CAIRNS SHIPPING DEVELOPMENT PROJECT

Revised Draft Environmental Impact Statement

APPENDIX N: Flooding Storm Tide and Hydrology Baseline Report (2016)

A part of BMT in Energy and Environment

-

Cairns Shipping Development EIS – Flooding Storm Tide and Hydrology Baseline Report

Reference: R.B22074.003.01.FSH_Baseline.docx
Date: June 2017
Confidential

Document Control Sheet

BMT WBM Pty Ltd Level 8, 200 Creek Street Brisbane Qld 4000 Australia PO Box 203, Spring Hill 4004 Tel: +61 7 3831 6744 Fax: + 61 7 3832 3627 ABN 54 010 830 421 www.bmtwbm.com.au	**Document:**	R.B22074.003.01.FSH_Baseline.docx
	Title:	Cairns Shipping Development EIS – Flooding Storm Tide and Hydrology Baseline Report
	Project Manager:	Greg Fisk
	Author:	Anthony Charlesworth
	Client:	Ports North/FCG
	Client Contact:	David Finnev
	Client Reference:	

Synopsis: This report presents the findings of the flooding, storm tide and hydrology baseline study for the Cairns Shipping Development (CSD) Environmental Impact Statement (EIS) land based placement. The assessment included the following two land placement options a.) Northern Sands and b.) East Trinity.

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0	4 June 2017	N. Collins	4.6.17	A. Charlesworth	4.6.17
1	5 June 2017	N. Collins	5.6.17	A. Charlesworth	5.6.17

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
Ports North/FCG	PDF	PDF									
BMT WBM File	PDF	PDF									
BMT WBM Library		PDF									

Key Findings and Implications for Project Refinement

Existing Values/Resources

The two dredge material land placement areas of Northern Sands and East Trinity are located within significant floodplain areas. Northern Sands is located adjacent to and within the Barron River floodplain and discharges into Trinity Bay. The East Trinity sites are located within the Hills and Firewood Creek floodplains, that discharge into Trinity Inlet.

Management of the existing surface water regime with regards to both quantity and quality is required to prevent adverse off-site flood impact and the loss of material to the receiving environment during construction and into perpetuity.

Threats

As discussed in other baseline reports, the receiving environment of the Barron River, Hills and Firewood Creeks and Trinity Inlet have important environmental values. Loss of placed dredge material to the receiving environment will impact upon these values if not appropriately managed. Furthermore, each of the identified dredge material placement areas has the potential to cause adverse off-site flood impact to other land tenures within the region.

Mitigation Opportunities

The Northern Sands site would provide a system of limited risk of inundation during the dredge campaign (i.e. June to August) from a Barron River flood and storm surge event, hence loss of dredge material to the floodplain and off-shore area would be unlikely.

The final dredge placement material could either below the existing groundwater level at -1.0m AHD and/or deeper in parts to limit the potential for mobilisation during a Barron River flood or capped and limited to a level of RL 3.5mAHD (i.e. 0.5m below the 2 year ARI Barron River flood) to limit off-site impacts. Containment of direct rainfall in the Northern Sands site would be unnecessary provided the water quality remains appropriate to either discharge back to the Barron River via the groundwater or surface drains.

East Trinity will require a bunded area to contain the dredge material and prevent inundation by storm surge and local catchment flooding. The bund height will also require an allowance for freeboard and climate change whilst the final bunded level will need to commensurate with the appropriate flood risk and sensitivity of overflows to the receiving environment (i.e. typically >100 year ARI storm surge level). For direct rainfall containment, the bund for the East Trinity will require a minimum freeboard in the order of 400mm to provide sufficient volume for a 10 year ARI 24 storm event. If environmental assessments indicate a sensitive environment to overflows, then additional freeboard would be required to be commensurate with the acceptable risk criteria.

Constraints

From the preliminary analysis undertaken to date, the Northern Sands site will be limited to a finished fill placement level of RL 3.5m AHD and would need to be capped and re-vegetated or provided at a level below the groundwater table and typically below -1.0m AHD or deeper in parts. At these levels the dredge material can be placed without causing adverse off-site impact.

With regards to the East Trinity site, a minimum bund level in the order of 2.4m AHD (i.e. typically 100 year ARI storm tide inundation risk + 400mm for freeboard and direct rainfall allowance) or preferably higher at RL 4.0m AHD (i.e. 10,000 year ARI storm tide) will be required to provide appropriate storm tide and local flood protection. The final level of the bunded area or final land form (i.e. wet and bunded or capped and revegetated) will need to commensurate with the period of exposure (i.e. allowance for climate change) and the sensitivity of a potential impact (i.e. overtopping of bund walls etc) upon the receiving environment. With each Site A, B or C a large open perimeter channel and increased conveyance through the outer East Trinity bund wall would be necessary to reduce the flood impacts.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Overview

This report presents the findings of the flooding, storm tide and hydrology baseline study for the Cairns Shipping Development (CSD) revised Environmental Impact Statement (EIS). The assessment included the following two land placement options:

(1) Northern Sands

(2) East Trinity

With the EIS now considering land placement options for dredged material, management of regional and local catchment surface waters will be an important aspect in ensuring no adverse off-site flooding and water quality impacts are attributable to the dredge material placement area, whilst also ensuring a stable platform will occur under frequent, large and extreme storms events.

Runoff water quantity and quality from the soil placement area in perpetuity will also be an integral aspect of the site's surface water management system. Runoff from the placement area may occur from local rainfall events or from being inundated by regional flood waters.

1.2 Study Objectives

The objective of this assessment was to undertake a qualitative and quantitative hydrological, hydraulic and preliminary water quality assessment of the proposed dredge material placement to assist in determining the preferred location, whilst being cognisant of the Terms or Reference (TOR) as detailed in Section 1.3. Where required, mitigation measures were identified for each of the proposed land placement sites to enable management of the surface water system entering and leaving the site during construction and into perpetuity.

1.3 Terms of Reference

The Terms of Reference (TOR) are provided by the Coordinator-General, Cairns Shipping Development Project (2012) and the relevant sections of the TOR are presented below:

(1) Section 4.1 (land based placement) - Describe the interference with watercourses and floodplain areas, including wetlands, salt marsh areas and mangroves and intertidal areas.

(2) Section 5.5 (water resources) -

(a) Provide an overview of the quality and quantity of any water resources in the vicinity of the project area and the relevance to the project.

(b) Assess the project's potential impacts on water resource environmental values and with regards to this assessment 1.) potential impacts on the flow, and 2.) on existing infrastructure.

(3) Section 8.1 (hazard and risks) -

(a) Identification of the defined flood event level and the relationship between that level and the location of bulk hazardous materials storage facilities in accordance with State Planning Policy 1/03; and

(b) Identify the susceptibility of the project from flooding, potential impacts of the project on flooding to adjacent properties and the impact of the project on existing flood characteristics.

2 Methodology

2.1 Overview

Presently, two potential placement areas for the dredge material have been identified as follows:

(1) **Northern Sands** - Placement within the existing sand pit void. It is envisaged a significant portion of the material will be below the minimum groundwater level (approx. RL 0m AHD) and bunded above ground to provide additional storage if required; and

(2) **East Trinity** - Three (3) potential locations are proposed with placement of the material being above ground. The dredge material site will be contained within a wet bunded area during the dredge campaign and could ultimately be compacted, dried and potentially capped into perpetuity.

An assessment of the existing surface water regime and the potential impact of the placement area was undertaken.

2.2 Northern Sands Site

The BMT WBM TUFLOW hydraulic model of the Barron River was used to determine:

(1) the potential flood impact of filling the Northern Sands site into perpetuity; and

(2) the level of bunding that could be provided to protect and contain the material during construction.

Provided in Figure 2-1 below is the full extent of the Barron River delta, whilst Figure 2-2 shows the topography of the Northern Sands Site.

2.3 East Trinity

The East Trinity Site is impacted by storm surge and local catchment flooding. The three placement locations are presented on Figure 2-3, which also depicts the topography of the East Trinity Site.

The 3 proposed placement locations were assessed through a review of current storm-tide assessments completed for the area and a quantitative assessment of local catchment runoff undertaken by BMT WBM. Details of the hydrological and hydraulic model build are presented in Appendix A.

It should be appreciated the assessment should be considered preliminary since bathymetry of the local creeks and local culverts crossing were either unavailable or incomplete.

