Department of Natural Resources, Mines and Energy

ABN 59 020 847 551

Application by an entity for licence to interfere with the course of flow

Water Act 2000

Purpose of the form

This form is used to apply for a water licence to interfere with the flow of water by a prescribed entity under section 104 of the *Water Act 2000*.

To submit this form, please save a digital copy and email as an attachment to your local departmental office.

In accordance with the Anti-Discrimination Act 2001, submitted forms must be viewable by people with visual accessibility requirements. If you submit this form in hardcopy or as a scan, you may be required to pay for an additional public notice.

Part A Licence information

Is this application to amend an existing licence? ☐ No ☑ Yes

If yes, please supply the licence reference number: 30970F

Part B Applicant details

Full name: BM Alliance Coal Operations Pty Ltd as the duly appointed attorney for the Joint Venture parties: BHP Coal Pty Ltd, BHP Queensland Coal Investment Pty Ltd, Mitsubishi Development Pty Ltd, QCT Investment Pty Ltd, QCT Mining Pty Ltd, QCT Resources Pty Ltd, Umal Consolidated Pty Ltd

If the applicant is a corporation, please supply the ACN: 096 412 752

Attention (Optional) (e.g. Principal, Secretary, Managing Director, etc.)

Street address: Level 14, 480 Queen Street
Brisbane QLD 4000

Mailing address: As above

Contact details

The contact details provided will be used by the department for the purpose of communications under the *Water Act 2000*. The department may be required or authorised by legislation to disclose your information to other third parties.

Title: ☑ Mr ☐ Mrs ☐ Ms ☐ Miss ☐ Other (specify)

Full name: [redacted]

Preferred phone: [redacted]	Alternative phone:	Facsimile:

Email: [redacted]

Privacy statement: Collection of information on this form is authorised by section 107 of the Water Act 2000 and will be used by the Department for the purpose of processing your application. For these purposes disclosure to other third parties may be required by or of the Department. The information may be searchable, disclosed to and used by the public as allowed, authorised or required by legislation. A copy of your application and any supporting information will be published on the department's website.

OFFICE USE ONLY	Application ref.	Fee received $	Office Stamp Only
	Client ref.	Receipt no.	
	Authorisation ref.	Registration date / / Initials	

Final as submitted to DNRME

© The State of Queensland (Department of Natural Resources, Mines and Energy) 2019

Part C Description of land			
Specify the Lot on Plan numbers for the land over, under or adjoining where the activity will occur.			
Lot	Plan	Lot	Plan
ML70142			

Part D Source and location of water

Specify the name of the watercourse, lake, spring or aquifer within which the flow of water is to be diverted or changed:

Barrett Creek

Part E Proposed activity

Describe how the course of flow will be diverted or changed. If insufficient space, attach separate pages with details of the proposal.

Barrett Creek diversion (Water Lience 30970F) was constructed in approximately 1976 to facilitate the development of Saraji Mine and included the construction of Dudley's Dam.

BMA propose a temporary realignment of Barrett Creek Diversion on the western side of the haul road.

For further details, please refer to the Design Plan Report prepared by Jacobs (2020).

Attach a map showing the location of the activity. Include property boundaries, lot on plan descriptions, existing water facilities, and the location of the watercourse, lake, spring or aquifer.

Part F Reason for interference

Describe the reason for the proposed diversion or change to the course of flow.

The realignment of Barrett Creek diversion will allow mining operations to recommence in Coolibah Pit which has been used as a water storage since 1999.

The realignment of Barrett Creek Diversion will improve water management through more effective separation of clean water and mine affected water.

Part G Comments

Final as submitted to DNRME

Part H Declaration

All parties to complete and sign the declaration below. If more signature space is required, copy or print a blank copy of this page, complete and attach.

I/we declare that the information contained in this application and materials submitted in support is true and correct.

Individual

Name:	Name:
Electronic signature ☐ By ticking this box you agree to the use of an electronic signature to submit this form*. *By submitting this form using your email address nominated in Part A of this form, you will have provided an electronic signature. If you do not wish to use an electronic signature, you must sign the form in the space provided below.	**Electronic signature** ☐ By ticking this box you agree to the use of an electronic signature to submit this form*. *By submitting this form using your email address nominated in part A of this form, you will have provided an electronic signature. If you do not wish to use an electronic signature, you must sign the form in the space provided below.
Date: / /	Date: / /
Manual signature (optional):	Manual signature (optional):

Corporation Executed for and on behalf of

Organisation name: BM Alliance Coal Operations Pty Ltd

ACN: 096 412 752

By (name): [redacted]	By (name): [redacted]
Position: [redacted]	Position: [redacted]
Electronic signature ☑ By ticking this box you agree to the use of an electronic signature to submit this form*. *By submitting this form using your email address nominated in Part A of this form, you will have provided an electronic signature. If you do not wish to use an electronic signature, you must sign the form in the space provided below.	**Electronic signature** ☐ By ticking this box you agree to the use of an electronic signature to submit this form*. *By submitting this form using your email address nominated in Part A of this form, you will have provided an electronic signature. If you do not wish to use an electronic signature, you must sign the form in the space provided below.
Date: 27 / 05 / 2020	Date: 27 / 05 / 2020
Manual signature (optional):	Manual signature (optional):

Save

Final as submitted to DNRME

Department of Natural Resources , Mines and Energy

Guidelines for Application by an entity for licence to interfere with the course of flow

Water Act 2000

Purpose of form

The application form is a document approved for use within the state of Queensland under the provisions of the *Water Act 2000* (Water Act). Under this legislation, this department's chief executive may grant water licences for taking water and interfering with the flow of water.

This form is used where the applicant wishes to interfere with the flow of water by diverting or changing the course of the water's flow over, under or adjoining any of the applicant's land. Before commencing any activity which would result in water being diverted or changed for the first time, or would change the manner or extent to which flow is currently authorised to be diverted or changed, the owner of the land must make prior application by completing and lodging this form.

The words 'diverting' or 'changing' in the context of this application do not refer to an action where water is taken from the watercourse, lake or spring by mechanical means and used on land. Any increase to, or reduction of, the flow that occurs between the upstream and downstream extent of the diversion must solely be as a result of changes in the characteristics of the watercourse, lake or spring. Such changes are the subject of this application. Any other associated activities, which contemplate the taking and use of the diverted or changed flow, should be the subject of a separate application.

If the water diverted or changed is also to impound at the point at which the interference with flow first occurs, this form should not be used. The form "Application for a water licence" should be completed.

An entity who is already a licensee under the Water Act or holds a licence issued under previous legislation (for instance a licence for works issued under the *Water Resources Act 1989*) can also use this form to apply to amend the existing licence.

Unless otherwise indicated, all parts of the form should be completed. The department may require the applicant to provide additional information. You will be contacted if this is the case.

Approval of this application does not authorise construction or installation of new works or any associated development. Further information relating to the assessment and approvals of works to take or interfere with water can be accessed at www.business.qld.gov.au.

Part A Licence information

If the application is to amend an existing licence, then the 'Yes' box should be clearly ticked and the number of the existing licence must be entered. If possible, a copy of the licence should be provided.

Part B Applicant details

For the purpose of this application, 'applicant' only refers to an entity as defined by section 104 of the Water Act applying for:

- a new licence to interfere with the course of flow
- amendment of an existing licence.

Final as submitted to DNRME

© The State of Queensland (Department of Natural Resources , Mines and Energy) 2019

Part C Description of land

This part is used to describe the land over which the interference with flow will occur. Land is described as a lot on a plan and you will find these on the local government rates notice or a valuation notice. Separately list each parcel of land as lot and plan.

For example	Lot	Plan
	13	RP134507
	158	W314657

Provide a separate attachment if more parcels need to be listed on the application.

To be able to make a proper application, the applicant must be the owner of land entered here. An owner of land is defined above in Part B of these guidelines. The parcels listed must also be contiguous in nature.

Part D Source and location of water

This part is used to indicate where the planned activity will result in an interference with flow. Write the name of the watercourse, lake, spring or aquifer in which the flow is to be diverted or changed. If the flow in more than one watercourse, lake, spring or aquifer will be affected by the proposed activity, write the names of all the water features.

Applicants must also, to the best of their ability, complete the sketch plan on the application, or alternately provide a cadastral map with the relevant features indicated. The furthermost downstream and upstream extent of the interference with flow should be clearly marked.

Part E Proposed activity

This part is used to indicate to what extent the planned activity will result in interfering with flow, and to generally assess the impact of the proposal.

Applicants are advised that under the legislation, the chief executive must, amongst other things, consider:

- existing water entitlements and authorities to take or interfere with water
- any information about the effects of taking, or interfering with water on natural ecosystems
- any information about the effects of taking, or interfering with, water on the physical integrity of watercourses, lakes, springs or aquifers
- policies developed in consultation with local communities for the sustainable management of local water
- the sustainable resource management strategies and policies for the catchment, including, any relevant coastal zone
- the public interest.

In order to properly meet these provisions, the department may require the applicant to provide additional information about the application.

Part F Reason for diversion

Describe in general terms, the reason for the proposed interference with flow in the watercourse, lake or spring.

Industrial users, or other applicants who may need to have special factors considered as part of the application, should attach specific details of the proposal (such as a project plan) which will be used to assist the department in assessing the application.

Part G Comments

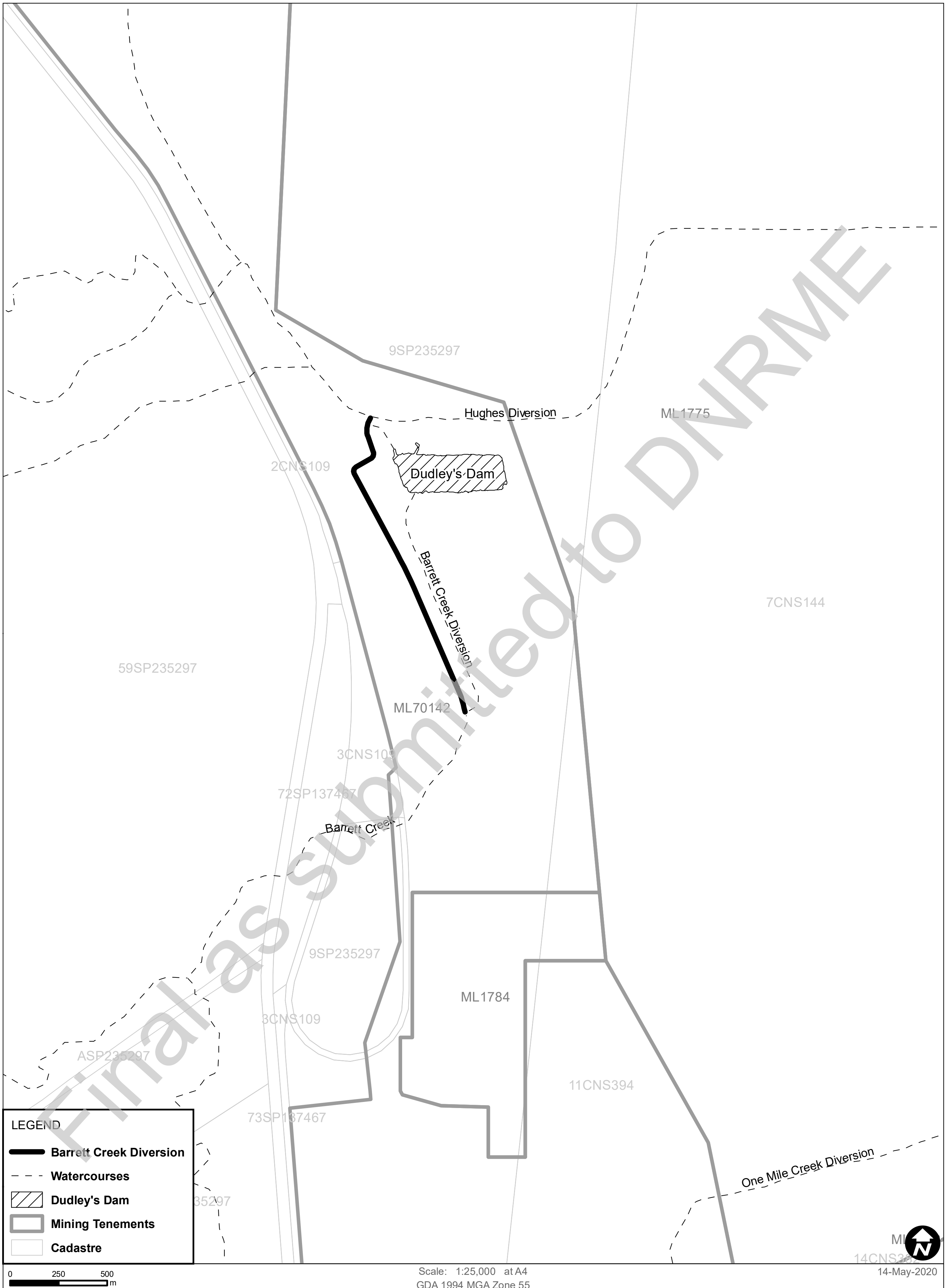
This part is used where the applicant wishes to provide any further comments or information that may be of assistance in assessing this application. Refer to a separate attachment if insufficient space has been provided.

Final as submitted to DNRME

Fees and charges
The prescribed fee payable at the time of application is changed each year with the consumer price index (CPI) and takes effect from 1 July each year. Prior to submitting an application immediately following 1 July contact your nearest departmental office to obtain details of the current fees.

Final as submitted to DNRME

© The State of Queensland (Department of Natural Resources , Mines and Energy) 2019



Final as submitted to DNRME

Scale: 1:25,000 at A4
GDA 1994 MGA Zone 55

14-May-2020

SLR
www.slrconsulting.com

Barrett Creek Diversion Realignment

FIGURE 1

Barrett Creek Diversion Water License Amendment Application

Statement of certification

I hereby state that I meet the requirements of the definition of 'suitably qualified and experienced person' for watercourse diversions as stated in *Guideline: Works that interfere with water in a watercourse for a resource activity - watercourse diversions authorised under the Water Act 2000*.

Statement of certification

I hereby certify that the *Detailed Design Plan* titled *Barrett Creek Diversion Realignment (SR07-JCB-8200-RPT-00016)* and dated *7 May 2020* for the *Barrett Creek diversion*:

- Relates to watercourse diversion of *Barrett Creek* between *-22.404 148.279 upstream limit of watercourse diversion* and *-22.389 148.274 downstream limit of watercourse diversion.*
- Includes all relevant material relied on by me.
- Is in accordance with all relevant requirements of the *Guideline: Works that interfere with water in a watercourse for a resource activity - watercourse diversions authorised under the Water Act 2000.*
- Is in accordance with all relevant conditions of Environmental Authority EPML00862313.

I further certify that the component certifications for the specialist components listed above are appropriate and that the content of those certifications can be relied on in determining that the watercourse diversion design will achieve required outcomes.

This certification does not include the geotechnical investigations which was undertaken as part of the study.

I [redacted], declare that the information and opinions provided as part of this certification is true to the best of my knowledge and belief. I acknowledge that it is an offence under section 480 of the *Environmental Protection Act 1994* to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

Signature: [redacted]

Signed: [redacted]
RPEQ No: [redacted]
Date: 7th July 2020

Final as submitted to DNRME

Certification extracted from Appendix B of Guideline: Works that interfere with water in a watercourse for a resource activity—watercourse diversions authorised under the *Water Act 2000*, Department of Natural Resources,

Barrett Creek Diversion Realignment

Design Plan Report

SR07-JCB-8200-RPT-00016 | 4

7 May 2020

BHP

Final as submitted to DNRME

Barrett Creek Diversion Realignment

Project No:	IH173600
Document Title:	Barrett Creek Realignment, Design Plan Report
Document No.:	SR07-JCB-8200-RPT-00016
Revision:	4
Document Status:	Final
Date:	7 May 2020
Client Name:	BHP
Client No:	
Project Manager:	[redacted]
Author:	[redacted]
File Name:	Barrett Creek Diversion Design_Report_Rev 4

Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
1st Floor, 54 Ovens Street
Wangaratta VIC 3677
T +61 7 3026 8619
www.jacobs.com

© Copyright 2019 Jacobs Group (Australia) Pty Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright.

Limitation: This document has been prepared on behalf of, and for the exclusive use of Jacobs' client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this document by any third party.

Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
1	20/02/20	Final Working Document	[redacted]	[redacted]	[redacted]	[redacted]
2	20/03/20	Final Working Document	[redacted]	[redacted]	[redacted]	[redacted]
3	26/03/20	Final Working Document	[redacted]	[redacted]	[redacted]	[redacted]
4	07/05/20	Final Document	[redacted]	[redacted]	[redacted]	[redacted]

Final as submitted to DNRME

Contents

Final as submitted to DNRME

Final as submitted to DNRME

Table of Figures

Final as submitted to DNRME

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is the Design Plan of the Barrett Creek Diversion at the Saraji Mine in accordance with the scope of services set out in the contract between Jacobs and BMA. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, Jacobs's Client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the Client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

Final as submitted to DNRME

1. Introduction

1.1 Overview of Barrett Creek

Since June 1999, Coolibah Pit has been used as the primary water storage and supply source at Saraji Mine (SRM). Recently BHP confirmed that re-commencing mining within Coolibah Pit appears to present incremental value for SRM. Jacobs Group Australia (Jacobs) was commissioned to investigate options to achieve dewatering of Coolibah Pit and enable further mining. To enable mining in Coolibah Pit, the project is required to provide a new water supply to the coal handling and processing plant (CHPP), close Ramp 6 Tailings Storage Facility (TSF) and construct a series of water management infrastructure alternations to eliminate water flowing into Coolibah Pit.

Barrett Creek runs into the Saraji Mine site from the South West. The existing alignment enters the Saraji Mining Lease from the west, crosses under the Saraji Mine Main Haul Road and runs parallel to the Haul Road where it flows into Dudley's Dam (refer Figure 2-1). At Dudley's Dam there is an authorised release point into Hughes Creek. The existing diversion is governed by water licence 30970F. Details of this licence are provided in Table 7.1. Development of the Coolibah Pit will necessitate re-directing the Barrett Creek diversion to the western side of the Haul Road. Culverts will then pass flow beneath the Haul Road, and a further short section of open channel will connect into Hughes Creek. This diversion will be temporary through the remaining life of mine, after which a permanent diversion will be constructed.

Barrett Creek remains a high sand bed load stream upstream and downstream of the Saraji Mine.

1.2 Purpose of This Report

The purpose of this report is to support an amendment to the existing water licence for Barrett Creek 30970F. Due to the maturity of the engineering design for the proposed creek diversion, this report documents the Design Plan in accordance with the DNRME 2019 guidelines. This Phase 2 of the design process is Design Plan of the temporary diversion. In this phase of the project, Jacobs has further developed the selection phase design, which includes:

- Hydraulic modelling to test flood immunity.
- Hydraulic modelling to confirm erosion risk thresholds (bed shear stress, stream power).
- Geomorphic review of the design.
- Geotechnical review.
- Monitoring program development.

The Design Plan is submitted to DNRME as part of the application process to re-direct the temporary diversion of Barrett Creek.

The design is prepared in accordance with *Guideline: Works that interfere with water in a watercourse for a resource activity—watercourse diversions authorised under the Water Act 2000 (DNRME 2019).* As summarised below the location of the response to each requirement is listed.

As prescribed in the Guideline, the following content is provided for the Design Plan Report:

- geomorphic and vegetation assessment of the existing watercourse.
  - See Section 2
- hydrologic conditions of the existing watercourse.
  - See Section 4
- the proposed watercourse diversion route.
  - Temporary Section 3

Final as submitted to DNRME

  - Permanent Section 9
- details of any temporary diversions that may be required as part of a staged process towards the final permanent watercourse diversion.
  - Section 3
- hydraulic conditions of the existing watercourse and proposed watercourse diversion
  - Section 5.
- details of the substrate on which the watercourse diversion will be constructed.
  - Section 3
- proposed revegetation plan.
  - Section 6
- proposed operation and monitoring plan.
  - Section 7
- a statement of how the watercourse diversion meets the outcomes.
  - Section 8

Final as submitted to DNRME

2. Existing Barrett Creek

2.1 Geomorphic Review

2.1.1 Overview

The proposed Barrett Creek Diversion will replace the existing diversion which currently crosses under the Saraji Mine Main Haul Road and then running parallel until it flows into Dudley's Dam (Refer Figure 2-1). The existing diversion replaced a natural drainage path which ran from south-west to north-east.

Figure 2-1: Existing Diversion

The existing diversion was constructed to facilitate the development of the mine and included the construction of Dudley's Dam.

2.1.2 Site Assessment of Existing Conditions including Sediment Movement

The existing Barrett Creek Diversion and associated tributaries was inspected by Jacobs on 8th July 2019. The existing diversion is essentially a straight cut channel. Inflows are limited by the culverts crossing the haul road at the commencement of the diversion, and localised drainage flows from Ramp 5 and from rehabilitation zone batters.

The bed features of Barrett Creek are highly influenced by sediment inputs from the upper Barrett Creek catchment. The upper catchment is characterised by a headwater drainage network that has formed over weathered and eroded bedrock surfaces then transitions into the Barrett Creek alluvial channel. The general form of the upper catchment is characterised by historic erosion of surrounding bedrock controls (sandstone, shale and associated weathered materials). Hence the high sand-bed load dominates and smothers most bed features.

The existing diversion has limited geomorphic features given its channelised form, however it remains relatively stable. The creek is now heavily vegetated with a mixture of native and exotic trees and grasses. A low flow channel has naturally developed within this constructed trapezoidal channel. The low flow channel appears to have formed via vegetation and debris blockages coupled with the movement of sediment, rather than a defined and constructed low flow channel. This low flow channel currently passes the sand bed load present above the diversion, passing this sediment through the system. Localised build up is evidenced over time in the vicinity of culverts, however this can be managed with suitably sized culverts set to the channel invert.

The development of the low flow channel indicates future developments need to provide a low flow channel in conjunction with revegetation to ensure the channel provides suitable capacity and will remain stable within its confines particularly during relatively small flow events less than the 50% AEP event.

Final as submitted to DNRME

The existing diversion channel spillway discharges into Dudley's Dam (Refer Figure 2-2). Once the dam is full, it discharges into a spillway channel then directs the flow into Hughes Creek. This spillway channel is currently experiencing active erosion and has undercut the channel banks. As part of the new diversion, the existing spillway outlet channel will become redundant and a new stable channel outlet will be constructed.

Figure 2-2: Spillway Channel Downstream of Dudley's Dam to Become Redundant

Key features of the existing diversion are labelled in Figure 2-3 below:

- grassed upper batters.
- scattered stands of Acacia sp. recolonisation and possibly revegetation.
- weed, grass and reed covered bed. This vegetation probably covers sediment which continues to mobilise through this reach.
- Incised low flow channel which includes some localised pools.

Final as submitted to DNRME

Figure 2-3: Typical features of existing diversion

2.2 Geotechnical Review

A geotechnical review of the available data for the Barrett Creek Diversion and discharge area has been carried out and is presented below. Test pit logs, laboratory test results and further detailed discussions of the geotechnical behaviour of the soils is presented in geotechnical report "Saraji Mine Coolibah Pit - Enabling Infrastructure, Factual and Interpretive Geotechnical Report" (Refer Section 3.3).

2.2.1 Site Geology

The geology of Saraji Mine is dominated by Quaternary to Tertiary alluvial deposits (sand, silt clay, gravel) which unconformably overlie the Late Permian Moranbah Coal Measures (Pwb), situated within the uppermost portion of the Blackwater Group. Sedimentary rock types likely to be present, include sandstone, siltstone, mudstone and coal measures (Refer Figure 2-4).

The site is situated over an extensive alluvial floodplain which has formed as part of the Isaac River drainage system. A number of creek tributaries feed off the Isaac River and carry sediments for deposition over the vast drainage basin. Hughes Creek is the main natural watercourse that passes through the project area.

The alluvial deposits are likely characterised by sequences of granular (sand and gravel) and cohesive (clay and silt) soils. The type of deposit depends on the location of the site versus ancient and current creek beds, as well as different rates of season flow energy, which in turn controls the grain sizes deposited. Coarser grain sizes (sands and gravels) are deposited during high energy cycles (high water flow) and finer grain sizes (clays and silts) are deposited during low energy cycles.

Final as submitted to DNRME

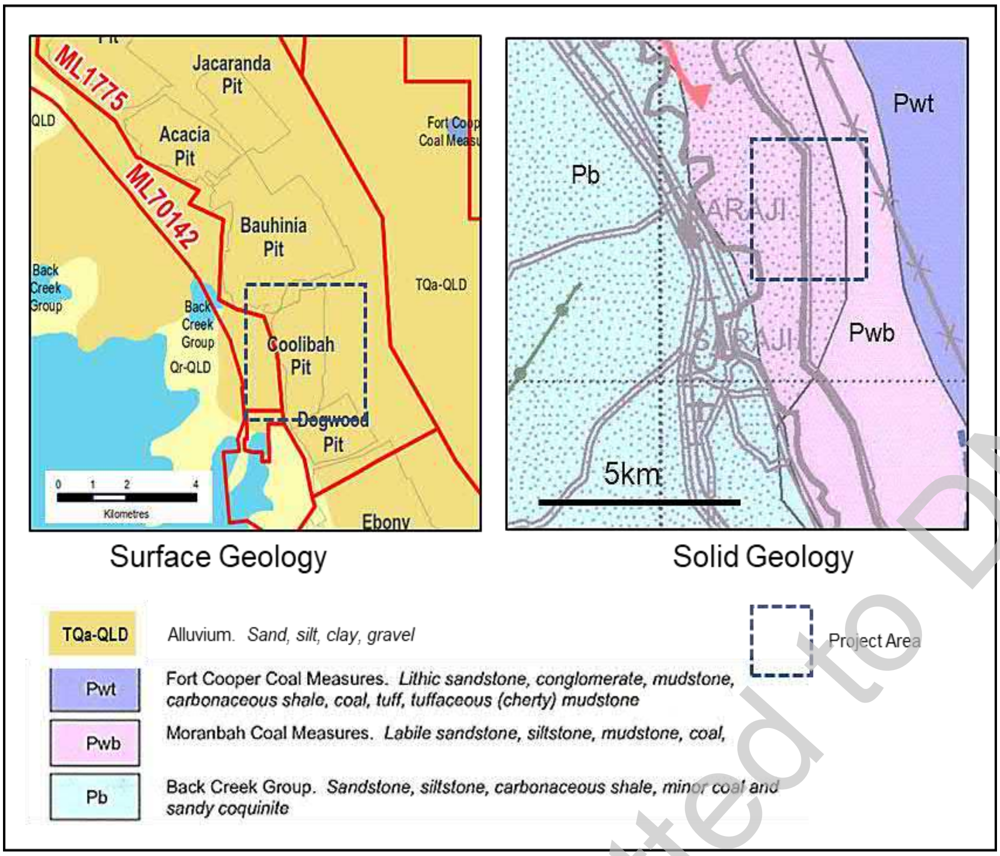


Figure 2-4 Geological Setting of Saraji Mine

2.3 Flora and Fauna Review

2.3.1 Overview

The vegetation of the existing diversion was found to comprise non remnant regrowth vegetation dominated by *Acacia salinica*. No threatened flora or fauna species have been recorded within the diversion, however scattered eucalypts in regrowth in the southwest section (where Barrett Creek enters the Mine Lease) may provide habitat for koala (BAAM 2020).

