APPENDIX 11
Surface Water Assessment

HYDRO ENGINEERING & CONSULTING PTY LTD

REPORT

Mangoola Coal Continued Operations Project

Environmental Impact Statement

Surface Water Assessment

Prepared for: Mangoola Coal Pty Ltd

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1.0 INTRODUCTION

1.1 BACKGROUND

Hydro Engineering & Consulting Pty Ltd (HEC) has been engaged by Umwelt (Australia) Pty Limited (Umwelt) on behalf of Mangoola Coal Operations Pty Limited (Mangoola) to complete a Surface Water Assessment (SWA) for the Mangoola Coal Continued Operations Project (MCCO Project). The purpose of the assessment is to form part of an Environmental Impact Statement (EIS) being prepared by Umwelt to accompany an application for development consent under Divisions 4.1 and 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for the MCCO Project.

1.2 OVERVIEW OF THE PROJECT

The Mangoola Coal Mine is an open cut coal mine located approximately 20 kilometres (km) west of Muswellbrook and 10 km north of Denman in the Upper Hunter Valley of NSW (refer Figure 1). Mangoola has operated the Mangoola Coal Mine in accordance with Project Approval (PA) 06_0014 since mining commenced at the site in September 2010.

The MCCO Project will allow for the continuation of mining at Mangoola Coal Mine into a new mining area to the immediate north of the existing operations. The MCCO Project will extend the life of the existing operation providing for ongoing employment opportunities for the Mangoola workforce. The MCCO Project Area includes the existing approved Project Area for the Mangoola Coal Mine and the MCCO Additional Project Area as shown on Figure 1.

The MCCO Project generally comprises:

- open cut mining at up to the same rate as that currently approved – i.e. 13.5 Million tonnes per annum (Mtpa) of run-of-mine (ROM) coal using truck and excavator mining methods;
- continued operations within the existing Mangoola Coal Mine;
- mining operations in a new mining area located north of the existing Mangoola Coal Mine, Wybong Road, south of Ridgelands Road and east of an existing 500 kV Electricity Transmission Line;
- construction of a haul road overpass over Big Flat Creek and Wybong Road to provide access from the existing mine to the proposed Additional Mining Area;
- establishment of an out-of-pit overburden emplacement area;
- distribution of overburden between the proposed Additional Mining Area and the existing mine in order to optimise the final landform design of the integrated operation;
- realignment of a portion of Wybong Post Office Road;
- the use of all existing or approved infrastructure and equipment for the Mangoola Coal Mine with some minor additions to the existing mobile equipment fleet;
- construction of a water management system to manage sediment laden water runoff, divert undisturbed area catchment, provide flood protection from Big Flat Creek and provide for reticulation of mine affected water (the water management system will be connected to that of the existing Mangoola Coal Mine);
- future use of the approved and scheduled for construction (but not yet constructed) water discharge facility to discharge excess water in accordance with the Hunter River Salinity Trading Scheme (HRSTS);
- establishment of a final landform in line with current design standards at the Mangoola Coal Mine including use of natural landform design principles consistent with the existing site;

- rehabilitation of the MCCO Project using the same revegetation techniques as at the existing Mangoola Coal Mine;
- a likely construction workforce of approximately 145 persons (no change to the existing approved operational workforce); and
- continued use of the mine access road for the existing operational mine and access to/from Wybong Road, Wybong Post Office Road and Ridgelands Road to the MCCO Additional Project Area for construction, emergency services, environmental monitoring and property maintenance.

The key features of the MCCO Project are illustrated in Figure 2.

1.3 PURPOSE OF REPORT

This report assesses likely impacts of the MCCO Project on surface water resources both within and downstream of the MCCO Project Area. This includes potential impacts on water quality, streamflow and the local flood regime. The report also considers water management for the MCCO Project, both in terms of upslope runoff diversions and management of water within disturbed portions of the MCCO Project Area. The assessment also includes water and salt balance modelling that forecasts the water supply and discharge requirements for the Mangoola mine with the MCCO Project during the operational phase and the behaviour of the final void pit lakes.

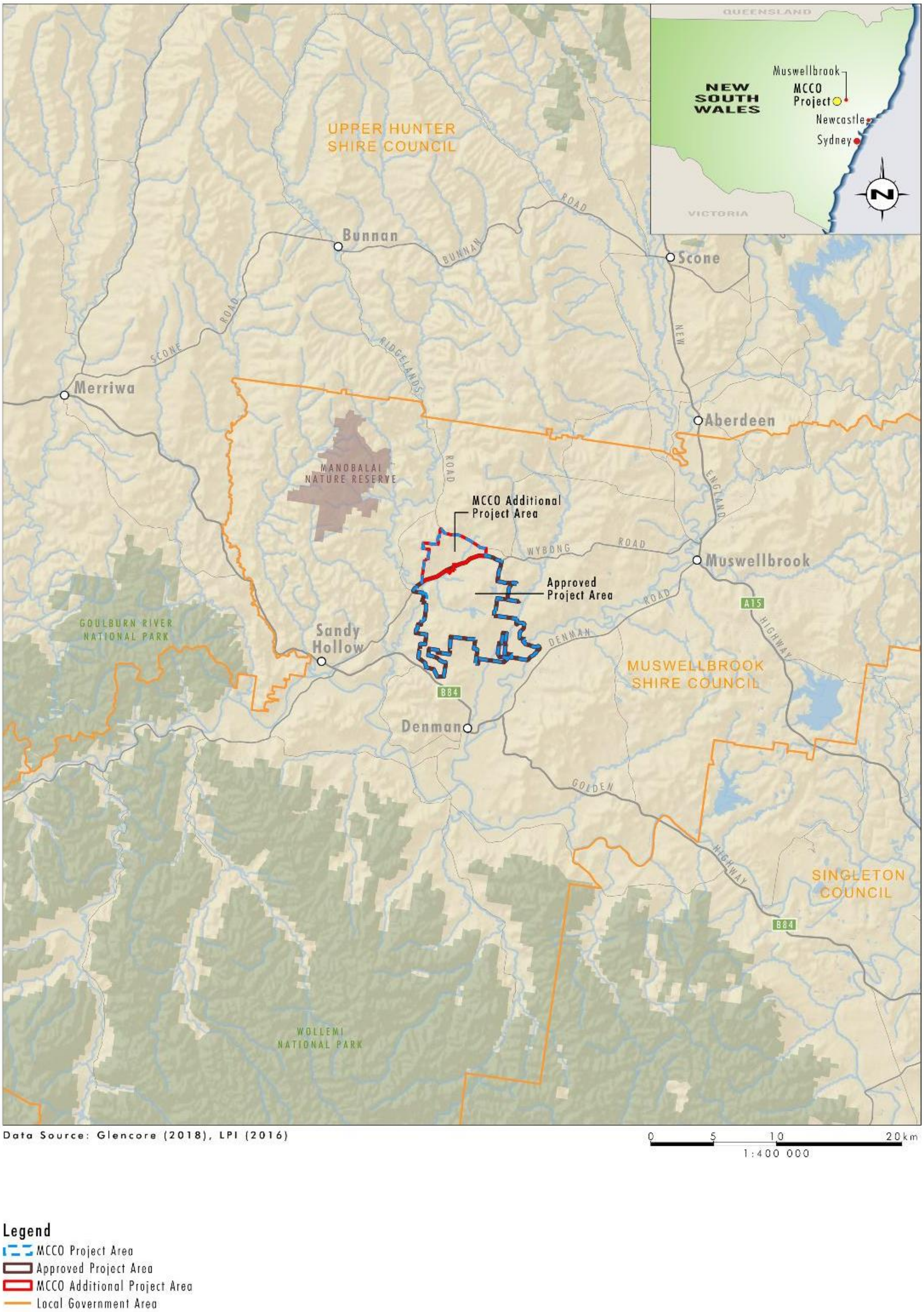

Figure 1 Regional Locality

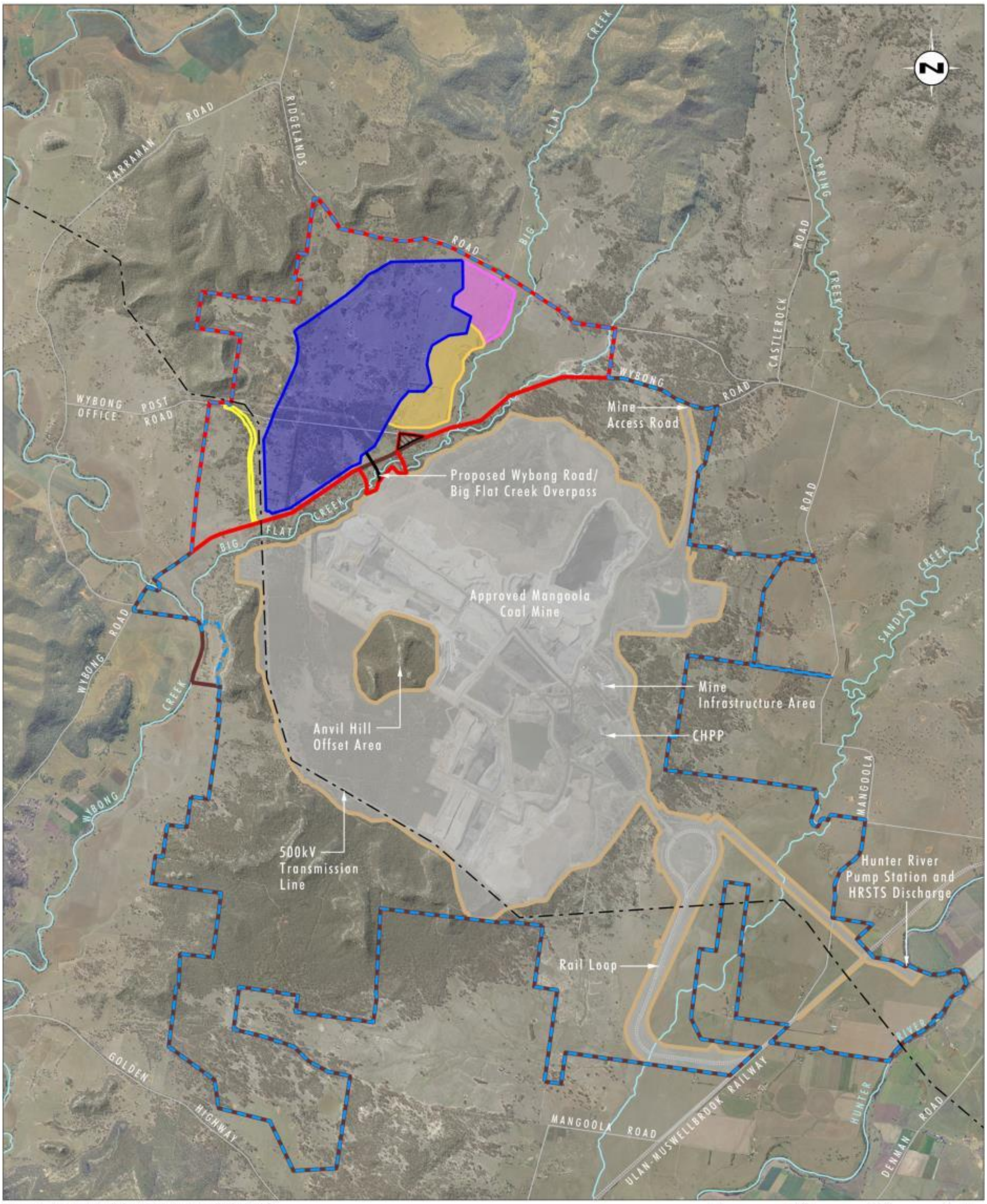

Image Source: Glencore (April 2018)
Data Source: Glencore (2019)

Legend
MCCO Project Area
Approved Project Area
Approved Mangoola Coal Mine Disturbance Area
MCCO Additional Project Area
Proposed Additional Mining Area
Proposed Emplacement Area
Proposed Topsoil Stockpile Area
Wybong Post Office Road Realignment
Crown Land (TSR) Excluded from MCCO Project Area

Figure 2 Conceptual Mangoola Coal Continued Operations Project

1.4 STUDY REQUIREMENTS

The SWA is guided by the Secretary's Environmental Assessment Requirements (SEARs) issued by the Department of Planning and Environment on 15 February 2019 for SSD 8642 (the MCCO Project). The requirements relating to water are outlined in Table 1, including where they have been addressed for surface water – for groundwater refer to the Groundwater Impact Assessment also prepared as part of the Environmental Impact Statement (AGEC, 2019). Detailed agency requests/comments have also been addressed in this and other specialists' reports including those from the NSW Environment Protection Authority (EPA), NSW Office of Environment & Heritage (OEH) and the Department of Primary Industries (DPI) – refer Table 2.

Table 1 Secretary's Environmental Assessment Requirements – Surface Water

Requirement	Where Addressed or Why not Addressed
Water - including:	
— a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures;	Section 3.3
— identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000*;	Section 2.4
— demonstration that water for the construction and operation of the proposed development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP) or water source embargo;	Section 3.3.5.3
— an assessment of any likely flooding impacts of the development;	Section 3.2.3
— the measures which would be put in place to control sediment run-off and avoid erosion;	Section 3.2.1
— an assessment of the likely impacts of the development on the quantity and quality of existing surface and groundwater resources including a detailed assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives;	Sections 2.6.2, 3.3.5.6 and 3.3.5.7
— an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users; and	Sections 3.2.3 to 3.2.4.3
— an assessment of the likely impacts of the development on a water resource, in relation to coal seam gas development and large coal mining development under the *Environment Protection and Biodiversity Conservation Act 1999*.	Refer Table 3

Table 2 Individual Agency Requests – Surface Water

Agency	Requirement	Where Addressed or Why not Addressed
Department of Primary Industries	Outline how proposed development will address the following legislation, policies and guidelines: o The relevant provisions of the Water Sharing Plan for the *Hunter Unregulated and Alluvial Water Sources 2009*	Sections 2.4 and 0
Environment Protection Authority	In summary, the EPA's key information requirements for the project include an adequate description and assessment of: 4. Water management onsite including process and stormwater management, sedimentation ponds, details and justification for any proposed discharge(s) and the sensitivity of the receiving environment. 6. A proposed monitoring plan to assess the impact on the environment and surrounding receivers over time. 7. An assessment of the cumulative impacts associated with this proposal and other activities in the local area. 8. Actions that will be taken to avoid or mitigate impacts or compensate for any unavoidable impacts associated with proposed operations.	Sections 2.6.2, 3.2.1, 3.2.3, 3.3.3.9 and 3.3.5.6 Section 5.0 Section 3.2.6 Sections 3.2.4 and 5.4
Office of Environment & Heritage	**Water and soils**: The EIS must map the following features relevant to water and soils including… - Rivers, streams, wetlands, estuaries… - Proposed intake and discharge locations The EIS must describe background conditions for any water resource likely to be affected by the development, including: a. Existing surface and groundwater. b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations. c. Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htrn) including groundwater as appropriate that represent the community's uses and values for the receiving waters. d. Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	Section 2.6.3 Figure 3 Section 2.6 Sections 2.6 and 3.3.5.6 Section 2.6.2 Section 2.6.2

Table 2 Individual Agency Requests – Surface Water (Continued)

Agency	Requirement	Where Addressed or Why not Addressed
Office of Environment & Heritage (continued)	**Water and soils (continued)**:	
	The EIS must assess the impacts of the development on water quality, including:	
	a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.	Sections 2.6.2, 3.2.1, 3.2.4, 3.2.4.3 and 3.3.5.6
	b. Identification of proposed monitoring of water quality.	Section 5.0
	The EIS must assess the impact of the development on hydrology, including:	
	a. Water balance including quantity, quality and source.	Section 3.3
	b. Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas…	Sections 3.2.3 to 3.2.4.3
	d. Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches).	Sections 3.2.3 and 3.2.4 and Biodiversity Assessment Report
	e. Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water.	Section 3.2.4
	f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options.	Sections 3.2 and 3.3
	g. Identification of proposed monitoring of hydrological attributes.	Sections 2.6.1 and 5.0
	Flooding and Coastal Erosion	
	The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including:	
	a. Flood prone land.	Section 2.7.5
	b. Flood planning area, the area below the flood planning level (areas below the 1 in 100 flood level plus a freeboard).	Section 2.7.5
	c. Hydraulic categorisation (floodways and flood storage areas).	Section 2.7.5

Table 2 Individual Agency Requests – Surface Water (Continued)

Agency	Requirement	Where Addressed or Why not Addressed
Office of Environment & Heritage (continued)	**Flooding and Coastal Erosion (continued)**	
	The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 1 in 10 year, 1 in 100 year flood levels and the probable maximum flood or an equivalent extreme event.	Section 2.7
	The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios:	
	a. Current flood behaviour for a range of design events as identified above. The 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 2.7.4
	Modelling in the EIS must consider and document:	
	a. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood.	Sections 2.7.4, 3.2.3
	b. Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories.	Sections 3.2.3
	c. Relevant provisions of the NSW Floodplain Development Manual 2005.	Section 2.7.5
	The EIS must assess the impacts on the proposed development on flood behaviour, including:	
	a. Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	Section 3.2.3
	b. Consistency with Council floodplain risk management plans.	No Council management plan for Big Flat Creek
	c. Compatibility with the flood hazard of the land.	Sections 2.7.4 and 3.2.3
	d. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	Sections 2.7.5 and 3.2.3
	e. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	Section 3.2.3.
	f. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	Section 3.2.3
	g. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council.	Not relevant because no significant changes to flood extent predicted – Section 3.2.3

Table 2 Individual Agency Requests – Surface Water (Continued)

Agency	Requirement	Where Addressed or Why not Addressed
Office of Environment & Heritage (continued)	**Flooding and Coastal Erosion (continued)** The EIS must assess the impacts on the proposed development on flood behaviour, including:	
	h. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the SES and Council.	Section 3.2.3
	i. Emergency management, evacuation and access, and contingency measures for the development considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the SES.	Not relevant because no significant changes to flood extent predicted – Section 3.2.3

The SWA is also guided by the Australian Government's "Information guidelines for proponents preparing coal seam gas and large coal mining development proposals" – Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) (Commonwealth of Australia, 2018) and "Significant impact guidelines 1.3: Coal seam gas and large coal mining developments - impacts on water resources" (Commonwealth of Australia, 2013). The SEARs include (as Attachment 3) the Commonwealth Department of Environment and Energy's assessment requirements. These requirements, as they relate to surface water, are summarised in Table 3 including where they have been addressed in this report.

Table 3 Commonwealth Department of Environment and Energy Assessment Requirements– Surface Water

Requirement	Where Addressed
b) Surface water assessment:	
i. An assessment of predicted changes to surface water flows and flood extents (e.g. using numerical model).	Section 3.2.3
ii. . Provision of mine water balances detailing onsite storages and discharge to surface water requirements.	Section 3.3
iii. Reference all of the above to analysis (sic) on surface water quality and quantity data gathered from the existing project.	Section 2.6
d) Cumulative impact assessment:	
i. Identify all surrounding existing and known future operations that could contribute cumulatively to surface water and groundwater impacts.	Section 3.2.6
e) Final landform and rehabilitation assessment: ii. Predictions of final void water quality and quantity.	Section 4.0

2.0 ASSESSMENT OF SURFACE WATER RESOURCES OF THE ADDITIONAL PROJECT AREA

2.1 OUTLINE OF CLIMATE AND TOPOGRAPHY

Mangoola operate two meteorological monitoring stations located north and south of the existing operations (refer Figure 3), with data available from 2010 onwards. The "Weather Station North" (WSN) station is located along Wybong Post Office Road and within the MCCO Additional Project Area and has been considered in this assessment. Mangoola also operate an automatic rain gauge within the upper catchment of Big Flat Creek and a second weather station ("Weather Station South") – both as shown in Figure 3. The Bureau of Meteorology (BoM) operates four rainfall recording stations nearby at Denman Palace Street (061016), Muswellbrook Lindisfarne (061168), Muswellbrook Spring Creek (Castle Vale) (061192) and Sandy Hollow Mt Danger Vineyards (061317) which are shown on Figure 3. These stations have varying periods of record. The Denman station has the longest period of data (1883-2014) in the area and has a recorded average annual rainfall for this period of 591.8 mm. Average monthly rainfall, calculated from long term data, recorded at Denman (061016) is shown in Table 4. Also shown in Table 4 are data for WSN as well as long term synthetic rainfall obtained from the SILO Data Drill[1] system for the MCCO Project Area.

Table 4 Average Monthly Rainfall

Data Source:	SILO Data Drill for MCCO Project Area	Denman Palace Street (061016)	Mangoola WSN
	millimetres		
Number of Years of Record	129	132	8
January	73.0	72.2	52.2
February	62.2	66.5	47.8
March	55.8	54.2	60.9
April	40.2	40.1	37.4
May	37.1	36.3	28.1
June	42.9	42.4	35.6
July	37.8	38.8	31.5
August	34.7	34.7	31.5
September	38.9	38.9	38.6
October	47.7	48	32.0
November	54.8	55.5	76.1
December	64.1	64.6	71.7
Annual Average	589.6	591.8	549.1

The data in Table 4 indicate a long term average annual rainfall for the area of approximately 590 mm, with higher total rainfalls occurring in summer months. The SILO Data Drill is based on records from the BoM, hence the two long term records are similar as expected and the SILO Data Drill has therefore been used for MCCO Project water balance simulations (refer Section 3.3.3). The recorded eight year Mangoola WSN average is lower than the long term regional average and lower than the corresponding period SILO Data Drill eight year average of 609 mm. This may indicate slightly lower rainfall locally at the Mangoola Coal Mine however the period of data is too short to demonstrate this definitively. As the SILO data is generated from long term rainfall data it is considered to be the most appropriate data for use in this assessment.

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

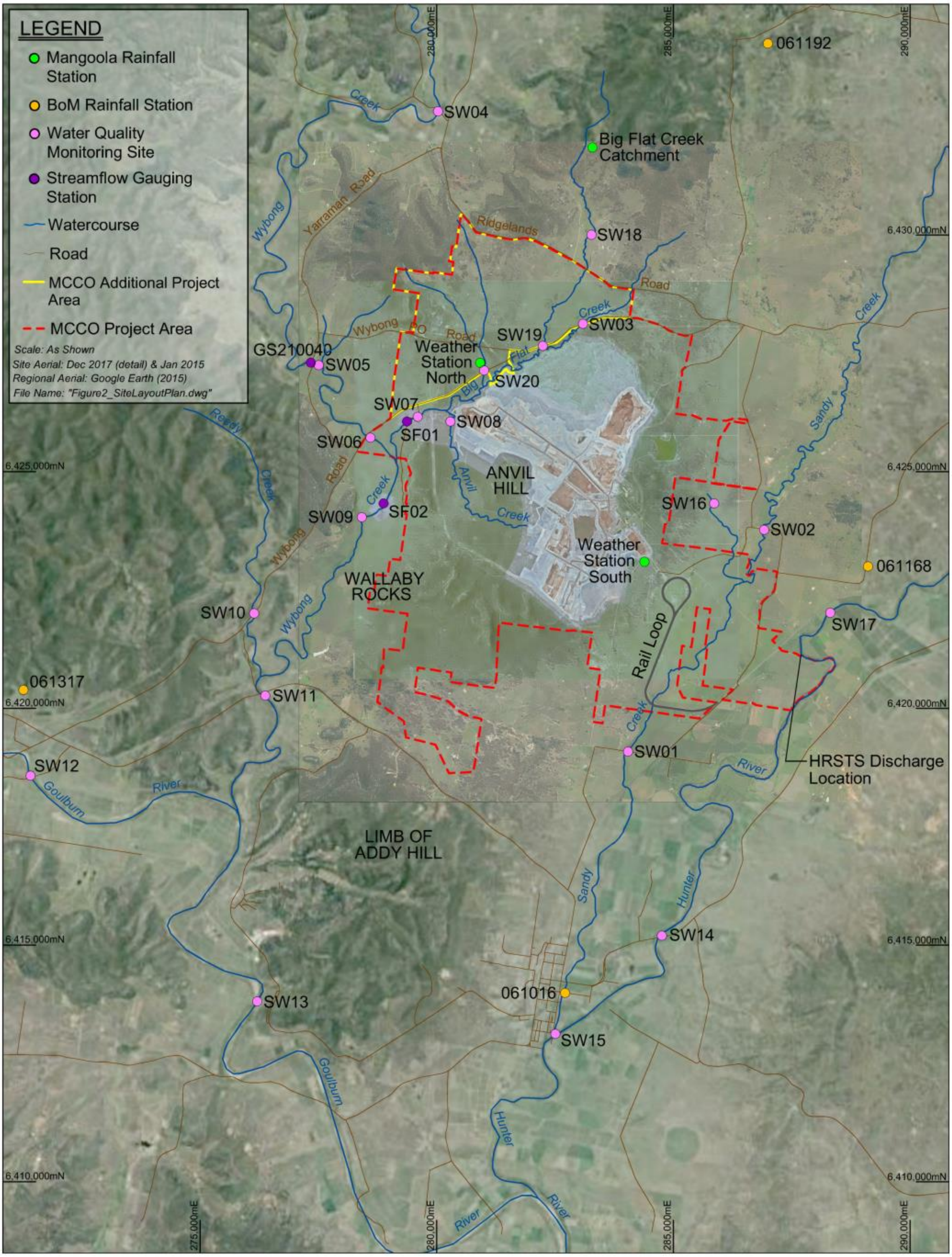

Figure 3 Site Layout Plan and Surface Water Monitoring Network

Average monthly pan evaporation, calculated from long term data recorded at the BoM station at Scone SCS (061089) is summarised in Table 5 together with long term synthetic rainfall obtained from the SILO Data Drill for the MCCO Project Area. The two data sets are similar and the SILO Data Drill has been used for MCCO Project water balance simulations (refer Section 3.3.3) – this data is considered the most appropriate for the assessment because it is generated for the site location from long term data.

Table 5 Average Monthly Evaporation

Data Source:	**SILO Data Drill for MCCO Project Area**	**Scone SCS (0610896)**
	millimetres	
Number of Years of Record	129	47
January	217.5	217
February	171.2	175.1
March	151.8	151.9
April	104.4	108
May	72.2	71.3
June	54.0	48
July	62.5	55.8
August	86.9	86.8
September	114.0	120
October	154.1	158.1
November	185.3	186
December	217.8	220.1
Annual Average	1592.7	1607.1

The topography within the Approved Mangoola Coal Mine Disturbance Boundary ranges from lower slopes to hills and rock outcrops. Anvil Hill is the dominant topographic feature within the Approved Mangoola Coal Mine Disturbance Boundary peaking at 285 mAHD (metres above Australian Height Datum). Wallaby Rocks (hills to the west of Anvil Hill) and Limb of Addy Hill (rocky area to the south) are other notable topographic features peaking at 264 mAHD and 302 mAHD respectively. These features are all labelled on Figure 3.

The topography of the MCCO Additional Project Area is similar with rocky slopes to the north and north-west peaking at 352 mAHD. The topography falls to the lower slopes towards the south adjacent to Big Flat Creek. The elevation of Big Flat Creek in the vicinity of the MCCO Additional Project Area varies from 177 mAHD to 132 mAHD.

2.2 DESCRIPTION OF REGIONAL DRAINAGE

Regionally, the MCCO Additional Project Area lies within the catchment of Wybong Creek. Wybong Creek, which has an estimated total catchment area of 792 km^2, is a tributary of the Goulburn River which in turn flows to the Hunter River, one of the major river systems in eastern NSW. Regulating storages on the Hunter River assist in providing reliable water supply for potable use, livestock, agriculture and industry. The Goulburn River and Wybong Creek are unregulated.

2.3 DESCRIPTION OF LOCAL DRAINAGE

The existing approved operations area lies within the catchments of Sandy Creek to the south-east, Anvil Creek and Clarks Gully to the west and Big Flat Creek to the north (refer Figure 3). The MCCO Additional Project Area lies within the catchment of Big Flat Creek. Sandy Creek is a tributary of the Hunter River and flows generally north-east to south-west. Anvil Creek flows generally south-east to north-west into Big Flat Creek which in turn flows generally from north-east to south-west to join Wybong Creek. Anvil Creek was mined through during 2018 with much of this catchment area now reporting to the mine water management system.

Big Flat Creek has an estimated total catchment area of 36.5 square kilometres (km^2) (based on the existing [2017] area of the approved Mangoola Coal Mine). Photographs of typical reaches of Wybong Creek and Big Flat Creek are given in Photo 1 and Photo 2 below (refer also Section 2.6.3.5).

Photo 1 Wybong Creek Downstream of Big Flat Creek Confluence

Photo 2 Big Flat Creek Adjacent to the MCCO Additional Project Area

The MCCO Additional Project Area is principally drained by Big Flat Creek and its tributaries (refer Figure 3). A small portion of the MCCO Additional Project Area, near its north-western limit, lies within the catchment of Wybong Creek however no disturbance is proposed in that portion. The main channel of Big Flat Creek parallels Wybong Road and separates the MCCO Additional Project Area from the existing approved operations. The main northern leg of Big Flat Creek rises in hills to the north of the MCCO Additional Project Area. Big Flat Creek joins Wybong Creek to the south-west of the MCCO Additional Project Area. A number of small un-named drainage lines traverse the MCCO Additional Project Area from north to south and drain into Big Flat Creek to the south of the MCCO Additional Project Area. These drainage lines comprise mainly first and second order streams varying from wide open swales with no defined banks to eroding gullies. The presence of farm dams has modified flow paths of these gullies. Further characterisation is provided in Section 2.6.3.5.

2.4 LOCAL SURFACE WATER USAGE AND LICENSING

The main surface water resource in the region is the Hunter River, one of the largest coastal catchments in NSW. The Hunter River catchment drains a total area of approximately 22,000 km^2. Flow in the Hunter River adjacent to the Mangoola Coal Mine is regulated by releases from Glenbawn Dam. Extraction and use of water from the Hunter River is subject to regulation under the *Water Sharing Plan for the Hunter Regulated River Water Source 2003*, which was enacted under the *Water Management Act 2000* in 2004. Key objectives of the Water Sharing Plan (WSP) are to:

(a) *protect, preserve, maintain or enhance the important river flow dependent and high priority groundwater dependent ecosystems of these water sources,*

(b) protect, preserve, maintain or enhance the Aboriginal, cultural and heritage values of these water sources,
(c) protect basic landholder rights,
(d) manage these water sources to ensure equitable sharing between users,
(e) provide opportunities for market based trading of access licences and water allocations within sustainability and system constraints,
(f) provide recognition of the connectivity between surface water and groundwater,
(g) provide sufficient flexibility in water account management to encourage responsible use of available water, and
(h) adaptively manage these water sources.

Water is extracted from the Hunter River for basic landholder stock and domestic rights, while extraction licences for water utility provision, power generation, agriculture, mining and industry via high security water access licences (WALs) and general security WALs have also been issued. The Hunter River is the major regional source of farm water supply for irrigation, stock watering and domestic use. Away from the Hunter River, land adjacent to the Mangoola Coal Mine is used primarily for cattle grazing.

Locally, surface water usage occurs within the Wybong Creek Water Source which is part of the Hunter Unregulated and Alluvial Water Sources. The creeks within the greater Wybong Creek catchment have a total of 132 approved water supply works and of these, 119 have WALs associated with them (email from WaterNSW, 5 February 2019), with water used for stock, domestic and irrigation purposes. The majority of these (95) are on Wybong Creek upstream of the confluence with Big Flat Creek. There are two located on Big Flat Creek, upstream of the MCCO Additional Project Area that are owned by Mangoola, with a further 22 on or near Wybong Creek downstream of the confluence with Big Flat Creek (many of these are owned by Mangoola-). Figure 4 shows the location of the surface water users (i.e. approved water supply works with WALs) on Wybong and Big Flat Creeks, with those owned by Mangoola highlighted in green.

In accordance with Schedule 3, Condition 25 of the Mangoola Coal Mine Project Approval PA 06_0014 (Project Approval) Mangoola do not use any licensable water from the Wybong Creek Water Source for mining purposes other than that incidentally collected by approved mining operations (Mangoola Open Cut, 2018). A summary of share components of surface WALs held by Mangoola in each different water source is shown in Table 6 (refer Mangoola Open Cut, 2018a).

Table 6 Summary of Surface Water Allocation Licence Share Components Held by Mangoola

Water Source	Share Component Held (ML)
Wybong Creek Unregulated	861
Muswellbrook Unregulated	28
Hunter River Regulated General Security	2,758
Hunter River Regulated High Security	17

2.5 MONITORING NETWORK

Surface water monitoring at the Mangoola Coal Mine is undertaken in accordance with the Mangoola Coal Surface Water Monitoring Plan (Mangoola, 2018). Streamflow and water quality are monitored at a number of sites as shown in Figure 3 (including the MCCO Additional Project Area) and are summarised in Table 7.

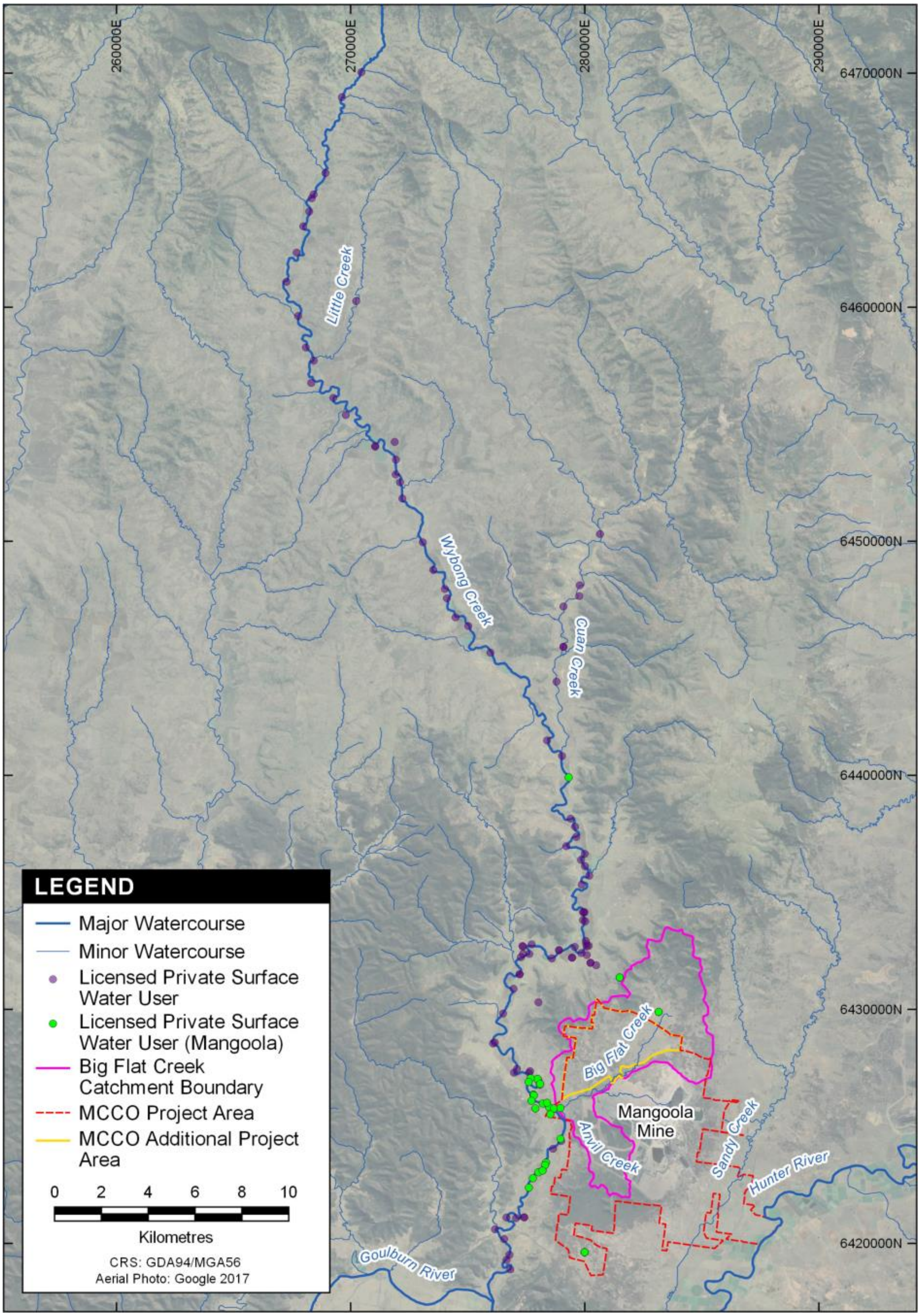

Figure 4 Wybong Creek Licensed Private Surface Water Users

Table 7 Summary of Surface Water Monitoring Sites

	ID	Watercourse	Description
Streamflow	GS210040	Wybong Creek	Stream flow gauging station maintained by Department of Industry (DI) - Water (upstream of the Big Flat Creek confluence)
	SF01	Big Flat Creek	Stream flow gauging station maintained by Mangoola
	SF02	Wybong Creek	Stream flow gauging station maintained by Mangoola (downstream of Big Flat Creek confluence)
Water Quality	SW01	Sandy Creek	Downstream of operation
	SW02	Sandy Creek	Upstream of operation
	SW03 (EPA 8)	Big Flat Creek	Upstream of operation
	SW04 (EPA 9)	Wybong Creek	Headwaters of Wybong Creek
	SW05	Wybong Creek	Upstream of Big Flat Creek
	SW06	Wybong Creek	At confluence with Big Flat Creek
	SW07	Big Flat Creek	Upstream of confluence with Wybong Creek
	SW08 (EPA 6)	Anvil Creek	Upstream of confluence with Big Flat Creek
	SW09	Wybong Creek	Downstream of operation
	SW10	Reedy Creek	Upstream of confluence with Wybong Creek
	SW11	Wybong Creek	Downstream of confluence with Reedy Creek
	SW12	Goulburn River	Upstream of confluence with Wybong Creek
	SW13	Goulburn River	Downstream of confluence with Wybong Creek
	SW14	Hunter River	Upstream of confluence with Sandy Creek
	SW15	Hunter River	Downstream of confluence with Sandy Creek
	SW16 (EPA 7)	Sandy Creek	Tributary of Sandy Creek
	SW17	Hunter River	Hunter River pipeline pump station
	SW18	Big Flat Creek Tributary	Tributary 1 of Big Flat Creek upstream of Ridgelands Road
	SW19	Big Flat Creek Tributary	Tributary 1 upstream of confluence with Big Flat Creek
	SW20	Big Flat Creek Tributary	Tributary 2 upstream of confluence with Big Flat Creek

Sites SW18, SW19 and SW20 were added in early 2015 in order to monitor and characterise the water quality in Big Flat Creek within and upstream of the MCCO Additional Project Area.

2.6 SURFACE WATER CHARACTERISTICS

2.6.1 Streamflow

2.6.1.1 Wybong Creek

The available DI – Water streamflow record for GS 210040 on Wybong Creek (refer to Figure 3 for location of the station) spans the period from mid-1955 to 2018, with some intermittent data gaps amounting to 4% of the recorded period. Figure 5 below shows the flow duration curve for the period of record. The record indicates that Wybong Creek is effectively perennial with no flow only recorded on approximately 3% of days in the record. The gauging station is located in an area of rock outcrop, providing good flow control.

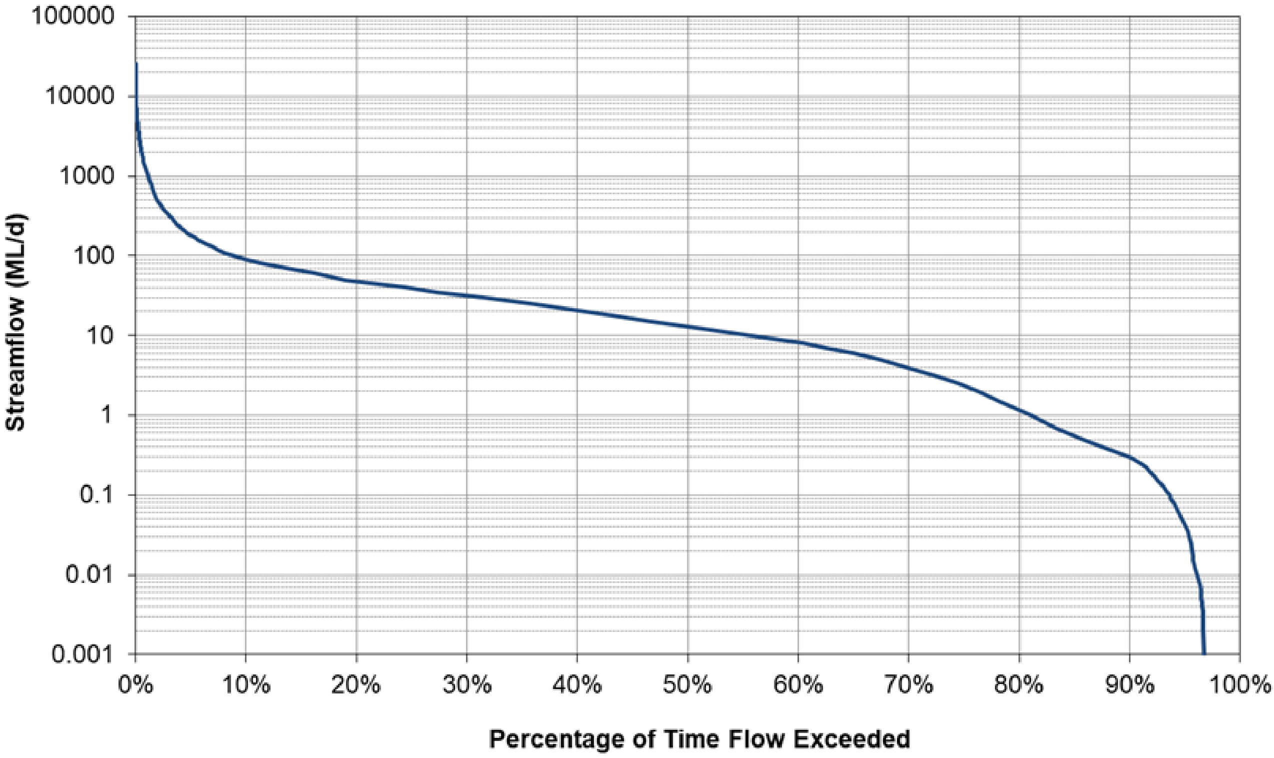

Figure 5   Flow Duration Plot for Wybong Creek at GS 210040

Calculated or estimated flow statistics for the recorded data[2] are as follows:

- Mean annual flow: 26,455 Megalitres (ML).
- Mean daily flow: 72.4 Megalitres per day (ML/d).
- Median daily flow: 12.9 ML/d.
- Average catchment yield (streamflow per unit area as a proportion of rainfall): 0.056 (5.6%).
- Baseflow index (baseflow as a proportion of total flow): 0.27.

Baseflow is the portion of streamflow that persists and sustains flow in between rainfall events. Following a flow event, it is initially derived from water recharged from stream-bank storage, but in longer dry weather periods it is derived from groundwater discharging to the stream. The high baseflow component of flows in Wybong Creek likely represents the release of groundwater stored within the alluvium in the upgradient catchment (AGEC, 2019). Flow persistence is also evident at another DI – Water gauging station located further upstream on Wybong Creek[3]. The baseflow persistence would be important in sustaining supply to licensed users during prolonged low rainfall periods.

Mangoola's streamflow gauging station on Wybong Creek (SF02) has been recording stream depth data continuously since late 2010. Recent development of a theoretical rating relationship for this station (relating recorded depth to flow rate) has enabled recorded stream depth data to be converted to estimated flow rate. Figure 6 shows the flow duration curve for 2010-2018[4] for this station.

[2] Data period 16 June 1955 to 17 October 2018, with 10% missing days.
[3] GS210147 – Wybong Creek at Manobalai.
[4] Data period 12 August 2010 to 10 May 2018

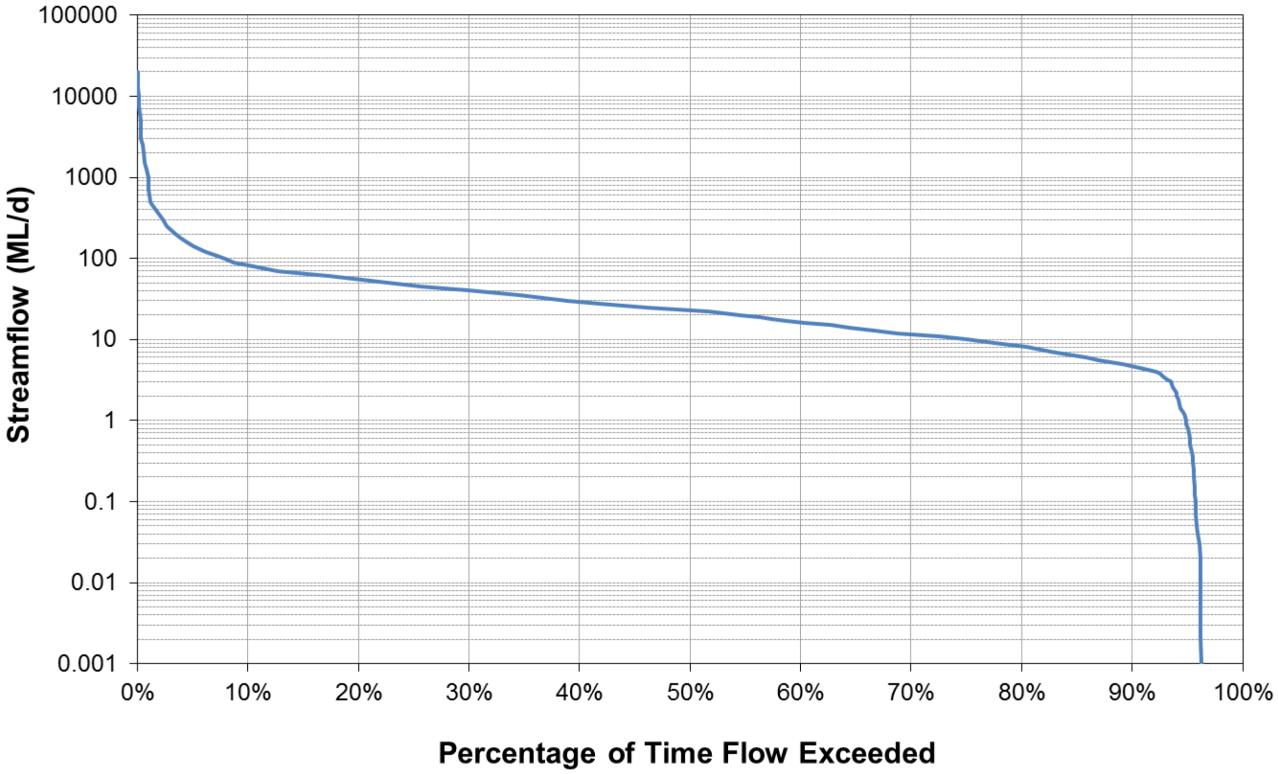

Figure 6 Flow Duration Plot for Wybong Creek at SF02 (2010-2018)

The record for SF02 indicates similar flow properties as recorded for GS210040, with slightly higher median and high flows (as would be expected given the larger catchment area reporting to SF02) and slightly reduced flow persistence, with no flow recorded on approximately 4% of days. The slightly reduced flow persistence may be related to the shorter period of record and/or the presence of alluvium in the stream bed which forms the flow control for the station.

2.6.1.2 Big Flat Creek

Mangoola's streamflow gauging station on Big Flat Creek (SF01) has also been recording stream depth data continuously since late 2010. A theoretical rating relationship for this station has recently been developed but has not yet been verified by repeated field flow gaugings and is affected by a variable downstream flow control (culvert through an access track that is prone to blockage). Furthermore, review of the station infrastructure has indicated that the location of the stream depth sensor was for many years above the stream cease-to-flow level. Therefore, estimated streamflow for the period of record has limited accuracy, particularly for the more frequent flow events and is not suitable for use in this assessment.

The SF01 water level record indicates 'zero' depth (depth below sensor location) has been recorded 42% of the time in a slightly below average rainfall period (551 mm average annual rainfall compared with the long term annual average of 590 mm), although zero flow is likely to have occurred on less than 42% of days due to the positioning of the stream depth sensor. The significant proportion of periods of recorded zero water level at SF01, combined with recent reported observations that flow in Big Flat Creek only persists for a limited period after rainfall, suggests that flow in this creek is ephemeral, that any baseflow is likely to be a low proportion of total flow and is unlikely to be persistent.

In order to characterise the streamflow behaviour of streams without a reliable flow record, it is normal practice in Australia to use records of nearby gauging stations with similar catchment characteristics. The record from Wybong Creek is not considered suitable because of its flow persistence (refer Section 2.6.1.1). Gauging station GS 210088 was previously operated by the then Department of Primary Industries – Water on Dart Brook near the town of Aberdeen[5] between 1970 and 1983 and again from 2002 to 2008. Figure 7 shows the recorded flow duration curve for this station. Zero flow was recorded on 28% of days.

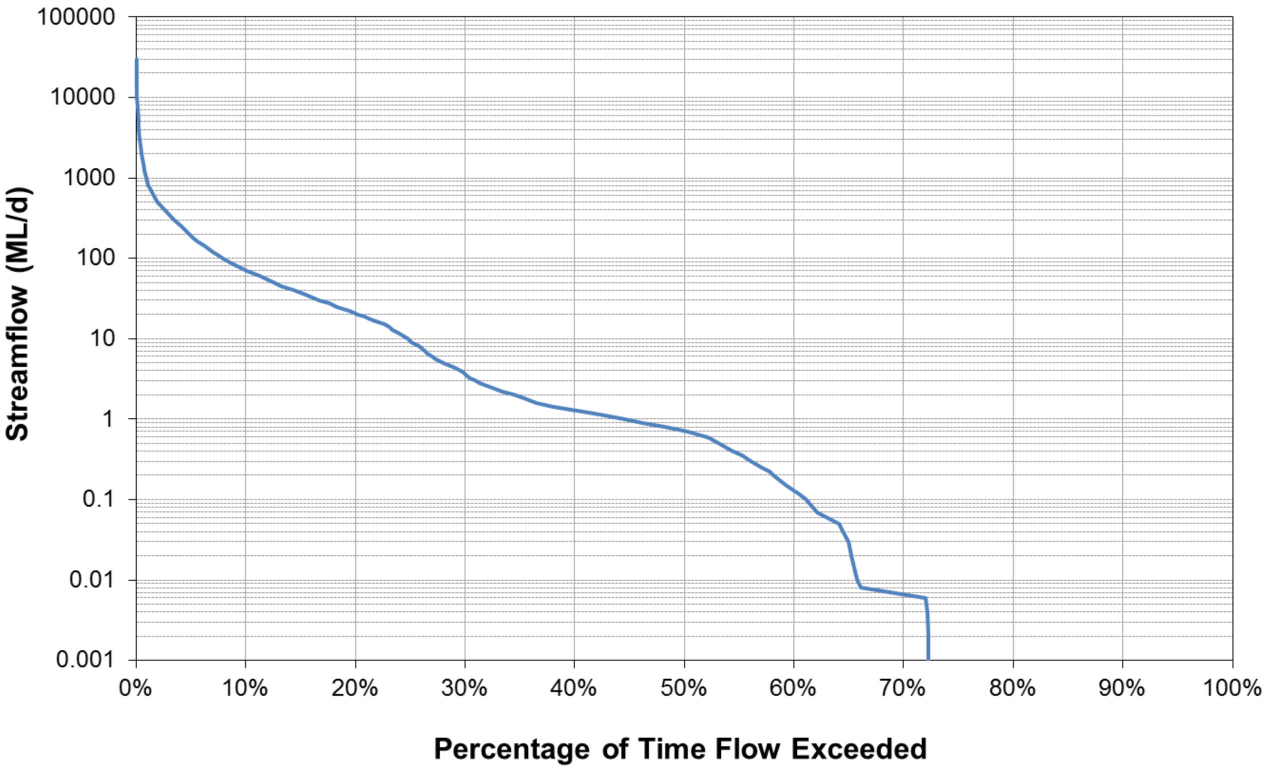

Figure 7 Flow Duration Plot for Dart Brook at GS 210088

The station record for GS 210088 was adjusted by factoring the recorded flow by the ratio of its catchment area to that of Big Flat Creek in order to generate the following flow statistics (applicable to the existing 39.6 km^2 catchment area of Big Flat Creek).

- Mean annual flow: 1,244 Megalitres (ML).
- Mean daily flow: 3.4 Megalitres per day (ML/d).
- Median daily flow: 0.036 ML/d.
- Average catchment yield (streamflow per unit area as a proportion of rainfall): 0.047 (4.7%).
- Baseflow index (baseflow as a proportion of total flow): 0.22[6].

It is likely that the above over-estimates the baseflow component of Big Flat Creek because AGEC (2019) have noted that there is no alluvium underlying Big Flat Creek and groundwater modelling indicates a baseflow flux to Big Flat Creek of 10 ML/year – which would have diminished to zero as a result of the approved Mangoola Coal Mine. As noted above, the depth record from SF01 indicates that flow in Big Flat Creek is ephemeral and that any baseflow is likely to be a low proportion of total flow. Therefore the use of the flow characteristics of Dart Brook to characterise flow conditions and assess impact to flow in Big Flat Creek is likely conservative.

[5] Approximately 18 km north-east of the Big Flat Creek catchment.
[6] Baseflow index obtained from Boughton and Chiew (2003).

2.6.2 Water Quality

2.6.2.1 Creeks near the MCCO Additional Project Area

The existing surface water quality monitoring sites shown in Figure 3 and listed in Table 7 are sampled and analysed on a regular basis in accordance with Mangoola's surface water monitoring plan (Mangoola Open Cut, 2018c). Flow conditions are also qualitatively recorded on a monthly basis.

Summary statistics for recorded pH, electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS) and turbidity data for sites relevant to the MCCO Additional Project Area are provided in Table 8.

Table 8 Summary of Surface Water Quality Data near MCCO Additional Project Area – Physical Parameters and pH

Locations	Statistic	pH	EC (µS/cm)	TSS (mg/L)	TDS (mg/L)	Turbidity (NTU)
Big Flat Creek Upstream (SW03)	Median	8.10	10,270	30	5,840	37
	Average	7.94	12,430	260	7,787	262
	Minimum	6.10	74	1	111	2
	Maximum	10.0	50,500	8,930	31,700	6,100
	No. Samples	215	216	213	212	105
	% Exceedance†	57%	89%	-	58%	59%
	Site Specific Trigger Value	7.3-8.5	24,000	146	14,908	212
Big Flat Creek Upstream Tributary (SW18, SW19)	Median	7.00	918	18	525	27
	Average	7.02	1,160	35	689	42
	Minimum	6.00	83	1	152	2
	Maximum	9.40	5,300	364	3,030	290
	No. Samples	91	91	84	91	84
	% Exceedance†	16%	90%	-	0%	52%
SW18	Site Specific Trigger Value	6.6-7.2	1,208	39.0	720	65
SW19	Site Specific Trigger Value	7.0-7.66	3,326	32.4	1,796	33
Big Flat Creek Tributary 2 (SW20)	Median	6.55	104	25	188	60
	Average	6.60	188	60	271	115
	Minimum	5.60	193	2	50	17
	Maximum	8.40	2,990	460	1,870	450
	No. Samples	50	50	50	50	50
	% Exceedance†	44%	6%	-	0%	90%

† Exceedance of ANZECC (2000) guideline default trigger values

Table 8 Summary of Surface Water Quality Data near MCCO Additional Project Area – Physical Parameters and pH (Continued)

Locations	Statistic	pH	EC (µS/cm)	TSS (mg/L)	TDS (mg/L)	Turbidity (NTU)
Big Flat Creek Downstream (SW07)	Median	8.00	5,165	11	3,108	13
	Average	7.97	6,857	42	4,201	57
	Minimum	6.67	144	1	200	1
	Maximum	9.76	48,500	1,890	40,300	2,600
	No. Samples	236	236	236	236	124
	% Exceedance†	47%	98%	-	41%	42%
	Site Specific Trigger Value	7.5-8.4	10,900	40	6,060	77
Wybong Creek Upstream of Big Flat Creek (SW04, SW05, SW06)	Median	8.20	1,626	9	952	10
	Average	8.09	1,801	61	1,064	79
	Minimum	5.80	143	1	1	0
	Maximum	9.20	5,630	3,280	6,740	3,000
	No. Samples	801	801	780	801	401
	% Exceedance†	64%	96%	-	0.1%	30%
SW04	Site Specific Trigger Value	7.6-8.3	2,518	23.0	1,408	25
SW05	Site Specific Trigger Value	8.0-8.4	2,356	24.0	1,380	32
SW06	Site Specific Trigger Value	7.8-8.4	2,978	29.0	1,775	37
Wybong Creek Downstream of Big Flat Creek (SW09, SW11)	Median	8.00	2,040	9	1,170	10
	Average	7.98	2,338	51	1,412	64
	Minimum	6.30	142	1	151	0.3
	Maximum	9.40	8,845	1,880	9,295	1,600
	No. Samples	545	545	531	545	270
	% Exceedance†	50%	96%	-	2.8%	20%
SW09	Site Specific Trigger Value	7.8-8.3	3,690	27.2	2,088	37
SW11	Site Specific Trigger Value	7.7-8.2	2,800	22.6	1,600	25
ANZECC (2000) Guideline Default Trigger Values	Protection of Aquatic Ecosystems (upland river)	6.5 – 8.0*	30 – 350*	-*	-*	2 – 25*
	Primary Industries (Livestock Drinking Water)	6.0 – 9.0	-*	-*	4,000* (beef)	-*

† Exceedance of ANZECC (2000) guideline default trigger values

* Same as NSW Water Quality Objectives

Data for pH, EC and turbidity has been compared in Table 8 with guideline trigger values (ANZECC, 2000) for protection of aquatic ecosystems in south-eastern Australian upland rivers and guideline values for Primary Industries water supplies (livestock drinking water quality). TDS data has been compared with ANZECC (2000) guideline values for Primary Industries water supplies (livestock drinking water quality). Note that NSW water quality objectives are the same as ANZECC (2000) guideline trigger values for these parameters as indicated in Table 8. The percentage of samples at each site that have exceeded the guideline trigger values are given in Table 8, with values in red indicating a 50% exceedance or more. Exceedances of the guideline trigger values can be as a result of natural catchment conditions and/or land use modification (including mining and non-mining related changes).

Site specific trigger values have been derived from the monitored data as the 80th percentile of monitored values (as well as the 20th percentile for pH) and are included in Table 8. Note that no trigger value is given for SW20 because it is within the disturbance boundary of the MCCO Additional Project Area and will not be relevant for ongoing monitoring during the MCCO Project. In accordance with Mangoola's water management plan (Mangoola Open Cut, 2018a), if an exceedance of water quality criteria (trigger values) is identified, then a surface water and groundwater response plan is activated (refer Section 5.2).

Data in Table 8 indicate that average pH values in the two creeks have a tendency to trend towards slightly alkaline levels, with the majority of samples in Big Flat Creek and Wybong Creek falling outside the ANZECC (2000) guideline trigger range - except in the Big Flat Creek tributaries (SW18, SW19 and SW20) and the Big Flat Creek downstream monitoring location (SW07), where less than 50% of samples fell outside this range).

TSS levels vary over a wide range, with average values in Big Flat Creek higher than Wybong Creek and higher in upstream Big Flat Creek than downstream. Lower values were recorded in the Big Flat Creek tributaries.

Recorded turbidity values in upstream Big Flat Creek and its tributaries exceeded the ANZECC (2000) guideline default trigger value in more than half of the samples collected. The proportion was slightly lower in downstream Big Flat Creek and lower again in Wybong Creek. Note that the monitoring sites on upstream Big Flat Creek and its tributaries are upstream of mining operations and therefore reflect background variability.

Average EC (a measure of salinity) exceeds the ANZECC (2000) guideline default trigger value upper bound in the majority of samples at all monitoring locations except SW20 (Big Flat Creek tributary passing through the MCCO Additional Project Area). Recorded EC and TDS values in Big Flat Creek appear particularly high. The most likely cause of higher salinity is considered to be evapo-concentration of shallow groundwater where it comes close to the surface[7]. Figure 8 shows a plot of recorded EC values for the five sites on Big Flat Creek and its tributaries from 2008 to early 2018. Also plotted is recorded flow depth at SF01, indicating periods of wet weather. It is evident from Figure 8 and Table 8 that, on average, the highest recorded EC and TDS values are at SW03 on upstream Big Flat Creek, which is located upstream of the approved mining operations. Therefore, it appears that the higher salinity reflects background conditions and is not affected by mining operations.

[7] Australasian Groundwater and Environmental Consultants Pty Ltd – personal communication.

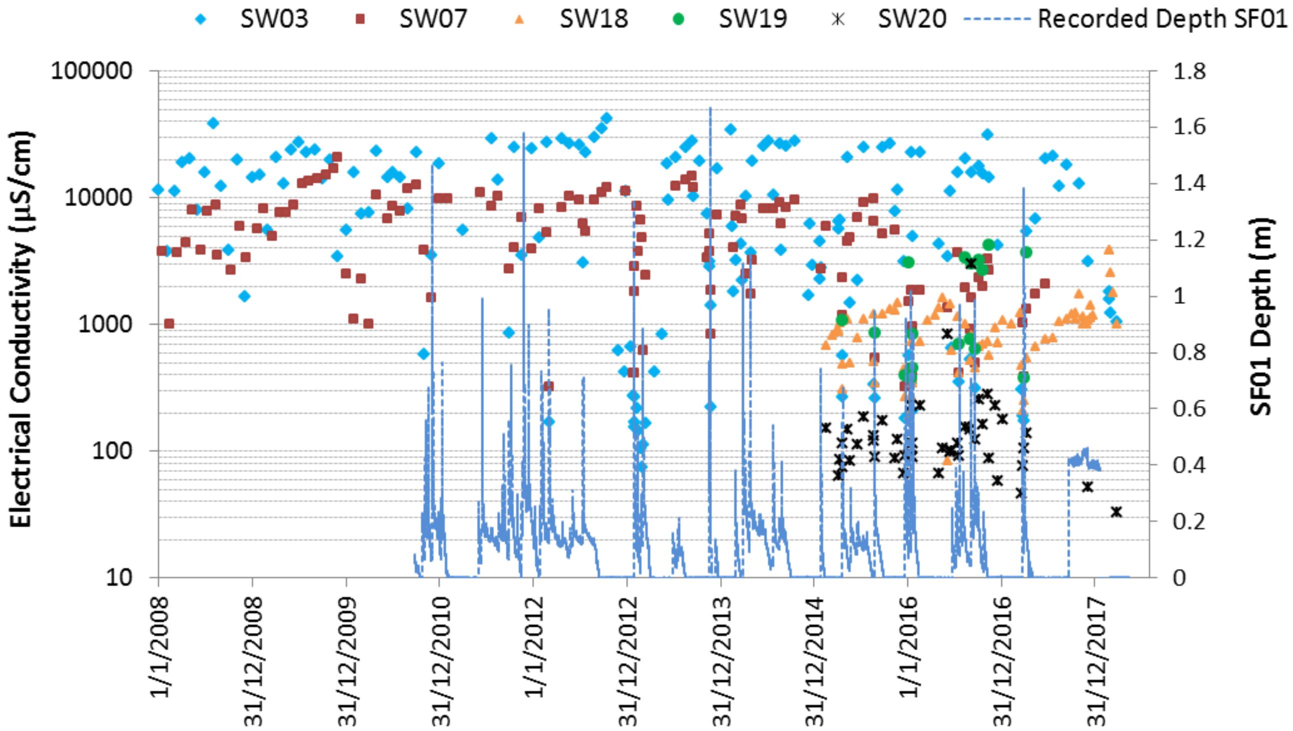

Figure 8 Recorded Electrical Conductivity and Flow Depth for Big Flat Creek and Tributaries

Figure 8 indicates increased salinity during periods of low stream depth and lower salinity during and following periods of flow. With the exception of SW20, the overall salinity values in Big Flat Creek are considered high for a natural stream, with a long term average EC of approximately 13,000 µS/cm at SW03. It appears that the high salinity in upstream Big Flat Creek (SW03) is affecting salinity further downstream (SW07) with lower salinity inflow from tributaries (SW19, SW20). The high salinity is considered likely to affect aquatic ecology and in-stream vegetation in Big Flat Creek.