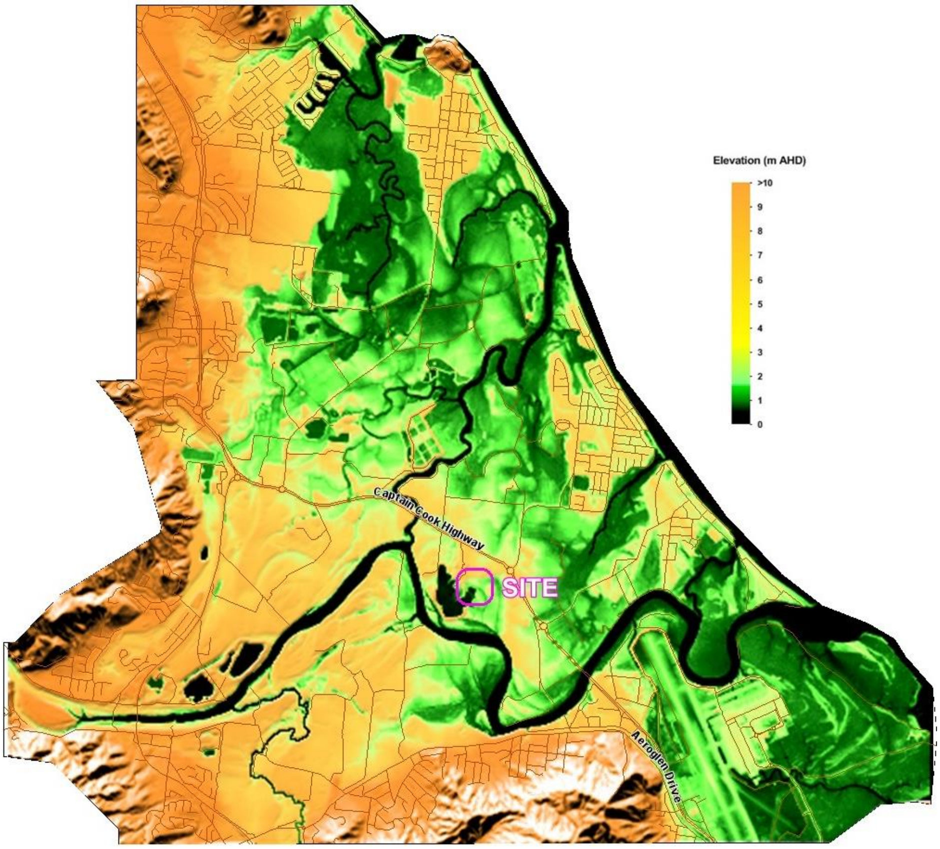


Figure 2-1 Barron River Delta & Proposed Northern Sands Placement Locations

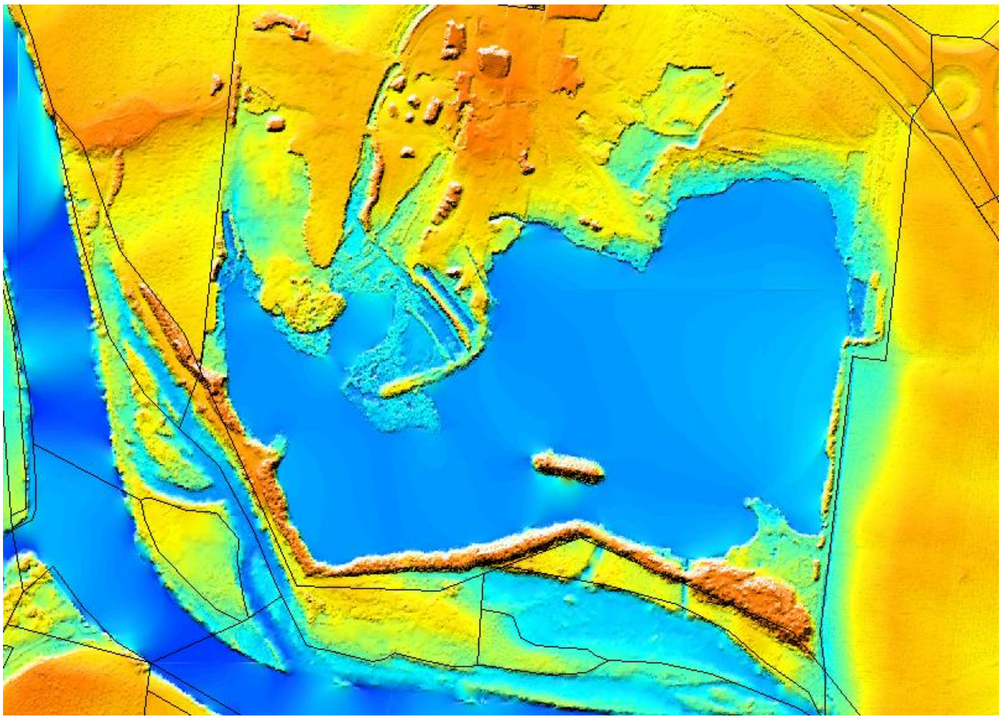


Figure 2-2 Proposed Northern Sands Local Topography

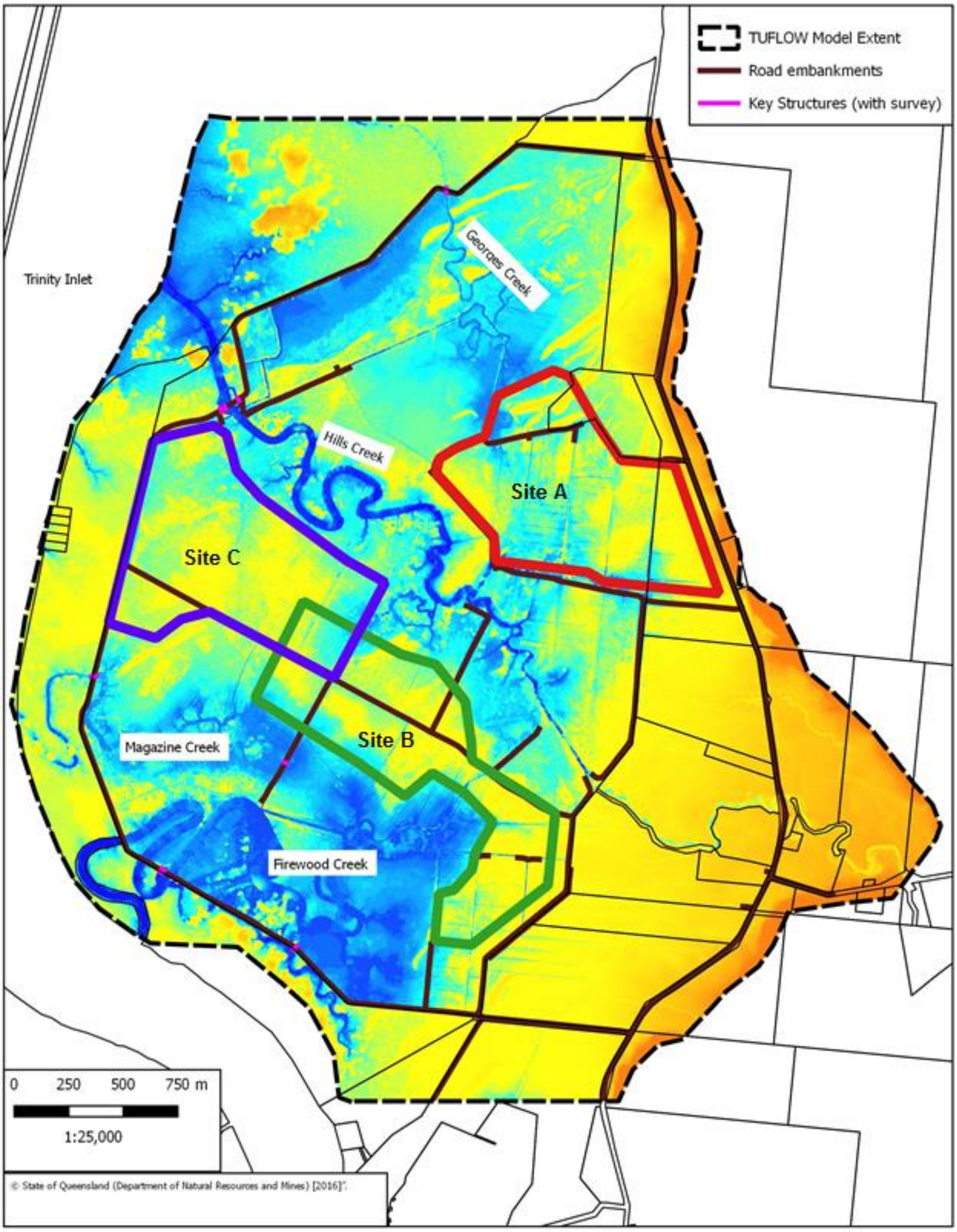


Figure 2-3 Topography of East Trinity and Proposed Sites

3 Findings

3.1 Storm Surge and Tide Levels

A review of the current storm tide planning levels was undertaken for the Northern Sands and East Trinity Sites-based on latest approved storm tide investigations including:

(1) BMT WBM 2013, 'Cairns Region Storm Tide Inundation Review' and

(2) James Cook University, JCU, 2004, Queensland Government 2001 and 2004, 'Queensland Climate Change and Community Vulnerability to Tropical Cyclones.

Presented in Table 3-1 are the resulting peak tide and storm tide levels that could inundate the material placement locations.

Table 3-1 Storm Tide Data

			Peak Tide and Storm Tide Levels (mAHD)					
Study Reference	**MHWS**	**HAT**	**1%**	**0.5%**	**0.2%**	**0.1%**	**0.01%**	**PME**
BMT WBM (2013)	0.97	1.857	1.99	2.24	2.65	3.02	4.11	8.44
JCU (2004)	-	-	2.04	-	2.58	2.89	-	-

The peak storm tide level does not include sea level rise due to climate change and based on current predictions an additional 0.8m would need to be added to these level over the next 100 years. Wave set-up and run-up was also considered, however each of the sites are at least 200m from the shore and will not further influence the design level provided in the above table.

The influence of storm surge on each site is discussed in the corresponding Northern Sands and East Trinity sections presented below.

3.2 Northern Sands

A review of the Northern Sands site was assessed through the topographic, storm surge and Barron River flooding assessments.

3.2.1 Topography

The topography of the Northern Sands site is presented on Figure 2-2. Along its western and north-western boundary, ground levels range from RL 3.5m AHD to 5m AHD, and on the southern boundary the site is protected by a bund at a level of approximately RL 6m AHD. Levels on the eastern boundary level are approximately RL 2.0m AHD and reduce to levels in the order of 1.25m AHD primarily in the drainage channels towards the Barron River.

Local catchment runoff is largely confined to the Northern Sands site with local runoff draining towards the existing pit. Based on topography and discussion with site operational personnel, overflow from the pit indicate it will drain to the Barron River.

3.2.2 Flood Risk and Storm Surge Assessment Summary

The peak flood levels, storm surge and tide levels are presented in Table 3-2 for the Northern Sands Site.

Table 3-2 Barron River and Storm Tide Data

Flooding Source	ARI / Peak Level (m AHD)					
	MHWS		HAT			100yr
Storm Surge (m AHD) BMT WBM (2013)	0.97		1.857			1.99
Barron River (m AHD)	2yr	5yr	10yr	20yr	50yr	100yr
	4.0	4.8	5.2	5.4	5.8	6.20

When compared to the site ground levels (refer to 3.2.1), the Northern Sands Site has the potential to be impacted by both storm surge and flooding from the Barron River. Detailed inspection of the topography surrounding the pit indicates a minimum level of RL 2.0m AHD (based upon LiDAR that has an accuracy of +/- 150mm) and therefore inundation from typical seasonal tides are unlikely.

A 100 year ARI storm surge level of RL 1.99m AHD may slightly overtop existing ground levels adjacent to the pit. As previously noted, detailed survey of the perimeters of the existing pit would be required to confirm that storm surge levels up to the 100 year ARI would be prevented from entering the pit.

River flooding from the Barron is the predominant risk of inundation into the proposed placement area. Floods with a frequency as low as the 2 year ARI event are predicted to inundate the proposed placement area by up to 2m, and during the 100 year ARI design flood event by up to 4m.

At this stage of the assessment, and given the low river flood immunity of the material placement location, two assessments were undertaken to determine:

(1) flood risk during the dredge campaign; and

(2) flood protection into perpetuity;

The results are presented in the following two sections.

3.2.3 Flood Protection during Dredge Campaign

The dredging campaign is programmed to be completed within 3 months from June to August. Determining the flood risk (i.e. potential for inundation) during the dredge campaign is difficult since:

(1) Cairns is dominated by a wet season as depicted in the rainfall statistics presented in Figure 3-1 below; and

(2) design flood predictions (i.e. average recurrence interval, ARI) are statistically based on an annual series;

However, as a qualitative estimate only of the flood risk, the maximum recorded monthly flow at Myola during June to August was 134m^3/s based on a 34 year record (i.e. 1982 - 2016), whilst the 1 year ARI design event flow is 500m^3/s (i.e. based on interpolation of Connell Wagner, Aug 2007). Consequently, the risk of a Barron River flood exceeding the annual 1 year ARI flood event during the dredging campaign would appear to be relatively low and has not occurred since the start of records at Myloa.

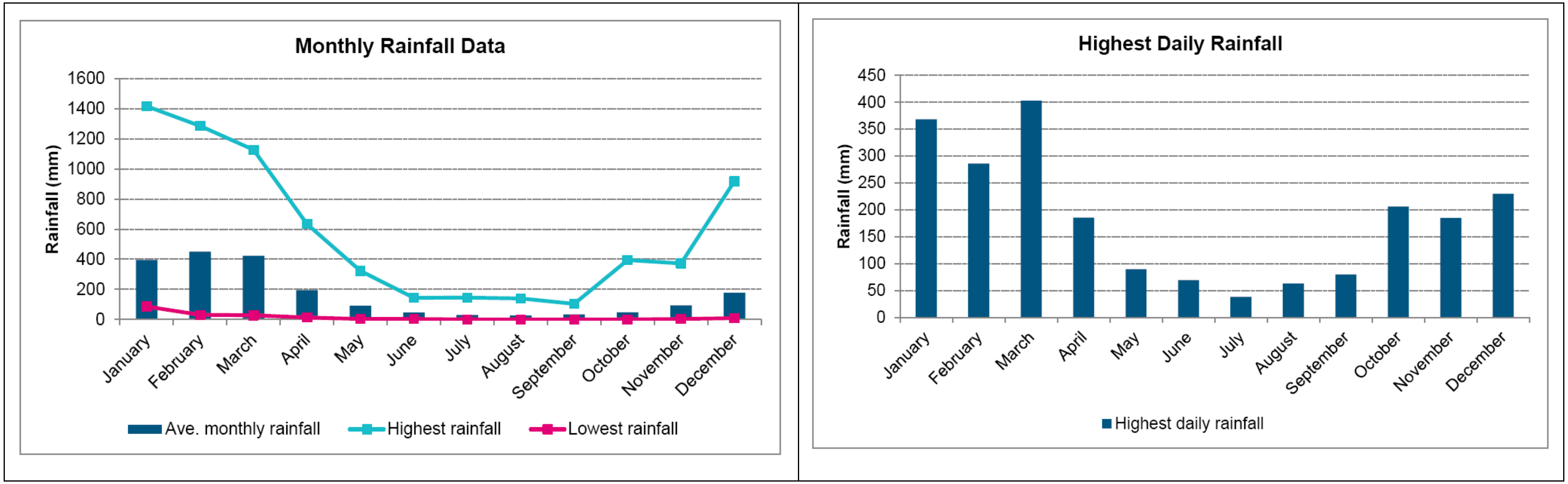


Figure 3-1 Monthly Rainfall Statistics

3.2.4 Finished Dredge Material Placement Level

Finished dredge material placement levels into perpetuity were investigated with regards to ensuring:

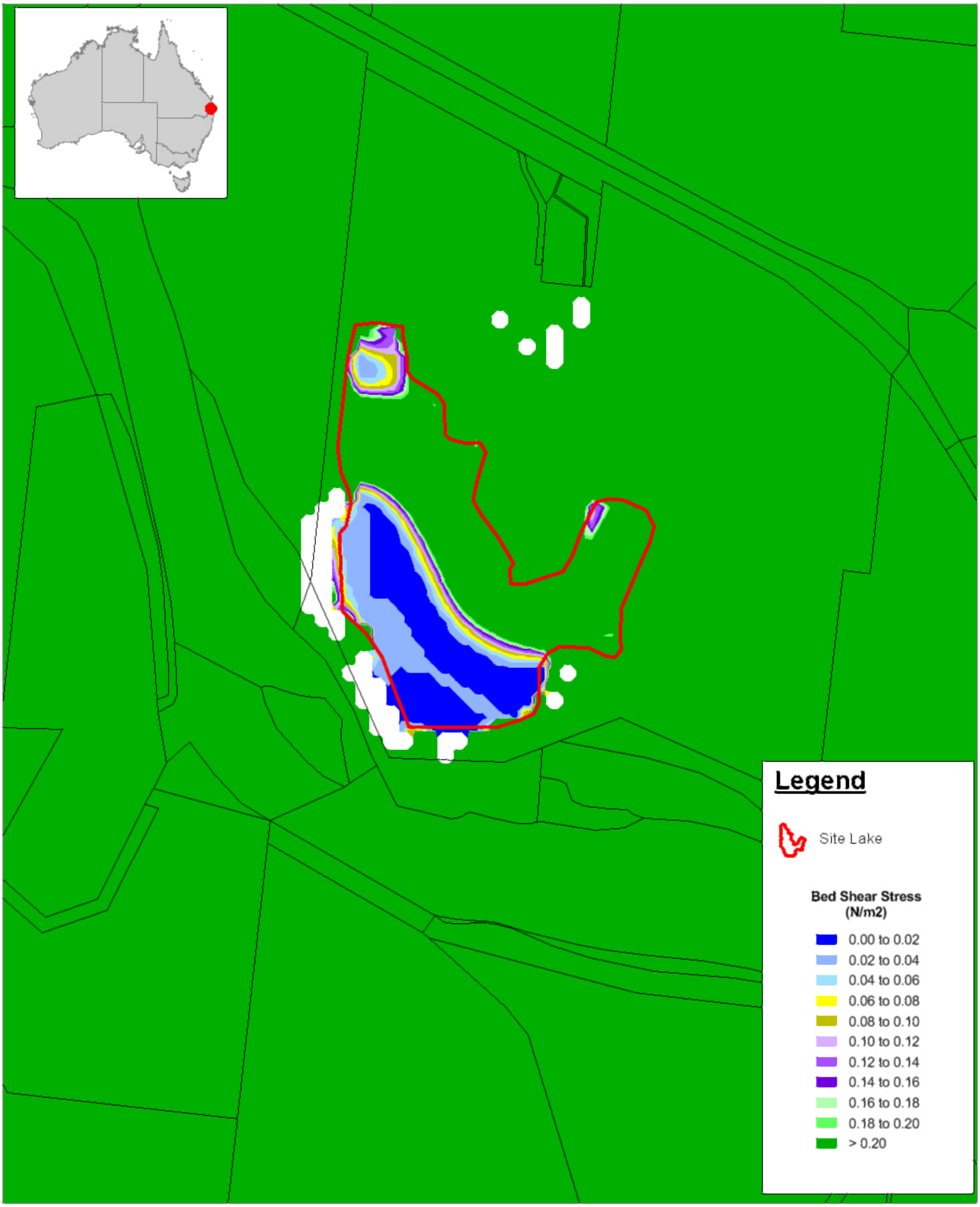
(1) The dredge material does not become mobilised and transported off-site; and

(2) A permanent adverse off-site flood impact is avoided;

The assessment was undertaken using the BMT WBM TUFLOW flood model with design flood events.

3.2.4.1 Bed Shear Stresses

From our preliminary analysis of bed shear stresses during a 100 year ARI flood event, a maximum placement level at RL -1.5m AHD indicates that the dredge material would potentially be stable into perpetuity. As presented in Figure 3-2, bed shear stresses are typically below 0.02N/m^2 in part and above 0.2N/m^2 in other parts. In absence of in-situ material properties, a critical bed shear stress below 0.038 - 0.063 for a fine silt (refer to USGS Scientific Investigation Report 2008) would indicate a stable bed.



Title:
Northern Sands Site Lake Bed @ -1.5m AHD
100 Year ARI Bed Shear Stress

Figure: 3-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

BMT WBM
www.bmtwbm.com.au

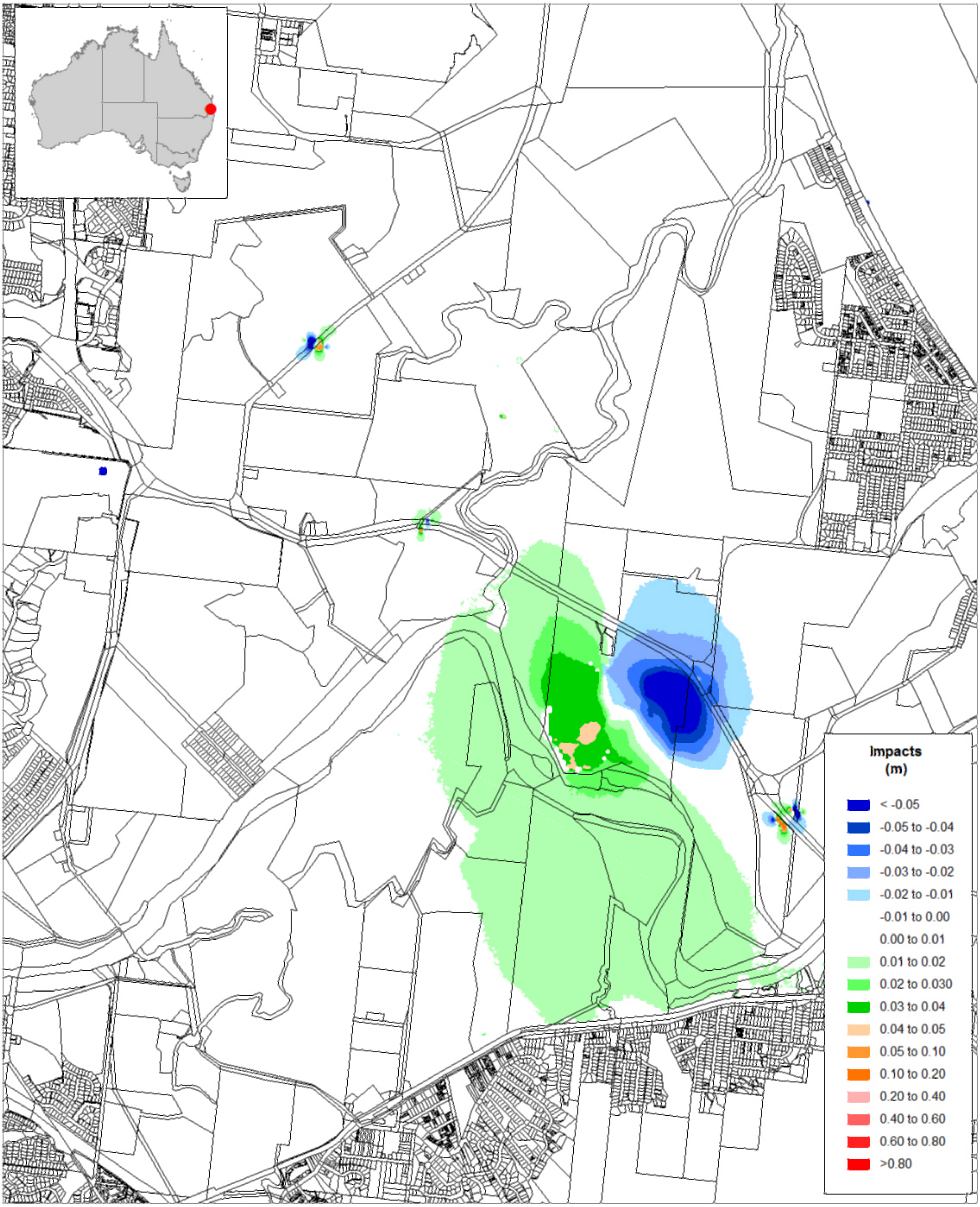
Filepath: I:\B22074.I.Cairns EIS Update\DRG\Flood\100yBSS_NorthernSands_site_lake_-1.5mAHD_0-0.2 reporting_05062017.WOR

However, it should be appreciated that detailed 2 and 3 dimensional modelling and in-situ material properties are required to confirm this preliminary placement level.

3.2.4.2 Maximum Fill Levels

From our initial hydraulic assessments of finished fill levels, a level slightly lower than a 2 year ARI flood event (i.e. RL 3.5m AHD, refer to Table 3-2) is considered the maximum fill height (i.e. with capping to prevent erosion) that will not cause adverse off-site impacts. The resulting flood impact maps with a finished fill level of RL 3.5m AHD is presented in Figure 3-3.

Refinement and optimisation of the final surface within the pit placement area could potentially increase the final fill volume.



Title:

Northern Sands Site lake filled to 3.5m AHD
100 Year ARI Peak Water level Impacts

Figure: 3-3

Rev: A

N

0 250 500
metres

BMT WBM
www.bmtwbm.com.au

Filepath: I:\B22074.I.Cairns EIS Update\DRG\Flood\100y Impacts_Northern Sands_site_filled_05062017.WOR

3.2.5 Local Stormwater Runoff and Quality

3.2.5.1 Construction - Dredge Placement Campaign

Since rainfall during the June to August period is typically minimal, control of local stormwater runoff during the dredge placement campaign from the Northern Sands Site will require limited containment.

Direct rainfall onto the dredge placement area could be adequately contained and managed by the tailwater system required for the placement operation.

3.2.5.2 Permanent

Depending upon the final finish level (i.e. below lake/groundwater level or above), management of local stormwater runoff into perpetuity would best be managed by providing a stable material surface that is not subject to mobilisation or erosion.

If the placement material was sited below the groundwater surface (i.e. an open lake), then detailed 3D hydraulic modelling would be required to determine the potential for resuspension and confirm the final placement level. As noted in Section 3.2.4.1, it is likely that the dredge material would need to be below -1.0m AHD and potentially deeper in other parts (i.e. to be assessed in detail), to ensure the bed shear stresses were sufficiently low to prevent re-suspension. If the final placement material is to be above the groundwater surface, capping and re-vegetation of the surface would be required to ensure a stable surface.

Depending upon the final water quality criteria to be achieved, if dredge material is placed beneath the surface water level, containment of direct rainfall will not be necessary and overflow may occur back to the Barron River as per the current drainage system. If the dredge material was capped and above ground, the runoff will be similar to adjacent surrounding land and again containment of direct rainfall will not be necessary.

3.2.6 Summary

The Northern Sands site would provide a system of limited risk of inundation during the dredge campaign (i.e. June to August) from a Barron River flood and hence loss of dredge material to the floodplain and off-shore area would be unlikely.

The final dredge placement material will either be:

(1) below the existing groundwater level at -1.0m AHD and/or deeper in parts to limit the potential for mobilisation during a Barron River flood; or

(2) capped and limited to a level of RL 3.5mAHD (i.e. 0.5m below the 2 year ARI Barron River flood) to limit off-site impacts.

Containment of direct rainfall in the Northern Sands site would be unnecessary provided the water quality remains appropriate to either discharge back to the Barron River via the groundwater or via surface drains.

3.3 East Trinity

Review of the three (3) East Trinity Site dredge material placement areas was undertaken with regards to seasonal tides, storm surge and local catchment flooding. As previously noted, details of the hydrological and hydraulic model are presented in Appendix A. The results of this modelling are presented in the following sections.

3.3.1 Topography and Local Drainage

Topography of the East Trinity area as presented in Figure 2-3 has indicated the site is generally below RL 2.0m AHD and typically ranging from RL 1.0m AHD to 1.5mAHD.

The site is currently bunded around the western perimeter at a level of RL 2.0m AHD to 2.25mAHD (i.e. +/- 150mm from LiDAR) and there are a number of tide locks on the existing creeks that allow drainage of the site. The current bund will typically prevent tidal inundation up to HAT event and a 100 year ARI Storm Surge event (refer to Table 3-2), however there could be portions of the bund below RL 2.0mAHD that would enable overtopping to occur.

3.3.2 Storm Surge (Design)

A review of the storm tide design levels are presented in Table 3-3 without climate change and wave run up. As previously noted, wave run-up is unlikely to extend into the site, due the distance from the shoreline exceeding 200m to the bund, notwithstanding the proposed placement area are further away.

