DOUGLAS SHOAL

PRELIMINARY SITE ASSESSMENT REPORT

Australian Government

Great Barrier Reef
Marine Park Authority

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Executive Summary

The Chinese bulk carrier 'Shen Neng 1 (Figure 1-1) ran aground on Douglas Shoal in April 2010 and caused the largest known direct impact on a coral reef (within the Great Barrier Reef World Heritage Area) by a ship grounding' (GBRMPA, 2015).

Following the court settlement associated with the grounding incident, the Great Barrier Reef Marine Park Authority (GBRMPA) established the Douglas Shoal Environmental Remediation Project. As part of a broad planning exercise, GBRMPA engaged Cardno to review 10 previously commissioned studies relating to the grounding of Shen Neng 1, and incorporate relevant data into an ArcGIS database.

This report presents the current consolidated state of knowledge regarding Douglas Shoal, including the environmental conditions and values.

Situated in approximately 40 m of water, Douglas Shoal is a non-biogenic, 'submerged shoal-reef' located approximately 90 km east of Yeppoon. The benthic substrate is predominantly hard limestone pavement (85%), with the remainder comprising gutters and holes filled with carbonate dominated rubble and sand. Benthic habitats are dominated by macro algae, with Sargassum abundant over 53% of surveyed tracks. A further 38% was classified as macro algae and filter feeder dominated communities, including various algal species, and hard and soft corals. A diverse assemblage of benthic invertebrate animals take advantage of these habitats.

The morphology of Douglas Shoal comprises a distinct 'Reefal Shoal Top', which includes a 'Low Relief Terrace' and a 'High Relief Terrace'. Undamaged benthic habitat within the grounding footprint are consistent with other areas of Douglas Shoal.

On 3 April 2010, Shen Neng 1 grounded on Douglas Shoal, moving across some 42 hectares during the 10 days before she was re-floated and towed away. The vessel suffered extensive plate damage during the grounding, which comprised plate indentation, push-up, buckling and cracking. The rudder was slightly damaged but the propeller was not.

Underwater inspection and sampling of the hull was undertaken some 6 weeks following the grounding incident indicated that damaged sections of the hull showed evidence of significant paint loss. Chemical analysis of paint samples confirmed the presence of active (biocide) ingredients including tributyltin, zinc oxide and copper oxide, copper pyrithione and zineb at environmentally significant concentrations.

Data provided by GBRMPA were used to develop a series of figures and maps that broadly define the nature and scale of physical damage and contamination associated with the grounding incident. Importantly, most physical damage and contamination is situated in a single low relief morphological zone at the western end of Douglas Shoal. These figures also show extensive areas of contamination associated with antifouling paint particles.

While no data are available for 77% of the grounding footprint, the distribution of physical damage and contamination is focussed at four quite distinct areas. These distinct areas, annotated A, C, E and F are predominantly within the grounding footprint and represent priorities for further investigation and possible remediation.

A number of important data and information gaps were identified which may require consideration before any remediation works commence. These include mapping of each priority area to help establish specific remediation objectives and project success criteria.

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Glossary of commonly used terms

The glossary below provides definitions for terminology used throughout this report.

Antifouling Paint: *A marine paint composition containing Biocides, which prevent or retard fouling or growth on vessel hulls.*
Antifouling Paint Particle: *a particle antifouling paint abraded from the hull of Shen Neng 1*
Benthic: *The bottom of the seafloor which includes the collection of organisms living on or in the bottom*
Biocide: *The active ingredient in Antifouling Paint that prevent the settlement, adhesion and growth of organisms to a painted surface Biocides may include heavy metals, organometallics, herbicides and pesticides.*
Fauna: *the animals of a particular region, habitat, or geological period*
Geomorphology*: Scientific study of landforms and the processes that shape them. (Australia State of the Environment Report 2011)*
Geomorphic Zone: *a zone with discrete morphological features*
Georeferenced: *Geographic data aligned to a known coordinate system (ESRI 2017)*
Grounding Footprint: *The area of Douglas Shoal over which the Shen Neng 1 moved during the incident*
Habitat: *The environment occupied by an organism or groups of organisms. (Adapted from EPBC Act)*
High Relief Terrace*: a morphological zone of Douglas Shoal comprising high relief gutters and holes. Part of the Reefal Shoal Top*
Impact: *An event or circumstance which has an effect, either positive or negative, on a value*
Incident: *The events associated with the grounding, refloating and salvage of Shen Neng 1*
Indirect impact: *An impact that is not the direct result of a particular action but has been made possible by that action. These include downstream or upstream impacts, as well as facilitated or consequential impacts resulting from further actions (including actions by third parties. Indirect impacts may manifest over the longer term.*
Low Relief Terrace: *a morphological zone of Douglas Shoal comprising low relief features such as gutters and holes. Part of the Reefal Shoal Top*
Macro algae: *a collective term used for seaweeds and other benthic marine algae that are generally visible to the naked eye*
Marine Park: Great Barrier Reef Marine Park
Matters of national environmental significance: *Those matters defined in the Environment Protection and Biodiversity Conservation Act 1999*
Mean Low Water: *The average of all the low water heights observed over a 19-year period*
Morphology: *The form and structure of animals and plants, without regard to their functions*
Natural Recovery: *recovery of a system without active intervention*
Nature: *In this report, the location and type of physical damage or a contaminants chemical or physical properties*
Non-biogenic: *non-reef building*
Outstanding universal value: *Cultural and/or natural heritage which is exceptional as to transcend national boundaries and to be of such significance to humanity as a whole to make it worthy of special protection. (Adapted from Operational guidelines for the implementation of the World Heritage Convention)*
Protected species: *A species that is prescribed as endangered wildlife, vulnerable wildlife or rare wildlife under the Nature Conservation Act 1992 (Qld); as defined in the GBRMP Act*
Reefal Shoal Top: *Morphological zone, top of Douglas Shoal. Comprises a Low Relief Terrace and a High Relief Terrace*
Reefal Shoal Slope*: Morphological feature or zone. Gentle and or steep slope of a shoal*
Rehabilitation: *the act of partially or, more rarely, fully replacing structural or functional characteristics of an ecosystem that have been diminished or lost, or the substitution of alternative qualities or characteristics than those originally present with the proviso that they have more social, economic or ecological value than existed in the disturbed or degraded state*
Remediation: *the act or process of remedying or repairing damage including the removal of contamination and / or pollutants.*
Resilience: the capacity of an ecosystem to recover from disturbance or withstand ongoing pressures
Responsible party: *The owner and insurers of Shen Neng 1*

Restoration: *the act of bringing a degraded ecosystem back into, as nearly as possible, its original condition*
Risk: *effect of uncertainty on objectives (Australian Standard for Risk Assessment (AS/NZS ISO 31000:2009))*
Submerged Reefal Shoal: *Reefs not at modern sea level, but with some growth over the older foundations*
Substrate: *the surface or material on or from which an organism lives, grows, or obtains its nourishment (Merriam-Webster 2017)*
Traditional Owner: An Indigenous person recognised in the Indigenous community or by a relevant representative Aboriginal or Torres Strait Islander body as having spiritual or cultural affiliations with a site or area in the Marine Park, or as holding native title in relation to that site or area; and who is entitled to undertake activities under Aboriginal or Torres Strait Islander custom or tradition in that site or area
Value: Those aspects or attributes of an environment that make it of significance
Vessel – *Shen Neng 1*
World Heritage Area: Great Barrier Reef World Heritage Area
Zones of influence: Areas where impacts have detectable effects on values

Acronyms

AMSA: *Australian Marine Safety Authority*
AFP particle: *Antifouling paint particle*
AFP: *Antifouling paint*
ATSB: *Australian Transport Safety Bureau*
C'th: *Commonwealth*
DPSIR: *Driver, Pressure, State, Impact, Response framework*
GBRMP: *Great Barrier Reef Marine Park*
GBRMPA: *Great Barrier Reef Marine Park Authority*
GBRWHA: *Great Barrier Reef World Heritage Area*
MLW: *Mean Low Water*
Sp.: *Species*
TBT: *Tributyltin*

1 Introduction

1.1 Background

The Chinese bulk carrier Shen Neng 1 (Figure 1-1) ran aground on Douglas Shoal in April 2010 and caused the largest known direct impact on a coral reef by a ship grounding (GBRMPA, 2015).

The Great Barrier Reef Marine Park Authority (GBRMPA) established the Douglas Shoal Environmental Remediation Project (the project) in late 2016 with funds from a court settlement associated with the grounding incident.

The primary objective of the Douglas Shoal Environmental Remediation Project (the project) is to "*ensure that settlement funds provided by the responsible party deliver the greatest long-term environmental benefits*". The project will focus on maximising the chances for natural recovery and minimising the environmental and human risks of remediation activities[1].

As part of a broader planning exercise, the Douglas Shoal Environmental Remediation Project team (the project team) identified the need to synthesise findings from 10 studies (Table 1-1) commissioned by GBRMPA between 2010 and 2016[2] and compile a Preliminary Site Assessment Report. GBRMPA engaged Cardno in July 2017 to assist the project team deliver this report.

Figure 1-1 Shen Neng 1 aground on Douglas Shoal – 4 April 2010 (AMSA 2010)

1.2 Purpose and Intended Audience

The purpose of this Douglas Shoal Preliminary Site Assessment Report ('this report') is to:

- Present the current consolidated state of knowledge regarding Douglas Shoal, including the:
  - Environmental conditions and values (pre and post incident)
  - Nature and scale of physical damage associated with the grounding incident
  - Nature and scale of contamination associated with the grounding incident

[1] Objectives and performance indicators for the Douglas Shoal Environmental Remediation Project are included in Appendix A

[2] Excluded from this review - data and reports commissioned by the responsible party.

- Identify possible priority areas for remediation
- Identify critical information gaps that represent risks to the successful delivery of key project objectives, including the effective planning of remediation activities.

The intended audience include:

- Great Barrier Reef Marine Park Authority staff, project team members and the Great Barrier Reef Marine Park Authority Board
- Partner agencies, research institutions and interested members of the public
- Potential contractors.

1.3 Scope

Cardno's scope comprised the following:[3]:

1. Compile a summary table of previous studies, site visits and reports (existing information)
2. Prepare a report plus supporting maps or diagrams summarising what is known about:
   a) Douglas Shoal pre-disturbance (inferred), including typical habitat type(s), the values present and their condition
   b) The typical oceanic and meteorological conditions at Douglas Shoal
   c) The location and nature of disturbance (e.g. cause, width, depth) at Douglas Shoal caused by the Shen Neng incident, including any observed changes in habitat type(s) or the condition of values in impacted areas
   d) The location, extent, composition, concentration and migration of grounding-generated antifouling paint particles, and its environmental impacts that have been observed (past/present) and have been predicted (future)
   e) The location, extent, composition and migration of grounding-generated rubble, and its environmental impacts that have been observed (past/present) and have been predicted (future).
3. Based on (a) to (e):
   f) Possible priority geographical areas of Douglas Shoal for remediation
   g) Critical knowledge gaps that pose a major risk to successful remediation of Douglas Shoal.
4. In addition to the above, GBRMPA requested Cardno:
   h) Create a project specific geographic information (GIS) dataset comprising information available to the project
   i) Prepare any maps, figures and tables required to support the development of this Preliminary Site Assessment Report.

Explicitly excluded from Cardno's scope of work were:

- Fieldwork or site visits to Douglas Shoal
- Scientific review or critique (critical assessment) of GBRMPA-commissioned studies
- Literature review or research into the potential environmental impacts of antifouling paint or rubble on natural recovery of tropical marine environments
- Literature review or research into possible remediation methods.

1.4 Approach

Cardno's team, data / information sources used, and the approach to develop this report are summarised below with further detail provided in each section (where required).

[3] See Appendix B for a copy of GBRMPA's request for quote

1.4.1 Cardno's Team

Prior to the project inception meeting, Cardno established a team comprising specialist staff to deliver the scope of work. The project team was led by Andrew Costen, who worked closely with GBRMPA's project manager. CV's for Cardno staff are included in Appendix C.

1.4.2 Key Terms

Where possible, language and key terminology used in this report, reflects that found in the *Great Barrier Reef Strategic Assessment: Strategic Assessment Report* (GBRMPA, 2014). A glossary of terms is provided.

1.4.3 Data and Information Sources

A list of GBRMPA-commissioned site assessments, reviews and reports provided to Cardno are included in Table 1-1. GBRMPA also provided Cardno with 35.9 gigabytes of electronic data relating to the grounding of Shen Neng 1. This data included 10,672 files sorted into 164 different folders.

1.4.4 Synthesis of Data and Information

This task, largely a desk top exercise comprised:

- A review of written reports listed in Table 1-1 and the development of a summary table
- A search for relevant and publicly available information and data
- Sorting the GBRMPA-provided electronic data and building a GIS database for this project
- Interrogation of data within the GIS database and development of consolidated maps and figures for use in this report.

The structure and content of the project GIS database is shown in Appendix D. References for publically available information and data, where used to support the development of this report, are included in Section 7. Photos that appear in this report are supplied by GBRMPA or other organisations where noted. Data sources for figures developed by Cardno have been referenced accordingly. Build reports for figures and maps are provided in Appendix E.

1.4.5 Information Gaps and Risks

A key task for Cardno, was identifying critical information gaps, and rating these gaps as risks to the project realising its objectives.

In this report, a 'gap' refers to the space between "where we are" (the present state) and "where we want to be" (project success). In other words, the gap between what is known about the grounding of Shen Neng 1, and what information is needed to effectively plan and implement remediation works.

The "what we know" component is essentially the information presented in sections 2, 3, 4 and 5 of this this report. Qualitative descriptions of key gaps and uncertainties are provided at the conclusion of each section.

In order to systematically identify information gaps that may present a risk to project success (the "where we want to be" component), Cardno completed a literature search to identify information needs for the effective planning of ship grounding remediation activities. No specific guidelines for the remediation of coral reefs were identified. Following discussions with Cardno land remediation specialists, and consultation with the project team, it was decided to evaluate identified information gaps (for each section of this report) as risks to remediation planning and monitoring of remediation (the likely next phases of the project). This approach is deliberately descriptive and qualitative.

GBRMPA's Integrated Risk Rating Tool (Rev 4) was used to assign risk levels for identified information gaps. Risks are presented as untreated. However, suggested treatment actions are included. Further detail is provided in Section 6 of this report.

Table 1-1 GBRMPA-commissioned site investigations and reports

Year	Report Title	Citation
2010	*Structural Damage to Douglas Shoal Caused by Grounding of Shen Neng 1 - Derived from High-resolution Multibeam Sonar Bathymetry and Backscatter Strength (data only)*	Stieglitz 2010
2010	*Grounding of the Shen Neng 1 on Douglas Shoal: Multibeam Sonar Bathymetry and Towed Video Assessments*	Negri et al. 2010
2010	*Preliminary Impact Assessment: Grounding of the Shen Neng 1 on Douglas Shoal Great Barrier Reef - Summary*	Marshall 2010
2010	*Shen Neng 1 Hull Sampling: 21 May 2010*	Monkivitch 2010
2011	*Grounding of the Shen Neng 1 on Douglas Shoal, April 2010: Impact Assessment Report*	GBRMPA 2011
2011	*Independent Review of Impact Assessment Report "Grounding of the Shen Neng 1 on Douglas Shoal, April 2010"*	Kettle 2011
2014	*October 2013 Reef Damage Reassessment of the Shen Neng 1 Grounding Site, Douglas Shoal, Great Barrier Reef, Australia**	Kettle 2014
2015	*Remediation Trial for the Shen Neng 1 Grounding Site, Douglas Shoal, Great Barrier Reef, Australia.**	Kettle 2015[a]
2015	*Supplementary Report: Remediation Trial for the Shen Neng 1 Grounding Site, Douglas Shoal, Great Barrier Reef, Australia.**	Kettle 2015[b]
2016	*Douglas Shoal Trophic Contamination Survey*	Marshall 2016

*Reports produced by Dr Brett Kettle between 2014 and 2015 were provided to Cardno in redacted form.

1.5 Report Structure

The structure and content of this report is shown in Table 1-2. Where possible, call out boxes, tables and figures are used to help expedite review and relay key messages. Supporting information is provided in a series of appendices. Identified information gaps are listed at the end of Sections 2 through 5 and consolidated in Section 6.

1.6 Assumptions and Limitations

Please note the following qualification when reading this report:

- It is not the intention of this report to present the results of previous studies in their entirety, nor is it a critical review of GBRMPA-commissioned investigations and reports
- Interpolations, predictions of damage (for example predictions of the possible migration of AFP), are not included (however, reference is made to the potential for migration)
- Figures / maps (herein) incorporate georeferenced data from the project GIS only
- While based on georeferenced data, locations of data reflect the inaccuracies associated with the original source.

Where required, additional qualifications are included in each section.

Table 1-2 Report structure / concordance with scope

Section		Content and Purpose
1	Introduction	- Context, approach and structure of this report
2	Setting, Values and Condition	- Provides an overview of management arrangements for the Marine Park (relevant to Douglas Shoal) - Describes the Marine Park Values of Douglas Shoal - Likely pre-disturbance (inferred/interpreted) condition of Douglas Shoal, including substrate, habitats and biota - Identifies gaps and uncertainties that may represent a risk to remediation planning and monitoring.
3	Incident Summary	- Provides a synopsis of the grounding of Shen Neng 1 - Includes a summary of damaged sustained by Shen Neng 1 - The purpose of this section is to help contextualise the description of physical damage and antifouling paint contamination associated with the grounding incident (Section 4) - Identifies gaps and uncertainties that may represent a risk to remediation planning and monitoring.
4	Physical Damage and Contamination	- Summarises the results of damage to Douglas Shoal and contamination reported in GBRMPA-commissioned studies / reports - Presents a series of figures / maps that incorporate relevant and available georeferenced data - Describes the nature and scale of physical damage and contamination associated with the grounding incident (as shown in supporting figures) - Informs the identification of possible priority areas for remediation - Identifies gaps and uncertainties that may represent a risk to remediation planning and monitoring.
5	Possible Priority Areas for Remediation	- Identifies and describes possible priority areas of Douglas Shoal for remediation - Identifies gaps and uncertainties that may represent a risk to remediation planning and monitoring.
6	Critical Information Gaps and Risks	- Presents the results of the gap analysis - Evaluates the identified gaps as risks - Includes suggestions to ameliorate risks
7	References	
Appendices		

2 Setting, Environmental Values and Condition

2.1 Overview

This section:

- Includes locational information
- Provides and overview of management arrangements for the Marine Park (relevant to Douglas Shoal)
- Describes the Marine Park Values of Douglas Shoal
- Includes a description of the likely pre-disturbance (inferred/interpreted) condition of Douglas Shoal, including substrate, habitats and biota.

The purpose of this section is to:

- Identify the Marine Park Values likely affected by the grounding incident
- Help guide future discussions regarding what 'natural recovery' may look like for areas of Douglas Shoal impacted by the grounding incident
- Inform future contractors regarding working conditions at the site (potential constraints)
- Identify gaps and uncertainties that may represent a risk to remediation planning and monitoring.

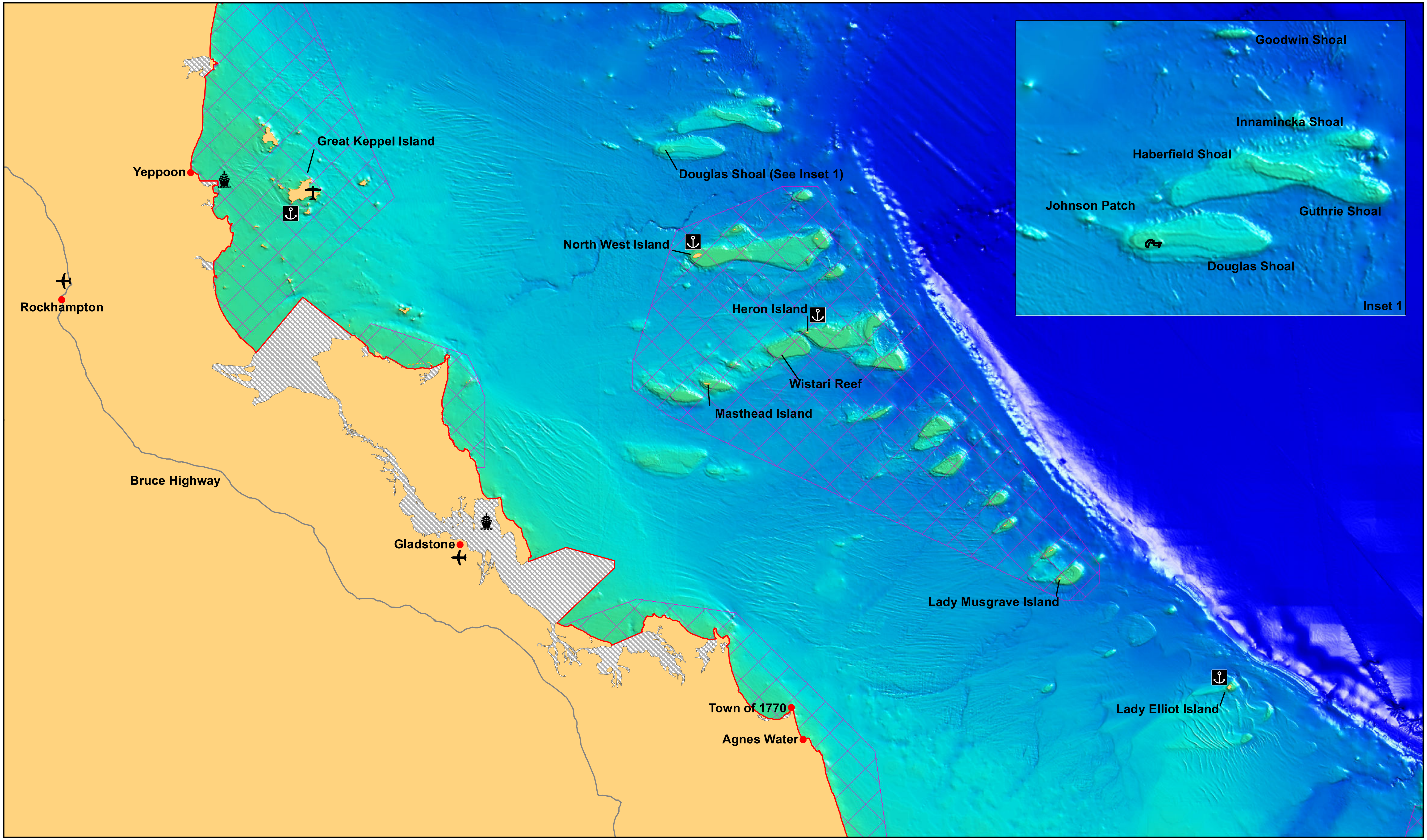
Key points are presented below. Identified gaps are included at the end of this section.

Key Points

- Douglas Shoal is in the sea country of the Gooreng Gooreng, Gurang, Byellee and Tarebilang Bunda people.
- Situated in approximately 40 m of water, Douglas Shoal is a non-biogenic, 'submerged shoal-reef' located approximately 90 km east of Yeppoon.
- The benthic substrate is predominantly hard limestone pavement (85%), with the remainder comprising gutters and holes filled with carbonate dominated rubble and sand.
- Benthic habitats are dominated by macro algae, with *Sargassum* abundant over 53% of surveyed tracks. A further 38% was classified as macro algae and filter feeder dominated communities, including various algal species, and hard and soft corals.
- A diverse assemblage of benthic invertebrate animals take advantage of these habitats.
- The morphology of Douglas Shoal comprises a distinct 'Reefal Shoal Top', which includes a 'Low Relief Terrace' and a 'High Relief Terrace'.
- The grounding footprint is situated entirely within the Low Relief Terrace.
- Undamaged benthic habitat within the grounding footprint are consistent with other areas of Douglas Shoal.
- Pelagic and coral associated fish are common.
- Other vertebrate taxa observed included turtles, dolphins and large stingrays, with abundant sea snakes.
- Trawling is prohibited over most of Douglas Shoal (Habitat Protection Zone), however, commercial line fishers targeting coral trout and Spanish mackerel may work the area.
- Due to the exposed location of Douglas Shoal, it is unlikely that it is heavily visited by tourism operators. However, it holds considerable value to recreational fishers who visit it during calmer conditions.

2.2 Location

Douglas Shoal is situated within the 'Southern Region' of the Great Barrier Reef, which extends from 20° S to 24° S and includes the Swains Reefs and the Capricorn-Bunker group. Douglas Shoal is located approximately 90 km east of Yeppoon (151º40'E, 23º5'S), and north of the Capricorn Group of reefs and islands (Figure 2-1). Table 2-1 identifies distances to anchorages, coastal ports and harbours.



Legend

- Airfield
- Airport
- Anchorage
- Marina/Port/Harbour
- Location of Douglas Shoal
- Town
- Bruce highway
- Great barrier reef marine park boundary
- Grounding footprint
- Great barrier reef marine park exclusion area
- Shipping exclusion area
- Land

Bathymetry (eAtlas)

250 m -220 m

Douglas Shoal - Location

FIGURE 2 - 1

Not to be used for navigation.
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N

1:750,000 Scale at A3

Kilometres

0 10 20 30

Map Produced by: NSW Water & Environment
Date: 2017-10-13
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: 2_1_DouglasShoalLocation.mxd 01

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\2_1_DouglasShoalLocation.mxd

Build Sheet: Appendix E

Table 2-1 Distances to known anchorages, ports and harbours

Place	Kilometres (km)	Nautical Miles(NM)
Lady Musgrave Island	117.4	63.4
Gladstone	93.3	50.4
Heron Island	47.32	25.5
Northwest Island	23.5	12.7
Great Keppel Island	72.5	39.1
Yeppoon	93.6	50.5

2.3 Management Arrangements

GBRMPA uses a wide range of tools to manage the Marine Park. Key instruments are summarised below. Further details are available at www.gbrmpa.gov.au

2.3.1 Key Legislation

Douglas Shoal is one of the 2900 reefs and shoals within the Marine Park and the Great Barrier Reef World Heritage Area (GBRWHA). The Marine Park is managed by the Great Barrier Reef Marine Park Authority. Key legislation includes the *Great Barrier Reef Marine Park Act (1975*) the *Great Barrier Reef Marine Park Regulations (1983)* and the *Environment Protection and Biodiversity Conservation Act (1999)*.

2.3.2 Marine Park Zoning

The Great Barrier Reef Marine Park is a multiple-use area. *The Great Barrier Reef Marine Park Zoning Plan 2003*[4] provides for a range of ecologically sustainable recreational, commercial and research opportunities and for the continuation of traditional activities. Zoning helps to manage and protect the values of the Marine Park that people enjoy. Each zone has different rules for the activities that are allowed, the activities that are prohibited, and the activities that require a permit. Zones may also place restrictions on how some activities are conducted.

Most of Douglas Shoal falls within the Habitat Protection Zone (HPZ); however, a small part of the northern and eastern shoal margins falls within the General Use Zone (GUZ). The grounding footprint is located entirely within the HPZ. For a map showing the zoning, see:

http://elibrary.gbrmpa.gov.au/jspui/bitstream/11017/609/4/Map17-EditionV-Capricorn.pdf

The objectives of the HPZ are to provide for the conservation of Douglas Shoal through the protection and management of sensitive habitats by being generally free from potentially damaging activities while providing opportunities for its reasonable use. A notable difference between HPZ and GUZ is that trawling is prohibited in HPZ, as the focus is on protecting sensitive benthic habitat. This is relevant as the grounding incident specifically damaged sensitive benthic habitat that the Zoning Plan aims to protect.

2.3.3 Relevant Policies

The following policies are likely to be relevant to the project and can be found on GBRMPA's website:

- *Policy on moorings in the Great Barrier Reef*
- *Dredging and spoil disposal policy*
- *Guidelines for the use of hydrodynamic numerical modelling for dredging projects in the Great Barrier Reef Marine Park*.

2.3.4 Regulatory Environment

A range of permits, licences and approvals may be required for remediation-related activities. These include:

- Permits or authorisations for carrying out works and/or conducting research under the Great Barrier Reef Marine Park Zoning Plan 2003

[4] Great Barrier Reef Marine Park Zoning Plan 2003 GBRMPA (2004)

- Approval under the Environment Protection (Sea Dumping) Act 1981 for dumping at sea of material including the placement of materials to form artificial reefs.
- Local or State approvals for land-based, coastal or island activities.

