CAIRNS SHIPPING DEVELOPMENT PROJECT

Revised Draft Environmental Impact Statement

APPENDIX AD: Flood and Dredge Spoil Mobilisation: Northern Sands Report (2017)

A part of BMT in Energy and Environment

Cairns Shipping Development Project EIS - Flood and Dredge Spoil Mobilisation Technical Studies Investigations for the Northern Sands Placement Site Option

Reference: R.B22074.009.00_Flood and Spoil Mobilisation Final
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Confidential

Cairns Shipping Development Project EIS - Flood and Dredge Spoil Mobilisation Technical Studies Investigations for the Northern Sands Placement Site Option

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Contents

List of Figures

List of Tables

1 Introduction and Purpose of the Report

This report has been prepared for the Impact Assessment Technical Studies investigation of the refined Barron Delta void (Northern Sands) placement site option, and provides details of predicted impacts of the placement option on Barron River delta flood levels, should major river flooding occur prior to removal of flood control bunding. This includes consideration of impacts on flood levels and velocities, as well as consideration of remobilisation of the placed dredge spoil material by floods. It also provides an assessment of the level of risk of adverse flooding impacts occurring during the limited duration when bunds will be in place to protect the dredge spoil from resuspension due to flooding.

The refined Northern Sands placement site option is detailed in Flanagan Consulting Group (FCG) drawing number 3527-SK09D, which is included in Appendix A of this report.

2 Background

The Cairns Shipping Development Project (CSDP) aims to develop Port infrastructure in order to secure a greater share of the international cruise ship market, enhance Naval capacity and improve Port efficiencies.

The project involves the preparation of a revised draft Environmental Impact Statement (EIS) for the Cairns Shipping Development project. The revised draft EIS will be developed in accordance with the following documents:

- Terms of Reference issued by the Coordinator General (State)
- EIS Guidelines issued by DoE / SEWPaC (Commonwealth)
- Draft CSD Project EIS, Ports North, November 2014
- CG review of draft EIS (including public submissions analysis register)
- Dredge Material Placement Scoping Report, FCG, April 2016.

To address the changed regulatory circumstances of the Project that now preclude the placement of capital dredge material at sea, the recalibrated CSDP is being re-designed so as to significantly reduce the required capital dredge volume that needs to be managed and to explore two land-based disposal options for potential placement or treatment of the material. These options include precincts at and around the Northern Sands site on the Barron Delta and several sites at East Trinity.

The revised draft EIS assesses the environmental, social and economic impacts of each of the selected land based placement site options to determine the optimum dredge material placement site for the project. The EIS document will be finalised based on the Revised Project, including the shipping channel, the preferred land based placement site and the landside infrastructure works.

3 The Refined Proposal

The refined proposal is detailed in the FCG plan included in Appendix A.

Key elements relevant to flooding are as follows:

(1) The existing eastern portion of the sand pit east of Reedy and Snake Islands is excluded from the proposed placement zones, therefore no flood protection bunding is proposed around this area;

(2) The remainder of the placement pond has been expanded, generally to the north and east, with an enlarged potential dredged material storage of 2.4 million m^3.

(3) Bund height has been increased to RL 7.5m, well above ARI 100 year flood level.

Based on advice by FCG, initial placement will occur in the dry season, after which rapid settlement of the dredge spoil will occur. Bunds are to remain in place through one wet season following completion of placement.

Hence, whilst the protection bunds have the potential to interfere with flood flows and cause off site flood level increases, the period of exposure is low. This is further considered in Section6.

4 Scope of Methodology

4.1 Scope

The scope of this assessment is to provide an input into operational design consideration for the Northern Sands Dredge Material disposal opportunity. A key requirement is to determine remobilisation risks associated with using proposed expanded onsite void at the Northern Sands for dredge spoil storage and to investigate options for placement void filling and/or bunding to reduce the remobilisation risk. In addition, impacts on flooding due to bunding has been assessed.

4.2 Methodology

The methodology behind this investigation is based around the use of bunds surrounding the disposal area to firstly provide the maximum amount of void volume available for dredge spoil disposal and secondly to provide a suitable degree of protection against remobilisation of dredge material within the disposal area during periods of Barron River flooding.

Detailed full two dimensional flood modelling of the Northern Sands site was utilised to determine possible bund heights, bed shear stress and risk of resuspension of placed dredged material, as well as consideration of flooding impacts of a range of dredge spoil containment options.

4.2.1 Bund Assessment

Bund heights determined for the study covered a range of design flood immunity levels for the site.

Table 4-1 lists the bund heights assessed in this study.

Table 4-1 Bund Levels

Bund Height (mAHD)	ARI Immunity level (Years)
4.0	2
4.6	5
4.8	10
5.0	20
5.3	50
5.5	100
7.5	200+

A number of bunding options were considered before adopting the layout as shown on FCG Sketch 3527-Sk09, a copy of which is provided in Appendix A. Figure 4-1 shows pre-dredge spoil placement topography for the site, and Figure 4-2 the assumed post placement topography.

Each bund height from Table 4-1 was assessed against design flood events ranging from the ARI 2 year through to the 100 year flood events. Results for the adopted SK09 layout are detailed in Figures 4-3 to 4-9.

4.2.2 Bed Shear Stress

Bed shear stress analysis of the disposal area was conducted in conjunction with the bund analysis described above to determine suitable depths of submersion with clean water above the top of the placed material that provides minimal risk of remobilisation during flood events.

For this analysis the disposal areas was assumed to be filled to a level such that 3.8m depth of clear water is provided for ARI 20, 50 and 100 year events.

Table 4-2 presents the top of placed spoil level assumed for each of the assessed bund levels.

Table 4-2 Top of Spoil level -v- Bund Level Assumed

Bund Level (mAHD)	Top of Spoil Level (m AHD)
5.0	1.2
5.3	1.5
5.5	1.7

This range of options was tested to determine the sensitivity of spoil to remobilisation under a range of conditions.

As guideline for comparison of bed shear stress levels, results from the analysis were compared against critical bed shear stress levels derived by the U.S. Geological Survey (USGS). These derived levels are presented in Appendix A.

The USGS has derived critical bed shear stress values for a range of materials ranging from fine silts to course cobbles. Advice from BMT JFA indicates that the range of material expected within the dredge disposal material will consist of predominantly fine silt to coarse sand.

Based on this advice critical bed shear stress levels for remobilisation for the disposal area immediately after placement will range from 0.04 to 0.15 N/m^2 as determined by the USGS values to which reflects the fine silt to coarse sand range. The USGS values are widely used in industry practice and has been accepted on several recent sand extraction pit approvals. With settlement, consolidation and surface drying and crusting in the dry season, it is expected that the critical bed shear stress for remobilisation will increase.

4.2.3 Modelling Methodology

To carry out this investigation BMT WBM Pty Ltd used the following methodology as the basis for the hydraulic modelling investigation:

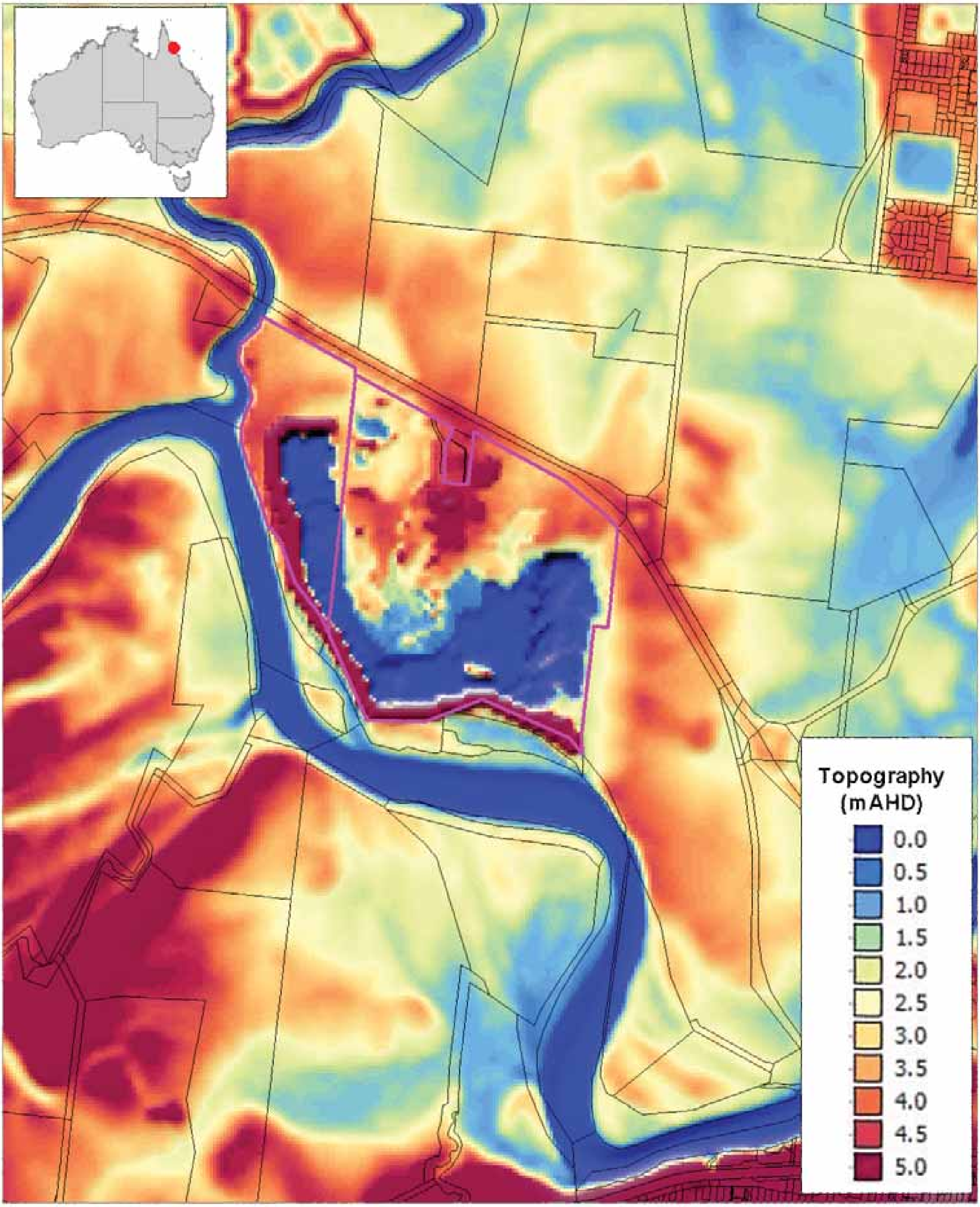
- Obtain latest LIDAR for the site
- Update the TUFLOW *model with LIDAR to reflect current conditions
- Obtain current proposed lake bathymetry, ultimate site levels and bunding options to be considered from FCG
- Re-run base case model for full range of ARI events

- Investigate options for both lake filling and bunding and determine flood impacts and bed shear stress for each option.

  *The Barron Delta TUFLOW model was built to test the AQUIS Casino Project and was approved for use on that project by Cairns Regional Council.

For the hydraulic assessment our existing TUFLOW 2D flood model of the Barron River Delta was used to determine baseline flooding characteristics for the site.

Based on the latest LIDAR (2011) available, lake bathymetry and advice provided by FCG, a pre-disposal site DTM was developed and incorporated in to the model.



Title:

Northern Sands Disposal Site
Pre-Disposal Topography

Figure: 4-1

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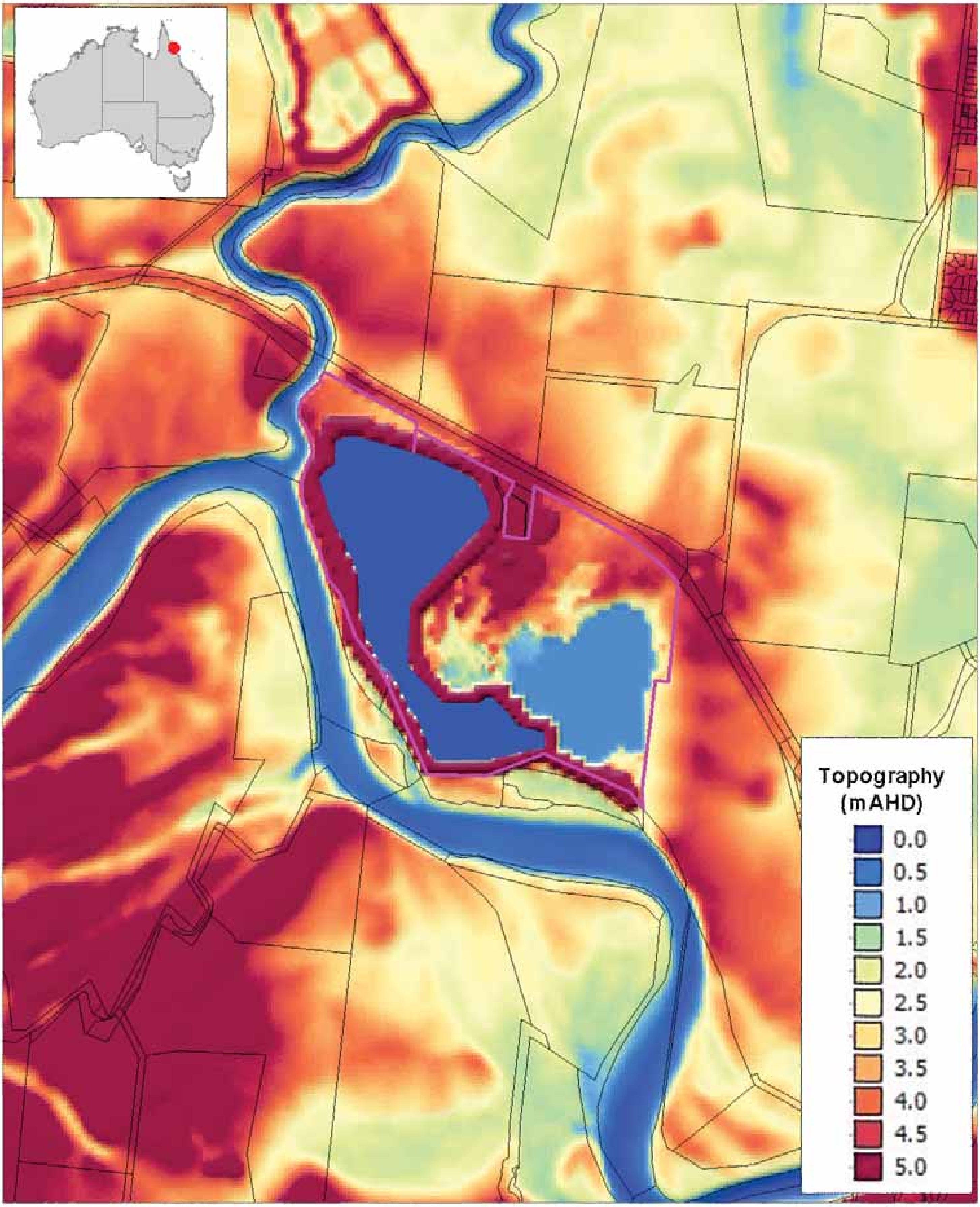

Title:

Northern Sands Disposal Site
Disposal BundTopography

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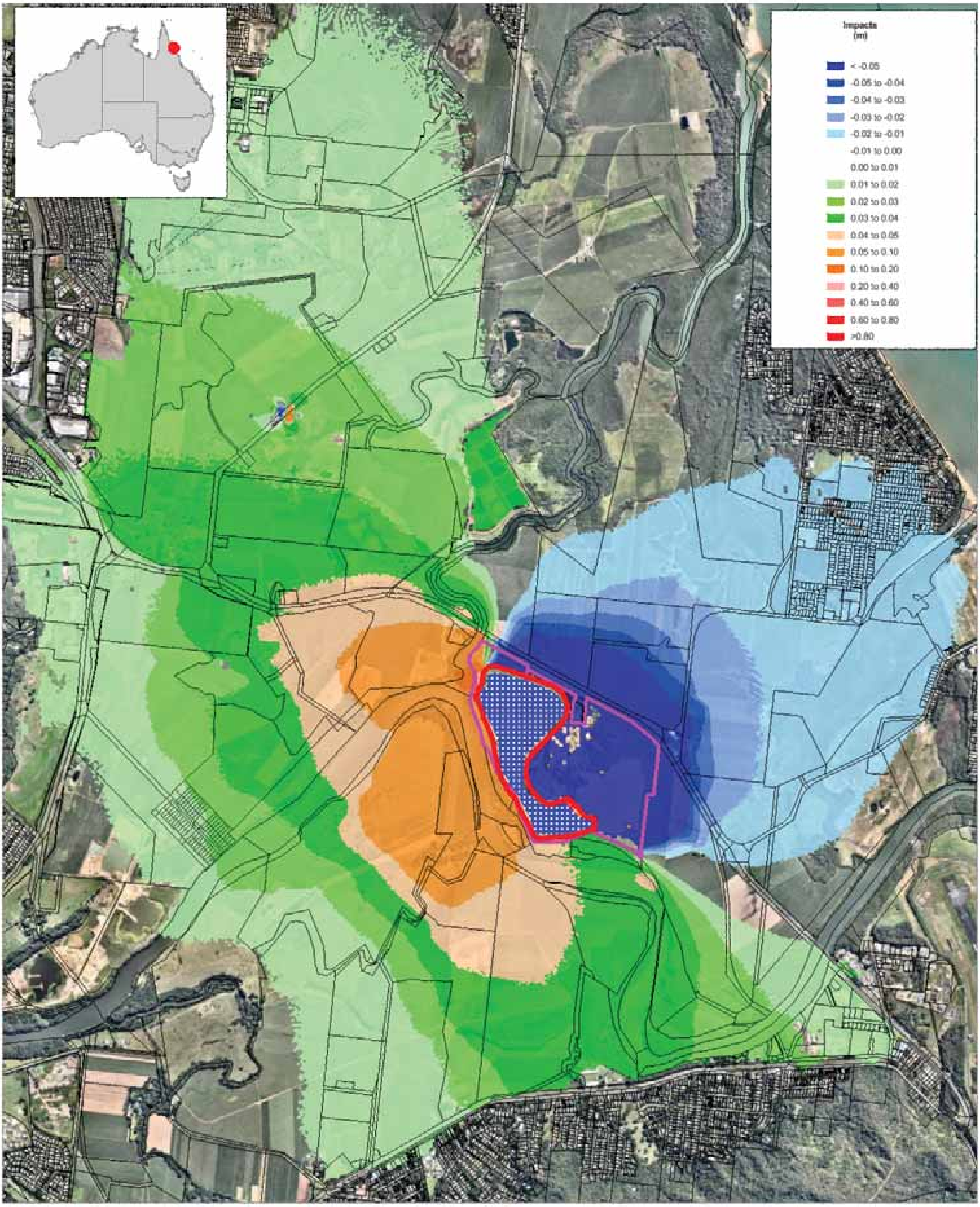

Title:

Northern Sands Disposal Site
RL 7.5m Bund - ARI 100 Year Flood Impacts

Figure: **4-3**

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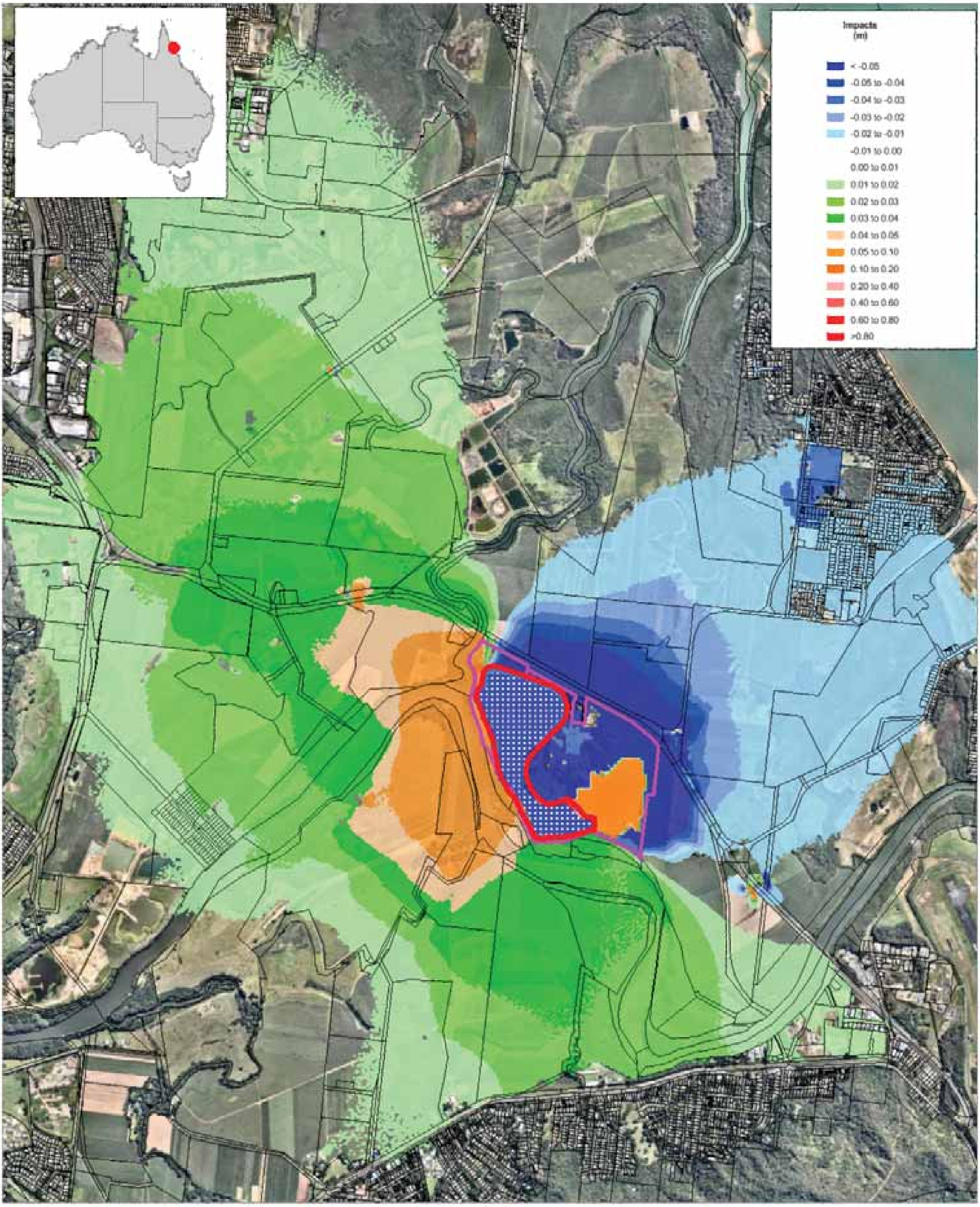

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Northern Sands Disposal Site
RL 7.5m Bund - ARI 50 Year Flood Impacts

