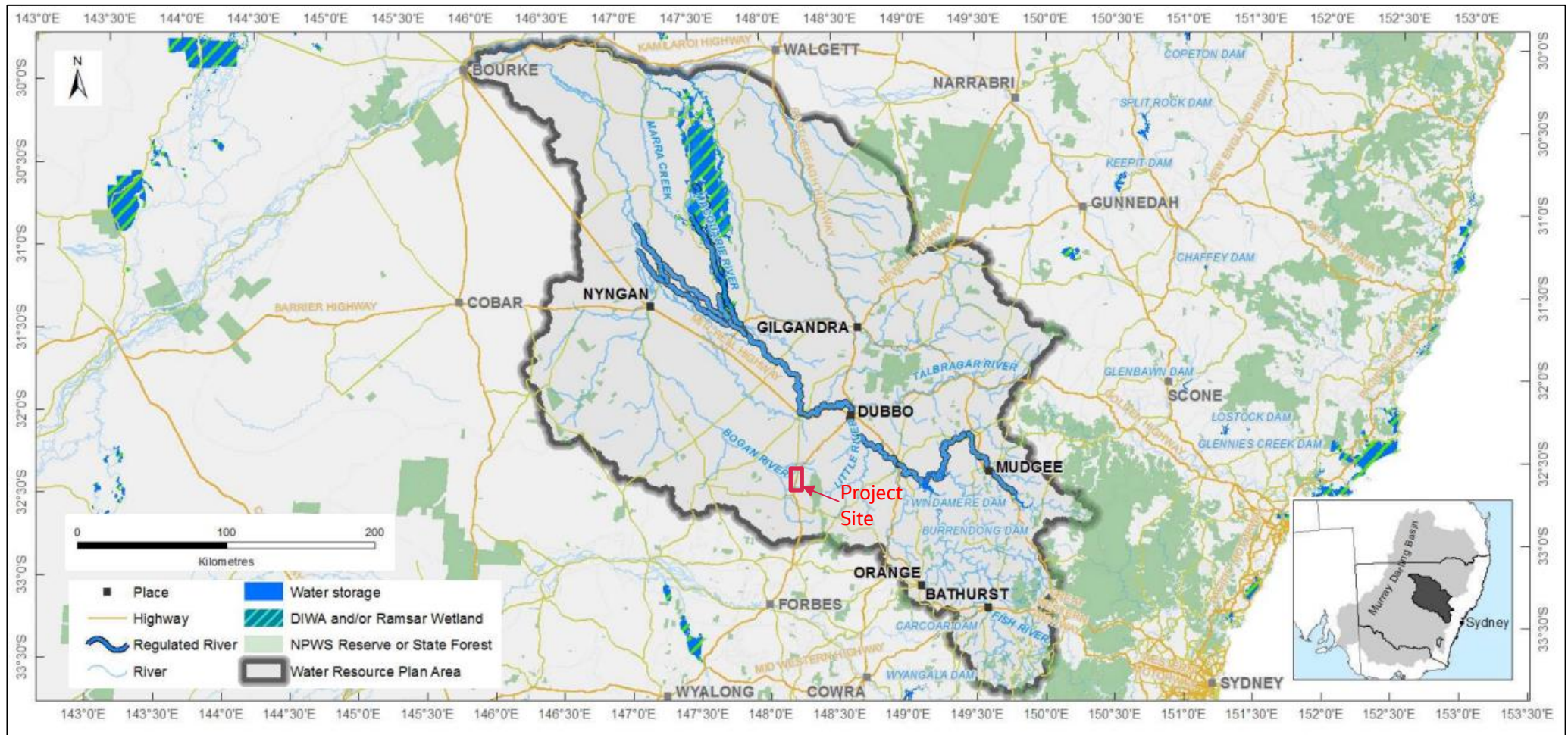


Figure 5-1: Macquarie - Bogan Catchment (Adapted from *Macquarie-Castlereagh Water Resources Plan* DPI, 2017)

5.1.3 Climate

5.1.3.1 Rainfall and evaporation

For the purpose of this assessment, rainfall and evaporation data has been obtained from both the onsite Automatic Weather Station (TGO AWS) and from Queensland Government's online SILO database of Australian climate data. The onsite AWS climatic record which commenced in October 2013 is considered relatively short for the purposes of analysing long term climatic trends and as such, is supplemented with the use of the SILO dataset. The long-term statistics for the onsite AWS are presented alongside the SILO dataset which has a significantly longer historical record, with data commencing from 1889.

SILO data can be acquired for individual weather station points, or as point or gridded dataset with a resolution of approximately 5 km x 5 km. The SILO data used in this report is a point dataset from January 1970 and consists of interpolated daily data. The SILO data was extracted for the now closed Tomingley weather station (Bureau of Meteorology station # 050091) point Latitude -32.60 degrees north and Longitude 148.20 degrees east.

Key rainfall and evaporation statistics are provided in **Table 5-1** and depicted on **Figure 5-2**.

The climate statistical trends between the SILO and the TGO AWS dataset are in general agreeance except for the months of February and March which can be attributed to the relatively short dataset of TGO AWS. Mean monthly pan evaporation exceeds mean monthly rainfall for all months in both datasets. Mean monthly FAO56 Penman-Monteith evaporation (SILO) exceeds mean monthly rainfall for all months. The difference between evaporation and rainfall is most pronounced during summer months.

Table 5-1 Tomingley (Lat -32.60 N, Long 148.20 E) and TGO AWS rainfall and evaporation summary (Source: SILO)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual total
Mean monthly rainfall (mm) (TGO) ¹	65	35	85	46	37	40	44	37	42	46	61	65	603
Mean monthly rainfall (mm) (SILO) ²	59	50	51	41	44	37	44	39	42	45	53	56	562
Mean monthly pan evaporation (mm) (TGO) ¹	244	207	165	118	81	53	69	95	127	171	204	229	1762
Mean monthly pan evaporation (mm) (SILO) ²	278	221	189	120	73	48	53	77	114	172	218	272	1833
Mean monthly FAO56 evaporation (mm) (SILO) ²	203	164	146	98	63	43	46	66	95	139	168	199	1432
Rainfall surplus (mm) (TGO) ³	-179	-171	-80	-72	-45	-13	-24	-58	-85	-125	-143	-165	-1158
Rainfall surplus (mm) (SILO) ³	-219	-171	-137	-79	-29	-11	-8	-38	-72	-127	-164	-216	-1271

Notes: ¹ Based on record from Oct 2013 to end of Apr 2021. ² Based on record from 1970 to Apr 2021. ³ Calculated by subtracting pan evaporation from rainfall.

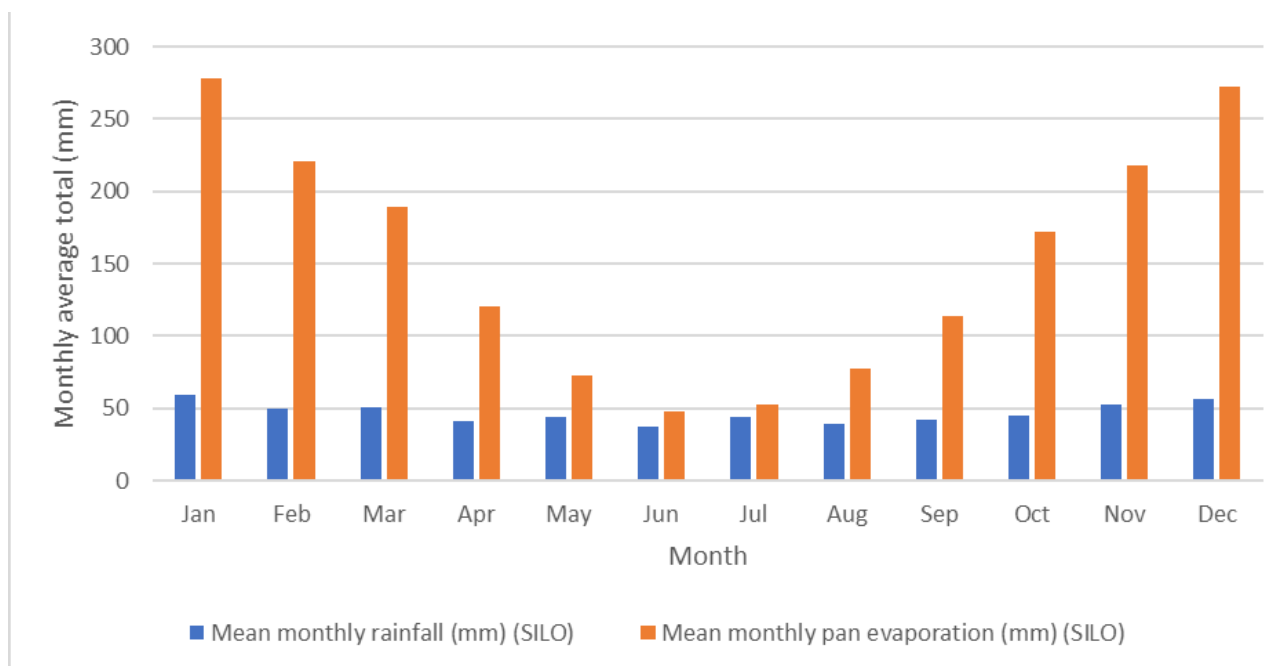


Figure 5-2 Average total monthly rainfall and evaporation between 1970 and 2021; SILO data based on records from Tomingley Weather Station (#50091)

5.1.3.2 Temperature

Long term temperature data from Peak Hill Post Office Weather Station (BOM, 2021b) was reviewed and is presented in **Figure 5-3**. **Figure 5-3** indicates monthly average maximum and minimum temperature ranges for 20 years of data (2000 to 2020).

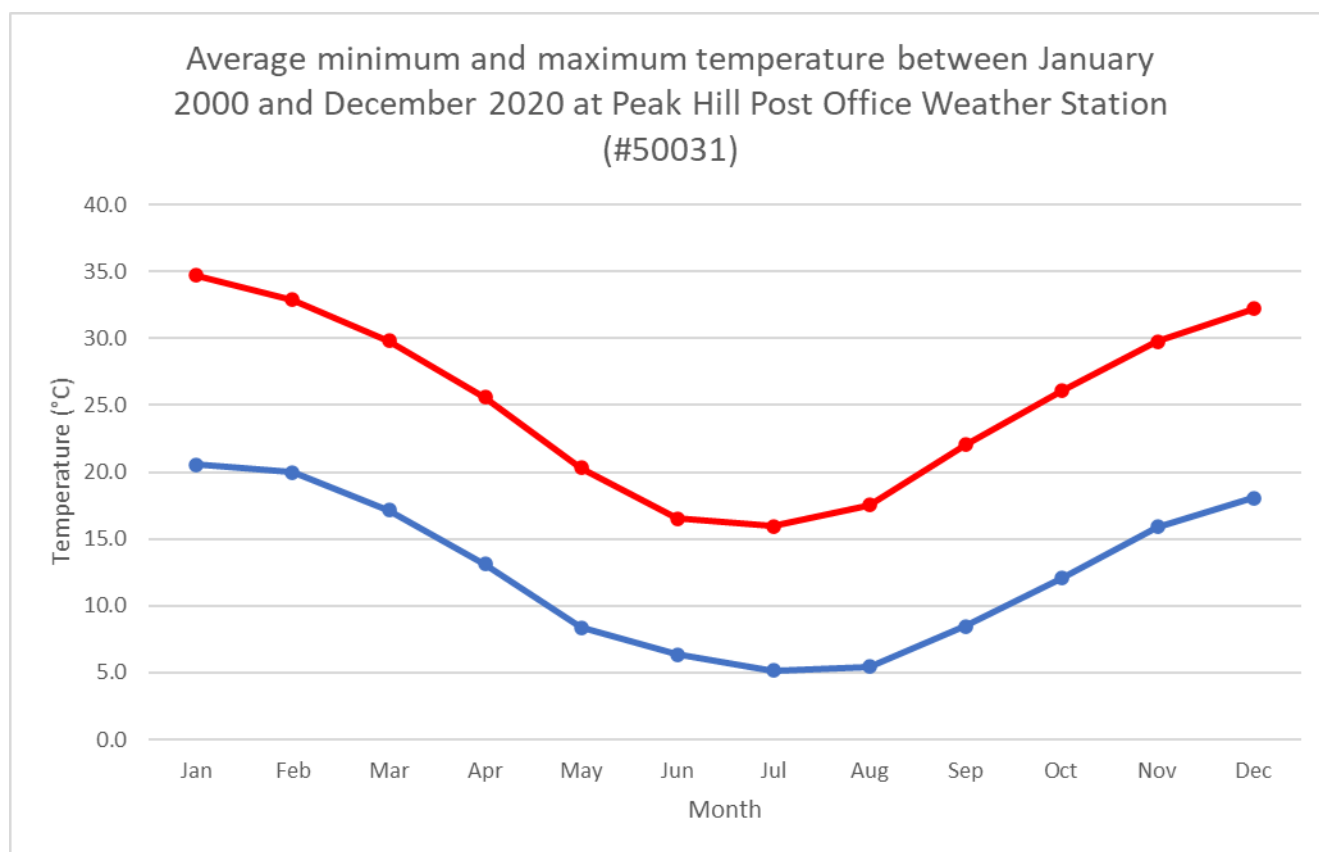


Figure 5-3 Average minimum and maximum temperature between 2000 and 2020, as recorded at Peak Hill Post Office Weather Station (#50031)

The analysis of available temperature data indicates that the area experiences a distinct seasonal variation in temperature. Average minimum and maximum temperatures range from approximately 18.1 – 34.7 Degrees Celsius (December to February) to 5.2 – 16.0 Degrees Celsius (June to August) seasonally, with predominantly mild to high temperatures in the autumn and spring months.

5.1.4 Land use

The SAR Infrastructure Area and surrounding area is largely zoned RU1 –Primary Production, with the dominant activities being cropping and grazing. The RU1 zoned land within the SAR Infrastructure Area is intersected by the Newell Highway which is zoned as SP2 – Special Infrastructure (Classified Road) (DPIE, 2021c). Other important land uses and activities in proximity of the SAR Infrastructure Area include:

- North: Existing TGO mine site and Tomingley township
- East: Goobang National Park
- West: Bogan River
- South: Peak Hill township

5.1.5 Topography

The SAR Infrastructure Area is located on the gently undulating terrain of the Gundong/Bulldog Creek sub-catchment on the western side of the Herveys Range. Surface elevations in the vicinity of the SAR Infrastructure Area typically range between 265 m AHD to 270 m AHD, and more broadly between 370 m AHD and 260 m AHD across the region. The area slopes east to west and typical topographic gradients are of the order of 1:250

(V:H). Occasional low hills and rises are present with maximum elevations of between 280 m AHD and 373 m AHD and slopes between 1:10 (V:H) and 1:50 (V:H). The rolling terrain continues north and south of the SAR Infrastructure Area. To the west towards the Bogan River, the gentle slopes flatten even further; whereas, to the east, slopes increase towards the foothills of the Harveys Range that in places is in excess of 500 m AHD.

5.2 Geology and soils

The Parkes Special 1:100,000 Geological Sheet (Krynen *et al.*, 1990) indicates that the majority of the SAR Infrastructure Area is covered by Cainozoic alluvial and colluvial deposits with occasional outcrops of Ordovician Mingelo volcanics and Silurian siltstones of the Cotton and Mumbidgle Formations. The Cainozoic deposits typically comprise alluvial clays to sandy clays with thicknesses ranging from 20 m to 60 m. At the historic Myalls United gold mine, located between the TGO and SAR Deposits, the basement rocks (Cotton Formation) outcrop on a low rise. There is potential for minor sandy alluvial deposits within the main drainage channels with a minor alluvial aquifer associated with Gundong Creek.

The geotechnical report for the Project describes five geotechnical horizons found in the SAR Infrastructure Area (WSP, 2021), these are:

1. Quaternary Alluvium (QA) of brown sandy clays, sandy silty clays and minor sands and gravels.
2. Tertiary Alluvium (TA) of grey mottled red orange sandy clays and silty clays and sands.
3. Saprolite defined as extremely weathered rock with soil consistency and relict geological structure and referred to operationally as saprock.
4. Weathered Rock (WR) oxidised and highly to moderately weathered rock.
5. Slightly Weathered and Fresh Rock (SW/FR).

Furthermore, according to NSW soil and land information database “eSpade” (DPIE, 2021d), the region broadly falls within the Mickibri Hydrogeological Landscape (HGL), the Mickibri HGL profile indicates that in addition to the alluvial soils, the region also has gilgai areas, meaning small ephemeral lakes formed from a depression in the soil surface in expanding clay soils (DPIE, 2021d). Portions of Mickibri HGL are observed to be highly erodible with highly dispersive subsoils. The Mickibri HGL is prone to gully erosion and soil structure decline.

5.3 Hydrology

5.3.1 Surface water features

Key surface water features including waterways and drainage channels within the water quality and flood study areas are shown in Figure 4-1 and have been described in **Table 5-2** according to:

- The Strahler stream classification system where waterways are given an order according to the number of additional tributaries associated with each waterway (Strahler, 1952);
- Key hydrological characteristics including stream type and general direction of stream flow;
- Whether the waterway or waterbody is classified as Key Fish Habitat (KFH), based on published KFH mapping of NSW by NSW Fisheries (DPIE, 2021a); and
- Other relevant features within, or in proximity to the waterway or drainage channel including channel geomorphology and vegetation cover.

Due to the topographic nature of the SAR Infrastructure Area, several mapped hydrological features are minor drainage depressions which are present on the landscape that do not drain to a key waterway. Waterways which have been described below include those in the water quality and flood study areas which have a stream order greater than 3 (as these are most likely to retain water and flows during and following a rainfall event) or any

minor drainage channels (stream order less than 3) which are intersected by the SAR Infrastructure Area and have a drainage pathway to a key waterway.

Table 5-2 Description of key surface water features within the water quality and flood study areas and determination of SREs

Watercourse	Stream order	Stream Type	Traverses Project Site	Description	Sensitive Receiving Environment / sensitivity
Gundong Creek	Five	Ephemeral stream	Traverses the TGO mine site.	- Minor channel definition near the Project Site but is a well-defined channel upstream. - Waterway is mapped as Key Fish Habitat (DPIE, 2021a). - No riparian vegetation near the Project Site but some present in the upstream extent and potential instream habitat features. - Water usually not present. - Flows in a south-westerly direction to Bogan Creek during and following rainfall. - Minor erosion potential if experiences high flows. - No threatened aquatic species distribution mapped in the waterway (DPIE, 2021a)	Yes – low
Drainage Line E	One	Drainage depression	Yes	- No channel definition. Minor depression in landscape. - Occasional flow in a south westerly direction toward Bulldog Creek. - Water may pond in depression occasionally following rainfall. - No aquatic environment present.	No – very low
Drainage Line F	Two	Drainage depression	Yes	- No channel definition. Minor depression in landscape. - Occasional flow in a westerly direction toward Bulldog Creek. - Water may pond in depression occasionally following rainfall. - No aquatic environment present.	No – very low
Bulldog Creek	Four	Ephemeral stream and wetland	Yes	- No channel definition - Waterway is mapped as KFH (DPIE, 2021a) - No aquatic features or riparian vegetation in proximity of the	SRE – low

Watercourse	Stream order	Stream Type	Traverses Project Site	Description	Sensitive Receiving Environment / sensitivity
				Project Site although potentially some aquatic habitat upstream. ▪ Water usually not present. ▪ Generally flows in a westerly direction to Bogan River during and following rainfall. ▪ Minor erosion potential if experiences high flows. ▪ No threatened aquatic species distribution mapped in the waterway (DPI, 2021a)	

5.3.2 Hydrological regime of the water quality and flood study areas

Surface water flows typically occur as sheet flows, with occasional, poorly to moderately defined, west flowing waterways, including, from north to south, Gundong Creek, Bulldog Creek and a number of unnamed tributaries of these waterways.

The total catchment area of Gundong and Bulldog Creeks to the model downstream boundary is approximately 209.6 km² and flows east to west draining to the Bogan River some 10km downstream. The catchment within the SAR Mine Site is flat with ill-defined catchment boundaries and an average vectored slope of about 1.07%. The upper catchment is heavily forested with steeper channel reaches. Bulldog Creek, a tributary of Gundong Creek, flows through the SAR Mine Site. The catchment area of the Bulldog Creek tributary that flows through the SAR Mine Site is about 30 km² with an average vectored slope of 0.86%. It is the flows from this sub-catchment that are required to be diverted from the proposed SAR Open Cut.

5.3.3 Existing Newell Highway Immunity

The existing Newell Highway flood immunity varies across the SAR Infrastructure Area. Overall, most sections of the existing Highway have a flood immunity below the 20% AEP event (i.e. there is more than a 20% chance in each year that the Newell Highway is cut by flooding at this location) with overtopping depths of between 10 mm and 295 mm.

5.3.4 Groundwater-surface water interaction

The region is known to have low levels of connection between surface water and groundwater processes. Waterways in proximity to the Project Site have no groundwater base flow and are highly ephemeral, drying up soon after rainfall/runoff events. Impacts to groundwater are addressed in the Groundwater Assessment for the Project.

5.4 Water Quality

5.4.1 Gundong Creek

Gundong Creek flows in a south-westerly direction from Tomingley, through the existing mine lease and to the west of the Project Site. Water quality monitoring has been undertaken at two sites (SW1 and SW2) between July 2015 and September 2021 (refer Figure 5-4). It should be noted that due to limited flow, water quality monitoring has been undertaken irregularly over this timeframe and generally only when sufficient instream flow

was available to collect samples. No samples were collected between 2018 and 2019 as there was no water available in the creek due to drought conditions. The water quality site SW1 is located on Gundong Creek upstream of the existing mine site, adjacent to Tomingley Road. The other site, SW2 is located on Gundong Creek, downstream of the TGO Mine Site

Water quality results from sampling undertaken in Gundong Creek indicates that Gundong Creek exhibits variable water quality and many indicators do not meet the nominated targets for protection of aquatic ecosystems as show in (bold text) **Table 5-3**. There was also very little difference in water quality between the two sites, with the downstream site (SW2) generally having slightly lower concentrations of nutrients, but similar or marginally higher concentrations of metals. Electrical conductivity, ammonia and the metals mercury, molybdenum, nickel, arsenic, boron and cadmium were the only indicators that complied with the relevant targets for protection of aquatic ecosystems. pH levels were at the higher end of the acceptable range, with median levels at SW2 marginally exceeding the upper limit of 8 recommended under the Basin Plan. Turbidity was elevated at both sites exceeding the limit of 20NTU, which is probably attributable to recent rainfall generating flow prior to sampling. Nutrient concentrations in Gundong Creek are very high, with median concentration of oxidised nitrogen, total nitrogen and total phosphorus more than double the recommended guideline limits.

Median concentrations of the trace metals aluminium, iron, chromium, copper, zinc, selenium and lead were elevated exceeding the recommend trigger value for 95% species protection. Trace metals of greatest concern at both sites are aluminium, selenium and iron which exceeded the recommended trigger value by 73, 20 and 12 times respectively.

Table 5-3 Median water quality of Gundong Creek between July 2015 and December 2021 and compliance with WQO

Indicator	SW1 (number of samples)	SW2 (number of samples)	WQO (aquatic ecosystems)	Source^
Electrical conductivity (µS/cm)	168 (58)	175 (57)	<456	DOI (2018)
pH	7.42 (58)	8.3 (57)	7-8	DOI (2018)
Turbidity (NTU)	165 (6)	138 (6)	<20	DOI (2018)
Total suspended solids (mg/L)	16.5 (58)	14 (57)	No guideline	No guideline
Ammonia (mg/L)	0.01 (58)	0.0075 (58)	0.013	ANZECC/AMRCANZ (2000c)
Oxidised nitrogen (mg/L)	0.35 (58)	0.295 (58)	0.015	ANZECC/AMRCANZ (2000c)
Total nitrogen (mg/L)	1.3 (58)	1.25 (58)	0.6	DOI (2018)
Total phosphorus (mg/L)	0.085 (56)	0.075 (56)	0.035	DOI (2018)
Aluminium (total) (mg/L)	3.99 (57)	4.03 (57)	0.055	ANZG (2018)
Iron (total) (mg/L)	3.7 (57)	3.59 (57)	0.3	ANZG (2018)
Mercury (total) (mg/L)	<0.0001 (56)	<0.0001 (56)	0.00006	ANZG (2018)
Molybdenum (total) (mg/L)	0.001 (26)	0.001 (26)	0.034	ANZG (2018)
Nickel (total) (mg/L)	0.003 (57)	0.003 (57)	0.011	ANZG (2018)
Arsenic (total) (mg/L)	0.002 (57)	0.002 (57)	0.013	ANZG (2018)
Boron (total) (mg/L)	0.025 (28)	0.025 (29)	0.94	ANZG (2018)
Cadmium (total) (mg/L)	0.00005 (57)	0.00005 (57)	0.0002	ANZG (2018)
Chromium (total) (mg/L)	0.004 (57)	0.004 (57)	0.001	ANZG (2018)

Indicator	SW1 (number of samples)	SW2 (number of samples)	WQO (aquatic ecosystems)	Source^
Copper (total) (mg/L)	0.004 (57)	0.004 (57)	0.0014	ANZG (2018)
Zinc (total) (mg/L)	0.01 (57)	0.01 (57)	0.008	ANZG (2018)
Selenium (total) (mg/L)	0.005 (57)	0.01 (57)	0.0005	ANZG (2018)
Lead (total) (mg/L)	0.005 (57)	0.004 (57)	0.0034	ANZG (2018)

^ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (upland rivers)

DoI (2018) Macquarie-Castlereagh water management plan

ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (95% species protection)

Bold font denotes exceedance of WQO

Surface water monitoring is undertaken under the requirements of the EPL, as well as additional monitoring undertaken by TGO. Due to the general absence of rainfall and creek discharge, monitoring is generally limited to during times of flow. Two off site locations (SW1 and SW2) are sampled, with the remainder being on-site sediment dams and other water management structures.

GHD (2017) identified that both SW1, and SW2 (which is adjacent to the TGO site and downstream of SW1) demonstrated that background concentrations of copper, nitrogen, phosphorous, and zinc exceeded the limits included in the EPL. Additional monitoring locations may be necessary along Gundong Creek to monitor the impact of discharges from the proposed action.

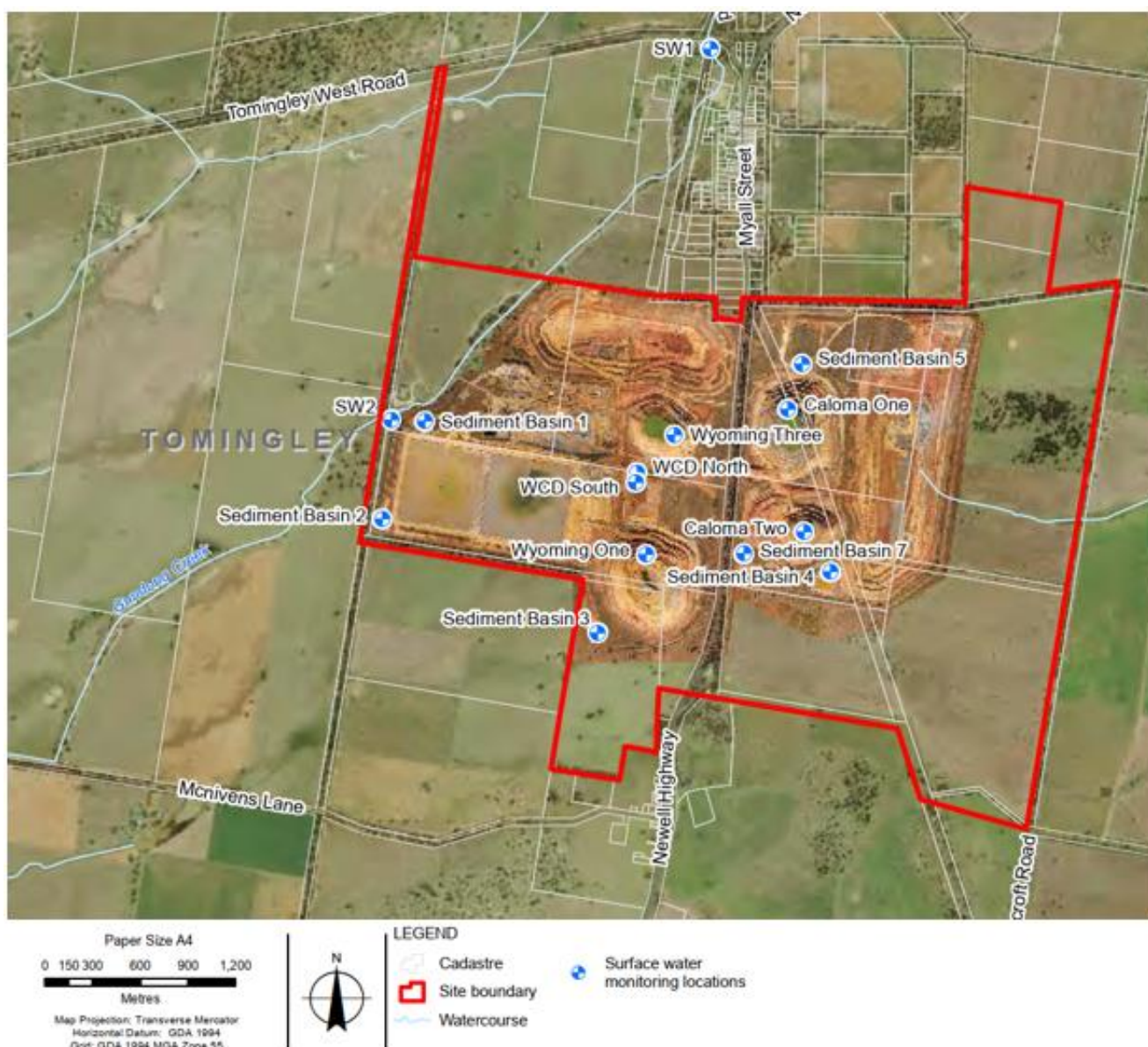


Figure 5-4 Surface Water Quality Monitoring Locations (TGO) (Source: GHD, 2017)

5.4.2 Bulldog Creek

Bulldog Creek which traverses the southern extent of the water quality and flood study areas has been monitored opportunistically following rainfall on three occasions in June, November and December of 2021. Site BCOLL was monitored on all three occasions, BCW was monitored in June and December, and BCE was only monitored once in June. Monitoring locations are shown in **Figure 5-5**. Site BCOLL was located on Bulldog Creek at OLearys Lane upstream of the Project Site and BCE and BCW are located downstream of the Project Site on Bulldog Creek east and west of Back Tomingley West Road respectively. Since BCE was only sampled once, raw water quality results recorded at the site in June 2021 have been provided in **Table 5-4**, while a value range has been provided for BCOLL and BCW where they have been sampled multiple times. Due to limited data, no statistical analysis has been undertaken for these sites. It should also be noted that water quality is representative of conditions at that time.

Based on the data available, it appears that water quality in Bulldog Creek is poor when water is present instream with many indicators not meeting the recommended guideline limits for protection of aquatic ecosystems. Indicators that did comply at all sites on all occasions in Bulldog Creek were pH, electrical conductivity and the trace metals mercury, nickel, arsenic, and cadmium. Similar to Gundong Creek, concentrations of TN, TP,

aluminium and iron were significantly elevated above recommended guideline values at all sites on Bulldog Creek on all monitoring occasions. Ammonia was above guideline limits at BCW and BCOLL in November and December, respectively. Oxidised nitrogen was above guidelines at BCOLL on all occasions and at BCW in November. Copper, chromium and zinc were also above guideline limits most of the time except for at site BCOLL. Selenium was below detection limit at all sites on all occasions.

Table 5-4 Existing water quality of Bulldog Creek in June, November and December 2021 and compliance with WQO

Indicator	BCOLL	BCE	BCW	WQO (aquatic ecosystems)	Source^
Electrical conductivity (µS/cm)	101-152	107	107-179	<456	Dol (2018)
pH	7.17-7.36	7.09	6.92-7.12	7-8	Dol (2018)
Total suspended solids (mg/L)	2.5-18	22	2.5-22	No guideline	No guideline
Ammonia (mg/L)	0.005- 0.04	<0.01	0.005- 0.02	0.013	ANZECC/AMRCANZ (2000c)
Oxidised nitrogen (mg/L)	0.04-1.37	0.01	0.01- 0.04	0.015	ANZECC/AMRCANZ (2000c)
Total nitrogen (mg/L)	1.5-3.0	1.8	1.7-2.0	0.6	Dol (2018)
Total phosphorus (mg/L)	0.08-0.14	0.22	0.11-0.18	0.035	Dol (2018)
Aluminium (total) (mg/L)	0.54-4.54	9.7	0.15-5.63	0.055	ANZG (2018)
Iron (total) (mg/L)	0.60-4.48	6.7	0.62-5.52	0.3	ANZG (2018)
Mercury (total) (mg/L)	<0.0001	<0.0001	<0.0001	0.00006	ANZG (2018)
Molybdenum (total) (mg/L)	0.0005-0.026	<0.001	<0.001	0.034	ANZG (2018)
Nickel (total) (mg/L)	0.004-0.005	0.007	0.003-0.005	0.011	ANZG (2018)
Arsenic (total) (mg/L)	0.001-0.002	0.003	0.002	0.013	ANZG (2018)
Boron (total) (mg/L)	0.0025-0.13	<0.05	0.025-0.08	0.94	ANZG (2018)
Cadmium (total) (mg/L)	<0.0001	<0.0001	<0.0001	0.0002	ANZG (2018)
Chromium (total) (mg/L)	0.001-0.005	0.009	0.001-0.006	0.001	ANZG (2018)
Copper (total) (mg/L)	0.0005- 0.003	0.007	0.005-0.006	0.0014	ANZG (2018)
Zinc (total) (mg/L)	0.0025-0.007	0.027	0.0025- 0.013	0.008	ANZG (2018)
Selenium (total) (mg/L)	<0.01	<0.01	<0.01	0.0005	ANZG (2018)

Indicator	BCOLL	BCE	BCW	WQO (aquatic ecosystems)	Source [^]
Lead (total) (mg/L)	0.0005- 0.007	0.003	0.0005- 0.002	0.0034	ANZG (2018)

[^]ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (upland rivers)

DoI (2018) Macquarie-Castlereagh water management plan

ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (95% species protection)

Bold font denotes exceedance of WQO

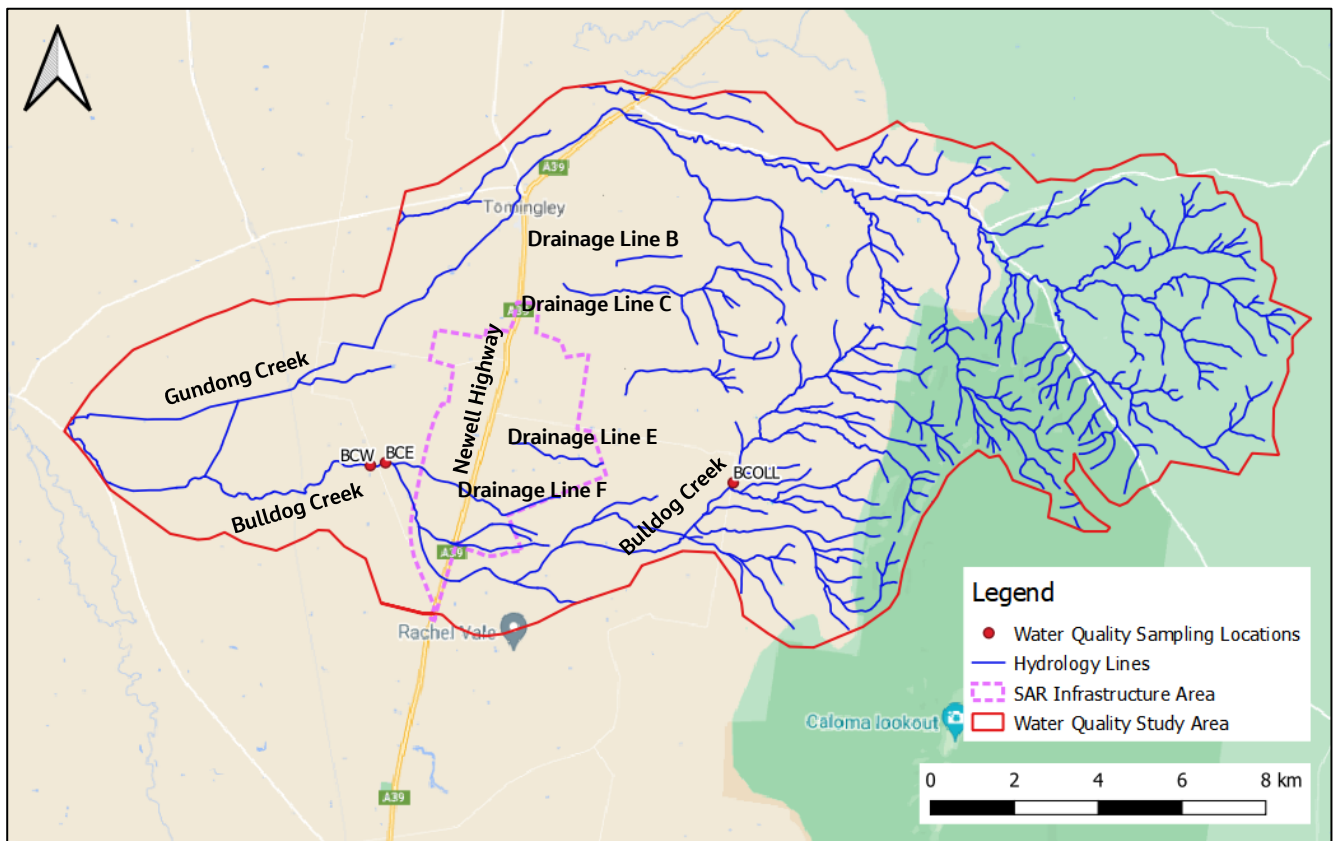


Figure 5-5: Surface Water Quality Monitoring Locations on Bulldog Creek

6. Impact Assessment –Water Quality

6.1 Construction

Construction of the Proposed SAR operations and modifications to TGO operations has potential to result in changes to surface water hydrology and degradation of downstream water quality if management measures are not implemented, monitored and maintained throughout the construction phase.

Potential impacts to surface water hydrology and water quality could occur due to the following construction activities:

- Site establishment, which would include:
 - Removal of existing infrastructure within the Project Site such as power lines and communication lines;
 - Demolition or relocation of other existing features in the Project Site, including fences, buildings and sheds;
 - Establishment of additional services for the Project such as power lines, communication lines, and pipelines;
 - Establishment of erosion and sediment control structures including clean and dirty water structures and inundation bunds
 - Establishment of laydown areas
 - Vegetation clearing;
 - Stripping and stockpiling of soils; and,
 - Establishment of borrow pits, as well as construction of the Haul Road, Service Road, SAR Amenity Bund, the Administration Area, and other site infrastructure.
- Realignment of roads, including the Newell Highway, Kyalite Road, Back Tomingley West Road, MvNivens Lane and associated intersections. These works would include:
 - Earthworks;
 - Establishment of culverts
 - Movement and use of vehicles across exposed earth;
 - Road construction works, including concreting, steel works and laying down asphalt;
 - Demolition and modification of existing road surfaces; and,
 - Construction of culverts.
- Site restoration and landscaping of disturbed areas as required.

Potential impacts and their associated risk during construction are identified in **Section 6.1.1**. With the implementation of environmental controls, an assessment of significance for surface water features in the water quality and flood study areas is provided in **Section 6.1.2**.

6.1.1 Identification of potential impacts

6.1.1.1 Erosion and sedimentation

There are a number of construction activities that have the potential to result in soil erosion and subsequent sedimentation in downstream environments if stormwater runoff, flood water or wind mobilises exposed soils, including:

- Vegetation clearance – vegetation would be cleared as part of the Project as discussed in the Biodiversity Development Assessment Report prepared for the EIS. Vegetation removal would expose soils to

weathering processes, increasing the risk of erosion and sedimentation. Removal of vegetation may also lead to increased volumes of surface runoff and therefore increased sediment load reaching downstream receivers.

- Earthworks, including stripping topsoil and excavation – construction of the Project would require general earthworks to prepare the Project Site, construction of and upgrading internal haul roads and public roads, and installation of on-site infrastructure and environmental controls (i.e. construction of stormwater basins and site drainage). Soils exposed during earthworks have the potential to be mobilised to downstream environments via wind and stormwater runoff.
- Stockpiling – excavated material and spoil material would require stockpiling before being reused on the Project. If stockpiles are not adequately stabilised, material may erode during high rainfall or by wind and subsequently deposit in downstream receivers.
- Movement and use of heavy vehicles – construction of the Project will require movement and use of heavy machinery, plant and equipment across exposed earth for the installation of civil, mechanical and electrical components of the Project. This could result in generation of dust and increase ground disturbance resulting in increased risk of erosion and sedimentation.
- Drainage work – installation of culverts and temporary diversion of surface waters could result in transportation of soils, exposed sediment and contaminants associated with the earthworks to downstream receiving environments by wind and stormwater runoff. This could result in increased turbidity and poor water clarity and elevated concentrations of metals and other contaminants which can negatively impact on aquatic life.

The impacts of erosion and sedimentation on surface water features may include:

- Increased sedimentation can alter the geomorphology of waterways. Increased turbidity concentrations in water can result in poor water clarity. Elevated turbidity can reduce biological productivity of aquatic systems through clogging fish gills, reduced light penetration and smothering of aquatic vegetation thereby decreasing available plant material for fish to feed on.
- Sediments may also contain high concentrations of nutrients which can lead to algal blooms, and subsequently result in reduced light penetration that limits the growth of aquatic vegetation. Algal blooms may also cause a reduction of dissolved oxygen content in water which can lead to the creation of 'dead zones' where aquatic life cannot survive.
- Mobilised sediments may contain elevated concentrations of metals and other contaminants which can negatively impact aquatic organisms that may be sensitive to changes in water quality.