Additionally, once a remediation plan is developed, the project team will evaluate whether the proposed works may require referral to the Federal Minister for the Environment under the Environment Protection and Biodiversity Conservation Act 1999 (C'th).

2.4 Great Barrier Reef Marine Park Values

The Great Barrier Reef Marine Park is one of the seven relevant matters of national environmental significance (GBRMPA 2014). The values of the Marine Park are grouped into four categories:

1. Biodiversity values including physical processes, geomorphology, habitats and marine fauna species
2. Traditional Owner heritage values
3. Historic heritage values
4. Social and economic values.

2.5 Biodiversity Values

2.5.1 Physical Processes

Key Information and Data Sources

The Commonwealth Bureau of Meteorology (BOM) maintains weather stations on Heron Island, North Reef and Lady Elliot Island and has recorded data since 1963. The Great Barrier Reef Ocean Observing System (GBROOS) sensor located on Heron Reef provides current and historic weather information including air and water temperature, humidity, pressure, rainfall and wind speed and direction.

Maxwell (1968) and Hopley (1982) summarised the hydrology of the Great Barrier Reef and Wolanski (1994) reviewed its oceanography and hydrodynamics. Marshall (1977), and Hopley et al (2007) provided general details for the Capricorn-Bunker Group.

An analysis of the hydrodynamic conditions for three-16-day periods (during 2015) was undertaken by Cardno using data obtained from the eReefs website's data portal.

Observations relating to physical conditions (weather, currents) experienced at Douglas Shoal during site visits were recorded by Marshall 2010, GBRMPA 2011 and Kettle 2011, Kettle 2014(a) and Marshall 2016. These observations are summarised in Table 2-2 and provide useful qualitative information.

Historic wave and current data are available from the Great Barrier Reef Ocean Observing System (GBROOS) portal: http://data.aims.gov.au/gbroos

Climate and Weather

The climate is subtropical with summer conditions occurring around November / December to May and slightly milder (winter) conditions between June and late October. The yearly mean temperature is 24.5°C. Monthly average maximums range from 21.5 to 30°C and minimums from 16.5 to 24.2°C. Sea-surface temperatures vary from a summer maximum of 27°C, to a winter low of 21.5°C (AIMS, 2014).

Rainfall averages 1047 mm (BOM 2017), with December to May the wettest months. June to September is the driest period of the year, as anticyclones that track east across the Australian continent at this time bring mostly calm and settled conditions to region. The wind regime is dominated by the southeasterly trade winds, while a more westerly component develops during winter following the passage of cold fronts over southern Australia. Wind direction becomes more variable in summer with the occurrence of occasional strong northeasterlies, although southeasterly winds still dominate. The strongest winds are associated with the passage of tropical cyclones during the summer.

For weather forecast information see: www.bom.gov.au/qld/forecasts/map.shtml

Regional Oceanographic Conditions

Prevailing currents are driven by the tides and wind forcing, with the contribution from wind forcing being proportional to the wind strength.

During periods of south-south easterly winds, flow on the inner- and mid-shelf is predominantly north-north-west with tidal motion superimposed on the wind driven circulation. On the outer shelf, the flood tide sets west and the ebb east, producing strong currents through the Capricorn reefs.

Swell and wind waves from the east and southeast provide the greatest sources of wave energy to Douglas Shoal. Large southerly swells refract around Fraser Island and the southern tip of the Capricorn Bunker to Douglas Shoal, but wave heights are significantly reduced during this refraction. Guthrie and Innamincka Shoals to the north-east offer little protection from east to southeast swells and seas, which frequently reach 2-3 m in height east of the Capricorn-Bunker Group, and occasionally become much larger during storm and cyclone events.

Wind, Currents and Tidal Measurements

An analysis of hydrodynamic conditions was undertaken using data obtained from the eReefs website's data portal. This interactive platform provides access to a diverse range of modelled and measured data for the Great Barrier Reef, including the CSIRO's GBR1 shelf model, a 1km resolution model that integrates hydrodynamics, biogeochemistry and sediment processes.

The hydrodynamic components were extracted from the nearest grid point to Douglas Shoal (~ 1 km to the south west of the grounding footprint) for three 16-day periods in February, June and October 2015. Plots for wind, wave and currents for February, June and October are included in Appendix F (Figures F-1, F-2 and F-3 respectively). This snapshot provides some context regarding variations in the hydrodynamic conditions due to tides and seasonality. Analysis of this hourly data set showed the following:

- Winds
  - Winds speeds on average, ranged between 2 m/s(~ 7 km/hr) and 15 m/s (54 km/hr)
  - Winds are predominantly from the south easterly and southerly direction\Strongest winds were found to be slightly higher during February with the maximum of 14.1 m/s (~ 50 km/hr)
  - Wind direction during June was more varied, ranging from south to south easterly, while directions remained reasonably constant from south east during February and October.
- Currents
  - The current appears to the largely bidirectional along the north westerly- south easterly plane.
  - Magnitudes range between 0.1 m/s (0.194 knots) to 0.8 m/s (1.55 knots)
  - Magnitudes drop off significantly (<0.5 m/s or less than 1 knot) during the neap tides
  - Current magnitudes are highest during the spring tides.
- Tides
  - The tides at Douglas Shoal range between -1.8 m AHD and 1.8 m AHD across two daily cycles
  - This tidal range was found to diminish slightly during October
  - Tidal range of approximately 1 m during neap tides and up to 3.6 m during spring tides
  - Tide times lag Gladstone tide times by approximately 30 minutes.

Tide forecasts for Heron Island are available here: https://www.tide-forecast.com/locations/Heron-Island-Australia/tides/latest

Site Visit Observations

Observations, including wind, wave and current conditions at Douglas Shoal and how they impacted field work are reproduced in Table 2-2. While unlikely to be representative of the full range of local oceanographic conditions, they do provide a useful description of some of the constraints to working at Douglas Shoal.

Table 2-2 Reported / Observed site conditions

Reference	Date of Site Visit	Reported / Observed Site Conditions
Stieglitz 2010	15-17 April 2010	- 'Adverse weather conditions reduced data quality (multibeam bathymetry and backscatter)'
Negri et al. 2010	15-18 April 2010	- 'Adverse weather conditions reduced the sensitivity and resolution of both sonar and towed video surveys' - Collection of sediment samples… 'was not attempted due to poor weather conditions' - 'Rough weather and strong currents precluded data collection in replicated transects' - 'Visual survey was severely limited by sea surface conditions and strong currents due to spring tides' - 'Prevailing sea conditions resulted in a meandering track intersecting the known position of the Shen Neng 1'
Marshall 2010	12-13 April 2010	- '…strong currents and rough seas….'
GBRMPA 2011	11-12 May 2010	- 'strong winds and resultant waves made it too difficult to manage diving operations, especially in such an exposed location, with no emergent reef or island for shelter'. - 'very strong tidal currents at Douglas Shoal make diving work very difficult except at the turn of the tides, when a 1-2 hour period of minimal water movement provided easier conditions' - 'The depth of the impact site (generally 12+ metres) is beyond snorkelling depth for all but very brief inspections, and limited scuba dive times due to limits for no-decompression diving' - 'The remoteness of the shoal from safety facilities (~7-8 hours travel) increased the need for margins of error in safety procedures especially regarding diving practices' - 'The variable nature of the substratum (shoal bottom), made it difficult to collect sufficient loose sediment in some areas'
Kettle 2011	12 May 2011	- 'Water currents are very strong at the site, and limit underwater work by divers to 1 – 1.5 hours per high or low tide' - Water depth….'14 m to 15 m of actual water depth, meaning that divers will run into bottom time limits, or will need to switch to nitrox gas mixes'
Kettle 2014	9-13 October 2013	- "Other than periods of moderate seas hampering surface operations, underwater conditions were comfortable for performing observations and sampling, and visibility was good"
Kettle 2015(a)	11-18 November 2014	- 'At 13 m to 16 m water depth, divers have approximately 50 minutes of breathing air before nitrogen builds to dangerous levels in the blood' - 'Visibility less than 15 m (typically)' - 'Water temperatures pose no risks to divers' - 'Currents and waves limit operational safety from time-to-time and the work method therefore needs to be adapted to making the most of favourable conditions'.
Marshall 2016	10-13 July 2016	- 'The site visit was undertaken 10-13 July 2016 during a period of favourable tidal and sea conditions'

Weather windows

Noting the above descriptions and the authors own experience on-site, metocean conditions are likely to impact field related remediation tasks. And while June through to October may present the best 'window' with regard to avoiding cyclones, careful planning and selection of appropriate equipment will be critical to realising the projects key objectives.

2.5.2 Geomorphological Setting and Features

Maxwell (1968) identified three broad regions of common bathymetry and dissimilar reef distributions on the continental shelf of the Great Barrier Reef (Northern, Central and Southern). Douglas Shoal is situated in the 'Southern Region', between 20°S and 24°S, the widest section of shelf, which gradually slopes toward the shelf-edge (Maxwell, 1968).

A majority of coral reefs within the Capricorn-Bunker group are mature lagoonal or planar platform reefs that reach the surface. However, this section of the shelf is also lined with numerous submerged (at all tides) reefal platforms or shoals (GBRMPA 1979)[5]. The submerged state of these non-biogenic shoals is most often attributed to 'drowning' when rapid post-glacial sea level rise out-paced vertical reef accretion, which was limited by difficult conditions for coral reef growth associated with the last deglaciation (e.g. Fairbanks, 1989; Abbey and Webster, 2011).

Regional bathymetric data collected as part of Project 3DGBR and the Negri et al. (2010) high resolution multibeam bathymetry data[6] (shown in Figure 2-2) indicate that Douglas Shoal is large (5180ha[7]), solitary, wholly sub-tidal, and elongated east – west. The western section of the shoal is the dominant morphological feature, rising some 45 m from the mid-shelf floor to a relatively low relief reefal-shoal top (10 to 15 m below MLW). East of this feature, the shoal dips gently for approximately 7 km's before sharply dipping to the off-reefal-shoal floor (Figure 2-2).

The morphology of Douglas Shoal is consistent with the nearby Haberfield and Innamincka shoals (see Figure 2-3, which includes cross-section A-B) and the classification of a 'submerged shoal reef' by Hopley et al. (2007:152); that is, they are "reefs not at modern sea level, but with some growth over the older foundations, usually most prolific on the highest parts of these Pleistocene foundations."

The focus of this report is on the south-western section of Douglas Shoal, where the grounding incident occurred. The grounding footprint is shown as an orange polygon. A series of cross sections derived from high resolution multibeam bathymetry data collected by Negri et al. (2010) are provided in Figure 2-4. Of these cross sections, A-B corresponds to a truncated portion of the line shown in Figure 2-3. Cross section C-D intersects part of the grounding footprint from west to east. The north-south cross section (E-F) also intersects the grounding footprint (Figure 2-4). These cross sections were used to describe the local scale morphology of Douglas Shoal.

This report adopts the following terms to refer to the geomorphic zones:

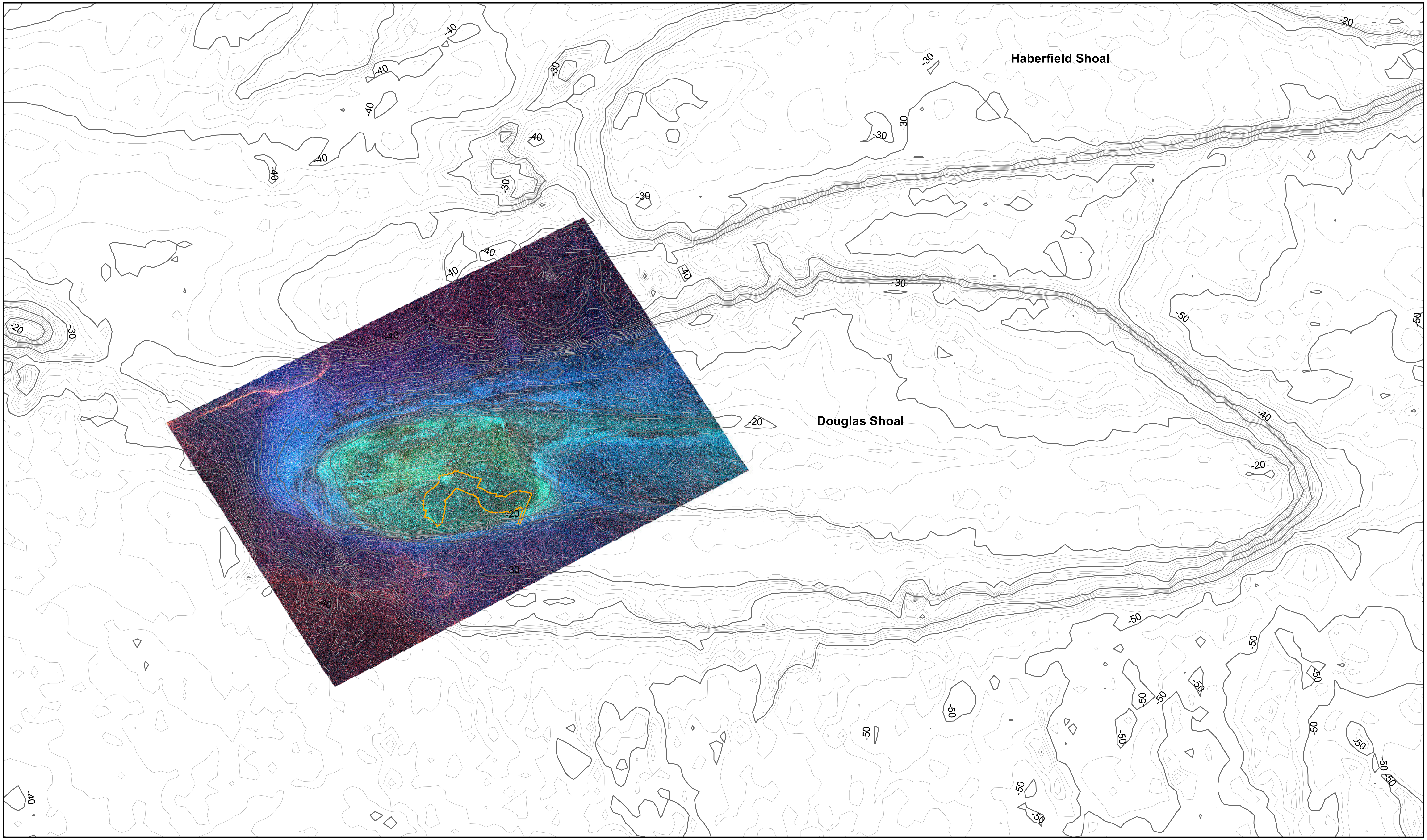
1. Off Reefal Shoal Floor
2. Reefal Shoal Slope (windward and leeward)
3. Reefal Shoal Top
4. Low Relief Terrace
5. High Relief Terrace.

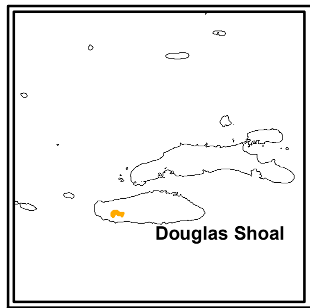
At the south western margin of Douglas Shoal, and between Haberfield Shoal and Douglas Shoal, the Off Reefal Shoal Floor lies 40 to 45 m below MLW (cross section shown in Figure 2-3) and corresponds to the geological mid-shelf. Seward of Innamincka Shoal, this feature is greater than 60 m below MLW and is contiguous with the carbonate sediment dominated geological outer-shelf.

[5] Note there are numerous other unnamed submerged deep shoals throughout the region (Harris 2011).

[6] The bathymetry data collected by Negri et al. (2010) does not cover the entire area of Douglas Shoal.

[7] The area of Douglas Shoal was calculated using the bathymetry data – the point at which the reefal shoal slope meets the off reefal shoal floor was traced, a polygon created and an estimated area (ha) generated.





Legend

Contour (eAtlas Bathymetry)

5m Contour

1m Contour

Grounding footprint

World view 2 satellite imagery (date taken: 13/09/2016)

Quick Bird image and bathymetry data

FIGURE 2 - 2

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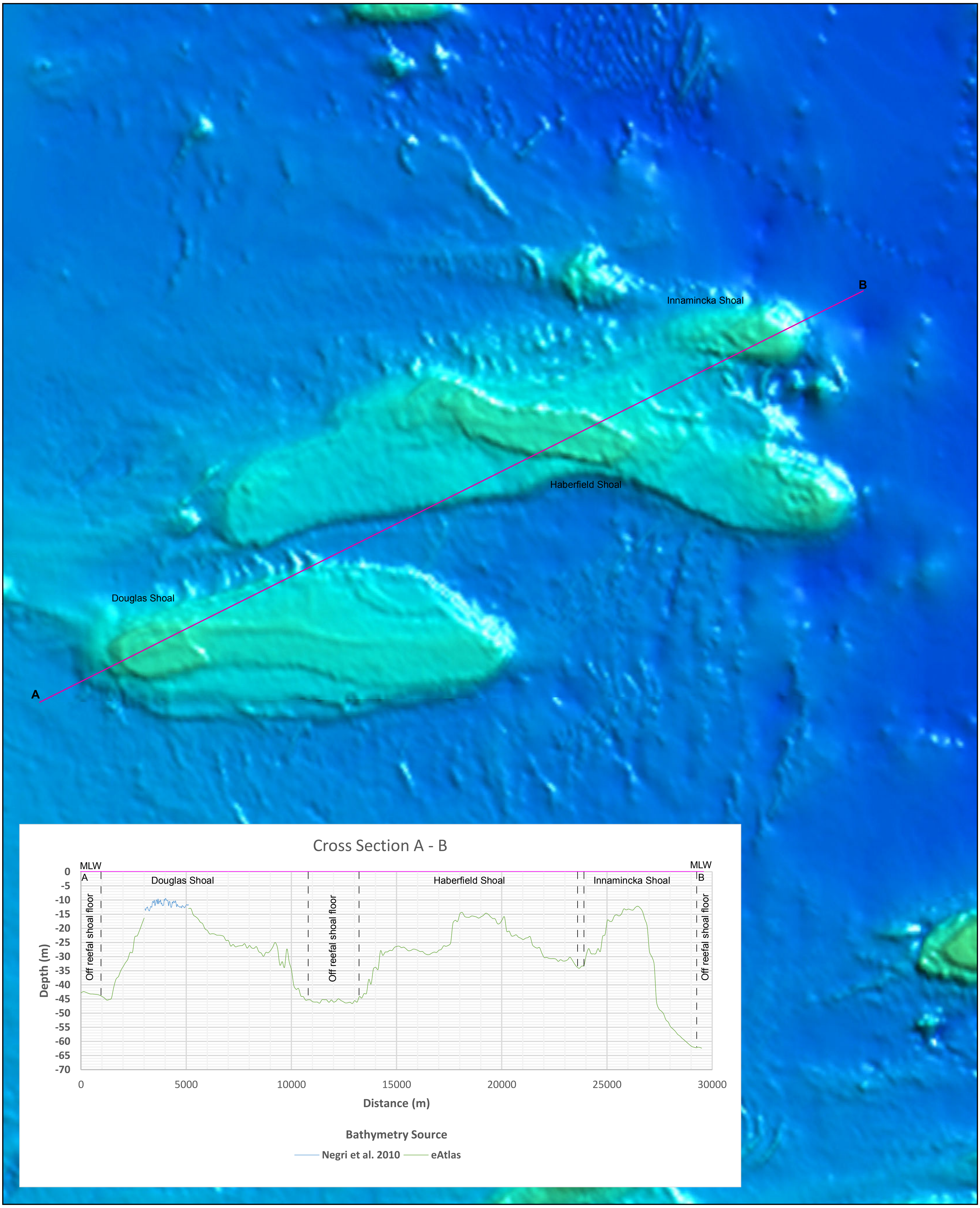
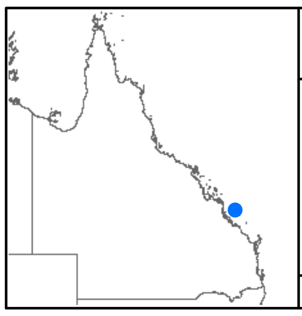
Build Sheet: Appendix E





Bathymetry of Capricorn-Bunker Group and the location of cross section (A-B) Douglas, Haberfield and Innamincka shoals

FIGURE 2 - 3

Legend

- Location of Douglas Shoal
- Cross section
- Relief plot (Negri et al. 2010)
- Relief plot (eAtlas)

Bathymetry (eAtlas)

250 m   -220 m

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Build Sheet: Appendix E

The Reefal Shoal Slope, with a substrate comprising hard limestone intersected by shallow sand and gravel filled gutters, rises sharply from the Off Reefal Shoal-Floor where it meets the Reefal Shoal Top. As shown in cross sections C–D and E–F (Figure 2-4), the Reefal Shoal Top comprises a Low Relief Terrace, and High Relief Terrace. The Low Relief Terrace rises to within 14 m of MLW, with disconnected gutters and holes the dominant fine scale morphological features. The High Relief Terrace rises to within 9 m of MLW with increased rugosity associated with greater frequency of deep gutters. The substrate of these zones is described in the following section.

Due to the 'drowned' nature of Douglas Shoal, geomorphic zonation and features are somewhat simplified. For example, there is no emergent reef flat. It is also likely that the gutters, holes and ridges are relic drainage features that developed during the Pleistocene, when the now Douglas Shoal was a coastal limestone hill, rising some 40 to 50 m above the then adjacent coast.

2.5.3 Benthic Substrate an Habitat

Key Information and Data Sources

No known baseline habitat, coral cover and health data are available for Douglas Shoal. For example:

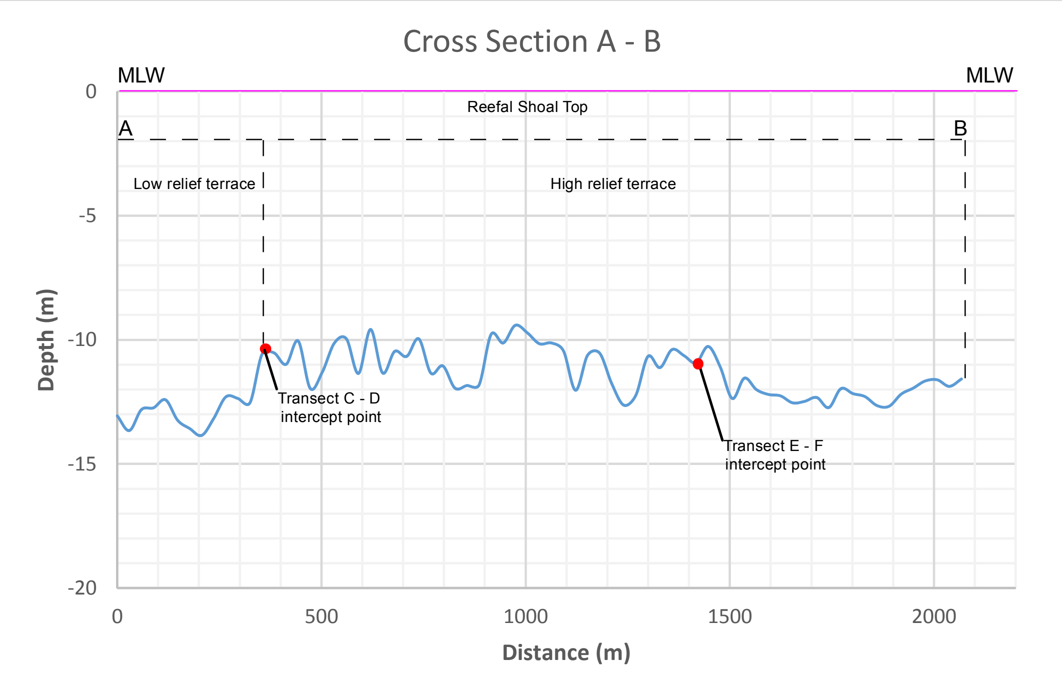
- Douglas Shoal is not surveyed as part of the AIMS Reef Wide Monitoring Program
- No published reports, papers or reviews relating to the pre-incident condition of Douglas Shoal (habitat type, composition, health) were identified during the literature search component of this study.

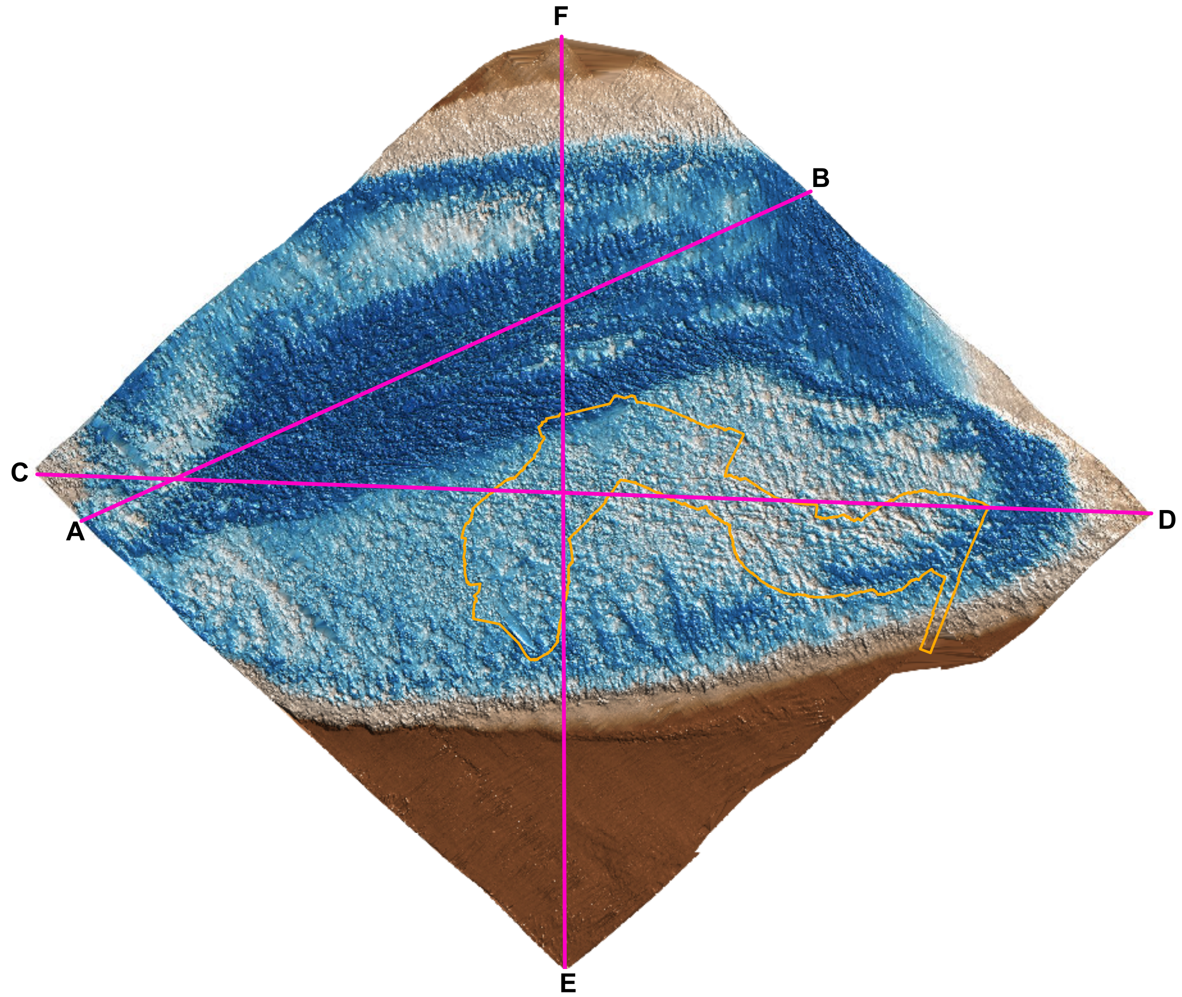
Post grounding incident benthic substrate and habitat data (within and outside the grounding footprint), were captured by Negri et al. (2010), Marshall (2010) and (GBRMPA 2011). The relative contribution of benthic substrate and habitat classes is inferred using these data.