Monitoring (Engeny, 2016) reported poor scores for vegetation cover, native species cover and debris throughout the existing diversion. There is limited or no canopy present and native understorey regeneration was noted to be limited. Groundcover was recorded to be dominated by buffel grass and green panic (Engeny, 2016).

Harrisia Martini (moonlight cactus) has been recorded within the existing diversion (BAAM, 2020).

2.3.2 Threatened Ecological Communities

A review of BAAM reports concludes that there are no threatened ecological communities (TEC) present.

Final as submitted to DNRME

3. Proposed Barrett Creek Temporary Diversion

3.1 Design Criteria

As this Design Plan is for the temporary diversion key outcomes from Table 9 of *Works that interfere with water in a watercourse for a resource activity—watercourse diversions authorised under the Water Act 2000 (DNRME 2019)* are summarised below:

Outcome 1: The temporary watercourse diversion maintains the existing hydrological characteristics of the surface water systems.

- a detailed description of the development and calibration or sensitivity analysis of the hydrological model
- reference to the methodologies used to generate flood frequency analysis

Outcome 2: The hydraulic characteristics of the temporary watercourse diversion are comparable with other local watercourses and are suitable for the region in which the watercourse diversion is located.

- detailed description of the development and calibration or sensitivity analysis of the hydraulic model,
- hydraulic modelling results provide evidence that impacts upstream and downstream of the temporary watercourse diversion footprint can be managed or mitigated,
- a sensitivity analysis for hydraulic roughness during the temporary watercourse diversion life to determine if proposed roughness levels will provide conditions necessary to ensure the equilibrium and performance of the temporary watercourse diversion,
- a hydraulic analysis that identifies if the extent and depth of inundation between existing and post-diversion conditions has changed,
- a staged development of the floodplain (if relevant) when planning for resource activities adjacent to the temporary watercourse diversion,
- hydraulic modelling is performed at each development period to determine the impact on the temporary watercourse diversion and adjacent watercourse,
- the location and hydraulic effect of features, and
- the effect on hydraulic conditions within the temporary watercourse diversion of features (e.g. batter drains) that direct overland flow to the watercourse diversion.

Outcome 3: The temporary watercourse diversion maintains a sediment transport regime that minimises any impact to upstream and downstream reaches.

- The design plan should include a sediment transport analysis that identifies how the temporary watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.

Outcome 4: The temporary watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

- a geotechnical analysis and accompanying map of all substrate material encountered within the temporary watercourse diversion alignment that identifies soil chemical and physical properties including constraints to equilibrium of temporary watercourse diversion surfaces, vegetation establishment and persistence.
- system for ensuring appropriate remedial actions are undertaken where potential or existing change to equilibrium is identified as a result of substrate or spoil characteristics.

Final as submitted to DNRME

3.2 Design Features

3.2.1 Existing and Proposed Channel Design Features

The natural features of the existing diversion in the vicinity of the proposed Barrett Creek are largely undefined with no significant geomorphic features evident. Replacing the existing Barrett Creek Diversion with a similar trapezoidal grassed channel is considered appropriate for a channel which largely intersects un-channelled hillslope and floodplain.

The proposed diversion channel features are summarised in Table 3-1 below:

Table 3-1: Proposed diversion channel features

Item	Units	Existing Diversion Value	Proposed Temporary Diversion Value
Diversion Typical Channel Depth	m	1.5m typical Varies 1m min. – 2m max.	1.5m typical Varies 1m min. – 2m max.
Diversion Bed Width	m	7-10m typical	8m
Diversion Low-Flow Bed Dimensions	m	Naturally scoured channel 0.5m deep by 1m wide typical	0.5m deep by 1m wide typical
Diversion Overall Width	m	15-20m typical	38.5. typical Varies 30 m min. – 50m max. Increased width reflected by flattened stable batters
Diversion Batter Slope	V: H	Varies 1:1 to 1:3	Varies; 1:2 to 1:4
Diversion Channel Grade	V: H	1:277	1:288

Key features of the proposed alignment and cross section include:

- Provision of a low flow channel to reflect the natural low flow channel which has developed in the existing diversion.
- The length of the proposed diversion will replicate the existing diversion as closely as possible, therefore the gradient of the diversion will remain similar. By way of comparison, the existing diversion drops 5.06m over 1,400m, while the proposed temporary diversion drops 4.86m over 1,400m, with no material increase in channel flow velocity or bed shear stress.
- The alignment of the diversion can be visualised in Figure 3-1 below, and drawing SR07-28171-C-DRG-00001 in Appendix A.
- At the downstream extent of the diversion; Barrett Creek will smoothly transition into Hughes Creek. The channel has been aligned to avoid erosion risk to the banks of Hughes Creek. Similarly, the bed profile of Hughes Creek and Barrett Creek will be smoothly transitioned as closely as possible. Hydraulic Modelling has indicated that no bed armouring is necessary.
- The diversion is a temporary diversion which will function over the mine life. As such it will include engineered structures to assist in the passage of flow and to facilitate the mine operation.
- The key structures include:
  - Upstream hydraulic control structure controlling flow into the diversion via a berm and culverts (Refer Section 3.2.4).
  - Haul Road Culverts (Refer Section 3.2.5)

Final as submitted to DNRME

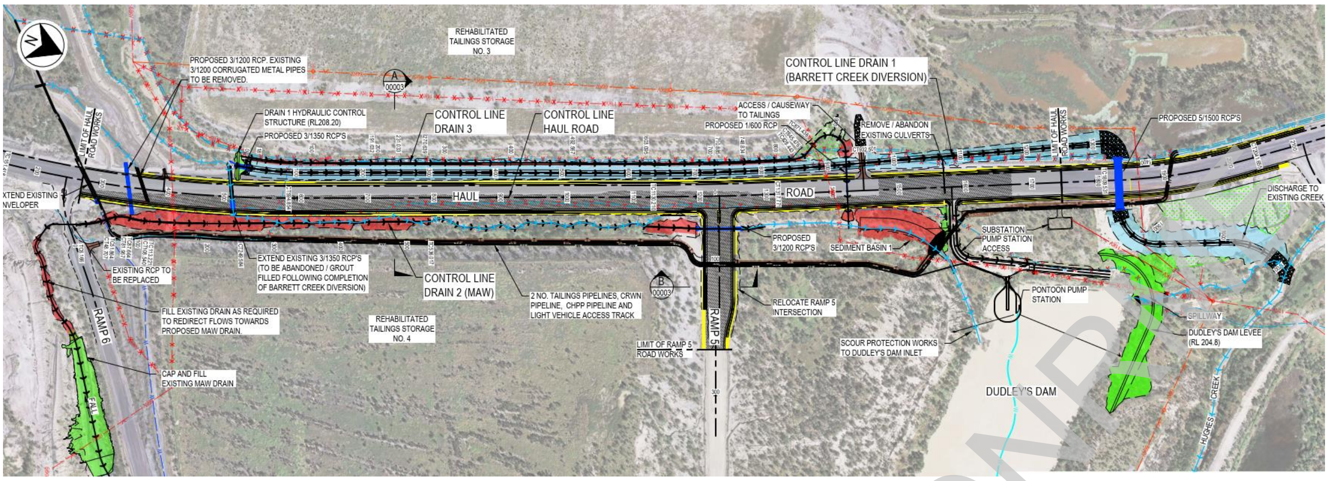


Figure 3-1: Proposed Temporary Diversion Plan View (proposed diversion in blue)

3.2.2 Proposed Temporary Diversion Alignment

The proposed temporary diversion is located to the west of the haul road. The diversion is a trapezoidal channel with a similar gradient to the existing Barrett Creek Diversion.

The Barrett Creek diversion design is based on providing separation of clean and mine affected water for a 0.1% AEP flood event.

The Barrett Creek diversion has been positioned with careful consideration of its proximity to the toe of the existing rehabilitated tailings storage that runs adjacent to the western side of the Saraji Mine Main Haul Road for 1,000 m of the diversion channel length. The batter slopes of the channel are at 1:2 to limit the footprint of the channel diversion; this arrangement was agreed during a constructability review.

The tailings rehabilitation storage finishes part way along the channel diversion, where the terrain changes to a low lying partially ponded area. This provides additional scope for the channel configuration. The channel has been aligned to an existing natural channel through this section to minimise excavation works and to utilise the current preferred water flow path. An existing vehicle access track from the haul road up onto the northern end of the tailings storage mound is to be maintained, and a causeway with nominal culverting is provided to maintain access over the creek diversion.

The proposed diversion channel flows under the Saraji Mine Main Haul Road through a new culvert arrangement consisting of 5 No. DN1,500 RCPs. In rare flood events, flood flows overtop the haul road which is designed at the location of the culverts to act as a control causeway. Longitudinal reprofiling of the haul road raises the haul road level to the south of this crossing location to retain the 0.1% AEP to this causeway crossing location. With very high dilution effects in such extreme flood events, the contribution of any surface water runoff from the haul road would be minor in comparison to the volume of clean water flowing through the proposed diversion culvert crossing. The contributing catchment area for Barrett Creek to this location is 29.32 km2, whilst the haul road causeway area inundated at the peak of the 0.1% AEP event is only 0.009 km2.

An open channel is to be cut through the existing Go-Line to connect to Hughes Creek at the same location that the existing spillway channel from Dudley's Dam currently connects to Hughes Creek. Some earthworks and rehabilitation will be required on either side of the clean water diversion through the Go-Line.

3.2.3 Channel Cross Section

The typical cross section of the proposed diversion is shown below in 3-2.

Final as Submitted to DNRME

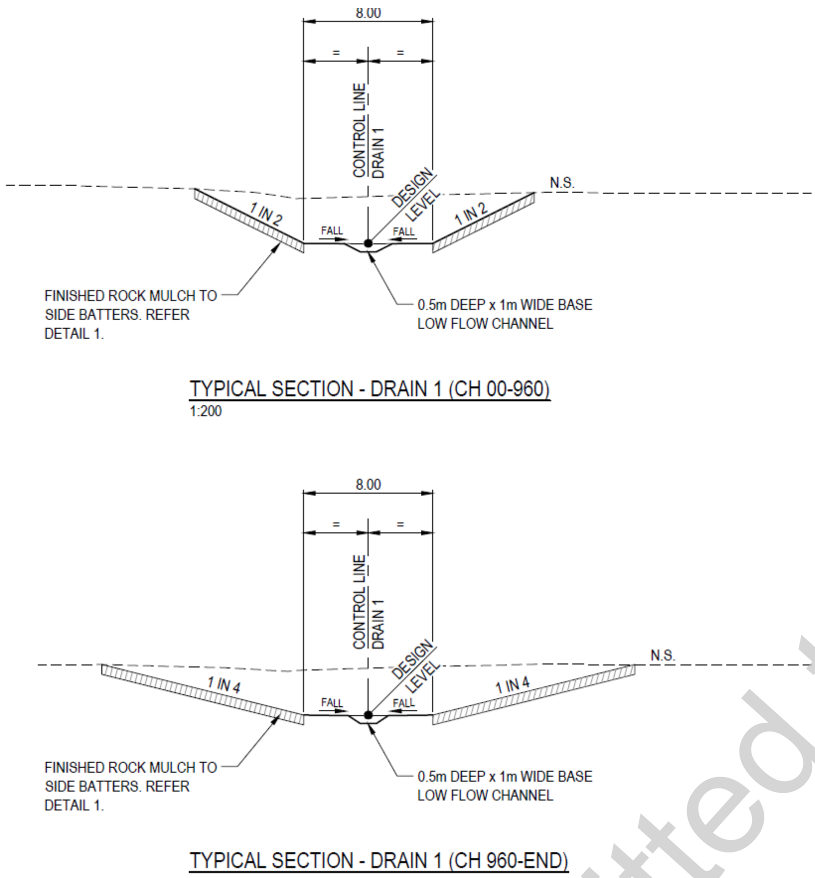


Figure 3-2: Typical Cross Section Details

The proposed channel cross sections have been designed to remain stable in the natural environment for the mine life. The typical cross sections provided reflect the different geographical conditions along the channel.

The cross section includes batters of 1:2 where the channel is adjacent to Tailings Storage Facility No. 3, and 1:4 downstream of the tailings storage facility. A bed width of 8m has been determined to allow suitable channel capacity for flood protection and to maintain Shear Stress and Stream Power within the DNRME Guidelines. Running parallel to the Haul Road and revegetated rehabilitation area, it is preferable to minimise disturbance to the rehabilitation, hence, the batters are at 1:2. Downstream of the tailings storage facility the batters are 1:4 enabling a smooth transition out of the culverts and into Hughes Creek.

3.2.4 Control Structure

A control structure comprising a levee with Three 1,350 RCPs through is required at the head of the diversion channel. This controls the discharge from the Dudley's Dam into the diversion channel and utilises storage upstream of the control structure in larger flood events. In the vicinity of the control structure at the commencement of the diversion, rock armouring is to be provided to manage potential erosion.

3.2.5 Haul Road Culvert Crossing

The Haul Road Culverts are set to the same invert as the channel to avoid the risk of sedimentation. The culverts consist of Five 1,500mm diameter Reinforced Concrete Pipes (RCPs).

The Haul Road crossing will act as a spillway in larger flow events, similar to its existing flooding mechanism. Hydraulic modelling completed for this study shows the Haul Road has immunity for the 50% AEP event.

Final as submitted to DNRME

3.2.6 Confluence with Hughes Creek

The confluence of the Barret Creek Diversion with Hughes Creek has been designed to minimise any potential erosion resulting from Barrett Creek; this is achieved by creating sufficient channel capacity upstream in Barrett Creek and entering on a stable grade and by avoiding a tight bend in Barrett Creek at the confluence. Furthermore, hydraulic modelling confirms there are no measurable changes in stream power, velocity and bed shear stress resulting from the diversion inputs. As such the proposed diversion will not have an adverse erosion risk on Hughes Creek.

This is demonstrated by looking at the existing hydraulic conditions in Hughes Creek, and comparing them to the developed case for the temporary diversion. For example, for the 50% AEP event stream power results, the following outputs are provided for Hughes Creek.

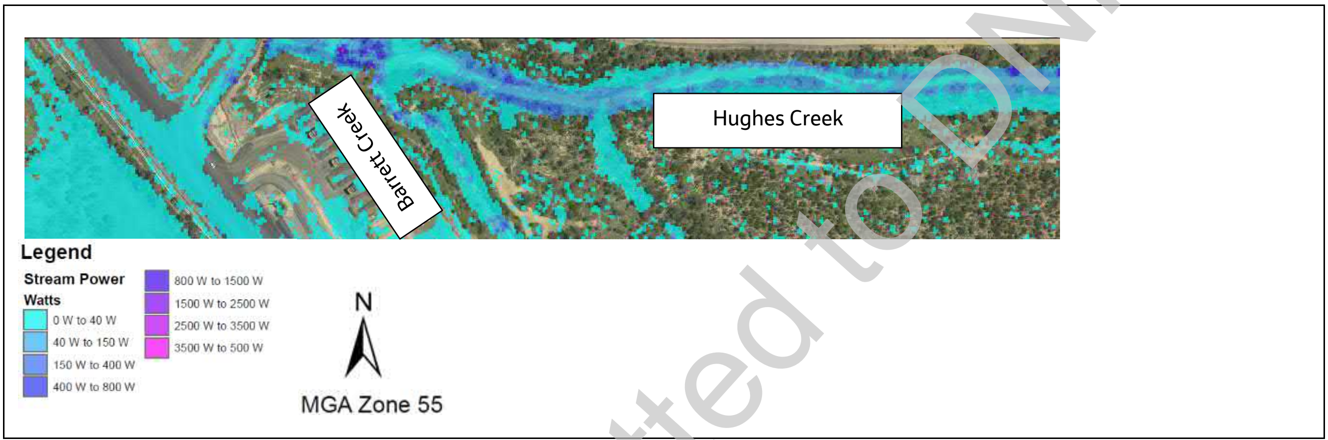


Figure 3-3: 50% AEP Event Stream Power Existing Case

Comparing these results for the temporary diversion case, it can be seen the impact on Hughes Creek is negligible and difficult to measure any difference. As such no works within Hughes Creek are deemed necessary.

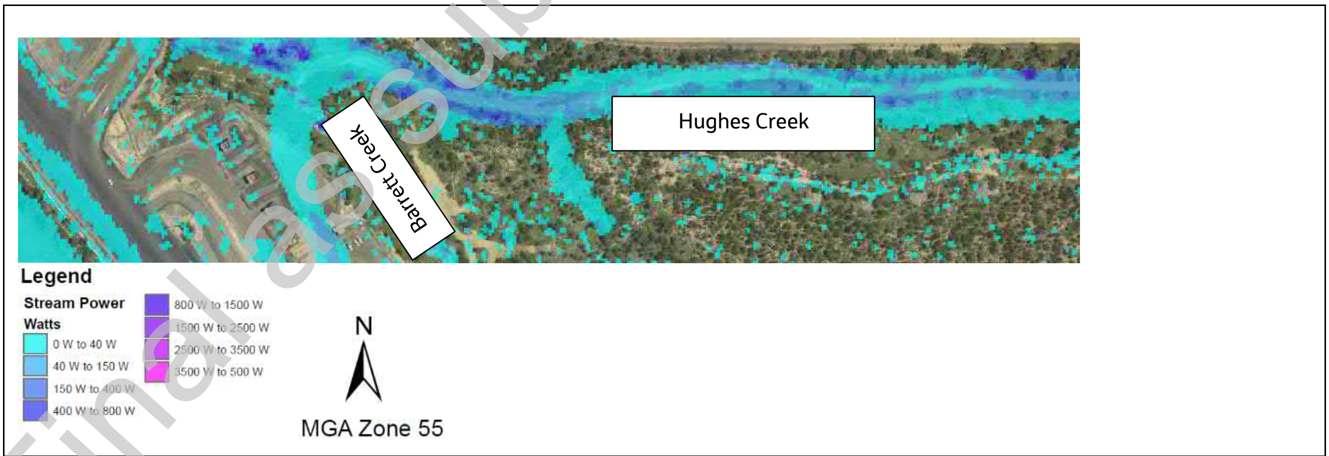


Figure 3-4: 50% AEP Event Stream Power Temporary Diversion

3.2.7 Barrett Creek Construction Sequencing

The staging of construction allows for the new channel to be constructed offline of the existing flows, with a final channel cut at the location of the upstream control structure. This is adjacent to the existing culverts that currently convey Barrett Creek under the haul road, and which are to be decommissioned during the switch over.

Final as Submitted to DNRME

3.3 Geotechnical Review

3.3.1 Geotechnical Investigations

A series of geotechnical test pits were undertaken by Jacobs in December 2018, February 2019 and November 2019 along the proposed creek diversion along the western side of the haul road, as well as the discharge area on the eastern side of the haul road (Refer Figure 3-5).

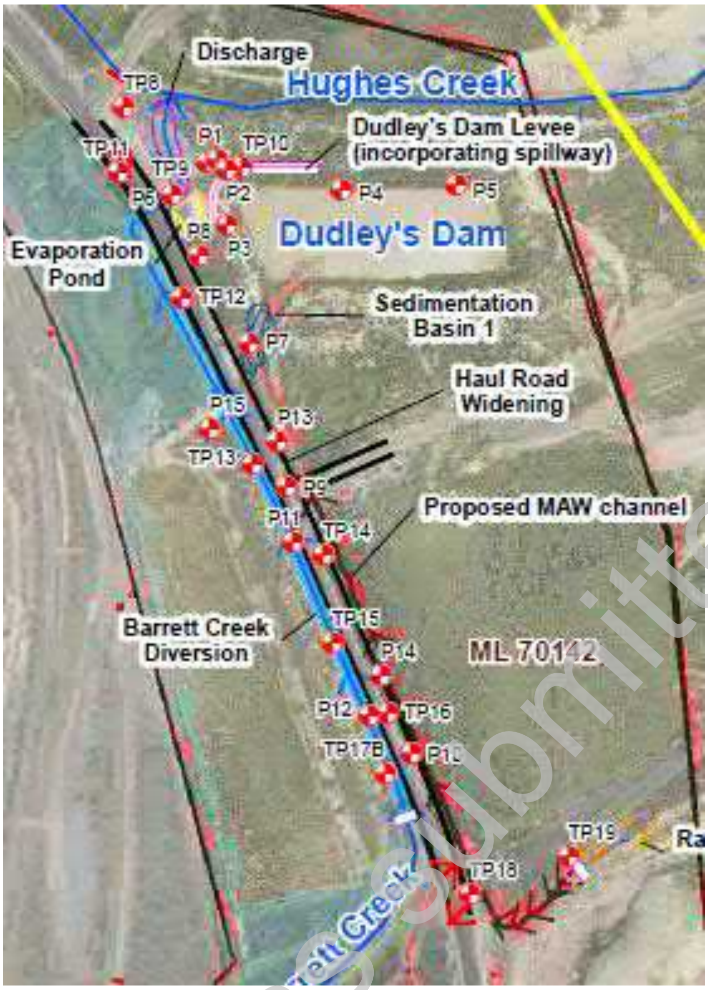


Figure 3-5: Test Pit Locations for Barrett Creek Diversion

Seven (7) test pits were undertaken along the proposed Barrett Creek Diversion located on the western side of the haul road. The materials encountered in the test pits are shown in Table 3-2, with the test pits in order from south to north. The test pit results show that the generalised ground profile is as follows:

- FILL made up of a variety of material types (gravels, sands, clays and silts) to at least 1.9m depth; underlain by;
- ALLUVIUM generally comprising very stiff to hard, low to medium plasticity CLAY or Sandy CLAY. Dense to very dense SILTY or CLAYEY SAND lenses or layers were encountered between the clay at TP17B and TP12, i.e. on the northern and southern end of this section of the diversion.

Final as Submitted to DNRME

Table 3-2: Subsurface Material – Proposed Barrett Creek Diversion on Western Side of Haul Road

Soil Type	Depth of Soil Type (m)						
	TP17B (RL206.5m)	P12 (RL 205.5m)	TP15 (RL204.6m)	P11 (RL203.58)	TP13 (RL203.9m)	P15 (RL203.4)	TP12 (RL201.8m)
TOPSOIL: CLAYEY SAND (SC)	-	-	-	-	-	0 – 0.2	-
FILL: Sandy CLAYEY GRAVEL (GC) / CLAYEY GRAVEL (GC) / Sandy GRAVEL (GP)	0 – 0.6	0 – 0.7	-	0 – 0.3	0 – 1.7	-	-
FILL: Sandy CLAY (CL-CI)	-	-	0 – 0.9	0.3 – 0.9	-	0.2 – 0.4	0 – 0.5
FILL: SILTY SAND (SM) / Sandy SILT (ML)	-	-	-	-	-	0.4 – 1.9	-
CLAY (CL-CI) Very Stiff to Hard	0.6 – 1.7	-	-	-	-	-	-
SILTY SAND (SM) / Clayey SAND (SC) Dense to Very Dense	1.7 – 3.4	-	-	-	-	-	0.5 – 2.2
CLAY / Sandy CLAY(CL) Hard	3.4 – 4.2	-	-	-	-	-	2.2 – 2.7
CLAYEY SAND (SC) Dense	-	-	-	-	-	-	2.07 – 3.4
CLAY / Sandy CLAY (CL-CI) Very Stiff – Hard	3.4 – 4.2	0.7 – 4.0	0.9 – 4.0	0.9 – 4.0	1.7 – 4.0	1.9 – 4.0	3.4 – 4.0

The majority of the Barrett Creek Discharge area is situated over a fill platform. Test pits TP8 and TP6 were excavated directly to the north and south of the platform. The materials encountered in the test pits are shown in Table 3-3. Subsurface characteristics based on those test pits are as follows:

- FILL comprising Sandy CLAY to 0.8m (only observed in P6); underlain by;
- ALLUVIUM comprising a sequence of sand and sandy clay layers with sand layers varying from SAND to SILTY / CLAYEY SAND.