Table 3-3 Storm Tide Data

Storm Surge Study Reference Study Reference	ARI					
	100	200	500	1,000	10,000	PME
BMT WBM, 2013 (m AHD)	1.99	2.24	2.65	3.02	4.11	8.44
JCU, 2004 (m AHD)	2.04	-	2.58	2.89	-	-

To commensurate with the risk of impacting upon the receiving environment, a bund height to a level between RL 2.0m AHD for 100 year ARI and preferably towards RL 4.0m AHD (10,000 ARI) would be necessary to ensure protection from a storm surge event. As previously noted, these levels do not include sea level rise due to climate change and an additional +0.8m would need to be added to these levels (over the next 100 years).

3.3.3 Pre Dredge Placement - Flood Results and Discussion

The major inflow to the floodplain originates from the Hills Creek catchment, once this runoff passes west of Pine Creek, Yarrabah Road, the water spreads over the entire floodplain. Mapped peak depths for the 2 year ARI design storm event are presented on Figure 3-4, with results for the 100 year ARI design storm event presented in Figure 3-5.

The bund wall surrounding the site prevents water from freely draining to Trinity Inlet, with water generally only able to drain via the existing drainage structures/culverts. The hydraulic results show that the majority of the East Trinity area is bounded by the perimeter bund wall and Pine Creek, Yarrabah Road is inundated in both the 2 year and 100 year ARI events.

Flood depths through the East Trinity area in the 100 year ARI event are generally in the range of 0.5m to 2.0m, with flood velocities generally not exceeding 0.2 m/s across the floodplain area in the 100 year ARI event (excluding the creek channels). The flooding characteristics of the floodplain are heavily influenced by the presence of the road embankments surrounding the floodplain, resulting in higher flood levels/depths and lower flood velocities than those that would be expected for a scenario with no embankments.

3.3.4 Design Option Assessment

The results described in Section 3.3.3 (i.e. Pre Dredge Placement) were adopted as the existing / base case against which proposed post dredge placement works have been assessed. The three conceptual designs provided were hydraulically assessed.

Assessment of each footprint was assessed by effectively filling each placement area above the 100 year ARI flood level to represent the ultimate blockage to flow and loss of floodplain storage from each placement area. These sites (Site A, Site B, Site C) are shown in Figure 2-3.

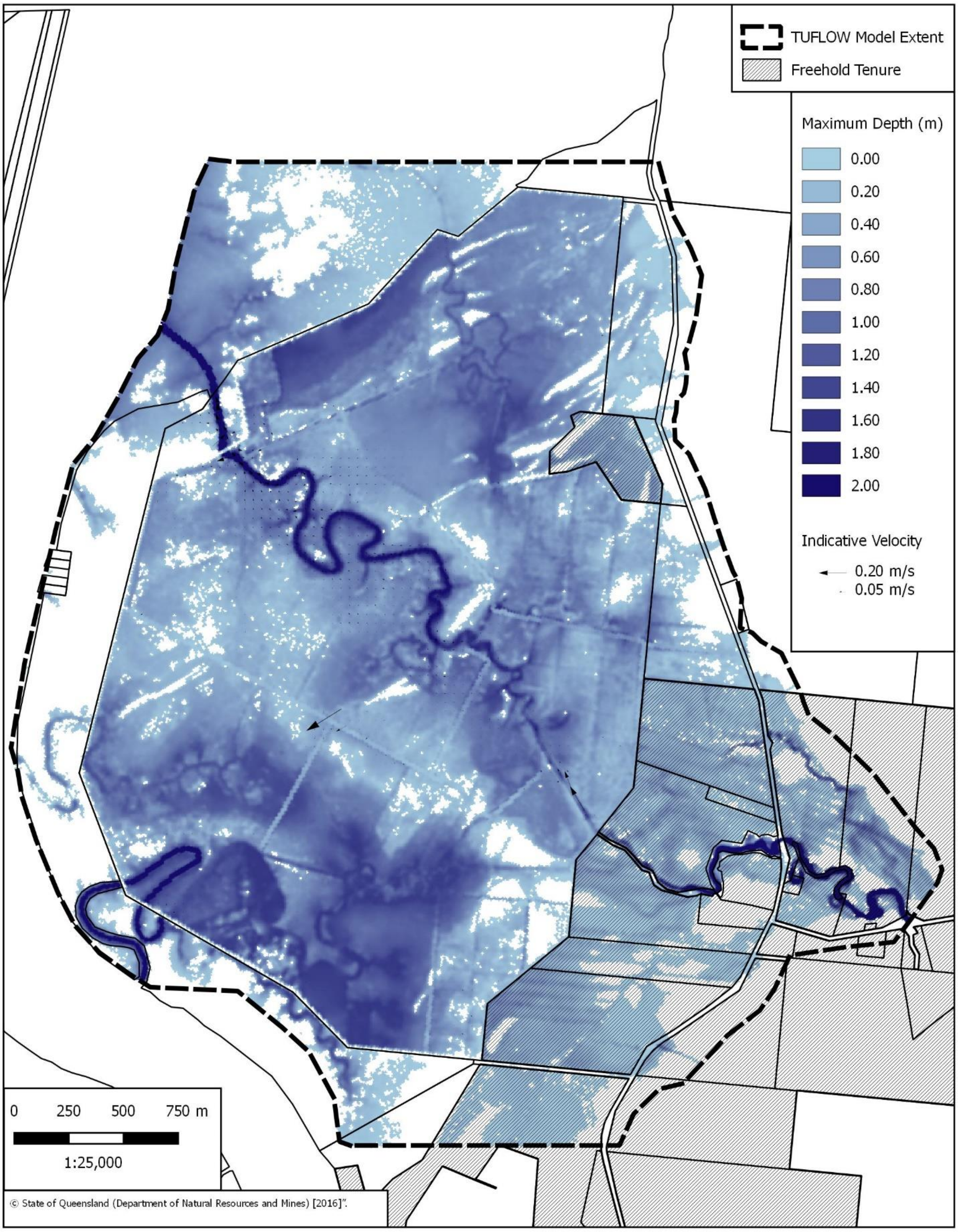


Figure 3-4 Existing Case – 2 Year ARI Peak Depths and Indicative Velocity Vectors[1]

[1] Vectors beyond the site boundary have not been shown here for clarity

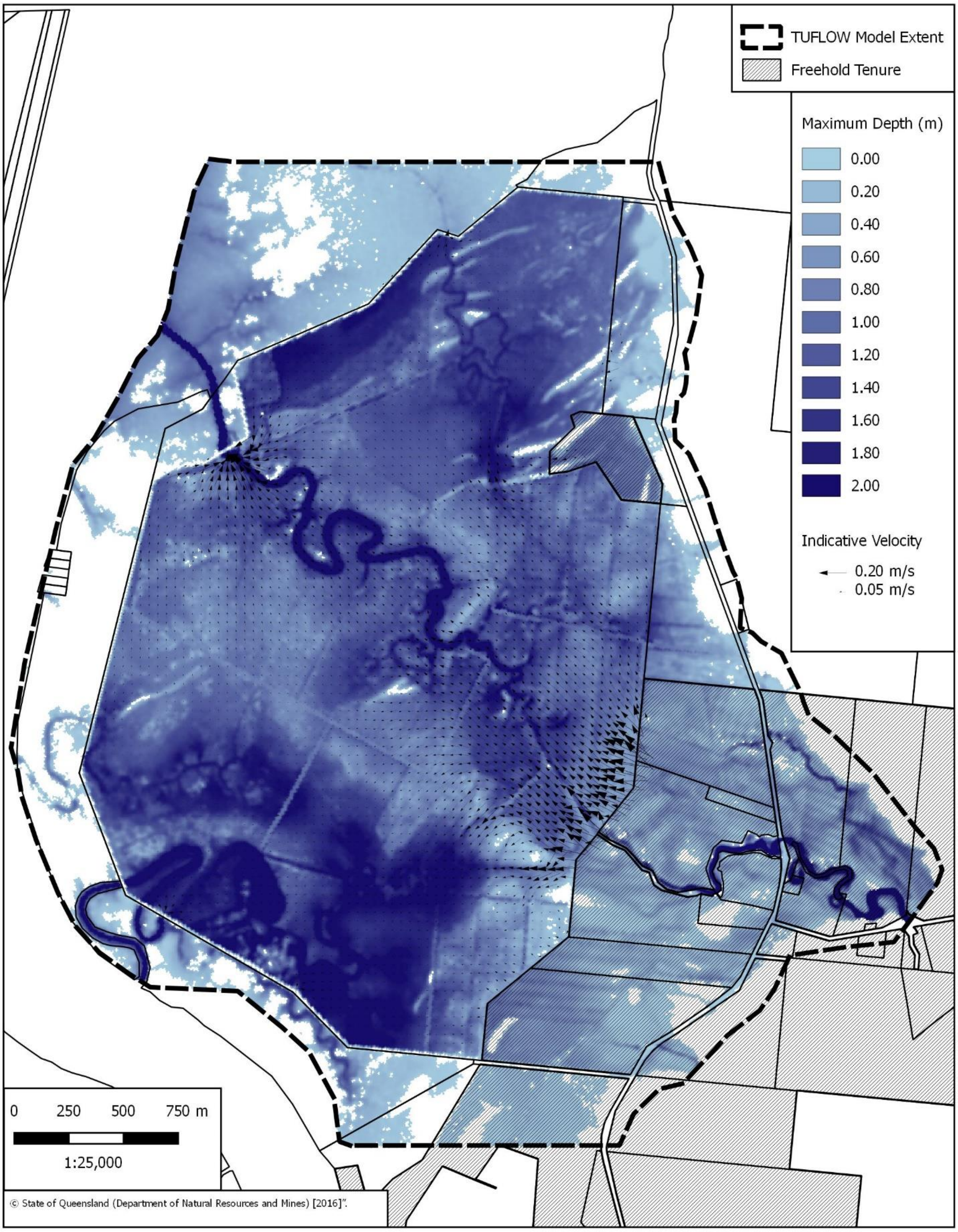


Figure 3-5 Existing Case – 100 Year ARI Peak Depths and Indicative Velocity Vectors[2]

[2] Vectors beyond the site boundary have not been shown here for clarity

3.3.4.1 Site A Assessment

Site A is located on the northern side of Hills Creek immediately west of Pine Creek Yarrabah Road. The north-eastern side of this site borders an area of freehold land (as derived from Queensland Globe[3] data).

The placement area and peak water level differences for the 2 Year ARI event are shown in Figure 3-6, and for the 100 year ARI event in Figure 3-7. Assessment of Site A indicated that:

(1) For the 2 year ARI event:

(a) There are water level increases on the freehold land adjacent to the site in excess of 0.90m;

(b) There are water level increases of up to 1.41m adjacent to Pine Creek Yarrabah Road; and

(c) There are water level increases up to 0.076m at the freehold property boundary south of the site, although this only affects a relatively small portion of land. For the remainder of the freehold property boundary south of the site there are generally no changes in peak water level.

(2) For the 100 year ARI event:

(a) There are water level increases on the freehold land adjacent to the site in excess of 0.50m;

(b) There are water level increases of up to 1.53m adjacent to Pine Creek Yarrabah Road; and

(c) There are water level increases up to 0.032m at the freehold property boundary south of site.

These changes in peak water level indicate that:

(1) This Site blocks the runoff from Hills Creek that is flowing in a northerly direction, resulting in the water level increases to the south of the site; and

(2) the proximity of this Site to the immediately adjacent freehold land to the north and Pine Creek Yarrabah Road to the east leads to significant localised increases in water level.

Given the significant increases in water level and the proximity of this site to the adjacent freehold land and Pine Creek Yarrabah Road, significant drainage works would be required should this location be considered further. With regards to the potential drainage works, it is envisaged that a large open channel around its perimeter and increased conveyance through the existing East Trinity bund would be necessary to off-set the loss of floodplain storage and conveyance caused by the placement area.