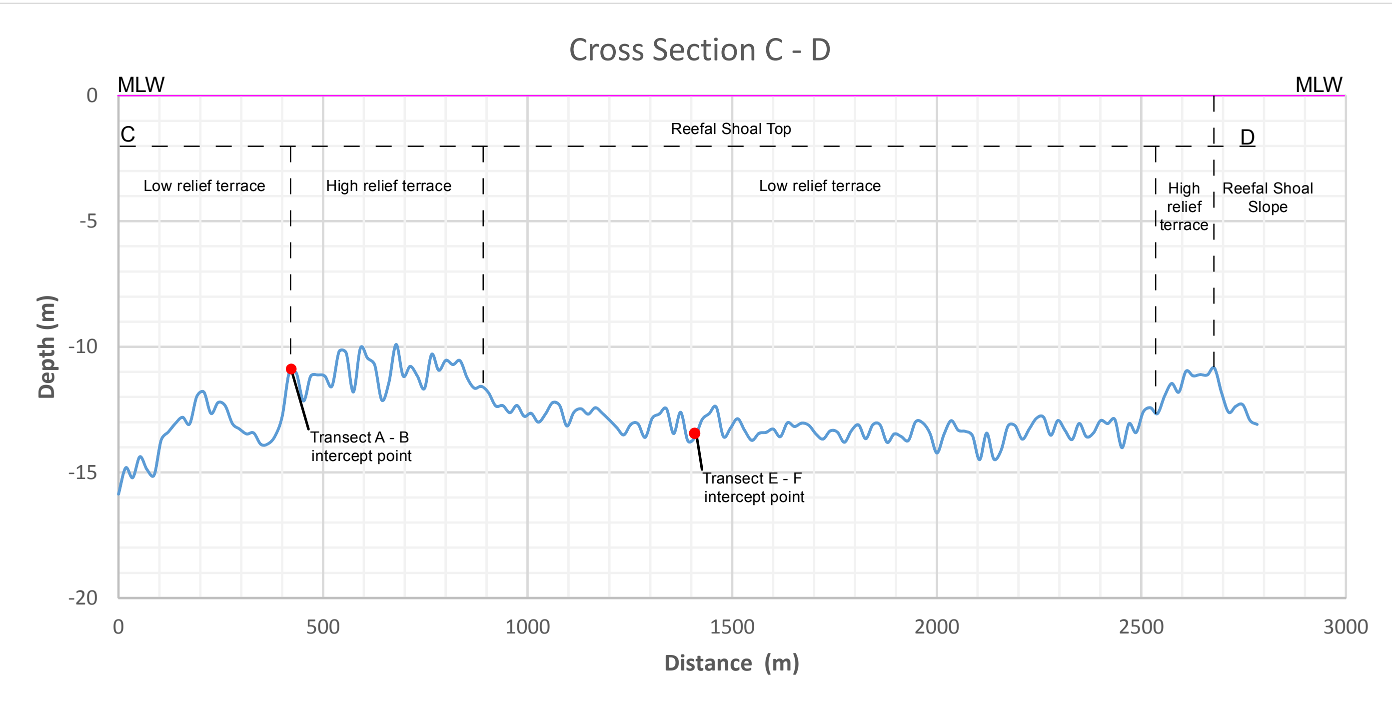
Benthic Substrate

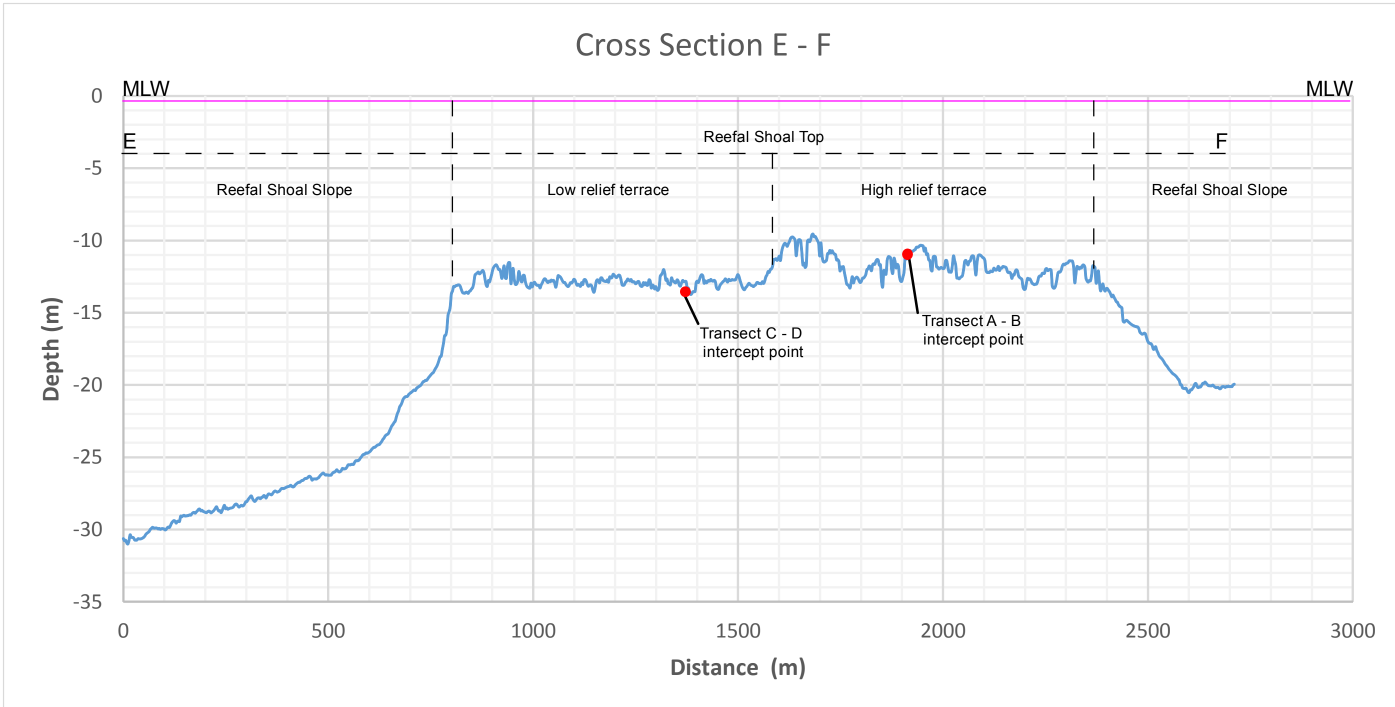
Towed Underwater Video (TUV) collected by Negri et al (2010) from undamaged areas of Douglas Shoal indicates that the dominant substrate class across the western section is hard limestone pavement (85%), with gutters and holes filled with carbonate dominated gravel / rubble (10%) and sand (5%).

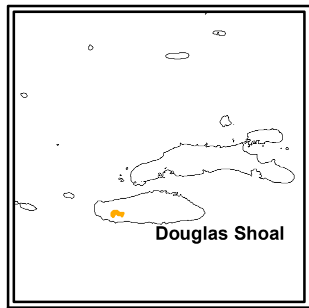
Images of undamaged benthic substrate are shown in Figure 2-5. A review of the video and still images collected by Negri et al. (2010) indicates that undamaged benthic substrate within the grounding footprint is consistent with other areas of the Low Relief Terrace.











Legend

- Cross section
- Relief plot (Negri et al. 2010)
- Grounding footprint

Bathymetry (Negri et al. 2010)
-5 m -30 m

Geomorphic features and zones of the south western section of Douglas Shoal

FIGURE 2 - 4

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Build Sheet: Appendix E

Benthic Habitat

TUV data (Negri et al. 2010), indicate that (undamaged) benthic habitats are dominated by macro algae, with *Sargassum* abundant over 53% of surveyed tracks. A further 38% was classified as macro algae and filter feeder dominated communities, including various algal species, and hard and soft corals (Figure 2-6). The TUV data indicate that approximately 8% of the surveyed area was dominated by small hard coral colonies and the remaining 1% uncolonised.

Select images of benthic habitat are shown in Figure 2-6. The location of these images is shown in Appendix F, Figure F-5. Of these images A, B, C and F are from Low Relief Terrace and D and E from the High Relief Terrace. These images (and a review of other images within the GIS database collected by Negri et al. 2010), suggest that undamaged benthic habitats (type and composition) within the grounding footprint are consistent with other areas of the Low Relief Terrace, and likely representative of habitat physically damaged by the grounding incident.

Results from other site inspections and surveys of habitat outside the grounding footprint (Marshall 2010, GBRMPA 2011) are consistent with Negri et al. (2010). For example, Marshall (2010) noted that macroalgae visually dominated the shoal substrate, with Sargassum, the most abundant genus. These macro algae were interspersed with coralline red algae and a range of other seaweeds.

A qualitative review of the TUV data provided by Negri et al. (2010) suggests that while hard corals are relatively abundant, they are sparse and tend to occur as individual colonies. These colonies appear to be attached to bare limestone substrate and rarely exceed more than 1 m in diameter. These observations are consistent with the non-biogenic status of Douglas Shoal, and or environments that experience frequent perturbations (disturbances such as cyclones) or are at the outer range of conditions suitable for biogenic reef development.

Another important observation was that made by Kettle (2014). Field work for this study was undertaken in October 2013, while other surveys were completed in either April, May or June. During Kettle's visit, high standing crops of macro algae (*Sargassum)* were reported as visually dominant, with a diverse range of small algal species present as understory. Sargassum are strongly seasonal, with peaks in biomass and reproduction during the summer and lowest biomass during the winter (McCook 1999). These high stands of *Sargassum* may limit future mapping of damaged areas during summer.

2.5.4 Marine Species

A summary of marine species observed at Douglas Shoal is provided below.

Marshall (2010) describes a diverse assemblage of benthic invertebrate animals inhabiting Douglas Shoal. This assemblage included sponges (up to 20 cm), ascidians, zooanthids, anemones, soft corals (particularly Sarcophytyon, Lobophytum, and Sinularia), hard corals, echinoderms (Asteroidea and Crinoidea), and crustaceans (Palinuridae). Hard coral colonies represented approximately 10% of benthic cover, and included the genera, Acropora, Stylophora, Pocillopora, Porites, Montipora, Goniastrea, Goniopora, Scolymia, Turbinaria and various other faviid species. Turbinaria and plating Acropora were the most visually dominant hard corals. (Figure 2-9), many of which were 0.5 to 1 m in diameter.

Abundant fish life was observed on areas of Douglas Shoal by Marshall (2010). Species of emperor (Lethrinidae) and sweetlip (Haemulidae) were observed congregating around small outcrops amidst schools of fusiliers (Caesionidae), damselfishes (Pomacentridae) and other small fish. Coral trout (Plectropomus sp.) and other cods (Serranidae) were observed commonly over the shoal, as were breams (Sparidae), wrasses (Labridae), parrotfishes (Scaridae), and large schools of pelagic fish such as mackerels (Scombridae) and trevally (Carangidae) (Figure 2-9).

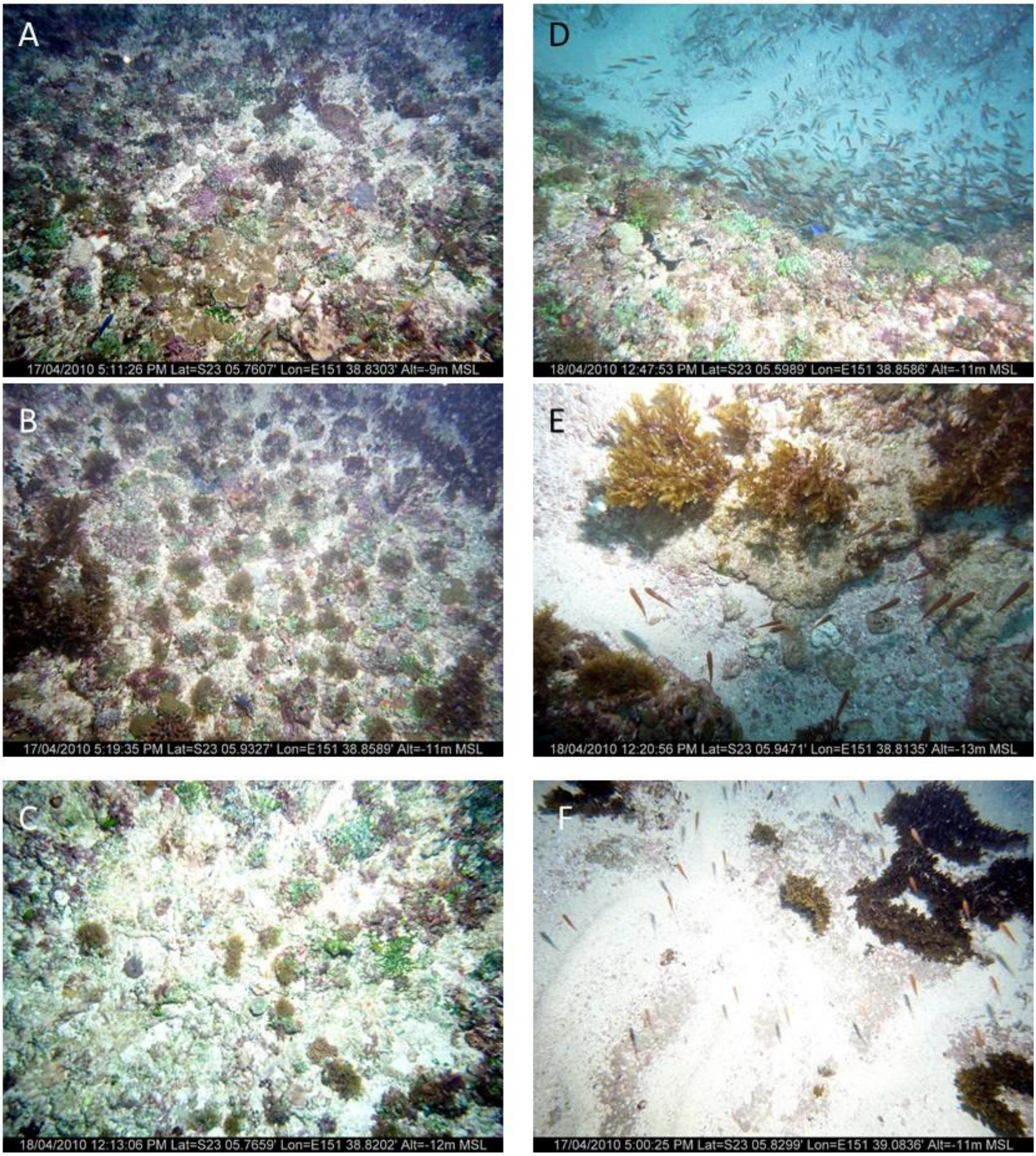


Figure 2-5 Representative images from of benthic substrate types within the south-western section of Douglas Shoal (outside the grounding footprint)

Figure 2-5: Images **A**, **B** and **C**) limestone substrate (with macro algae); **D**) limestone substrate (covered with macro algae with a sandy gutter; **E**) rubble with sparse macro algae; **F**) sand with macro algae.

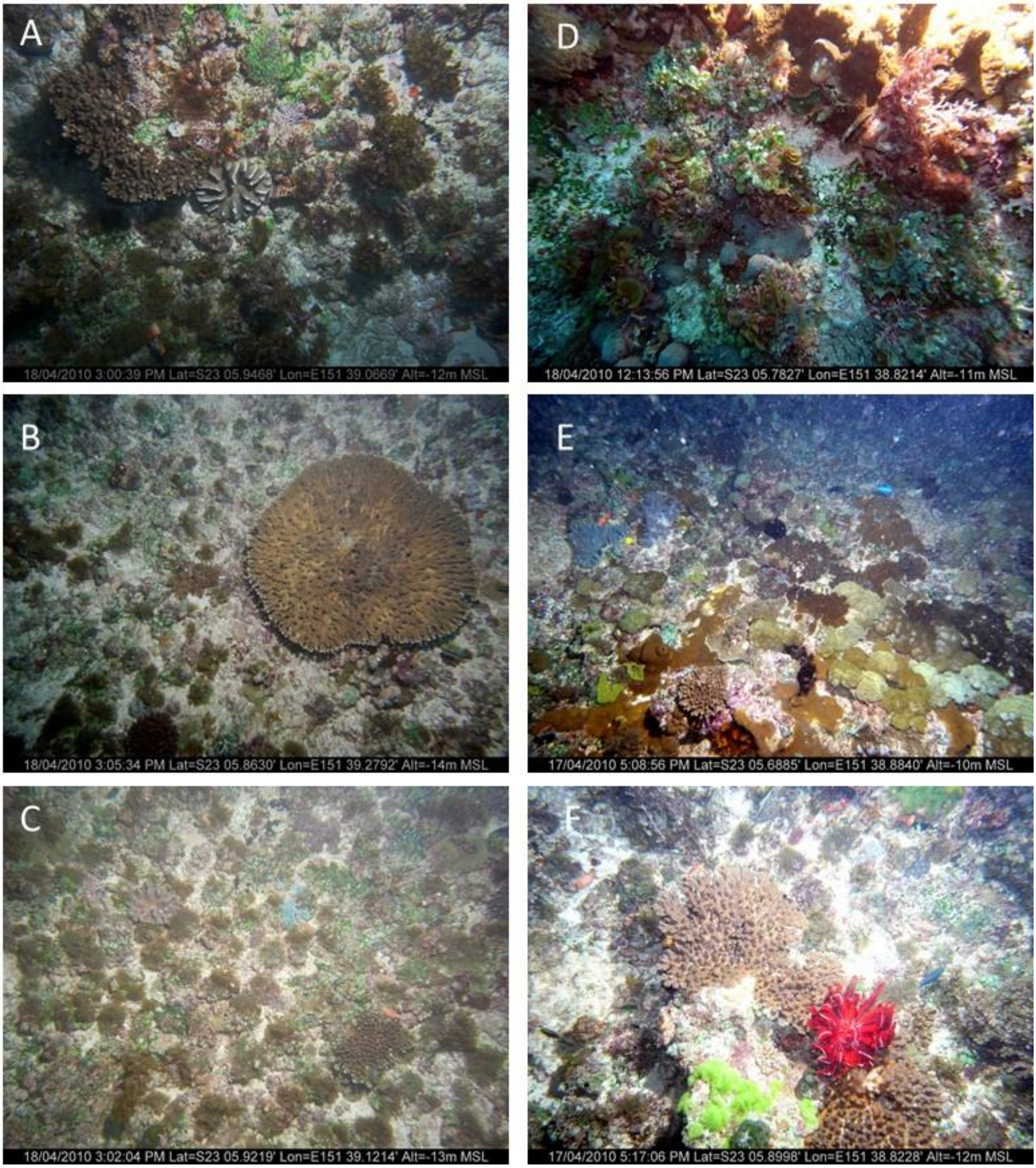


Figure 2-6 Select images of benthic habitats from outside grounding footprint (Negri et al. (2010)

Figure 2-6: **A**) macro algae and filter feeders with coral; **B**) macro algae with Acopora spp hard coral; **C)** macro algae and filter feeders; **D)** macro algae and filter feeders; **E)** soft corals, hard corals with filter feeders; **F)** hard coral and filter feeders.

Figure 2-7 Turbinaria sp coral on macro algae dominated limestone substrate (Marshall 2010)[8]

Figure 2-8 Visually dominant macro algae – October 2013 (Kettle 2014)[9]

8 Location unknown

9 Location unknown

Figure 2-9 School of Trevally and a diver (Marshall 2010)

Coral associated fish included butterfly fishes (Chaetodontidae), angel fishes (Pomacanthidae), blennies (Blennidae), and gobies (Gobidae) as well as extremely large schools of cardinalfishes (Apogonidae), which blanketed large areas of the shoal Negri et al. (2010).

Other vertebrate taxa observed included turtles, dolphins and large stingrays, with abundant sea snakes (Marshall 2010).

No data or information were available regarding the biological connectivity of Douglas Shoal, including sources of coral larvae, dispersal of recruits and patterns of fauna movement.

2.5.5 Listed Threatened and Migratory Species

An EPBC Protected Matters Report was generated on 19 July 2017. The search was undertaken within a 1 km radius of the grounding footprint. In summary, the report identified 19 Listed Threatened Species, including Green Turtles (*Chelonia mydas*) and 31 Listed Migratory Species, including Tryon's Pipefish (*Campichthys tryoni*). The complete report is included in Appendix G.

Figure 2-10 Aggregation of fish over area of higher relief (Marshall 2010)

Figure 2-11 Sea snakes were abundant during the site visits (Marshall 2010)

2.6 Traditional Owner Heritage Values

Heritage is a central element in Indigenous custom, and its conservation ensures continued respect for Indigenous ancestors and the ancestral beings who shaped the land and waterways GBRMPA (2014). The Great Barrier Reef Region Strategic Assessment combines indigenous heritage values into four broad categories:

- Cultural practices, observances, customs and lore
- Sacred sites, sites of particular significance, places important for cultural tradition
- Stories, songlines, totems and languages
- Indigenous structures, technology, tools and archaeology.

Douglas Shoal is situated within the Port Curtis Coral Coast Traditional Use of Marine Resource Area (TUMRA)[10] in the sea country of the Gooreng Gooreng, Gurang, Byellee and Tarebilang Bunda people.

No published information relating to the area's use or values of traditional owners were identified in previous studies. However, the project team is now engaging with the Traditional Owners to understand their values and interests related to Douglas Shoal and its remediation.

2.7 Historic Heritage Values

Historic heritage relates to the occupation and use of an area since the arrival of European and other migrants, and describes the way in which the many cultures of Australian people have modified, shaped and created the cultural environment (GBRMPA 2017[a]). Historic heritage values of the GBRMP include:

- World War II features and sites
- Historic voyages and shipwrecks
- Other places of historic significance.

No information relating to historic heritage values of Douglas Shoal was identified during the development of this report. Previous surveys have not reported any evidence of historic heritage, such as shipwrecks or artefacts.

2.8 Social and Economic Values

The Great Barrier Reef Region Strategic Assessment (GBRMPA (2014), groups cultural, social and economic benefits derived from the environment into the following broad elements: income and employment; access to Reef resources; understanding, appreciation and enjoyment; personal connection; health benefits; and aesthetics.

Most of Douglas Shoal falls within the Habitat Protection Zone (HPZ); however, a small part of the northern and eastern shoal margins falls within the General Use Zone (GUZ). In these zones, activities such as recreational and commercial line-fishing, recreational diving, photography and boating are allowed without permission of GBRMPA. However, other activities such as tourism or commercial collections of marine species require the written approval of GBRMPA.

Due to the exposed location of Douglas Shoal, it is unlikely that it is heavily visited by tourism operators. However, it holds considerable value to recreational fishers who visit it during calmer conditions.

Douglas Shoal falls within commercial catch grid T29, which covers much of the northern Capricorn Bunker Reef group, including Wistari, Wreck, Wilson, Northwest, Tryon, Bloomfield, and North Reefs, as well as Guthrie, Haberfield, Innamincka, Jason, and several other unnamed shoals and parts of Erskine and Heron Reefs.

Raw commercial fishing catch data are available for the entire T29 grid for all fisheries between 1988 and 2005, and from individual sites within this grid between 2001 and 2005 (DEH 2006). Commercial fishing between 1988 and 2005 within grid T29 comprised 54 species or species groups. Ten of these groups

[10] TUMRA's describe how Great Barrier Reef Traditional Owner groups work in partnership with the Australian and Queensland governments to manage traditional use activities on their sea country.

dominated the commercial catch, making up 89.8% of total GVP within. The top 10 fisheries and their relative contributions to total GVP ($AUD 41.8 mil) were: scallops (46.5%) bugs (12.2%) king prawns (9.2%), coral trout (6.1%) red-throated emperor (4.9%), Spanish mackerel (2.1%), coral prawns (1.7%), hussar (1.7%), and mixed reef fish (1.3%).

Importantly, although scallops, bugs & prawns make up 70% of the catch in T29, none of this occurs at Douglas Shoal due to zoning restrictions. Trawlers do transit Douglas Shoal between port and the trawling grounds.

Because vessel tracking is at this time only implemented on trawl, shark and beche-de-mer fleets, no data for commercial line fishing in the vicinity of Douglas Shoal is available. There is anecdotal evidence that Douglas Shoal may be commercially fished for coral trout and Spanish mackerel by fleets based in Rosslyn Bay, Gladstone and Bundaberg. These line fishers utilising Douglas Shoal would likely be smaller vessels without dories. The larger vessels with dories are more likely to head out further, toward the Swains and Outer Reef.

With relevance to remediation planning, the scallop fishery is closed from 1 May to 31 October every year, so timing remediation works for this period would minimise disruptions to the scallop fleet (noting they are only transiting past Douglas Shoal). During the scallop closure, some vessels tie up at home port while others shift to prawn trawling.

2.9 Gaps

Key gaps are listed below. Potential risks associated with these gaps are presented in Section 6.

G2.1 No site specific hydrodynamic time-series (wind, wave and current) data exist.

G2.2 No published reports, papers or reviews specifically relating to the pre-disturbance condition of Douglas Shoal (habitat type, composition, health, water quality and sediment quality) were identified.

G2.3 No data or information were available regarding the biological connectivity of Douglas Shoal, including sources of coral larvae, dispersal of recruits and patterns of fauna movement.

G2.4 No published information relating to the area’s use or values of traditional owners were identified in previous studies.

G2.5 No information relating to historic heritage values of Douglas Shoal were identified during the development of this report.

G2.6 No information relating to the potential driver for the observed abundance of sea snakes.

G2.7 The biodiversity value of submerged reefal shoals in the Southern Region of the Great Barrier Reef are poorly understood.

3 Incident Summary

3.1 Overview

This section provides a synopsis of the grounding incident, including the movement of Shen Neng 1 over Douglas Shoal. A summary of damaged sustained by Shen Neng 1 is also included. The purpose of this section is to help contextualise the description of physical damage and antifouling paint contamination provided in Section 4. Key points are summarised below. Information and data gaps are included at the end of this section.

Key Points

- Shen Neng 1, a Chinese bulk carrier, was constructed in 1993 at 36,575 gross tonnes (71,181 DWT), 225 m long with a beam of 32.66 m and a draught of 13.29 m.
- The hull of Shen Neng 1 was originally covered with antifouling paint containing tributyltin (TBT).
- TBT is a highly effective biocide that was banned internationally in 2009.
- While in dry-dock (2008) the hull of Shen Neng 1 was coated with Interswift 655 and Interswift 455FB, third generation copper oxide based antifouling paints.
- On 3 April 2010, Shen Neng 1 grounded on Douglas Shoal, moving across some 42 hectares during the 10 days before she was re-floated and towed away.
- Shen Neng 1 suffered extensive plate damage during the grounding. This damage comprised plate indentation, push-up, buckling and cracking. The rudder was slightly damaged but the propeller was not.
- Underwater inspection and sampling of the hull was undertaken by Monkivitch (2010), some 6 weeks following the grounding incident indicated that:
  - Damaged sections (sides of the hull) showed evidence of significant paint loss.
  - The entire underside (flats) of the hull is highly likely to have been in contact with the shoal at some time during the grounding.
  - Whilst only target areas of the hull were inspected, during the grounding antifouling paint is highly likely to have been lost from most of the underside of the Shen Neng 1 to similar extents to that observed (to the sides of the hull).
  - Chemical analysis of paint samples confirmed the presence of active (biocide) ingredients including tributyltin, zinc oxide and copper oxide, copper pyrithione and zineb at environmentally significant concentrations.
- No accurate calculations of total paint and biocide lost during the grounding were available in any of the reports reviewed.

3.2 Key Information and Data Sources

Negri et al (2010), (GBRMPA 2011) and Kettle (2011) provide excellent summaries of the incident. A comprehensive description of the grounding and the subsequent response is provided by ATSB (2011) - available here: https://www.atsb.gov.au/publications/investigation_reports/2010/mair/274-mo-2010-003

Monkivitch (2010) completed an assessment of the post grounding condition of the vessel's hull, identified the antifouling paint (AFP) products[11] applied, and provided estimates of volume of AFP (kg) applied to the hull of Shen Neng 1 when in dry dock (2008). Data sources and build reports for Figures 3-1 and 3-2 are provided in Appendix E.

