BARALABA SOUTH PROJECT

Geomorphic Impact Assessment

Baralaba South Pty Ltd

20 November 2023

0876-17-D1

DETAILS

Report Title	Baralaba South Project, Geomorphic Impact Assessment
Client	Baralaba South Pty Ltd

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Reviewer	GR

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1 INTRODUCTION

1.1 OVERVIEW

Baralaba South Pty Ltd (the Proponant) proposes to develop the Baralaba South Project (the Project). The Project would be located approximately 8 kilometres (km) south of the township of Baralaba and 115 km west of Rockhampton in the lower Bowen Basin region of Central Queensland as shown in Figure 1.1.

The Project is a greenfield, open-cut metallurgical coal mine which would extract up to 2.5 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal to produce pulverised coal injection (PCI) coal for international export to the steel production industry over a life of 23 years. Mining activities are to be undertaken within the area of Mining Lease Application (MLA) 700057, which covers a total of 2,214 ha.

Open-cut coal mining activities would target the Baralaba Coal Measures, including the basal sub-unit Kaloola Member, where the structural dip of the Permian geology brings them to or near the surface within MLA 700057. The total resource targeted comprises 48.6 Mt of ROM coal estimated to produce approximately 34.6 Mt of PCI product coal over the life of the Project. Overburden and interburden will be disposed of in out-of-pit spoil dumps located contiguous with the pit excavation, and in-pit dumps as part of ongoing progressive rehabilitation behind the advancing operations.

The Project will provide a continuation of mining operations within the local area, wherein mining operations decline at the Baralaba North Mine, mining operations will ramp up at the Project.

The main activities associated with the Project include:

- A greenfield open-cut coal mine to be developed within Mining Lease Application (MLA) 700057; including:
  - Open-cut mining operations using conventional truck and excavator methods.
  - A Coal Handling Preparation Plant (CHPP).
  - A mining infrastructure area, including workshops, administration buildings, fuel and chemical storage facilities, warehouse and hardstand areas.
  - ROM coal and product coal stockpile pads.
  - Topsoil stockpiles, laydown areas and borrow areas.
  - Haul roads and internal roads.
  - Water management infrastructure.
  - Backfilling of mine voids with waste rock behind the advancing open-cut mining operations and the placement of waste rock in out-of-pit emplacements adjacent to the pit extents.
  - Dewatering of CHPP coal rejects and disposal on-site within mine voids behind the advancing open-cut mining operation.
  - Recovery and recycling of processed wastewater through the CHPP.
  - Other associated minor infrastructure, plant, equipment, and activities; and
  - Exploration activities.

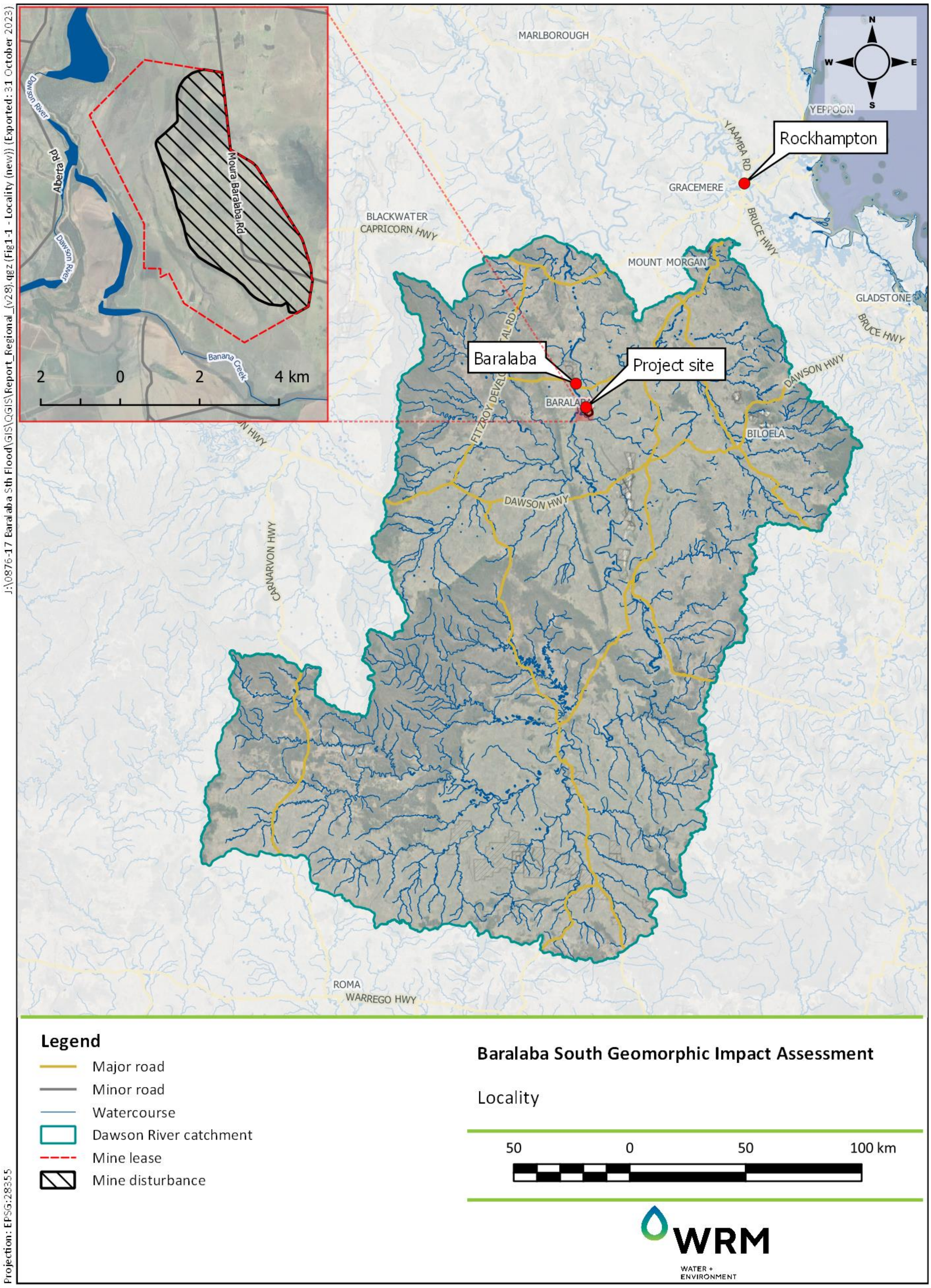

Figure 1.1 Project location and regional drainage characteristics

- realignment of approximately 4.5 km section of Moura Baralaba Road to the east of MLA 700057 (Realignment of Moura Baralaba Road is subject to separate approvals).
- product coal road transport approximately 40 km via the existing and adjacent Baralaba North Mine haul route on public Council-controlled roads to the existing train load-out facility located approximately 2 km east of Moura; and
- product coal rail transport to the Port of Gladstone for export to international markets; and

The Project includes development of an electricity transmission line (ETL) of approximately 8 km in length within a 20 m wide easement. The ETL will link the Project with the Baralaba Substation, located approximately 6 km east-south-east of the Baralaba township. Two ETL alignment options are being considered for the Project and the final ETL alignment will be determined at a later date in consideration of the outcomes of the assessments conducted for the EIS. The ETL will be subject to separate approvals, for which the necessary permitting will be undertaken by Ergon.

The final landform layout of the Project and the local drainage characteristics in the vicinity of the Project are shown in Figure 1.2.

1.2 SCOPE OF WORK

WRM Water & Environment Pty Ltd (WRM) was engaged by Baralaba South to undertake a desktop assessment of the potential impacts of the Project on the geomorphology of the Dawson River channel, floodplain and tributaries, in support of the impact assessment for the Project. The scope of this study is to:

- assess the potential impacts of the Project on the geomorphology of the Dawson River channel, floodplain and tributaries;
- define the consequential impacts on environmental values of the Dawson River system; and
- describe the geomorphic properties and behaviour of the Dawson River to characterise the dominant erosion mechanisms and potential for landform changes because of the Project.

The report relies upon the results of detailed hydraulic modelling undertaken by Engeny (2023) as part of the preparation of the Flood Impact Assessment for the Project to define hydraulic characteristics (velocity, shear stress and stream power) of the Dawson River and floodplain under existing conditions and following development of the Project.

1.3 REPORT STRUCTURE

The report is structured as follows:

- Section 2 provides an overview of government legislation and policies relevant to assessment of the impacts of the Project;
- Section 3 describes the geomorphic characteristics of the Dawson River and its tributaries and floodplain in the vicinity of the Project;
- Section 4 provides an assessment of the geomorphic impacts of the Project;
- Section 5 presents a summary and the conclusions of the assessment;
- Section 6 provides a list of references; and
- Section 7 lists a glossary of terms.

Figure 1.2 Baralaba South Project conceptual final landform

2 LEGISLATION AND POLICY

The Project will require environmental approvals under State and Commonwealth legislation. An overview of policies and legislation potentially relevant to the geomorphic impacts of the Project is provided in the following sections.

2.1 COMMONWEALTH LEGISLATION

The *Environment Protection and Biodiversity Conservation Act 1999 (Cth*) (EPBC Act) outlines the requirements relating to the management and protection of matters of national environmental significance (MNES). An action that has, will have or is likely to have a significant impact on MNES may be referred to the Australian Government Minister for the Environment (the Minister) for assessment. If the Minister decides that significant impacts are likely, then the action is known as a 'controlled action' and requires approval under the EPBC Act.

2.2 STATE LEGISLATION AND GUIDELINES

2.2.1 Environmental Protection Act 1994

Resource activities are defined as environmentally relevant activities (ERAs) under the *Environmental Protection Act 1994 (Qld)* (EP Act). The environmental aspects of the Project are regulated by the EP Act. The object of the EP Act is to:

> *Protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).*

2.2.2 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water) is the primary instrument for surface water management under the EP Act. The EPP Water governs discharge to land, surface water and groundwater, aims to protect environmental values (EVs) and sets water quality guidelines and objectives.

The processes to identify EVs and to determine Water Quality Guidelines and Water Quality Objectives (WQOs) in Queensland waters are based on the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018).

2.2.3 Dawson River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Dawson River Sub-basin except the Callide Creek catchment, September 2011

This document is referenced in Schedule 1 of the EPP Water. It contains EVs and WQOs for waters in the Dawson River Sub-basin. Note that EV's for waterway health other than water quality are not specified in the EPP Water or as part of the sub basin EV's.

3 EXISTING ENVIRONMENT

3.1 REGIONAL DRAINAGE CHARACTERISTICS

The Project is located in the catchment of the Dawson River (a tributary of the Fitzroy River). Figure 3.1 shows the drainage network of the Dawson River catchment.

The major drainage features in the vicinity of the Project are the Dawson River and Banana Creek, a tributary of the Dawson River (see Figure 1.2). The Dawson River rises in the Carnarvon Range, about 240 km southeast of the Project. The Dawson River flows to the Project from the south, before meeting the Mackenzie River about 69 km north of the Project. The Dawson and Mackenzie rivers combine to form the Fitzroy River, which discharges to the Coral Sea at Keppel Bay, about 130 km northeast of the Project and about 39 km southeast of Rockhampton.

According to the "Ordered drainage 100K - Queensland" dataset prepared by the Department of Natural Resources and Mines (DNRM)[1], the Dawson River at the Project site is an 8th order watercourse, while Banana Creek at the confluence with Dawson River is a 5th order watercourse.

Flows in the Dawson River are regulated under the Dawson Valley Water Supply Scheme (see Figure 3.2). The scheme relies on six in-stream weirs:

- Theodore Weir – with a capacity of 4,760 ML
- Orange Creek Weir – with a capacity of 6,780 ML
- Moura Weir – with a capacity of 7,700 ML
- Glebe Weir – with a capacity of 17,700 ML
- Neville Hewitt Weir – with a capacity of 11,300 ML
- Gyranda Weir – with a capacity of 16,500 ML

Water from the scheme is used to supply irrigation water for agriculture, including cotton, fodder, cereal and horticultural crop. It also provides urban water supply for Theodore, Moura, Baralaba and Duraringa; and industrial water supply, primarily for mining.

The scheme is licenced under the *Water Plan (Fitzroy Basin) (2011)* and operated in accordance with the Resource Operations Licence held by Sunwater. Since October 2018, Theodore Water has ownership and management of the scheme. Sunwater manages the bulk assets, including the Dawson River Weirs.

Given the size of the weirs in relation to the total catchment flow, the scheme would likely impact on the small to moderate flow regime of the Dawson River. The weirs would have only a minor impact on large flows.