While sediment-laden runoff and pollutants from soil disturbance have the potential to temporarily reduce water quality if able to mobilise downstream, impacts to surrounding sensitive waterways are considered highly unlikely to occur as construction runoff would be managed with the implementation of erosion and sediment controls and additional environmental management measures outlined in **Section 8**. Site erosion and sediment controls and other management measures would be established as the first step in commencement of construction activities to ensure all runoff is contained on-site, and to avoid and/or manage erosion and sedimentation impacts in waterways within the Project Site.

6.1.1.2 Release of Tannins

In addition to increased risk of erosion and sedimentation from exposure of topsoil, vegetation clearing and subsequent mulching may result in the release of tannin leachate that could mobilise to downstream receiving waterways via stormwater runoff.

Tannin leachate is dark coloured water which can alter downstream pH, and reduce visibility and light penetration. Tannins can also increase biochemical oxygen demand (BOD) which can decrease in-stream dissolved oxygen concentrations that may lead to fish kills.

The overall risk of tannin leachate mobilising to downstream receivers is considered negligible as vegetation clearing required for the Project is minimal and erosion and sediment controls, as well as additional management measures (detailed in **Section 8**) would be established on-site prior to any vegetation clearance works being carried out.

6.1.1.3 Release of concrete waste

Concrete works are expected for site establishment works and realignment works for public roads, including in situ pouring for culvert works at Bulldog Creek and elsewhere.

Concrete works can result in concrete dust, concrete slurries or washout water entering downstream waterways. Concrete by-products are alkaline, with a pH of around 12, and therefore have the potential to alter the pH of downstream watercourses which can be harmful to aquatic life that are sensitive to changes in pH.

The risk of transportation of concrete waste is considered low as concreting will not occur within proximity of waterways apart from some in situ pouring required for building culverts over Bulldog Creek. The risk for Bulldog Creek is also considered to be low as the waterway generally does not contain water and management measures, such as conducting concrete works when the streambed is dry, temporarily diverting flows around work areas and timing works to avoid wet weather or when the waterway is flowing, would be implemented to minimise the opportunity for mobilisation of concrete waste downstream. Additionally, other water quality controls and management measures (detailed in **Section 8**) would be implemented to ensure runoff is contained on-site and captured in on-site construction sediment basins.

6.1.1.4 Release of heavy metals, hydrocarbons and other pollutants

The release of potentially harmful substances to the environment may occur accidentally during construction. Sources of contaminants may include:

- Accidental spills which may occur as a result of inappropriate storage, handling and use of plant and equipment. These contaminants could include acids and chemicals from washing down of vehicles, construction fuels, oils, lubricants and hydraulic fluids. Spills may cause oily films to be transported to downstream receiving waters via stormwater runoff which may accumulate in the surface water and reduce visual amenity or result in loss of habitat and aquatic organisms from increased concentrations of toxicant and altered pH levels.
- Leaching of heavy metals and polyaromatic hydrocarbons (PAHs) from batching asphalt which can be toxic to aquatic life.
- Steel cuttings and other heavy metals may be mobilised to downstream waterways during steelworks.
- Mobilisation of litter to waterways may lead to the introduction of gross pollutants (rubbish), nutrients, hydrocarbons and heavy metals into waterways which may be harmful to aquatic life and reduce visual amenity.

While there is potential for accidental spills, leaks and litter from construction activities, it is unlikely that contaminants would reach downstream receivers or result in any major or long-term impact to downstream water quality as impacts would be temporary and manageable through erosion and sediment controls and additional management measures (as outlined in **Section 8**) which would be further developed and implemented as part of the CEMP.

6.1.2 Impact Assessment

As described in **Section 6.1.1**, all identified impacts relate to the risk of construction runoff mobilising to downstream waterways via wind or stormwater. An assessment of the significance of impacts to downstream waterways is provided in **Table 6-1**.

Table 6-1 Determination of impact significance per waterway

Watercourse	Sensitivity	Magnitude	Significance	Rationale
Gundong Creek	Low	Minor	Minor	- No proposed drainage path to Gundong Creek as it is located outside of the SAR Mine Site and runoff is currently diverted to on-site sediment basins. - Discharging sediment basins to Gundong Creek is not proposed. - Flows reaching Gundong Creek would only eventuate in a large flood event. - Potential for runoff to reach Bogan River downstream is highly unlikely due to significant distance from site and lack of permanent flow in Gundong Creek. - Any sediment transported via aeolian processes are unlikely to deposit into available water within the waterway, although may be transported downstream during subsequent flows. - Sediment transport via aeolian processes is considered highly unlikely as dust generated from the construction site will be managed appropriately, ie. using collected runoff for dust suppression activities.
Drainage Line E	Very low	Minor	Insignificant	- Drainage depression is located within the SAR Mine Site and therefore runoff may flow to it during rainfall and potentially pond following rainfall. - Under normal conditions, flows will be diverted to sediment basins via diversion drains however during a flood event, flows are likely to drain via this drainage channel toward Bulldog Creek. - No defined channel banks therefore erosion potential is low. No in-channel vegetation or habitat features, therefore considered unlikely fish habitat. - Any sediment transported via aeolian processes are unlikely to deposit into available water within the drainage channel, although may be transported downstream during subsequent flows. - Sediment transport via aeolian processes is considered highly unlikely as dust generated from the construction site will be managed appropriately, ie. using collected runoff for dust suppression activities.
Drainage Line F	Very low	Minor	Insignificant	The drainage depression is located within the SAR Mine Site and therefore runoff may

				flow to it during rainfall and potentially pond following rainfall. ▪ Under normal conditions, flows will be diverted to sediment basins via diversion drains however during a flood event, flows will drain via this drainage channel toward Bulldog Creek. ▪ The drainage depression has no defined channel banks therefore erosion potential is low. No in-channel vegetation or habitat features, therefore considered unlikely fish habitat. ▪ Any sediment transported via aeolian processes are unlikely to deposit into available water within the drainage channel, although may be transported downstream during subsequent flows. ▪ Sediment transport via aeolian processes is considered highly unlikely as dust generated from the construction site will be managed appropriately, ie. using collected runoff for dust suppression activities.
Bulldog Creek	Low	Minor	Minor	▪ Bulldog Creek is located within the SAR Mine Site therefore runoff may flow to it during rainfall and potentially pond following rainfall. ▪ Under normal conditions, flows will be directed via diversion drains toward sediment basins however during a flood event, overland flows have potential to reach Bulldog Creek. ▪ Construction activities related to building culverts over Bulldog Creek present a minor risk to Bulldog Creek downstream if flows mobilise sediment and contaminants during in-channel works. Erosion and sediment controls, as well as other management measures will be implemented to ensure no transport of pollutants downstream. ▪ Bulldog Creek does not have a well-defined channel therefore erosion potential is low. Where Bulldog Creek crosses the SAR Mine Site, there is no in-channel vegetation or habitat features, therefore considered minimal fish habitat. ▪ Potential for runoff to reach Bogan River downstream is highly unlikely due to significant distance from site and lack of permanent flow in Bulldog Creek. ▪ Any sediment transported via aeolian processes are unlikely to deposit into available water within the waterway,

				although may be transported downstream during subsequent flows. ▪ Sediment transport via aeolian processes is considered highly unlikely as dust generated from the construction site will be managed appropriately, ie. using collected runoff for dust suppression activities.
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6.2 Operation

During operation of the Project, the potential for impacts to surface water hydrology and water quality would primarily be related to mining operations and proposed water management, as well as potential increases in runoff from new impervious surfaces.

Operational activities which present a risk to surface water include:

- Mining operations, both open cut mining and underground mining.
 - Open cut mining would initially involve free dig, load and haul techniques. When more competent material is exposed, this would be extracted using conventional drill, blast, load and haul techniques. The excavated open cut ore would be transported via the haul road to various sites or stockpiled until transport of the material is undertaken.
 - Underground mining operations will result in minimal ground disturbance aside from where the open cuts would occur. Underground mining operations do however have surface infrastructure such as ventilation rises, a paste fill plant and services such as power, water and compressed air. The paste fill plant presents the greatest risk to water quality which could occur if there is a paste spill.
- Water Management which would include:
 - Surface water diversion structures that will convey water via low, grass contoured banks at non-erosive velocities;
 - An inundation bund (located east of the SAR Open Cut) to provide protection during an from erosion and sedimentation
 - SAR Site Water Storage Dam would capture and store water to provide protection following rainfall events. Water would be re-used for dust suppression.

Potential impacts and their associated risks during construction are identified in **Section 6.2.1**. With the implementation of environmental controls, an assessment of significance for surface water features in the water quality and flood study areas is provided in **Section 6.2.2**.

6.2.1 Identification of potential impacts

6.2.1.1 Erosion and sedimentation

Following construction, the potential for impacts to water quality due to erosion and downstream sedimentation would be limited to the following sources:

- Exposed earth – Erosion in areas of disturbed earth not yet rehabilitated from the construction period. Rehabilitation will occur progressively and will be managed using adequate erosion and sediment controls.
- Potential overtopping of water quality controls – Barriers to flow on site, particularly the Inundation Bund, if not constructed and designed properly could overflow and potentially reach surface water receptors on site through accidental release.

The potential impacts of erosion and sedimentation on waterways resulting from the abovementioned sources would be as described in **Section 6.1.1.1** associated with construction but on a lower scale.

Under normal operation, the risk of erosion and sedimentation impacts from the aforementioned sources are considered to be very low as environmental controls such as dust suppression (refer to **Section 8** for proposed mitigation and management measures), and the proposed water management system would be designed and implemented to provide adequate containment of surface water runoff on-site such that no runoff leaves the Project Site. With regard to overflows of water quality controls the risk is associated with the SAR site water storage dam and water quality control basins which during very large flood events may fail or be overtopped. This presents a risk to downstream water quality as water released from the storage dam would be high in sediment which could be transported downstream or into the SAR Open Cut Mine. Where possible water would be retained and treated prior to discharge or re-used on site.

6.2.1.2 Release of heavy metals, hydrocarbons and other pollutants

General operation of the Project may result in the accidental release of potentially harmful substances to the environment. Sources of contaminants may include:

- Accidental leaks and spills – Spills/leaks may occur as a result of inappropriate storage, handling and use of plant and equipment on-site and during transport. These contaminants could include acids and chemicals from washing down of vehicles, fuels, oils, lubricants and hydraulic fluids. Spills may cause oily films to be transported to downstream receiving waters via stormwater runoff which may accumulate in the surface water and reduce visual amenity or result in loss of habitat and aquatic organisms from increased concentrations of toxicant and altered pH levels.
- Waste rock – During operation of the Project, ore will be extracted and waste rock stockpiled within the RIM Pad, ROM Pad or the SAR and Caloma Waste Rock Emplacements. Stockpiles will be managed during mining operations and stabilised during and following progressive rehabilitation, however, material may be mobilised during rainfall or by wind and subsequently deposit in downstream receivers. Waste rock at the TGO site is generally classified as non-acid forming and total metal concentrations are generally not significantly enriched when compared to relevant water quality guidelines (RGS, 2021). There is a risk that aluminium, arsenic and chromium may be marginally more soluble and slightly exceed the ANZG (2018) guidelines for freshwater aquatic ecosystems, however remain well below the criteria for livestock drinking water supplies (RGS, 2021).
- Paste fill plant – Paste fill would be produced on-site to assist with ore extraction activities. Potential leaks or spills from the plant may result in transport of contaminants which may be harmful to aquatic ecosystems.

Under normal operation, the risk of contaminants reaching downstream receivers is considered very low as diversion drains and sediment ponds would retain dirty water on the SAR Mine site, where it would be pumped back to the SAR Site Water Storage and inundation bunds will divert clean water around the disturbed areas. As mentioned previously, the risk to water quality would occur only if the controls failed resulting in the release of dirty water

6.2.2 Impact assessment

An assessment of the significance of operational impacts to downstream waterways is provided in **Table 6-2**.

Table 6-2 Determination of impact significance per waterway

Watercourse	Sensitivity	Magnitude	Significance	Rationale
Gundong Creek	Low	Minor	Minor	▪ No proposed flow path changes to Gundong Creek as it is located outside SAR Infrastructure Area. ▪ Mine water would not be permitted to be discharged from site.

Watercourse	Sensitivity	Magnitude	Significance	Rationale
				- Potential for runoff to reach Bogan River downstream is highly unlikely due to significant distance from site and lack of permanent flow in Gundong Creek. - Any sediment or waste rock material transported via aeolian processes are unlikely to deposit into available water within the waterway, although may be transported downstream during subsequent flows.
Drainage Line E	Very low	Minor	Insignificant	- Drainage depression is located within the SAR Mine Site boundary therefore runoff may flow to it during rainfall and potentially pond following rainfall. - Under normal conditions, flows will be contained to the SAR Mine Site using diversion drains and sediment ponds that will direct flows to the on-site water storage facility, however during a flood event or if water quality controls fail, flows may drain via this drainage channel toward Bulldog Creek. - No defined channel banks therefore erosion potential is low. - No permanent water therefore any sediment or waste rock material transported via aeolian processes is unlikely to deposit into available water within the channel, although may be transported downstream during subsequent flows.
Drainage Line F	Very low	Minor	Insignificant	- The drainage depression is located within the SAR Mine Site boundary therefore runoff may flow to it during rainfall and potentially pond following rainfall. - Under normal conditions, flows will be contained to the SAR Mine Site using diversion drains and sediment ponds that will direct flow to the on-site water storage facility, however during a flood event, or if water quality controls fail flows may drain via this drainage channel toward Bulldog Creek. - The drainage depression has no defined channel banks therefore erosion potential is low. - No permanent water therefore any sediment or waste rock material transported via aeolian processes is unlikely to deposit into available water within the channel, although may be transported downstream during subsequent flows.

Watercourse	Sensitivity	Magnitude	Significance	Rationale
Bulldog Creek	Low	Minor	Minor	▪ Bulldog Creek is located within the SAR Mine Site boundary therefore runoff may flow to it during rainfall and potentially pond following rainfall. ▪ Under normal conditions, flows will be contained to the SAR Mine Site using diversion drains and sediment ponds that will direct flow to the on-site water storage facility however during a flood event or of water quality controls fail, overland flows have potential to reach Bulldog Creek. ▪ New culverts have been designed so that velocities through the culverts do not exceed 3 m/s. ▪ Potential for runoff to reach Bogan River downstream is highly unlikely due to significant distance from site and lack of permanent flow in Bulldog Creek. ▪ No permanent water therefore any sediment or waste rock material transported via aeolian processes is unlikely to deposit into available water within the waterway, although may be transported downstream during subsequent flows.

6.3 Decommissioning and final landform

During decommissioning works for the Project, the potential for impacts to surface water hydrology and water quality would be related to required rehabilitation activities and subsequently the final landform of the site once it has been decommissioned.

Activities and features which present a risk to surface water include:

- Rehabilitation works, which would include:
 - Reduction of the Haul Road, or re-sizing of on-site roads such as the Services Road
 - Removal of the Administration Area and other on-site infrastructure such as magazines, RIM Pad and Pastefill Plant
 - Landscaping works.
- Final landform, which would include:
 - Two bunded and fenced voids
 - Three fully backfilled open cuts
 - Three shaped and rehabilitated Waste Rock Emplacements
 - Water management structures, particularly an Abandonment Bund which would include the Inundation Bund and reduced Services Road
 - The realigned Newell Highway, Kyalite Road and Back Tomingley West Road.

Potential impacts and their associated risk during decommissioning and final landform are identified in **Section 6.1**. With the implementation of environmental controls, an assessment of significance for surface water features in the water quality and flood study areas is provided in **Section 6.3.2**.

6.3.1 Identification of potential impacts

6.3.1.1 Erosion and sedimentation

Erosion and sedimentation impacts may result from decommissioning site infrastructure and rehabilitating disturbed areas.

The potential impacts of erosion and sedimentation on waterways resulting from the abovementioned sources would be as described in **Section 6.1.1.1** associated with construction.

The risk of erosion and sedimentation impacts from these activities are considered to be very low as environmental controls such as dust suppression (refer to **Section 8** for proposed mitigation and management measures), and the proposed water management structures would be designed and implemented to provide adequate containment of surface water runoff such that no runoff leaves the Project Site. Any surface water structures not retained for the final landform would be dismantled as a final step in the decommissioning process.

6.3.1.2 Release of heavy metals, hydrocarbons and other pollutants

The release of potentially harmful substances to the environment may occur accidentally during decommissioning and final landform establishment. Sources of contaminants may include:

- Accidental spills which may occur as a result of inappropriate storage, handling and use of plant and equipment. These contaminants could include acids and chemicals from washing down of vehicles, construction fuels, oils, lubricants and hydraulic fluids. Spills may cause oily films to be transported to downstream receiving waters via stormwater runoff which may accumulate in the surface water and reduce visual amenity or result in loss of habitat and aquatic organisms from increased concentrations of toxicant and altered pH levels.
- Mobilisation of litter to waterways may lead to the introduction of gross pollutants (rubbish), nutrients, hydrocarbons and heavy metals into waterways which may be harmful to aquatic life and reduce visual amenity.

While there is potential for accidental spills, leaks and litter from decommissioning activities, it is unlikely that contaminants would reach downstream receivers as it is expected that the water management system would be designed and implemented to provide adequate containment of surface water runoff such that no runoff leaves the Project Site under normal conditions. Any surface water structures not retained for the final landform would be dismantled as a final step in the decommissioning process. As with during the construction and operational phases, the residual risk is associated with only very large flood events when water management features such as the diversion drains, sediment basins and storage dams fail or are overtopped. As mentioned previously if this occurs, the risk is the releases of sediment laden water downstream.

6.3.1.3 Alteration of hydrological regime

The design and implementation of the final landform will determine the potential impact on the hydrological regime. Significant alteration of the hydrological regime is not expected as the proposed final landform has been designed to ensure runoff and flow paths are similar to original conditions and almost identical to that during the operational phase. New landscape features would be appropriately constructed and landscaped such that changed flows are minimised as far as practicable. In particular, the rock emplacement structures will be vegetated and the retained water management structure, the Abandonment Bund, will assist to contain flows around the decommissioned site and will assimilate into the agricultural landscape

6.3.2 Impact assessment

An assessment of the significance of impacts to downstream waterways during decommissioning and final landform establishment is provided in **Table 6-3**.

Table 6-3 Determination of impact significance per waterway

Watercourse	Sensitivity	Magnitude	Significance	Rationale
Gundong Creek	Low	Minor	Minor	- Runoff would be contained on the Project site and flows would not reach Gundong Creek. - Potential for runoff to reach Bogan River downstream is highly unlikely due to significant distance from site and lack of permanent flow in Gundong Creek. - Any sediment transported via aeolian processes are unlikely to deposit into available water within the waterway, although may be transported downstream during subsequent flows.
Drainage Line E	Very low	Minor	Insignificant	- Drainage depression is located within the SAR Mine Site boundary therefore runoff may flow to it during rainfall and potentially pond following rainfall. - Runoff will be captured by the retained surface water management system, however during a flood event, flows may drain via this drainage channel toward Bulldog Creek. - No defined channel banks therefore erosion and scour potential is low. - No permanent water therefore any sediment transported via aeolian processes is unlikely to deposit into available water within the channel, although may be transported downstream during subsequent flows.
Drainage Line F	Very low	Minor	Insignificant	- The drainage depression is located within the SAR Mine Site boundary therefore runoff may flow to it during rainfall and potentially pond following rainfall. - Runoff will be captured by the retained surface water management system, however during a flood event, flows may drain via this drainage channel toward Bulldog Creek. - The drainage depression has no defined channel banks therefore erosion and scour potential is low. - No permanent water therefore any sediment or waste rock material transported via aeolian processes is unlikely to deposit into available water within the channel, although

Watercourse	Sensitivity	Magnitude	Significance	Rationale
				may be transported downstream during subsequent flows.
Bulldog Creek	Low	Minor	Minor	▪ Bulldog Creek is located within the SAR Mine Site boundary therefore runoff may flow to it during rainfall and potentially pond following rainfall. ▪ Runoff will be captured by the retained surface water management system, however during a flood event, flows may drain to Bulldog Creek. ▪ culverts have been designed so that flood water flowing under the new culverts at Bulldog Creek on the New alignment of the Newell Highway do not result in higher flows or velocities ▪ Potential for runoff to reach Bogan River downstream is highly unlikely due to significant distance from site and lack of permanent flow in Bulldog Creek. ▪ No permanent water therefore any sediment transported via aeolian processes is unlikely to deposit into available water within the waterway, although may be transported downstream during subsequent flows.

6.4 Performance against NSW Water Quality Objectives

With the implementation of proposed water quality controls and management measures (as outlined in **Section 8**), it is anticipated that runoff generated during construction, operation and decommissioning of the Project would not reach downstream receivers, therefore Project operations are not expected to impact on achieving the environmental values of protection of aquatic ecosystems or visual amenity.

The Project is also not expected to impact on achieving the environmental values of primary or secondary contact recreation, as the key indicators of concern relevant are pathogens, algae and toxins. Risk of bacteriological impacts is only associated with the unlikely event of a malfunction in the sewage treatment facilities, however it is expected that the proposed water management system will ensure any spills or leaks would be contained within the Project boundary and would be cleaned up prior to reaching any downstream receivers. Further to this, while waterways within the Project Site boundary have been nominated recreation use values, it is unlikely that these areas are used for this purpose as key waterways in the area are dry most of the time and minor waterways are located on private properties.

The default guideline values for indicators relevant to the environmental values of irrigation water supply and homestead water supply are less stringent than those which have been outlined for the protection of aquatic ecosystems and recreational water use. Therefore, by meeting the water quality objectives for protection of aquatic ecosystems, primary contact recreation and secondary contact recreation, the objectives of irrigation water supply and homestead water supply will also be achieved. As such, it is expected that the Project will not impact on achieving the environmental values of irrigation water supply and homestead water supply.

7. Impact Assessment – Flooding

7.1 Operational Impact

The SAR Infrastructure Area design elements have been simulated in the hydraulic model for a range of AEP events to assess the impact on the realigned Newell Highway and downstream properties. The simulated events include:

- 20% AEP
- 10% AEP
- 5% AEP
- 5% AEP with Climate Change
- 2% AEP
- 1% AEP
- 0.1% AEP

Assessment details and flood maps can be found in the *"Hydrology and Hydraulics Technical Report"* (see Annexure B).

Modelling results suggest that, upstream of the Newell Highway, the same flow paths will be maintained in the design case as the existing case. During the Operational Phase, the Haul Road will act as a control structure for flow arriving at the realigned Newell Highway.

Modelling results predict that ponding at the peak of the flood at the realigned Newell Highway would reach a maximum flood depth of 1.5 m above the natural surface in the 5% AEP event. The ponding is due to the proposed increase in the vertical elevations of the realigned Newell Highway to improve flood immunity. The higher road would no longer be overtopped in the 5% AEP. Results show that in the existing case, the existing Newell Highway is overtopped by up to 295 mm in the 5% AEP.

Downstream of the realigned Newell Highway, hydraulic behaviour will change due to the higher road and new flow paths created by the transverse culverts under the Highway.

Figure 7-1 shows the identified flow paths and the main ponding areas in the 5% AEP event with the TGEP in place.

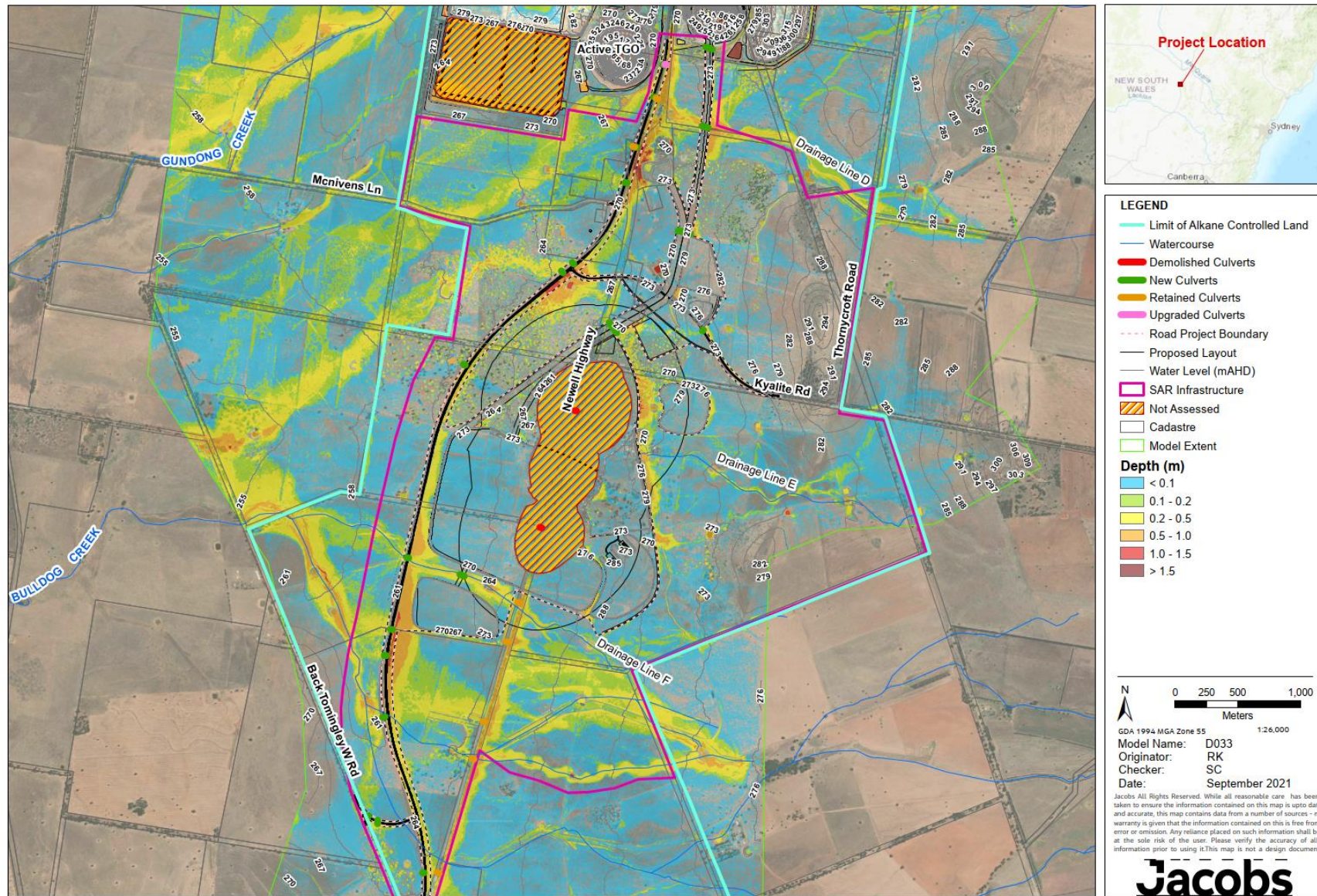


Figure 7-1: Indicative Design flow paths and main ponding areas – 5% AEP

7.1.1 Design Transverse Culvert Crossings

Preliminary design for the transverse culverts under the realigned Newell Highway has aimed to keep velocities below 3 m/s in a 5% AEP event to minimise scour risks. The hydraulic model results indicate that velocities would be below 3 m/s in all the events assessed up to the 5% AEP event.

7.1.2 Culvert Outlet Design

Preliminary design of outlet protection for the transverse culverts under the realigned Newell Highway has been based on the velocity outputs from the hydraulic model. The protection would be an apron of loose rock as recommended by Austroads (2013).

7.1.3 Realigned Newell Highway Immunity

The proposed Newell Highway would achieve 1% AEP flood immunity with a minimum freeboard of 200 mm across the entire stretch of highway upgrade. Many sections of the road would achieve a flood immunity up to the 0.1% AEP event. This represents a significant improvement compared to the existing Newell Highway, which has less than 20% AEP flood immunity.

7.1.4 Flood Impacts

Flood maps showing the potential changes in flood levels relative to existing conditions are presented in the “*Hydrology and Hydraulics Technical Report*” (Annexure B). Overall, flood levels would increase upstream of the Haul Road and the proposed Newell Highway. Downstream of the Newell Highway, flow paths would be changed due to the location of the new culverts. Where there are new flow paths, flood levels would increase whilst at other locations, flood levels would reduce.

The 1% AEP afflux (change in flood level) map is replicated in **Figure 7-2**. Afflux maps for all other events are presented in the “*Hydrology and Hydraulics Technical Report*” (Annexure B).

Figure C5: 1% AEP Flood Level Difference - Design vs Existing

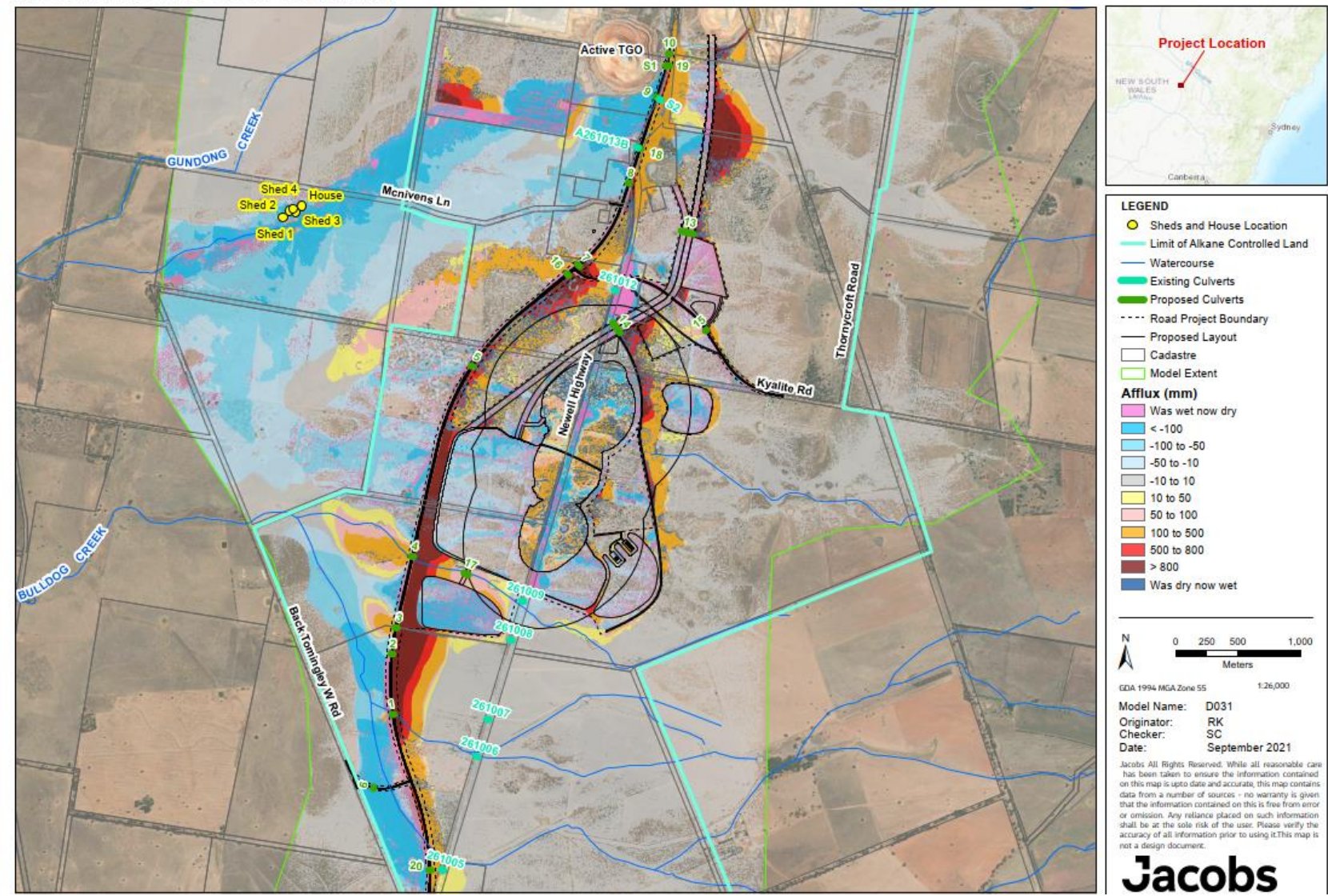


Figure 7-2: 1% AEP Flood Level Difference

Figure 7-3 shows the comparison between the hydrographs at properties downstream of the realigned Newell Highway for the Existing and Design case 5% AEP event. The peak flow is predicted to be 9% lower in the design case compared to the existing case by 16% and the time to peak is delayed by at least 2 hours. The flood volume reaching downstream properties is estimated to be lower by up to 2.9%. This is consistent with the reduced catchment size that results from the SAR open cut in the developed scenario.

The downstream properties subject to these potential changes in flooding are rural and are mostly used for grazing or agricultural purposes. In the 1% AEP event, one house and four sheds were identified to be in the zone of reduced flood depths (Lot 165 Plan DP755093). The floor level of the house has not been surveyed and the model currently assumes ground level to be the floor level. The depth of flooding based on the ground level was predicted to be 126 mm in the 1% AEP in the existing case, and 32 mm in the design case. There would be a reduction of 94 mm as a result of the changed flow paths, i.e. a net flood benefit. As the house is lifted above ground, the flood depths indicate that the floor level would not be inundated in either the existing or design cases. Similar to the house, the depth of flooding would be reduced at the shed locations.

The predicted flood impacts are considered minor and unlikely to cause any material impacts. Upstream impacts are restricted to Alkane Controlled Land.

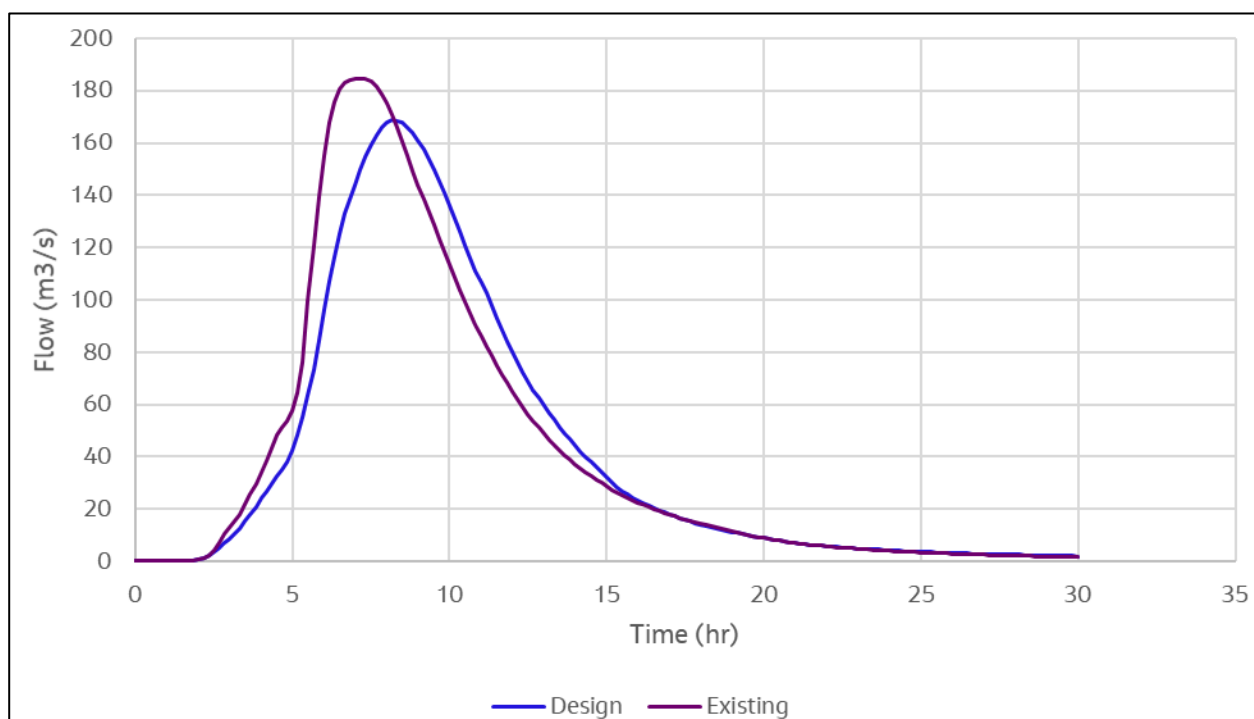


Figure 7-3: Existing vs Design hydrographs downstream the proposed Newell Highway in the 5% AEP event

7.1.5 Culvert Blockage

A blockage assessment was undertaken for the transverse culverts under the proposed Newell Highway as per ARR 2019 guidelines. A 25% of blockage was adopted for all culverts and simulated for the 5% AEP event to assess the impact on the proposed Newell Highway immunity.

It was found that a 5% AEP flood immunity would still be achieved by the realigned Newell Highway. The road design, therefore, has sufficient freeboard to account for blockage.

7.1.6 Climate Change

A climate change scenario was modelled for the 5% AEP event based on RCP 6 and the year 2090. This equates to a 13.1% increase in design rainfall intensity.

Flood levels upstream of the realigned Newell Highway was found to increase by up to 280 mm. Despite this, a 5% AEP flood immunity would still be achieved by the realigned Newell Highway. The road design, therefore, has sufficient freeboard to account for climate change.

7.2 Decommissioning and final landform

The design and implementation of the final landform will determine the potential impact on the hydrological regime. Significant alteration of the hydrological regime is not expected as the proposed final landform has been designed to ensure runoff and flow paths are similar to original conditions and almost identical to that during the operational phase. New landscape features would be appropriately constructed and landscaped such that changed flows are minimised as far as practicable. In particular, the rock emplacement structures will be vegetated and the retained water management structure, the Abandonment Bund, will assist to contain flows around the decommissioned site and will assimilate into the agricultural landscape

Transverse culverts under the Newell Highway have been designed to pass flow from the final landform currently proposed. Outlet protection has also been designed based on the velocities from the hydraulic model. This minimises the risk of scour and downstream sedimentation. Future refinement of the final landform will need to consider flooding constraints including culvert exist velocities.

The landform with the Haul Road removed was simulated in the hydraulic model to assess the impact on the realigned Newell Highway. It was found that flood levels upstream of the Highway would increase by up to 230 mm and velocities in the culverts would remain below 3 m/s. Despite the increase in flood level, a 5% AEP flood immunity would still be achieved by the realigned Newell Highway.

Flood levels downstream of Alkane Controlled Land would increase by up to 70 mm compared to the operational phase. As with the operational phase, increases in flood levels would affect only rural or grazing land.

8. Environmental safeguards and management measures

With regard to surface water quality and hydrology, the key objective is to ensure downstream waterways are protected against potential impacts from construction, operation and decommissioning of the Project. For construction, these measures would be outlined in the Construction Environment Management Plan (CEMP), and would include (but not be limited to) preparation of a Construction Soil and Water Management Plan (CSWMP), Erosion and Sediment Control Plans (ESCP) and emergency spill response procedures. The operational water management system would be designed to achieve water quality and flooding performance outcomes and any necessary maintenance and emergency isolation requirements documented in the Operational Environmental Management Plan (OEMP) and emergency response procedures.

Measures to avoid, minimise or manage surface water impacts as a result of the Project are detailed in **Table 8-1**.

Table 8-1 Recommended environmental safeguards and management measures

Impact	Reference	Environmental Management Measure	Timing
Stormwater runoff	SW01	A CSWMP will be prepared as a sub-plan of the CEMP for each stage of the Project. The plan will outline measures to manage soil and water impacts associated with the construction works. The CSWMP will include but not be limited to: - Measures to minimise/manage erosion and sediment transport both within the construction footprint and off-site including requirements for the preparation of ESCP for construction; - Measures to manage accidental spills including the requirement to maintain materials such as spill kits; Management procedures for reuse of collected construction runoff; and; - Details of surface water monitoring to be undertaken throughout construction (refer to SW03 for further information).	Pre-construction, Construction
	SW02	A Construction ESCP would be developed as a sub plan of the CEMP and would detail the specific erosion and sediment control measures to be implemented in the Project Site boundary in accordance with the principles and requirements of <i>Managing Urban Stormwater – Soils and Construction, Volume 1</i> (Landcom, 2004), commonly referred to as the “Blue Book”. The Construction ESCP would include but not be limited to: - Plans for temporary drainage, scour protection and control measures to reduce erosion and water quality impacts from increased sediment loads from the construction site. - The ESCP would identify locations and design criteria of proposed construction sediment basins; and other water management features	Pre-construction, Construction
	SW03	The design of drainage and water management during operation would demonstrate ability to meet project performance outcomes of no pollution of waterways.	Operation

		Any necessary maintenance or emergency isolation requirements would be documented in the OEMP. With regard to surface water, the OEMP would include (but not be limited too): ▪ Details for regular surveillance inspections of drainage and water management infrastructure and rectification requirements; ▪ Operational procedures for emergency isolation in response to spills, leaks or other emergency events as necessary; and, ▪ Stormwater / flooding detention facilities to mitigate against increases in peak runoff rates from the Project.	
	SW04	A surface water monitoring program will be designed and implemented during construction, operation and decommissioning. The monitoring program will include (but not be limited to): ▪ Regular visual water quality checks (for hydrocarbon spills/slicks, turbid plumes and other water quality issues) will be carried out at identified downstream receivers. ▪ Visual assessment of water management structures at least once every week and also following any heavy rain during construction, operation and decommissioning, to ensure all water structures are operating effectively for their designed purpose, and to promptly address any deficiency in their operation. ▪ Should any deficiency in water management system operation or downstream water quality be identified, prompt remedial actions will be employed to address issues, including clearing sediment traps of sediment, storing and disposing of sediment (if required) in accordance with the Blue Book, and repairing any damaged structure immediately after the damage is identified.	Pre-construction, Construction, Operation, Decommissioning
	Erosion, sediment and water quality controls	SW05 Consistent with any specific requirements of the approved CSWMP, control measures will be implemented to minimise risks associated with erosion and sedimentation and entry of materials to drainage lines and waterways. This will include, but not necessarily be limited to: ▪ Ensuring that all sediment basins are emptied as soon as practicable following rainfall to maintain maximum storage capacity. ▪ Installing pegs to mark the minimum freeboard in all water storages and, in the event that the water level is above the marked freeboard and water cannot be removed to an alternate water storage in the short-term, collect a water sample in the event of an unplanned discharge.	Construction, Operation, Decommissioning

		▪ Installing scour protection at the culvert outlets.	
Spills and litter	SW06	Site specific controls and procedures would be developed and implemented as part of the CSWMP for construction and the OEMP during operation and decommissioning, to reduce the risk of litter, spills and leaks entering downstream waterways. The CSWMP would include (but not be limited to) the following measures: ▪ All fuels, chemicals and liquids would be stored on level ground away from waterways or drainage channels and would be stored in a sealed bunded area within the construction site or Administration Area; ▪ Refuelling and maintenance activities would be limited to designated areas with established spill capture and management controls; ▪ An emergency spill response procedure would be prepared as part of the CSWMP and OEMP; and, ▪ Installing and maintaining control measures such as silt fencing and gross pollutant traps, etc.	Construction, Operation, Decommissioning
Concrete works	SW07	To avoid ingress of concrete waste material into downstream waterways, the CEMP would outline procedures to capture, contain and appropriately dispose of any concrete waste from concrete works including designated lined, bunded and controlled concrete wash-out areas.	Pre-construction, Construction
Flooding Impacts	SW08	Construction planning and the layout of construction work sites and compounds would be undertaken with consideration of overland flow paths and flood risk, avoiding flood liable land and flood events where practicable.	Construction
	SW09	The current design minimises flood impact to properties outside Alkane Controlled Land. Any refinement to the current design would consider potential changes to: • Building and property inundation (including floor level surveys and consideration of existing inundation levels) • Road flood levels and extent of flooding along roads • Overland flow paths and storage effects of construction and operational infrastructure Flood modelling would have regard to the guidelines listed in Section 3. Outcomes of the modelling would be discussed with relevant stakeholders, including potentially impacted landholders.	Detailed Design

9. Conclusions

The water assessment for the construction, operation and decommissioning of the Project has been prepared based on design information dated August 2021 and a review and analysis of available data, aerial photography, topography, database searches, relevant literature, background reports, and applicable legislation, policies and guidelines.