Figure 9 shows a similar plot for five of the monitoring sites on Wybong Creek as well as recorded streamflow at SF02. The recorded salinity in Wybong Creek is significantly lower than in Big Flat Creek. It is noteworthy that the recorded EC at site SW09, just downstream of the Big Flat Creek confluence, is significantly higher than at the sites located upstream of the Big Flat Creek confluence (SW04, SW05 and SW06) indicating that the higher salinity inflow from Big Flat Creek is affecting the salinity of Wybong Creek. As noted above, the highest recorded salinity in Big Flat Creek is upstream of mining operations (SW03) and reflects background conditions.

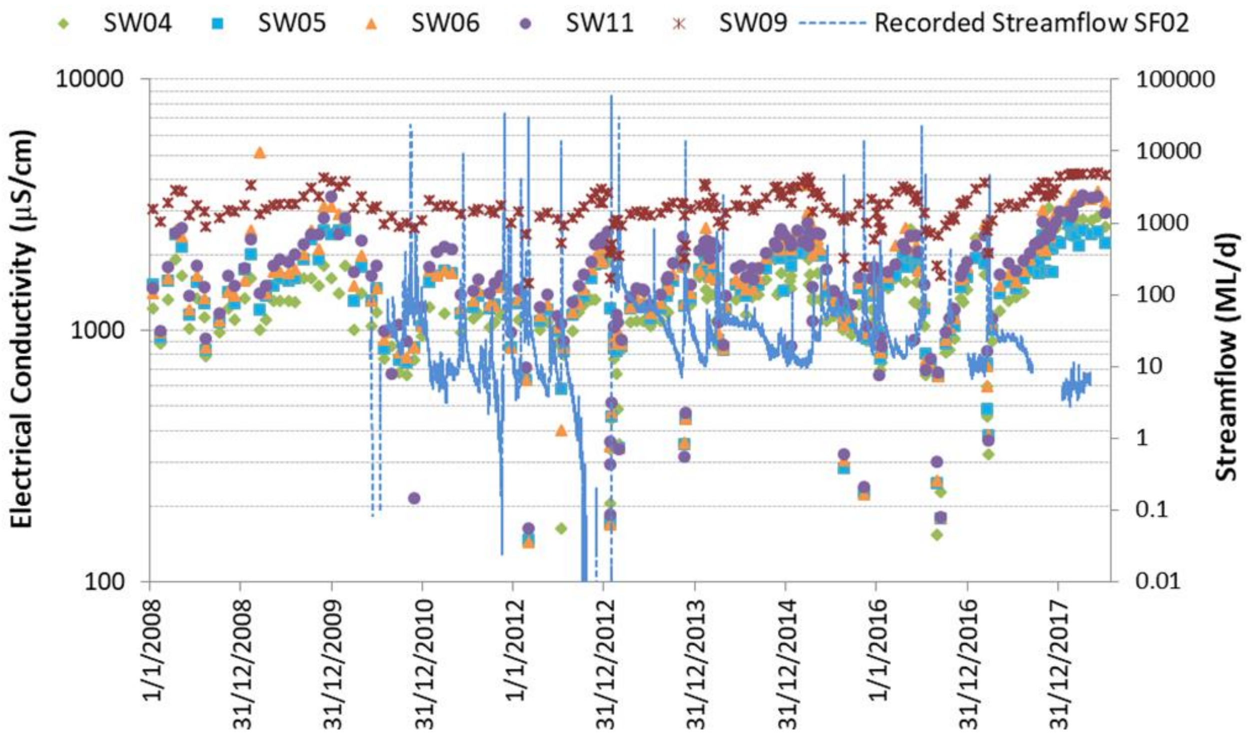

Figure 9 Recorded Electrical Conductivity and Streamflow for Wybong Creek

The Wybong Creek data again indicates increased salinity during periods of low or no recorded flow and low salinity during and following periods of increased flow.

Summary statistics for monitored total metals concentration data for sites relevant to the MCCO Additional Project Area are provided in Table 9. This data has again been compared with default guideline trigger values (ANZECC, 2000) for protection of aquatic ecosystems in south-eastern Australian upland rivers and guideline values for Primary Industries water supplies (livestock drinking water quality). Note that in calculating statistics, where the sample was recorded at less than the laboratory limit of detection, the concentration was assumed equal to the laboratory limit of detection. The percentage of samples at each site that have exceeded the guideline trigger values are given in Table 9 with values in red indicating a 50% exceedance or more. Exceedances of the guideline trigger values can be as a result of natural catchment conditions and/or land use modification (including mining and non-mining related changes). Site specific trigger values have been derived from the monitored data as the 80th percentile of monitored values where sufficient monitored data are available to derive this statistic (a minimum of ten records). The range of metals analysed was expanded in late 2017, however since then there have been limited opportunities for sample collection due to prevailing no flow conditions resulting from low rainfall.

The majority of recorded concentrations of metals do not exceed the default guideline trigger values (ANZECC, 2000), where such a value exists. The exceptions are: chromium (in upstream Big Flat Creek), copper, lead and zinc (zinc in Wybong Creek and some points in Big Flat Creek) which generally exceed the default guideline trigger value in less than around half of samples and aluminium, sliver and zinc (zinc only at some points in Big Flat Creek, not Wybong Creek) which exceed the default guideline trigger value in most samples. The exceedances of silver are due to the default guideline trigger value being less than the laboratory limit of detection,

Overall, the recorded metals data indicates that Wybong Creek water quality is good, with generally low metals concentrations, while the water quality in upstream Big Flat Creek and its tributaries is poorer, with greater prevalence of elevated concentrations of some environmentally significant metals. The conditions in upstream Big Flat Creek are not affected by mining operations and reflect background conditions.

Table 9 Summary of Surface Water Quality Data near MCCO Additional Project Area – Total Metals

Locations	Statistic	Aluminium	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
Big Flat Creek Upstream (SW03)	Median (mg/L)	3.90	-	0.003	0.230	-	0.095	-	-
	Average (mg/L)	3.90	-	0.005	0.243	-	0.098	-	-
	Minimum (mg/L)	0.290	-	<0.001	<0.1	-	0.060	-	<0.001
	Maximum (mg/L)	7.50	<0.001	0.010	0.493	<0.001	0.200	<0.0001	0.010
	No. Samples	2	2	8	8	1	8	7	2
	% Exceedance†	100%	-	0%	-	0%	0%	0%	50%
Big Flat Creek Upstream Tributary (SW18, SW19)	Median (mg/L)	0.110	-	<0.001	0.120	-	0.060	-	-
	Average (mg/L)	0.413	-	<0.001	0.127	-	0.080	-	-
	Minimum (mg/L)	<0.01	-	<0.001	0.043	-	<0.1	-	-
	Maximum (mg/L)	2.22	<0.001	<0.010	0.304	<0.001	0.200	<0.0001	<0.001
	No. Samples	8	9	11	11	3	11	6	8
	% Exceedance†	75%	-	0%	-	0%	0%	0%	0%
SW18	Site Specific Trigger Value	ID	ID	<0.001	0.159	ID	0.10	ID	ID
SW19	Site Specific Trigger Value	ID	ID	ID	ID	ID	ID	ID	ID
Big Flat Creek Tributary 2 (SW20)	Median (mg/L)	-	-	-	-	-	-	-	-
	Average (mg/L)	-	-	-	-	-	-	-	-
	Minimum (mg/L)	-	-	<0.001	0.030	-	-	-	-
	Maximum (mg/L)	-	-	<0.01	<0.1	-	<0.1	<0.0001	-
	No. Samples	0	0	2	2	0	2	2	0
	% Exceedance†	-	-	0%	-	-	0%	0%	-
Big Flat Creek Downstream (SW07)	Median (mg/L)	-	-	0.010	0.200	-	-	-	-
	Average (mg/L)	-	-	0.007	0.195	-	-	-	-
	Minimum (mg/L)	-	-	<0.001	0.070	-	-	-	-
	Maximum (mg/L)	-	-	0.010	0.400	-	<0.10	<0.0001	-
	No. Samples	0	0	6	6	0	6	6	0
	% Exceedance†	-	-	0%	-	-	0%	0%	-

† Exceedance of ANZECC (2000) guideline default trigger values (lowest value)

ID: insufficient data to generate a site specific trigger value

Table 9 Summary of Surface Water Quality Data – Total Metals (Continued)

Locations	Statistic	Aluminium	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
Wybong Creek Upstream of Big Flat Creek (SW04, SW05, SW06)	Median (mg/L)	0.280	-	-	0.020	-	-	-	-
	Average (mg/L)	0.425	-	-	0.046	-	-	-	-
	Minimum (mg/L)	0.040	-	<0.001	0.010	-	<0.05	-	-
	Maximum (mg/L)	1.62	<0.001	<0.01	<0.1	<0.001	<0.1	<0.0001	<0.001
	No. Samples	20	20	47	48	9	46	36	20
	% Exceedance†	95%	-	0%	-	0%	0%	0%	0%
SW04	Site Specific Trigger Value	ID	ID	<0.010	<0.100	ID	<0.100	<0.0001	ID
SW05	Site Specific Trigger Value	ID	ID	<0.010	<0.100	ID	<0.100	<0.0001	ID
SW06	Site Specific Trigger Value	ID	ID	<0.010	<0.100	ID	<0.100	<0.0001	ID
Wybong Creek Downstream of Big Flat Creek (SW09, SW11)	Median (mg/L)	0.065	-	-	0.032	-	-	-	-
	Average (mg/L)	0.144	-	-	0.051	-	-	-	-
	Minimum (mg/L)	<0.010	-	<0.001	0.010	-	-	-	-
	Maximum (mg/L)	0.570	<0.001	<0.01	<0.1	<0.001	<0.1	<0.0001	<0.001
	No. Samples	14	14	32	32	6	32	24	14
	% Exceedance†	57%	-	0%	-	0%	0%	0%	0%
SW09	Site Specific Trigger Value	ID	ID	<0.010	<0.100	ID	<0.100	<0.0001	ID
SW11	Site Specific Trigger Value	ID	ID	<0.010	<0.100	ID	<0.100	<0.0001	ID
ANZECC (2000) Guideline Default Trigger Values	Protection of Aquatic Ecosystems (upland river)	0.055*	-	As (iii) 0.024 As (v) 0.013*	-	-	0.37*	0.0002*	Cr (vi) 0.001*
	Primary Industries (Livestock Drinking Water)	5*	-	0.5*	-	-	5*	0.01*	1*
	Primary Industries (Irrigation – short term use)	20*	-	2*	-	0.5*	0.5 – 15*‡	0.05*	1*

† Exceedance of ANZECC (2000) guideline default trigger values (lowest value)

* Same as NSW Water Quality Objectives

‡ Depending on crop tolerance

ID: insufficient data to generate a site specific trigger value

Table 9 Summary of Surface Water Quality Data near MCCO Additional Project Area – Total Metals (Continued)

Locations	Statistic	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel
Big Flat Creek Upstream (SW03)	Median (mg/L)	-	0.006	0.305	0.0030	0.092	-	-	-
	Average (mg/L)	-	0.005	1.12	0.0049	0.116	-	-	-
	Minimum (mg/L)	-	>0.001	<0.05	<0.001	0.030	-	-	<0.001
	Maximum (mg/L)	<0.001	0.010	6.27	0.0100	0.300	<0.0001	<0.001	0.010
	No. Samples	2	8	8	8	8	8	1	2
	% Exceedance†	0%	62%	0%	50%	0%	0%	0%	0%
Big Flat Creek Upstream Tributary (SW18, SW19)	Median (mg/L)	0.001	0.001	3.75	-	3.39	-	-	0.001
	Average (mg/L)	0.078	0.002	5.825	-	8.91	-	-	0.048
	Minimum (mg/L)	<0.001	<0.001	0.850	<0.001	0.285	-	-	<0.001
	Maximum (mg/L)	0.620	<0.01	25.0	<0.010	58.9	<0.0001	<0.001	0.380
	No. Samples	8	11	11	12	11	7	4	8
	% Exceedance†	13%	18%	18%	9%	64%	0%	0%	13%
SW18	Site Specific Trigger Value	ID	<0.001	7.340	<0.001	7.82	ID	ID	ID
SW19	Site Specific Trigger Value	ID	ID	ID	ID	ID	ID	ID	ID
Big Flat Creek Tributary 2 (SW20)	Median (mg/L)	-	-	7.80	-	-	-	-	-
	Average (mg/L)	-	-	7.80	-	0.095	-	-	-
	Minimum (mg/L)	-	<0.001	3.81	<0.001	0.020	-	-	-
	Maximum (mg/L)	-	0.020	11.8	<0.010	0.170	<0.0001	-	-
	No. Samples	0	2	2	2	2	2	0	0
	% Exceedance†	-	50%	50%	50%	0%	0%	-	-
Big Flat Creek Downstream (SW07)	Median (mg/L)	-	0.010	0.100	-	0.040	-	-	-
	Average (mg/L)	-	0.007	0.230	-	0.080	-	-	-
	Minimum (mg/L)	-	<0.001	<0.05	<0.001	<0.01	-	-	-
	Maximum (mg/L)	-	0.010	0.760	<0.010	0.220	<0.0001	-	-
	No. Samples	0	6	6	6	6	6	0	0
	% Exceedance†	-	67%	0%	67%	0%	0%	-	-

† Exceedance of ANZECC (2000) guideline default trigger values (lowest value)

ID: insufficient data to generate a site specific trigger value

Table 9 Summary of Surface Water Quality Data near MCCO Additional Project Area – Total Metals (Continued)

Locations	Statistic	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel
Wybong Creek Upstream of Big Flat Creek (SW04, SW05, SW06)	Median (mg/L)	-	-	0.250	<0.001	0.034	-	-	-
	Average (mg/L)	-	-	0.447	0.0039	0.046	-	-	-
	Minimum (mg/L)	-	<0.001	<0.05	<0.001	<0.01	-	-	-
	Maximum (mg/L)	<0.001	0.090	1.800	0.0100	0.230	<0.0001	<0.001	<0.001
	No. Samples	20	47	47	47	49	38	12	20
	% Exceedance†	0%	34%	0%	32%	0%	0%	0%	0%
SW04	Site Specific Trigger Value	ID	<0.010	0.520	<0.010	0.080	<0.0001	ID	ID
SW05	Site Specific Trigger Value	ID	<0.010	0.330	<0.010	0.040	<0.0001	ID	ID
SW06	Site Specific Trigger Value	ID	<0.010	0.688	<0.010	0.084	<0.0001	ID	ID
Wybong Creek Downstream of Big Flat Creek (SW09, SW11)	Median (mg/L)	-	<0.001	0.295	-	0.055	-	-	-
	Average (mg/L)	-	0.005	0.378	-	0.157	-	-	-
	Minimum (mg/L)	-	<0.001	<0.05	<0.001	0.020	-	-	-
	Maximum (mg/L)	<0.001	0.030	1.870	<0.01	0.450	<0.0001	<0.001	<0.001
	No. Samples	146	32	32	32	32	26	8	14
	% Exceedance†	0%	31%	0%	31%	0%	0%	0%	0%
SW09	Site Specific Trigger Value	ID	<0.010	0.478	<0.010	0.202	<0.0001	ID	ID
SW11	Site Specific Trigger Value	ID	<0.010	0.402	<0.010	0.344	<0.0001	ID	ID
ANZECC (2000) Guideline Default Trigger Values	Protection of Aquatic Ecosystems (upland river)	-	0.0014	-	0.0034	1.9	0.0006	-	0.011
	Primary Industries (Livestock Drinking Water)	1	1 (Cattle)	-	0.1	-	0.002	0.15	1
	Primary Industries (Irrigation – short term use)	0.1*	5*	10*	5*	10*	0.002*	0.05*	2*

† Exceedance of ANZECC (2000) guideline default trigger values (lowest value)

* Same as NSW Water Quality Objectives

ID: insufficient data to generate a site specific trigger value

Table 9 Summary of Surface Water Quality Data near MCCO Additional Project Area – Total Metals (Continued)

Locations	Statistic	Selenium	Silver	Strontium	Vanadium	Zinc
Big Flat Creek Upstream (SW03)	Median (mg/L)	<0.01	-		-	0.010
	Average (mg/L)	<0.01	-	6.5	-	0.008
	Minimum (mg/L)	<0.01	<0.001	1.51	-	<0.005
	Maximum (mg/L)	0.010	<0.01	11.5	<0.01	0.013
	No. Samples	8	8	2	1	8
	% Exceedance†	0%	100%	-	0%	63%
Big Flat Creek Upstream Tributary (SW18, SW19)	Median (mg/L)	-	-	0.340	-	0.005
	Average (mg/L)	-	-	0.489	-	0.049
	Minimum (mg/L)	-	<0.001	0.236	-	0.005
	Maximum (mg/L)	<0.01	<0.010	1.67	<0.01	0.520
	No. Samples	11	11	8	3	11
	% Exceedance†	0%	100%	-	0%	27%
SW18	Site Specific Trigger Value	<0.010	<0.001	ID	ID	ID
SW19	Site Specific Trigger Value	ID	ID	ID	ID	ID
Big Flat Creek Tributary 2 (SW20)	Median (mg/L)	-	-	-	-	-
	Average (mg/L)	-	-	-	-	0.025
	Minimum (mg/L)	-	<0.001	-	-	0.010
	Maximum (mg/L)	<0.01	<0.010	-	-	0.040
	No. Samples	2	2	0	0	2
	% Exceedance†	0%	100%	-	-	100%
Big Flat Creek Downstream (SW07)	Median (mg/L)	-	-	-	-	-
	Average (mg/L)	-	-	-	-	-
	Minimum (mg/L)	-	<0.001	-	-	<0.005
	Maximum (mg/L)	<0.01	<0.010	-	-	<0.010
	No. Samples	6	6	0	0	6
	% Exceedance†	0%	100%	-	-	67%

† Exceedance of ANZECC (2000) guideline default trigger values (lowest value)

ID: insufficient data to generate a site specific trigger value

Table 9 Summary of Surface Water Quality Data near MCCO Additional Project Area – Total Metals (Continued)

Locations	Statistic	Selenium	Silver	Strontium	Vanadium	Zinc
Wybong Creek Upstream of Big Flat Creek (SW04, SW05, SW06)	Median (mg/L)	<0.010	-	0.769	<0.01	0.005
	Average (mg/L)	0.010	-	0.861	0.010	0.007
	Minimum (mg/L)	<0.010	<0.001	0.682	<0.01	<0.005
	Maximum (mg/L)	0.020	<0.01	1.20	0.010	0.030
	No. Samples	47	47	20	9	47
	% Exceedance†	2%	100%	-	0%	34%
SW04	Site Specific Trigger Value	<0.010	<0.010	ID	ID	<0.010
SW05	Site Specific Trigger Value	<0.010	<0.010	ID	ID	<0.010
SW06	Site Specific Trigger Value	<0.010	<0.010	ID	ID	<0.010
Wybong Creek Downstream of Big Flat Creek (SW09, SW11)	Median (mg/L)	-	--	0.994	-	0.005
	Average (mg/L)	-	-	1.074	-	0.007
	Minimum (mg/L)	-	<0.001	0.844	-	<0.005
	Maximum (mg/L)	<0.01	>0.01	1.64	<0.01	0.010
	No. Samples	32	32	14	6	32
	% Exceedance†	0%	100%	-	0%	34%
SW09	Site Specific Trigger Value	<0.010	<0.010	ID	ID	<0.010
SW11	Site Specific Trigger Value	<0.010	<0.010	ID	ID	<0.010
ANZECC (2000) Guideline Default Trigger Values	Protection of Aquatic Ecosystems (upland river)	0.011	0.00005	-	-	0.008
	Primary Industries (Livestock Drinking Water)	0.02	-	-	-	20
	Primary Industries (Irrigation – short term use)	0.05*			0.5*	5*

† Exceedance of ANZECC (2000) guideline default trigger values (lowest value)

ID: insufficient data to generate a site specific trigger value

2.6.2.2 Site Water Storages

Water quality in site water storages is highly variable, depending on prevailing climatic conditions and mining operations. For example, the EC in the main mine water storage, the Pit Water Dam (PWD), varied in 2014 between approximately 2,300 µS/cm and 4,200 µS/cm. The mine water management system has, to date, been maintained as a closed system, although controlled release from the PWD is permitted in accordance with the HRSTS.

Summary statistics for recorded pH, EC, TSS, TDS and turbidity data for site water storages and sediment dams within the existing surface water management system at the Mangoola Coal Mine are given in Table 10 for the period of available data for each storage.

Table 10 Summary of Site Storages Water Quality Data Mangoola Coal Mine – Physical Parameters and pH

Storage*	Statistic	pH	EC (µS/cm)	TSS (mg/L)	TDS (mg/L)	Turbidity (NTU)
PWD (Feb 2011 – Feb 2019)	Median	8.50	3,390	19	1,960	20
	Average	8.54	3,650	32	2,136	31
	Minimum	7.80	615	2	394	1
	Maximum	9.20	9,740	343	5,400	200
	No. Samples	109	109	101	109	101
NOOP1† (Feb 2011 – Dec 2017)	Median	8.25	4,880	34	2,685	40
	Average	8.35	6,770	108	4,092	98
	Minimum	7.30	413	2	304	2
	Maximum	9.40	18,400	4,210	12,630	750
	No. Samples	86	86	80	86	79
NAR South SD† (Jul 2013 – Jul 2017)	Median	8.70	998	40	610	53
	Average	8.57	1,198	155	739	227
	Minimum	7.40	236	1	271	9
	Maximum	9.20	7,100	1,730	4,570	2,300
	No. Samples	42	42	42	42	42
Rail Loop Dam (Feb 2011 – Feb 2019)	Median	8.30	1,152	24	641	30
	Average	8.39	1,807	44	1,074	56
	Minimum	7.30	455	4	303	2
	Maximum	9.90	10,410	309	6,630	400
	No. Samples	100	100	91	100	92
MPW Dam (Apr 2015 – Sep 2018)	Median	8.20	10,050	19	5,910	15
	Average	8.19	9,837	86	5,903	248
	Minimum	7.50	405	3	1,710	4
	Maximum	9.20	15,250	1,880	9,690	6,430
	No. Samples	47	47	40	47	37
SOOP1† (Jan 2015 – Feb 2019)	Median	8.14	791	148	880	550
	Average	8.19	969	588	1,115	1,050
	Minimum	7.00	345	6	478	5
	Maximum	9.70	5,970	5,660	3,420	5,600
	No. Samples	57	57	51	57	50

* Refer Section 3.1 for storage description and locations. Storages with a '†' are sediment dams which are designed to discharge following rainfall.

Table 10 Summary of Site Storages Water Quality Data Mangoola Coal Mine – Physical Parameters and pH (Continued)

Storage*	Statistic	pH	EC (µS/cm)	TSS (mg/L)	TDS (mg/L)	Turbidity (NTU)
SOOP2† (Jan 2015 – Feb 2019)	Median	8.15	645	279	820	650
	Average	8.06	809	1,134	1,149	1,725
	Minimum	6.94	303	8	416	16
	Maximum	9.00	6,770	9,620	4,330	15,200
	No. Samples	49	49	46	49	45
CHPP Area Sediment Dam† (Feb 2011 – Feb 2019)	Median	8.50	3,335	17	1,955	21
	Average	8.48	3396	88	2,063	107
	Minimum	7.40	266	3	160	5
	Maximum	9.50	8,560	1,290	5,690	2,200
	No. Samples	104	104	97	104	96

* Refer Section 3.1 for storage description and locations. Storages with a '†' are sediment dams which are designed to discharge following rainfall.

The data in Table 10 indicates that water contained in site water storages and sediment dams is typically slightly to moderately alkaline but that the remaining physical parameters vary over a wide range, likely in response to catchment and rainfall conditions. Note that the results of standard geochemical tests on overburden/interburden samples by EGi (2019) indicate that runoff from these areas should be of low salinity.

Summary statistics for monitored total metals concentration data for site water storages and sediment dams within the existing surface water management system at the Mangoola Coal Mine are given in Table 11 for the period of available data for each storage. Note that in calculating statistics, where the sample was recorded at less than the laboratory limit of detection, the concentration was assumed equal to the laboratory limit of detection. However where insufficient samples were recorded above the laboratory limit of detection, statistics were not calculated.

Table 11 Summary of Site Storages Water Quality Data Mangoola Coal Mine – Total Metals

Location*	Statistic	Aluminium	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
PWD (Dec 2011 – Jun 2018)	Median (mg/L)	0.23	-	0.002	0.112	-	0.120	-	-
	Average (mg/L)	0.40	-	0.004	0.123	-	0.134	-	-
	Minimum (mg/L)	0.06	-	<0.001	0.073	-	0.090	-	-
	Maximum (mg/L)	2.41	<0.001	0.010	0.200	<0.001	0.200	<0.0001	<0.001
	No. Samples	13	13	20	20	9	20	16	13
	No. Samples > Limit of Detection	13	0	8	18	0	19	0	0
NOOP1† (Jun 2012 – Dec 2017)	Median (mg/L)	1.66	-	0.010	0.310	-	0.100	-	-
	Average (mg/L)	1.81	-	0.007	0.311	-	0.123	-	-
	Minimum (mg/L)	0.60	-	<0.001	0.140	-	0.080	-	-
	Maximum (mg/L)	3.82	<0.001	0.013	0.574	<0.001	0.200	<0.0001	<0.001
	No. Samples	6	6	12	12	3	12	9	6
	No. Samples > Limit of Detection	6	0	6	12	0	8	0	0
NAR South SD† (Jun 2014 – Jun 2017)	Median (mg/L)	-	-	-	0.250	-	-	-	-
	Average (mg/L)	-	-	-	0.233	-	-	-	-
	Minimum (mg/L)	-	-	-	0.130	-	-	-	-
	Maximum (mg/L)	-	-	<0.001	0.300	-	<0.1	<0.0001	-
	No. Samples	0	0	4	4	0	4	4	0
	No. Samples > Limit of Detection	0	0	0	4	0	0	0	0
Rail Loop Dam (Jun 2012 – Jun 2018)	Median (mg/L)	1.02	-	0.004	0.460	-	0.130	-	-
	Average (mg/L)	0.87	-	0.005	0.440	-	0.144	-	-
	Minimum (mg/L)	0.23	-	<0.001	0.100	-	0.060	-	-
	Maximum (mg/L)	1.24	<0.001	0.010	0.713	<0.001	0.260	<0.0001	<0.001
	No. Samples	7	7	14	14	3	14	10	7
	No. Samples > Limit of Detection	7	0	8	14	0	9	0	0

* Refer Section 3.1 for storage description and locations. Storages with a '†' are sediment dams which are designed to discharge following rainfall.

Table 11 Summary of Site Storages Water Quality Data Mangoola Coal Mine – Total Metals (Continued)

Locations	Statistic	Aluminium	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
MPW Dam (Jun 2015 – Jun 2018)	Median (mg/L)	0.04	-	0.012	0.259	-	0.190	-	-
	Average (mg/L)	0.06	-	0.019	0.952	-	0.258	-	-
	Minimum (mg/L)	0.02	-	<0.001	0.170	-	0.090	-	-
	Maximum (mg/L)	0.13	<0.001	0.050	7.100	<0.001	1.000	<0.0001	<0.001
	No. Samples	7	7	10	10	3	10	6	7
	No. Samples > Limit of Detection	7	0	10	10	0	10	0	0
SOOP1† (Jun 2015 – Jun 2018)	Median (mg/L)	0.73	-	0.005	0.167	-	0.100	-	-
	Average (mg/L)	1.16	-	0.009	0.725	-	0.158	-	-
	Minimum (mg/L)	0.24	-	<0.001	0.099	-	0.050	-	-
	Maximum (mg/L)	4.82	<0.001	0.050	6.000	<0.001	0.900	<0.0001	<0.001
	No. Samples	7	7	11	11	3	11	7	7
	No. Samples > Limit of Detection	7	0	10	11	0	5	0	0
SOOP2† (Jun 2015 – Jun 2018)	Median (mg/L)	5.37	-	0.009	0.232	-	0.100	-	-
	Average (mg/L)	6.94	-	0.013	0.314	-	0.115	-	-
	Minimum (mg/L)	2.32	-	<0.001	0.100	-	0.100	-	<0.001
	Maximum (mg/L)	14.70	<0.001	0.040	0.700	<0.001	0.150	<0.0001	0.02
	No. Samples	4	4	8	8	2	8	6	4
	No. Samples > Limit of Detection	4	0	7	8	0	4	0	2
CHPP Area Sediment Dam† (Jun 2012 – Jun 2018)	Median (mg/L)	0.10	-	0.002	0.156	-	0.145	-	-
	Average (mg/L)	0.12	-	0.005	0.145	-	0.151	-	-
	Minimum (mg/L)	0.06	-	<0.001	0.098	-	0.080	-	-
	Maximum (mg/L)	0.21	<0.001	0.010	0.200	<0.001	0.240	<0.0001	<0.001
	No. Samples	7	7	14	14	3	14	10	7
	No. Samples > Limit of Detection	7	0	8	14	0	12	0	0

* Refer Section 3.1 for storage description and locations. Storages with a '†' are sediment dams which are designed to discharge following rainfall.

Table 11 Summary of Site Storages Water Quality Data Mangoola Coal Mine – Total Metals (Continued)

Location*	Statistic	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel
PWD (Dec 2011 – Jun 2018)	Median (mg/L)	-	-	0.13	-	0.02	-	0.020	-
	Average (mg/L)	-	-	0.26	-	0.02	-	0.019	-
	Minimum (mg/L)	-	-	<0.05	-	<0.01	-	0.010	<0.001
	Maximum (mg/L)	<0.001	0.060	1.92	<0.001	0.09	<0.0001	0.020	0.030
	No. Samples	13	20	20	20	20	17	9	13
	No. Samples > Limit of Detection	0	1	18	0	18	0	9	2
NOOP1† (Jun 2012 – Dec 2017)	Median (mg/L)	-	0.004	0.98	0.001	0.05	-	-	-
	Average (mg/L)	-	0.006	1.32	0.002	0.15	-	-	-
	Minimum (mg/L)	-	<0.001	<0.05	<0.001	<0.01	-	-	<0.001
	Maximum (mg/L)	<0.001	0.010	3.50	0.004	0.63	<0.0001	<0.001	0.010
	No. Samples	6	12	12	12	12	10	3	6
	No. Samples > Limit of Detection	0	6	11	3	12	0	0	2
NAR South SD† (Jun 2014 – Jun 2017)	Median (mg/L)	-	-	1.89	-	0.03	-	-	-
	Average (mg/L)	-	-	2.33	-	0.03	-	-	-
	Minimum (mg/L)	-	-	<0.05	-	<0.01	-	-	-
	Maximum (mg/L)	-	<0.001	5.45	<0.001	0.06	<0.0001	-	-
	No. Samples	0	4	4	4	4	4	0	0
	No. Samples > Limit of Detection	0	0	4	0	3	0	0	0
Rail Loop Dam (Jun 2012 – Jun 2018)	Median (mg/L)	-	0.002	0.54	-	0.15	-	-	-
	Average (mg/L)	-	0.004	0.74	-	0.18	-	-	-
	Minimum (mg/L)	-	<0.001	0.13	-	<0.01	-	-	<0.001
	Maximum (mg/L)	<0.001	0.010	2.52	<0.001	0.45	<0.0001	0.010	0.010
	No. Samples	7	14	14	14	14	11	3	7
	No. Samples > Limit of Detection	0	3	14	0	13	0	1	2

* Refer Section 3.1 for storage description and locations. Storages with a '†' are sediment dams which are designed to discharge following rainfall.

Table 11 Summary of Site Storages Water Quality Data Mangoola Coal Mine – Total Metals (Continued)

Locations	Statistic	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel
MPW Dam (Jun 2015 – Jun 2018)	Median (mg/L)	-	0.001	0.05	-	0.02	-	0.020	0.010
	Average (mg/L)	-	0.005	5.95	-	0.16	-	0.023	0.010
	Minimum (mg/L)	-	<0.001	0.05	-	<0.01	-	0.020	<0.001
	Maximum (mg/L)	<0.001	0.040	57.30	0.170	0.75	<0.0001	0.030	0.010
	No. Samples	7	10	10	10	10	7	3	7
	No. Samples > Limit of Detection	0	3	4	1	10	0	3	7
SOOP1† (Jun 2015 – Jun 2018)	Median (mg/L)	-	0.002	0.40	0.001	0.02	-	0.020	-
	Average (mg/L)	-	0.005	5.91	0.018	0.07	-	0.020	-
	Minimum (mg/L)	-	<0.001	<0.05	<0.001	<0.01	-	0.020	-
	Maximum (mg/L)	<0.001	0.020	33.70	0.120	0.40	<0.0001	0.020	<0.001
	No. Samples	7	11	11	11	11	8	3	7
	No. Samples > Limit of Detection	0	7	9	4	11	0	3	0
SOOP2† (Jun 2015 – Jun 2018)	Median (mg/L)	-	0.008	5.88	0.017	0.22	-	-	0.010
	Average (mg/L)	-	0.009	9.30	0.026	0.49	-	-	0.013
	Minimum (mg/L)	-	<0.001	<0.05	<0.001	<0.01	<0.0001	<0.001	<0.001
	Maximum (mg/L)	<0.001	0.030	38.20	0.110	1.40	0.0002	0.080	0.020
	No. Samples	4	8	8	8	8	7	2	4
	No. Samples > Limit of Detection	0	6	7	7	8	1	1	4
CHPP Area Sediment Dam† (Jun 2012 – Jun 2018)	Median (mg/L)	-	-	0.09	-	0.03	-	0.030	-
	Average (mg/L)	-	-	0.22	-	0.04	-	0.033	-
	Minimum (mg/L)	-	-	<0.05	-	<0.01	-	0.030	-
	Maximum (mg/L)	<0.001	0.003	1.02	<0.001	0.11	<0.0001	0.040	<0.001
	No. Samples	7	14	14	14	14	11	3	7
	No. Samples > Limit of Detection	0	1	11	0	14	0	3	0

* Refer Section 3.1 for storage description and locations. Storages with a '†' are sediment dams which are designed to discharge following rainfall.

Table 11 Summary of Site Storages Water Quality Data Mangoola Coal Mine – Total Metals (Continued)

Location*	Statistic	Selenium	Silver	Strontium	Vanadium	Zinc
PWD	Median (mg/L)	-	-	5.050	-	0.010
	Average (mg/L)	-	-	4.769	-	0.010
	Minimum (mg/L)	-	-	2.730	-	<0.005
	Maximum (mg/L)	<0.01	<0.001	6.190	<0.01	0.028
	No. Samples	20	20	7	9	20
	No. Samples > Limit of Detection	0	0	7	0	6
NOOP1†	Median (mg/L)	-	-	1.140	-	-
	Average (mg/L)	-	-	1.138	-	-
	Minimum (mg/L)	-	-	0.940	-	-
	Maximum (mg/L)	<0.01	<0.001	1.310	<0.01	0.007
	No. Samples	12	12	6	3	12
	No. Samples > Limit of Detection	0	0	6	0	1
NAR South SD†	Median (mg/L)	-	-	-	-	-
	Average (mg/L)	-	-	-	-	-
	Minimum (mg/L)	-	-	-	-	-
	Maximum (mg/L)	<0.01	<0.001	-	-	<0.005
	No. Samples	4	4	0	0	4
	No. Samples > Limit of Detection	0	0	0	0	0
Rail Loop Dam	Median (mg/L)	-	-	2.800	-	-
	Average (mg/L)	-	-	2.669	-	-
	Minimum (mg/L)	-	-	1.430	-	<0.005
	Maximum (mg/L)	<0.01	<0.001	3.170	<0.01	0.035
	No. Samples	14	14	7	3	14
	No. Samples > Limit of Detection	0	0	7	0	2
MPW Dam	Median (mg/L)	-	-	2.640	-	0.005
	Average (mg/L)	-	-	2.801	-	0.189
	Minimum (mg/L)	-	-	1.900	-	<0.005
	Maximum (mg/L)	<0.01	0.001	3.910	<0.01	1.830
	No. Samples	10	10	7	3	10
	No. Samples > Limit of Detection	0	1	7	0	2
SOOP1†	Median (mg/L)	-	-	1.010	-	0.005
	Average (mg/L)	-	-	1.063	-	0.160
	Minimum (mg/L)	-	-	0.938	-	<0.005
	Maximum (mg/L)	<0.01	<0.001	1.220	<0.01	1.630
	No. Samples	11	11	7	3	11
	No. Samples > Limit of Detection	0	0	7	0	5

* Refer Section 3.1 for storage description and locations. Storages with a '†' are sediment dams which are designed to discharge following rainfall.

Table 11 Summary of Site Storages Water Quality Data Mangoola Coal Mine – Total Metals (Continued)

Location*	Statistic	Selenium	Silver	Strontium	Vanadium	Zinc
SOOP2†	Median (mg/L)	-	-	1.130	-	0.036
	Average (mg/L)	-	-	1.205	-	0.049
	Minimum (mg/L)	-	-	0.869	0.01	<0.005
	Maximum (mg/L)	<0.01	<0.001	1.690	0.03	0.170
	No. Samples	8	8	4	2	8
	No. Samples > Limit of Detection	0	0	4	2	7
CHPP Area Sediment Dam†	Median (mg/L)	-	-	4.770	-	0.009
	Average (mg/L)	-	-	4.451	-	0.014
	Minimum (mg/L)	-	-	3.300	-	<0.005
	Maximum (mg/L)	<0.01	<0.001	5.360	<0.01	0.058
	No. Samples	14	14	7	3	14
	No. Samples > Limit of Detection	0	0	7	0	5

* Refer Section 3.1 for storage description and locations. Storages with a '†' are sediment dams which are designed to discharge following rainfall.

Of the metals analysed in site water storage samples, the results of standard geochemical tests on overburden/interburden samples by EGi (2019) indicate that overburden may be slightly enriched with selenium and beryllium. However these metals remained below detectable levels in the site storages.

The data given in Table 11 indicates higher metals concentrations in site storages for some metals compared with the monitored values in stream samples (e.g. arsenic, boron, lead, zinc) while others remain at very low or non-detectable concentrations (e.g. mercury, silver, cobalt, cadmium, chromium). Given the nature of open cut mining operations, it is expected that some metals would be mobilised more readily than in the background environment. For the PWD (from which licensed discharges can occur via the HRSTS) the only metals for which average concentrations exceed ANZECC (2000) guideline values are aluminium (0.4 mg/L) and zinc (0.01 mg/L). It appears that aluminium is naturally elevated in local streams, with average concentrations in Big Flat Creek ranging from 0.4 to 3.9 mg/L and in Wybong Creek from 0.14 to 0.42 mg/L. The average concentration of zinc is very close to the ANZECC (2000) guideline value of 0.008 mg/L. Licensed discharge from the PWD will be discharged according to the provisions of the HRSTS which involve substantial dilution (refer also Section 3.3.5.6).

2.6.3 Geomorphology

2.6.3.1 Objective and Methodology

In order to assess the geomorphology of stream lines within the MCCO Additional Project Area, a stream geomorphological assessment was carried out to document the geomorphological characteristics and condition of the streams in the MCCO Additional Project Area.

The stream geomorphological assessment comprised a desktop assessment of aerial photography, available topographical and geological mapping of the study area and ground reconnaissance of the main streams in the MCCO Additional Project Area.

2.6.3.2 Topographical Information

Topographical mapping of the MCCO Additional Project Area shows that the catchment boundary in the headwaters of Big Flat Creek comprises a ridgeline escarpment of Hawkesbury Sandstone (AGEC, 2017). From the escarpment toe, Big Flat Creek flows across the foothill slopes and out onto a wide gently sloping valley. The Big Flat Creek stream network has been classified according to the Strahler classification scheme (Strahler, 1952) using 1:25,000 scale topographical mapping[8]. At the downstream end of the MCCO Additional Project Area and its junction with Wybong Creek, Big Flat Creek is a 4th order stream with three main mapped tributaries which have been denoted as Tributaries 1, 2 and 3 – refer Figure 10.

A summary of attributes calculated from a combination of the local 1:25,000 scale topographic map and other topographic data (including aerial/LIDAR survey) are provided in Table 12 for Big Flat Creek and each of the three tributaries.

Table 12 Summary of Stream Attributes

Geomorphic Parameter	Big Flat Creek	Tributary 1	Tributary 2	Tributary 3
Catchment area (km^2)	40.82	6.22	4.39	2.11
Stream length (km)	12.76	4.54	3.72	2.47
Average bed gradient (%)	2.23	1.67	2.77	3.00
Sinuosity[9]	1.37	1.18	1.04	1.07

2.6.3.3 Surface Geology

As noted by AGEC (2017), the Mangoola Coal mine is located along the western outcrop of the Permian coal measures. MER (2015) described the regional geology as comprising Permian Newcastle Coal Measures overlain by younger, Triassic Narrabeen Group sandstones and conglomerates which form rocky hills and ridges in the area. AGEC (2017) state that the depth of weathering of the conglomerates in Big Flat Creek is 20-25 m below ground level. The conglomerate weathers to a friable sandy material with rounded pebbles forming the shallow material that has been classified as colluvium[10]. The colluvial material comprises sands, silts and clays sourced from the weathered sandstones, siltstones and tuffs and are generally no more than 4-5 m thick. Downstream of the confluence of Anvil Creek with Big Flat Creek, the colluvium transitions to alluvium[11] associated with the much larger Wybong Creek.

2.6.3.4 Vegetation and Land Use

The catchment has been substantially cleared for grazing with vegetation over the majority of the catchment comprising grassland derived from clearing of woodland vegetation, with some improved pasture areas. Some remnant woodland areas are evident in the elevated escarpment parts of the catchment and some stands of trees were observed along the banks and overbank areas.

[8] http://spatialservices.finance.nsw.gov.au/mapping_and_imagery/maps

[9] Sinuosity is defined as the stream length divided by the straight-line stream length.

[10] Sediments deposited at the base of hillslopes by either sheet flow, slow continuous downslope creep or a variable combination of these processes.

[11] Sediments deposited by streams or floods in a valley.

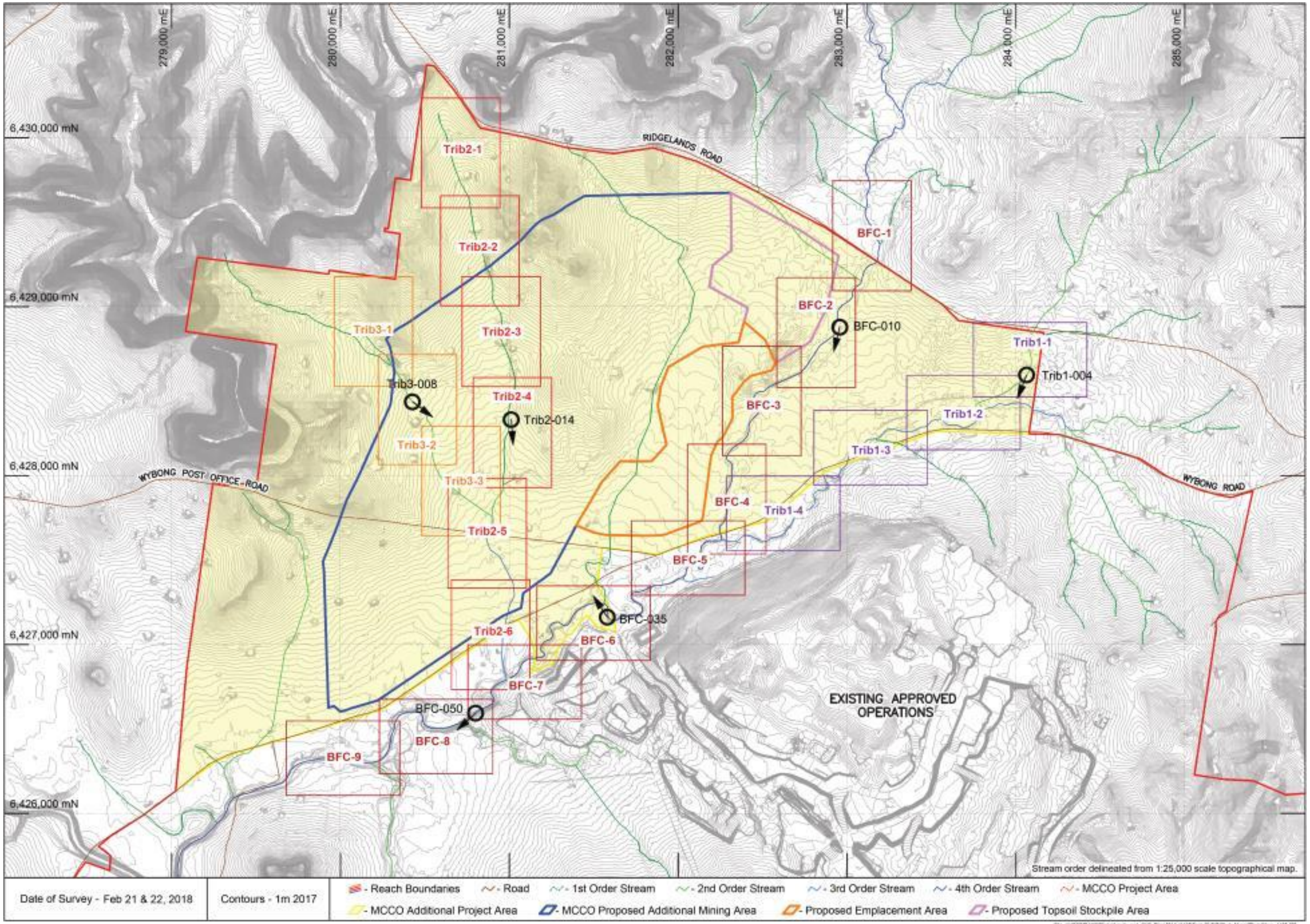

Figure 10 Overview Reach Map

2.6.3.5 Ground Reconnaissance

The ground reconnaissance was conducted on 21st and 22nd of February 2018 and focused on reaches of Big Flat Creek within or near the MCCO Additional Project Area including the three main mapped tributaries. A series of Global Positioning System (GPS) referenced photographs were taken along each stream detailing features and geomorphic characteristics. The features and geomorphic characteristics of the stream reaches were noted on a series of reach maps (refer Appendix A) which form a baseline record of the stream characteristics in the MCCO Additional Project Area.

The reconnaissance was conducted on days with no rainfall recorded at Mangoola's WSN however prior to the reconnaissance there was 3.2 mm and 2.4 mm recorded on the 19th and 20th of February respectively. There was no visible flow in any of the inspected streams which were dry with the exception of a few pools. The ground appeared dry with no visible signs of recent rainfall however rainfall for the year to date totalled 9.4 mm hence rainfall on the 19th and 20th of February was unlikely to result in runoff due to low antecedent moisture.

The following sections provide a generalised description of Big Flat Creek and the three main tributaries as well as a section summarising the streams in the MCCO Additional Project Area.

2.6.3.5.1 Big Flat Creek

Upstream of the confluence with Tributary 1 (Reaches BFC-1 to BFC-4 – refer Figure 10 and Appendix A) the main arm of Big Flat Creek comprises a fourth order stream which flows through grazing paddocks. The creek generally comprises a discontinuous shallow swale profile with no defined bed or banks – refer typical section in Photo 3. Instream and riparian vegetation were predominately degraded pasture and isolated stands of regrowth trees. The presence of several on-stream dams and a road crossing (Ridgelands Road) has resulted in localised erosion and changes to the original channel form.

Photo 3 Typical Section: Big Flat Creek Upstream of Tributary 1 (BFC-010-Downstream)

Downstream of the Wybong Road crossing and the confluence with Tributary 1 (Reaches BFC-5 to BFC-7) the riparian vegetation in the stream was significantly denser than in upper reaches with increased sinuosity which may be influenced by the additional catchment inflow from Tributary 1 – refer typical section in Photo 4. Near the confluence with Tributary 2 (Reach BFC-7), there were significant exposures of rock in the channel and banks which appear to control the flow through this reach of the creek.

Photo 4 Typical Section: Big Flat Creek Upstream of Tributary 2 (BFC-035-Downstream)

Downstream of the Tributary 2 inflow (Reaches BFC-7 through BFC-9) the creek channel comprised a more defined, mature form with defined bed and banks, pools and riffles and floodplain features – refer typical section in Photo 5. There were some areas of active rilling and severe undercutting of the bank toe on the steeper banks associated with the large bends near the downstream end of the creek.

Photo 5 Typical Section: Big Flat Creek Downstream of Tributary 2 (BFC-050 Downstream)

2.6.3.5.2 Tributary 1

The upstream inspected reaches of Tributary 1 (Reaches Trib1-1 and Trib1-2 – refer Figure 10) comprise a second order stream which flowed through grazing paddocks. A number of on-stream farm dams have been constructed across the creek. The stream generally comprises a mixture of ill-defined depressions, shallow swales and small incised channel profiles – refer typical section in Photo 6. Vegetation was predominantly denuded grasses and occasional stands of regrowth trees. Midway through Reach Trib1-2, the stream becomes third order with inflow from a small tributary. At the start of Reach Trib1-3, it appears that a channel has been previously excavated presumably to direct flow toward the culverts under Wybong Road. The excavated channel was generally poorly vegetated and sections of the bed appeared to be slowly downcutting[12] and the banks widening. A knick point was apparent upstream of the excavated channel suggesting erosion had travelled upstream. Downstream of the Wybong Road crossing (Reach Trib1-4), Tributary 1 flowed through a more vegetated area and the stream followed a more meandering path with increased riparian vegetation.

[12] The process of erosion downward through the bed of a stream.

Photo 6 Typical Section: Tributary 1 (Trib1-004 Downstream)

2.6.3.5.3 Tributary 2

The upstream inspected reaches of Tributary 2 (Reaches Trib2-1 and Trib2-2 – refer Figure 10) comprise a small first order stream. The channel comprises a small swale which followed a relatively straight alignment. Vegetation comprised sparse grass with isolated trees. There were also a number of small farm dams and associated overflow channels. The middle inspected reaches (Reaches Trib2-3 to Trib2-5) were characterised by past bed downcutting and a more incised channel with continuous defined bed and banks. The overbank areas supported pasture grasses and isolated trees. The channel was mostly vegetated by Spiny Rush (*Juncus acutus*), which is a known salt tolerant species, and banks were generally bare with active rilling – refer typical section in Photo 7. Downstream of the Wybong Road crossing and upstream of the Big Flat Creek confluence (Reach Trib2-6), Tributary 2 comprises a third order stream and a moderately incised channel with defined bed and banks. Overbank areas support a moderately dense cover of immature casuarina trees.

Photo 7 Typical Section: Tributary 2 (Trib2-014 Downstream)

2.6.3.5.4 Tributary 3

The upstream inspected reach of Tributary 3 (Reaches Trib3-1 and Trib3-2 – refer Figure 10) transitioned from a wide, open shallow swale into an actively downcutting gully form and back to an open shallow swale. The presence of on-stream dams had modified flow paths and caused areas of concentrated flow, resulting in the observed actively downcutting sections. Vegetation comprised denuded grassland with isolated stands of mostly immature regrowth. The downstream inspected reach of Tributary 3 (Reach Trib3-3) comprised mostly a second order stream with a series of ill-defined depressions and minor swales – refer typical section in Photo 8.

Photo 8 Typical Section: Tributary 3 (Trib3-008 Downstream)

2.6.3.5.5 Summary

Big Flat Creek and its tributaries comprise ephemeral watercourses which have been impacted by past land clearing, construction of on-stream farm storage dams and road crossings. The condition of the streams found during the ground reconnaissance was variable over relatively short reaches ranging from ill-defined shallow swales and drainage depressions to well-defined deeply incised channels with overbank areas. The channel form appears to reflect the stream characteristics such as:

- the size of the upstream catchment;
- the local stream gradient;
- the density of riparian and instream vegetation;
- local surface geology; and
- associated anthropogenic land use disturbance.

The streams are noticeably degraded in some sections and are of higher quality in other less disturbed areas. The primary determinant of stream condition appears to be riparian vegetation. At its closest point to the MCCO Additional Project Area, Big Flat Creek generally comprises a discontinuous swale with no defined bed or banks and vegetation consisting predominately of degraded pasture. Within the MCCO Additional Project Area, tributaries generally comprise small swales/depressions with denuded vegetation in the upper reaches and channels in the lower reaches with active erosion.

2.7 FLOOD REGIME

2.7.1 Description of Flood Modelling

Flood modelling of Big Flat Creek was undertaken extending from upstream of Ridgelands Road to downstream of SF01 (refer Figure 3) – i.e. in the reach adjacent to the MCCO Additional Project Area. Modelling was undertaken of the existing creek (with the approved Mangoola operations as at 2017) and a scenario with the fully developed proposed MCCO Project (as at Year 8 – the scheduled end of coal extraction). Results of the former are described in this section, while results for the latter are described in Section 3.2.3. The aim of the flood modelling was to:

- characterise the existing flood regime and flood levels;
- assess changes to flood levels likely as a result of the MCCO Project;
- calculate elevations for key project infrastructure including the haul road crossing of the creek and adjacent flood levee; and
- indicate areas where armouring may be required to protect against high velocity flows that may result from the MCCO Project development.

No permanent diversion or redirection of flow in Big Flat Creek is proposed as part of the MCCO Project. A construction phase Erosion and Sediment Control Plan will be prepared for the MCCO Project to detail the controls required to manage construction works in and adjacent to Big Flat Creek including temporary drainage.

Modelling was undertaken in two parts: hydrologic modelling to assess design flow rates, followed by hydraulic modelling using the design flow rates to calculate design flood levels.

2.7.2 Hydrologic Modelling

Hydrologic modelling was undertaken using the RORB model (Laurenson and Mein, 1997). RORB is a widely accepted rainfall routing model for simulating flood hydrographs generated from rainfall events falling on the modelled catchment. RORB model rainfall losses and routing parameters were derived using guidelines provided for ungauged catchments in the Australian Rainfall and Runoff flood estimation guidelines – ARR 2016 (Ball, et al, 2016). ARR 2016 guideline initial loss values are typically high because these are based on recorded events – most of which have a higher annual exceedance probability (AEP) (i.e. are more common) than the design events modelled. A conservative approach was taken to the selection of design rainfall losses, to reflect ARR 2016 recommendations – i.e. the adoption of relatively low values for design rainfall events with a low AEP (rarer events).

Modelling was undertaken for eight design rainfall events – 1:10 AEP, 1:20 AEP, 1:100 AEP, 1:200 AEP, 1:250 AEP, 1:500 AEP, 1:1,000 AEP and the probable maximum flood (PMF). Design rainfall temporal patterns and areal reduction factors were also derived from ARR 2016. Rainfall for the 1:250 AEP events was derived using interpolation procedures outlined in ARR 2016. Design rainfall for the Probable Maximum Precipitation (PMP) rainfall was undertaken using methods described in BoM (2005) and BoM (2006).

In line with the ARR 2016 guidelines, there are 10 'ensemble' temporal patterns applicable to each design rainfall event, each with different durations. Different temporal patterns apply within each of four (AEP) categories of severity'[13]. For each AEP, the RORB model was run using the ten temporal patterns[14] for the range of applicable event durations. For each duration, the modelled hydrograph

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[13] Ensemble temporal patterns are broken up into four groups: frequent (more frequent than 14.4% AEP), intermediate (between 14.4% and 3.2% AEP), rare (between 3.2% and approximately 1% AEP) and very rare.

[14] Sourced from the ARR Data Hub: http://data.arr-software.org/

which produced the closest peak flow to the median peak flow (of 10) at the location of the proposed haul road crossing of the creek was selected as the hydrograph for that duration. For each AEP, the rainfall duration which gave the highest peak flow rate at the location of the proposed haul road crossing of the creek (i.e. the 'critical duration') was selected for use in subsequent hydraulic modelling. This process was repeated for all design AEPs. Model predicted peak flow rates at three locations on Big Flat Creek for the eight design AEP rainfall events are summarised in Table 13. The higher peak flow rates for the "with MCCO Project" case reflect the proposed diversion of upslope catchment around the MCCO Additional Project Area and into Big Flat Creek upstream of the MCCO Additional Project Area (refer Section 3.2.1). Note that changes in flow rate in Big Flat Creek do not affect other water users on Big Flat Creek because the land along Big Flat Creek from the Additional Project Area to Wybong Creek is owned by Mangoola.

Table 13 Summary of Big Flat Creek Peak Design Flow Rates

Case	Location*	Peak flow resulting from AEP rainfall event (m^3/s)							
		1:10	1:20	1:100	1:200	1:250	1:500	1:1,000	PMF
Existing	Upstream of MCCO Additional Project Area	21.9	26.6	34.4	42.8	44	53.5	60.7	476.6
	Location of Proposed Haul Road Crossing	31.2	38.3	55.2	67.4	69.2	83.9	94.1	693.2
	Gauging Station SF01	62.9	77.4	114.3	143.4	147.5	183	206.1	1373
With MCCO Project	Upstream of MCCO Additional Project Area	32.5	38.9	55.6	69	70.2	84.1	95.9	746.4
	Location of Proposed Haul Road Crossing	45.6	55.3	69.4	96.5	98.8	120.6	136.2	987.3
	Gauging Station SF01	71.8	88	125.2	154.6	158.6	197.6	225.8	1599

* Refer Figure 11 to Figure 13

Design flood hydrographs (flow rate vs time) produced by RORB were used as input to the hydraulic model.

2.7.3 Hydraulic Modelling

Hydraulic modelling was conducted using the two dimensional numerical hydraulic model TUFLOW (BMT WBM, 2017). TUFLOW is a commonly used flood modelling software system which produces predictions of flood levels, flow velocities and other hydraulic parameters in two dimensional space using finite difference simulation methods.

TUFLOW input information includes:

- A digital elevation model (DEM) of the ground surface in the study area. A DEM of the existing topography was obtained by combining LiDAR data for areas generally north of Big Flat Creek with available topography (contours and other 3-dimensional survey lines) for the existing Mangoola operations as at 2017. A 4 m square TUFLOW finite difference mesh was set up using this data, with a resulting modelled node spacing of 2 m (including intermediate nodes) For the "with MCCO Project" case, the proposed flood bund was simulated by setting a model no-flow boundary on this alignment.
- Estimates of channel or natural creek roughness/friction factors. The estimates for this study were obtained from interpretation of aerial and terrestrial photographs and literature guidelines.

- Flow hydrographs for the design AEP events as generated from the hydrological flood model (RORB) – refer Section 2.7.2.
- Water level at the downstream model boundary – calculated from separate steady state TUFLOW model simulations of the Wybong Creek/Big Flat Creek confluence (for the same storm duration as the simulated critical rainfall event in Big Flat Creek). The confluence is located approximately 1.3 km downstream of the planned most downstream disturbance within the MCCO Additional Project Area and therefore this downstream boundary approximation will have little effect on flood levels in Big Flat Creek adjacent to the MCCO Additional Project Area.
- Geometric data pertaining to flow structures such as culverts, bridges and roads. For existing culverts, data was provided by Mangoola Coal. For proposed future haul road crossings, culvert sizing, locations and road geometry were provided by Arkhill Engineers on behalf of Mangoola Coal. This includes the proposed Wybong Road overpass, which was simulated as comprising three, 3 m diameter culverts (or culverts with equivalent flow characteristics) within a conventional earthfill embankment for the Big Flat Creek crossing and a proprietary arch structure within an earthfill embankment for the Wybong Road crossing.

The hydraulic model uses sophisticated numerical processes to simulate routing of design flows through the DEM and this is more accurate and robust than the flow routing performed by the hydrological model. The hydrologic model did however provide inflow hydrographs for a series of 'inflow' points at the upstream boundary of the hydraulic model and local inflow points along Big Flat Creek. Flood levels predicted by TUFLOW varied with time as the simulated hydrograph passed through the modelled reaches – the modelled maximum flood levels for each modelled event were recorded and were used to generate predicted peak flood levels and extents presented in this report. The above methodology and data are considered fit for the purpose of assessing the changes resulting from the altered flow rates and changes in geometry relating to the haul road crossing, the proposed Wybong Road overpass and flood levee that are part of the MCCO Project.

2.7.4 Predicted Existing Flood Levels in Big Flat Creek

Predicted flood levels for the existing Big Flat Creek are shown Figure 11 to Figure 13 for three of the flood events modelled – the remainder are given in Appendix B. Note that there are only small differences between the predicted flood levels in Figure 11 to Figure 13 (1:20 to 1:1000 AEP). It may be seen from these results that all AEP floods extend, to a small degree, upon the MCCO Additional Project Area. Therefore a flood levee will be constructed to protect the MCCO Additional Project Area from the risk of flooding (refer Section 3.2.3). It may also be seen that the existing Wybong Road is inundated over a significant length.

Predicted flood levels are affected by proposed MCCO Project infrastructure – in particular the proposed haul road crossing of Big Flat Creek. Predicted effects of the MCCO Project on flood levels are given in Section 3.2.3.

2.7.5 Floodplain Mapping

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

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

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

Floodway areas are defined as areas where significant discharge occurs during floods and are often aligned with naturally defined channels (NSW Government, 2005). For the purposes of this study and in the context of Big Flat Creek in the vicinity of the MCCO Additional Project Area, this has been assumed to be approximately the 10% AEP flood level. Flood level and extent maps for the 10% AEP flood are included in Appendix A. Note that the majority of modelled flow in Big Flat Creek in such an event is contained within the creek banks in reaches where the creek has defined banks (refer Section 2.7.3).