[1] http://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={2E074A5A-F00B-40C3-9C67-31F087F1F16F}

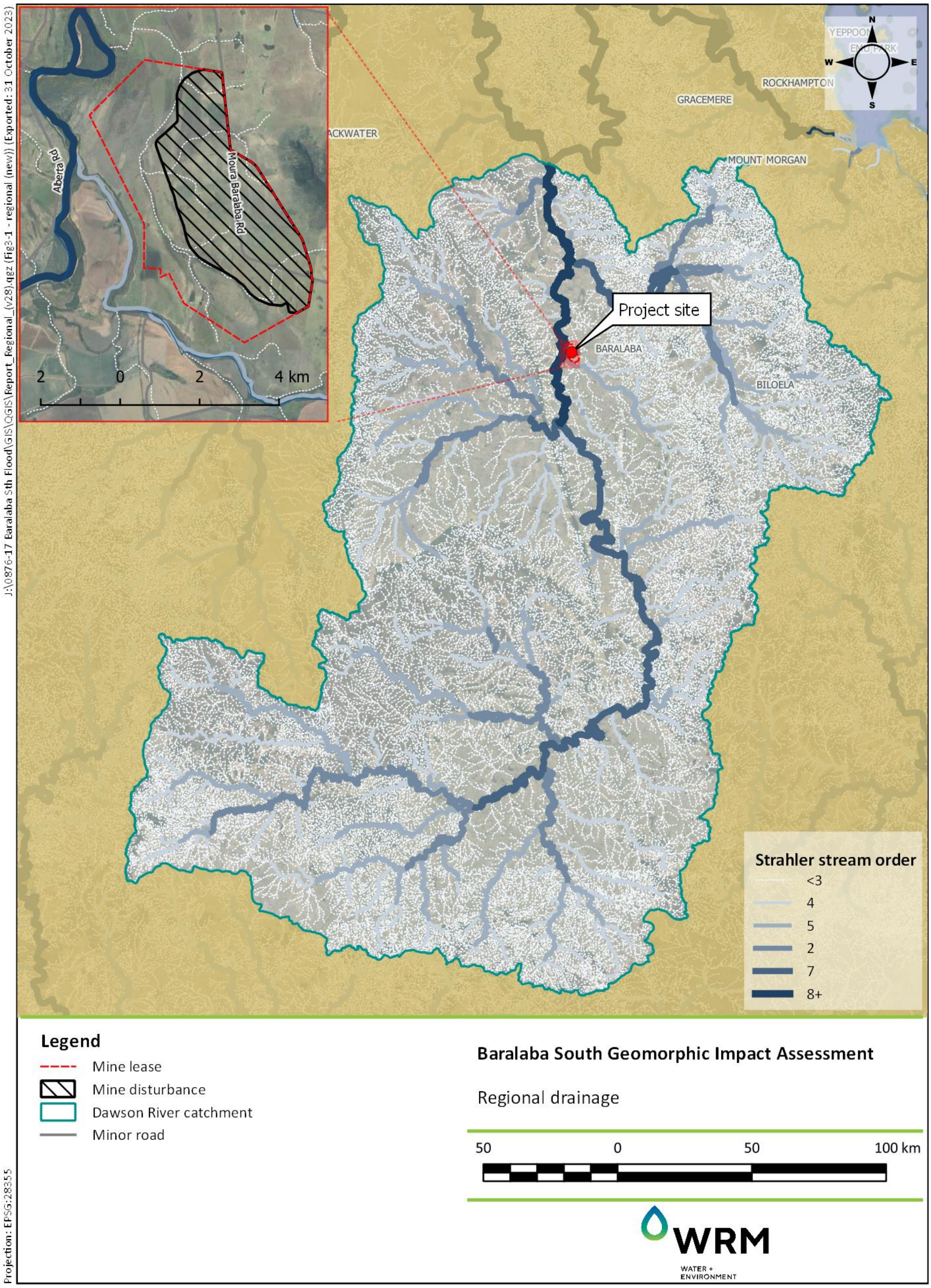

Figure 3.1 Regional drainage characteristics

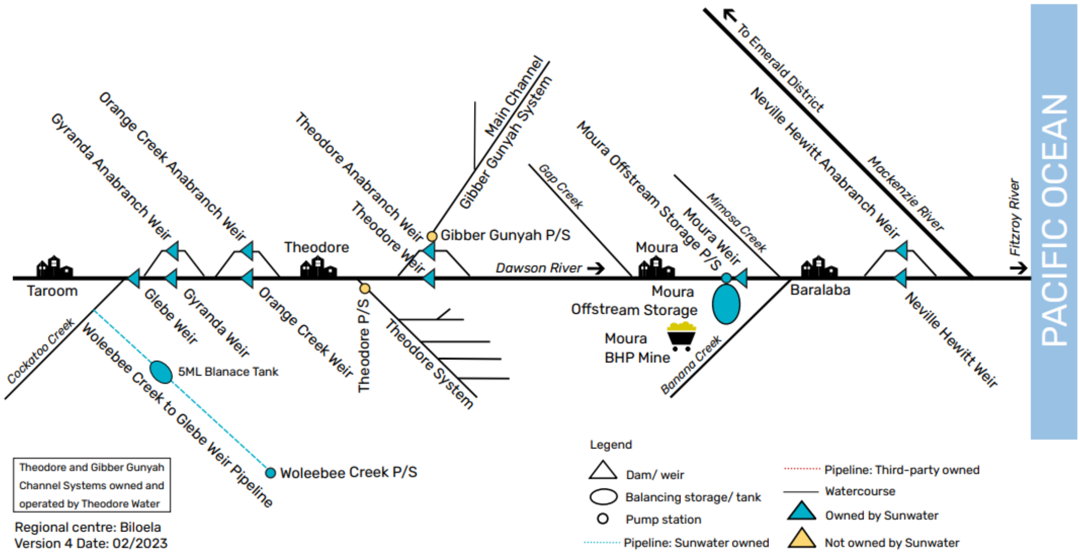

Figure 3.2 Dawson Valley Water Supply Scheme schematic

3.2 GEOLOGY

3.2.1 Geological history

The CSIRO (1968) compiled a series of papers on the Lands of the Dawson and Fitzroy area which included a summary of the geological history of the Dawson River prepared by Wright (1968). The oldest rocks occur in the north-east of the area, where interbedded sediments and volcanics were laid down in lower Palaeozoic (possibly Precambrian) times and metamorphosed to mainly schist and quartzite by mid Devonian. From middle Devonian through to middle Carboniferous times sediments and volcanics were laid down in the Yarrol Basin adjacent to the older rocks.

After a terrestrial period during upper Carboniferous and lower Permian times the sediments and volcanics of the Bowen Basin were deposited over most of the area during Permian times. Marine and non-marine sequences are represented. During Mesozoic times the northern part of the area was subject to erosion but in the south and centre, thick terrestrial deposits (mainly shale and sandstone) were laid down during the Triassic.

Subsequently a period of orogeny occurred during which the Bowen Basin rocks were folded, faulted, and intruded to varying degrees throughout the area. After the orogeny, the whole area, except the Surat Basin in the south, was exposed to erosion during Jurassic and Cretaceous times. In the Surat Basin non-marine sandstones, siltstones, and shales were deposited in the Jurassic and early Cretaceous. Later in the Cretaceous, marine sandstones and claystones were deposited. From late Cretaceous, erosion characterised the area.

3.2.2 Local geomorphology

The local geology of the study area is described in the Soil and Lands Suitability assessment prepared for the Project (Environmental Earth Sciences, 2019). In summary, the main units of direct relevance to the study area are the Quaternary Alluvium (Qa); the Cainozoic (Tertiary) depositional materials (Qr [previously Cz]), variously termed 'soil' and alluvium, but also include unconsolidated colluvial materials of different forms depending on local provenance.

Quaternary alluvial sediments are found in the flatter areas of the western and southern portion of the Baralaba South Project area along the Dawson River floodplain and are of direct relevance to this assessment. Environmental Earth Sciences (2019) describe four soil landscapes as follows:

Soil Landscape 1: The active river channel of the Dawson River and its anabranches. This includes the channel banks and low-lying in-channel benches that are subject to frequent flooding. The dominant soils in this landscape are unstable, sometimes deep cracking clays (Vertosols) of upper catchment origin.

Soil Landscape 2: The active channelled 'lower' floodplain of the Dawson River anabranches that is relatively low-lying and subject to regular flooding. The dominant soils in this landscape are unstable, sometimes deep cracking clays (Vertosols) of upper catchment origin. They often display well-developed melon hole and normal gilgai microrelief.

Soil Landscape 3: Flood channels within the 'upper' floodplain represent both local and main channel flooding. These are back-plain channels, flood channels, and chutes. The dominant soils in this landscape are the sometimes deep cracking clays (Vertosols) of upper catchment origin that remain wetter than the surrounding soils.

Soil Landscape 4: The elevated, or 'upper' floodplain, which is typically level with extensive, swampy, back-plains that include the channels of Soil Landscape 3. These areas are still commonly flooded from the combination of both local and regional inundation.

3.3 LOCAL DRAINAGE CHARACTERISTICS

Figure 3.3 shows the local drainage characteristics of the Dawson River floodplain and Banana Creek in the vicinity of the Project.

The main drainage feature is the Dawson River, which drains from south to north across a broad floodplain. There are a number of anabranches and flood channels across the floodplain which become active as floodwaters rise. The Baralaba Weir pool (formed behind Neville Hewitt Weir) extends upstream past the Project site along both the Dawson River and Banana Creek.

One particularly significant flood channel (referred to as Flood Channel A, see Figure 3.3) starts about 10 km south (upstream) of the Project and causes Dawson River floodwaters to interact with Kianga Creek and Banana Creek flows for Dawson River 10% annual exceedance probability (AEP) flows and larger.

The connectivity of the various floodplain channels for the 10% AEP flooding (Dawson River and Banana Creek) is shown in Figure 3.3. The characteristics of these floodplain channels, as well as the Dawson River floodplain are discussed below. The Adopted Middle Thread Distances (AMTD) have been estimated for discussion purposes only.

3.3.1 Dawson River

The Dawson River in the reach passing the Project site (91 km AMTD to about 100 km AMTD) has a well-defined channel, about 150 m to 200 m wide and approximately 10 m to 15 m deep, carved through a relatively flat floodplain. The river channel forms the weir pool of Neville Hewitt Weir and as such, the bedform is wholly drowned in this reach.

The Dawson River has a perched channel, where the riverbanks are raised higher than the adjacent floodplain. The floodplain is between about 5 km to 6 km wide in the vicinity of the Project.

The river channel comprises a continuous active channel carrying the regulated flows, with multiple anabranches and flood channels in the vicinity of the Project. The presence of multiple anabranches and flood channels indicates historical and ongoing lateral activity of the Dawson River channel in the vicinity of the Project.

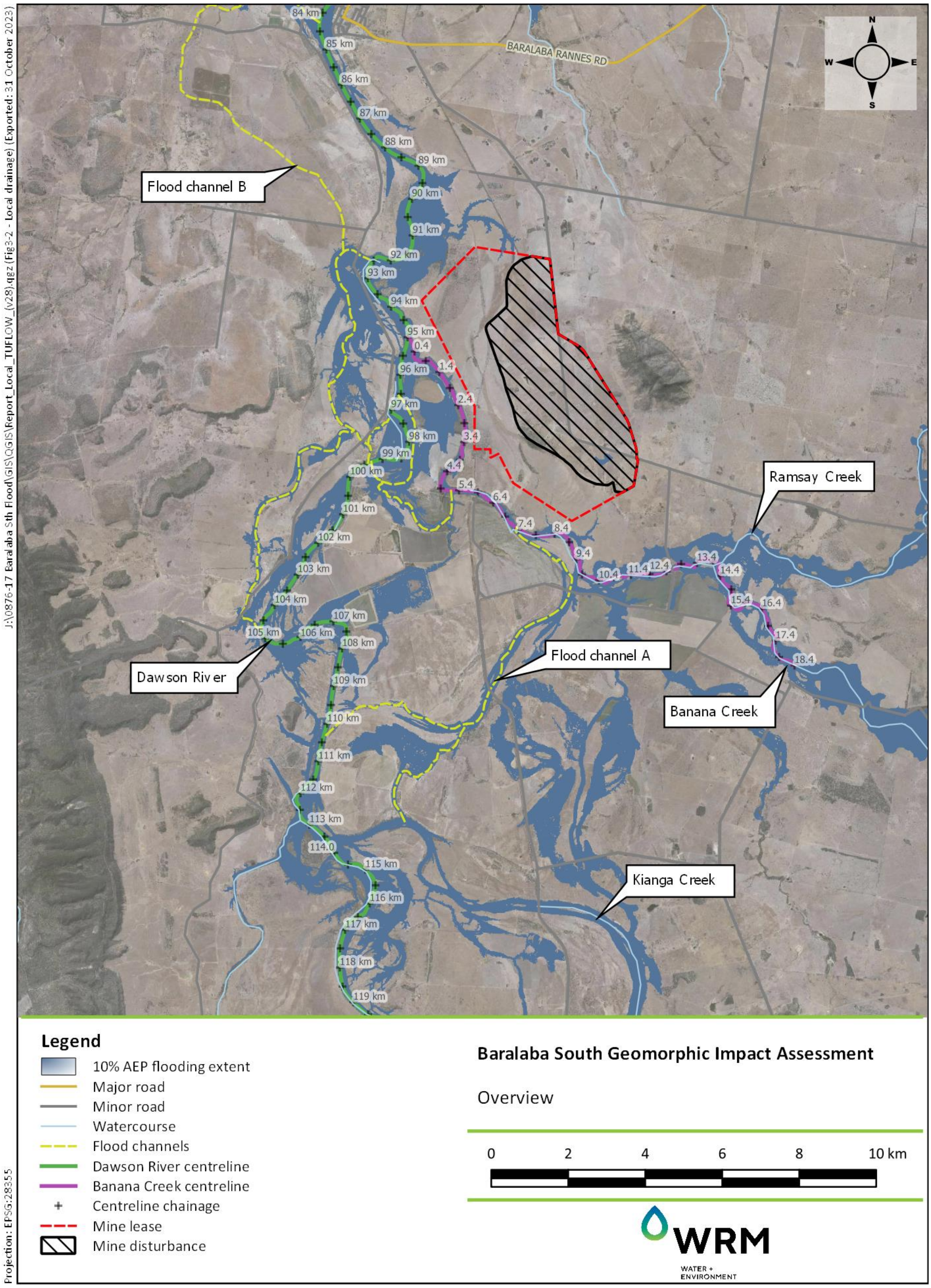

Figure 3.3 Local drainage characteristics

3.3.2 Banana Creek

Banana Creek discharges to the Dawson River at approximately 95 km AMTD, about 0.7 km west of the proposed Project boundary. Banana Creek in the vicinity of the Project is an ephemeral stream, with the final 9 km of the lower reach crossing the Dawson River floodplain adjacent to the Project and consequently impacted by Dawson River backwater and floodwater as shown in Figure 3.3. It is likely that this section of the Banana Creek channel is a palaeo channel of the Dawson River.