Table 3-3: Subsurface Material Barrett Creek Discharge Area and Evaporation Pond

Soil Type	Depth of Soil Type (m)		
	P8 (RL202.8)	P6 (RL 201.6m)	TP8 (RL201.9m)
TOPSOIL: Sandy CLAY (Cl-CI) / SAND (SP) / CLAYEY GRAVEL (GC)	0 – 0.2	0 – 0.2	0 – 0.2
FILL: Sandy CLAY (CL-CI)	-	0.2 – 0.8	-
Sandy CLAY (CL-CI) Very Stiff to Hard	0.2 – 1.0	0.8 – 1.8	-

Final as submitted to DNRME

Soil Type	Depth of Soil Type (m)		
	P8 (RL202.8)	P6 (RL 201.6m)	TP8 (RL201.9m)
Clayey SAND (SC) Medium Dense	1.0 – 1.6	-	-
Sandy CLAY (CL-CI) Very Stiff	1.6 – 1.8	-	-
CLAYEY SAND (SC) / Silty SAND (SM) Medium Dense to Very Dense	1.8 – 2.7	1.8 – 4.0	0.2 – 1.6
Sandy CLAY (CL-CI) Hard	2.7 – 4.0	-	1.6 – 3.5

3.3.2 Excavatability/rippability of soils

The test pit investigations indicate that the materials present across the site will comprise a combination of mine spoil fill and alluvial soil, generally comprising very stiff to hard clay and medium dense to very dense sands. At the Barrett Creek Diversion alignment between test pit TP17B and TP13, a layer of gravel is present, which was encountered up to depths of 1.7m.

Cobbles and boulders were not observed in the test pits along the Barrett Creek Diversion corridor, however site observations of existing bunds indicate that cobbles and boulders may be present throughout fill areas across the site.

Based on the test pit and site observations, it is expected that excavation, ripping and moving of materials at the assessed sites can be undertaken with conventional earthworks machinery such as tracked excavators, bulldozers, graders and scrapers. The excavation equipment will need to have the potential of moving or breaking boulders of up to 1.5m diameter.

3.3.3 Batter angles of the temporary diversion

As discussed in Section 3.3.1 excavations are anticipated in fill and alluvial (natural) soils. The natural soils are anticipated to comprise very stiff to hard cohesive soils (SILT and CLAY) and medium dense to very dense SILTY or CLAYEY SAND. The consistency and density of the fill is likely to vary significantly and, based on the test pit data. Table 3-4 provides recommended temporary batter profiles for soils likely to be encountered in the project area. The recommended batter profiles assumes the excavated materials are in a dry to moist state (i.e., groundwater is below the base of the excavation and the soils are not saturated).

If groundwater is found to be present above the excavations or excavated slopes become saturated from rainfall infiltration, temporary batter profiles would need to be re-assessed at the time to manage these conditions. Dewatering of the excavations and retention of the batters may need to be considered under this scenario ensuring manageable constructability of the batters.

Table 3-4: Recommended batter profiles for temporary excavations

Material	Consistency / Relative Density	Temporary Batter Profile
SAND, CLAYEY SAND, SILTY SAND, Gravelly SAND	Very Loose	1V:2.5H
SAND, CLAYEY SAND, SILTY SAND, Gravelly SAND	Loose	1V:2H
SAND, CLAYEY SAND, SILTY SAND, Gravelly SAND	Medium Dense to Very Dense	1V:1.5H to 1V:2H(1)

Final as submitted to DNRME

Material	Consistency / Relative Density	Temporary Batter Profile
Sandy SILT, Sandy CLAY, CLAY	Firm	1V:2H
Sandy SILT, Sandy CLAY, CLAY	Stiff to Hard	1V:1H

Notes:
1. Suitable batter profile will be dependent on fines content of sandy material. Assessment will be required by a geotechnical engineer at the time of excavation.

3.3.4 Erodibility of soils

Available sodicity suite testing results show that the presence of moderately saline, alkaline, sodic and magnesic soils are extensive throughout the project area. The reported values indicate cation imbalances in the soil structure and consequently strongly dispersive behaviour.

Additionally, the chemical properties of the soils are not conducive to promoting vegetation, which would otherwise assist with combatting surface erosion of embankments and channel slopes. Therefore, amelioration of the slope surfaces would assist to promote vegetation establishment.

To reduce the susceptibility of sodic soils to soil erosion (especially subsurface piping and tunnel erosion), the cation imbalance can be altered by increasing the relative proportion of calcium in the soil while reducing the relative proportion of exchangeable sodium (and usually to a lesser extent exchangeable magnesium in the analysed soils). This can be achieved by incorporating a calcium dressing into the soil using gypsum (calcium sulphate, $CaSO_4$). Gypsum is the most commonly used source of calcium ions because of its solubility and price and may be used in alkaline soils because it has no effect on soil pH. Addition of gypsum as a soil ameliorant for the revegetation of slope surfaces can also be applied, as it acts as a soluble source of the essential plant nutrients calcium and sulphur, which would in turn improve overall plant growth.

Available Emerson Class Number (ECN) test results also indicates that 11 samples of the 26 samples tested across the site showed dispersive characteristics ranging from complete dispersion (Class 1) to partial dispersion (Class 2(1) or 2(2)), with the soils most likely being sodic, which supports the results of chemical testing. Three (3) of the 11 samples identified as dispersive were located along the Barret Creek Diversion alignment.

The remaining samples showed Classes of 5 or 6 indicating undisturbed or remoulded soils would not disperse when in contact with static water, but, when in contact with moving water, would show some degree of dispersion (Class 5) or to a lesser extent, flocculation (Class 6). It should be noted that an ECN of greater or equal to Class 4 is indicative of stable, productive soil, therefore, values of Class 5 are likely to indicate surficial erosion only (e.g. rill erosion on embankment or cut bank slopes).

Pinhole dispersion testing was also undertaken on representative fill and alluvial clay samples recovered from test pits, including TP15, which is located along the Barrett Creek Diversion alignment. The results indicated that fill tested from TP15 was considered highly dispersive, while the alluvial clay tested was considered dispersive.

Based on the available test results, it should be assumed that the soils are dispersive and require protective treatment. The following protective treatments (in line with advice provided by Jacobs as part of previous design phase) to reduce the risk of subsurface erosion; along with additional protective measures to reduce scour should be considered:

- Treatment of newly cut batters and fill batters with gypsum should be undertaken for an indicative depth of 300mm from the design surface. Following treatment, a seeded compost blanket should also be applied to further minimise erosion on the crest and slopes of the embankment;
- Rock protection should be adopted in areas of potential for hydraulic scour particularly in the vicinity of culverts.

Final as submitted to DNRME

3.4 Flora Survey

3.4.1 Vegetation Clearing

Construction for the proposed temporary diversion will require vegetation clearing and earthworks, all of it within relatively young regrowth vegetation on rehabilitated mine lands of poor quality.

BAAM (2018) state the following:

- No Matters of National Environmental Significance (MNES) are likely to occur in the Project area; therefore, the Project is unlikely to impact on any MNES.
- No Matters of State Environmental Significance (MSES) are likely to occur in the Project area; therefore, the Project is unlikely to impact on any MSES. A pre-clear survey of animal breeding places is recommended.

3.4.2 Revegetation

Revegetation of the site is a key component of the long-term stabilisation of the temporary diversion and should occur immediately following the completion of the diversion earthworks. Vegetation will increase channel roughness and reduce the risk of piping failure and rill erosion on the banks of Barrett Creek. Disturbed areas shall be top-soiled and revegetated in accordance with the Saraji Mine Revegetation Plan.

All vegetation clearing, revegetation and topsoil recovery and use will be undertaken in accordance with Saraji Mine's rehabilitation procedures.

Final as submitted to DNRME

4. Barrett Creek Temporary Diversion – Hydrology Analysis

4.1 Barrett Creek Hydrology Overview

As a component of Coolibah Pit Dewatering Early Works, Barrett Creek Identification Phase Study Concept Design Report (Jacobs, 2018), a hydrological assessment was conducted to provide inflows into the hydraulic (TUFLOW) model. The hydrological assessment was undertaken as follows:

- The two external catchments to the west of the Coolibah Pit generate the majority of the clean water, which form Barrett Creek and Hughes Creek. The inflow for these catchments was derived by using the hydrology modelling software XP-RAFTs (version 2018); and

- The internal catchments (i.e. rain falling directly within the mine site) generate the majority of the Mine Affected Water (MAW). The inflows for these catchments were produced by the rain-on-grid approach.

These approaches are discussed further in the following sections.

4.2 XP-RAFTS

During the project, BHP provided the existing XP-RAFTS model (Engeny, July 2018), which contained the drainage catchments for Barrett Creek and Hughes Creek. After a review of the Engeny XP-RAFTS model, which is understood to have been completed to inform a regional flood assessment, a number of updates were undertaken to refine the model to ensure it was fit-for-purpose for the diversion design, as follows:

- Redefined the sub-catchment for Barrett Creek;

- Updated the roughness of the sub-catchments to 0.045 for upstream catchments, and 0.04 for downstream, cleared catchments.

- Adopted the Australian Rainfall and Runoff 2016 (ARR 2016) recommended losses of 47 mm and 1.9 mm/hr (http://data.arr-software.org/); and

- Updated aerial reductions factors (ARFs) based on Hughes Creek catchment size and Barrett Creek catchment size.

For the creek flooding models, ensemble temporal patterns for the "East Coast North" region sourced from ARR 16 Data Hub (http://data.arr-software.org/) were adopted for all design events. For this approach ten temporal patterns were simulated for each duration event, with the average of ten resultant flows adopted as the representative design flow for that duration. The ensemble temporal patterns which results in the flow closest to the calculated average is selected as the design temporal pattern. The updated XP-RAFTS model was used to simulate the 10 temporal patterns for the "East Coast North" region sourced from ARR 2016 Data Hub for a range of storm durations (1hr to 72hr), for the four design events (50%, 2%, 1% and 0.1% AEP).

The 50%, 2%, 1% and 0.1% AEP flows were validated against Regional Flood Frequency Estimation (RFFE) results for Hughes Creek and Barrett Creek to assist in estimating peak flows for these events. This method transfers flood frequency characteristics from a group of gauged catchments to the location of interest (Ball et al., 2016). Results show that the Hughes Creek flows are within the confidence interval predicted by the RFFE, while the Barrett Creek flows are above the upper confidence interval. This is considered high but conservative, and suitable for Detailed Design. Without gauged data within the catchment, there is no other means of validating the hydrology.

The peak flow from the updated XP-RAFTS model was compared to the previous XP-RAFTS model (Engeny, July 2018). Table 4-1 shows that:

Final as submitted to DNRME

- The updated model produces a marginally higher (7% increase) peak flow at the outfall of Hughes Creek in the 10% AEP event;
- The updated model generates the same peak flow for the 0.1% AEP event; and
- The updated XP-RAFTS model indicates that the critical storm duration is 6 hours with the temporal pattern ensemble 7.

Table 4-1: Comparison of XP-RAFTS flows

AEP (%)	Peak flow (m3/s)		Difference (%)
	XP-RAFTS - Engeny	XP-RAFTS - Jacobs	
10	248	266	7
0.1	1,150	1,149	0

The Peak Flood Depth and Flood Difference (Pre-Diversion versus Post-Diversion Afflux) Mapping can be found in Appendix B, showing the ability of the proposed diversion to accommodate the above calculated flows.

4.3 Rain on Grid

In addition to the XP RAFTS model, a Rain on Grid approach was used to estimate the internal Mine Affected Water being generated from within the site.

Rain-on-grid applies a temporally varying rainfall depth on each active cell within the 2D domain. The hydraulic modelling software (TUFLOW) is able to automatically route the flow and define the localised catchments depending on the elevation of the topography.

The design rainfall depths for the 10% and 0.1% AEP events were sourced from ARR 2016 (Ball et al. 2016). An ARF, based on the Barrett Creek catchment size, was applied to the rain-on-grid design rainfall depths. Rainfall depths for each of the 10 temporal patterns, storm durations and AEP events were generated. All of these events were simulated within the TUFLOW model to determine the critical storm. A rain-on-grid simulation was used to define the relevant drainage catchments for this study and help inform the extent of the 2D domain.

4.4 Critical Storm Duration

In accordance with the ARR Guidelines (2019), the hydrologic model was used to generate flows for a range of storm durations, each with 10 temporal patterns. The hydrologic model indicated that the critical storm duration would be 6 hours and ensemble number 7 would produce the mean flow for the 0.1% AEP event.

The full suite of storm durations (1hr to 72hr) and temporal patterns were simulated within the TUFLOW model to confirm the critical storm duration and temporal pattern. The hydraulic model indicated the following events generate the peak water level adjacent to the haul road, near Ramp 6:

- 10% AEP = 6hr storm duration and temporal pattern ensemble number 7; and
- 0.1% AEP = 6hr storm duration and temporal pattern ensemble number 1.

Figure 4-1 below shows the results of the hydrologic model.

Final as submitted to DNRME

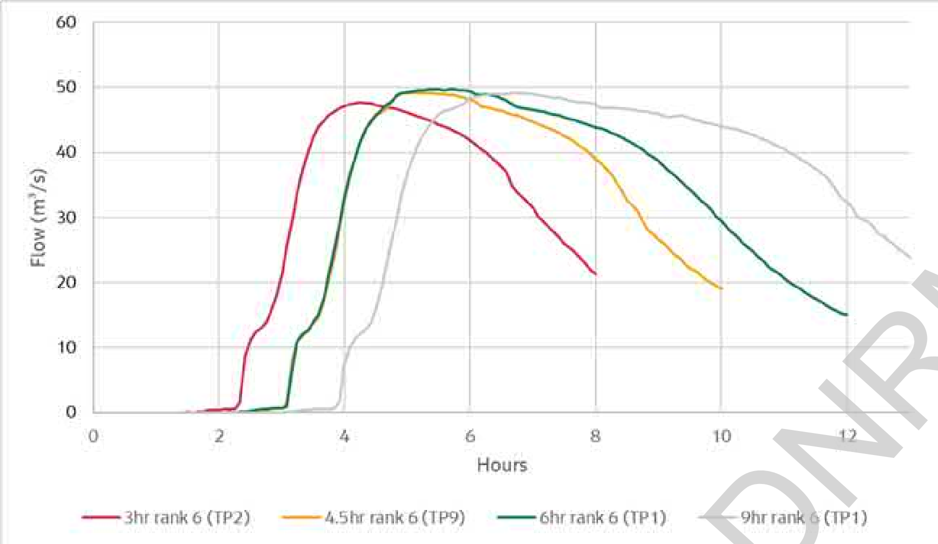


Figure 4-1: Hydrologic Model Results

4.5 Mine Affected Water Flows

It was assumed all catchments upstream of the mine are generating clean water. All the internal catchments inside of the mine site were considered to generate MAW, including the haul road and rehabilitated tailing storage. A preliminary simulation was used to identify the catchments and peak flows for the MAW.
The second step in the design process was to determine the existing peak flow entering the site from Barrett Creek in the 10% AEP event. In the current situation (10% AEP event), Barrett Creek undergoes a flow split around the rehabilitated tailing storage to the west of the haul road. The model results indicate that in the 10% AEP event, approximately 16 m3/s passes under the haul road through 3/1350mm diameter culverts and approximately 9 m3/s goes over the haul road. The rest (19 m3/s) of Barrett Creek flows in a northerly direction, to the west of the rehabilitated tailing storage and runs parallel with Saraji Road towards the wetland area.

4.6 DNRME Requirements

This section provides an overview of the hydraulic analysis process undertaken for the proposed Barrett Creek Diversion. The purpose of the hydraulic analysis is twofold;

- To calculate the estimated erosion potential indicators (shear stress, stream power and stream velocity) for the 1% AEP and 50% AEP flow events and to determine the level of conformance with Works that interfere with water in a watercourse for a resource activity—watercourse diversions authorised under the Water Act 2000 (DNRME 2019); and
- To ascertaining estimated flood levels including the 0.1% AEP flow event to inform total containment within the channel during these significant flood event.

The outcomes of the above have been used to assist and tailor the design of the Barrett Creek Diversion channel so that it conforms to the requirements of both DNRME and BHP. The modelling results are presented in the following sub-sections.

Table 4-2: Guideline values for average stream powers, velocity and shear stress for streams within the Bowen Basin (source ACARP 8030 – Maintenance of Geomorphic Processes in Bowen Basin River Diversions

Scenario	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
50% AEP – Non-Vegetated Scenario	< 35	< 1.0	< 40
50% AEP – Vegetated Scenario	< 60	< 1.5	< 40

Final as submitted to DNRME

2% AEP	< 150	< 2.5	< 80

*Derived from ACARP Guidelines

4.7 Flood Mapping

Flood mapping is provided in Appendix B, summarising Flood Depth, Difference in Flood Levels, Velocity, Stream Power and Bed Shear Stress.

4.8 The 0.1% AEP Inundation

Mapping has been undertaken to demonstrate differences in flood inundation that might result from the diversion, for the 0.1% AEP event. This can be viewed in detail in Appendix B. The primary outcome is shown in Figure 4-2.

Final as submitted to DNRME

Flood Level difference for 0.1%AEP Flood Event

Figure 4-2: Afflux map for 0.1%AEP flood event

Final as Submitted to DNRME

4.9 Overview of Hydraulic Modelling

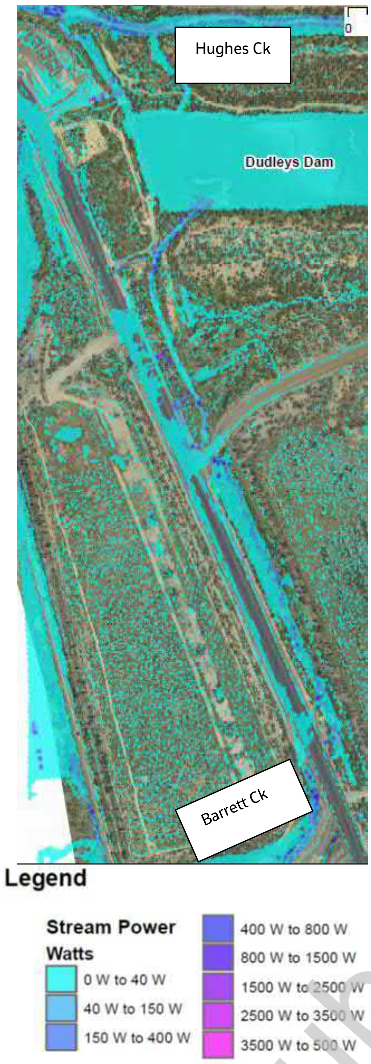
The erosion potential indicators (shear stress, stream power and velocity) were output from the hydraulic model for the 1% AEP and 50% AEP flood events. Bed sheer stress and stream power are not typical model outputs so additional hydraulic modelling was required to generate these data.

The identified critical storms (50% AEP, 24 hr, TP 1 & 1% AEP, 6 hr, TP2) were run in the TUFLOW model for the design case scenario. The bed sheer stress (BSS), stream power (SP) and velocity (V) outputs were activated. An alternative design case scenario was also set up and simulated with the identified critical storms. The alternative design scenario removed inflows and rainfall from Hughes Creek. This was done to simulate a more conservative scenario whereby lower tailwater levels in Hughes Creek would encourage higher velocities, bed sheer stress and stream power in the Barrett Creek bypass channel. Mapped results from both design scenarios were used to inform the geomorphic review.

4.10 Comparison of Existing Barrett Creek Versus Proposed Temporary Barrett Creek Diversion

The specific dimensions of the proposed temporary diversion closely replicate those of the current diversion. As a check to confirm the channels will essentially function the same, the following comparison of Stream Power for the 50% AEP event can be visualised for the vegetated channel. Values are within the same range. Demonstration that the proposed temporary diversion operates within DNRME (2019) hydraulic criteria is further developed in Section 5.6 and 5.7.

Final as submitted to DNRME



50% AEP Stream Power Existing Diversion

50% AEP Stream Power Proposed Temporary Diversion

Figure 4-3: 50% AEP stream power comparison for existing and proposed temporary diversion

4.11 Roughness Sensitivity Analysis

Within the model, Mannings roughness coefficient has been modified within specific runs as a sensitivity analysis to largely ascertain how the diversion will function under the scenario where no vegetation is present (initial years following construction), and if vegetation is established. These different values are shown in Table 4-3.

Table 4-3: Mannings roughness coefficients

Layout in Channel Profile	Vegetated Diversion Channel	Non-Vegetated Diversion Channel
Channel bed	0.035	0.035
Channel batters	0.065	0.045

Final as submitted to DNRME

4.12 Analysis of Proposed Barrett Creek Temporary diversion

Table 4-4 below represents the outputs from the hydraulic modelling for the 2% AEP and 50% AEP flood events. For each of these scenarios, specific detail has been provided for zones of particular interest. The zones are where typically similar erosion risks have been observed. In the instances where an exceedance occurs for the temporary diversion, erosion control measures will be employed to manage that erosion risk. These specific zones are:

- Upstream extents at the entry structure to the diversion (upstream of Ch 100).
- Middle reaches from Chainage 100 to 1300 adjacent to the Haul Road.
- Upstream of the Haul Road in the vicinity of the culvert (Ch1300 to Haul Road).
- Immediately downstream of the Haul Road to Hughes Creek.

Table 4-4 Hydraulic Modelling Results

		50% AEP (vegetated scenario)			50% AEP (non-veg scenario, Earthen Channel)			2% AEP		
		Stream Power	Shear Stress	Velocity	Stream Power	Shear Stress	Velocity	Stream Power	Shear Stress	Velocity
		W/m²	N/m²	m/s	W/m²	N/m²	m/s	W/m²	N/m²	m/s
Upstream Extents	Highest Values	40	**500**	**2.5**	**40**	**500**	**3**	**4000**	**1000**	2
	Mean Values	20	**40**	0.8	20	**50**	1	**400**	**80**	2
Middle Reaches	Highest Values	40	20	**2**	**40**	20	**2**	150	**200**	2
	Mean Values	20	10	0.8	20	10	1	40	20	1.5
Upstream of Haul Road	Highest Values	**150**	**500**	1	**150**	**500**	1	**800**	**1000**	1
	Mean Values	20	20	0.5	20	20	0.5	40	**100**	1
Downstream of Haul Road	Highest Values	**150**	**100**	**2**	**150**	**100**	**2**	**800**	**1000**	1.5
	Mean Values	40	**80**	0.5	30	**80**	0.5	80	40	1
DNRME Mean Target Criteria		*<60*	*<40*	*<1*	*<35*	*<40*	*<1.5*	*<150*	*<50*	*<2.5*

*Note bold **RED** values are above DNRME Criteria

The following should be noted when interpreting the results:

- Where DNRME mean criteria are exceeded, this occurs in areas where engineered works are designed. The engineered works typically comprise of rip rap and rock aprons. In zones for the 50% non vegetated scenario, Rock mulch is applied to increase roughness, and reduce the erosion risk while vegetation establishes.

Final as submitted to DNRME

- **Stream Power**: Unit Stream Power (ω) values are calculated, according to equation $\omega = \rho g Q S / w$, where ρ is the density of water (1,000 kg/m^3), g is acceleration due to gravity (9.81 m/s^2), Q is discharge (m^3/s), S is the channel slope and w (m) is the width of flow.
- **Shear Stress**: Shear stress has been calculated with reference to channel flow depth, to provide a measure of upper level channel boundary shear stresses that could be expected to occur. The equation for boundary shear stress (τ) is, $\tau = \gamma DS$ where γ is the specific weight of water, $D$is the channel depth and S is the channel slope.
- **Velocity**: =Velocity is measured in m/s.

4.13 Comparison to DNRME Guidelines

4.13.1 Overview

Hydraulic analysis of the diversion model has been undertaken to determine the adequacy of the design in meeting the limits of the DNRME diversion design criteria. These guideline limits shown in Table 4-4 indicate thresholds at which erosion may be induced for a specific flood event. In the case of the 50% AEP, this assumes an unvegetated channel which would scour topsoil and organic mulch which might be in place prior to vegetation establishing. For the purpose of the temporary diversion design plan case, analysis has been broadly undertaken against DNRME criteria with the following assumptions:

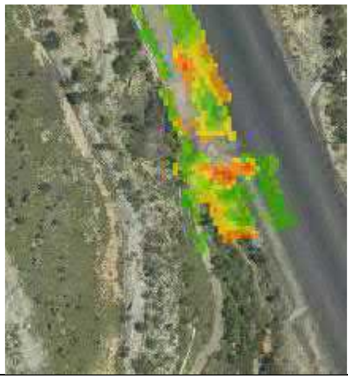
- Velocity, Bed Shear Stress and Stream Power have been assessed as readily available.
- The non-vegetated scenario with topsoiled batters has been assessed as the worst case for the newly established diversion.

The flood maps used for this assessment are attached in Appendix B.

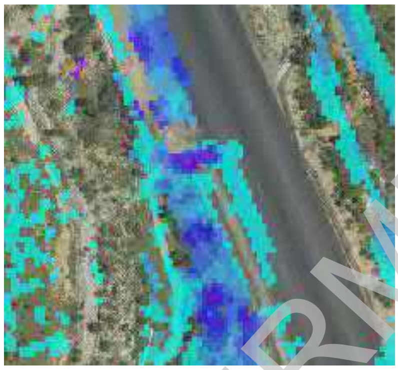
4.13.2 Upstream extents at the entry structure to the diversion

In the vicinity of the commencement of the diversion at the entry structure, localised high velocity, bed shear stress and stream power is present. This is as expected where a hydraulic control structure is provided. It is anticipated suitable rock scour protection will be required in the bed downstream of the structure and particularly on the batters downstream of the structure. The structure is designed to regulate flows; therefore, modification of the channel cross-section is not possible. The bed and bank armouring will suitably control these ongoing high bed shear stress and stream power values. Screen shots from the model are shown for each scenario in the tables below. It is particularly clear for the 2% AEP event for bed shear stress, that high values are present immediately upstream and downstream of the culvert. While this reduces significantly for the 50% AEP rock armouring is necessary and provided.