[3] © State of Queensland 2015

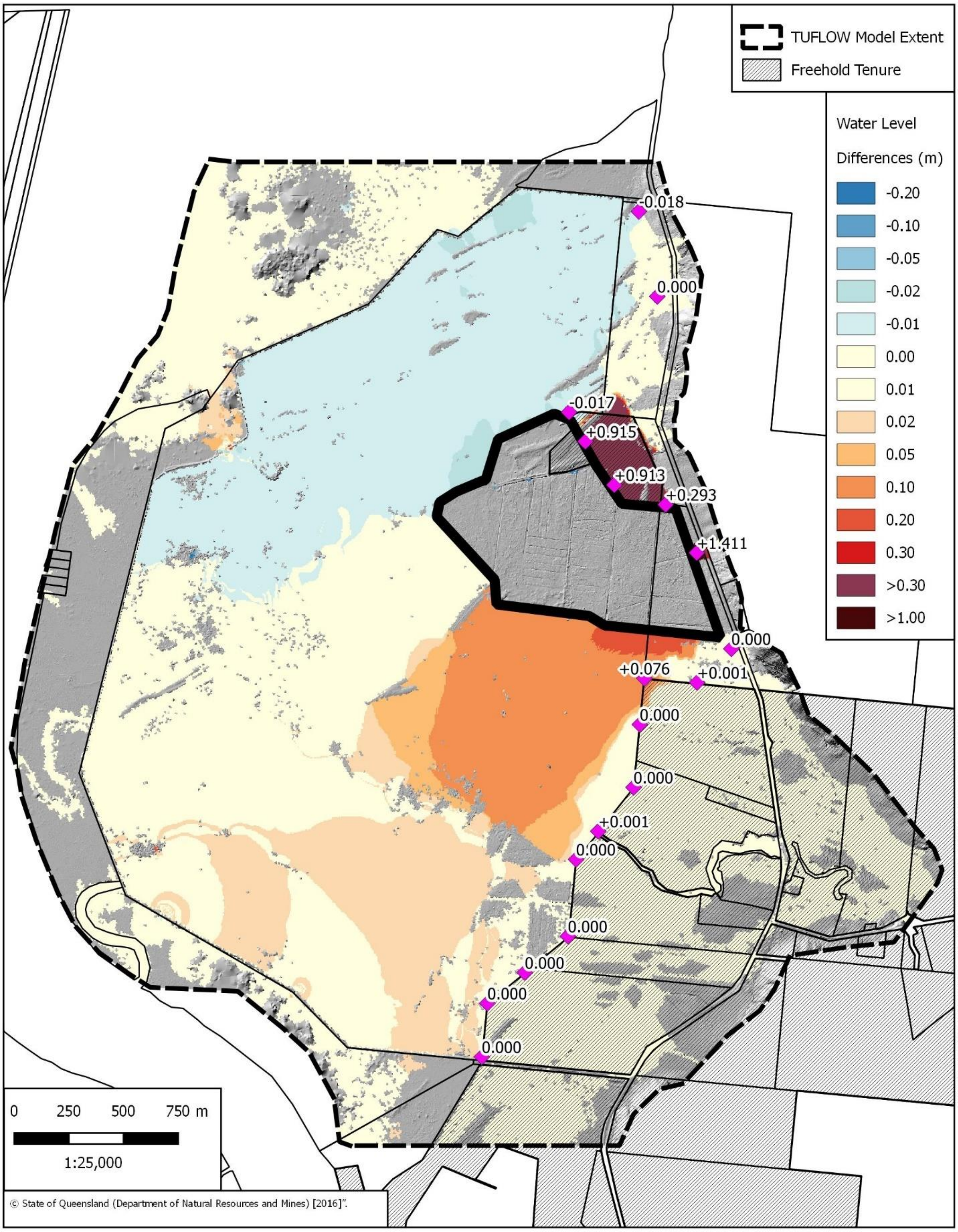


Figure 3-6 Conceptual Site A Water Level Differences – 2 Year ARI Event

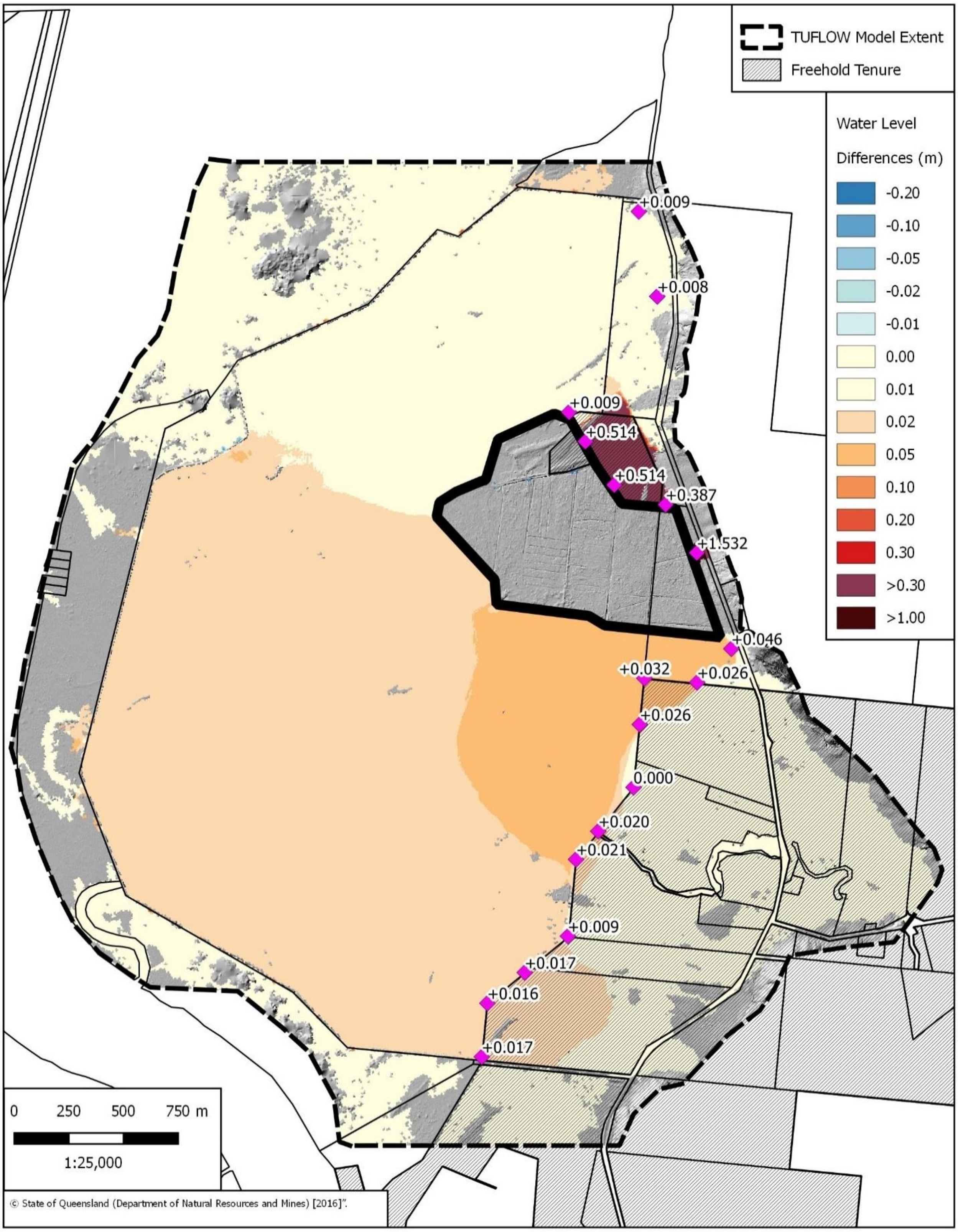


Figure 3-7 Conceptual Site A Water Level Differences – 100 Year ARI Event

3.3.4.2 Site B Assessment

Site B is located on the southern side of Hills Creek and north-east of Firewood Creek, spanning some of the existing drainage channels between these two watercourses.

Peak water level differences for the 2 Year ARI event are shown in Figure 3-8, and for the 100 year ARI event in Figure 3-9. Assessment of Site B shows that:

(1) For the 2 year ARI event:

  (a) There are water level increases on freehold land north of the site of up to 0.086m;

  (b) There are no changes in peak water levels at Pine Creek Yarrabah Road; and

  (c) There are water level increases up to 40mm at the freehold property boundary east of site.

(2) For the 100 year ARI event:

  (a) There are water level increases on the freehold land north of the site of up to 0.051m;

  (b) There are no changes in peak water levels at Pine Creek Yarrabah Road; and

  (c) There are water level increases up to 86mm at the freehold property boundary east of site.

These changes in peak water level indicate that this site blocks the flow of water from Hills Creek to Firewood Creeks, resulting in an increase in flow towards the north.

Mitigation assessments of Site B, has shown that acceptable impacts can only be achieved by, significantly reducing the footprint, by removing the entire eastern half of this site to remain as per pre-dredge conditions. As a consequence, this significantly changes the intended footprint (i.e. volume) of the placement area and operation of this site with respect to the tailwater discharge location. Similar to Site A, a large open channel around the perimeter of the placement area, including increased conveyance through the outer East Trinity bund wall, would be required to reduce the flood impacts.