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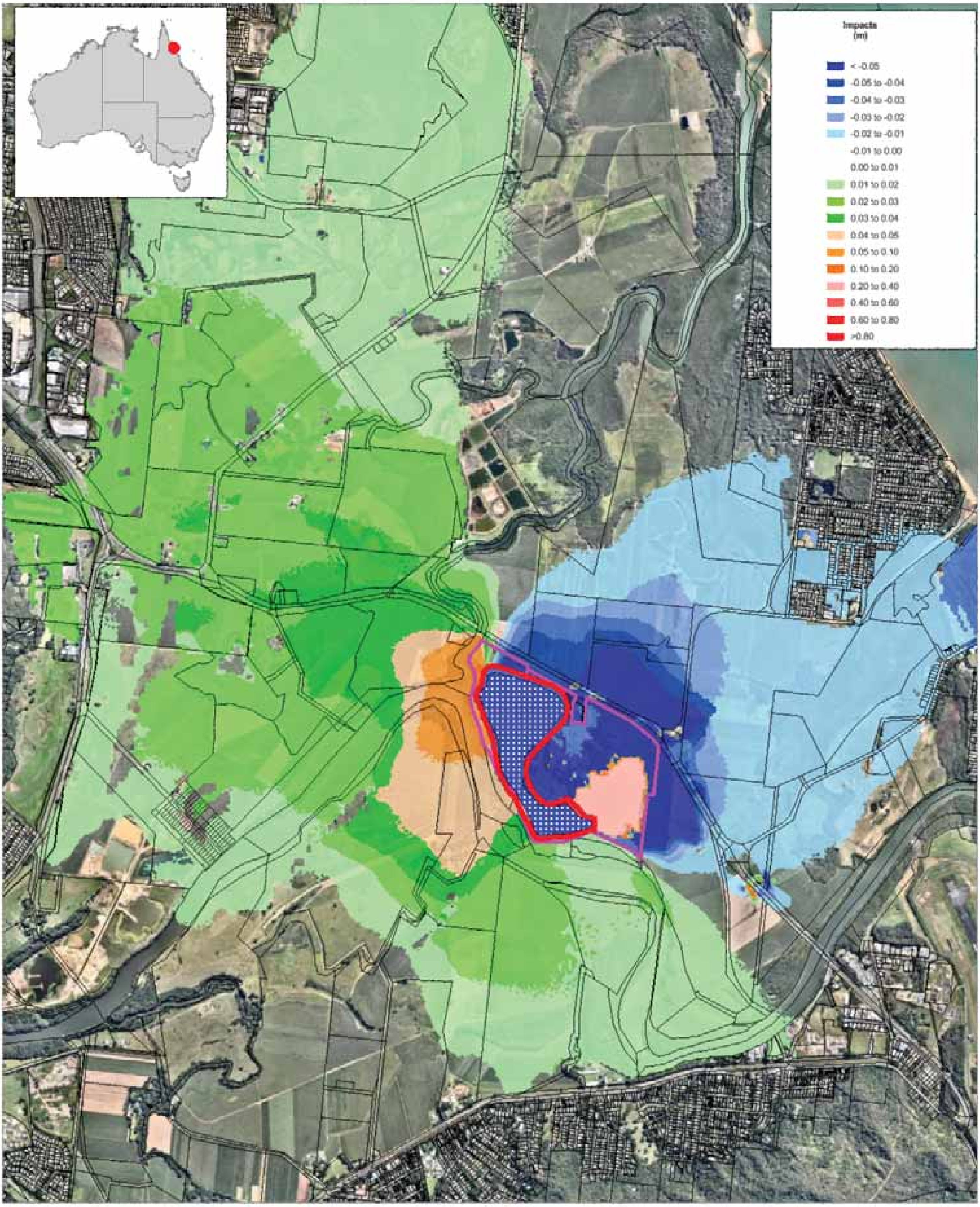

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Northern Sands Disposal Site
RL 7.5m Bund - ARI 20 Year Flood Impacts

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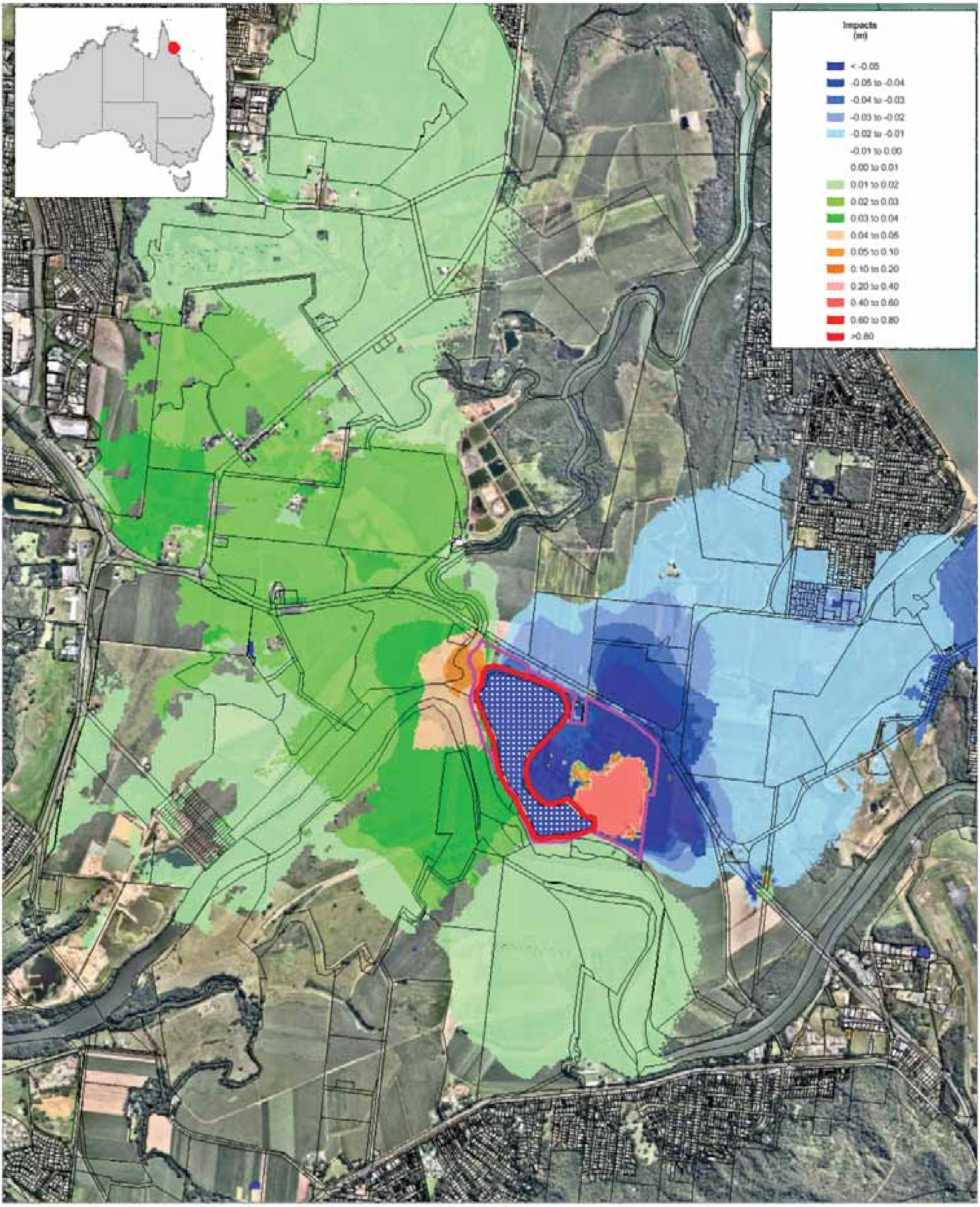

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Northern Sands Disposal Site
RL 7.5m Bund - ARI 10 Year Flood Impacts

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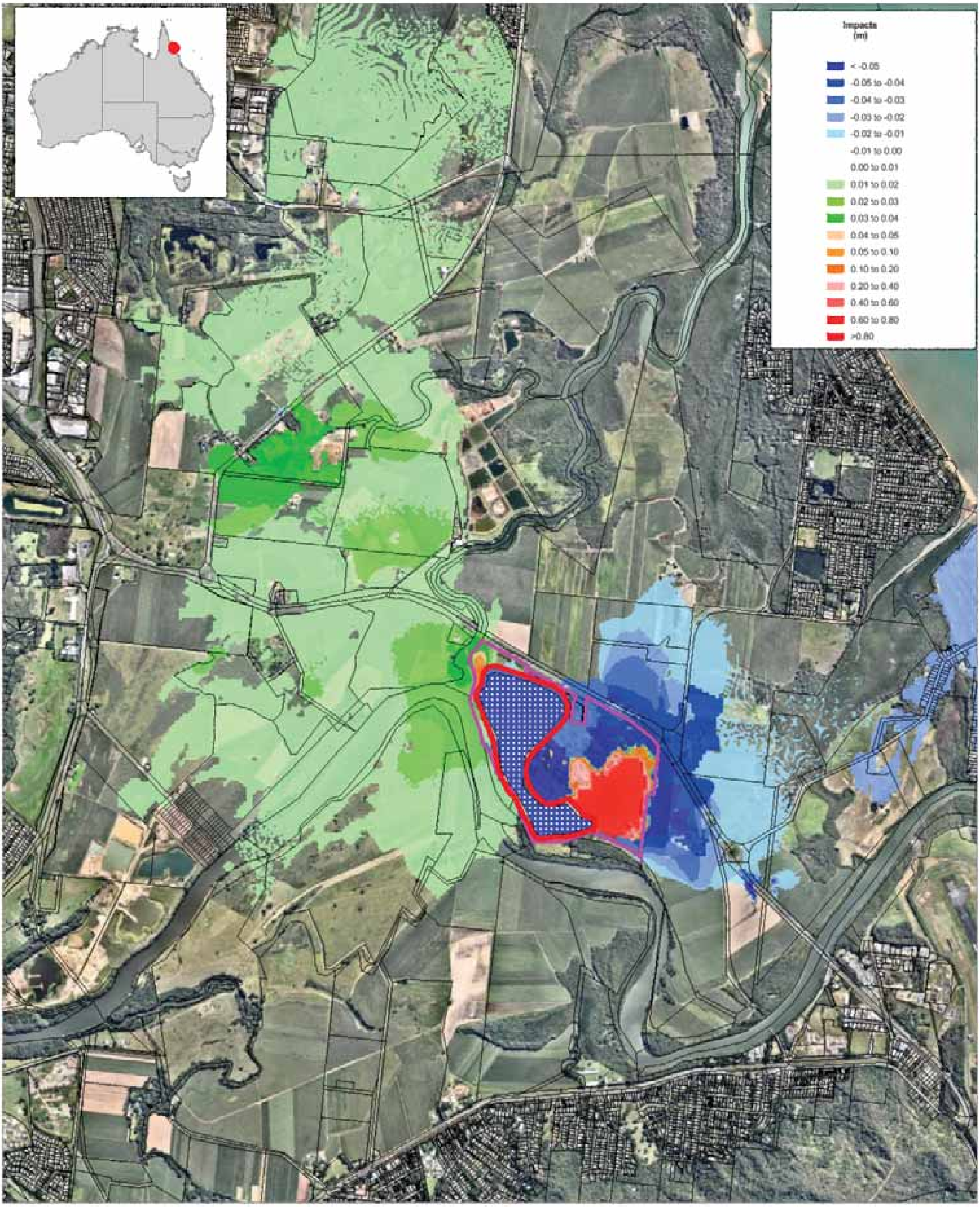

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Northern Sands Disposal Site
RL 7.5m Bund - ARI 5 Year Flood Impacts

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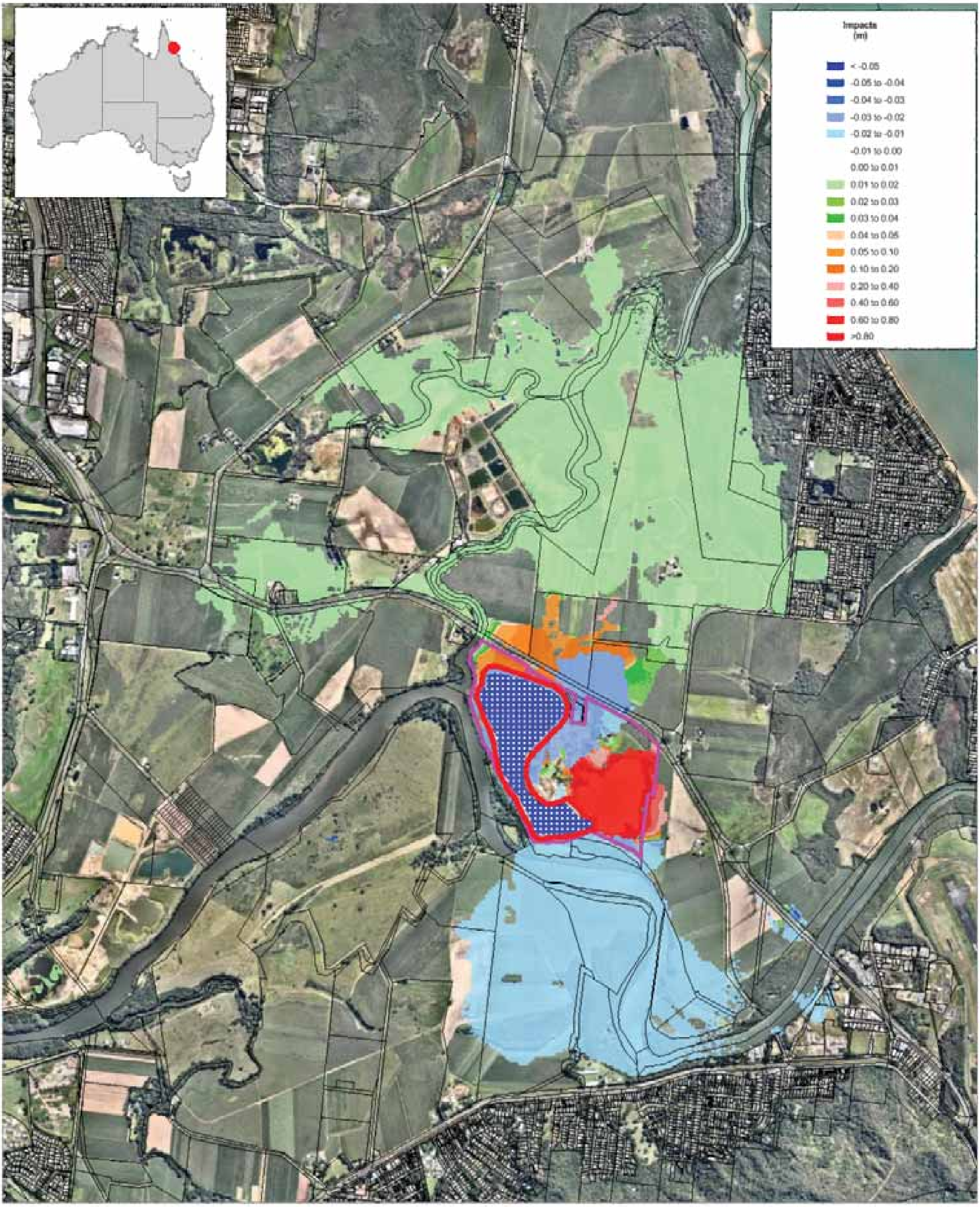

Title:

Northern Sands Disposal Site
RL 7.5m Bund - ARI 2 Year Flood Impacts

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5 Results

5.1 Pre-disposal Assessment

Appendix B contains the detailed results for the pre-disposal case and presents mapped output of peak water levels, depths and velocities for the full range of ARI design storm events.

A summary of peak water level at the disposal site is presented in Table 5-1.

Table 5-1 Site Peak Water level

ARI (Years)	Peak Water Level (mAHD)
2	3.811
5	4.496
10	4.747
20	4.926
50	5.164
100	5.424

5.2 Bund and Bed Shear Stress Sensitivity Assessment

Due to the quantity of results produced and bed shear stress results are provided in the following appendices:

- Appendix B – Q20 bund level (RL 5.0m AHD)
- Appendix C – Q50 bund level (RL 5.3m AHD)
- Appendix D – Q100 bund level (RL 5.5m AHD)

Each appendix contains mapped output of bed shear stress for the site for the range of sensitivity tests conducted.

From the results presented we predict bunding to RL 3.8mAHD can be designed to fully comply with Cairns Regional Council Planning Scheme requirements. Bunding to a higher level may also be acceptable subject to a risk assessment, taking account of the relatively short period of the time that bunds may be in place. The level of risk is assessed in the following Section.

Secondary to this investigation a bed shear stress investigation has also been carried out to determine suitable depths of submersion with clean water above top of placed material.

Based on the modelling results and the known properties of the placed spoil material, minimal resuspension will occur during a Barron River flood that overtops the bund, provided 3.8m minimum submergence is in place.

At this level, the majority of the disposal area has bed shear stress levels at or below the critical levels as described by the USGS. Due to the limitations of depth averaging of velocity in 2D models, it is recommended that, as a component of the detailed design, full 3D modelling of bed shear stress within the disposal area is conducted to confirm levels in these areas.

As would be expected, as bund levels increase, remobilisation is prevented until eventual bund overtopping. Once overtopped, bed shear stress further reduces as minimum submergence depths increase.

5.3 Consideration of Dredge Spoil Re-Suspension after Drying and Crusting

With dredge spoil placement proposed in the dry season, drying and crusting of the surface of the dredge spoil above the water table will occur. Based on our observations of crusting dredge spoil from previous projects, as well as on the red mud dams in Gladstone, once crusting occurs, we believe that remobilisation potential is significantly reduced with crusting and that it would exhibit properties close to that of loose to compacted clay, which have a critical bed shear stress (threshold of movement) in the range of $1N/m^2$ to $14N/m^2$.

From interrogation of the various sensitivity test model runs, we conclude that provided there is a minimum of 1.7m (loose) to 0.7m (compacted) depth submergence in place when flood overtopping occurs, significant resuspension of dredge spoil should not occur.

We understand that bunding will be progressively removed to natural level once settlement of dredge spoil and surface crusting occurs. The above minimum submergence criteria provides a guide as to the level of the top of dredge spoil, relative to minimum bunding height / natural surface level.

6 Assessment of Impacts and Risk

6.1 General

The dredging works are proposed to be carried out during the dry season where the probability of river flooding is low. However, there is the need for consideration of remobilisation during the subsequent wet season. The final settlement is predicted to be achieved prior to a second wet season, and the bunds can be removed at that time, subject to verification of the settled surface levels. Retention of a suitable void buffer, between top of spoil and top of bund or natural surface over the dredge material will also assist in mitigating remobilisation risk and the target level of cover, assuming crusting of the dredge spoil surface, is 0.7m to 1.7m, depending on the degree of crusting. From the flood impact plots, the following observation can be made:

(1) ARI 2 year flood impacts beyond the Northern Sands site only affect flood affected caneland north of the highway, with no buildings affected. The potential for actionable nuisance under such a flood event is low.

(2) ARI 5 year flood impacts beyond the Northern Sands site are at worst, 3 to 4 cm and these impacts occur over flood affected caneland. The only building affected is a high set Queenslander house on Lot 3, RP800591, which is on an elevated fill platform, adjacent to the highway on the western site of Richters Creek. Over floor flooding is not predicted to occur. The potential for actionable nuisance under such a flood event is low. There is only a 20% chance that the ARI 5 year event will occur in any given year.

(3) ARI 10 year flood impacts beyond the Northern Sand site are generally less than 5cm and these impacts occur over flood affected canelands. The same high set Queenslander house is predicted to be affected by 4 to 5 cm; however, over floor flooding is not predicted to occur. Hence, the potential for actionable nuisance under such a flood event is low. There is only a 10% chance that the ARI 10 year flood will occur in any given year.

(4) ARI 20 flood impacts, beyond The Northern Sands site are up to 0.1m; however, these impacts occur over flood affected caneland. The same high set Queenslander is predicted to be affected by 5 to 6 cm; however, over floor flooding is not predicted to occur. No other buildings are impacted. Hence, the potential for actionable nuisance under such a flood event is low. There is only a 5% chance that the ARI 20 year flood will occur in any given year.

(5) ARI 50 year flood impacts beyond the Northern Sands site are up to 0.15m; however, these impacts occur over flood affected caneland generally. The same high set Queenslander is predicted to be affected by up to 0.1m. There are lesser impacts on the go-cart site and prawn farm site to the north; however all buildings on these sites are on elevated fill platforms above flood. There is only a 2% change of this flood occurring in any year. Risk level is further discussed in Section 5.3 below.

(6) ARI 100 year flood impacts beyond the Northern Sands site are extension though primarily over flood affected caneland. There is only a 1% change of this flood occurring in any year. Risk level is further discussed in Section 5.4 below.

(7) There are positive benefits predicted, in terms of significant flood level reductions, in the Machans Beach township to the east of the Northern Sands site, with over 100 properties predicted to have 1 to 2cm flood level reductions in the ARI 100 year event.

(8) With the bunds set at RL 7.5m AHD, the risk of resuspension of placed dredged material is very low, with less than 0.5% chance of an overtopping flood occurring in a year.

6.2 Methodology

In order to address the terms of reference, guidelines and other requirements for the currently defined project, the following methodology was adopted:

- Assess impacts (based on the risk assessment format outlined below);
- Provide recommendations for mitigation by design changes; and
- Provide recommendations for mitigation by management.

FCG has extracted relevant items from the Queensland Government Terms of Reference.

The initial assessment of impacts utilises a significance table based on that shown in Table 6-1.

Table 6-1 Significance Criteria

Impact Significance / Consequence	Description of Significance (examples)
Very High	The impact is considered critical to the decision-making process. Impacts tend to be permanent or irreversible or otherwise long term and can occur over large scale areas. Very high risk to people or of property damage. Very high risk of harm to receiving environment.
High	The impact is considered likely to be important to decision-making. Impacts tend to be permanent or irreversible or otherwise long to medium term. Impacts can occur over large or medium scale areas. High risk to people or of property damage. High risk to the receiving environment.

Impact Significance / Consequence	Description of Significance (examples)
Moderate	The effects of the impact are relevant to decision making including the development of mitigation measures Impacts can range from long term to short term in duration Impacts can occur over medium scale areas or otherwise represents a significant impact at the local scale Moderate risk to people or of property damage. Moderate risk to receiving environment.
Minor	Impacts are recognisable/detectable but acceptable. These impacts are unlikely to be of importance in the decision making process. Nevertheless, they are relevant in the consideration of standard mitigation measures. Impacts tend to be short term or temporary and/or occur at local scale. (Low risk to people or of property damage. Low risk to receiving environment.
Negligible	Minimal change to the existing situation. This could include, for example, impacts which are beneath levels of detection, impacts that are within the normal bounds of variation, or impacts that are within the margin of forecasting error.
Beneficial	Impacts have a positive outcome on the existing situation. This could include for example, an improvement in flood immunity as a result of the project.

The approach to classifying the duration of identified impacts is presented in Table 6-2.

Table 6-2 Classifications of the duration of identified impacts

Relative Duration Of Impacts	
Temporary	Days to Months
Short Term	Up to one year
Medium Term	From one to five Years
Long Term	From five to 50 Years
Permanent/Irreversible	In excess of 50 Years

The likelihood of an impact occurring is assessed as per Table 6-3.

Table 6-3 Likelihood of Impact

Likelihood of Impacts	Risk Probability Categories
Highly Unlikely	Highly unlikely to occur but theoretically possible
Unlikely	May occur during construction of the project but probability well below 50%; unlikely, but not negligible
Possible	Less likely than not but still appreciable; probability of about 50%
Likely	Likely to occur during construction or during a 12 month timeframe; probability greater than 50%
Almost Certain	Very likely to occur as a result of the proposed project construction and/or operations; could occur multiple times during relevant impacting period

A risk rating is assigned by assessing significance versus likelihood within a risk matrix. Risk is described as the product of likelihood and significance as shown in Table 6-4.

Table 6-4 Risk Matrix

Likelihood	Significance				
	Negligible	Minor	Moderate	High	Very high
Highly Unlikely/ Rare	Negligible	Negligible	Low	Medium	High
Unlikely	Negligible	Low	Low	Medium	High
Possible	Negligible	Low	Medium	Medium	High
Likely	Negligible	Medium	Medium	High	Extreme
Almost Certain	Low	Medium	High	Extreme	Extreme

The rating of risk assessed in the risk matrix is presented in Table 6-5.

Table 6-5 Risk Rating Legend

Extreme Risk	An issue requiring change in project scope; almost certain to result in a 'significant' impact on a Matter of National or State Environmental Significance
High Risk	An issue requiring further detailed investigation and planning to manage and reduce risk; likely to result in a 'significant' impact on a Matter of National or State Environmental Significance
Medium Risk	An issue requiring project specific controls and procedures to manage
Low Risk	Manageable by standard mitigation and similar operating procedures
Negligible Risk	No additional management required

After assessing the nature and severity of impacts they are summarised under the following categories:

- Adverse/beneficial;
- Consequential;
- Cumulative;
- Short-term/long term;
- Reversible/irreversible; and
- Predictable/unpredictable.

6.3 Results of Impact Assessment

The following potential impacts relating to flooding and resuspension of dredge spoilt have been identified:

- Increase in flood levels and velocities beyond the Northern Sands site.
- Resuspension of dredged spoil material in extreme flood events

An assessment of these impacts is presented in Table 6-6.

Table 6-6 Assessment of Impacts

All impacts are ‘short term’ (risk period is less than a year).

	Primary Impacting Process	Assessment with Proposed Bunding in Place			Comment
		Significance of Impact	Likelihood of Impact	Risk Rating	
1	Increased in flood levels beyond the Northern Sands site	‘minor’ on ARI 2, 5, 10 and 20 years	5% to 50% change, therefore ‘possible’	Low	The potential for actionable nuisance on there ARI events is low.
		‘moderate’ on ARI 50 and 100 years	1% to 2% chance therefore ‘unlikely’	Low	The chance of these events occurring is low.
2	Resuspension of dredged spoil material in extreme flood events	‘minor’	‘highly unlikely’	Negligible	The proposed bunds provide protection to well above the ARI 100 year flood levels. Even if overtopped, the amount of material resuspended will be small and this volume is insignificant compared to the sediment load in the river flood.