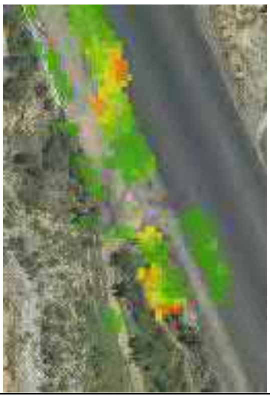
Final as submitted to DNRME



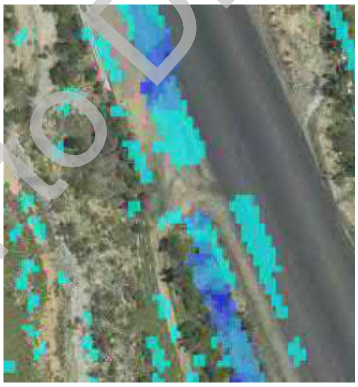
2% AEP Bed Shear Stress



2% AEP Stream Power



50% AEP Shear Stress



50% AEP Stream Power

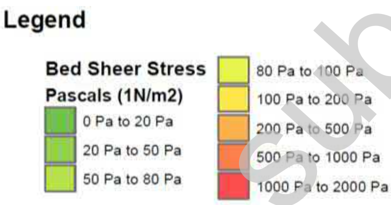


Figure 4-4: Visual Overview of Hydraulic Modelling Results

4.13.3 Middle reaches from Chainage 100 to 1,300 adjacent to the Haul Road

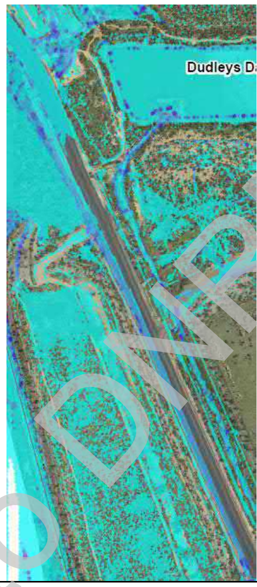
This reach covers the majority of the diversion channel and is essentially the section which runs parallel to the Haul Road. The hydraulic modelling typically indicates relatively low hydraulic values as summarised in Table 4-4. That said there appear to be localised scour points on the upper left batter, however it appears likely these are anomalies in the model where the batter has been trimmed; these can be refined in more detail as the design progresses. Most values in this reach appear to be in the vicinity of or less than the DNRME threshold criteria. It is noted high velocities can occur downstream of the control structure and will need to be managed with a rock protection apron for the 2% AEP event.

Otherwise it is likely the main form of batter treatment for this reach is likely to be a combination of soil amelioration, topsoil and organic mulch. This means the need for a roughened batter to manage erosion while vegetation establishes using rock mulch is not likely to be justified; the use of rock mulch would not however have any adverse impact, should BHP choose to utilise this treatment option.

Final as submitted to DNRME

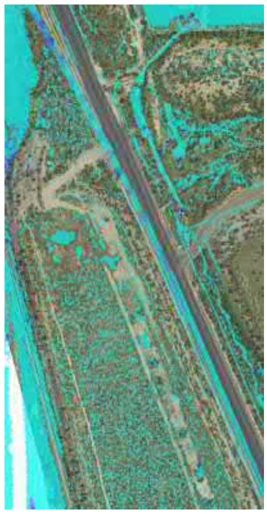
Given hydraulically there is no need for the roughened channel. Geotechnical considerations ultimately would drive the batter treatment options.

2% AEP Bed Shear Stress



2% AEP Stream Power

50% AEP Bed Shear Stress



50% AEP Stream Power

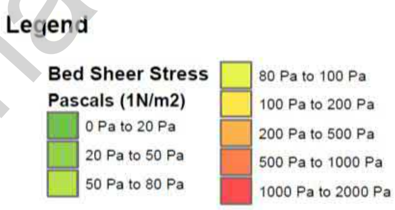


Figure 4-5: Visual Overview of Hydraulic Modelling Results in the middle reach of the diversion channel

Final as Submitted to DNRME

4.13.4 Upstream of the Haul Road

At the Haul Road a series of culverts to transfer flows further down the Barrett Creek are required. The hydraulic modelling indicates that immediately upstream of the culverts there are localised points of high velocity, bed shear stress and stream power, however the typical values are within the DNRME guidelines. However, it is prudent to provide batter protection in particular to minimise channel batter scour process. The bed of the creek approaching the culverts appears relatively stable, however it is likely eddying and channelling of flow into the culverts is creating high stream power, which if left unchecked it may lead to scour and outflanking of the culverts.

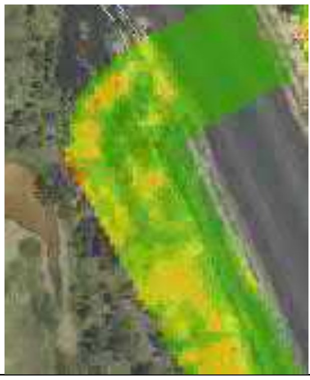
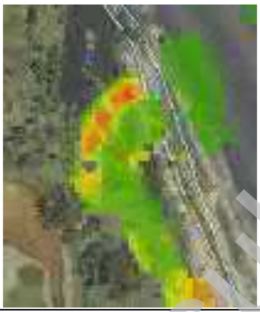
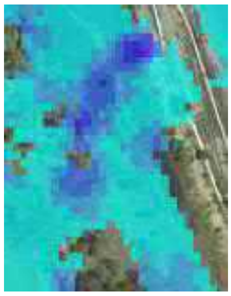
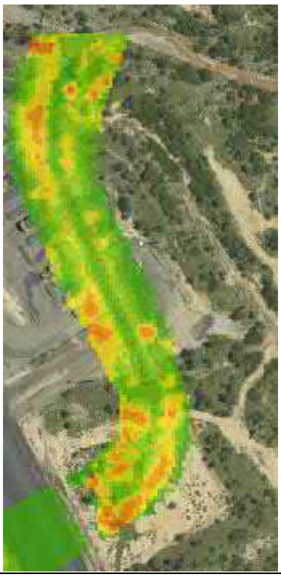
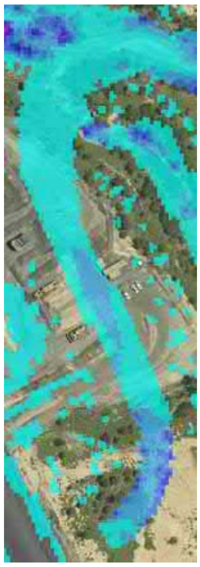
	
2% AEP Bed Shear Stress	2% AEP Stream Power
	
50% AEP Bed Shear Stress	50% AEP Stream Power
	

Figure 4-6: Visual Overview of Hydraulic Modelling Results

Final as submitted to DNRME

4.13.5 Immediately downstream of the Haul Road

At the Haul Road a series of culverts to transfer flows further down Barrett Creek are required. Hydraulic modelling results indicates that immediately downstream of the culverts there are consistent high velocities, high bed shear stress and high stream power, above the DNRME Guidelines thresholds. This is as would be expected given the culverts transfer all Barrett Creek flow. It is recommended to provide a rock apron downstream of the culverts, and batter protection in the form of rock rip rap downstream of the culverts.

	
2% AEP Bed Shear Stress	2% AEP Stream Power
	
50% AEP Bed Shear Stress	50% AEP Stream Power

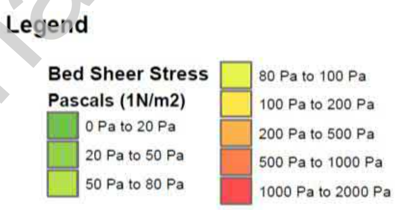


Figure 4-7: Visual Overview of Hydraulic Modelling Results

Final as Submitted to DNRME

5. Barrett Creek Temporary Diversion – Geomorphic Design Features

5.1 Erosion Risk Assessment

5.1.1 Introduction

The following analysis is made to determine the need for batter protection to reduce the risk of erosion from creek in the Barrett Creek diversion prior to the establishment of vegetation. Treatments such as Rock Mulch increases roughness typically on the channel batters replicating the roughness of vegetation and reducing the risk of scour of topsoil while vegetation is establishing in the initial years while the diversion establishes.

Depending of the outcomes of geotechnical analysis, imported topsoil and soil amelioration may be needed to manage dispersive soils. Rock mulch does not remove the need for this but provides protection against soil mobilisation by water moving in the channel.

5.1.2 Shields Equation

Shields Equation can be utilised to broadly estimate the size of material that might be mobilised for a specific bed shear stress value

Using Shields equation:

Bed Shear Stress (BSS) = θ_C x g x d_i x (p_s – p)

Where:

- Bed shear stress varies depending on modelled values
- θ_c = 0.032 (sandy material);
- Specific gravity particles = 2,650g

Therefore, bed shear stress = 0.032 x 9.81 x D_{50} x (2650 – 1000) = BSS N/m^2

For a range of BSS modelled for the site, the following D_{50} rock sizes are calculated to act as the threshold D_{50} sediment size at which scour of the sediment might be anticipated.

Table 5-1 Bed Sheer Stress Values

Bed Shear Stress (N/m^2)	Calculated threshold D50 rock size (mm)
1N/m^2	1.9mm
5N/m^2	9.7mm
10N/m^2	19.3mm
15N/m^2	29.0mm

5.1.3 Batter Treatment

The 50% AEP event is analysed to assess the need for batter protection to increase roughness and therefore reduce the risk of erosion. Typical Bed Shear Stress for this event is of the order 10N/m2 in the middle reaches based on hydraulic modelling

Final as submitted to DNRME

Shields equation broadly indicates a sediment of the order 19mm diameter might be mobilised in this event.

Depending on the proposed topsoil mix structure, it would need to be assumed topsoil with a gravelly mix of 20mm material would be required to maintain stable batters while vegetation establishes.

The bulk of the proposed channel adjacent to the haul road would require amelioration with gypsum, as discussed in Section 2, to reduce the impact of dispersive soils, reducing the soil pH. It has therefore been assessed that rock mulch and topsoil should be applied across all batters to remove the need for such amelioration while providing the secondary benefit of increasing roughness and reducing the risk of erosion while vegetation establishes.

The invert batter toe areas are to be seeded with a mix of native tree and shrub species, reflecting remnant areas on and near to the mine lease. The remaining topsoil batter upslope areas could be seeded to a pasture species mix in accordance with the Saraji Mine's rehabilitation procedures..

5.1.4 Channel Base Treatment and Sediment Transport

The existing environment along the Barrett Creek is relatively stable and includes a defined low flow channel. Additionally, a constant sediment load passes through this sand-bed stream, within the low flow channel and depositing on benches. It is anticipated sediment loads from upstream will continue to pass through the system, therefore the design will include suitably sized culverts to avoid sediment build up, a narrow low flow channel to allow scour of sand in smaller flow events, and the provision of benches on which some sediment can deposit, provide nutrients for vegetation growth, then naturally scour in larger flow events. No treatment of the bed in the form of rock or vegetation is deemed necessary as the sand bed load will dominate the feature.

Engeny 2016 indicates adjacent stockpiles are also generating sediment. Provision of appropriate sediment control measures for these stockpiles should be provided during the construction phase, while the ongoing management of their rehabilitation is managed by BMA to ensure sediment runoff decreases over time.

5.1.5 Scour protection in High Erosion Risk Zones

Scour protection in the form of rock rip rap and rock aprons in the bed will be required in the vicinity of the control structure and Haul Road culvert.

Downstream of each structure, a rock apron has been designed in accordance with Outlet Scour Design, Queensland Urban Drainage Manual (QUDM) (2019), using figure 10.12 as the design tool. The features of this design are listed in below:

Table 5-2 Design of bed Scour Protection in accordance with QUDM (2019)

Item	Control Structure	Haul Road Culvert
Peak Velocity Downstream of culvert 1% AEP	2.7m/s	1.8m/s
Culvert Diameter	1500mm	1500mm
Length of Scour Protection	4 x diameter = 6m	3 x diameter = 4.5m
Apply Factor of Safety	1.33	1.33

Final as submitted to DNRME

Design length of scour protection	8m	6m
D50 Rock	300mm	200mm (use 300mm for consistency)

On batters, rock rip rap will b required in zones of high stream power and velocity, which have been identified in modelling as being present downstream of the control structure, upstream of the Haul Road and downstream of the Haul Road. In accordance 9.9.4 of QUDM (2019), D50 = 0.04 xV^2. Using a worse case scenario in the vicinity of the Haul Road, D50= 0.04 x 1.8^2 = 130mm. In the vicinity of the control structure, D50= 0.04 x 2.7^2 = 300mm. therefore, applying a D50 of 300mm is acceptable across these areas, as shown on the design drawings.

5.2 Surface Water Management During Construction

The proposed temporary diversion will be constructed off line with the existing diversion continuing to function until the completion of civil works. As such construction should only need to manage localised runoff during construction. A sediment management plan will be prepared prior to the commencement of works to manage sediment and water quality and shall be prepared in accordance with an appropriate standard such as AustRoads or Queensland Urban Drainage Manual.

5.3 Revegetation

Revegetation of the site is a key component of the long-term stabilisation of the temporary diversion and should occur immediately following the completion of the diversion earthworks. Vegetation will increase channel roughness and reduce the risk of piping failure and rill erosion on the banks of Barrett Creek. Disturbed areas shall be topsoiled and revegetated with grasses as well as trees and shrubs.

All vegetation clearing, revegetation and topsoil recovery and use will be undertaken in accordance with Saraji Mine's rehabilitation procedures.

An assessment of existing ecological values is provided in BAAM 2018.

5.4 Rock Protection

In zones of high stream power and velocity it is anticipated rock rip rap will be required to reduce the erosion risk. This is particularly evident in the vicinity of the Haul Road culvert.

Rock Rip Rap is designed in accordance with CRC Toolbox Rip Rap and checked against an appropriate manual such as QUDM to provide a stable environment in these zones.

Final as submitted to DNRME

6. Barrett Creek Temporary Diversion - Monitoring Program

6.1 Overview of the Monitoring Plan and Most Recent Outcomes

The Saraji Mine is required to manage the Barrett's Creek diversion in accordance with the conditions outlined in the water licence issued by Department of Natural Resources and Mines. The site is monitored in accordance with Watercourse Diversion Monitoring and Evaluation Procedure, BMA 2018. The Barrett Creek Diversion Monitoring Program is referenced in this document.

The most recent Monitoring program was completed by Engeny, in 2016. Outcomes of this monitoring report are summarised herein.

The Watercourse Diversion Monitoring and Evaluation Program for BMA Operations (BMA 2018) was developed to provide guidance in regards to suitable creek diversion surveillance activities and associated frequencies to comply with the Department of Natural Resources and Mines (DNRME) model licence conditions for creek diversions.

The Watercourse Diversion Monitoring and Evaluation Program adopted a risk-based approach determining the type of monitoring activities and frequency of monitoring required for individual creek diversions. Diversions rated as 'high risk' require major monitoring every 2 years, while 'low risk' diversions require major monitoring every 5 years.

The Barrett's Creek Diversion was rated as low risk (Engeny 2016) due to the combined comparable total IDC scores for the diversion reach compared to the total IDC scores for the upstream control reach; and the diversion scores improving over the previous 3 monitoring periods. As such it is required to have a major monitoring assessment undertaken every 5 years.

The 2016 major monitoring assessment is the first surveillance monitoring activity undertaken for the Barrett's Creek Diversion under the new DNRM model licence conditions and is the first round of monitoring since 2013.

The objective of the major monitoring assessment is to assess whether the creek diversion is progressing toward meeting the following outcomes;

- Developing geomorphic and vegetation features similar to those in the local landscape.
- Maintaining a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Diversions and structures are maintaining equilibrium and functionality and do not require ongoing maintenance.

Additionally, the licence conditions require the monitoring and evaluation report to provide a timetable for implementation of appropriate measures which must be implemented and monitored in the event the condition outcomes are not being met.

6.2 Diversion Details

The following details are provided from the diversion licence; the temporary diversion forms part of the licence area.

Final as submitted to DNRME

Table 6-1 Barret Creek Diversion Licence Details

Creek Name: Barrett Creek	
Licence Number	30970F
River Catchment	Isaac River, Fitzroy River
Total Length	2.57km
Catchment Area	35km^2
Stream Order	3
Date of Construction	1976 (approx.)
Engineering Design	Unknown
Rehabilitation Plan	No
Local Ecosystem Description	Acacia harpophylia shrubby woodland with Terminalia oblongata on Cainozoic clay plains; Eucalypytus populnea woodland on alluvial plains
Diversion Risk Rating (Engeny, 2015)	Low
Historical Monitoring Record	2011[1], 2013

1. No IDC undertaken in 2011

6.3 Monitoring Point Locations

Current monitoring points are shown below.

Final as submitted to DNRME

Figure 6-1: Creek Diversion Monitoring Points

6.4 Objectives of a Monitoring Program

Monitoring of the Barrett Creek Temporary Diversion will be incorporated within the Barrett Creek Diversion Monitoring Program, which is developed in accordance with Watercourse Diversion Monitoring and Evaluation Procedure, BMA 2018. The main objective of watercourse diversion monitoring during operations is to monitor channel condition, reduce risk to mining infrastructure and ensure the diversion is on the path to relinquishment. DNRM (2014: 13-14) guidelines state that channel condition and functional design of permanent watercourse diversions should be judged by whether the diversion meets several objectives. These are:

A. Incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
B. Maintains the existing hydrologic characteristics of surface water and groundwater systems.
C. Consists of hydraulic characteristics comparable with other local watercourses and suitable for the region in which it is located.
D. Maintains sediment transport and water quality regimes that allow to be self-sustaining, while minimising the impacts to upstream and downstream reaches.
E. Maintains equilibrium and functionality and is appropriate for all substrate conditions they encounter.

By adopting and thoroughly executing a well-structured monitoring and evaluation program and actioning the recommendations of each evaluation, all of these objectives can be fulfilled.

6.5 Overview of Monitoring Timing

The monitoring of the Barrett Creek Diversion will be part of the Barrett Creek Diversion Monitoring program but will require a refinement to the current program to reflect the construction and post-construction phases of the diversion.

In accordance with BMA 2018, a monitoring report should be prepared at the following times:

A. At each renewal of the water licence, or
B. At any time if alarming, unusual or otherwise unsatisfactory conditions are observed.
C. Monitoring of the interference must include recommendations as per ACARP (2001).
D. The report must detail:

Final as submitted to DNRME

a. The performance of the works by way of comparison with the design report, approved plans and specifications.
b. Any remedial works to be undertaken with a timetable for remedial works.
c. Any recommendations on measures to be taken to ensure the physical integrity of the works.
d. Survey information to quantify any changes to the channel bed and profiles.

Furthermore, all new diversions should be monitored in years 1, 3 and 5 following construction using the Major Monitoring methodology (Section 6, BMA 2018) to enable an initial environmental compliance/relinquishment risk to be determined. If no flows occur between monitoring efforts, monitoring can be delayed by a maximum of one year. Following three monitoring efforts, a new risk category can be assigned based on the monitoring results. On the years where these monitoring efforts overlap with the internal Minor Monitoring, no Minor Monitoring is required.

6.5.1 Major Monitoring Methodology

In accordance with Table 6.1 of BMA 2018, the following major monitoring methodology would be applied for the whole of Barrett Creek, incorporating new transects T2, T3 and T4, within the zone where the temporary diversion will be constructed.

Table 6-2 Major Monitoring Methodology Tasks and relevant model licence conditions

Monitoring Task	Relevant Model Licence Condition
Index of Diversion Condition (IDC) monitoring	1. a) Paragraph 2, dot point 1 and 2
Fixed point photographs, including analysis of historical photographs to determine changes over time	1. a) Paragraph 2, dot point 1 and 2
Aerial photograph analysis to identify lateral shifts in channel position	1. a) Paragraph 2, dot point 3
Flow event overview/analysis to identify natural flow disturbance since diversion design and the previous monitoring effort	1. a) Paragraph 2, dot point 1, 2 and 3
Comparative Lidar assessment to determine changes in elevation since the previous monitoring effort to approximate sediment transport. This should include a cross- section analysis at each identified cross-section location and a longitudinal profile assessment, as per ACARP (2001). The assessment should also consider whether geomorphic features (e.g. benches/bars) are forming within the diversion.	1. a) Paragraph 2, dot point 1, 2 and 3
An assessment of the condition of any rectification or rehabilitation measure (e.g. bank stabilisation works, structures) that has been installed within the diversion to ensure it complies with the model licence conditions. This should include an informed visual assessment of whether the measure is operating as it was designed.	1. d)
A full walk-through of all diversion, upstream and downstream reaches to get an overview of the diversion performance and to understand whether natural features are developing throughout. This should include photographs with GPS coordinates.	1. a) Paragraph 2 dot point 2
A detailed vegetation survey that meets ensures that the diversion will meet the relevant model licence condition outcomes.	1. a) Paragraph 2, dot point 1
A review of recent minor monitoring efforts undertaken to ensure data quality and inform assessment of diversion performance.	1. a) Paragraph 2, dot point 2
Preparation of a monitoring and evaluation report that:	1. a), b), c) and d)

Final as submitted to DNRME

Evaluates monitoring activities between monitoring periods in order to demonstrate whether the diversion is meeting or progressing towards achieving the outcomes of Condition 1a of the model licence conditions outlined in Appendix A. Provide recommendations for the implementation and monitoring of appropriate measures that ensure the diversion will meet these licence condition outcomes. Provide a timetable for completion of the proposed measures.	
Reassess risk rating of each diversion to inform the timing of the next Major Monitoring event.	
All raw data, including cross-section/longitudinal profile locations, topography, photographs, models, vegetation, IDC scores etc. should be provided to BMA as part of reporting and stored on site and centrally to enable future replication.	1. a), b), c) and d)

6.5.2 Construction Monitoring Execution Outputs

The first monitoring activity to occur commences at the start of diversion construction and carries on through to the end of the construction. The objective is to determine any discrepancies between the diversion design and as constructed and provides details of any modification to the design. The outputs of this activity are also typically included in the as-constructed/completion report, therefore serving multiple purposes. The following list includes, but is not limited to, specific works which should be monitored as the construction of the diversion progresses.

Table 6-3: Execution outputs to be monitored during construction

Phase of Construction	Work item
Bulk Excavation	Stripping depth; topsoil
	Placement; stockpiles
	Buffer zones; stockpiles, access tracks
	Diversion channel; bed width, bed grade
Detailed Excavation	Diversion channel; batter slopes
	Stockpile; batter slopes
	Plug construction; material specification
Topsoiling	Diversion and stockpile; topsoil thickness
	Catch drains; thickness of rock, fall
Reinstatement	Revegetation of Trees, Shrubs and Grasses specification, coverage
Throughout	Monitor Water quality upstream and downstream of work site
	Provide appropriate bunding, sediment traps and any biofilters within a construction sediment management plan

6.5.3 Monitoring Recommendations of Temporary Diversion Post-construction

At the completion of construction, the Barrett Creek Monitoring Program will be modified to reflect the new diversion. The diversion essentially runs adjacent to the existing diversion; therefore it is anticipated the transects will be established at similar intervals to the existing diversion. It is recommended a transect be installed immediately downstream of the control structure (replacing T2), adjacent to the haul road, opposite T3, (replacing T3) and downstream of the haul road upstream of Hughes Creek (replacing T4). As summarised in section 6.5, the following is recommended:

- The monitoring of the Barrett Creek Diversion will be part of the Barrett Creek Diversion Monitoring program

Final as submitted to DNRME

- At renewal of the water licence (year 1)
- At any time if alarming, unusual or otherwise unsatisfactory conditions are observed.
- Subsequently in Year 3 and Year 5.
- The report must detail:
    a. The performance of the works by way of comparison with the design report, approved plans and specifications.
    b. Any remedial works to be undertaken with a timetable for remedial works.
    c. Any recommendations on measures to be taken to ensure the physical integrity of the works.
    d. Survey information to quantify any changes to the channel bed and profiles.

Final as submitted to DNRME

7. How the Barrett Creek Temporary diversion meets the outcomes of the DNRME Guidelines 2019

The following table summarises how the Barrett Creek Diversion meets the outcomes specified in table 8 of Works that interfere with water in a watercourse for a resource activity—watercourse diversions authorised under the Water Act 2000 (DNRME 2019)

Outcome 1: The temporary watercourse diversion maintains the existing hydrological characteristics of surface water systems. The proposed temporary diversion conforms to this requirement	
▪ a detailed description of the development and calibration or sensitivity analysis of the hydrologic model. ▪ reference to the methodologies used to generate flood frequency analysis.	As summarised in Section 4, the proposed diversion replicates as closely as possible the hydrologic and hydraulic conditions of the currently stable and functioning Barrett Creek Diversion. Details of the hydrology and hydraulics are provided in Section 4 and 5 of this report. The proposed diversion is at the downstream extent of Barrett Creek. The proposed diversion closely matches the existing channel capacity, and flows within the proposed Barrett Creek diversion converge into Hughes Creek at the same location as the existing diversion.
Outcome 2: The hydraulic characteristics of the temporary watercourse diversion are comparable with other local watercourses and are suitable for the region in which the watercourse diversion is located. The proposed temporary diversion conforms to this requirement	
▪ detailed description of the development and calibration or sensitivity analysis of the hydraulic model. ▪ hydraulic modelling results provide evidence that impacts upstream and downstream of the temporary watercourse diversion footprint can be managed or mitigated. ▪ a sensitivity analysis for hydraulic roughness during the temporary watercourse diversion life to determine if proposed roughness levels will provide conditions necessary to ensure the equilibrium and performance of the temporary watercourse diversion. ▪ a hydraulic analysis that identifies if the extent and depth of inundation between existing and post-diversion conditions has changed. ▪ a staged development of the floodplain (if relevant) when planning for resource activities adjacent to the temporary watercourse diversion. ▪ hydraulic modelling must be performed at each development period to determine the impact on	Section 5 summarises the hydraulic modelling undertaken for the Design Plan of the temporary diversion of Barrett Creek. The modelling as discussed in Section 5 looks at various flood events to assess the likelihood of scour and inundation. In particular for the 50% AEP event it is possible to model the likely hydraulic parameters that might be expected in the initial years following construction when the channel might be prone to scour prior to full vegetation establishment. The model applies appropriate channel roughness that might be expected for various feature channel situations within the channel including vegetated zones and sand bed channel inverts as an example. Hydraulic features including the approach structure, haul road culvert and confluence with Hughes Creek are included. Hydraulic modelling demonstrates modelling is typical for what might be expected for a Bowen Basin stream. Where thresholds are exceeded in the vicinity of engineered structures, appropriate erosion

Final as submitted to DNRME

the temporary watercourse diversion and adjacent watercourse. ▪ the location and hydraulic effect of features. ▪ the effect on hydraulic conditions within the temporary watercourse diversion of features (e.g. batter drains) that direct overland flow to the watercourse diversion.	control measures are designed for this temporary diversion.
Outcome 3: The temporary watercourse diversion maintains a sediment transport regime that minimises any impact to upstream and downstream reaches. The proposed temporary diversion indirectly conforms to this requirement.	
▪ The design plan should include a sediment transport analysis that identifies how the temporary watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	A full sediment transport analysis has not been completed for this investigation. Barrett Creek is similar to most creeks passing through the Saraji Mine and surrounding Dysart catchments. It is a sand bed stream with a high sand bed load in the creek upstream and downstream in Hughes Creek. The model sufficiently demonstrates bed shear stress and stream power are within the limits of the DNRME criteria for a Bowen Basin stream. The proposed diversion closely replicates the cross section, plan form and gradient of the existing diversion which passes sediment and maintains a stable channel. Further evidence the diversion will pass sediment can be evidenced by a check with Shields Equation (Section 6) which estimates the mobilisation of sediment of the order 20mm for a 50% AEP event.
Outcome 4: The temporary watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter. The proposed temporary diversion indirectly conforms to this requirement.	
▪ a geotechnical analysis and accompanying map of all substrate material encountered within the temporary watercourse diversion alignment that identifies soil chemical and physical properties including constraints to equilibrium of temporary watercourse diversion surfaces, vegetation establishment and persistence ▪ system for ensuring appropriate remedial actions are undertaken where potential or existing change to equilibrium is identified as a result of substrate or spoil characteristics.	Section 2 summarises the expected substrate material which will be encountered, and remedial actions required to maintain a stable temporary diversion over time.