The Banana Creek channel on the Dawson River floodplain is about 150 m wide and is incised about 8 m to 10 m below the adjacent floodplain consistent with the Dawson River main channel. Like the Dawson River, the Banana Creek channel is slightly perched above the adjacent floodplain. The creek channel comprises of a 40 m wide low flow channel that has incised into the only Dawson River palaeo-channel surrounded by a lower bench about 8 m below the surrounding floodplain. The creek channel is heavily vegetated (including stands of mature trees), which indicates a reasonably stable channel.

The upper reach of Banana Creek that is not affected by Dawson River floodwaters is only 40 m wide and about 2 m to 4 m deep. The channel has low flood carrying capacity with significant flood flows draining along multiple flood channels.

3.3.3 Floodplain channels

There are several flood channels on the Dawson River floodplain in the vicinity of the Project. These channels only become active once Dawson River floodwaters reach a sufficiently high level, generally at about or even just below the 'bank-full' level.

Two notable flood channels on the Dawson River floodplain in the vicinity of the Project include:

- Flood Channel A (see Figure 3.3), connecting the Dawson River (about 110 km AMTD) and Banana Creek (about 7.5 km AMTD). Flood channel A is likely to be a remnant or palaeo channel of the Dawson River.
- Flood Channel B (see Figure 3.3), connecting Dawson River (about 84.5 km AMDT) to an anabranch which loops northwest to bypass Baralaba Town and the Neville Hewitt Weir, before turning east to pass north of the Baralaba North coal mine and re-join the Dawson River at about 76.5 km AMTD. There is no specific channel in this location. However, it is important for this assessment because of the potential changes in distribution of flows due to the Project.

The flood channel across the Project area potentially becomes active for a concurrent Dawson River and Banana Creek 10% AEP event. The flood channel drains local catchment flows for more frequent events or backwater flooding directly from the Dawson River.

3.4 EXISTING FLOODING CHARACTERISTICS

3.4.1 Overview

Flood modelling of the Dawson River and Banana Creek for the Project had been undertaken by Engeny (2023) (Appendix A of the EIS). The Engeny model results have been used to characterise hydraulic conditions of relevance to the floodplain geomorphology (e.g., velocity, bed shear stress and stream power). Modelling has been undertaken for two storm event scenarios:

- Scenario 1 has the storm centred across the entire Dawson River (Dawson River flood). Design discharges for this scenario use Dawson River design rainfalls (factored for catchment area) and Dawson River storm durations.
- Scenario 2 has the storm centred across the Banana Creek catchment (Banana Creek flood). Design discharges for this scenario use Banana Creek design rainfalls (factored for catchment

area) and Banana Creek storm durations, which are shorter than for the Dawson River flood. Scenario 2 assumes that a 10% AEP design event is occurring concurrently in the Dawson River.

Note that Banana Creek discharges are larger for Scenario 2 than for Scenario 1 due to the differences in aerial reduction factors and storm durations. A detailed description of the modelling scenarios is given in the Flood Impact Assessment report (Engeny, 2023).

For both scenarios, modelling has included:

- An assessment of the 10% AEP design flood to represent the behaviour of the river/creek for an event moderately larger than the bank full flow conditions. The bank full flow is the maximum flow that the channel can carry before it overflows onto the adjacent floodplain. In geomorphologic studies, the bank full flow is often considered to be the stream-forming flow, because it often exerts the greatest influence on channel geometry. to represent a moderate overbank flood. Figure 3.3 shows that the 10% AEP event generally just exceeds the Dawson River and Banana Creek channel capacities. A smaller event was not assessed by Engeny and as such the true bank full flow has not been determined.
- An assessment of the 1% AEP design flood to represent a rare flood event that has significantly engaged the floodplain flows. This type of event has been used to assess the potential for a significant morphological change (such as a channel avulsion).
- An assessment of the 0.1% AEP design flood, to represent extreme flooding conditions.

3.4.2 Flood depths and extents

Figure 3.4 to Figure 3.6 show the predicted peak flood depths for the 10% AEP, 1% AEP and 0.1% AEP Dawson River design flood events for existing conditions. Figure 3.7 to Figure 3.9 show the predicted peak flood depths for the 10% AEP, 1% AEP and 0.1% AEP Banana Creek design flood events for existing conditions (including a Dawson River 10% AEP design flood event).

The results show that the Dawson River is confined to the main channel and the primary flood channels for the 10% AEP event, whereas the Banana Creek floodplain is mostly engaged for this event. The mine disturbance area would not be impacted by the Dawson River 10% AEP event but the northern sections of the mine disturbance area would be moderately inundated by a Banana Creek 10% AEP event.

Most of the floodplain is engaged for a 1% AEP Dawson River flood with the northern section of the mine disturbance area inundated by 1% AEP events from both the Dawson River and Banana Creek.

3.4.3 Flood velocity

Figure 3.10 to Figure 3.12 show the predicted peak flood velocities for the 10% AEP, 1% AEP and 0.1% AEP Dawson River design flood events for existing conditions. Figure 3.13 to Figure 3.15 show the predicted peak flood velocities for the 10% AEP, 1% AEP and 0.1% AEP Banana Creek design flood events for existing conditions (including a Dawson River 10% AEP design flood event).

Velocities along the Dawson River and Banana Creek channel generally vary between 1m/s to 2 m/s. Floodplain velocities are generally less than 0.5 m/s for the 1% AEP event increasing to 0.75 m/s for the 0.1% AEP event. A further assessment of channel velocities is given in Section 3.5.