The desktop review revealed that the SAR Infrastructure Area was generally flat with only some minor surface water features present. Two key waterways were identified within the vicinity of the project, including Bulldog Creek which is located within the SAR Mine Site boundary, and Gundong Creek which is located within the TGO Mine Site. Both creeks were determined to be minimally sensitive to hydrological and water quality impacts based on identified characteristics of the waterways.

Upon review of the project design and construction methodology, potential impacts during construction were determined to be related to mobilisation of sediment and contaminants to downstream receivers by wind or stormwater runoff. During construction, the following potential impacts were identified if no mitigation measures were implemented:

- Erosion of soils and subsequent sedimentation of waterways;
- Reduced water quality from elevated turbidity, nutrients and heavy metal contaminants;
- Migration of litter off-site; and
- Contamination from accidental leaks or spills of chemicals and fuels.

These potential impacts are considered highly unlikely to occur and would be managed through implementation of proposed erosion and sediment controls and other identified management measures. No construction discharges are proposed and water collected in the water management system would be re-used on-site.

During operation, the proposed surface water management system is anticipated to contain all runoff generated from the Project which would then be re-used on-site for mining-related purposes. Potential impacts are therefore considered to be limited to the unlikely event of a failure of the water management system and uncontrolled runoff flows to downstream receivers as a result of a major flood event.

The realigned Newell Highway would achieve a 1% AEP flood immunity during the operational phase of the project which is a substantial improvement on the existing Highway which achieves a less than 20% AEP flood immunity. Scour protection for the culvert outlets has been designed based on velocities from the hydraulic model. The scour protection minimises the risk of scouring, erosion and sedimentation.

Hydraulic behaviour downstream of the Newell Highway would be expected to be changed due to the higher road level of the proposed Newell Highway and new flow paths created by the proposed transverse culverts under the Highway. The peak flow would be reduced compared to the existing case whilst the overall duration of flooding would be longer. The total volume of water arriving at downstream properties is expected to reduce by up to 2.9%. The landuses that would experience an increase in flood depth would exclusively be agricultural or grazing land. Four sheds and potentially one house (subject to confirmation of floor level) was identified to experience a reduction in flood depth (i.e. a net flood benefit) as a result of the proposed design.

Decommissioning activities present a low risk. Significant alteration of the hydrological regime is not expected as the proposed final landform has been designed to ensure runoff and flow paths are similar to original conditions and almost identical to that during the operational phase.

Overall, on the basis of the assessment of the existing data, surrounding environment, the design of the Project, and on the basis that recommended safeguards and management measures are implemented, the assessment concludes that there would be minimal impacts to the surface water. As such, water quality and flooding objectives for downstream receivers are likely to be met and the functionality, long-term viability of their aquatic ecosystems would be maintained.

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Annexure A. Applicable Water Quality Guidelines

Table A-1 Key water quality indicators and related numerical criteria for environmental values using the ANZG (2018) Water Quality Guidelines

Environmental value	Indicator	Default guideline value – Lowland rivers
Aquatic ecosystems – maintaining or improving the ecological condition of waterbodies and riparian zones over the long term	Total phosphorus	0.02mg/L
	Total nitrogen	0.25mg/L
	Chlorophyll-a	N/A
	Turbidity	2-25NTU
	Salinity (electrical conductivity)	30-350µS/cm
	Dissolved oxygen	90-110% saturation
	pH	6.5-8.0
	Toxicants	As per ANZG (2018) toxicant default guideline values (95% level of protection for slightly to moderately disturbed ecosystems and 99% level of protection for toxicants that bioaccumulate).
Visual amenity – aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter n/a (no quantitative value specified)
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts n/a (no quantitative value specified)
Secondary contact recreation – maintaining or improving water quality of activities such as boating and wading, where there is a low probability of water being swallowed	Faecal coliforms, enterococci, algae and blue-green algae	Median over bathing season of <230 enterococci per 100 mL (maximum number in any one sample: 450-700 organisms/100 mL) Median over bathing season of <1000 faecal coliforms per 100 mL, with 4 out of 5 samples < 4000/100 mL Algae <15000 cells/mL
	Nuisance organisms	As per the visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.

Environmental value	Indicator	Default guideline value – Lowland rivers
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in Table 9.3 of NHMRC (2008) guidelines.
	Visual clarity and colour	As per the visual amenity guidelines.
	Surface films	As per the visual amenity guidelines.
Primary contact recreation – maintaining or improving water quality for activities such as swimming where there is a high probability of water being swallowed	Faecal coliforms, enterococci, algae and blue-green algae	Median over bathing season of < 35 enterococci per 100 mL (maximum number in any one sample: 60 – 100 organisms/100 mL) Median over bathing season of < 150 faecal coliforms per 100 mL, with 4 out of 5 samples < 600/100 mL Algae <15000 cells/mL.
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed values in table 9.3 of the NHMRC (2008) guidelines.
	Visual clarity and colour	As per the visual amenity guidelines.
	Temperature	15°-35°C for prolonged exposure.
Irrigation water supply – protecting the quality of waters applied to crops and pastures	Algae and blue-green algae	Should not be visible. No more than low algal levels are desired to protect irrigation equipment.
	Salinity (electrical conductivity)	To assess the salinity and sodicity of water for irrigation use, a number of interactive factors must be considered including irrigation water quality, soil properties, plant salt tolerance, climate, landscapes and water and soil management. For more information, refer to Chapter 4.2.4 of ANZECC/ARMCANZ 2000 Guidelines.
	Thermotolerant coliforms (faecal coliforms)	Trigger values for thermotolerant coliforms in irrigation water used for food and non-food crops are provided in Table 4.2.2 of the ANZECC/ARMCANZ 2000 Guidelines.
	Heavy metals and metalloids	Long term trigger values (LTV) and short-term trigger values (STV) for heavy metals and metalloids in irrigation water are presented in Table 4.2.10 of the ANZECC/ARMCANZ 2000 guidelines.

Environmental value	Indicator	Default guideline value – Lowland rivers
Livestock water supply – protecting water quality to maximise production of healthy livestock.	Algae & blue-green algae	An increasing risk to livestock health is likely when cell counts of microcystins exceed 11 500 cells/mL and/or concentrations of microcystins exceed 0.0023mg/L expressed as microcystin-LR toxicity equivalents.
	Salinity (electrical conductivity)	Recommended concentrations of total dissolved solids in drinking water for livestock are given in Table 4.3.1 of the ANZECC/ARMCANZ 2000 Guidelines.
	Thermotolerant coliforms (faecal coliforms)	Drinking water for livestock should contain less than 100 thermotolerant coliforms per 100 mL (median value).
	Chemical contaminants	Refer to Table 4.3.2 (ANZECC/ARMCANZ 2000 Guidelines) for heavy metals and metalloids in livestock drinking water. Refer to Australian Drinking Water Guidelines (NHMRC and NRMMC 2011) for information regarding pesticides and other organic contaminants, using criteria for raw drinking water.
Aquatic foods (cooked) – refers to protecting water quality so that it is suitable for production of aquatic foods for human consumption and aquaculture activities	Algae and blue-green algae	No guideline is directly applicable, but toxins present in blue-green algae may accumulated in other aquatic organisms.
	Faecal coliforms	Guideline in water for shellfish: The median faecal coliform concentration should not exceed 14 MPN/100 mL; with no more than 10 per cent of the samples exceeding 43 MPN/100 mL. Standard in edible tissue: Fish destined for human consumption should not exceed a limit of 2.3 MPN E Coli/g of flesh with a standard plate count of 100,000 organisms /g.
	Toxicants (as applied to aquaculture activities)	Metals: Copper – less than 0.005mg/L Mercury – less than 0.001mg/L Zinc – less than 0.005mg/L. Organochlorines: Chlordane – less than 0.004mg/L (saltwater production) PCBs – less than 0.002mg/L.
	Physico-chemical indicators (as applied to aquaculture activities)	Suspended solids: less than 0.04mg/L Temperature: less than 2°C change over one hour.

Annexure B. Hydrology and Hydraulics Technical Report



Tomingley Gold Mine Expansion Project
Hydrology and Hydraulics Technical Report

002 | 0

September 24, 2021

RW Corkery & Co



Tomingley Gold Mine Expansion Project

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Appendix A. Flood Maps Existing Situation

Appendix B. Flood Maps Design Situation

Appendix C. Flood Maps Difference in Flood level

Appendix D. XP-RAFTS Inputs

Important note about your report

This report is confidential and is provided solely for the purposes of the Tomingley Gold Mine Expansion Project. This report is provided pursuant to a Consultancy Agreement between the Jacobs and RW Corkery & Co to perform a specific and limited task for RW Corkery & Co. This report is strictly limited to the matters stated in it and subject to the various assumptions, qualifications and limitations in it and does not apply by implication to other matters. Jacobs makes no representation that the scope, assumptions, qualifications and exclusions set out in this report will be suitable or sufficient for other purposes nor that the content of the report covers all matters which you may regard as material for your purposes.

This report must be read as a whole. The executive summary is not a substitute for this. Any subsequent report must be read in conjunction with this report.

The report supersedes all previous draft or interim reports, whether written or presented orally, before the date of this report. This report has not and will not be updated for events or transactions occurring after the date of the report or any other matters which might have a material effect on its contents or which come to light after the date of the report. Jacobs is not obliged to inform you of any such event, transaction or matter nor to update the report for anything that occurs, or of which Jacobs becomes aware, after the date of this report.

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Australian Rainfall and Runoff (ARR 2019) outlines several fundamental themes which are also particularly relevant to this Study:

- All models are coarse simplifications of very complex processes. No model can therefore be perfect, and no model can represent all of the important processes accurately.
- Model accuracy and reliability will always be limited by the accuracy of the terrain and other input data.
- Model accuracy and reliability will always be limited by the reliability / uncertainty of the inflow data.
- No model is 'correct' therefore the results require interpretation.
- A model developed for a specific purpose is probably unsuitable for another purpose without modification, adjustment, and recalibration. The responsibility must always remain with the modeller to determine whether the model is suitable for a given problem.
- Recognition that no two flood events behave in exactly the same manner.
- Design floods are a best estimate of an "average" flood for their probability of occurrence.

The interpretation of results and other presentations in this report should be done with an appreciation of any limitations in their accuracy, as noted above.

1. Introduction

Tomingley Gold Operations Pty Ltd (the Applicant), a subsidiary company of Alkane Resources Ltd, owns and operates Tomingley Gold Operations (TGO), an active gold mine, located immediately to the south of the town of Tomingley approximately 50 km southwest of Dubbo in central-western NSW.

The Applicant is proposing additional or modified TGO operations, plus extension of open cut and underground mining, at the San Antonio and Roswell Deposits (SAR) approximately 2 km south of TGO, hereafter referred to as SAR. Collectively, TGO and SAR are referred to as the Tomingley Gold Extension Project (TGEP or the Project).

The Project has been classified as a "State Significant Development" under Schedule 1 (7(a)) of the State Environmental Planning Policy (State and Regional Development) 2011. As a result, the application for development consent is made under Division 4.7 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

1.1 Purpose of this document

Jacobs Australia Pty Ltd (Jacobs) has been commissioned by RW Corkery & Co, on behalf of the Applicant, to prepare a Surface Water Impact Assessment for the Project's Environmental Impact Statement (EIS). The scope of Jacobs' assessment is as follows:

- Establishment of existing surface water conditions;
- Development of hydrologic and hydraulic model of the SAR Infrastructure Area for the flood impact assessment; and
- Water quality impact assessment

The following elements are **excluded** from Jacobs' scope of works:

- Stormwater Management Plan;
- Erosion and Sediment Control Plan; and
- SAR Infrastructure Area Water Balance Assessment

This Hydrology and Hydraulics Technical Report is supplementary to the Surface Water Assessment Report and provides technical details on the development of the hydrologic and hydraulic models and the hydraulic assessment of the TGEP. It is intended to be read in conjunction with the main Surface Water Assessment Report.

1.2 Glossary

The following terms and acronyms are used within this document.

Table 1-1 Terms and Acronyms used in this Report

Term or Acronym	Description
AEP	Annual Exceedance Probability. The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. For example, the 1% AEP flood would have a 1% chance of occurring in any given year.
AHD	Australian Height Datum
ARF	Areal Reduction Factor
ARR 2019	Australian Rainfall and Runoff Guidelines – 2019 Edition
BoM	Bureau of Meteorology
Design Case	Hydraulic modelling case with Project in place
EIS	Environmental Impact Statement
EP&A	Environmental Planning and Assessment
Existing Case	Hydraulic modelling case pre- Project
FFA	Flood Frequency Analysis
IFD	Intensity-Frequency-Duration
LiDAR	Light Detection and Ranging
PMF	Probable Maximum Flood
SAR	San Antonio and Roswell Deposits
TGEP	Tomingley Gold Extension Project
TGO	Tomingley Gold Operations
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe (in the context of pipe materials)
RCP (Climate Change)	Representative Concentration Pathway (in the context of Climate Change scenarios)

2. Hydrologic Modelling

The hydrologic modelling was undertaken using the software XP-RAFTS 2018.1. The model was parametrised with catchment areas, fractions impervious, Manning's n values and lag times. The RAFTS model was simulated using Storm Injector, a hydrologic modelling and post processing tool.

The following events were simulated for the project:

- 20% AEP
- 10% AEP
- 5% AEP
- 5% AEP with Climate Change
- 2% AEP
- 1% AEP
- 0.1% AEP

2.1 Catchment Representation

The catchment details adopted within the XP-RAFTS model can be seen in **Appendix D**. The catchment to downstream of the Newell Highway was delineated into 30 sub-catchments as shown in **Figure 2-1**. The catchment delineation was undertaken using QGIS and based on available 5 m contour data. Manual corrections of the automated process were undertaken during the review of the sub-catchments.

The total catchment area is approximately 209.6 km².

All sub-catchments were represented as fully pervious as the current land use is exclusively agricultural and mining.

2.2 Design rainfall

Design rainfall depths and intensities were adopted based on the Bureau of Meteorology (BoM) IFD for the centroid of the full catchment. The IFD was extracted in July 2021, representing the most up-to-date rainfall information at the time of writing. It was found that spatial variation of rainfall across the sub-catchments was less than 2% across the modelled events for durations up to 12 hours. No spatial variation was therefore applied.

Table 2-1: Adopted IFD Rainfall Depth (2021)

Duration	Rainfall Depth (mm)					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.1% AEP
30 min	25.4	30.5	35.7	42.9	48.6	72.4
45 min	29.3	35.2	41.2	49.5	56.1	83.4
1 hour	32.1	38.6	45.2	54.2	61.3	91.1
1.5 hour	36.3	43.6	51	61	68.9	102
2 hour	39.4	47.3	55.3	65.9	74.3	111
3 hour	44.4	53	61.7	73.4	82.5	123

Duration	Rainfall Depth (mm)					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.1% AEP
4.5 hour	49.9	59.4	68.8	81.6	91.5	137
6 hour	54.4	64.5	74.5	88.1	98.7	148
9 hour	61.5	72.5	83.3	98.4	110	166
12 hour	67.1	78.9	90.3	107	119	180

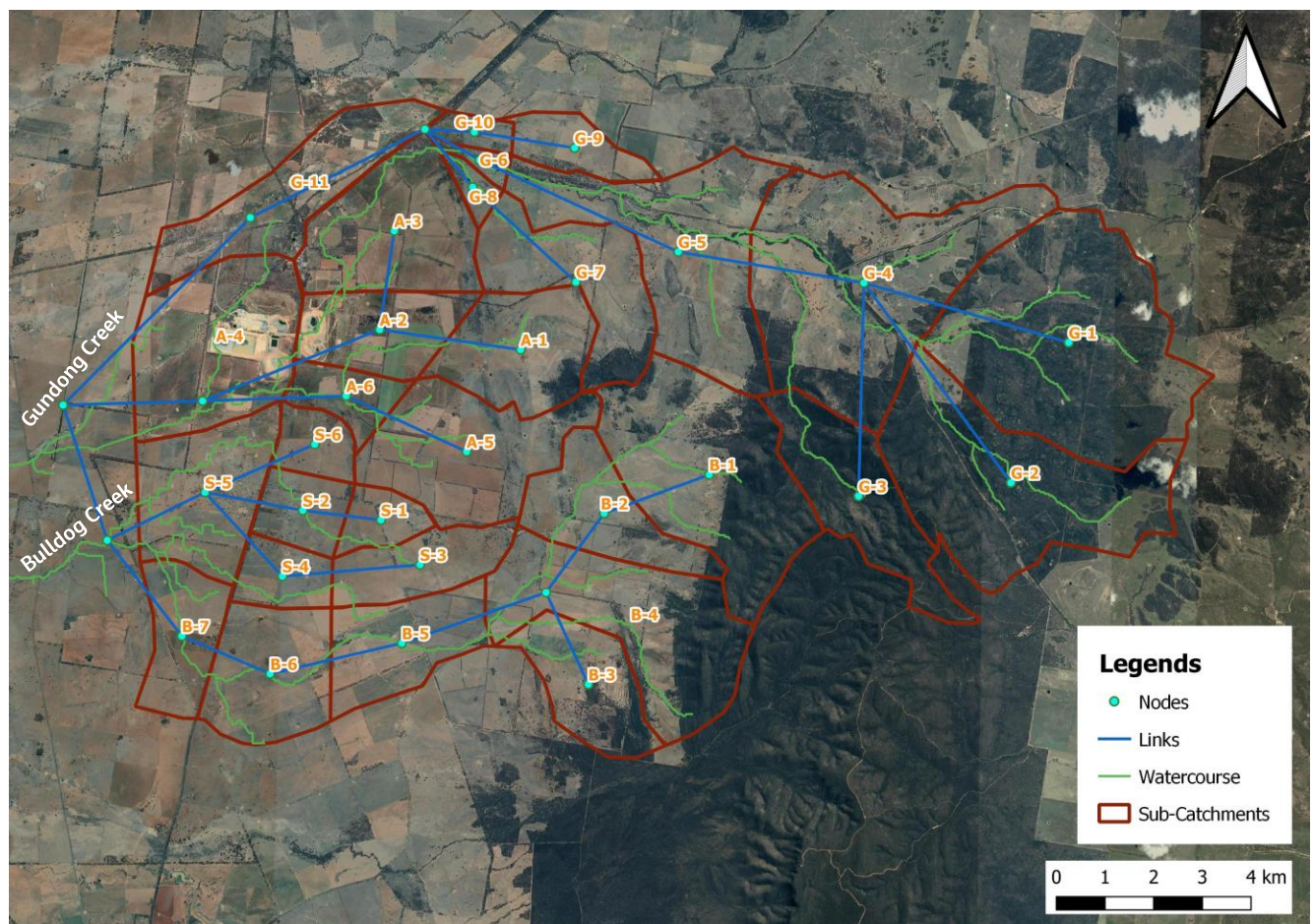


Figure 2-1: Bulldog and Gundong Creek Catchment Layout

2.3 Temporal patterns

An ensemble of 10 temporal patterns using ARR 2019 point temporal patterns were modelled in XP-RAFTS for the 20 to 0.1% AEP flood events.

The ten temporal patterns were simulated in the hydraulic model, rather than the hydrologic model, to identify the critical duration and temporal pattern. This methodology was adopted as the hydraulic model is able to provide a more accurate representation of catchment storage, ponding and routing, compared to the hydrologic model.

2.4 Areal Reduction Factor

The Areal Reduction Factor (ARF) applied to the rainfall was determined based on the size of the catchment to the combined catchment area at the model outlet. This catchment had a total area of 209.6 km² which resulted in ARFs at the SAR Infrastructure Area as shown in **Table 2-2**.

Table 2-2: Adopted Areal Reduction Factors (TGO Expansion Catchment)

Duration	Areal Reduction Factor (ARF)					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.1% AEP
30 min	0.69	0.68	0.67	0.66	0.65	0.62
45 min	0.74	0.73	0.72	0.70	0.69	0.66
1 hour	0.76	0.75	0.74	0.72	0.71	0.67
1.5 hour	0.80	0.78	0.77	0.75	0.74	0.69
2 hour	0.81	0.80	0.78	0.76	0.75	0.69
3 hour	0.84	0.82	0.80	0.78	0.76	0.70
4.5 hour	0.86	0.85	0.83	0.81	0.80	0.75
6 hour	0.88	0.88	0.87	0.85	0.84	0.81
9 hour	0.91	0.90	0.90	0.89	0.88	0.87
12 hour	0.92	0.91	0.91	0.90	0.89	0.88

2.5 Catchment losses

The initial and continuing losses were based on the FFA-Reconciled (Probability Neutral) losses specific to NSW developed by the NSW Office of Environment and Heritage. These losses supersede those recommended by ARR 2019. The adopted initial loss was the Probability Neutral loss and the adopted continuing loss was 1.9 mm.

Table 2-3: Adopted Initial and Continuing Losses

Event AEP	Initial Loss	Continuing Loss
20% AEP	15.1	1.9
10% AEP	12.4	1.9
5% AEP	11	1.9
2% AEP	8.7	1.9
1% AEP	4.7	1.9
0.1% AEP	4.7	1.9

2.6 Flow validation

Due to the absence of flow gauging data in the region, a calibration to historical flood events was not possible.

The flows from the RAFTS model were instead validated to flows from the RFFE (Regional Flood Frequency Estimation) tool. The Bulldog Creek catchment (confluence of Catchment B7 and S5) was selected for the analysis as it was found that this catchment produced the greatest variance in flow between the RAFTS model and the RFFE.

The catchment similarity and consistency with the donor catchments was compared. It was found that the Bulldog Creek catchment was on the smaller end of the catchments used to derive the RFFE flows, but still considered acceptable.

Initial estimates using the recommended ARR 19 and RAFTS parameters produced peak flows that were up to 200% higher than the median flows estimated by the RFFE (in the 20% AEP event). The difference was around 100% for the 1% AEP event.

The Mannings' n value, losses and storage factor were adjusted, within reasonable bounds, until the modelled design flows were within the confidence limits of the RFFE. This process was an iterative one and the parameters presented in the previous sections represent the adopted parameters.

The adopted flows, whilst falling within the 5% and 95% confidence limits, are still significantly higher than the RFFE flows. Any further changes to the parameters would be considered outside of reasonable bounds. At this stage of design, the higher flows would give a more conservative estimate of flood levels and is considered appropriate.

A comparison of the RFFE and adopted flows for the Bulldog Creek catchment is shown in **Figure 2-2** and **Table 2-4**

Table 2-4: Comparison of RFFE and Adopted Flows (Catchment B7/S5)

Event AEP	RFFE Median Flows (m ³ /s)	Adopted Peak Flow (m ³ /s)	Difference (%)
20% AEP	43	83	94%
10% AEP	67	109	62%
5% AEP	98	139	42%
2% AEP	150	169	13%
1% AEP	201	208	4%
0.1% AEP	-	331.5	-

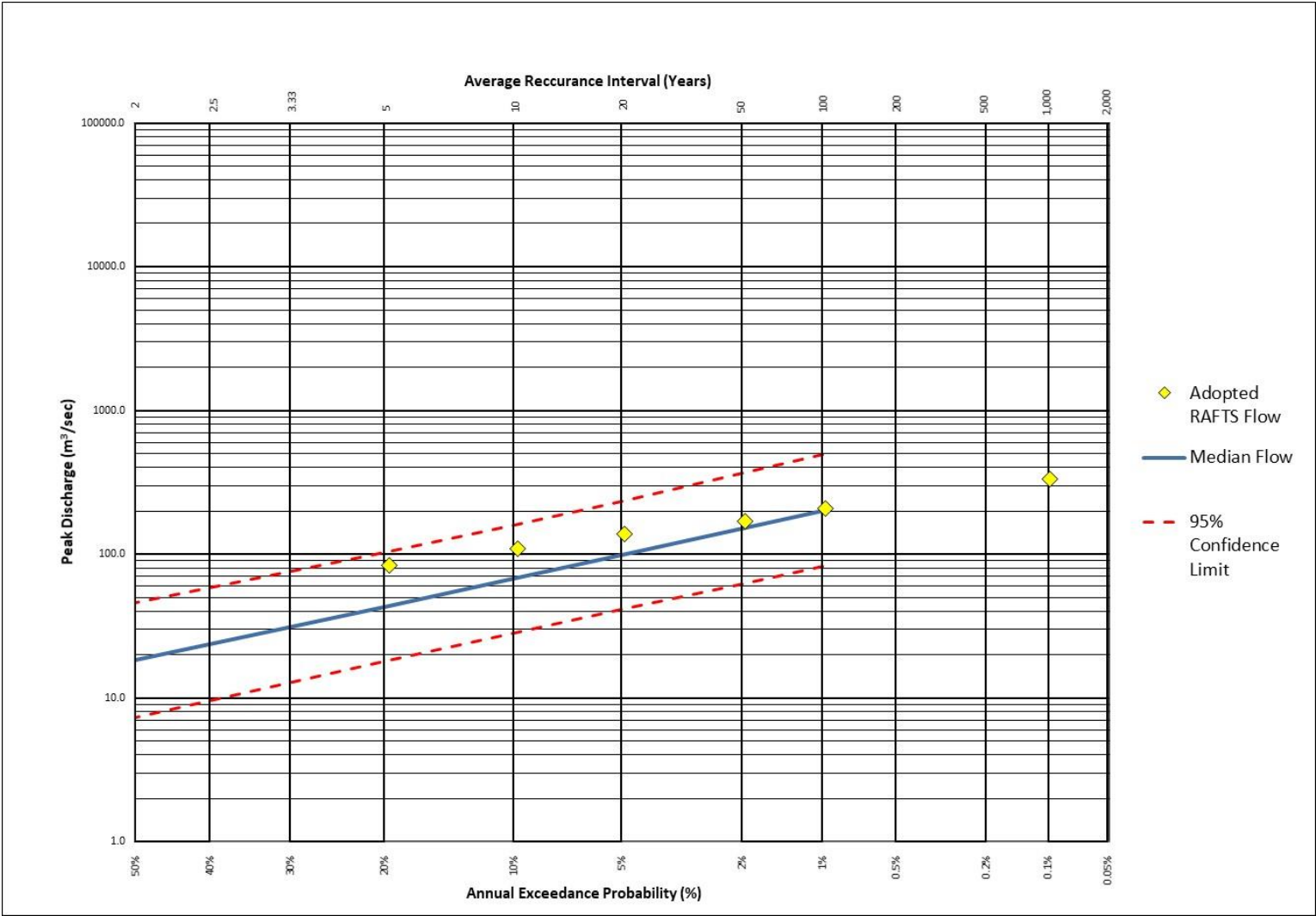


Figure 2-2: Comparison of RFFE Confidence Limits and Adopted Flows (Catchment B7/S5)

2.7 Climate Change

The 5% AEP with climate change has been included as a sensitivity run. The ARR 2019 guidelines for climate change are based on the Representative Concentration Pathways, which predict time-dependent future scenarios of greenhouse gas emissions. The RCPs describe four different 21st century pathways of greenhouse gas emissions and atmospheric concentrations, air pollutant emissions and land use. They include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6) and one scenario with very high greenhouse gas emissions (RCP8.5),

For this project, RCP6 for the year 2090 was selected. This equates to a 13.1% increase in rainfall intensity.

The temperature change and rainfall intensity growth factors for RCP 6 are shown from 2030 to the year 2090 in **Table 2-5**.

Table 2-5: Interim Climate Change Factors – RCP 6

Year	RCP 6
	Temperature Increase (Rainfall Intensity % Increase)
2030	0.847 (4.2%)
2040	1.127 (5.7%)
2050	1.406 (7.1%)
2060	1.685 (8.6%)
2070	1.963 (10.1%)
2080	2.241 (11.6%)
2090	2.518 (13.1%)

3. Hydraulic Modelling

A 1D/2D hydrodynamic TUFLOW model was developed to estimate flood levels and flow velocities at the transverse drainage structures on the Newell Highway and assess the flood immunity and impacts of the proposed design. TUFLOW is a two-dimensional (2D) hydrodynamic modelling software, which is the industry standard for modelling of both urban and rural waterways or rivers. TUFLOW includes the 1D modelling engine 'Estry', which allows for embedded 1D pipes and culverts for representation of storm water networks and transverse drainage structures. For this project the TUFLOW HPC (Heavily Parallelised Compute) has been used.

HPC allows for faster run times than what would be typically expected when running TUFLOW Classic. TUFLOW version 2020-01-AB-iSP-w64 (the most up-to-date version at the time of model development) has been used. The model utilised the flows generated by the XP-RAFTS hydrologic model described in **Section 2**.

3.1 Hydraulic Model Setup – Existing Situation

3.1.1 Model Extent & Terrain

The model consists of one domain with a regular grid cell size of 5 m. This grid size was deemed appropriate as it enabled a good representation of the area while maintaining a practicable simulation time. The sub-grid sampling (SGS) function was applied, with a sample distance of 1m. This was considered a fine enough resolution to adequately represent micro-terrain features such as open drains.

The model extent covers 10.7 km length of the Newell Highway and extends approximately 3.5 km upstream and 3.7 km downstream of the road as shown in **Figure 3-1**. The total area of the 2D domain is 58 km². The 2D model terrain was based on a 1 m resolution LiDAR, which was flown in 2020.

2D Z Shapes were used to enhance the representation of topographical features, such as soil stockpile areas, diversion bunds, and the road median. Z-shapes were used to adjust the terrain level at the inlet of the exiting culverts.

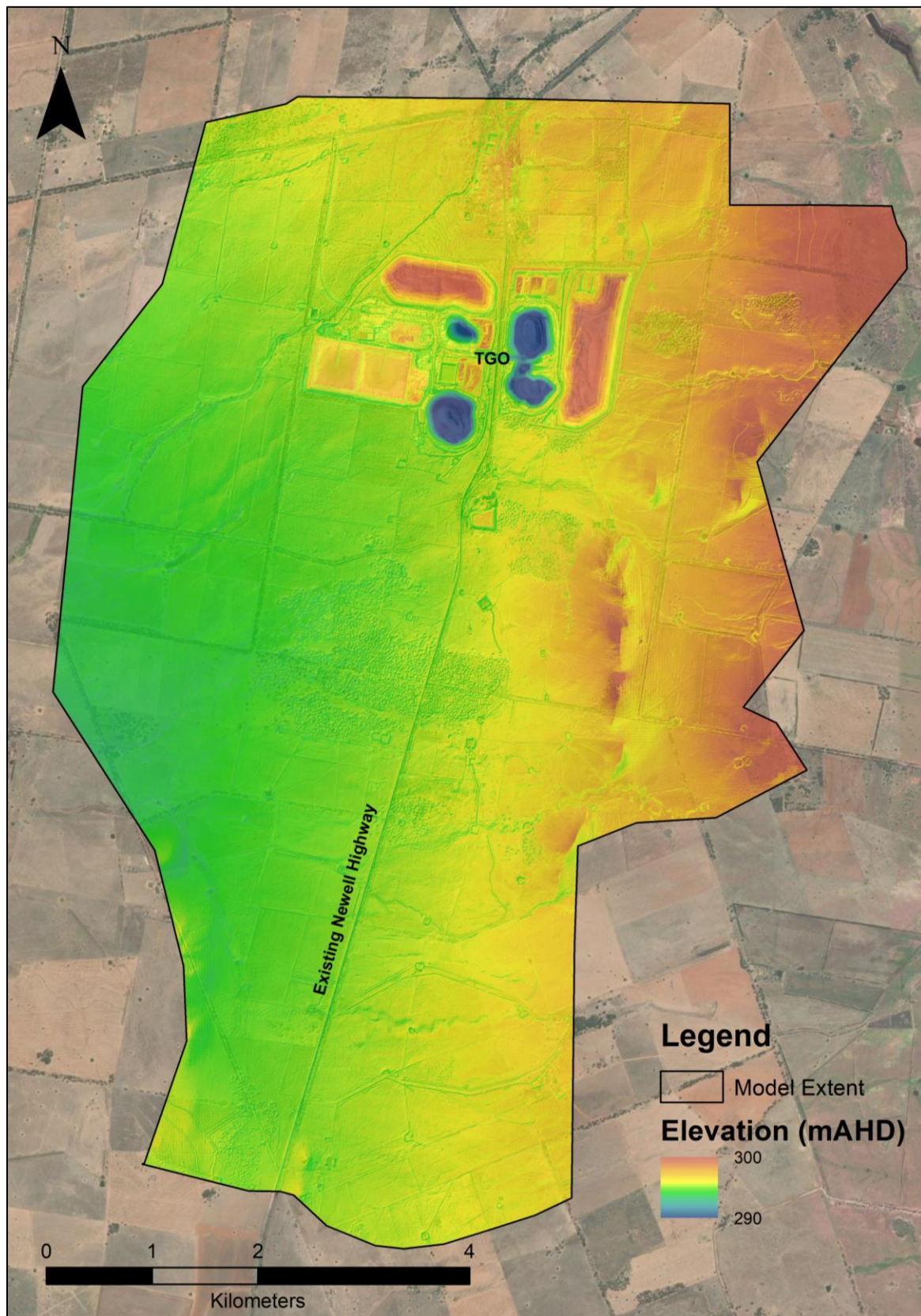


Figure 3-1: Existing Situation - Model extent and terrain

3.1.2 Boundary Conditions

The direct rainfall approach (rain-on-grid) was applied to most of the active 2D domain using a RF rainfall layer. Direct rainfall allows rainfall hyetographs to be applied directly on the active cells. Runoff is routed within the hydraulic model using the underlying DEM. The advantage of using direct rainfall on the SAR Infrastructure Area is that it allows for a high definition of flow behaviour, and more accurate representation of change in flow when comparing the existing and design scenarios.

The rainfall data applied to the hydraulic model was sourced from the ARR data Hub as described in **Section 2.2**. The losses on the direct rainfall area were applied through the materials database and were the same as those adopted in the XP-RAFTS model (refer to **Section 2.5**).

Additional inflows representing the catchments external to the rain-on-grid model area were incorporated based on the flows generated by the XP-RAFTS hydrologic model described in **Section 2**. The external catchment inflow locations can be seen in **Figure 3-2**.

The downstream boundary was modelled as a free flow boundary (HQ) with a slope of 0.004 which is consistent with the hydraulic grade at that location.

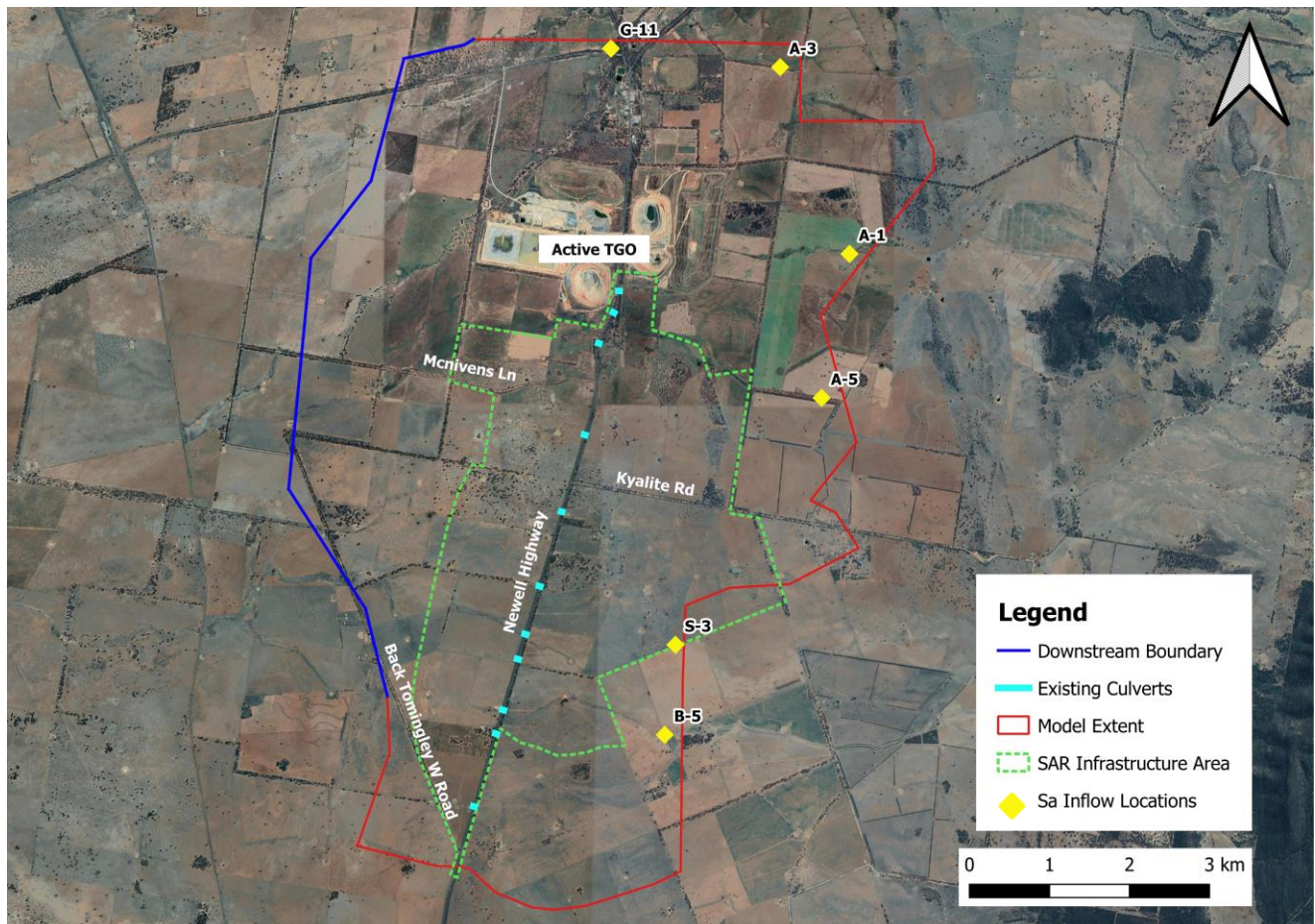


Figure 3-2: Existing case - Hydraulic model schematisation

3.1.3 Manning's n Roughness

Each grid cell is assigned a Manning's 'n' roughness value based upon land use. The GIS layer of existing land use was generated using a combination of aerial imagery, street-view photography, and engineering experience in 2D hydraulic modelling. **Table 3-1** shows the roughness "n" applied to each particular land use. These values are consistent with those recommended by ARR2019. A different material layer was used for the design scenario, which considers the changes in the design road footprint and the extension of the mine.

The manning's n definitions file also defines the rainfall losses for the rain on grid component of the model. These are also shown in **Table 3-1** and have only been applied to permeable land use areas. The losses have been adopted as described in **Section 2.5**.

Table 3-1: Material's layer parameters

Material ID	Land Use	Adopted Manning's n	Initial and Continuing Losses
1	Roads	0.018	IL=0.0, CL=0.0
4	Unmaintained Grass	0.05	As per RAFTS losses
7	Medium to dense vegetation	0.07	As per RAFTS losses
8	Mine/soil stockpile areas	0.04	As per RAFTS losses
9	Low density residential area	0.15	As per RAFTS losses

3.1.4 Hydraulic Structures

Existing transverse culverts along the Newell Highway were modelled as 1D structures within the TUFLOW model. The culvert sizes were defined based on as constructed drawings, site photos and confirmation from site personnel. Engineering judgement was applied at some locations to set the culvert invert levels in the absence of better information. It was assumed that all structures were clear of debris and without blockage. **Table 3-2** presents the transverse culvert information and **Figure 3-3** identifies their location.