Final as submitted to DNRME

8. Barrett Creek Permanent Diversion

8.1 Design

This study specifically focuses on the Design Plan of the temporary diversion of Barrett Creek for the proposed mine life. Post closure, Barrett Creek will revert to a permanent diversion which will aim to match the features that Barrett Creek would have exhibited prior to the construction of the diversion in the 1970's; the final alignment will be influenced by the constraints of the final landform design. The final diversion is visualised in Figure 8-1 below, with the following features highlighted:

- Replicate the same channel length as the current and proposed temporary diversion
- No engineered structures within the diversion to avoid ongoing maintenance and asset replacement
- Adopt a cross section profile typically the same as the temporary diversion, which will be revegetated and remain stable and in geomorphic equilibrium over time
- Construct the diversion through in-situ material or stable backfill material. Therefore, avoid realignment through Dudley's Dam alignment post closure.
- Allow provision of a low flow channel to maintain a stable channel form at low flow.
- Smoothly transition the diversion alignment into Hughes Creek to avoid stability issues such as head cuts in Barrett Creek and destabilising bank erosion in Hughes Creek
- Avoid constrictions, particularly at the upstream extent which may create bank scour and potentially cause instabilities upstream in Barrett Creek.

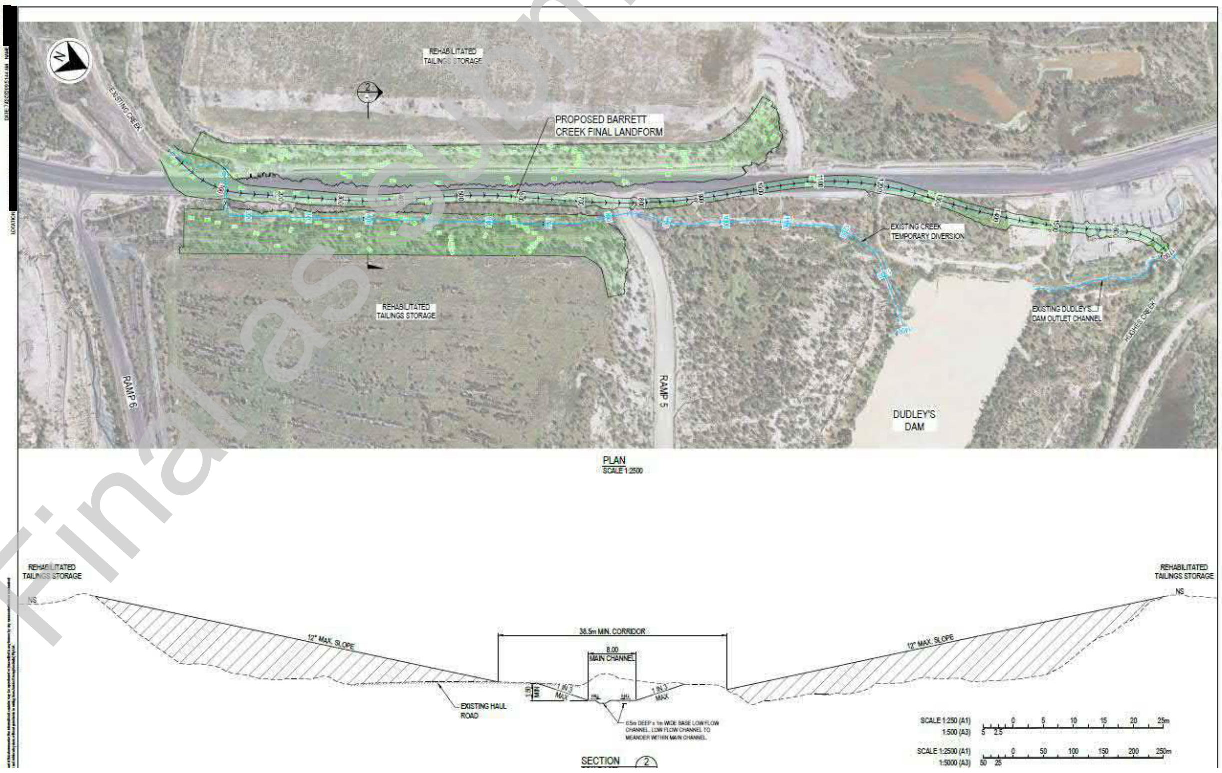


Figure 8-1 Proposed Alignment and Cross Section profile

Final as Submitted to DNRME

Details for consideration in a permanent diversion design could include:

- Transition from Barrett Creek into the permanent diversion avoiding all engineered structures, ensuring the diversion will be self-sustaining and replicating a natural creek into the future.
- Transition from permanent diversion to Hughes Creek ensuring a stable alignment and transition which avoids engineered structures. This ensures the diversion will be self-sustaining and replicating a natural creek into the future and has no adverse impact on Hughes Creek.
- Geomorphic features including localised pools if appropriate, a low flow channel, benches alternating from the low flow channel.
- Revegetation design
- Monitoring program
- Hydraulic modelling to demonstrate the permanent diversion meets DNRME guidelines or replicates a natural waterway for this type of waterway in the Bowen Basin.

8.2 Timing

The permanent creek diversion will be constructed upon Mine Closure or final Area Rehabilitation, whichever is earlier.

8.3 Permanent Diversion Compliance to DNRME 2019 Guidelines

The following table summarises the Design Plan requirements for the construction of a permanent diversion, and comment on the level of detail provided in this report for the concept for the permanent diversion of Barrett Creek, which will be constructed following mine closure in approximately 100 years' time.

The Design Plan documentation should include, but not be limited to:	Comment on Permanent Diversion Concept
Geomorphic and vegetation assessment of the existing watercourse.	The same assessment as the temporary diversion is used.
Hydrologic conditions of the existing watercourse.	The same assessment as the temporary diversion is used.
The proposed watercourse diversion route.	As described in this report.
Details of any temporary diversions that may be required as part of a staged process towards the final permanent watercourse diversion.	As described in this report.
Hydraulic conditions of the existing watercourse and proposed watercourse diversion.	As the design process progresses, hydraulic modelling of the permanent diversion shall occur. The diversion replicates the temporary diversion features. Therefore, it is expected there will be no issues with the proposed diversion.
Details of the substrate on which the watercourse diversion will be constructed.	The geotechnical data as the temporary diversion is used. The main detail for the permanent diversion if to avoid backfill material in Dudley's Dam post closure.
Proposed revegetation plan.	To be developed over time and will be consistent with the requirements of DNRME
Proposed operation and monitoring plan.	Given the proposed diversion shall occur in approximately 100 years' time this has not yet been detailed.
A statement of how the watercourse diversion meets the outcomes.	The proposed diversion will be constructed in approximately 100 years' time. The full diversion design has not been completed, but largely replicates the temporary diversion, and is therefore considered to conform with DNRME requirements.

Final as Submitted to DNRME

9. References

BAAM (2018). Ecological Assessment, Coolibah Re-Start Project (Clean / Mine Affected Water Separated Infrastructure) Saraji Mine

Ball et al. (2016). Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

BMA (2018). Watercourse Diversion Monitoring and Evaluation Procedure

Department of Natural Resources Mines and Energy (2019). Guideline: Works that interfere with water in a watercourse for a resource activity—watercourse diversions authorised under the Water Act 2000

Engeny (2016). Barrett's Creek Diversion Major Monitoring Assessment

Engeny (2018). Saraji Mine Flood Study

Geoscience Australia (2019) Australian Rainfall and Runoff, ARR 2019 Guidelines

IPWEA (2018) Queensland Urban Drainage Manual

Jacobs (2019). Coolibah Pit Dewatering Early Works: Barrett Creek Identification Phase Study Concept Design Report

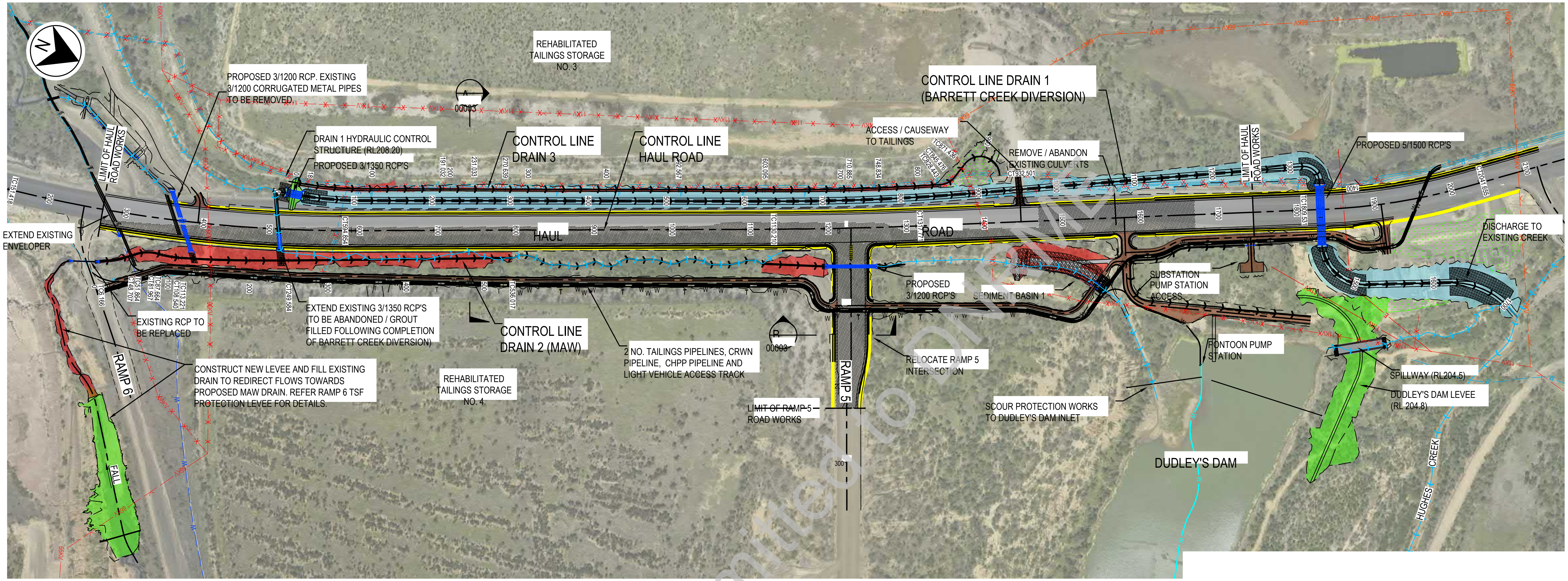
Jacobs (2019). BMA Saraji Mine Coolibah Pit - Enabling Infrastructure: Factual and Interpretive Geotechnical Report

Final as submitted to DNRME

Appendix A. Barrett Creek Diversion Drawings

Drawing No	Drawing Name
SR07-28171-C-DRG-00001 (Revision E)	Coolibah Pit Enabling Infrastructure Barrett Creek Diversion (Temporary) General Arrangement
IH173600-0000-CD-SKT-210 (Revision A)	Coolibah Pit Enabling Infrastructure Barrett Creek Final Landform Concept Alignment

Final as submitted to DNRME



PLAN
SCALE 1:2500

LEGEND

- EXTENT OF EARTHWORKS - BARRETT CREEK DIVERSION
- EXTENT OF EARTHWORKS - MAW DRAINS / SEDIMENT BASINS
- EXTENT OF EARTHWORKS - FILL
- PROPOSED REHABILITATION
- PROPOSED ROAD RELOCATION
- ROCK SCOUR PROTECTION
- LIGHT VEHICLE ACCESS TRACK & PIPELINE CORRIDOR
- TRUCK SAFETY BERM
- BATTER
- PROPOSED DRAIN
- PROPOSED CULVERT
- PROPOSED WATER
- PROPOSED TAILINGS PIPELINE
- PROPOSED BURIED ELECTRICITY (11KV)
- PROPOSED BURIED ELECTRICITY (66KV & 11KV)
- PROPOSED OVERHEAD ELECTRICITY (66KV & 11KV UNDER-SLUNG)
- EXISTING WATERCOURSE
- EXISTING CULVERT
- EXISTING WATER
- EXISTING TAILINGS PIPELINE
- EXISTING OVERHEAD ELECTRICITY (11KV)
- EXISTING OVERHEAD ELECTRICITY (66KV)
- EXISTING SERVICE TO BE REMOVED / RELOCATED

SCALE 1:2500 (A1) 0 50 100 150 200 250m
1:5000 (A3) 50 25

PRELIMINARY ISSUE

Final as submitted to DNRME

VENDOR DETAILS:

VENDOR DRAWING No.
IH173600-1000-CI-DRG-0001

REFERENCES

DRAWING NUMBER	TITLE

REVISIONS

REV	DATE	DESCRIPTION	DRN BY	CHK BY
D	06.02.20	60% DESIGN ISSUE	[redacted]	[redacted]
C	29.11.19	60% DESIGN REVIEW	[redacted]	[redacted]
B	27.11.19	30% DESIGN REVIEW	[redacted]	[redacted]
A	20.09.19	PRELIMINARY ISSUE	[redacted]	[redacted]

APPROVAL

1SAP :	SIGNATURE	DATE
DRAWN BY	[redacted]	-
DESIGNED BY	[redacted]	-
CHECKED BY	[redacted]	-
R.P.E.Q ENGINEER	-	
ENGINEER R.P.E.Q No.	-	

BHP Billiton Mitsubishi Alliance

COOLIBAH PIT ENABLING INFRASTRUCTURE
BARRETT CREEK DIVERSION
GENERAL ARRANGEMENT

SARAJI MINE

BMA DRAWING No.
SR07-28171-C-DRG-00001

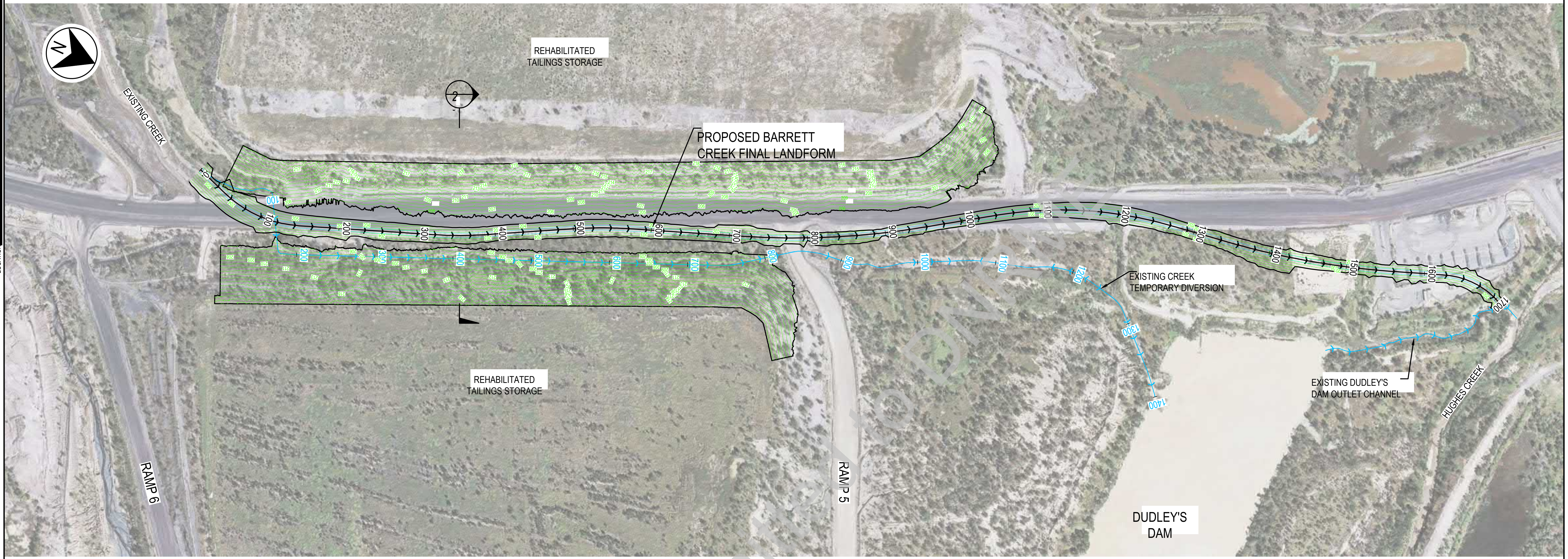
STATUS
PRELIMINARY

SCALE	SIZE	SHEETS	REVISION
AS SHOWN	A1	/	D

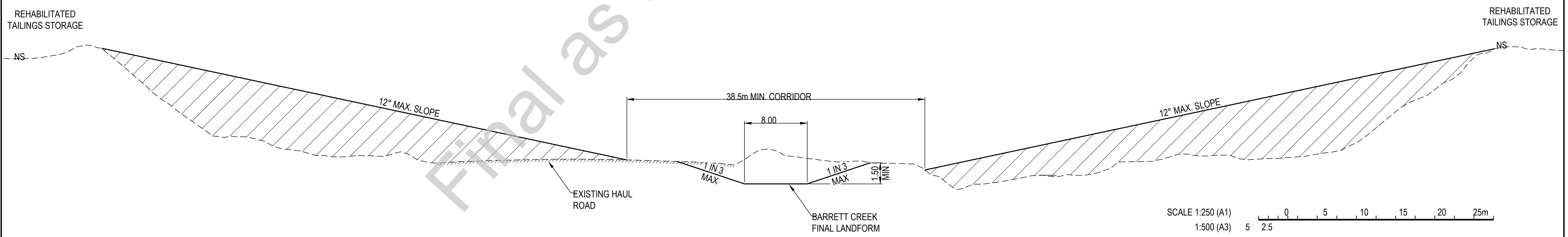
COPYRIGHT. THE DESIGN AND ENGINEERING CONTENT SHOWN ON THIS DRAWING REMAINS THE PROPERTY OF BMA, AND MAY NOT BE COPIED IN ANY WAY WITHOUT PRIOR WRITTEN APPROVAL FROM THE COMPANY.

DATE: 13/12/2019 9:10:32 AM NAME: [redacted]

LOCATION:



PLAN
SCALE 1:2500



SECTION 2
SCALE 1:250

SCALE 1:250 (A1) 0 5 10 15 20 25m
1:500 (A3) 5 2.5

SCALE 1:2500 (A1) 0 50 100 150 200 250m
1:5000 (A3) 50 25

PRELIMINARY

Final as submitted to DN

REV	DATE	DRAWN	REV'D	APP'D	REVISION	DRAWING NUMBER	REFERENCE DRAWING TITLE
A	12.12.19	[redacted]	-	-	INITIAL ISSUE		

JACOBS

CLIENT: BHP
PROJECT: COOLIBAH PIT ENABLING INFRASTRUCTURE
DRAWN: [redacted] DRAWING CHECK: [redacted] REVIEWED: - APPROVED:
DESIGNED: [redacted] DESIGN REVIEW: [redacted] DATE DATE

TITLE: BARRETT CREEK FINAL LANDFORM
CONCEPT ALIGNMENT

SCALE: AS SHOWN
DRAWING No: IH173600-0000-CD-SKT-0210
REV: A

© Jacobs Group (Australia) Pty Ltd ABN 37 001 024 095. No part of this document or the information it contains may be reproduced or transmitted in any form or by any means electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from Jacobs Group (Australia) Pty Ltd.

Appendix B. Hydraulic Mapping Outputs from TUFLOW Model

Map No	Map Name
1	Design Case 50% AEP Peak Depth
2	Design Case 50% AEP Flood Difference
3	Design Case 50% AEP Peak Velocity
4	Design Case 50% AEP Bed Shear Stress
5	Design Case 50% AEP Stream Power
6	Existing Case 50% AEP Bed Shear Stress
7	Existing Case 50% AEP Stream Power
8	Design Case 2% AEP Flood Depth
9	Design Case 2% AEP Flood Difference
10	Design Case 2% AEP Velocity
11	Design Case 2% AEP Bed Shear Stress
12	Design Case 2% AEP Stream Power
13	Existing Case 2% AEP Bed Shear Stress
14	Existing Case 2% AEP Stream Power
15	Design Case 1% AEP Flood Depth
16	Design Case 1% AEP Flood Difference
17	Design Case 1% AEP Flood Velocity
18	Design Case 1% AEP Bed Shear Stress
19	Design Case 1% AEP Stream Power
20	Existing Case 1% AEP Bed Shear Stress
21	Existing Case 1% AEP Stream Power
22	Design Case 0.1% AEP Flood Depth
23	Design Case 0.1% AEP Flood Difference
24	Design Case 0.1% AEP Flood Velocity
25	Design Case 0.1% AEP Bed Shear Stress
26	Design Case 0.1% AEP Stream Power
27	Existing Case 0.1% AEP Bed Shear Stress
28	Existing Case 0.1% AEP Stream Power

Final as submitted to DNRME

Map 1

Design Case 50% AEP Peak Depth

Barrett Creek

Job No: IH154800

By: [redacted]

Last Modified: 25/03/2020

Jacobs

Legend

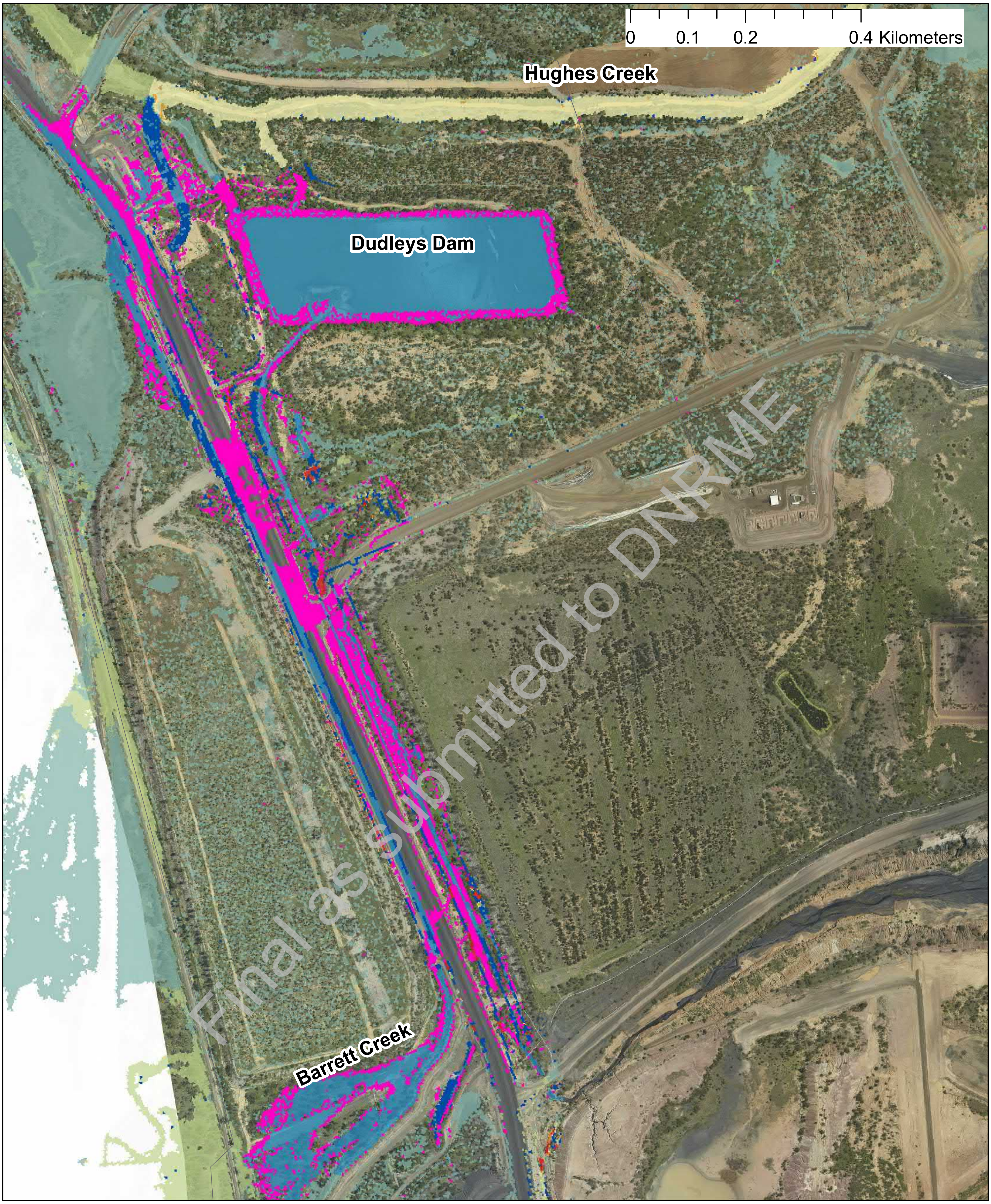
- Boundaries
- **Depth (m)**
- < 0.01
- 0.0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Map 2