Appendix A Flanagan Consulting Group Northern Sands Dredge Material Placement Plan

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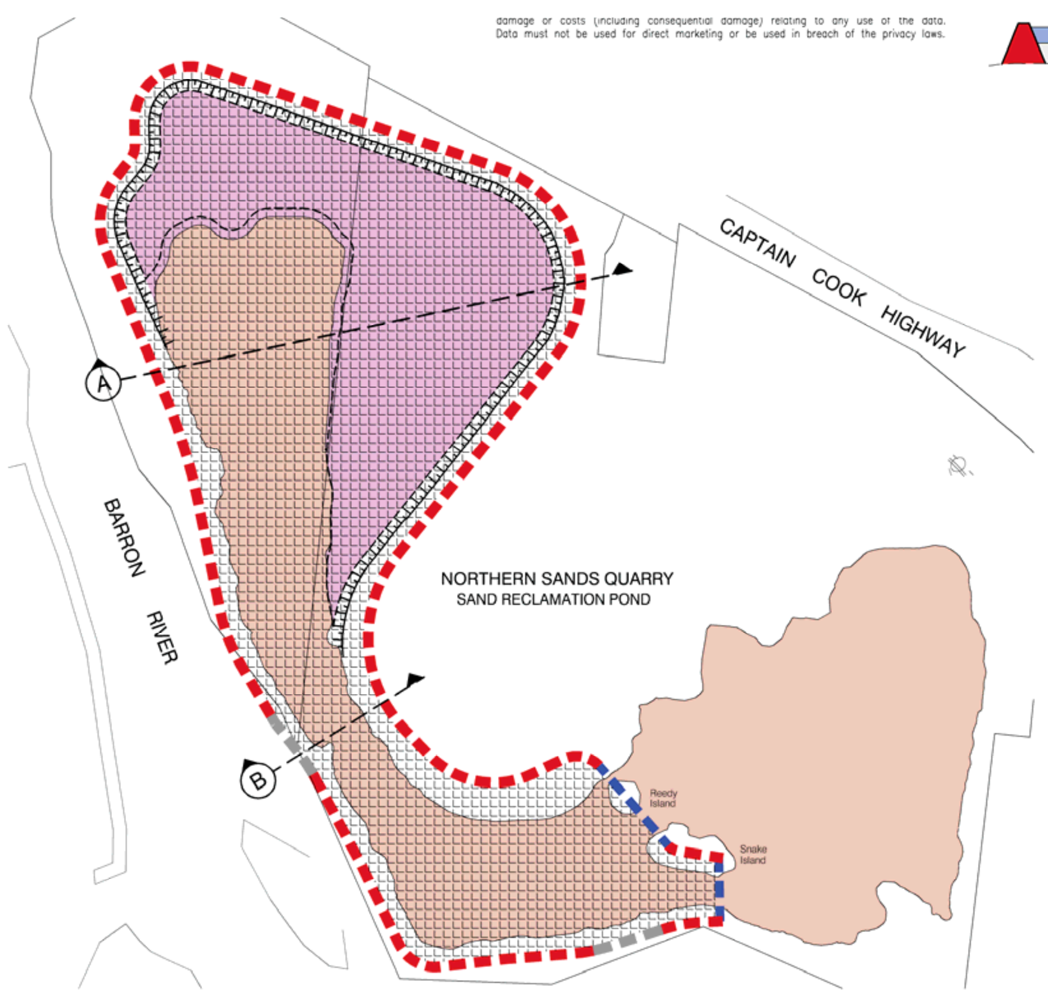

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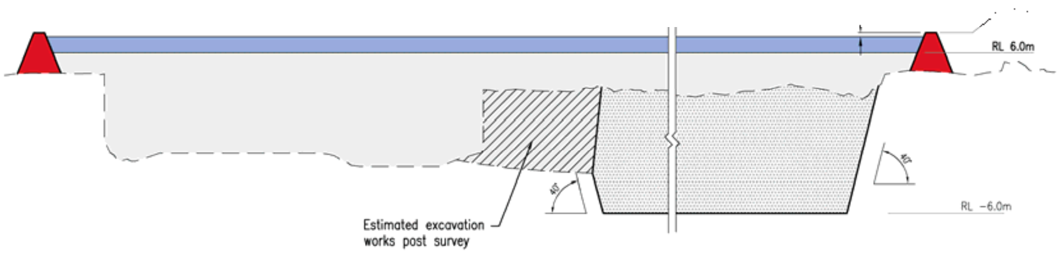
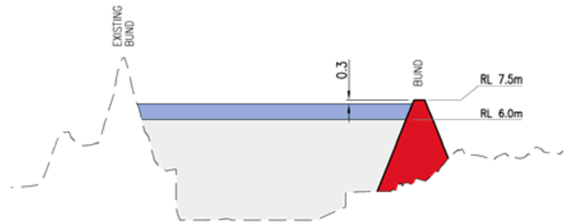


SECTION A
1:1000 Horiz / 1:200 Vert



SECTION B
1:1000 Horiz / 1:200 Vert

STORAGE VOLUMES

LEVEL (AHD) (m)	VOLUME BELOW (m^3)	COMMENT
7.5	3,117,635	Top of Bund
7.2	3,024,767	Max Water Level
7.0	2,963,175	
6.5	2,810,290	
6.0	2,658,938	Top of Placed Material
5.5	2,509,220	
5.0	2,361,522	
4.5	2,215,627	
4.0	2,072,855	
3.5	1,933,482	
3.0	1,796,642	
2.5	1,662,167	
2.0	1,529,199	
1.5	1,397,299	
1.0	1,266,613	Approx Settled Volume
0.5	1,138,662	
0.0	1,015,592	
−0.5	892,944	
−1.0	771,590	
−1.5	652,301	
−2.0	547,800	
−2.5	450,563	
−3.0	369,082	
−3.5	295,698	
−4.0	232,316	
−4.5	171,559	
−5.0	114,233	
−5.5	57,935	
−6.0	2,735	
−6.5	0	

VOLUMES

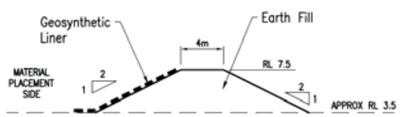
- EXCAVATION (1,039,000 m^3 approx)
- PERIMETER EARTH BUND (124,000 m^3 approx)
- POTENTIAL DREDGED MATERIAL STORAGE (2,658,900 m^3 approx)
- POTENTIAL WATER STORAGE (365,800 m^3 approx)

NOTES

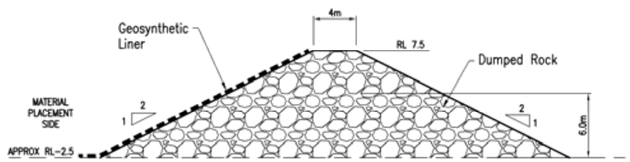
1. Volumes shown are approximate only and based on a combination of site hydrographic survey and LiDAR survey.

LEGEND

- EXISTING SAND RECLAMATION AREA
- FUTURE SAND RECLAMATION AREA (TO RL −6.0)
- DREDGE MATERIAL PLACEMENT ZONE (301,600 m^2 – SURFACE AREA AT RL 6.0)
- EARTH BUND (APPROX 2,750m)
- SEPARATION BUND (APPROX 195m)
- EXISTING EARTH BUND (APPROX 165m)



PERIMETER EARTH BUND
NTS



SEPARATION BUND
NTS

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CAIRNS (07) 4031 3199 | DARWIN (08) 8943 0620 | MACKAY (07) 4944 1200 | TOWNSVILLE (07) 4724 5737
www.flanaganconsulting.com.au

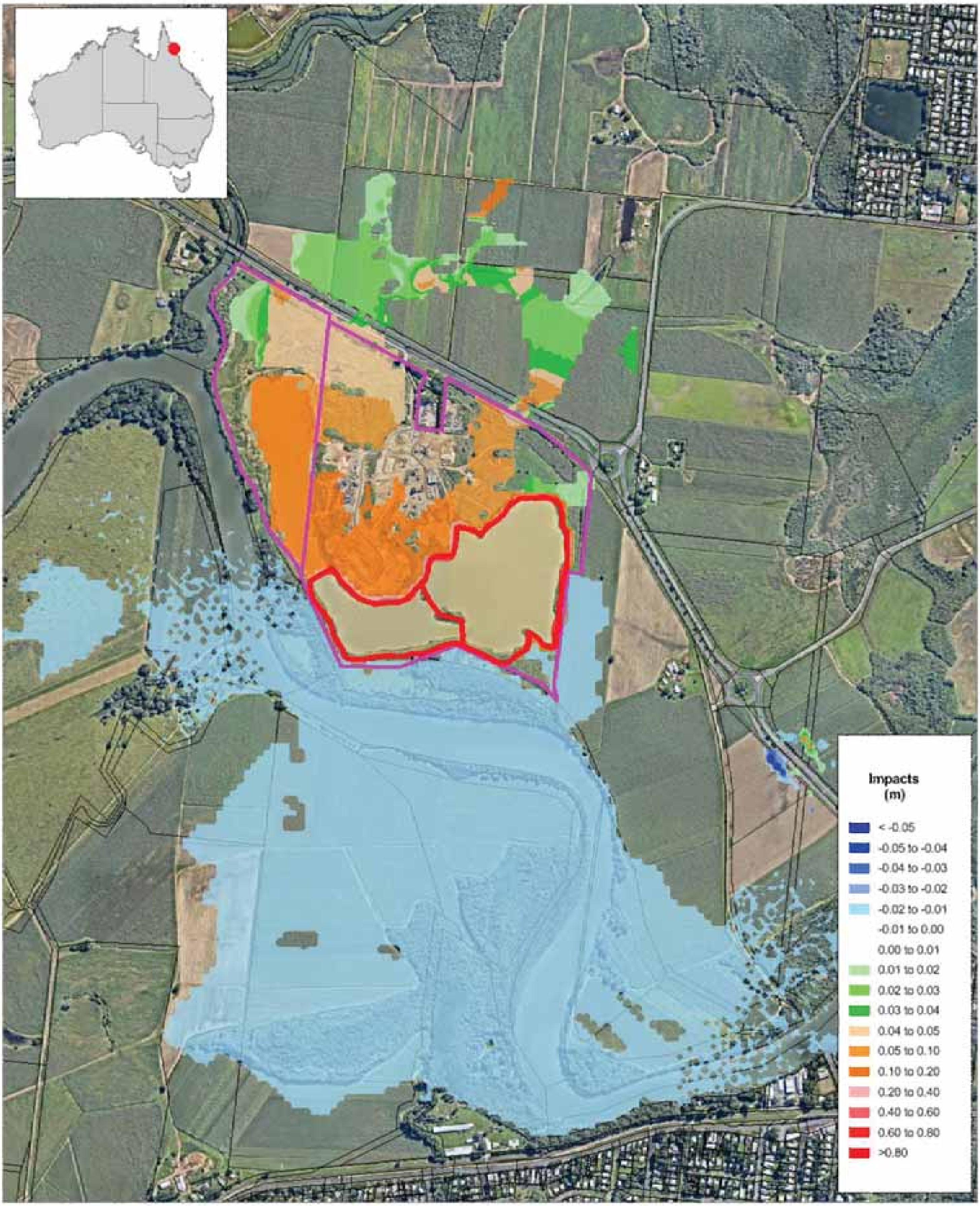
NORTHERN SANDS

Dredge Material Placement
Bund Height RL 7.5m
Concept Only

3527-SK09D
1:3000
A1 Full Size

Acad No.: 3527-SK09D
26 April 2017

Appendix B Q20 bund level (RL 5.0m AHD) Results



Title:

Northan Sands Disposal Site
Q10 Bund - ARI 2 Year Flood Impacts

Figure: **B-1**

Rev: **A**

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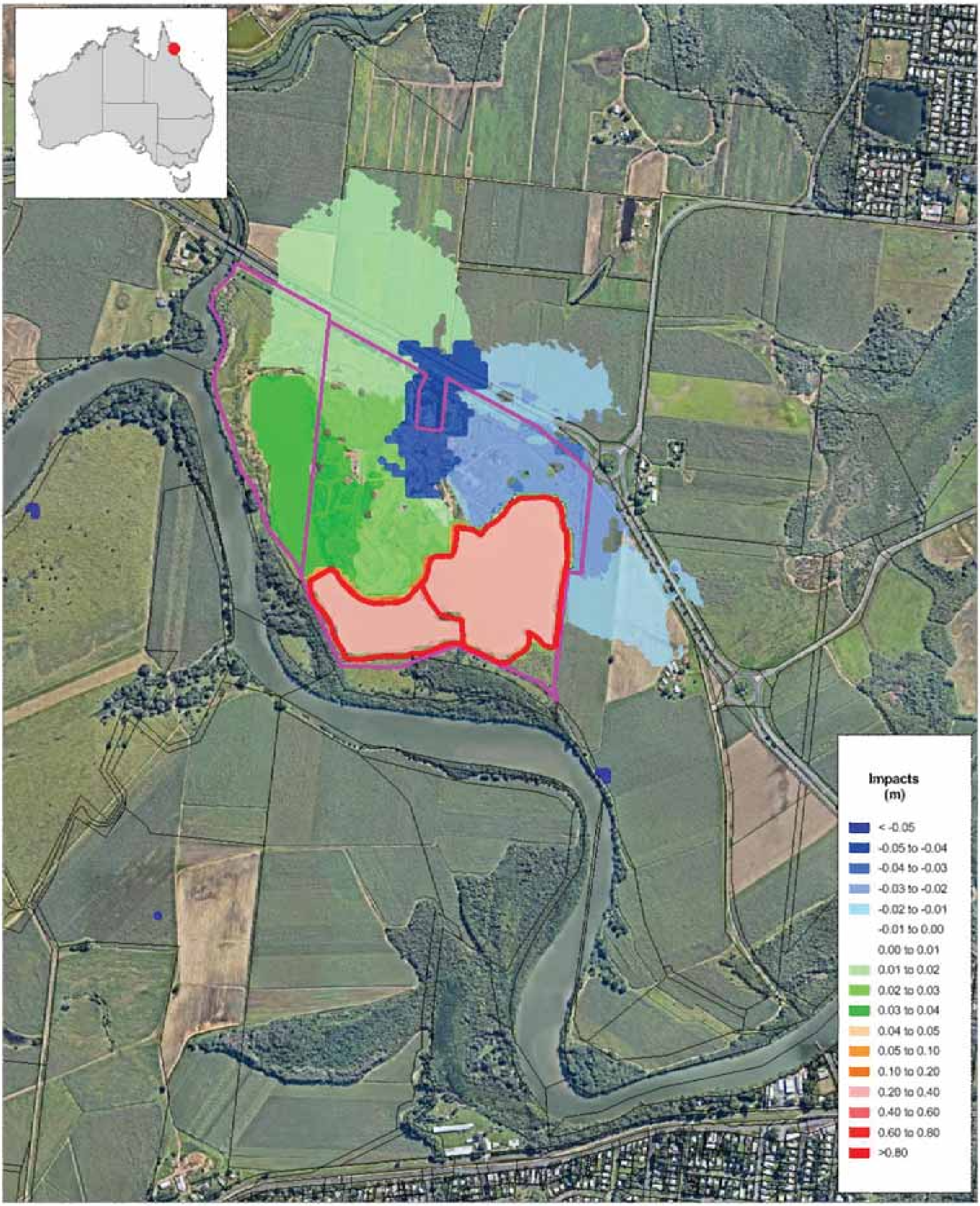

Title:

Northan Sands Disposal Site
Q10 Bund - ARI 5 Year Flood Impacts

Figure: **B-2**

Rev: **A**

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N

metres

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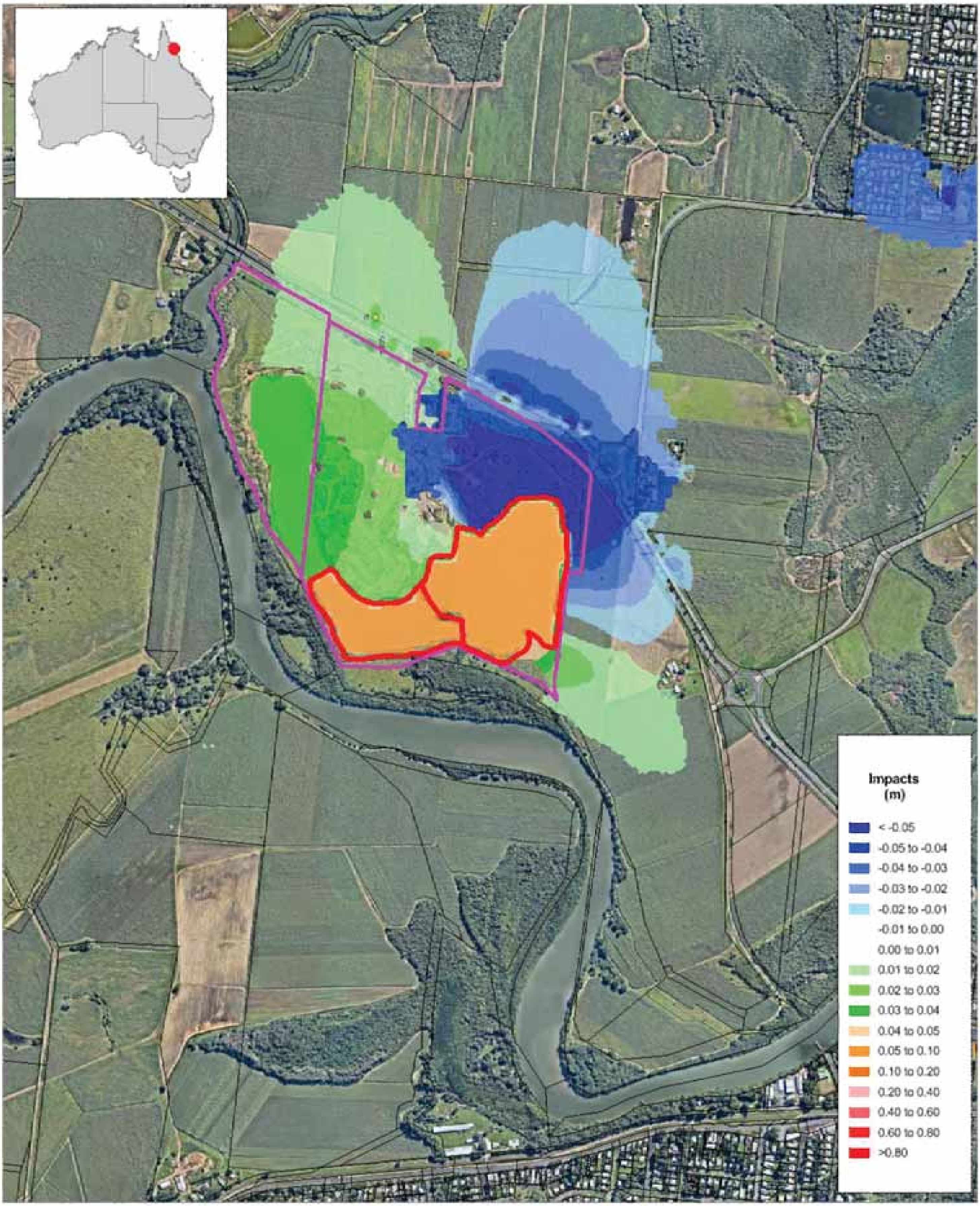

Title: **Northan Sands Disposal Site Q10 Bund - ARI 10 Year Flood Impacts**	Figure: **B-3**	Rev: **A**

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Metres

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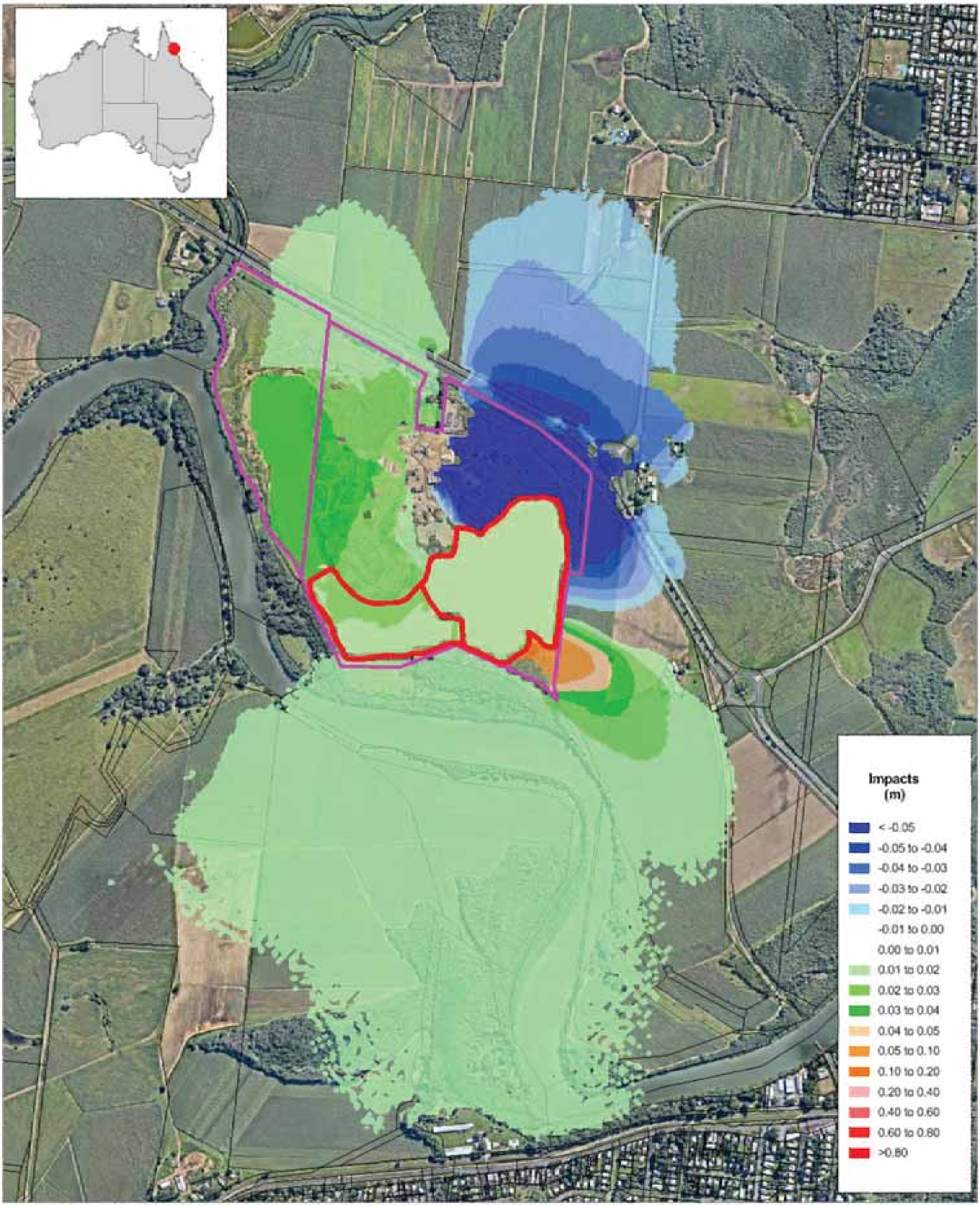

Title:

Northan Sands Disposal Site
Q10 Bund - ARI 20 Year Flood Impacts

Figure: **B-4**

Rev: **A**

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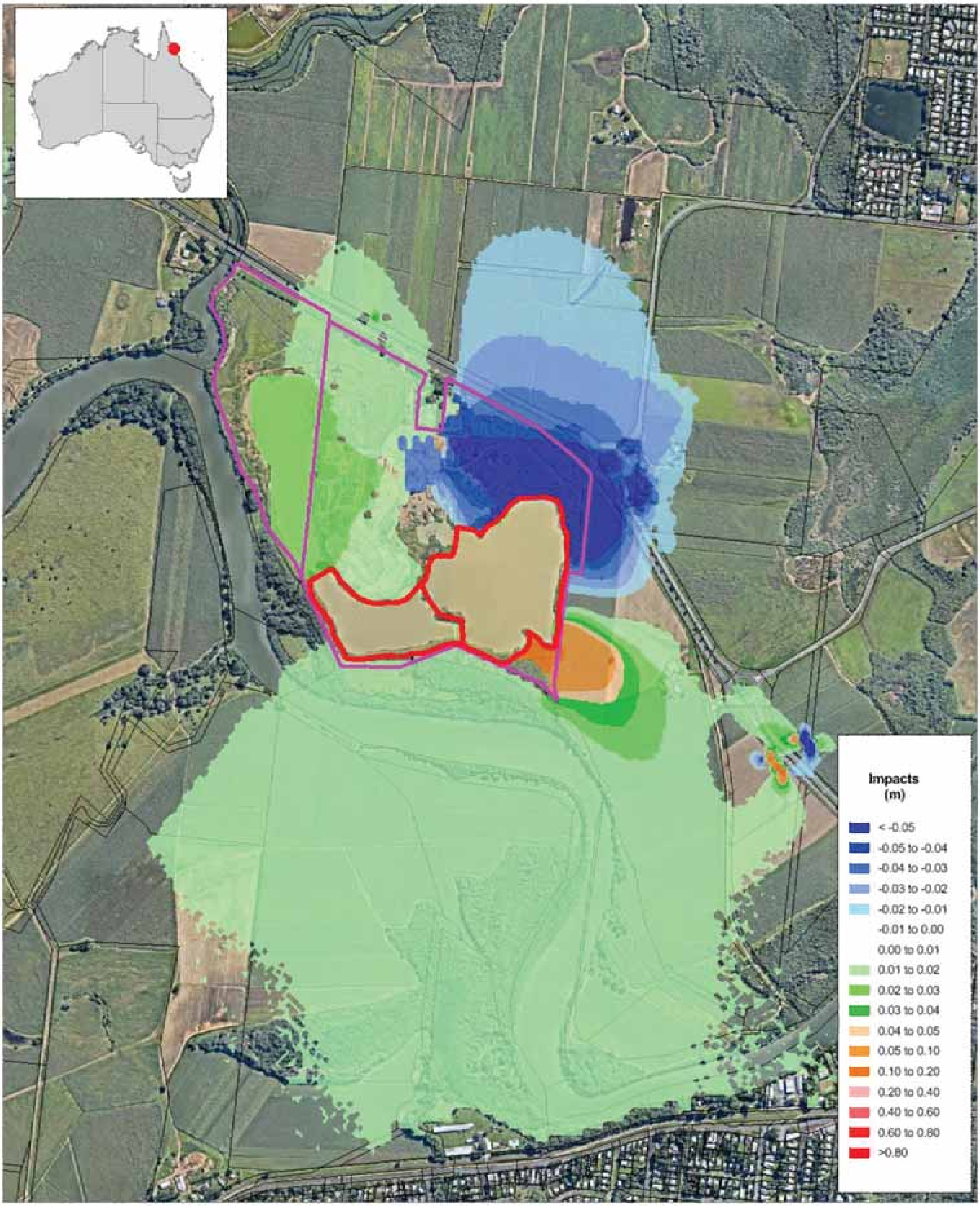

Title:

Northan Sands Disposal Site
Q10 Bund - ARI 50 Year Flood Impacts

Figure: **B-5**

Rev: **A**

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metres

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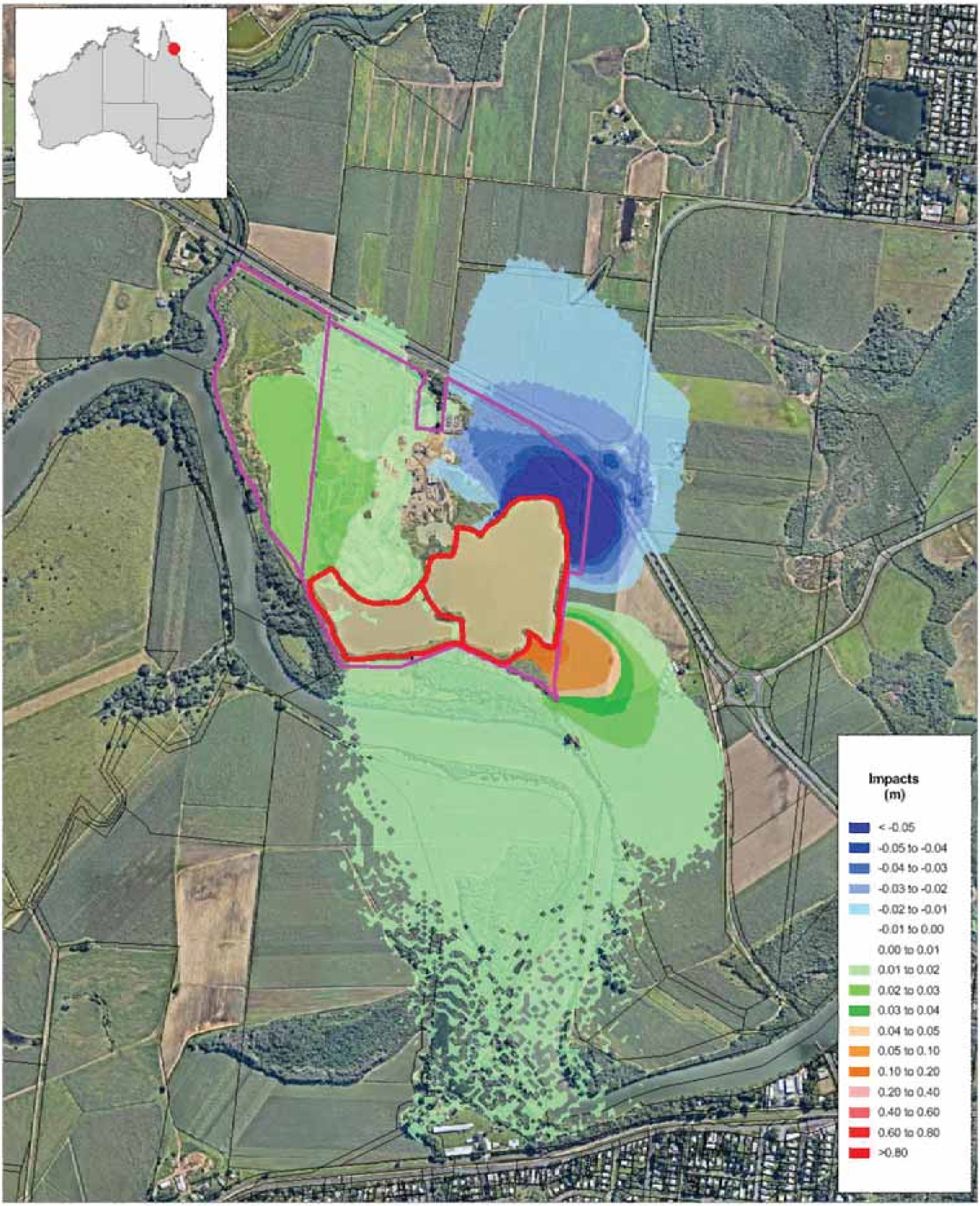

Title:

Northan Sands Disposal Site
Q10 Bund - ARI 100 Year Flood Impacts

Figure: **B-6**

Rev: **A**

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metres

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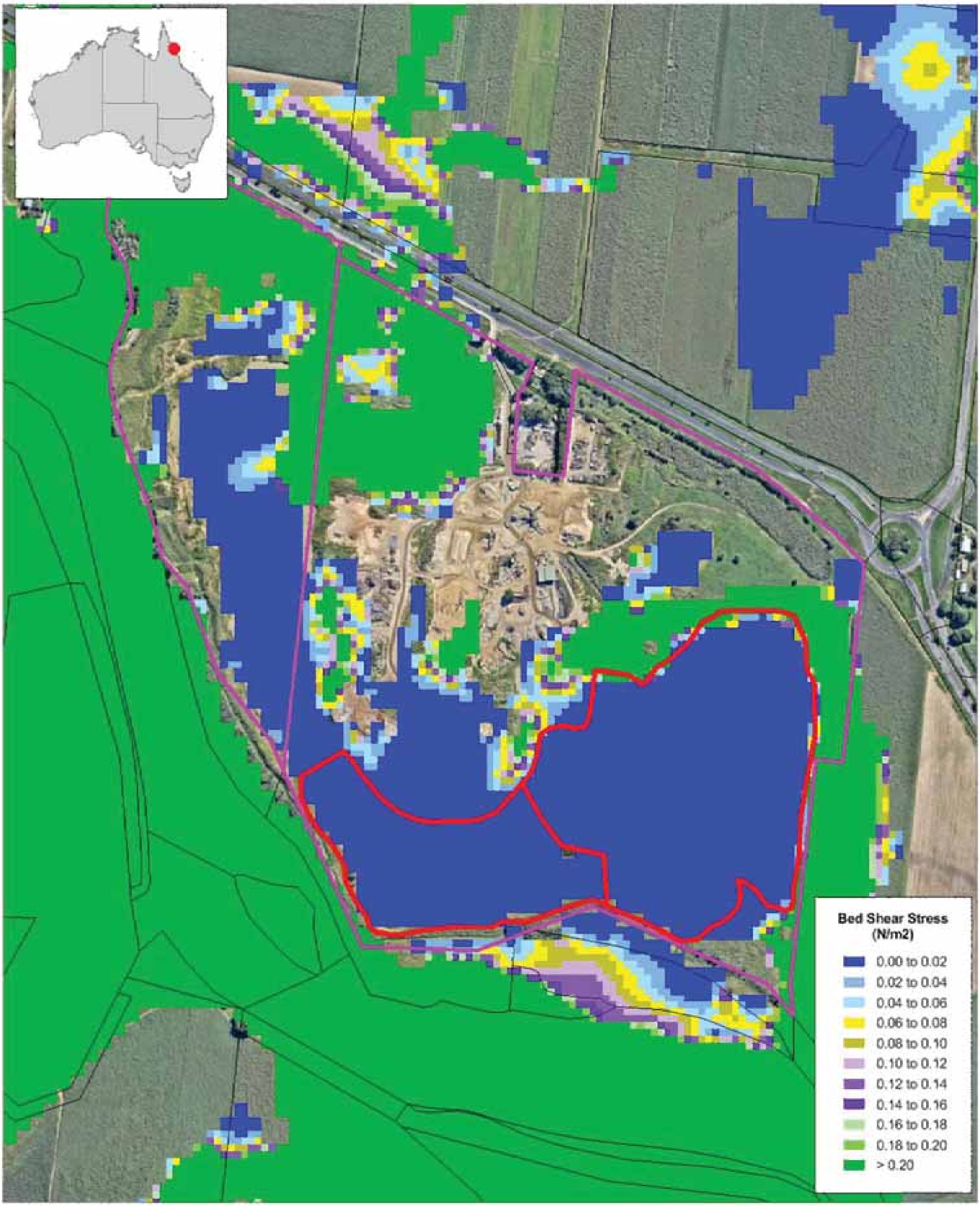

Title:

Northan Sands Disposal Site
Q10 Bund - ARI 2 Year Bed Shear Stress

Figure: **B-7**

Rev: **A**

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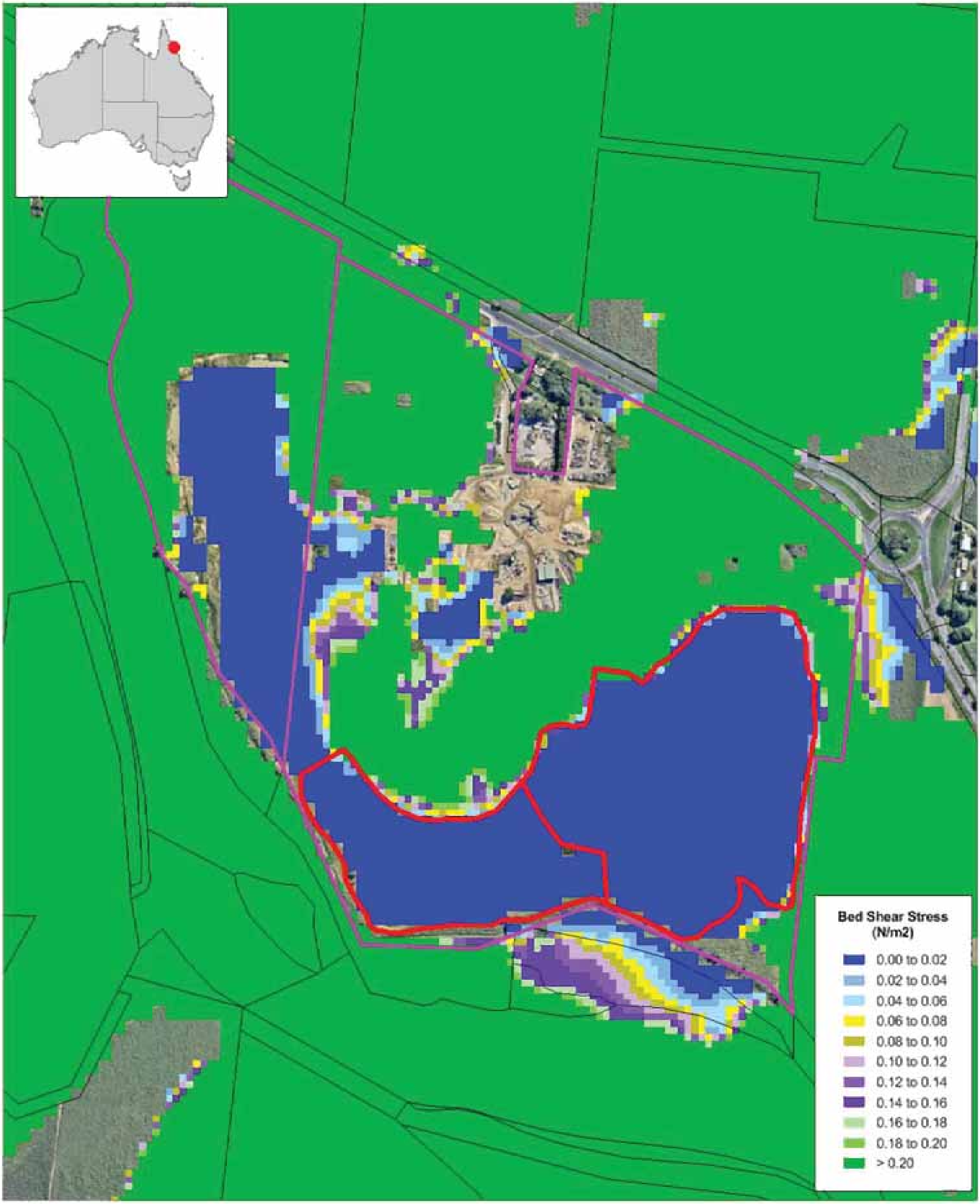

Title:

Northan Sands Disposal Site
Q10 Bund - ARI 5 Year Bed Shear Stress

Figure: **B-8**

Rev: **A**

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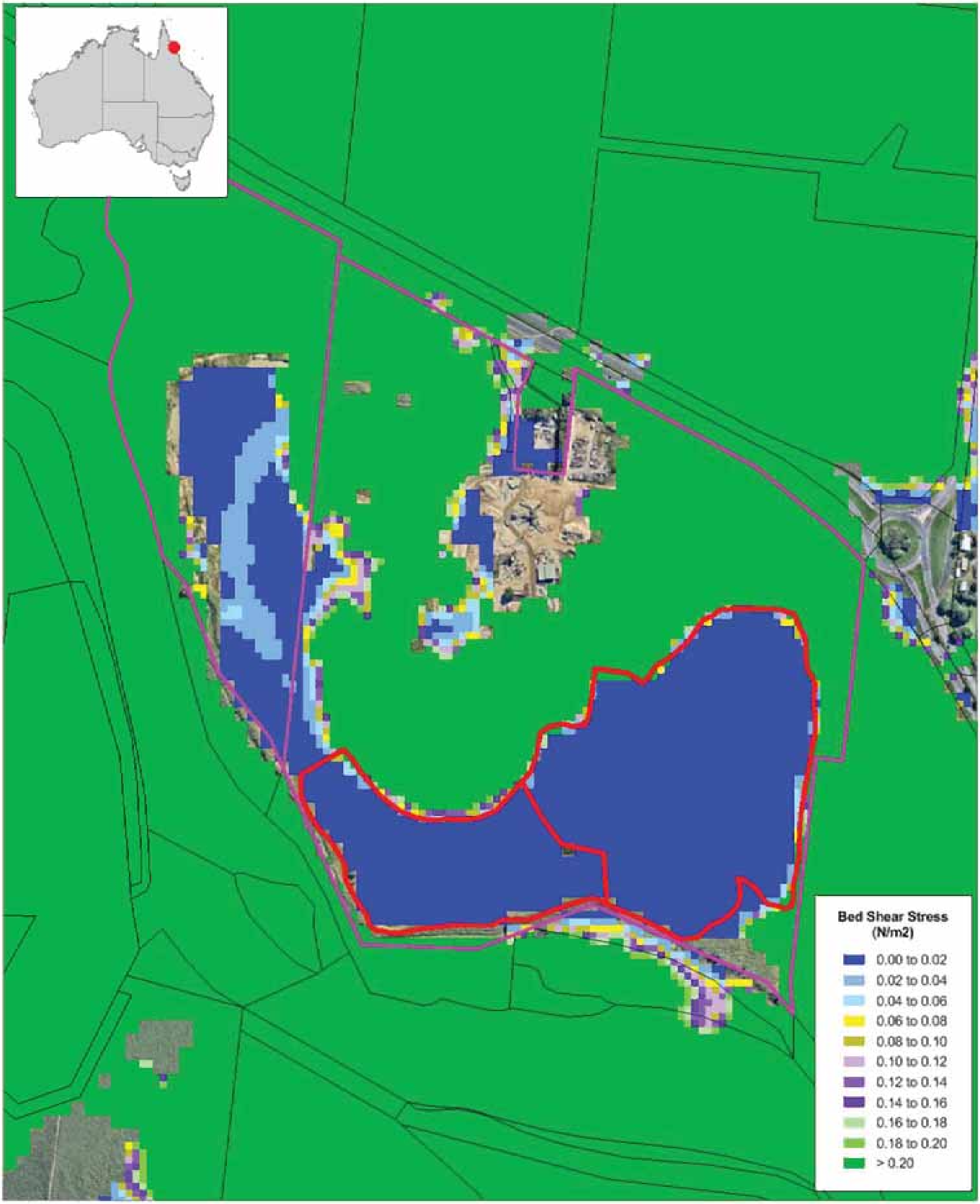

Title:
Northan Sands Disposal Site
Q10 Bund - ARI 10 Year Bed Shear Stress

Figure: **B-9**

Rev: **A**

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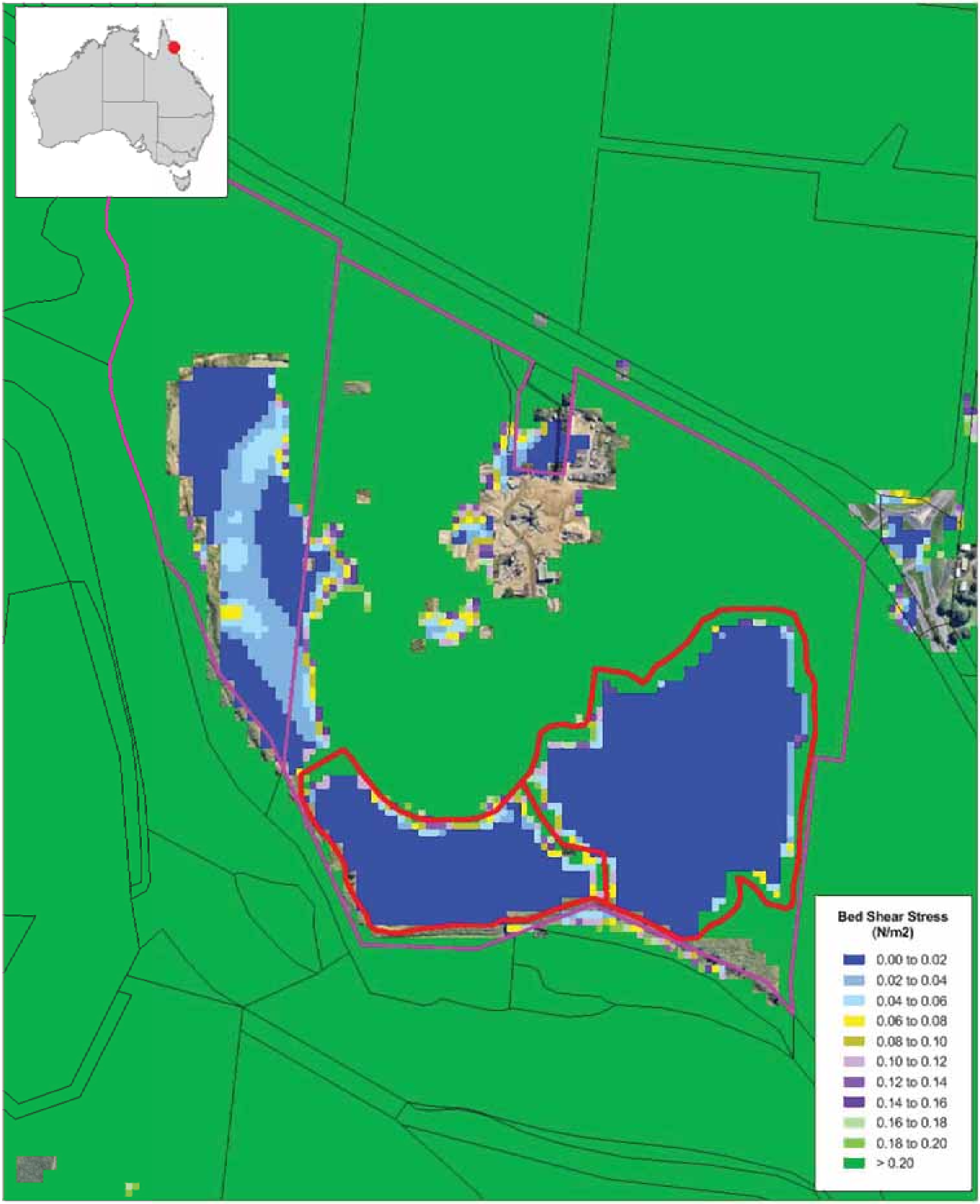

Title:
Northan Sands Disposal Site
Q10 Bund - ARI 20 Year Bed Shear Stress

Figure: **B-10**

Rev: **A**

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metres

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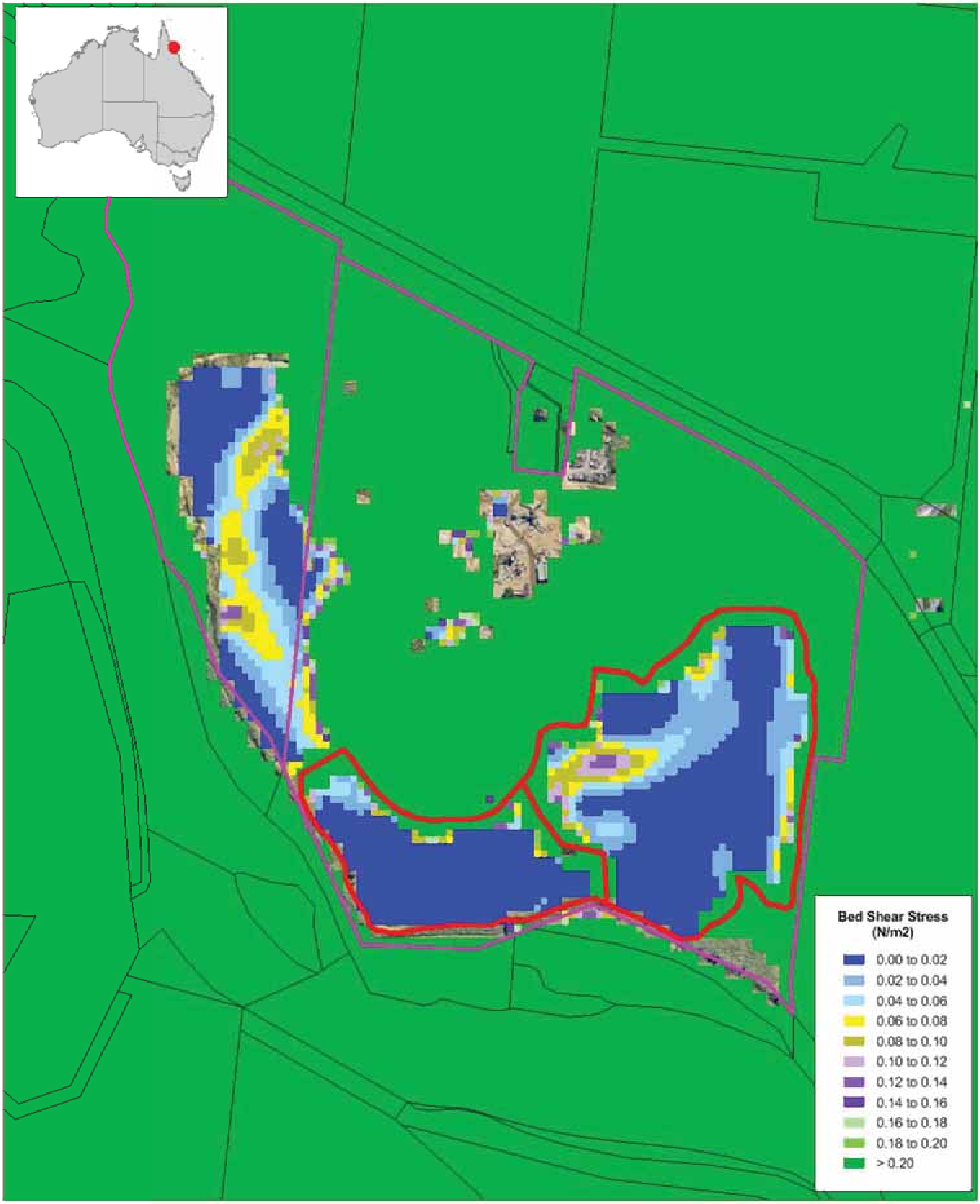