Flood planning areas are determined by plotting the extent of the flood planning level, which is usually based on the design flood level plus a suitable freeboard (typically around 0.5m). For this study, the flood planning level is assumed to be the 1% AEP design flood, with the flood planning area approximated by the 1% AEP flood extent. A flood extent map for the 1% AEP flood is shown in Figure 12 and Section 3.2.3.

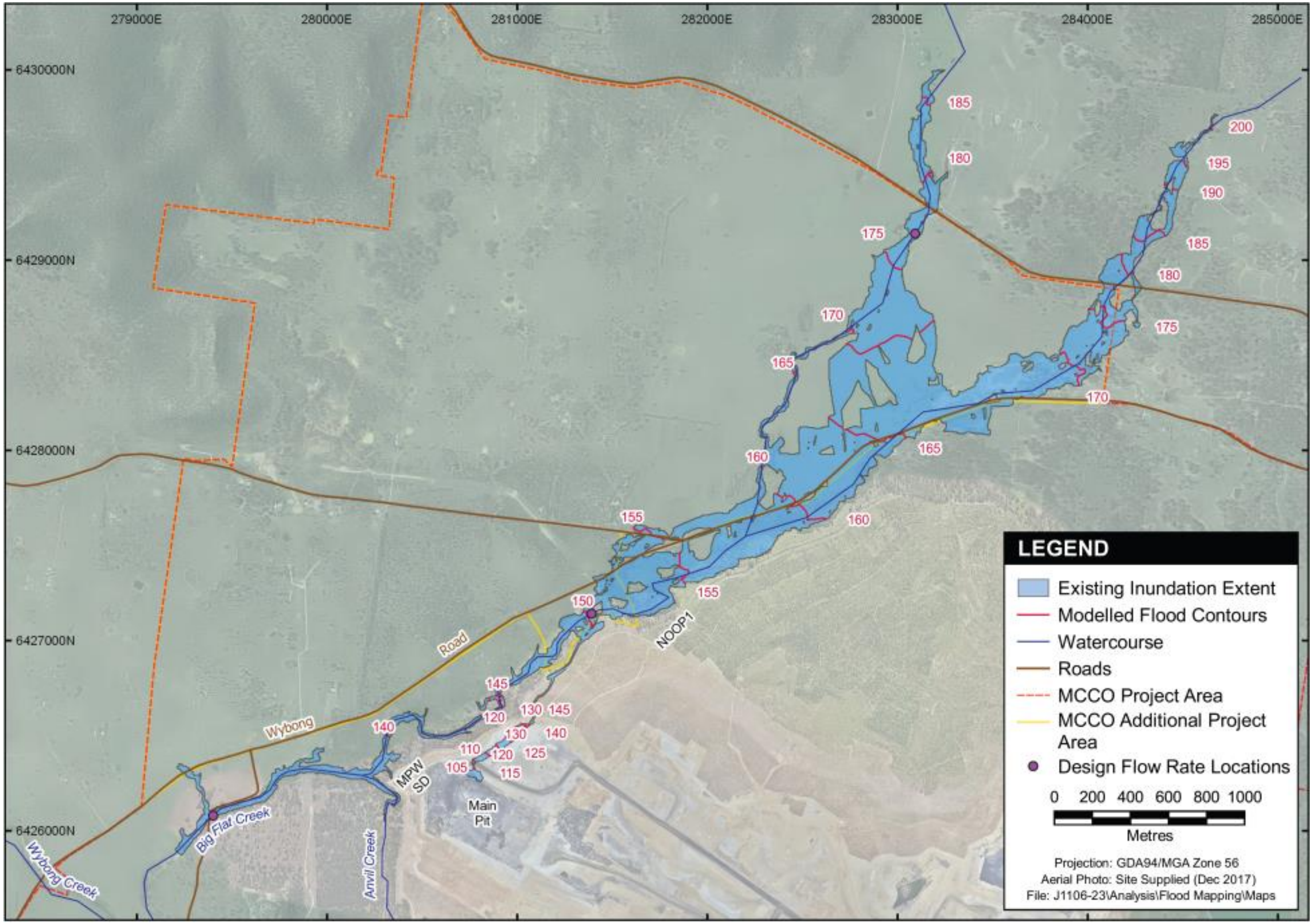

Figure 11 Predicted Existing Flood Levels (mAHD) and Flooding Extent – 1:20 AEP

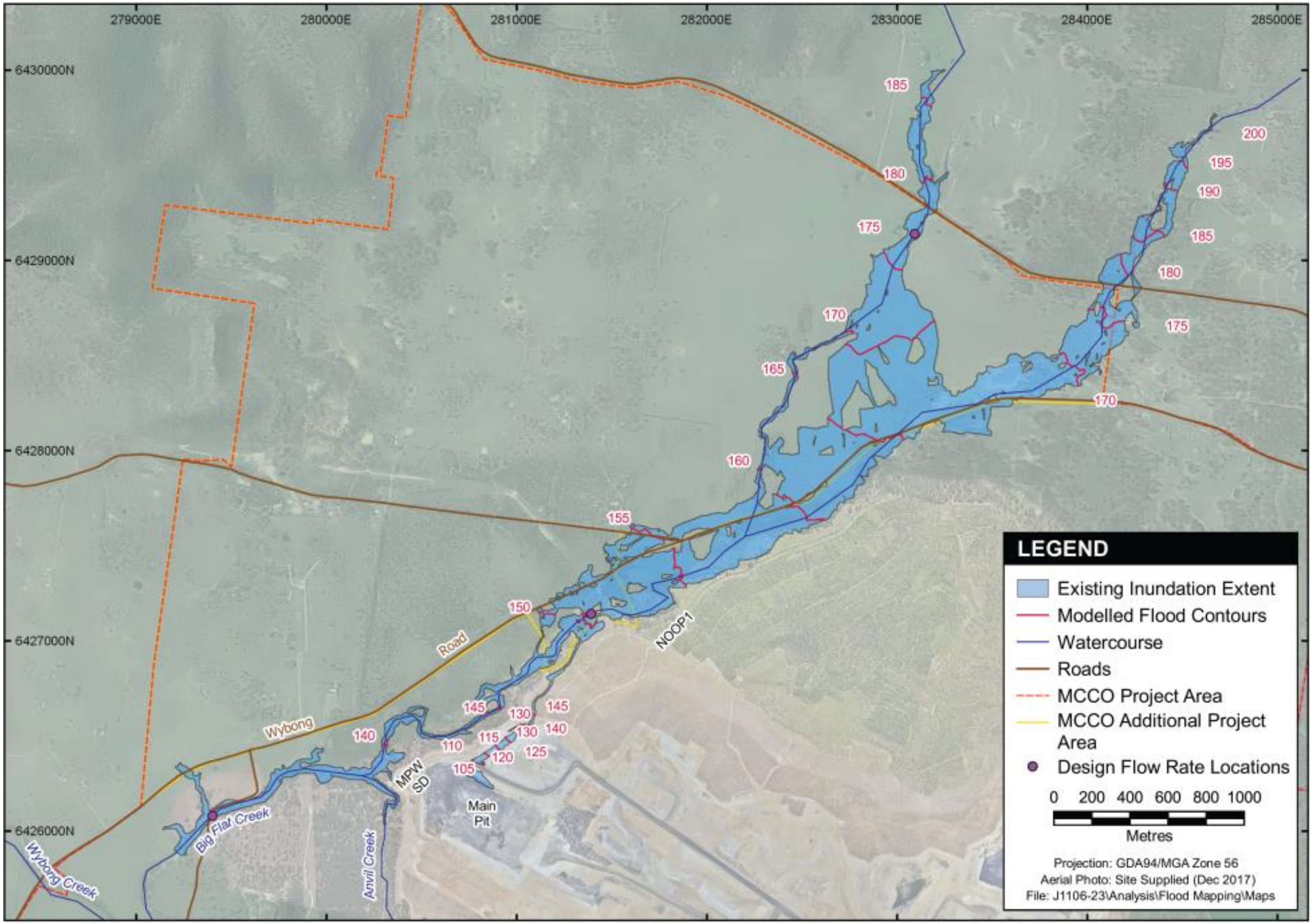

Figure 12 Predicted Existing Flood Levels (mAHD) and Flooding Extent – 1:100 AEP

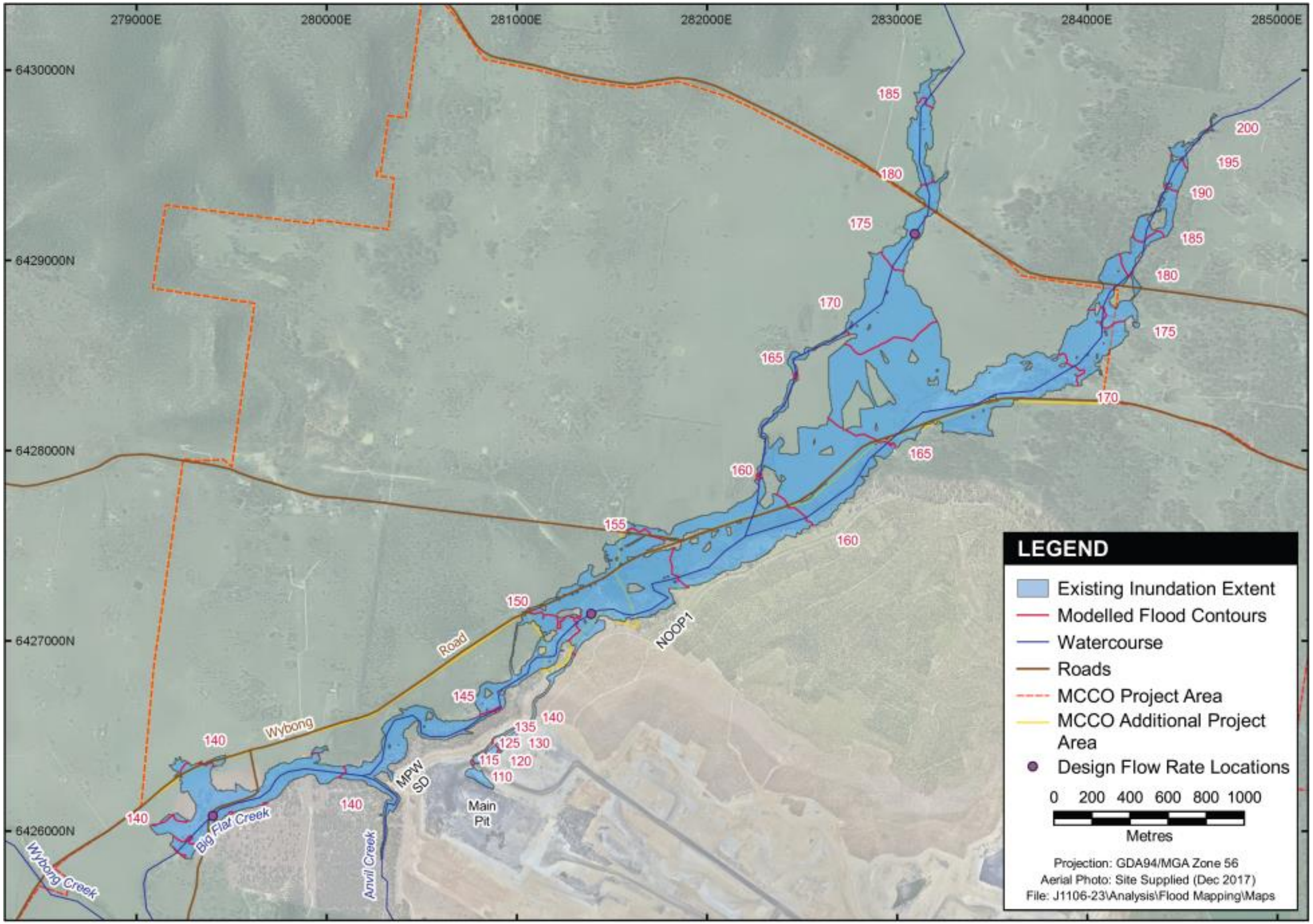

Figure 13 Predicted Existing Flood Levels (mAHD) and Flooding Extent – 1:1,000 AEP

3.0 SURFACE WATER MANAGEMENT

3.1 EXISTING MANGOOLA MINE WATER MANAGEMENT SYSTEM

The existing surface water management system at the Mangoola Coal Mine involves a number of interlinked dams, pits and tailings storage voids, their catchments, the CHPP and water pumping systems. Figure 14 shows the locations of the key existing surface storages. The existing water management system is shown in schematic form in Figure 15 which also includes proposed system additions as part of the MCCO Additional Project Area.

The majority of mine water supply is obtained from runoff captured from disturbed mine landforms, with water reclaimed from the tailings storage also comprising a significant component. These sources of water are given priority in supplying operational water requirements. Additional operational (make-up) water supply is obtained by pumping from the Hunter River via general and high security WALs when necessary.

The PWD is the main water storage on site with an estimated capacity of 1,505 ML. Runoff and groundwater reporting to the Main Pit and South Pit areas is pumped to the PWD. Runoff accumulating in a number of sediment dams located around the overburden[15] emplacements and pre-strip areas is also pumped to the PWD. The PWD supplies the two main water demands on site: for CHPP use and haul road dust suppression. Water from the Hunter River is pumped to the Raw Water Dam (RWD) which in turn can supply the PWD. A small seepage sump downslope of the RWD captures seepage which is pumped back to the RWD.

CHPP tailings are discharged to Tailings Dam 4 (TD4) with liberated water seeping to the adjacent TD4 Decant. Decant water is reclaimed by pumping to the PWD for reuse in the mine water management system. Former tailings storage voids TD1, TD2, TD3 and the TD1 Decant are in the planning phase of being covered and rehabilitated. TD3 has been filled with overburden as it is not required as a tailings void for the MCCO Project.

Runoff from the mine infrastructure area (MIA) and CHPP area is captured by a number of small dams namely the MIA Dam, CHPP Sediment Dam, CHPP Area Sediment Dam and the Product Stockpile Dam (PSD), with accumulated water pumped to the PWD. Runoff from the rail loop area is directed to the Rail Loop Dam (RLD) and pumped to the CHPP Area Sediment Dam. Runoff from mainly rehabilitated overburden emplacement areas reports to northern out of pit (NOOP)1, southern out of pit (SOOP)1 and 2, the northern access road (NAR) south sediment dam (SD) and the Main Pit West (MPW) Dam. The catchment of the Anvil Creek sediment dam (SD) currently comprises mainly pre-strip. The approved Anvil Creek reinstatement has yet to be constructed as active mining is ongoing in this area.

Current approved operations will see the Main Pit progressing in a south-westerly direction, including the development of an additional dam adjacent to the MPW Dam to capture runoff from overburden and rehabilitation areas (also designated as Main 2 in previously approved mine plans). The South Pit will progress in a north-westerly direction until combining with Main Pit West in the future and leaving a final void to the south-west of Anvil Hill. Tailings will continue to be discharged to TD4 for the remainder of the approved mine life – TD4 has sufficient capacity for the MCCO Project tailings (see Section 3.3.3.4). Mine plans supplied by Mangoola have been used to derive relevant storage parameters for water balance modelling (refer Section 3.3.3).

[15] The term “overburden” in this report refers to both overburden and interburden – i.e. material removed from open cut operations to allow access to coal.

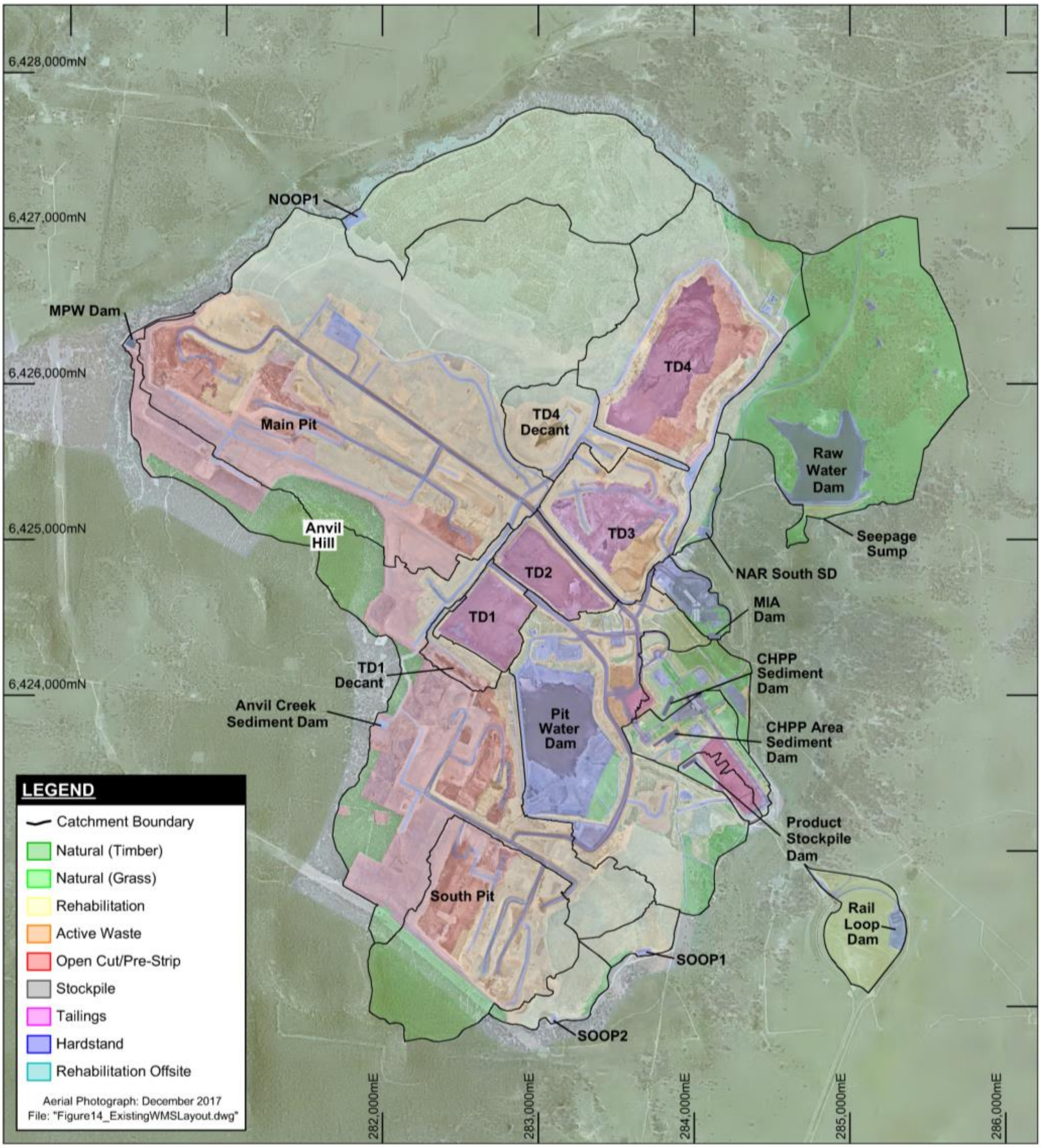

Figure 14 Existing (2018) Water Storage Layout

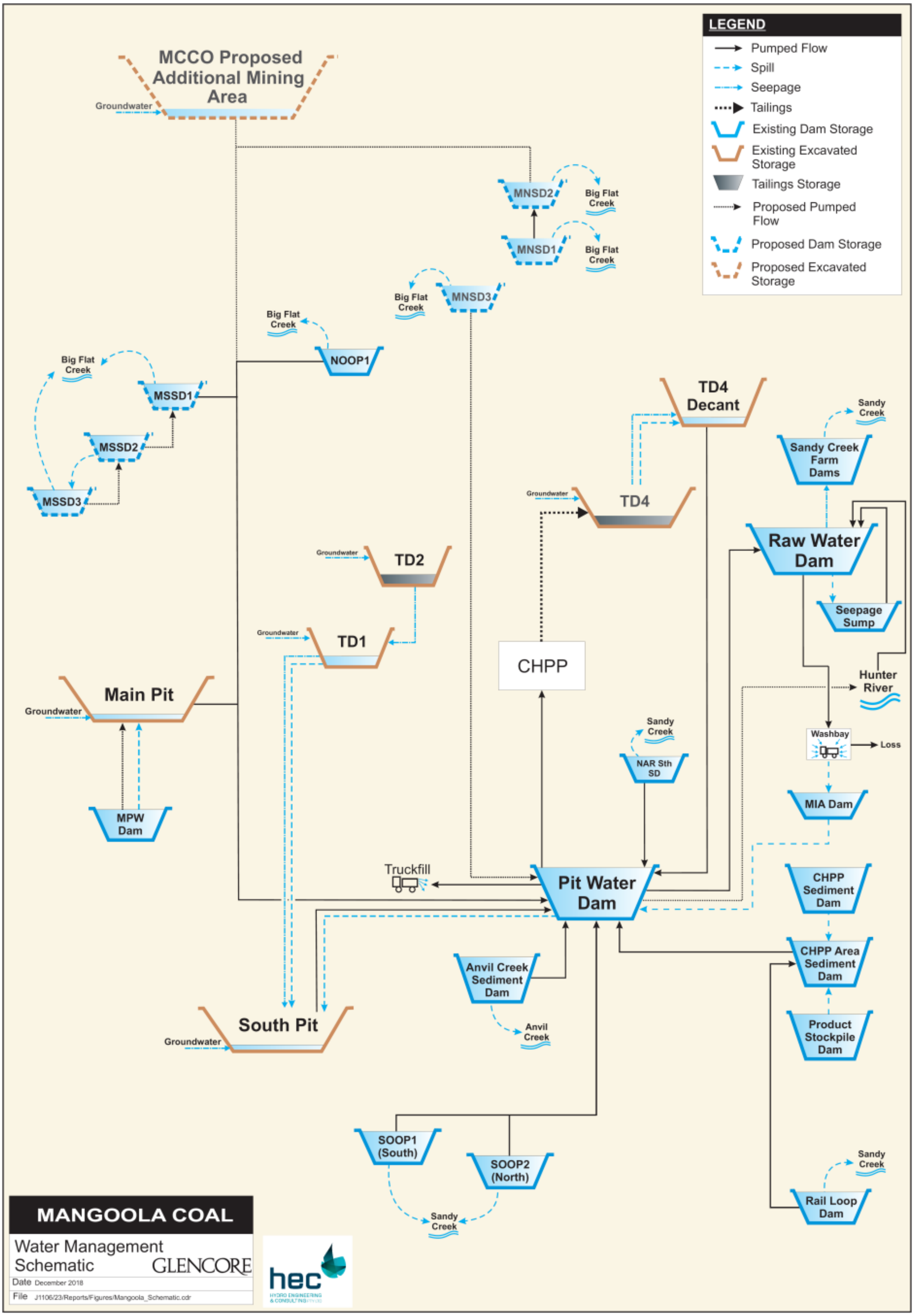

Figure 15 Water Management System Schematic

3.2 PROPOSED SURFACE WATER MANAGEMENT AND IMPACTS

3.2.1 Staged Development of MCCO Project Water Management and Integration with Existing Operations

The extent of existing operations is shown in Figure 14. Stage plans for Year 1, Year 3, Year 5 and Year 8 were provided by Mangoola and are the basis of Figure 16 to Figure 19 which illustrate the progression of the proposed MCCO Project.

The water management and supply system for the MCCO Project will be integrated with the existing system. A number of new dams would be constructed over the life of the MCCO Project for sediment control: Mangoola North Sediment Dam 1 (MNSD1), Mangoola North Sediment Dam 2 (MNSD2), Mangoola North Sediment Dam 3 (MNSD3), Mangoola South Sediment Dam 1 (MSSD1), Mangoola South Sediment Dam 2 (MSSD2), and Mangoola South Sediment Dam 3 (MSSD3). These have been sized in accordance with the 'Blue Book' (Landcom, 2004 and DECCW, 2008) guidelines to capture runoff from a 95th percentile, 5-day rainfall event (settling zone[16] plus an allowance for sediment storage[17]), assuming the maximum catchment area reporting to the sediment dam over the MCCO Project life. Calculated minimum storage capacities are summarised in Table 14.

Table 14 Summary of Proposed MCCO Project Sediment Dams

Sediment Dam	Maximum Catchment Area Reporting to the Sediment Dam over the MCCO Project Life (ha)	Minimum Required Total Capacity (ML)
MNSD1	105.4	60.0
MNSD2	320.3	74.5
MNSD3	80.0	45.5
MSSD1	92.0	52.4
MSSD2	423.1	240.9
MSSD3	43.6	24.8

* MNSD1 pumped to MNSD2 ** MSSD2 pumped to MSSD1

† MSSD3 pumped to MSSD2

Note that these dams are exempt from licensing under the Water Management (General) Regulation 2018 because they are necessary for the purpose of control of soil erosion and capture, containment and recirculation of drainage to prevent the contamination of a water source.

These sediment dams would be dewatered to the PWD as indicated in Figure 15 either directly or via other sediment dams (refer also Table 14). Sufficient pump capacity would be provided to enable dewatering of these storages to reinstate their design settling zone volume in five days as required by Landcom (2004). Sufficient infrastructure would be provided to pump water back from the PWD to meet dust suppression requirements at the MCCO Additional Mining Area during periods of dry weather.

Note that the capacity of and pumping capacities from all other sediment dams on site (relating to the existing approved Mangoola Coal mine) have been based on design information or as-built plans provided by Mangoola.

Pumped transfer of water from the MCCO Additional Mining Area direct to the PWD would occur at a rate of 200 L/s.

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[16] Assumes a Type F or D sediment basin with greater than 3 years duration of disturbance and a sensitive receiving environment, 5-day rainfall total 51.3 mm for Scone, volumetric runoff coefficient 0.74 assuming high runoff potential (uniform across catchment).

[17] Equal to half the settling zone capacity.

3.2.1.1 Year 1

Figure 16 shows the Year 1 contours along with derived total catchment area and sub-catchment area delineation[18] for each storage.

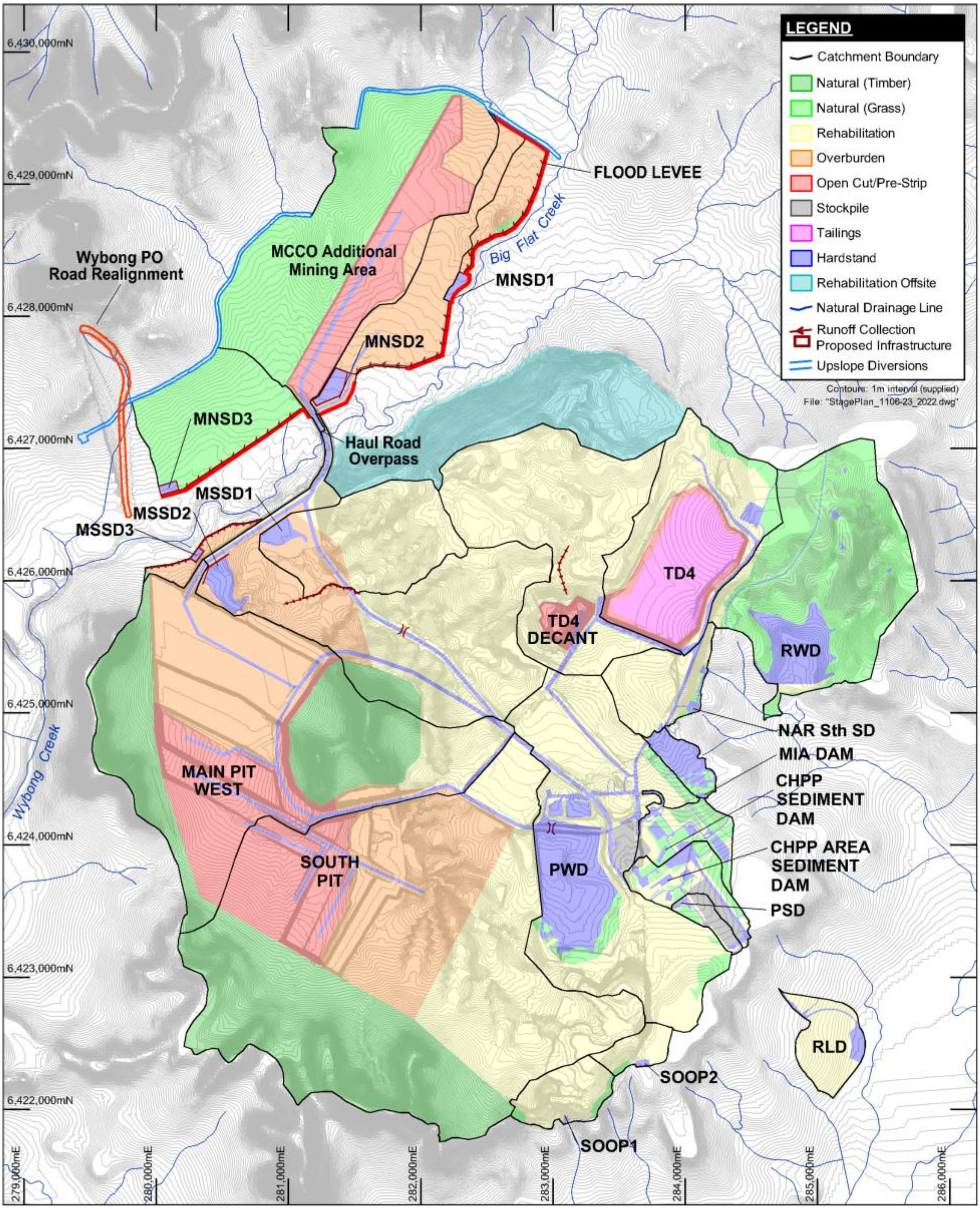

Figure 16 Water Management System Layout – Year 1

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[18] Different sub-catchments have different rainfall-runoff responses – refer Section 3.3.3.1.

At this stage the MCCO Additional Mining Area open cut pit and adjacent overburden emplacement would have commenced development with a haul road linking this area to the approved operations. The haul road includes an overpass over Big Flat Creek and Wybong Road. Sediment dams MNSD1, MNSD2 and MNSD3 would have been constructed in advance of MCCO Additional Project Area disturbance to capture sediment laden runoff from these disturbed areas. Two upslope diversions would have been constructed – one to the north of the MCCO Additional Mining Area open cut pit and one to the west (refer Section 3.2.1) to limit undisturbed catchment area reporting to the MCCO Additional Mining Area. The alignment and extent of the upslope diversions has been designed to minimise impacts on biodiversity.

A flood levee (bund) would have been constructed between the new MCCO mining areas and Big Flat Creek to a crest level equal to a 1:1,000 AEP peak flood level plus 0.5 m freeboard (refer Section 3.2.3). The flood levee would integrate with the proposed haul road overpass.

Mining in the approved Mangoola operations' Main Pit and South Pit would have advanced such that the South Pit and Main Pit were virtually merged into Main Pit West. Overburden emplacement behind (north of) Main Pit West would require sediment dams MSSD1, MSSD2 and MSSD3 to be in place. Runoff from a significant portion of the overburden emplacements would report to nearby open cut pits. Runoff from the rehabilitated area formerly reporting to NOOP1 (refer Figure 14) would be allowed to drain to Big Flat Creek, having been in place for five years, subject to rehabilitation inspections and necessary approvals confirming an appropriate quality of rehabilitation has been achieved at that time. Runoff from rehabilitated areas north of the TD4 Decant storage would be directed to the TD4 Decant storage via a constructed drain to reduce the catchment which would otherwise report to MSSD2. Rehabilitated areas to the west of the TD4 Decant storage would be directed to the south of the haul road and into the catchment of MSSD2 via a culvert and another constructed drain. Tailings would continue to be emplaced in TD4 with supernatant water seepage occurring to the adjacent TD4 Decant storage. Tailings storages TD1, TD2 and TD3 would be undergoing rehabilitation with runoff from these areas reporting to the PWD, NAR South Sediment Dam or South Pit.

3.2.1.2 Year 3

The Year 3 contours are shown in Figure 17 along with total catchment area and sub-catchment area delineation for each storage. By this stage the MCCO Additional Mining Area open cut pit and adjacent overburden emplacement would have advanced further to the north-west with rehabilitation of the overburden emplacement commenced. Mining in the approved Mangoola operations' open cut pits would have completely merged into one: Main Pit West, with overburden emplacement and rehabilitation occurring to its north and east. The catchment area of sediment dam MSSD2 would have increased and would comprise mostly rehabilitated areas. Tailings deposition would continue to TD4 with reclaim of supernatant water via the adjacent TD4 Decant.

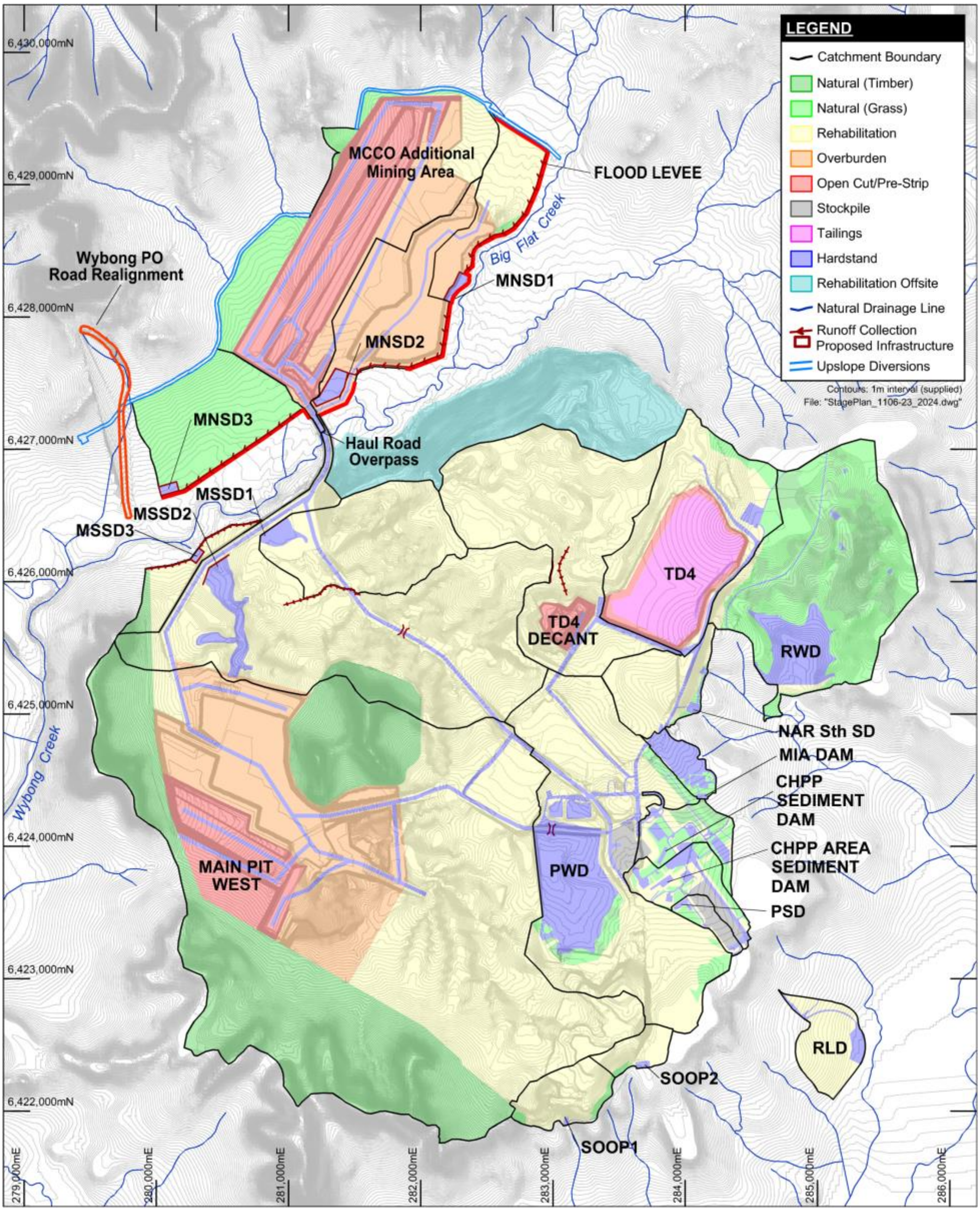

Figure 17 Water Management System Layout – Year 3

3.2.1.3 Year 5

The Year 5 contours are shown in Figure 18 along with assumed total catchment area and sub-catchment area delineation for each storage. By this stage the MCCO Additional Mining Area open cut pit and adjacent overburden emplacement would have advanced further to the north-west and south-west, mining through MNSD3 and much of the upslope south-western diversion and a portion of the upslope northern diversion. Upslope diversions would not be reconstructed further upslope in order to limit impacts on biodiversity. Mining in the approved Mangoola operations' Main Pit West would be close to being completed. The catchment area of sediment dam MSSD2 would have increased and reached its maximum extent. Tailings emplacement would continue to TD4 with reclaim of supernatant water via the adjacent TD4 Decant.

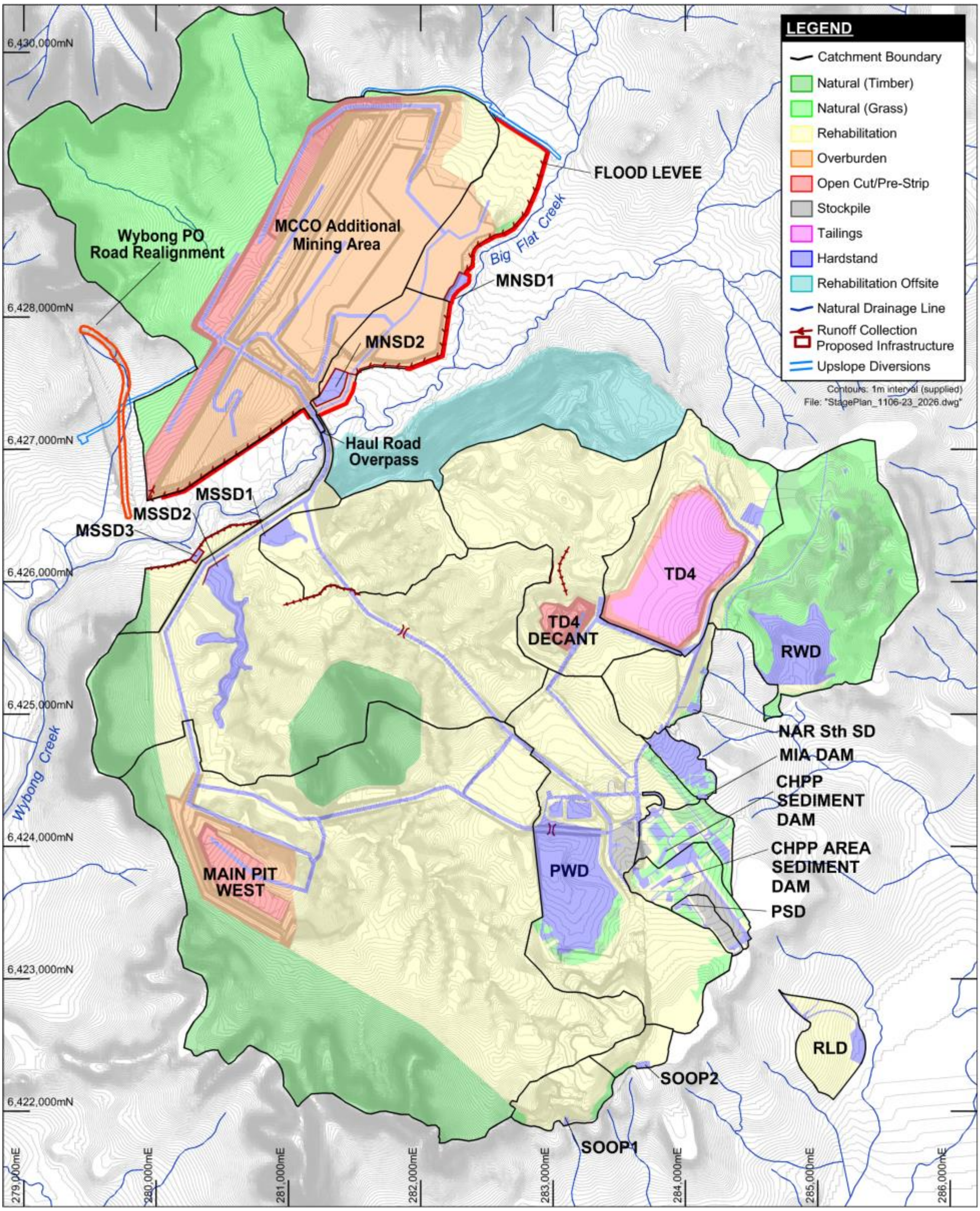

Figure 18 Water Management System Layout – Year 5

3.2.1.4 Year 8

The Year 8 contours are shown in Figure 19 along with assumed total catchment area and sub-catchment area delineation for each storage.

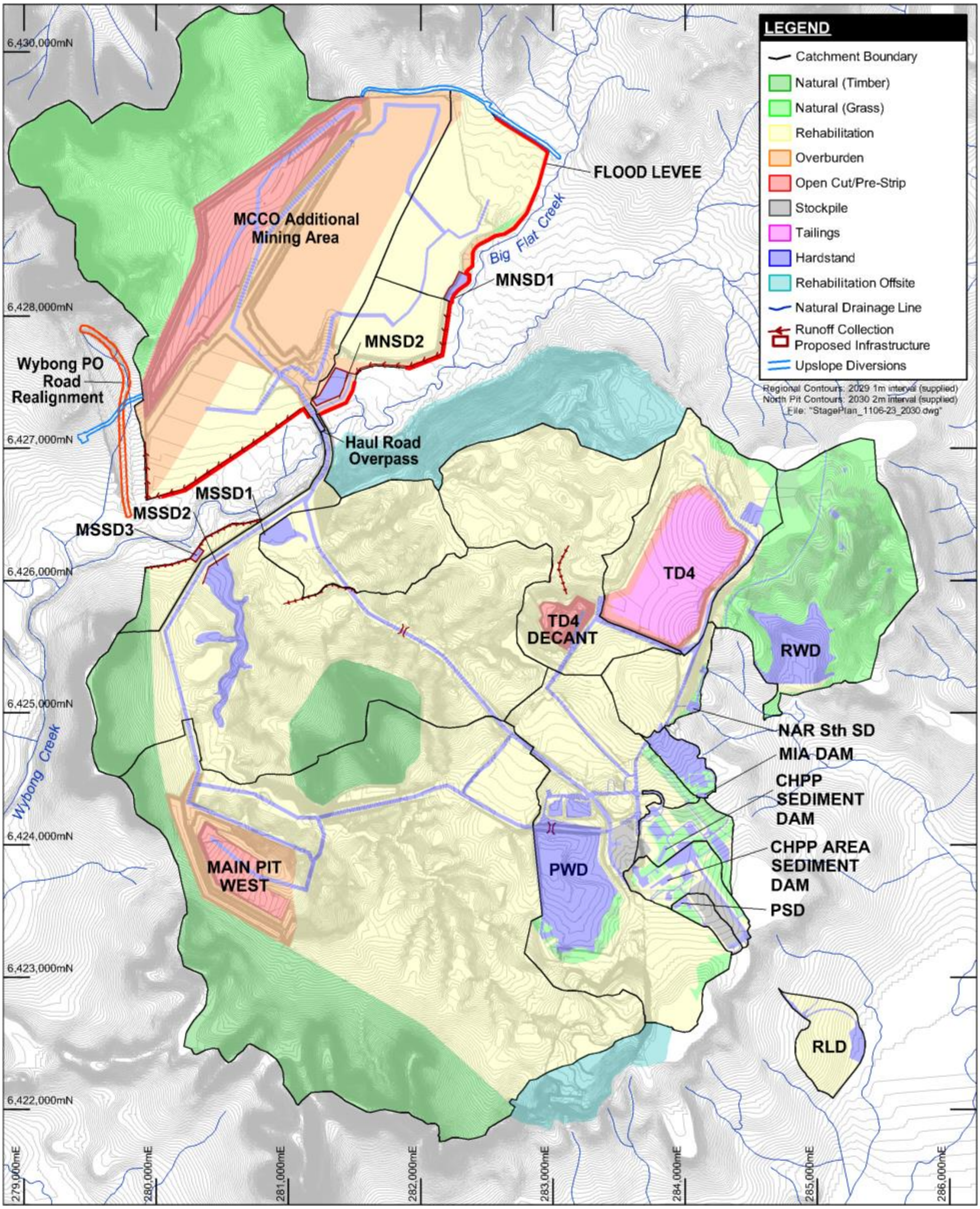

Figure 19 Water Management System Layout –Year 8

By this stage the MCCO Additional Mining Area open cut pit and adjacent overburden emplacement would have advanced further to the north-west again and the open cut pit would be close to its final extent. The rehabilitated extent of the overburden emplacement would also have advanced. There would be little change in the approved Mangoola operations' Main Pit West with on-going rehabilitation occurring after Year 5. Tailings emplacement would continue to TD4 with reclaim of supernatant water via the adjacent TD4 Decant.

3.2.1.5 Final Landform

The final landform drainage for the MCCO Project is shown in Figure 20. As is currently implemented at the Mangoola Coal Mine, the development of the final landform for the MCCO Project will include the continued use of natural landform design processes incorporating micro-relief principles. In this regard, Mangoola aims to return the site to a condition where the landforms, soils, hydrology, flora and fauna are self-sustaining and compatible with the surrounding land uses meaning that traditional contour banks for drainage are not required. The key design principles to be used in the natural landform design approach include:

- the drainage density of the final landform is to reflect the nature of the drainage patterns in surrounding landforms;
- steeper slopes are to be located higher in the catchment (that is, where water flows are smallest), with slope gradients flattening out downstream;
- drainage lines will have both channel and floodplain components to provide stability during frequent flood events; and
- gentle flow transitions which emulate natural transitions and maintain a balance between scour risk and sediment load.

Only a small remnant upslope drain is proposed upslope of the MCCO Additional Mining Area open cut pit because the relatively steep gradient and prevalence of rocky outcrops limits the sustainability of stable permanent diversions and development of a more extensive drain to that proposed would result in increased impacts on biodiversity. Diversion of runoff from the adjacent rehabilitated overburden emplacement (south-east of the final void) would occur via a bund that is permanently integrated with the final landform. The flood levee adjacent to Big Flat Creek would be removed.

Similarly a diversion upslope (north) of the existing Mangoola Main Pit West void would be permanently integrated into the final landform to limit runoff from rehabilitated areas entering the final void. The steepness of the natural terrain to the south of this final void again limits the practicality of diverting this catchment. Diversions would be designed to be stable in the long term in a manner similar to the remainder of the overburden emplacement landforms.

The final landform design and resulting detailed engineering of water management structures at mine closure will be included in future mine closure plans subject to approval by relevant regulatory agencies.

The predicted final void pit lake water balance is described in Section 4.0.

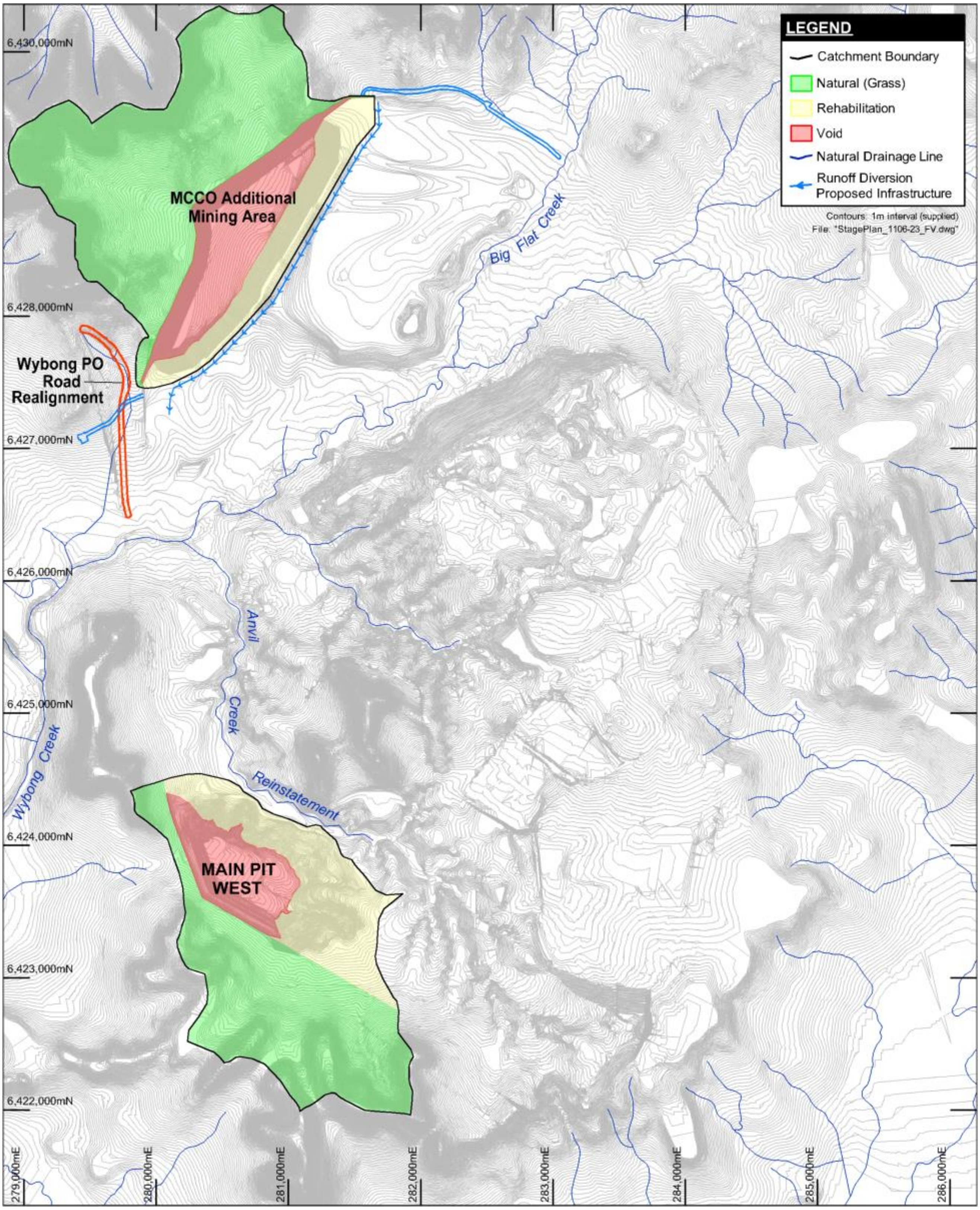

Figure 20 Water Management System Layout – Conceptual Final Landform

3.2.2 Harvestable Rights Assessment

Rural landholders in eastern NSW can capture up to 10% of the average regional runoff from their total landholding – known as "harvestable rights". Using the WaterNSW online maximum harvestable right calculator[19] and a total landholding area of 10,654 ha for Mangoola Coal, gave a maximum harvestable right dam capacity of 692.51 ML. This equates to a yield rate of 0.65 ML/ha per year (i.e. 692.51 ML = 10% x 0.65 ML/ha x 10,654 ha). The estimated total capacity of existing farm dams on Mangoola Coal's landholdings totals 404 ML (Engeny, 2016). Therefore the remaining harvestable right, subtracting the existing total farm dam capacity, equals 288.51 ML. This equates to capture of all runoff (at a rate of 0.65 ML/ha per year) from an area of 443.9 ha. The maximum undisturbed area captured within the MCCO Project Area (based on staged development of the MCCO Project water management system – refer Section 3.2.1) is estimated to be 890.7 ha. This exceeds the remaining harvestable right area by 446.8 ha or a yield (at 0.65 ML/ha per year) of 290.4 ML/year. This excess volume is less than Mangoola's total of 861 ML of Wybong Creek unregulated WALs (refer Section 2.4). Therefore Mangoola holds enough share components of Wybong Creek unregulated WALs to account for interception of undisturbed area runoff from the MCCO Project Area in excess of harvestable rights. Mangoola may also decommission farm dams on their landholdings to reduce runoff capture from these landholdings.

3.2.3 Potential Impacts – Flooding and Channel Stability

3.2.2.1 Description of Surface Water Diversions and Creek Crossing

Upslope diversions are planned to the north and west of the proposed MCCO Additional Mining Area open cut pit as shown on the stage plans in Section 3.2.1. The northern upslope diversion would discharge directly into Big Flat Creek while the south-western diversion would include a culvert crossing under the realigned Wybong PO Road and a stilling basin further to the south-west, with discharge to an existing natural drainage line. Diversions will accommodate a design 1:100 AEP peak flow rate with a minimum 0.5 m freeboard.

A haul road overpass of Big Flat Creek and the adjacent Wybong Road is proposed in order to allow access to the MCCO Additional Mining Area. The concept design of the creek crossing used in this assessment includes three 3 m culverts (or culverts with equivalent flow characteristics) within a conventional earthfill embankment. In addition, the concept design for the Wybong Road overpass incorporates a proprietary arch structure. Culvert dimensions and preliminary details for modelling were provided by Arkhill Engineers on behalf of Mangoola Coal. A haul road overpass crest level of 162 mAHD was modelled. These details were included in the TUFLOW flood model for the "with MCCO Project" case (refer Section 2.7.3).

3.2.2.2 Predicted Changes to Flooding and Flood Levels in Big Flat Creek

The predicted changes in extent of flooding with and without the MCCO Project for three of the flood events simulated using the TUFLOW flood model (refer Section 2.7) are shown in Figure 21 to Figure 23, with the remaining figures provided in Appendix B. The cyan shading in these figures indicates areas where there would no longer be flooding as a result of the MCCO Project, while the magenta areas highlight areas where flooding would extend further as a result of the MCCO Project. For the 1:20 AEP (Figure 21), most increased inundation areas are associated with the presence of the proposed flood levee in the north-eastern portion of the MCCO Additional Project Area and increased flow associated with the northern upslope diversion. For the 1:100 AEP (Figure 22), the increased inundation area downstream of the proposed haul road crossing is associated with flow which would

[19] https://www.waternsw.com.au/customer-service/water-licensing/basic-water-rights/harvestable-rights-dams/maximum-harvestable-right-calculator - accessed 19 December 2018.

pass through the proposed Wybong Road overpass – the depth of this predicted increase in inundation area diminishes with distance downstream. For the 1:1,000 AEP (Figure 23), the increased inundation area downstream of the proposed haul road crossing extends further downstream because more flow would pass through the proposed Wybong Road overpass. Figure 21 to Figure 23 also show the extent of non Mangoola-owned land. The only such area within the model extent is a small parcel of Crown Land (Travelling Stock Reserve) which is located on the north side of Big Flat Creek just upstream of the proposed haul road crossing. Modelling predicts that there would be no increase in inundation extent over this area up to and including a 1:100 AEP.

The model results show that the haul road crossing of Big Flat Creek would not overtop in a PMF event. Results also show that a portion of the design flow for modelled events rarer than a 1:20 AEP would pass through the proposed arch structure supporting the haul road over Wybong Road. Note that the existing Wybong Road is predicted to be inundated over a significant length in such events (refer Section 2.7.4 and Figure 11). A longitudinal section along Wybong Road (primarily upstream of the Wybong Road Overpass) is plotted in Figure 24 together with modelled peak 1:20 AEP flood levels. This indicates that 1:20 AEP flooding affects the existing Wybong Road and that the change due to the MCCO Project, in terms of additional flooding should be negligible. Table 15 provides a summary of the predicted flood depths over Wybong Road at a location just upstream of the proposed haul road crossing for without the MCCO Project and with the MCCO Project for a range of AEP events. The results in Table 15 indicate that the trafficability of Wybong Road should remain unaffected for flood events up to a 1:100 AEP.

Table 15 Predicted Peak Flood Depths over Wybong Road Upstream of Haul Road Crossing

Annual Exceedance Probability	Predicted Peak Flood Depth over Wybong Road (m)	
	Without MCCO Project	With MCCO Project
1:10	0	0
1:20	0	0
1:100	0.30	0.34

It is recommended that appropriate flood warning signage, including flood depth indicators, be installed along Wybong Road in the vicinity of the overpass as a safety measure regardless of the MCCO Project.

3.2.2.3 Potential Impacts on Channel Stability in Big Flat Creek

The 1:20 AEP was chosen as being the greatest peak flow rate at which the channel could reasonably be expected to remain stable. Results of TUFLOW flood modelling were used to assess the effects of project-related changes to flow and flow velocity distribution in Big Flat Creek under peak 1:20 AEP flood flow conditions. This was achieved by comparing the simulated flow velocity distribution in Big Flat Creek and its upstream northern tributary obtained from models set-up to reflect existing conditions and with the fully developed MCCO Additional Project Area.

The simulated distribution of 1:20 AEP peak flow velocity in Big Flat Creek for the scenario with the fully developed MCCO Project is shown in Figure 25. The change between the predicted velocities from existing conditions to the fully developed MCCO Project was calculated by subtracting the velocity distributions for the two model set-ups. The predicted increase is shown in Figure 26.