Design Case 50% AEP Flood Difference

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Afflux (m)

- < -0.1
- -0.1 - 0
- 0 - 0.025
- 0.025 - 0.05
- 0.05 - 0.075
- 0.075 - 0.1
- > 0.1

Wet/Dry

- Was Wet Now Dry
- Was Dry Now Wet

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd

Map 3

Design Case 50% AEP Peak Velocity

Barrett Creek

Job No: IH154800

By: [redacted]

Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Velocity (m/s)

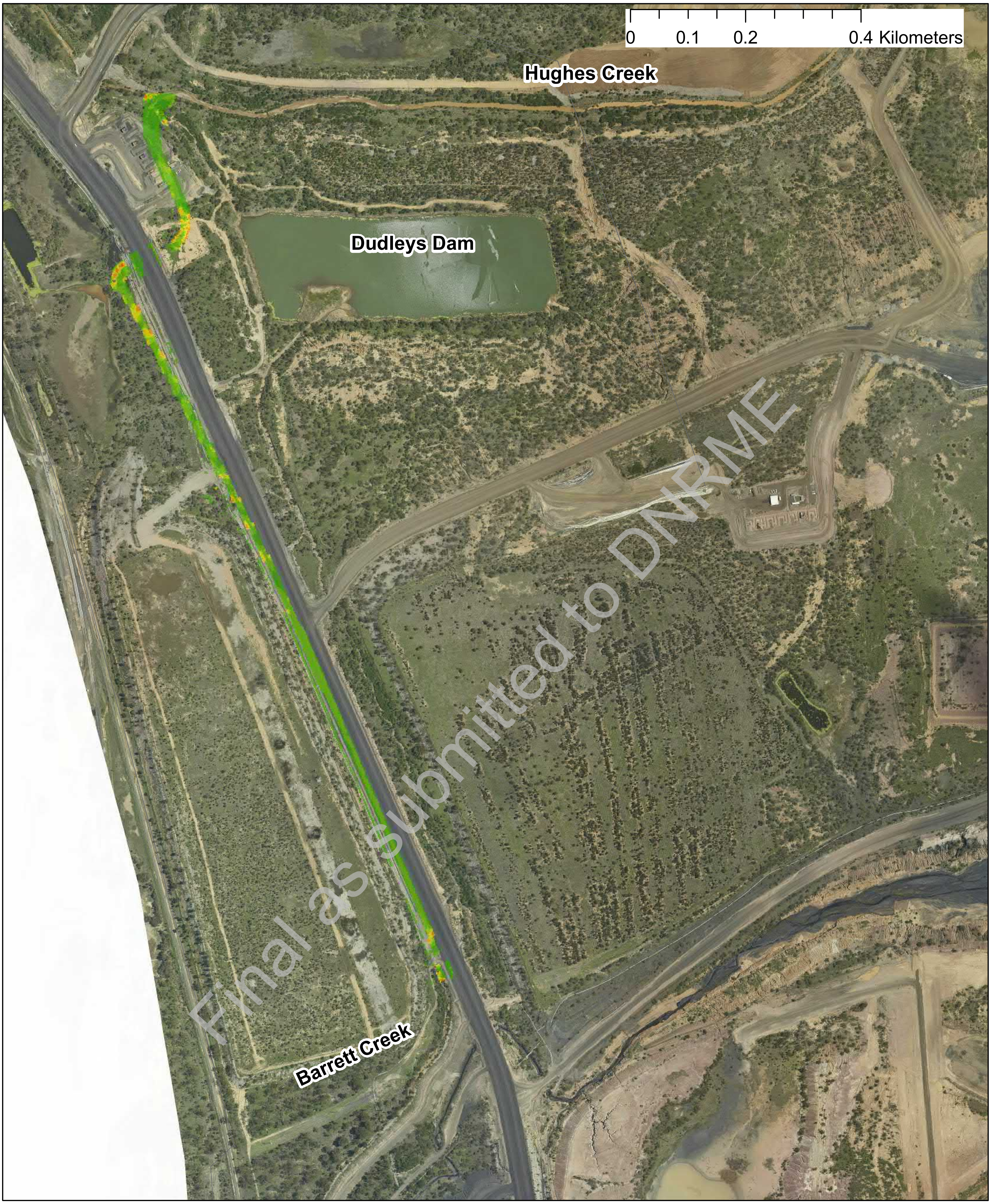
- < 0.01
- 0.0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Final as Submitted to DNRME

Map 4

Design Case 50% AEP Bed Shear Stress

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Bed Shear Stress Pascals (N/m2)

- 0 Pa to 20 Pa
- 20 Pa to 50 Pa
- 50 Pa to 80 Pa
- 80 Pa to 100 Pa
- 100 Pa to 200 Pa
- 200 Pa to 500 Pa
- 500 Pa to 1000 Pa
- 1000 Pa to 2000 Pa

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd

Final as Submitted to DNRME

Map 5

Design Case 50% AEP Stream Power

Barrett Creek

Job No: IH154800

By: [redacted]

Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Stream Power

Watts

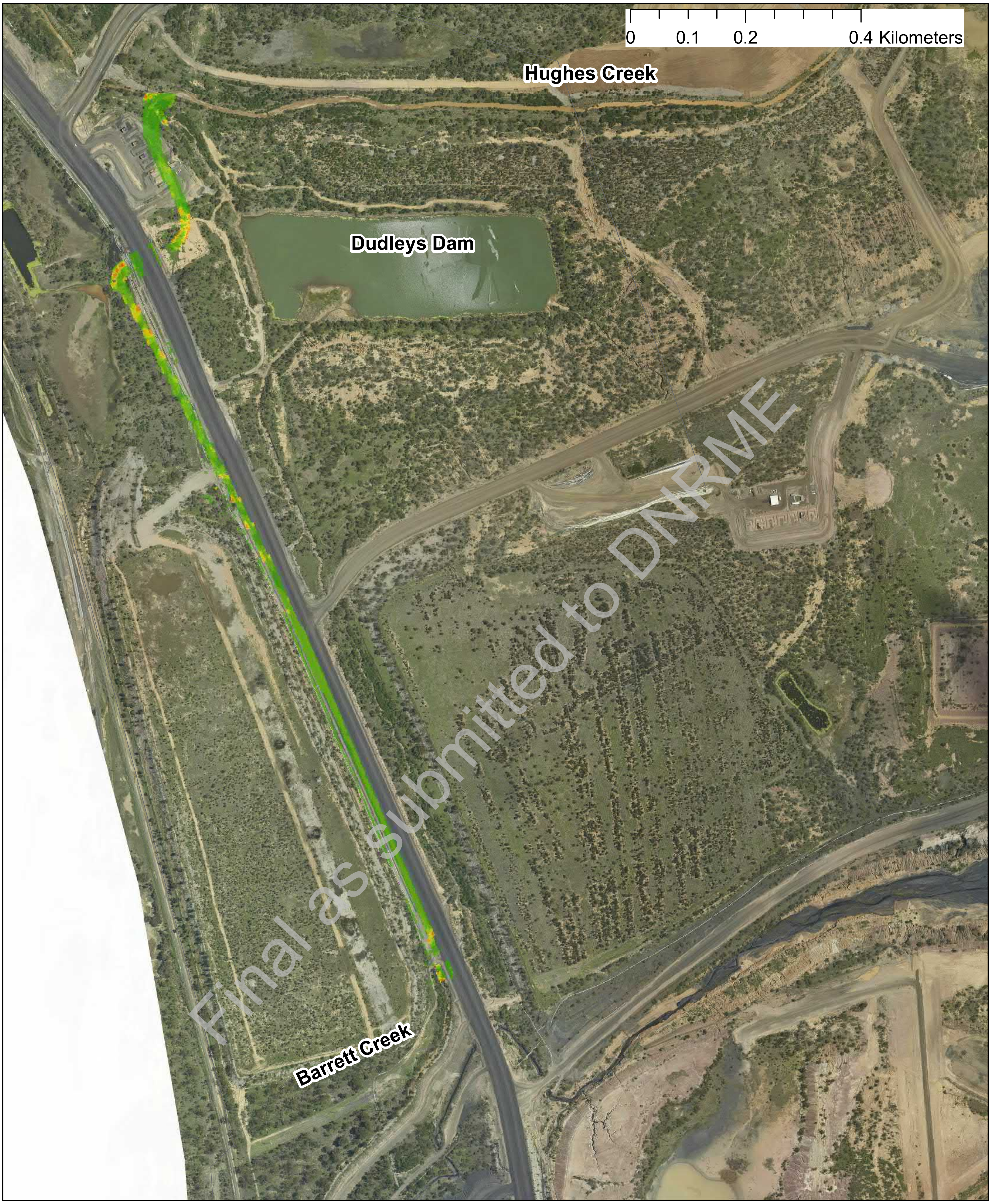
- 0 W to 40 W
- 40 W to 150 W
- 150 W to 400 W
- 400 W to 800 W
- 800 W to 1500 W
- 1500 W to 2500 W
- 2500 W to 3500 W
- 3500 W to 500 W

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Map 6

Existing Case 50% AEP Bed Shear Stress

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Bed Shear Stress Pascals (N/m2)

- 0 Pa to 20 Pa
- 20 Pa to 50 Pa
- 50 Pa to 80 Pa
- 80 Pa to 100 Pa
- 100 Pa to 200 Pa
- 200 Pa to 500 Pa
- 500 Pa to 1000 Pa
- 1000 Pa to 2000 Pa

1:6,000

N

MGA Zone 55

Map 7

Existing Case 50% AEP Stream Power

Barrett Creek

Job No: IH154800

By: [redacted]

Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Stream Power

Watts

- 0 W to 40 W
- 40 W to 150 W
- 150 W to 400 W
- 400 W to 800 W
- 800 W to 1500 W
- 1500 W to 2500 W
- 2500 W to 3500 W
- 3500 W to 500 W

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd

Final as submitted to DNRME

Map 8

Design Case 2% AEP Flood Depth

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 24/03/2020
Jacobs

Legend

Boundaries

PkDepth

Depth (m)

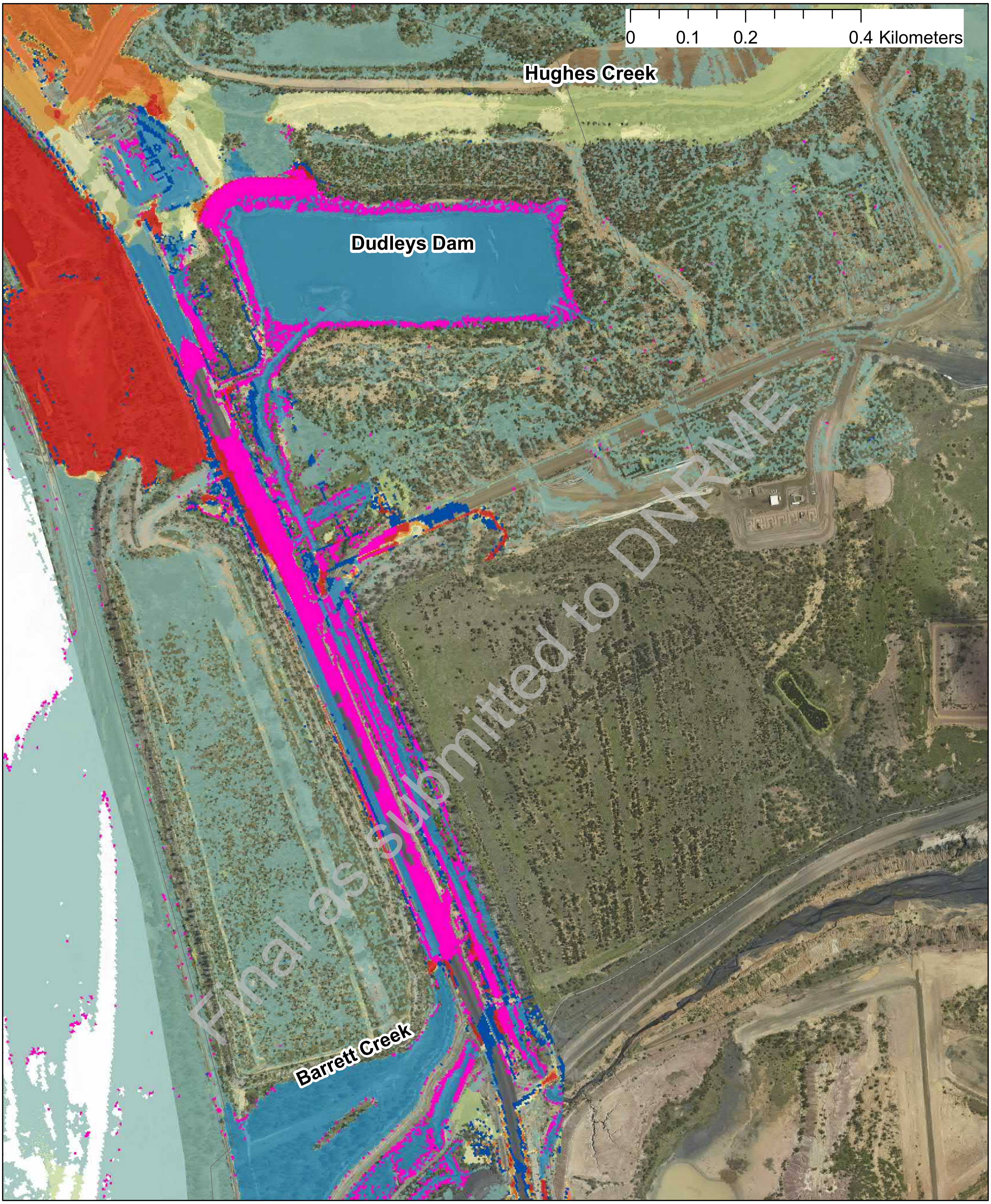
< 0.01
0.0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Map 9

Design Case 2% AEP Flood Difference

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 24/03/2020

Jacobs

Legend

Boundaries

Afflux (m)

- < -0.1
- -0.1 - 0
- 0 - 0.025
- 0.025 - 0.05
- 0.05 - 0.075
- 0.075 - 0.1
- > 0.1

Wet/Dry

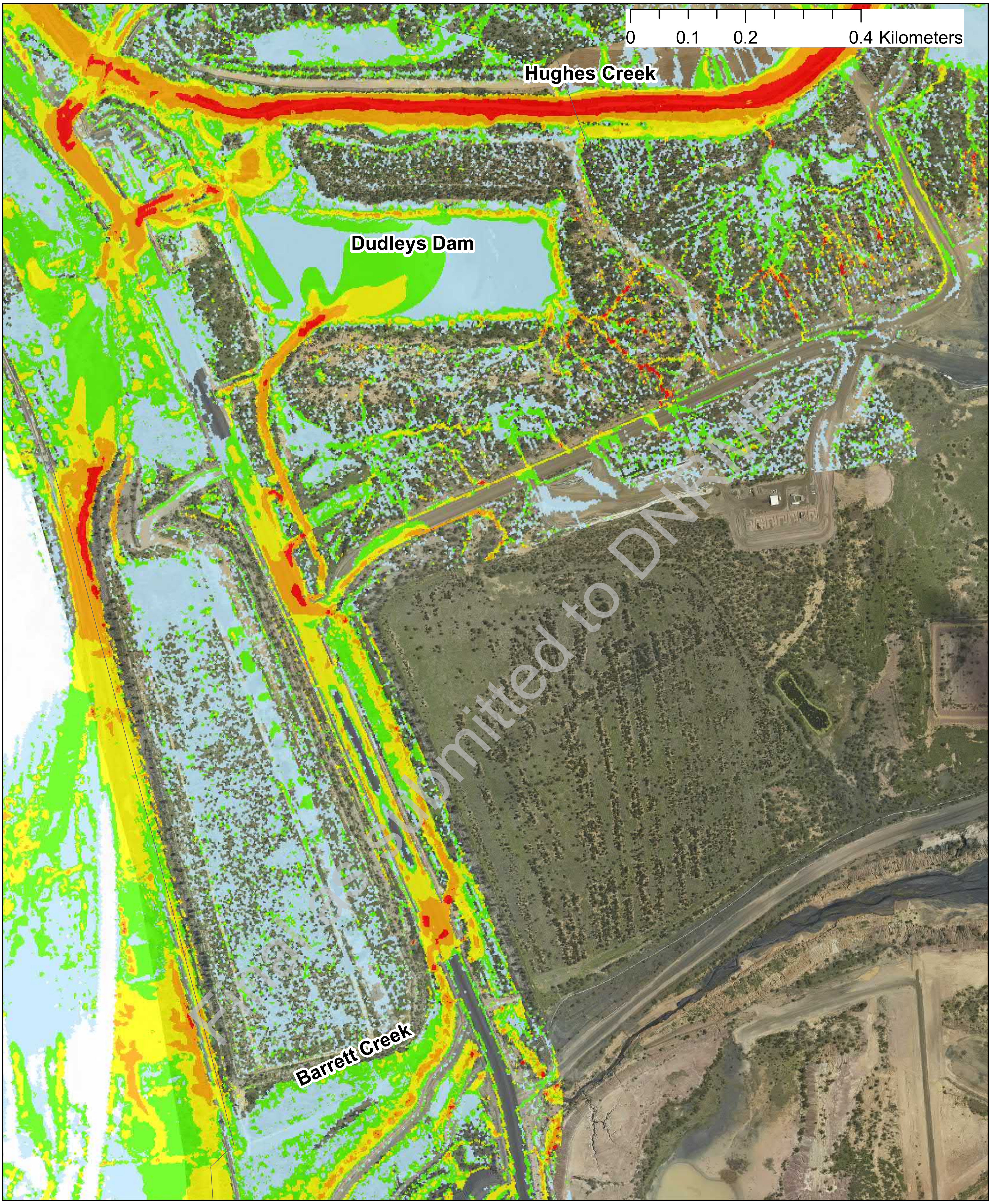
- Was Wet Now Dry
- Was Dry Now Wet

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD012_Afflux.mxd



Map 10

Design Case 2% AEP Velocity

Barrett Creek

Job No: IH154800

By: [redacted]

Last Modified: 24/03/2020

Jacobs

Legend

	Boundaries

Vel

Velocity (m/s)

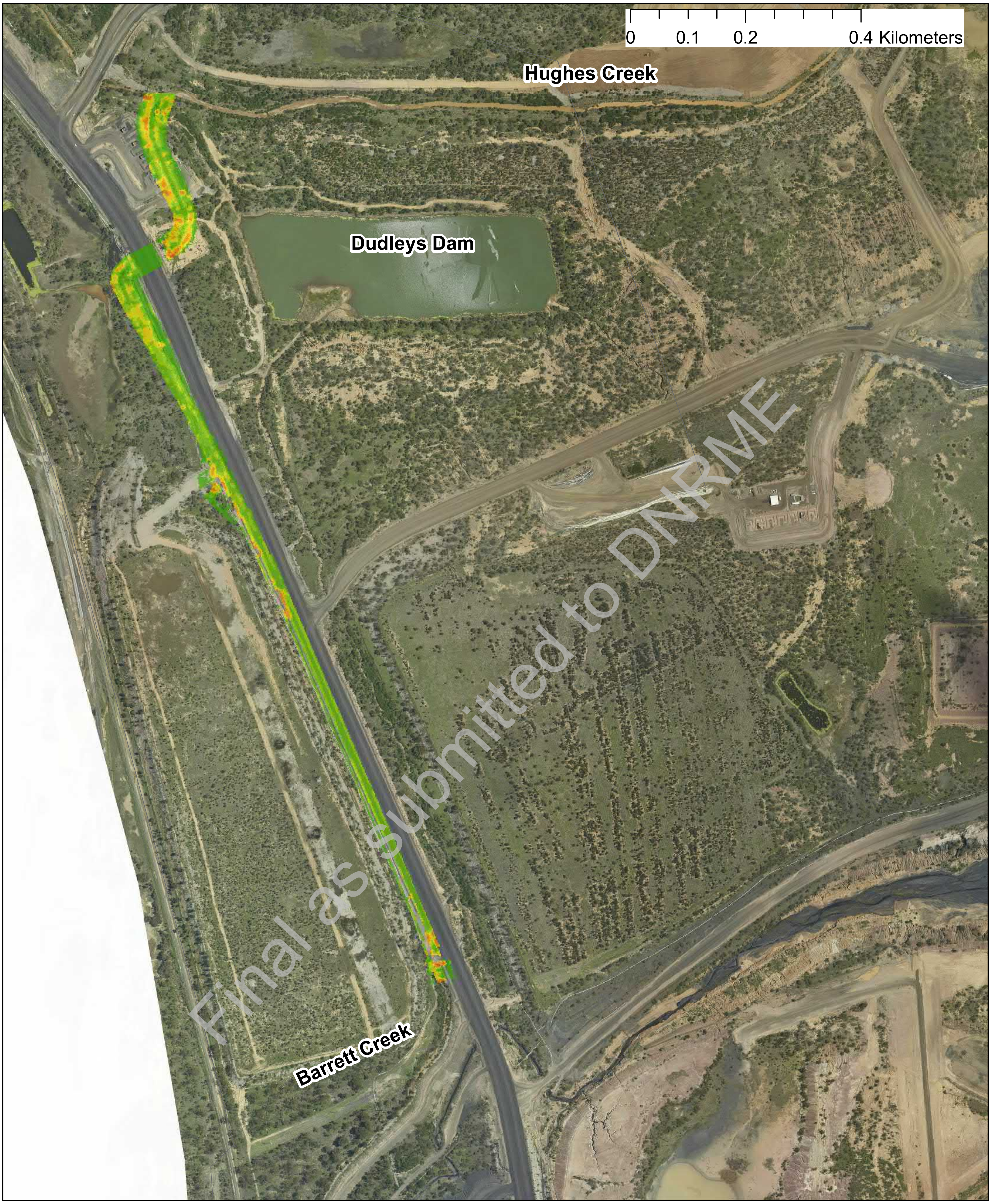
< 0.01
0.0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Final as Submitted to DNRME

Map 11

Design Case 2% AEP
Bed Shear Stress

Barrett Creek
Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020
Jacobs

Legend

Boundaries

Bed Shear Stress
Pascals (N/m2)

- 0 Pa to 20 Pa
- 20 Pa to 50 Pa
- 50 Pa to 80 Pa
- 80 Pa to 100 Pa
- 100 Pa to 200 Pa
- 200 Pa to 500 Pa
- 500 Pa to 1000 Pa
- 1000 Pa to 2000 Pa

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd

Map 12

Design Case 2% AEP Stream Power

Barrett Creek
Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020
Jacobs

Legend

Boundaries

Stream Power

Watts

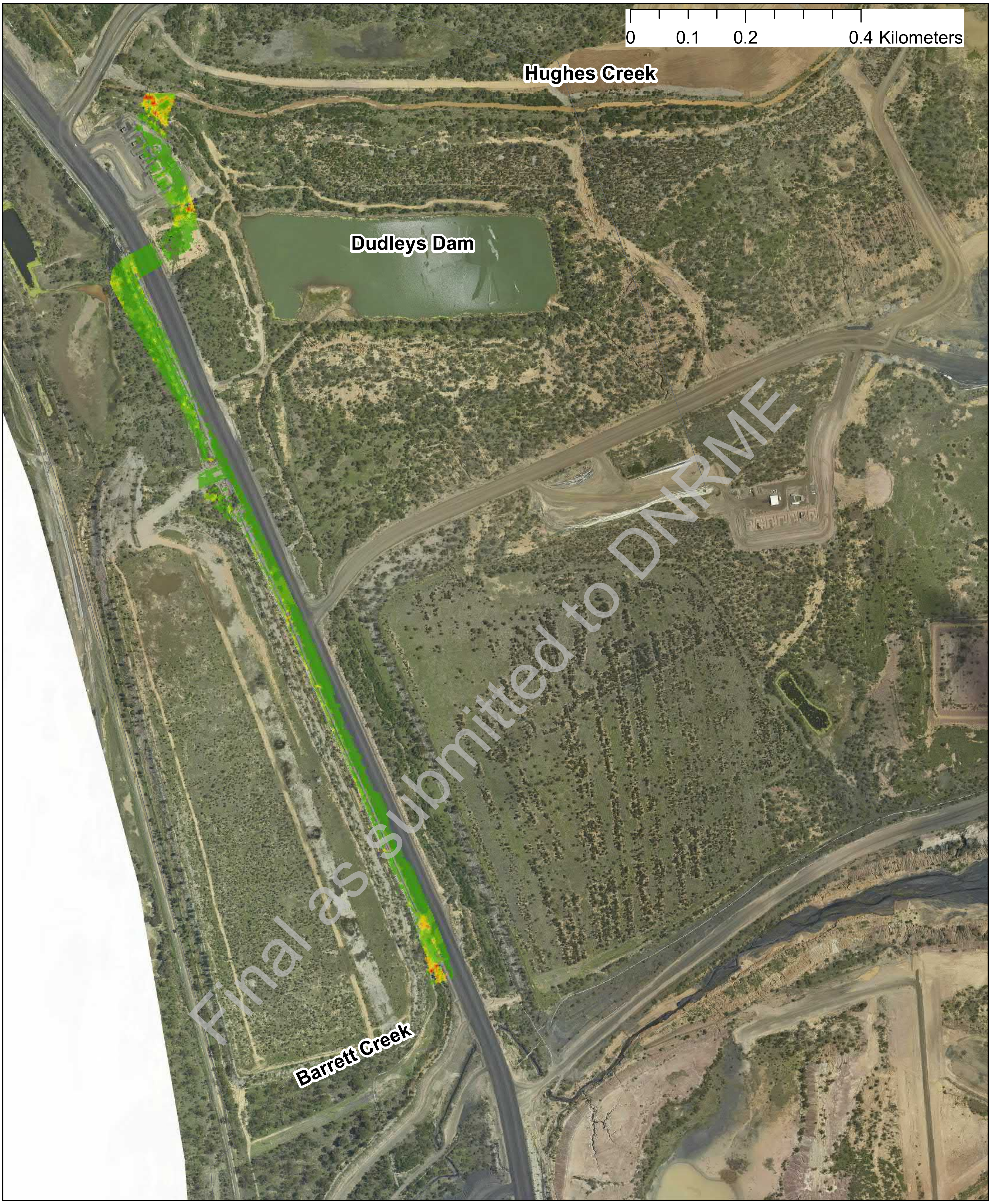
0 W to 40 W
40 W to 150 W
150 W to 400 W
400 W to 800 W
800 W to 1500 W
1500 W to 2500 W
2500 W to 3500 W
3500 W to 500 W