Title:

Northan Sands Disposal Site
Q10 Bund - ARI 50 Year Bed Shear Stress

Figure: **B-11**

Rev: **A**

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metres

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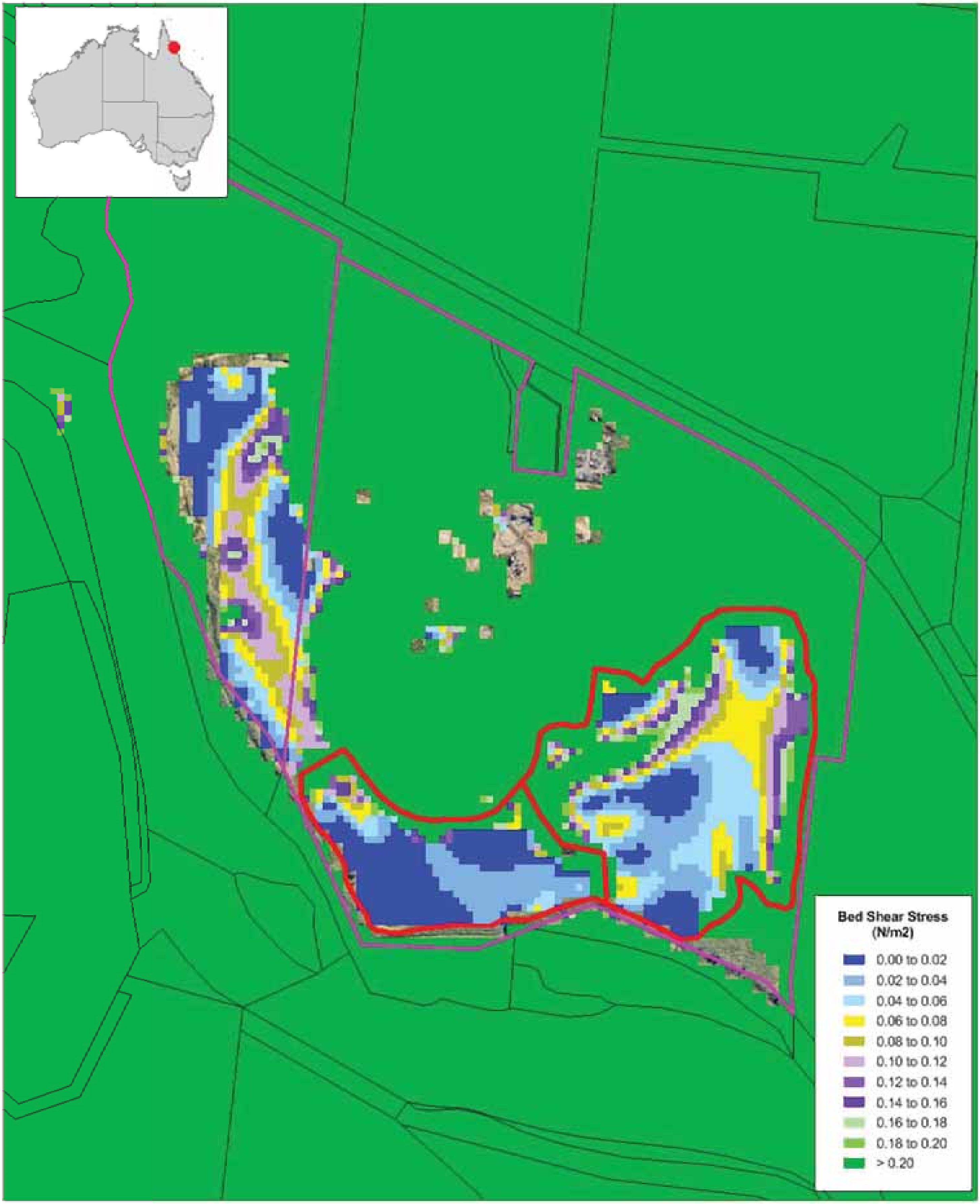

Title:

Northan Sands Disposal Site
Q10 Bund - ARI 100 Year Bed Shear Stress

Figure: **B-12**

Rev: **A**

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metres

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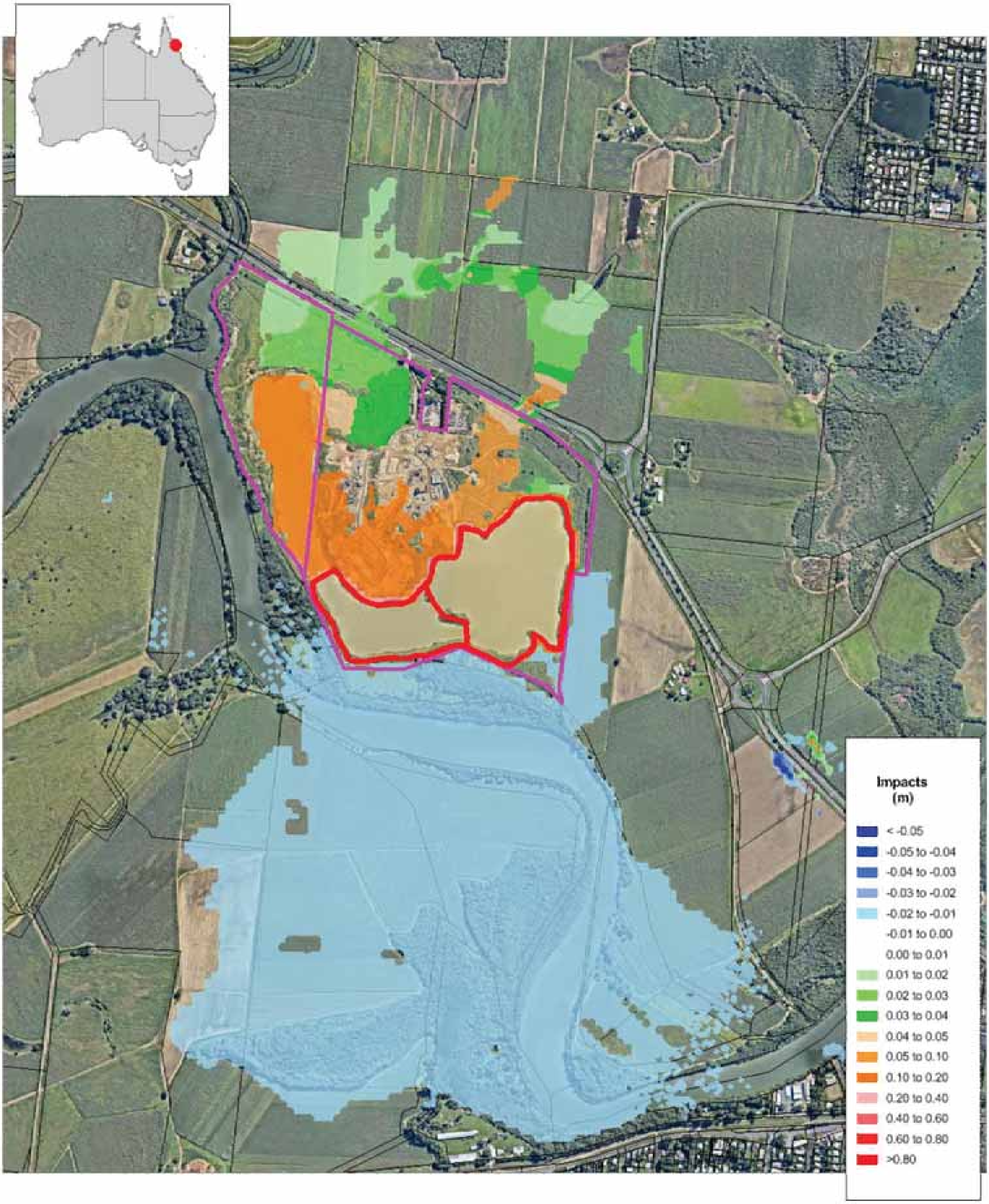
Appendix C Q50 bund level (RL 5.3m AHD) Results



Title:

Northan Sands Disposal Site
Q20 Bund - ARI 2 Year Flood Impacts

Figure: **C-1**

Rev: **A**

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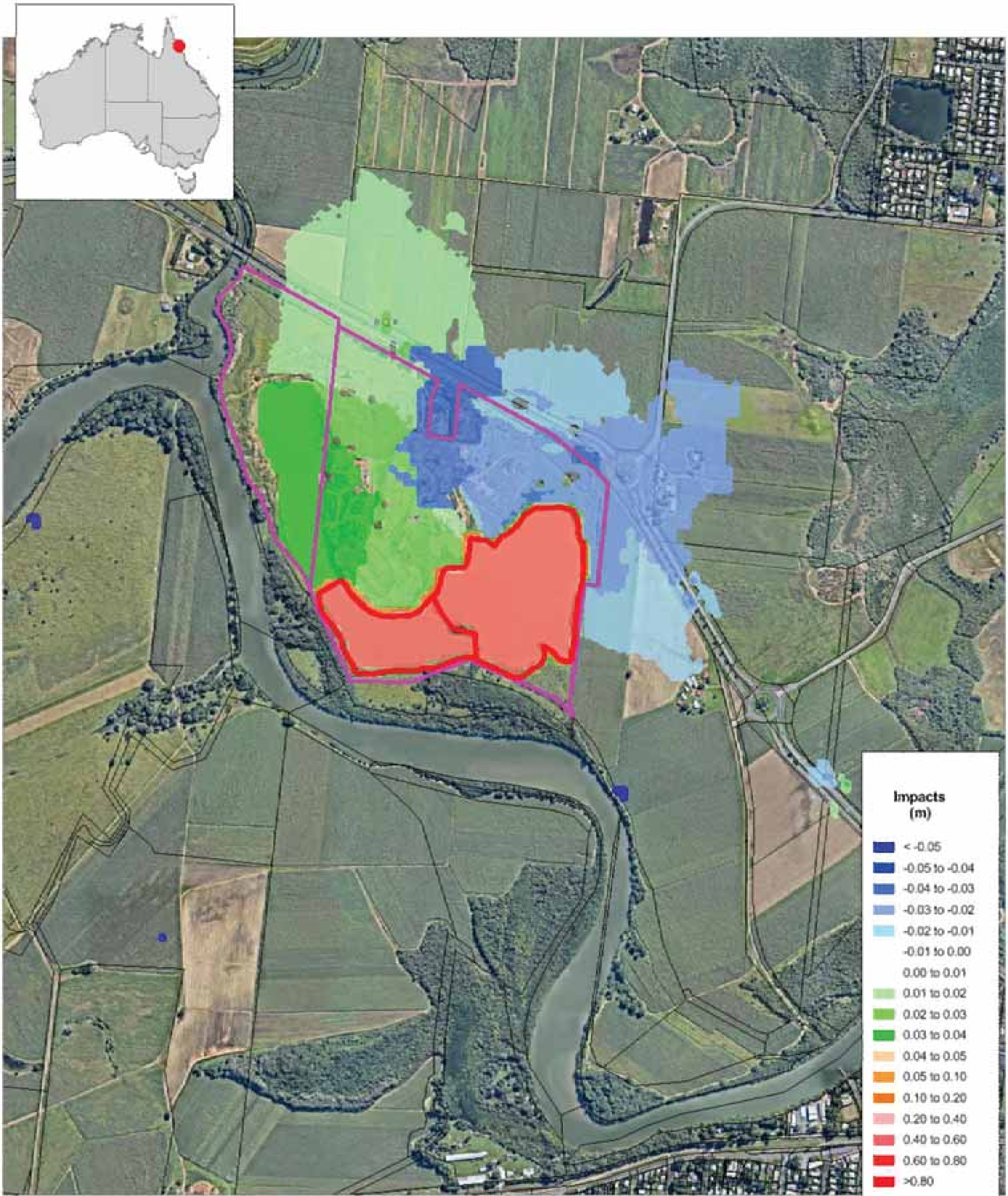

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 5 Year Flood Impacts

Figure: **C-2**

Rev: **A**

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metres

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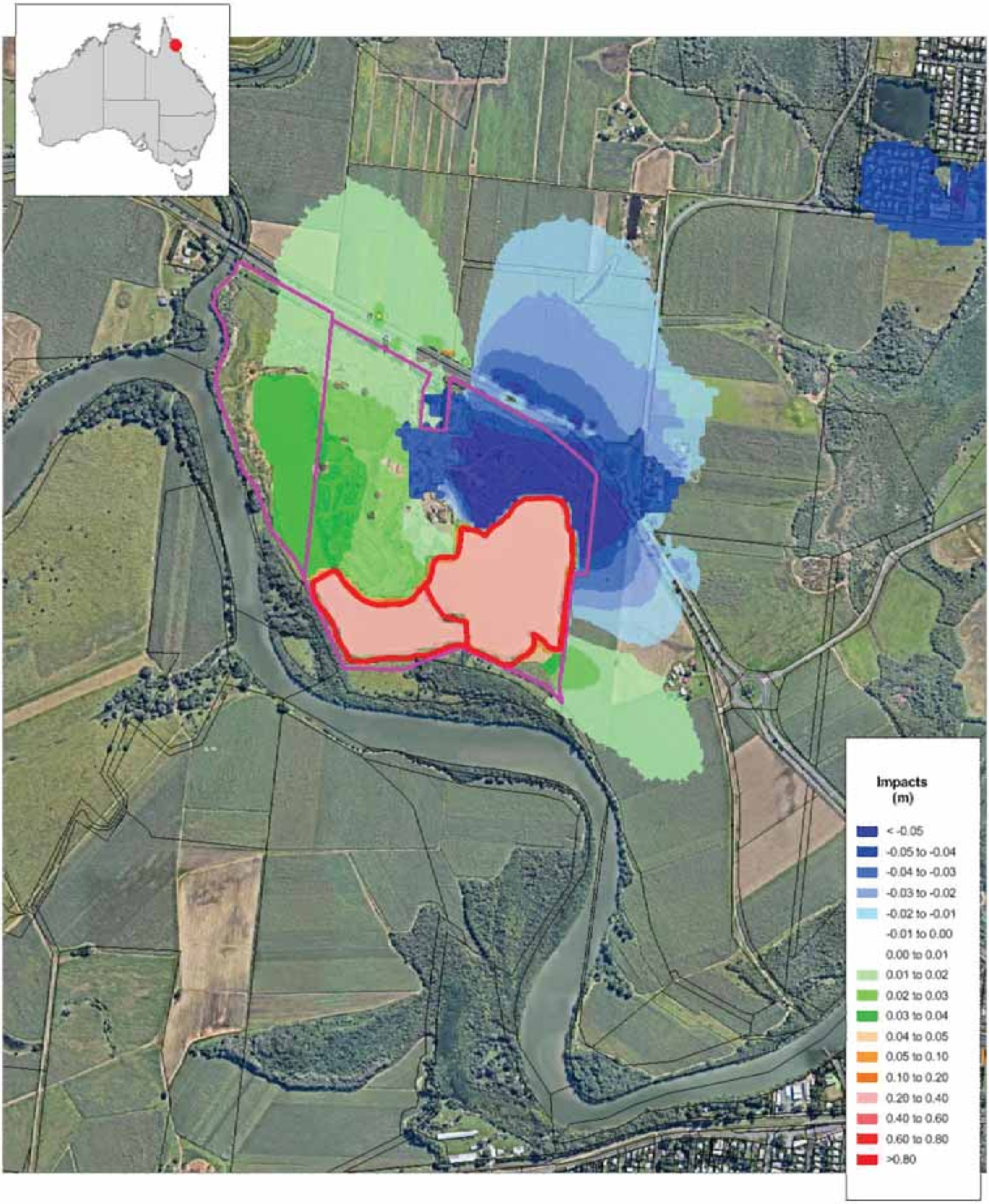

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 10 Year Flood Impacts

Figure: C-3

Rev: A

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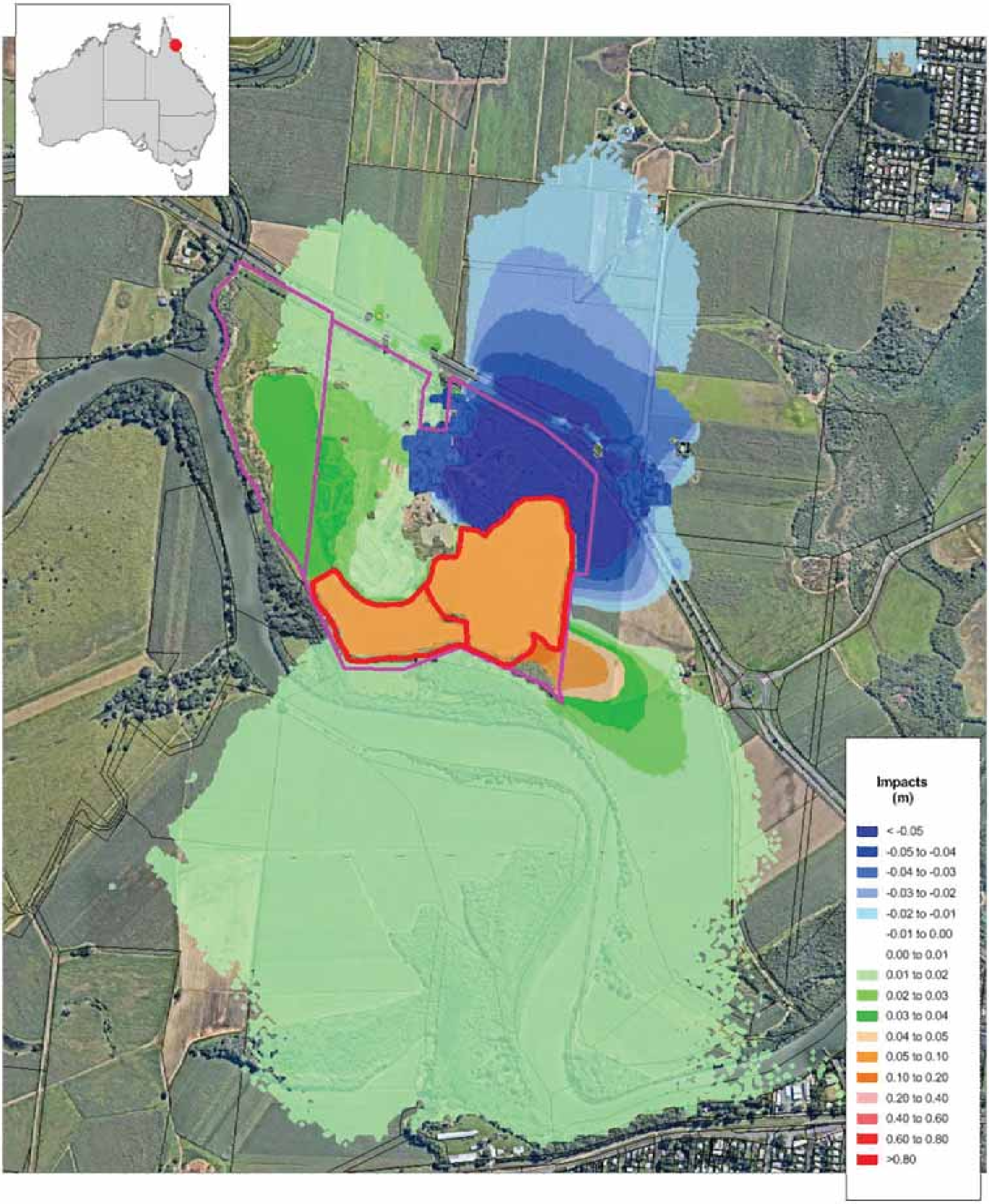

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 20 Year Flood Impacts

Figure: **C-4**

Rev: **A**

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metres

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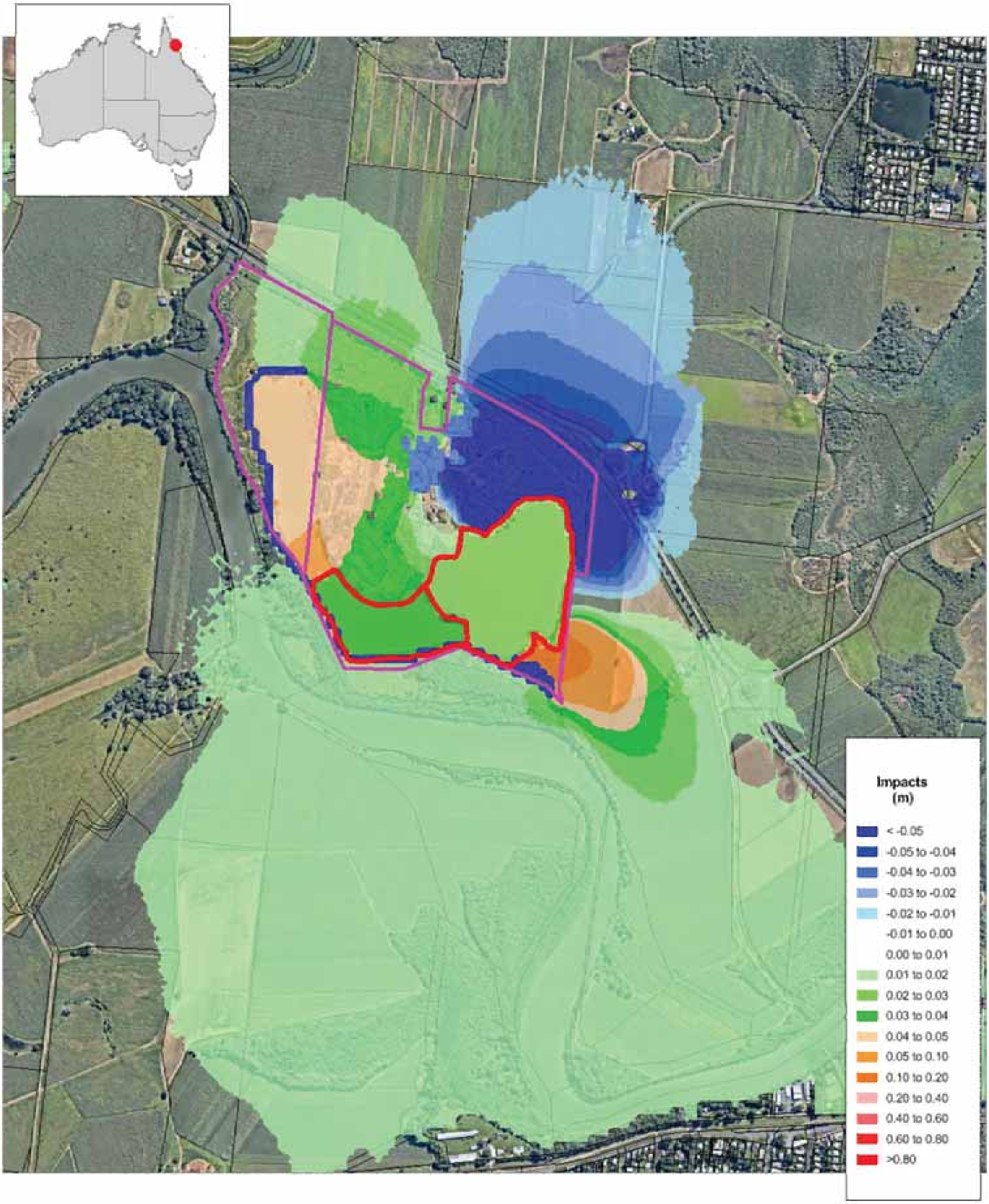