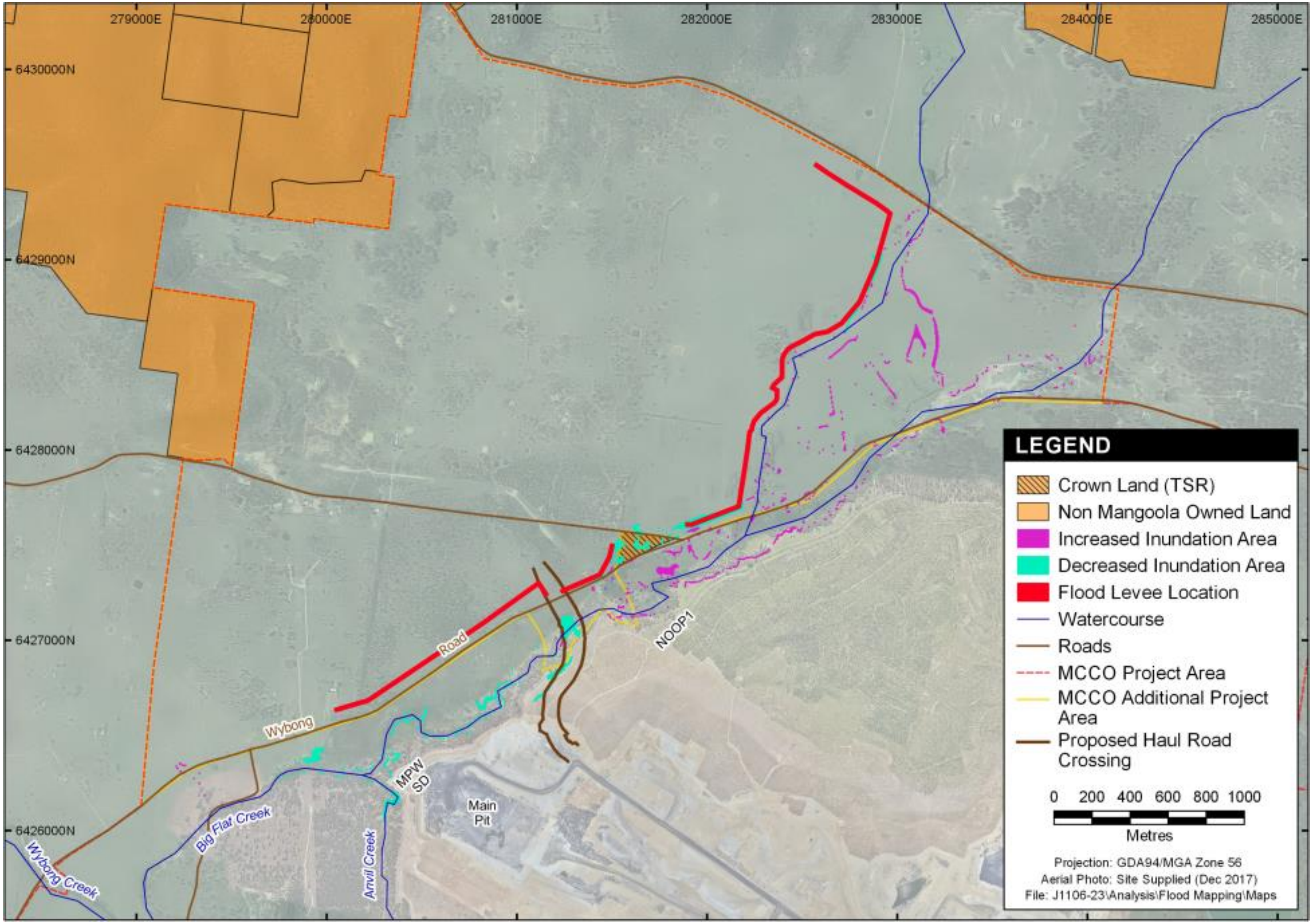

Figure 21 Predicted Changes to Flood Extent – 1:20 AEP

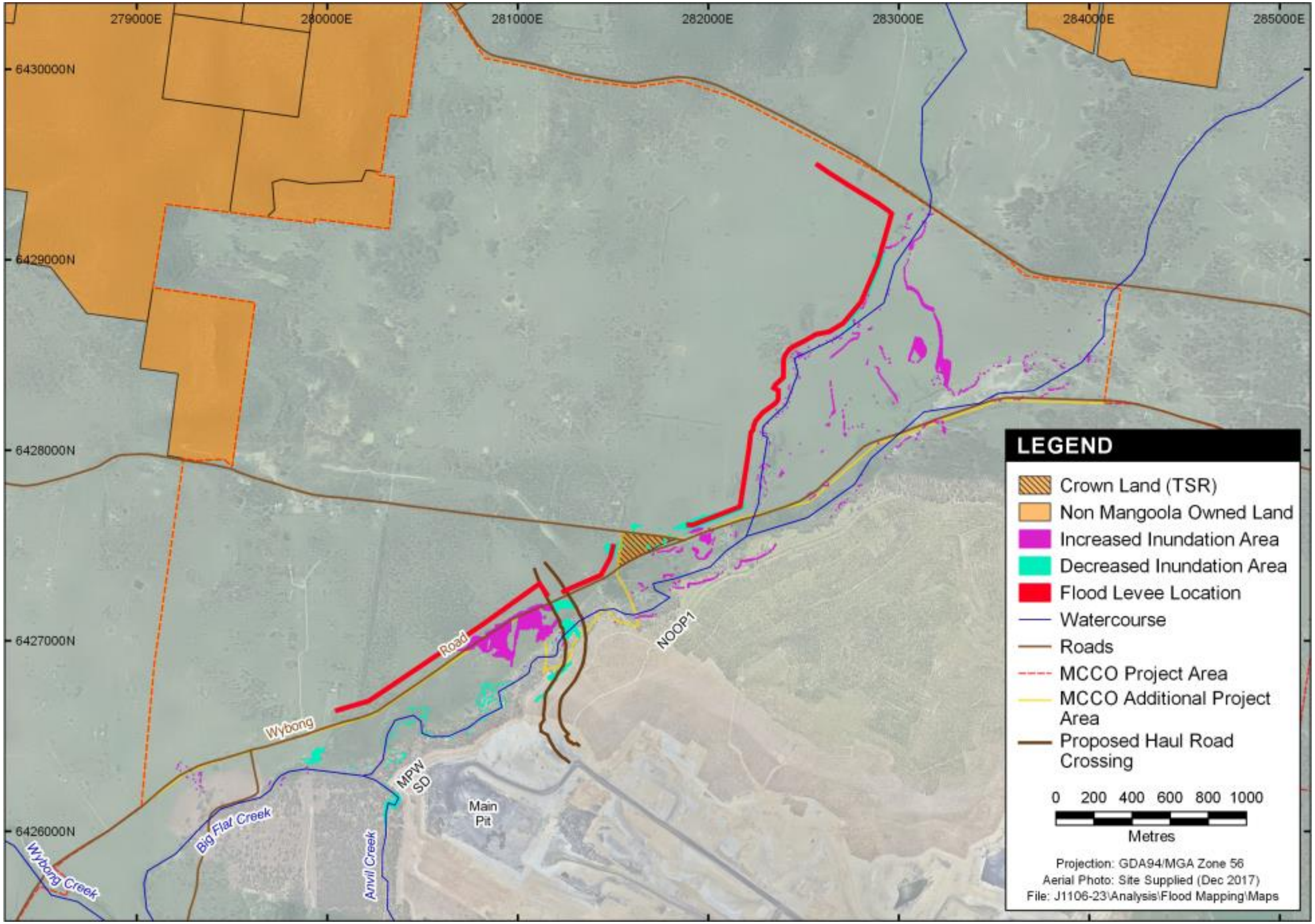

Figure 22 Predicted Changes to Flood Extent – 1:100 AEP

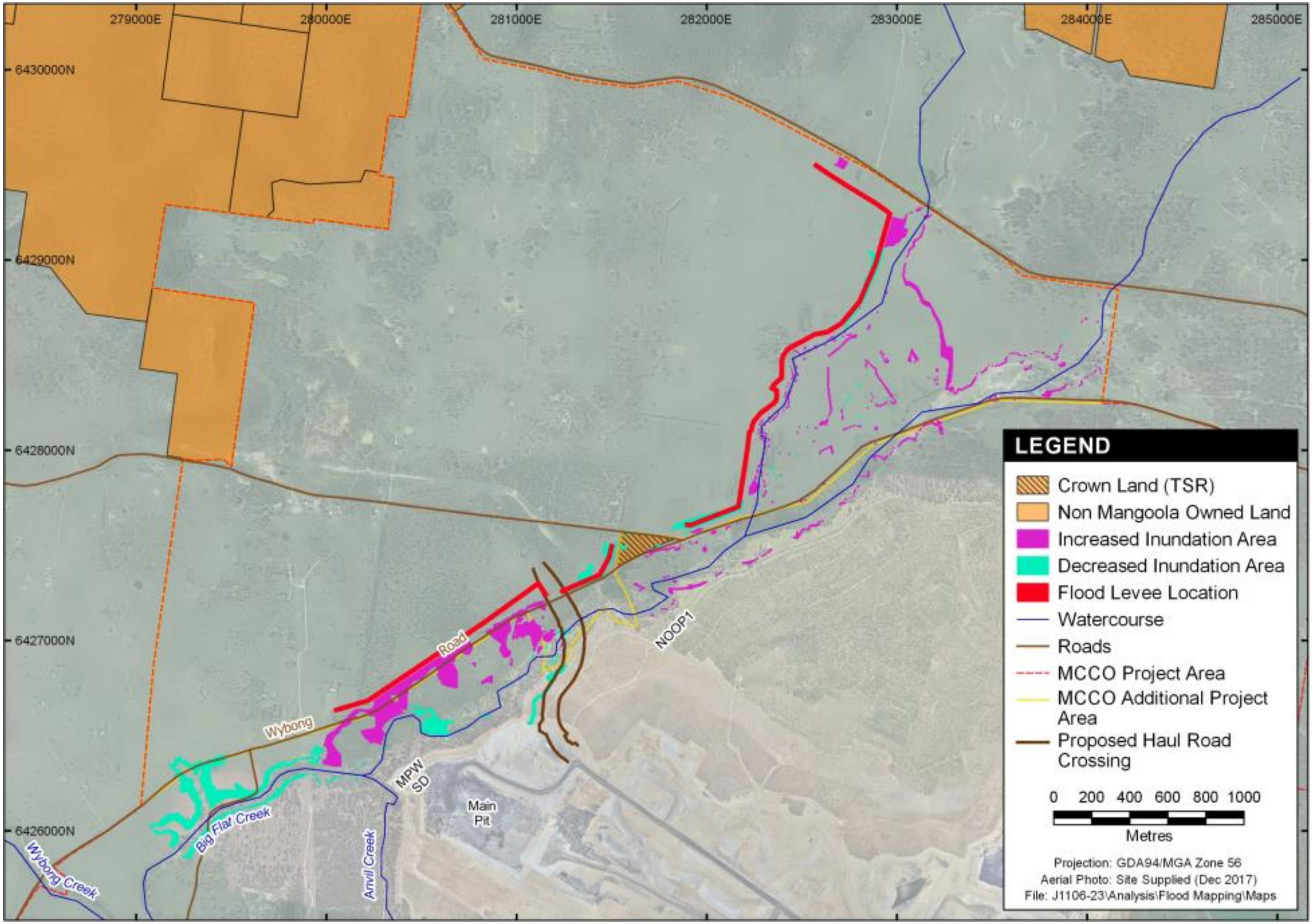

Figure 23 Predicted Changes to Flood Extent – 1:1,000 AEP

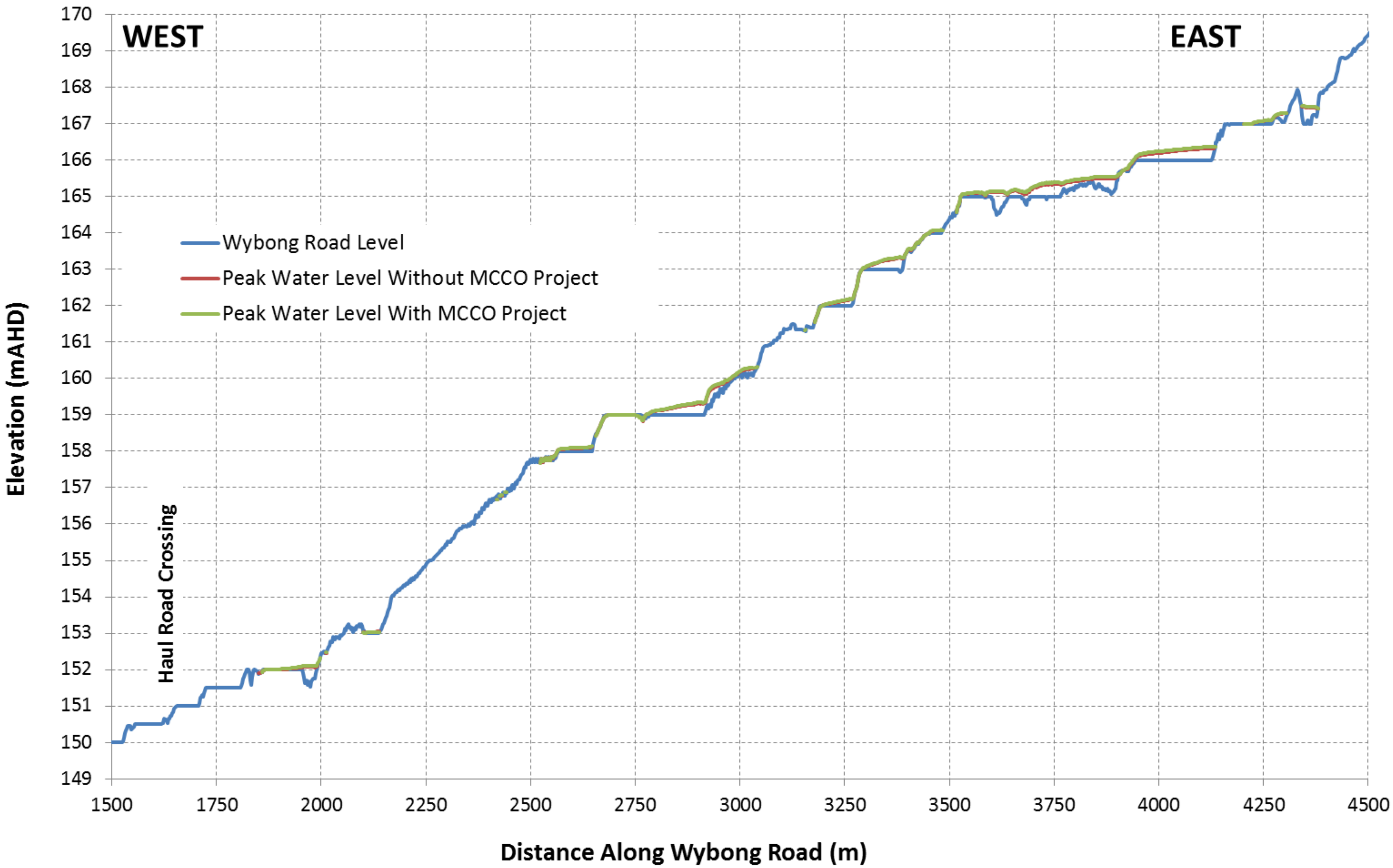

Figure 24 Longitudinal Section Along Wybong Road with Predicted Big Flat Creek Flood Levels – 1:20 AEP

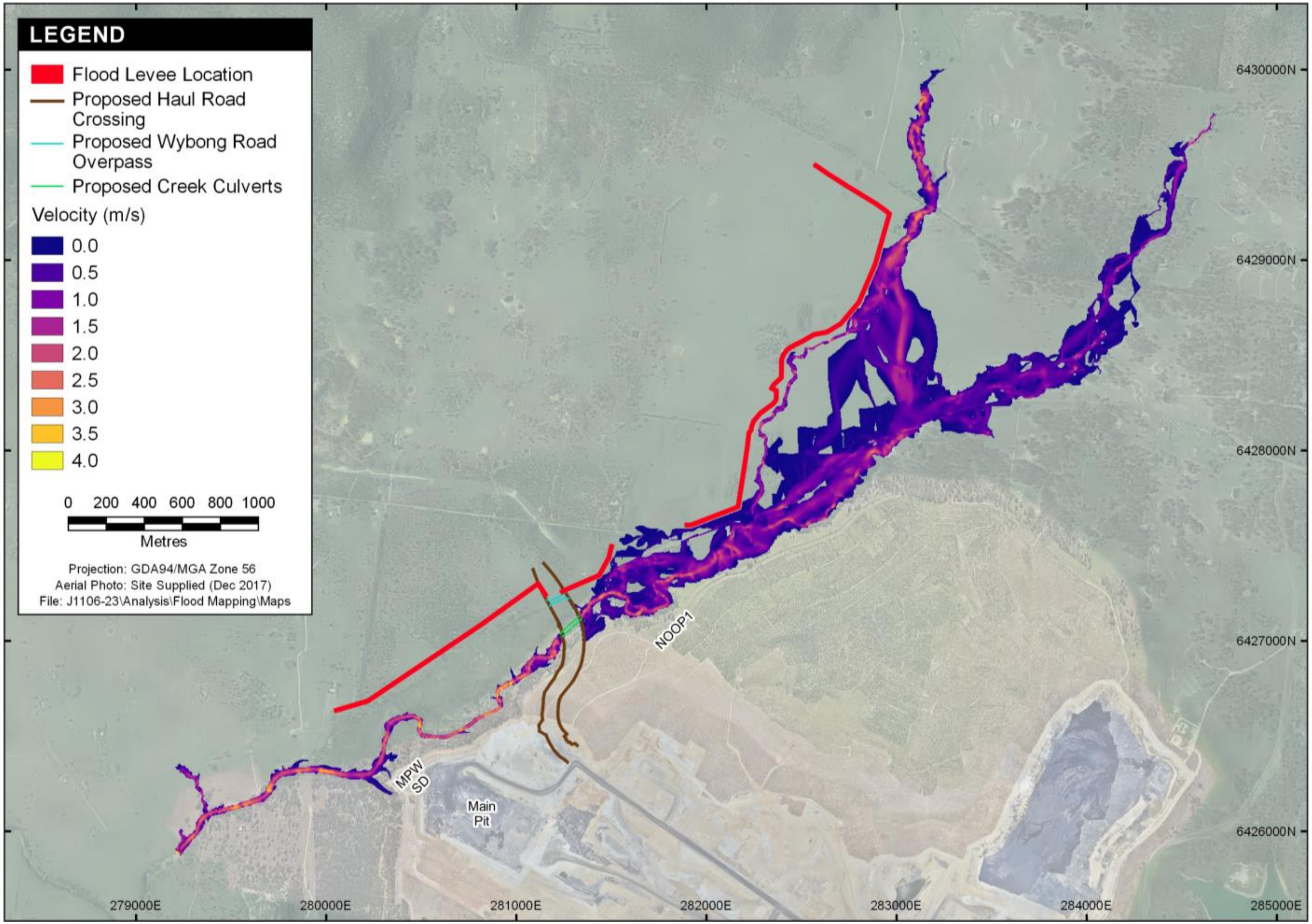

Figure 25 Predicted Peak 1:20 AEP Flood Flow Velocity Distribution in Big Flat Creek with MCCO Project

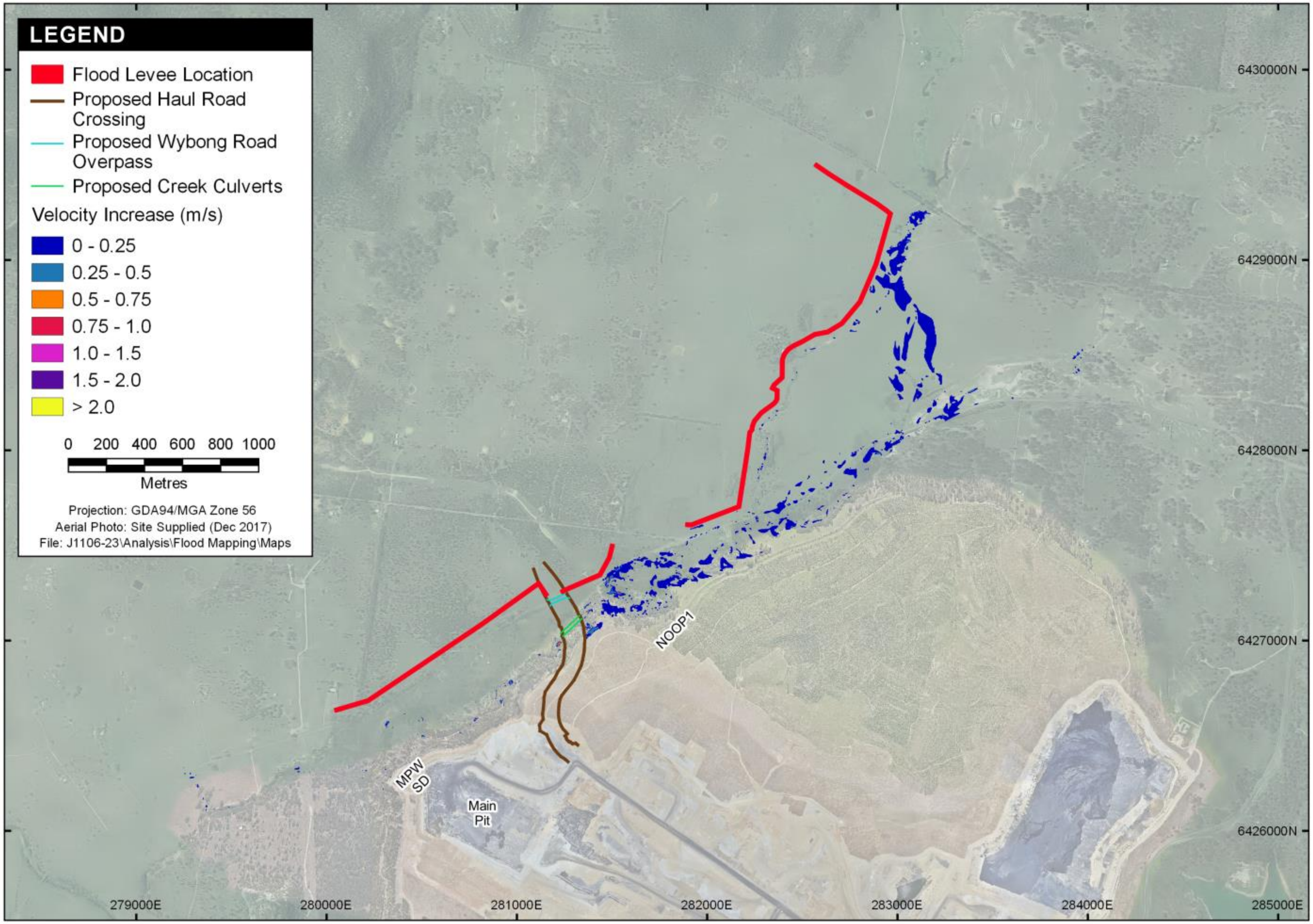

Figure 26 Predicted Peak 1:20 AEP Flood Flow Velocity Increase in Big Flat Creek with MCCO Project

In Figure 26, areas where there was a reduction in flow velocity are not shaded, while areas where there was a small predicted increase in velocity as a result of MCCO Project development (less than 0.25 metres/second [m/s]) are shown in dark blue. The majority of predicted areas of increased velocity comprise a less than 0.25 m/s increase and therefore the overall impact on channel stability in the majority of areas is expected to be negligible. Areas where flow velocity was predicted to increase more significantly as a result of MCCO Project development appear as light blue, yellow, orange and red – where these colours reflect progressively greater increases in predicted flow velocity. These areas are very small indicating that the MCCO Project is not predicted overall to result in significant increases in flow velocity in Big Flat Creek and therefore the risk of increased erosion in most areas is negligible. Small areas of predicted significant increases in flow velocity occur in areas near the proposed haul road crossing of Big Flat Creek and are shown in more detail in Figure 27. As might be expected, high velocity flows would occur at the outlet of the proposed culverts and near their inlet and therefore erosion protection (e.g. with rip-rap) will be included in the design. An example of the use of erosion protection used at another creek culvert crossing at the Mangoola Coal Mine is shown in Photo 9.

Photo 9 Existing Mangoola Rail Crossing of Sandy Creek

Other areas of predicted velocity increase appear to be localised, generally small and associated with changed flow patterns caused by the proposed haul road and (to a lesser extent) the flood levee. These areas occur within Mangoola owned land. Apart from the culvert outlet, there is no material effect predicted downstream of the proposed haul road crossing. These localised areas should be monitored during the operational life of the MCCO Project in order to assess the need for mitigation measures such as armouring (refer Section 5.2). The combination of appropriate design, armouring if required and monitoring is adequate to mitigate the risk of erosion as a result of the MCCO Project.

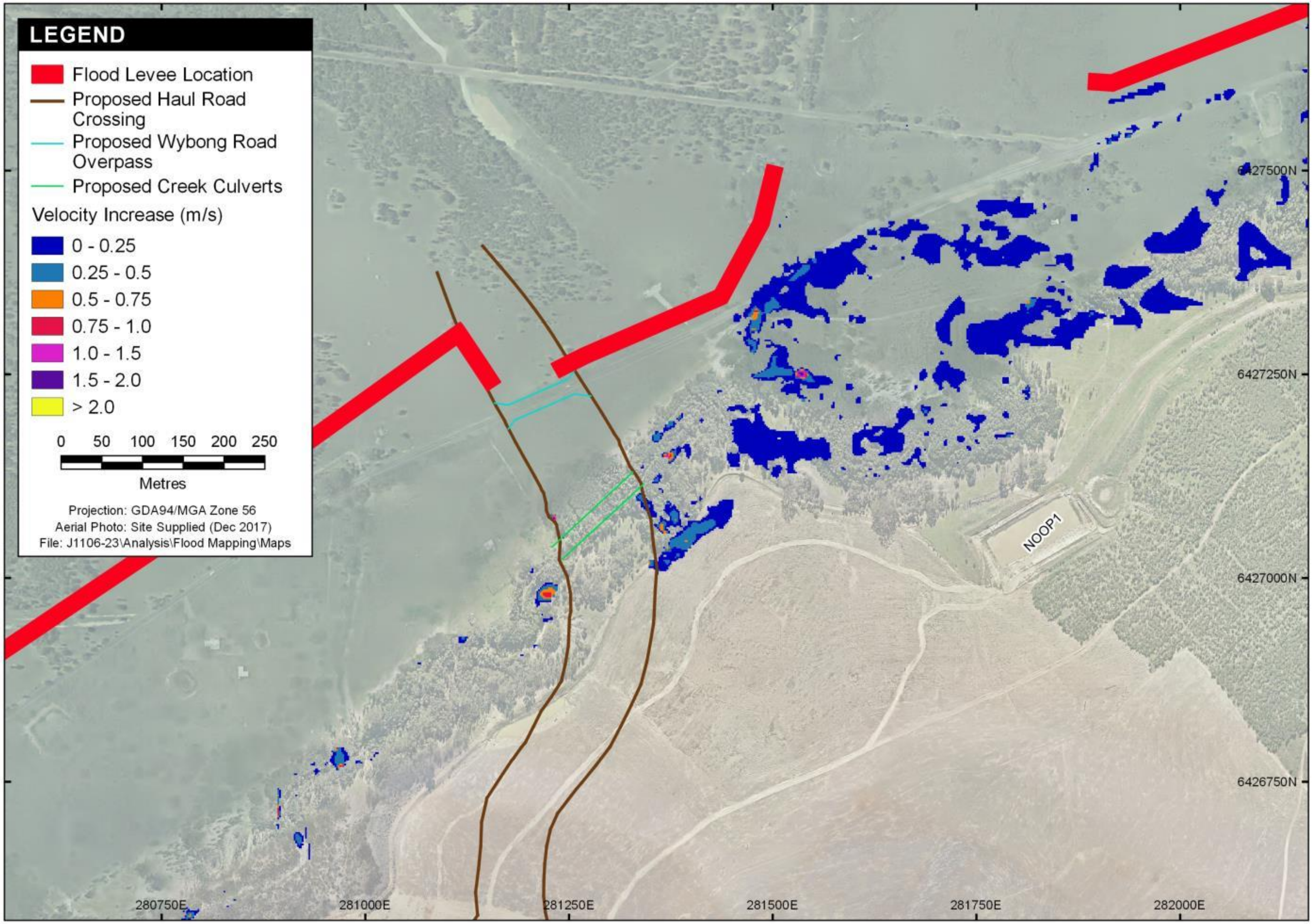

Figure 27 Predicted Peak 1:20 AEP Flood Flow Velocity Increase in Big Flat Creek with MCCO Project – Near Proposed Haul Road

3.2.4 Potential Impacts - Catchment Yield and Flow in Local Creeks

The MCCO Additional Project Area (including the currently approved Mangoola operations) will result in reduced catchment area and hence catchment yield in Big Flat Creek. Therefore there will also be a small effect on Wybong Creek (of which Big Flat Creek is a tributary) due to the small proportion of the Wybong Creek catchment that will be captured by the MCCO Project Area. This would result in a small reduction in flow (surface flow and baseflow) in Wybong Creek which is discussed in greater detail below.

3.2.4.1 Catchment Area Reduction and Catchment Yield Effects

The potential effects on total surface flow in the downstream creeks can be assessed on the basis of reduction in catchment area. The area and percentage of Wybong Creek captured within the MCCO Additional Project Area water management system over the life of the MCCO Project at different years (estimated from mine stage plans – Section 3.2.1) are shown in Table 16.

Table 16 Wybong Creek Catchment Area Captured by MCCO Additional Project Area

Year	Captured Area (km^2)	Percentage of Wybong Creek Catchment	
		Area Upstream of and Including Big Flat Creek	Total Area
Year 1	4.2	0.63%	0.53%
Year 3	4.3	0.64%	0.54%
Year 5	7.8	1.17%	0.98%
Year 8	8.0	**1.20%**	**1.01%**
Final Landform	4.1	0.62%	0.52%

The Table 16 maximum percentages of 1.20% and 1.01% are in addition to maximum reductions of 1.4% and 1.1% of the ‘catchment of Wybong Creek upstream of Big Flat Creek and in total respectively. It would be expected that average total flow volumes in Wybong Creek would reduce as a result of the MCCO Additional Project Area approximately by the above percentages. Note that the peak reduction only occurs toward the end of the MCCO Project life and that in the initial years the reduction is much less. A 1.2% reduction in the mean annual flow at GS210040 (26,455 ML - refer Section 2.6.1) would amount to an annual average reduction of approximately 317 ML. This volume is less than Mangoola’s total of Wybong Creek unregulated WALs, even allowing for a reduction in net WALs, if required, for harvestable rights (refer Section 0).

The captured areas given in Table 16 would currently report (or in the past have reported) to Big Flat Creek. The estimated pre-mine catchment area of Big Flat Creek is 50.6 km^2, while as at 2017, the catchment area was 36.5 km^2. Near the end of the MCCO Project life, it is estimated that the catchment area of Big Flat Creek would have reduced to 23.7 km^2 (with the mining of the approved Mangoola Coal Mine and the development of the MCCO Project). This means that 53% of the pre-mine catchment area of Big Flat Creek would be captured in the water management system (note that this would reduce to 14% of the pre-mine catchment following the completion of mining and rehabilitation – refer Section 4.0). No surface water users would be impacted by flow reductions on Big Flat Creek – given that there are no private licensed surface water users on Big Flat Creek (refer Figure 4). The MCCO Project is not expected to have an adverse effect on downstream surface water resources such that aquatic biodiversity are adversely impacted (Umwelt, 2019).

The impact of these catchment changes on the flow regime in Big Flat Creek has been assessed by adopting the flow characteristics of a nearby gauged stream (Dart Brook) for simulating flow in Big

Flat Creek (refer Section 2.6.1.2). Simulation of streamflow over a long period of time was undertaken using the Australian Water Balance Model (AWBM) (Boughton, 2004). Calibrated model parameters for GS 210088 (Dart Brook) were obtained from Boughton and Chiew (2003). The model was run with more than 129 years of climate data sourced from the SILO Data Drill for a location within the Big Flat Creek catchment. Three catchment cases were simulated: pre-mine, existing (2017) and at the end of the MCCO Project life (maximum catchment area reduction). Figure 28 shows modelled flow-duration curves for these three cases (and a fourth case with predicted baseflow loss – refer Section 3.2.4.2). Figure 28 shows that a flow rate of 0.05 ML/d is predicted to be exceeded 50% of the time in the existing Big Flat Creek, while near the end of the MCCO Project life this is modelled to reduce to approximately 0.03 ML/d. The prevalence of effectively zero flow (less than 0.001 ML/d) is estimated to increase from approximately 26.5% of days to 28.3% of days. These predicted changes are small and not considered material given the ephemeral nature of Big Flat Creek (refer Section 2.6.1.2) and that there are no licenced surface water users on Big Flat Creek other than Mangoola (refer Section 2.4).

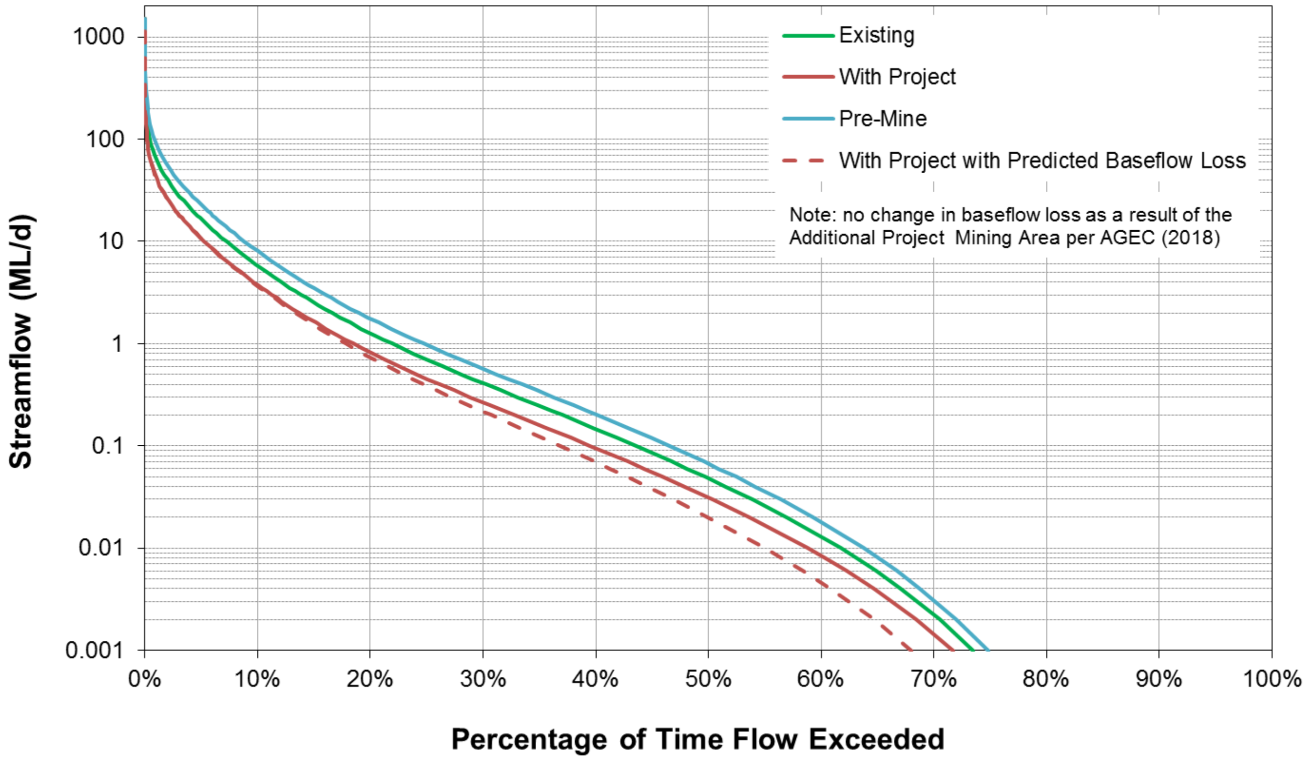

Figure 28 Modelled Flow Duration Plot for Big Flat Creek

In terms of long term (final void) reduction in catchment area reporting to both creeks, it is estimated that this would total 7.32 km^2 (this compares with an estimated 4 km^2 for the approved final void. This amounts to 1.1% of the Wybong Creek catchment area upstream of and including Big Flat Creek and 0.9% of the total catchment of Wybong Creek. A 1.1% reduction in the mean annual flow in 'Wybong Creek upstream of and including Big Flat Creek would amount to an annual average reduction of 291 ML plus a predicted annual reduction of 29 ML in baseflow (MCCO Project including approved Mangoola Coal Mine) from groundwater modelling (AGEC, 2019). An average annual reduction of 320 ML in flow represents a small and likely indiscernible impact to flow in Wybong Creek. Mitigation would involve the permanent retirement of this volume of WAL from the Wybong Creek Water Source within the Hunter Unregulated and Alluvial Water Sources WSP (refer also Section 2.4). Mangoola hold sufficient WAL to achieve this.

3.2.4.2 Baseflow Effects

Changes in groundwater-derived baseflow have been predicted for Wybong and Big Flat Creeks by AGEC (2019) and are summarised in Figure 29. In Big Flat Creek, baseflow changes resulting from the MCCO Additional Mining Area are predicted to be negligible. The effect of an (unchanged) baseflow reduction on total streamflow will vary with the magnitude of flow and this is illustrated by the dashed plot in Figure 28.

For Wybong Creek along its full length to the Goulburn River, the predicted additional baseflow loss as a result of the MCCO Additional Mining Area is up to approximately 13 ML/year. Total baseflow reductions of up to 30 ML/year (0.082 ML/d) have been forecast as a result of the approved Mangoola Coal Mine with the MCCO Additional Mining Area. The predicted reductions increase during the MCCO Project life and the maximum predicted reduction is reached several years after the end of mining (AGEC, 2019). The reduction as a result of the MCCO Additional Mining Area amounts to less than 0.05% of the mean annual total flow at GS 210040 (refer Section 2.6.1) or 0.18% of the mean annual baseflow at this location. The total reduction due to the approved Mangoola Coal Mine with the MCCO Additional Mining Area (up to 30 ML/year) amounts to approximately 0.11% of the mean annual total flow at GS 210040 (note that flow would be expected to be greater at the confluence with the Goulburn River and hence the relative reduction would be lower). This is an order of magnitude lower than the estimated reduction due to catchment area effects (refer Section 3.2.4 and Table 16). This represents a small and likely indiscernible impact to flow in Wybong Creek. A comparison of baseflow reductions to groundwater licensing is provided by AGEC (2019), which concludes that Mangoola Coal hold sufficient licences to account for the predicted 'water take'.

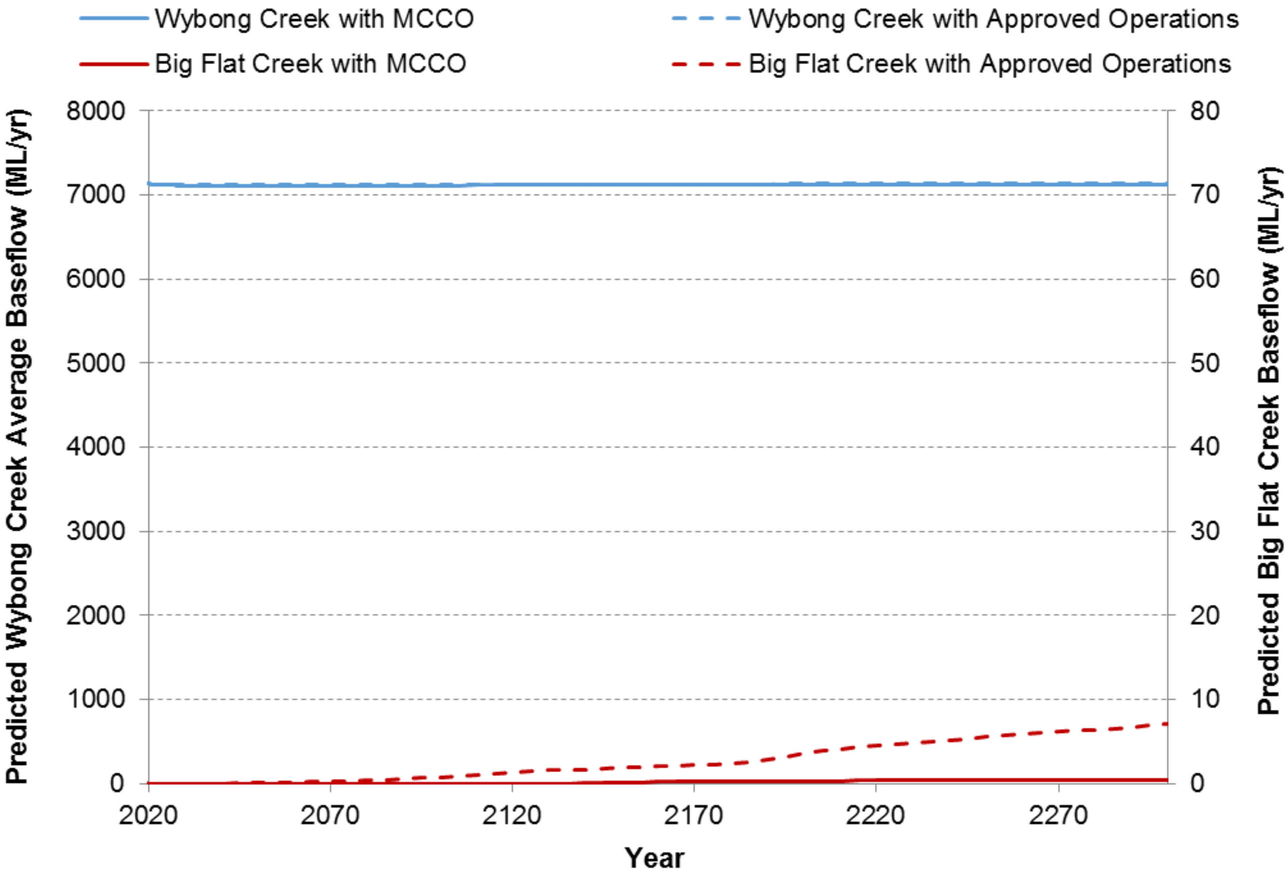

Figure 29 Forecast Creek Baseflow Change (AGEC, 2019)

3.2.4.3 Water Quality Effects

In terms of water quality impacts, the MCCO Project proposes to discharge surplus water from the water management system (via the PWD) in accordance with Environment Protection Licence (EPL) limits and consistent with the provisions of the HRSTS. Discharges will be monitored prior to release to ensure compliance with the limit conditions of EPL 12894 and the requirements of the HRSTS. With these measures in place, given the low recorded average environmentally significant metals concentrations in the PWD (refer Section 2.6.2) and considering the management of cumulative salt loads to the Hunter River system under the HRSTS, discharges of water from the MCCO Project are not considered likely to result in significant impacts to downstream waters. The risk to downstream waters associated with sediment laden water are mitigated by the design of the MCCO Project's water management system in accordance with design criteria established by the NSW Government specifically for sediment control at mining and quarrying operations. By managing sediment laden water and mine water within the MCCO Project water management system and, based on flood modelling predictions of small, localised increases in flood flow velocities and associated scour potential in Big Flat Creek (refer Section 3.2.3), it is not anticipated that water quality in downstream watercourses will be adversely impacted by the MCCO Project.

3.2.5 Potential Impacts on Flow in the Goulburn River

Wybong Creek is a tributary of the Goulburn River, which in turn is a major tributary of the Hunter River. The catchment area of the Goulburn River upstream of the Wybong Creek confluence is estimated to be 6,824 km^2. Therefore the maximum reduction of the catchment area of the Goulburn River just downstream of the confluence with Wybong Creek due to the MCCO Project (8 km^2 – refer Table 16) would amount to 0.12% of its total at that point. This level of change would be imperceptible and very small compared to natural variability in catchment conditions and is therefore considered to be negligible.

3.2.6 Potential Regional Cumulative Impacts

Cumulative impacts have been described in a mining context by Franks, et al (2010) as:

> *"…arise from compounding activities of a single operation or multiple mining and processing operations, as well as the aggregation and interaction of mining impacts with other past, current and future activities that may not be related to mining."*

In the context of surface water resources potentially impacted by the MCCO Project there has been significant past development in the upstream, immediate and downstream catchment areas which, if taken from European settlement, include widespread agricultural development and urbanisation. There has also been significant development of the surface water resources themselves - including regulation and extraction of water from local and regional surface water resources. The effects of past development are inevitably incorporated into the baseline descriptions of surface water resources developed for the MCCO Project which are based on contemporary monitoring.

Several additional coal mining projects are located within the catchment of the Goulburn River – as summarised in Table 17.

Table 17 Coal Mining Projects Located in the Goulburn River Catchment

Project Name	Catchment Area at Maximum Project Extent (km^2)	Source of Data
Ulan Coal Mine	15.2	UCML (2016)*
Moolarben Coal Project	39.7	WRM (2013)
Wilpinjong Coal Mine	38.1	WRM (2015a)
Bylong Coal Project**	10.5	WRM (2015b)

* Ulan Coal Mines Limited have submitted a Modification 4 Environmental Assessment which is currently undergoing assessment. This modification relates to underground mine plans and does not affect surface catchments.

** Not yet determined

The total of the catchment areas listed in Table 17 is 103.5 km^2. This combined with the maximum reduction of Wybong Creek catchment area as a result of the MCCO Additional Project Area (8.0 km^2 – refer Table 16) would see a cumulative maximum 1.6% reduction in the catchment area of the Goulburn River just downstream of the confluence with Wybong Creek, however the MCCO Additional Project Area represents only 0.12% of the total reduction in Goulburn River catchment. This assessment of cumulative impact is very conservative because it is highly unlikely that all five projects would reach their maximum extents at the same time. The reduction in Goulburn River catchment area would decrease with time as progressive rehabilitation results in reductions to impacted catchment areas for each of these projects. The reduction in catchment area as a result of the MCCO Project would halve in the long term (refer Table 16).

In terms of flooding impacts (Sections 3.2.3), these are localised to Big Flat Creek which contains no other projects. Therefore there would be no cumulative flooding impacts beyond those forecast for the MCCO Project.

The assessment in Section 3.2.4.3 of the potential water quality effects of the MCCO Project applies equally to cumulative impacts. The MCCO Project is therefore considered to have a low potential to contribute to cumulative impacts on water quality in downstream watercourses.

3.2.7 Summary of Potential Impacts

The following provides a summary of the potential surface water impacts of the MCCO Project discussed in the preceding sub-sections.

Flooding and Channel Stability:

- Some increase in areas of inundation upstream of the proposed haul road crossing of Big Flat Creek is predicted, however no increase in inundation extent is predicted over non-Mangoola owned land up to and including a 1:100 AEP.
- Existing Wybong Road is currently affected by flooding. The MCCO Project is not predicted to materially increase existing flood levels and the trafficability of Wybong Road will remain unaffected for flood events up to the 1:100 AEP.
- Overall, the MCCO Project is not predicted to result in significant increases in flow velocity in Big Flat Creek and therefore the risk of increased erosion in most areas is negligible. Small areas of predicted significant increases in flow velocity occur in areas near the proposed haul road crossing, particularly near the outlet of the proposed culverts. Erosion protection will be included in the design. Apart from the culvert outlet, there is no material effect downstream of the proposed haul road crossing.

Catchment Yield and Streamflow

Wybong Creek

- Average total flow volumes in Wybong Creek would be expected to reduce as a result of catchment area intercepted by the MCCO Additional Project Area by up to 1.2% (maximum during MCCO Project life). A 1.2% reduction in the mean annual flow at the DI – Water gauging station on Wybong Creek would amount to an annual average reduction of approximately 317 ML compared to a mean annual flow of 26,455 ML.
- In terms of long term (final void) reduction in catchment area, it is estimated that this would amount to a 1.1% reduction in the catchment yield of Wybong Creek (compared with a reduction of 0.6% for the approved Mangoola Coal Mine final void). An average annual reduction in total flow of 320 ML is estimated in Wybong Creek at its confluence with Big Flat Creek. Such an average annual reduction in flow represents a small and likely indiscernible impact to flow in Wybong Creek. Mitigation would involve the permanent retirement of this volume of WAL from the Wybong Creek Water Source within the Hunter Unregulated and Alluvial Water Sources WSP. Mangoola hold sufficient WALs to achieve this (refer 'Licensing' below).
- For Wybong Creek along its full length to the Goulburn River, the predicted additional baseflow loss as a result of the MCCO Additional Mining Area is approximately 4 to 5 ML/year. Total baseflow reductions of up to 30 ML/year have been forecast as a result of the approved Mangoola Coal Mine with the MCCO Additional Mining Area (AGEC, 2019). This amounts to approximately 0.11% of the mean annual flow in Wybong Creek at its confluence with Big Flat Creek. This is an order of magnitude lower than the estimated reduction calculated for catchment area interception and represents a small and likely indiscernible impact to flow in Wybong Creek.

Big Flat Creek

- Average total flow volumes are expected to reduce in Big Flat Creek as a result of catchment area intercepted by the MCCO Additional Project Area, with median daily flow reducing from 0.05 ML/d to 0.03 ML/d and the prevalence of effectively zero flow increasing by 1.8% (maximum impact during MCCO Project life). The predicted changes are based on a conservative assessment undertaken by adopting the flow characteristics of a nearby gauged stream (Dart Brook) for simulating flow in Big Flat Creek. These predicted changes are small and not considered material given the ephemeral nature of Big Flat Creek and the fact that there are no licenced surface water users on Big Flat Creek other than Mangoola.
- In Big Flat Creek, reduction in groundwater-derived baseflow (AGEC, 2019) resulting from the MCCO Additional Mining Area is predicted to be negligible, with up to a 10 ML/year reduction in baseflow predicted as a result of the approved Mangoola Coal Mine.

Goulburn River

- The maximum reduction in the catchment reporting to the Goulburn River as a result of the MCCO Additional Project Area would amount to 0.12% of its total at its confluence with Wybong Creek. This level of change would be imperceptible and very small compared to natural variability in catchment conditions and is therefore considered to be negligible.

Cumulative Effects

- Several mining projects are located within the catchment of the Goulburn River (refer Table 17). At the maximum extent of each project, including the MCCO Additional Project Area, it is estimated that there would be a reduction of 1.6% in the catchment area (and hence average flow) reporting to the Goulburn River just downstream of the confluence with Wybong Creek (of which the MCCO Additional Project Area amounts to 0.12%). This assessment of cumulative impact is very conservative because it is highly unlikely that all five projects would reach their maximum extents at the same time and would decrease in line with progressive rehabilitation at each of these projects.

- Flooding impacts are localised to Big Flat Creek which contains no other projects and therefore there would be no cumulative flooding impacts beyond those forecast for the MCCO Project.

Water Quality

- Surplus water will be released in accordance with EPL 12894 and the requirements of the HRSTS. The storage from which discharges will occur (the PWD) contains low recorded average concentrations of environmentally significant metals. Therefore licensed discharges of water from the MCCO Project are not considered likely to result in significant impacts to downstream waters.
- Sediment dams have been sized in accordance with design criteria established by the NSW Government specifically for sediment control at mining and quarrying operations. Therefore discharges from sediment dams are not anticipated to adversely impact water quality in downstream watercourses.
- Flood modelling predicts small, localised increases in flood flow velocities and associated scour potential in Big Flat Creek which will be mitigated by the use of erosion protection. Therefore erosion resulting from the MCCO Project is not anticipated to adversely impact water quality in downstream watercourses.

Licensing

- Mangoola hold 861 ML water allocation licence share components in the Wybong Creek Water Source.
- Based on Mangoola's landholdings and the estimated volume of existing farm dams on those landholdings (404 ML), it is estimated that the maximum undisturbed area captured within the MCCO Project area (890.7 ha), exceeds Mangoola's maximum harvestable right area (443.9 ha) which equates to 290.4 ML/year. Mangoola hold enough share components of Wybong Creek unregulated WALs to account for this and may also decommission farm dams on their landholdings to reduce runoff capture which would reduce this number accordingly.
- Notwithstanding this, Mangoola hold sufficient WALs to offset the predicted long term average annual reduction in total flow of 320 ML in Wybong Creek (refer 'Catchment Yield and Streamflow' above).

3.3 OPERATIONAL WATER AND SALINITY BALANCE MODELLING

3.3.1 Aim

A water and salt balance model of the MCCO Project has been developed to simulate the management of water over the MCCO Project life. The overall aim of the model is to enable assessment of MCCO Project water supply/demand and inform planning of water management. Key outcomes include assessing:

- water supply reliability for future demands (CHPP and dust suppression);
- the risk of disruption to mining as a result of excess water in the open cut pits;
- the volume and frequency of licensed discharge via the HRSTS; and
- the risk of spill from mine water storages.

3.3.2 Model Description

The water and salt balance model has been developed to simulate the majority of the storages and linkages shown in schematic form in Figure 15. The model has been developed to represent the total mine operation (approved mining plus the MCCO Additional Project Area) using the GoldSim® simulation package. The model simulates the volume of water and mass of salt held in and pumped between all simulated water storages. For each storage, the model simulates:

Change in Storage = Inflow – Outflow

Where:

Inflow includes rainfall runoff, groundwater inflow (for the open cut pits and tailings storage void), water liberated from settling tailings, water sourced from Hunter River WALs and all pumped inflows from other storages.

Outflow includes evaporation, spill, pumped outflows to other storages or to a demand sink (for example, the CHPP) and controlled release via the HRSTS.

The model operates on a less than daily time step. Model simulations begin in October 2018 (i.e. the current approved operations, prior to the start of the MCCO Project) with then current stored water volumes and continue to the end of 2030 (i.e. 12¼ years). For modelling purposes (and with reference to Figure 16 to Figure 19) Year 1 of the MCCO Project has been assumed to be 2022, Year 3 is 2024 and so on. The model simulates 121 "realizations" derived using historical daily climatic data[20] from 1892 to 2012. The first realization uses climatic data from 1892 to 1904, the second uses data from 1893 to 1905 and the third from 1894 to 1906 and so on. The results from all realizations are used to generate water storage volume estimates, supply reliability and other relevant water balance statistics. This method effectively includes all recorded historical climatic events in the water balance model, including high, low and median rainfall periods.

The model has been linked to output from the Hunter River Integrated Quantity and Quality Model (IQQM). The IQQM is the model used by DI – Water to make available water determinations (AWDs) in the Hunter Valley, in accordance and in conjunction with the WSP. The IQQM was run using climatic data from 1892 to 2012 to generate predictions of general security WAL AWDs, periods of uncontrolled flow and historical river daily flow data for simulating periods available for controlled release via the HRSTS (refer Section 3.3.3).

3.3.3 Model Data

A summary of key model assumptions and supplied data are provided in the sub-sections that follow.

3.3.3.1 Rainfall Runoff Modelling

Rainfall runoff in the model is simulated using the AWBM (Boughton, 2004). The AWBM is a nationally-recognised catchment-scale water balance model that estimates catchment yield (flow) from rainfall and evaporation.

AWBM simulation of flow from eight different sub-catchment types was undertaken, namely: undisturbed (natural) grassed areas, undisturbed timbered areas, hardstand (for example, roads and infrastructure areas), open cut pit, overburden, rehabilitated overburden, stockpile areas and tailings. Each storage's catchment area was divided into these sub-catchment areas which were estimated from aerial photography, recent mine contour plans and future stage plans (refer Section 3.2.1). For the undisturbed sub-catchment type, model parameters were derived from regionally calibrated values. For other sub-catchment types, model parameters were initially taken from literature-based

[20] Data sourced from the SILO Data Drill for the mine location (refer Section 2.1).

guideline values or experience with similar projects and were then adjusted on the basis of calibration (refer Section 3.3.4).

3.3.3.2 Catchment Areas

Surface catchment areas were used to calculate the surface runoff reporting to modelled storages. These were calculated from an early 2017 mine contour plan and aerial photograph as well as from the mine stage plans (refer Section 3.2.1) for the MCCO Project. Figure 30 summarises the total catchment areas reporting to the water management system over time (note that these areas exclude those areas of mature rehabilitated overburden from which runoff has been planned to be directed off site – 'rehabilitation offsite' areas in Figure 16 to Figure 19).

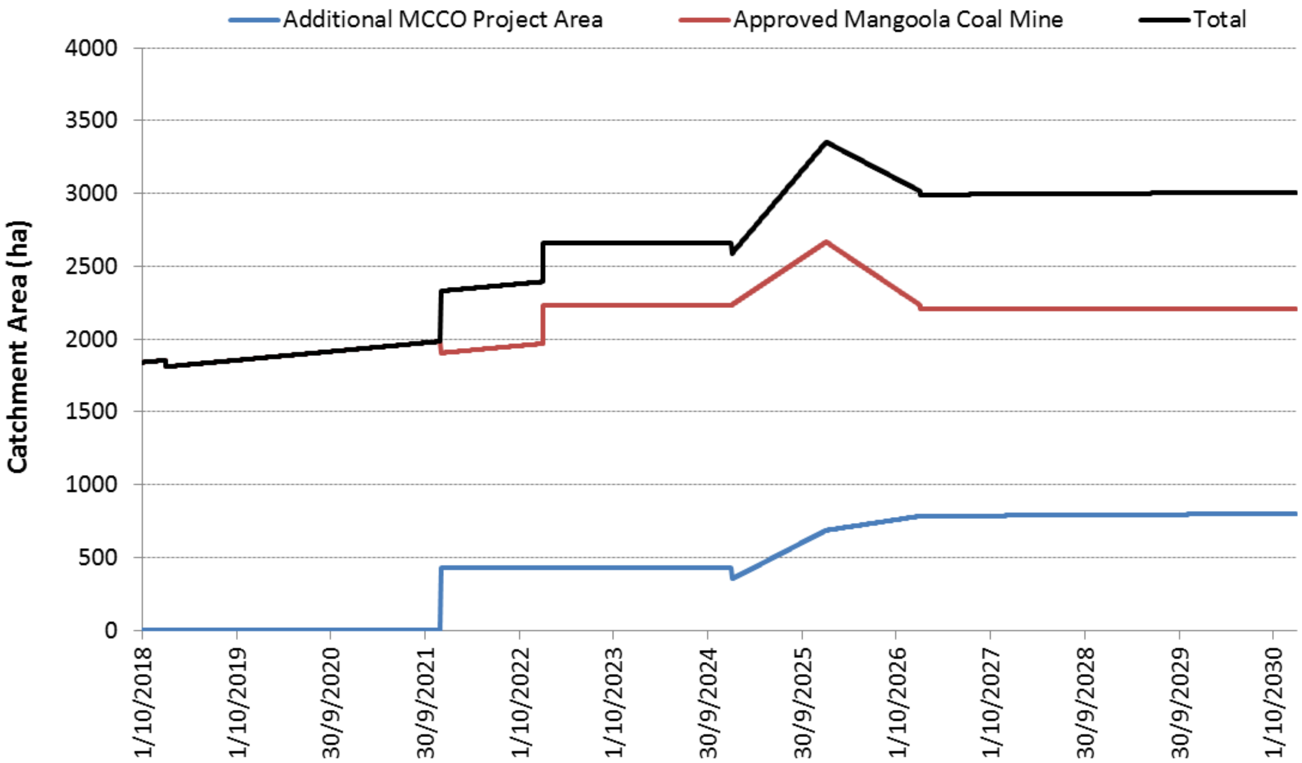

Figure 30 Water Management System Catchment Area Over Time

Figure 30 indicates that the catchment area contribution of the MCCO Additional Project Area is a maximum of approximately 800 ha or approximately one third of that of the approved Mangoola Coal Mine.

3.3.3.3 Evaporation from Storage Surfaces

Storage volumes simulated by the model are used to calculate storage surface area (i.e. water area) based on storage level-volume-area relationships for each water storage either provided by Mangoola personnel or developed as part of storage conceptual design for MCCO Project storages (refer Table 14). For the tailings storages, level-volume-area relationships were developed using projected future tailings surfaces (per supplied stage plans – refer Section 3.2.1).

Daily pan evaporation was multiplied by a pan factor in the calculation of storage evaporation losses for water storage dams. Monthly pan factors were taken from McMahon et al. (2013) data for Scone (located 30 km north-east of Mangoola) and are listed in Table 18.

Table 18 Adopted Monthly Pan Evaporation Factors

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pan Factor:	0.86	0.85	0.84	0.87	0.88	0.89	0.91	0.93	0.95	0.94	0.89	0.85

A pan factor of 1.1 was used in the estimation of evaporation from wet tailings surfaces (due to the darker tailings surface). A pan factor of 0.8 was used for calculation of evaporation from water stored in-pit (due to shading effects and lower wind speed at depth).

3.3.3.4 Tailings Disposal

Modelling assumed tailings discharge to TD4 for the duration of the simulation, with supernatant water seepage to the TD4 Decant and reclaimed to the PWD.

Tailings are subject to secondary flocculation at the discharge point (pipe head floc) and it has been assumed that this will continue for the duration of the MCCO Project. A tailings settled density of 0.725 tonnes/cubic metre (as advised by Mangoola) was used to calculate the rate of generation of tailings supernatant water. This water is subject to evaporative loss, with the balance combining with rainfall runoff and seeping through to the TD4 Decant adjacent.

3.3.3.5 CHPP Demand

Relevant coal and tailings properties which affect CHPP water demand and tailings water calculations in the model are summarised below (data either obtained directly from Mangoola or calculated from data supplied):

- ROM (CHPP feed) moisture: 8.6%.
- Product coal moisture: 11.3%.
- Coarse rejects moisture: 15%.
- Tailings solids concentration: 28%.

It has been assumed that all ROM coal would be processed in the CHPP (i.e. no bypass). Figure 31 shows simulated annual dry tonnages[21] for CHPP ROM feed, product, tailings and coarse rejects. These, together with the above moistures, were used to calculate time-varying CHPP demand (Figure 32).

[21] ROM and product data provided by Mangoola; coarse rejects assumed to equal 10% of ROM (as advised by Umwelt); tailings calculated as remainder.

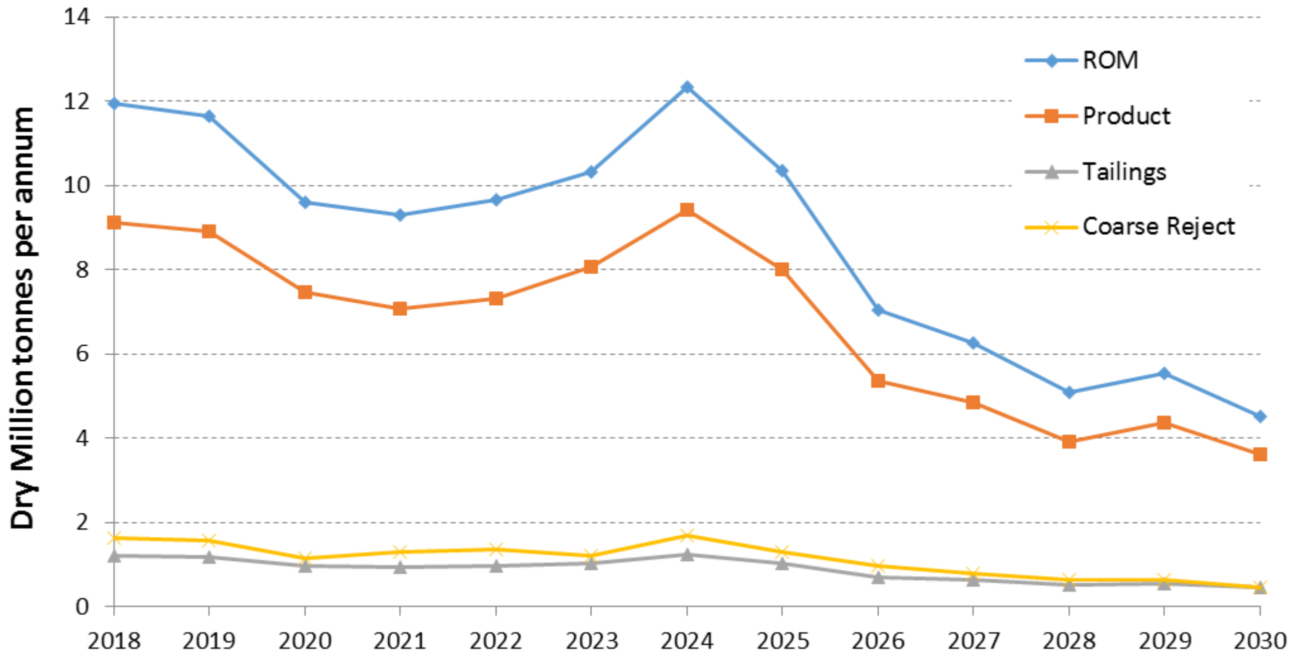

Figure 31 Annual CHPP Tonnages

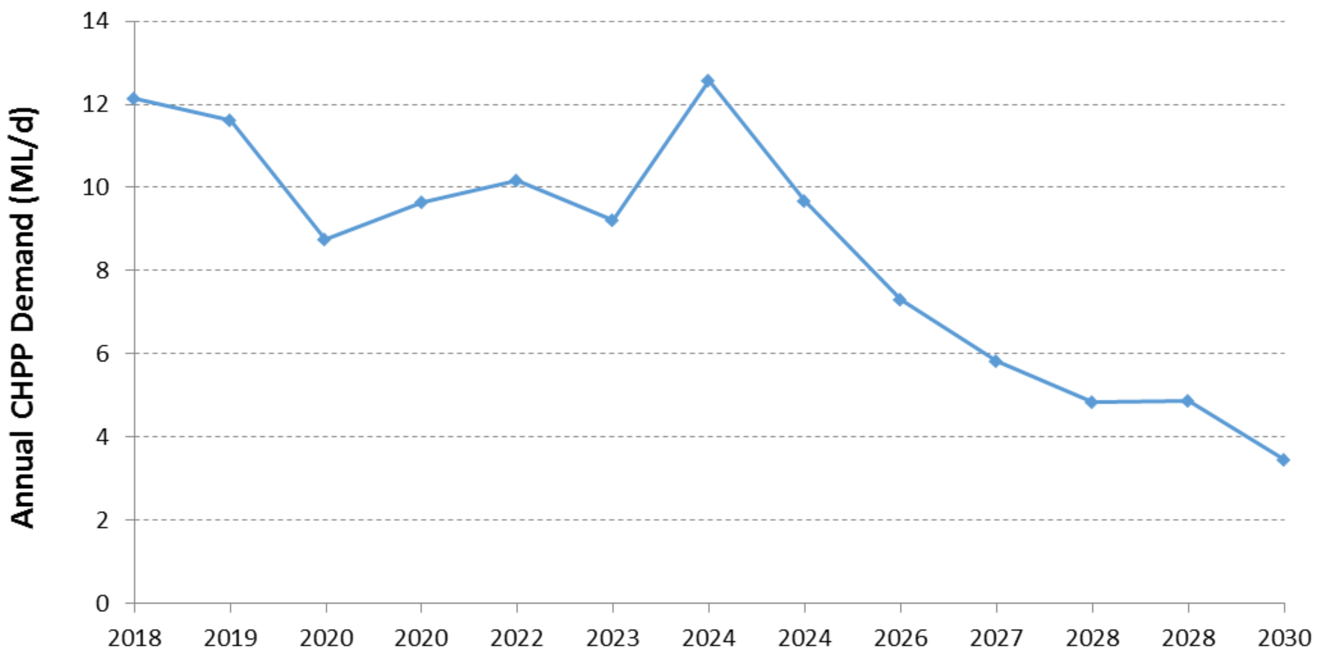

Figure 32 Calculated CHPP Water Demand

3.3.3.6 Haul Road Dust Suppression Demand

On-going dust suppresion demand was calculated based on active haul road lengths calculated from the 2017 mine plan and future stage plans (Section 3.2.1) multiplied by an assumed 30 m watering width. Haul road areas are given in Table 19, with areas interpolated between the given years.

Table 19 Haul Road Areas

Year:	2017	2022 (Year 1)	2024 (Year 3)	2026 (Year 5)	2029 (Year 8)
Area (ha):	81.4	86.0	103.0	105.6	68.1

These areas were multiplied by the daily pan evaporation excess over rainfall (on days where rainfall exeeded evaporation, zero demand was assumed). Calculated haul road dust suppression demand varied from approximately 1.5 ML/d in winter months early in the simulation period to 10.5 ML/d on extremely hot summer days around 2026. For modelling purposes demand was assumed drawn only from the PWD.