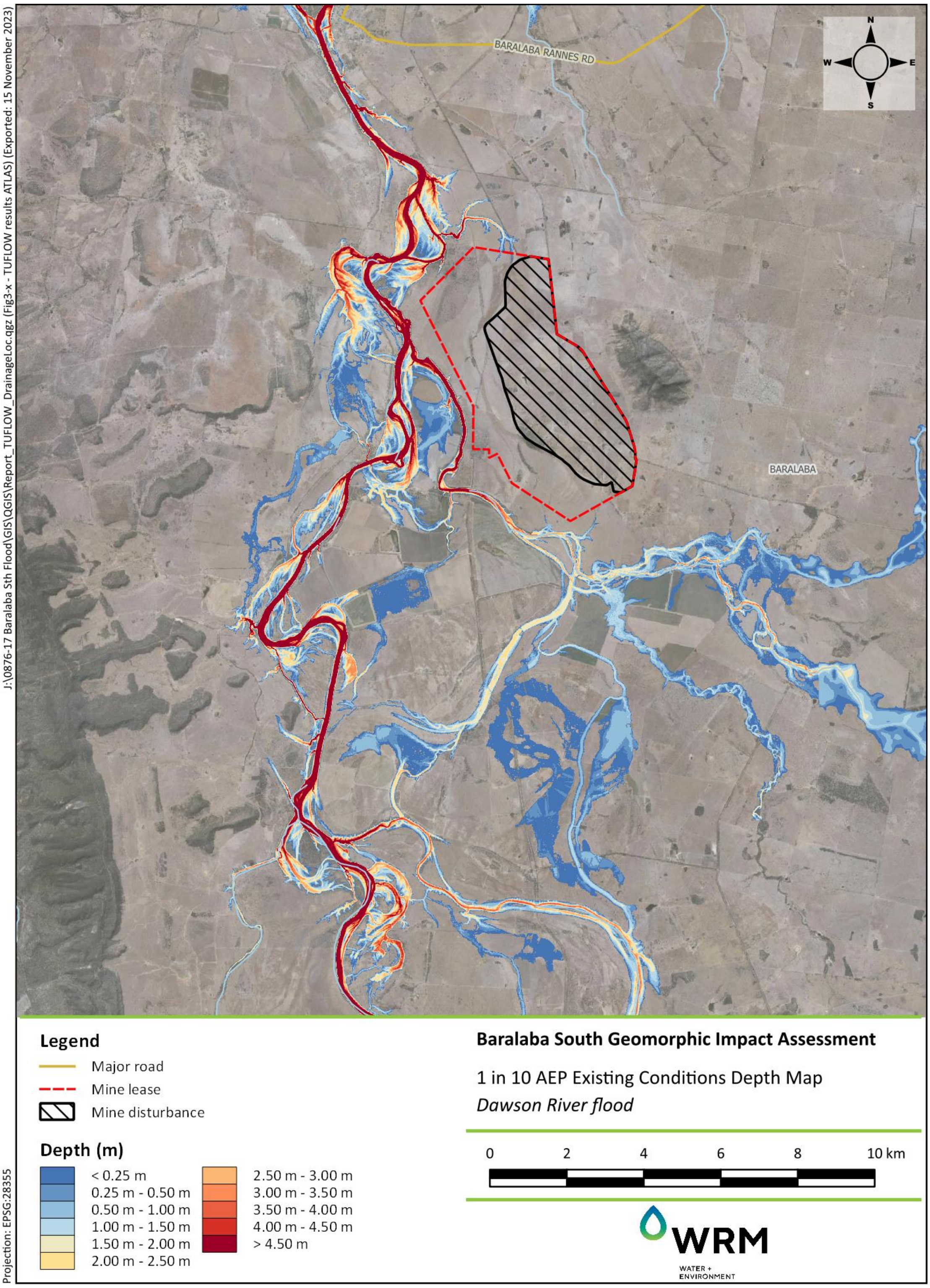

Figure 3.4 Existing conditions peak depth, Dawson River flood, 10% AEP event

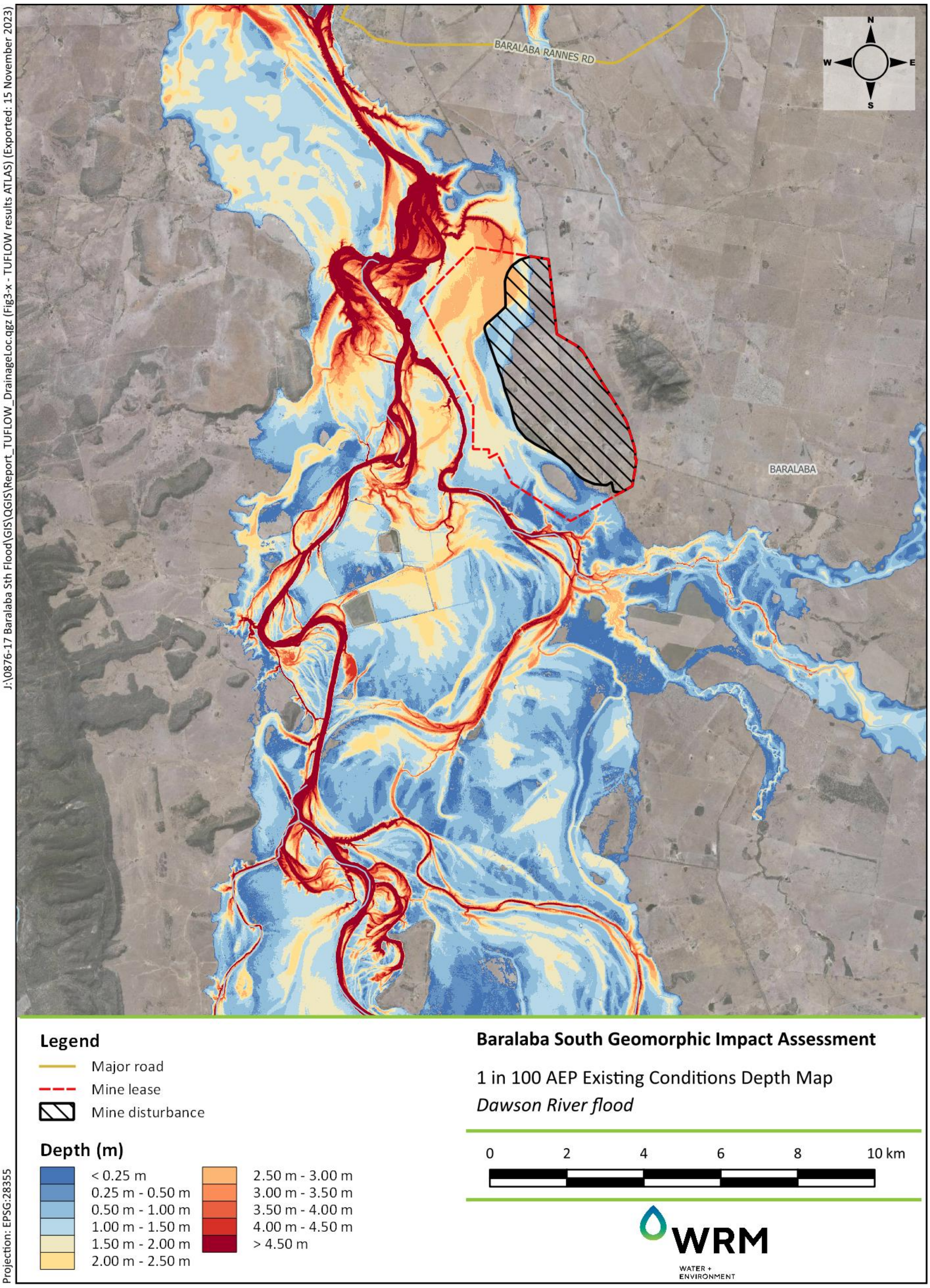

Figure 3.5 Existing conditions peak depth, Dawson River flood, 1% AEP event

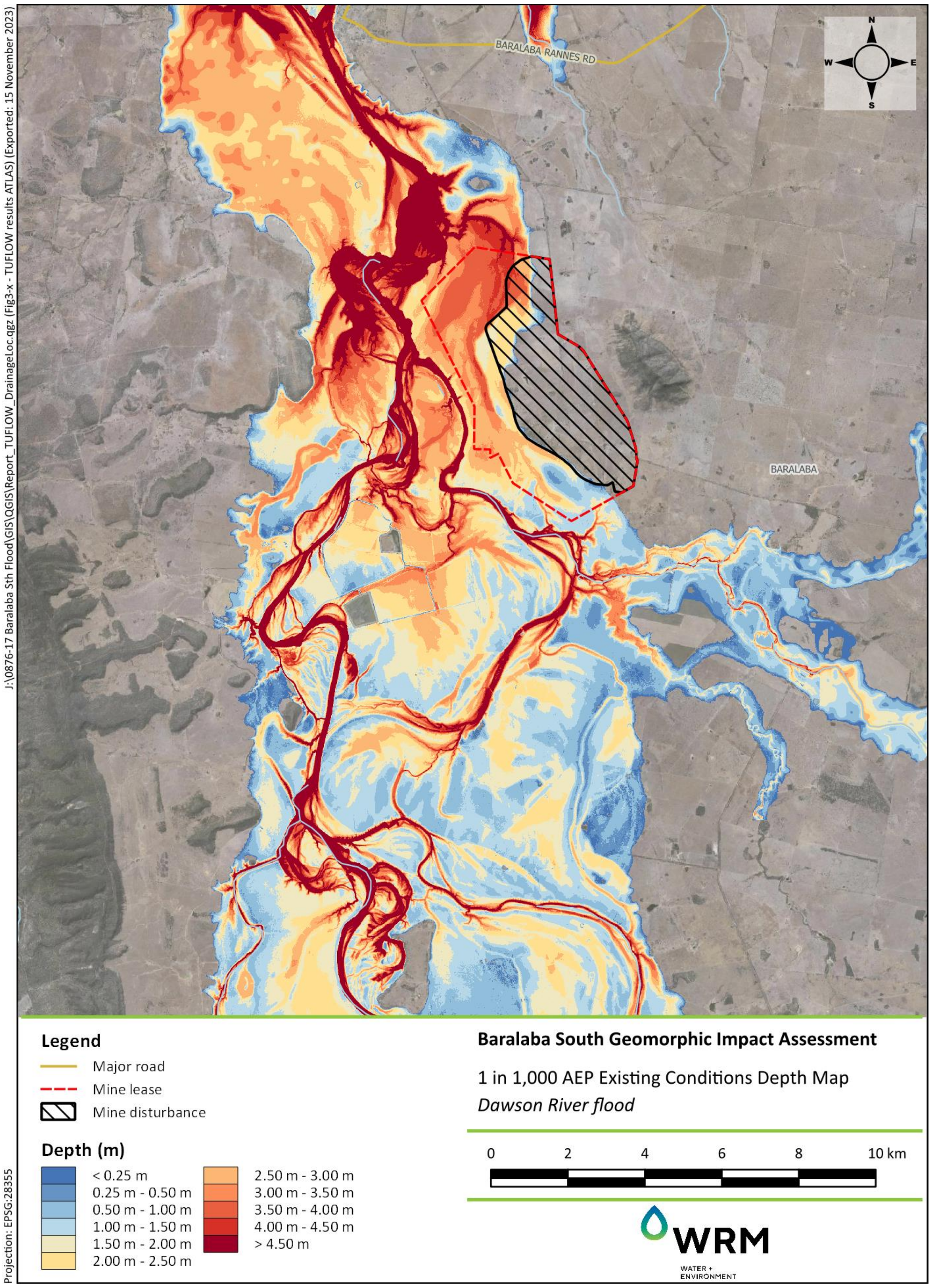

Figure 3.6 Existing conditions peak depth, Dawson River flood, 0.1% AEP event

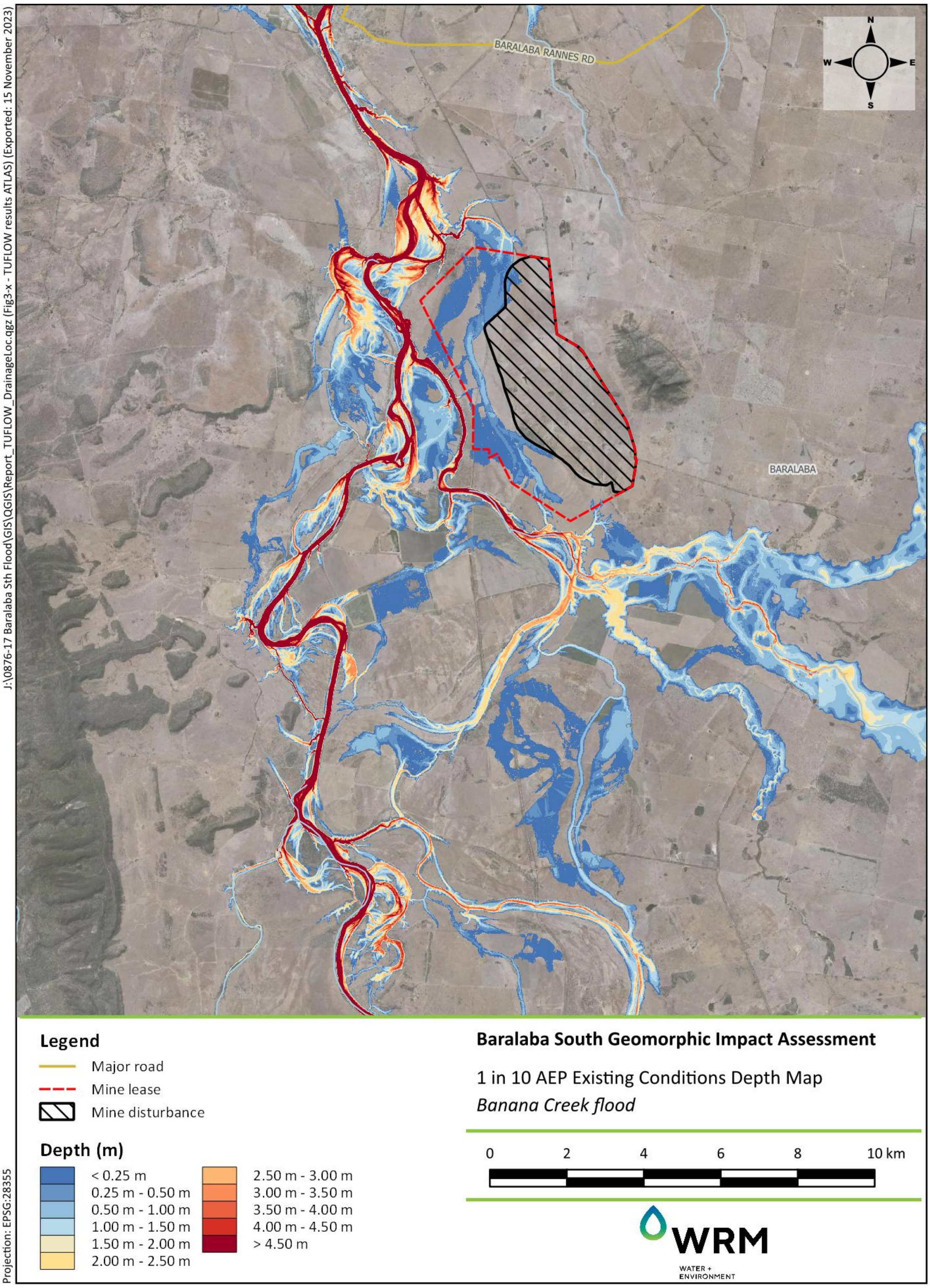

Figure 3.7 Existing conditions peak depth, Banana Creek flood, 10% AEP event

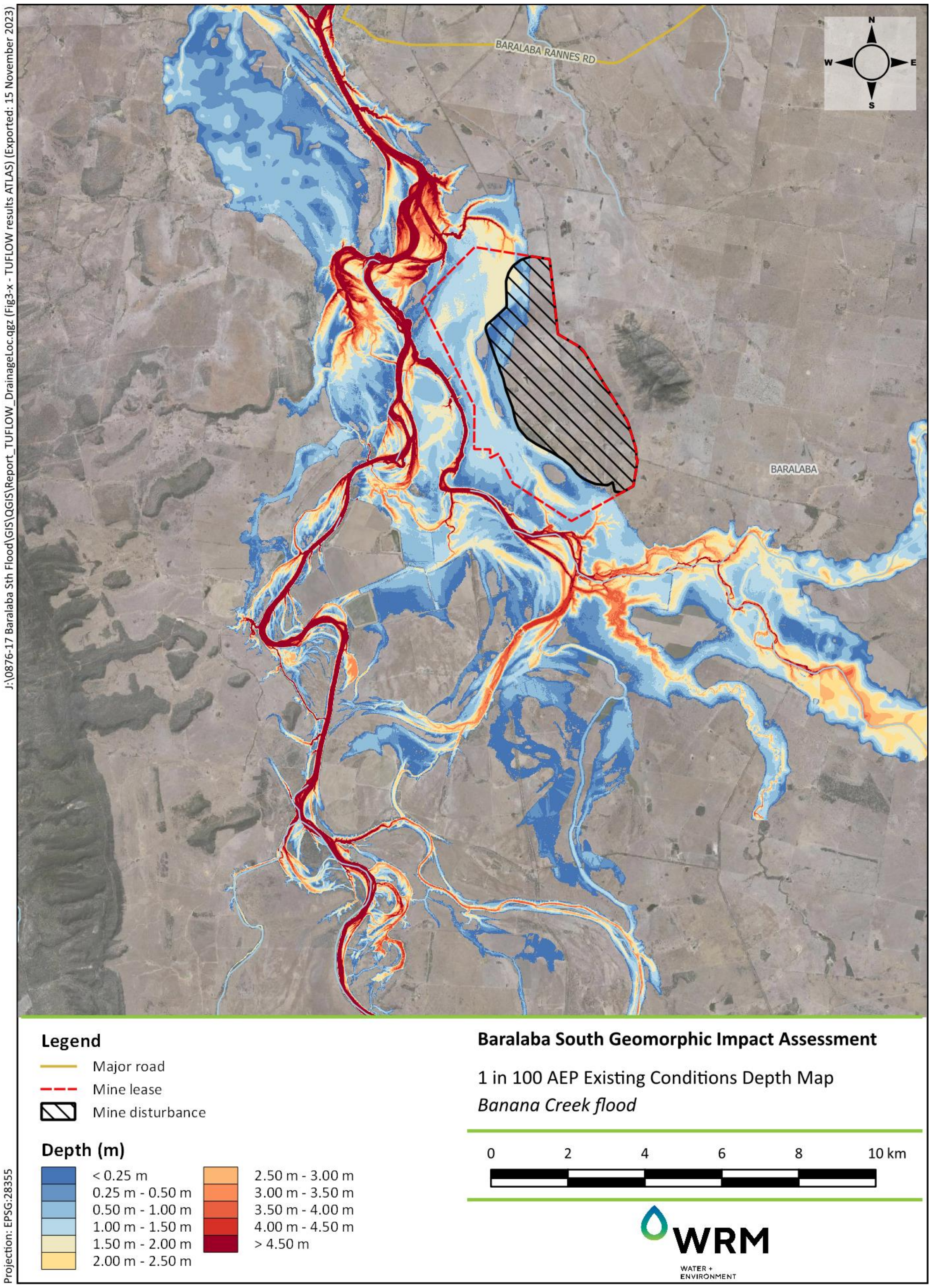