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 50 Year Flood Impacts

Figure:
C-5

Rev:
A

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metres

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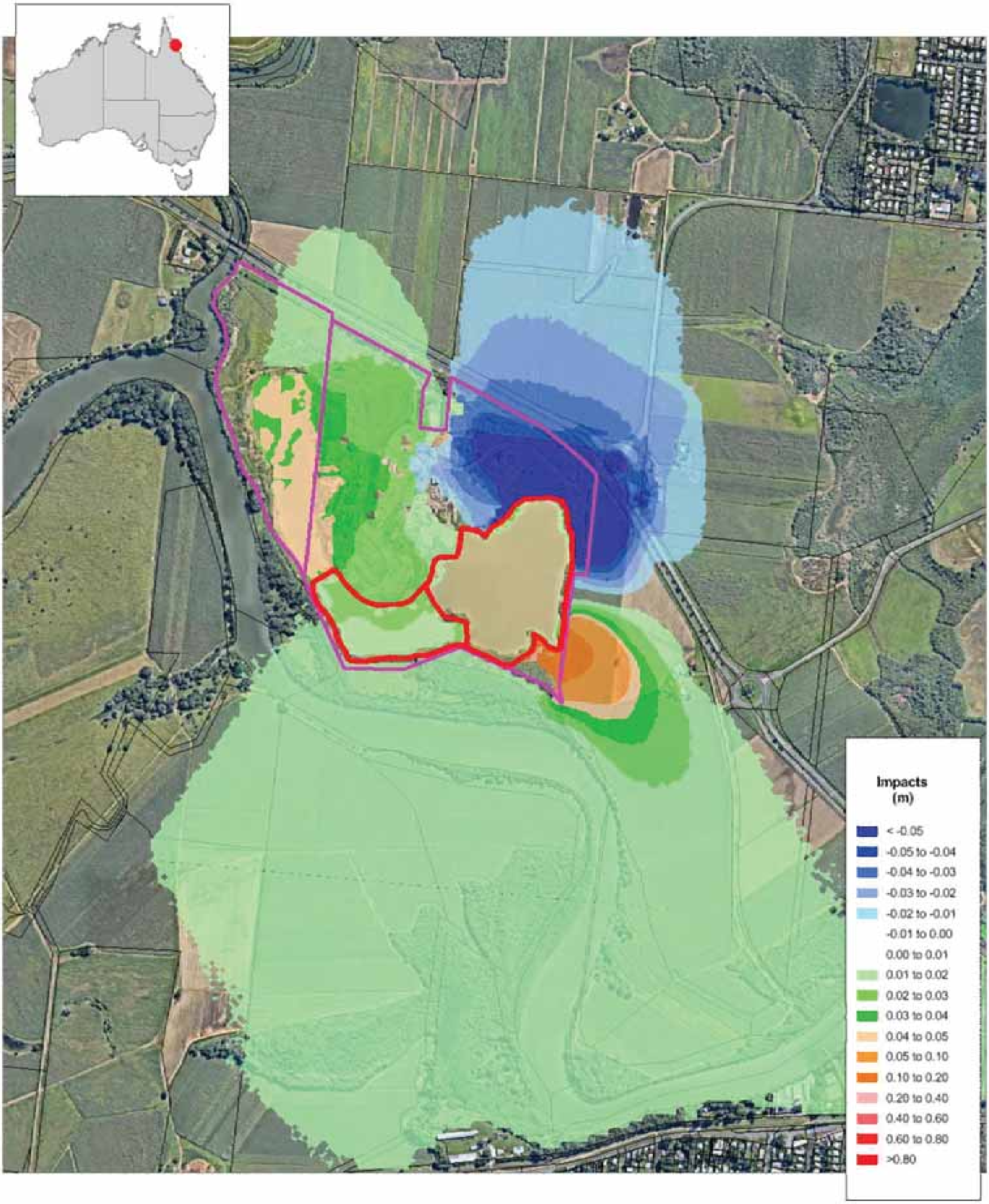

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 100 Year Flood Impacts

Figure: **C-6**

Rev: **A**

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metres

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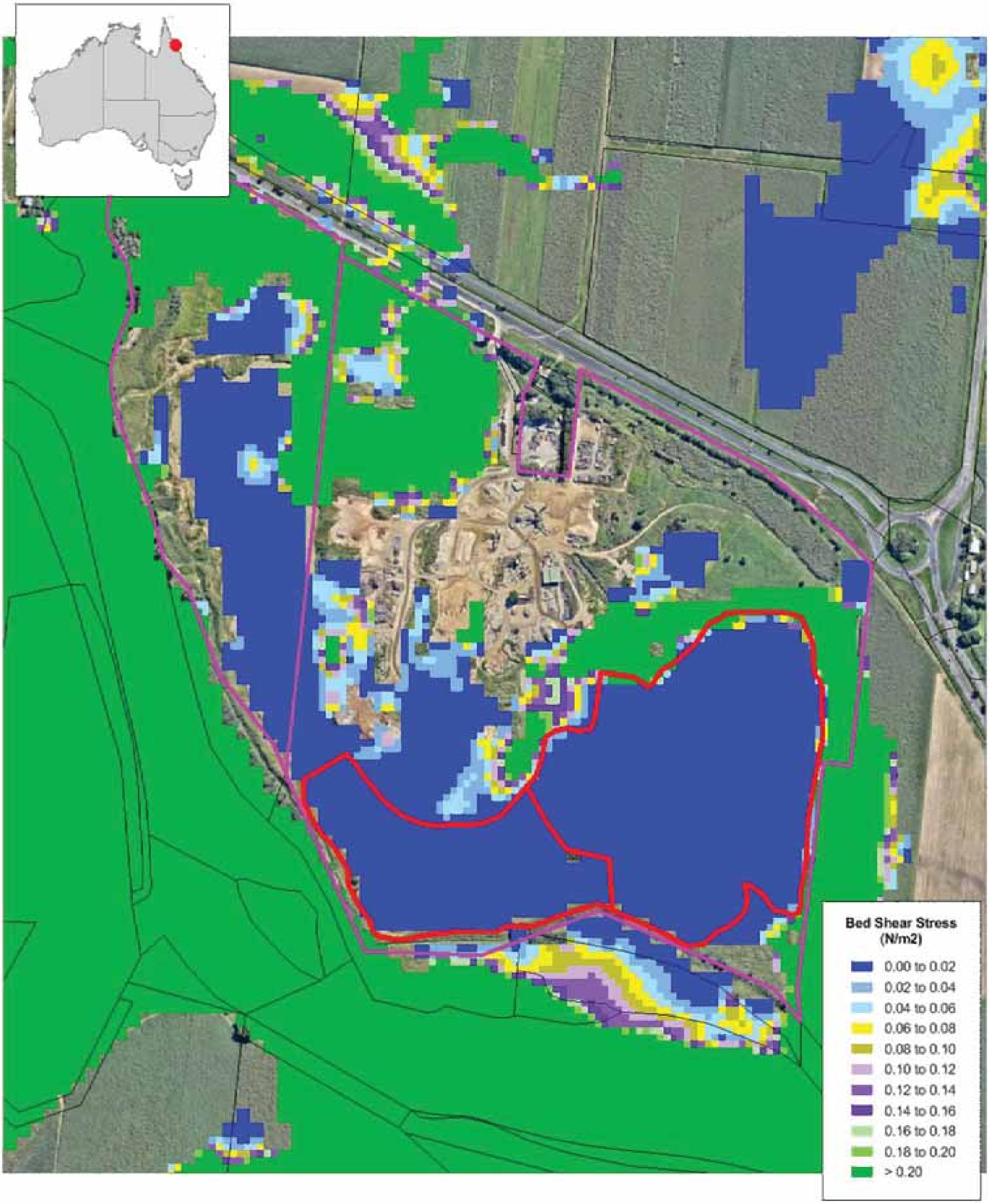

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 2 Year Bed Shear Stress

Figure: **C-7**

Rev: **A**

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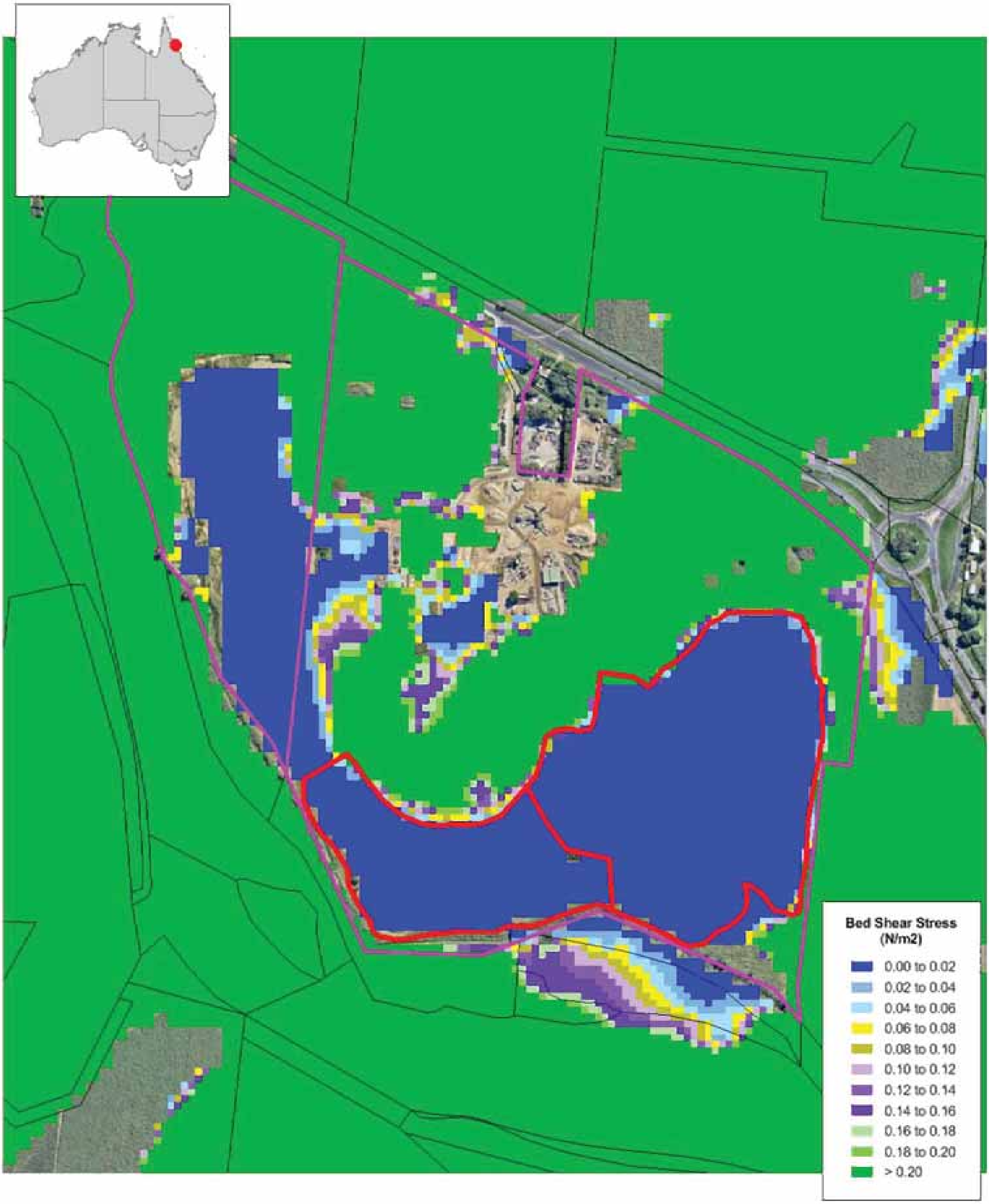

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 5 Year Bed Shear Stress

Figure: **C-8**

Rev: **A**

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BMT WBM

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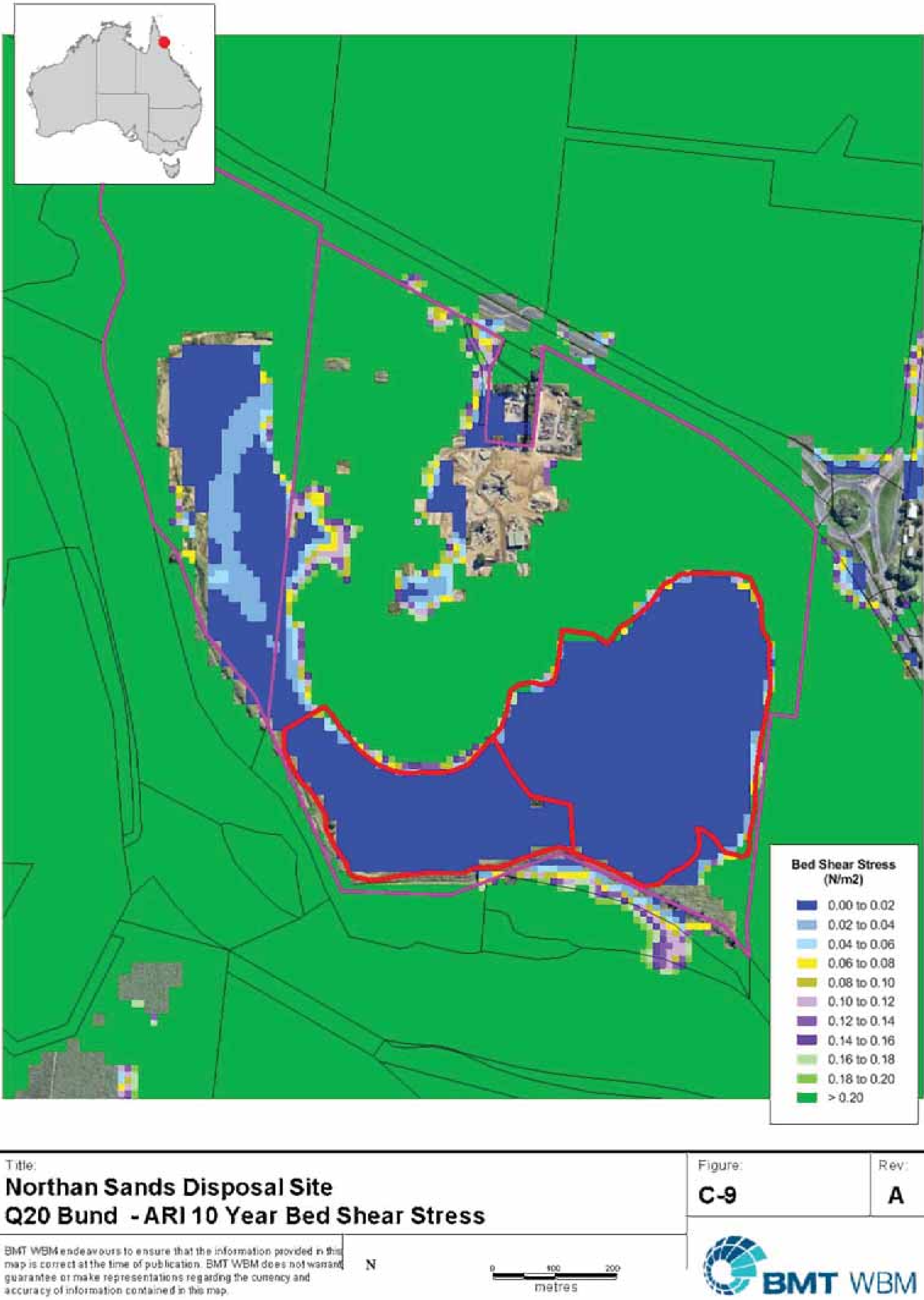

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 10 Year Bed Shear Stress

Figure: C-9

Rev: A

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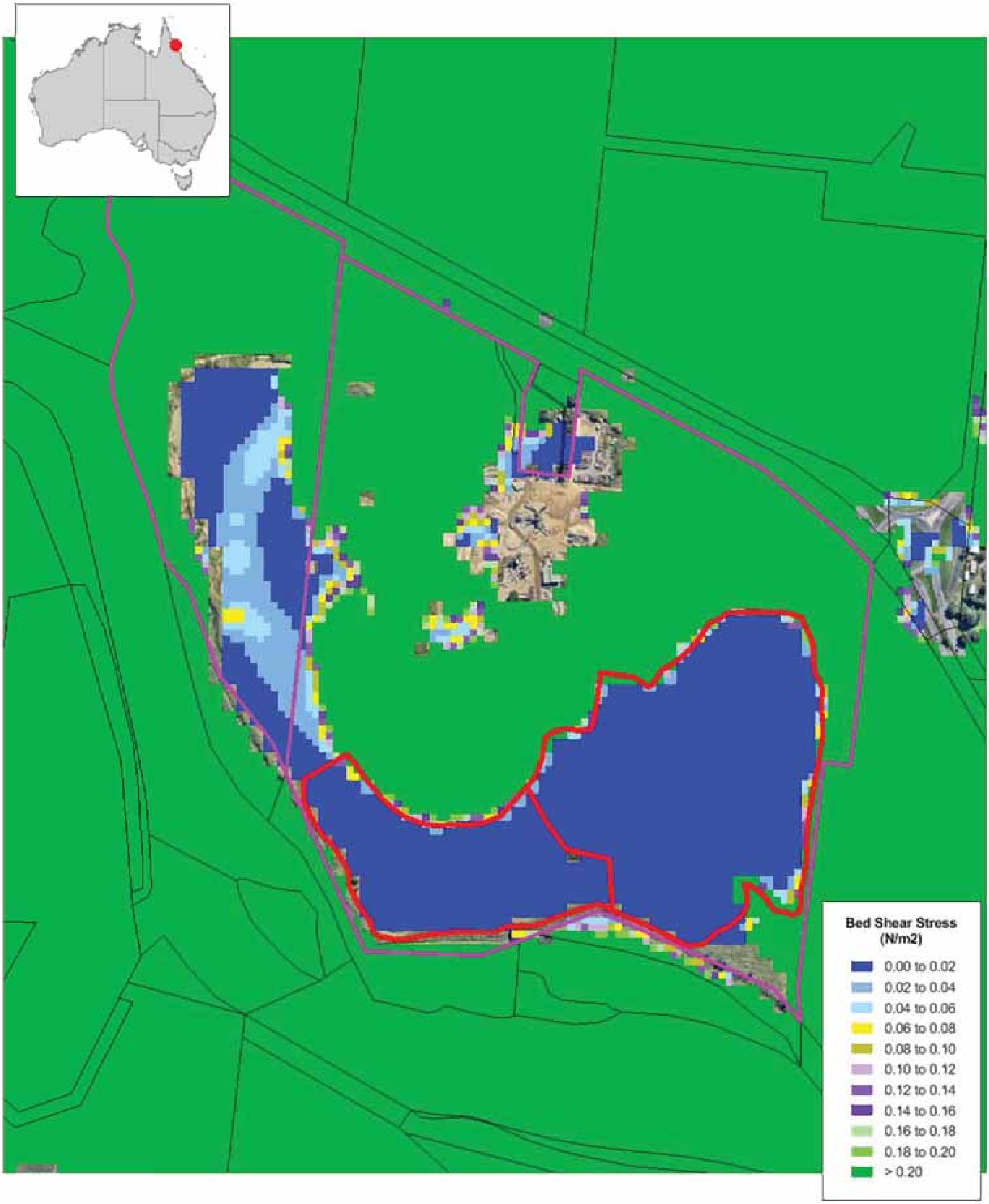

Title:
Northan Sands Disposal Site
Q20 Bund - ARI 20 Year Bed Shear Stress

Figure: **C-10**

Rev: **A**

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metres

BMT WBM

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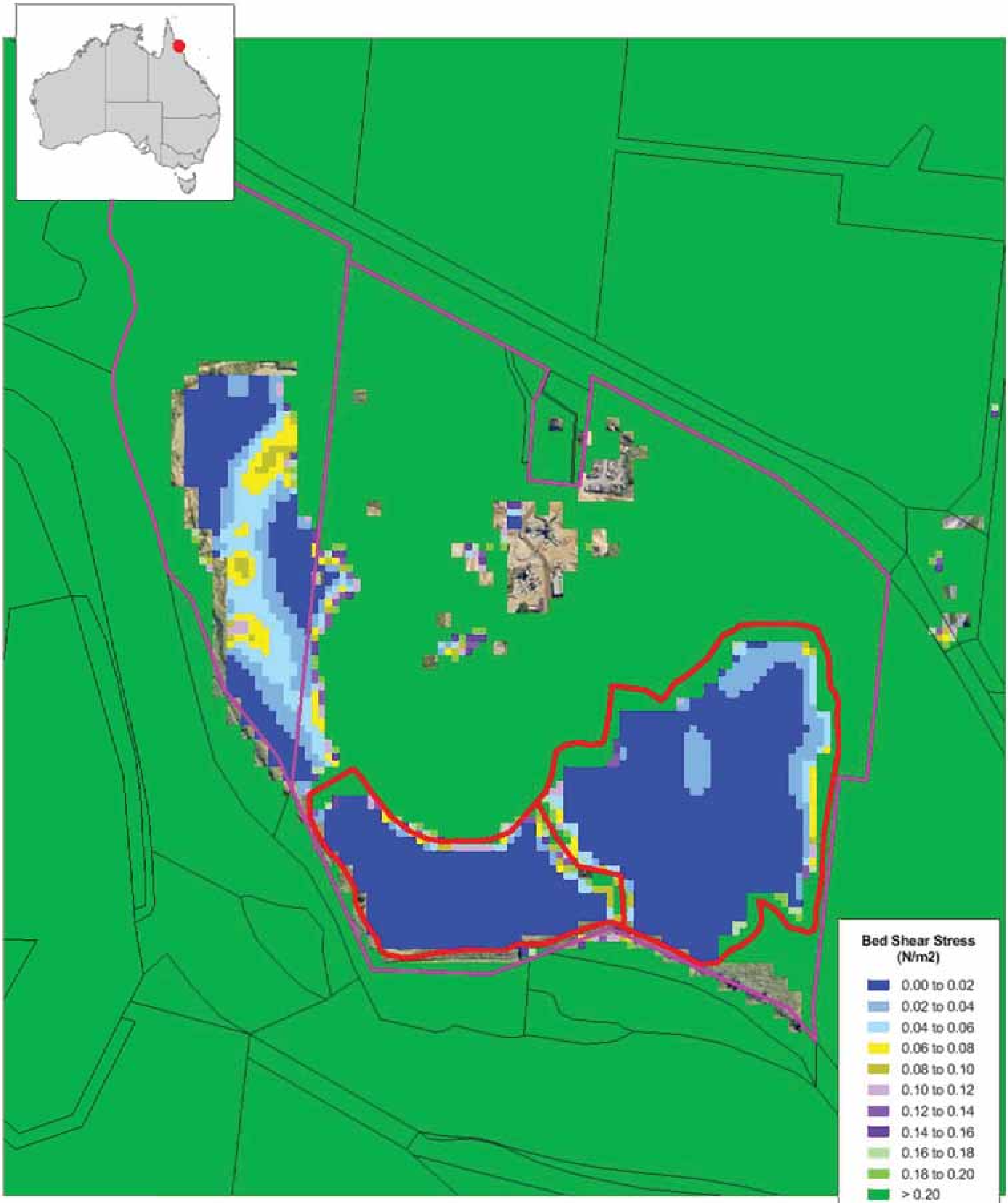