3.3.3.7 Groundwater Inflow

Prediction of groundwater inflow rates to the MCCO Additional Mining Area and concurrent inflow to the existing approved Mangoola open cut pits (refer Section 3.1) has been undertaken by AGEC (2019). Separate predictions have been provided for individual pits. Figure 33 summarises the predicted groundwater inflow rates that have been used as input to the water balance model. Figure 33 shows that the predicted groundwater inflow rates for the MCCO Additional Mining Area are greater than those for the remaining open cut pits from 2022 (Year 1) onwards.

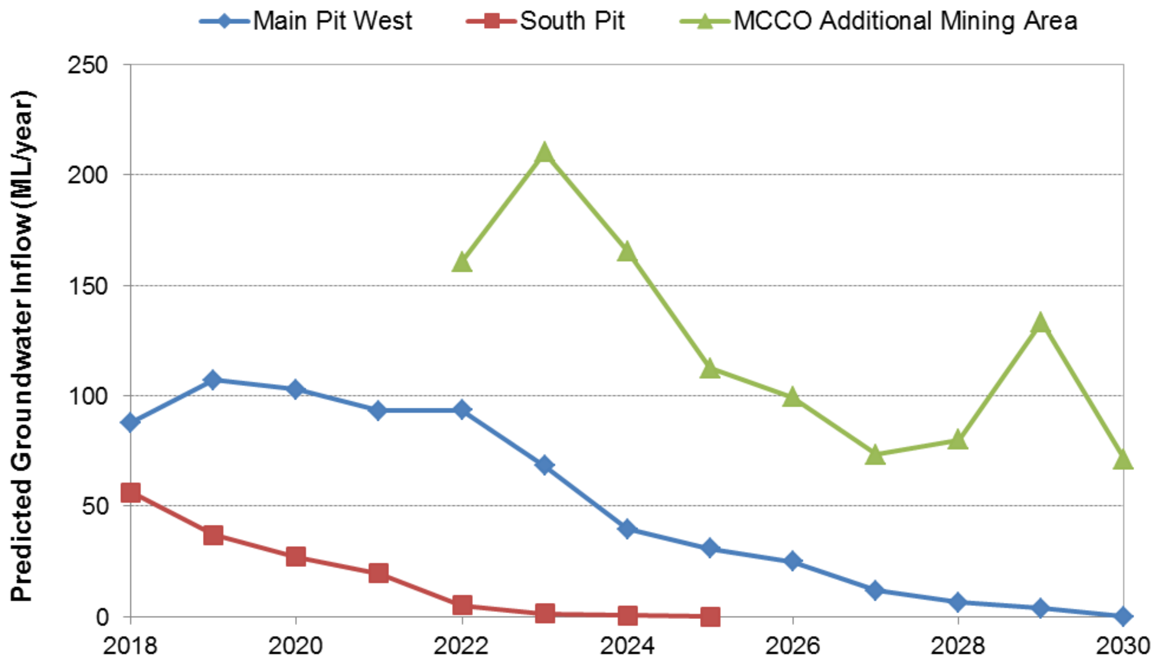

Figure 33 Predicted Open Cut Groundwater Inflow Rates

3.3.3.8 Hunter River Supply

The water balance model has the ability to include water sourced from the Hunter River WALs. The DI - Water Hunter River IQQM was run using the same period of climate data as used in the water balance model (refer Section 3.3) and the IQQM output used as input to the water balance model. Key output sourced from the IQQM and used as input to the water balance model comprised:

- Daily simulated AWDs for general security WAL holders.
- Daily Hunter River flows at Singleton, Greta and Liddell gauging stations - used to determine periods of uncontrolled flows, when extractions are not limited by AWDs, in accordance with the WSP.
- Daily simulated volume stored in Glenbawn and Glennies Creek Dams, which were used to estimate AWD for high security, WAL holders at times of zero general security AWD.

As noted in Section 2.4, Mangoola currently hold 2,758 ML share components of Hunter River regulated general security WAL and 17 ML share components of Hunter River regulated high security WAL. Extraction occurs direct from a Hunter River pump station via a large bore pipeline to the RWD. Operating levels have been set in the RWD to govern when extraction occurs (refer Section 3.3.3.13).

3.3.3.9 Hunter River Controlled Release

Controlled release under the HRSTS is consented under PA 06_0014 (EPL 12894 was updated in August 2016) and Mangoola currently hold 35 credits. Simulation of licensed release via the HRSTS was included in the model from the end of 2019 onwards (based on the expected timing of construction of the approved discharge facility).

Simulating periods available for licensed release involved firstly developing a relationship between river flow rate and river registers for declared “high” flow events. This was carried out using historical river registers sourced from NOW (2015), correlated against recorded Hunter River daily flows. This correlation was extended to “flood” flow events in the Hunter River (during which no daily discharge restriction applies). Hunter River flow rates at Denman were simulated by the IQQM for the same period of historical climate data as used in the water balance model (refer Section 3.3.3) and these flows used with the above correlation relationship to simulate river registers.

Simulation of controlled release was assumed to occur from the PWD. The TDS of water stored in the PWD was calculated based on simulated salinity (refer 3.3.2).

3.3.3.10 Salinity Values

Modelled source salinity (EC) data for different modelled inflow components is summarised in Table 20. An EC to TDS conversion factor of 0.64 mg/L was assumed.

Table 20 Modelled Inflow Salinity

Component		EC (µS/cm)	Basis
Hunter River		550	Long term average recorded at DI – Water Denman gauging station[22]
Groundwater		10,000	Mangoola coal monitoring bore data (near open cut pit)
Tailings Supernatant		7,150	Experience with similar Hunter Valley coal operation
Sub-catchment Runoff	Undisturbed	550	Same as Hunter River average
	Hardstand	5,100	Calibration (refer Section 3.3.4.2)
	Open Cut Pit	6,000	Calibration (refer Section 3.3.4.2)
	Overburden (surface runoff)	2,500	Calibration (refer Section 3.3.4.2)
	Overburden (baseflow/seepage)	3,900	Calibration (refer Section 3.3.4.2)
	Rehabilitated Overburden	550	Same as Hunter River average
	Stockpiles	6,000	Calibration (refer Section 3.3.4.2)
	Tailings Runoff	6,000	Calibration (refer Section 3.3.4.2)

3.3.3.11 Storage Capacities and Initial Storage Volumes

Capacites of existing storages were derived from level-volume-area relationships or contour data provided by Mangoola, while required capacities for proposed MCCO Project storages (sediment dams) were calculated (refer Table 14). Modelled storage capacities are summarised in Table 21 together with stored water volumes as at the 1st October 2018 (commencement of model simulations).

[22] GS 210055: refer https://realtimedata.waternsw.com.au/

Table 21 Modelled Existing Storage Capacities and Initial Stored Water Volumes

Storage	Capacity (ML)	Initial Stored Water Volume (ML)
Anvil Creek Sediment Dam	36.3	1
CHPP Sediment Dam	1.5	1
CHPP Area Sediment Dam	*	2
Product Stockpile Dam	6.9	5.2
MIA Dam	2.0	0.3
MPW Dam/MSSD1	49.5	0
NOOP1	46.4	0
NAR South Sediment Dam	19.6	0
Rail Loop Dam	28.3	5.6
SOOP1	7.4	0.5
SOOP2	7.1	1.8
TD4 Decant	4,177	23
TD4	12,112†	0
Pit Water Dam	1,505	697
Raw Water Dam	2,567	772

* Unlimited modelled capacity due to spillway infill by haul road

† Diminishing with time

3.3.3.12 Pumping Rates

Table 22 lists modelled pumped transfer rates from the existing storages to the PWD (pump rates for MCCO storages are given in Table 14). The pump rate for the MCCO Additional Mining Area open cut pit was assumed to be 200 L/s. Contingency pumping from the PWD to the RWD (refer Section 3.3.3.13) has been allowed for at a rate of 250 L/s. Pumping from the PWD for controlled release via the HRSTS has been simulated at a rate of 1,157 L/s or 100 ML/d (GHD, 2018). A Hunter River pumped extraction rate of 580 L/s has been simulated

Table 22 System Pump Rates – to Pit Water Dam

Source Storage	Pump Rate (L/s)
Anvil Creek Sediment Dam	70
CHPP Area Sediment Dam	240
NOOP1	80
NAR South Sediment Dam	38*
Rail Loop Dam	170
SOOP1	70†
SOOP2	150
TD4 Decant	140
Main Pit & Main Pit West	90
South Pit	100
RWD	125

* From start of 2019 (zero prior) † Pumping to SOOP2

3.3.3.13 Storage Operating (Trigger) Volumes

Operating levels/volumes were set in the model which affect when pumping to and from the PWD and RWD is triggered. Table 23 provides a summary of the assumed operating volumes and the operating conditions that they affect.

Table 23 Operating Trigger Volumes

Storage	Operating Volume	Operating Conditions
PWD	Very Low = 350 ML	If below this, commence sourcing water from RWD
	Normal = 500 ML	If above this, allow controlled discharge via HRSTS and attempt to transfer to RWD (RWD level permitting)
	High = 1,069 ML	If above this, no pumping in allowed (minimum freeboard)
RWD	Low = 500 ML	If below this, commence sourcing water from Hunter River WALs (allocations permitting)
	Normal = 850 ML	Once above this, stop sourcing water from Hunter River WALs until volume falls below “Low”
	High = 2,080 ML	If above this, no pumping in allowed (minimum freeboard)

The above volumes were set based on the Mangoola Operational Water Management Plan (Mangoola Open Cut, 2014).

3.3.4 Model Calibration

3.3.4.1 Volumetric

Water balance model calibration was undertaken by comparing model estimates of total water volume stored in all monitored water storages against water volumes estimated from monthly monitoring records for the period 1 July 2011 to 1 March 2015. The following data was used in model calibration:

- Recorded daily rainfall data from the Mangoola rainfall stations.
- Daily pan evaporation data sourced from the SILO Data Drill for the period of calibration.
- Open cut pit and site water storage catchment and sub-catchment areas estimated from historical contour plans and aerial photography.
- Recorded water storage levels provided by Mangoola, which were used along with storage volume-area-level relationships for each water storage to estimate water storage volumes over the calibration.
- Recorded monthly CHPP and haul road water usage volumes.
- Recorded monthly volumes of water sourced from Hunter River WALs.
- Recorded monthly volumes of water pumped from the Main Pit to the PWD (from May 2014).
- Monthly records of CHPP feed, product, coarse rejects and tailings tonnages, which were used, together with CHPP usage volumes, to calculate monthly tailings water volumes. Tailings settled densities given in ATC Williams (2011) were then used to calculate tailings bleed water from the tailings water volumes. Tailings storage TD2 was assumed to commence receiving tailings from the beginning of 2013 – prior to this, tailings were assumed to discharge solely to TD1. From the start of 2013, 90% of tailings produced were modelled as discharged to TD2, with the balance discharged to TD1.

- Open cut pit groundwater inflow estimates (for each open cut pit) as reported in MER (2006). These were then adjusted as part of the calibration process.
- Monthly records of potable water used in the MIA – assumed all returned to the MIA Dam as treated wastewater.

As part of calibration, AWBM (rainfall-runoff) parameters (refer Section 3.3.3.2) for sub-catchments, were adjusted iteratively to improve the match between modelled and estimated actual total stored water volume.

Figure 34 shows a comparison between estimated actual total stored water volumes in the monitored water storages and those generated by the calibrated model, as well as the difference between the two and daily rainfall. It should be noted that the 'recorded' volumes plotted continuously in Figure 34 are based on a series of level records taken at discrete points in time (not daily) with intermediate levels interpolated between these points and volumes estimated from storage level-volume relationships. Volumes predominantly comprise the volumes stored in the PWD and RWD.

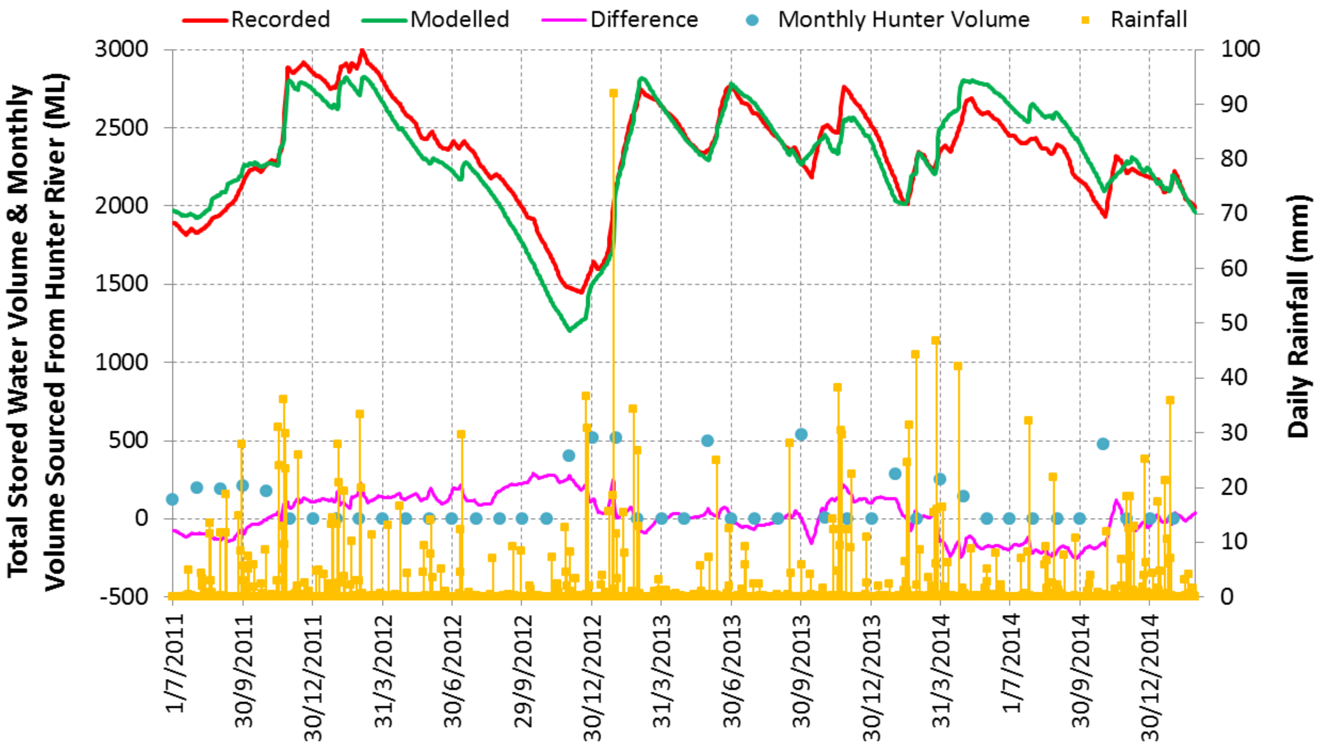

Figure 34 Model Volumetric Calibration

Figure 34 indicates a close match of modelled to recorded water volumes, particularly during the period since 2013. The linear correlation coefficient for the modelled to recorded total stored water volumes is 0.87. The good calibration results, achieved over a multi-year period with high and low rainfall periods, provide a water balance model that is well suited to assessing operational performance and MCCO Project impacts.

The sub-catchment AWBM parameters derived from the calibration are provided in Table 24.

Table 24 Calibrated AWBM Parameters

Parameter	Sub-catchment Type							
	Natural (Grass)	Natural (Timbered)	Hardstand	Open Cut Pit	Over-burden	Rehabilitated Overburden	Stockpiles	Tailings
C_1 (mm)	8	25	5	5	5	8	5	0
C_2 (mm)	80	170	-	25	85	70	50	-
C_3 (mm)	165	339	-	-	-	-	-	-
A_1	0.23	0.1	1	0.2	0.05	0.1	0.1	1
A_2	0.4	0.4	0	0.8	0.95	0.3	0.9	0
A_3	0.37	0.5	0	0	0	0.6	0	0
K_s (d^{-1})	0.2	0.2	0	0.1	0.5	0.3	0	0
BFI	0.22	0.22	0	0.1	0.8	0.22	0.5	0
K_b (d^{-1})	0.861	0.861	-	0.96	0.985	0.861	0.98	-

As is usually the case, the model calibration and the robustness of model predictions are dependent on the available data and assumptions made regarding input parameters and any data gaps. A process has been followed to assess the veracity of data, with reasonable assumptions used where necessary. The resulting sound calibration results, achieved over a multi-year period with high and low rainfall periods, provides a water balance model that is well suited to assessing operational performance and MCCO Project impacts.

3.3.4.2 Salinity

A similar process was followed to calibrate modelled salinity values for inflows (refer Table 20). Given that the majority of the stored water inventory is normally held in the PWD and RWD and that monitored salinity data is available for these storages on at least a monthly basis, calibration was focussed on these two storages. Monitored EC data for these storages for the 2011 to 2015 calibration period was obtained from the Mangoola Environmental Monitoring Database. Modelled EC values were adjusted as part of calibration (within the bounds of reasonable values) to improve the match between modelled and recorded EC in the two storages.

Figure 35 shows a comparison between modelled and recorded EC in the PWD, while Figure 36 shows a similar plot for the RWD. A cumulative rainfall plot is also included to highlight the periods of wet weather (runoff). These figures indicate a reasonable match of modelled and recorded EC values, sufficient for the purpose of MCCO Project surface water assessment.

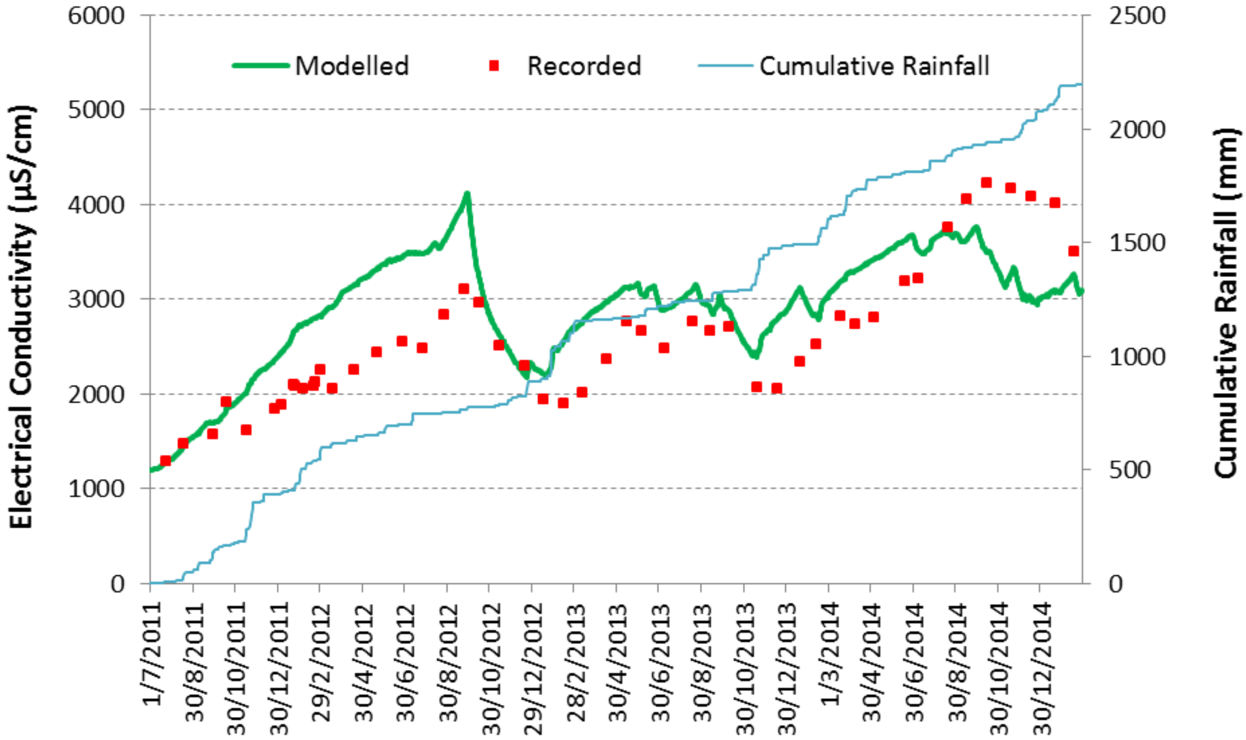

Figure 35 Model Salinity Calibration - PWD

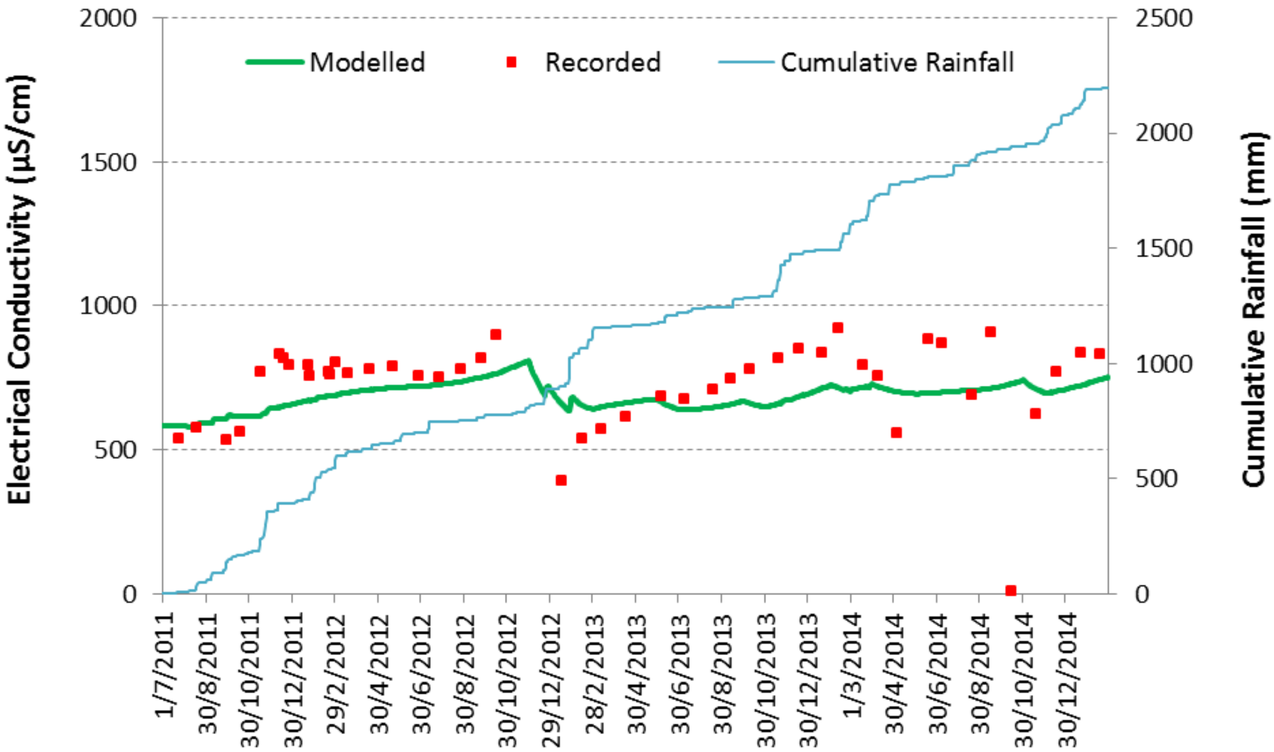

Figure 36 Model Salinity Calibration - RWD

3.3.5 *Forecast Results for MCCO Project Life*

3.3.5.1 Overall Site Water Balance

Model predicted average inflows and outflows (averaged over the 12¼ year simulation period and all realizations) are shown in Figure 37. Model results indicate that, on average, rainfall runoff provides the highest system inflow and 40% of the total inflow. It is predicted that the MCCO Project would rely on Hunter River WALs to supply approximately one quarter of inflows. The majority of outflows (59%) comprise CHPP supply, with more than half the 3,012 ML/year average supply available as tailings supernatant (1,696 ML/year average).

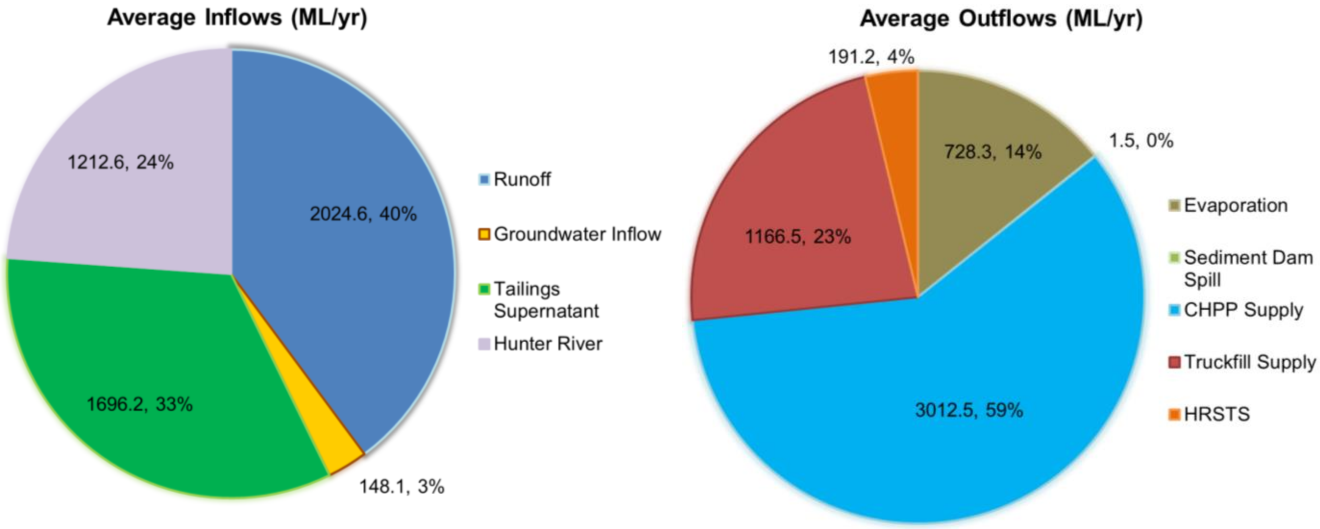

Figure 37 Average Predicted System Water Balance

3.3.5.2 Stored Water Volumes

Predicted total stored water volumes (in all storages – including open cut pits) are shown in Figure 38 as probability plots over the simulation period. These probability plots show the range of likely total stored water volumes, with the solid plot representing the median or "50th percentile" volumes and the broken lines the 5th/95th percentile volumes which represent long term drier and wetter weather conditions respectively. There is a 90% chance that the total water volume will fall in between the 5th/95th percentile volume plots. It is important to note that none of these plots represents a single climatic realization – these probability plots are compiled from all 121 realizations (refer Section 3.3.3) – e.g. the median volume plot does not represent model forecast volume for median climatic conditions. Also shown is the combined capacity of the PWD and RWD – the forecast 95th percentile inventory rarely exceeds this volume and then only near the end of the simulation period when CHPP demand is relatively low (refer Figure 32) . The median forecast volume is close to the combined 'normal' operating volume of the PWD and RWD of 1,350 ML (refer Table 23). In the near-term there is low risk implied that the total stored water volume will fall towards zero in any of the cases simulated. There is inherent uncertainty in these levels being maintained in the longer term and hence lower stored water volumes are predicted in dry periods (represented by the 5th percentile plots) from about 2024 (Year 3) onwards (note that 2024 coincides with a peak in CHPP water demand – refer Figure 32).

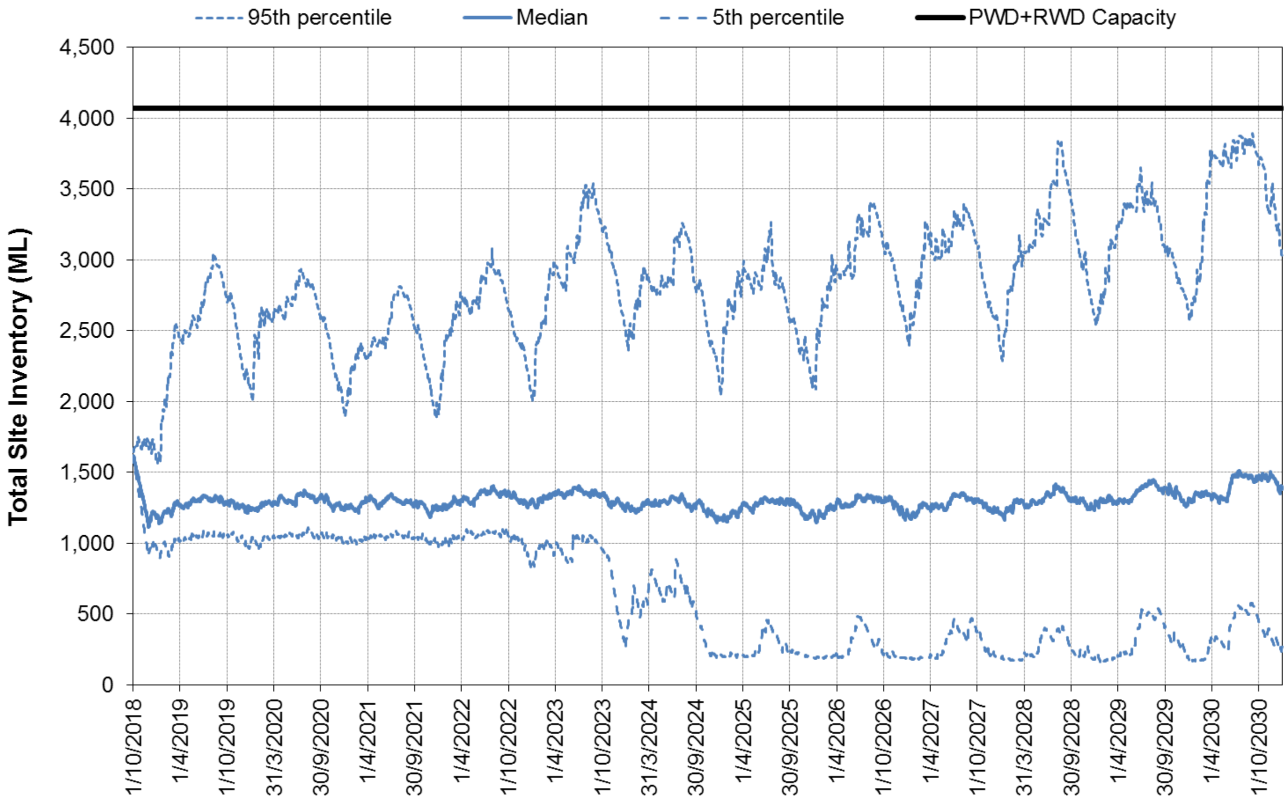

Figure 38 Simulated Total Water Inventory

3.3.5.3 Water Supply Reliability

Predicted average supply reliability is expressed as total water supplied divided by total demand (i.e. a volumetric reliability) over the simulation period. Average supply reliability over all climatic realizations, as well as the lowest single realization reliability (representing a simulated 'worst case' 12¼ year period), for CHPP supply and haul road dust suppression are summarised in Table 25.

Table 25 Summary of Modelled Water Supply Reliability

	CHPP Supply	Haul Road Dust Suppression
Average	98.7%	97.2%
Lowest	88.4%	79.2%

The results in Table 25 indicate a predicted high level of average supply reliability, particularly for CHPP supply.

Model simulations indicate that there is a low risk of shortfall in the near term. Figure 39 shows a plot of forecast annual shortfall volumes at the 95th percentile level (i.e. forecast 5% chance of being exceeded). This indicates a peak shortfall volume of approximately 655 ML in FY 2025 at this risk level. Note that at the 75th percentile risk level (i.e. forecast 25% chance of being exceeded) all forecast annual shortfalls are zero.

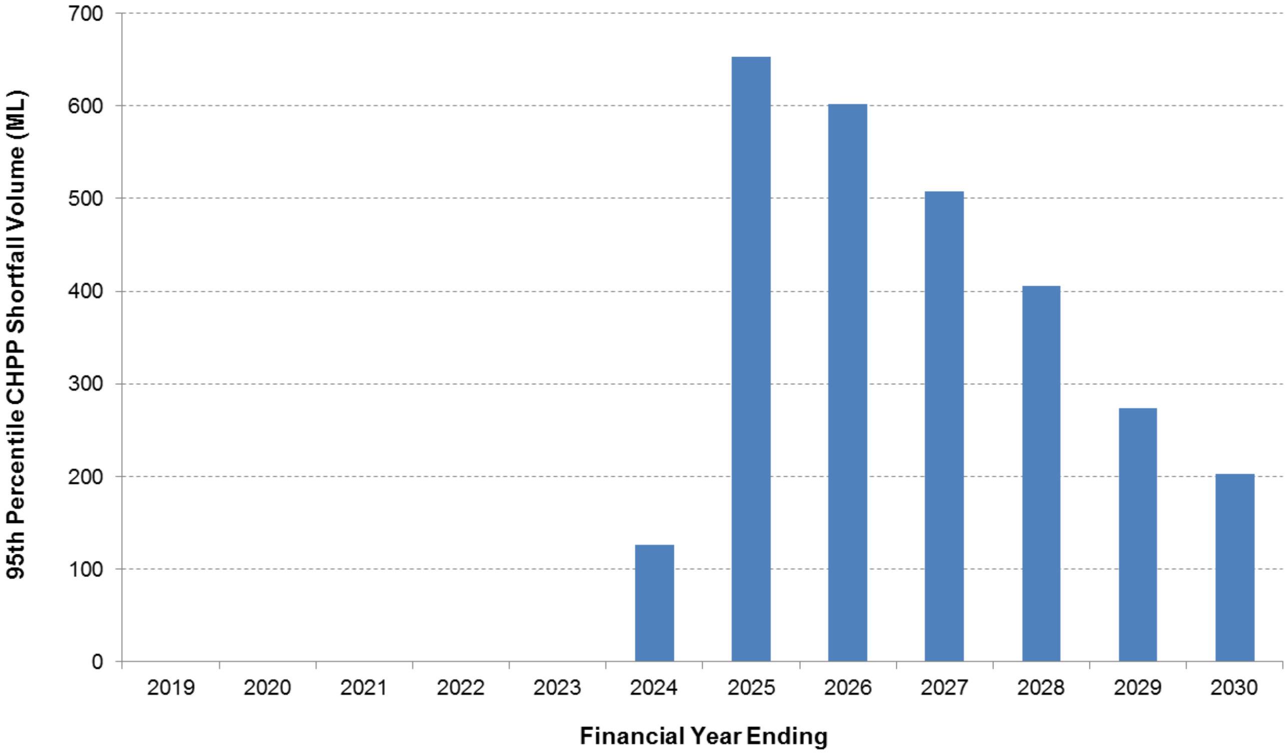

Figure 39 Simulated 95th Percentile CHPP Shortfall Volumes

In practice, where a shortfall in required water occurred, Mangoola would source additional water via purchase of additional WALs (if available) or, if appropriate at the time, investigate one or more of the following actions:

- reduce haul road dust suppression demand by the use of dust suppression agents;
- reduce CHPP water demand by increasing bypass coal (which has a significantly lower water demand compared to washed coal);
- reduce site water demand by scaling back production; and/or
- investigate alternative water supplies.

Annual forecast water balance modelling will inform near term water supply reliability for the MCCO Project as it progresses. Such forecasts will allow Mangoola to plan for contingency measures such as acquisition of additional WALs or implementation or water reduction measures.

3.3.5.4 Potential Mining Disruption

The risk of mining disruption has been assessed by comparing the number of days per year that more than 200 ML is held in a given open cut pit (an arbitrary volume chosen to represent conditions which *could* lead to mining disruption). This has been calculated for the two approved Mangoola open cut pits and for the MCCO Additional Mining Area open cut pit. Model predictions are summarised in Table 26 below. In Table 26 the 95th percentile values are the number of days per year which would be expected to be exceeded in 5% of years, while the 75th percentile values are those which would be expected to be exceeded in 25% of years.

Table 26 Predicted Annual Number of Days in Excess of 200 ML Stored in Pit

Open Cut Pit	Average over all realizations	75th percentile	95th percentile
Main Pit & Main Pit West	11	13	33
South Pit (up to 1/1/2023)	0	0	2
MCCO Pit (from 31/12/2022)	4	4	19

Note that the South Pit would only be in operation for the first few years of the simulation period until mining is completed in this area and it connects to the Main Pit West.

Figure 40 shows a plot of predicted stored water volume in the open cut pits at the 95th percentile risk level (i.e. forecast 5% risk of exceedance). At this risk level no more than 387 ML is predicted to be stored in any open cut and then only for relatively short periods of time. These results indicate that at this low risk level, mining operations would not be significantly impacted by rainfall.

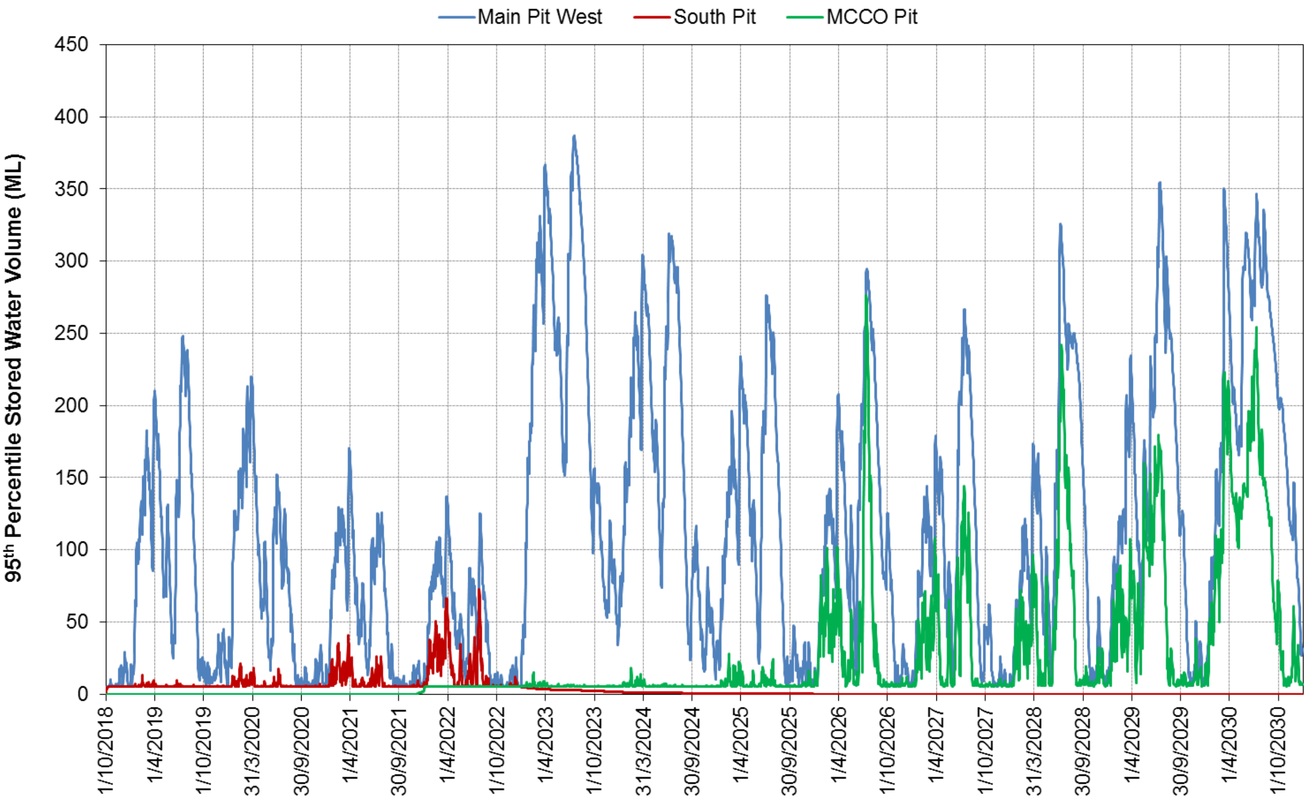

Figure 40 Simulated 95th Percentile Open Cut Water Volumes

3.3.5.5 Hunter River Licensed Extraction

Supply drawn from Hunter River licensed extraction would vary through the MCCO Project life. Figure 41 shows predicted annual water year (July to June) extraction at different probabilities. The 95th percentile values are those that would be expected to have a 5% chance of being exceeded. Median annual licensed extraction is predicted to peak in 2020 (ahead of the start of the MCCO Project in 2022). Model results indicate that, during periods of low rainfall (indicated by the 95th percentile result) Mangoola would make close to full use of its WALs up until about mid-way through the MCCO Project life. An increase in WAL volume would improve predicted supply reliability (refer Section 3.3.5.3) because it is during such low runoff periods that shortfalls tend to occur. However, under most circumstances, the existing Mangoola WALs would be under-utilised.

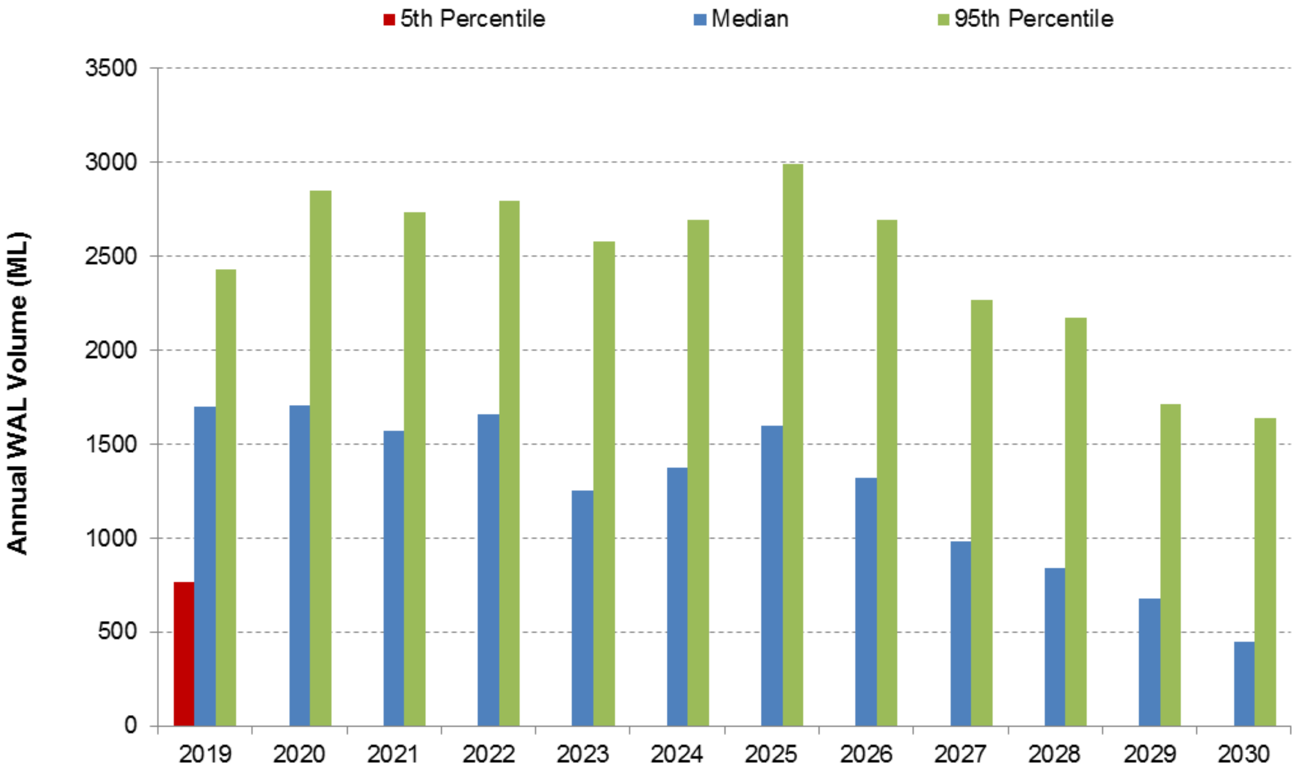

Figure 41 Predicted Annual (Water Year) Hunter River (WAL) Extraction

3.3.5.6 Controlled Release

Figure 42 shows model predicted annual (water year) controlled releases from the PWD, undertaken in accordance with the HRSTS, at different probabilities. Predicted median annual releases are low (up to 102 ML), while predicted 95th percentile annual releases are up to approximately 1,469 ML during higher rainfall years.

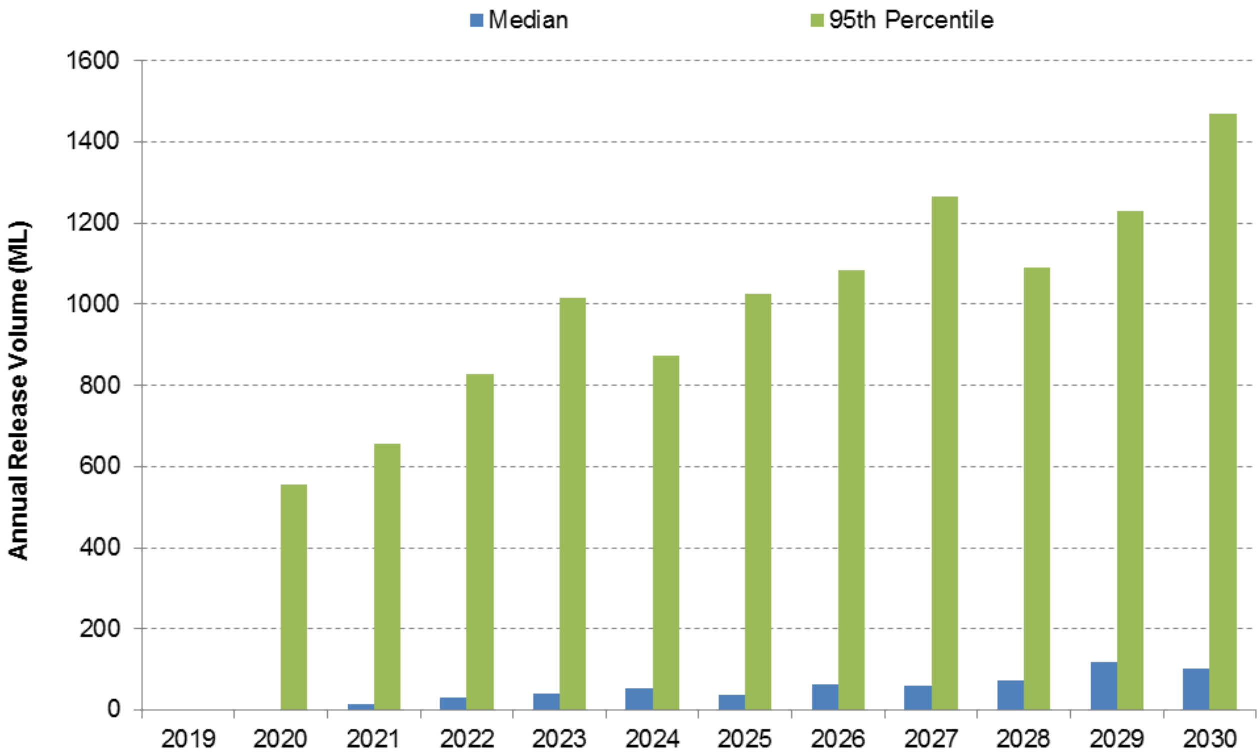

Figure 42 Predicted Annual (Water Year) HRSTS Discharge

Figure 43 shows predicted EC in the PWD at different risk levels. Seasonal oscillations are evident in the forecasts, related to higher rates of runoff from mine landforms in winter months. Lower EC values are predicted at the 5th percentile level (typically approximately 1000 µS/cm lower) – these values would be more typical of higher rainfall conditions that would lead to the need for controlled discharge.

Figure 43 Predicted PWD Electrical Conductivity

The average salt discharge is predicted to total 6,216 tonnes. This spans the period 2020 (assumed commencement of controlled release) to 2030 (11 years) and therefore equates to an annual average 565 tonnes/year for this period. The long term monitored average salt load for the Hunter River at Denman[23] is calculated to be 196 tonnes/day or 71,589 tonnes/year. Therefore the predicted average total salt discharge equates to 0.8% of the monitored historical average salt load for the Hunter River at Denman. The HRSTS discharge location is on the Hunter River upstream of Denman, as shown in Figure 3.

All controlled releases from the PWD would be undertaken in accordance with the HRSTS and the conditions of EPL 12894. The HRSTS allows for controlled releases only during periods of high or flood flow in the Hunter River in order to provide for dilution. WaterNSW control when discharges can occur, with the scheme designed to limit the volume released depending on the salinity of the release water, in order that the mixture of river flow and controlled releases result in downstream water which meets the accepted water quality standards to support downstream water users, primarily irrigators[24].

[23] GS 210055: refer https://realtimedata.waternsw.com.au/

[24] Refer: https://www.epa.nsw.gov.au/licensing-and-regulation/licensing/environment-protection-licences/emissions-trading/hunter-river-salinity-trading-scheme/how-the-scheme-works

3.3.5.7 Discharges from Dams

Predicted discharges volumes from dams (other than HRSTS discharge) are shown in Figure 44 at different probabilities. These are expressed in total megalitres over the 12¼ year simulation period. These are only predicted from sediment dams, which are intended to spill periodically in accordance with Landcom (2004) during rainfall events that exceed sediment dam design capacity. The majority of sub-catchment area reporting to sediment dams comprises active overburden or rehabilitated areas – the results of standard geochemical tests on overburden/interburden samples by EGi (2019) indicates that runoff from these areas should be of low salinity. The magnitude of the predicted external discharge volumes is related to the catchment area reporting to each storage and the period for which the given storage will be in service. No spills are predicted from any other dams in any realization.

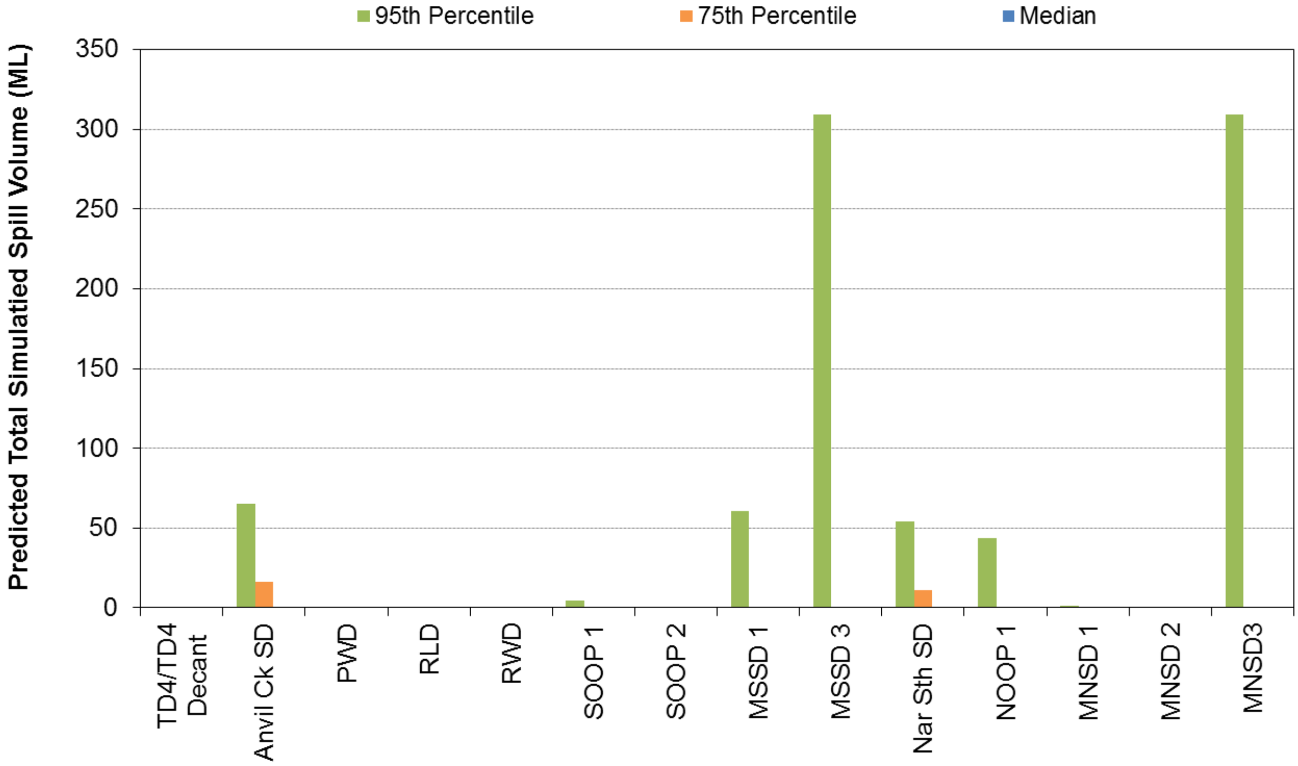

Figure 44 Predicted Spill Volumes

3.3.5.8 Summary Outcomes

Operational water balance forecasts for the MCCO Project may be summarised as follows:

1. Site rainfall runoff provides the greatest average modelled system inflow, while the largest average outflow comprises supply to the CHPP.
2. Total median site water inventory is predicted to remain close to the combined 'normal' operating volumes of the two main water storages. In the near-term there is low risk that the total water inventory will fall towards zero in any of the cases simulated. In the longer term there is a 5% risk that the water inventory could fall to low levels from about 2024 (Year 3). There is a less than a 5% risk that the predicted water inventory would exceed the combined capacity of the two main water storages.
3. Average predicted supply reliability is high, particularly for the CHPP, with 98.7% of demand able to be supplied. Out of 121 simulated climate scenarios, the lowest reliability for supply to the CHPP was 88.4%.

4. On average, 1,213 ML/year would be sourced from Hunter River supply via WALs. During periods of low site rainfall, Mangoola would make close to full use of their WALs up until about mid-way through the MCCO Project life.
5. Modelling predicts a low risk of significant accumulation of water within the open cut pits. There is a 5% forecast risk that no more than 387 ML would be held in any open cut and then only for relatively short periods of time.
6. Predicted median HRSTS controlled releases are low (up to 102 ML), while there is a 5% probability of annual release up to 1,469 ML. The average annual salt discharge totals 565 tonnes/year, which equates to 0.8% of the monitored historical average salt load for the Hunter River at Denman.
7. Other than HRSTS controlled release, discharges are only predicted from sediment dams, which are intended to spill periodically in accordance with Landcom (2004) during rainfall events that exceed sediment dam design capacity. No spills are predicted from any other dams.

3.3.6 Climate Change Implications

Recent (post 1950) changes to temperature are evident in many parts of the world including Australia. The Intergovernmental Panel on Climate Change (IPCC) has, in its 2015 assessment (IPCC, 2015), concluded that:

> *Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, and in global mean sea level rise; and it is extremely likely to have been the dominant cause of the observed warming since the mid-20th century.*

Predicting future climate using global climate models is now undertaken by a large number of research organizations around the world. In Australia much of this effort has been conducted and co-ordinated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CSIRO and BoM have recently published a comprehensive assessment of future climate change effects on Australia and future projections (CSIRO and BoM, 2015a). This is based on an understanding of the climate system, historical trends and model simulations of climate response to future global scenarios. Simulations have been drawn from an archive of more than 40 global climate models (GCMs) developed by groups around the world. Modelling has been undertaken for four Representative Concentration Pathways (RCPs) used by the latest IPCC assessment, which represent different future scenarios of greenhouse gas and aerosol emission changes and land-use change.

Predictions of future climate from these various models and RCPs have been used to formulate probability distributions for a range of climate variables including temperature, mean and extreme rainfall and potential evapotranspiration. Predictions are made relative to the IPCC reference period 1986 to 2005 for up to 13 future time periods between 2030 and 2090. Predictions for 2030 are relatively insensitive to future emission scenarios because they largely reflect greenhouse gases that have already been emitted. Longer term predictions become increasingly more sensitive to future emission scenarios.

Assessments of likely future concurrent rainfall and evapotranspiration changes have been undertaken using the online Climate Futures Tool (CSIRO and BoM, 2015b). Projected changes from all available climate models are classified into broad categories of future change defined by these two variables, which are the most relevant available parameters affecting rainfall runoff. The Climate Futures Tool excludes GCMs which were not found to perform satisfactorily over the Australian region. The assessments assumed a conservatively high emissions scenario – RCP 8.5

(representing a future with little curbing of emissions, with a carbon dioxide level continuing to rapidly rise to the end of the century). Assessments were performed for 2030 (i.e. just after the end of the MCCO Project life) and 2090 (latest projected year available – which is of relevance for the post-mine period) for the east coast region of the continent. Table 27 presents mean annual changes for these two climate variables.

Table 27 Predicted Mean Change in Annual Rainfall and Evapotranspiration using Climate Futures Tool

Climate Variable	Mean Change From Reference Period by	
	2030	2090
Annual Rainfall	-4.5%	-7.0%
Annual Evaporation	3.9%	13.7%

The most likely climate future in 2030 is predicted to involve "little change"[25] in annual rainfall with a "small increase" in annual evapotranspiration, while the most likely climate future in 2090 is for a "large increase" in annual evapotranspiration combined with a "drier" rainfall scenario. These effects are likely to, in the longer term, lead to reductions in rainfall runoff in the MCCO Project Area and the east coast region generally.

An assessment was also carried out of the change in extreme (1:20 AEP) annual rainfall. The predicted most likely scenario by 2030 is for "little change" or a "small increase", while by 2090 the prediction is for a "small increase".

The implications of climate change predictions on water management are unlikely to be significant over the MCCO Project life because they are fairly small compared to natural climatic variability and the relatively short duration of the MCCO Project.

Longer term climate change predictions do however have potential implications for post mine water management (refer Section 4.0).

[25] The Climate Futures Tool uses standard terms to describe future magnitudes of change – these have been shown in quotation marks. "Little change" in annual rainfall is for a change between -5% to 5%, "small increase" in evapotranspiration is an increase of between 1% to 4.59%, "large increase" in evapotranspiration is an increase of more than 4.59% and a "drier" annual rainfall scenario is a change of between -5% to -15%. In the context of extreme (1:20 AEP) annual rainfall, "little change" is for a change between -10% to 10%, while "small increase" is a change of between 10% to 30%.

4.0 FINAL PIT LAKE WATER AND SALT BALANCE

The planned final landform is described in Section 3.2.1.5 and shown in Figure 20. Two final voids are planned: Main Pit West and the MCCO Additional Mining Area open cut pit. A final void water and salt balance model has been set up to simulate the behaviour of the pit lake that would form in each of the final voids. Based on a geochemical assessment by EGi (2019), runoff and seepage from overburden is not expected to be acidic and should not contain significant metals concentrations. Therefore long term salinity is the likely main issue for pit lake water quality.

The model simulates inflow from remnant final void catchment rainfall runoff (including direct rainfall), groundwater inflow from bedrock and spoil seepage as well as outflow due to evaporation and groundwater outflow on a daily basis. Key model assumptions include the following.

- Catchment areas of 323 ha and 409 ha for Main Pit West and the MCCO Additional Mining Area respectively.
- Final pit lake level-volume-area relationships derived from the final landform contour plan (Figure 20).
- A 129 year climatic data set (1889 to 2017 inclusive) obtained from the SILO Data Drill for the MCCO Project location (refer Section 3.3.2). The data set was repeated several times over to generate an extended period of data for final pit lake simulation – to ensure equilibrium water levels were reached during the simulation period.
- A constant pan factor of 0.75 was assumed for calculation of evaporation from the final pit lake.
- Rainfall runoff from the remnant rehabilitated overburden and undisturbed catchment was estimated using the AWBM applied to the final void sub-catchments, in a manner similar to the operational water and salinity balance model (refer Section 3.3.3), with the exception of seepage from the adjacent overburden emplacements (refer below).
- Predicted rates of bedrock groundwater flux and seepage from/to the adjacent overburden emplacements were provided by AGEC (2019) - provided as time series for the same period as the final pit lake water balance models. These included an initial period of saturation of the adjacent overburden emplacements, followed by (longer term) seepage from the overburden to the final pit lakes. The data provided by AGEC (2019) included three overburden recharge rates (as a percentage of rainfall): 1%, 2% and 5%. The 2% value is understood to be considered as the 'most likely' scenario, while the other two rates were included to assess sensitivity of model results.
- Catchment runoff salinity values for final void remnant rehabilitated overburden and undisturbed catchment areas were assumed the same as for the operational water and salinity balance model (refer Table 20). Overburden seepage salinity was based on the results of standard geochemical tests on overburden/interburden samples by EGi (2019)[26]. This was varied with time, with an initial adopted EC value of 1,790 µS/cm (single highest value from all test results on overburden/interburden), reducing to 452 µS/cm (80th percentile value of all samples excluding that with the highest EC) over a period of 100 years. Salinity of runoff from remnant non-rehabilitated pit areas was assumed the same as overburden seepage salinity.
- Bedrock groundwater inflow EC was based on a monitored average value of 9,100 µS/cm (average from all Mangoola monitoring bores)[27].

In simulating pit lake salinity, the model assumes conservation of mass and fully mixed conditions.

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[26] Sample EC was determined by equilibrating the sample in deionised water for a minimum of 12 hours (or overnight), typically at a solid to water ratio of 1:2 (w/w).

[27] AGEC – personal communication 26 October 2018.

Model predicted final pit lake water levels and EC values are shown in Figure 45 and Figure 46 for the 'most likely' scenario, while model sensitivity results are given in Appendix C.