3.3 Shen Neng 1

Shen Neng 1 (now the 'Jia Yong') a Chinese bulk carrier was constructed in 1993 at 36,575 gross tonnes (71,181 DWT), 225 m long with a beam of 32.66 m and a draught of 13.29 m.

[11] - are applied to the hulls of vessel's to prevent the build-up of marine organisms

In 2008, Shen Neng 1 was in dry dock for maintenance and repair. According to the Coating and Inspection Report (appendices to Monkivitch (2010), the hull was largely free of biofouling organisms, suggesting the antifoulant properties of the pre-existing paint (containing tributyltin) were still effective. Due to the global ban on tributyltin (TBT) based antifoulants, Shen Neng 1 was coated with Interswift 655 and Interswift 455FB, third generation copper oxide based antifouling paints-[12] (AFP).

Table 3-1 (reproduced from (Monkivitch 2016) includes a list of paint products applied to the vessel's hull, the active ingredient and their concentrations[13]. No similar data relating to the TBT based antifouling paint layer was available.

Table 3-1 Applied paint products, volumes and key active ingredients

Hull section	Surface area (m^2)	Paint type	Paint volume (l)	Density wet (kg/l)	Paint applied wet (kg)	Active ingredient	Concentration by weight (%)*	Amount applied (kg)
Underwater Sides	3819	Interswift 655 Brown (BMA008)	740	1.935	1431.9	Copper Oxide	25-<50	358 - 716
						Zinc Oxide	10-<25	143 - 358
Underwater Sides	3819	Interswift 655 Dark Red (BMA004)	740	1.935	1431.9	Copper Oxide	25-<50	358 - 716
						Zinc Oxide	10-<25	143 - 358
Flats	7000	Interswift 455FB Dark Red (BBA004)	1560	1.925	3003_0	Copper Oxide	25-<50	751- 1502
						Zinc Oxide	10-<25	300 - 751

Complemented with copper pyrithione 2.5-10%, xylene 10-25%, Rosin 2.5-10%, N-butanol 1-2.5%, Amorphous formed silica 1-2.5%, Silica (as quartz) 1-2.5%, Iron oxide <1%.

3.4 Grounding of the Shen Neng 1

The ship's initial grounding position and movement over the shoal (with corresponding tidal information and dates) are shown in Figure 3-1. The vessel's stern position and the outside boundary of the vessel's 'path' are included in Figure 3-2. This path (orange polygon) delineates the grounding footprint.

A brief description of the grounding, incident response and salvage is provided below:

- At approximately 11:00 hours on Saturday 3 April 2010, the Shen Neng 1 left its berth in Gladstone Harbour bound for China. She was loaded with 68,052 tonnes of coal and had a forward draft of 13.29m and an aft draft of 13.38 m (ATSB 2010).
- At 17:10 hours on 3 April 2010 the Shen Neng 1 ran aground on the south-western section of Douglas Shoal[14] (Figure 3-1).
- At 17:30 hours, under the command of the Master of the Shen Neng 1, a single starboard anchor was dropped with approximately 60 m of chain.
- Following the initial impact, an estimated 3.0 to 3.9 long tons of heavy fuel oil was lost (see Figure 3-3 Plate A), creating a narrow oil slick some 3.7 km in length.
- Over the next 3 days (due to being inadequately secured) the vessel moved to the west, then northwest, then to the southwest before settling on 6 April 2010 at 23°06.11'S, 151°39.93'E with a heading of 322°.
- The vessel's heading and location varied little after 6 April 2010 (Figure 3-1).
- Shortly after 18:00 on 12 April 2010 three tugs (under the direction of Maritime Safety Queensland - MSQ) with cables hooked up to the Shen Neng 1 began pulling the vessel off Douglas Shoal. At 19:48 the ship was successfully re-floated and towed to an anchorage to enable a safety inspection.

12 Antifouling paints incorporate biocides (active ingredients), which retard or prevent growth of marine organisms on the hull of ship's

13 These data do not reflect the actual amount of paint lost only what was on the hull (to[p coat) prior to the grounding

14 see Figure 2-2 which shows the shoal in its entirety

3.5 Damage to Shen Neng 1

ATSB (2010) found that that the bottom of Shen Neng 1 had suffered extensive plate damage during the grounding. This damage comprised plate indentation, push-up, buckling and cracking. The rudder was slightly damaged but the propeller was not.

Inspection and sampling of the hull was undertaken by Monkivitch (2010), some 6 weeks following the grounding incident. Monkivitch (2010) states that:

- Paint loss from the hull varied from significantly damaged areas of bare exposed metal with corrosion (underside of hull holds 1, 2, 3, 4 and 5) to areas with no noticeable impact and with full paint coverage such as the stern areas adjacent the propeller shaft.
- Observations of the ship’s sides, where only minor abrasion/damage occurred, indicate that loss of the top coats of paint was sufficient to expose the grey barrier coat. Areas receiving more abrasion such as the underside of holds clearly resulted in loss of topcoats, exposure of historic paints and loss of historic paints to the extent of exposing bare metal
- The entire underside (flats) of the hull is highly likely to have been in contact with the shoal at some time during the grounding.
- Whilst only target areas of the hull were inspected, during the grounding antifouling paint is highly likely to have been lost from the underside of the Shen Neng 1 to similar extents to that observed.

To characterise the nature of AFP applied to the hull of Shen Neng 1, thirty three (33) hull scrapings and 146 images were collected. Chemical analysis of paint samples confirmed the presence of active (biocide) ingredients (37.1% of AFP by weight, pers. comm., Gilbert 2017), including tributyltin (TBT), zinc oxide and copper oxide, at environmentally significant concentrations.

3.6 Data and Information Gaps

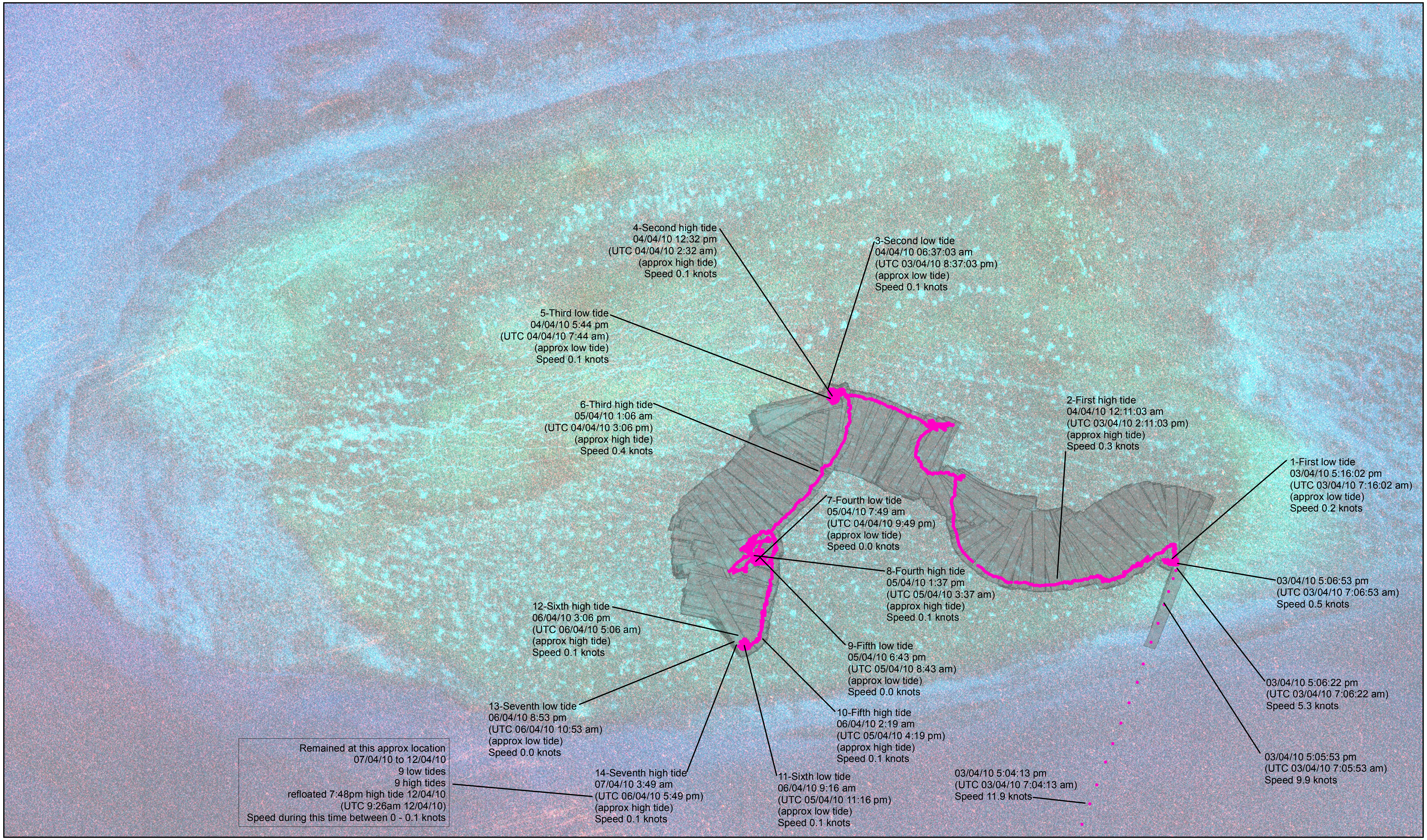
Key gaps are listed below. Potential risks associated with these gaps are presented in Section 6.

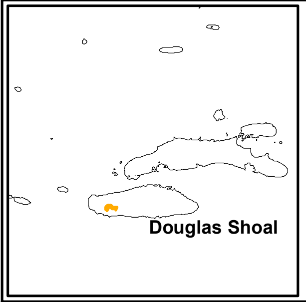
G3.1 The chemical composition (including biocides) of all AFP layers applied to the hull of Shen Neng 1 is unknown.

G3.2 The total amount of AFP abraded from the hull of Shen Neng 1 is not known.

G3.3 The efficacy (toxicity) of AFP particles abraded from the hull of Shen Neng 1 is not understood.

G3.4 The long term behaviour (for example half-life, leach-ability, effects of abrasion and susceptibility to weathering) of abraded AFP at Douglas Shoal are unknown.





Legend

- Stern of Shen Neng 1
- Grounding footprint
- Vessel heading and bearing
- World view 2 satellite imagery (date taken 13/09/2016)

Location, path and speed during grounding incident

FIGURE 3 - 1

Not to be used for navigation.
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N

1:10,000 Scale at A3

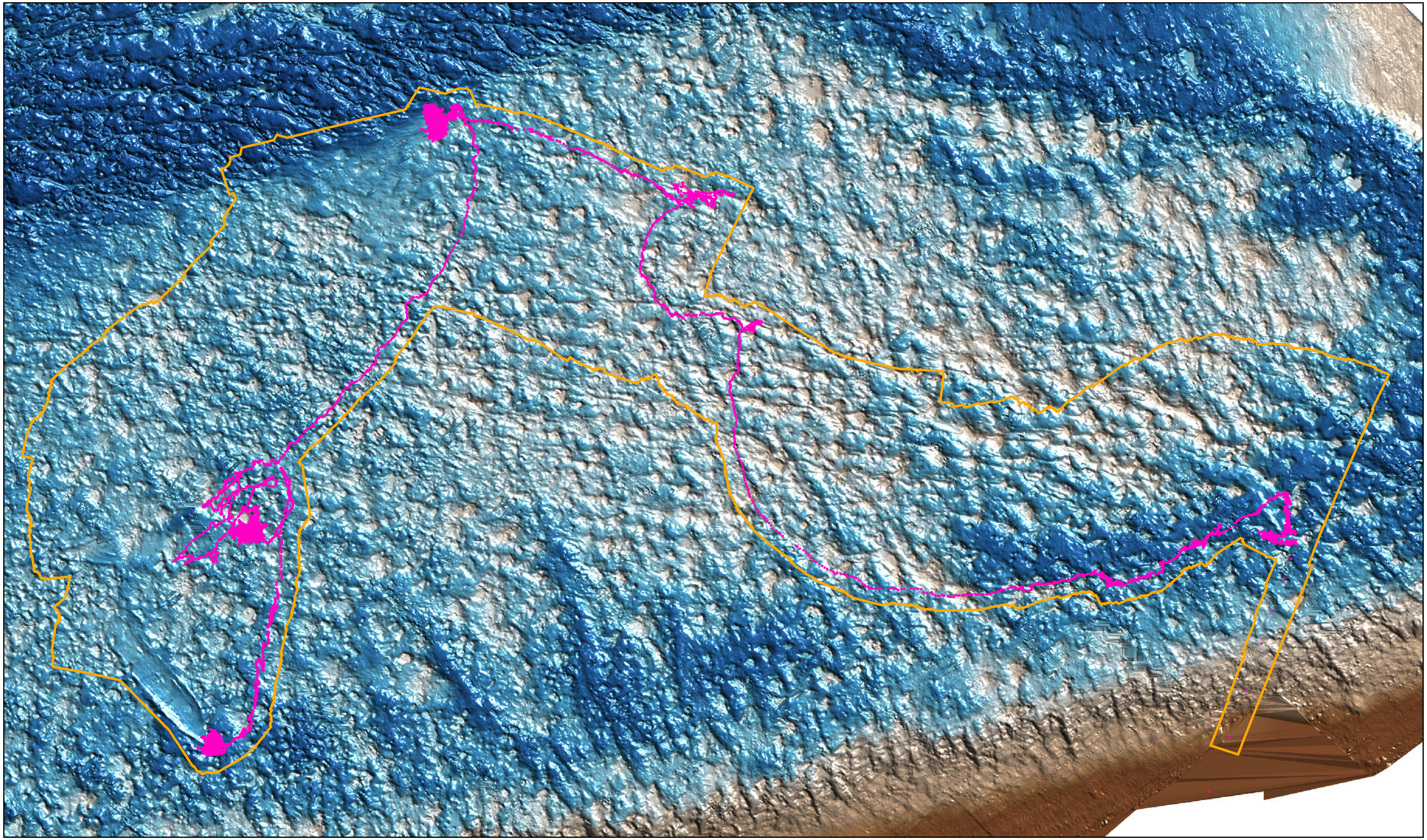
Metres
0 75 150 225 300 375 450

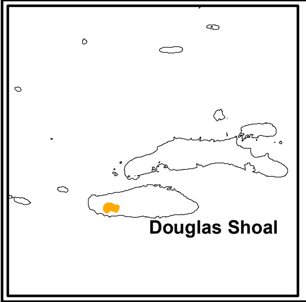
Map Produced by: NSW Water & Environment
Date: 2017-10-13
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: 3_1_LocationPathSpeed.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\3_1_LocationPathSpeed.mxd

Build Sheet: Appendix E





Legend

- Stern of Shen Neng 1
- Grounding footprint

Bathymetry (Negri et al. 2010)

-5 m   -30 m

Grounding footprint

FIGURE 3 - 2

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N

1:4,000 **Scale at A3**

Metres

0 75 150

Map Produced by: NSW Water & Environment
Date: 2017-09-22
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: 3_2_GroundingFootprint.mxd 01

Cardno

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Build Sheet: Appendix E

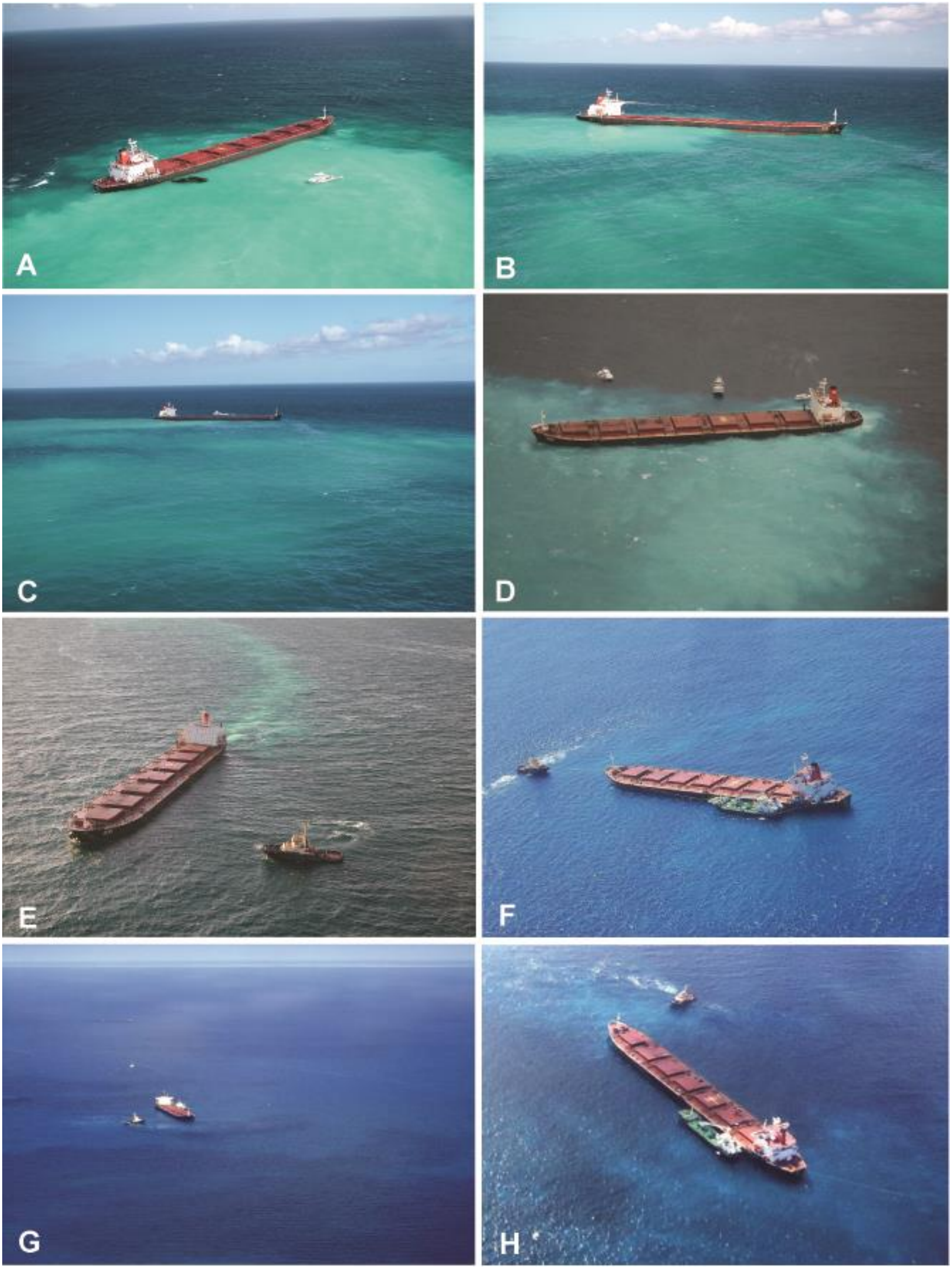


Figure 3-3 Images of Shen Neng 1 aground at Douglas Shoal. Aerial imagery of sediment plumes created during the Shen Neng 1 grounding period. Flood tide (A, B, C; MSQ 2010) and ebb tide (D; AMSA 2010) plume movement on April 4. Aerial images from April 6 (E), (F) (G & H) (MSQ, 2010)

4 Physical Damage and Contamination

4.1 Overview

This section:

- Summarises the results of damage and contamination reported in GBRMPA-commissioned studies / reports (Table 4-1)
- Presents a series of figures / maps that combine all relevant georeferenced data from each GBRMPA-commissioned study
- Describes (using the above figures / maps) the nature and scale of physical damage and contamination.

The purpose of this section is to:

- Inform the identification of possible priority areas for remediation
- Identify gaps and uncertainties that may represent a risk to effective remediation planning and monitoring.

Key points are summarised below. Information gaps included at the end of this section.

Key Points

- The grounding footprint is located at the western section of Douglas Shoal.
- Figures herein suggest there is a close correlation between the area traversed by Shen Neng 1 during the grounding incident and the physical damage and contamination recorded
- The morphology of the adjoining High Relief Terrace constrained the movement of Shen Neng 1 during the grounding incident, with most physical damage identified situated within the Low Relief Terrace.
- While no data are available for 77% of the grounding footprint, the distribution of physical damage is focussed at four quite distinct areas with patches of physical damage recorded between these locations.
- Physical damage includes fractured and displaced benthic substrate and habitat.
- Due to low rates of cementation / coral accretion, fractured and or displaced benthic substrate is unlikely to repair itself at rates similar to biogenic reefs. This includes displaced and fractured substrate in the form rubble, which are unlikely to consolidate. These morphological features are likely to remain for decades.
- Unconsolidated rubble is likely to cause secondary impacts to the natural environment of Douglas Shoal by preventing new growth and possibly mobilising during storms, damaging previously unaffected areas.
- Distribution of antifouling paint particles (AFP particles) and concentrations of TBT, copper and zinc are highly variable across the grounding footprint.
- Some contamination was recorded outside the grounding footprint.
- The geotextural properties (shape, size) of abraded AFP particles lost from the hull of Shen Neng 1 vary significantly.
- The amount (by weight) of AFP particles present at Douglas Shoal is estimated to be in the many tonnes.

4.2 GBRMPA-commissioned Studies – Summary of Damage and Contamination

Table 4-1 summarises the purpose, objectives and approach for the 10 GBRMPA-commissioned studies. Reported results / key observations together with date / timing of site visits are also included.

4.3 Approach to Consolidating Results and Findings

4.3.1 Rationale

During the development of this report, Cardno identified a number of differences between GBRMPA-commissioned studies and reports. For example, earlier studies (Marshall, 2010) used rapid assessment techniques to broadly define and characterise physical damage and contamination, others focussed on potential remediation techniques or were developed to support legal proceedings. Additionally, different terms are used to describe physical damage and impacts. While the reasons for these inconstancies are likely to relate to the timing and objectives of each study, direct comparison between data sets is problematic.

4.3.2 Concepts and Definitions

Framework / Structure

The structure and language of this section is based on the Driver, Pressure, State, Impact, Response framework (DPSIR). DPSIR is a framework that conceptualises the cause-and-effect chain that links drivers, activities and impacts to the state of relevant environmental values and the benefits these values provide (Oesterwind et al. 2016).

Definitions

While the DPSIR is a widely used framework for identifying and evaluating environmental effects, inconsistent use of language can cause confusion and affect the delivery of key messages being communicated (Oesterwind et al. 2016). For example, GBRMPA-commissioned reports tend to use the terms damage and impact interchangeably, yet most data relate to damage or contamination, not impacts.

It is suggested that the clear differentiation between the ‘environmental receptor state change’ and ‘impacts’ may help to strategically focus future remediation planning effort. Definitions are provided in Table 4-2. These are further expanded upon below.

Driver

The driver is the grounding of Shen Neng 1 (Section 3); the action that resulted in changes in condition of the environmental receptor state (Douglas Shoal).

Pressures

Pressures can be considered either as direct or secondary.

Direct pressures include:

- Contact with the hull of Shen Neng 1
- Contact with the vessel’s anchor while Shen Neng 1 was adrift
- Contact with anchors deployed by the incident response team
- Contact with the propeller of Shen Neng 1
- Smothering by sediment generated during the grounding incident
- Loss of bunker fuel
- Loss of AFP particles from the hull of Shen Neng 1.

Secondary pressures are mechanisms created by a receptor state change. These include:

- Movement of displaced benthic habitat in the form of rubble
- Modified water quality
- Modified sediment quality.

Environmental Receptor State

The environmental receptor state is the inferred composition and condition of benthic substrate and habitat within the Low Relief Terrace (Section 2) prior to the grounding incident.

Table 4-1 Summary of results / observations relating to physical damage and contamination (GBRMPA-commissioned studies)[15]

Citation	Purpose / Key Objectives	Data captured / Approach	Reported results / observations
Stieglitz 2010	Assess and delineate structural damage of the Reefal Shoal structural impact	High-resolution multibeam sonar bathymetry (15 - 17 April 2010)	- Sonar data detected structural impact at four locations within the grounding footprint - Strong correlation between these four locations and locations where Shen Neng 1's stern remained stationary for 'some duration' - Structural damage was not detected at locations where the stern of Shen Neng 1was either moving or stationary for 'short periods of time' - Movement of Shen Neng 1 between locations with the grounding footprint correlate to increase clearance (under keel) associated with tidal fluctuations
Negri et al. 2010	Map Douglas Shoal using high-resolution multibeam sonar to: - Quantitatively estimate the extent and severity of damage - Assess the benthic habitat and biota within the grounding footprint - Assess the benthic habitat and biota outside the grounding footprint	Georeferenced imagery (~ 16 km of towed underwater video 17 - 18 April 2010) paired with the High-resolution multibeam sonar bathymetry data (collected by Steiglitz 2010 between 15 - 17 April 2010)	- Presents the results of Steiglitz 2010 (above) - Identified extensive areas of unconsolidated rubble (within the grounding footprint) associated with contact of the hull of Shen Neng 1 - Identified 'broad areas levelled by Shen Neng 1 - Identified dislodged corals and or reef substrate - Identified distinctive drag marks associated with anchor drag - Identified areas of undamaged substrate and benthic habitat
Marshall 2010	1) Inspect areas of Douglas Shoal in the vicinity of the known path of the grounded vessel and identify areas that had suffered recent physical damage 2) Delineate areas of recent physical damage and characterise the type and severity of damage 3) Collect indicative samples of sediments, including samples of any reef material visibly affected by antifoulant paint 4) Collect water samples (if there was any indication of oil leakage or hydrocarbon contamination of discharged ballast water) 5) Collect photos and video footage representative of damaged and undamaged areas of Douglas Shoal.	- Still photographs and video footage paired with handheld GPS towed on a boogie board - Samples of sediments and antifoulant paint and metal debris - Contemporaneous field reports / logs (12 – 13 April 2010)	- Found spatially extensive and severe damage to the reef community on Douglas Shoal - Severely damaged areas (13,448 m^2) were characterised by near-complete destruction of the ecological community, with the underlying reef substrate either scraped clear or covered in expanses of freshly created coral rubble - Estimated 4,293 m^2 of seabed was moderately damaged and approximately 1,346 m2 had minor damage - Estimated that 19,087 m^2 of reef area to be damaged (in-total) - Particles of antifouling paint were observed amongst the rubble and smeared onto the reef substrate in some of the severely damaged areas - Additional, more detailed surveys will help ascertain the full extent of physical damage, the severity and distribution of contamination from antifoulant paints, and inform evaluation of remediation options
Monkivitch 2010	- Estimate the amount of damage to the hull of Shen Neng 1 - Inform an assessment of paint lost from the vessel during grounding incident - Determine the chemical composition of hull coatings	- Underwater inspection and sampling of the hull of Shen Neng 1 - Thirty three (33) hull scrapings and 146 images were collected during a single day inspection (21 May 2010)	- Recorded damage for all underside areas of the hull with extensive areas of paint loss - Chemical analysis of paint samples confirmed the presence of active (biocide) ingredients, including tributyltin (TBT), zinc oxide and copper oxide, at environmentally significant concentrations - Observations confirmed that the damage to the hull was sufficient to expose and abrade the underlying TBT containing paints from the hull and therefore contamination of the sediments of Douglas Shoal with antifouling paints including TBT is certain to have occurred as a result of the grounding incident
GBRMPA 2011	Compiles the results of Steiglitz (2010, Negri et al. (2010) and Marshall (2010)	- Additional site visit 11 – 12 May 2010 - Sediment samples - Photographic data - Contemporaneous field reports / logs - Plus desktop review of Steiglitz (2010, Negri et al. (2010) and Marshall (2010)	- Estimated 116,353 m2 of severe damage - Estimated 290,985 m^2 of 'patchy moderate to severe' damage'
Kettle 2011	Independent technical review / analysis of: - GBRMPA (2011) - Monkivitch 2010	- Desktop review - 1 day site visit - Sediment sampling - Dive observations	- Estimated 187,246 m^2 of severe physical damage within the grounding footprint - Estimated 220,092 m^2 of minor physical damage within the grounding footprint Estimated 1000 m^2 of physical damage outside the grounding footprint - No estimate of AFP contamination within the grounding footprint - Estimated 173,823 m^2 of AFP contamination outside the grounding footprint
Kettle 2014	Analysis of: - Damage, including type, extent and severity - Changes in nature and extent of damage since Kettle (2011) - Extent of any natural recovery Recommended steps to remediate the site	- Five day site visit (9 to 13 October 2013) - SCUBA - Observations - Sediment samples collected from 5 'rubble filled' depressions - Laboratory analysis - Video transects of benthic habitat - Trialling diver operated dredging and water treatment - Sampling of sediment as part of the remediation trial - Analysis of samples - Diver observations and field logs	- Found that physical damage associated with the grounding incident was still 'readily identifiable' - Found some evidence of weathering of AFP flakes and smears - Found small areas of rubble colonised by algae and other organisms - Found macro algae dominated Douglas Shoal, with *Dictyopteris sp*. six times more abundant within the grounding footprint - Found evidence of TBT degrading to DBT (in one location only) - Observed that 'pollutants are well mixed into the sediment profile' - Concluded that remediation will require larger scale operations compared to that trialled - Little if any reef stabilisation or recovery was observed - AFP particles include smeared rubble, aggregates, and flakes - Found evidence of contamination outside the grounding footprint - Potential for resuspension of contaminants exists
Kettle 2015 (a)	Development of an effective method for remediating Douglas Shoal – pre cyclone Marcia work		
Kettle 2015 (b)	Develop an effective method for remediating Douglas Shoal – post cyclone Marcia work	- Sampling of sediment as part of the remediation trial - Analysis of samples - Diver observations and field logs	- Found evidence of contamination outside the grounding footprint - AFP particles were observed outside the vessel path

15 Summary of relevant results / observations only. Please see the original reports for complete results.

Citation	Purpose / Key Objectives	Data captured / Approach	Reported results / observations
Marshall 2016	The objectives of the survey were to: - Determine the concentrations of contaminants associated with antifoulant compounds in mobile fauna inhabiting the contamination sites at Douglas Shoal - Determine if levels of contamination in biota from Douglas Shoal are significantly different from adjacent reefs - Determine if there are detectable differences in the levels of contamination of mobile fauna between the different contamination sites within Douglas Shoal - Determine if there are indications of bioaccumulation or biomagnification of contaminants through the trophic system at Douglas Shoal - Determine if contamination in species of mobile fauna targeted by fishers exceed thresholds for human health.	- Collection of mobile fauna from contaminated and reference sites (Douglas Shoal, Haberfield and Tryon shoals) 10 – 13 July 2016 - Sampling of tissue from specimens - Laboratory analysis for organotins, copper and zinc	- Mobile fauna inhabiting the contamination site at Douglas Shoal did not have consistent or high levels of contamination from antifoulant chemicals, compared to reference sites+ - Only 2% (3 out of 157 specimens) of mobile fauna sampled in the survey had detectable concentrations of organotins (TBT and its breakdown products) in their tissues - All specimens had detectable concentrations of copper and zinc, but there was no evidence of consistently elevated levels in specimens from Douglas Shoal compared to Reference locations. - Provides evidence that there is negligible risk to the health of humans consuming seafood caught at Douglas Shoal in relation to contamination from TBT, copper or zinc.