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 50 Year Bed Shear Stress

Figure: **C-11**

Rev: **A**

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metres

BMT WBM

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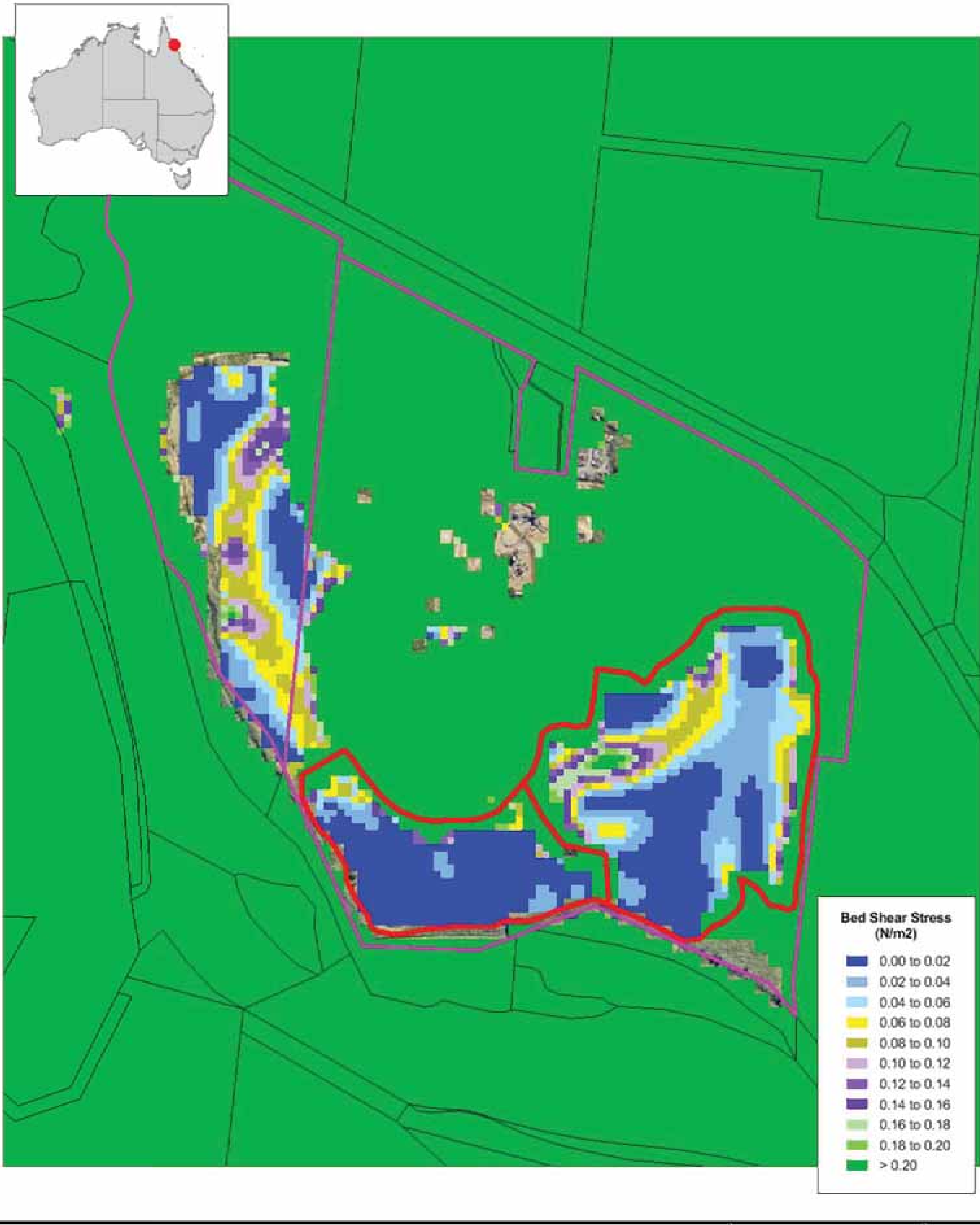

Title:

Northan Sands Disposal Site
Q20 Bund - ARI 100 Year Bed Shear Stress

Figure: **C-12**

Rev: **A**

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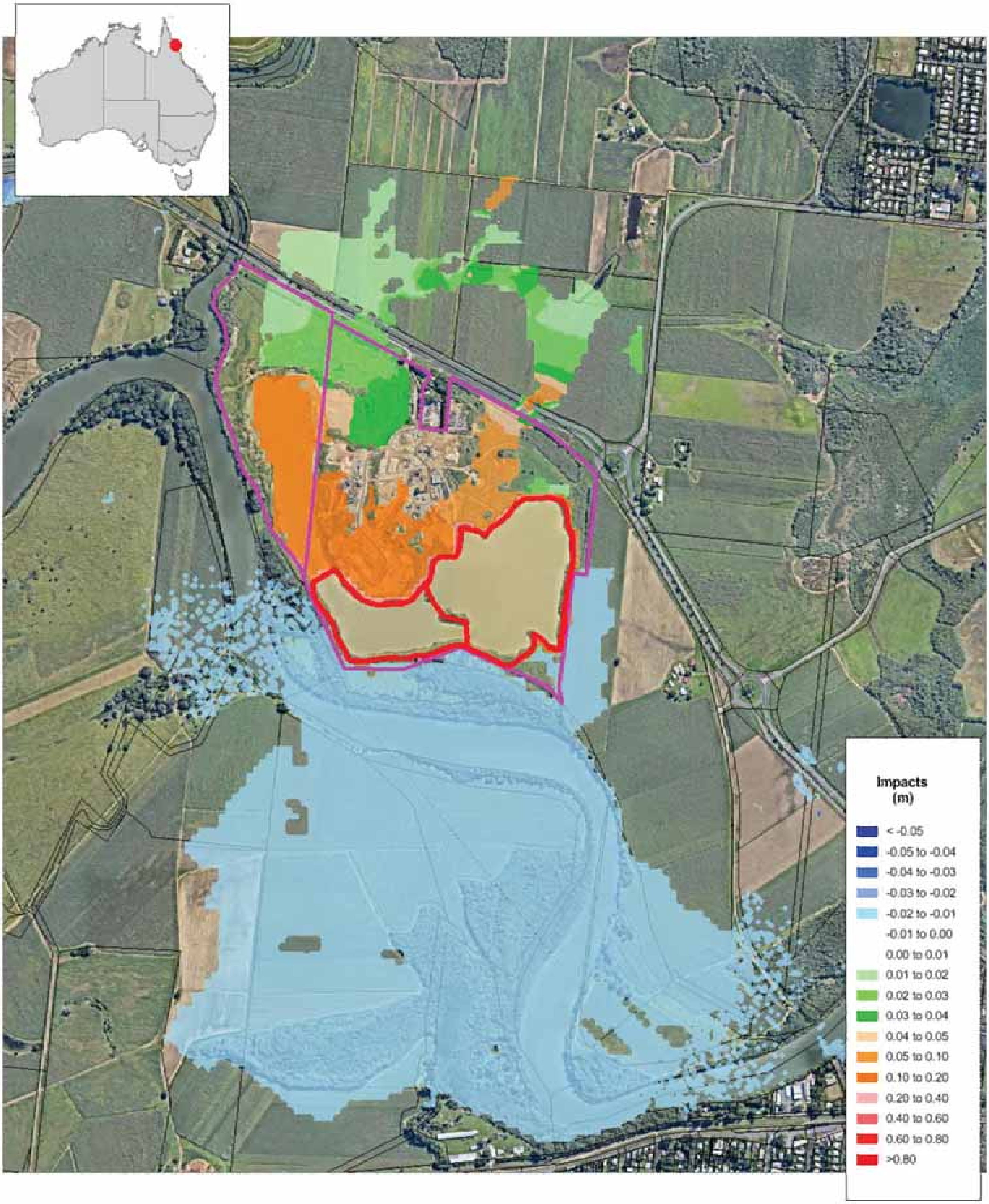
Appendix D Q100 bund level (RL 5.3m AHD) Results



Title:

Northan Sands Disposal Site
Q50 Bund - ARI 2 Year Flood Impacts

Figure: **D-1**

Rev: **A**

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N

metres

BMT WBM

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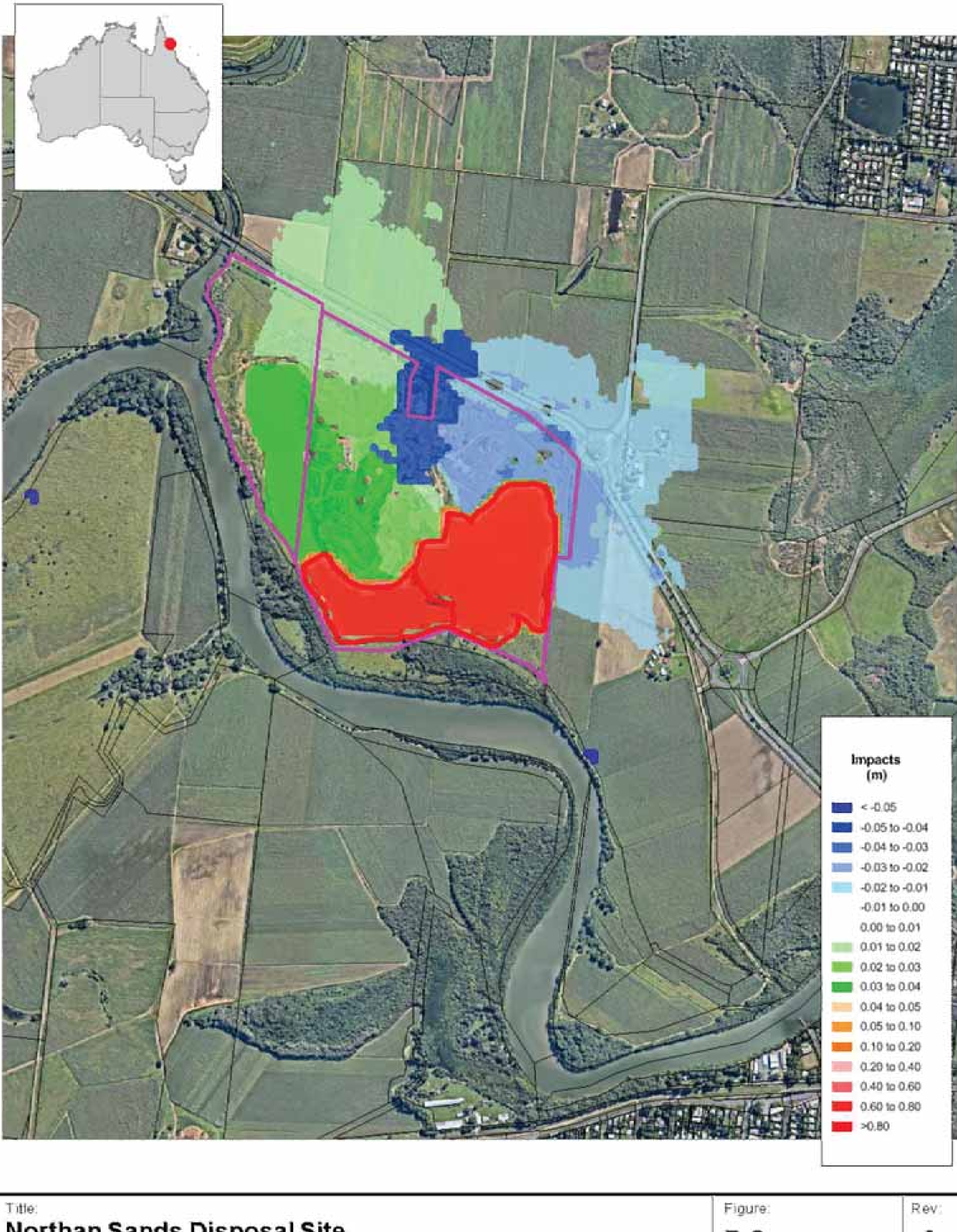

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 5 Year Flood Impacts

Figure: **D-2**

Rev: **A**

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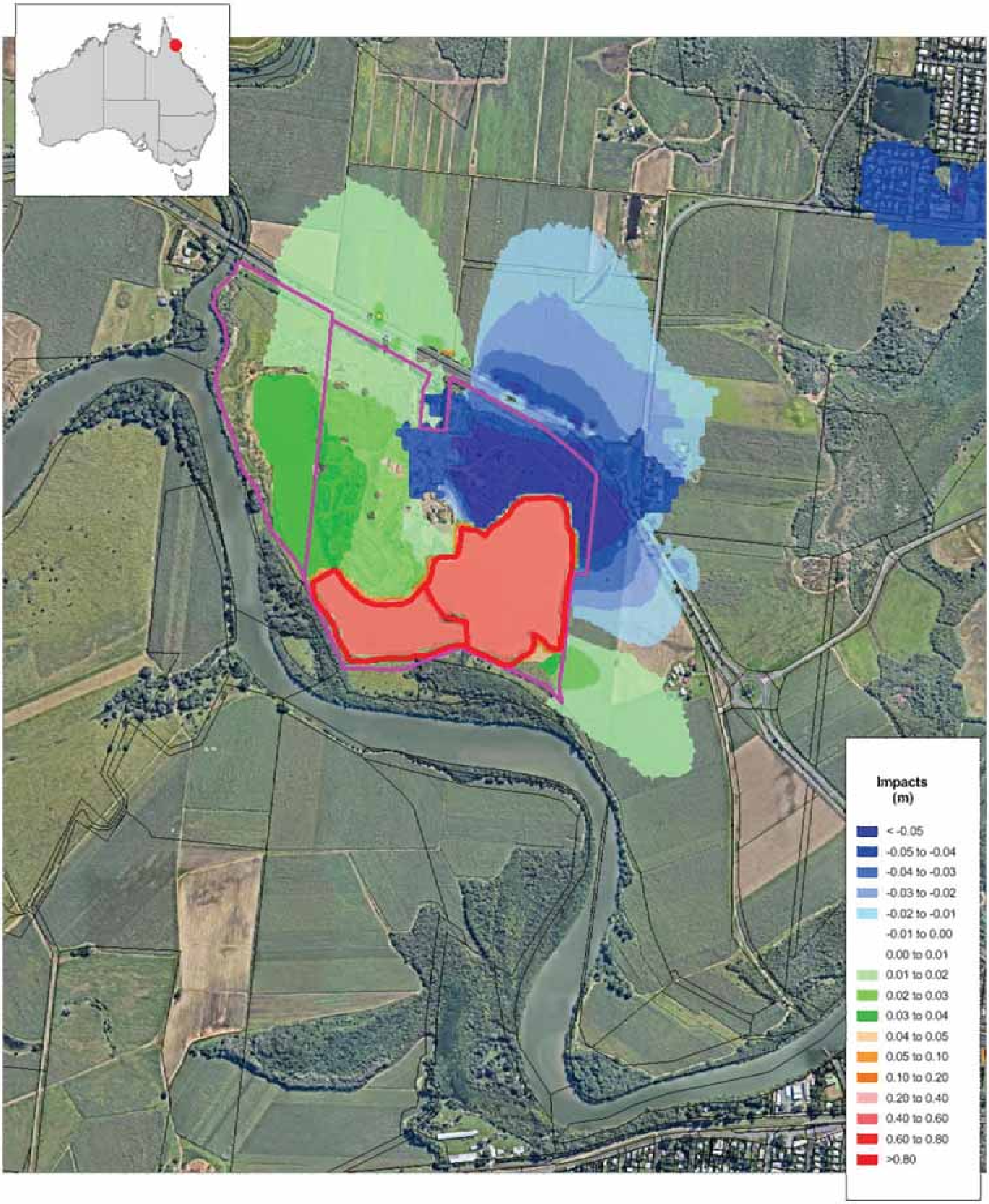

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 10 Year Flood Impacts

Figure: **D-3**

Rev: **A**

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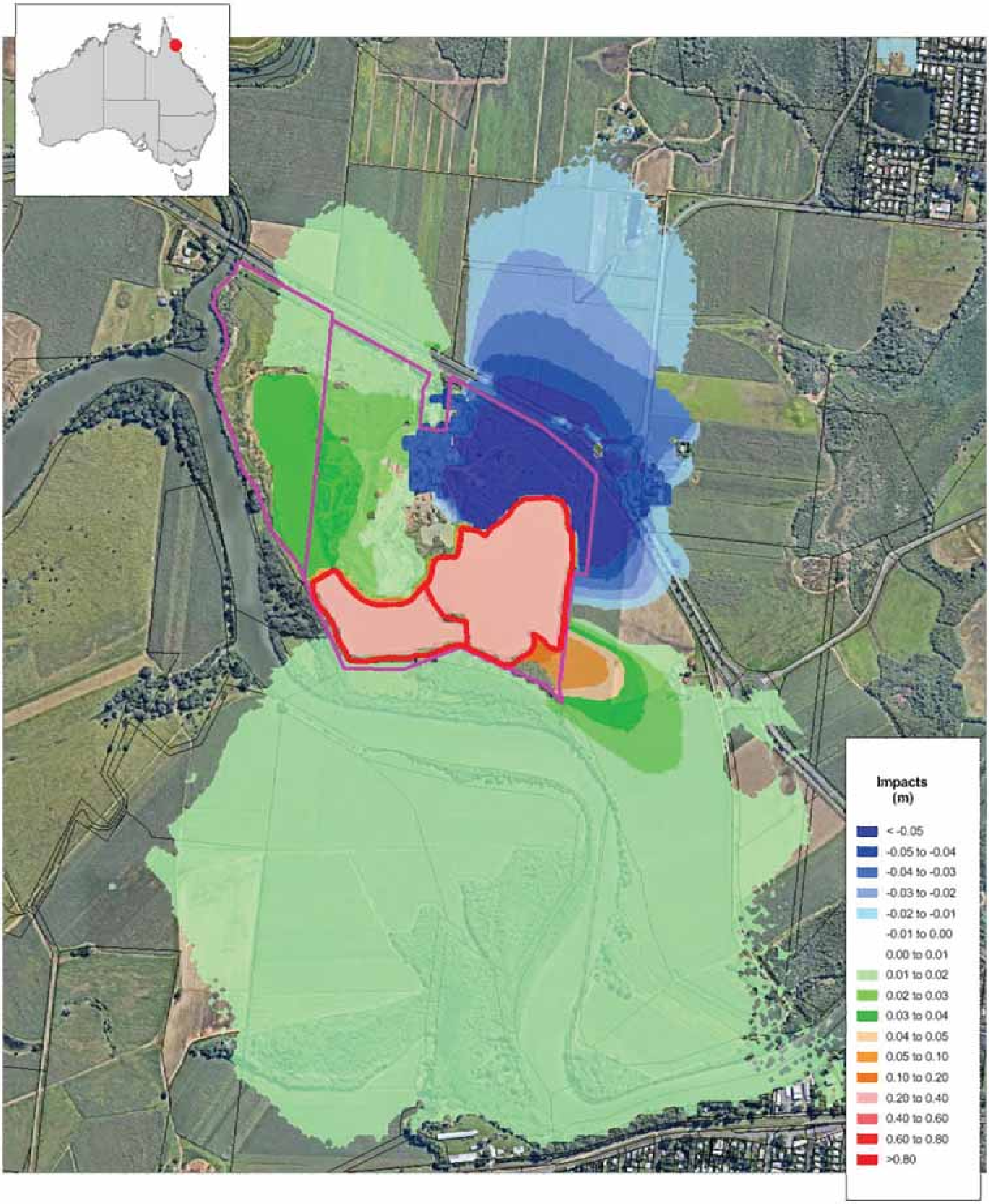

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 20 Year Flood Impacts

Figure: **D-4**

Rev: **A**

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N

metres

BMT WBM

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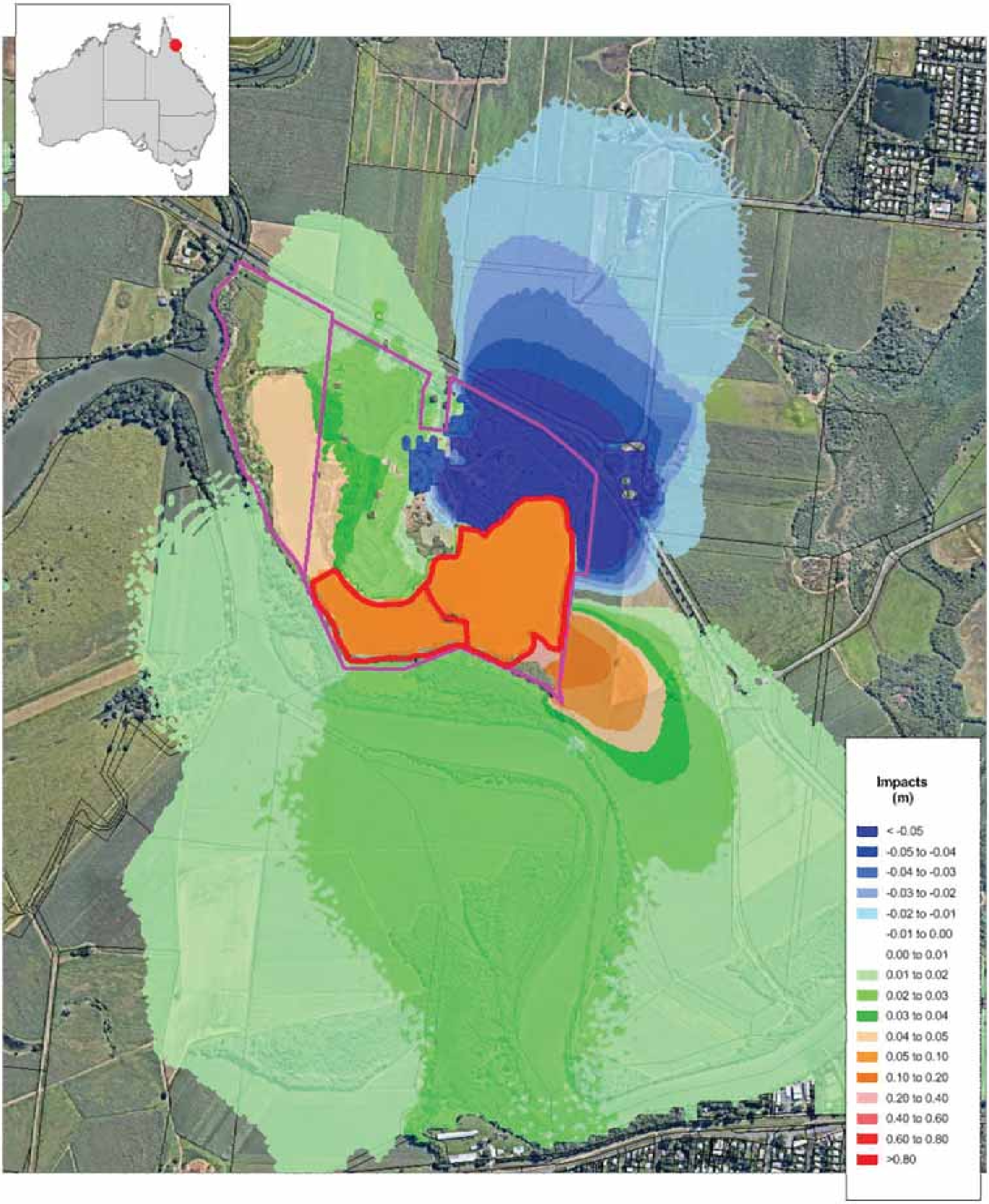

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 50 Year Flood Impacts

Figure: **D-5**

Rev: **A**

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N

metres

BMT WBM

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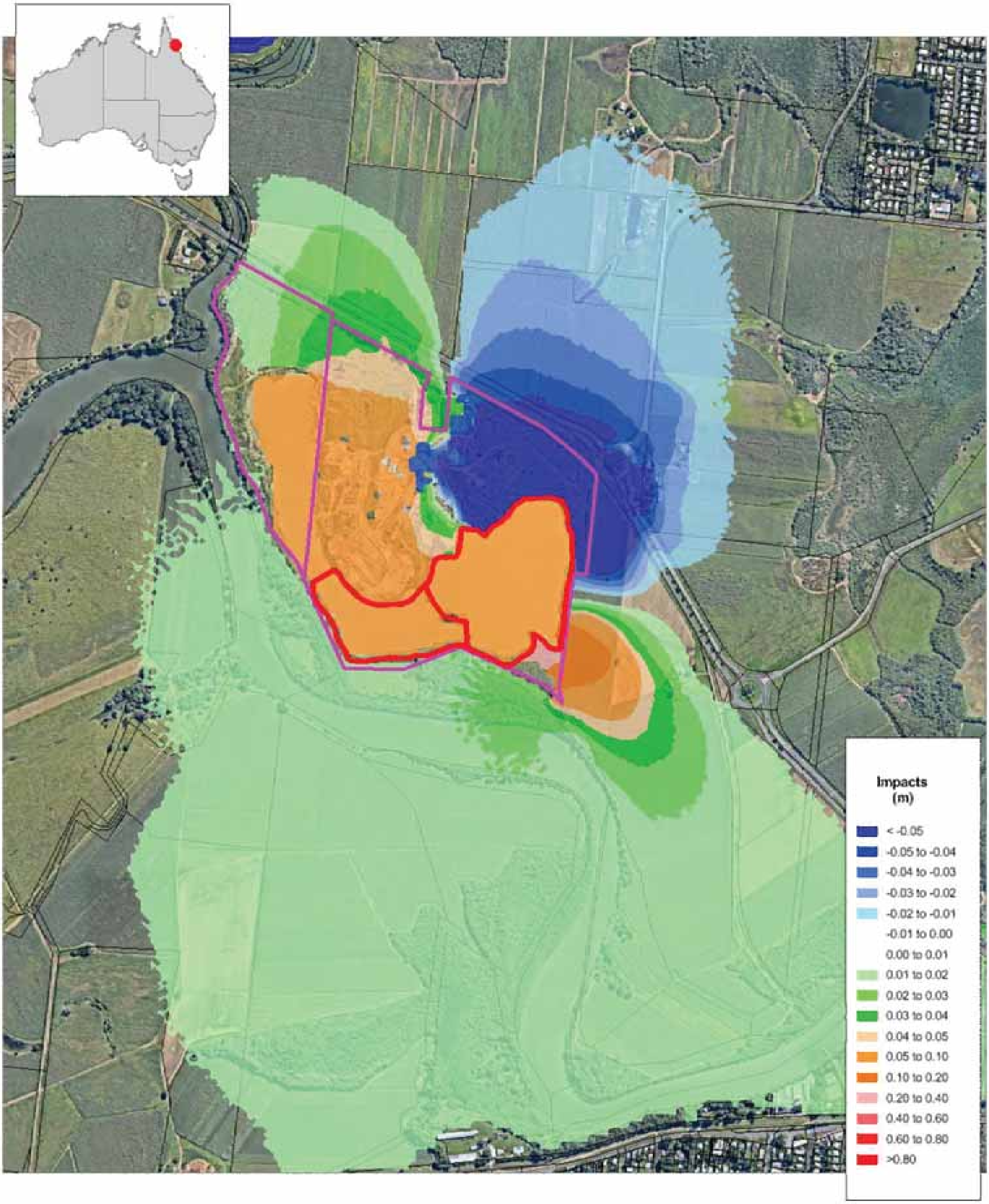