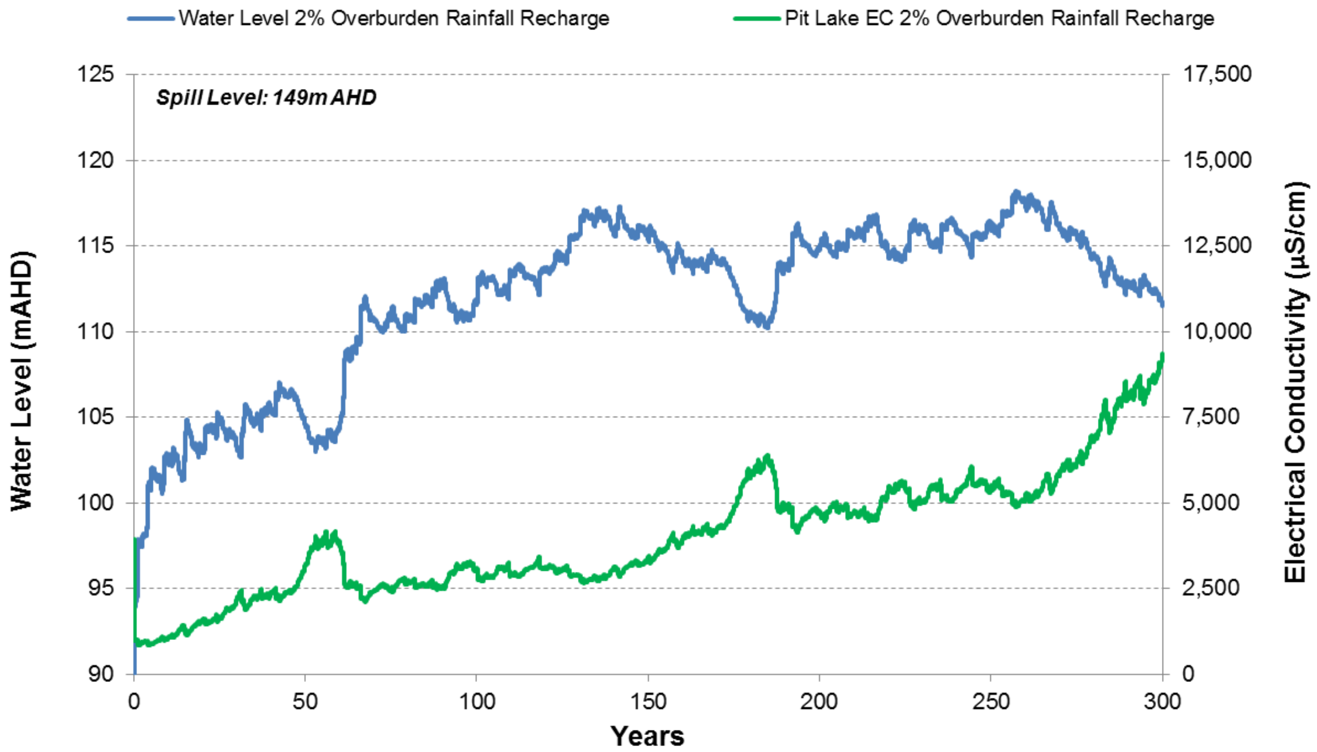

Figure 45 Predicted Final Pit Lake Water Levels - Main Pit West

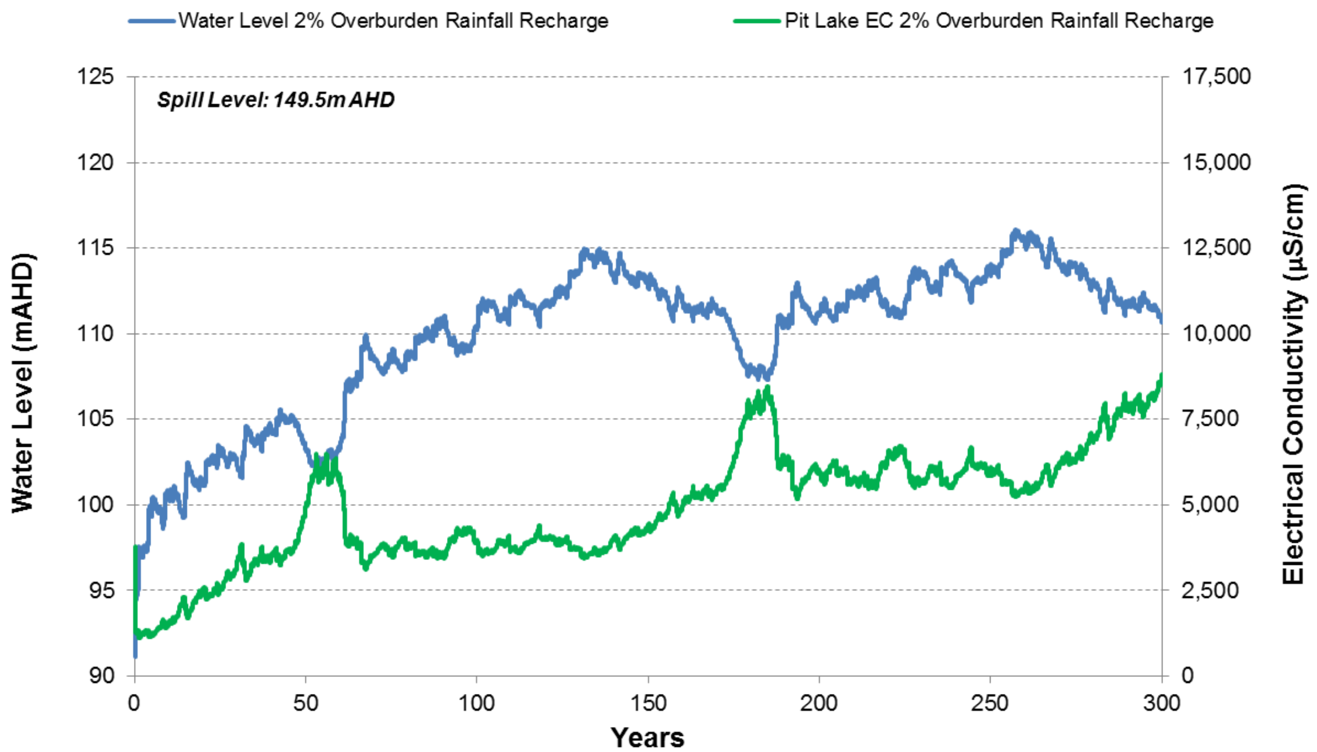

Figure 46 Predicted Final Pit Lake Water Levels - MCCO Additional Mining Area

Results indicate that both the final pit lakes would reach an equilibrium level more than 30 m below their respective spill levels (i.e. the lakes are contained). Equilibrium levels would be reached slowly over a period of more than two hundred years. Final pit lake salinity levels would increase slowly as a result of evapo-concentration[28]. The occasional rises in modelled salinity and concurrent falls in water level represent historical drought periods. The most likely longer term climate change prediction (Section 3.3.6) would result in lower equilibrium water levels, these being reached sooner and with an increased rate of salinity rise. Possible uses of the final pit lakes may include recreational activities and freshwater aquaculture (for the periods where salinity remains below 4,700 µS/cm or 3,000 mg/L TDS – the ANZECC [2000] guideline maximum value).

[28] The concentration of salt in the pit lake as a result of evaporation from the lake surface.

5.0 MONITORING, MITIGATION AND MANAGEMENT

The following monitoring, mitigation and management measures are recommended as a result of the foregoing assessment. Mangoola have undertaken to adopt these measures following approval of the MCCO Project.

Monitoring of surface water quality, channel stability, the water management system and discharge of water should continue in accordance with Mangoola's existing surface water monitoring plan (Mangoola Open Cut, 2018c). The surface water management plan for the approved works (Mangoola Open Cut, 2018a) would be updated to accommodate water management and mitigation measures for the MCCO Project Area. These measures should be informed by an appropriate on-going monitoring program which should be updated as required to assist in meeting MCCO Project environmental objectives. The following monitoring recommendations are made in relation to assessing the performance of the updated water management system as it relates to surface water. A summary is provided in Table 28.

Table 28 Existing and Recommended Surface Water Monitoring

Monitoring Sites/Locations	Parameters	Frequency	Recommendation
SW01 to SW07, SW09 to SW19 and HRSTS discharge*	pH, EC, TSS, TDS, flow conditions	Monthly (flow permitting)	Continue
SW20*			Discontinue (within disturbance boundary of MCCO Additional Project Area)
SW01 to SW07 and SW09 to SW19	Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Sulphate, Chloride, Iron, Silver, Arsenic, Boron, Barium, Cadmium, Copper, Manganese, Lead, Selenium, Zinc, Mercury, Fluoride, Nitrite, Nitrate, Total Kjeldahl Nitrogen, Total Nitrogen, Total Phosphorous	Annual (flow permitting)	Continue
SW20*			Discontinue (within disturbance boundary of MCCO Additional Project Area)
WSN, WSS and Big Flat Creek catchment rainfall stations*	Rainfall	Continuous (tipping bucket rain gauge)	Continue
PWD and RWD**	Stored water level	Daily	Continue
All water management system dams	Stored water level	Weekly	Continue existing dams and expand to include new dams**
	pH, EC, TSS, TDS	Monthly	Continue existing dams and expand to include new dams**
		Freeboard dependent†	Continue existing dams and expand to include new dams**
	Volume transferred and where to	Monthly	Continue existing dams and expand to include new dams**

Location per Figure 3 and/or surface water monitoring plan (Mangoola Open Cut, 2018c) Figure 2.1.

**Refer Section 3.2.1

† Upon freeboard reducing to less than 1 m or volume increasing by more than 10% where maximum designed freeboard is less than 1 m.

Table 28 Existing and Recommended Surface Water Monitoring (Continued)

Monitoring Sites/Locations	Parameters	Frequency	Recommendation
Hunter River Pipeline	Volume imported or discharged	Daily	Continue
SW14 and SW17	pH, EC, TSS, TDS and flow rate	Daily during discharge and for five days after	Continue
Channel stability monitoring locations: Big Flat and Sandy Creeks	Documenting locations and dimensions of significant erosive or depositional features, photographs at fixed photo-points on Big Flat and Sandy Creeks, written descriptions focusing on evidence of erosion and exposed soils	Annual	Review requirement for existing stability monitoring program on Sandy Creek. Include sites along the MCCO Additional Project Area upslope diversions, Big Flat Creek reaches BFC-1 to BFC-4 (refer Figure 10) and immediately downstream of proposed haul road crossing
Erosion and sediment control structures	Integrity/function, water level, silt build up, functioning of real-time monitoring*	Weekly and within 5 days of high rainfall event	Continue existing and add proposed additional sediment controls**

* Per erosion and sediment control plan (Mangoola Open Cut, 2018d).

** Refer Section 3.2.1

5.1 BASELINE MONITORING

The current water quality monitoring program for the MCCO Additional Project Area (refer Section 2.5) should continue in order to further add to the baseline data collected and further refine site specific trigger values. Monitoring of rainfall in the catchment of Big Flat Creek should continue.

5.2 OPERATIONAL MONITORING AND MANAGMENT

The above baseline and current operational monitoring should continue up to the start of and through the MCCO Project life. It is recommended that the following additional surface water related monitoring occur during operations:

- Monthly water quality monitoring in the MCCO Project Area including: MNSD1, MNSD2, MNSD3, MSSD1, MSSD2 and MSSD3.
- Weekly monitoring of proposed erosion and sediment controls in the MCCO Project Area.
- Monitoring of monthly volumes of water pumped from the MCCO Additional Project Area to the PWD.
- Monitoring of monthly volumes of water pumped from sediment dams to the water management system, as well as water reclaimed from TD4.
- Annual monitoring of channel stability of the proposed upslope diversions (refer Section 3.2.1), Big Flat Creek adjacent to the MCCO Additional Project Area and just downstream of the proposed haul road crossing via established photo-points (to be established following construction) and assessment points at approximately 50 m intervals.

On-going water quality monitoring (refer Section 2.5) and comparison to site specific trigger values (refer Section 2.6.2) will allow for ongoing analysis and management of water quality impacts. If an exceedance of a water quality trigger value occurs, in accordance with the Mangoola Surface and Groundwater Response Plan (Mangoola Open Cut, 2018b), actions would include reviewing monitoring results against historical data and data from adjacent sites, reviewing operations to determine if the result was a consequence of mining, consulting a suitably qualified water specialist and determining if an incident had occurred under EPL 12894 and/or the development consent. If an incident had been deemed to have occurred, responses would comprise assessing the risk of environmental harm, taking all preventative measures to prevent or minimise environmental harm, conducting an investigation into the incident, notify the relevant authorities in accordance with the EPL and Project Approval, submitting a detailed report regarding the incident to the relevant authorities within 7 days, prioritising actions to be taken to prevent a repeat incident, monitoring the completion of actions and reviewing and if necessary revising the Surface and Groundwater Response Plan and Water Management Plan.

Monitoring of erosion at-risk areas will allow early detection of these impacts and implementation of appropriate mitigation measures.

A construction phase Erosion and Sediment Control Plan (or equivalent) will be prepared for the MCCO Project to detail the controls required to manage construction works in and adjacent to Big Flat Creek. It is recommended that appropriate flood warning signage, including flood depth indicators, be installed along Wybong Road in the vicinity of the overpass as a safety measure.

It is recommended that the Mangoola Coal Mine water management system performance continue to be assessed annually against its predicted performance making due allowance for inclusion of the MCCO Project Area. This entails monitoring the climatic conditions on site, the main water transfers, including water sourced from off site, off site discharges and changes in stored water volumes. The performance of the updated water management system should continue to be assessed by comparing the monitored water balance with water balance model predictions as part of the annual review process.

5.3 POST-MINING MONITORING AND MANAGMENT

It is recommended that monitoring of streamflow, channel stability and water quality continue for two years following cessation of operations. Monitoring data should be reviewed at annual intervals (as part of the annual review process) over this period. Reviews should involve assessment against long term performance objectives that are based on baseline conditions or a justifiable departure from these, with due allowance for climatic variations. If objectives are not substantially met within the two year period, management measures should be revised and the monitoring period extended.

5.4 POTENTIAL CONTINGENCY MEASURES

Potential contingency measures in the event of unforeseen impacts or impacts in excess of those predicted would include:

- conducting additional monitoring (e.g. increase in monitoring frequency or additional sampling locations) to inform the proposed contingency measures;
- refinements to the water management system design such as additional sedimentation dams, increases to pumping capacity, installation of new structures as required to address the identified issue;
- the implementation of stream remediation measures and possible additional controls (e.g. rock armouring) to reduce the extent and effect of erosion; and/or
- the implementation of revegetation measures in conjunction with other stabilisation techniques (as required) to remediate impacts of vegetation loss due to erosion.

6.0 REFERENCES

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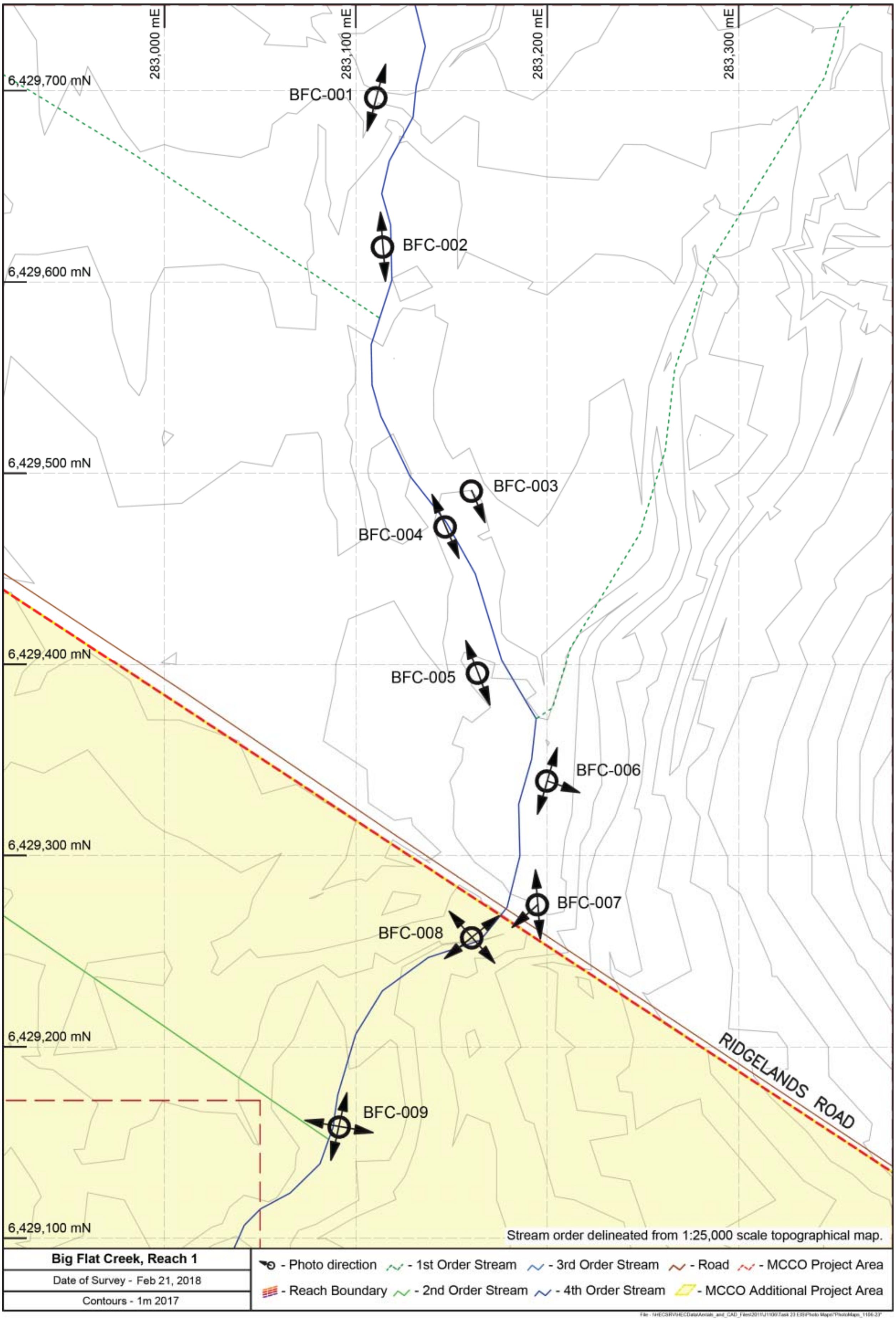
APPENDIX A
Results of Ground Reconnaissance

This appendix provides the results of the stream reconnaissance including individual stream maps and associated GPS referenced photographs, together with a description of the geomorphic characteristics, condition and specific features of each reach. Refer Figure 10 of the main report for the reach map overview.

BIG FLAT CREEK

Big Flat Creek is the named watercourse running generally north-east to south-west draining the MCCO Project Area and has been divided into nine reaches.

Reach BFC-1



283,000 mE
283,100 mE
283,200 mE
283,300 mE
6,429,700 mN
6,429,600 mN
6,429,500 mN
6,429,400 mN
6,429,300 mN
6,429,200 mN
6,429,100 mN
BFC-001
BFC-002
BFC-003
BFC-004
BFC-005
BFC-006
BFC-007
BFC-008
BFC-009
RIDGELANDS ROAD
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 1
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- 1st Order Stream
- 3rd Order Stream
- Road
- MCCO Project Area
- Reach Boundary
- 2nd Order Stream
- 4th Order Stream
- MCCO Additional Project Area

BFC-001 Upstream

BFC-001 Downstream

BFC-002 Upstream

BFC-002 Downstream

BFC-003 Downstream

BFC-004 Upstream

BFC-004 Downstream

BFC-005 Upstream

BFC-005 Downstream

BFC-006 Upstream

BFC-006 Downstream

BFC-006 Left Bank

BFC-007 Upstream

BFC-007 Downstream Pan Left

BFC-007 Downstream Pan Right

BFC-008 Upstream

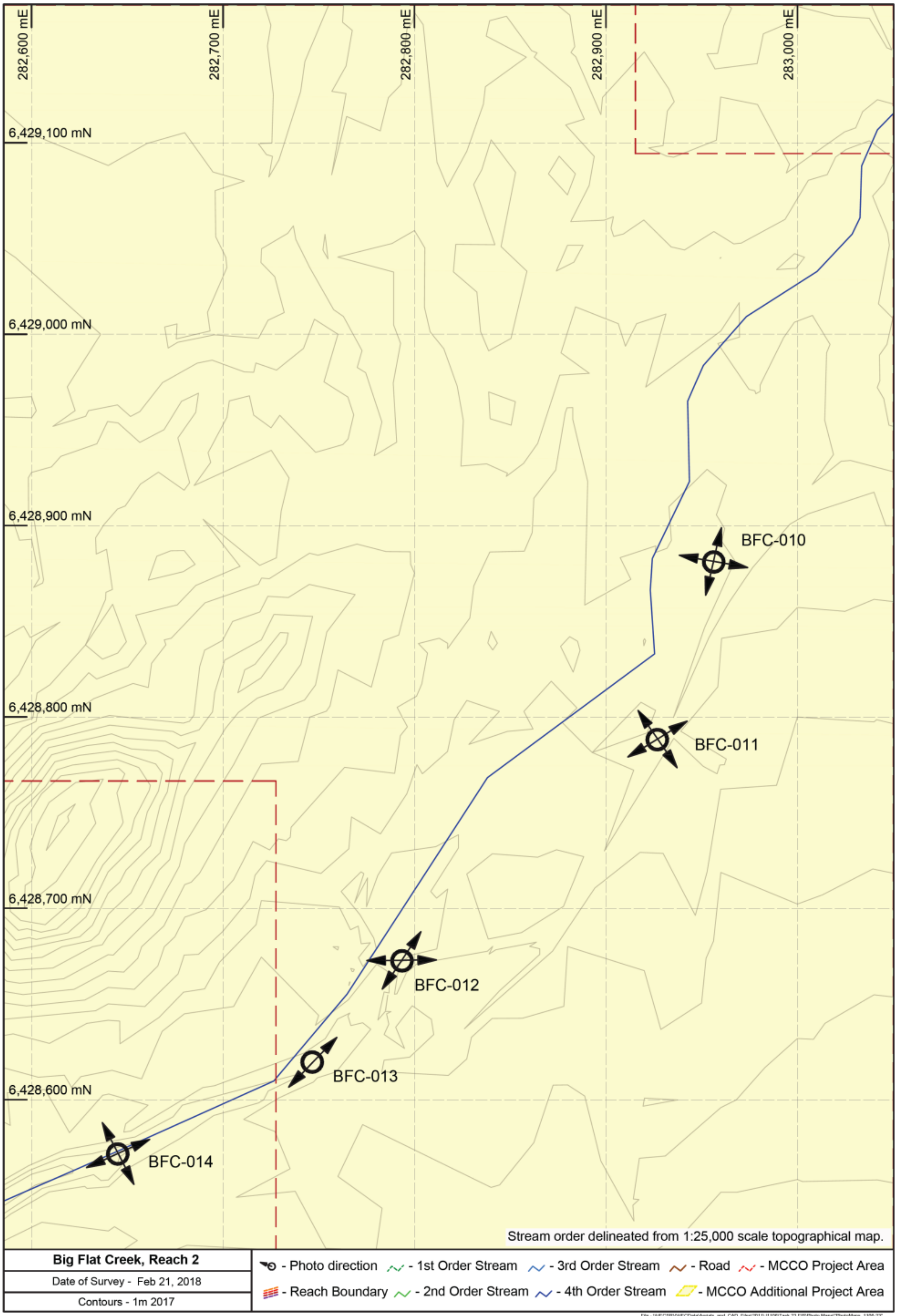
BFC-008 Downstream

BFC-008 Left Bank

		
BFC-008 Right Bank	**BFC-009 Upstream**	**BFC-009 Downstream**
		
BFC-009 Left Bank	**BFC-009 Right Bank**	

The upper portion of BFC-1 contained a farm dam with a grassed overflow channel. Further downstream (on the upstream side of Ridgelands Road) the channel became more incised with recent bed down-cutting evident in some areas. Localised bank erosion was also evident at several locations where the bed had down-cut. There were several groves of trees (*eucalypt* sp. and *casuarina* sp.) and aquatic reeds and weeds (including common rush) had colonised the bed in some flat areas. There was no evidence of recent bed sediment movement. The areas of exposed bed sediment comprised sandy silt. The crossing at Ridgelands Road comprised a set of box culverts. The culverts had become partially silted on the upstream side and some minor bed erosion was evident immediately downstream of the culverts. Downstream of the Ridgelands Road crossing, the stream varied from a small swale to a series of small depressions. Vegetation thinned and overbanks comprised a moderately dense cover of grass and isolated trees while the channel comprised thin grass and infrequent common rush. Evidence of cattle access was apparent along this reach (with the exception of Ridgelands Road crossing).

Reach BFC-2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282,700 mE
282,800 mE
282,900 mE
283,000 mE
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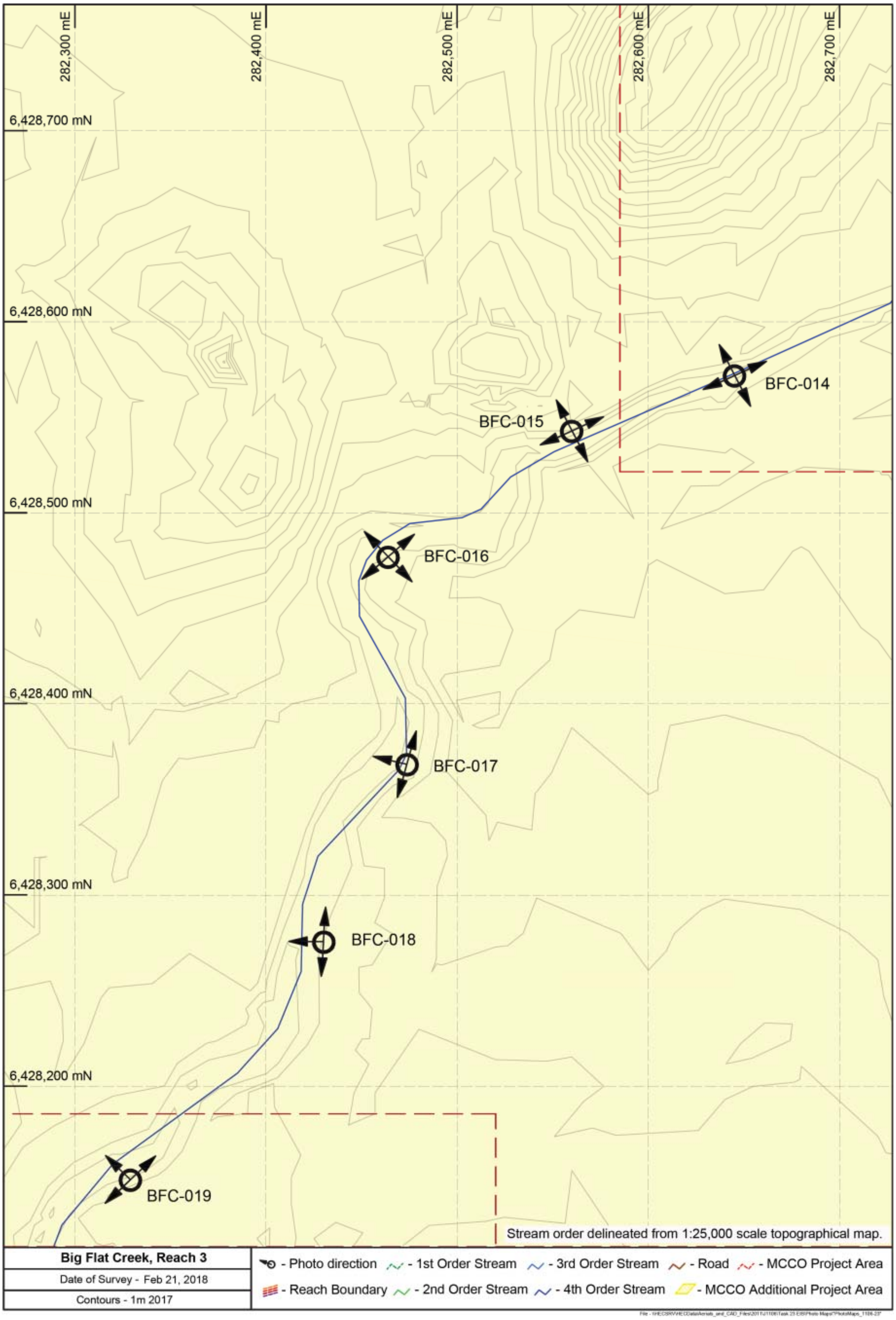
6,429,000 mN
6,428,900 mN
6,428,800 mN
6,428,700 mN
6,428,600 mN
BFC-010
BFC-011
BFC-012
BFC-013
BFC-014
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 2
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- 1st Order Stream
- 3rd Order Stream
- Road
- MCCO Project Area
- Reach Boundary
- 2nd Order Stream
- 4th Order Stream
- MCCO Additional Project Area

		
BFC-010 Upstream	**BFC-010 Downstream**	**BFC-010 Left Bank**
		
BFC-010 Right Bank	**BFC-011 Upstream**	**BFC-011 Downstream**
		
BFC-011 Left Bank	**BFC-011 Right Bank**	**BFC-012 Upstream Pan Left**

		
BFC-012 Upstream Pan Right	**BFC-012 Downstream**	**BFC-012 Right Bank**
		
BFC-013 Upstream	**BFC-013 Downstream**	

The stream over most of this reach varied from a small swale to a series of small depressions. Vegetation comprised a moderately dense cover of grass. Rock outcropped in the lower part of the reach corresponding to a steepening in the stream bed and the transition to a more incised and defined channel. A small concrete sill (origin unknown, refer photo “BFC-012 Right Bank”) caused localised erosion and partial under-mining of the channel downstream. The sill appeared to be part of a contour bank which had been constructed across the adjacent paddock. A zone of large rock had been placed on the stream channel at the end of this reach to arrest bed down-cutting (refer photo “BFC-013 Downstream”). These works corresponded to the upstream limit of the start of the more deeply incised and eroded channel which characterised the downstream reaches of Big Flat Creek.

Reach BFC-3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282,500 mE
282,600 mE
282,700 mE
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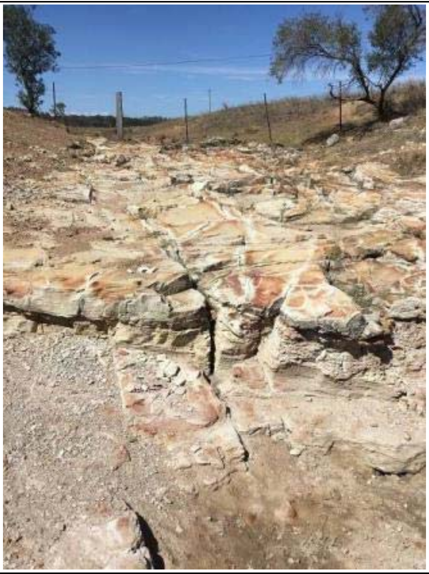
6,428,500 mN
6,428,400 mN
6,428,300 mN
6,428,200 mN
BFC-014
BFC-015
BFC-016
BFC-017
BFC-018
BFC-019
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 3
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- 1st Order Stream
- 3rd Order Stream
- Road
- MCCO Project Area
- Reach Boundary
- 2nd Order Stream
- 4th Order Stream
- MCCO Additional Project Area

		
BFC-014 Upstream	**BFC-014 Downstream**	**BFC-014 Left Bank**
		
BFC-014 Right Bank	**BFC-015 Upstream**	**BFC-015 Downstream**
		
BFC-015 Left Bank	**BFC-015 Upstream**	**BFC-015 Downstream**

BFC-015 Left Bank

BFC-015 Right Bank

BFC-016 Upstream

BFC-016 Downstream

BFC-016 Left Bank

BFC-016 Right Bank

BFC-017 Upstream

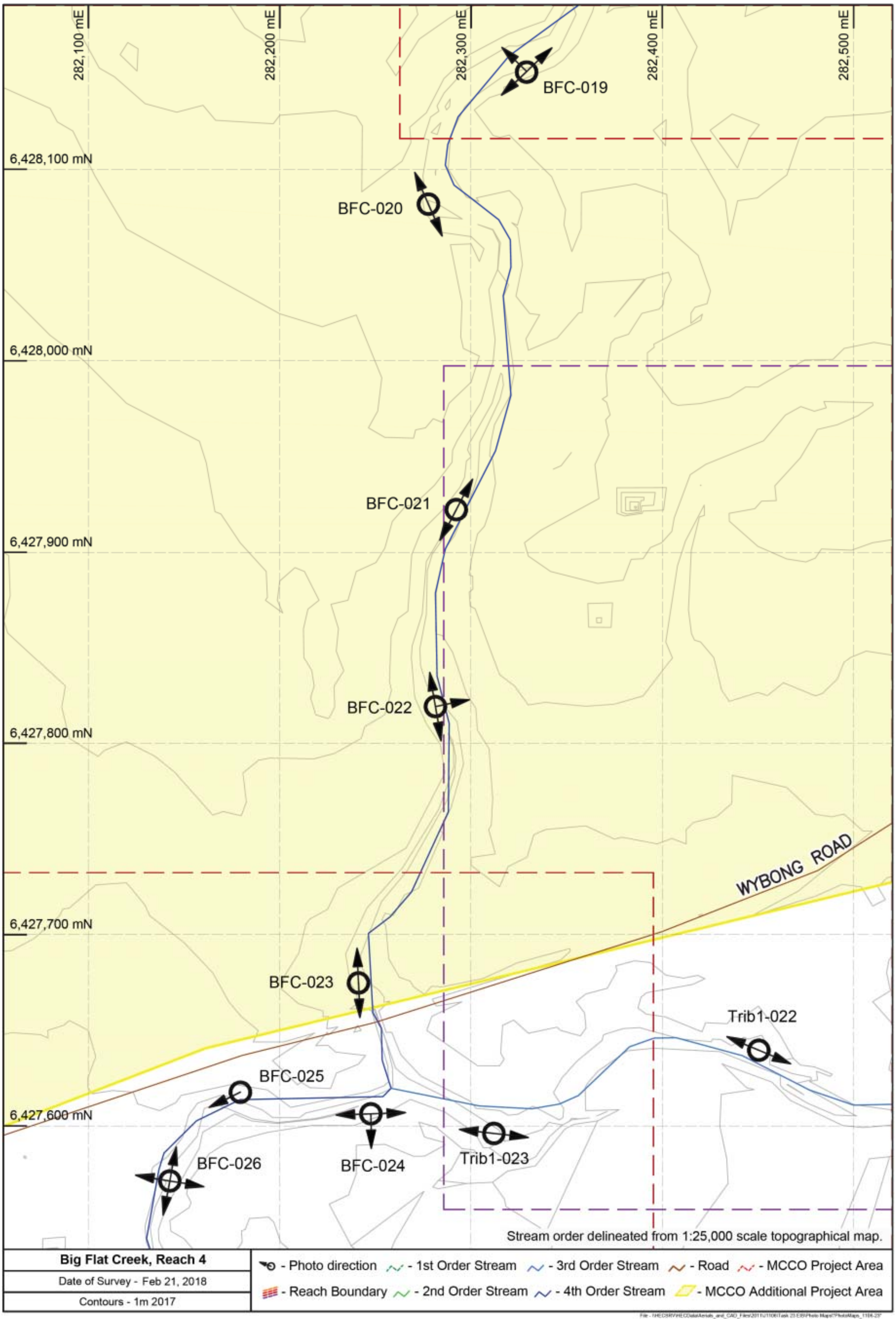
BFC-017 Downstream

BFC-017 Right Bank

		
BFC-018 Upstream	**BFC-018 Downstream**	**BFC-018 Right Bank**
		
BFC-019 Upstream	**BFC-019 Downstream**	**BFC-019 Right Bank**

The upper part of this reach comprised a degraded channel which had formed into a relatively narrow, moderately incised channel. Exposed rock comprised intensely jointed, friable silt stones. Further downstream the creek was characterised by a more deeply incised channel with a dense reed (mostly common rush) cover in its bed and isolated stands of trees on its banks.

Reach BFC-4



282,100 mE
282,200 mE
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282,400 mE
282,500 mE
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6,428,000 mN
6,427,900 mN
6,427,800 mN
6,427,700 mN
6,427,600 mN
BFC-019
BFC-020
BFC-021
BFC-022
BFC-023
BFC-024
BFC-025
BFC-026
Trib1-022
Trib1-023
WYBONG ROAD
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 4
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- 1st Order Stream
- 3rd Order Stream
- Road
- MCCO Project Area
- Reach Boundary
- 2nd Order Stream
- 4th Order Stream
- MCCO Additional Project Area

BFC-020 Upstream

BFC-020 Downstream

BFC-021 Upstream

BFC-021 Downstream

BFC-022 Upstream

BFC-022 Downstream

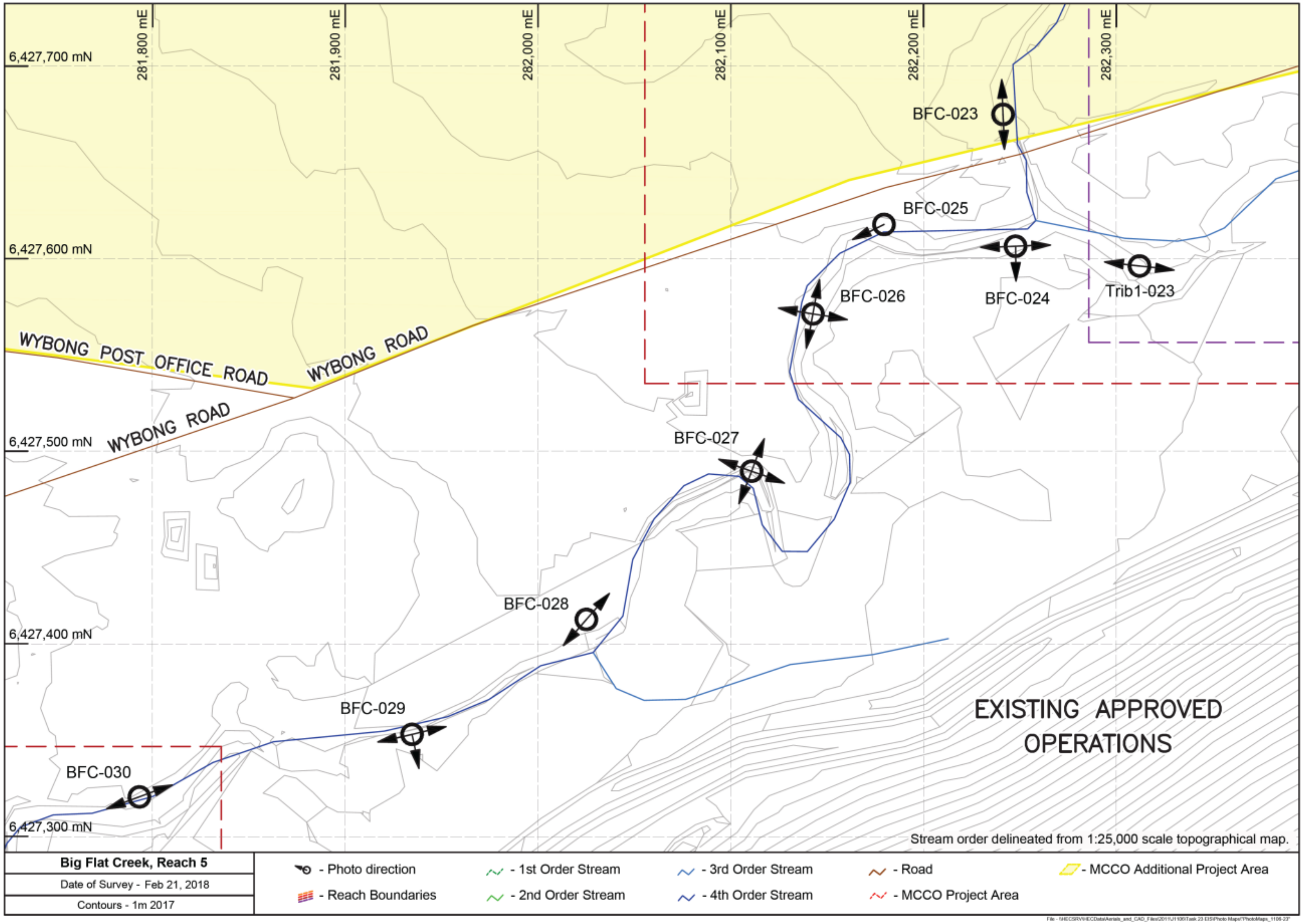
BFC-022 Left Bank

BFC-023 Upstream

BFC-023 Downstream

This reach comprised a wide moderately incised channel. The channel appeared to be aggrading following an episode of active down-cutting and bank widening. There was extensive reed growth in the bed and isolated groves of trees on some overbank areas. The reach ended at the Wybong Road crossing of Big Flat Creek which comprised a box culvert crossing.

Reach BFC-5



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6,427,600 mN
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6,427,400 mN
6,427,300 mN
281,800 mE
281,900 mE
282,000 mE
282,100 mE
282,200 mE
282,300 mE
WYBONG POST OFFICE ROAD
WYBONG ROAD
WYBONG ROAD
BFC-023
BFC-025
BFC-024
Trib1-023
BFC-026
BFC-027
BFC-028
BFC-029
BFC-030
EXISTING APPROVED OPERATIONS
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 5
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- Reach Boundaries
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order Stream
- Road
- MCCO Project Area
- MCCO Additional Project Area


BFC-024 Upstream


BFC-024 Downstream


BFC-024 Left Bank


BFC-025 Downstream


BFC-026 Upstream


BFC-026 Downstream


BFC-026 Left Bank

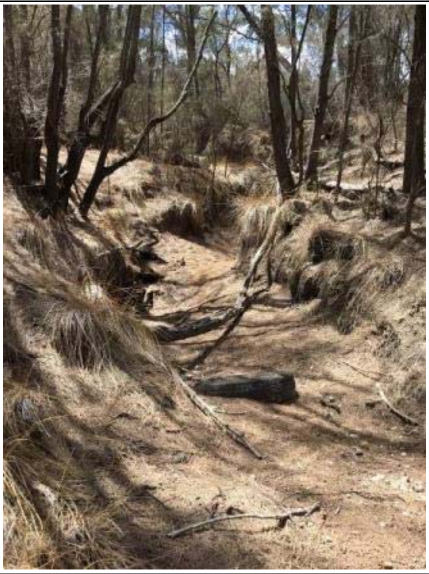

BFC-026 Right Bank


BFC-027 Upstream

BFC-027 Downstream

BFC-027 Left Bank

BFC-027 Right Bank



BFC-028 Upstream

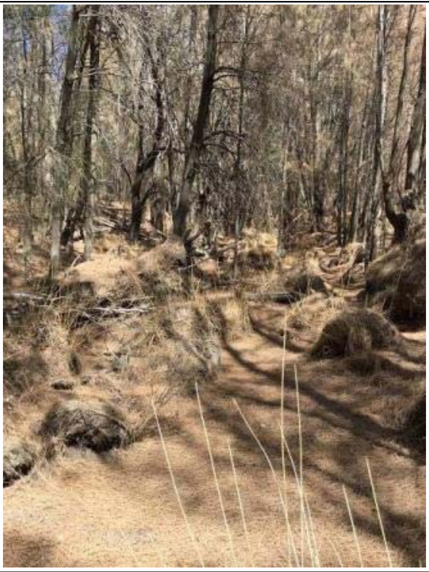
BFC-028 Downstream

BFC-029 Upstream

BFC-029 Downstream

BFC-029 Left Bank

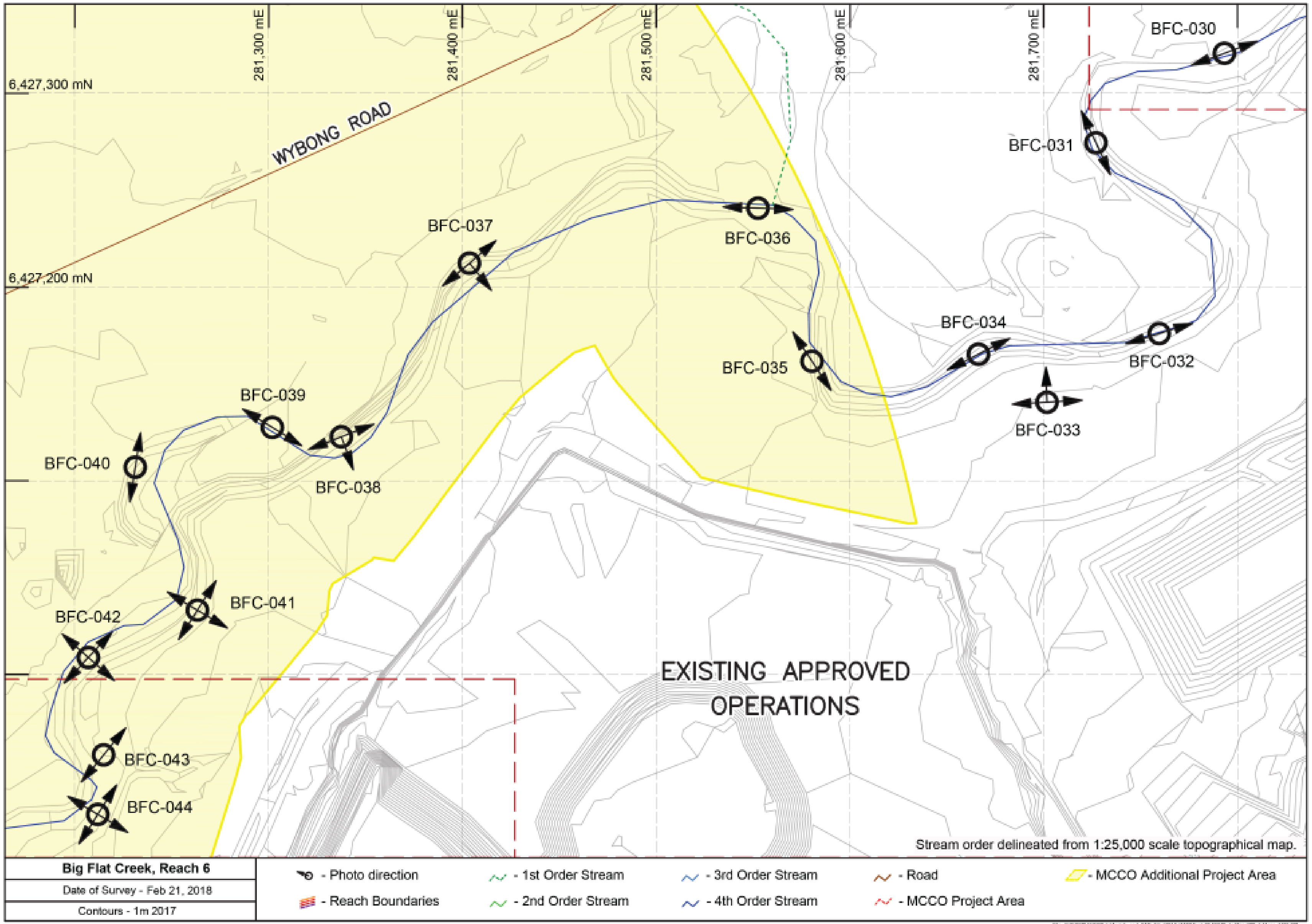
BFC-030 Upstream



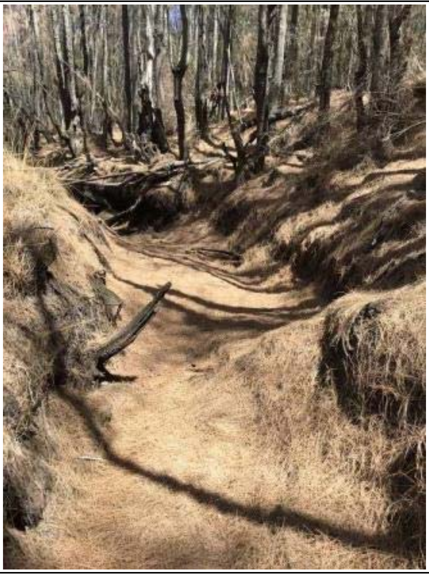
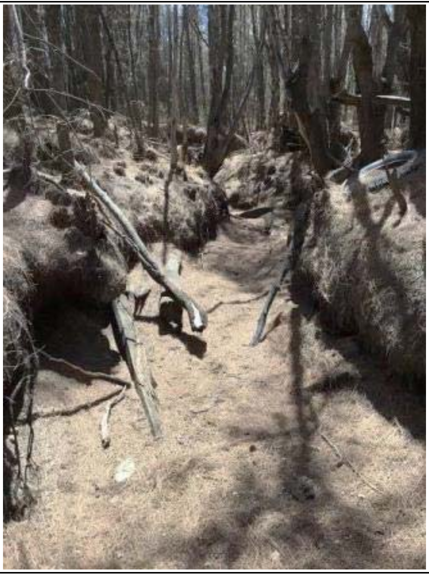
BFC-030 Downstream

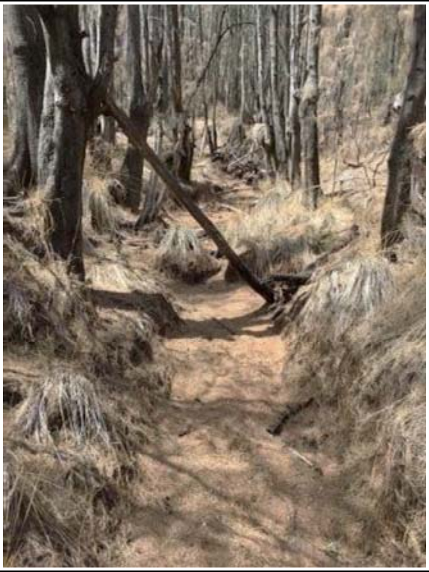
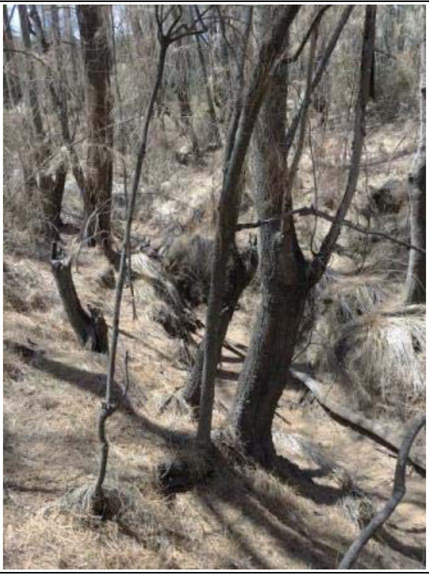
Downstream of Wybong Road the creek was joined by Tributary 1 where it became more sinuous than in its upper reaches. The stream flowed through a relatively densely vegetated riparian corridor – predominantly *casuarina* sp. The channel was well defined with gentle sloping banks (1.5 to 2 m high) and a 2 to 3 m wide primary banks. Defined overbank areas were also a feature of this section of Big Flat Creek. Bed sediments comprised mixed silts and sands. There was a build-up of wooded debris in sections with several prominent scour holes containing shallow pools.

Reach BFC-6



BFC-030
BFC-031
BFC-032
BFC-033
BFC-034
BFC-035
BFC-036
BFC-037
BFC-038
BFC-039
BFC-040
BFC-041
BFC-042
BFC-043
BFC-044
WYBONG ROAD
6,427,300 mN
6,427,200 mN
281,300 mE
281,400 mE
281,500 mE
281,600 mE
281,700 mE
EXISTING APPROVED
OPERATIONS
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 6
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- Reach Boundaries
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order Stream
- Road
- MCCO Project Area
- MCCO Additional Project Area

		
BFC-031 Upstream	**BFC-031 Downstream**	**BFC-032 Upstream**
		
BFC-032 Downstream	**BFC-033 Upstream**	**BFC-033 Downstream**
		
BFC-033 Right Bank	**BFC-034 Upstream**	**BFC-034 Downstream**

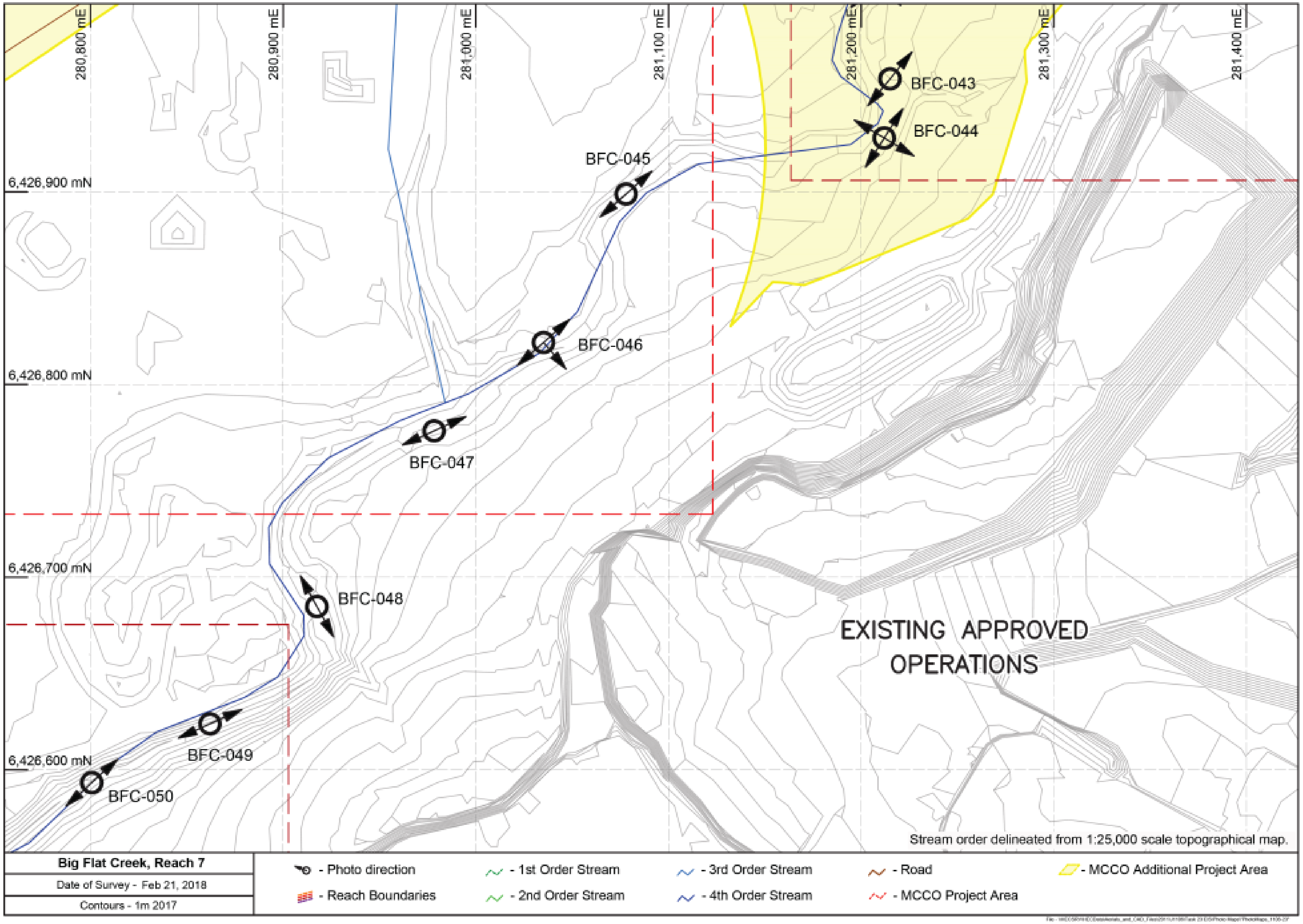
		
BFC-035 Upstream	**BFC-035 Downstream**	**BFC-036 Upstream**
		
BFC-036 Downstream	**BFC-037 Upstream**	**BFC-037 Downstream**
		
BFC-037 Left Bank	**BFC-038 Upstream**	**BFC-038 Downstream**

		
BFC-038 Left Bank	**BFC-039 Upstream**	**BFC-039 Downstream**
		
BFC-040 Upstream	**BFC-040 Downstream**	**BFC-041 Upstream**
		
BFC-041 Downstream	**BFC-041 Left Bank**	**BFC-041 Right Bank**

		
BFC-042 Upstream	**BFC-042 Downstream**	**BFC-042 Left Bank**
		
BFC-042 Right Bank	**BFC-043 Left Bank**	**BFC-043 Right Bank**

The creek followed a meandering path through this generally well vegetated reach. The channel profile was similar to Reach BFC-5. There were several sections with evidence of recent active bed material movement. Minor bank scours were also observed around the sharper bends and in the lower section of the reach – particularly where tree cover was less dense.

Reach BFC-7



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281,000 mE
281,100 mE
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281,400 mE
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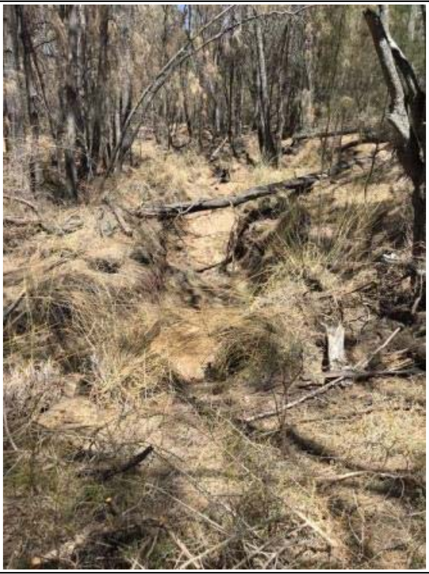
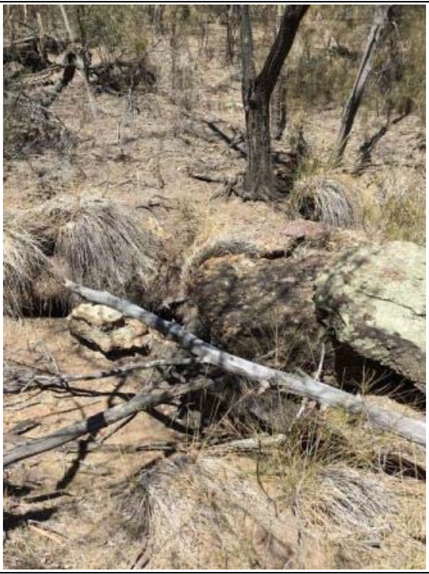
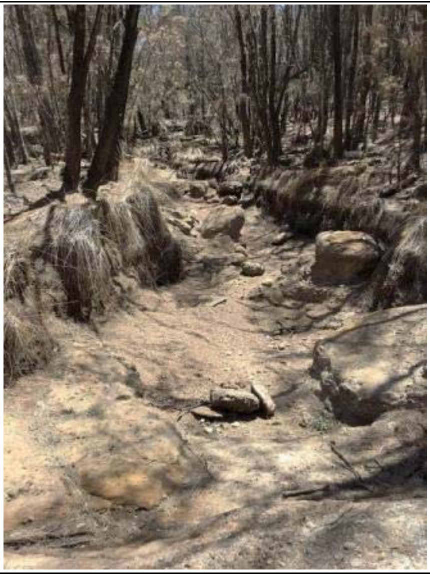
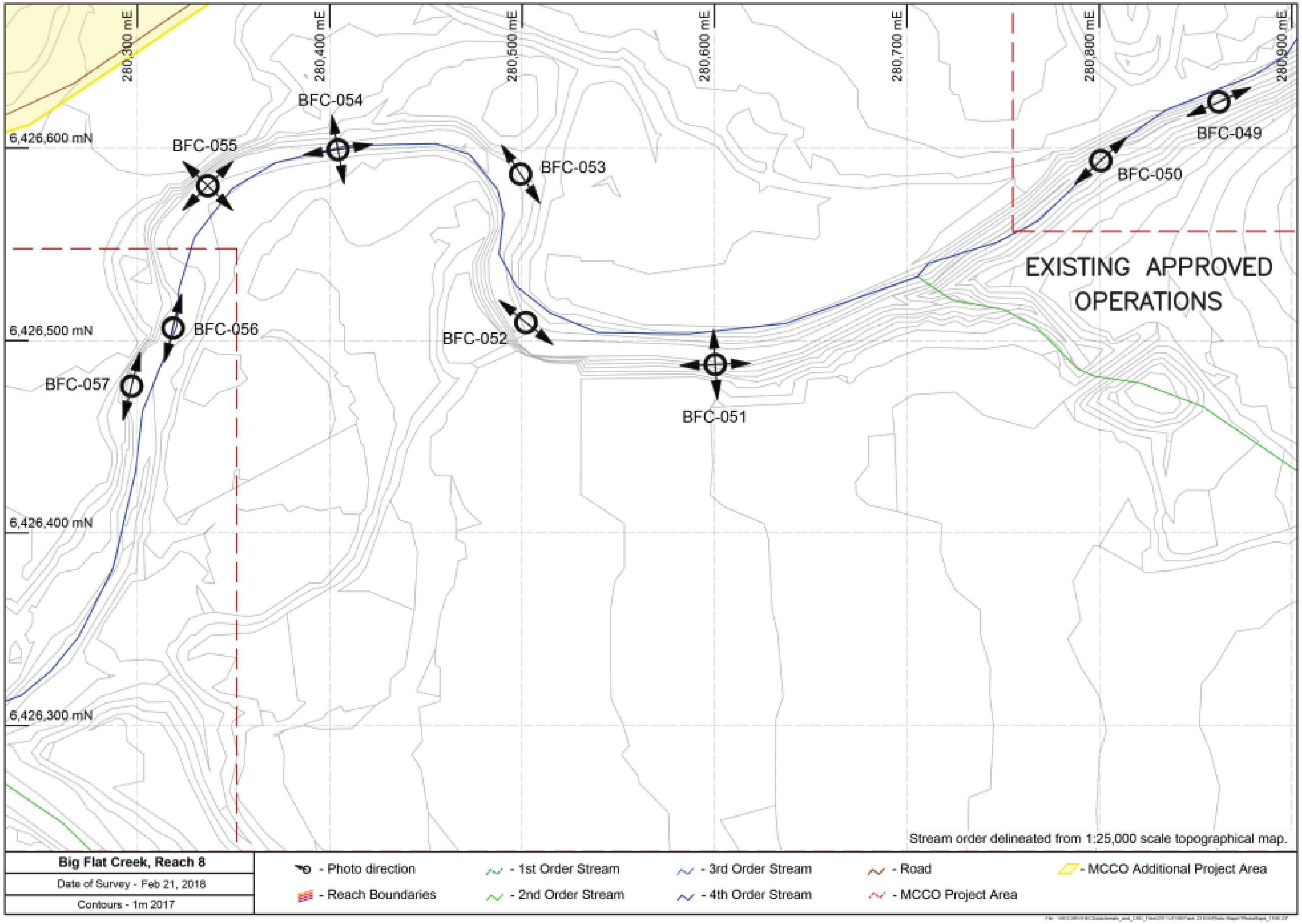
6,426,700 mN
6,426,600 mN
BFC-043
BFC-044
BFC-045
BFC-046
BFC-047
BFC-048
BFC-049
BFC-050
EXISTING APPROVED
OPERATIONS
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 7
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- Reach Boundaries
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order Stream
- Road
- MCCO Project Area
- MCCO Additional Project Area

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>BFC-044 Upstream</td><td>BFC-044 Downstream</td><td>BFC-044 Left Bank</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>BFC-044 Right Bank</td><td>BFC-045 Upstream</td><td>BFC-045 Downstream</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>BFC-046 Upstream</td><td>BFC-046 Downstream</td><td>BFC-046 Left Bank</td></tr>
</table>

		
BFC-047 Upstream	**BFC-047 Downstream**	**BFC-048 Upstream**
		
BFC-048 Downstream	**BFC-049 Upstream**	**BFC-049 Downstream**

This reach was dominated by extensive areas of rock outcrop. The channel profile appears to have been constrained by the rock to a relative shallow, irregular profile. There were some small bed scours in areas of less resistant bed material. The creek also followed a straighter (less meandering) planform. The vegetation comprised somewhat stunted *casuarina* sp. in the shallow skeletal soils.