Table 4-2 Framework components and definitions

Term	Definition
'Driver'	The action that resulted in change to the 'receptor state'
'Pressure'	The result of the driver-initiated mechanism causing an effect, that may alter the state of the receptor
'Environmental receptor state'	The actual condition of Douglas Shoal and its components (Marine Park values) prior to the grounding incident
'Environmental receptor change state'	The actual condition of Douglas Shoal and its components (Marine Park values) following the grounding incident
'Impacts'	The consequences of a receptor state change
'Response'	The management actions seeking to reduce or prevent an unwanted change or to develop a positive (desirable) change in the receptor state

Environmental Receptor State Change

The resultant changes to benthic substrate and habitat as a result of initial and secondary pressures. In this report they include physical damage and contamination.

Physical Damage Descriptors

In this report, physical damage is described as either displaced and or fractured. These simplified categories are adapted from Precht (2006). Figure 4-2 includes examples of physical damage sustained during the grounding incident.

Impacts

Impacts are the measurable consequences of an environmental state change and may include loss or modification of Marine Park Values.

4.4 Physical Damage

This section provides a description of nature and scale of physical damage (an environmental state change).

4.4.1 Nature of Physical Damage

Nature refers to location and type of physical damage.

Location

With regard to location of physical damage, Figure 4-1 presents data as 10 x 10 m colour coded grid cells. Where physical damage was recorded within a cell, it is coloured coded yellow. Where no damage was observed, cells are colour coded green and reported as undamaged. In the absence of data, grid cells are left empty (transparent). Please note that in most cases, each cell contains a single data point (interpolated to the full extent of the 10 x 10 m cell). Therefore, while a cluster of yellow cells may indicate a broad area of physical damage, the results displayed in Figure 4-1 may not be representative of physical damage for the entire cell (see Appendix E for build report).

Figure 4-1 shows that recorded physical damage is located predominantly within the Low Relief Terrace. It appears that the morphology of the adjoining High Relief Terrace constrained the movement of Shen Neng 1 (during the grounding incident) and may have influenced the nature of the associated physical damage. The scale (extent) of physical damage recorded within and immediately adjacent to the grounding footprint is described in Section 4.4.2.

Environmental Receptor State Change / Physical Damage Type

Environmental receptor state changes were described by Marshall (2010), GBRMPA (2011), and Kettle (2011). Figure 4-2 includes some images from within the grounding footprint showing displaced and fractured substrate and habitat. Additional photos taken by Marshall (2010) are included in Appendix F (Figures F - 14 through F – 17). These particular photos were taken 13 April 2010(immediately following the grounding incident). Please note that no locational data were available for these photos.

4.4.2 Scale of Physical Damage

Spatial Extent

Figure 4-1 shows the interpolated extent of recorded physical damage within and adjacent to the grounding footprint (in 10 x 10 m grid cells[16]).

Of the 4503 grid cells that are within the grounding footprint, or overlap its boundary, 598 (13.2 %) contain recorded physical damage, 418 (9.28%) have no observed physical damage and 3487 cells (77%) have no data.

The distribution of physical damage across the grounding footprint is focussed at four quite distinct areas. These include the location the Shen Neng 1 first ran aground and three locations where she was stationary for 6 hours or more. At the latter locations, displaced substrate, reflecting the shape of the hull of Shen Neng 1 are clearly identifiable. Patches of physical damage were recorded between these locations.

In addition to sonar (which measure depth from the device to the substrate), Steiglitz (2010) collected backscatter data. Backscatter records the strength of the signal being reflected off the substrate. Signal strength can be affected by nature of substrate e.g. sand or rubble versus intact limestone pavement. Interestingly, the number of cells with physical damage increases when the backscatter data are included for the eastern most segment of the grounding footprint (see inset of Figure 4-1) from 3,800 m^2 to 58,400 m^2. For the remainder of the grounding footprint, the number of yellow coded cells remain generally static (when the backscatter data is added). This variability is either anomalous or alternatively, it may indicate a different type of physical damage in the area where Shen Neng 1 first ran aground (e.g. displaced habitat with limited displacement of substrate).

Outside the grounding footprint, 25 cells contain recorded physical damage and 1063 have no observed physical damage. All other cells (N=78,431) have no data.

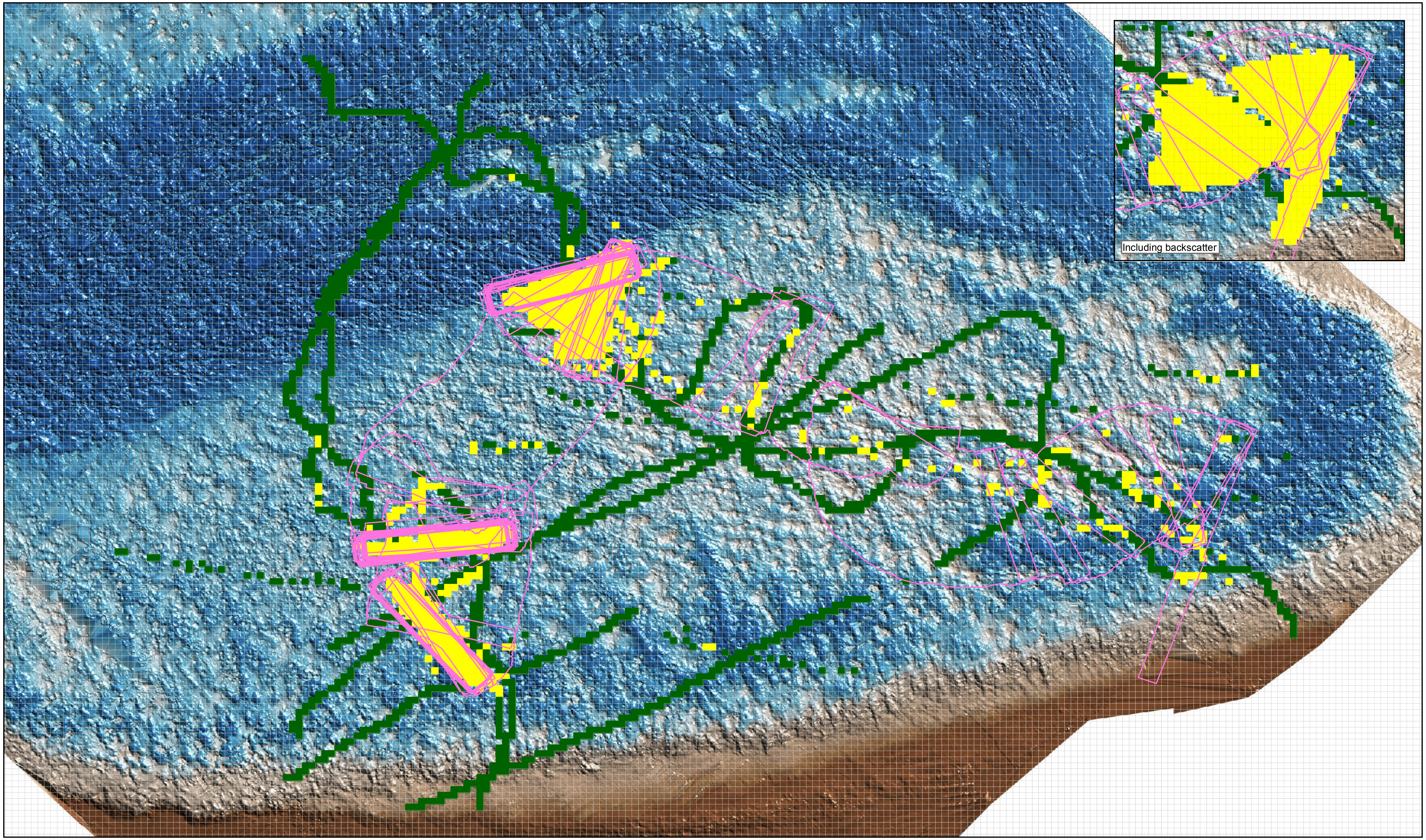
A qualitative review of TUV images suggest the damage identified in the northern most yellow coded cell shown in Figure 4-1 is an anomaly and appears to be a natural deep gutter with sand. The remaining 24 cells are categorised as damage. Further analysis of the TUV data could be undertaken and might reveal that some of these 24 other outliers are also naturally occurring features rather than physical damage.

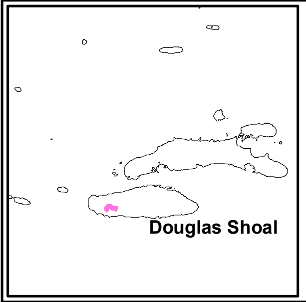
Persistence of Physical Damage

No data were collected regarding the likely persistence of physical damage. However, it is understood that:

- The scars shown in Figure 3-2 (2010) are still visible in satellite imagery captured in 2016 (Figure 4-6) and are likely to remain morphological features for decades.
- Due to low rates of cementation / coral accretion, fractured and or displaced benthic substrate is unlikely to repair itself at rates similar to biogenic reefs. This includes displaced and fractured substrate in the form of rubble, which are unlikely to consolidate.
- This unconsolidated rubble is likely to cause secondary impacts to the natural environment of Douglas Shoal by preventing new growth and possibly mobilising during storms, damaging previously unaffected areas.

[16] Based on towed underwater video imagery (Negri et al. (2010); manually delineation of visibly displaced substrate, and georeferenced images from Marshall (2010) – see Appendix E





Legend

Grounding footprint - 1 hour segments

Damage

- No data
- No physical damage
- Physical damage - less backscatter

Bathymetry (Negri et al. 2010)

-5 m — -30 m

Composite map of physical damage

FIGURE 4 - 1

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N

1:6,000 **Scale at A3**

Metres

0 200

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Coordinate System: GCS GDA 1994
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Map: 4_1_CompositePhysicalDamage.mxd 01

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Build Sheet: Appendix E

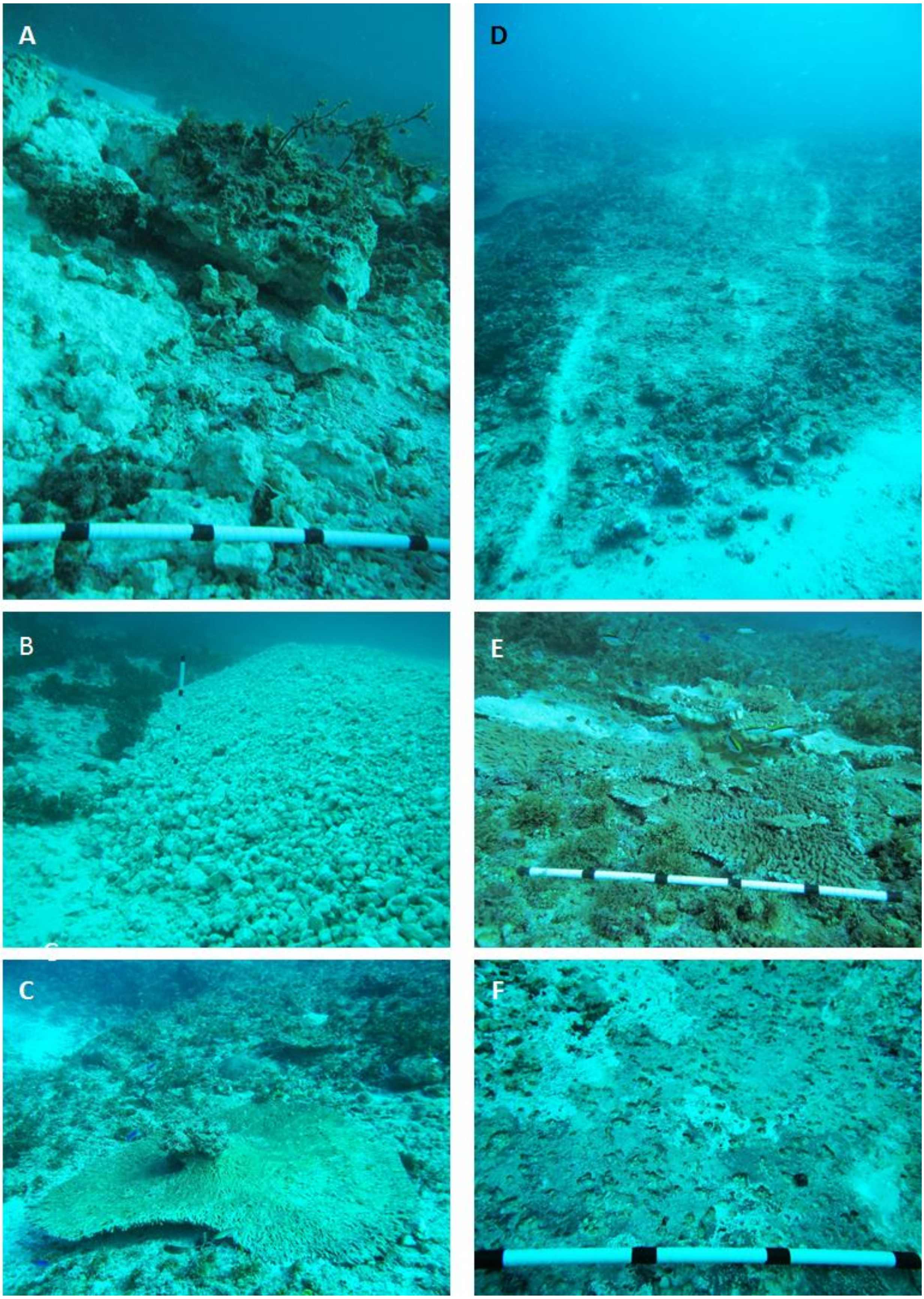


Figure 4-2 Images of physical damage

Figure 4-2: **A**) Substrate - fractured & displaced. **B**) Substrate - displaced (berm). **C**) Benthic fauna – displaced (toppled). **D**) Substrate – displaced (scarring). **E**) Benthic fauna – dislodged. **F**) Substrate – displaced (compressed).

4.5 Contamination

This section provides a description of nature and scale of contamination (an environmental receptor state change).

4.5.1 Nature

Nature refers to the location and type of contamination.

Location

Figure 4-3 (see Appendix E for build report) presents data as 10 x 10 m colour coded grid cells. Where contamination (TBT, copper or zinc) or AFP particles were recorded, the cell is orange. Where a sample was analysed, but nothing detected, cells are colour coded green and reported as 'no contamination detected'. In the absence of data, grid cells are left empty (transparent). As per Figure 4-1, each cell may contain a single data point (interpolated to the full extent of the 10 x 10 m cell). Therefore, the attributed status of each cell may not be representative of the entire area within that particular cell.

Similarly to physical damage, data presented suggest there is a clear relationship between the grounding footprint and recorded contamination. The distribution of contamination is discussed in Section 4.5.2.

Form of contamination

The source of contamination (the pressure) is the abraded antifouling paint particles lost from the hull of Shen Neng 1. A summary of these paints and their active constituents is provided in Section 3. Images of AFP taken within the grounding footprint are included in Figure 4-4. Kettle 2015(a) provides a comprehensive assessment of the 'types of AFP recovered' during a remediation trial. In summary, AFP particles include:

- Smears embedded onto substrate
- Smears on displaced and or fractured substrate (rubble)
- Flakes, ranging from 2-3 mm to 100 mm
- Chips 1-2 mm
- Microscopic < 1mm.

4.5.2 Scale of Contamination

Volume of AFP abraded from Shen Neng 1

The volume of paint abraded is unknown. However, conservative estimates provided by Gilbert (pers com. 2017) suggest tonnes of AFP particles were lost from the hull of Shen Neng 1 during the grounding incident.

Spatial extent / Distribution / Concentrations

Distribution of AFP particles and concentrations of TBT, copper and zinc are highly variable. Figure 4-3 shows the extent of recorded contamination derived from 412 samples[17]. Of these:

- 218 cells or ~ 53% contained no contamination; 62 cells were inside and 156 were outside the grounding footprint.
- 194 cells (~ 48%) contained either TBT, copper, zinc or AFP particles
- 135 cells (~ 69%) with recorded contamination, were situated within the grounding footprint or overlap its boundary, 59 (~30%) were located outside the grounding footprint.

Noting the high number of samples with no detected contamination (i.e. below laboratory detection limits), it is suggested that recorded concentrations of TBT, copper and zinc exceed pre-grounding values of these determinands.

[17] Not all samples were included due to locational reference issues

The location of TBT, copper, zinc sample results are available in Appendix F (Figures F-5 through F-8 respectively). AFP particle count sample locations and results are shown in Figure F-9 (Appendix F). These data indicate that:

- The area in which Shen Neng 1 initially ran aground contains the highest number of AFP particles per sample and concentrations of TBT, copper and zinc that exceed ANZECC High guideline (NAGD 2009).
- TBT, copper and zinc were detected in close proximity to areas where Shen Neng 1 was stationary or was moving slowly
- AFP particles were also detected in close proximity to areas where Shen Neng 1 was stationary or was moving slowly.
- 3 samples containing TBT were located outside the grounding footprint
- 2 samples containing copper were located outside the grounding footprint
- 2 samples containing zinc were located outside the grounding footprint
- AFFP were recorded outside the grounding footprint, but most within close proximity to the grounding footprint.

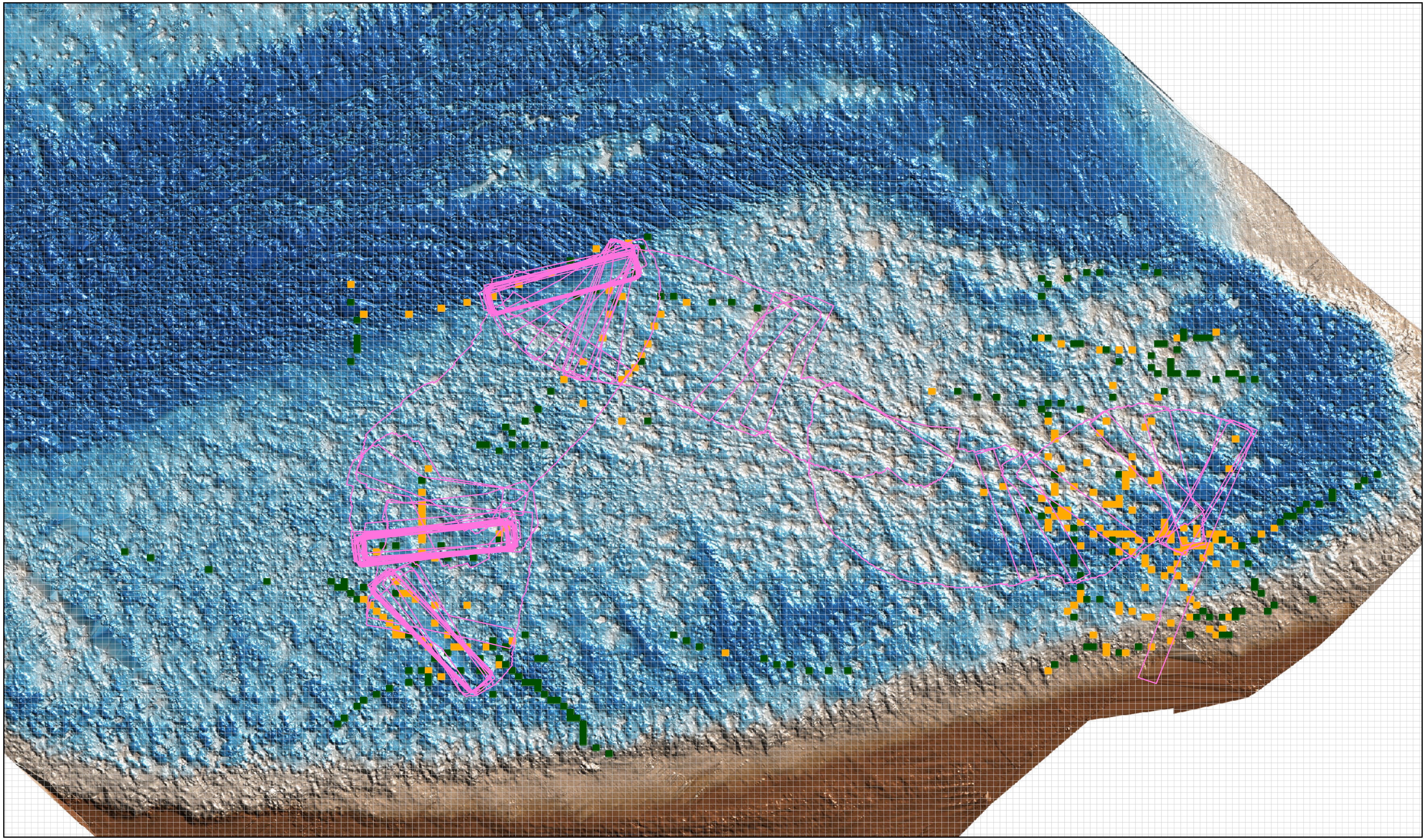
No data were available regarding:

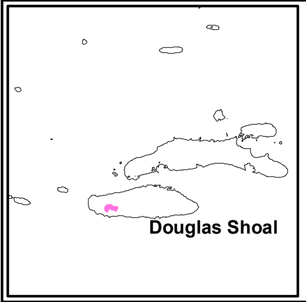
- The location of AFP particles smears (as shown in Figure 4-4)
- The vertical distribution of AFP particles or concentrations of contamination within sediment
- Bioavailability and toxicity of contamination as present
- The ecological risks of the contamination as present.

Persistence

Kettle 2015(a) does present results which suggest TBT is breaking down at some locations. However, no studies or investigations have systematically evaluated the likely persistence of contamination at Douglas Shoal. Including:

- Leaching rates of biocides
- The fate of AFP particles (spatially and temporally).





Legend

Grounding footprint - 1 hour segments

Contamination

No data

No contamination

Contamination

Bathymetry (Negri et al. 2010)

-5 m

-30 m

Composite map of contamination

FIGURE 4 - 3

N

1:6,000 **Scale at A3**

Metres

0 200

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Build Sheet: Appendix E

4.6 Physical Damage and Contamination

Data from Figure 4-1 and 4-3 were combined to develop Figure 4-5. This composite map presents data as 10 x 10 m coded grid cells. Where only physical damage was recorded, the cell is yellow. Where only contamination was recorded, cells are colour coded orange. A red colour code denotes locations where physical damage and contamination where recorded in the same cell. Where either no damage or no contamination were recorded, cells are colour coded green. In the absence of data, grid cells are left empty (transparent).

Of the 4503 grid cells that are within the grounding footprint, or overlap its boundary (Figure 4-5):

- 437 or 9.7% have no recorded contamination or damage (green)
- 68 or 1.5 % have recorded physical damage and contamination
- 530 or 11.8% have recorded physical damage only (yellow)
- 89 or 1.9% have recorded contamination only (orange)
- 3349 or ~ 75% have no data (transparent).

Figure 4-5 suggests there is a close correlation between the areas traversed by Shen Neng 1 during the grounding incident and the physical damage and contamination recorded. These results are consistent with observations made by GBRMPA (2011) and Kettle (2011).

Importantly, four broad areas with both physical damage and contamination are identifiable. These areas are further delineated and discussed in Section 5.

4.7 Potential Impacts

As previously stated, impacts are the measurable consequences of environmental receptor state changes. While scientific literature provides a general understanding of the likely impacts of physical damage and AFP contamination on the marine environment, there has been no systematic, deliberate assessment conducted to determine the actual or likely impacts at Douglas Shoal. It is suggested that without a sound understanding of how the local ecosystem functions, it may be difficult to attribute certain impacts to Shen Neng 1, or to evaluate how successful remediation has been.

Notwithstanding the above, and for completeness purposes, a brief summary of possible potential impacts to Marine Park values (identified in Section 2) are provided below. Please note that without a comprehensive study that identifies environmental receptor state change - impact relationships, the following section is descriptive and unlikely to be comprehensive.

4.7.1 Biodiversity

Impacts to biota may arise due to environmental state changes in the habitats and ecosystems on which they rely (Precht, 2006). For example, in relation to groundings, displacement of the substrate resulting in habitat reduction, at a local scale, can impact the health or survival of individual animals. Furthermore, populations may rely on specific habitat features to provide nursery, feeding and breeding areas and impacts to the benthic substrate and habitat may result in indirect impacts on populations. Impacts may also result from factors such as a reduction in available habitats for settlement of coral recruits or secondary physical damage from the movement of displaced substrate (rubble).

4.7.2 Traditional Owner Values

Traditional Owners have custodial responsibilities as part of their lore which ties them to country, thereby ensuring the maintenance of spiritual, cultural, biological and other values of such sites. As a result, impacts on biodiversity degrade and impact on Traditional Owner heritage values as biodiversity is fundamental to their connection to land and sea country.