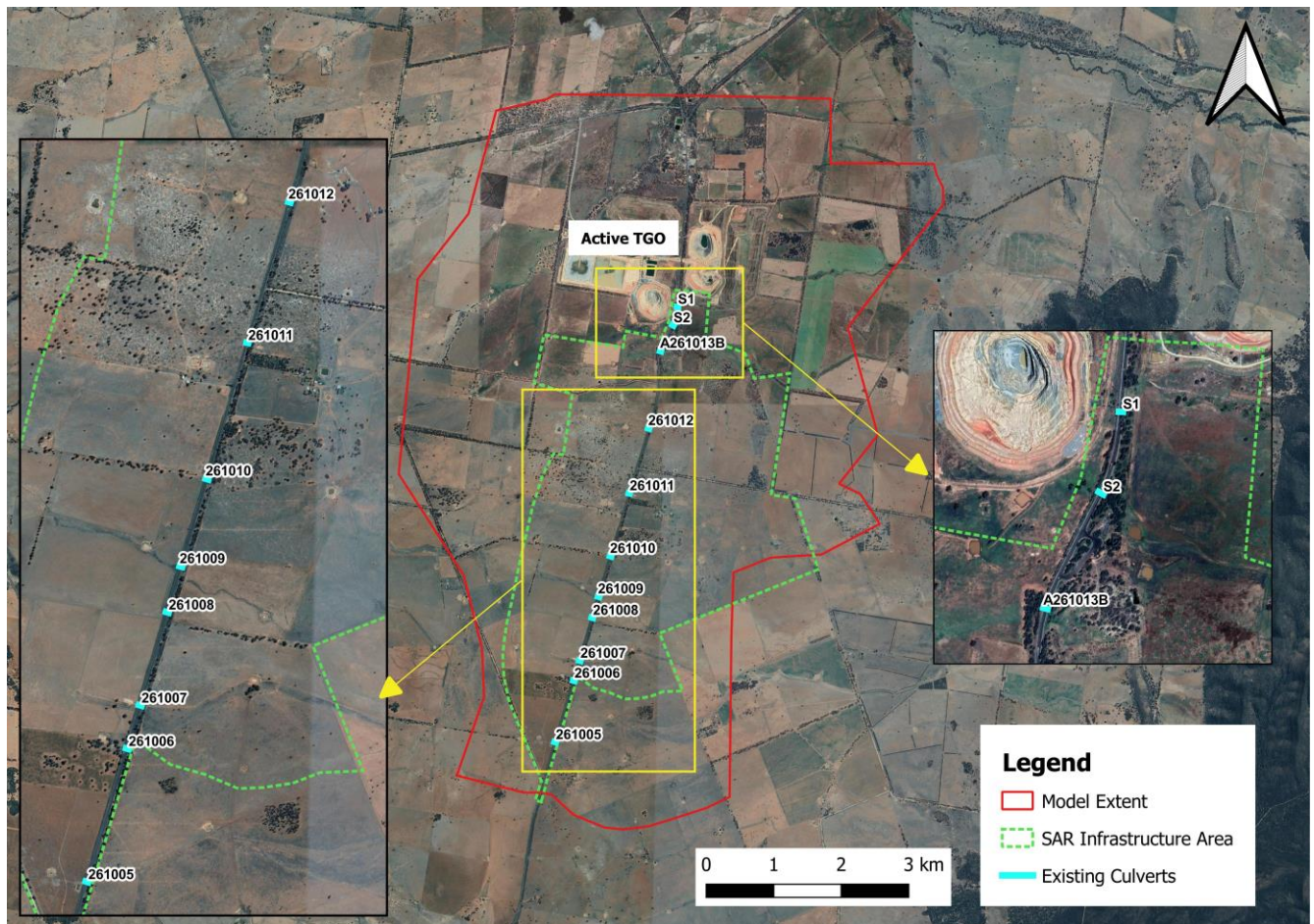


Figure 3-3: Existing Transverse Culverts

Table 3-2: Existing Transverse culverts

Culvert ID	Type	Dimensions (mm)
261005	RCBC	1800 x 600 (x6)
261006	RCBC	1800 x 600 (x3)
261007	RCBC	1800 x 450 (x3)
261008	RCBC	1800 x 450 (x2)
261009	RCBC	1800 x 450 (x5)
261010	RCBC	1800 x 450 (x3)
261011	RCBC	1800 x 600 (x1)
261012	RCBC	1800 x 450 (x2)
A261013B	RCBC	1800 x 450 (x2)
S2	RCBC	1800 x 450 (x2)
S1	RCBC	1800 x 600 (x2)

Note: RCBC = Reinforced Concrete Box Culvert

3.1.5 Critical Durations and Temporal Patterns

A range of durations from 30 minutes to 720 minutes was simulated to establish the critical duration for the seven events assessed (20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.1% AEP, and 5% AEP event with Climate Change). All ten (10) ARR 2019 temporal patterns were simulated and the temporal pattern that generated the storm above the median (Rank 6) flood level was identified as the critical storm.

In some AEP events, multiple durations and/or temporal patterns were critical in different locations of the model and it was difficult to select a single representative temporal pattern. In these cases, the temporal pattern which was critical upstream of the Newell Highway was selected as the highway was a primary location of interest. It was found that the difference in flood level between the different critical durations was less than 50 mm which was not considered significant.

The adopted temporal pattern and storm duration for each event is summarised **Table 3-3**.

Table 3-3: Adopted Durations Temporal Patterns

ARR 2019	Event	Critical Storm Duration	Adopted Temporal Pattern
Temporal Group		(min)	
Frequent	20% AEP	540	TP-03
Intermediate	10% AEP	360	TP-08
	5% AEP	360	TP-08
	5% AEP + CC	360	TP-08
Rare	2% AEP	360	TP-01
	1% AEP	360	TP-01
	0.1% AEP	360	TP-01

3.2 Hydraulic Model Results – Existing Situation

The critical storms identified in **Table 3-3** were used for analysis of the existing situation. **Appendix A** shows the flood levels, flood depths and velocities under the existing situation for the events assessed.

3.2.1 Existing Flood Behaviour

Runoff from the upstream catchments flows generally from east to west through three main flow paths. The northern flow path corresponds to Gundong Creek which flows towards the south-west passing by Tomingley township and the current active mine site. The central flow path (Drainage Line D) crosses the Newell Highway in the vicinity of South Tomingley Rest Area between culverts A261013B and S2, south of the active mine site. The most southern flow path corresponds to minor tributaries that eventually join with Bulldog creek downstream of the Newell Highway as shown in **Figure 3-4**.

The model suggests that a peak flow of 63 m³/s and 120 m³/s would arrive at the Newell Highway through the Drainage Line D and southern flow path (Bulldog Creek) respectively in the 5% AEP event. The 120 m³/s is comparable to the 98 m³/s predicted by the RFFE. It is less than the 139 m³/s predicted by RAFTS model which can be explained by attenuation in the hydraulic model.

Flood depths of up to 1.4 m immediately upstream of Newell Highway (in the vicinity of South Tomingley Rest Area) and up to 1.2 m upstream of culvert 261005 at the Bulldog Creek crossing can be observed. Flow

downstream of the highway is conveyed via the existing culverts under the Newell Highway, as well as via overtopping of the highway in the larger events (see Section 3.2.3).

In the 5% AEP event, modelled peak flood levels in the study area range from approximately 269 m AHD at the northern section of Newell Highway to approximately 265 m AHD at the southern section, near the intersection with Back Tomingley West Road.

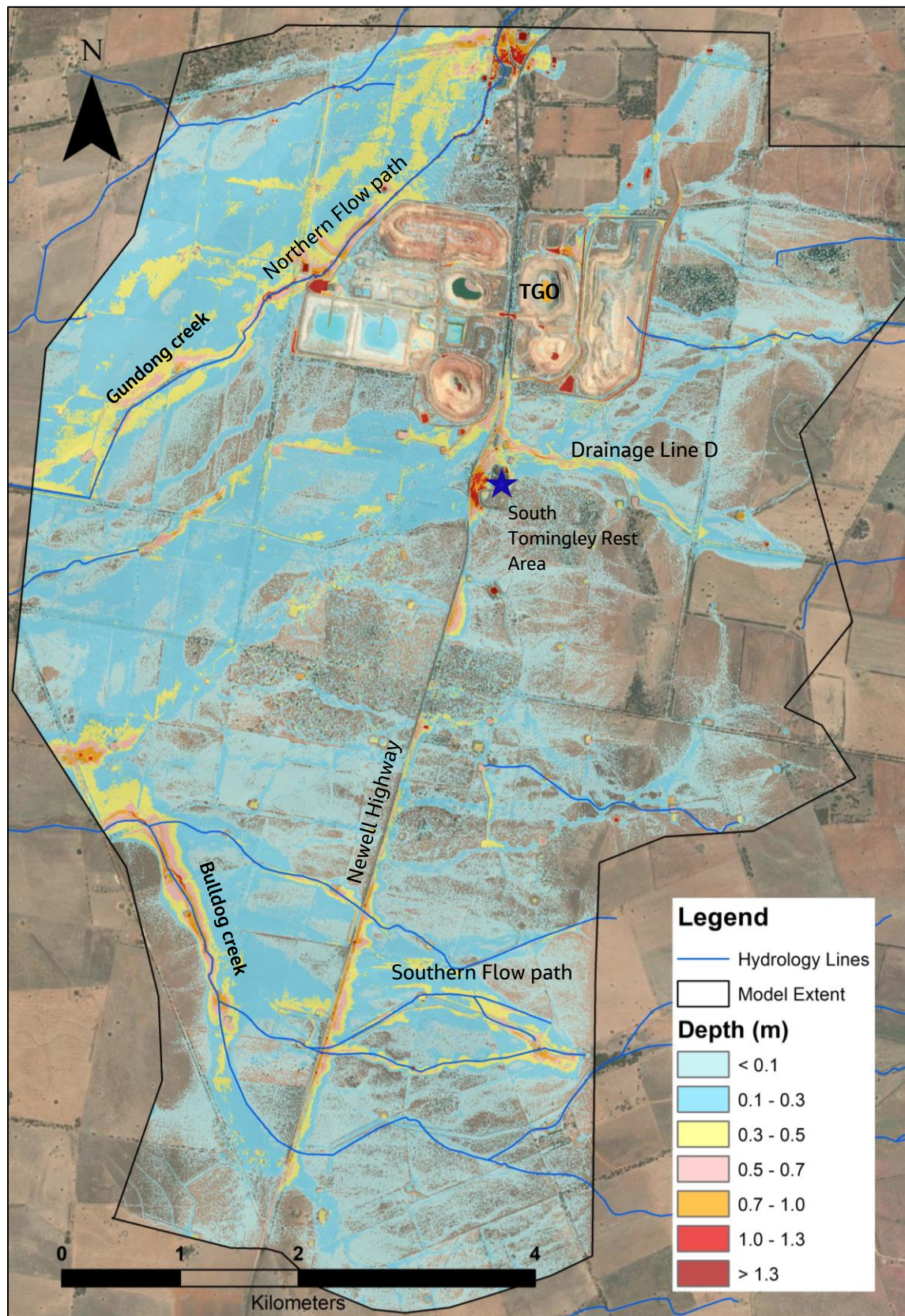


Figure 3-4: Indicative existing flow paths

3.2.2 Existing Transverse Culvert Crossings

Table 3-4 presents peak flows, peak velocities and peak flood levels upstream of the existing transverse culverts for the 5% AEP event.

Table 3-4: Existing Case transverse culverts - 5% AEP event

Culvert ID	Peak Flow	Peak Velocity	Peak Upstream Flood level	Remarks
	(m ³ /s)	(m/s)	(mAHD)	
261005	11.48	1.8	264.69	Overtopping
261006	9.10	4.7	265.28	Overtopping
261007	5.46	3.7	265.26	Overtopping
261008	3.39	2.1	265.43	Overtopping
261009	9.81	4.0	265.31	Overtopping
261010	3.92	1.6	265.58	No overtopping
261011	1.76	1.9	266.72	No overtopping
261012	2.94	3.0	267.03	Overtopping
A261013B	3.74	3.9	268.53	Overtopping
S2	3.68	3.9	268.71	Overtopping
S1	4.29	2.0	268.64	Overtopping

3.2.3 Newell Highway Immunity

The existing Newell Highway flood immunity varies across the study area. Overall, most sections of the existing highway have a flood immunity below the 20% AEP event (i.e. overtopped in the 20% AEP). Events smaller than the 20% AEP have not been modelled. The section of the road in the vicinity of culvert 261007 has the lowest flood immunity since it represents a road sag on the highway. **Table 3-5** presents the minimum road immunity at each existing culvert crossing, the respective freeboard in the identified immunity event, the overtopping event, and the respective overtopping depth. shows the locations of the existing culverts.

Table 3-5: Newell Highway immunity and overtopping event at the existing culvert locations

Culvert ID	Minimum Immunity	Freeboard (mm)	Overtopping Event	Overtopping Depth (mm)
261005	10% AEP	100	5% AEP	35
261006	< 20% AEP	-	20% AEP	95
261007	< 20% AEP	-	20% AEP	295
261008	20% AEP	10	10% AEP	100
261009	< 20% AEP	-	20% AEP	80
261010	1% AEP	150	0.1% AEP	10
261011	0.1% AEP	90	> 0.1% AEP	-
261012	20% AEP	10	10% AEP	100
A261013B	< 20% AEP	-	20% AEP	200
S2	< 20% AEP	-	20% AEP	200
S1	< 20% AEP	-	20% AEP	140

3.3 Hydraulic Model Setup - Design Case

This section of the report outlines the changes made to the existing case model to represent the design scenario with the proposed TGO expansion. The TGO expansion design has aimed to meet the following design criteria in relation to flooding:

- Achieve 5% AEP flood immunity for the realigned Newell Highway;
- Keep outlet velocities at the new Newell Highway culverts below 3 m/s;
- Minimise the loss of overland flow volume to properties downstream of the new Newell Highway.

An iterative design approach in collaboration with the road design team has been undertaken to achieve the design criteria set out above.

The following design elements were considered relevant to the flood assessment and were represented in the hydraulic model:

- Realigned Newell Highway and Kyalite Road and associated intersections with Back Tomingley West Road and McNivens Lane and Kyalite Road overpass
- The SAR Open Cut
- The Soil Stockpiles and the SAR waste rock emplacement
- Haul Road and Services Road between the SAR Open Cut and the Caloma 2 Open Cut
- Flood diversion bund (Inundation Bund)
- The Administration Area

Unless otherwise stated, no other changes have been made to the existing case model.

3.3.1 Terrain Modifications

The terrain was modified to represent the proposed development. The Newell Highway and Kyalite Road were represented using the Digital Elevation Model (DEM) provided by the road design team from Constructive Solutions on the 3rd September 2021.

The SAR Open Cut, soil stockpiles, flood diversion bunds, administration area and haul road were represented by raising or lowering the terrain following the outline of the 'Limit of Disturbance' provided by R W Corkery.

The Haul Road has been assumed to have the same height above ground as the proposed Newell Highway.

Sections of the existing Newell Highway were removed where it was considered that removal is necessary. Where possible, the existing Newell Highway and transverse culverts were retained.

Figure 3-5 shows the modified terrain adopted for the Design case and **Figure 3-6** shows the model schematisation.

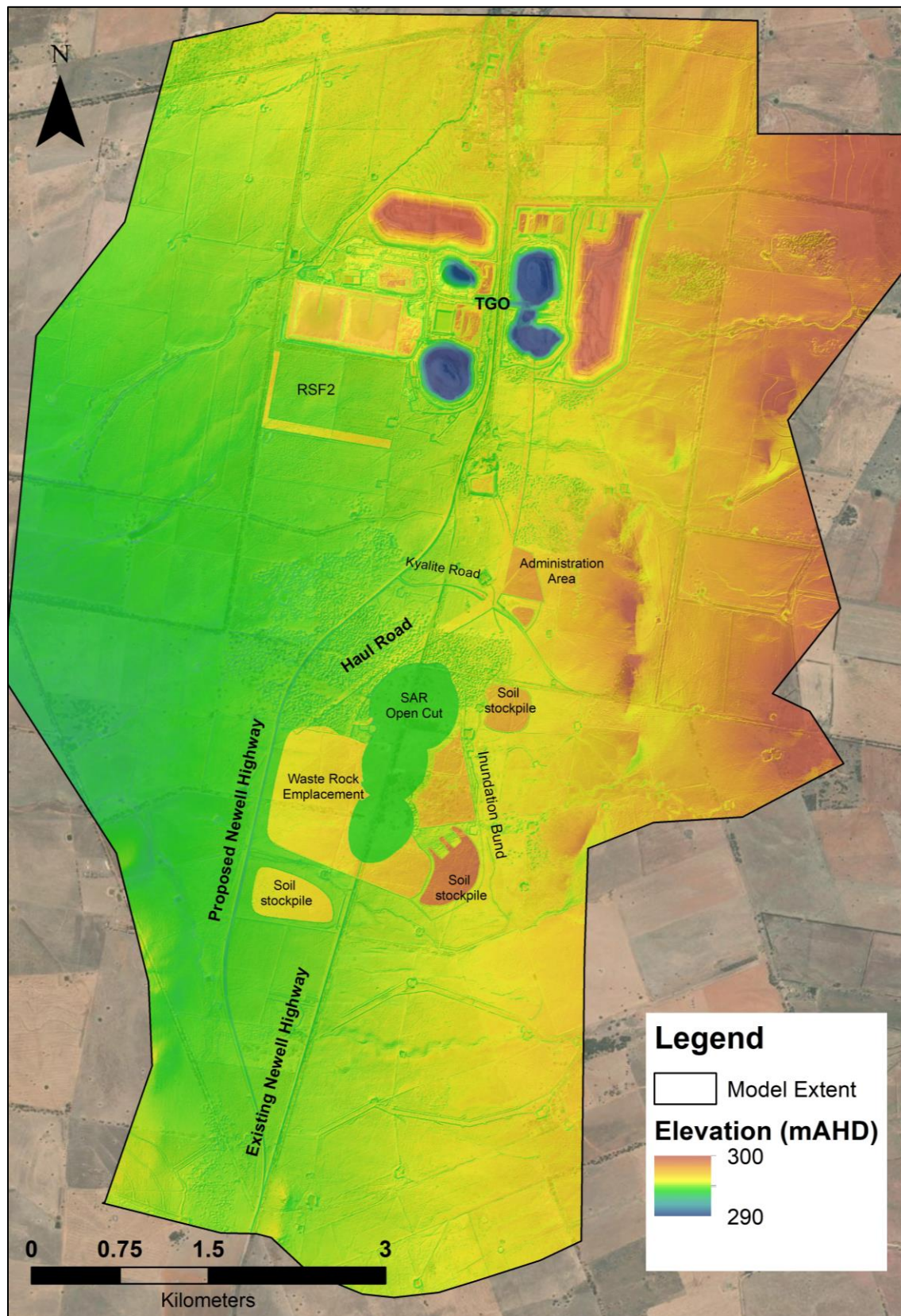


Figure 3-5: Design Case - Model extent and terrain

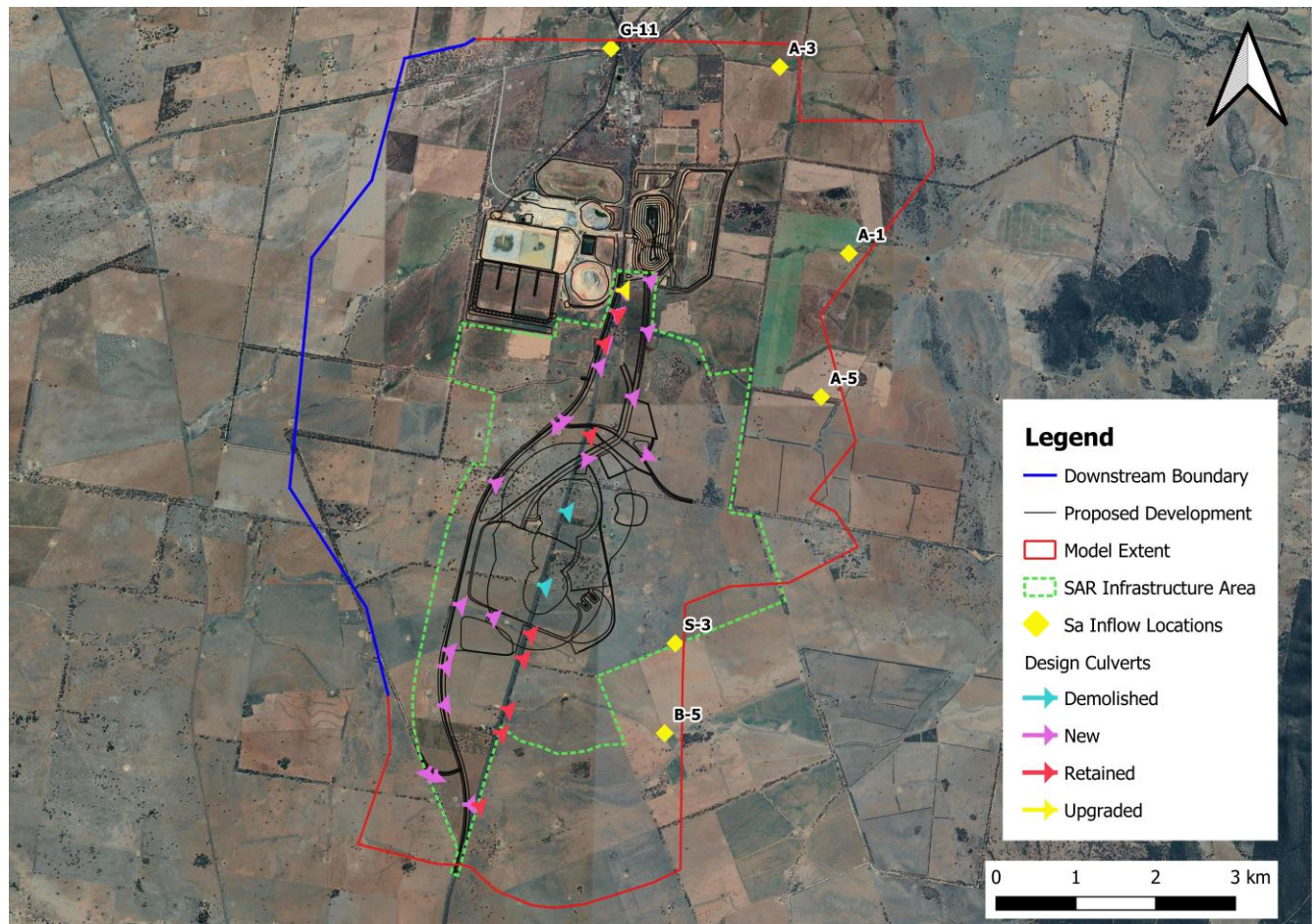


Figure 3-6: Design Case - Hydraulic model schematisation

3.3.2 Manning's n Roughness

The materials layer was adjusted to represent the new mine area, as well as the re-alignment of the Newell Highway, Kyalite road and the incorporation of the Haul Road. The Administration Area was represented with the same Manning's n values as roads to account for a hard and impermeable surface. The SAR Open Cut, soil stockpiles and SAR Waste Rock Emplacement were represented as Mine/soil stockpile areas. No further changes to the materials layer were made compared to the existing case model. The adopted Mannings' n values can be seen in **Table 3-6**.

Table 3-6: Material's layer parameters

Material ID	Land Use	Adopted Manning's n	Initial and Continuing Losses
1	Roads/ Administrative area	0.018	IL=0.0, CL=0.0
4	Unmaintained grass	0.05	As per RAFTS losses
7	Medium to dense vegetation	0.07	As per RAFTS losses
8	Mine/soil stockpile areas	0.04	As per RAFTS losses
9	Low density residential area	0.15	As per RAFTS losses

3.3.3 Hydraulic Structures

A series of modifications to the transverse drainage is required to facilitate the mine expansion. These have been simulated in the model as:

- 12 culverts to be constructed under the proposed alignment of Newell Highway;
- Four (4) culverts to be constructed under the Haul Road;
- One (1) culvert to be constructed under Kyalite Road;
- One (1) existing culvert under the existing Newell Highway to be upgraded; and,
- Two (2) existing culverts under the existing Newell Highway to be removed.

New culverts were designed to be aligned with existing flow paths or at low points in the terrain. Culverts have been sized to achieve a 5% AEP event flood immunity and less than 3 m/s in outlet velocity.

Table 3-7 presents the proposed dimensions of the design culverts. shows the design culvert locations. Blockage assessment has been performed in accordance with ARR 2019 requirements for the culverts along the proposed corridor of the realigned Newell Highway (refer to **Section 3.4.6**).

Table 3-7: Design Transverse Culverts

Road	Culvert ID	Type	Dimension (mm)	Note
Proposed Newell Highway	20	RCBC	1200 x 450	New
Proposed Newell Highway	1	RCBC	1800 x 900 (10)	New
Proposed Newell Highway	2	RCBC	1800 x 900 (3)	New
Proposed Newell Highway	3	RCBC	1800 x 1200 (10)	New
Proposed Newell Highway	4	RCBC	1800 x 900 (14)	New
Proposed Newell Highway	5	RCP	750	New
Proposed Newell Highway	16	RCBC	1800 x 900 (4)	New
Proposed Newell Highway	7	RCBC	1800 x 1200 (5)	New
Proposed Newell Highway	8	RCBC	1800 x 900 (4)	New
Proposed Newell Highway	18	RCBC	1800 x 450 (2)	New
Proposed Newell Highway	9	RCBC	1800 x 1200 (4)	New
Proposed Newell Highway	19	RCBC	1800 x 600 (5)	New
Existing Newell Highway	S1	RCBC	1800 x 600 (5)	Upgraded
Existing Newell Highway	261010	RCBC	1800 x 450 (x3)	Demolished
Existing Newell Highway	261011	RCBC	1800 x 600 (x1)	Demolished
Haul Road	14	RCBC	1800 x 900 (4)	New
Haul Road	13	RCP	375	New
Haul Road	12	RCBC	1800 x 1200 (8)	New
Haul Road	11	RCBC	1800 x 900 (3)	New
Kyalite Road	15	RCBC	1800 x 900 (2)	New
Back Tomingley West Road	6	RCP	450 (2)	New
Back Tomingley West Road	6B	RCP	450 (3)	New

Note: RCBC = Reinforced Concrete Box Culvert; RCP = Reinforced Concrete Pipe

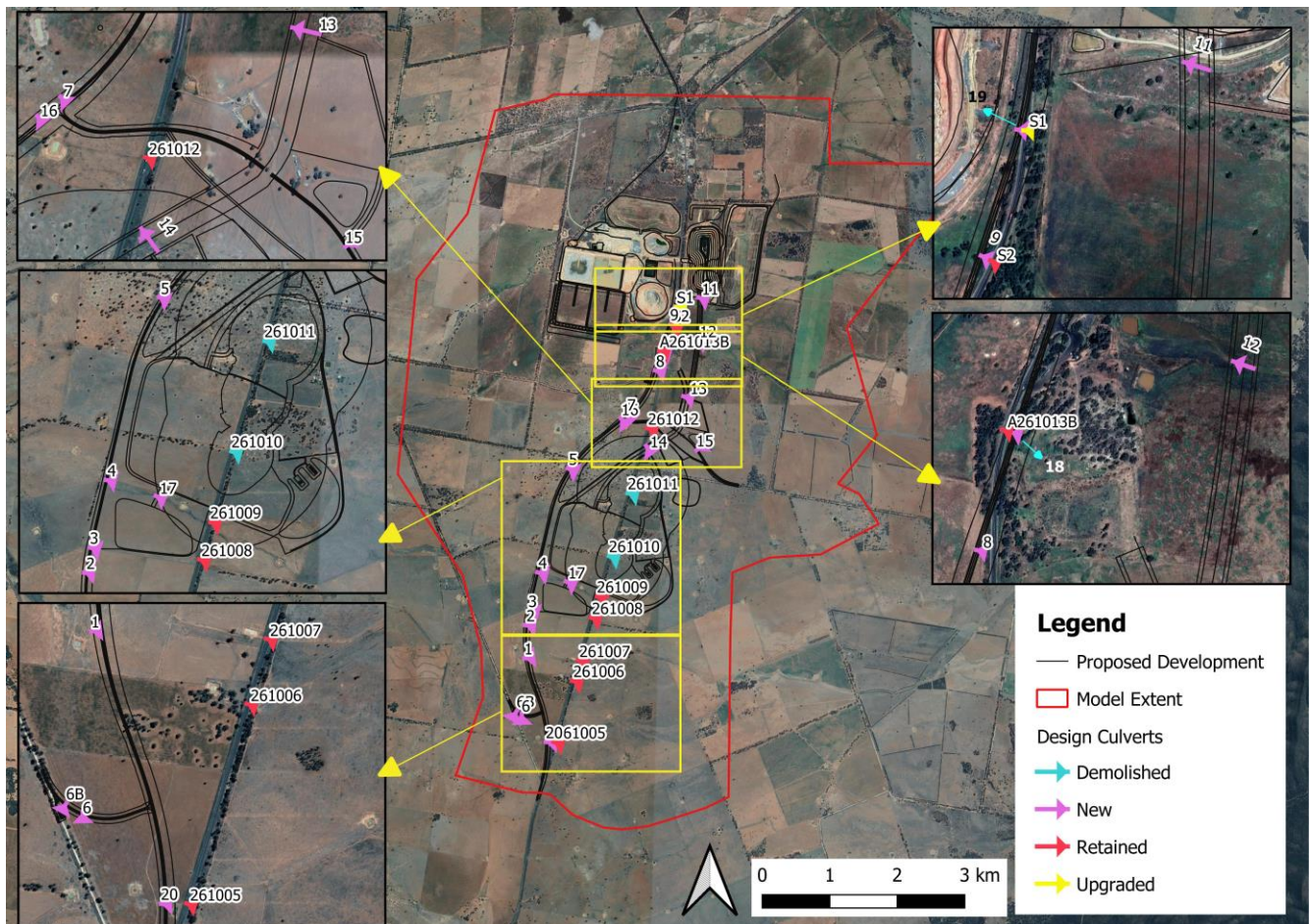


Figure 3-7: Design Transverse Culverts

3.4 Hydraulic Model Results – Design Case

The critical storms identified for the existing situation (refer to **Table 3-3**), have been adopted to produce the final results of the design case. Due to attenuation of flow upstream of the proposed new Newell Highway, these critical storms may have changed in the design case. This risk is considered low as there were minor flood level differences observed amongst the different storms. Nonetheless, the critical storms for the design case should be confirmed during detailed design. **Appendix B** shows the flood levels, flood depths and velocities under the Design Situation for the events assessed.

3.4.1 Flood Behaviour – Design Case

Modelling results suggest that the same three main flow paths discussed in **Section 3.2.1** are maintained in the design case. The northern flow path remains unchanged as the proposed TGO expansion proposes no further disturbances at this location.

The Haul Road acts as an obstruction to flow and ponding of up to 2 m is observed upstream of culvert 12 in the 5% AEP event, at the peak of the flood. The Haul Road is acting as a control structure for flow arriving at the Newell Highway.

Ponding at the peak of the flood was observed to occur at the Newell Highway between culverts 8 and 19. A maximum depth of 1.5 m was identified in this section in the 5% AEP event.

At Bulldog Creek, the existing Newell Highway has been retained and acts as the first obstruction to flow with ponding of up to 1 m at the peak of the flood identified in the 5% AEP event. As flow progresses to the west through the existing culverts and by overtopping the existing road, flow is obstructed by the realigned and lifted Newell Highway. Ponding of up to 1.5 m at the peak of the event was identified in the 5% AEP event at the new Newell Highway. **Figure 3-8** shows the identified flow paths and the main ponding areas in the 5% AEP event.

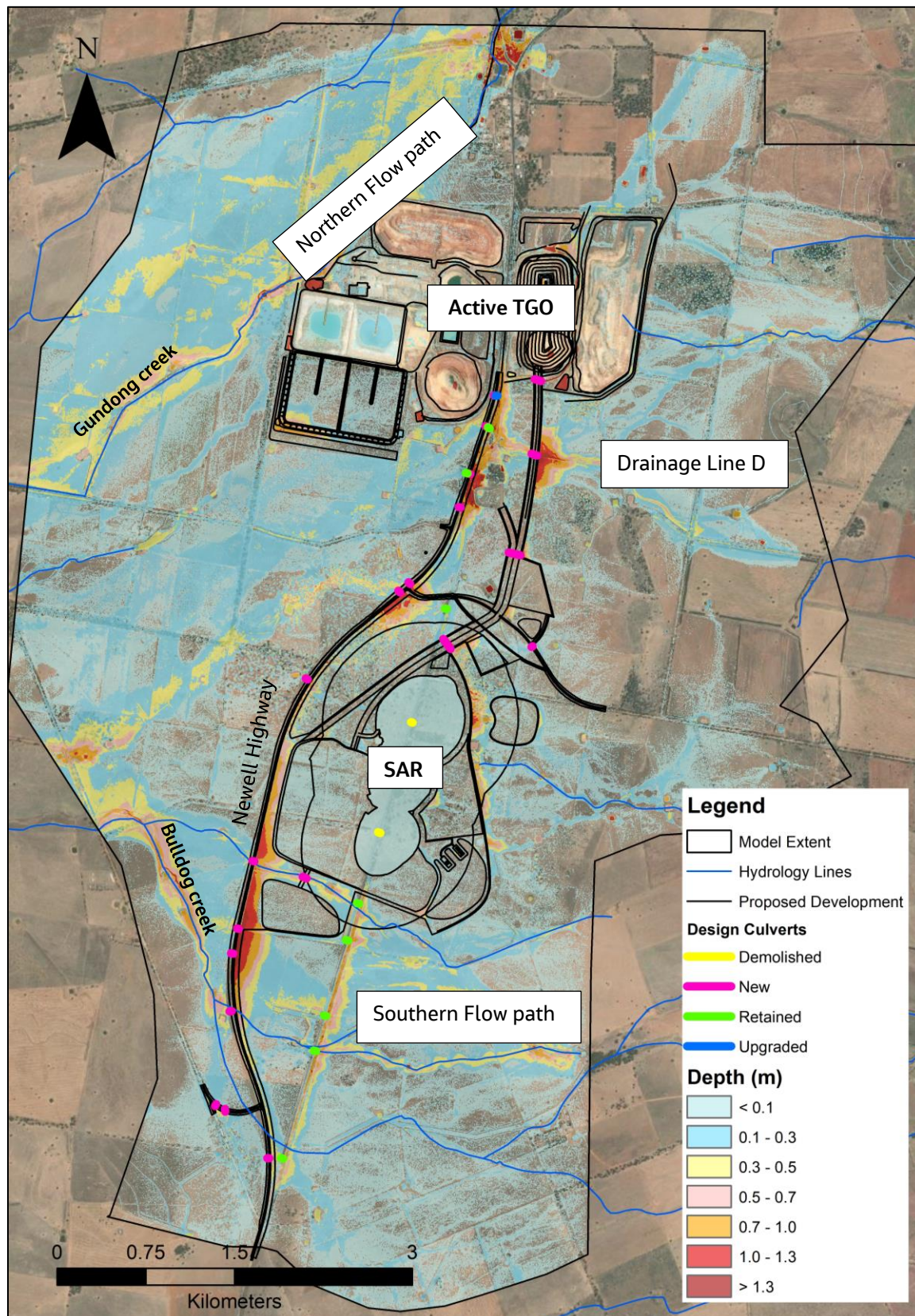


Figure 3-8: Indicative Design flow paths and main ponding areas in the 5% AEP event

3.4.2 Design Transverse Culvert Crossings

Table 3-8 presents peak flows, peak velocities and peak flood levels upstream of the design (new and upgraded) transverse culverts for the 5% AEP event.

Table 3-8: Design Case transverse culverts - 5% AEP event

Road	Culvert ID	Peak Flow	Peak Velocity	Peak Upstream Flood level	Remarks
		(m ³ /s)	(m/s)	(mAHD)	
Proposed Newell Highway	20	0.67	1.6	264.35	No overtopping
Proposed Newell Highway	1	23.47	2.4	261.56	No overtopping
Proposed Newell Highway	2	11.92	2.4	261.56	No overtopping
Proposed Newell Highway	3	42.20	2.8	261.51	No overtopping
Proposed Newell Highway	4	36.98	2.2	261.48	No overtopping
Proposed Newell Highway	5	0.72	2.0	262.57	No overtopping
Proposed Newell Highway	16	13.28	2.1	265.47	No overtopping
Proposed Newell Highway	7	8.46	1.0	265.40	No overtopping
Proposed Newell Highway	8	11.77	2.6	268.65	No overtopping
Proposed Newell Highway	18	2.47	1.5	268.77	No overtopping
Proposed Newell Highway	9	4.34	1.9	268.17	No overtopping
Proposed Newell Highway	19	11.58	2.2	268.72	No overtopping
Existing Newell Highway	S1	11.59	2.2	269.00	No overtopping
Haul Road	14	11.32	2.6	268.40	No overtopping
Haul Road	13	0.18	1.7	271.82	No overtopping
Haul Road	12	47.88	2.8	271.09	No overtopping
Haul Road	11	12.03	2.5	271.54	No overtopping
Kyalite Road	15	3.25	2.1	272.59	No overtopping
Back Tomingley West Road	6	0.47	1.5	262.64	No overtopping
Back Tomingley West Road	6B	0.78	1.6	262.62	Overtopped by 100 mm

As shown in **Table 3-8**, velocities for all of the culverts have been kept below 3 m/s to minimise scour protection requirements. The model results indicate that velocities would be below 3 m/s in all the events assessed up to the 5% AEP event.

3.4.3 Culvert Outlet Design

Outlet protection at the transverse culverts under the new Newell Highway has been considered using the Austroads (2013) guidance. The average rock size (d₅₀) and length (L) of the downstream protection has been sized based on Section 3.13 (Guide to Road Design Part 5B - AustRoads, 2013).

The guideline for the recommended minimum average rock size (d₅₀) for a 'multiple' pipe outlet is presented in **Figure 3-9**. A 36% increase in rock size is recommended if rounded rocks are used instead of angular rock.

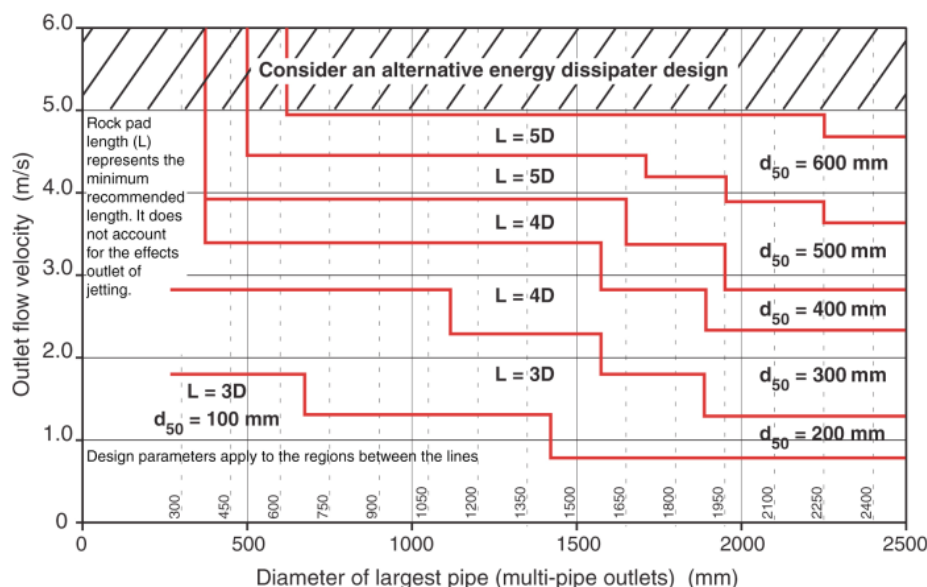


Figure 3-9: Sizing of rock pads for 'multiple' pipe outlets

A minimum thickness of $2 \times d_{50}$ has been adopted. The recommended minimum width of the rock pad at the outlet (W_1) is the greater of the width of the outlet apron or the pipe diameter plus 0.6 m. The minimum width of the rock pad at the downstream end of the rock pad (W_2) is the greater of W_1 or $(D + 0.4L)$.

A typical layout for the protection is shown in **Figure 3-10**. The recommended scour protection details are shown in **Table 3-9**.

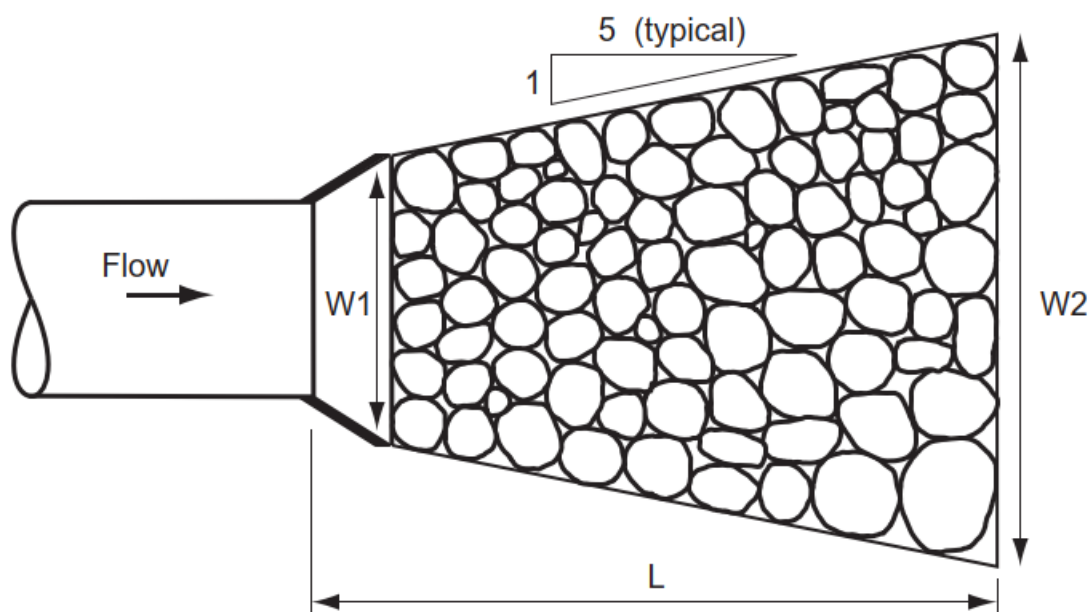


Figure 3-10: Typical layout of a rock pad outlet structure

Table 3-9: Scour Protection of Transverse Culverts at Newell Highway, Haul Road, Kyalite Road and BTW Road

Culvert ID	Culvert Diameter (D)	Peak Velocity	Length (L)	d50	Thickness
	m	(m/s)	(m)	mm	mm
20	1.2	1.6	3.6	200	400
1	1.8	2.4	7.2	300	600
2	1.8	2.4	7.2	300	600
3	1.8	2.8	7.2	300	600
4	1.8	2.2	5.4	300	600
5	0.75	2.0	2.25	200	400
16	1.8	2.1	7.2	300	600
7	1.8	1.0	5.4	200	400
8	1.8	2.6	7.2	300	600
18	1.8	1.5	5.4	200	400
9	1.8	1.9	5.4	200	400
19	1.8	2.2	7.2	300	600
14	1.8	2.6	7.2	400	800
13	0.375	1.7	1.125	100	200
12	1.8	2.8	7.2	400	800
11	1.8	2.5	7.2	400	800
15	1.8	2.1	7.2	300	600
6	0.45	1.5	1.35	100	200
6B	0.45	1.6	1.35	100	200

The rock pad should be aligned with the direction of flow. The surface elevation of the downstream end of the rock pad should be level with the invert of the receiving channel. The placement of a filter cloth under the rock pad is recommended. If larger rocks become difficult to source, reno mattresses can be used instead. Reno mattresses can either be filled with smaller sized rock which would work with improved restraint from the mattress, or be filled with more readily available fill material such as concrete demolition rubble to act in the prevention of scour from the outlet velocities.