Figure 3.8 Existing conditions peak depth, Banana Creek flood, 1% AEP event

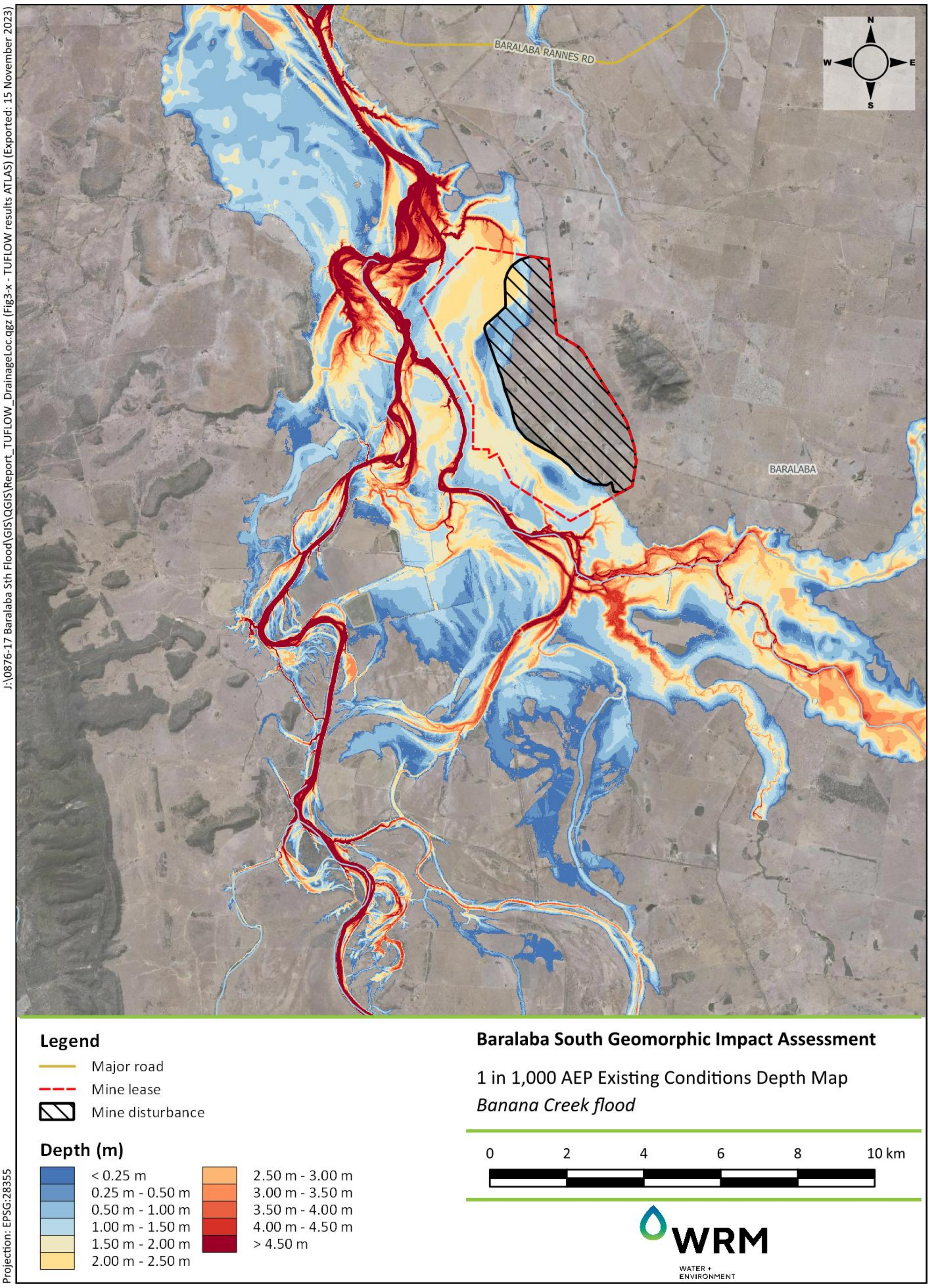

Figure 3.9 Existing conditions peak depth, Banana Creek flood, 0.1% AEP event

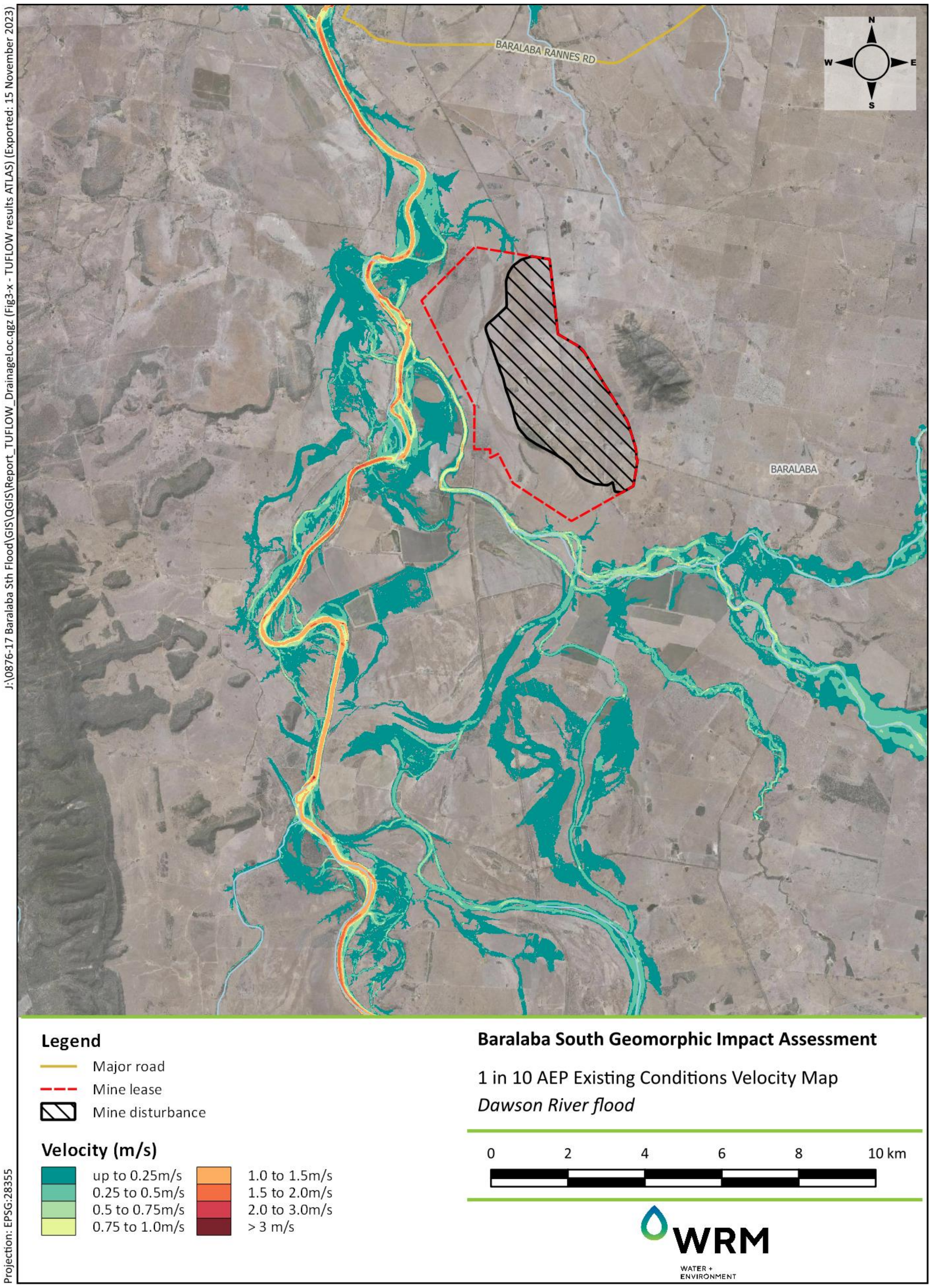

Figure 3.10 Existing conditions peak velocity, Dawson River flood, 10% AEP event

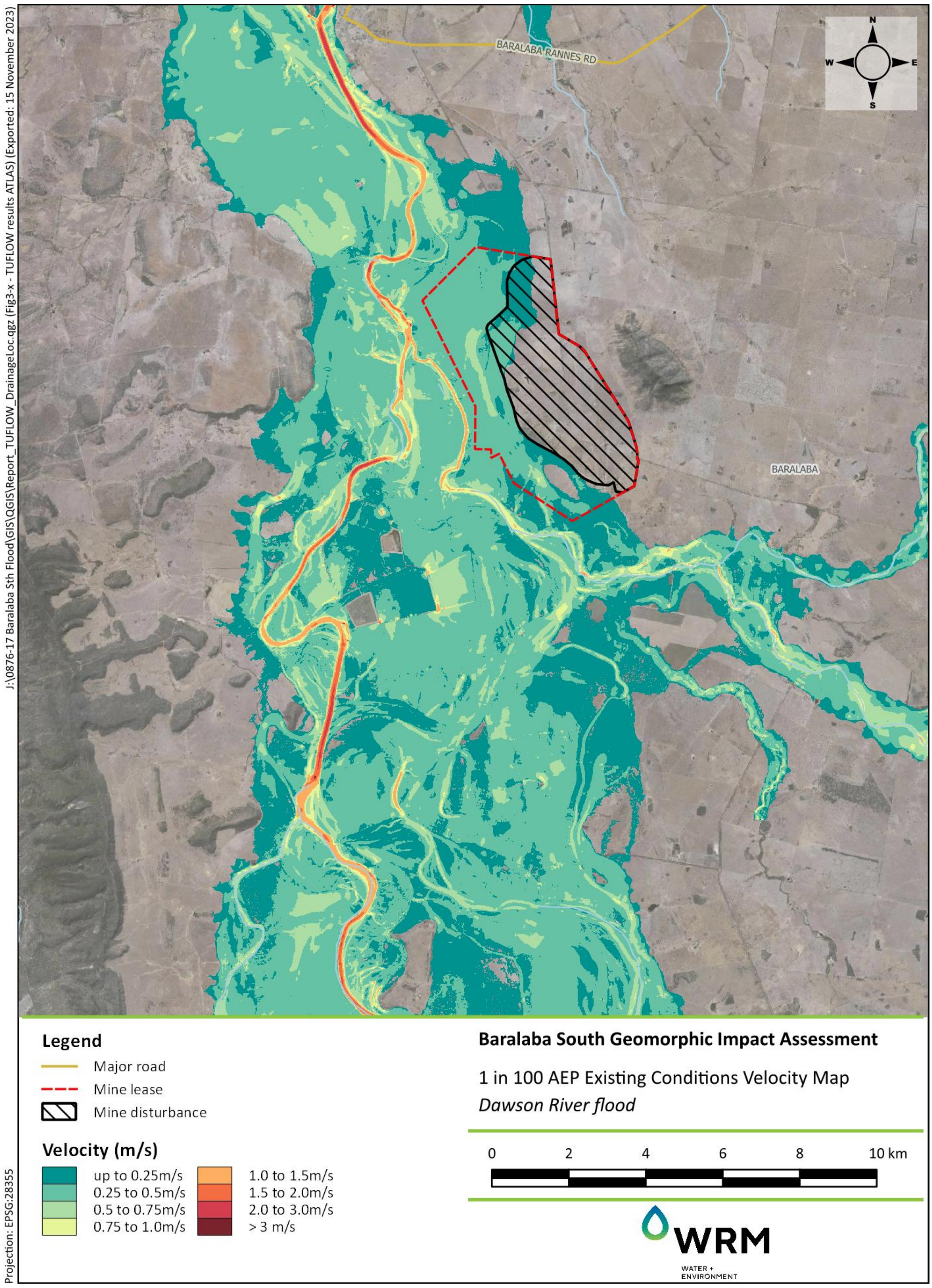

Figure 3.11 Existing conditions peak velocity, Dawson River flood, 1% AEP event

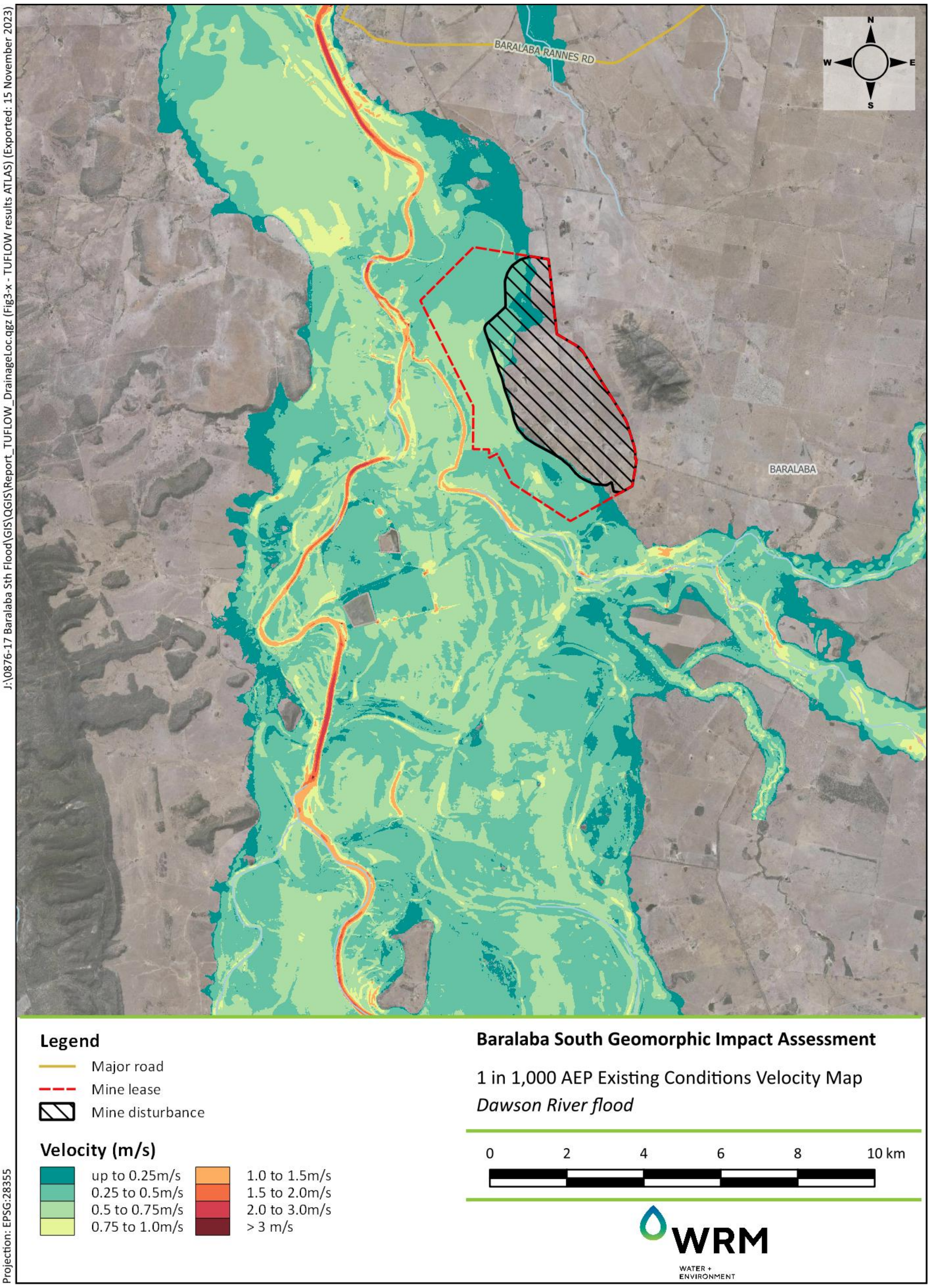

Figure 3.12 Existing conditions peak velocity, Dawson River flood, 0.1% AEP event