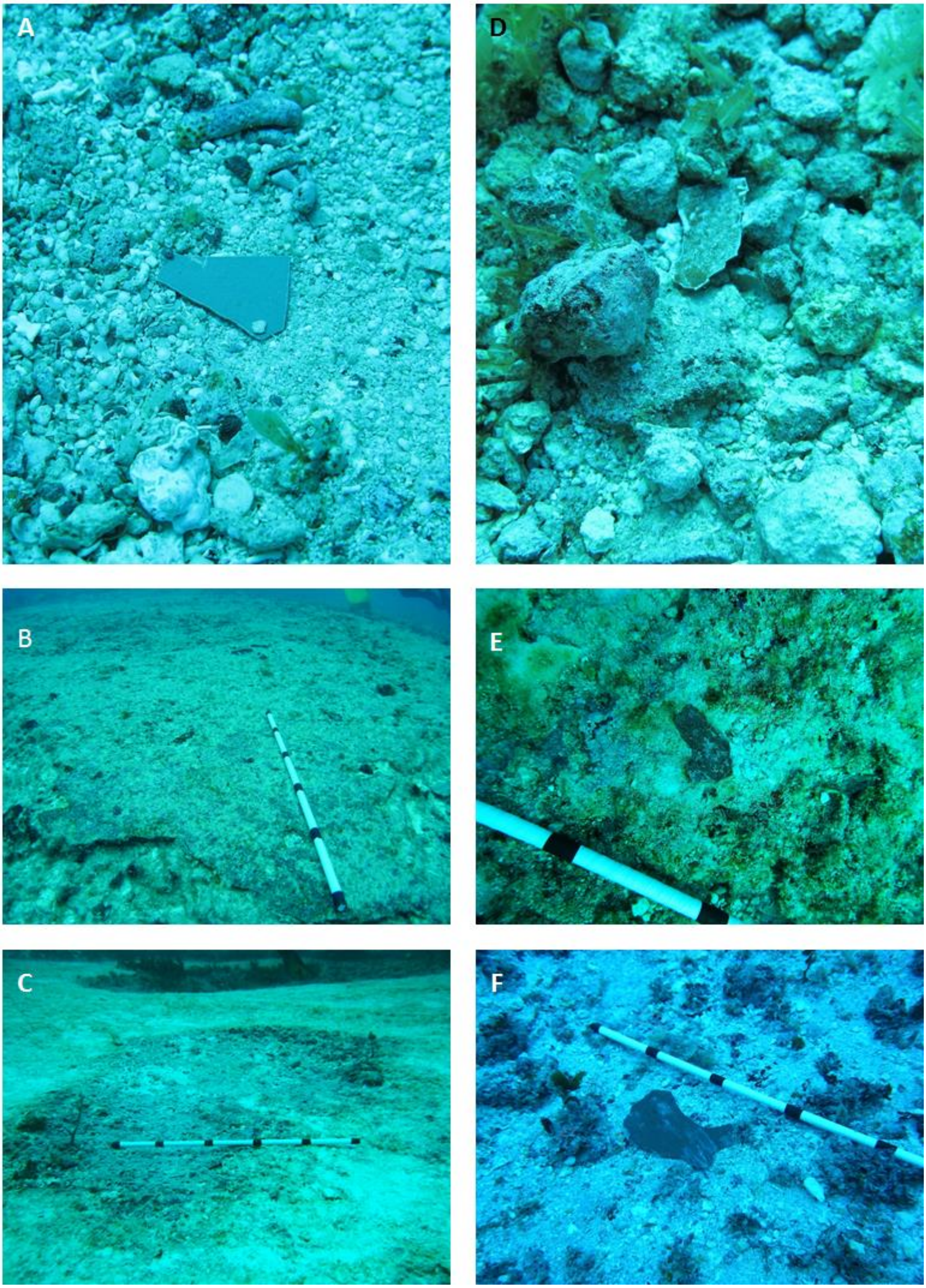
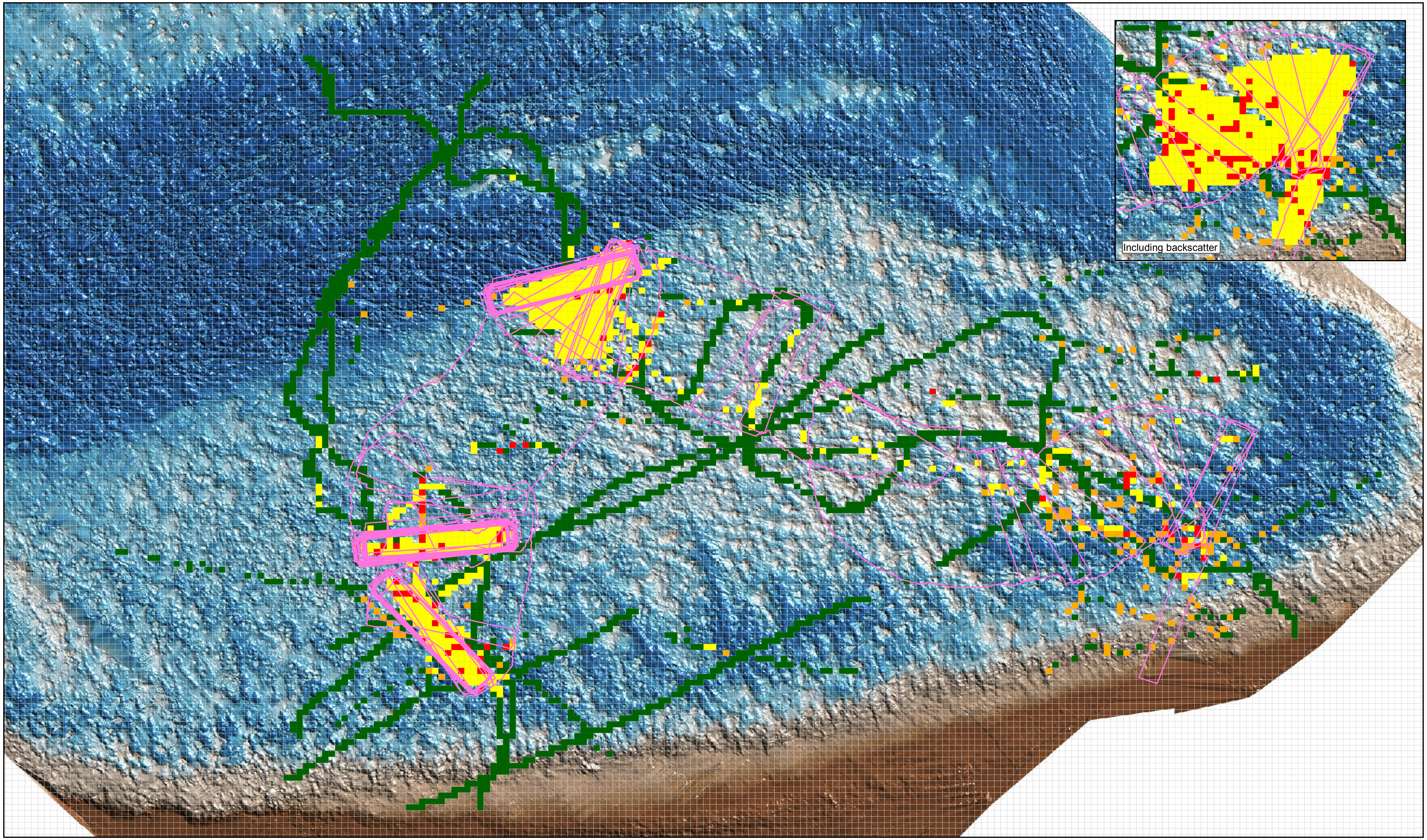
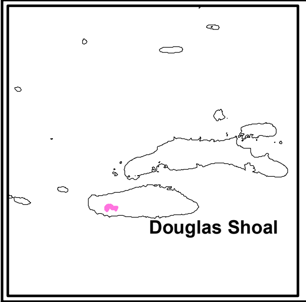


Figure 4-4 Images of in-situ AFP

Figure 4-4: A) Flake B) Large smear. C) Large smear (toppled). D) Flake amongst rubble. E) Small smear F) Large flake.





Legend

- No data
- Either no physical damage or contamination
- Physical damage - less backscatter
- Contamination
- Contamination and physical damage
- Grounding footprint - 1 hour segments

Bathymetry (Negri et al. 2010)

-5 m   -30 m

Composite map of physical damage and contamination

FIGURE 4 - 5

N

1:6,000 **Scale at A3**

Metres

0   200

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Build Sheet: Appendix E

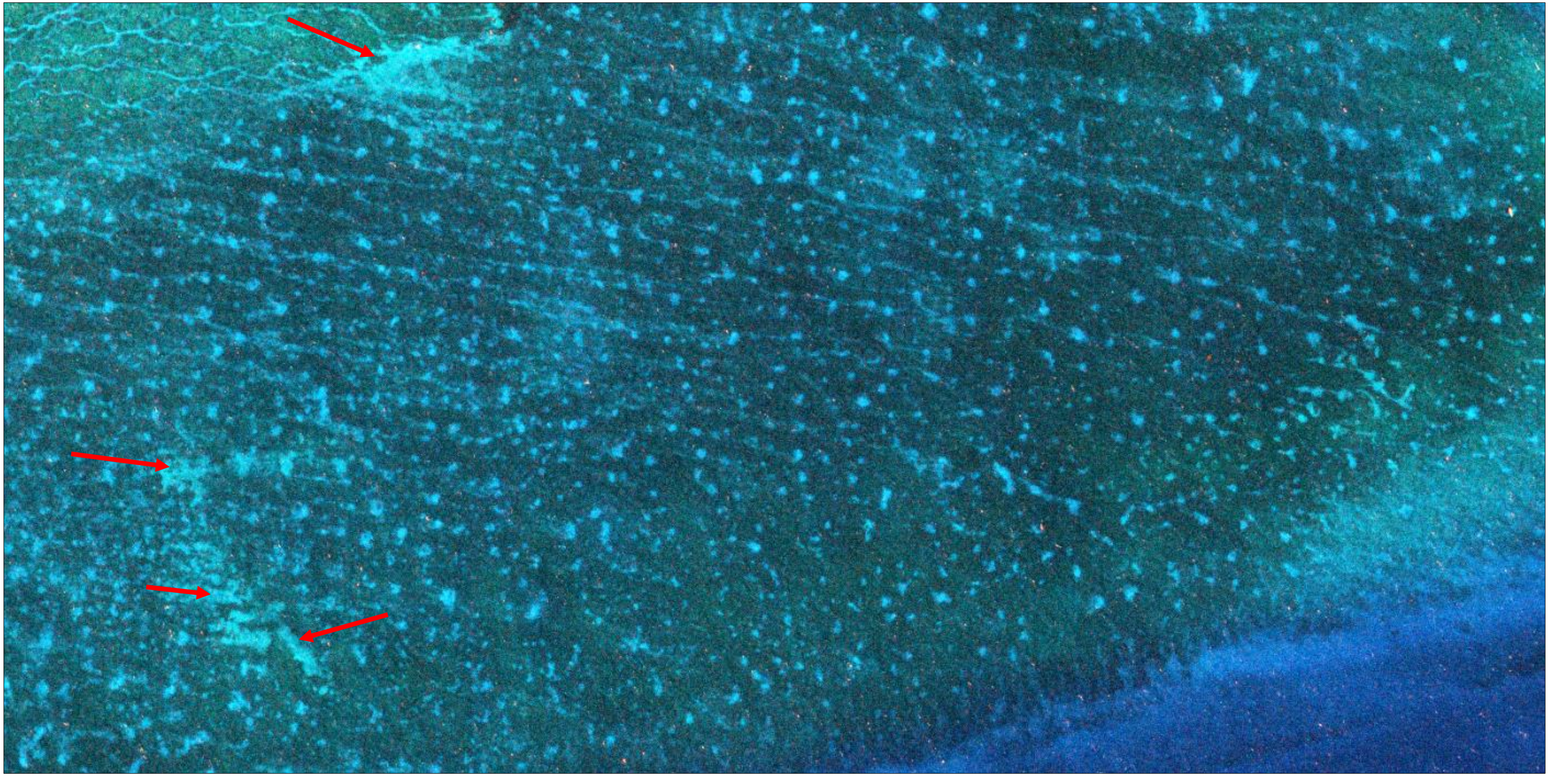


Figure 4-6 2016 World View 2 satellite imagery (red arrows point to visible scars, see Figure 3-2 for corresponding bathymetry)

4.7.3 Historic Heritage Values

While no historic heritage sites are known to exist at Douglas Shoal, it is important to consider during planning for remediation that historic heritage artefacts can be lost if accidentally disturbed. In addition, many people have personal connections to historic heritage through their ancestors and may feel personally impacted if a site is damaged.

4.7.4 Social and Economic Values

Potential impacts from the grounding may relate to the loss of perceived value associated with the grounding incident. Secondary impacts may include restrictions on access to sections of Douglas Shoal during the remediation works and subsequent performance monitoring programs.

4.8 Data and Information Gaps

Key gaps are listed below. Potential risks associated with these gaps are presented in Section 6.

G4.1 Data are not available to identify the nature (category) of all physical damage associated with the grounding incident.

G4.2 No data are available to further refine the extent of damaged and undamaged areas of Douglas Shoal.

G4.3 Data on the recovery potential of non-biogenic reefs from ship groundings (persistence of physical damage) or other perturbations is absent in the literature.

G4.4 No systematic, deliberate assessment of the consequences (impacts) from physical damage has been undertaken.

G4.5 No data are available to further refine the nature (form) and scale (extent and concentration) of contamination present

G4.6 No studies or investigations have systematically evaluated the likely persistence of contamination at Douglas Shoal. Including:

- Leaching rates of biocides
- The fate of AFP particles (spatially and temporally).

G4.7 No data exists regarding the vertical distribution of contamination within sediments.

G4.8 The geotextural properties of sediment (grain size, composition) have not been characterised, nor has a facies map been developed.

5 Possible Priority Areas

5.1 Overview

This section identifies and describes possible priority areas for remediation. Key points are summarised below. Gaps are identified at the end of this section.

Key Points

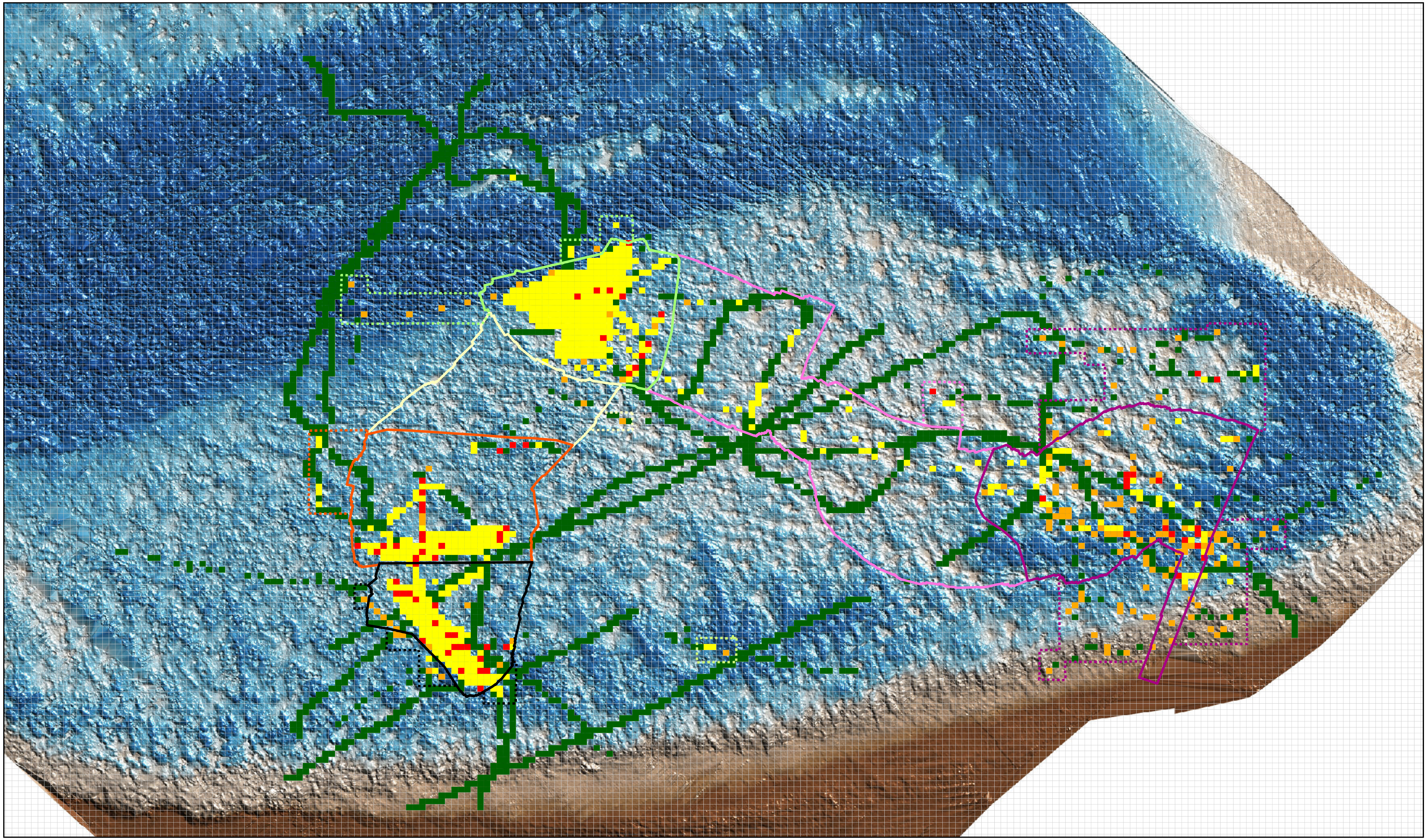
- Using the data presented in Section 4, four distinct areas where physical damage and contamination are concentrated have been delineated (Figure 5-1).
- These areas, annotated A, C, E and F are predominantly within the grounding footprint and represent priorities for further investigation and possible remediation.
- **Area A** covers some 202,700 m^2 and is located at the eastern extent of the grounding footprint, the site Shen Neng 1 first ran aground. The largest of the four areas, it comprises an extensive complex of dislocated holes and gutters filled with sand and rubble. These features are likely to contain AFP particles. Due to the size of Area A, remediation is likely to generate significant volumes of material for either treatment and or disposal.
- **Area C** covers some 81,600 m^2. Located north-west of **Area A**, physical damage associated with the movement of Shen Neng 1 over the benthic substrate is clearly identifiable.
- A scar in the shape of the hull of Shen Neng 1 is clearly visible at **Area E** which is located west of **Area A** and north of **Area F**. Berms comprised of fractured and displaced benthic substrate may contain AFP particles. It is suggested these may represent a potential priority for remediation.
- **Area F**, covers 51,800 m^2. A deep scar in the shape of Shen Neng 1 is clearly identifiable in this area. This is the location Shen Neng 1 remained for seven days prior to being removed from Douglas Shoal. Berms comprising fractured and displaced substrate may prove to be priorities for remediation in this area.
- Damage sustained at both **Area E** and **Area F**, resemble the scar at Sudbury Cay associated with the grounding of the Bunga Teratai Satu. While these areas are significantly larger, similar remediation strategies may prove effective.

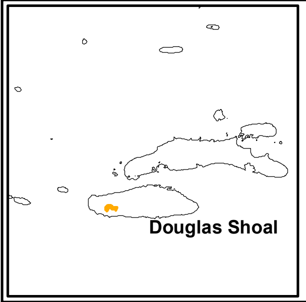
5.2 Approach

Using the data presented in Section 4, four distinct areas, where physical damage and contamination are concentrated have been delineated (Figure 5-1). These areas, annotated A, C, E and F are predominantly within the grounding footprint. However, nearby damage and contamination from outside the grounding footprint are included. These four areas are possible priority areas for further investigation and remediation.

An additional two areas (B and D), where reported physical damage and contamination are limited, have also been identified (Figure 5-1). A sixth area (G), to the south of the grounding footprint, comprising two cells with recorded damage and a single cell with reported contamination, has also been defined. It is suggested that these areas may represent less of a priority than areas A, C, E and F.

Descriptions of areas A, C, E and F are provided below.





Legend

Area: A, B, C, D, E, F, G

Grid - without backscatter
- No data
- No contamination and/or physical damage
- Physical damage
- Contamination
- Contamination and physical damage

Bathymetry (Negri et al. 2010)
-5 m to -30 m

Possible areas for remediation

FIGURE 5 - 1

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N

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Metres
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Build Sheet: Appendix E

5.3 Possible Priority Areas

5.3.1 Area A

Summary

Area A (Figure 5-2, Figure 5-6 and Figure F-10) is located at the eastern extent of the grounding footprint, the site Shen Neng 1 first ran aground. In summary, **Area A**:

- Covers some 202,700 m^2
- No data are available for 166,900 m^2, approximately 82% of the area
- Physical damage and contamination was recorded in 17 cells or 1%
- Cells with only contamination reported, total 112 or 5% of the area
- Cells with only recorded physical damage, total 52 or 3% of the area
- Cells with either no recorded physical damage or contamination represent 9% of the area.

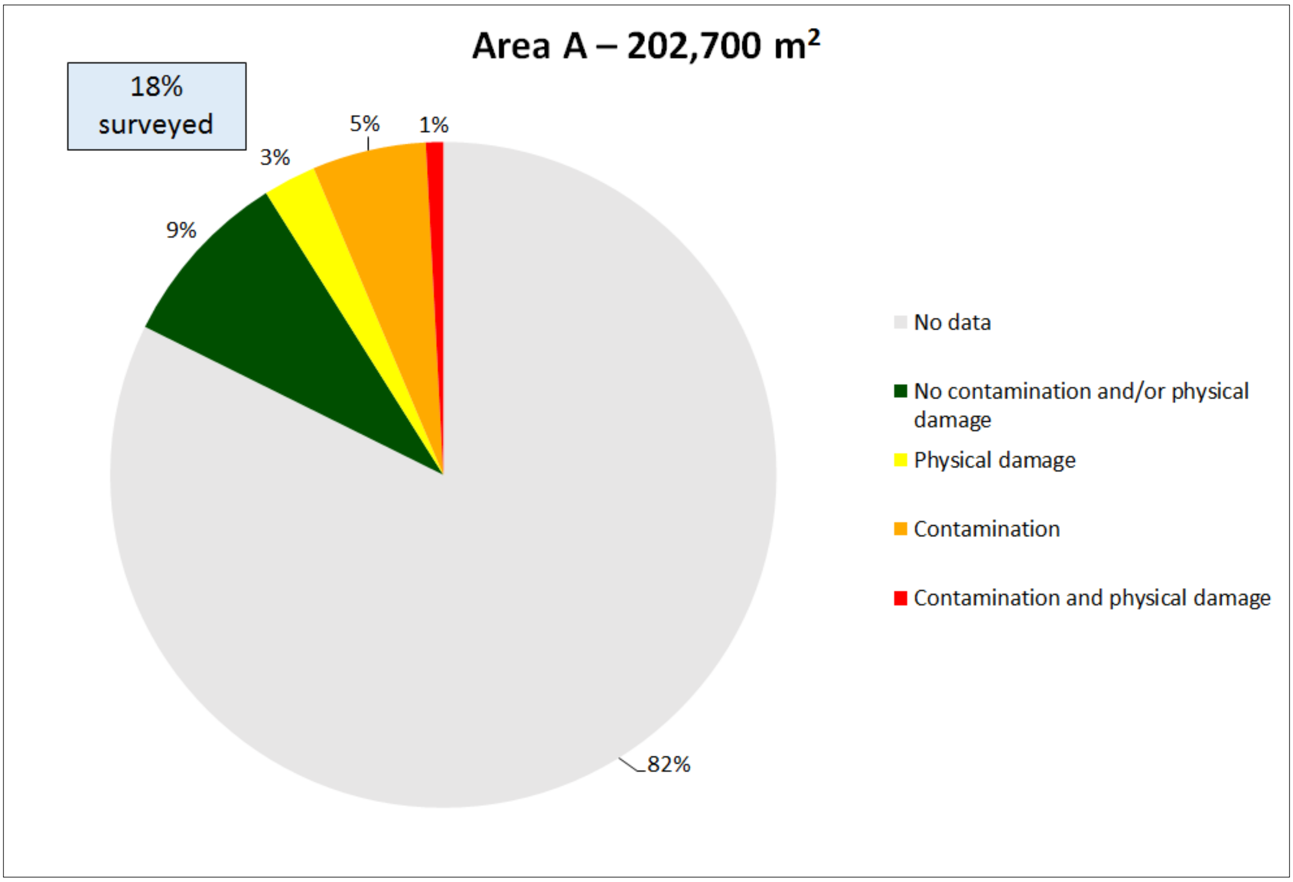


Figure 5-2 Area A - data summary

Observations and Descriptions

Area A, the largest of the possible priority areas, includes the site of the remediation trial completed by Kettle (2015). Kettle (2015a) describes the physical setting for the trial and summarises the distribution of AFP particles.

Negri et al. (2010) captured multibeam bathymetry and backscatter data across **Area A**, they state: 'the bathymetry and slope maps of the site of initial grounding (Site 1) show little to no structural difference to the adjacent reef matrix. However, a systematic increase in backscatter strength is associated with this site (see Appendix Figs. A1 and A2). This is likely caused by an abrasion and flattening of the reef top, without destruction of the reef matrix itself'.

Figure F-10 (Appendix A) is a high resolution image taken from the multibeam data collected by Negri et al. (2010). No displaced substrate are discernible. However, low relief morphology, including disconnected gutters and holes are clearly visible.

5.3.2 Area C

Summary

Area C (Figure 5-3, Figure 5-7 and Figure F-11) is located north-west of **Area A**. In summary, **Area C**:

- Covers some 81,600 m^2
- No data are available for 49,000 m^2, approximately 60% of the area
- Physical damage and contamination was recorded in 11 cells or 1% of the area
- Cells with only contamination reported, total 13 (AFP particles only) or 2% of the area
- Cells with only recorded physical damage, total 249 or 31%
- Cells with either no recorded physical damage or contamination represent 6% of the area.

Note that no sediment samples were collected from **Area C** for analysis of contaminant concentrations. However, Kettle (2014) did collect samples for AFP particle count analysis. Results indicate that 13 of the 24 samples, contained between 1 and 4 AFP particles (per sample).

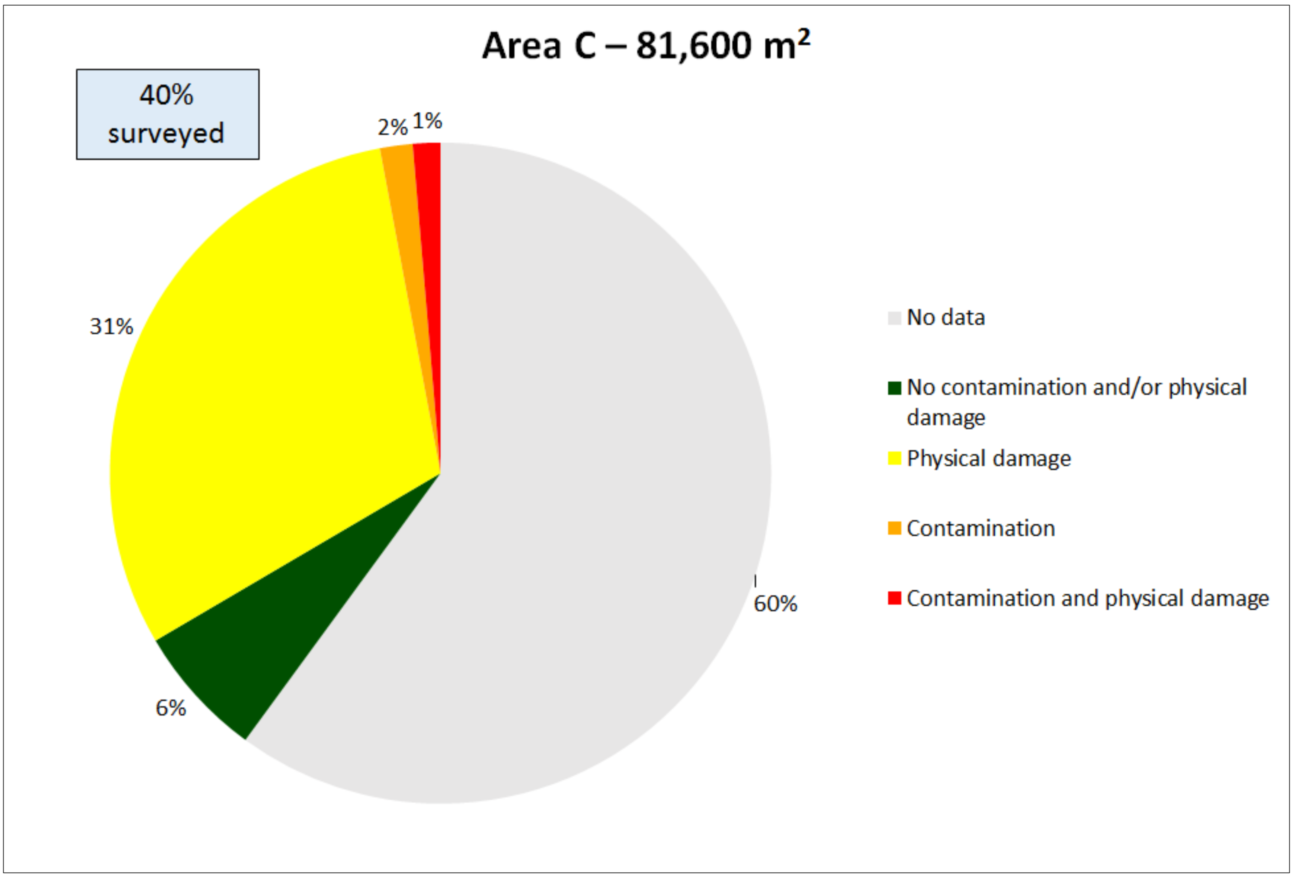


Figure 5-3 Area C – data summary

Observations and Descriptions

Figure 3-3, (plates a, b, c and d) show Shen Neng 1 aground on the Low Relief Terrace. Plumes of sediment are clearly visible on both the flood and ebb tide. The extent to which these plumes travelled is unknown.