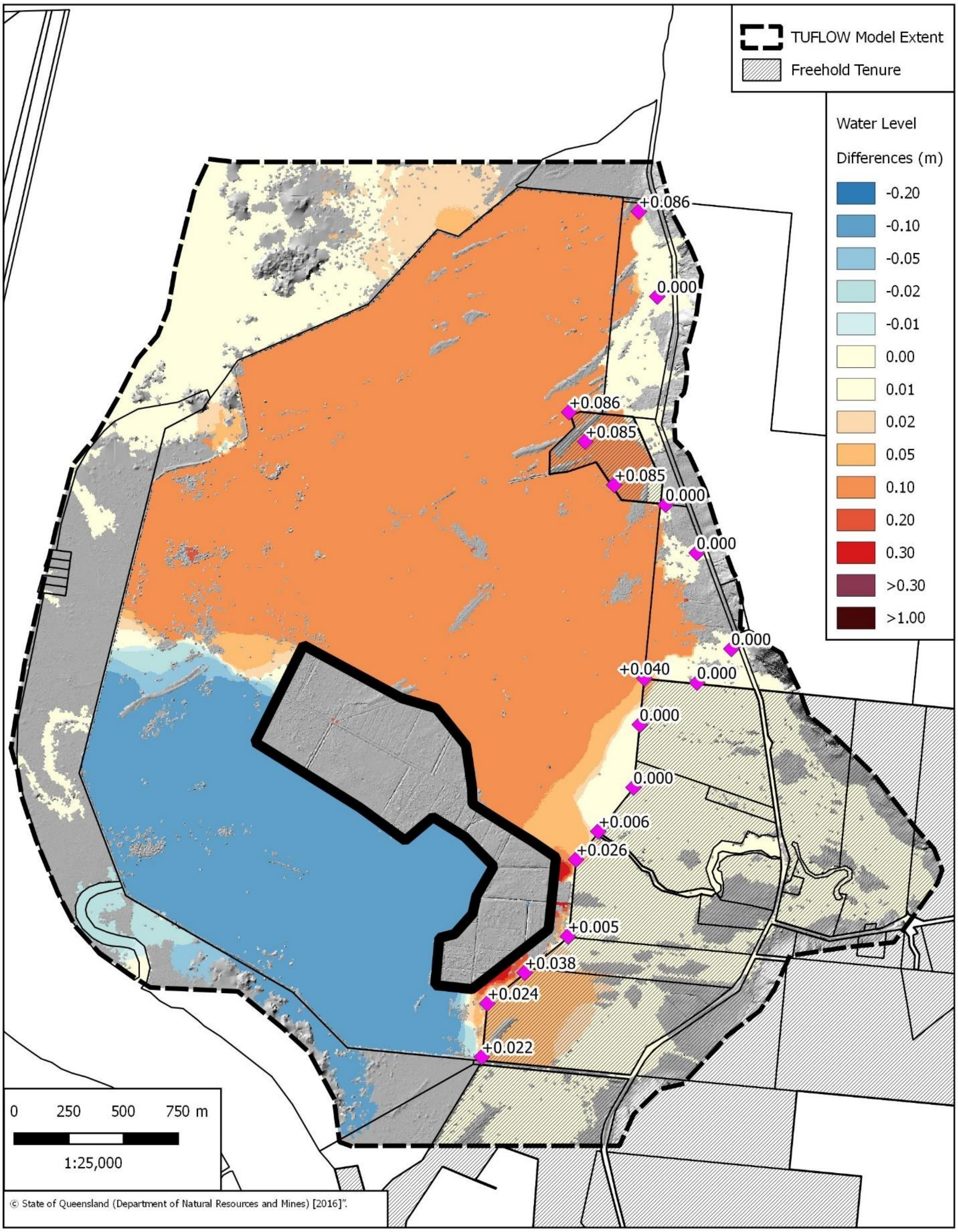


Figure 3-8 Conceptual Site B Water Level Differences – 2 Year ARI Event

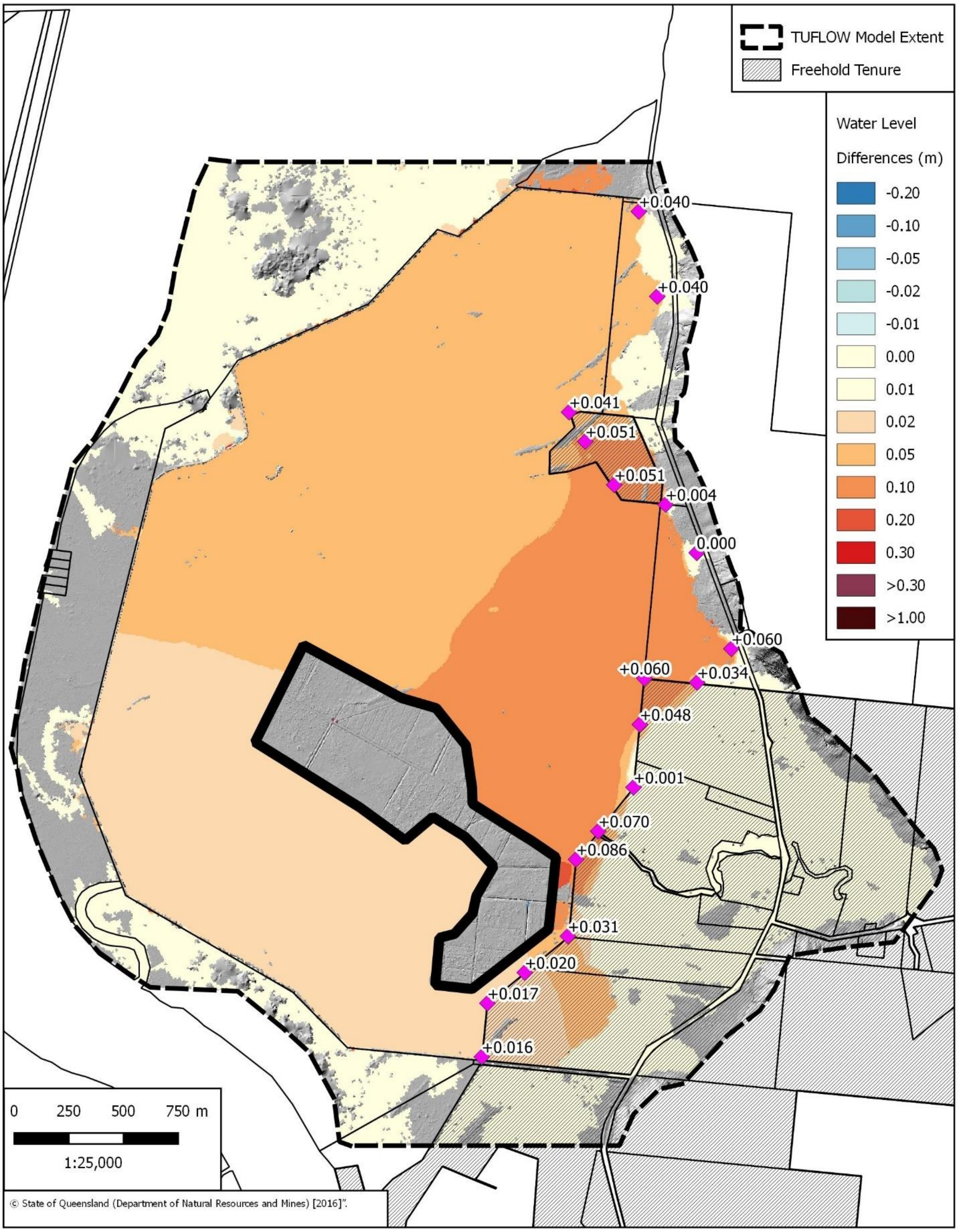


Figure 3-9 Conceptual Site B Water Level Differences – 100 Year ARI Event

3.3.4.3 Site C Assessment

Site C is located on the western boundary of the overall site on the southern side of Hills Creek and northern side of Magazine Creek.

Peak water level differences for the 2 year ARI event are shown in Figure 3-10, and for the 100 year ARI event in Figure 3-11. Assessment of Site C shows that:

(1) For the 2 year ARI event:

 (a) There are water level increases on freehold land north-east of the site of up to 0.034m;

 (b) There are no changes in peak water levels at Pine Creek Yarrabah Road; and

 (c) There is a maximum water level increase of 0.005m at the freehold property boundary east of site.

(2) For the 100 year ARI event:

 (a) There are water level increases on the freehold land north-east of the site of up to 0.031m;

 (b) There are no changes in peak water levels at Pine Creek Yarrabah Road; and

 (c) There are water level increases up to 37mm at the freehold property boundary east of Site.

These changes in peak water level indicate that this placement area blocks the flow of water from Hills Creek to Magazine Creek/Firewood Creeks in the 2 year ARI event, resulting in an increase in flow towards the north. However, in the 100 year ARI event the site blocks the flow from Magazine /Firewood Creeks northwards to Hills Creek, resulting in water level increases across the entire floodplain. Similar to Site A and B, increased conveyance through the outer East Trinity bund wall would assist in off-setting the loss of conveyance and flood storage.

3.3.5 Alternate Design Option Assessment - Site C

Further assessment of Site C was undertaken by modifying the extent of the site, taking into account the floodplain flow patterns predicted and the preferred tailwater discharge configuration for Site C.

The changes to the extent of Site C are as follows:

(1) Approximately 220m setback from the eastern boundary of the site;

 (a) This change increases the amount of floodplain flow between the Hills Creek and Magazine Creek/Firewood Creek systems.

(2) Setback in the south-western corner of the Site;

 (a) This change limits the impact of the south-western corner on peak water levels, allowing for water to flow northwards towards Hills Creek.

(3) Approximately 60m setback from the western boundary of the Site.

 (a) In conjunction with the previous change, this allows for water to flow from south to north along the western boundary of the Site.

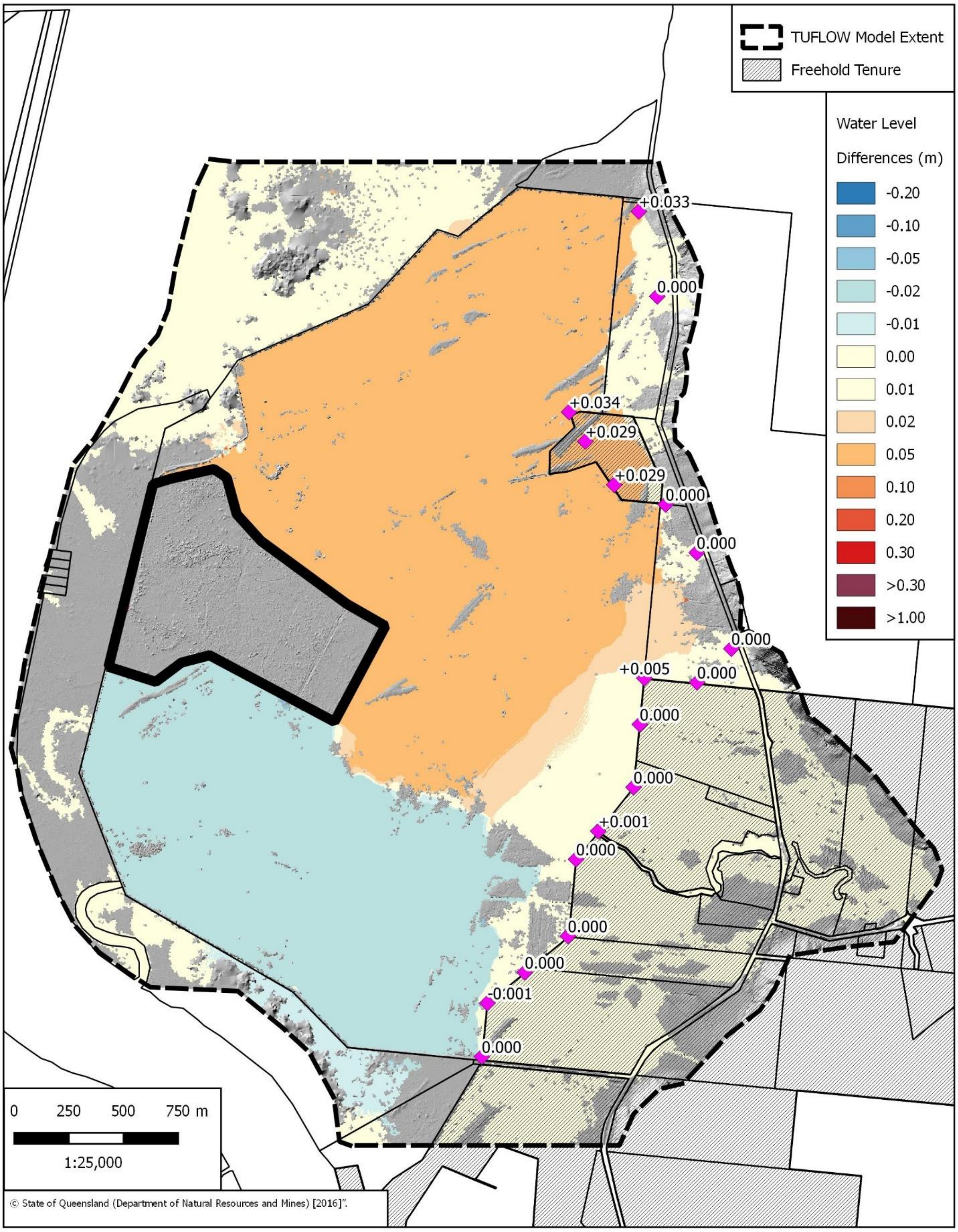


Figure 3-10 Conceptual Site C Water Level Differences – 2 Year ARI Event

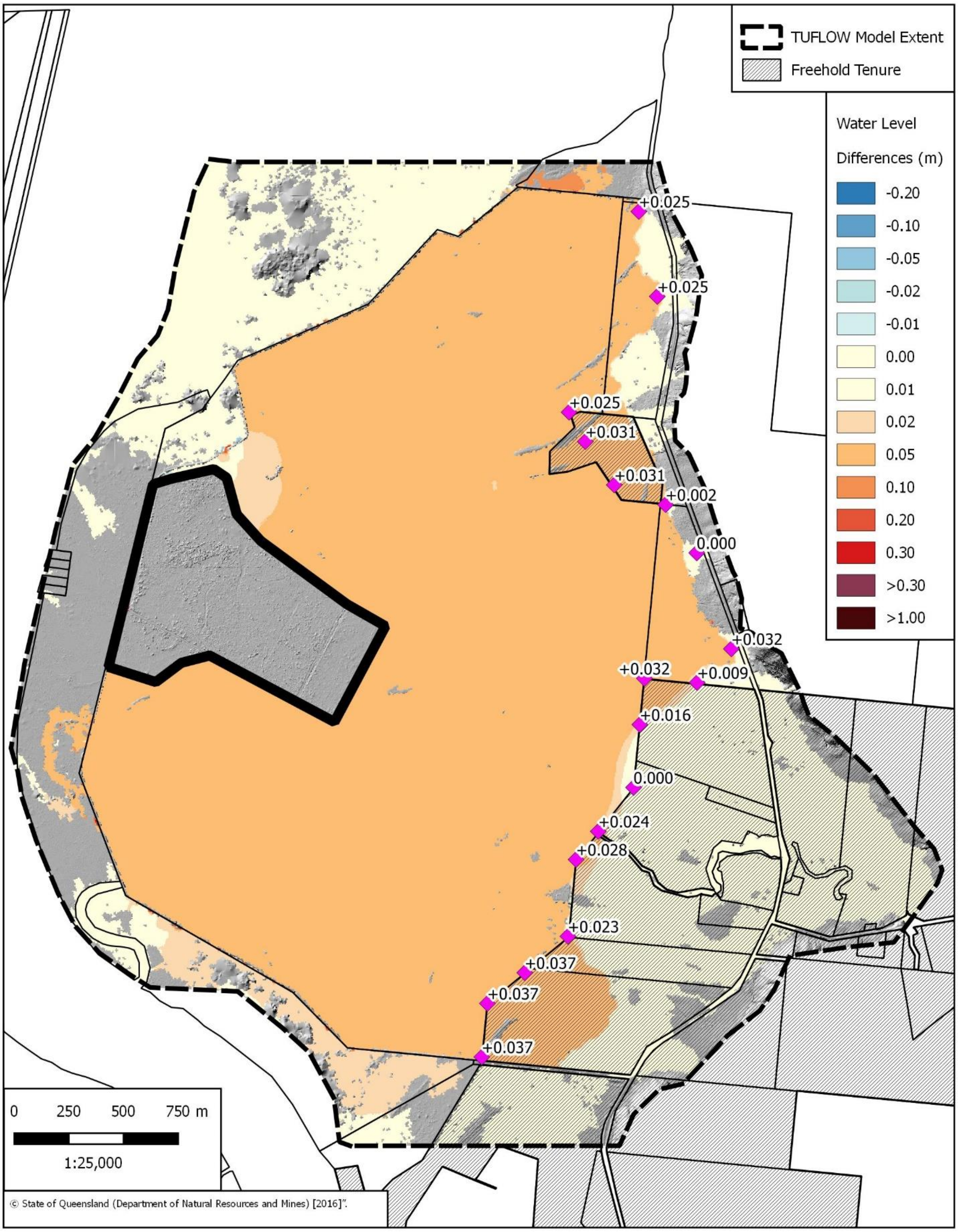


Figure 3-11 Conceptual Site C Water Level Differences – 100 Year ARI Event

Peak water level differences for the 2 Year ARI event are shown in Figure 3-12, and for the 100 year ARI event in Figure 3-13. Assessment of a modified Site C shows that:

(4) For the 2 year ARI event:

(a) There are water level increases on freehold land north-east of the site of up to 0.017m;

(b) There are no changes in peak water levels at Pine Creek Yarrabah Road; and

(c) There are no increases in peak water levels at the freehold property boundary east of site.