3.4.4 Newell Highway Immunity

The proposed Newell Highway achieves a 1% AEP flood immunity across the entire stretch assessed and fully meets the 5% AEP design criteria. Most sections of the road achieve immunity up to the 0.1% AEP event. The section near culvert five (5), is the lowest point and would be overtopped by 40 mm in the 0.1% AEP event. **Table 3-10** presents the road immunity at each existing culvert crossing, the freeboard in the identified immunity event, the overtopping event, and the overtopping depth.

Table 3-10: Newell Highway immunity and overtopping event at the design culvert locations

Culvert ID	Minimum Immunity	Freeboard (mm)	Overtopping Event	Overtopping Depth (mm)
20	0.1% AEP	790	> 0.1% AEP	-
1	0.1% AEP	420	> 0.1% AEP	-
2	0.1% AEP	380	> 0.1% AEP	-
3	0.1% AEP	280	> 0.1% AEP	-

Culvert ID	Minimum Immunity	Freeboard (mm)	Overtopping Event	Overtopping Depth (mm)
4	0.1% AEP	60	> 0.1% AEP	-
5	1% AEP	200	0.1% AEP	40
16	0.1% AEP	640	> 0.1% AEP	-
7	0.1% AEP	60	> 0.1% AEP	-
8	0.1% AEP	60	> 0.1% AEP	-
18	0.1% AEP	240	> 0.1% AEP	-
9	1% AEP	210	0.1% AEP	10
19	0.1% AEP	200	> 0.1% AEP	-

3.4.5 Flood Impacts

Figures showing the change in flood level relative to existing conditions are shown in **Appendix C**. Overall, flood levels have increased upstream of Haul Road and upstream of the proposed Newell Highway. Downstream of the Newell Highway, flow paths have changed due to the location of the new culverts. Where there are new flow paths (downstream of culverts 3, 4 and 16), flood levels have increased whilst at other locations, flood levels have reduced.

3.4.5.1 Afflux in the 1% AEP Event

Modelling results show that, at the peak of the flood, there would be an increase of flood levels up to 115 mm and 65 mm at two private properties outside of Alkane Controlled land as shown in **Figure 3-11**. These properties do not contain habitable structures and the impacts are limited to the agricultural land. The afflux is caused by the concentration of flow being conveyed through culverts 16 and 7.

Two properties outside of Alkane Controlled land would have a reduction in flood levels up to 390 mm at the peak of the flood in the 1% AEP event. On Lot 165 Plan DP755093, four sheds and one house were identified to be in the zone of reduced flood depths. The floor level of the house has not been surveyed and the model currently assumes ground level to be the floor level. The depth of flooding based on the ground level was predicted to be 126 mm in the 1% AEP in the existing case, and 32 mm in the design case. There would a reduction of 94 mm as a result of the changed flow paths, i.e. a net flood benefit. As the house is lifted above ground, the flood depths indicate that the floor level would not be inundated in either the existing or design cases. Similar to the house, the depth of flooding would be reduced at the shed locations.

The properties affected in the 1% AEP event are summarised in **Table 3-11**.

The difference in flood level at the model boundary would be, on average, less than -100 mm. The model was not extended due to the combination of a lack of LiDAR, the fact that there are no more increases in flood level, only decreases, and the expectation that this impact would dissipate to be negligible at the confluence of Bulldog Creek and Gundong Creek.

Table 3-11: Impacted properties in the 1% AEP event

Lot/Plan	Tenure	Afflux (mm)	Depth of Flooding Existing (mm)	Depth of Flooding Design (mm)	Land Use
163/DP755093	Freehold	-390		-	Agricultural
165/DP755093	Freehold	-306		-	Agricultural
165/DP755093	Freehold	-133	160	27	Shed 1
165/DP755093	Freehold	-128	147	19	Shed 2

Lot/Plan	Tenure	Afflux (mm)	Depth of Flooding Existing (mm)	Depth of Flooding Design (mm)	Land Use
165/DP755093	Freehold	-165	237	72	Shed 3
165/DP755093	Freehold	-114	180	66	Shed 4
165/DP755093	Freehold	-94	126	32	House (not flooded above habitable floor level)
100A/DP1271511	Freehold	115		-	Agricultural
100B/DP1271511	Freehold	65		-	Agricultural

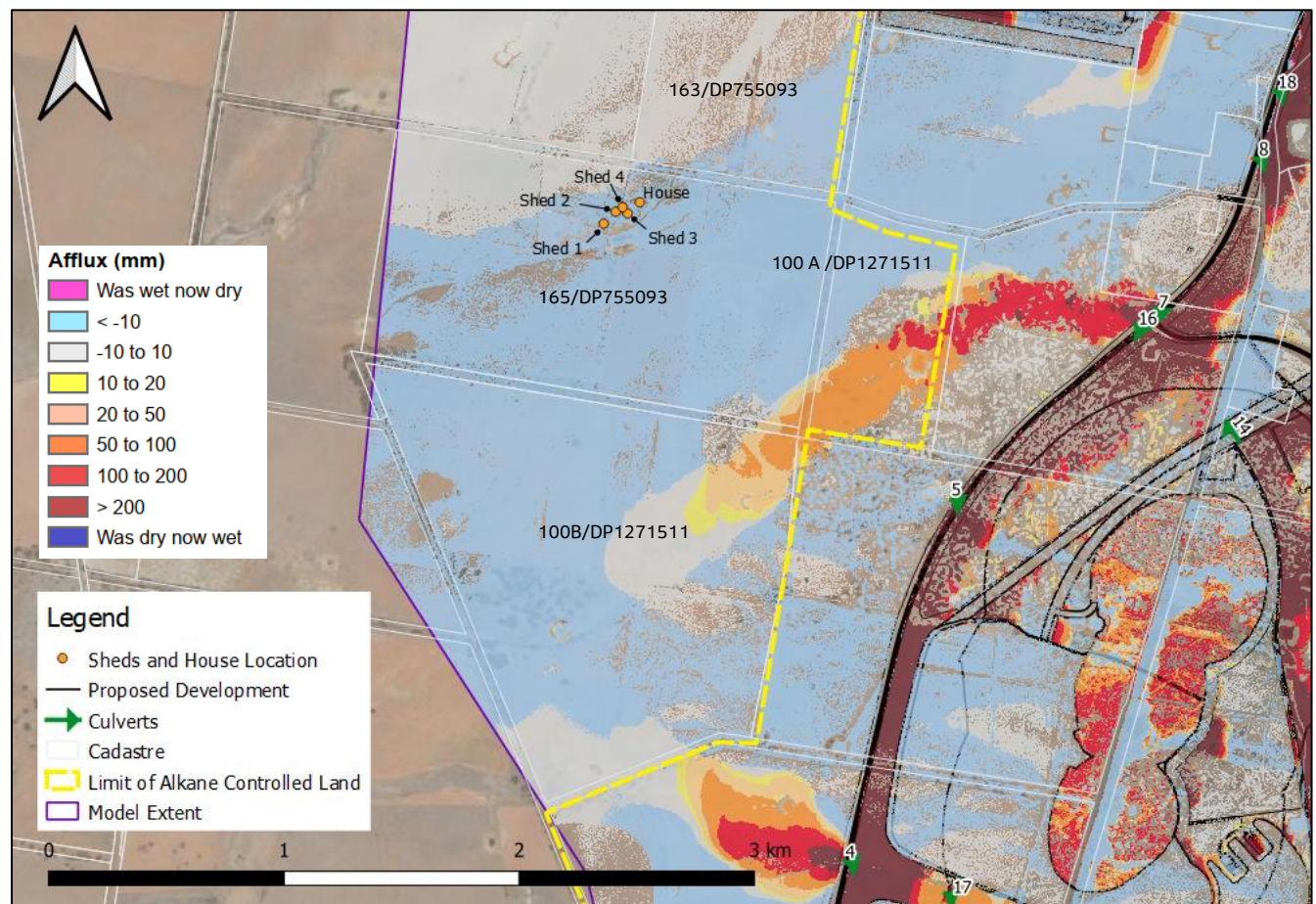


Figure 3-11: Impacted properties in the 1% AEP event

3.4.5.2 Afflux in the 5% AEP Event

Modelling results show that there would be an increase of flood levels up to 220 mm and 110 mm at two private properties outside the Alkane Controlled land as shown in **Figure 3-12**. These properties do not contain habitable

structures and the impacts are limited to agricultural land. The afflux is caused by the concentration of flow being conveyed through culverts 16 and 7.

Two properties outside of the Alkane Controlled land would have a reduction in flood levels up to 370 mm in the 5% AEP event. On Lot 165 Plan DP755093, two sheds and one house were identified to be in the zone of reduced flood depths. The floor level of the house has not been surveyed and the model currently assumes ground level to be the floor level. The depth of flooding based on the ground level was predicted to be 78 mm in the 1% AEP in the existing case, and 23 mm in the design case. There would a reduction of 55 mm as a result of the changed flow paths, i.e. a net flood benefit. As the house is lifted above ground, the flood depths indicate that the floor level would not be inundated in either the existing or design cases. Similar to the house, the depth of flooding would be reduced at the shed locations.

The properties affected in the 5% AEP event are summarised in **Table 3-12**.

The difference in flood level at the model boundary would be, on average, less than -100 mm. The model was not extended due to the combination of a lack of LiDAR, the fact that there are no more increases in flood level, only decreases, and the expectation that this impact would dissipate to be negligible at the confluence of Bulldog Creek and Gundong Creek.

Table 3-12: Impacted properties in the 5% AEP event

Lot/Plan	Tenure	Afflux (mm)	Depth of Flooding Existing (mm)	Depth of Flooding Design (mm)	Land Use
163/DP755093	Freehold	-370	-	-	Agricultural
165/DP755093	Freehold	-290	-	-	Agricultural
165/DP755093	Freehold	-143	184	41	Shed 3
165/DP755093	Freehold	-104	142	38	Shed 4
165/DP755093	Freehold	-55	78	23	House (not flooded above habitable floor level)
100A/DP1271511	Freehold	220	-	-	Agricultural
100B/DP1271511	Freehold	110	-	-	Agricultural

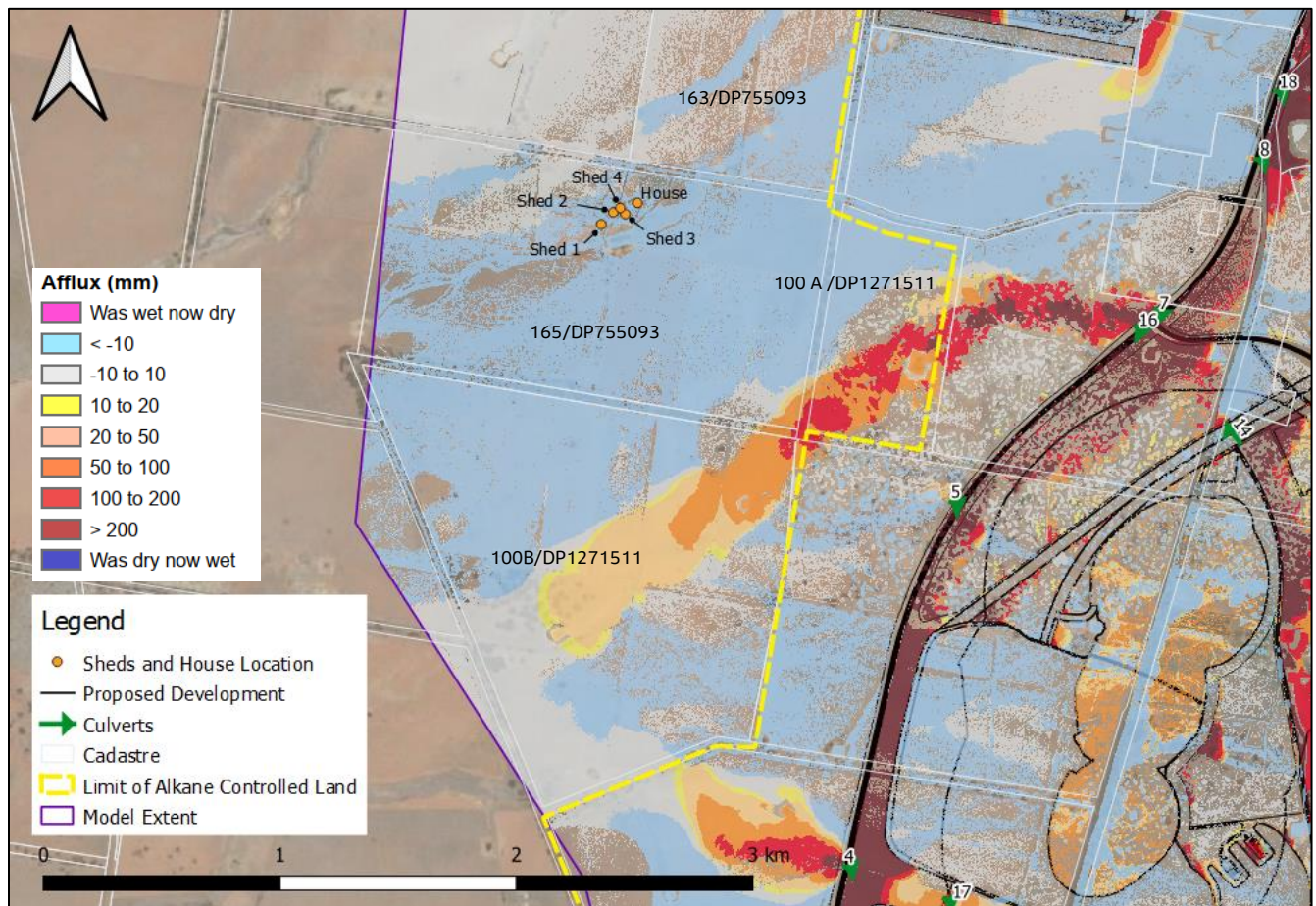


Figure 3-12: Impacted properties in the 5% AEP event

3.4.5.3 Volume Impact Downstream of Newell Highway

The Newell Highway has been raised to achieve 5% AEP flood immunity, from an existing immunity of less than 20% AEP. As a result, there are some differences in the flow behaviour downstream of the new Newell Highway. **Figure 3-13** and **Figure 3-14** show the comparison between the hydrographs downstream of the new Newell Highway for the Existing and Design case.

As shown in **Figure 3-13** and **Figure 3-14**, the peak flow is predicted to be lower in the design case compared to the existing case by $16 \text{ m}^3/\text{s}$ (or 9% lower than the existing peak flow) and by $46 \text{ m}^3/\text{s}$ (or 16% lower than the existing peak flow) for the 5% AEP event and the 1% AEP event respectively. Additionally, in both events, the time to peak is delayed by at least 2 hours in the design case. This can be explained by the higher highway acting to retard flow and only allowing flow downstream in a slower manner through the culverts as opposed to the overtopping of the road in the existing case.

The flood volume reaching downstream properties, is estimated to be lower in the design case compared to the existing case by 2.9% and 2.8% for the 5% AEP event and the 1% AEP event respectively. This is consistent with the reduced catchment size that results from the SAR open cut in the developed scenario.

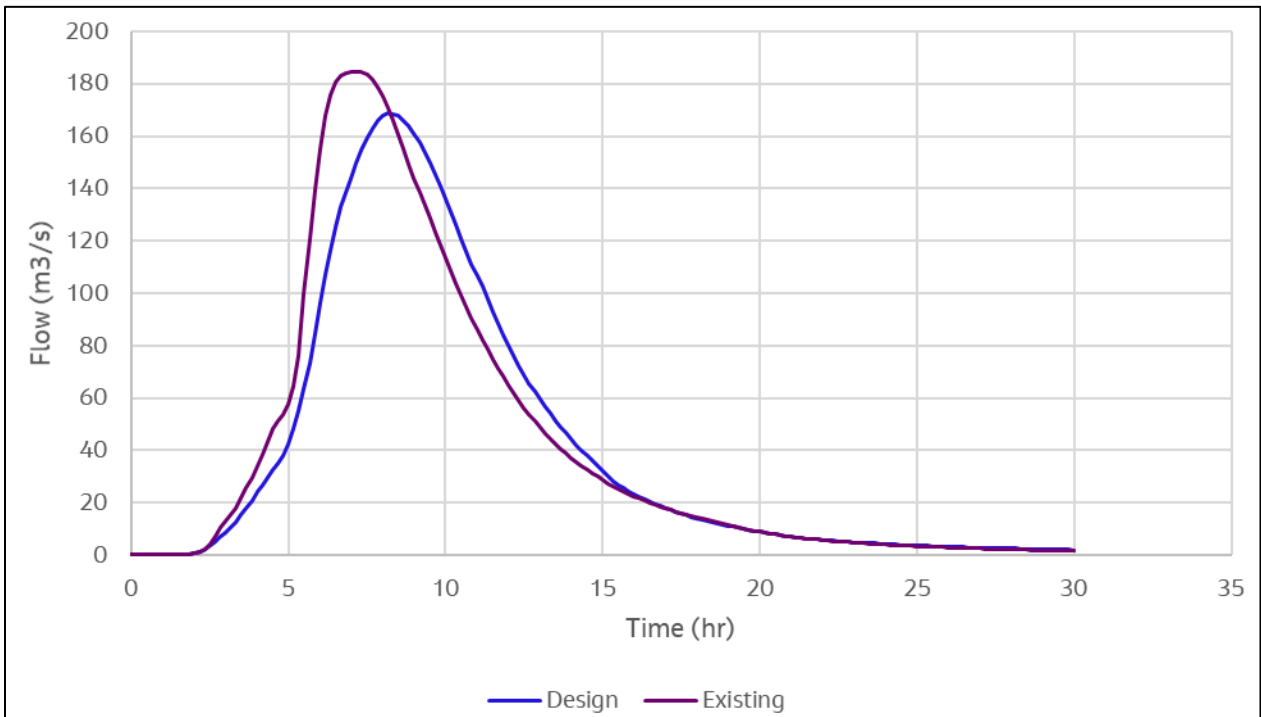


Figure 3-13: Existing vs Design hydrographs downstream the proposed Newell Highway in the 5% AEP event

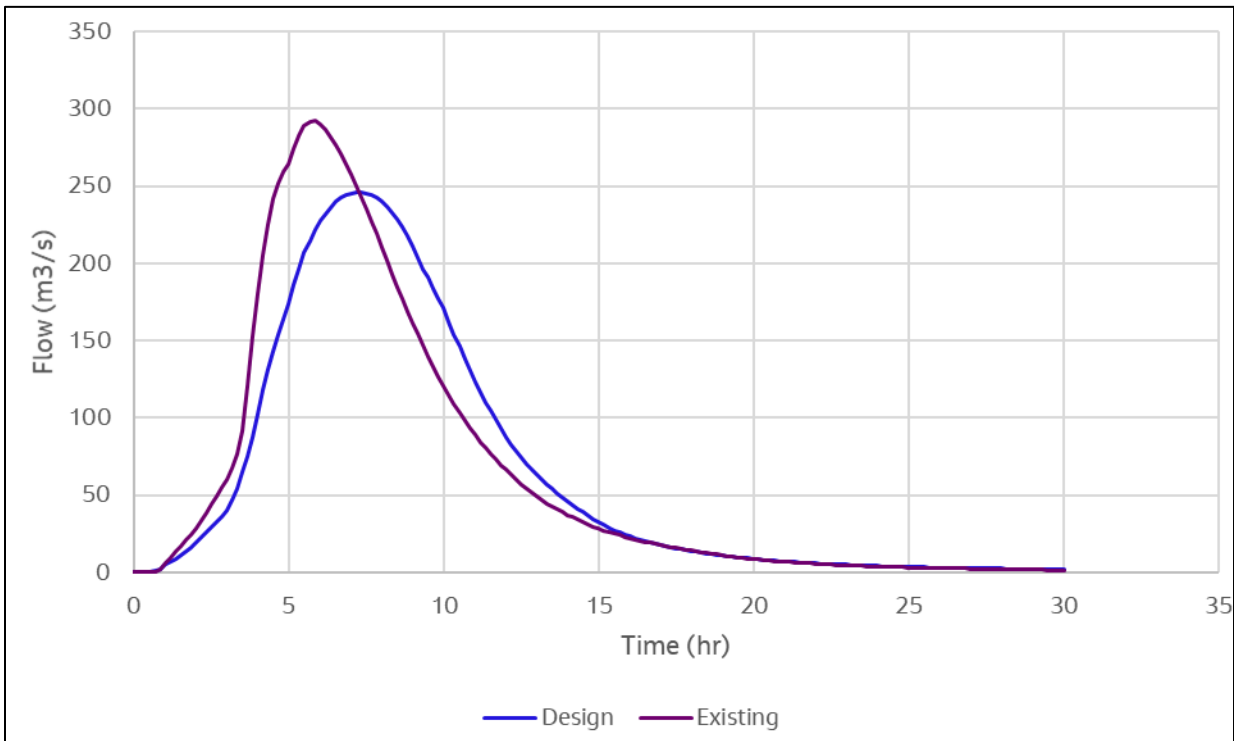


Figure 3-14: Existing vs Design hydrographs downstream the proposed Newell Highway in the 1% AEP event

3.4.6 Culvert Blockage Sensitivity Analysis

A blockage assessment was undertaken for the transverse culverts along the proposed Newell Highway as per ARR 2019 guidelines. Given the nature of the catchment and the proximity of the mine to the road embankment, it was considered appropriate to assess the Inlet and Barrel blockage mechanisms. While the Inlet mechanism accounts for floating and non-floating debris, the Barrel mechanism is typical for sediment material which progressively arrives and is deposited at the inlet and in the barrel itself. This leads to bottom-up blockage of both the barrel and inlet to the structure. The blockage mechanism which results in a larger impact on flood behaviour would be adopted.

One of the key parameters of the ARR 2019 Inlet blockage assessment is the L10 (the average length of the longest 10% of the debris that could arrive at the site), which heavily influences the percentage of blockage required. The ARR 2019 guidelines suggest sampling the debris trapped upstream of the culverts to estimate the L10. A conservative approach has been used to estimate the L10. The L10 was estimated to be 15m, which conservatively represents natural vegetation and mining artifacts in the upper catchments. With the low velocities and depth, it is unlikely that such large obstructions would be washed up against the culverts, therefore the blockage assessment was completed for sensitivity testing purposes only. **Table 3-13** and **Table 3-14** presents the parameters adopted for the Inlet and Barrel blockage assessments respectively.

Table 3-13: Inlet Blockage Assessment

Culvert ID	Dimension	L10	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	AEP Adjusted Debris Potential	Blockage percentage
	(mm)	(m)					AEP 5% - AEP 0.5%	W < L10
All	Various	15	Medium	Medium	Low	Low	Low	25%

Table 3-14: Barrel Blockage Assessment

Culvert ID	Peak Velocity	Mean Sediment Size	Likelihood of Sediment Being Deposited in Barrel	AEP Adjusted Debris Potential	Depositional Blockage
	(m/s)			AEP 5% - AEP 0.5%	
All	Various	Clay/Silt (0.001 to 0.04 mm)	Low	Low	0%

According to the assessment, the Inlet blockage mechanism would lead to a worse impact on flood behavior. Therefore, a 25% blockage was adopted for all of the culverts and simulated for the 5% AEP event in order to assess the impact on the proposed Newell Highway immunity.

When compared to the design scenario with no blockage, the maximum freeboard reduction occurs upstream of culvert 4. At this location, differences in flood level between the blocked and unblocked scenario reach up to 300 mm in the 5% AEP event (refer to **Figure 3-15**). Despite this, a 5% AEP flood immunity would still be achieved at this location and at all other locations along the proposed Newell Highway. The road design, therefore, has sufficient freeboard to account for blockage.

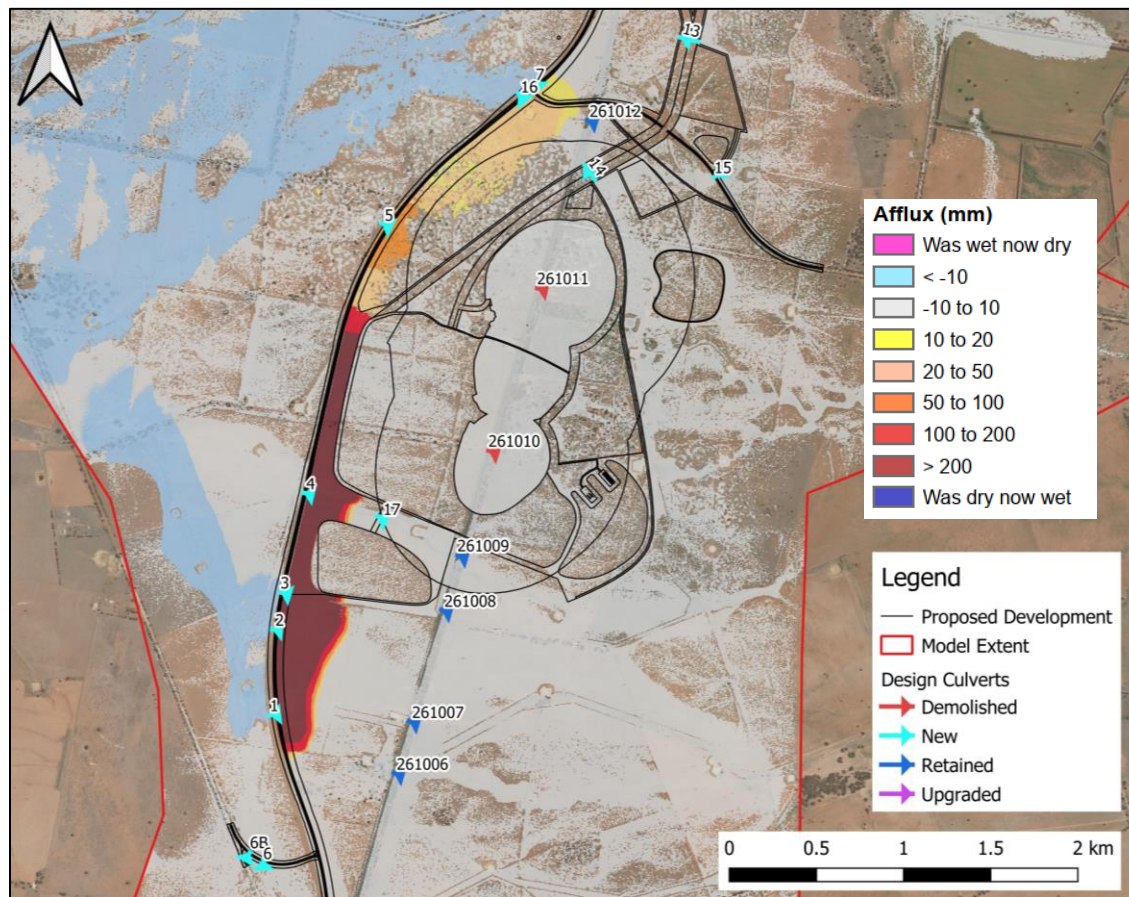


Figure 3-15: Difference in Flood level - Blocked vs Unblocked scenario 5% AEP event – Newell Highway

The blockage assessment was also undertaken for the culverts located under the local roads (Back Tomingley West Road, Kyalite Road, and Haul Road). Similar to the culverts under the proposed Newell Highway, a 25% blockage was adopted for all of the culverts and simulated for the 5% AEP event.

When compared to the design scenario with no blockage, the highest increase in flood levels would occur upstream of culverts 12 and 14 (culverts under Haul Road) being 370 mm and 210 mm respectively, as shown in **Figure 3-16**. 100 mm increase in flood level was observed upstream of Kyalite Road. Minor flood level increases (< 10 mm) were identified upstream of Back Tomingley West Road.

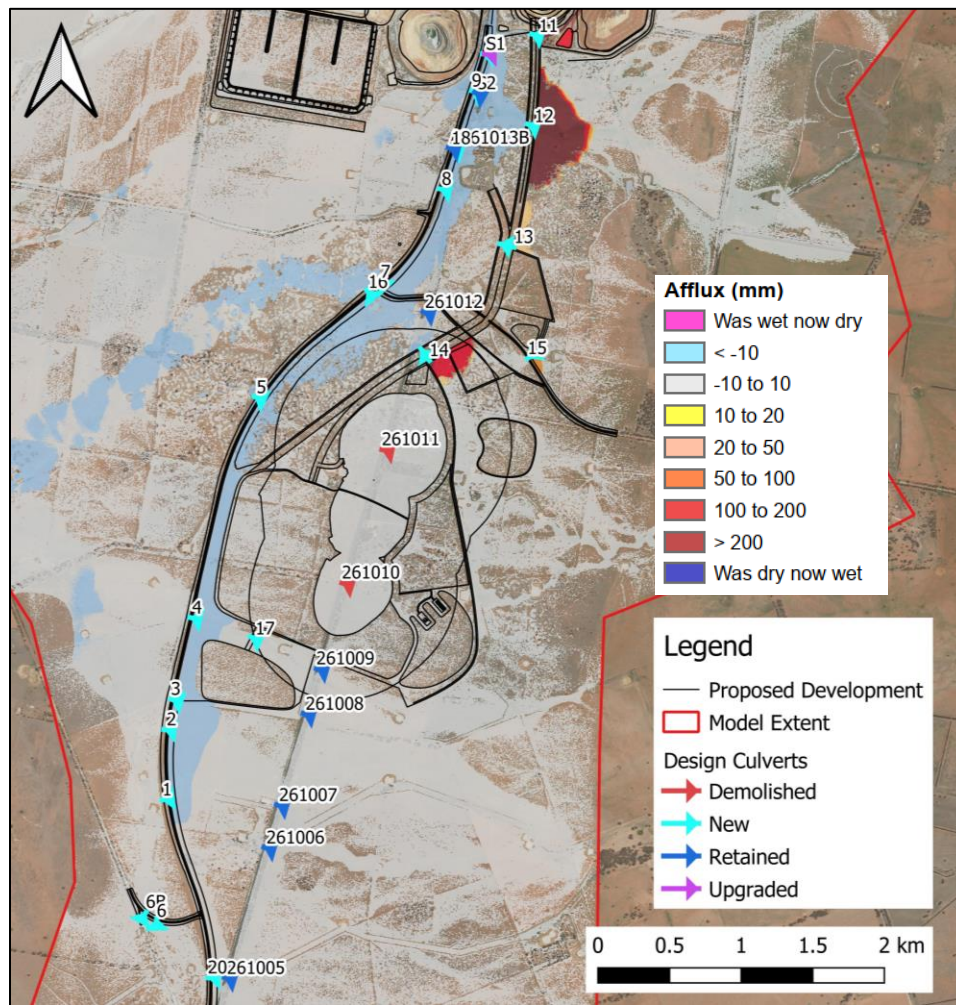


Figure 3-16: Difference in Flood level - Blocked vs Unblocked scenario 5% AEP event – Local Roads

3.4.7 Climate Change Sensitivity Analysis

A climate change scenario was modelled for the 5% AEP event based on RCP 6 and the year 2090. This equates to a 13.1% increase in design rainfall intensity.

Results suggest that the biggest increase in flood levels would occur upstream of culverts 4 and 12 being 230 mm and 280 mm respectively, as shown in **Figure 3-17**.

Along the proposed Newell Highway, flood immunity would still be achieved in the 5% AEP event. The road design, therefore, has sufficient freeboard to account for climate change.

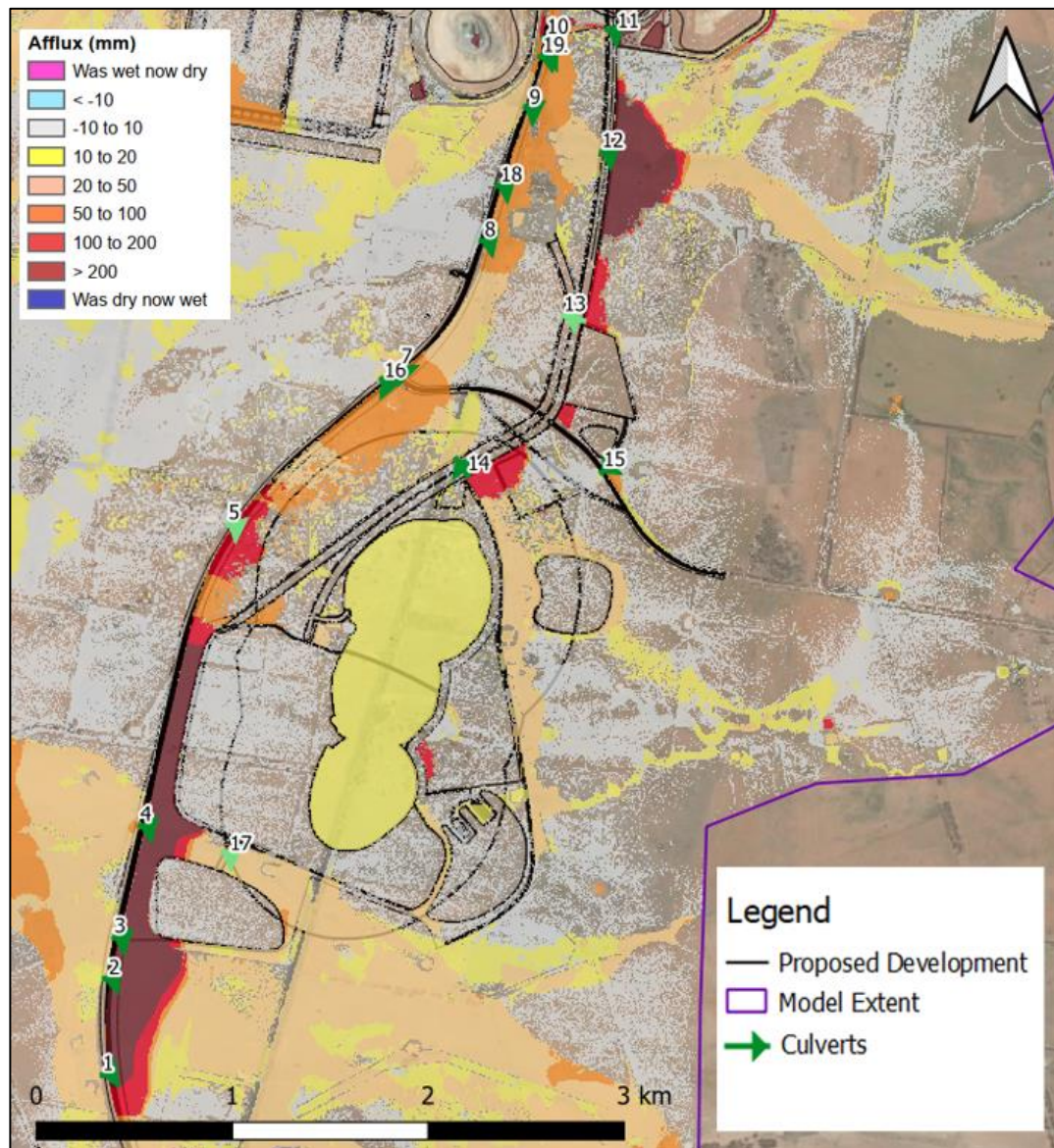


Figure 3-17: Difference in Flood level – 5% AEP event vs 5% AEP event with climate change

4. Limitations

The hydraulic modelling results presented in this report are based on the TGEP design received by Jacobs in August 2021. The hydraulic model was found to be sensitive to changes in the design and therefore the conclusions drawn in this report would not apply to any future design changes. Future design changes should be re-modelled.

Details of the surface water management plan such as drains, swales and sediment basins have not been included in the hydraulic model as they form a relatively small catchment area compared to the overall catchment. These features are not expected to impact the conclusions of this report.

The critical storms identified for the existing case have been adopted for the design case. Due to attenuation of flow upstream of the proposed new Newell Highway, these critical storms may have changed in the design case. The risk is considered low as there were minor differences in flood levels observed between the different storms. Additionally, the realigned Newell Highway has quite a large freeboard. It is recommended that critical storms be checked during detailed design.

No calibration to historic events has been performed for the hydrologic and hydraulic models due to the lack of available gauge data in the catchment. The hydrologic model has been validated to the RFFE, and an appropriately conservative flow has been adopted to provide a buffer for the lack of calibration.