Reach BFC-8



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280,500 mE
280,600 mE
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280,900 mE
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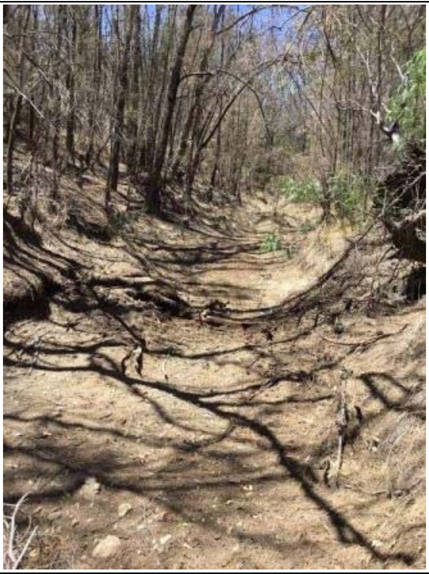
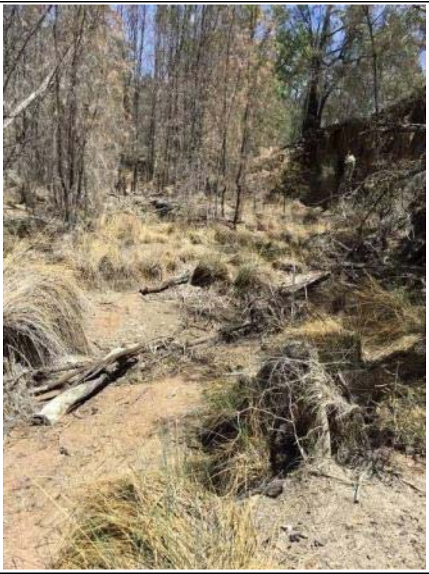
6,426,400 mN
6,426,300 mN
BFC-049
BFC-050
BFC-051
BFC-052
BFC-053
BFC-054
BFC-055
BFC-056
BFC-057
EXISTING APPROVED OPERATIONS
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 8
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- Reach Boundaries
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order Stream
- Road
- MCCO Project Area
- MCCO Additional Project Area

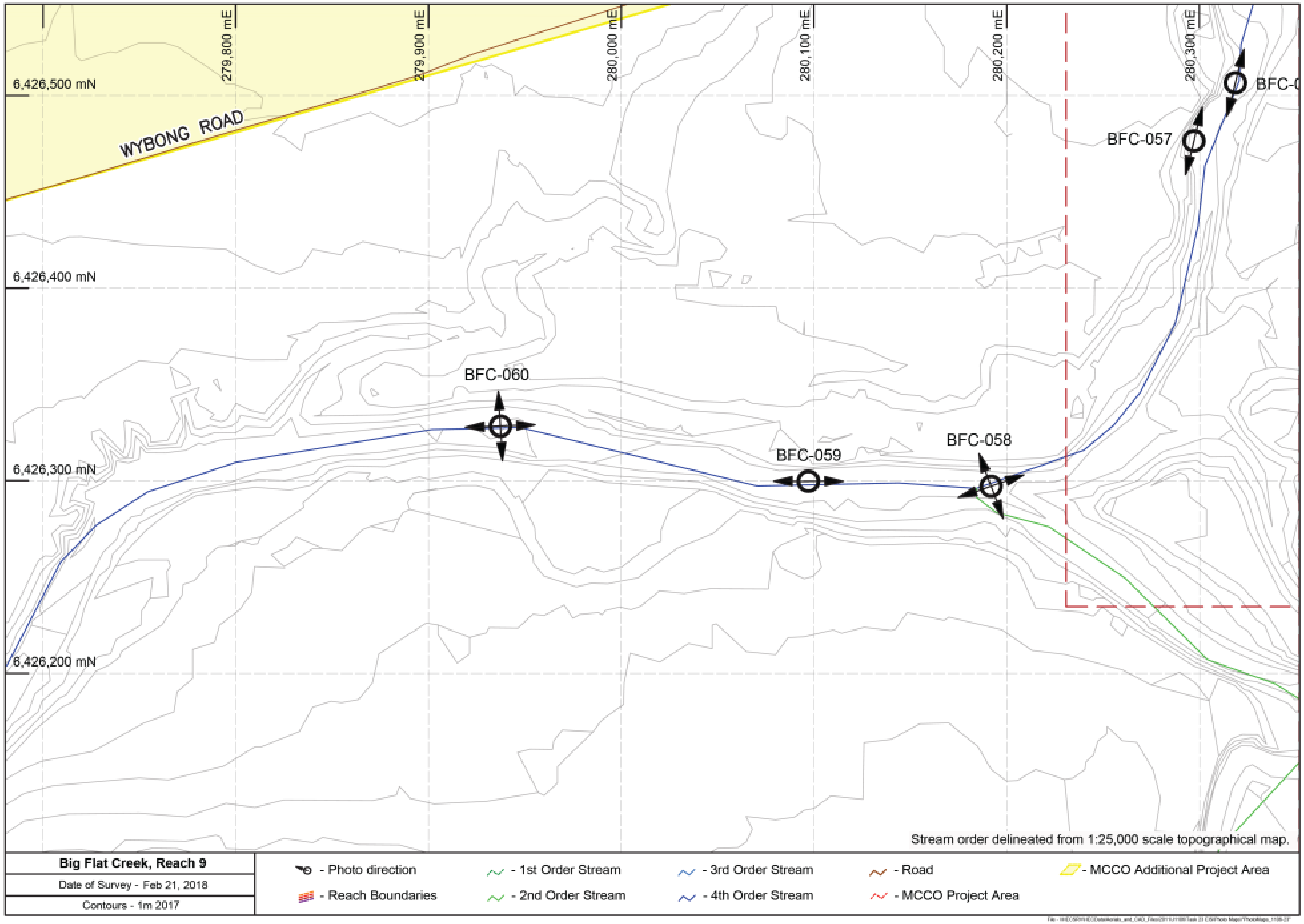
		
BFC-050 Upstream	**BFC-050 Downstream**	**BFC-051 Upstream**
		
BFC-051 Downstream	**BFC-051 Left Bank**	**BFC-051 Right Bank**
		
BFC-052 Upstream	**BFC-052 Downstream**	**BFC-053 Upstream**

		
BFC-053 Dowmstream	**BFC-054 Upstream**	**BFC-054 Downstream**
		
BFC-054 Left Bank	**BFC-054 Right Bank**	**BFC-055 Upstream**
		.2 
BFC-055 Downstream	**BFC-055 Left Bank**	**BFC-055 Right Bank**

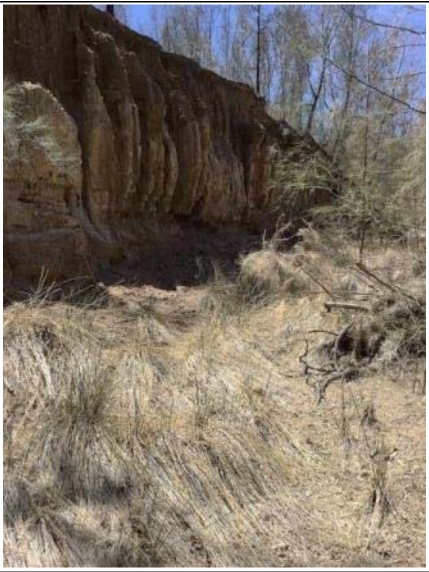
	
BFC-056 Upstream	**BFC-056 Downstream**

The upper section of this reach became more incised as the rock exposures became less pervasive. Further downstream the channel became deeply incised – with 2.5 to 4 m high banks. The banks comprised steep exposures of consolidated silts which have been prone to rilling and undercutting on the outside of the large bend in the lower part of the reach. The overbank areas supported a moderate density of *casuarina* sp. and *eucalypt* sp. with a mixture of native grasses and sedges as understory.

Reach BFC-9



279,800 mE
279,900 mE
280,000 mE
280,100 mE
280,200 mE
280,300 mE
6,426,500 mN
6,426,400 mN
6,426,300 mN
6,426,200 mN
WYBONG ROAD
BFC-060
BFC-059
BFC-058
BFC-057
Stream order delineated from 1:25,000 scale topographical map.
Big Flat Creek, Reach 9
Date of Survey - Feb 21, 2018
Contours - 1m 2017
- Photo direction
- Reach Boundaries
- 1st Order Stream
- 2nd Order Stream
- 3rd Order Stream
- 4th Order Stream
- Road
- MCCO Project Area
- MCCO Additional Project Area

		
BFC-057 Upstream	**BFC-057 Downstream**	**BFC-058 Upstream**
		
BFC-058 Downstream	**BFC-058 Left Bank**	**BFC-058 Right Bank**
		
BFC-059 Upstream	**BFC-059 Downstream**	**BFC-060 Upstream**

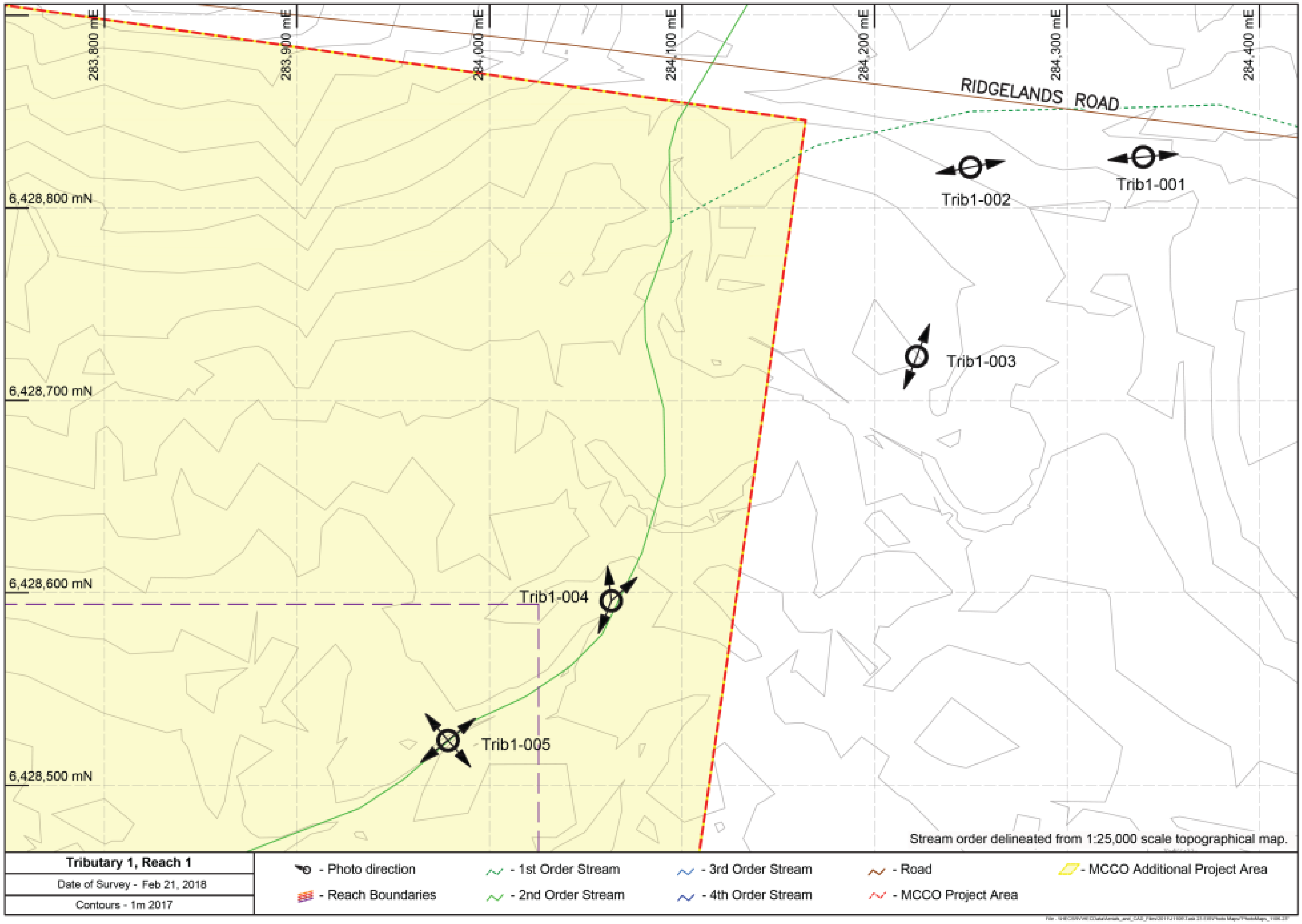
		
BFC-060 Dowmstream	**BFC-060 Left Bank**	**BFC-060 Right Bank**

The channel in this reach followed a relatively straight alignment. The channel profile transitioned from the deeply incised profile which dominated reach BFC-8 to a wide shallow braided form. The bed area appeared to be actively aggrading and comprised a mixture of sands and silts grading to coarse sand and gravel sized material. Vegetation comprised *casuarina* sp. with grass understorey.

TRIBUTARY 1

Tributary 1 is the most upstream tributary on Big Flat Creek flowing generally north-east to south-west and has been divided into four reach maps.

Reach Trib1-1



Trib1-001 Upstream

Trib1-001 Downstream

Trib1-002 Upstream

Trib1-002 Downstream

Trib1-003 Upstream

Trib1-003 Downstream

Trib1-004 Upstream Pan Left

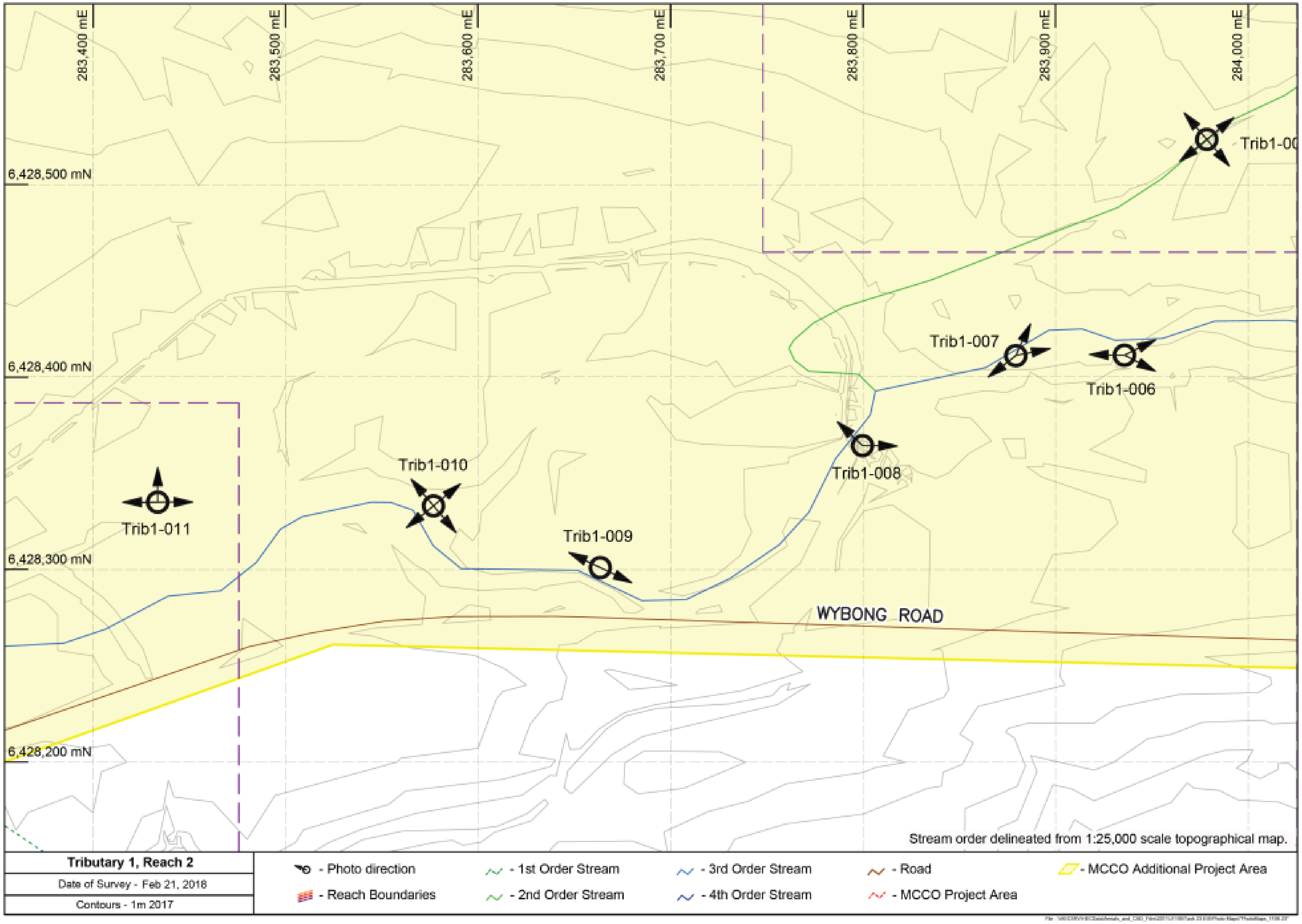
Trib1-004 Upstream Pan Right

Trib1-004 Downstream

		
Trib1-005 Upstream	**Trib1-005 Downstream**	**Trib1-005 Left Bank**
		
Trib1-005 Right Bank		

In the upper part of this reach the Tributary 1 stream comprises a shallow ill-defined depression. The flow path is crossed by Ridgelands Road as an at-grade crossing. A farm dam has been constructed over the tributary some 350 m downstream of the road redirecting the flow. The channel downstream of the dam was actively down-cutting forming a defined channel with defined bed and bank profile. There was a sparse grass cover over the bed and bank with some scattered *eucalypt* sp. on overbank areas.

Reach Trib1-2



<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>Trib1-006 Upstream Pan Left</td><td>Trib1-006 Upstream Pan Right</td><td>Trib1-006 Downstream</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Trib1-007 Upstream Pan Left</td><td>Trib1-007 Upstream Pan Right</td><td>Trib1-007 Downstream</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Trib1-008 North-West</td><td>Trib1-008 East</td><td>Trib1-009 Upstream</td></tr>
</table>

Trib1-009 Downstream

Trib1-010 Upstream

Trib1-010 Downstream

Trib1-010 Left Bank

Trib1-010 Right Bank

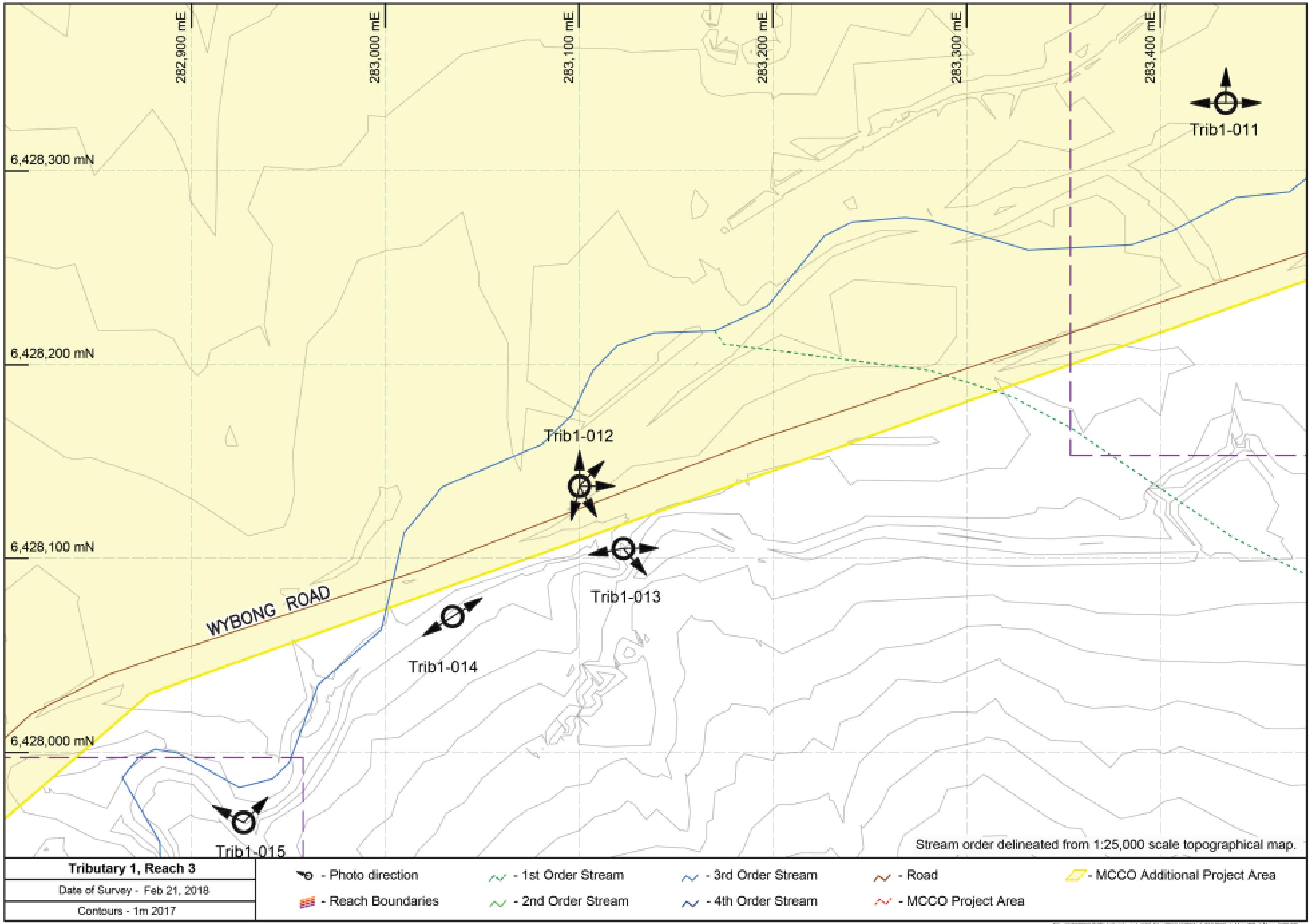
Trib1-011 Upstream Pan Left

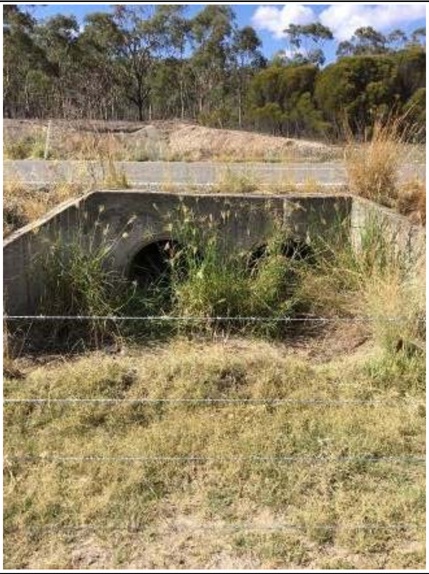
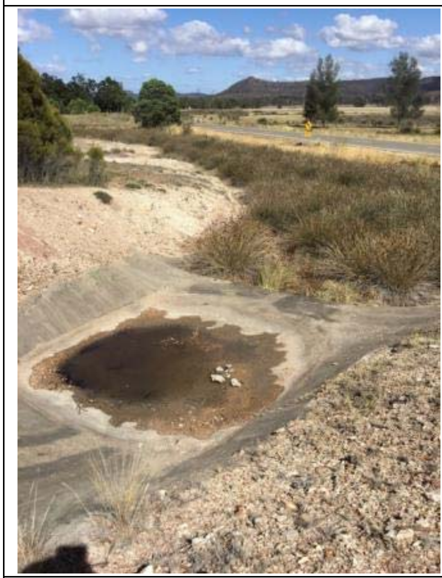
Trib1-011 Upstream Pan Right

Trib1-011 Downstream

There was a small farm dam near the upper part of Trib1-2 reach. Downstream the flow path comprised a shallow swale with several local depressions. Vegetation in these upper portions comprised sparse grass cover. Another larger on-stream farm dam was located in the lower part of the reach (refer photos “Trib-008”). The farm dam appeared to be up to 2 m deep and was fringed by aquatic reeds. Further downstream the channel became less distinct as it flowed across a wide, plain of denuded grass with isolated common rush. A straight channel appears to have been excavated across the lower section of the reach (refer photo “Trib1-011 Downstream”) presumably to direct flow toward the culverts under Wybong Road. The constructed drain comprised a wide trapezoidal shaped channel with bare bed and banks. It was actively down-cutting and the banks had slumped in places.

Reach Trib1-3

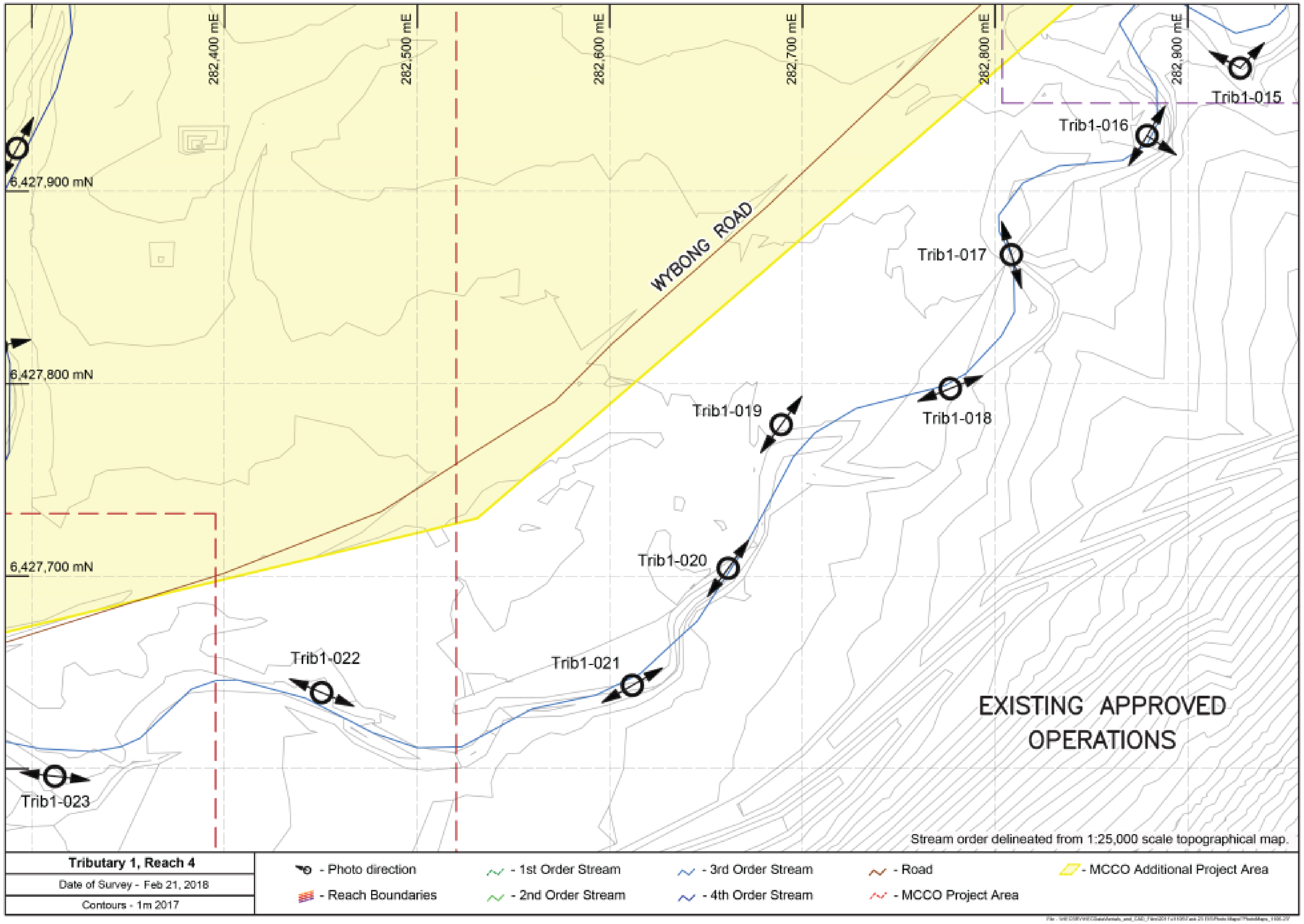


		
Trib1-012 Upstream Pan Left	**Trib1-012 Upstream Pan Mid**	**Trib1-012 Upstream Pan Right**
		
Trib1-012 Downstream Pan Left	**Trib1-012 Downstream Pan Right**	**Trib1-013 Upstream**
		
Trib1-013 Downstream	**Trib1-013 Left Bank**	**Trib1-014 Upstream**

		
Trib1-014 Downstream	**Trib1-015 Upstream**	**Trib1-015 Downstream**

Wybong Road crossed Tributary 1 mid-way through this reach (refer photo "Trib1-012"). The crossing comprised two concrete pipe culverts, partially blocked by sediment. Downstream of the road crossing Tributary 1 traversed a flat plain via an ill-defined swale channel form. A farm dam with a concrete lined spillway and energy dissipator had been constructed on a small tributary upstream of Tributary 1 just downstream of the Wybong Road crossing (refer photos "Trib1-013"). Downstream of this small tributary inflow, Tributary 1 followed a large diameter, left hand bend. The banks comprised bare eroded dispersive silts. The bed appears to be aggrading and supported a dense cover of common rush.

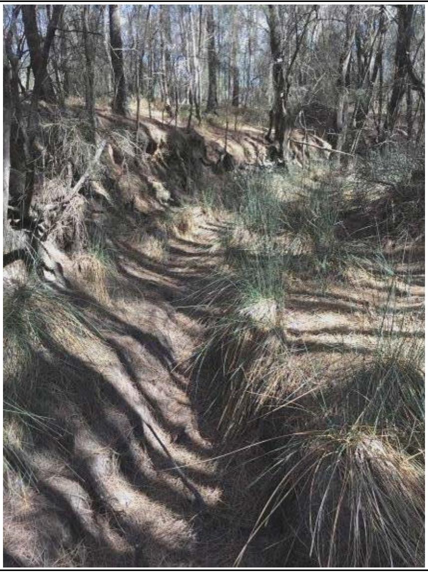
Reach Trib1-4



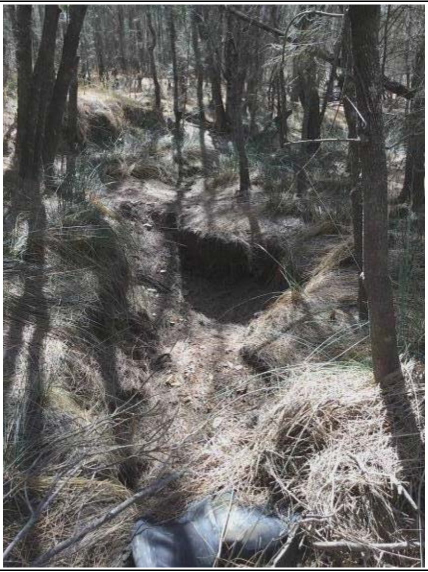
Trib1-016 Upstream

Trib1-016 Downstream

Trib1-016 Left Bank



Trib1-017 Upstream



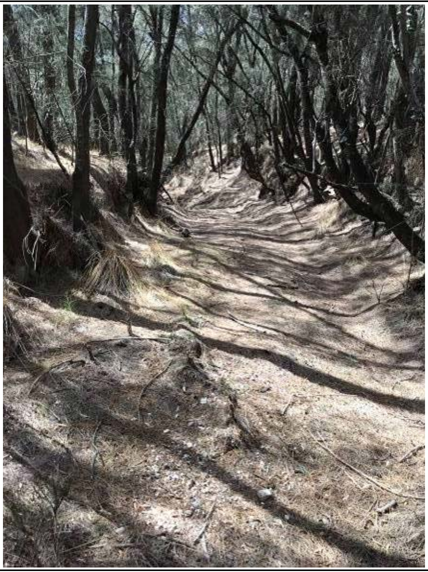
Trib1-017 Downstream

Trib1-018 Upstream

Trib1-018 Downstream

Trib1-019 Upstream

Trib1-019 Downstream

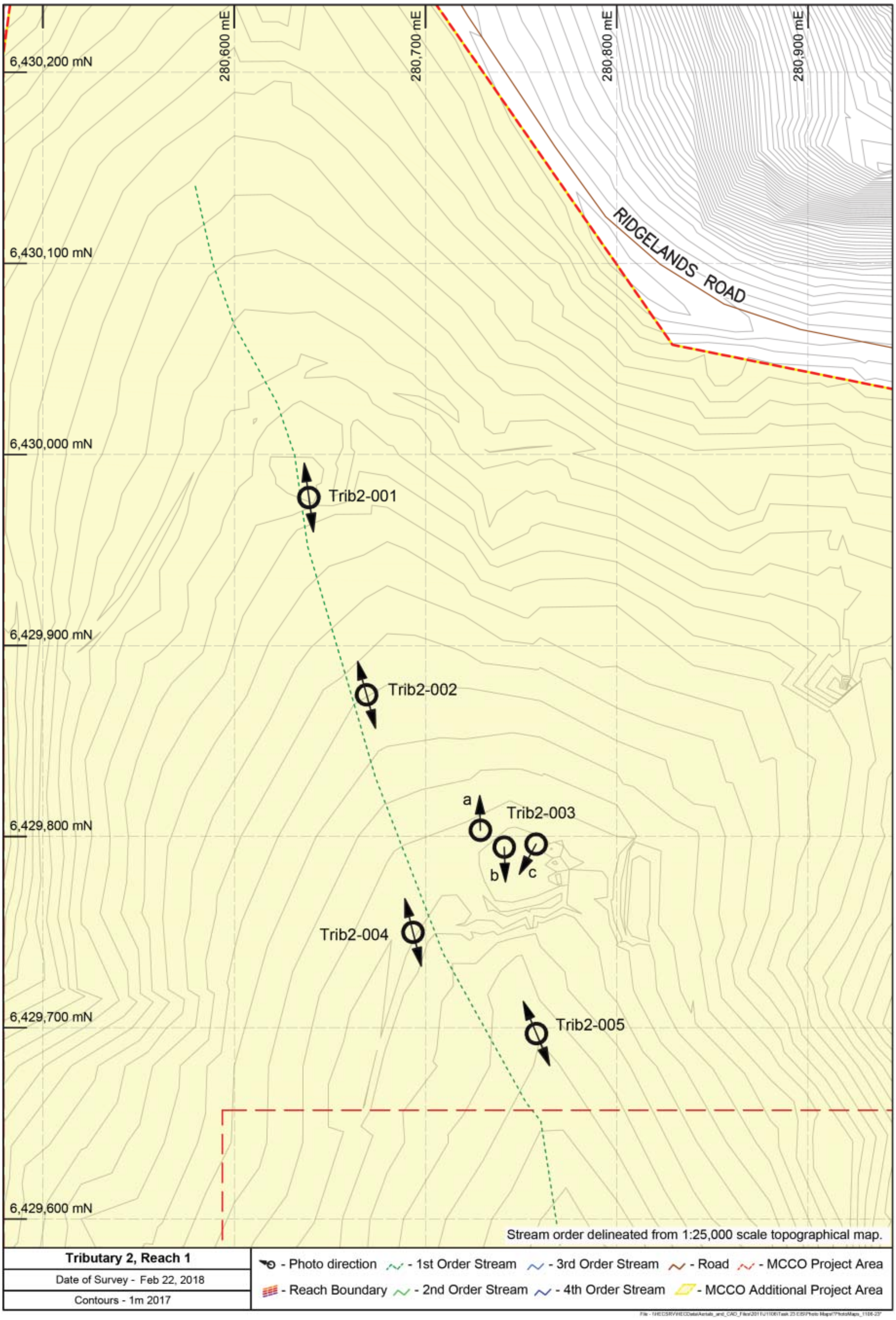
		
Trib1-020 Upstream	**Trib1-020 Downstream**	**Trib1-021 Upstream**
		
Trib1-021 Downstream	**Trib1-022 Upstream**	**Trib1-022 Downstream**
		
Trib1-023 Upstream	**Trib1-023 Downstream**	

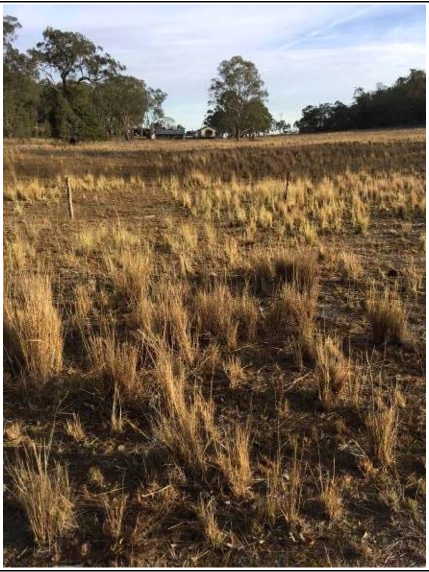
Trib1-4 comprises the reach immediately upstream of the confluence with Big Flat Creek. Trib1-4 generally comprised a well-defined, incised alluvial channel. The bed and banks supported a dense tree cover (predominantly *casuarina* sp.). The bed contained a series of erosion scours some of which supported semi-permanent pools.

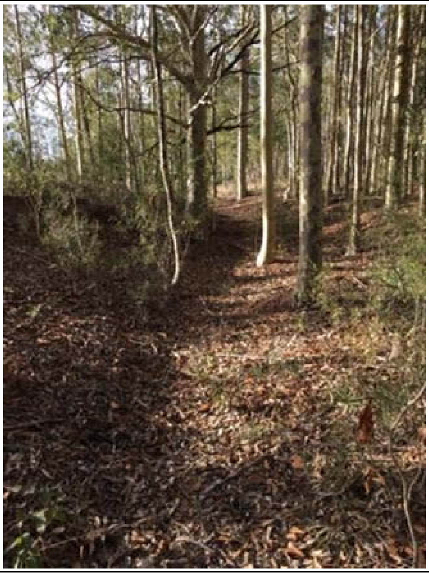
TRIBUTARY 2

Tributary 2 traverses the middle of the MCCO Additional Project Area flowing north to south and joins Tributary 3 in Reach Trib2-5 before joining Big Flat Creek further downstream.

Reach Trib2-1

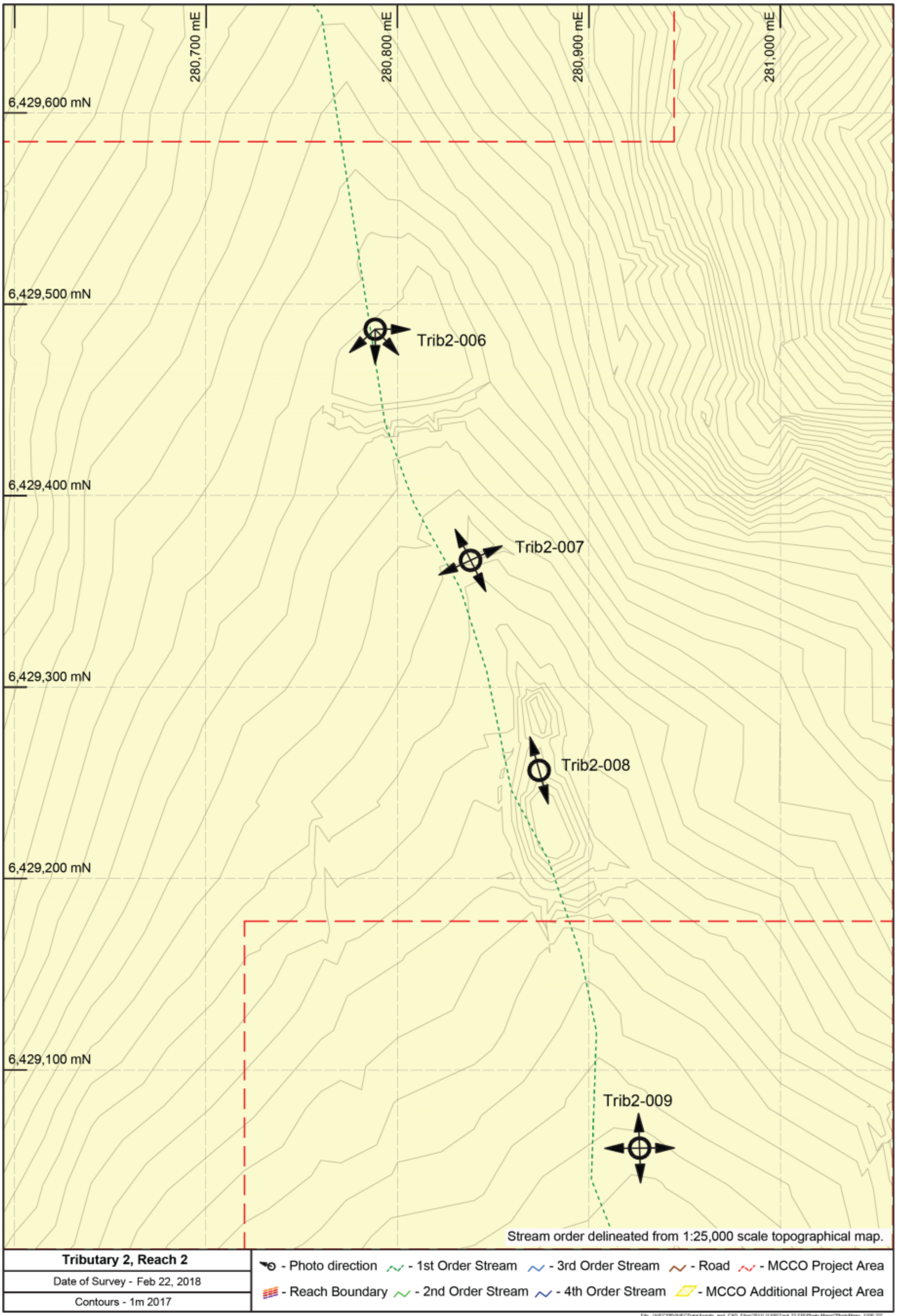


		
Trib2-001 Upstream	**Trib2-001 Downstream**	**Trib2-002 Upstream**
		
Trib2-002 Downstream	**Trib2-003a Upstream**	**Trib2-003b Downstream**
		
Trib2-003c Downstream	**Trib2-004 Upstream**	**Trib2-004 Downstream**

	
Trib2-005 Upstream	**Trib2-005 Downstream**

The upper inspected reaches of Tributary 2 comprised a small first order stream. The channel comprised a small swale which followed a relatively straight alignment. Vegetation in the upper reaches comprised grass with isolated trees. A farm dam had been constructed over the creek in the middle of the reach (refer photos “Trib2-003”). The drainage path downstream of the dam comprised a small, shallow channel. Vegetation comprised a sparse grass cover with a discontinuous cover of *eucalypt* sp. sapling regrowth.

Reach Trib2-2

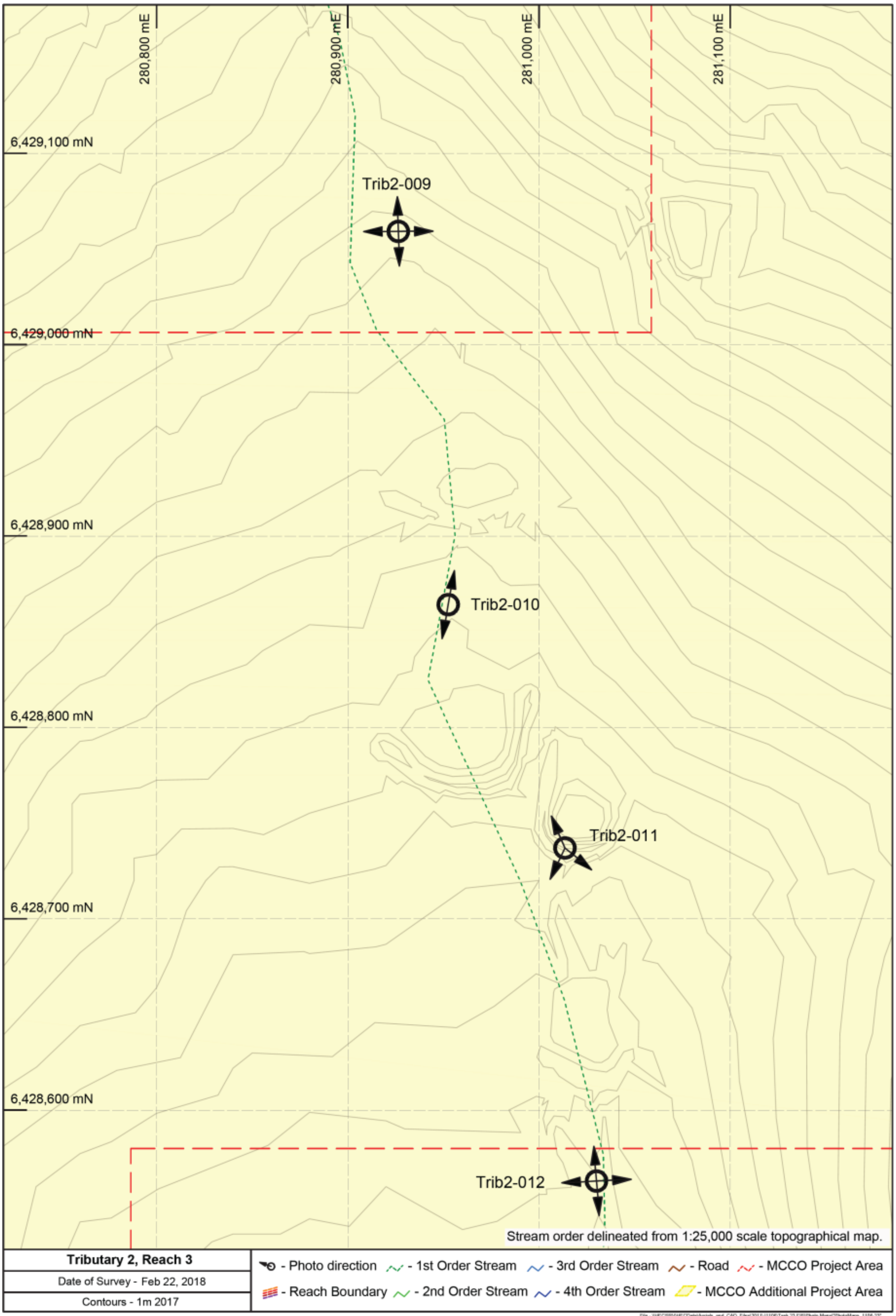


		
Trib2-006 Downstream Pan 1	**Trib2-006 Downstream Pan 2**	**Trib2-006 Downstream Pan 3**
		
Trib2-006 Downstream Pan 4	**Trib2-007 Upstream**	**Trib2-007 Downstream**
		
Trib2-007 Left Bank	**Trib2-007 Right Bank**	**Trib2-008 Upstream**

Trib2-008 Downstream

Reach Trib2-2 contained two moderately sized, on-stream farm dams (refer photos “Trib2-006” and “Trib2-008”). Overflow channels linking the dams comprised well defined, shallow swale like channels. The bed and banks of these channels supported grass and isolated regrowth trees (predominantly *eucalypt* sp.).

Reach Trib2-3




Trib2-009 Upstream


Trib2-009 Downstream


Trib2-009 Left Bank


Trib2-009 Right Bank


Trib2-010 Upstream


Trib2-010 Downstream


Trib2-011 Upstream

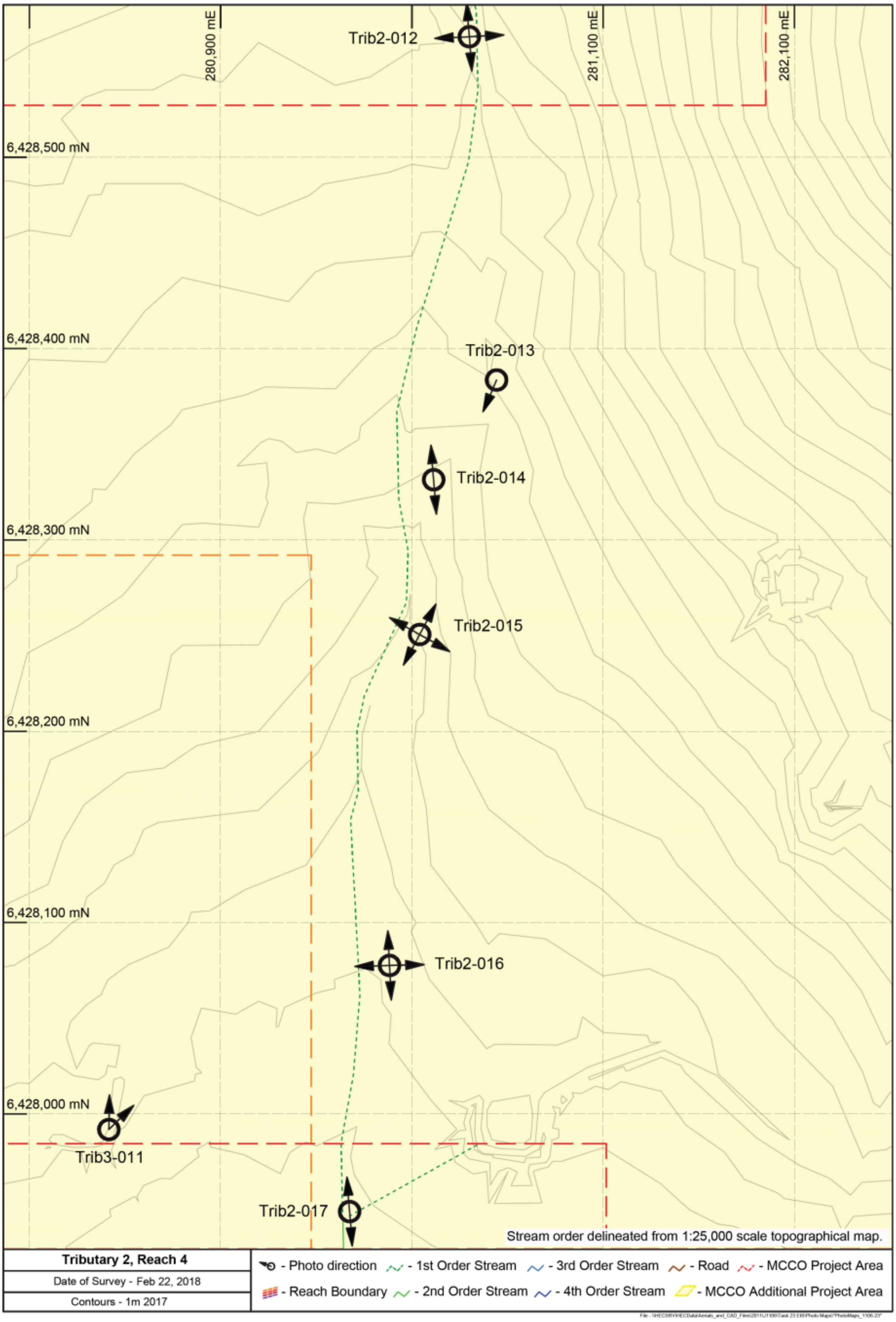

Trib2-011 Downstream Pan Left

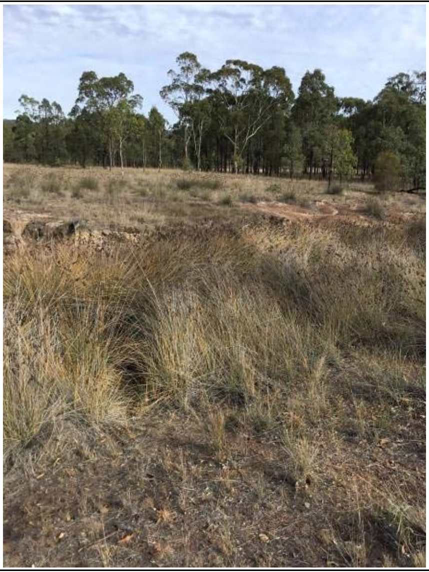

Trib2-011 Downstream Pan Right

		
Trib2-012 Upstream	**Trib2-012 Downstream**	**Trib2-012 Left Bank**
		
Trib2-012 Right Bank		

In the upper portions of this reach, Tributary 2 flowed through a cleared, open pasture paddock of denuded grass via a shallow swale. Reach Trib2-3 contained two farm dams. The drainage path leading into the upper dam comprised a shallow swale. Vegetation comprised a sparse grass cover. The farm dam downstream supported a fringe of reeds around the edge of the ponded water suggesting ponded water was semi-permanent. The flow path below the dam comprised a wide shallow channel with defined banks. The overbanks supported a grass cover whilst the bed supported a dense cover of common rush.

Reach Trib2-4

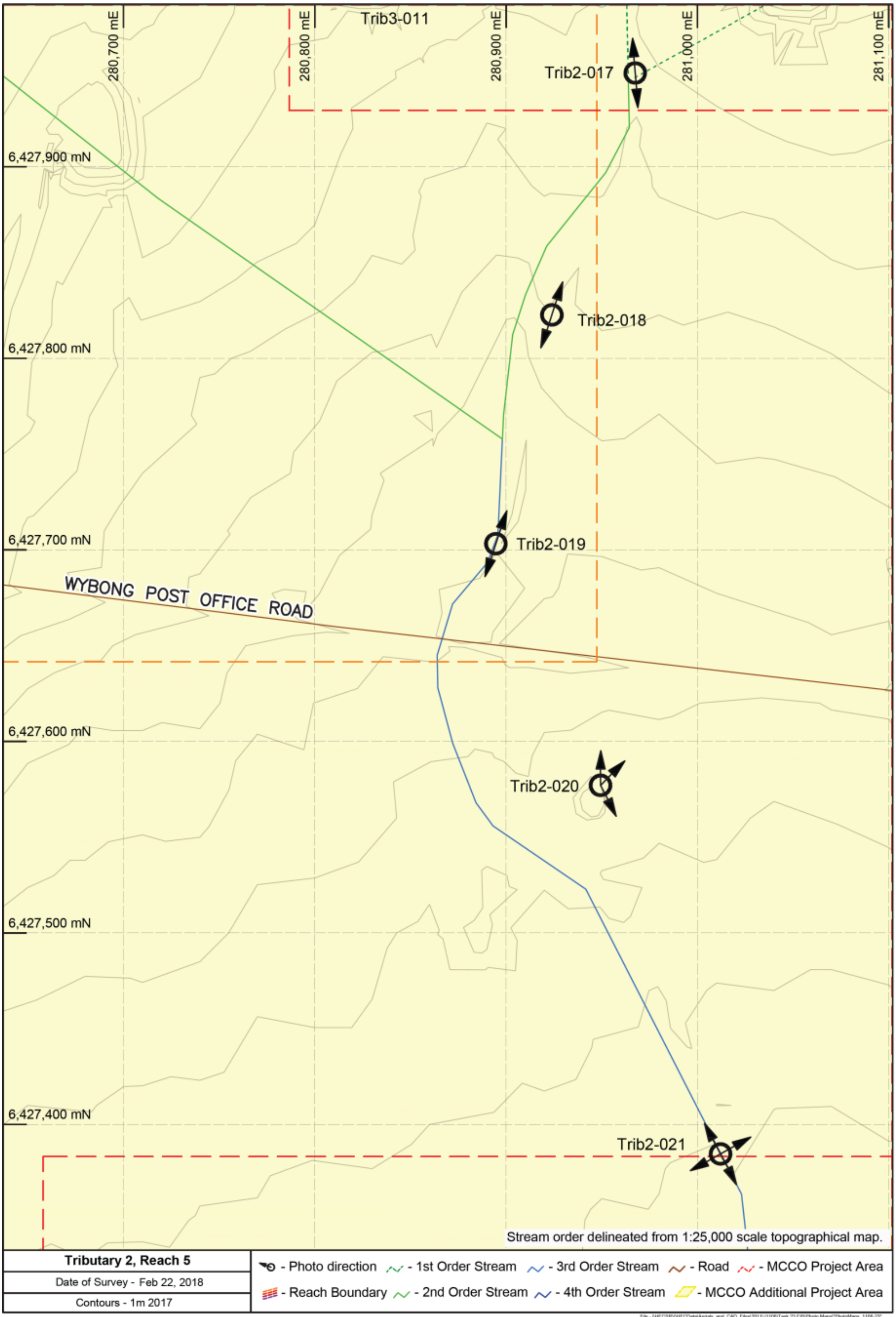


		
Trib2-013 Downstream	**Trib2-014 Upstream**	**Trib2-014 Downstream**
		
Trib2-015 Upstream	**Trib2-015 Downstream**	**Trib2-015 Left Bank**
		
Trib2-015 Right Bank	**Trib2-016 Upstream**	**Trib2-016 Downstream**

	
Trib2-016 Left Bank	**Trib2-016 Right Bank**

The upper section of Trib2-4 comprised a similar grass covered shallow swale as was observed in Trib2-3 upstream. An active knick-point and associated bed downcutting was observed near the start of the reach (refer photo “Trib2-013 Downstream”). The stream downstream of that point comprised a more incised channel with continuous defined bed and banks. The overbank areas supported pasture grasses and isolated tress. The banks were generally bare, with intense active rilling. The bed supported a mixture and pasture and reeds.

Reach Trib2-5



Trib2-017 Upstream

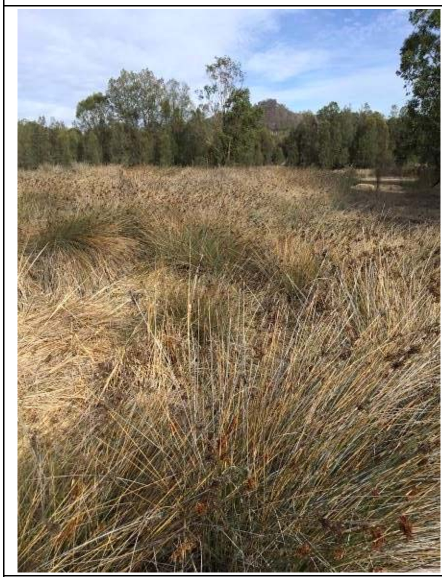
Trib2-017 Downstream

Trib2-018 Upstream

Trib2-018 Downstream

Trib2-019 Upstream

Trib2-019 Downstream



Trib2-020 Upstream Pan Left

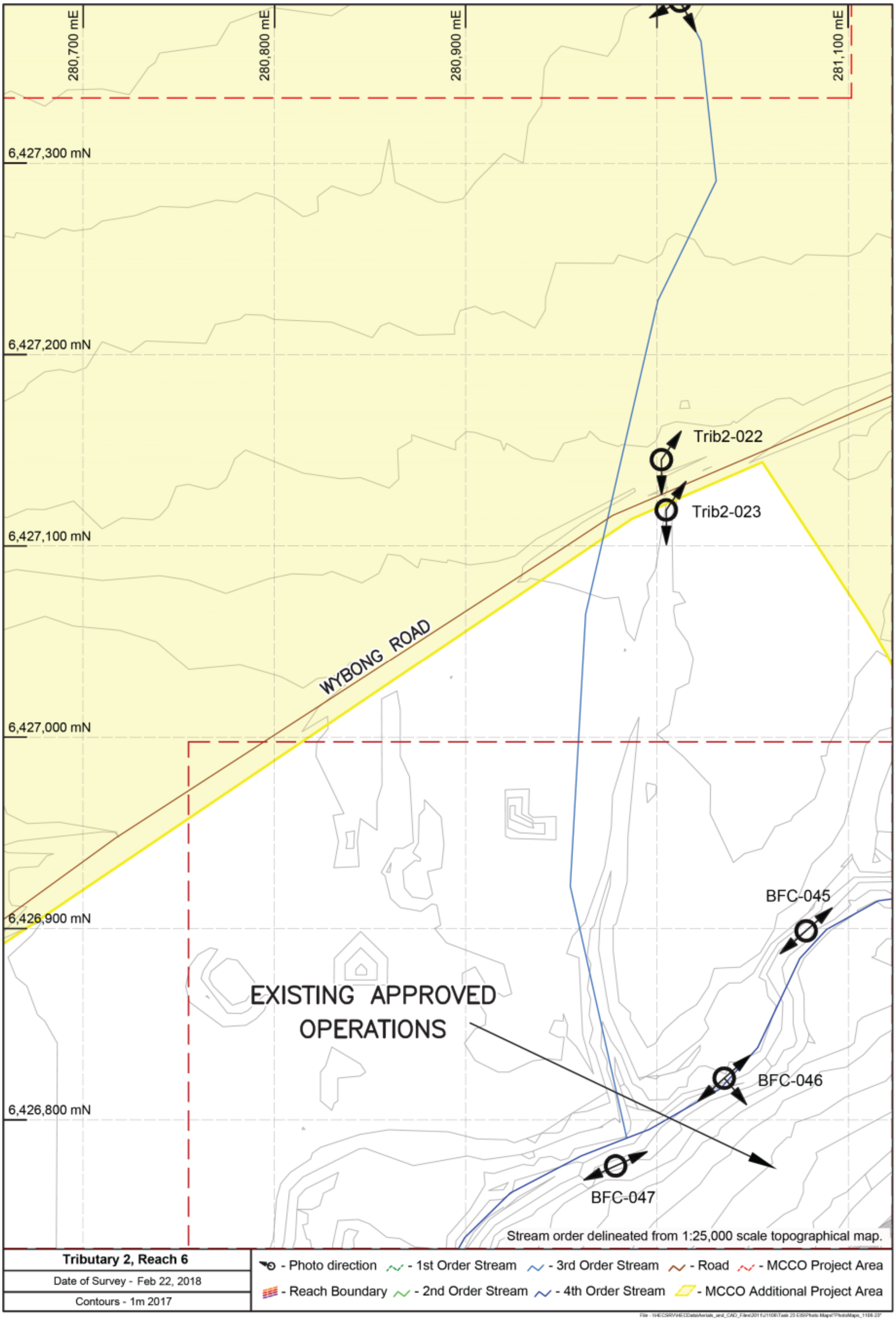
Trib2-020 Upstream Pan Right

Trib2-020 Downstream

		
Trib2-021 Upstream	**Trib2-021 Downstream**	**Trib2-021 Left Bank**
		
Trib2-021 Right Bank		

The upper parts of Trib2-5 comprised a similar channel profile to that observed in the lower parts of Trib2-4. The banks and overbank areas supported a moderate cover of trees (predominantly *casuarina* sp.) and denuded pasture. Toward the lower portion of this reach the channel transitioned back to a wide ill-defined shallow swale (refer photo “Trib2-021 Downstream”).