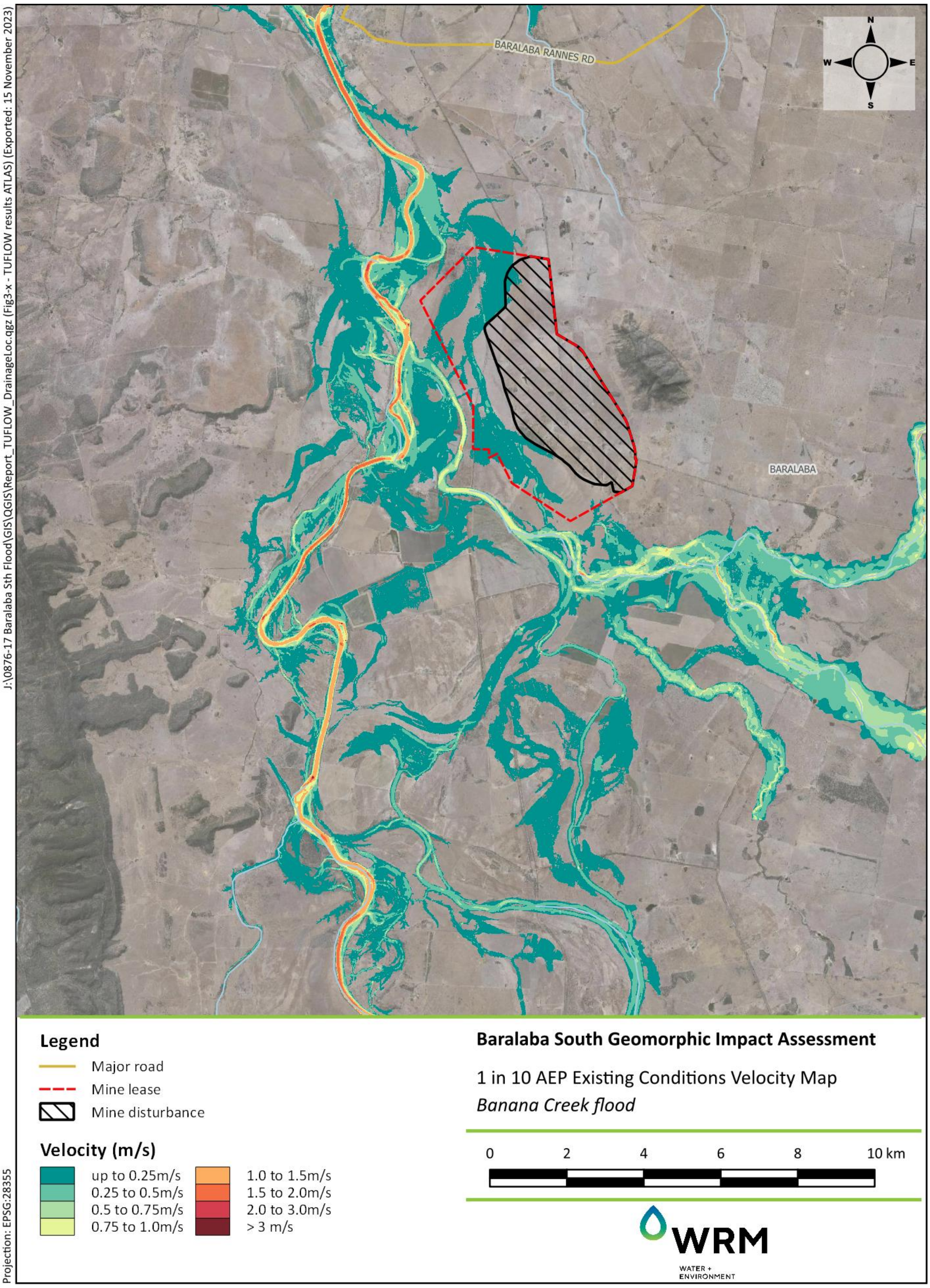

Figure 3.13 Existing conditions peak velocity, Banana Creek flood, 10% AEP event

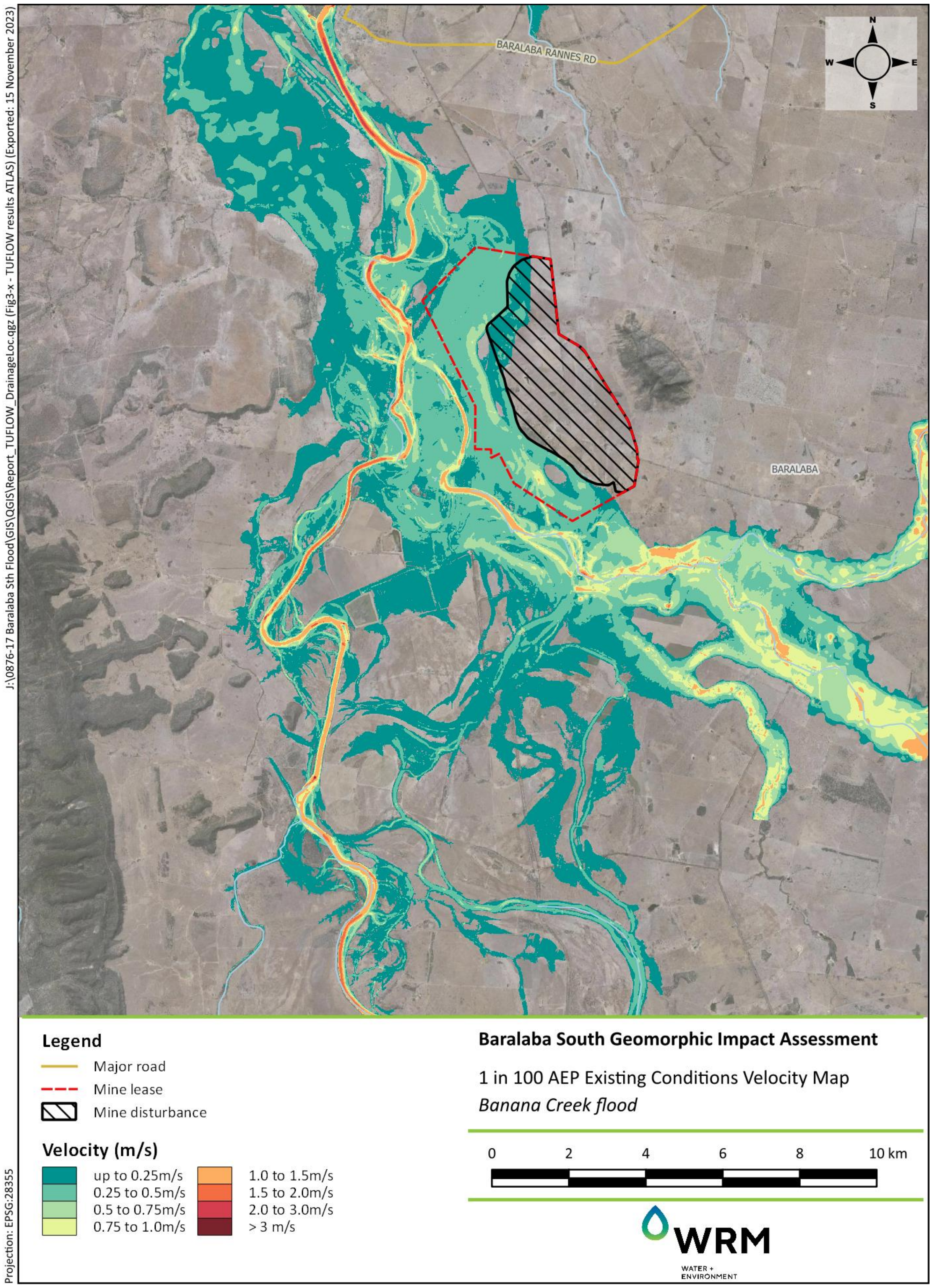

Figure 3.14 **Existing conditions peak velocity, Banana Creek flood, 1% AEP event**

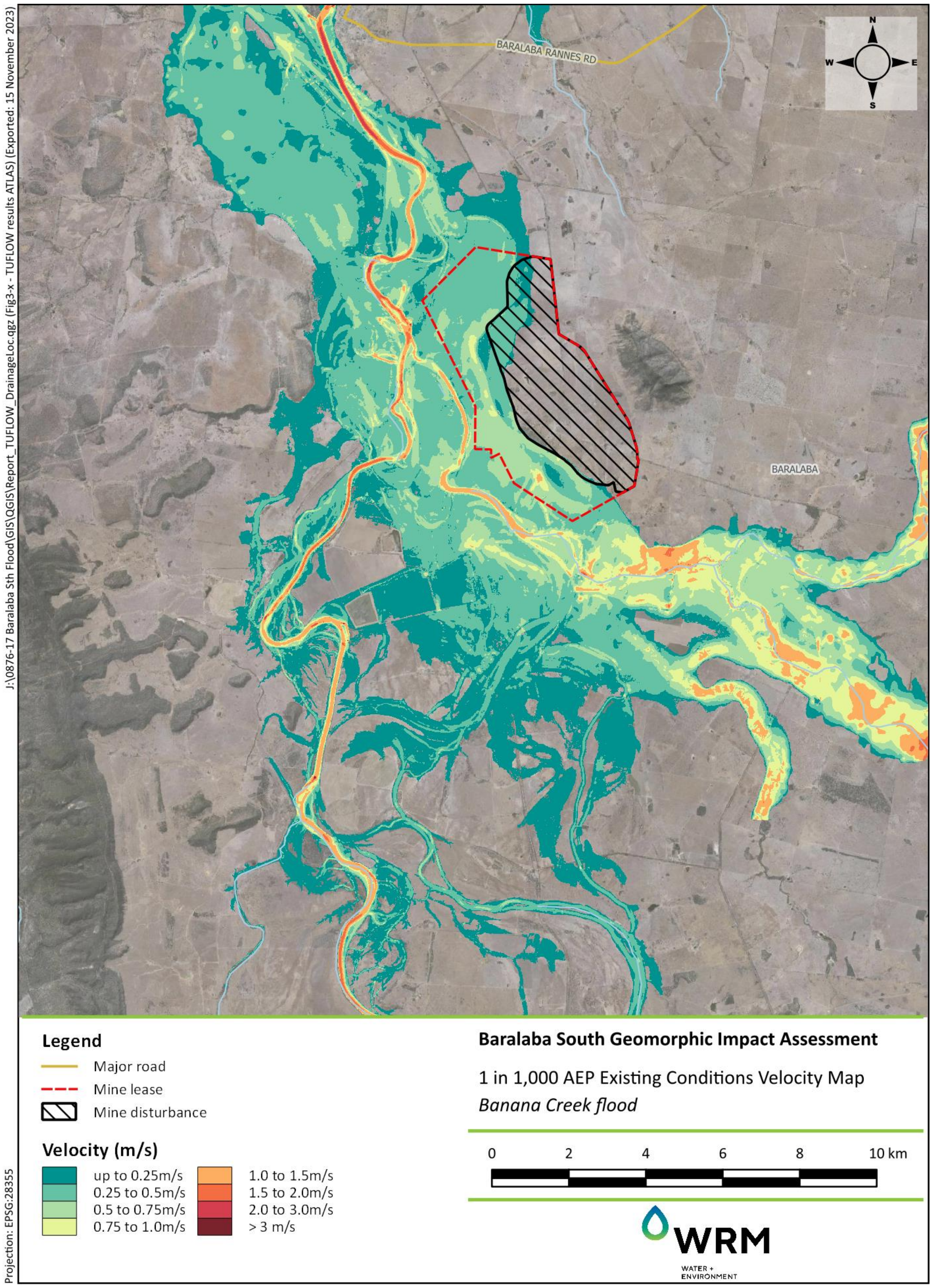

Figure 3.15 **Existing conditions peak velocity, Banana Creek flood, 0.1% AEP event**

3.4.4 Water surface level longitudinal profiles

Figure 3.16 and Figure 3.17 show longitudinal peak water level plots for the three design events along the centrelines of Dawson River and Banana Creek respectively. For assessment purposes, the Dawson River and Banana Creek have been divided into reaches based on their location to the Project. The reaches are shown on the longitudinal profiles (refer Figure 3.16 and Figure 3.17) and described as follows:

- Dawson River downstream of the Project, from 83 km AMTD (just upstream of the Neville Hewitt Weir) to 92 km AMTD, to account the effects of Neville Hewitt Weir;
- Dawson River adjacent to the Project, from 92 km AMTD to 97km AMTD. This includes the Banana Creek confluence at about 95 km AMTD;
- Dawson River upstream of the Project, from 97 km AMTD to 104 km AMTD;
- Banana Creek adjacent to the Project, from 0 km AMTD to 8.5 km. This section is located on the Dawson River floodplain and will be impacted by Dawson River flows (refer Figure 3.17). Results for this reach are reported separately for flood events in Banana Creek only, and for flood events in Dawson River whose backwater dominates flood levels in the downstream reach; and
- Banana Creek upstream of the Project, from 8.5 km AMTD to 17 km AMTD, which is usually not impacted by backwater flooding from Dawson River except for very large to rare events.