Appendix A. Flood Maps Existing Situation

Figure A1: 20% AEP Peak Depth and Peak Water Level - Existing Case

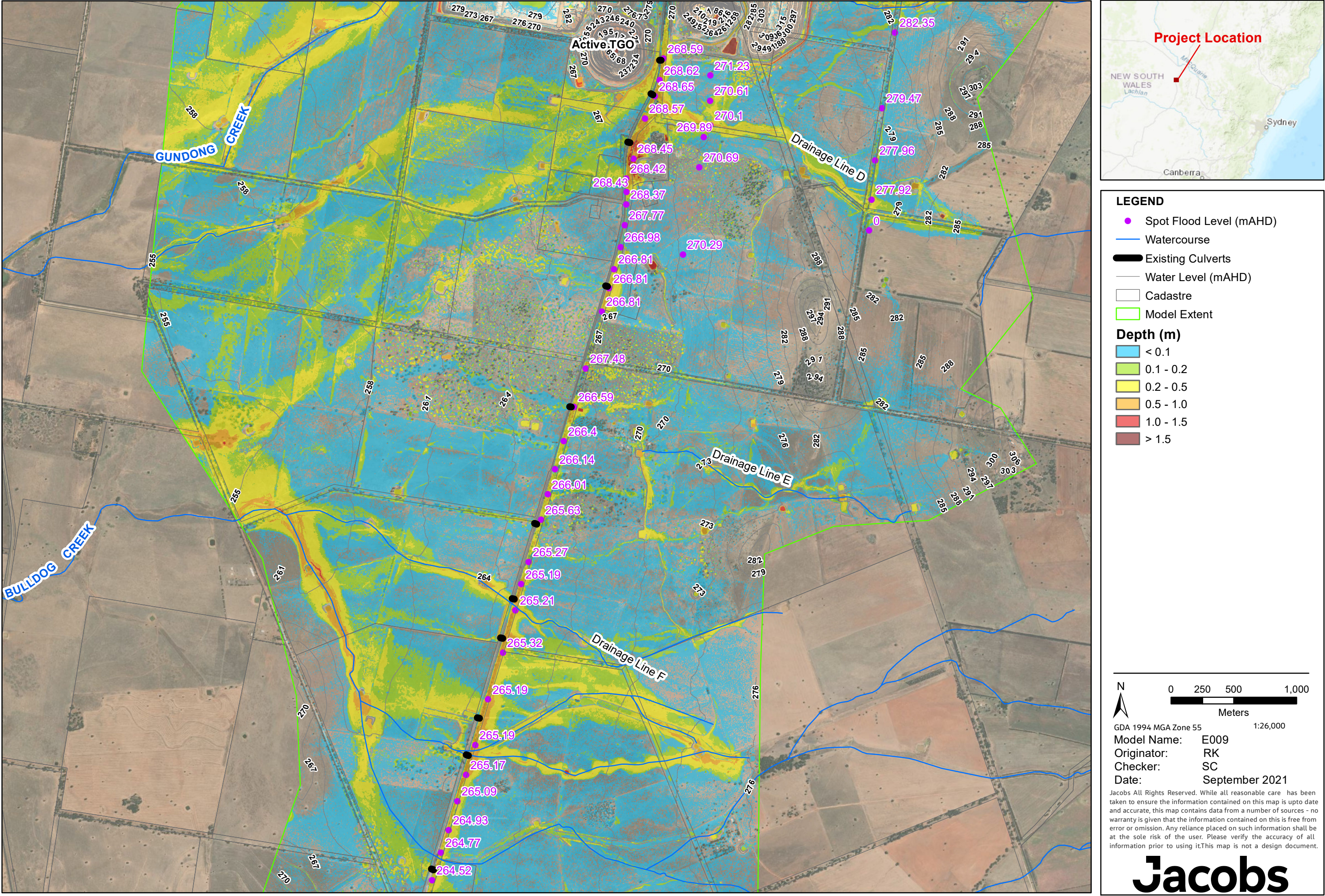


Figure A2: 10% AEP Peak Depth and Peak Water Level - Existing Case

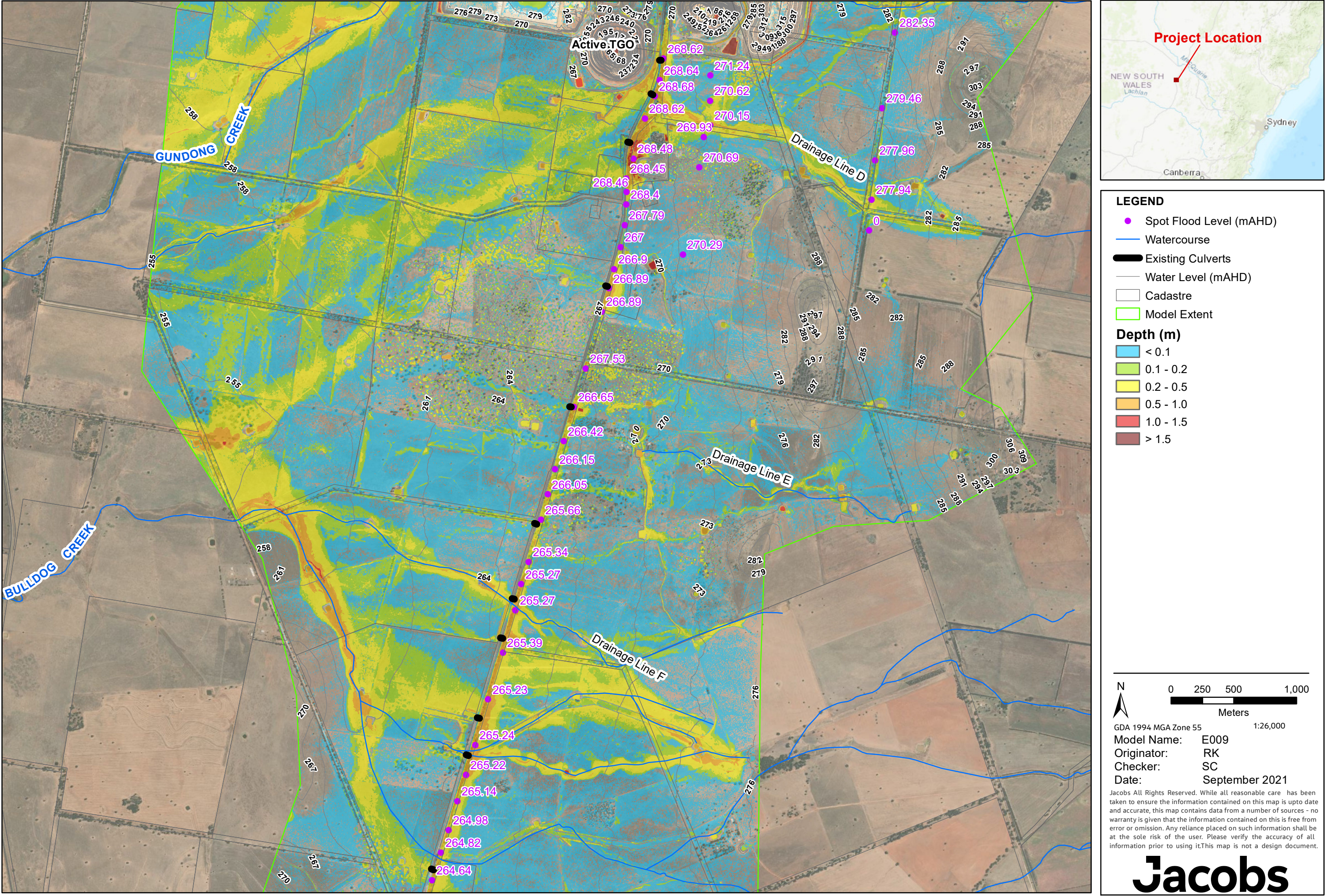


Figure A3: 5% AEP Peak Depth and Peak Water Level - Existing Case

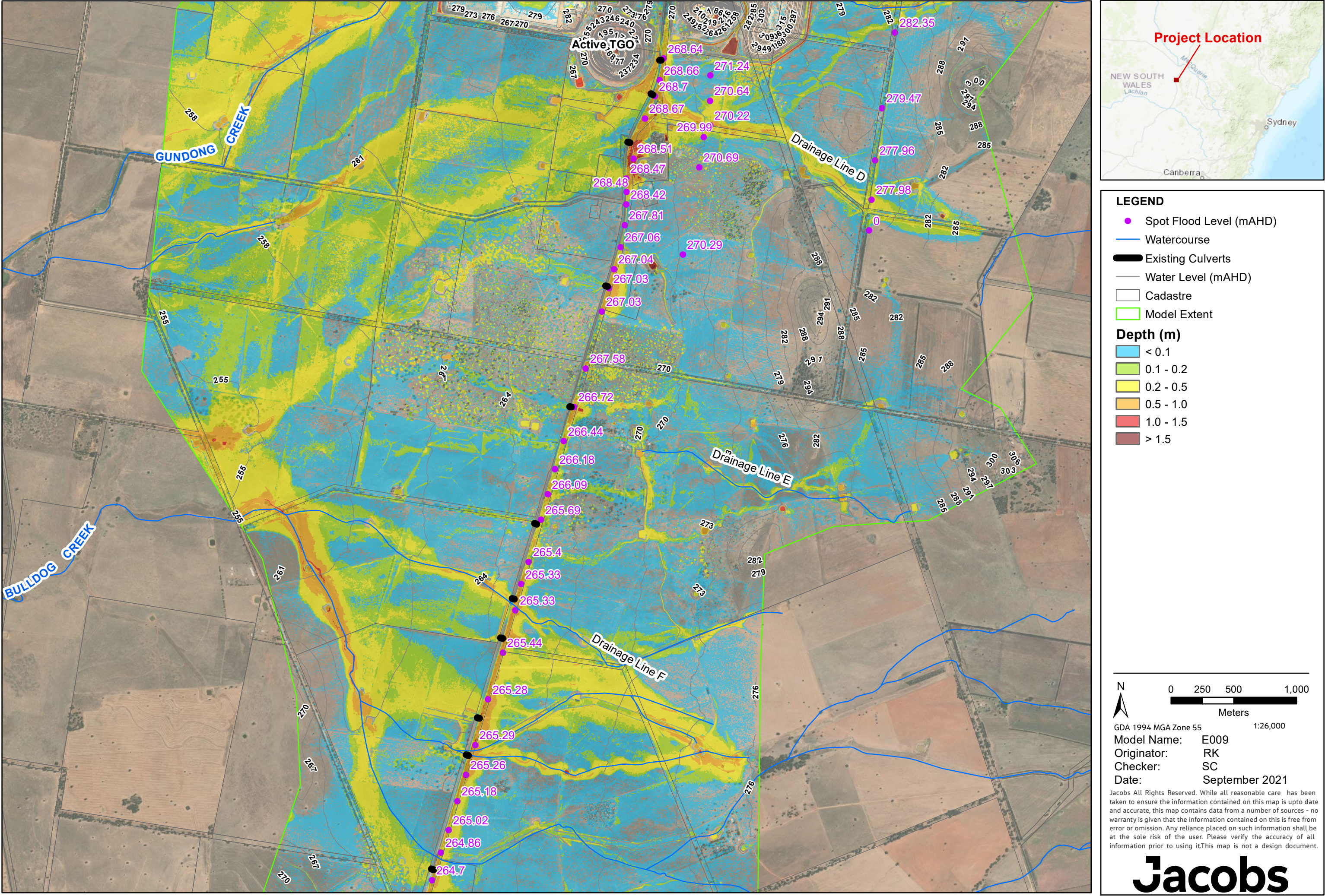


Figure A4: 2% AEP Peak Depth and Peak Water Level - Existing Case

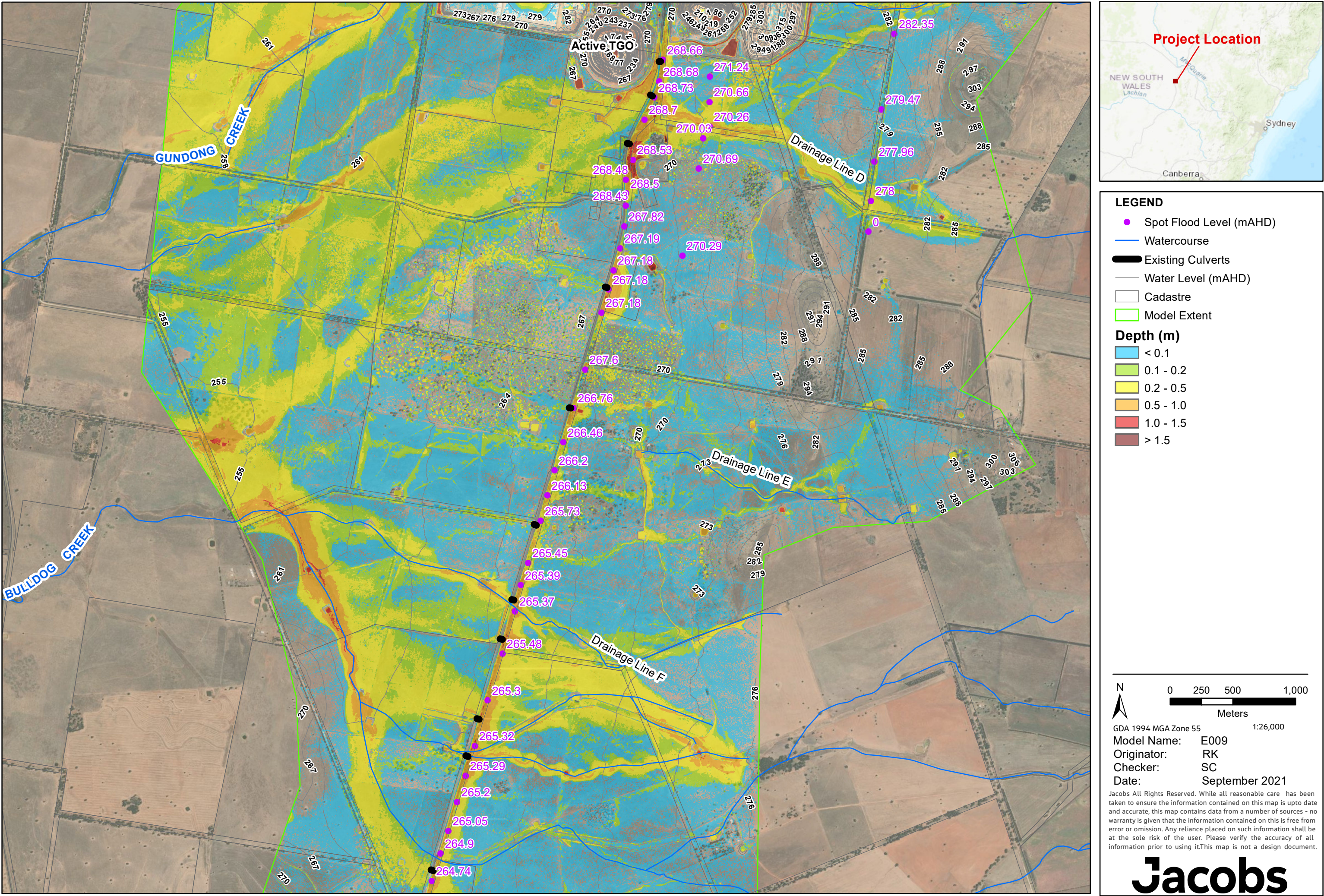


Figure A5: 1% AEP Peak Depth and Peak Water Level - Existing Case

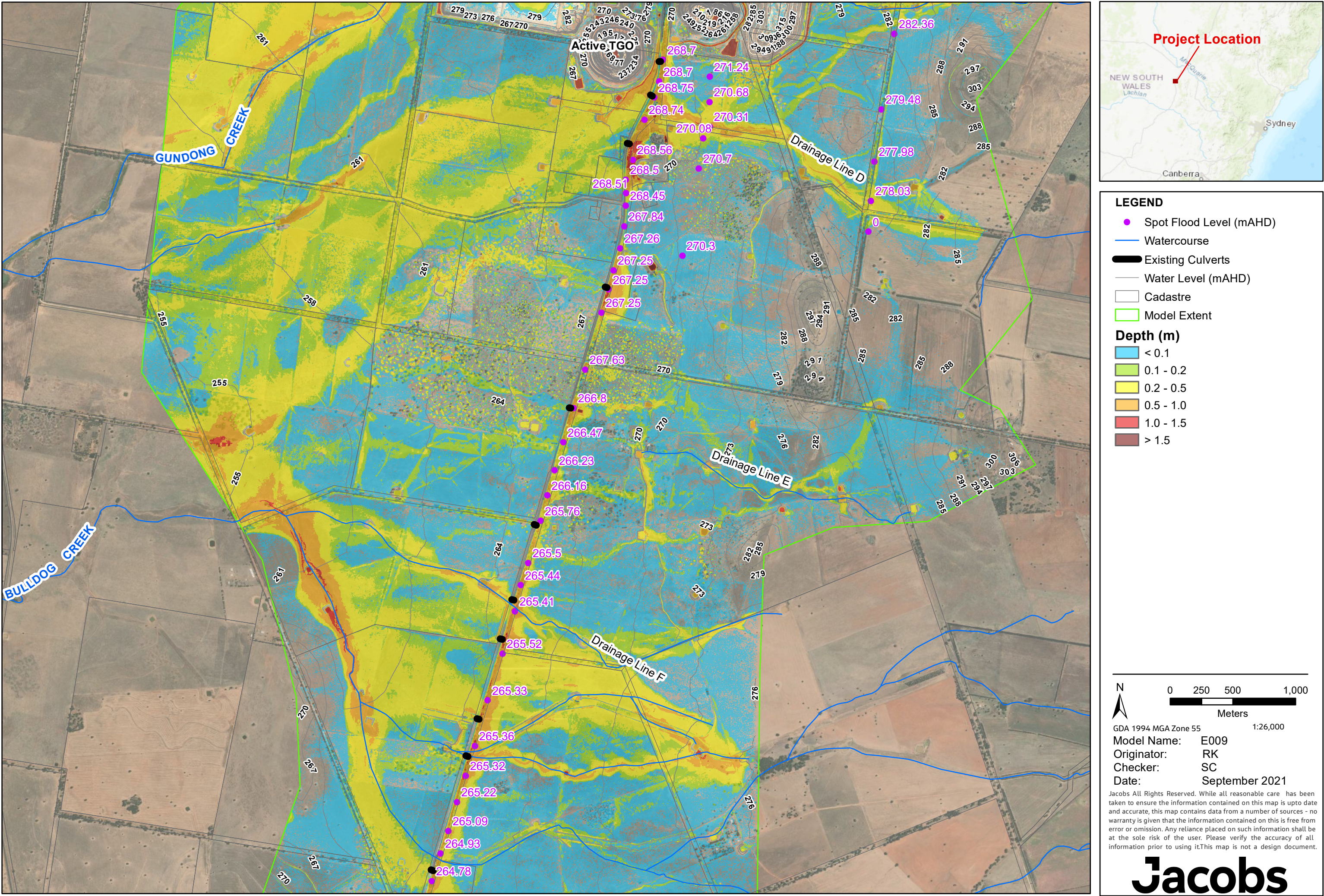


Figure A6: 0.1% AEP Peak Depth and Peak Water Level - Existing Case

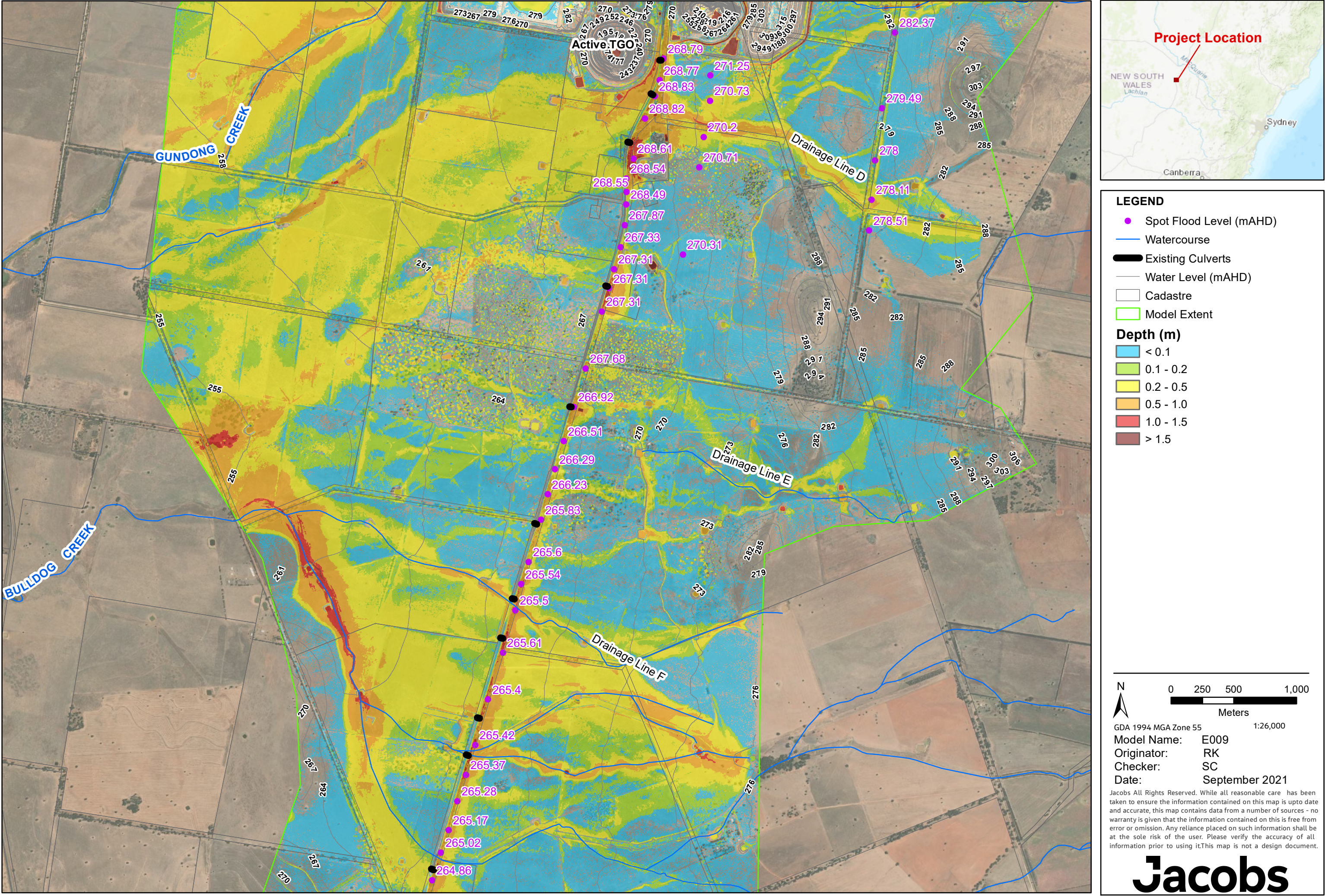


Figure A7: 20% AEP Peak Velocity - Existing Case

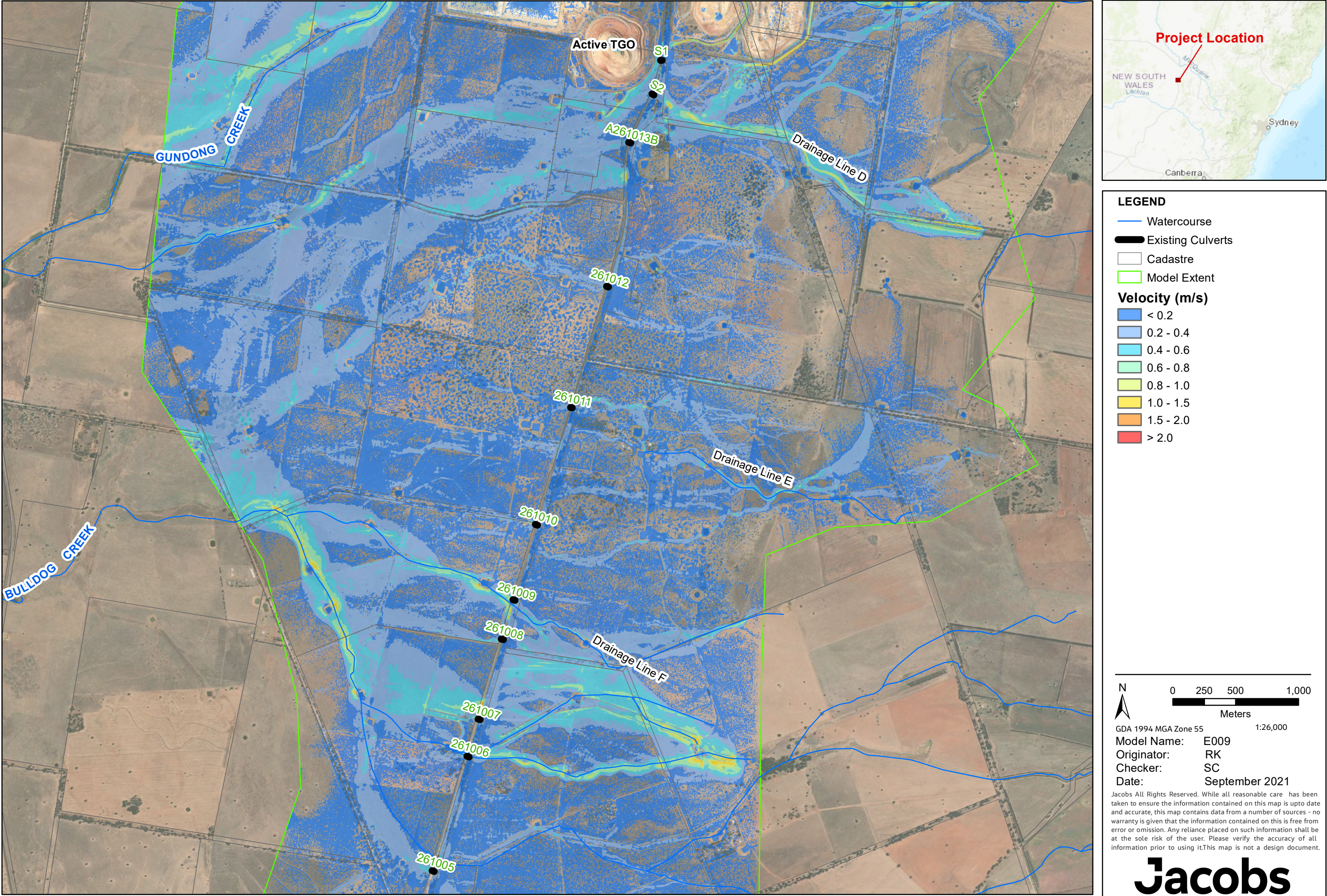
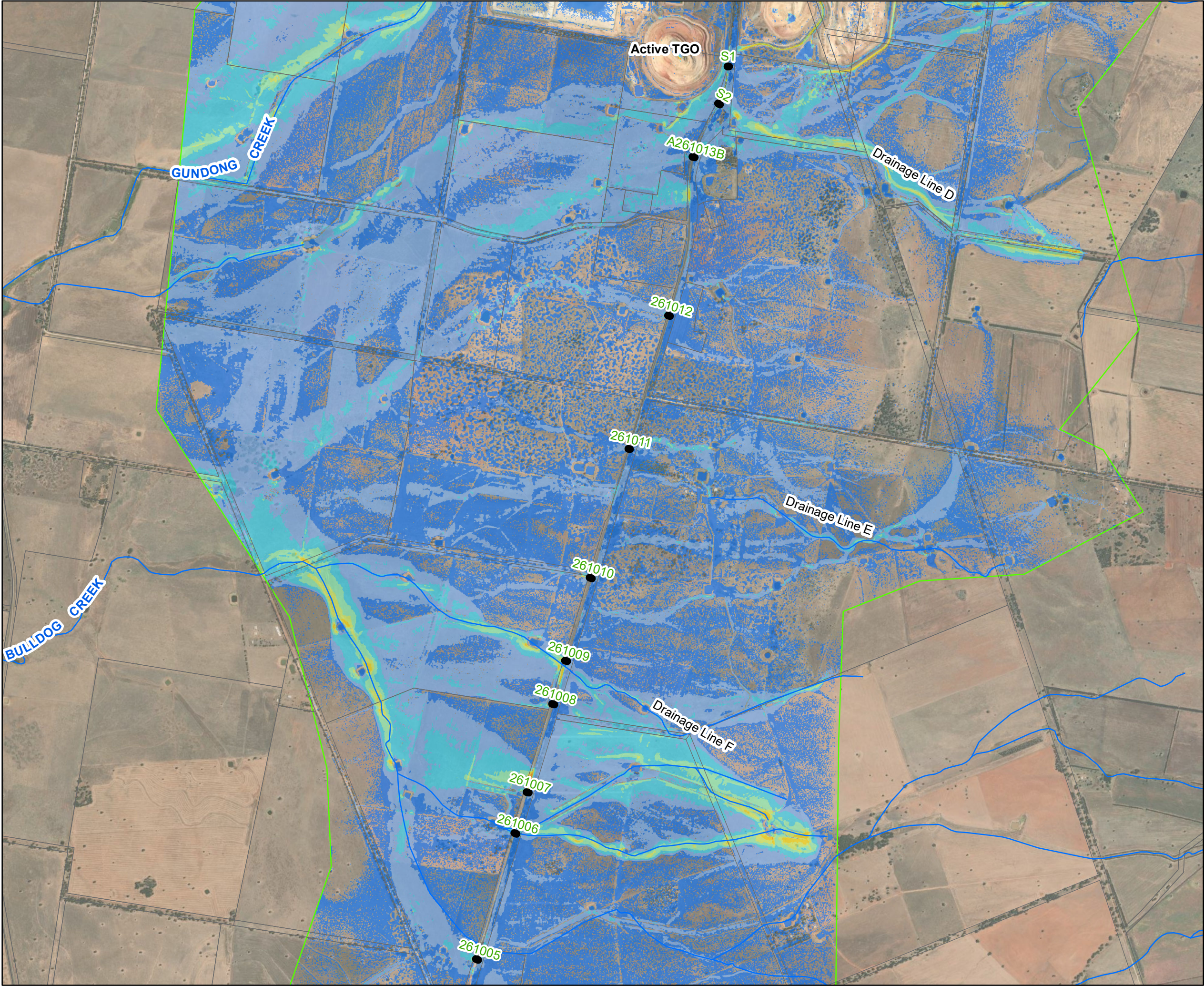
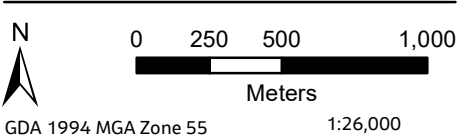


Figure A8: 10% AEP Peak Velocity - Existing Case



- LEGEND**
- Watercourse
 - Existing Culverts
 - Cadastre
 - Model Extent
- Velocity (m/s)**
- < 0.2
 - 0.2 - 0.4
 - 0.4 - 0.6
 - 0.6 - 0.8
 - 0.8 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - > 2.0

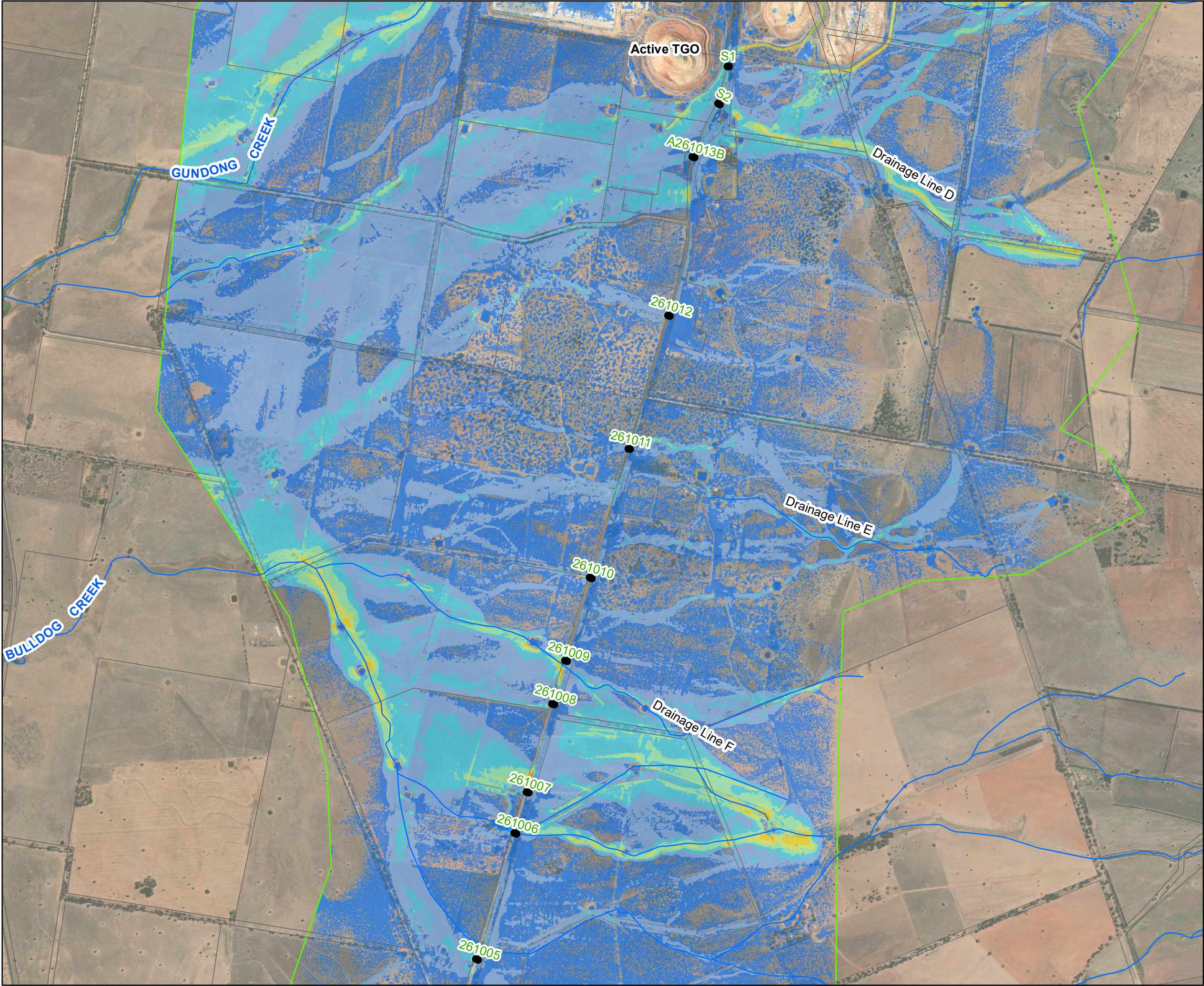


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Model Name: E009
Originator: RK
Checker: SC
Date: September 2021

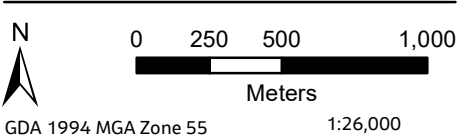
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Figure A9: 5% AEP Peak Velocity - Existing Case



- LEGEND**
- Watercourse
 - Existing Culverts
 - Cadastre
 - Model Extent
- Velocity (m/s)**
- < 0.2
 - 0.2 - 0.4
 - 0.4 - 0.6
 - 0.6 - 0.8
 - 0.8 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - > 2.0



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Model Name: E009

Originator: RK

Checker: SC

Date: September 2021

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Figure A10: 2% AEP Peak Velocity - Existing Case

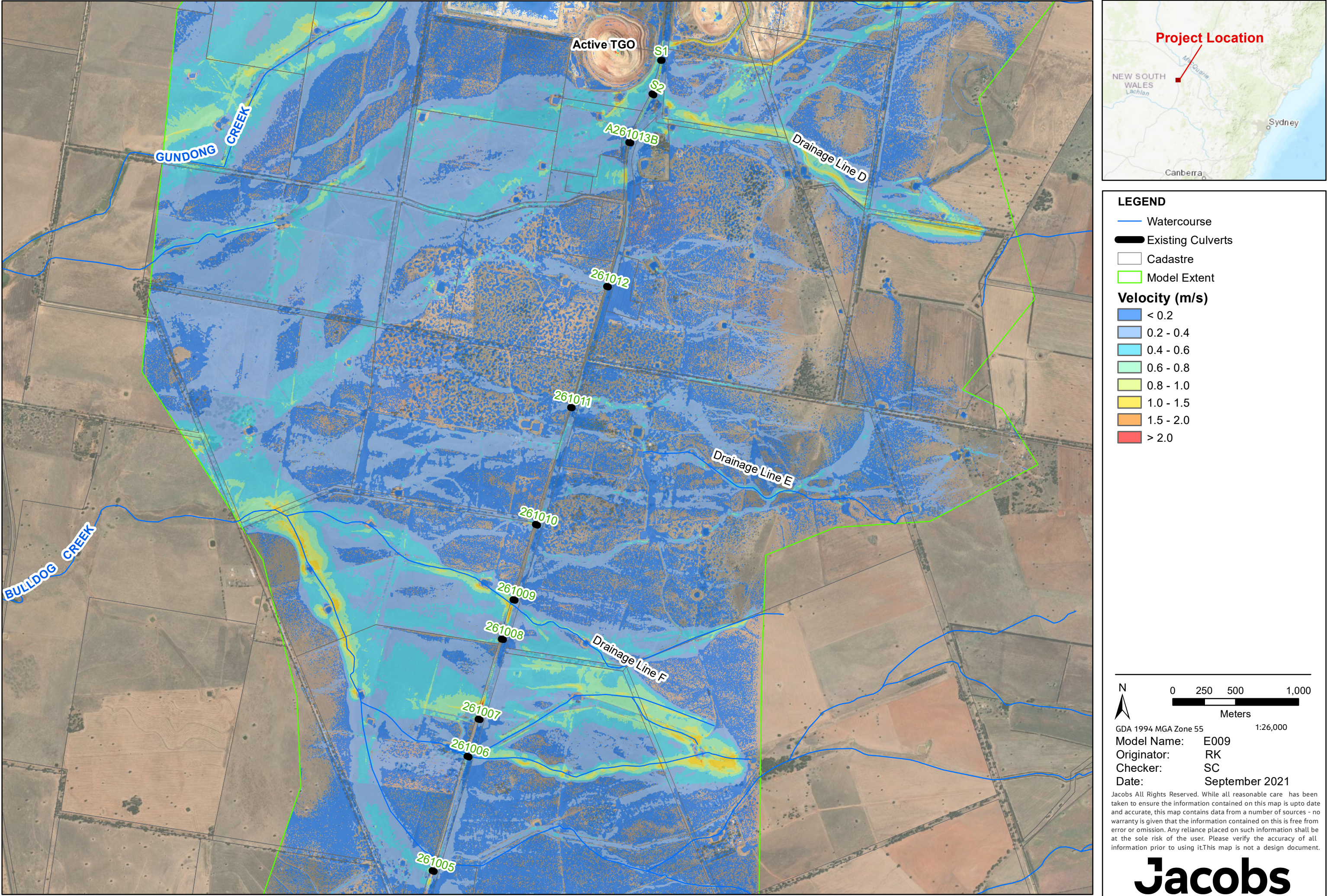


Figure A11: 1% AEP Peak Velocity - Existing Case

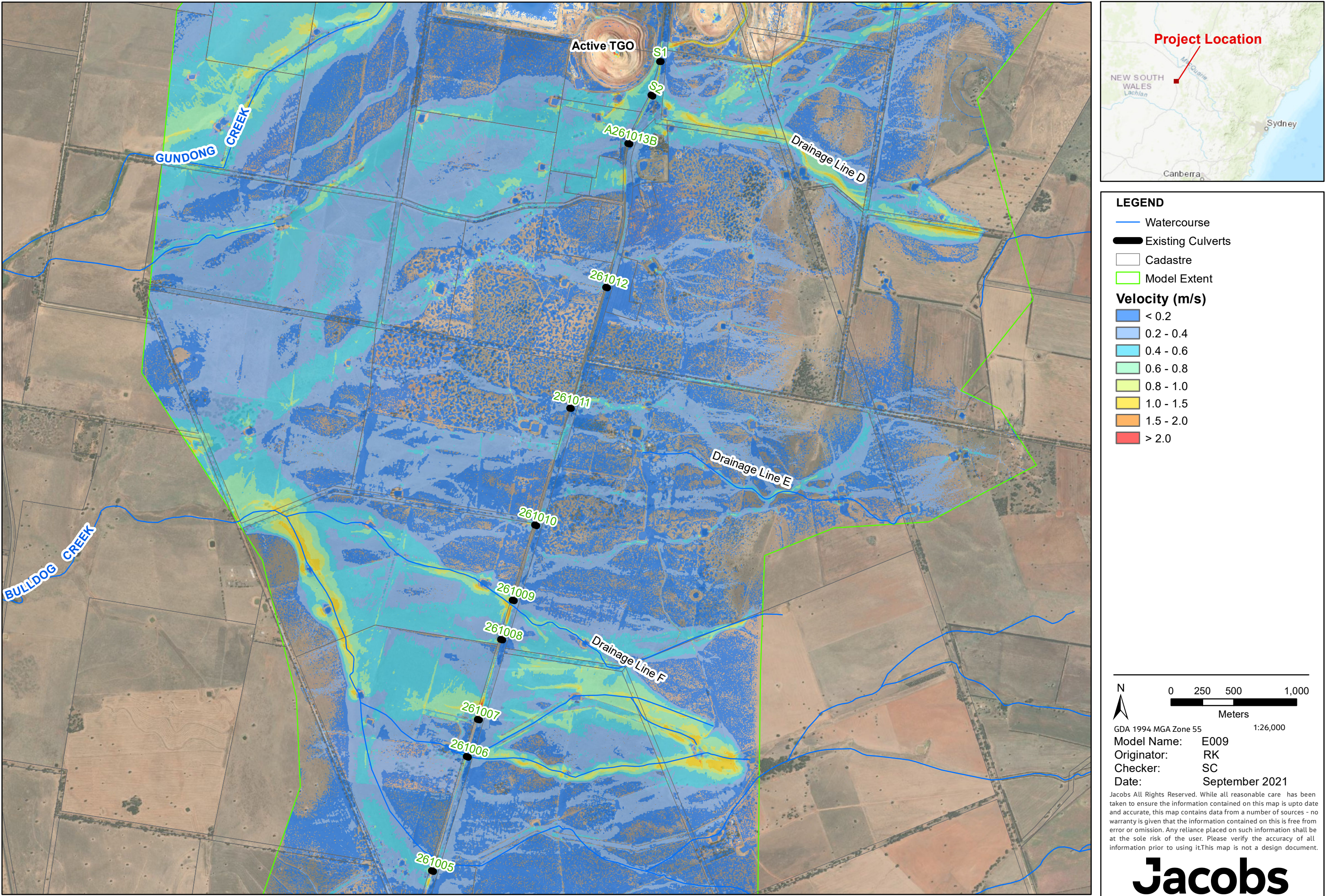
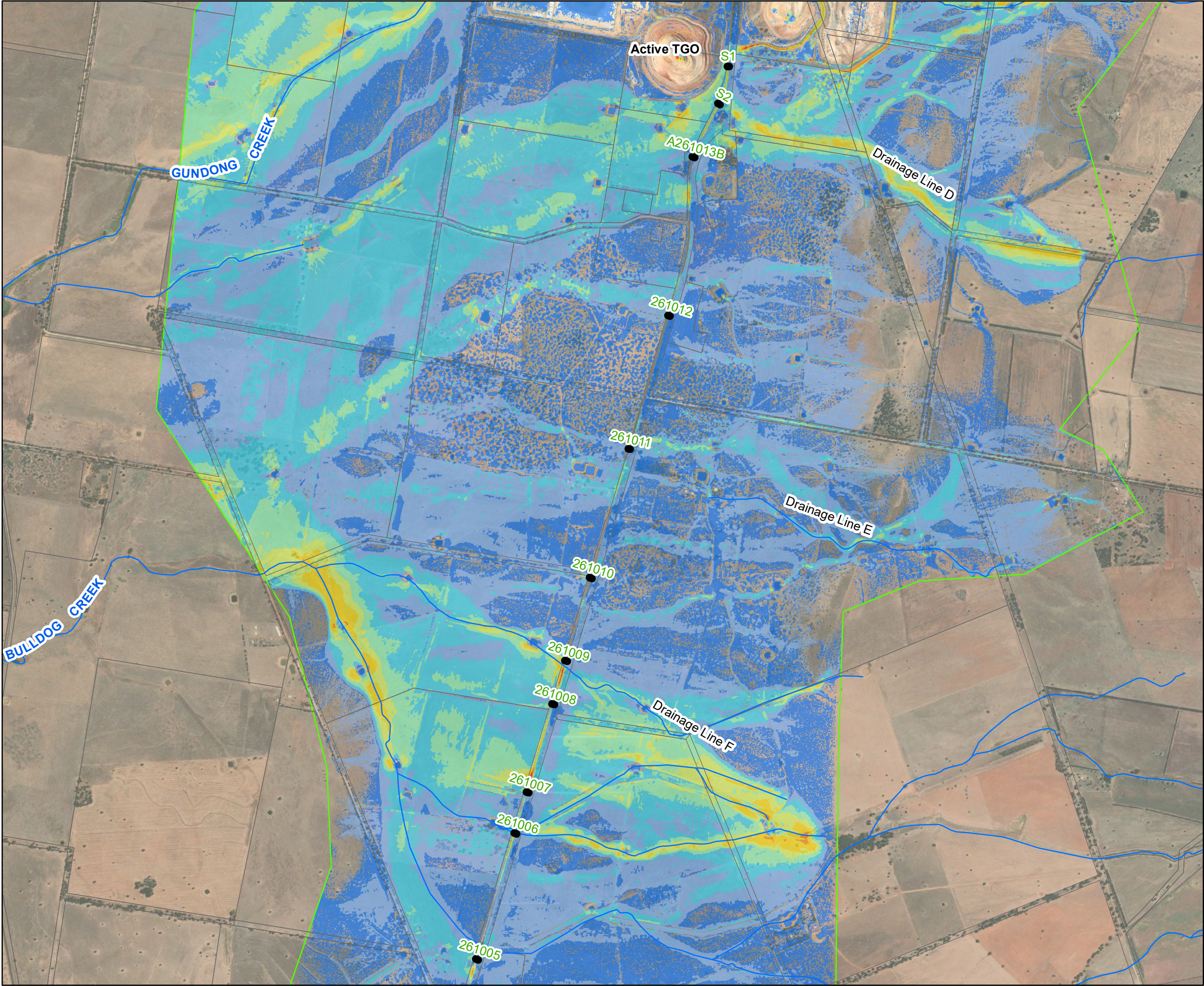