A large scar caused by Shen Neng 1 is clearly visible in Figure F-11 (Appendix F). Negri et al. (2010) state that: '*Shen Neng 1's* GPS and heading data shows that the stern remained in about the same location, whereas the bow was swaying in an approximately 45 degree arc, restricted to the north by the shallower reef (the

High Relief Terrace in this report). This caused significant wearing-down of the seafloor, which resulted in substantial destruction; little reef structure remains at this site'.

5.3.3 Area E

Summary

Area E (Figure 5-4, Figure 5-8 and Figure F-12) is located west of **Area A**. In summary, **Area E**:

- Covers some 80,800 m^2
- No data are available for 58,700 m^2, approximately 73% of the area
- Physical damage and contamination was recorded in 21 cells or 2% of the area
- Cells with only contamination recorded, total 3 (less than 1%)
- Cells with only reported physical damage, total 102 or 13% of the area
- Cells with either no recorded physical damage or contamination represent 12% of the area.

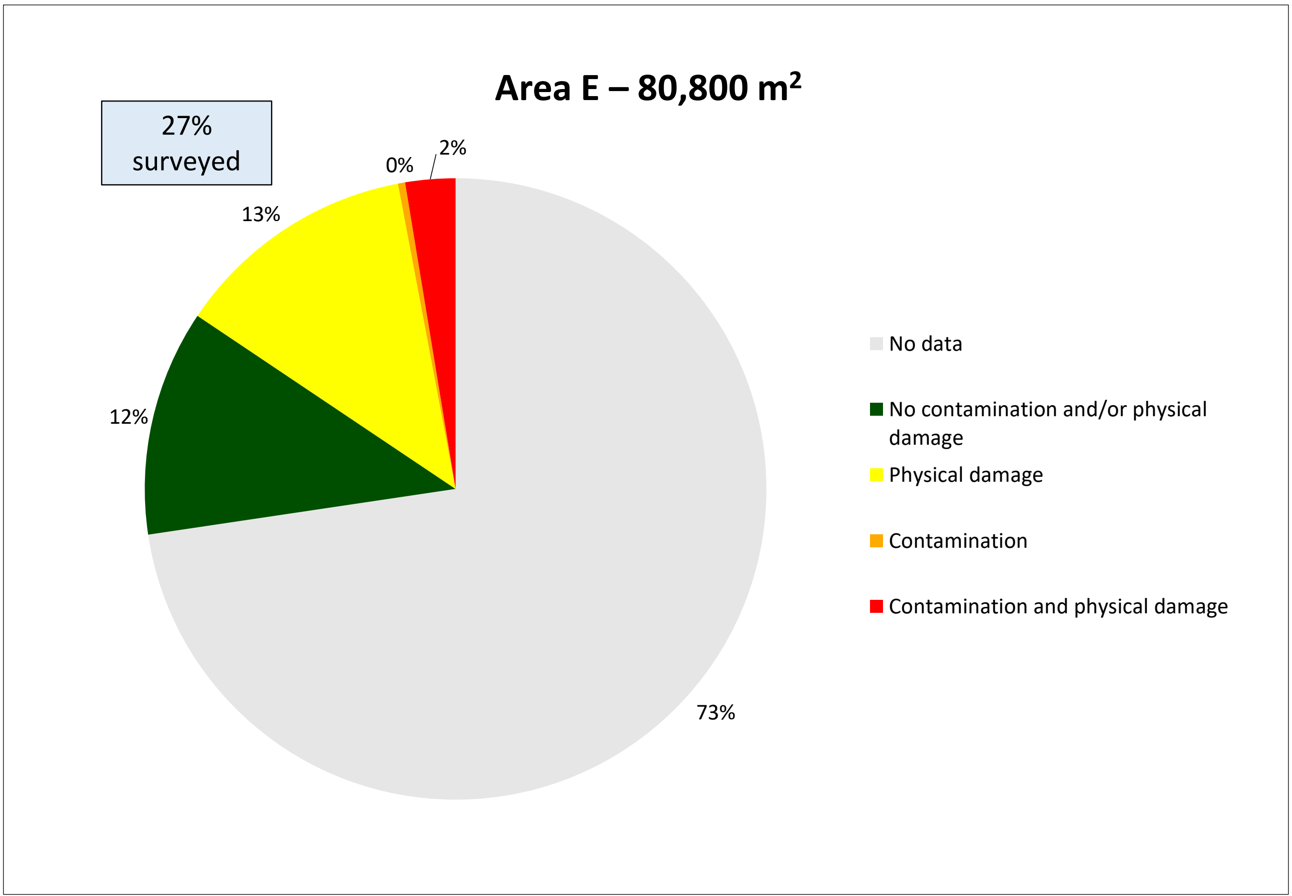


Figure 5-4 Area E – data summary

Observations and Descriptions

A scar in the shape of Shen Neng 1 is visible in Figure F-12 (Appendix F). In this figure, the impression left by the bow is obvious, with the aft sections of the hull less so. Negri et al. (2010) suggest that in the vicinity of the bow, substrate is fractured and displaced, while aft sections suffered lesser physical damage with abrasion 'of the top of the coral reef matrix' (displaced habitat).

5.3.4 Area F

Summary

Area F (Figure 5-5, Figure 5-9 and Figure F-13) is located west of **Area E**. In summary, **Area F**:

- Covers some 51,800 m^2
- No data are available for 28,000 m^2, approximately 54% of the area
- Physical damage and contamination was recorded in 22 cells or 4% of the area
- Cells with only contamination recorded, total 14 or 3% of the area
- Cells with only reported physical damage, total 114 or 22% of the area
- Cells with either no recorded physical damage or contamination represent 17% of the area.

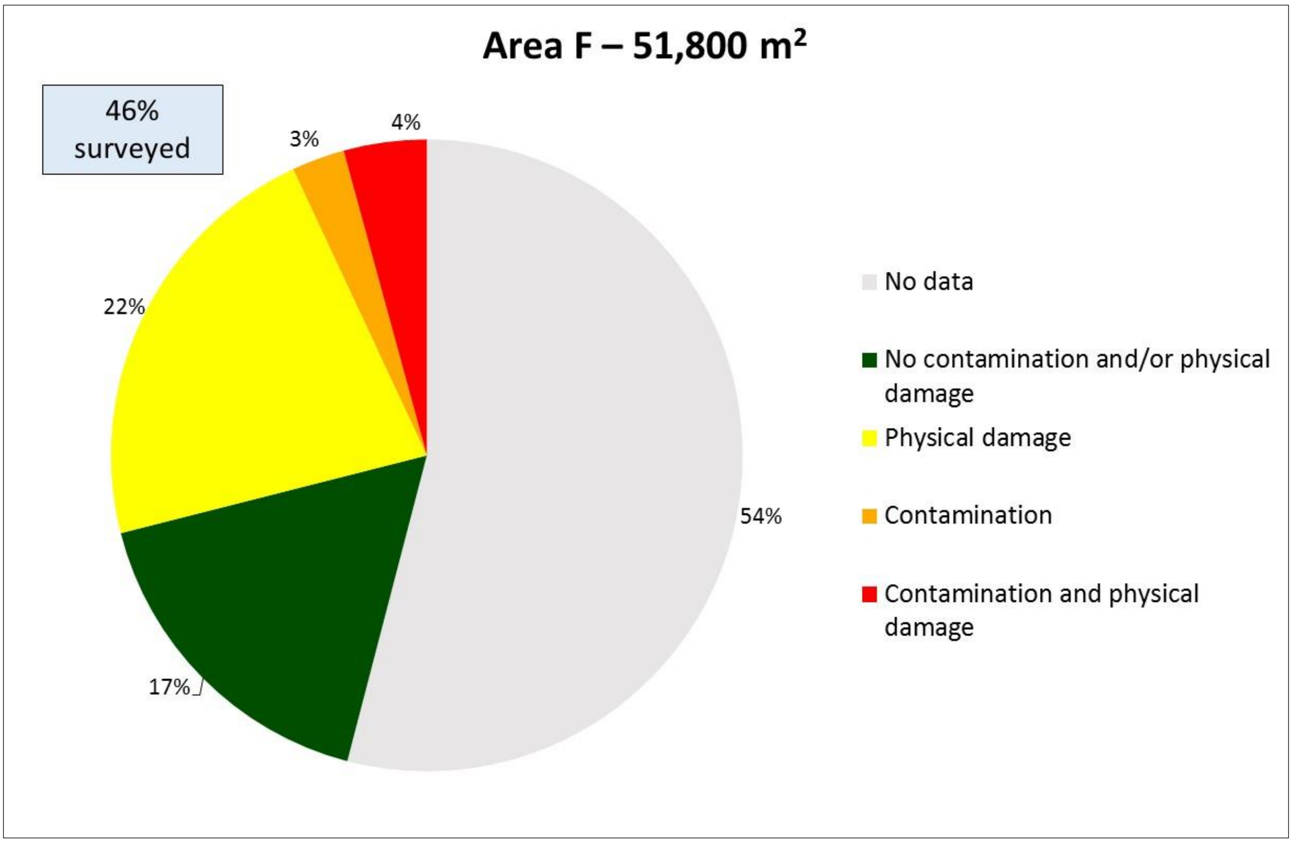


Figure 5-5 Area F – data summary

Observations and Descriptions

A deep scar in the shape of Shen Neng 1 is clearly identifiable in Figure F-13 (Appendix F). This is the location Shen Neng 1 remained for seven days prior to being removed from Douglas Shoal. Figure 3-3 (plates e, f, g and h) taken 6 April 2010, show Shen Neng 1 at this location. Negri et al. (2010) suggest that the increased seabed elevation at the eastern and western sides are likely the result of berms of displaced benthic substrate and habitat.

5.4 Data and Information Gaps

Key gaps are listed below. Potential risks associated with these gaps are presented in Section 6.

G5.1 **Area A:**

- No data are available for 166,900 m^2, approximately 80% of the area
- No data are available to further define the nature and scale of physical damage and contamination, allowing the refinement of the present boundary.

G5.2 **Area C**

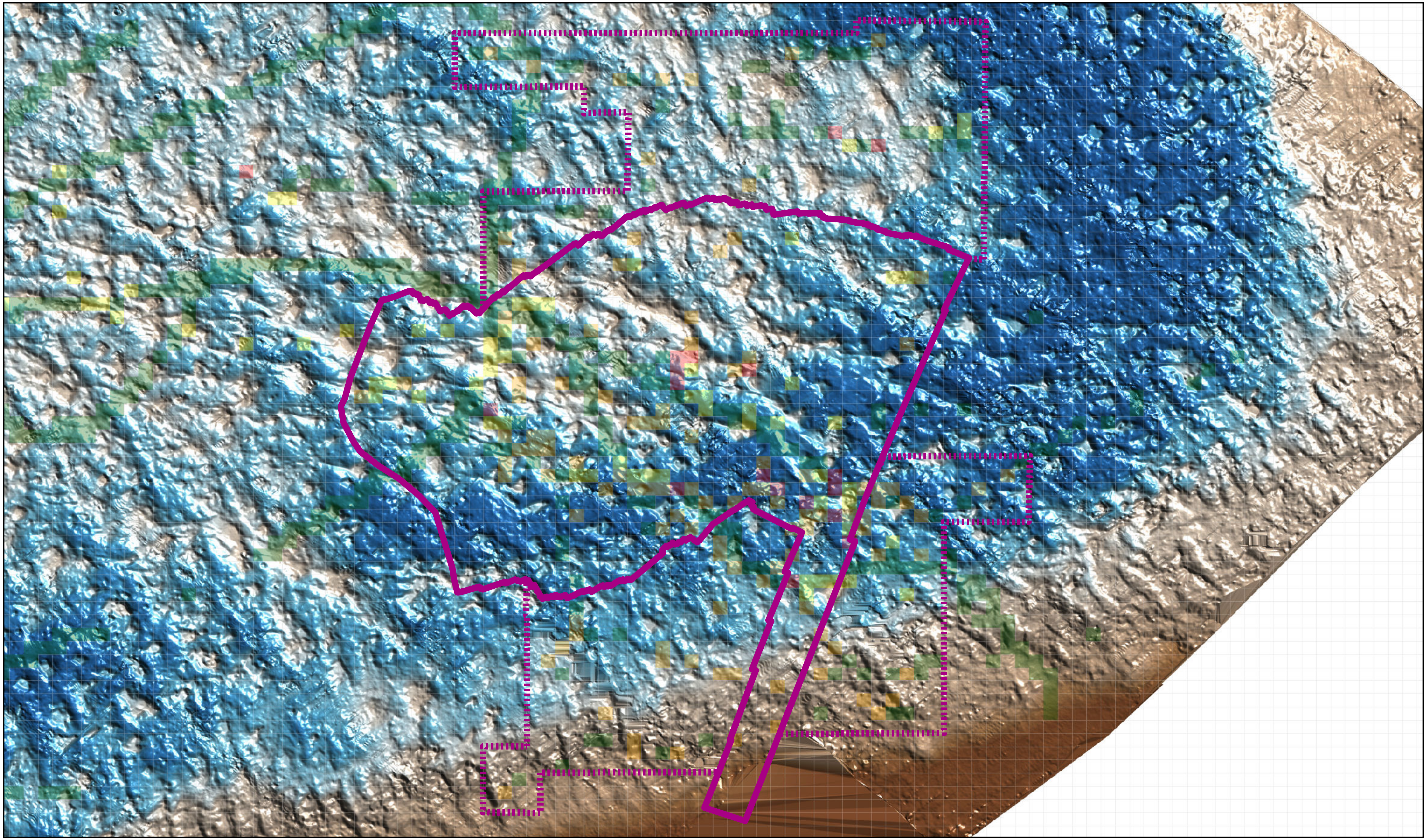
- No data are available for 49,000 m^2, approximately 60% of the area
- No contaminant concentration data were available
- No data are available to further define the nature and scale of physical damage and contamination, allowing the refinement of the present boundary.

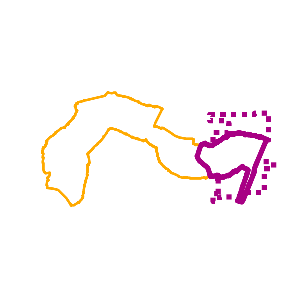
G5.3 **Area E**

- No data are available for 58,700 m^2, approximately 73% of the area
- No data are available to further define the nature and scale of physical damage and contamination, allowing the refinement of the present boundary.

G5.4 **Area F**

- No data are available for 28,000 m^2, approximately 54% of the area
- No data are available to further define the nature and scale of physical damage and contamination, allowing the refinement of the present boundary.





Legend

Area
A

Grid - without backscatter
- No data
- No contamination and/or physical
- Physical damage
- Contamination
- Contamination and physical

Bathymetry (Negri et al. 2010)
-5 m
-30 m

Possible priority area - A

FIGURE 5 - 6

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N

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Metres
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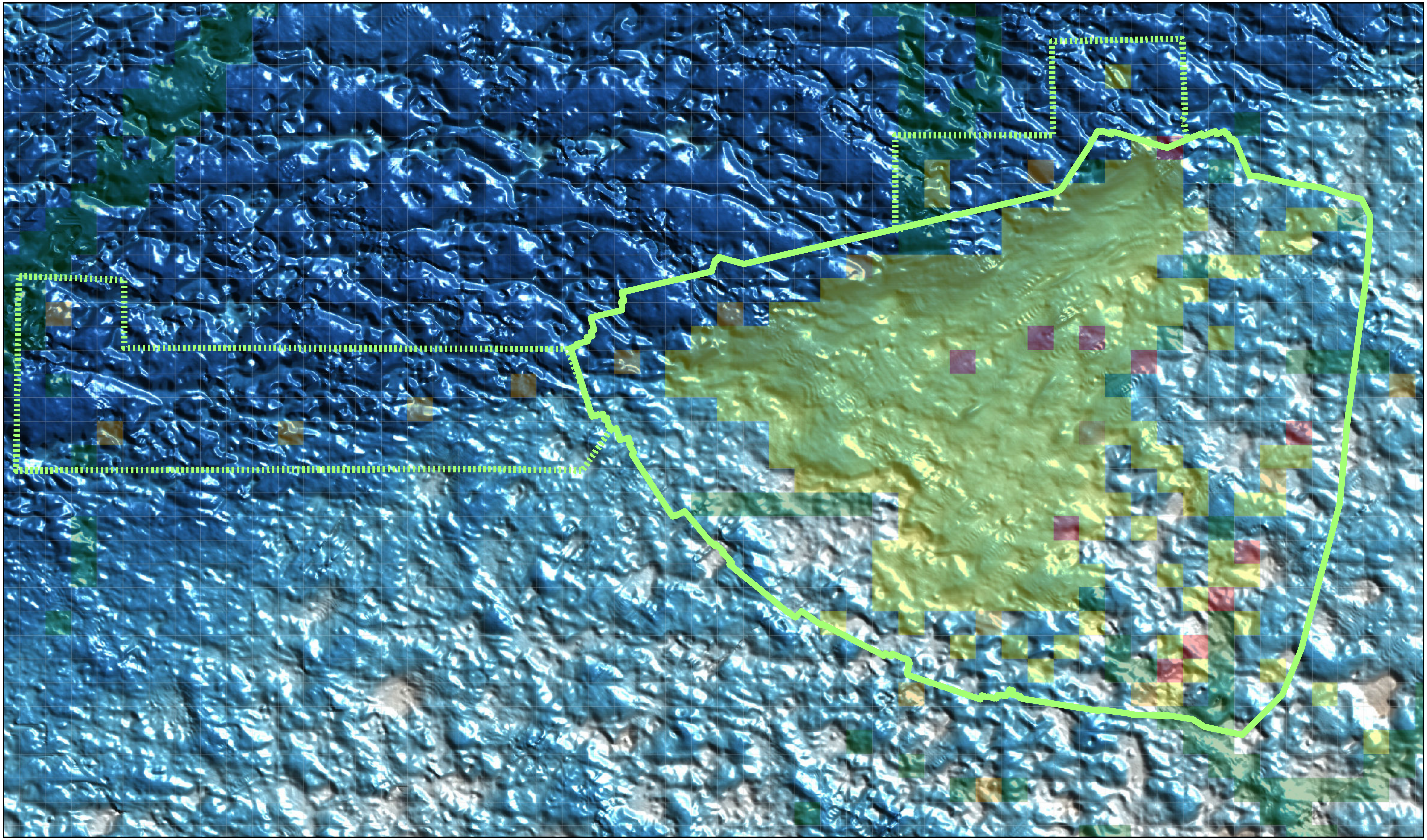

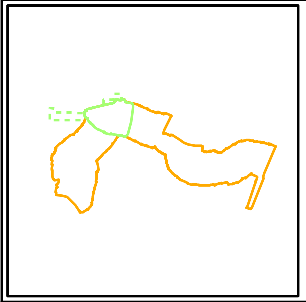

Possible priority area - C

FIGURE 5 - 7

Legend

Area
C

Grid - without backscatter
No data
No contamination and/or physical damage
Physical damage
Contamination
Contamination and physical damage

Bathymetry (Negri et al. 2010)
-5 m
-30 m

N

1:1,500 Scale at A3

Metres
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Project: 59918002_001
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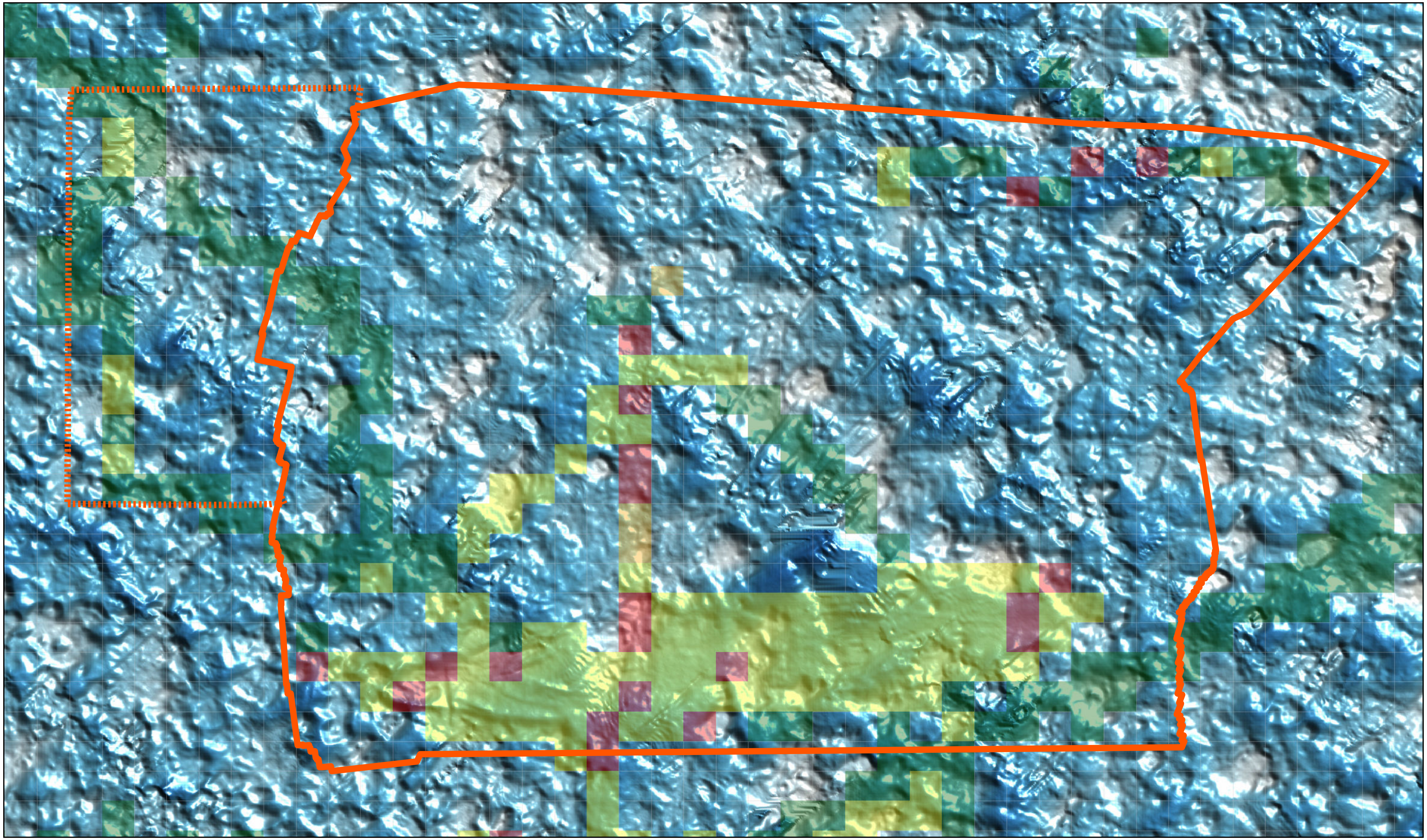
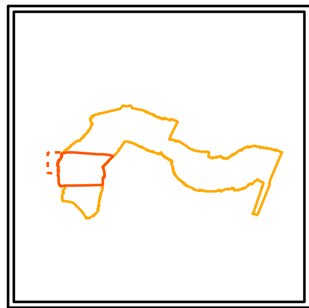
File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\5_7_PossibleRemediationAreaC.mxd

Build Sheet: Appendix E





Legend

Area
- E

Grid - without backscatter
- No data
- No contamination and/or physical damage
- Physical damage
- Contamination
- Contamination and physical damage

Bathymetry (Negri et al. 2010)
-5 m — -30 m

Possible priority area - E

FIGURE 5 - 8

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N

1:1,200 **Scale at A3**

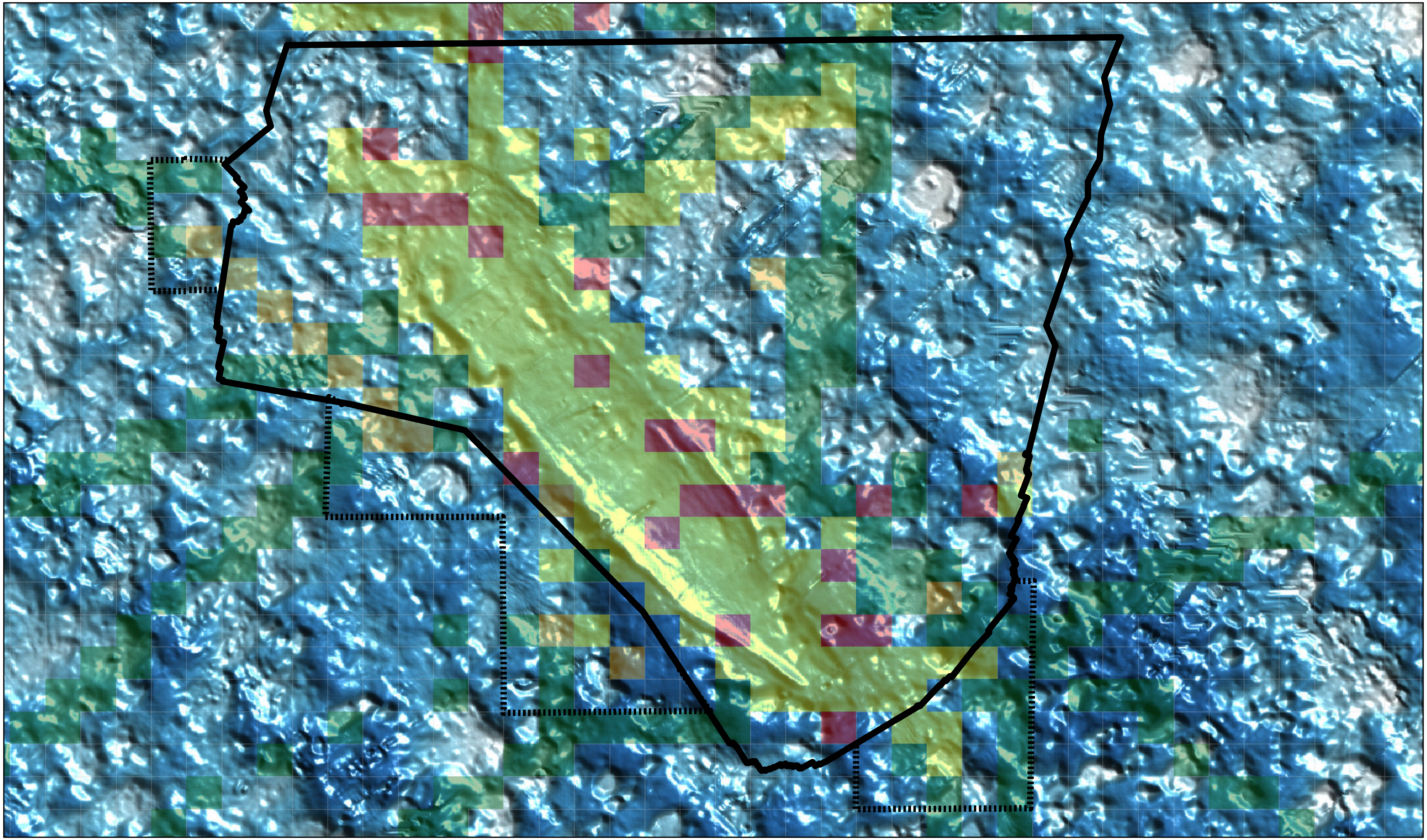
Metres
0 — 50

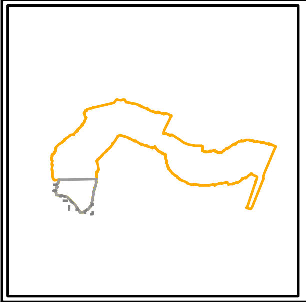
Map Produced by: NSW Water & Environment
Date: 2017-10-13
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: 5_8_PossibleRemediationAreaE.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\5_8_PossibleRemediationAreaE.mxd

Build Sheet: Appendix E





Legend

Area
F

Grid - without backscatter
No data
No contamination and/or physical damage
Physical damage
Contamination
Contamination and physical damage

Bathymetry (Negri et al. 2010)
-5 m
-30 m

Possible priority area - F

FIGURE 5 - 9

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N
1:1,100 Scale at A3
Metres
0 50

Map Produced by: NSW Water & Environment
Date: 2017-10-13
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: 5_9_PossibleRemediationAreaF.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\5_9_PossibleRemediationAreaF.mxd

Build Sheet: Appendix E

6 Summary of Critical Information Gaps and Associated Risks

6.1 Overview

This section (Table 6-1) presents the results of an analysis of information / data gaps / uncertainties for aspects relevant to the effective planning and monitoring of remediation. Consequences / Impacts are expressed as either negligible, minor, moderate, major or extreme. GBRMPA's Integrated Risk Rating Tool (Rev 4) was used to assign risk levels. Risk levels are untreated. Suggested treatment options are included.