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Map 13

Existing Case 2% AEP Bed Shear Stress

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020
Jacobs

Legend

Boundaries

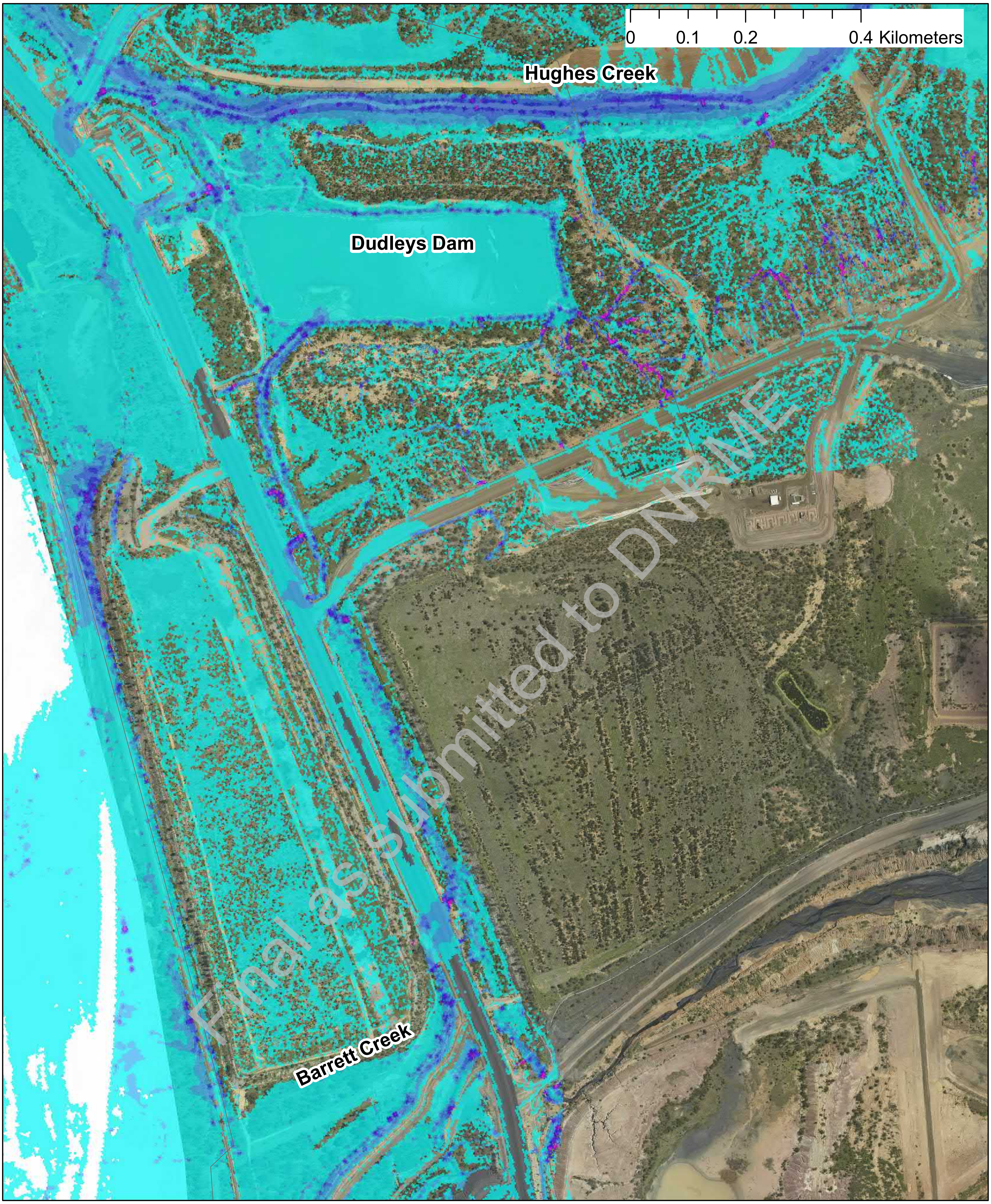
Bed Shear Stress Pascals (N/m2)

- 0 Pa to 20 Pa
- 20 Pa to 50 Pa
- 50 Pa to 80 Pa
- 80 Pa to 100 Pa
- 100 Pa to 200 Pa
- 200 Pa to 500 Pa
- 500 Pa to 1000 Pa
- 1000 Pa to 2000 Pa

1:6,000

N

MGA Zone 55



Final as Submitted to DNRME

Map 14

Existing Case 2% AEP Stream Power

Barrett Creek
Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020
Jacobs

Legend

Boundaries

Stream Power

Watts

- 0 W to 40 W
- 40 W to 150 W
- 150 W to 400 W
- 400 W to 800 W
- 800 W to 1500 W
- 1500 W to 2500 W
- 2500 W to 3500 W
- 3500 W to 500 W

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd

Map 15

Design Case 1% AEP Flood Depth

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Depth (m)

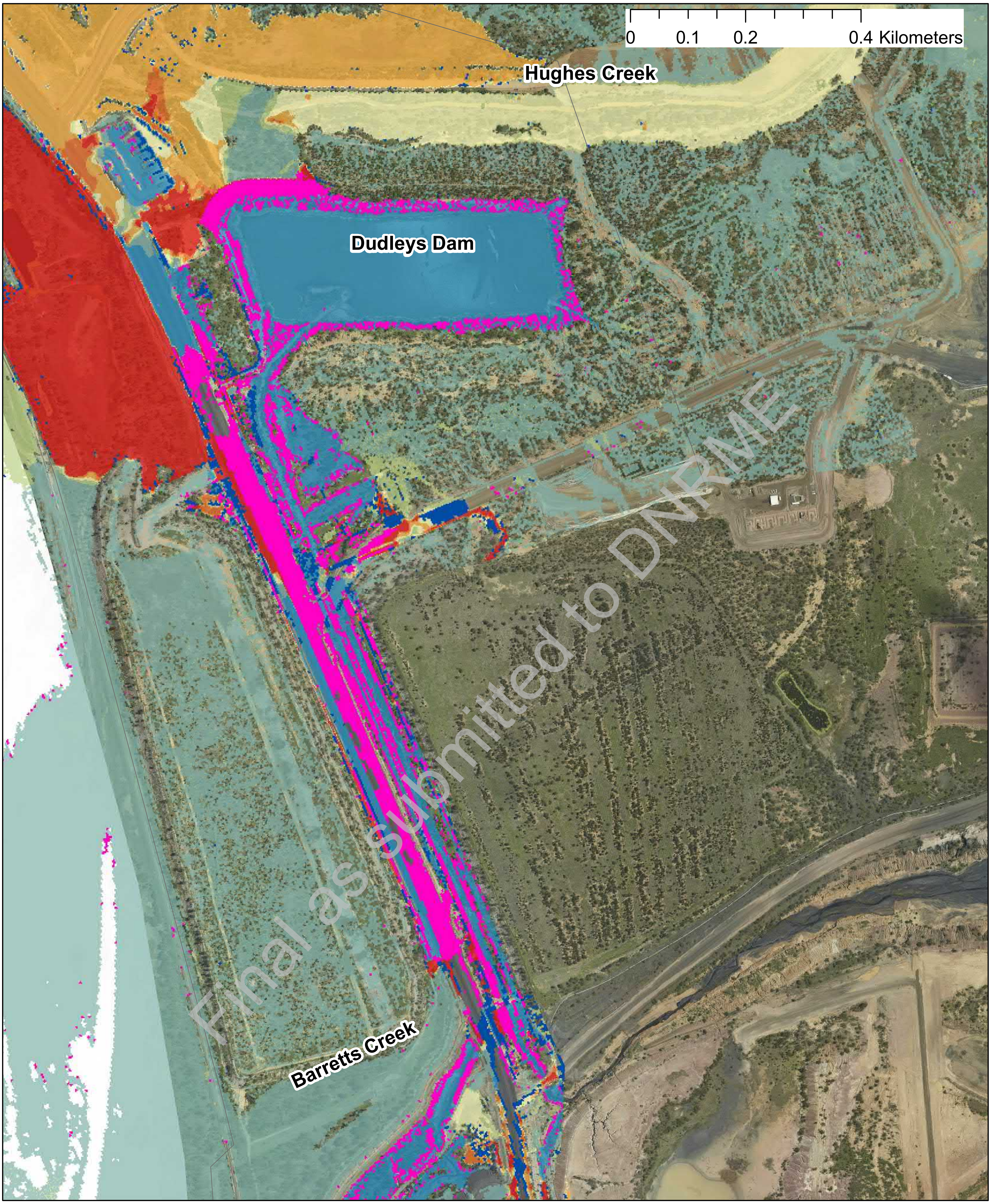
- < 0.01
- 0.0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Map 16

Design Case 1% AEP Flood Difference

Barrett Creek
Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020
Jacobs

Legend

Boundaries

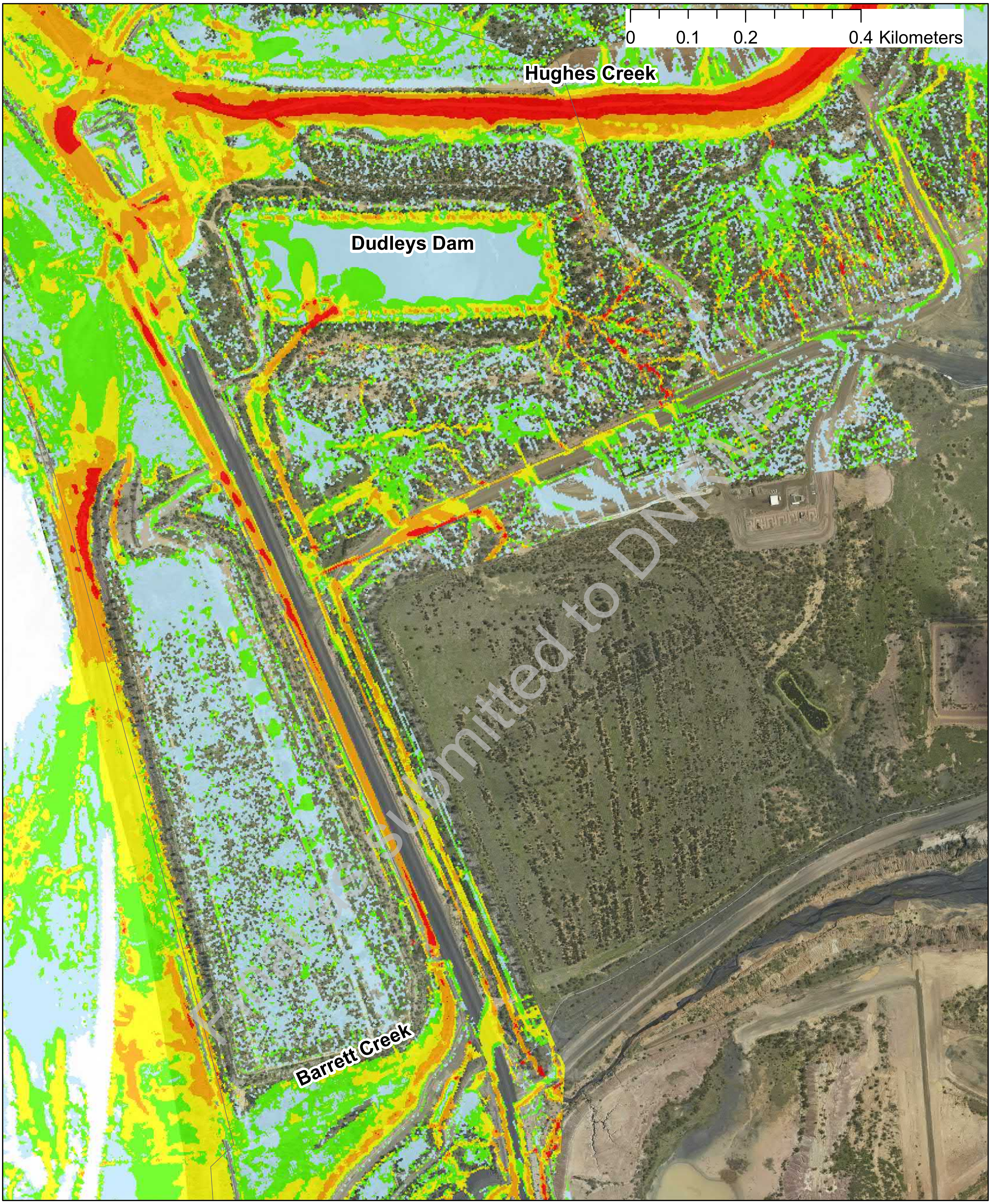
Afflux (m)

< -0.1
-0.1 - 0
0 - 0.025
0.025 - 0.05
0.05 - 0.075
0.075 - 0.1
> 0.1

Wet/Dry

Was Wet Now Dry
Was Dry Now Wet

1:6,000
N
MGA Zone 55



Map 17

Design Case 1% AEP Flood Velocity

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

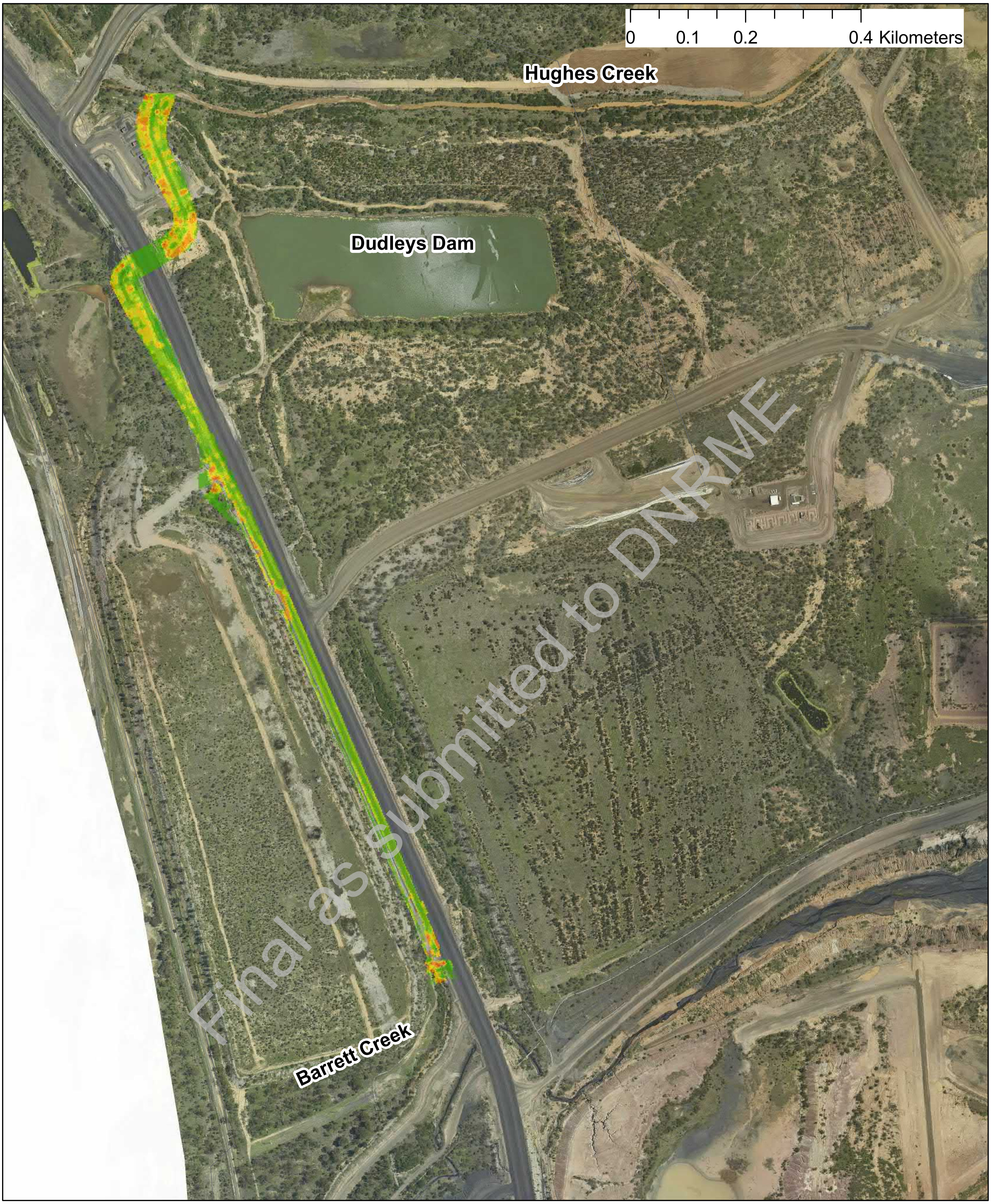
Boundaries	1 - 2
Velocity (m/s)	> 2
< 0.01	
0.0 - 0.25	
0.25 - 0.5	
0.5 - 1	

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Final as Submitted to DNRME

Map 18

Design Case 1% AEP
Bed Shear Stress

Barrett Creek
Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020
Jacobs

Legend

Boundaries

Bed Shear Stress

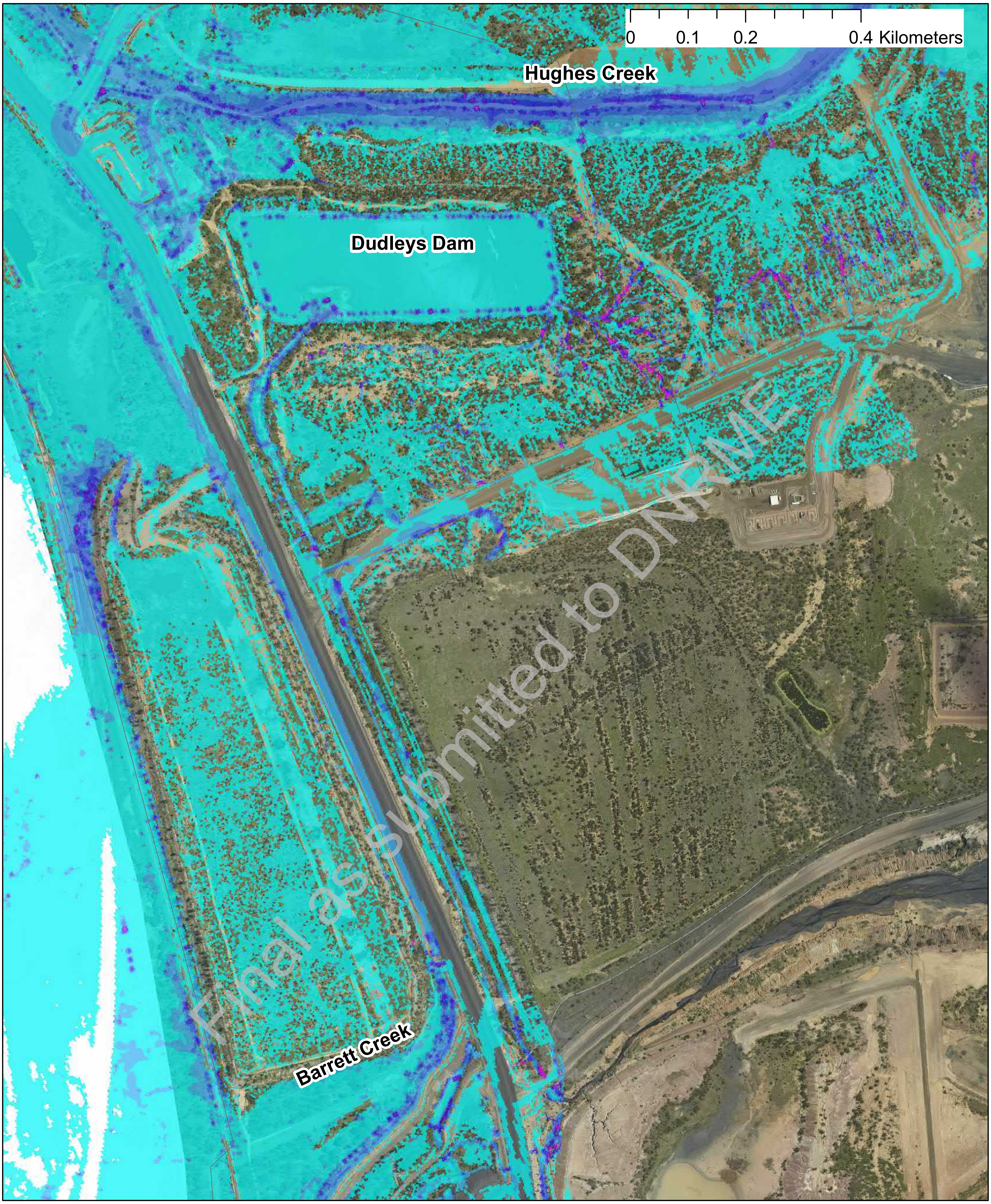
Pascals (N/m2)

0 Pa to 20 Pa
20 Pa to 50 Pa
50 Pa to 80 Pa
80 Pa to 100 Pa
100 Pa to 200 Pa
200 Pa to 500 Pa
500 Pa to 1000 Pa
1000 Pa to 2000 Pa

1:6,000

N

MGA Zone 55



Final as Submitted to DNRME

Map 19

Design Case 1% AEP Stream Power

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Stream Power

Watts

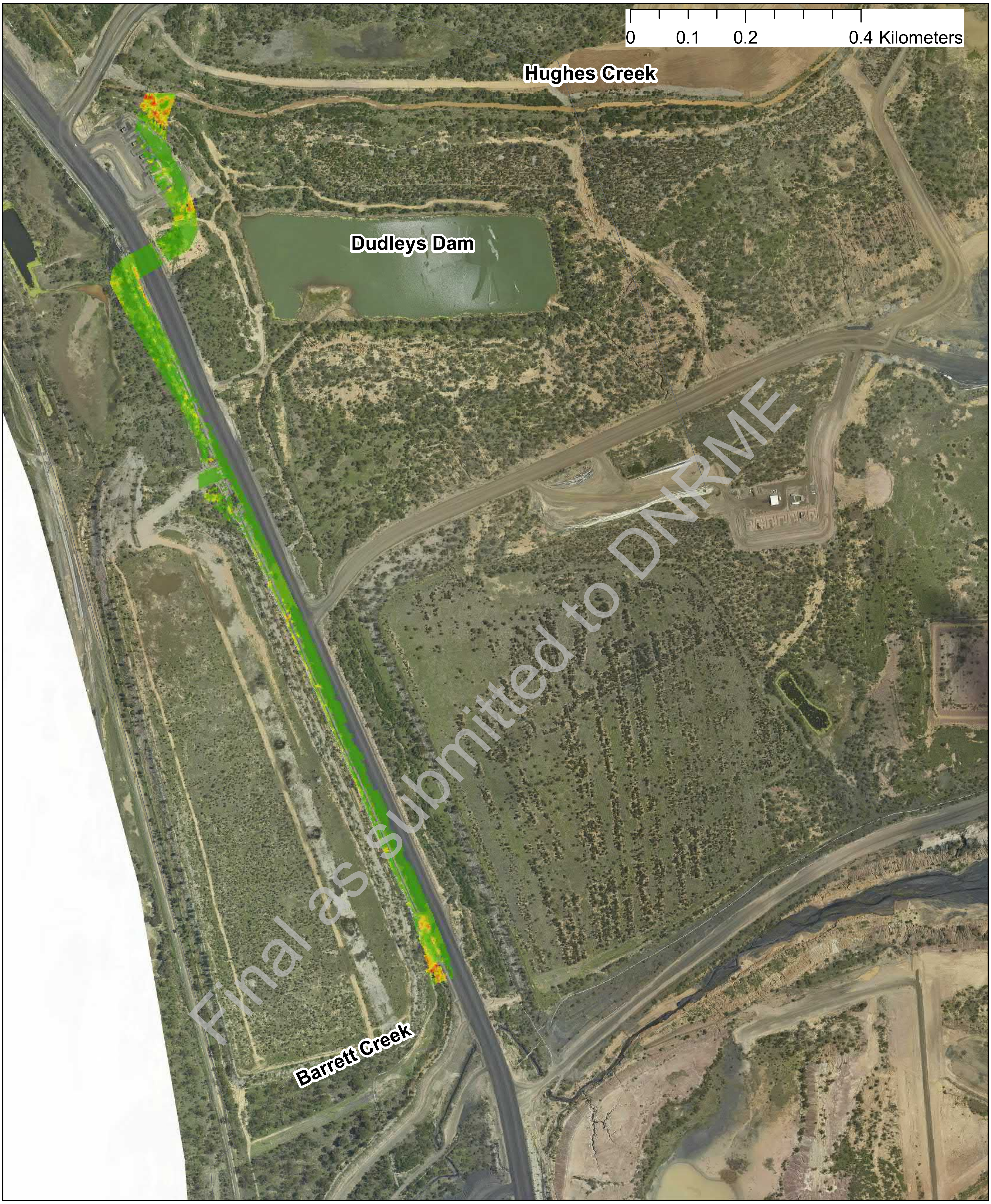
- 0 W to 40 W
- 40 W to 150 W
- 150 W to 400 W
- 400 W to 800 W
- 800 W to 1500 W
- 1500 W to 2500 W
- 2500 W to 3500 W
- 3500 W to 500 W