Figure A12: 0.1% AEP Peak Velocity - Existing Case



LEGEND

- Watercourse
- Existing Culverts
- Cadastre
- Model Extent

Velocity (m/s)

- < 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

N

0 250 500 1,000

Meters

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Model Name: E009

Originator: RK

Checker: SC

Date: September 2021

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Appendix B. Flood Maps Design Situation

Figure B1: 20% AEP Peak Depth and Peak Water Level - Design Case

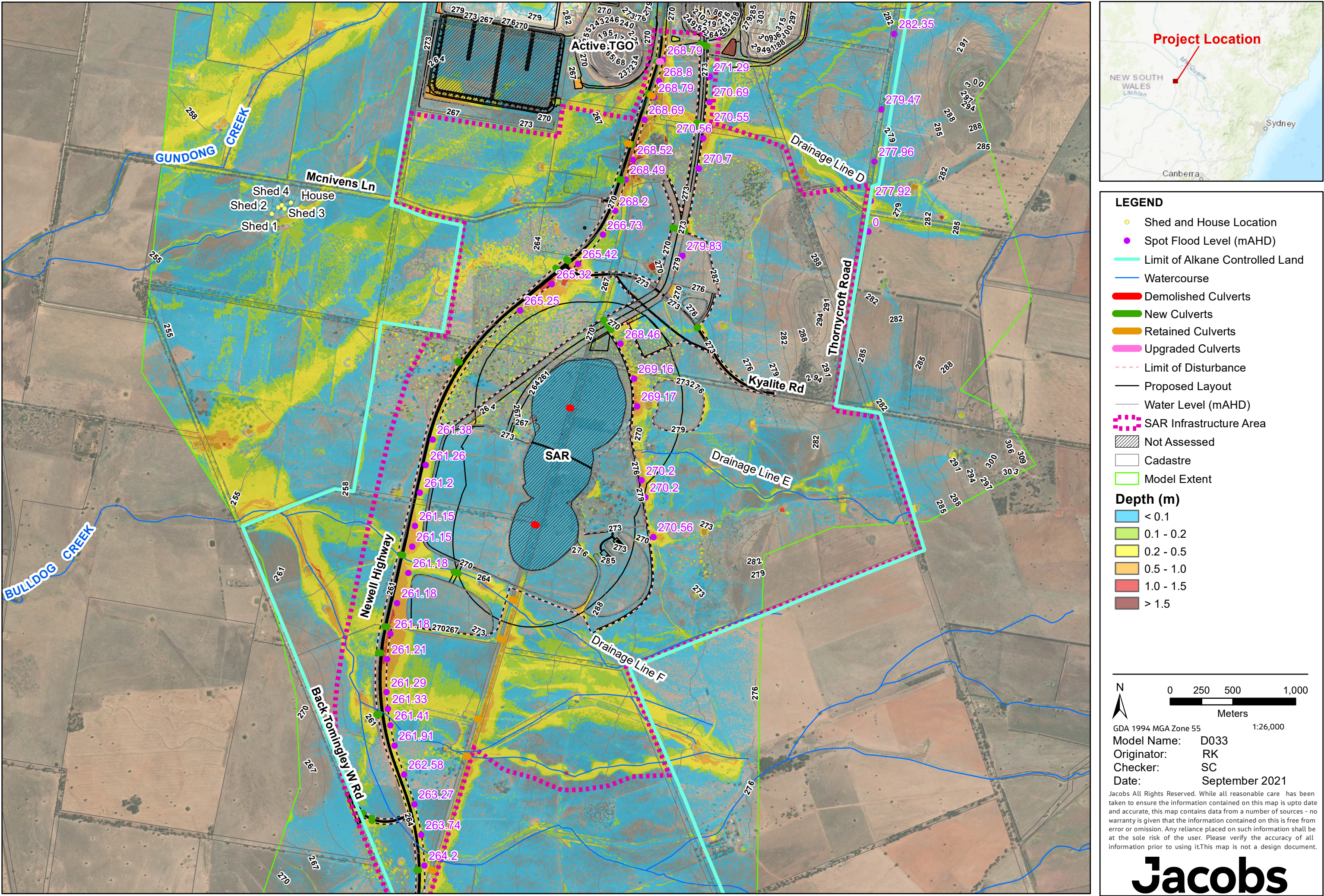


Figure B2: 10% AEP Peak Depth and Peak Water Level - Design Case

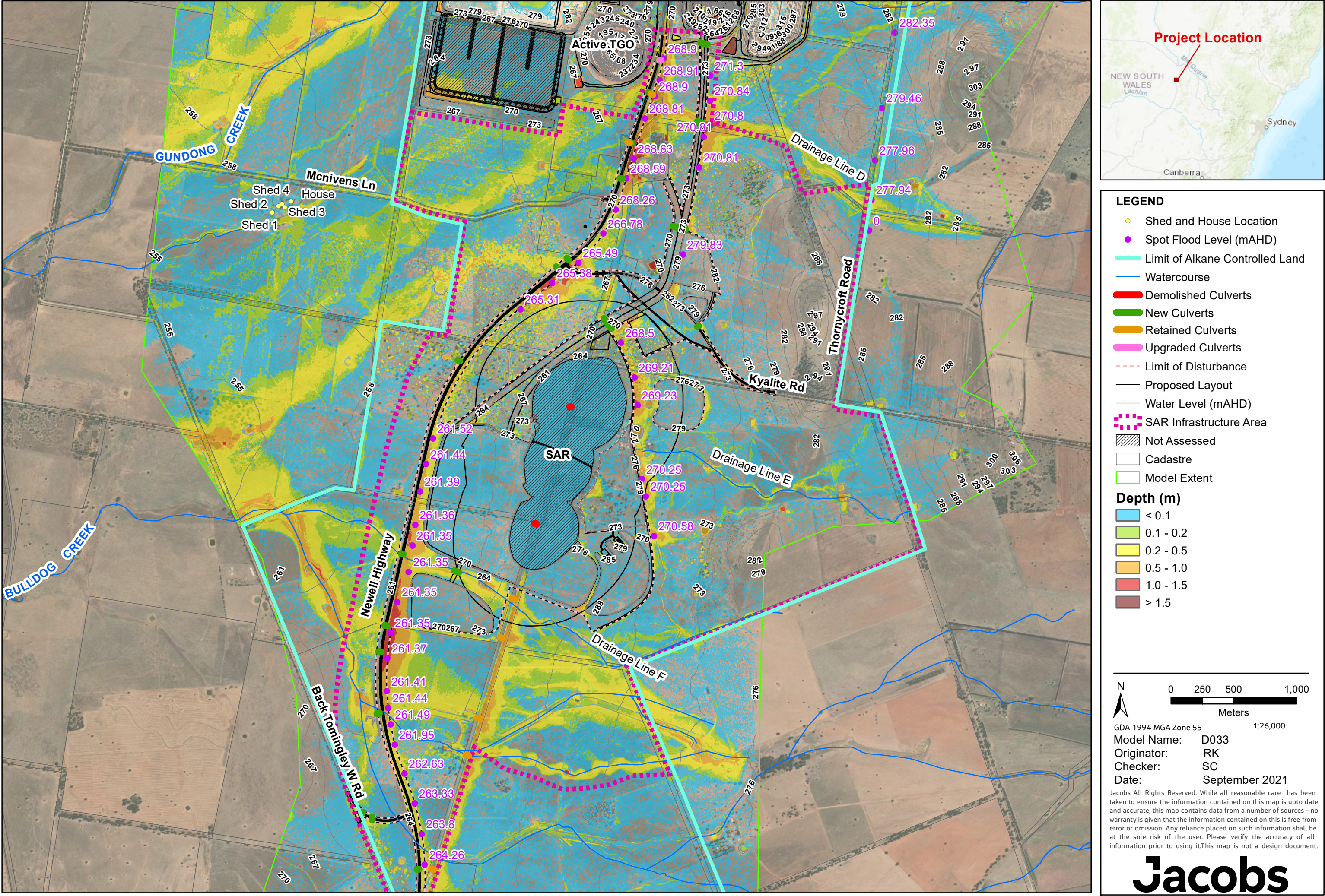


Figure B3: 5% AEP Peak Depth and Peak Water Level - Design Case

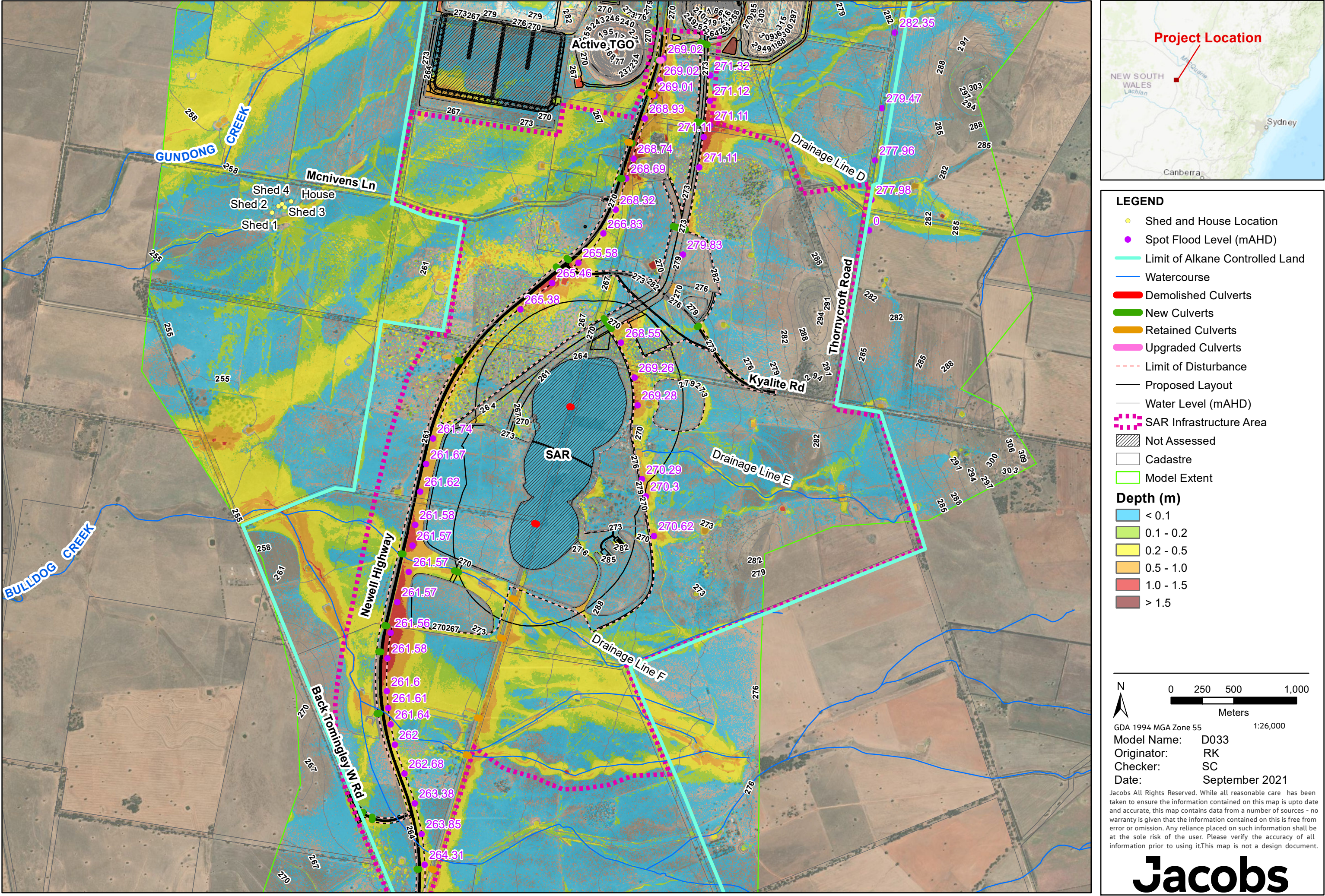


Figure B4: 2% AEP Peak Depth and Peak Water Level - Design Case

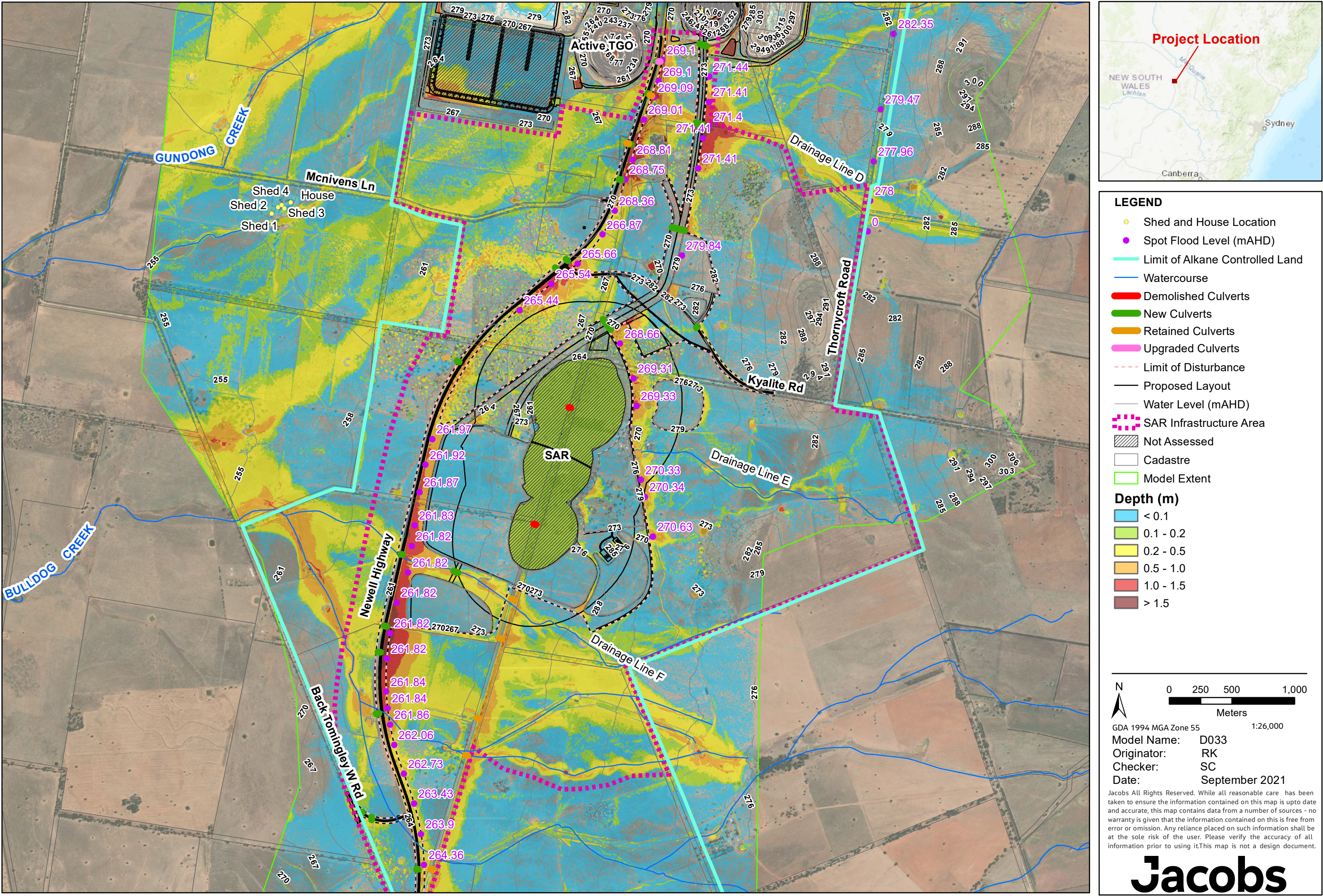


Figure B5: 1% AEP Peak Depth and Peak Water Level - Design Case

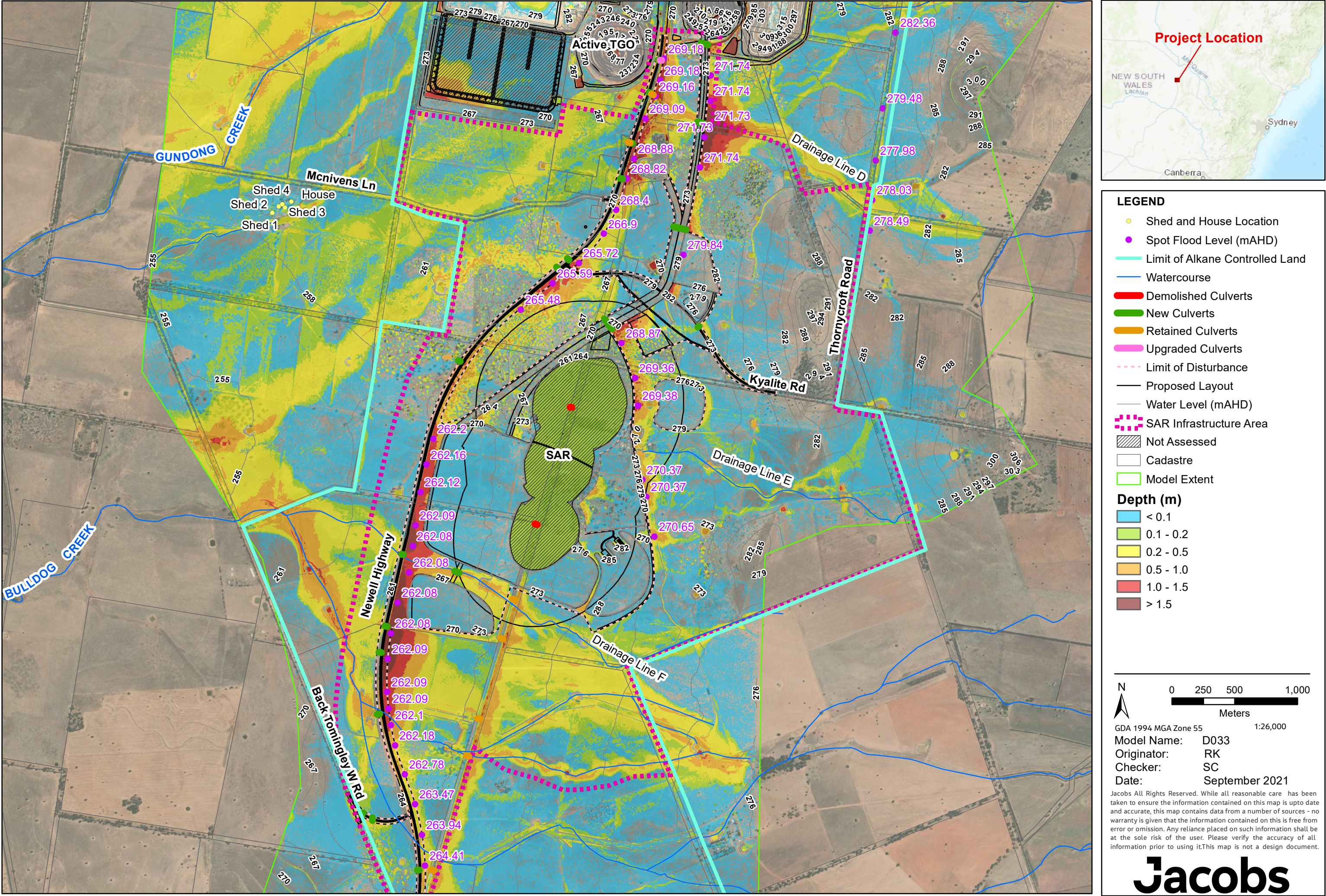


Figure B6: 0.1% AEP Peak Depth and Peak Water Level - Design Case

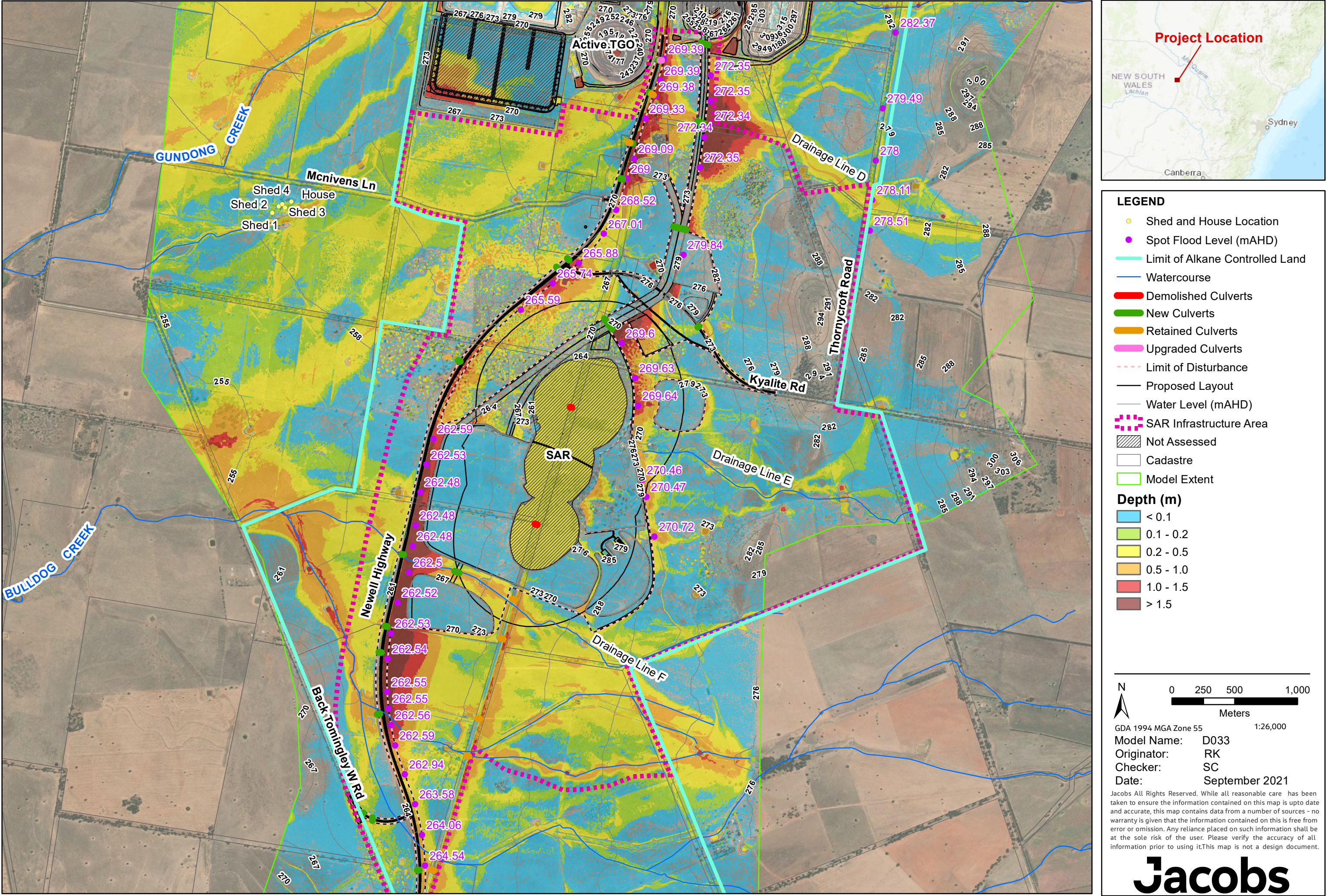


Figure B7: 20% AEP Peak Velocity - Design Case

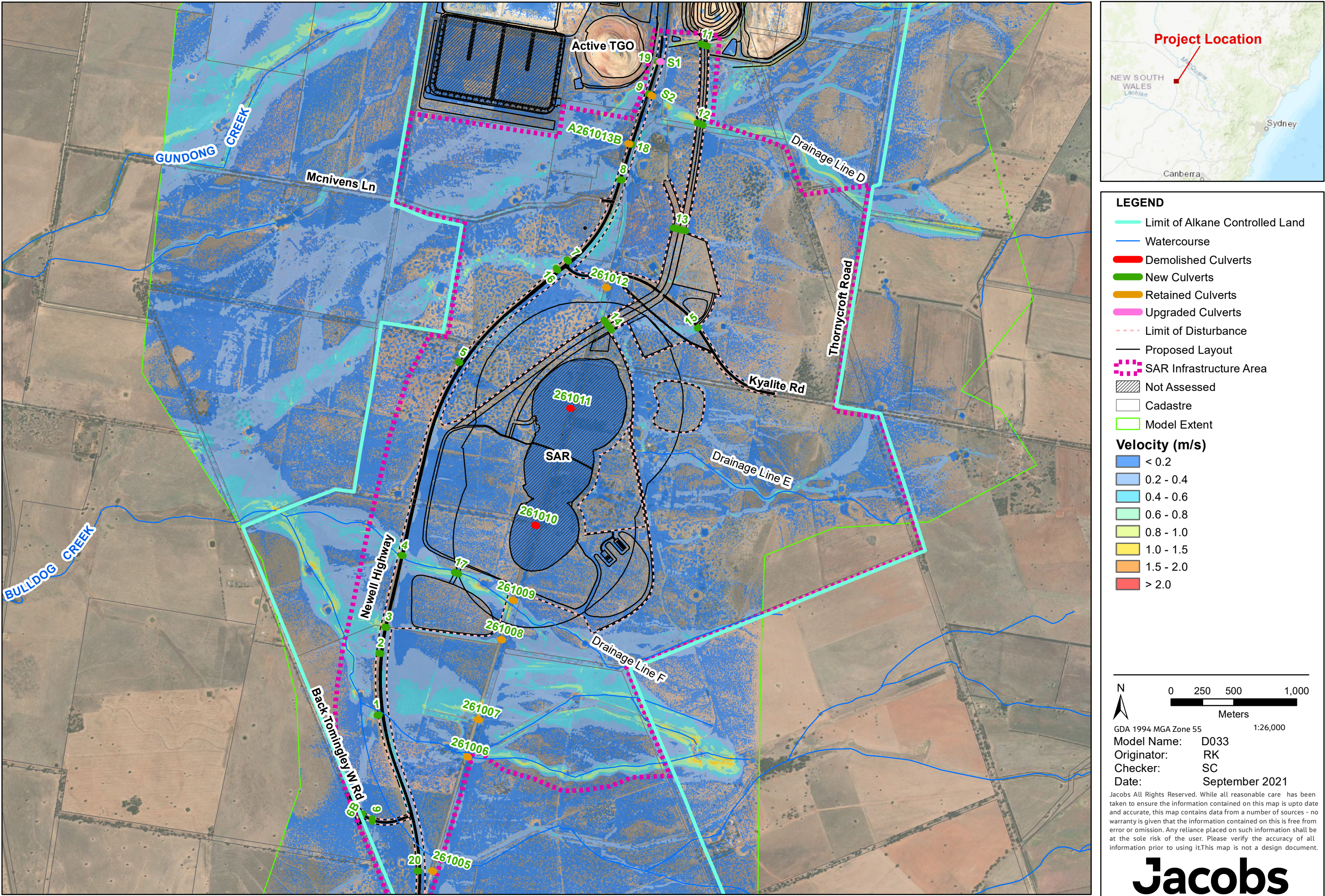


Figure B8: 10% AEP Peak Velocity - Design Case

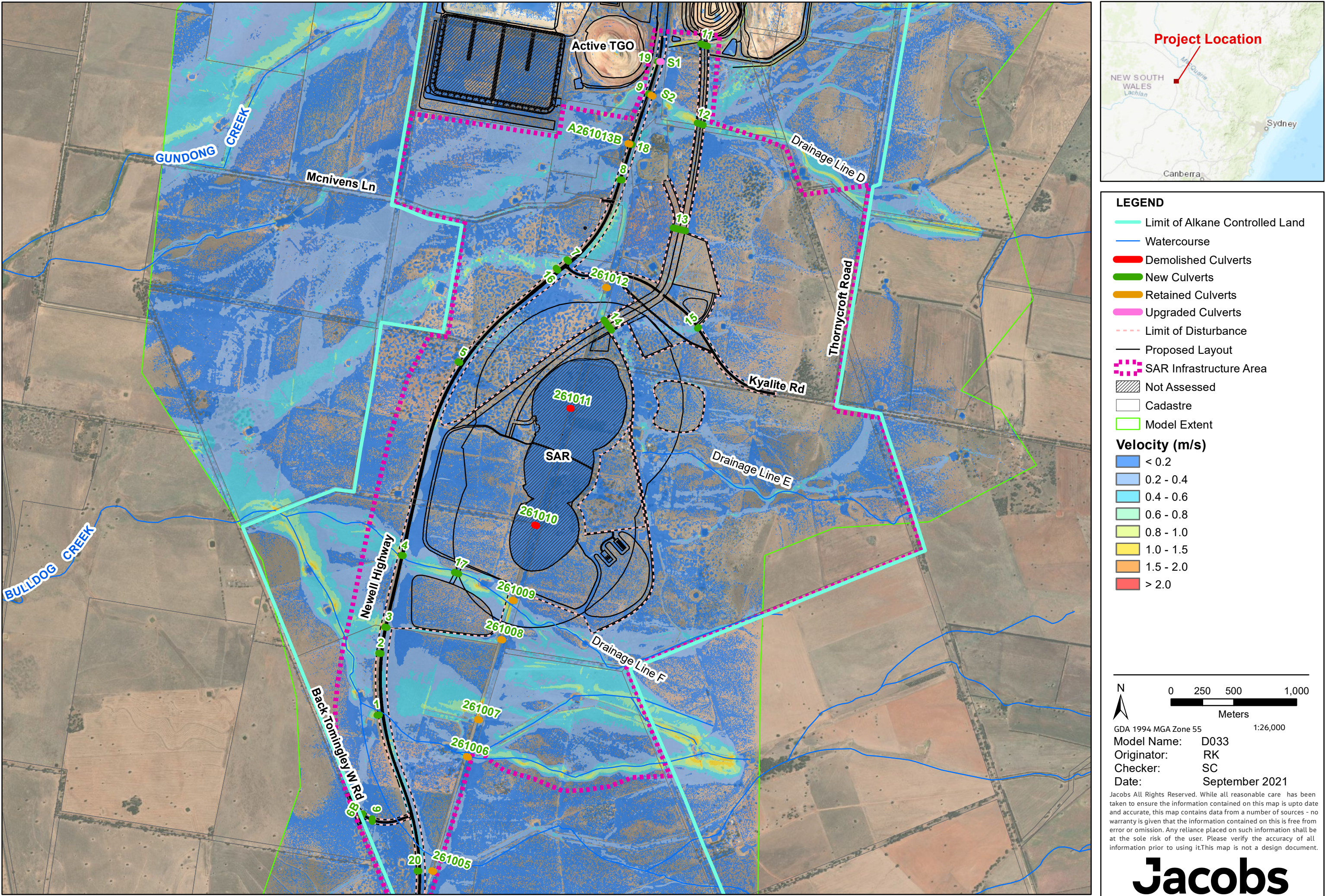
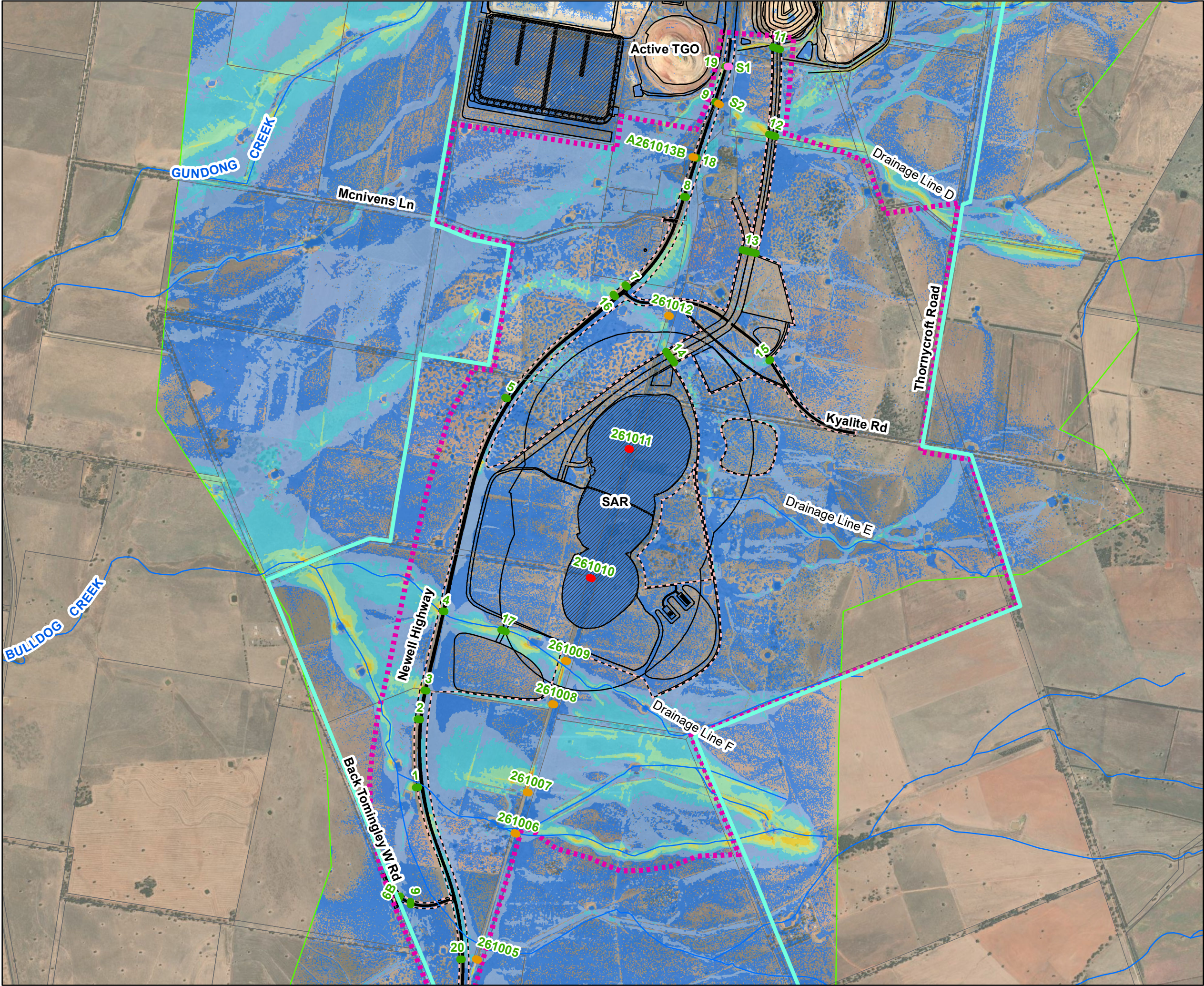
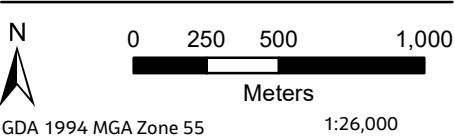


Figure B9: 5% AEP Peak Velocity - Design Case



- LEGEND**
- Limit of Alkane Controlled Land
 - Watercourse
 - Demolished Culverts
 - New Culverts
 - Retained Culverts
 - Upgraded Culverts
 - Limit of Disturbance
 - Proposed Layout
 - SAR Infrastructure Area
 - Not Assessed
 - Cadastre
 - Model Extent

- Velocity (m/s)**
- < 0.2
 - 0.2 - 0.4
 - 0.4 - 0.6
 - 0.6 - 0.8
 - 0.8 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - > 2.0

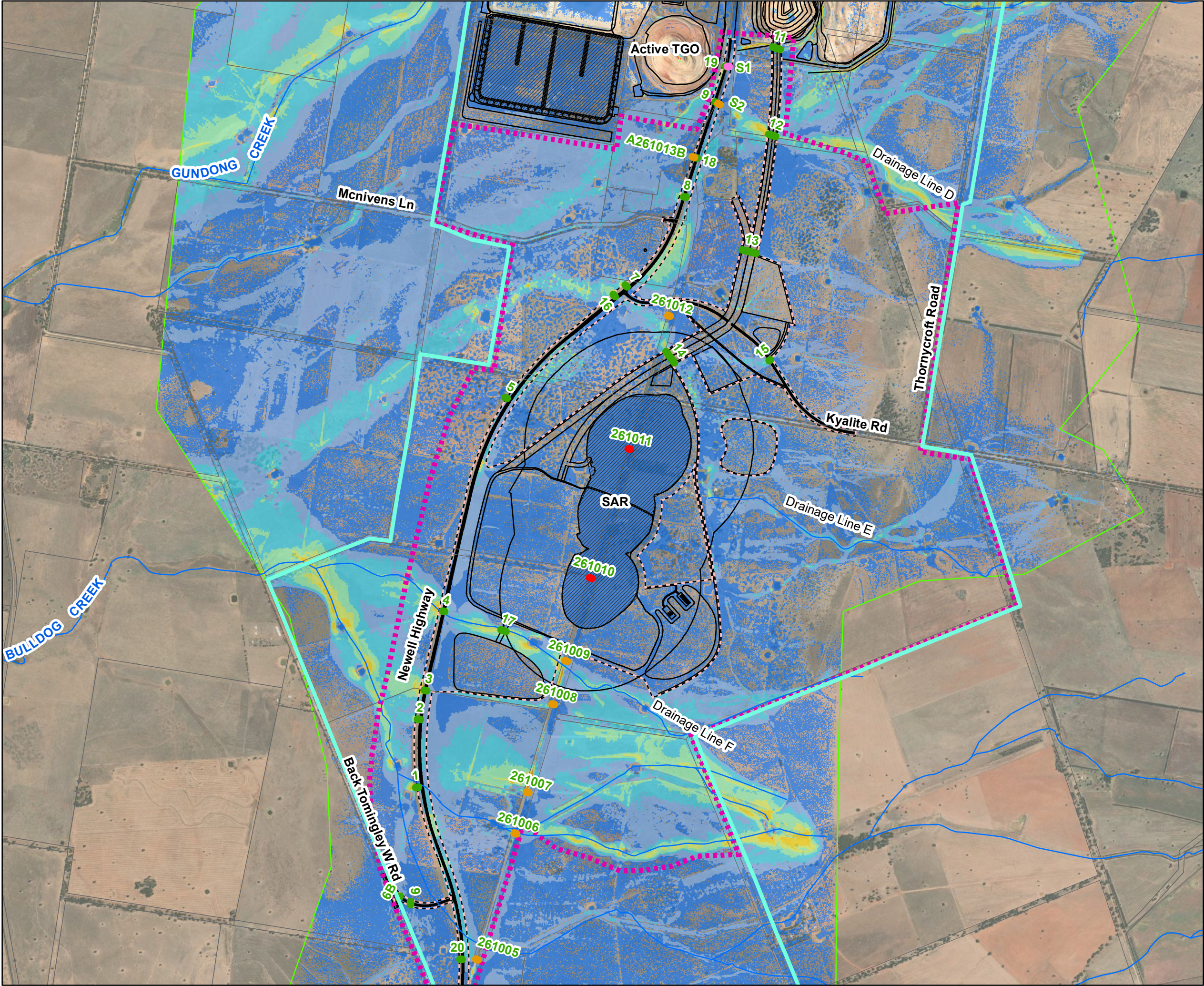


GDA 1994 MGA Zone 55 1:26,000
Model Name: D033
Originator: RK
Checker: SC
Date: September 2021

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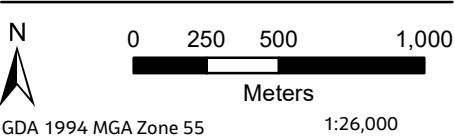
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Figure B10: 2% AEP Peak Velocity - Design Case



- LEGEND**
- Limit of Alkane Controlled Land
 - Watercourse
 - Demolished Culverts
 - New Culverts
 - Retained Culverts
 - Upgraded Culverts
 - Limit of Disturbance
 - Proposed Layout
 - SAR Infrastructure Area
 - Not Assessed
 - Cadastre
 - Model Extent

- Velocity (m/s)**
- < 0.2
 - 0.2 - 0.4
 - 0.4 - 0.6
 - 0.6 - 0.8
 - 0.8 - 1.0
 - 1.0 - 1.5
 - 1.5 - 2.0
 - > 2.0



Model Name: D033
Originator: RK
Checker: SC
Date: September 2021

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Figure B11: 1% AEP Peak Velocity - Design Case