(5) For the 100 year ARI event:

(a) There are water level increases on the freehold land north-east of the site of up to 0.016m;

(b) There are no changes in peak water levels at Pine Creek Yarrabah Road; and

(c) There are water level increases up to 0.019m at the freehold property boundary east of site.

The results show that modifications to the original Site C have reduced the peak water level impacts across the floodplain, with increases less than 20mm at the freehold tenure boundary.

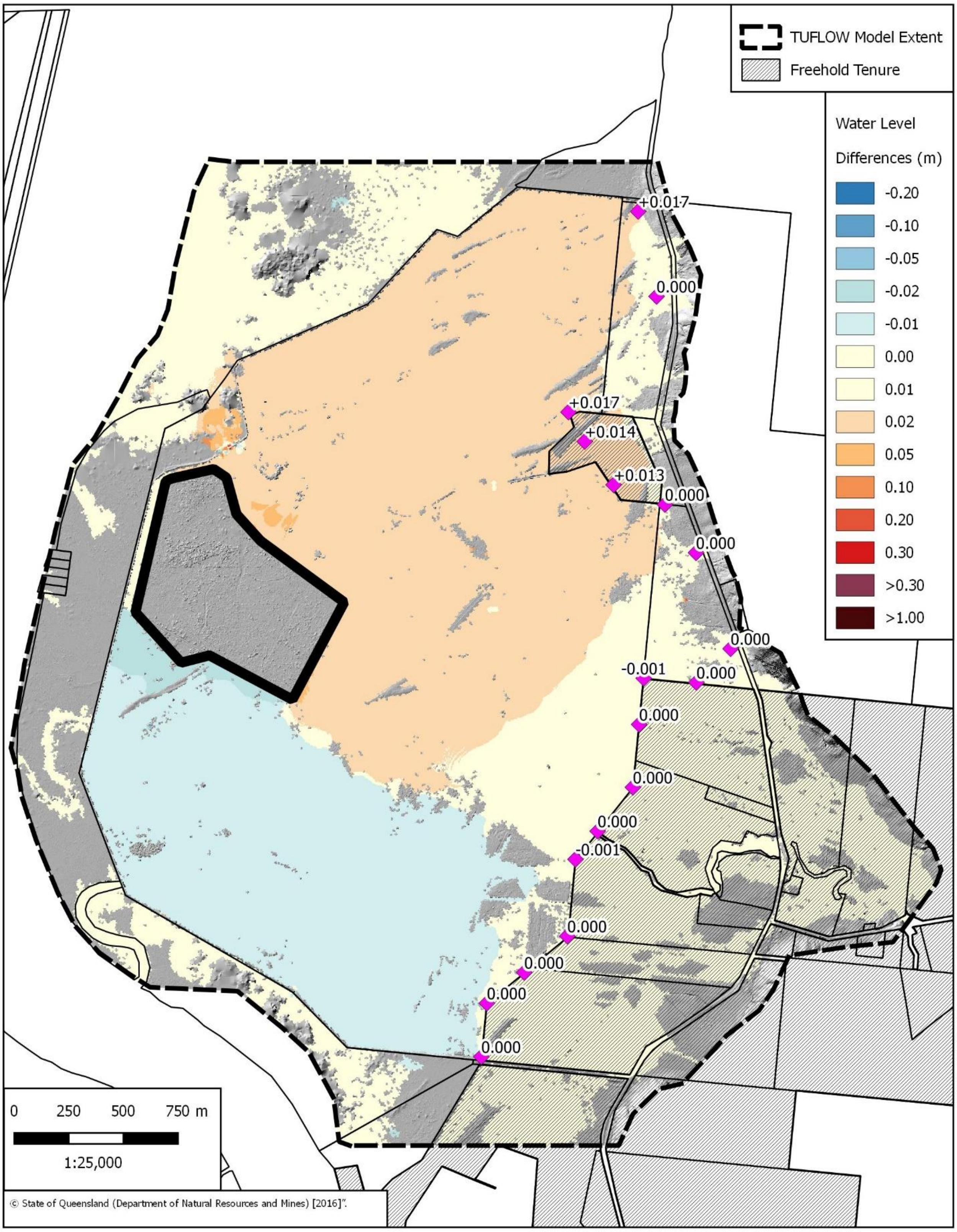


Figure 3-12 Modified Conceptual Site C Water Level Differences – 2 Year ARI Event

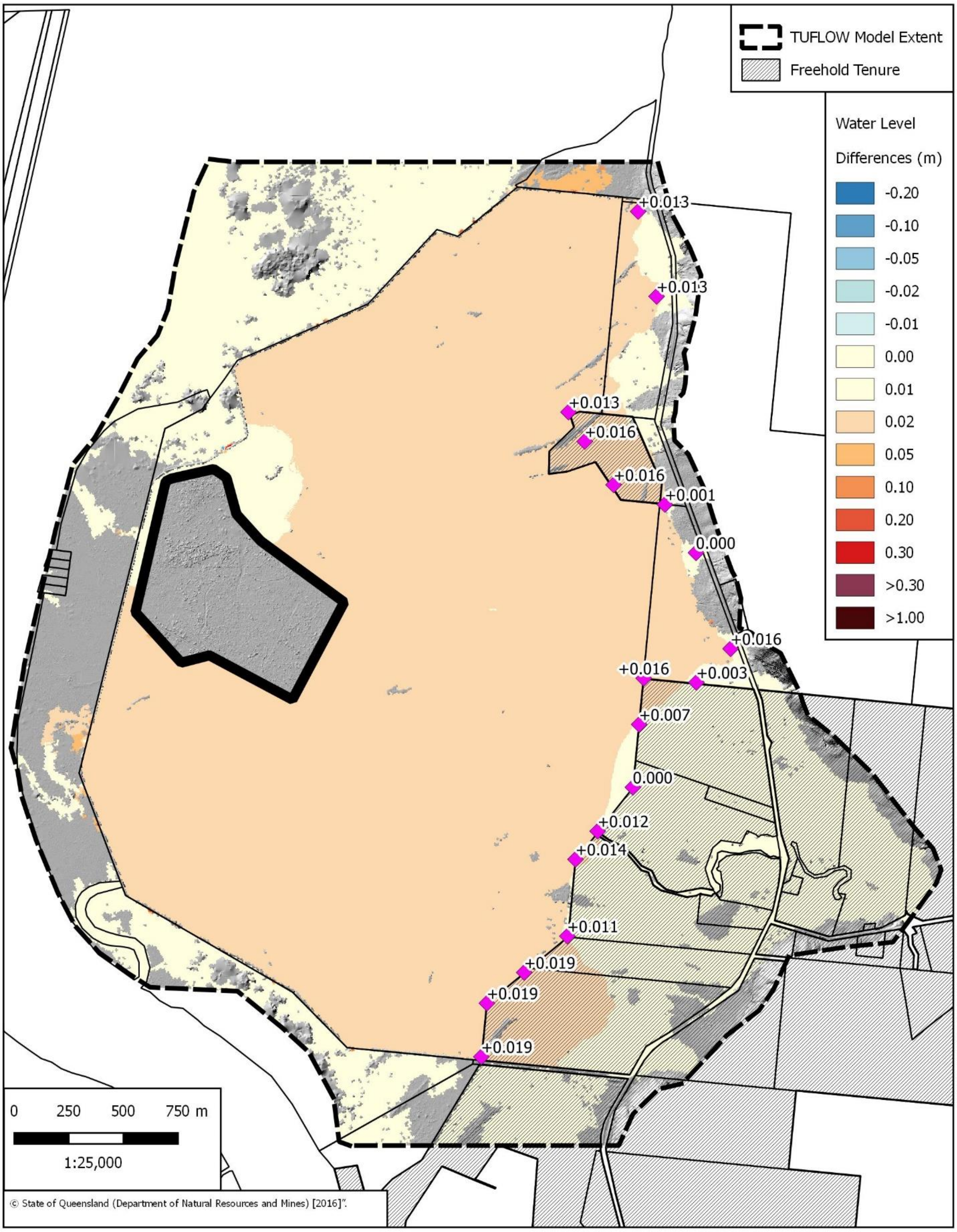


Figure 3-13 Modified Conceptual Site C Water Level Differences – 100 Year ARI Event

3.3.6 Summary of Design Option Assessment

The flooding characteristics of the floodplain are heavily influenced by the presence of the bund wall surrounding the floodplain, resulting in higher flood levels/depths and lower flood velocities than those that would be expected for a scenario with no embankments.

For all design options considered, the impacts on peak flood levels are sensitive to the location and extent of the area for each option. For the original options (Site A, Site B, Site C), the proposed extent of works results in a change of flow direction within the floodplain which, combined with the road embankment levels leads to increased water level at the freehold tenure boundaries.

The modified extent of Site C results in water level impacts less than 20mm at the freehold tenure boundaries. For Site A, B and the original Site footprint of C, increasing the conveyance through the East Trinity bund (i.e. outer perimeter road), including large open channel diversions around the site, may assist in reducing peak flood level impacts within the area. As an alternative a combination of a modified Site B and C may also provide an option to managing flood impacts.

4 Summary

4.1 Northern Sands

The Northern Sands site would provide a system of limited risk of inundation during the dredge campaign (i.e. June to August) from a Barron River flood and storm surge event, hence loss of dredge material to the floodplain and off-shore area would be unlikely.

The final dredge placement material could either be:

(6) below the existing groundwater level at -1.0m AHD and/or deeper in parts to limit the potential for mobilisation during a Barron River flood; or

(7) capped and limited to a level of RL 3.5mAHD (i.e. 0.5m below the 2 year ARI Barron River flood) to limit off-site impacts.

Containment of direct rainfall in the Northern Sands site would be unnecessary provided the water quality remains appropriate to either discharge back to the Barron River via the groundwater or via surface drains.

4.2 East Trinity

The East Trinity site floodplain characteristics are heavily influenced by the presence of the bund walls surrounding the floodplain, resulting in higher flood levels/depths and lower flood velocities than those that would be expected for a scenario with no embankments.

For all East Trinity design options considered, the impacts on peak flood levels are sensitive to the location and extent of the area for each option. For the Sites A, B and C, the proposed extent of works results in a change of flow direction within the floodplain, which combined with the road embankment levels, leads to permanent increased flood level at the freehold tenure boundaries and are typically not compliant with Council's flood codes.

The modified extent of Site C presented results in peak level impacts less than 20mm at the freehold tenure boundaries. Impacts less than 20mm are considered acceptable, however nuisance flooding through diversions of stormwater will need to be considered in further detail should one of these site be considered as a preferred placement option.