Reach Trib2-6



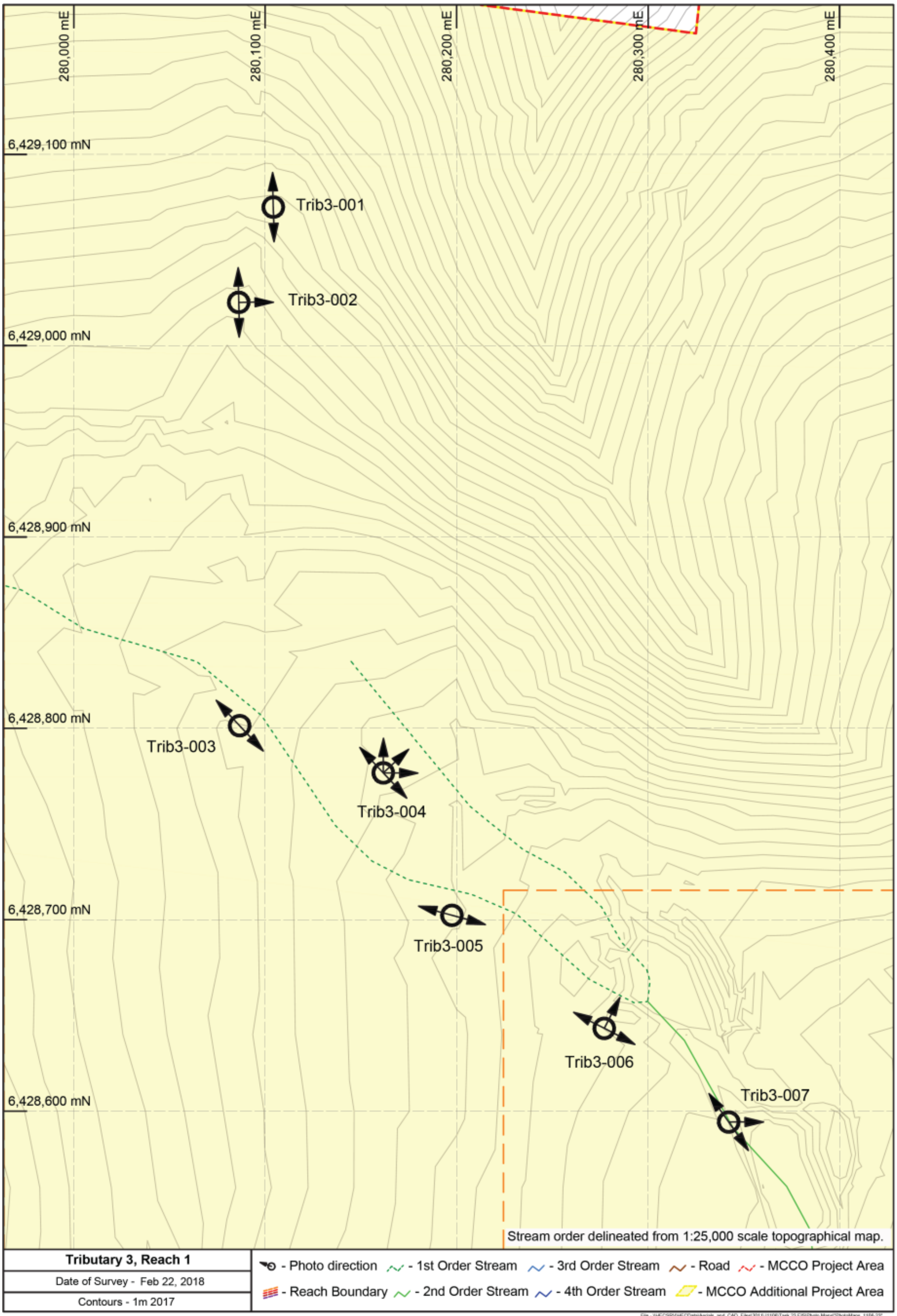
		
Trib2-022 Upstream	**Trib2-022 Downstream**	**Trib2-023 Upstream**
		
Trib2-023 Downstream		

Trib2-6 comprises the reach immediately upstream of the confluence with Big Flat Creek. The drainage path in the upper section of the reach flowed across a gently sloping, open plain supporting denuded pastures. The drainage path comprised a shallow swale. Wybong Road crossed Tributary 2 near the middle of the reach via a conventional pipe culvert crossing. The channel downstream of the crossing comprised a moderately incised channel with defined bed and banks. Overbank areas supported a moderately dense cover of immature *casuarina* sp. trees.

TRIBUTARY 3

Tributary 3 traverses the middle of the Additional Project Area generally flowing north-west to south-east and joins Tributary 2.

Reach Trib3-1



		
Trib3-001 Upstream	**Trib3-001 Downstream**	**Trib3-002 Upstream**
		
Trib3-002 Downstream	**Trib3-002 Left Bank**	**Trib3-003 Upstream**
		
Trib3-003 Downstream	**Trib3-004 Upstream Pan Left**	**Trib3-004 Upstream Pan Right**


Trib3-004 Downstream Pan Left


Trib3-004 Downstream Pan Right


Trib3-004 Left Bank


Trib3-005 Upstream


Trib3-005 Downstream

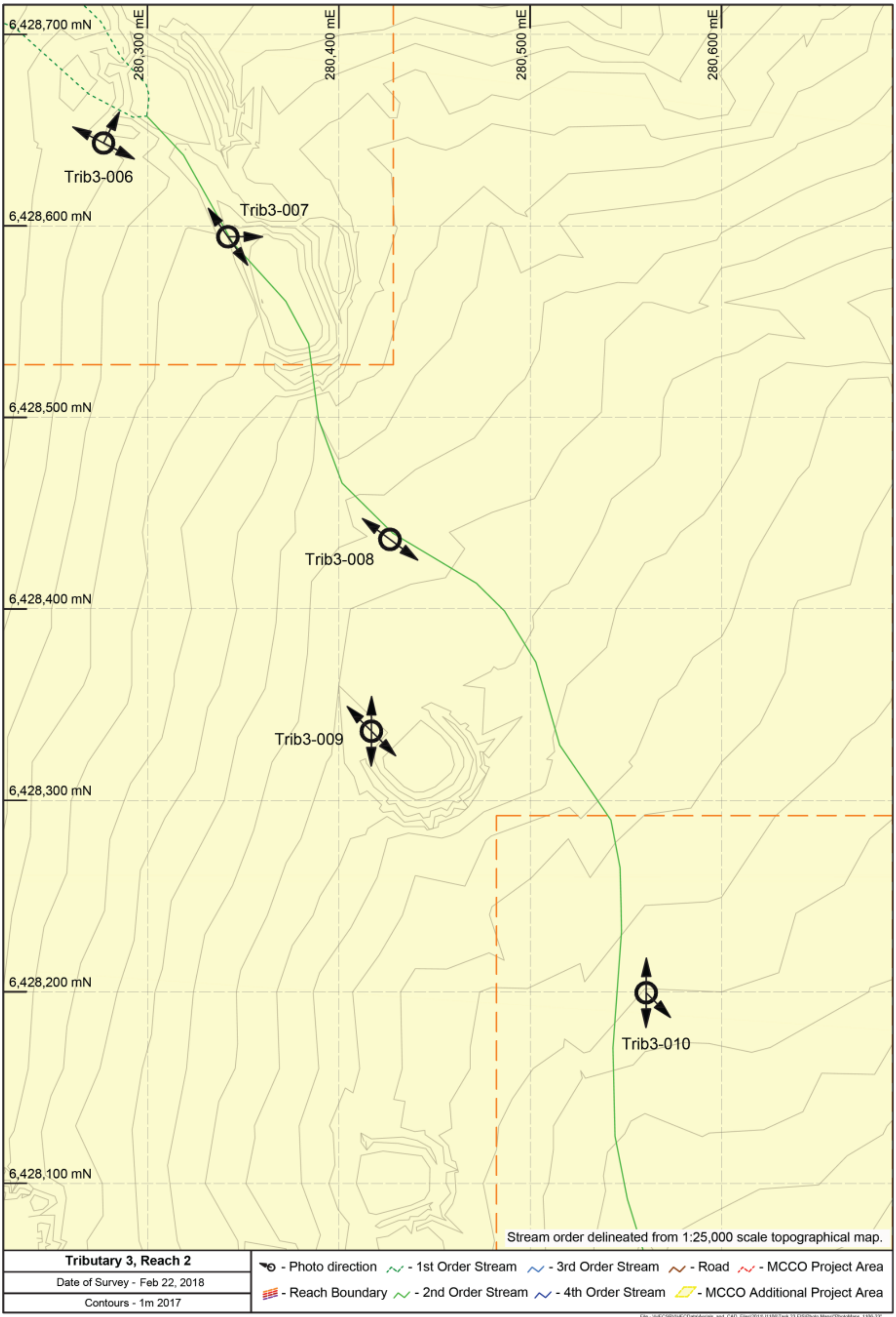

Trib3-006 Upstream


Trib3-006 Downstream


Trib3-006 Left Bank

A deep, headward migrating knick-point was observed in the bed of Tributary 3 near the top of this reach. The stream upstream of this point comprised an ill-defined depression. The stream downstream comprised a series of eroded (actively down-cutting gully form) sections separated by a wide, open swale form channel in flatter parts of the reach. Vegetation comprised denuded pasture with isolated stands of mostly immature, regrowth trees (predominantly *eucalypt* sp.).

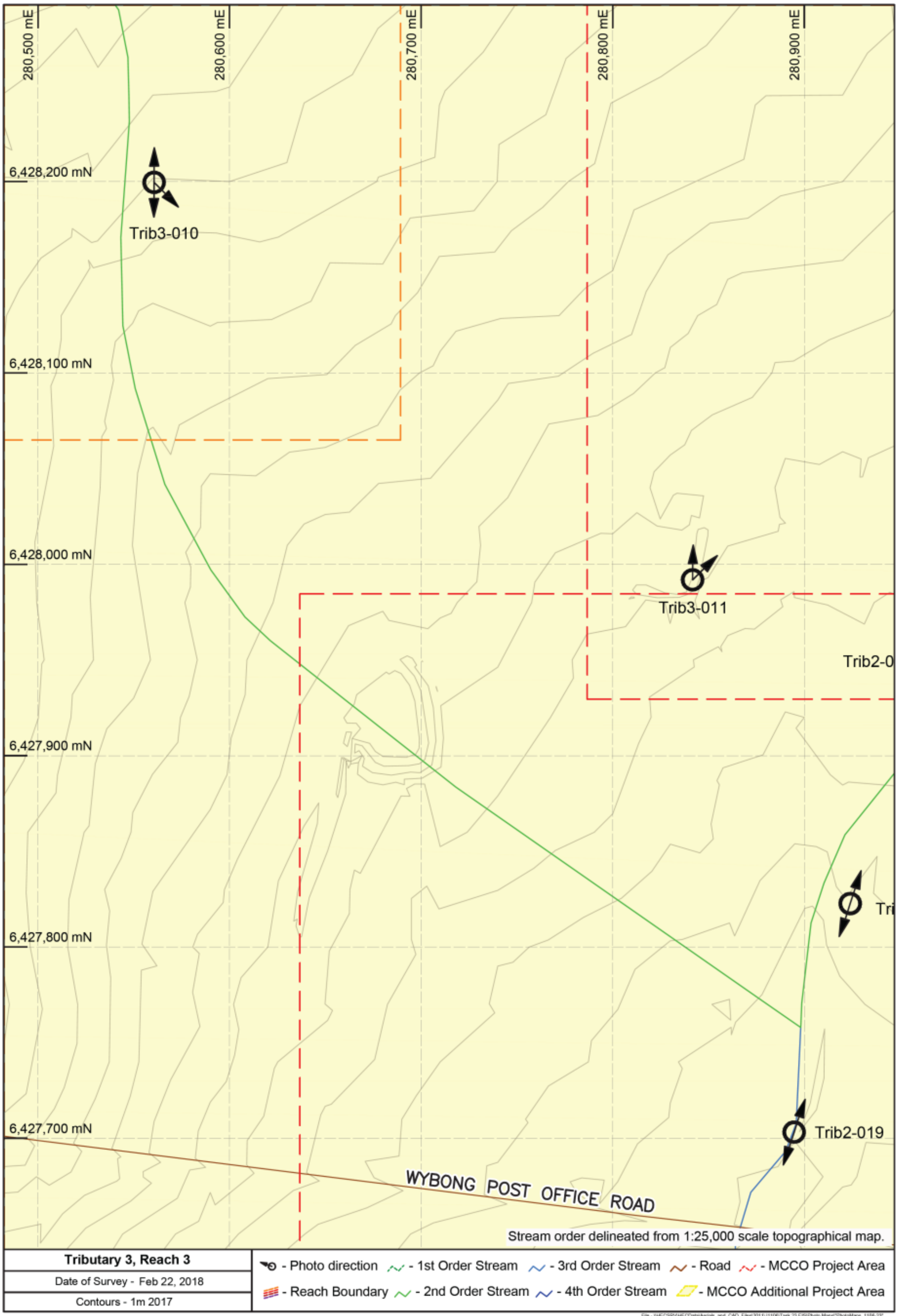
Reach Trib3-2



		
Trib3-007 Upstream	**Trib3-007 Downstream**	**Trib3-007 Left Bank**
		
Trib3-008 Upstream	**Trib3-008 Downstream**	**Trib3-009 Upstream Pan Left**
		
Trib3-009 Upstream Pan Right	**Trib3-009 Downstream Pan Left**	**Trib3-009 Downstream Pan Right**

A relatively large farm dam had been constructed across the upper part of Trib3-2 (refer photo “Trib3-007 Downstream”). The farm dam was dry. The dam overflow channel comprised a small, bare ‘V’ shaped channel. Another relatively large farm dam had been constructed across the stream further downstream (refer photos “Trib3-009 Downstream”). This dam contained a shallow pool which appeared to be a semi-permanent feature given the presence of fringing reed vegetation.

Reach Trib3-3



		
Trib3-010 Upstream	**Trib3-010 Downstream Pan Left**	**Trib3-010 Downstream Pan Right**
		
Trib3-011 Upstream Pan Left	**Trib3-011 Upstream Pan Right**	

Trib3-3 comprises the reach immediately upstream of the confluence with Tributary 2. In the upper portion of this reach, Tributary 3 flowed across a relatively flat plain of denuded pasture. The drainage path in this section comprised a series of ill-defined depressions and minor swales. The main feature in the reach was a relatively large farm dam which contained a semi-permanent pool (refer photos “Trib3-011 Upstream”). Vegetation along the channel downstream comprised denuded pastures and isolated regrowth (predominately *eucalypt* sp.).

APPENDIX B
Flood Modelling Results Maps

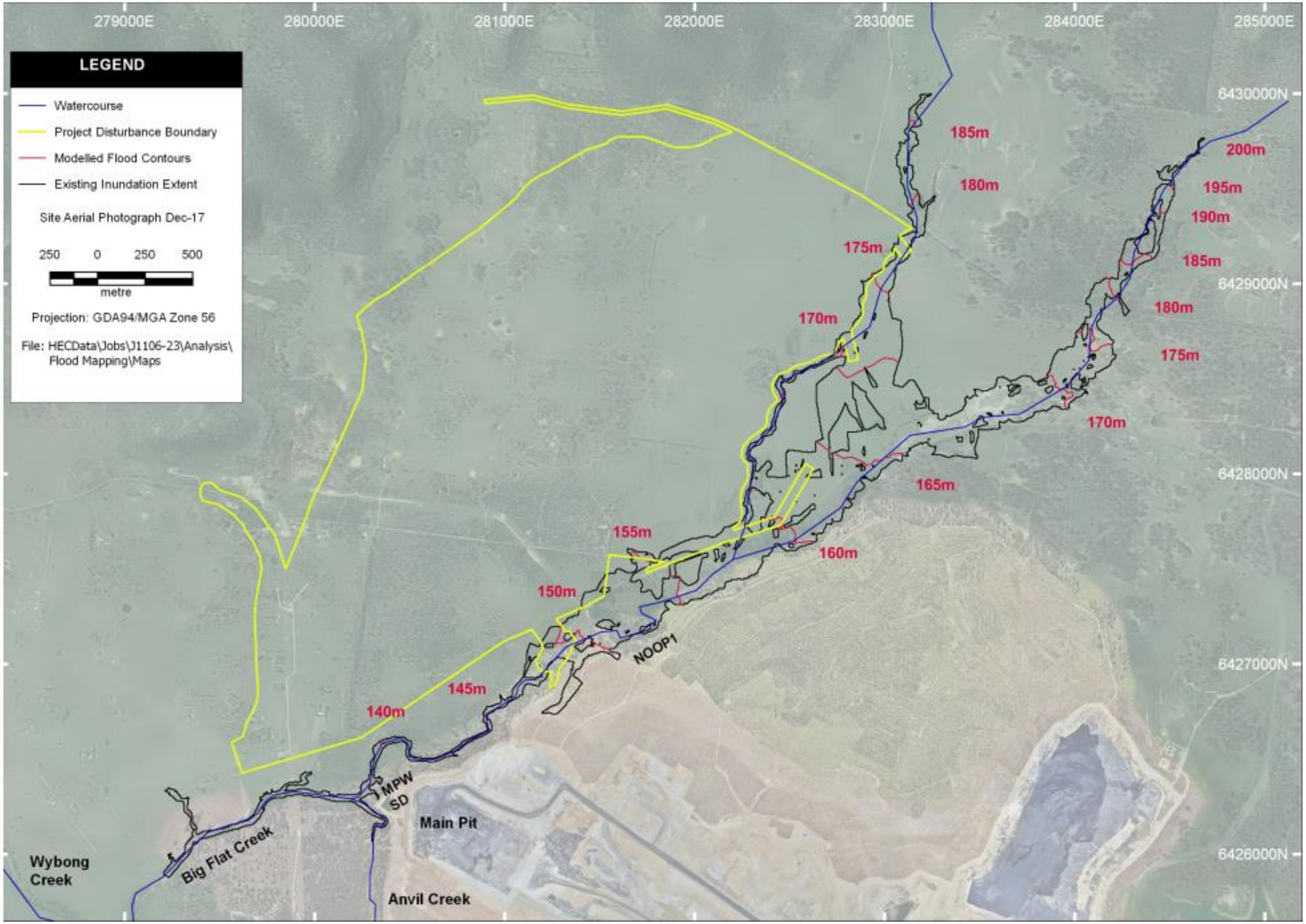


Figure B-1 Predicted Existing Flood Levels (mAHD) and Flooding Extent – 1:10 AEP

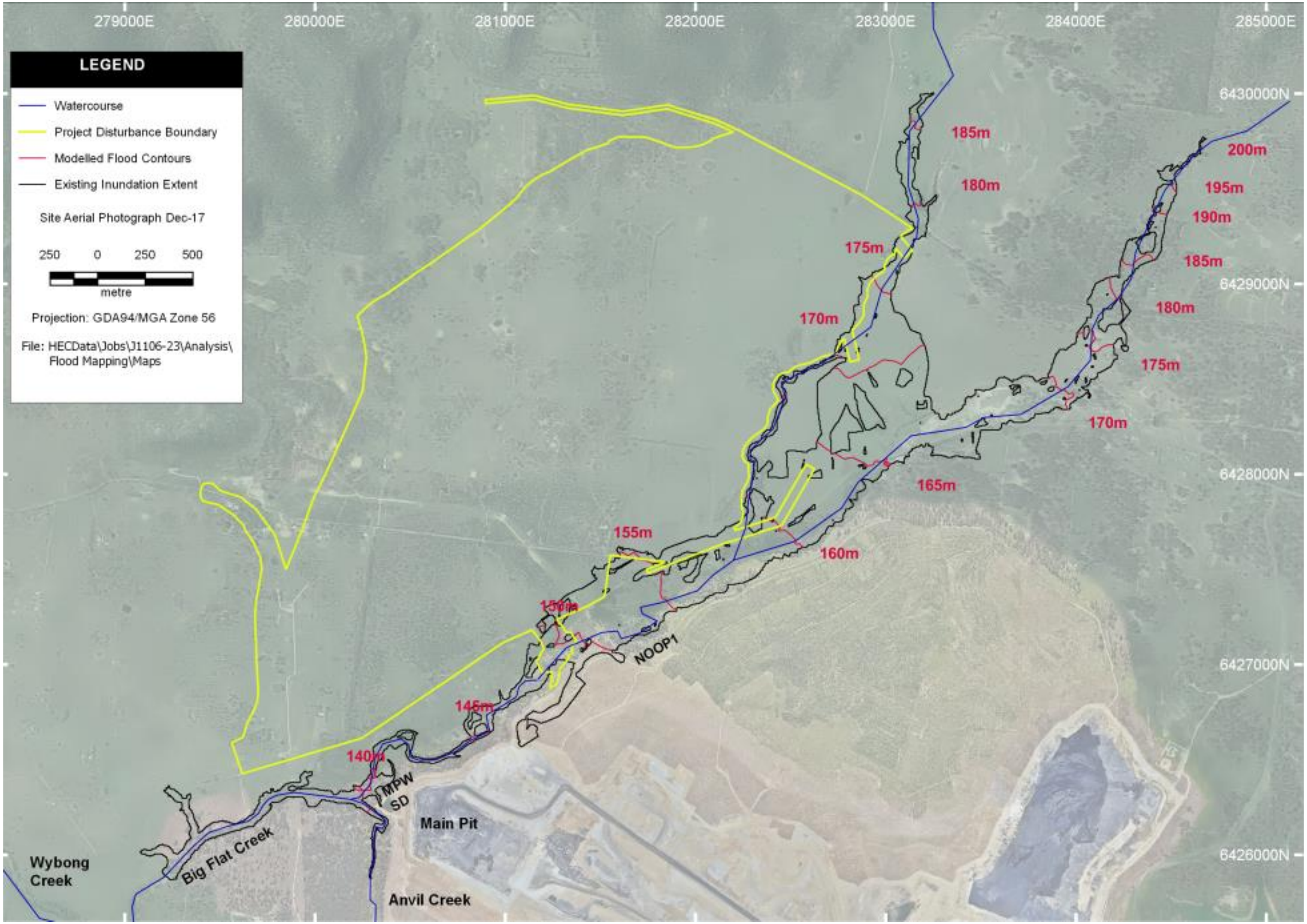


Figure B-2 Predicted Existing Flood Levels (mAHD) and Flooding Extent – 1:200 AEP

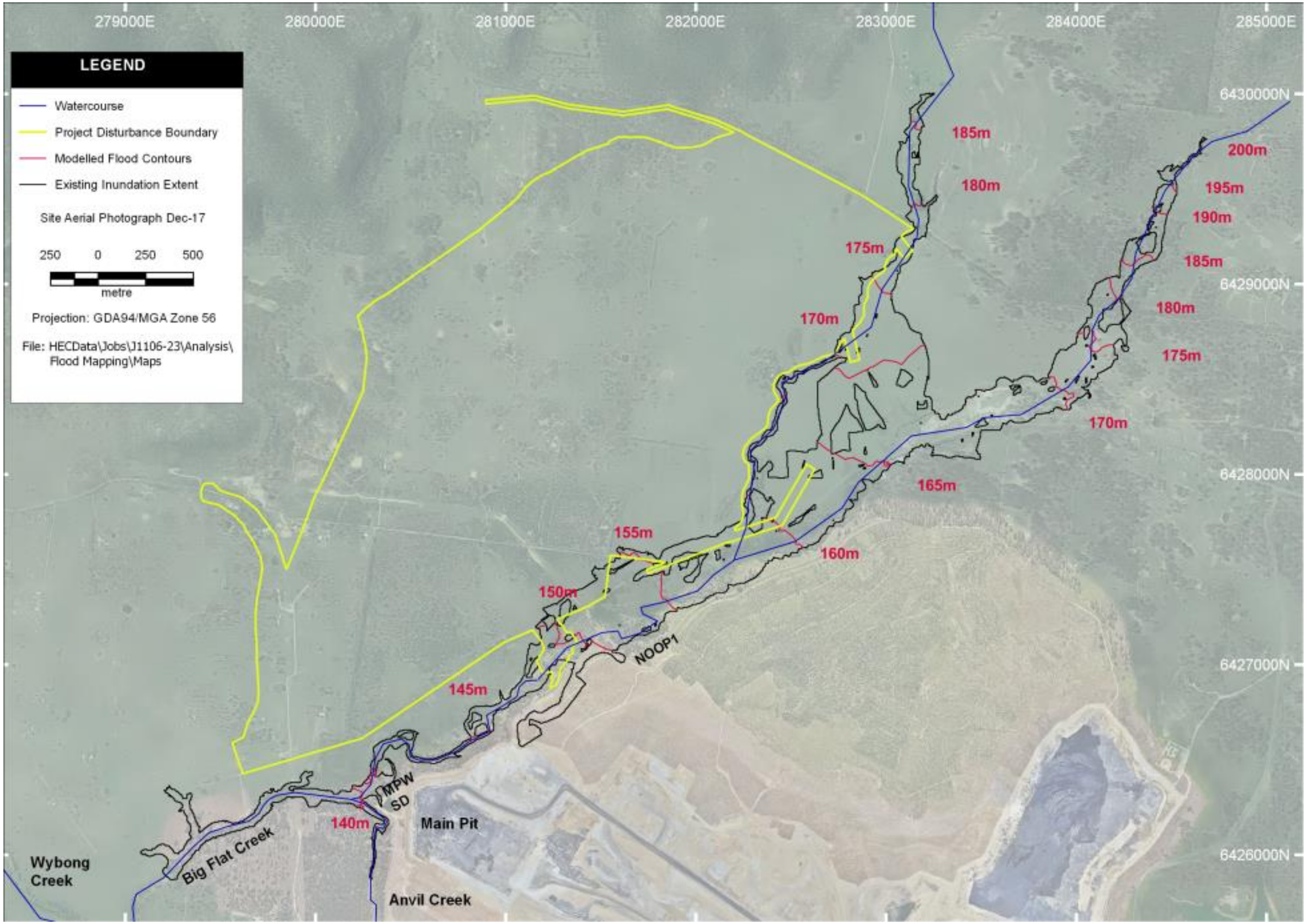


Figure B-3 Predicted Existing Flood Levels (mAHD) and Flooding Extent – 1:250 AEP

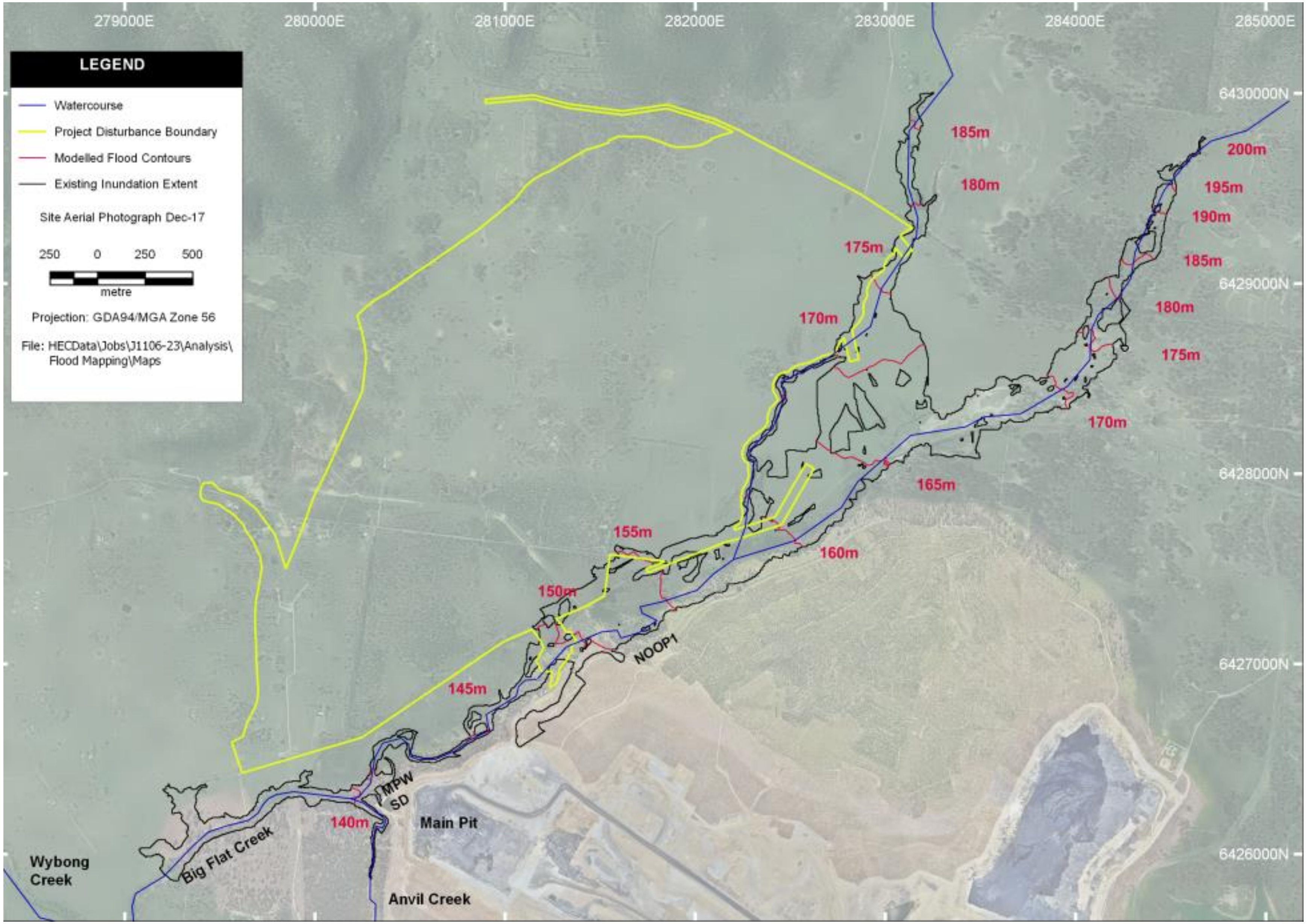


Figure B-4 Predicted Existing Flood Levels (mAHD) and Flooding Extent – 1:500 AEP

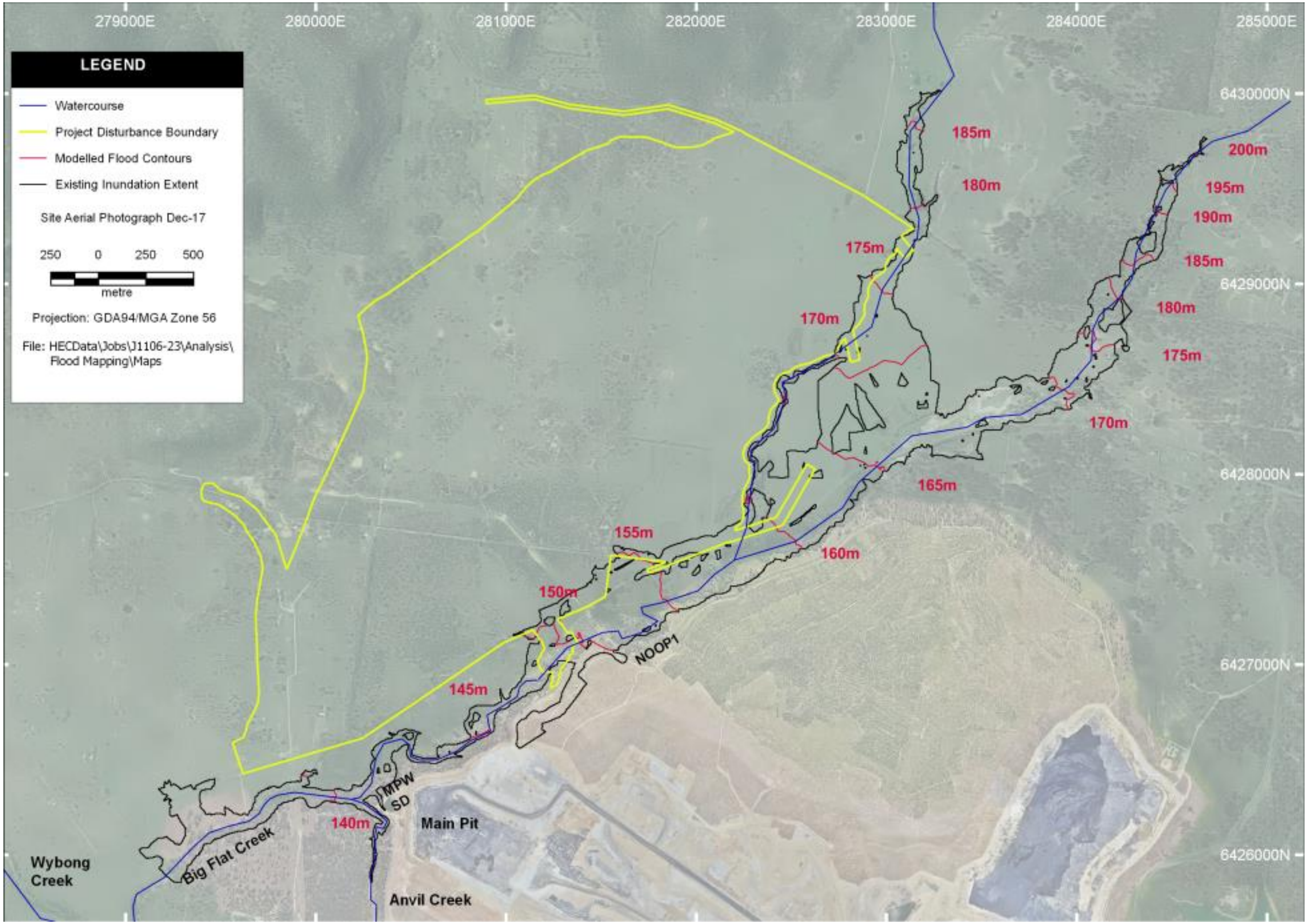


Figure B-5 Predicted Existing Flood Levels (mAHD) and Flooding Extent – 1:1,000 AEP

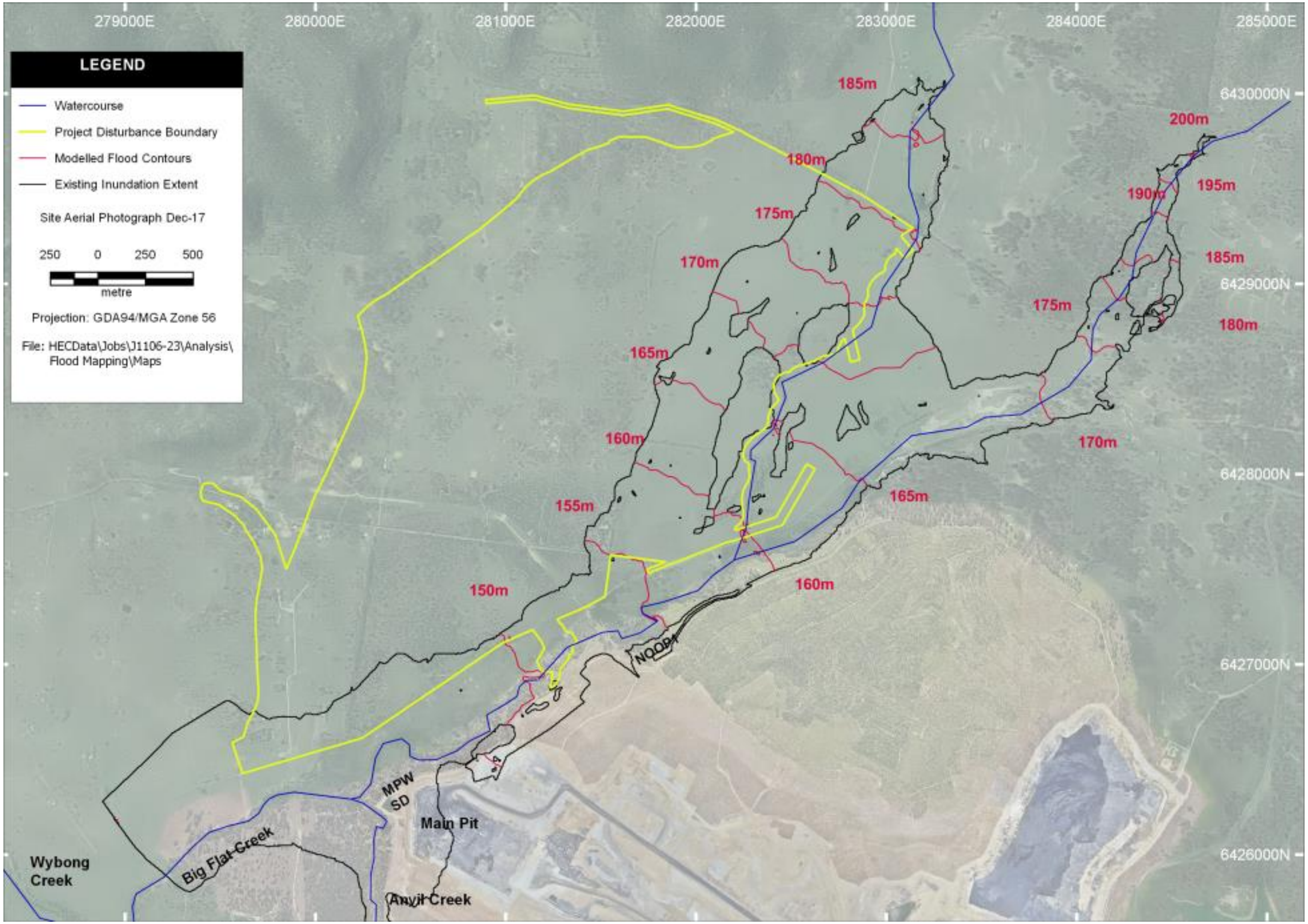


Figure B-6 Predicted Existing Flood Levels (mAHD) and Flooding Extent – PMF

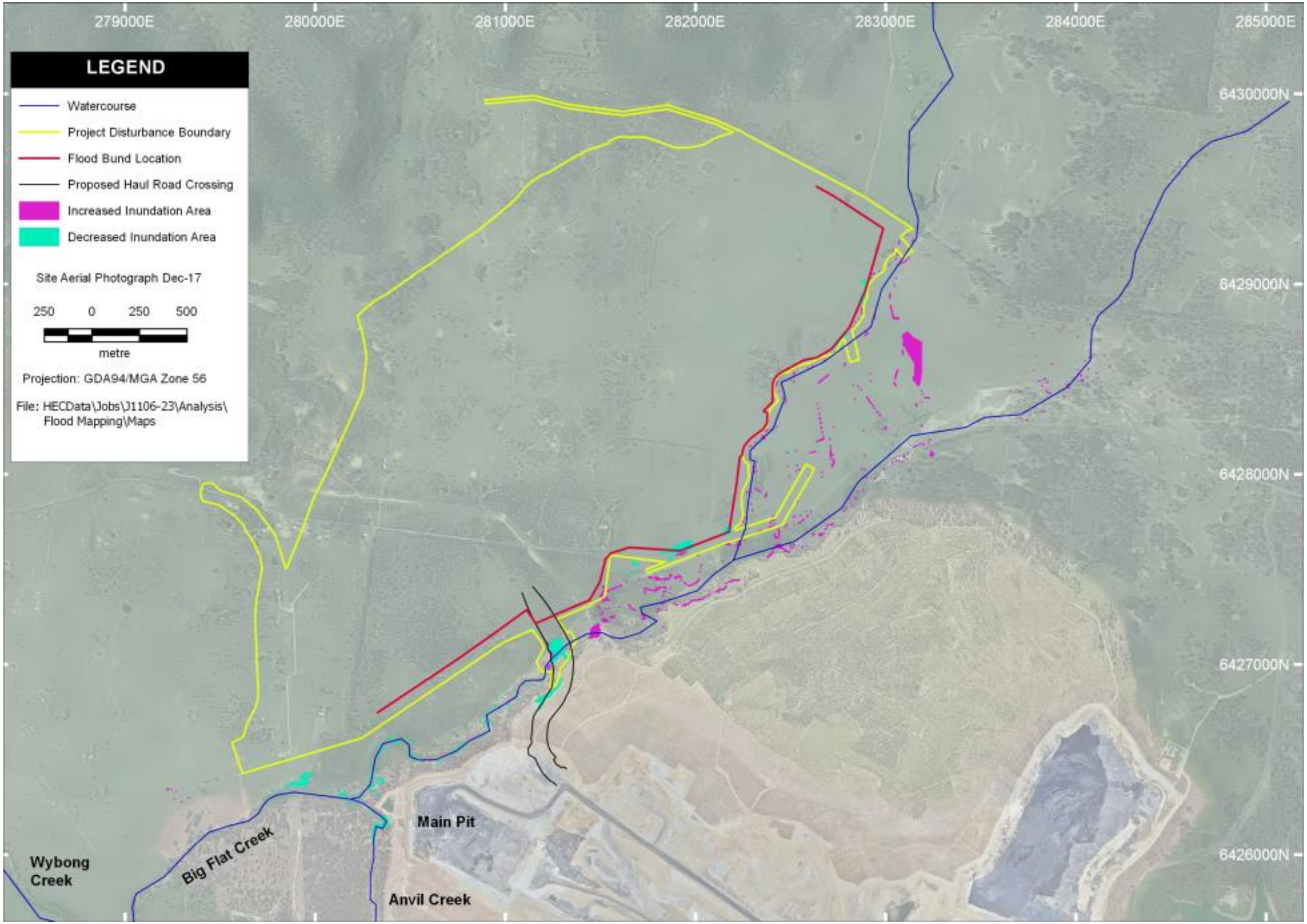


Figure B-7 Predicted Changes to Flood Extent – 1:200 AEP

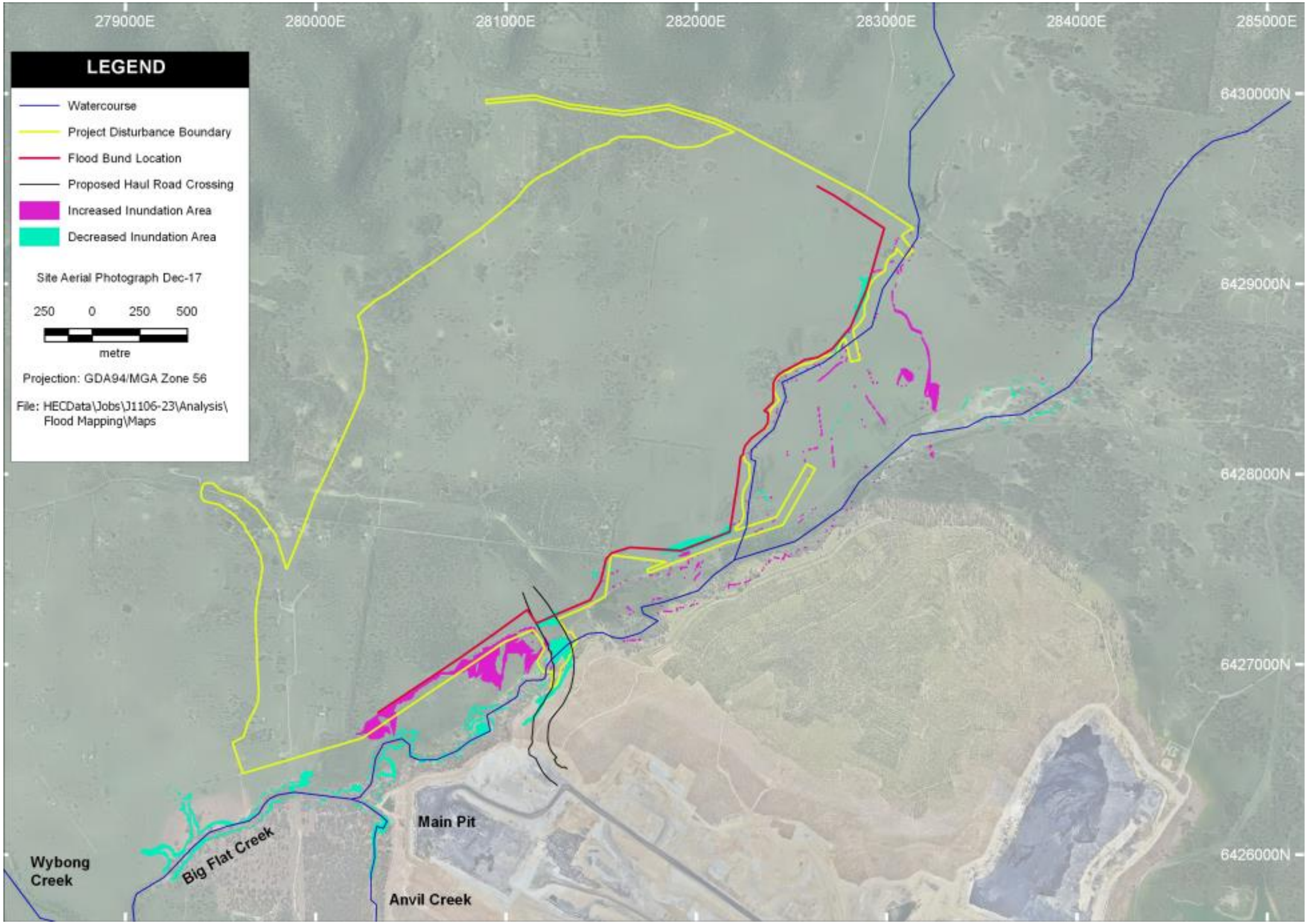


Figure B-8 Predicted Changes to Flood Extent – 1:200 AEP

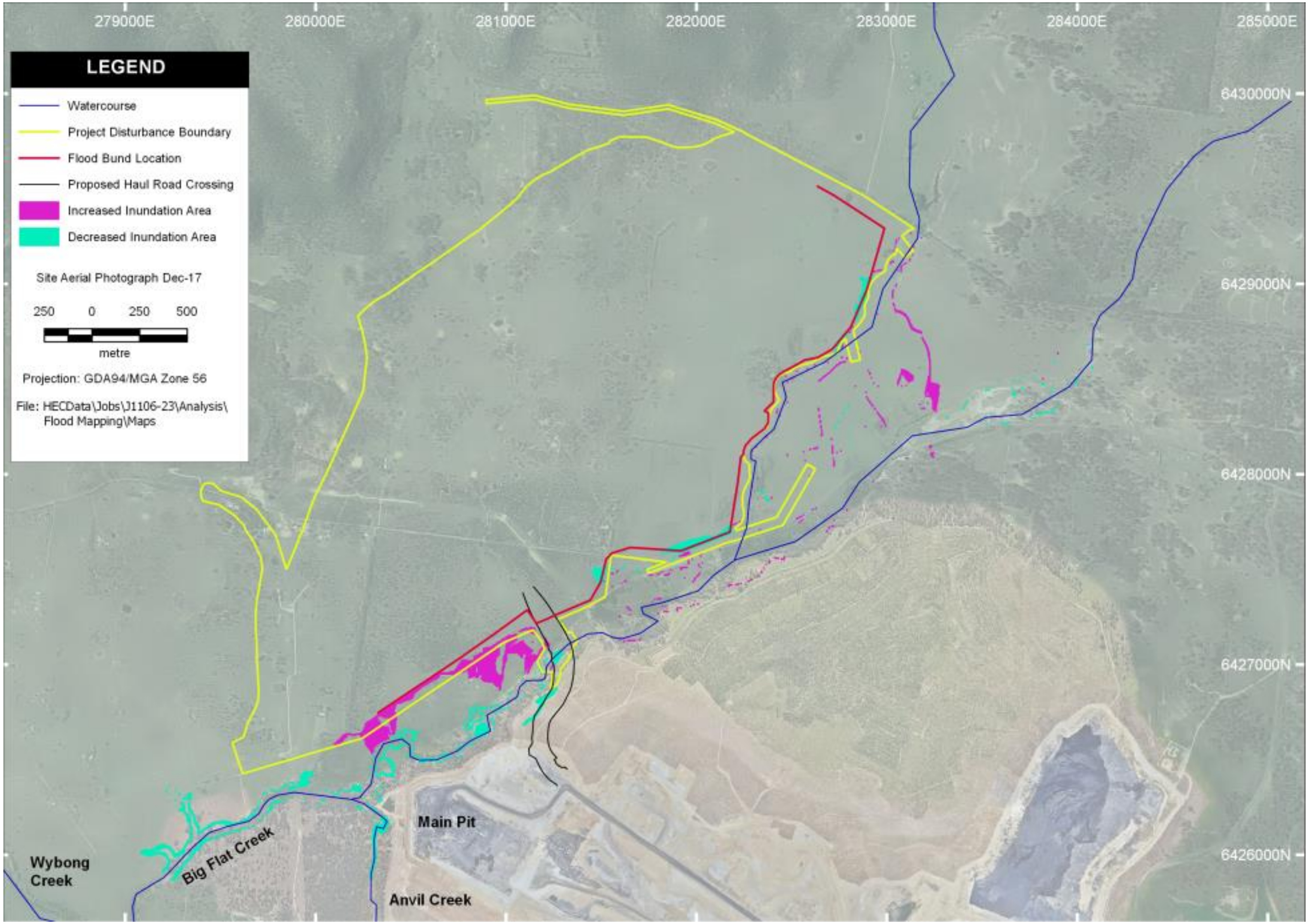


Figure B-9 Predicted Changes to Flood Extent – 1:250 AEP

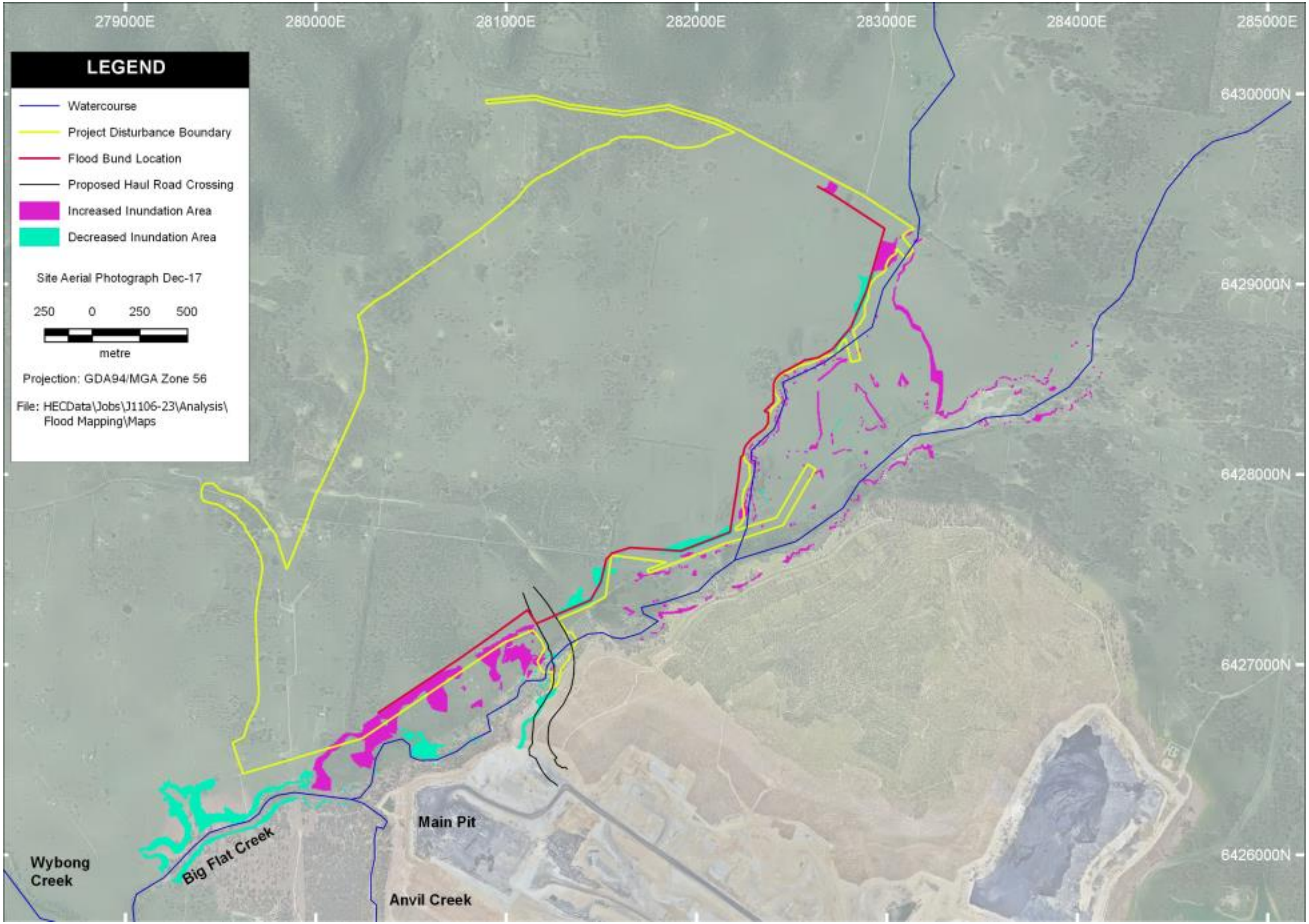


Figure B-10 Predicted Changes to Flood Extent – 1:1,000 AEP

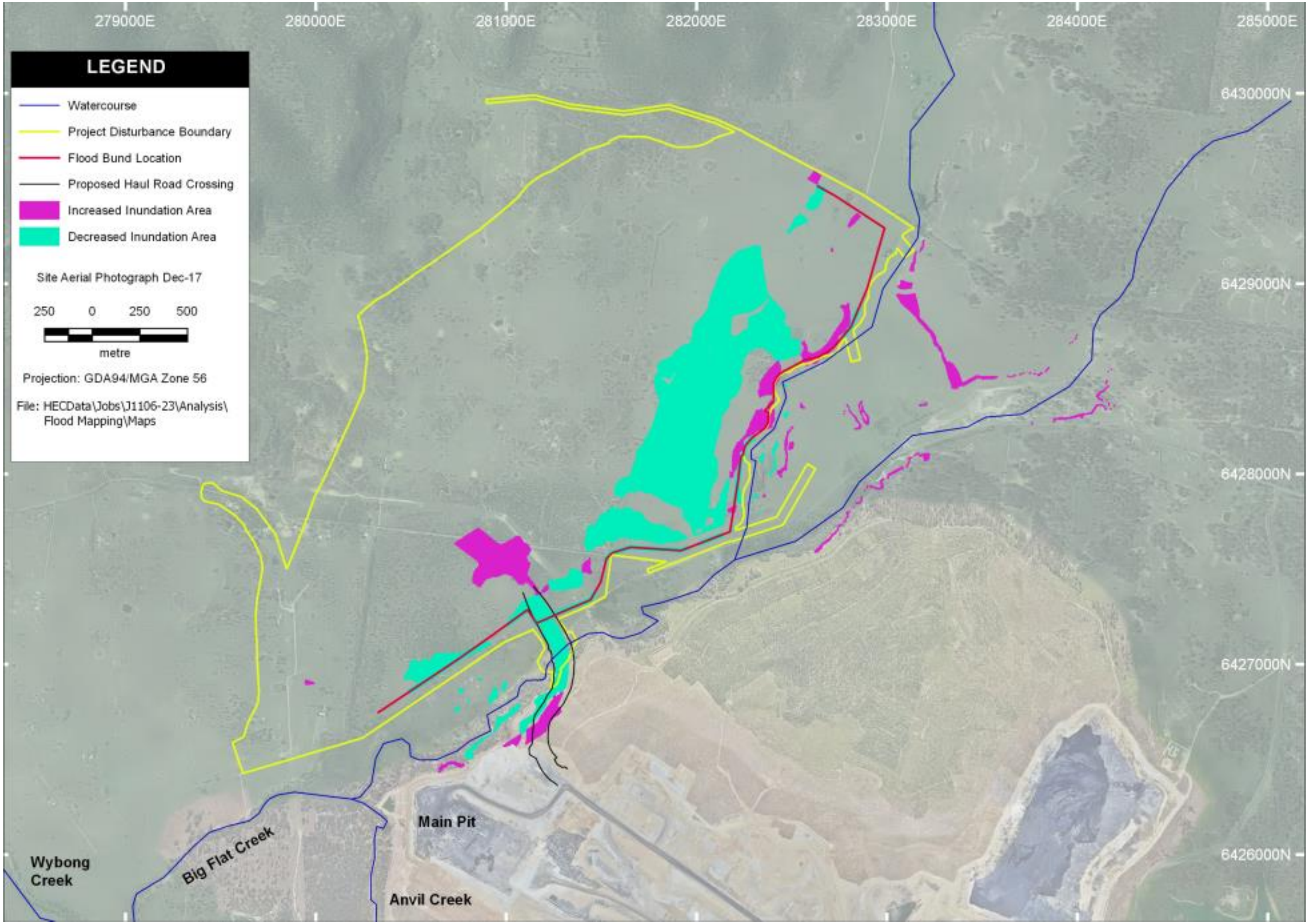


Figure B-11 Predicted Changes to Flood Extent – PMF

APPENDIX C
Final Void Pit Lake Water and Salt Balance Modelling Sensitivity Analysis Results

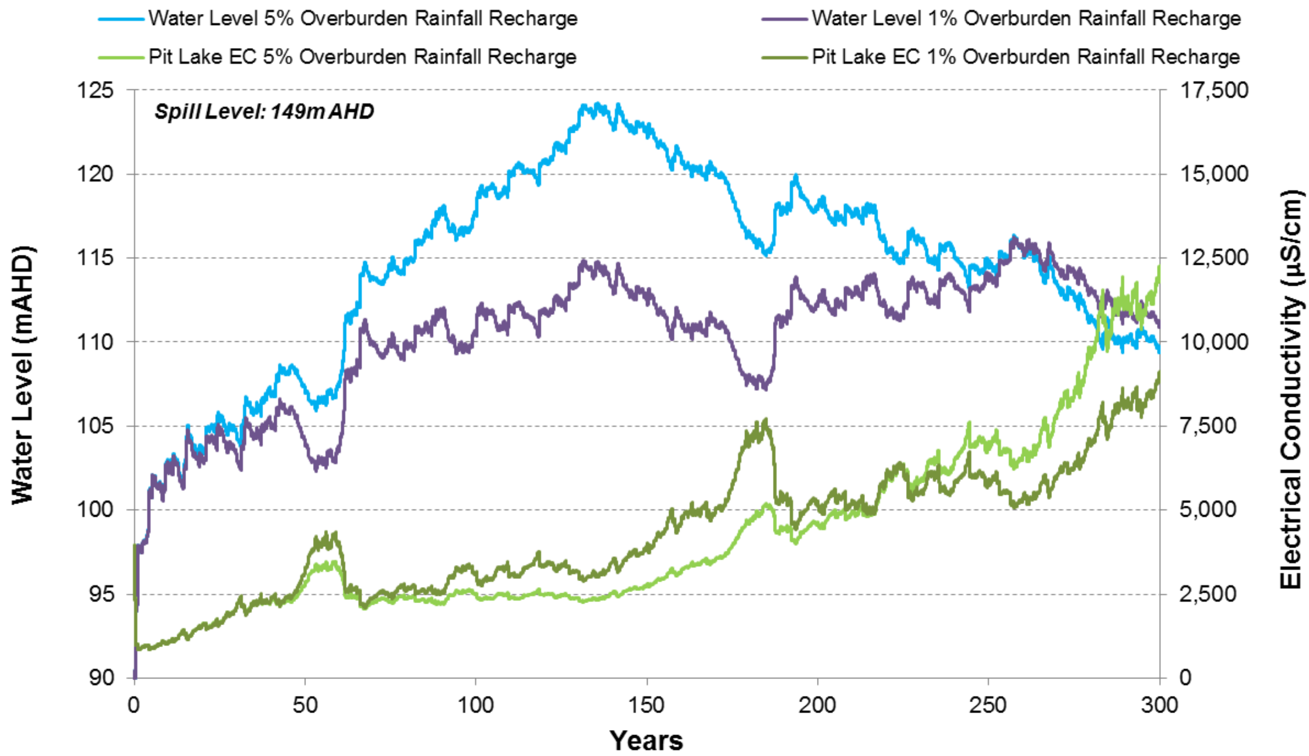


Figure C1 Predicted Final Pit Lake Water Levels - Main Pit West

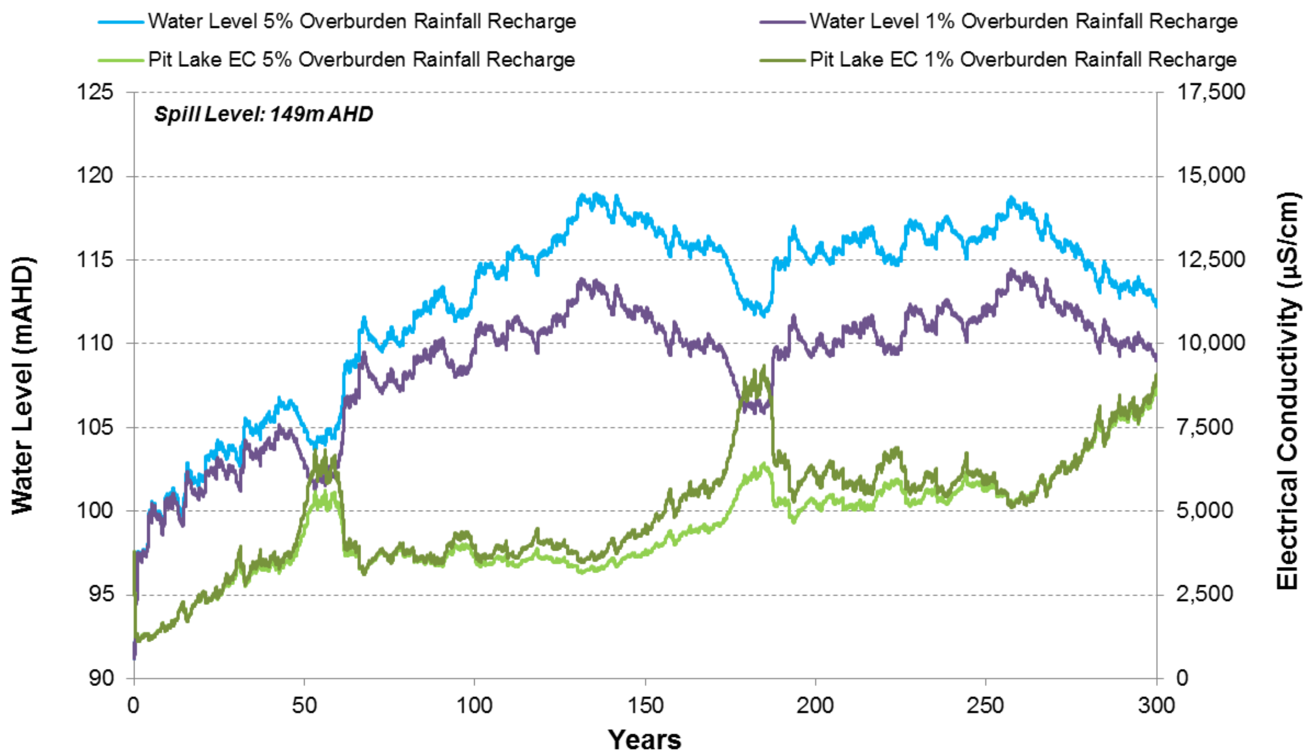


Figure C2 Predicted Final Pit Lake Water Levels - MCCO Additional Mining Area