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 100 Year Flood Impacts

Figure: **D-6**

Rev: **A**

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N

metres

BMT WBM

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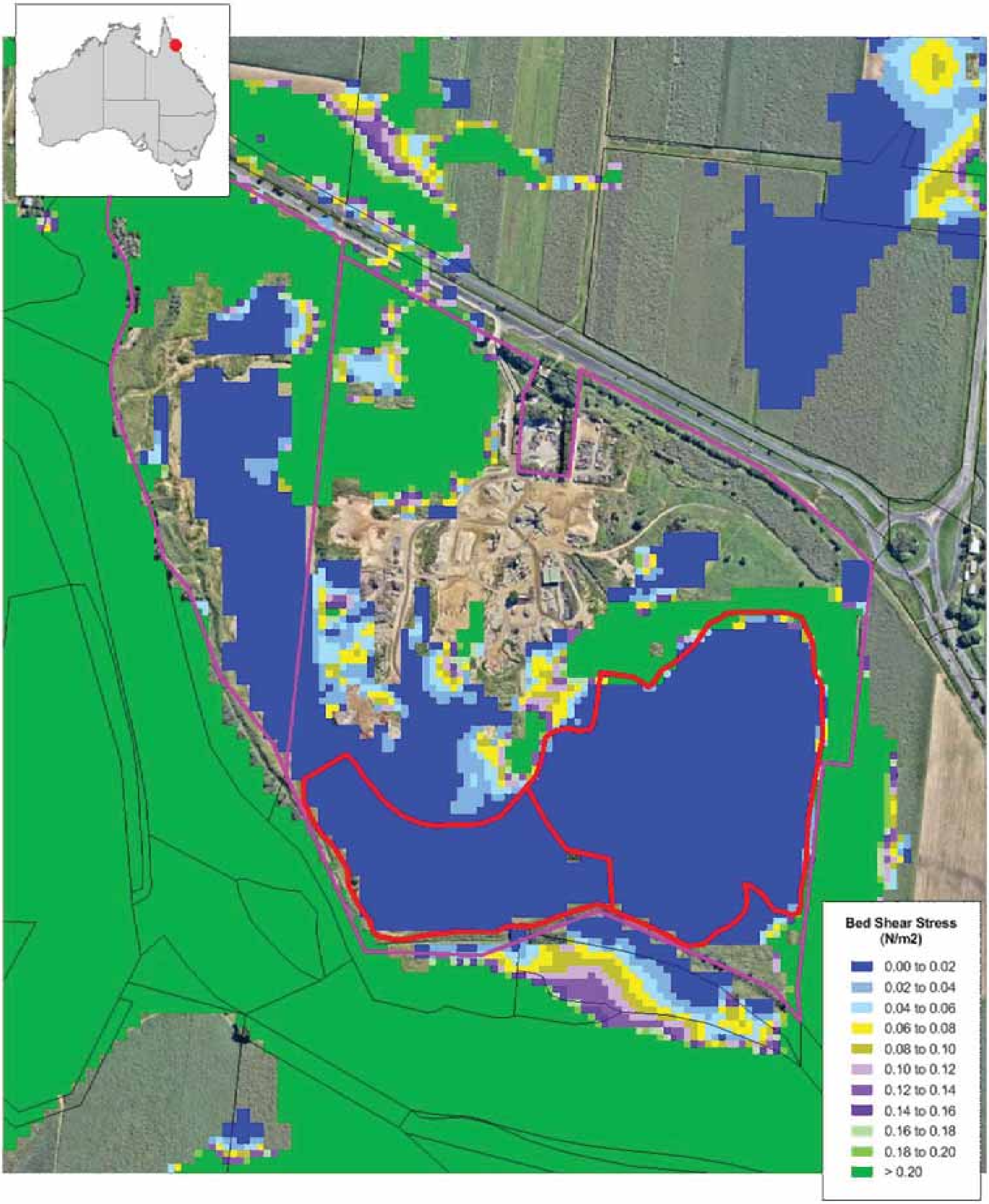

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 2 Year Bed Shear Stress

Figure: **D-7**

Rev: **A**

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N

0 100 200
metres

BMT WBM

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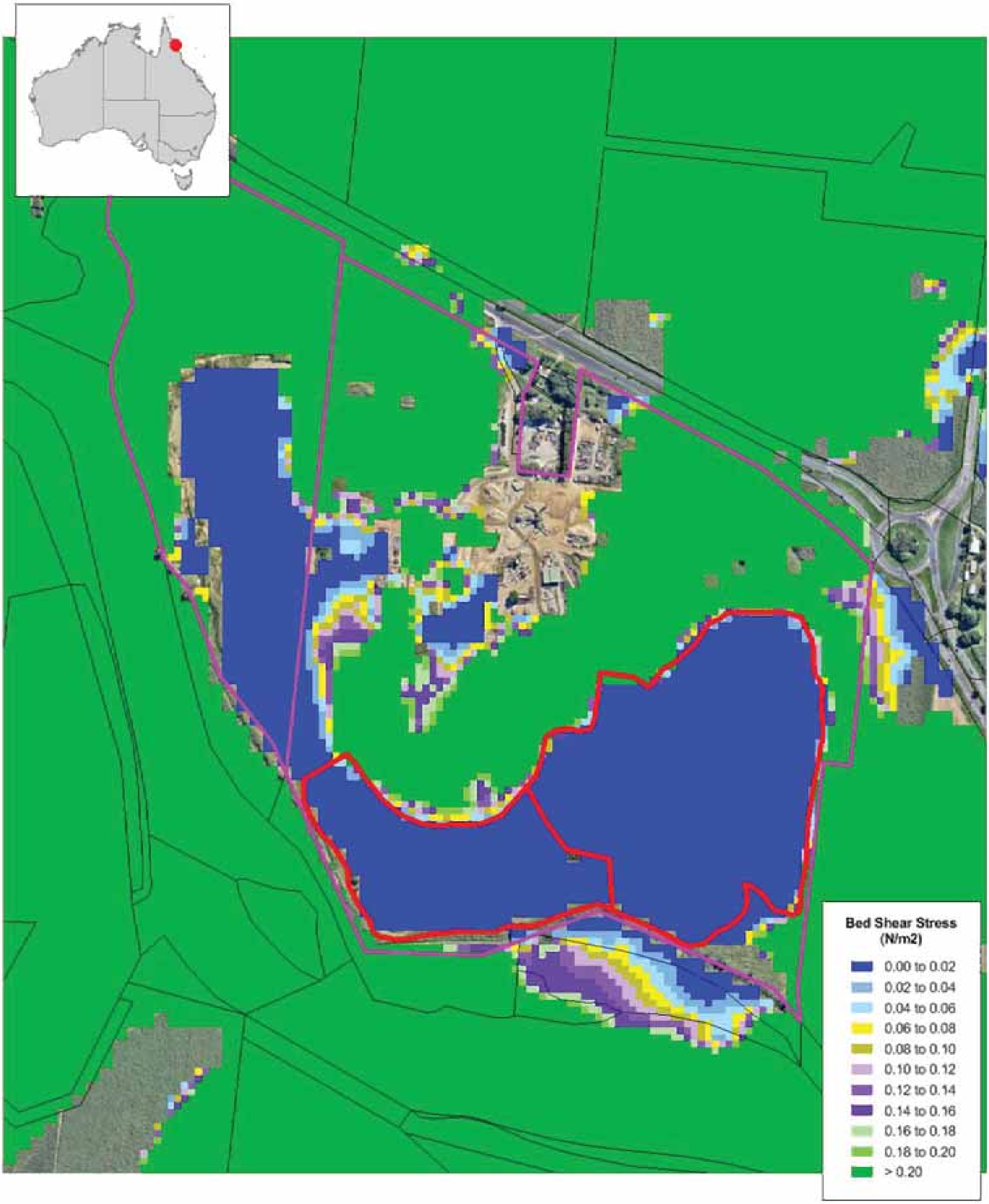

Title:	Figure:	Rev:
Northan Sands Disposal Site **Q50 Bund - ARI 5 Year Bed Shear Stress**	**D-8**	**A**

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0 100 200
metres

BMT WBM

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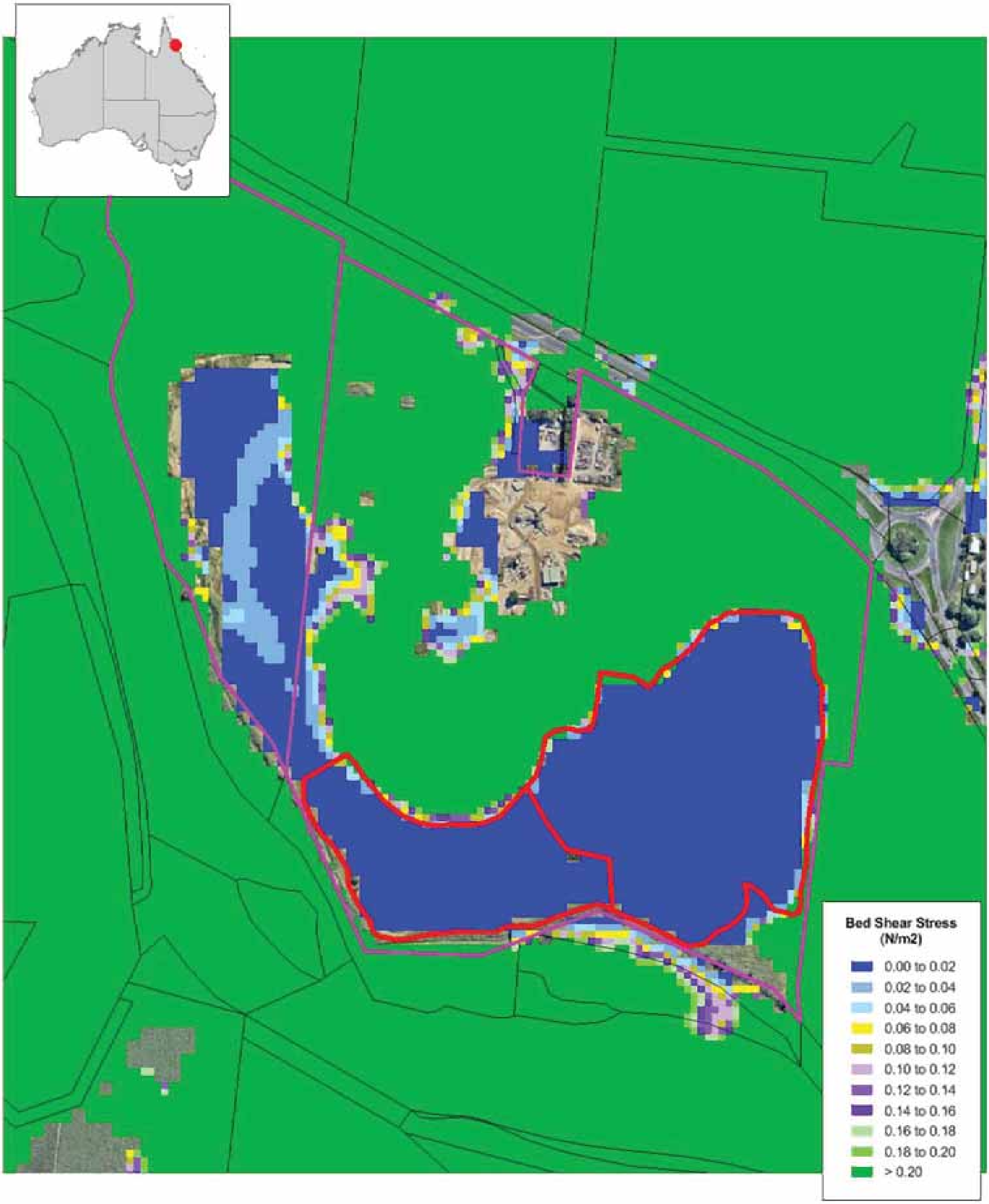

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 10 Year Bed Shear Stress

Figure: **D-9**

Rev: **A**

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metres

BMT WBM

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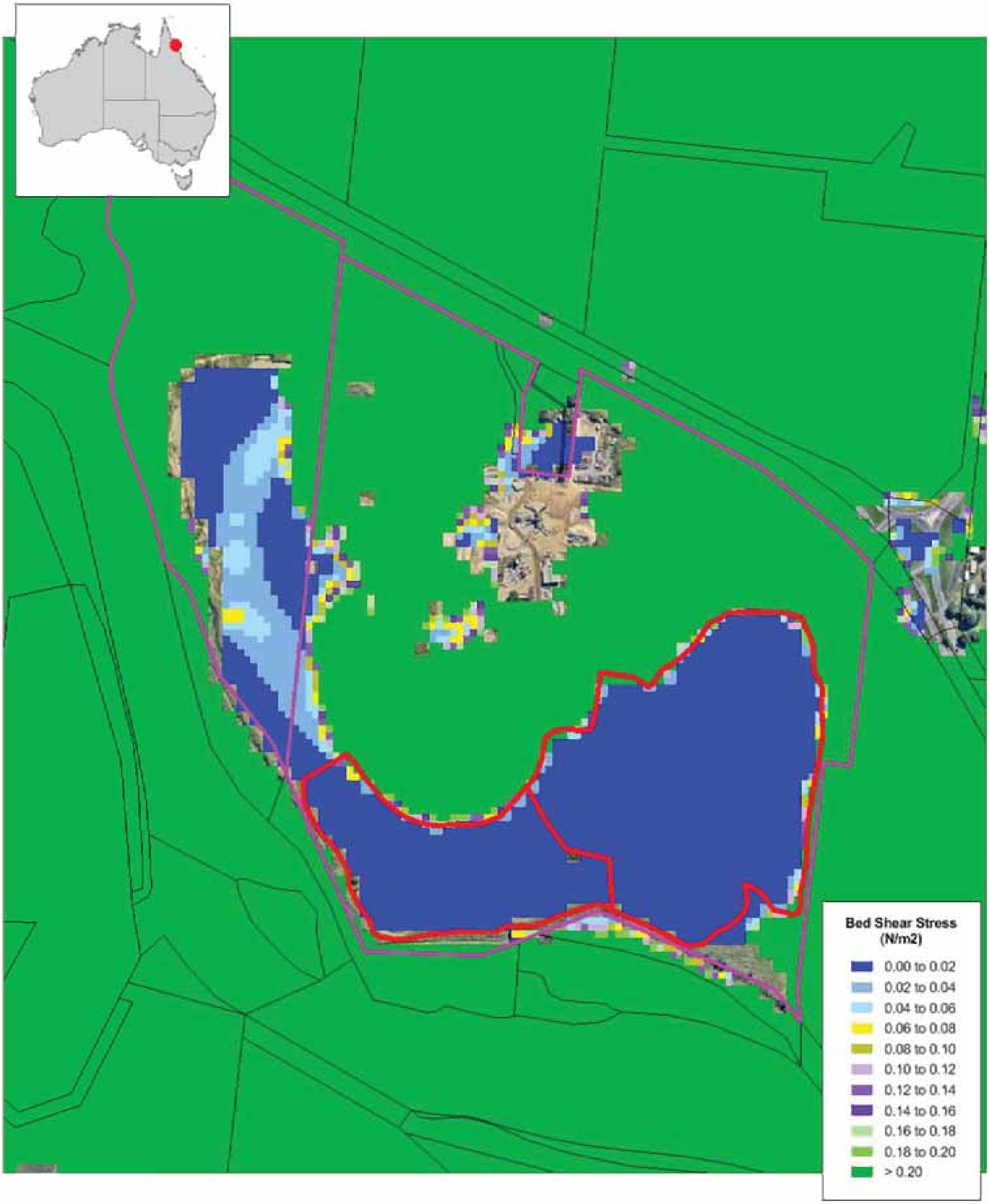

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 20 Year Bed Shear Stress

Figure: **D-10**

Rev: **A**

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metres

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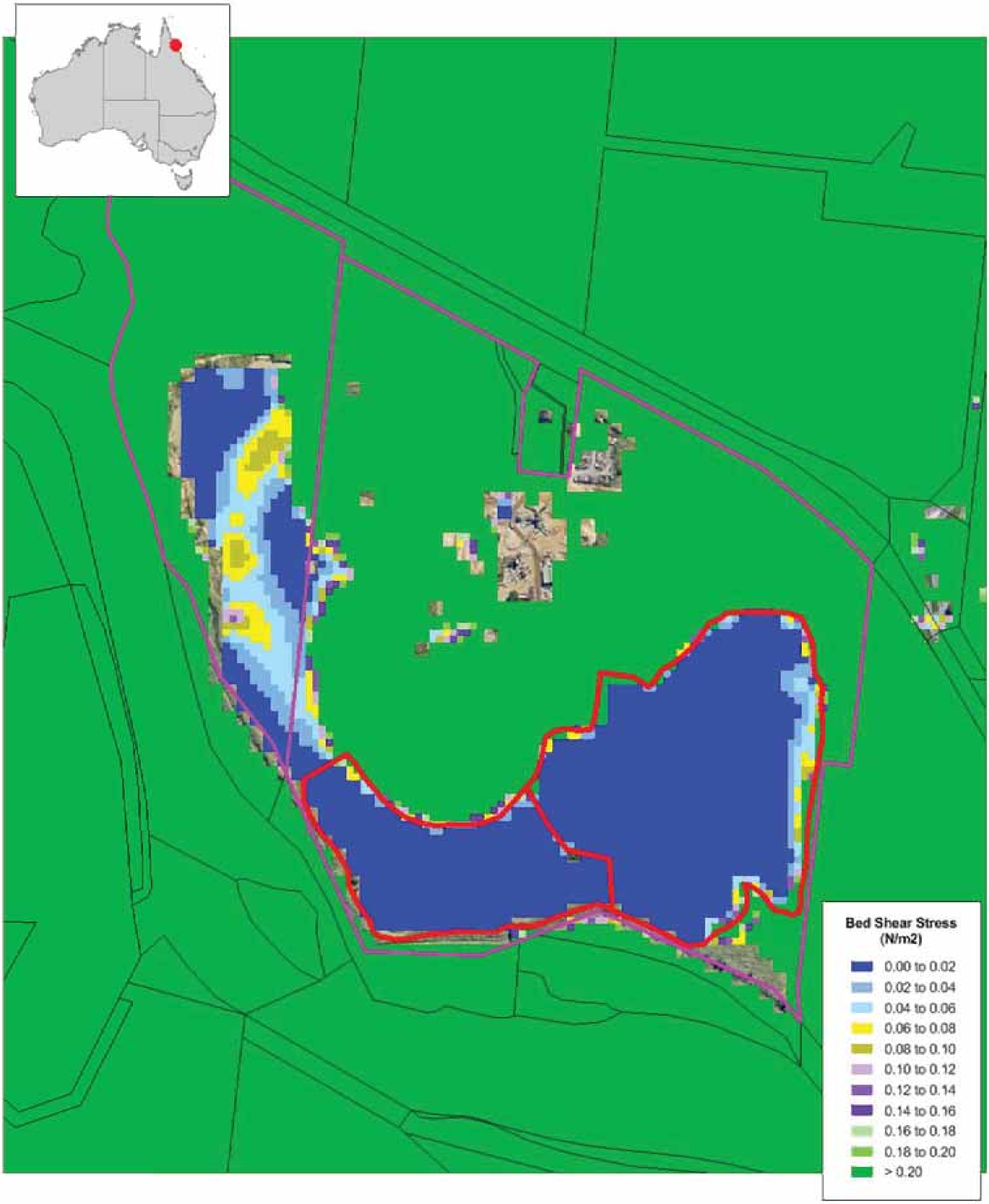

Title:

Northan Sands Disposal Site
Q50 Bund - ARI 50 Year Bed Shear Stress

Figure: **D-11**

Rev: **A**

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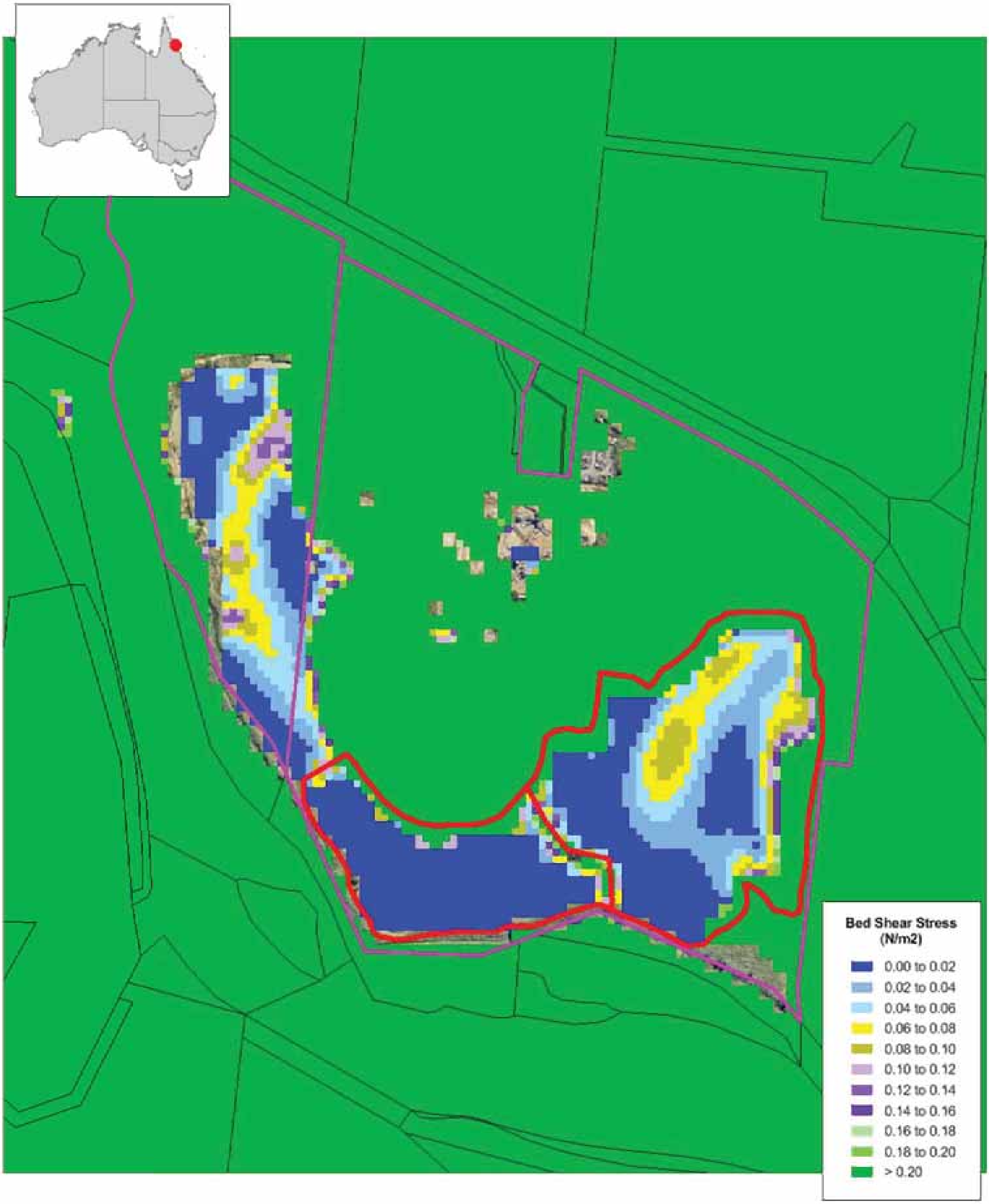
N

0 100 200
metres

BMT WBM



Title:

Northan Sands Disposal Site
Q50 Bund - ARI 100 Year Bed Shear Stress

Figure: **D-12**

Rev: **A**

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0 100 200
metres

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