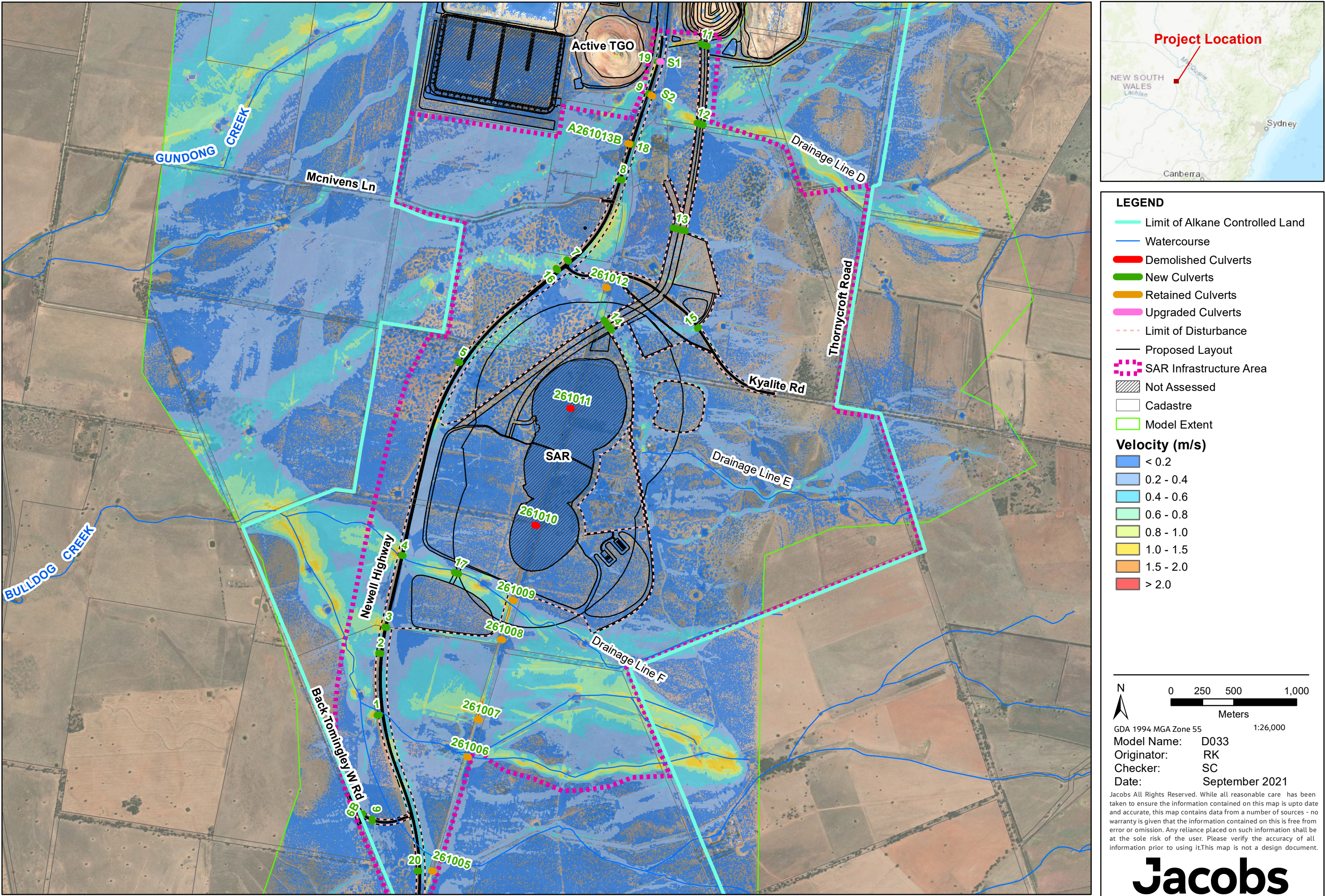
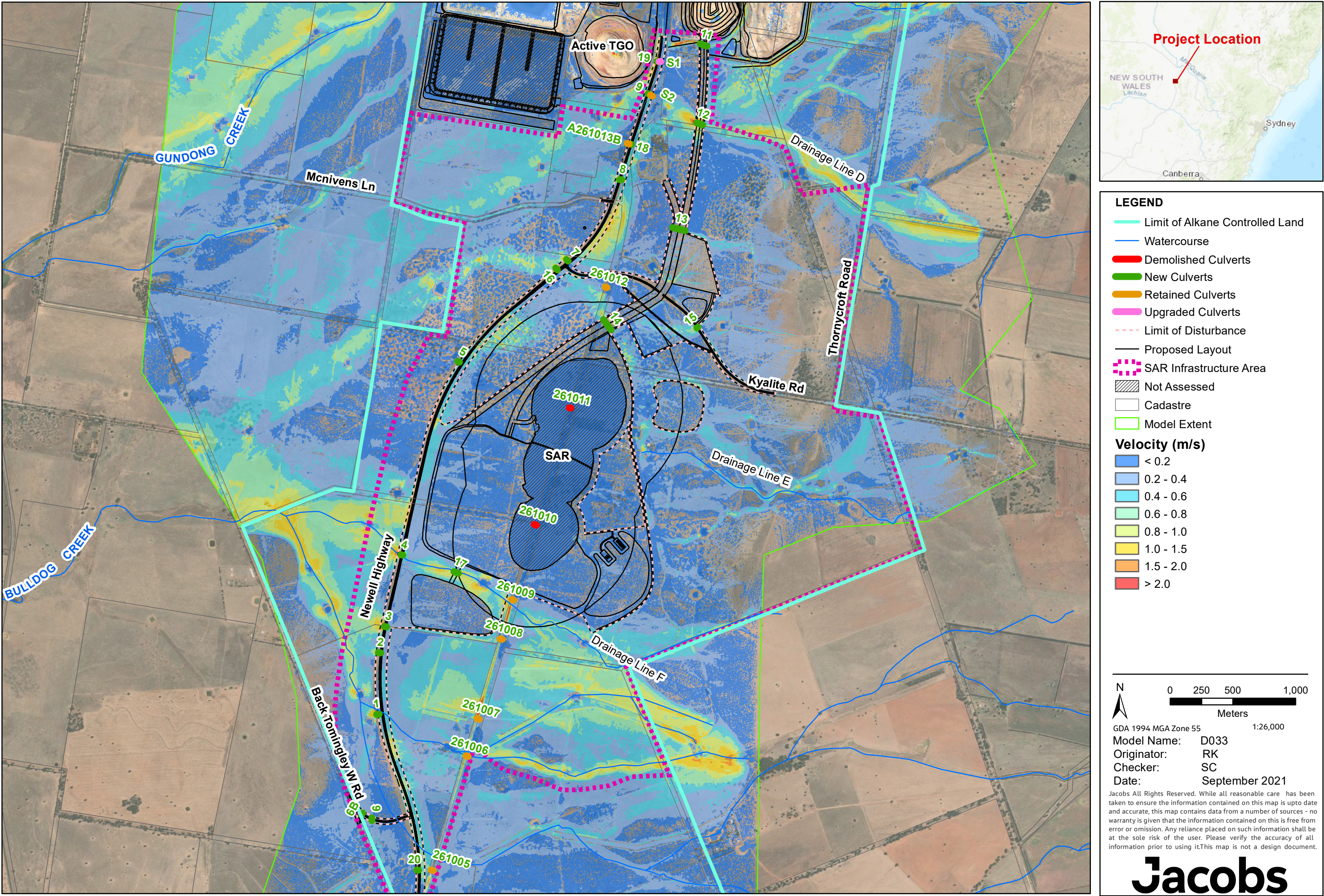


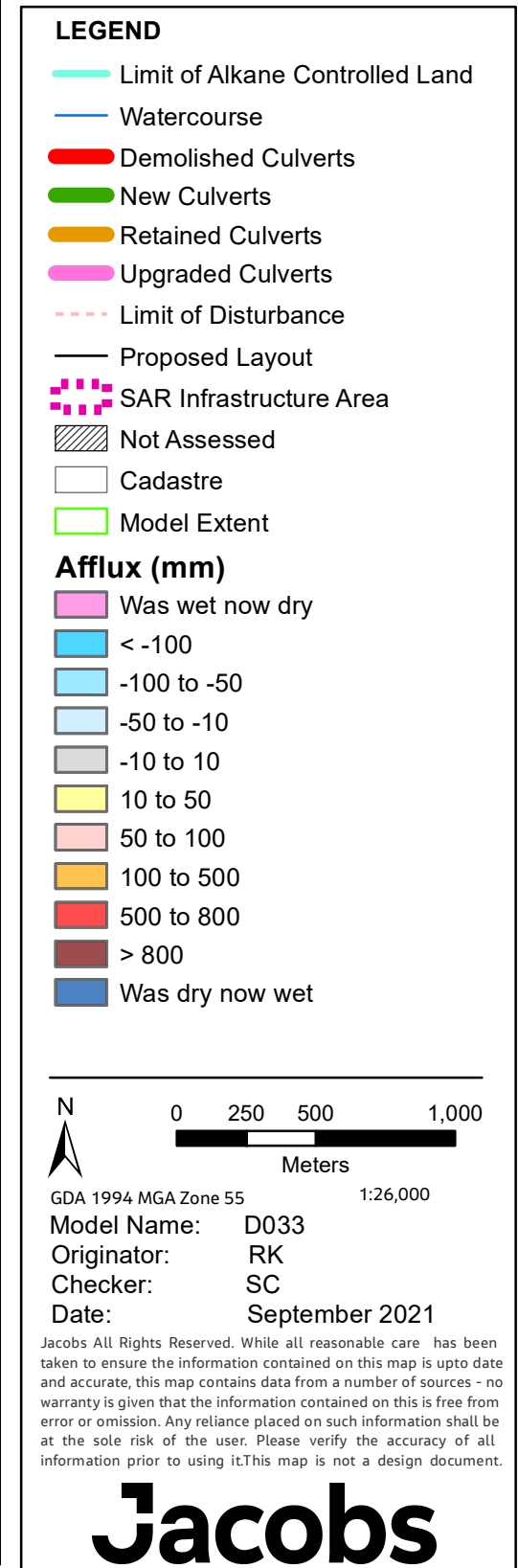
Figure B12: 0.1% AEP Peak Velocity - Design Case



Appendix C. Flood Maps Difference in Flood level

The map displays a site with various colored overlays and labels. Key features include:

- Roads:** Mcniven Ln, Newell Highway, Back Tomingley W Rd, Kyalite Rd, and Thornycroft Road.
- Water Features:** Gundong Creek and Bulldog Creek.
- Drainage Lines:** Drainage Line D, Drainage Line E, and Drainage Line F.
- Points of Interest:** Numbered points 1 through 20, and specific points 261005 through 261011.
- Other Labels:** Active TGO, SAR, A261013B, S1, S2, and 6B.



This aerial map displays a site with various geographical and infrastructure features. Roads shown include McNivens Ln, Kyalite Rd, Thornycroft Road, Newell Highway, and Back Tomingley W Rd. Water features include Gundong Creek and Bulldog Creek. Drainage lines are labeled D, E, and F. A central area is labeled 'SAR' and contains points 261010 and 261011. An 'Active TGO' area is located in the upper right. Numerous numbered points (1-20) and colored regions (yellow, orange, red, blue) are scattered across the site, likely representing specific locations or zones of interest.

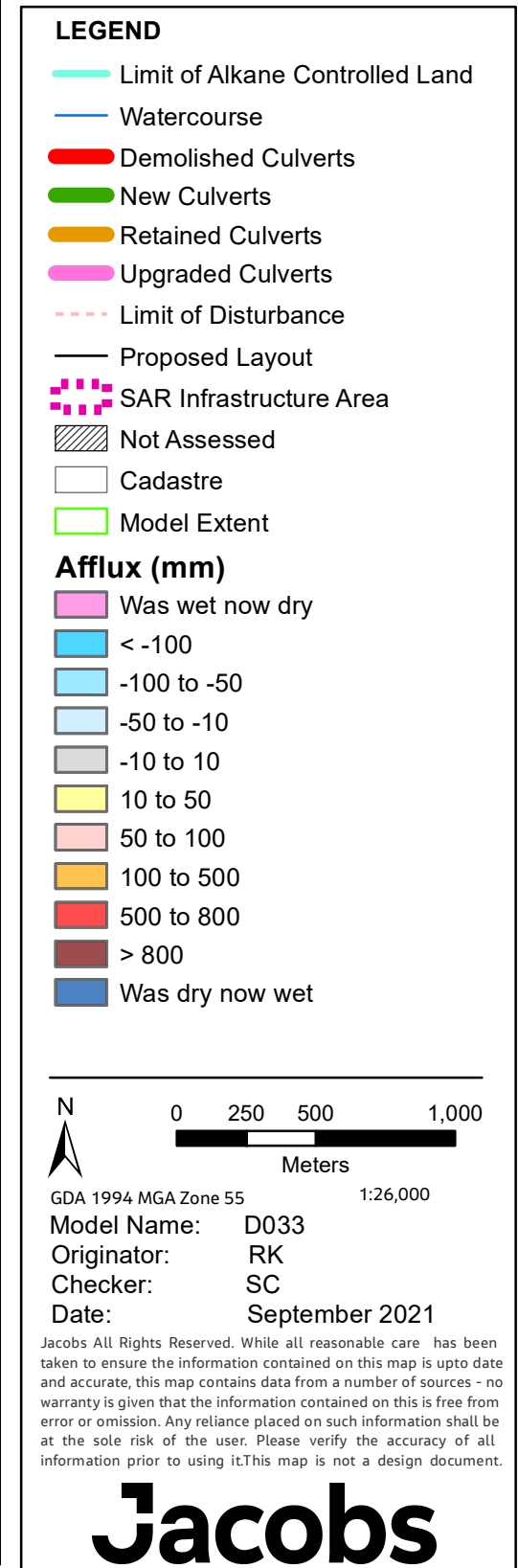


Figure C3: 5% AEP Flood Level Difference - Design vs Existing

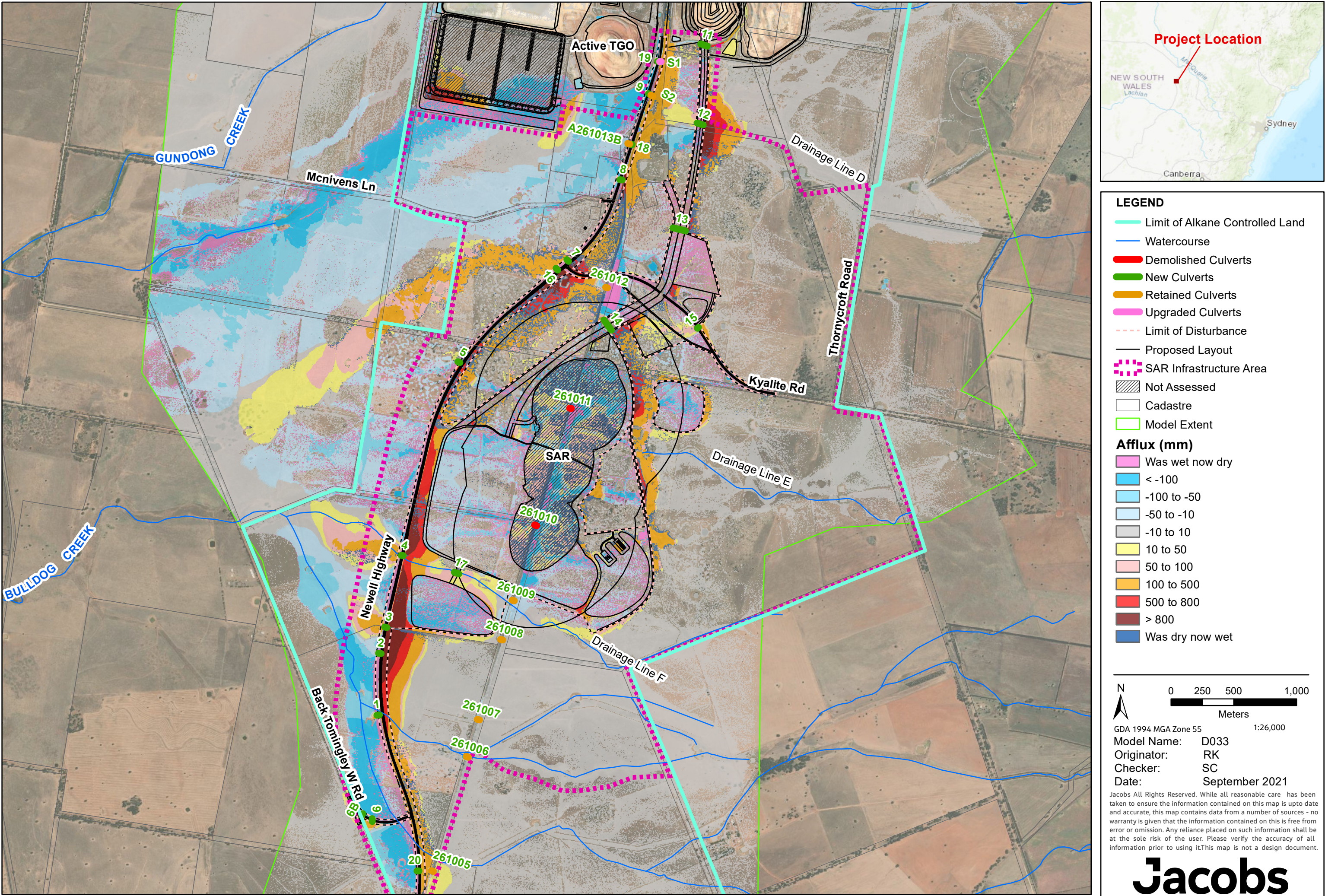
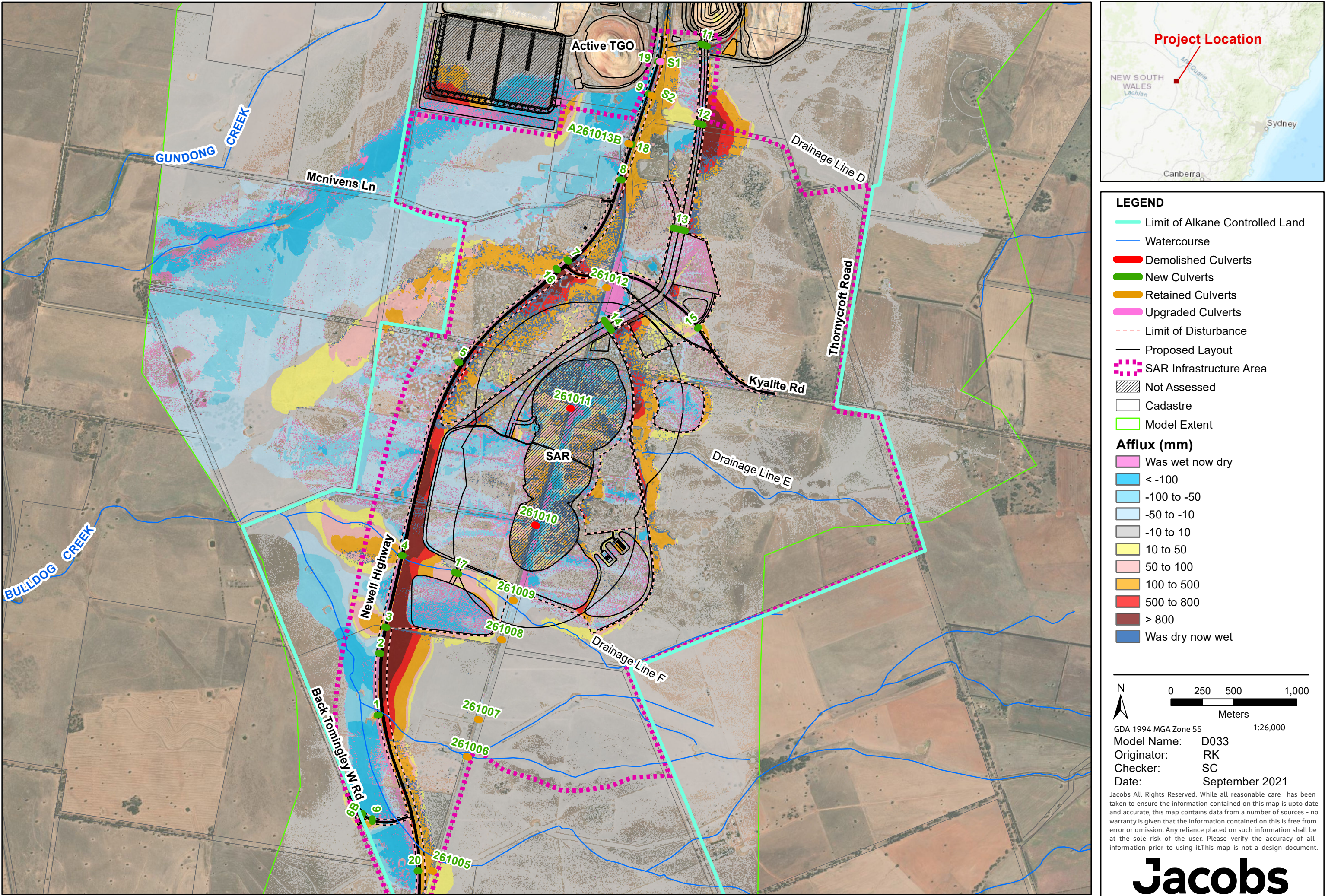
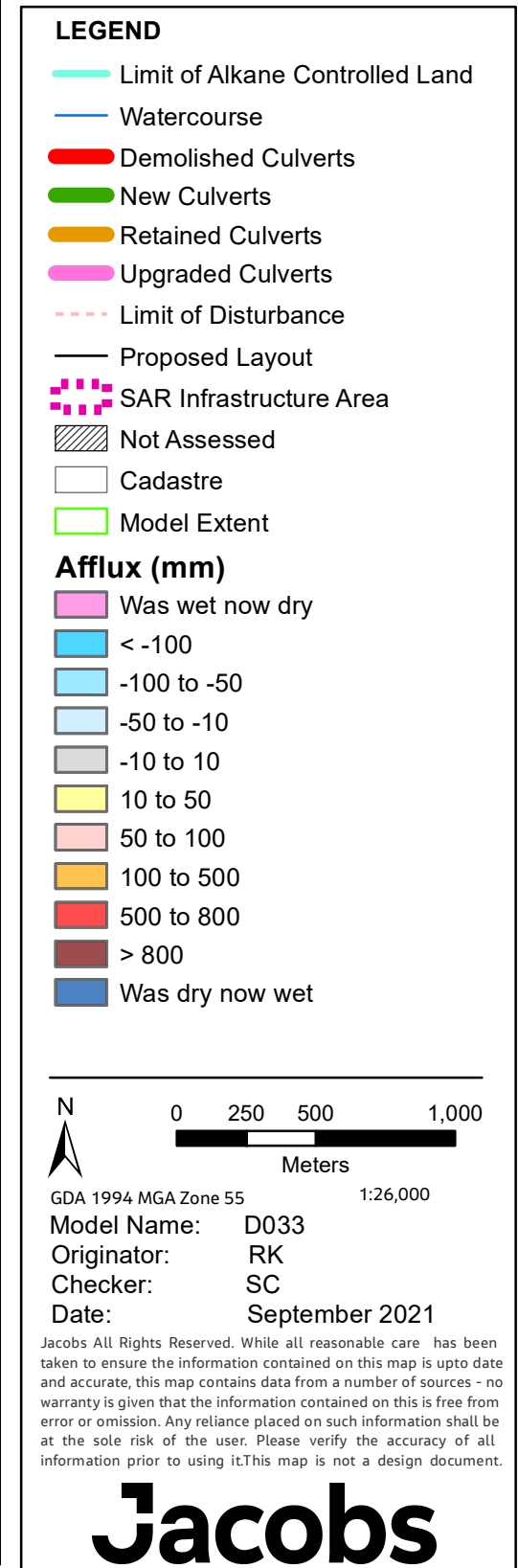


Figure C4: 2% AEP Flood Level Difference - Design vs Existing





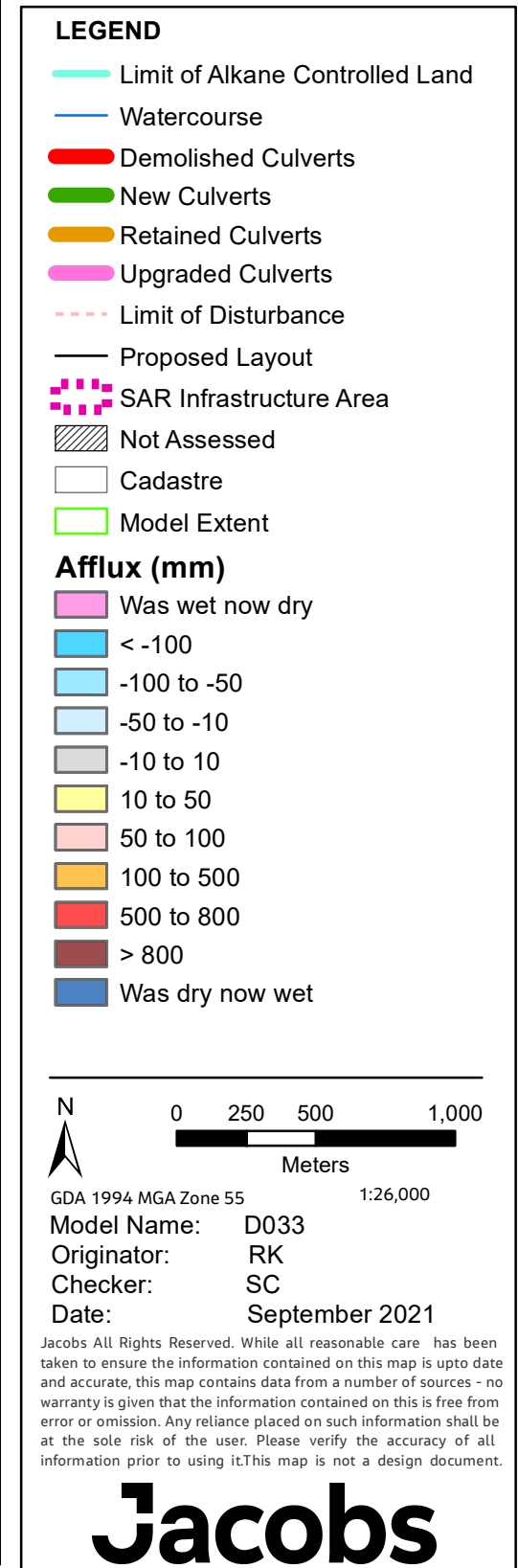
[illegible]

Figure C7: 5% AEP Flood Level Difference - Blockage vs No Blockage - Newell Highway

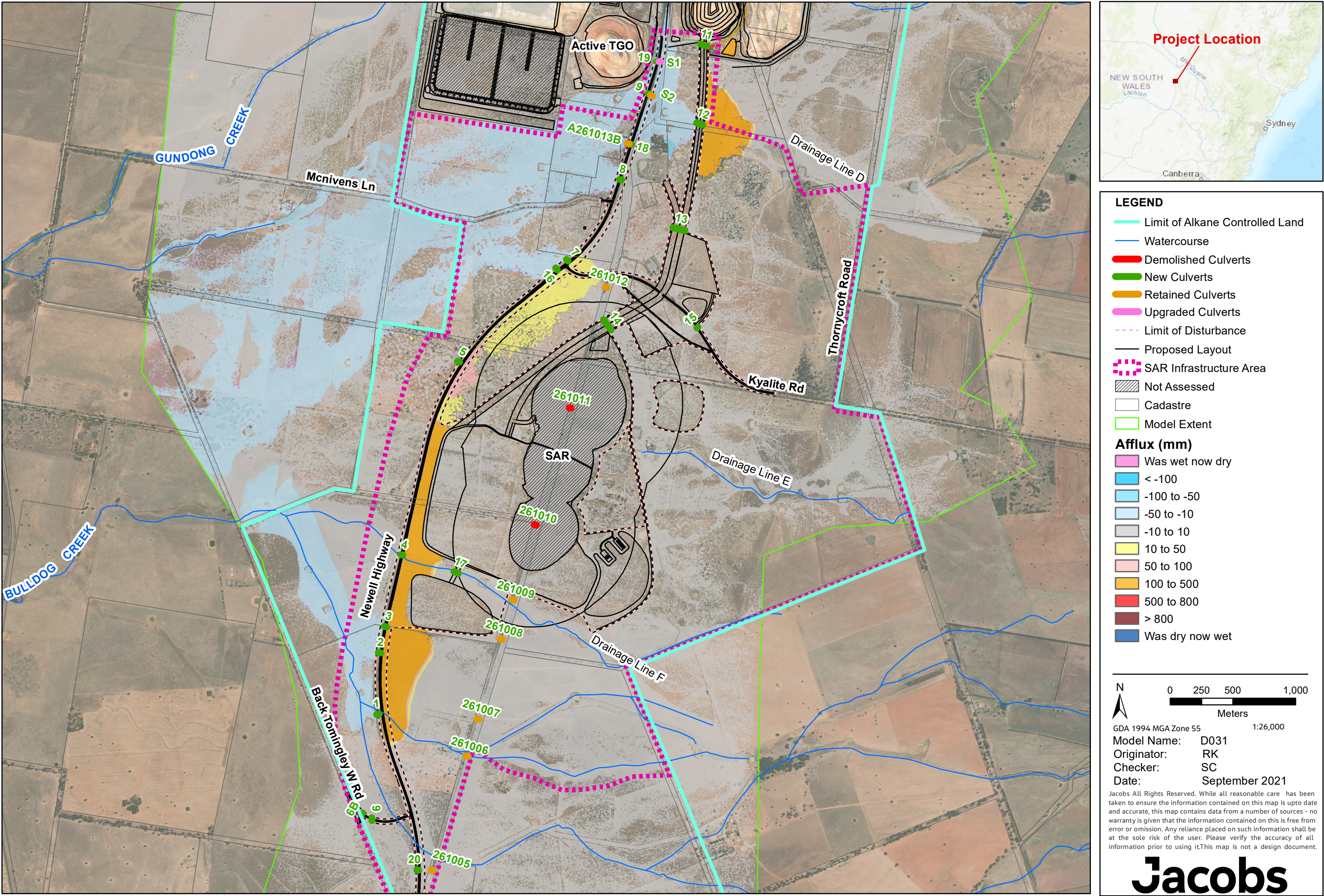
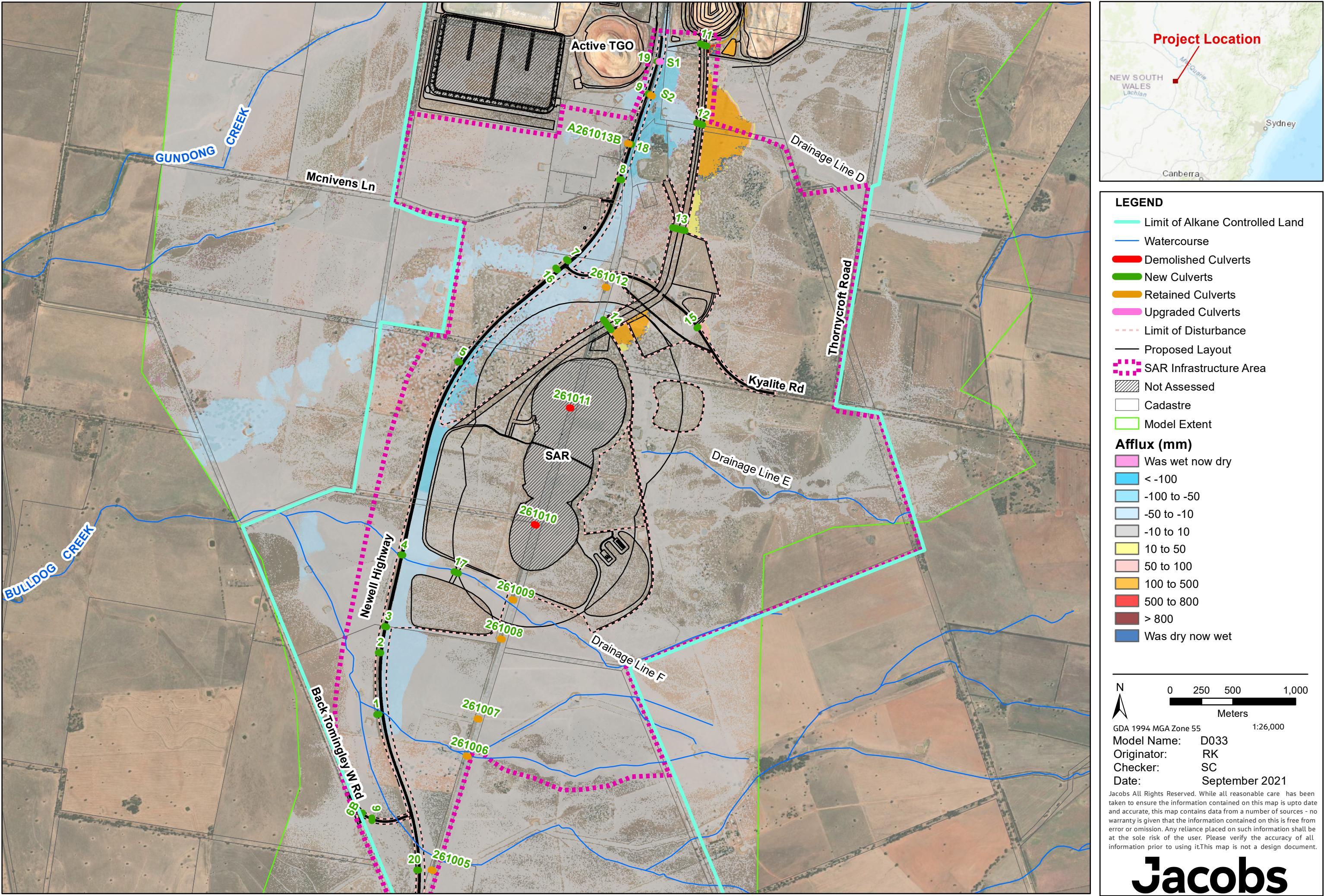
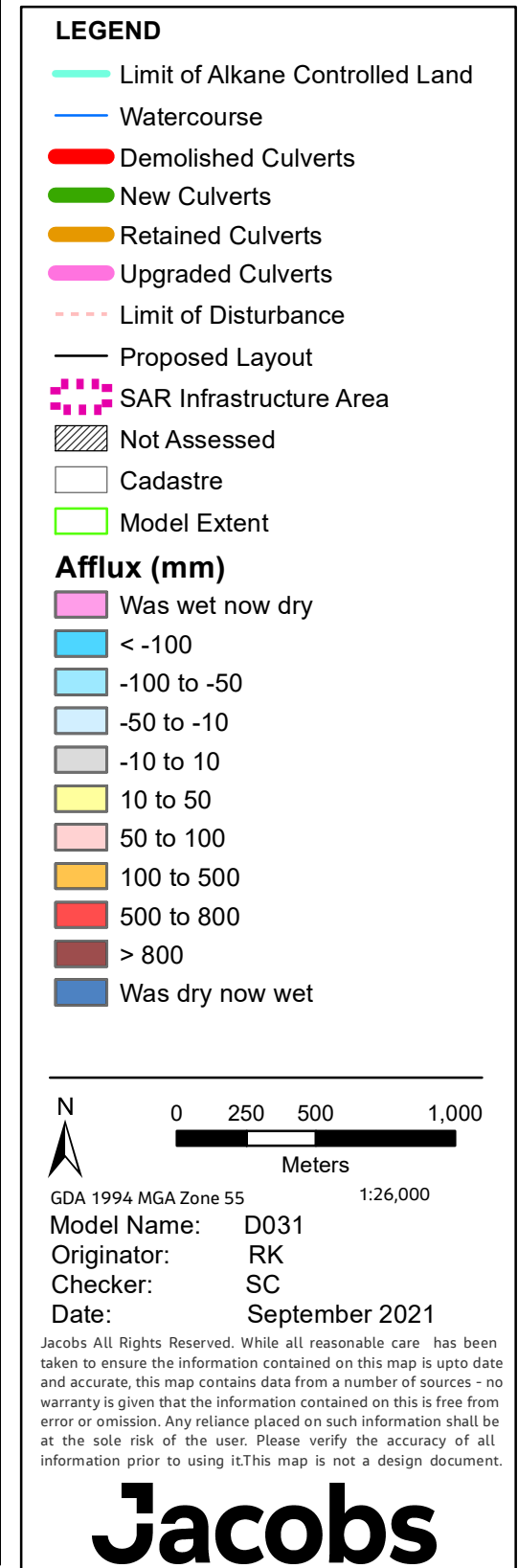


Figure C8: 5% AEP Flood Level Difference - Blockage vs No Blockage - Local Roads



This aerial map displays a site with several key features and labels:

- Water Features:** GUNDONG CREEK and BULLDOG CREEK are shown in blue. Drainage Lines D, E, and F are indicated by dashed lines.
- Roads:** Mcnivens Ln, Newell Highway, Back Tomingley W Rd, Kyalite Rd, and Thornycroft Road are labeled.
- Site Features:** An Active TGO (Topographic Observation) point is marked. A SAR (Synthetic Aperture Radar) area is highlighted in yellow. A261013B is labeled near the top center.
- Points of Interest:** Numerous numbered points (1-20) are marked along the site boundaries and roads. Specific points include 261011, 261010, 261009, 261008, 261007, 261006, 261005, 261012, 261013, 261014, 261015, 261016, 261017, 261018, 261019, 261020, 261021, 261022, 261023, 261024, 261025, 261026, 261027, 261028, 261029, 261030, 261031, 261032, 261033, 261034, 261035, 261036, 261037, 261038, 261039, 261040, 261041, 261042, 261043, 261044, 261045, 261046, 261047, 261048, 261049, 261050, 261051, 261052, 261053, 261054, 261055, 261056, 261057, 261058, 261059, 261060, 261061, 261062, 261063, 261064, 261065, 261066, 261067, 261068, 261069, 261070, 261071, 261072, 261073, 261074, 261075, 261076, 261077, 261078, 261079, 261080, 261081, 261082, 261083, 261084, 261085, 261086, 261087, 261088, 261089, 261090, 261091, 261092, 261093, 261094, 261095, 261096, 261097, 261098, 261099, 261100, 261101, 261102, 261103, 261104, 261105, 261106, 261107, 261108, 261109, 261110, 261111, 261112, 261113, 261114, 261115, 261116, 261117, 261118, 261119, 261120, 261121, 261122, 261123, 261124, 261125, 261126, 261127, 261128, 261129, 261130, 261131, 261132, 261133, 261134, 261135, 261136, 261137, 261138, 261139, 261140, 261141, 261142, 261143, 261144, 261145, 261146, 261147, 261148, 261149, 261150, 261151, 261152, 261153, 261154, 261155, 261156, 261157, 261158, 261159, 261160, 261161, 261162, 261163, 261164, 261165, 261166, 261167, 261168, 261169, 261170, 261171, 261172, 261173, 261174, 261175, 261176, 261177, 261178, 261179, 261180, 261181, 261182, 261183, 261184, 261185, 261186, 261187, 261188, 261189, 261190, 261191, 261192, 261193, 261194, 261195, 261196, 261197, 261198, 261199, 261200, 261201, 261202, 261203, 261204, 261205, 261206, 261207, 261208, 261209, 261210, 261211, 261212, 261213, 261214, 261215, 261216, 261217, 261218, 261219, 261220, 261221, 261222, 261223, 261224, 261225, 261226, 261227, 261228, 261229, 261230, 261231, 261232, 261233, 261234, 261235, 261236, 261237, 261238, 261239, 261240, 261241, 261242, 261243, 261244, 261245, 261246, 261247, 261248, 261249, 261250, 261251, 261252, 261253, 261254, 261255, 261256, 261257, 261258, 261259, 261260, 261261, 261262, 261263, 261264, 261265, 261266, 261267, 261268, 261269, 261270, 261271, 261272, 261273, 261274, 261275, 261276, 261277, 261278, 261279, 261280, 261281, 261282, 261283, 261284, 261285, 261286, 261287, 261288, 261289, 261290, 261291, 261292, 261293, 261294, 261295, 261296, 261297, 261298, 261299, 261300, 261301, 261302, 261303, 261304, 261305, 261306, 261307, 261308, 261309, 261310, 261311, 261312, 261313, 261314, 261315, 261316, 261317, 261318, 261319, 261320, 261321, 261322, 261323, 261324, 261325, 261326, 261327, 261328, 261329, 261330, 261331, 261332, 261333, 261334, 261335, 261336, 261337, 261338, 261339, 261340, 261341, 261342, 261343, 261344, 261345, 261346, 261347, 261348, 261349, 261350, 261351, 261352, 261353, 261354, 261355, 261356, 261357, 261358, 261359, 261360, 261361, 261362, 261363, 261364, 261365, 261366, 261367, 261368, 261369, 261370, 261371, 261372, 261373, 261374, 261375, 261376, 261377, 261378, 261379, 261380, 261381, 261382, 261383, 261384, 261385, 261386, 261387, 261388, 261389, 261390, 261391, 261392, 261393, 261394, 261395, 261396, 261397, 261398, 261399, 261400, 261401, 261402, 261403, 261404, 261405, 261406, 261407, 261408, 261409, 261410, 261411, 261412, 261413, 261414, 261415, 261416, 261417, 261418, 261419, 261420, 261421, 261422, 261423, 261424, 261425, 261426, 261427, 261428, 261429, 261430, 261431, 261432, 261433, 261434, 261435, 261436, 261437, 261438, 261439, 261440, 261441, 261442, 261443, 261444, 261445, 261446, 261447, 261448, 261449, 261450, 261451, 261452, 261453, 261454, 261455, 261456, 261457, 261458, 261459, 261460, 261461, 261462, 261463, 261464, 261465, 261466, 261467, 261468, 261469, 261470, 261471, 261472, 261473, 261474, 261475, 261476, 261477, 261478, 261479, 261480, 261481, 261482, 261483, 261484, 261485, 261486, 261487, 261488, 261489, 2614



Appendix D. XP-RAFTS Inputs

Catchment Name	Area (ha)	Slope (%)
A-1	654.8	2.13
A-2	516.9	1.01
A-3	864.1	0.75
A-4	1046.4	0.33
A-5	920.4	1.67
A-6	243.0	0.51
B-1	1374.1	2.51
B-2	560.9	1.35
B-3	520.0	1.62
B-4	1154.4	1.90
B-5	574.0	0.59
B-6	651.4	0.32
B-7	432.8	0.25
G-1	1942.5	1.91
G-2	1543.8	1.80
G-3	724.0	2.97
G-4	1829.1	1.44
G-5	1304.6	0.75
G-6	64.1	0.44
G-7	733.5	1.16
G-8	83.3	0.77
G-9	267.1	0.76
G-10	103.2	0.12
G-11	770.7	0.41

Catchment Name	Area (ha)	Slope (%)
S-1	187.7	1.04
S-2	271.3	0.58
S-3	425.8	0.93
S-4	248.5	0.60
S-5	739.5	0.40
S-6	207.9	1.16

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