For Site A and B, increasing the conveyance through the East Trinity bund (i.e. outer perimeter road), including large open channel diversions around the site, may assist in reducing peak flood level impacts within the area. As an alternative a combination of a modified Site B and C may also provide an option to managing flood impacts

Appendix A East Trinity Model Set-up

Hydrological Model

Rainfall Parameters

The rainfall parameters used in the WBNM model were extracted from AR&R (1987) for the study area. The parameters are presented in Table A-1 and an Intensity Frequency chart is presented in Figure A-1.

Table A-1 Design Rainfall Parameters

Parameter	Value
2 Year ARI 1 hour	61.86
2 Year ARI 12 hour	16.31
2 Year ARI 72 hour	5.67
50 Year ARI 1 hour	117.62
50 Year ARI 12 hour	34.97
50 Year ARI 72 hour	11.18
Skew Coefficient	0.11
Geographical Factor F2	3.87
Geographical Factor F50	17.16

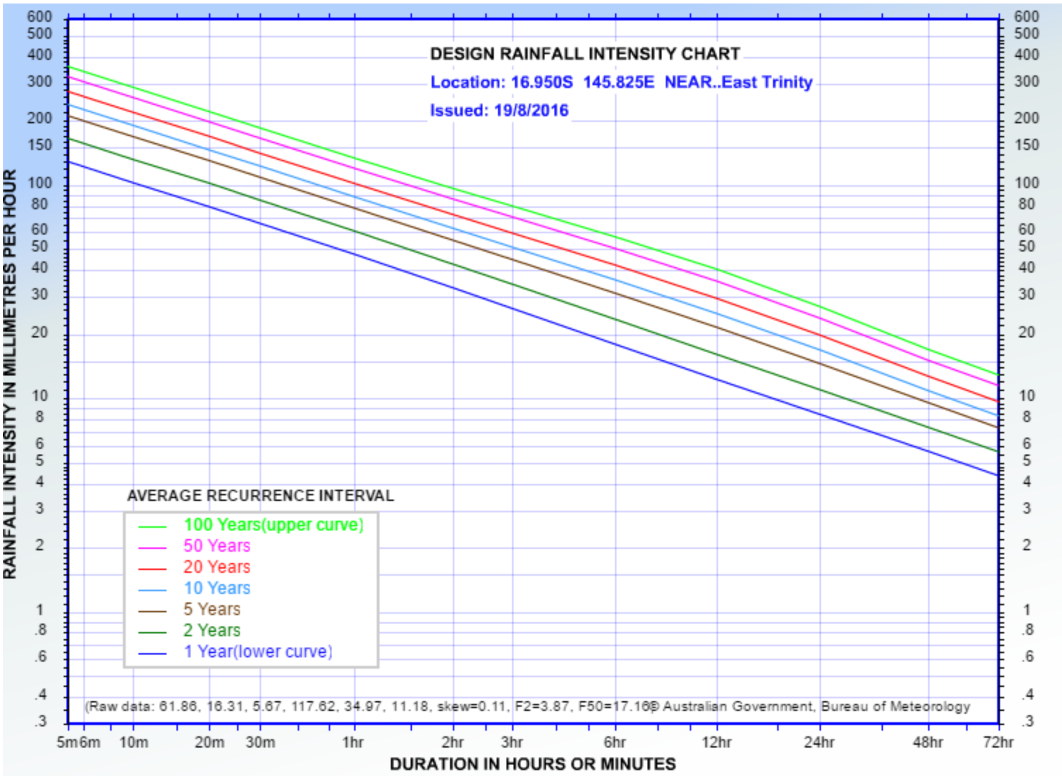


Figure A-1 Design Rainfall IFD Chart

Hydrologic Parameters

The hydrologic parameters adopted in the WBNM model are presented in Table A-2.

Table A-2 WBNM Parameters

Parameter	Value
Initial Loss (Pervious) (mm)	15
Initial Loss (Impervious) (mm)	1.0
Continuing Loss (Pervious) (mm)	2.5
Lag Parameter C (east of Pine Creek Yarrabah Rd)	1.25
Lag Parameter C (west of Pine Creek Yarrabah Rd)	1.60
Impervious Lag Factor	0.1
Stream Lag Factor	1.00

The initial losses and continuing losses are based on guidance from ARR (1987).

Hydrological Modelling Results

The peak flows calculated for the major inflow on Hills Creek at Pine Creek Yarrabah Road are summarised in Table A-3 and were used in the TUFLOW model as inflow boundaries.

Table A-3 WBNM Results – Hills Creek at Pine Creek Yarrabah Road

ARI (Years)	Peak Flow (m^3/s)
100	401.4
50	347.8
20	319.9
10	264.0
5	221.8
2	154.5

Hydraulic Model Setup

Model Extent and Topography

The TUFLOW model has been created for this assessment and covers an area of 13.3km^2. The 2D domain for the model was derived from 2010-2011 LIDAR survey data provided by Cairns Regional Council. The LIDAR survey has been used as the base elevation model data (DEM) in the hydraulic model.

The eastern boundary of the model is located to the east of Pine Creek Yarrabah Road with the western boundary located at the Trinity Inlet channel.

A 10m grid cell size has been used in the 2D domain which is considered adequate and detailed to represent the details of the study area. The TUFLOW model extent, drainage schematic and topography is presented in Figure A-2.

A Manning's roughness value of 0.06 has been applied across the entire model area.

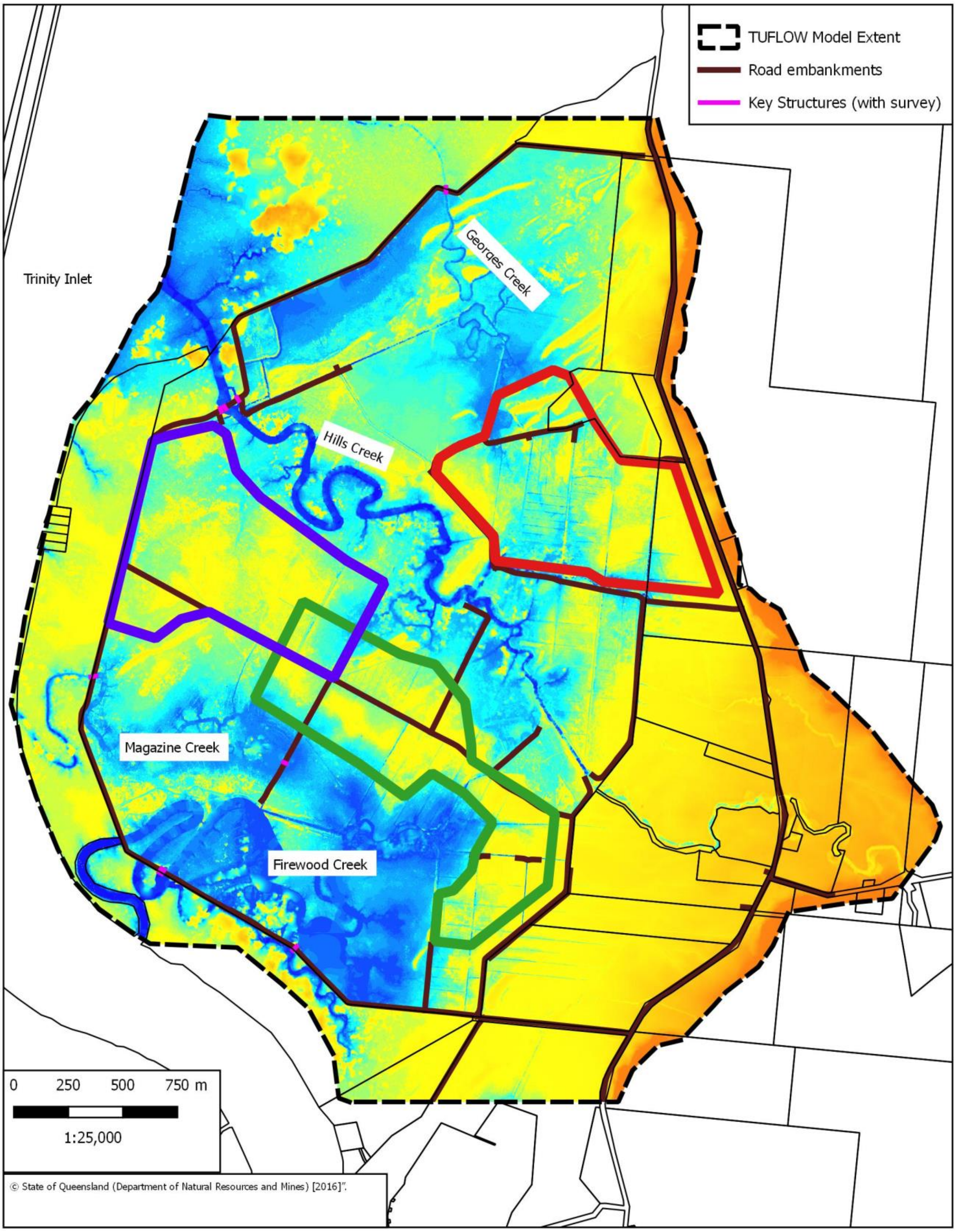


Figure A-2 TUFLOW Model Schematic

Hydraulic Structures and Topographic Controls

Details for a number of existing hydraulic structures across the site have been provided and incorporated into the TUFLOW model as 1D culverts. The locations of these key structures are shown in Figure A-2.

The site contains and is bounded on all sides by existing road embankments which influence the passage of water through the site. The TUFLOW model has been schematised to ensure that these hydraulic controls have been represented.

Boundary Conditions

The tailwater boundary condition adopted for use with the TUFLOW model was applied a fixed water level representing the Mean High Water Springs (MHWS) within Trinity Inlet (i.e. 0.977 m AHD) as provided in the 2016 Queensland Tide Tables[4].

By applying a fixed tailwater level, the modelling does not account for the tidal signal but is considered to represent a conservative scenario where the fluvial inflow is coincident with the peak MHWS tide level.

Hydraulic Assessment – Existing Case

Design storm events for the 2 year and the 100 year ARI for a range of storm durations, have been simulated using the previously described TUFLOW model. Assessment of the flood modelling results for all storm durations modelled showed that the critical storm durations are as given in Table A-4.

Table A-4 Existing Case Critical Storm Durations

ARI (Years)	Duration (min)	Duration (h)
100	1080 min	18 h
2	1800 min	30h

Results from the existing case assessment for these critical storm durations are presented in Section 3.3.3 below.

[4] http://www.msq.qld.gov.au/-/media/MSQInternet/MSQFiles/Home/Tides/2016queenslandtidetables.pdf?la=en

BMT WBM

BMT WBM Bangalow	6/20 Byron Street, Bangalow 2479 Tel +61 2 6687 0466 Fax +61 2 66870422 Email bmtwbm@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Brisbane	Level 8, 200 Creek Street, Brisbane 4000 PO Box 203, Spring Hill QLD 4004 Tel +61 7 3831 6744 Fax +61 7 3832 3627 Email bmtwbm@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Denver	8200 S. Akron Street, #B120 Centennial, Denver Colorado 80112 USA Tel +1 303 792 9814 Fax +1 303 792 9742 Email denver@bmtwbm.com Web www.bmtwbm.com
BMT WBM London	International House, 1st Floor St Katharine's Way, London E1W 1AY Email london@bmtwbm.co.uk Web www.bmtwbm.com
BMT WBM Mackay	PO Box 4447, Mackay QLD 4740 Tel +61 7 4953 5144 Fax +61 7 4953 5132 Email mackay@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Melbourne	Level 5, 99 King Street, Melbourne 3000 PO Box 604, Collins Street West VIC 8007 Tel +61 3 8620 6100 Fax +61 3 8620 6105 Email melbourne@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Newcastle	126 Belford Street, Broadmeadow 2292 PO Box 266, Broadmeadow NSW 2292 Tel +61 2 4940 8882 Fax +61 2 4940 8887 Email newcastle@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Perth	Level 3, 20 Parkland Road, Osborne, WA 6017 PO Box 1027, Innaloo WA 6918 Tel +61 8 9328 2029 Fax +61 8 9486 7588 Email perth@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Sydney	Level 1, 256-258 Norton Street, Leichhardt 2040 PO Box 194, Leichhardt NSW 2040 Tel +61 2 8987 2900 Fax +61 2 8987 2999 Email sydney@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Vancouver	Suite 401, 611 Alexander Street Vancouver British Columbia V6A 1E1 Canada Tel +1 604 683 5777 Fax +1 604 608 3232 Email vancouver@bmtwbm.com Web www.bmtwbm.com