The AMTD locations are shown in Figure 3.3.

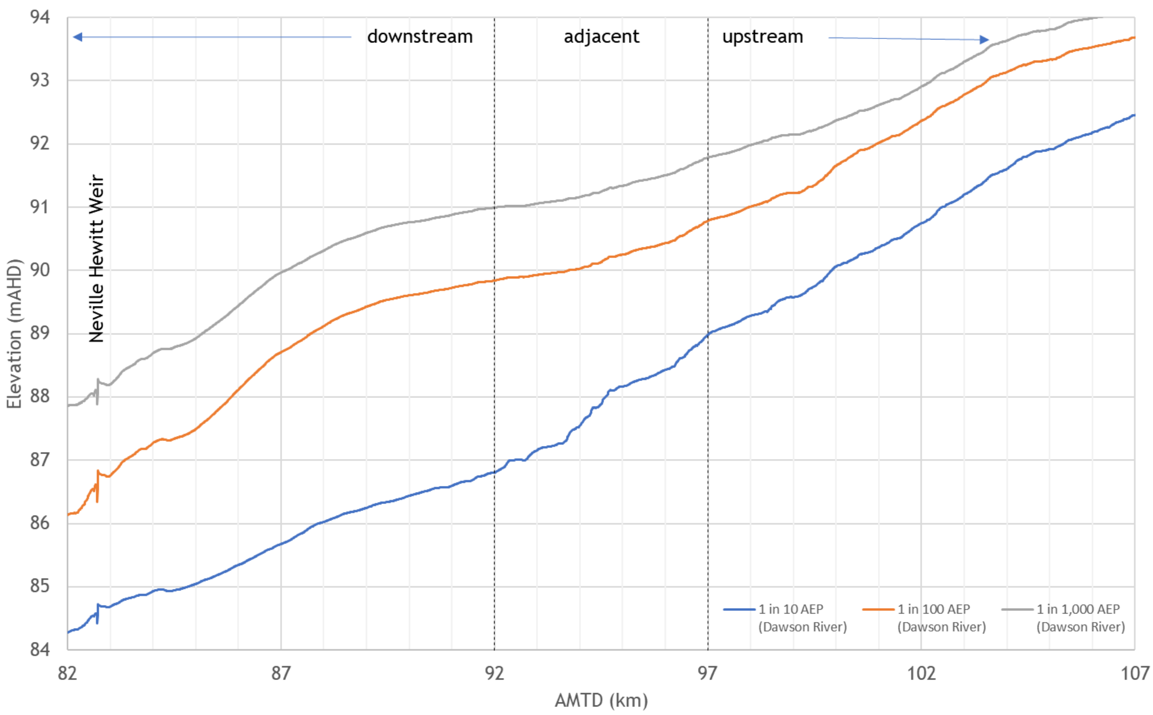

Figure 3.16 Longitudinal plot of Dawson River flood levels, 10%, 1% AEP and 0.1% AEP events

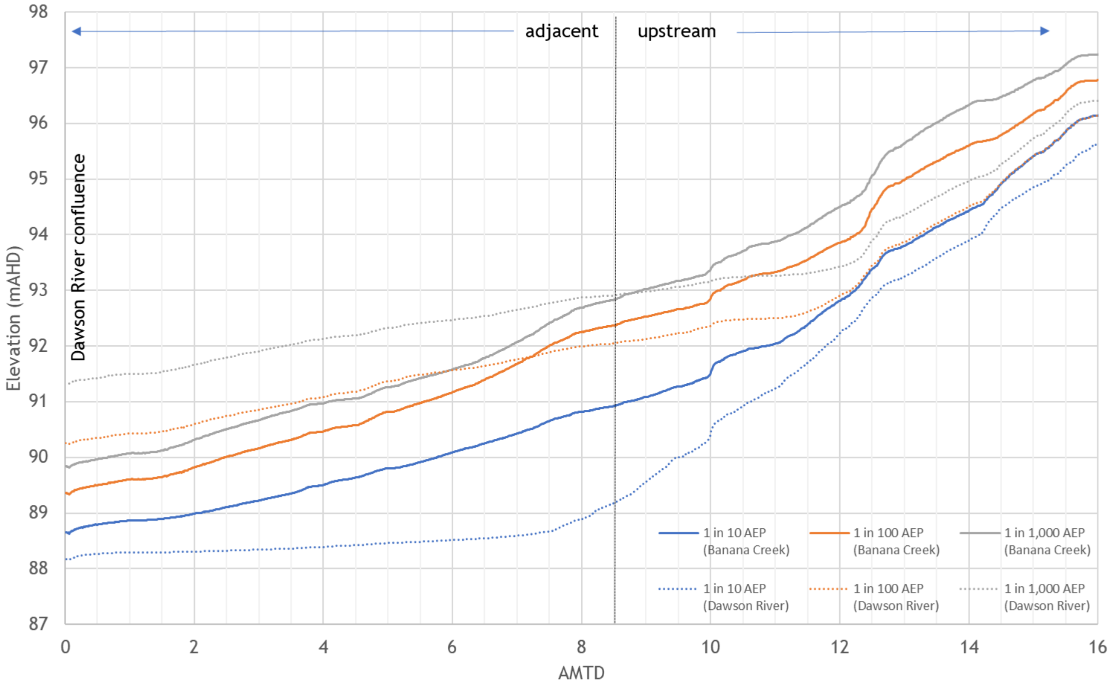

Figure 3.17 Longitudinal plot of Banana Creek flood levels, 10%, 1% AEP and 0.1% AEP events

3.5 CHANNEL HYDRAULIC CHARACTERISTICS

3.5.1 Assessment methodology

The following sections describe the key hydraulic characteristics of the Dawson River and Banana Creek. Channel velocity, shear stress and stream power, and are the main hydraulic characteristics of interest:

- Channel velocity is generally directly linked to channel slope. There is no direct relationship between velocity and the force exerted on soil particles at the boundary and thus stream power and shear stress are used as more reliable indicators of erosion potential and channel changes.
- Shear stress provides a measure of the tractive force acting on sediment particles at the boundary of the stream, and is used to determine the threshold of motion for bed material. It provides an indication of the potential for erosion of cohesive sediments or movement of non-cohesive sediments at the channel boundary.
- Stream power is a function of discharge, hydraulic gradient and flow width. It represents the energy that is available to do work in and on the channel. High stream powers are indicative of elevated erosion potential.

Channel velocity, bed shear stress and stream power results were derived for both the Dawson River and Banana Creek channels using the following process:

- Standard cross sections (the approximate top width of the channel) were generated at 500 m intervals along the channel (120 m wide for the Dawson River and 40 m for Banana Creek);
- At 1 m increments along each cross section, the flow depth and velocity were extracted from the TUFLOW depth and velocity grids generated for each event; and

- The data at each cross section was used to generate a depth-averaged channel velocity, hydraulic radius, flow, and slope, which was then used to calculate bed shear stress and stream power.

Shear stress was calculated as follows:

Shear stress = ρ g R S [N/m^2]

where ρ = water density, g = gravitational acceleration, R = hydraulic radius,
S = hydraulic gradient

Stream power was calculated by multiplying shear stress with the depth-averaged channel velocity.

3.5.2 Velocity

Table 3.1 shows the range of depth-averaged channel velocities (in m/s) along the Dawson River and Banana Creek channels in the vicinity of the Project. Results are shown for the reach average values, as well as the lower quartile (25th percentile) and upper quartile (75th percentile values).

Table 3.1 Dawson River and Banana Creek velocities (m/s), 10% AEP, 1% AEP and 0.1% AEP events, existing conditions

Event (AEP)	Dawson River			Banana Creek		
	Downstream	Adjacent	Upstream	Adjacent, Dawson River Flood*	Adjacent, Banana Creek Flood	Upstream
10% AEP						
25%	1.2	1.2	1.2	0.7	0.7	0.7
Average	1.3	1.2	1.3	0.8	0.8	0.9
75%	1.5	1.3	1.4	0.9	0.9	0.9
1% AEP						
25%	1.3	1.2	1.1	1.0	0.9	0.9
Average	1.7	1.3	1.3	1.0	1.0	1.1
75%	2.0	1.4	1.5	1.1	1.2	1.2
0.1% AEP						
25%	1.4	1.2	1.1	1.1	1.0	0.9
Average	1.7	1.3	1.3	1.1	1.1	1.1
75%	2.0	1.4	1.4	1.3	1.3	1.3

* assumed same extent for Dawson River influence zone regardless of event magnitude

Existing conditions model results show that:

- Velocities in the Dawson River channel in the vicinity of the Project range from about 1.2 m/s to about 1.4 m/s for events from 10% AEP to 0.1% AEP.
- Dawson River velocities in the downstream reach are moderately higher than the upstream reach for the moderate to rare events likely due to the narrower floodplain in the lower reach (see Figure 3.5).
- Banana Creek channel velocities adjacent to the Project are generally lower than the Dawson River velocities.
- The Banana Creek upstream reach velocities are moderately higher than the downstream (adjacent) for both Banana Creek and Dawson River scenarios.

3.5.3 Bed shear stress

Table 3.2 shows the range of peak channel bed shear stress (in N/m^2) along the Dawson River and Banana Creek channels in the vicinity of the Project. Results are shown for the reach average values, as well as the lower quartile (25th percentile) and upper quartile (75th percentile values).

Table 3.2 Dawson River and Banana Creek bed shear stress (N/m^2), 10% AEP, 1% AEP and 0.1% AEP events, existing conditions

Event (AEP)	Dawson River			Banana Creek		
	Downstream	Adjacent	Upstream	Adjacent, Dawson River Flood*	Adjacent, Banana Creek Flood	Upstream
10% AEP						
25%	6.1	7.2	7.1	2.8	2.0	3.3
Average	7.9	7.9	8.5	3.5	2.8	5.0
75%	9.7	8.5	9.7	3.8	3.6	5.6
1% AEP						
25%	7.2	6.7	5.7	4.2	3.4	4.3
Average	12.0	7.2	8.3	4.6	4.8	6.7
75%	15.6	8.6	10.4	5.3	6.4	7.9
0.1% AEP						
25%	7.4	6.6	5.5	5.2	4.3	4.2
Average	12.4	7.2	7.8	5.5	5.4	6.8
75%	16.1	8.7	9.4	6.6	6.9	9.2

* same extent assumed for Dawson River influence zone regardless of event magnitude

Existing conditions model results show the following:

- Bed shear stresses in the Dawson River channel in the vicinity of the Project range between 6.6 N/m^2 and 8.7 N/m^2 for events from 10% AEP to 0.1% AEP.
- Slightly higher bed shear stresses occur along the lower reach when compared to the upper reach for the two larger events.
- Banana Creek bed shear stresses adjacent to the Project are generally between 2.0 N/m^2 to 6.9 N/m^2.

3.5.4 Stream power

Table 3.3 shows the range of peak channel averaged stream power (in W/m^2) along the Dawson River and Banana Creek channels in the vicinity of the Project. Results are shown for the reach average values, as well as the lower quartile (25th percentile) and upper quartile (75th percentile values). Model results show that:

- Stream powers in the Dawson River channel in the vicinity of the Project ranges between 8.4 W/m^2 and 12.9 W/m^2 for events from 10% AEP to 0.1% AEP.
- Slightly higher stream powers occur in the downstream reach of the Dawson River when compared to the upstream reach.
- Banana Creek stream powers adjacent to the Project are generally between 1.4 W/m^2 and 8.6 W/m^2.