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Map 20

Existing Case 1% AEP Bed Shear Stress

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

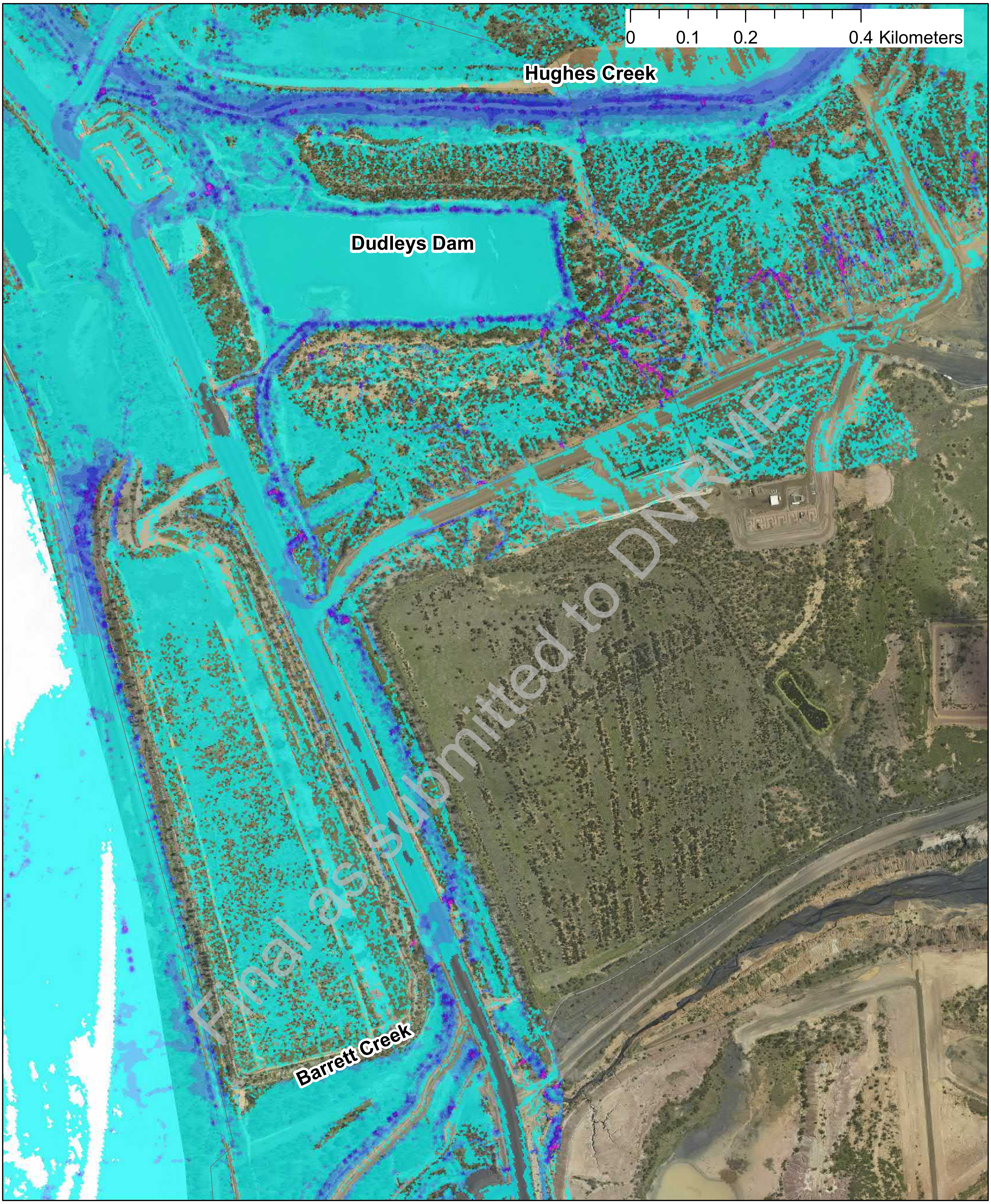
Boundaries	
Bed Shear Stress Pascals (N/m2)	
0 Pa to 20 Pa	100 Pa to 200 Pa
20 Pa to 50 Pa	200 Pa to 500 Pa
50 Pa to 80 Pa	500 Pa to 1000 Pa
80 Pa to 100 Pa	1000 Pa to 2000 Pa

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Final as Submitted to DNRME

Map 21

Existing Case 1% AEP Stream Power

Barrett Creek

Job No: IH154800

By: [redacted]

Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Stream Power

Watts

0 W to 40 W

40 W to 150 W

150 W to 400 W

400 W to 800 W

800 W to 1500 W

1500 W to 2500 W

2500 W to 3500 W

3500 W to 500 W

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd

Map 22

Design Case 0.1% AEP Flood Depth

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

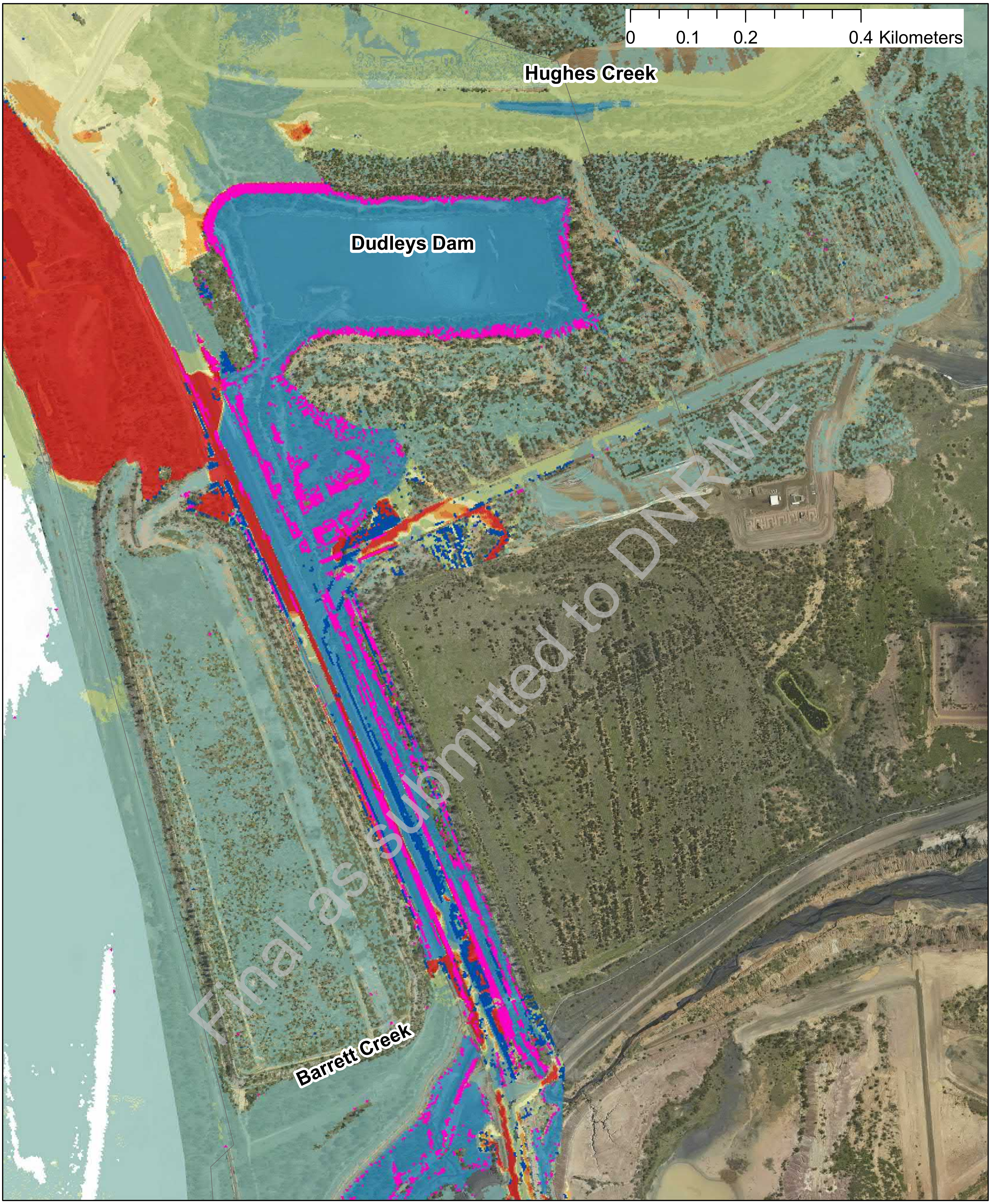
- Boundaries
- **Depth (m)**
- < 0.01
- 0.0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Map 23

Design Case 0.1% AEP Flood Difference

Barrett Creek

Job No: IH154800

By: [redacted]

Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Afflux (m)

- < -0.1
- -0.1 - 0
- 0 - 0.025
- 0.025 - 0.05
- 0.05 - 0.075
- 0.075 - 0.1
- > 0.1

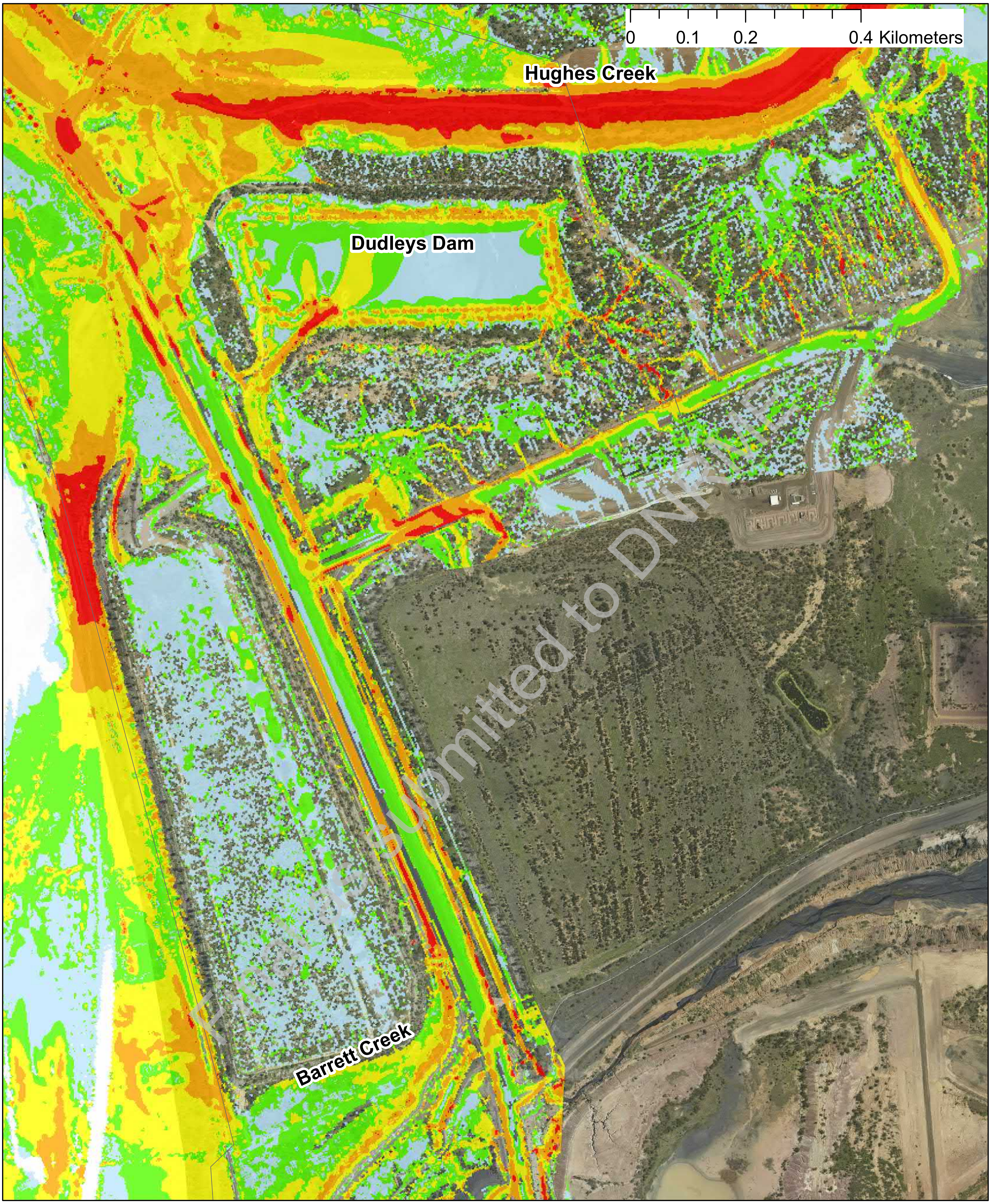
Wet/Dry

- Was Wet Now Dry
- Was Dry Now Wet

1:6,000

N

MGA Zone 55



Map 24

Design Case 0.1% AEP Flood Velocity

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

- Boundaries
- **Velocity (m/s)**
- < 0.01
- 0.0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- > 2

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd

Map 25

Design Case 0.1% AEP Bed Shear Stress

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Bed Shear Stress Pascals (N/m2)

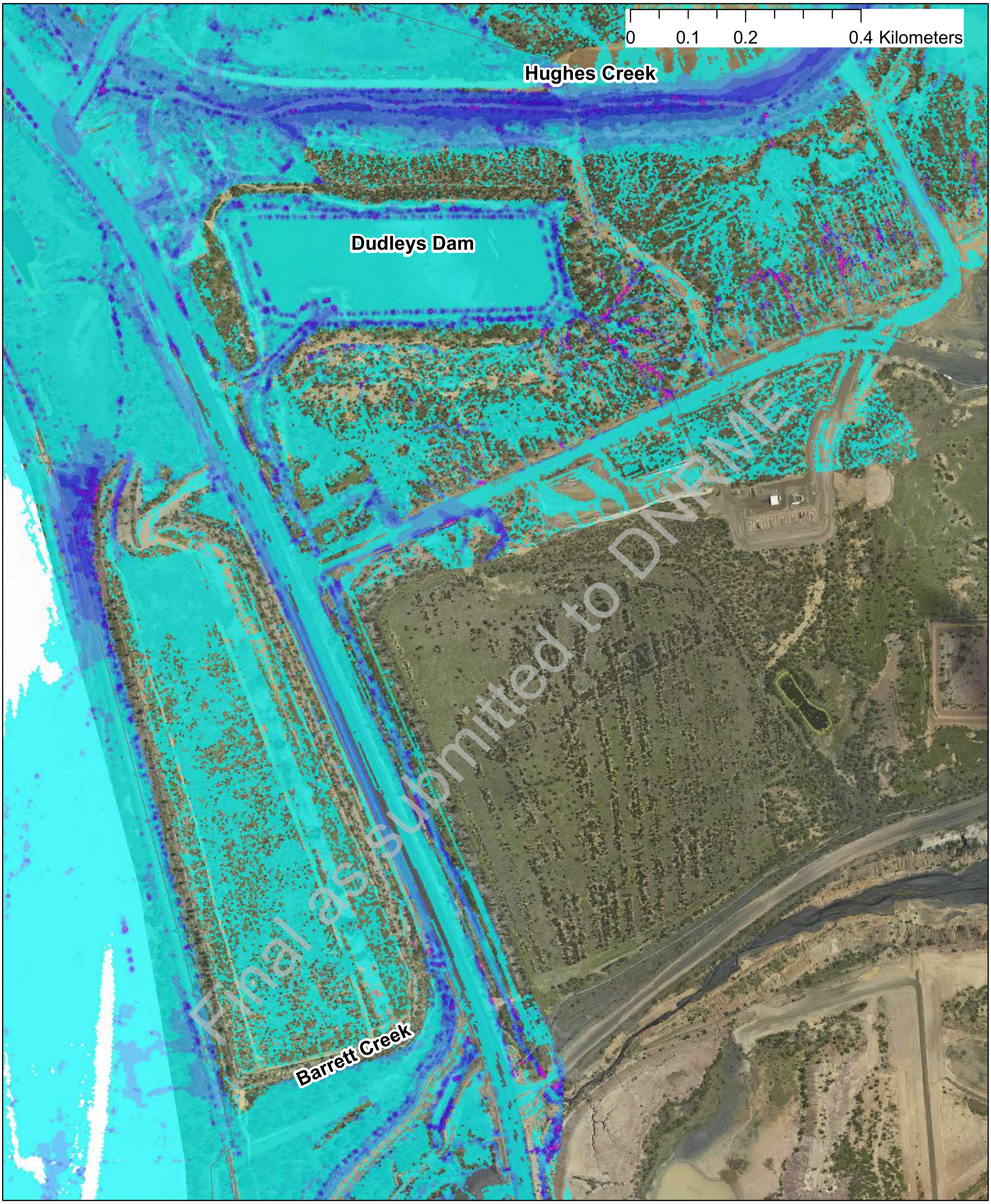
- 0 Pa to 20 Pa
- 20 Pa to 50 Pa
- 50 Pa to 80 Pa
- 80 Pa to 100 Pa
- 100 Pa to 200 Pa
- 200 Pa to 500 Pa
- 500 Pa to 1000 Pa
- 1000 Pa to 2000 Pa

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Final as Submitted to DNRME

Map 26

Design Case 0.1% AEP Stream Power

Barrett Creek

Job No: IH154800

By: [redacted]

Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Stream Power

Watts

0 W to 40 W

40 W to 150 W

150 W to 400 W

400 W to 800 W

800 W to 1500 W

1500 W to 2500 W

2500 W to 3500 W

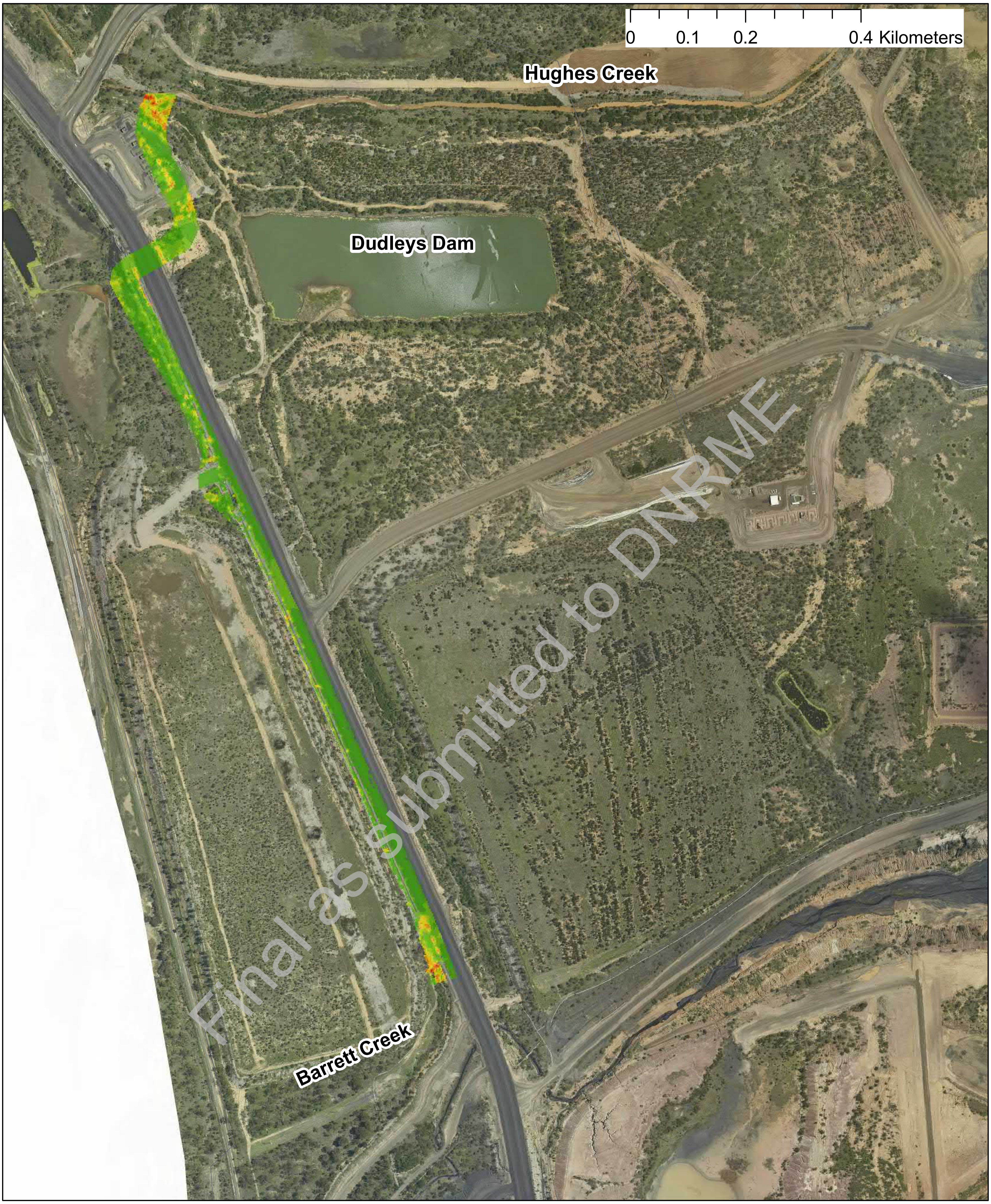
3500 W to 500 W

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd



Map 27

Existing Case 0.1% AEP
Bed Shear Stress

Barrett Creek
Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020
Jacobs

Legend

Boundaries

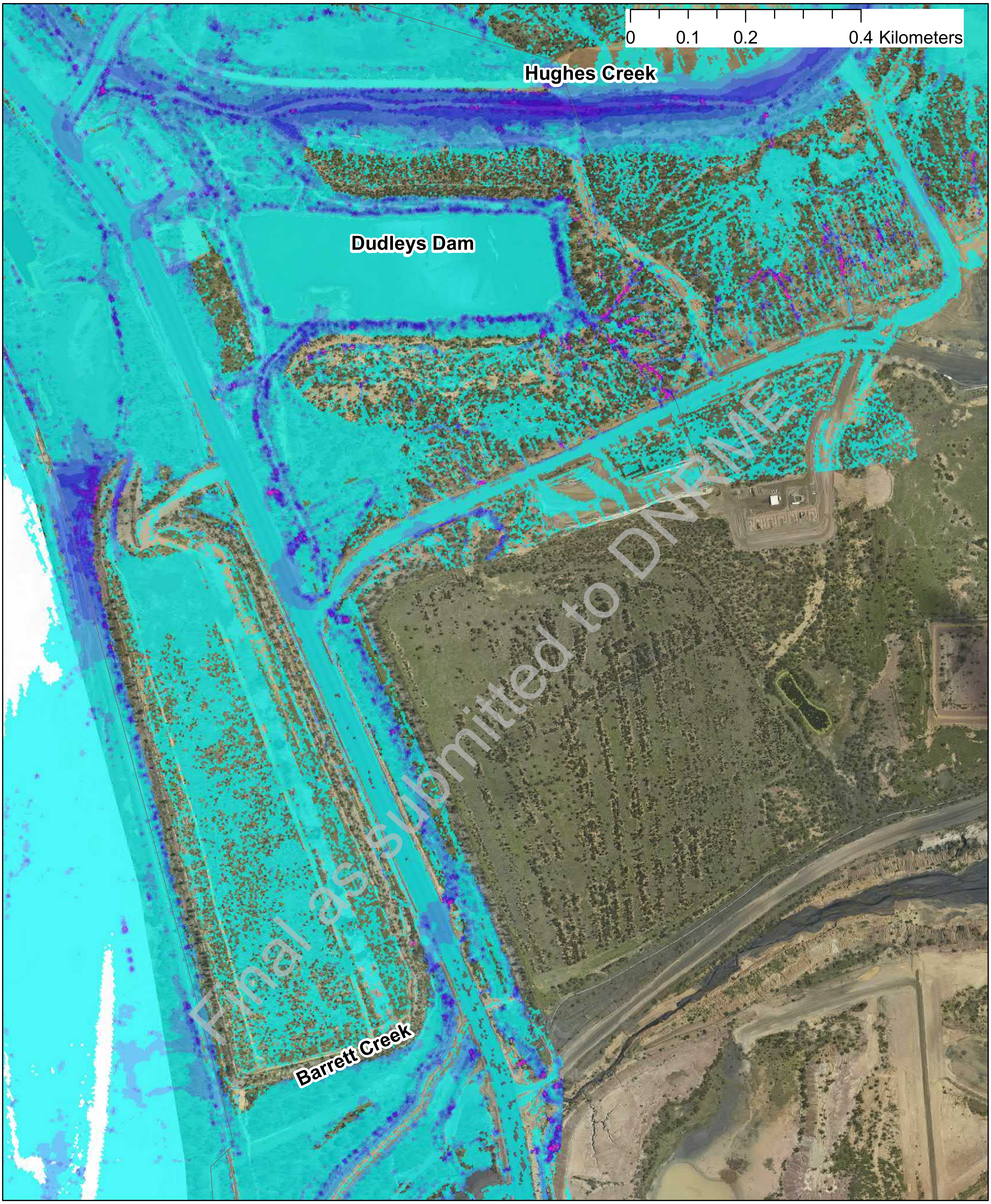
Bed Shear Stress
Pascals (N/m2)

- 0 Pa to 20 Pa
- 20 Pa to 50 Pa
- 50 Pa to 80 Pa
- 80 Pa to 100 Pa
- 100 Pa to 200 Pa
- 200 Pa to 500 Pa
- 500 Pa to 1000 Pa
- 1000 Pa to 2000 Pa

1:6,000

N

MGA Zone 55



Map 28

Existing Case 0.1% AEP Stream Power

Barrett Creek

Job No: IH154800
By: [redacted]
Last Modified: 25/03/2020

Jacobs

Legend

Boundaries

Stream Power

Watts

- 0 W to 40 W
- 40 W to 150 W
- 150 W to 400 W
- 400 W to 800 W
- 800 W to 1500 W
- 1500 W to 2500 W
- 2500 W to 3500 W
- 3500 W to 500 W

1:6,000

N

MGA Zone 55

J:\IE\Projects\05_Northern\IH154800\01 Design\Flooding\Spatial\ARCGIS\MXD\2pc_PD013_Afflux.mxd