Table 3.3 Dawson River and Banana Creek stream power (W/m²), 10% AEP, 1% AEP and 0.1% AEP events, existing conditions

Event (AEP)	Dawson River			Banana Creek		
	Downstream	Adjacent	Upstream	Adjacent, Dawson River Flood*	Adjacent, Banana Creek Flood	Upstream
10% AEP						
25%	7.3	9.2	8.9	2.1	1.4	2.3
Average	11.0	10.6	12.3	3.1	2.2	4.9
75%	14.7	11.9	14.5	3.5	3.1	5.3
1% AEP						
25%	9.9	8.8	6.7	4.0	3.1	3.9
Average	22.5	9.8	12.8	4.9	5.2	8.1
75%	31.2	12.6	16.4	5.8	7.6	9.6
0.1% AEP						
25%	10.4	8.4	6.4	5.5	4.0	3.7
Average	24.2	10.0	11.6	6.5	6.2	8.7
75%	33.3	12.9	14.4	8.6	8.6	12.1

* same extent assumed for Dawson River influence zone regardless of event magnitude

3.5.5 Discussion of results

The analysis shows that there is a minor but distinct change in the hydraulic behaviour of the Dawson River between the reaches upstream and downstream of the Project under existing conditions, particularly for the larger events. It would appear that the Neville Hewitt Weir does not have a significant impact on the channel behaviour for these events as shown in the longitudinal plot of water levels in Figure 3.16. Rather, the greatest impact occurs as a result of the main channel crossing from the western side of the floodplain to the eastern side between chainages 89 km and 93 km. The narrower floodplain downstream from 89 km may also cause higher channel velocities and stream power for the larger events. This section also forces engagement of the floodplain in events 2% AEP and greater.

Banana Creek adjacent to the Project would appear to be dominated by Dawson River flows (see Figure 3.17).

4 IMPACT ASSESSMENT

4.1 POTENTIAL IMPACTS

The Project will comprise open cut pits and related mining infrastructure constructed adjacent to the Dawson River floodplain. Only a small area of overburden will be placed on the floodplain. The mine disturbance boundary will be at least 1,300 m away from the top of bank (or edge of the channel) of Banana Creek and at least 2,000 m away from the Dawson River top of bank. No works are proposed within the Dawson River or Banana Creek channels, with the exception of proposed water release/extraction infrastructure on the bank of the Dawson River.

The resulting final mine landform can potentially affect geomorphological behaviour through:

- increased channel velocities, bed shear stress and stream power, which could increase the potential for channel erosion;
- reduced channel velocities, bed shear stress and stream power, which could increase the potential for channel sedimentation and reduced channel capacity; or
- changes in the distribution of flow, which could increase the erosion potential of the floodplain.

4.2 IMPACT ON DAWSON RIVER AND BANANA CREEK CHANNELS

The hydraulic model was modified to include the proposed final landform proposed for the Project and rerun for the three design events. The flood depth and flood velocity maps and the flood depth and velocity impact maps for the three events have been provided in the Flood Impact Assessment (Engeny, 2023) and are not repeated here.

An assessment of the impact on the Dawson River and Banana Creek channels was undertaken by first preparing depth averaged channel velocity, bed shear stress and stream power tables for proposed conditions (final landform) using the process described in Section 3.5 and then comparing the results to existing conditions.

Table 4.1 to Table 4.3 show the predicted changes to depth averaged channel velocities, bed shear stress and stream power for proposed conditions compared to existing conditions along the Dawson River and Banana Creek channels in the vicinity of the Project.

Model results show that predicted changes to Dawson River and Banana Creek channel flow characteristics in the vicinity of the Project are negligible for all events investigated, including the extreme event. Although peak flood levels increase along the channel for the larger events, the increase is not significant in comparison to the existing flood depths along each channel. For instance, average 1% AEP flood depths exceed 10 m and the increase in flood depth is generally less than 0.05 m (less than a 1% increase). Any changes are well with the existing range of velocities, bed shear and stream powers observed along the existing channel reaches.

Consequently, the Project is not expected to cause any material change in the morphology of the river channels. The change in sediment transport capability and erosion potential of the river channels for any of the events investigated is expected to be negligible.

Table 4.1 Dawson River and Banana Creek proposed minus existing velocities (m/s), 10% AEP, 1% AEP and 0.1% AEP events

Event (AEP)	Dawson River			Banana Creek		
	Downstream	Adjacent	Upstream	Adjacent, Dawson River Flood*	Adjacent, Banana Creek Flood	Upstream
10% AEP						
25%	0	0	0	0	0	0
Average	0	0	0	0	0	0
75%	0	0	0	0	0	0
1% AEP						
25%	0	0	0	0	0	0
Average	0	0	0	0	0	0
75%	0	0	0	0	0	0
0.1% AEP						
25%	0	-0.01	0	0	0	0
Average	0	0	0	0	0	0
75%	0	0	0	0	0	0

Table 4.2 Dawson River and Banana Creek proposed minus existing bed shear stress (N/m^2), 10% AEP, 1% AEP and 0.1% AEP events

Event (AEP)	Dawson River			Banana Creek		
	Downstream	Adjacent	Upstream	Adjacent, Dawson River Flood*	Adjacent, Banana Creek Flood	Upstream
10% AEP						
25%	0	0	0	0	0	0
Average	0	0	0	0	0	0
75%	0	0	0	0	0	0
1% AEP						
25%	0	-0.01	-0.02	0	0.02	0
Average	0	-0.01	-0.01	0	0	0
75%	0	0	-0.01	0	0	0
0.1% AEP						
25%	0	-0.07	-0.03	-0.01	0	0
Average	0	-0.02	-0.02	-0.01	0	0
75%	-0.01	0	-0.02	-0.01	0	0

Table 4.3 Dawson River and Banana Creek proposed minus existing stream power (W/m^2), 10% AEP, 1% AEP and 0.1% AEP events

Event (AEP)	Dawson River			Banana Creek		
	Downstream	Adjacent	Upstream	Adjacent, Dawson River Flood*	Adjacent, Banana Creek Flood	Upstream
10% AEP						
25%	0	0	0	0	0	0
Average	0	0	0	0	0	0
75%	0	0	0	0	0	0
1% AEP						
25%	0	-0.05	-0.03	0	0.03	0
Average	0	-0.01	-0.01	0.01	0	0
75%	0	-0.01	-0.01	0	0	0
0.1% AEP						
25%	-0.01	-0.13	-0.05	-0.01	0	0
Average	-0.01	-0.03	-0.04	-0.01	0.01	0
75%	-0.02	0	-0.05	-0.01	0	0

4.3 IMPACT ON THE FLOODPLAIN

The changes in velocities, stream power and shear stress across the floodplain are presented in a series of flood maps in Appendix E and Appendix H of the Flood Impact Assessment (Engeny, 2023). The results show that there are no velocity impacts to the floodplain for the 20% and 10% AEP events (because the final landform has little interaction with flood flows) with localised impacts adjacent to the final landform for the 1% AEP event. At the location of the mine disturbance, the peak velocities for the proposed conditions are no greater than at other locations on the floodplain (see Figure 3.11). Similarly, the change in stream power and shear stresses across the floodplain are negligible (see Appendix H of the Flood Impact Assessment (Engeny, 2023)). On this basis, the change in the erosion potential of the floodplain is expected to be negligible.

4.4 FUTURE GEOMORPHIC CHANGES

The above results suggest that the Project will not have a material impact on the geomorphic characteristics of the existing Dawson River and Banana Creek channel or floodplain as the hydraulic characteristics do not change. However, there is potential for either channel to alter course in the future due to circumstances not related to the Project, such as a flood event more extreme than what occurred during 2010.

A review of historical aerial imagery obtained from QImagery[2] for 1953 and 1965 show no observable change in channel location when compared to current conditions over the past 50 to 60 years. Note that there are observable changes in channel water levels due to Neville Hewitt Weir, but the channel location does not appear to have changed. There have been several very large floods since this time.

[2] https://qimagery.information.qld.gov.au/

This suggests that the lateral migration of stream channels is relatively slow in this reach of the river system and that any change in the alignment of the river due to lateral erosion would occur over hundreds if not thousands of years.

4.5 MITIGATION MEASURES

There are no material geomorphological impacts of the Project on the Dawson River and Banana Creek channels and floodplains and hence no mitigation measures are required.

4.6 RESIDUAL IMPACTS

There are no material residual geomorphological impacts of the Project that will affect surface water environmental values.

4.7 CUMULATIVE IMPACTS

The Project will have no material impacts on geomorphology and therefore cannot have any cumulative impacts.

4.8 MONITORING, EVALUATION AND REVIEW

Given the expected negligible impacts of the Project on the Dawson River and its floodplain and the fact that impacts of the project can only occur when floodwater has encroached upon the final landform (for events exceeding 10% AEP), no regular monitoring of the river channels is required.

It is expected that any change to the river channel would only occur as a result of a flood event. However, no imagery or monitoring data is available on channel changes that occur naturally as a result of a flood event to provide a baseline to compare against. Establishing a reference reach outside of the impacted zone to compare channel changes against would also be difficult given the impacted reach is within the Neville Hewitt Weir and it has a more sinuous meander geometry than the upstream and downstream reaches.

Notwithstanding, it is recommended the Proponent obtain aerial imagery of the river channels (possibly via drone or plane) prior to the commencement of construction and immediately following each flood that encroaches the final landform. It is recommended the aerial imagery extend a distance of 5 km along the watercourse upstream and downstream of the Banana Creek confluence and about 5 km of Banana Creek. The purpose of collecting the imagery would be to define the changes that occur (naturally or otherwise) along the reach for further assessment and evaluation by a suitably qualified person if required.

5 SUMMARY AND CONCLUSIONS

The Baralaba South Project is located adjacent to the Dawson River and Banana Creek. The Project will extend into the Dawson River and Banana Creek floodplain, which has the potential to change the geomorphic behaviour of the waterways and floodplain. The assessment of the impact of the Project on the Dawson River, Banana Creek and the floodplain is summarised below:

- The final landform will be at least 1,300m away from the top of bank of Banana Creek and at least 2,000 m away from the Dawson River top of bank. No works are proposed within the Dawson River or Banana Creek channels with the exception of proposed water release/extraction infrastructure on the bank of the Dawson River.
- The Project will have a negligible impact on the velocities, bed shear stress and stream powers along the Dawson River and Banana Creek channels for the 10% and 1% AEP events. Although peak flood levels increase along the channel for the larger events, the increase is negligible in comparison to the existing flood depths along each channel. Any changes are well within the range of velocities, bed shear stress and stream powers observed along the existing channel reaches. Consequently, the Project will not cause any material change in the morphology of the river channel. It will not change the sediment transport characteristics or erosion potential for any of the events investigated.
- There are no velocity impacts to the floodplain for the 10% AEP event, and only localised impacts adjacent to the final landform for the 1% AEP event. At this location, the peak velocities for the proposed conditions are no greater than at other locations on the floodplain. On this basis, the change in the erosion potential of the floodplain is expected to be negligible.
- A review of historical aerial photos suggests that the lateral migration of stream channels is relatively slow in this reach of the river system and that any change in the alignment of the river due to lateral erosion would occur over hundreds if not thousands of years.

Based on the above findings, there would be no material geomorphological impacts on the Dawson River and Banana Creek channels and floodplains associated with the Project. It is recommended that ongoing monitoring by way of aerial imagery be undertaken following any flood event that encroaches on the final landform for further assessment and evaluation by a suitably qualified person if required.

6 REFERENCES

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7 GLOSSARY

alluvium	material deposited by running water, typically rivers. It displays characteristics such as stratification and size sorting. The term is usually restricted to relatively young sediment and does not include lithified material such as sedimentary rock
anabranch	a section of a river or stream that diverts from the main channel or stem of the watercourse and rejoins the main stem downstream.
Annual exceedance probability (AEP)	the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. (see ARI)
Australian Height Datum (AHD)	a common national surface level datum approximately corresponding to mean sea level.
Average recurrence interval (ARI)	the long-term average number of years between the occurrence of a flood as big as or larger than the selected event.
Bank full flow	The discharge that fills a river discharge channel to the bank full level without spilling over to the floodplain.
Catchment	the land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Discharge	the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
flood	relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood mitigation standard	the average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
Floodplain	area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Floodplain risk management options	the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk

	management plan requires a detailed evaluation of floodplain risk management options.
Flood prone land	land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
Geomorphology	the study of landforms, their processes, form and sediments at the surface of the Earth. Study includes looking at landscapes to work out how the earth surface processes, such as air, water and ice, can mould the landscape.
Hazard	a source of potential harm or a situation with a potential to cause loss.
Historical flood	a flood which has actually occurred.
Hydraulics	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Palaeo channel	A remnant of an inactive river or stream channel that has been filled or buried by younger sediment. The sediments that the ancient channel is cut into or buried by can be unconsolidated, semi-consolidated, consolidated or lithified.
Peak discharge	the maximum discharge occurring during a flood event.
Probability	a statistical measure of the expected chance of flooding (see annual exceedance probability).
River terrace	Fragment of a former valley floor that now stands above the level of the present floodplain. It is caused by stream incision, which may be due to uplift of the land, to a fall in sea level, or to a change in climate.
River morphology	Describes the changes of river planform and cross-section shape due to sedimentation and erosion processes over time. In this field the dynamics of flow and sediment transport are principal elements.
risk	chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
shear stress	is a measure of the force of friction from a fluid acting on a body in the path of that fluid. In the case of open channel flow, it is the force of moving water against the bed of the channel.

stage	equivalent to water level (both measured with reference to a specified datum).
stage hydrograph	a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
velocity	the speed or rate of motion (distance per unit of time, e.g., metres per second) in a specific direction at which the flood waters are moving
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time

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