Table 6-1 Data and Information Gaps as Risks to effective remediation planning and monitoring

Gap	Data Gaps / Uncertainties	Needs for effective remediation planning / monitoring of remediation	Notes	Impact on planning	L/hood	Risk Level	Suggested treatment options
G2.1	No site-specific hydrodynamic time-series (wind, wave and current) data exist.	Linked to G3.1 and G3.3 • Needed to understand / predict / simulate - dilution / mixing rates / fate of any tail water discharge resulting from remediation. • Needed to understand possible impacts of discharging tail water. • Needed to support possible approvals to discharge tail water.	See Gap G3.1 and G3.3 regarding chemical composition of AFP particles and tail water.	Moderate	Almost certain	High 17	Prior to commencing works involving the discharge of tail water: • Engage a suitably qualified consultant to identify data requirements to predict / simulate - dilution / mixing rates / fate of any tail water discharge resulting from remediation. • Use the results to develop water quality criteria and objectives. • Include water quality criteria and objectives in performance requirements for discharge of tail water by contractors. • Validate the predictions for discharge of tail water by monitoring water quality.
G2.2	No published reports, papers or reviews specifically relating to the pre-disturbance condition of Douglas Shoal (habitat type, composition, health, water quality and sediment quality) were identified.	• Needed to help establish a baseline for remediation, including setting objectives and understanding what natural recovery may look like.	While no pre-disturbance data exist, a substantial amount of information were collected by the GBRMPA-commissioned studies. With regard to natural recovery of benthic habitat (a possible focus of long term monitoring), this report suggests that undamaged benthic habitat within the grounding footprint are consistent with other areas of Douglas Shoal.	Minor	Almost certain	Med 12	As part of planning for and developing the monitoring program consider: • Identifying areas of undamaged benthic habitat as a proxy for the absent baseline data. • Defining objectives for natural recovering using undamaged benthic habitat. • Establish fixed monitoring locations as a proxy for the absent baseline data. • Encouraging independent research of Douglas Shoal or nearby shoals
G2.3	No data or information were available regarding the biological connectivity of Douglas Shoal, including sources of coral larvae, dispersal of recruits and patterns of fauna movement.	This information is important: • To understand if Douglas Shoal could 'self-seed' and if so, help estimate recovery rates for coral following remediation. • If active restoration is being considered e.g. coral larvae translocation.	This information could be gathered during remediation planning or even during remediation.	Negligible	Almost certain	Low 5	As part of planning for and developing the monitoring program consider: • Addressing this information gap through funded (university) research • Encouraging independent research of Douglas Shoal or nearby shoals
G2.4	No published information relating to the area's use or values to Traditional Owners were identified in previous studies.	• Douglas Shoal is within the Port Curtis Coral Coast TUMRA area, along with nearby islands, which may serve as the base for fieldwork (such as North West Island and Heron Island). • It is critical to understand the traditional values associated with these areas and to look for opportunities to not only protect, but also to enhance, Traditional Owner values.	It is understood that the project team is actively engaging with the Traditional Owners	Negligible	Almost certain	Low 5	• The TUMRA Steering Committee continues to provide advice on the project's Traditional Owner Participation Strategy (start of project), including opportunities for internship's or employment through the project. • Agree cultural heritage protocols with Traditional Owners.
G2.5	No information relating to historic heritage values of Douglas Shoal were identified during the development of this report.	Needed to ensure remediation does not affect historic heritage values.	While no information regarding the presence or absence of historic heritage are available, risks could be addressed during the development of a remediation plan	Negligible	Almost certain	Low 5	As part of the planning and development of a remediation plan, consider: • Developing historic heritage protocols • Include these protocols as requirements to be implemented by any contractors
G2.6	No information relating to the potential driver for the observed abundance of sea snakes.	Not relevant for planning remediation or monitoring remediation	NA	Negligible	Almost certain	Low 5	As part of planning for and developing the monitoring program consider: • Addressing this information gap through funded (university) research • Encouraging independent research of Douglas Shoal or nearby shoals
G2.7	The biodiversity value of submerged reefal shoals in the Southern Region of the Great Barrier Reef are poorly understood.	Relevant to monitoring for example: • Understanding the pressures and processes that may affect natural recovery (including timeframes) • Establishing control / reference sites at any of the nearby shoals for compliance monitoring during remediation and longer term monitoring of project success	Long-term data would need to be collected and analysed. Unlikely to be fully resolved prior to commencing remediation.	Negligible	Almost certain	Low 5	As part of planning for and developing the monitoring program consider: • Establish long term monitoring sites at Douglas Shoal and nearby shoals • Establish compliance monitoring sites • Addressing this information gap through funded (university) research • Encouraging independent research of Douglas Shoal or nearby shoals

Gap	Data Gaps / Uncertainties	Needs for effective remediation planning / monitoring of remediation	Notes	Impact on planning	L/hood	Risk Level	Suggested treatment options
G3.1	The chemical composition (including biocides) of all AFP layers applied to the hull of Shen Neng 1 is unknown	Contamination is a key pressure and threat to natural recovery. This information is needed to determine: • Which biocides are in the AFP particles present • Impacts associated with remediation (see G2.1) Results may affect: • Remediation methods • Costs of remediation • Approval requirements	May inform feasibility of remediation methods, including discharge of tail water.	Moderate	Almost certain	High 17	As part of planning for and developing the monitoring program consider: • Analysing paint samples collected by Monkivitch (2010) for a wide range of biocides • Link results to G2.1
G3.2	The total amount of AFP particles abraded from the hull of Shen Neng 1 is not known	Contamination is a key pressure and threat to natural recovery. This information is needed to: • Estimate AFP particles abraded from Shen Neng 1 • Establish clean up objectives • Estimate likely costs for remediation	This will remain a gap unless the responsible party provides copies of damage reports / assessments undertaken following the grounding incident. These will be available through the insurer of Shen Neng 1.	Major	Almost certain	Very High 25	Consider: • Revisiting data (images) collected by Monkivitch (2010) and 'map' the loss of AFP particles • Requesting this information from the responsible party
G3.3	The efficacy (toxicity) of AFP particles abraded from the hull of Shen Neng 1 is not understood.	Contamination is a key pressure and threat to natural recovery. This information is needed to determine: • Toxicity of biocides in remediation tail water (see G2.1) • The impact of biocides, including on water quality and sediment quality Results may affect: • Remediation methods and costs • Approval requirements	May inform feasibility of remediation methods, including discharge of tail water.	Moderate	Almost certain	High 17	As part of planning for and developing the monitoring program consider: • Using results for G2.1
G3.4	The long term behaviour (for example half-life, leach-ability, effects of abrasion and susceptibility to weathering) of abraded AFP at Douglas Shoal are unknown	Contamination is a key pressure and threat to natural recovery. This information is needed to: • Understand the long term chronic pressures and impacts of biocides present • Understanding how long 'natural recovery' may take • Inform the time scale over which monitoring may be required Results may affect: • Remediation methods and costs • Approval requirements	May inform feasibility of remediation methods	Moderate	Almost certain	High 17	As part of planning for and developing the monitoring program consider: • Analysing the physical properties of paint samples collected by Monkivitch (2010) • Determining possible half-life of biocides present in paint samples (G3.1) and extrapolating this to the Douglas Shoal environment • Understanding how burial of AFP particles affects bioavailability of biocides present

Gap	Data Gaps / Uncertainties	Needs for effective remediation planning / monitoring of remediation	Notes	Impact on planning	L/hood	Risk Level	Suggested treatment options
G4.1	Data are not available to identify the nature (category) of all physical damage associated with the grounding incident	Information regarding the nature of physical damage across Douglas Shoal is needed to: • Inform the feasibility of remedial methods • Prioritise remedial actions (for example coral may establish, but substrate unlikely to) • Setting of measurable remediation objectives for physical damage categories • Monitoring recovery	The absence of such data is problematic to both planning of remediation and monitoring	Moderate	Almost certain	High 17	As part of planning the remediation works consider: • Establishing remediation objectives for physical damage • Mapping physical damage at a scale suitable to inform risk based decisions regarding prioritising remediation actions • Incorporating remediation objectives into the monitoring plan
G4.2	No data are available to further refine the extent of damaged and undamaged areas of Douglas Shoal.	Information regarding the extent of physical damage is needed to: • Inform the feasibility of remedial methods • Prioritise remedial actions • Setting of measurable remediation objectives for possible priority areas • Monitoring recovery • Estimating costs of remediation	The absence of such data may affect the setting of measurable remediation objectives for each priority area. Monitoring recovery will also be problematic.	Major	Almost certain	High 17	As part of planning the remediation works consider: • Mapping physical damage at a scale suitable to inform risk based decisions regarding prioritising remediation actions • Establishing remediation objectives for physical damage within each priority area • Incorporating remediation objectives into the monitoring plan
G4.3	Data on the recovery potential of non-biogenic reefs from ship groundings (persistence of physical damage) or other perturbations is absent in the literature.	Needed to: • Understand the recovery potential of habitat and consolidation potential of displaced / fractured substrate. • Inform the feasibility of remedial methods • Needed to prioritise remediation efforts	Difficult to understand risk to planning, as there are no detailed remediation objectives. If not considering active restoration, then these data maybe captured by monitoring	Minor		Medium	As part of planning the remediation works consider: • Establishing remediation objectives, including if active restoration of substrate is to be undertaken.

G4.4	No systematic, deliberate assessment of the consequences (impacts) from physical damage has been undertaken	Needed to: • Inform the development of a balanced monitoring program, by understanding the likely successional pattern and timeframes for natural recovery. • Plan remediation, by understanding which types of physical damage that pose barriers to natural recovery (allowing prioritisation).		Major	Almost certain	High 17	As part of planning the remediation works consider: • Identifying potential long term impacts associated with physical damage • Incorporating results into a long term monitoring program
G4.5	No data are available to further refine the nature (form) and scale (extent and concentration) of contamination present	Noting that contamination is likely to represent the highest risk to natural recovery, this information is needed to: • Inform the feasibility of remedial methods • Prioritise remedial actions • Setting of measurable remediation objectives for possible priority areas • Monitoring recovery • Estimating costs of remediation	Absence of data may affect the setting of measurable remediation objectives for each priority area. Monitoring recovery will also be problematic	Extreme	Almost certain	**Very High 25**	As part of planning the remediation works consider: • Establishing remediation objectives for contamination • Mapping contamination at a scale suitable to inform risk based decisions regarding prioritising remediation actions • Incorporating remediation objectives into the monitoring plan
G4.6	No studies or investigations have systematically evaluated the likely persistence of contamination at Douglas Shoal. Including: • Leaching rates of biocides • The fate of AFPP (spatially and temporally).	Noting that contamination is likely to represent the highest risk to natural recovery, this information is needed to understand: • Long term impacts of contamination • The advection and dispersal potential of AFP particles	These gaps could be filled during the planning phase or even later depending on the specific remediation objectives	Major	Almost certain	High 17	As part of planning the remediation works consider: • Identifying potential long term impacts associated with contamination • Use results from G2.1 • Incorporating results into a long term monitoring program
G4.7	No data exists regarding the vertical distribution of contamination within sediments	Noting that contamination is likely to represent the highest risk to natural recovery, this information is needed to understand: • The vertical depth / extent of any remediation works (sediment removal) • Volume of material to be removed and or treated • Clean up objectives • Feasibility of remediation methods • Cost estimates for remediation	The absence of such data may affect the setting of measurable remediation objectives for each priority area. Monitoring recovery will also be problematic	Major	Almost certain	High 17	As part of planning the remediation works consider: • Mapping of the vertical extent of contamination at each priority area at a scale suitable to inform risk based decisions regarding prioritising remediation actions • Establishing remediation objectives for clean-up depths within each priority area • Incorporating remediation objectives into the monitoring plan
G4.8	The geotextural properties of sediment (grain size, composition) have not been characterised, nor has a facies map been developed	Information relating to the physical properties of sediment is needed to understand: • Possible relationship between grain size and AFP particle distributions	Data would be captured as part of G4.5	Major	Almost certain	High 17	As part of planning the remediation works consider: • Collecting geotextural data as part of G4.5 • Incorporate results into remediation plan
Gap	Data Gaps / Uncertainties	Needs for effective remediation planning / monitoring of remediation	Notes	Impact on planning	L/hood	Risk Level	Suggested treatment options
G5.1	Area A: • No data are available for 166,900 m^2, approximately 80% of the area • No data are available to further define the nature and scale of physical damage and contamination, allowing the refinement of the present boundary.	Further delineation of the nature and scale of both physical damage and contamination is required to: • Inform the feasibility of remedial methods • Prioritise remedial actions within the priority area • Setting of measurable remediation objectives • Monitoring recovery • Estimating costs of remediation	With specific regard to Area A, because it is so large, defining the distribution of contamination will be critical to identifying a practical and cost effective remediation method	Extreme	Almost certain	**Very High 25**	As part of planning the remediation works consider: • Mapping physical damage and contamination at a scale suitable to inform risk based decisions regarding prioritising remediation actions • Establishing remediation objectives for physical damage • Incorporating remediation objectives into the monitoring plan
G5.2	Area C • No data are available for 49,000 m^2, approximately 60% of the area • No contaminant concentration data were available • No data are available to further define the nature and scale of physical damage and contamination, allowing the refinement of the present boundary	Further delineation of the nature and scale of both physical damage and contamination is required to: • Inform the feasibility of remedial methods • Prioritise remedial actions within the priority area • Setting of measurable remediation objectives • Monitoring recovery • Estimating costs of remediation	Further sampling of sediments for contamination required	Extreme	Almost certain	**Very High 25**	As part of planning the remediation works consider: • Mapping physical damage and contamination at a scale suitable to inform risk based decisions regarding prioritising remediation actions • Establishing remediation objectives for physical damage • Incorporating remediation objectives into the monitoring plan
G5.3	Area E • No data are available for 58,700 m^2, approximately 73% of the area	Further delineation of the nature and scale of both physical damage and contamination is required to: • Inform the feasibility of remedial methods • Prioritise remedial actions within the priority area	Damage to Area E and F resembles the scar at Sudbury Cay associated with the grounding of Bunga Teratai Satu. While these areas are significantly	Extreme	Almost certain	**Very High 25**	As part of planning the remediation works consider: • Mapping physical damage and contamination at a scale suitable to inform risk based decisions regarding prioritising remediation actions

	• No data are available to further define the nature and scale of physical damage and contamination, allowing the refinement of the present boundary.	• Setting of measurable remediation objectives • Monitoring recovery • Estimating costs of remediation	larger, similar remediation strategies may prove effective.				• Establishing remediation objectives for physical damage • Incorporating remediation objectives into the monitoring plan
G5.4	Area F • No data are available for 28,000 m^2, approximately 54% of the area • No data are available to further define the nature and scale of physical damage and contamination, allowing the refinement of the present boundary.	Further delineation of the nature and scale of both physical damage and contamination is required to: • Inform the feasibility of remedial methods • Prioritise remedial actions within the priority area • Setting of measurable remediation objectives • Monitoring recovery • Estimating costs of remediation	Area F is reasonably well defined. Similar remediation strategies to those used for the clean-up following the grounding of Bunga Teratai Satu. may prove effective.	Extreme	Almost certain	**Very High 25**	As part of planning the remediation works consider: • Mapping physical damage and contamination at a scale suitable to inform risk based decisions regarding prioritising remediation actions • Establishing remediation objectives for physical damage • Incorporating remediation objectives into the monitoring plan

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Appendix A – DSERP Objectives

Objective		Performance Indicator
The primary objective (outcome) of the project is to ensure that settlement funds provided by the responsible party deliver the greatest long-term environmental benefits	The project will focus on maximising the chances for natural recovery and minimising the environmental and human risks of remediation activities	Post-remediation evaluation indicates that detailed remediation objectives have satisfied their evaluation criteria*
Remediation activities support natural recovery at Douglas Shoal		
An effective Monitoring, Evaluation, Reporting and Improvement (MERI) framework delivers accountability and supports flexible, responsive decision-making	Indicators are selected to measure progress towards achieving detailed remediation objectives, monitoring results are analysed, and findings are reported and used to inform adaptive management decisions that continuously improve the project	Monitoring can reliably attribute changes at Douglas Shoal to remediation activities
		Project Sponsor has adequate information to make decisions about adjusting the project plan
Knowledge gained is recorded and shared to inform other remediation efforts worldwide	As one of the most significant marine remediation projects in the world, the DSER project has the potential to add substantially to management knowledge worldwide. It is critical that the project successfully captures and shares lessons learned to inform other management actions	Number of people accessing reports/presentations about lessons learned
	In addition, the project has the ability to attract related research that contributes significantly to GBRMPA's ability to better manage the Reef, and also to scientific knowledge worldwide. It is appropriate for the project to intentionally communicate research priorities and potentially establish policies (related to permission decisions) that encourage such research	Number of papers published / amount of data provided to GBRMPA from aligned research
Traditional Owner values and opportunities are enhanced through the project	Douglas Shoal is within the Port Curtis Coral Coast TUMRA area, along with nearby islands which may serve as the base for fieldwork (such as North West Island and Heron Island). It is critical to understand the traditional values associated with these areas and to look for opportunities to not only protect, but also to enhance, Traditional Owner values. This may include opportunities for internship's or employment through the project	TUMRA Steering Committee provides advice on the project's Traditional Owner Participation Strategy (start of project)
		– TUMRA Steering Committee provides advice on how well the project has delivered the strategy's actions (end of project)
***Detailed remediation objectives (outcomes) and associated evaluation criteria will be developed as part of the project**		

Appendix B – GBRMPA Request for Quote

Request for Quotes:
Assistance in compiling a Preliminary Site Assessment Report for Douglas Shoal

BACKGROUND
The Great Barrier Reef Marine Park Authority (GBRMPA) established the Douglas Shoal Environmental Remediation project in late 2016 with funds from a court settlement associated with the grounding of the ship *Shen Neng 1* in 2010. The project team has identified a need to compile a Preliminary Site Assessment Report. The report will synthesise findings from about 20 previous studies (conducted between 2010 and 2017), present the current state of knowledge about Douglas Shoal (both pre- and post-disturbance) and identify any critical knowledge gaps that pose a major risk to the project.

SCOPE OF WORKS
This is a desktop exercise with no field work component. The report is to be factual and pragmatic with a strong focus on informing further management decisions. It is primarily a summary/synthesis exercise requiring excellent technical writing skills. Most of the previous studies have already been reviewed and critiqued by peers. However, there is a minor 'value-add' task of recognising gaps or deficiencies and translating these into management risks.

Working under the direction of the Senior Project Manager, you will:
1. Compile a summary table of previous studies.
2. Prepare a report (less than 50 pages) plus supporting maps or diagrams summarising what is known (including confidence levels) about:
    a. description of Douglas Shoal pre-disturbance (inferred), including typical habitat type(s), the values present and their condition
    b. the typical oceanic and meteorological conditions at Douglas Shoal
    c. the location and nature of disturbance (eg, cause, width, depth) at Douglas Shoal caused by the *Shen Neng* incident, including any observed changes in habitat type(s) or the condition of values in impacted areas
    d. the location, extent, composition, concentration and migration of grounding-generated antifouling paint particles, and its environmental impacts that have been observed (past/present) and have been predicted (future)
    e. the location, extent, composition and migration of grounding-generated rubble, and its environmental impacts that have been observed (past/present) and have been predicted (future)
    f. based on (a) to (e):
        i. possible priority geographical areas of Douglas Shoal for remediation
        ii. critical knowledge gaps that pose a major risk to successful remediation of Douglas Shoal.

The following aspects are <u>out of scope</u>:
1. Fieldwork or site visits
2. Scientific review or critique of previous studies
3. Literature review or research into the environmental impacts of antifouling paint or rubble on natural recovery of tropical marine environments – *Note: The previous studies already cover this topic. The supplier may wish to improve their own understanding through reading scientific literature or case studies but this time is not to be charged to the project.*
4. Possible remediation methods – *Note: The next step in the Douglas Shoal Environmental Remediation project will be an analysis of remediation options and their feasibility.*

TIMEFRAMES
This contract is for 5 weeks from 4 July 2017 to 6 August 2017.

WORK SETTING

The supplier is to work from their own premises, using their own equipment. Meetings are to be held with the Senior Project Manager (either on-site in Townsville or remotely) as indicated:

- Inception meeting – by 7 July 2017
- Weekly progress meeting – minimum one hour each week during business hours.
- Close-out meeting – by 5 August 2017.

PROVIDED BY GBRMPA

The following resources will be provided by GBRMPA:

- Supervision, assistance and direction by the GBRMPA Senior Project Manager – up to 10 hours/week
- Two (2) summary tables of previous studies
- Digital and hard copies of all previous studies
- Digital access to photos, videos and other relevant raw data from previous studies (where GBRMPA holds this data)
- Digital and hard copies of all previous mapping, graphics or other images produced as part of previous studies or by the GBRMPA project team
- If needed – GIS and graphics support to amend/update existing maps or graphics and/or create new maps or graphics.
- Printing of final Preliminary Site Assessment Report.

QUOTE REQUIREMENTS

Submit a brief quote to rachel.reese@gbrmpa.gov.au **by 17:00 on 28 June 2017** specifying:

- Nominated personnel and their relevant experience
- General work breakdown based on the tasks indicated, including proposed dates for submitting draft and final chapters
- Hourly rate for each person
- Overall estimate – time and cost
- Declaration of any potential conflicts of interest, including any personal or professional associations with individual/groups that were involved in the *Shen Neng* grounding or court case
- Confirmation that you can meet the terms of the sample contract (attached).
- Brief (maximum 2 pages) response to the evaluation criteria (if not already addressed elsewhere):
  - 30% - Understanding of the task
  - 30% - Value for money
  - 20% - Nominated personnel's demonstrated successful delivery of technical synthesis/summary reports
  - 15% - Nominated personnel's understanding of marine science concepts
  - 5% - Evidence of working successfully with legally sensitive information

Appendix C - Cardno Team CVs

Andrew Costen

Current Position
Principal Marine and Coastal Scientist

Profession
Environmental Science and Natural Resource Management

Years' Experience
22

Joined Cardno
March 2017

Education
B.Sc. (Hons) Geology

Professional Registrations
CEnVP

Affiliations
PIANC, CEDA

Areas of Expertise
Environmental Impact Assessment

Coastal Processes

Sedimentology

Approvals Facilitation

Benthic Habitat Mapping

Sediment Quality Monitoring

Water Quality Monitoring

Incident Response

Risk Assessment

Project Management

Site and Option Assessments

Summary of Experience

Andrew is a Principal Marine and Coastal Scientist within Cardno's Asia-Pacific Water and Environment practice. He has worked extensively for specialist science and engineering consultancies and Government environmental management agencies.

Andrew has considerable experience in the design, capture and analysis of sediment and water quality data for complex, large scale coastal and maritime development projects. He has also developed expertise in coordinating multidisciplinary studies required to support environmental impact assessments, approval applications and monitoring programs.

Andrew has a particular academic and professional interest in the identification of impacts associated with dredging programs and delivering fit-for-purpose dredged material management solutions.

Select Project Experience: Sediment Quality – Sampling Design, Analysis and Assessment

- Douglas Shoal Remediation Study, Great Barrier Reef Marine Park Authority (2017 -)
- Yarra River Dredging Approvals and Management, Wesley College Melbourne (2017 -
- Paisley Bay Dredged Material Options Assessment, Hornsby Shire Council (2017)
- Intalco Alumina Diffuse and Point Source Pollutant Load Study, Alcoa (Washington) (2014 -2016)
- Yarra River Dredging Approvals and Management, Parks Victoria (2014)
- Port Phillip and Western Port Dredge Management Plan, Parks Victoria (2014)
- Bancroft Bay (Metung) Marina Redevelopment, East Gippsland Shire Council (2012-2014)
- Yaringa Boat Harbour Dredged Material Management Study, YBH Pty Ltd (2012-2014)
- Chinamans Creek Jetties Project, East Gippsland Shire Council (2012-2014)
- Tankerton Jetty Dredged Material Placement Site Identification, Parks Victoria (2012-2014)
- Landing Helicopter Dock Williamstown Shipyard Waterfront Project, BAE (2010-2012)
- Ship Grounding Assessment (including TBT contamination) Douglas Shoal, Great Barrier Reef , ITOIF (2010-2014)

- Dampier Port Berth 5 Port Upgrade, Dampier Port Authority (2007)
- Gorgon LNG Project, Dredge Material Sediment Study, Barrow Island, Chevron (2007)
- Pluto LNG Formation Water Discharge Sediment Quality Monitoring Program, Woodside (2007)
- Coral Bay Boat Landing Development Project (WA), Department of Environment and Conservation (2007)
- Gorgon LNG Project, Barrow Island, Department of Environment and Conservation (2007)
- Scott Reef Dredging Study, Baseline Sediment Quality Study, Department of Environment and Conservation (2006-2007)
- Cape Lambert Port Expansion, Department of Environment and Conservation (2007)
- Dalrymple Bay Coal Terminal Expansion Study, Great Barrier Reef Marine Park Authority (2005-2006
- Port of Hay Point Expansion, Great Barrier Reef Marine Park Authority (2005-2006)
- Port of Townsville Lead (Pb) Ore Loading Berth Dredging Study, Great Barrier Reef Marine Park Authority (2005)
- Port Douglas Dredge and Dredge Material Management Project, Great Barrier Reef Marine Park Authority (2005)
- Cooktown Harbour Dredging and Spoil Disposal Project, Great Barrier Reef Marine Park Authority (2005)
- HMAS Cairns Dredge Material Study, Department of Defence, Great Barrier Reef Marine Park Authority (2004)
- Cairns Port Authority LTDMS, Cairns Port Authority, Great Barrier Reef Marine Park Authority (2003)
- Invasive Species Assessment (benthic fauna), Cairns Port Authority, Great Barrier Reef Marine Park Authority (2000)
- Reef Wide Sedimentology of the Great Barrier Reef Lagoon, Great Barrier Reef Marine Park Authority (2000)
- TBT Contamination Remediation, Ship Grounding, Great Barrier Reef Marine Park Authority (2000

Dredging Related Publications

> CEDA Information Paper - Environmental Monitoring Procedures. Central Dredging Association, Rotterdam, Netherlands (contributing author).

> Costen, A. Smith, A, Monkivitch, J and Koloi, P. (2006), Management of dredging and spoil disposal projects in the Great Barrier Reef Marine Park associated with coral spawning. Pp 18-39 in Bourke, S.A and McDonald, J.I.M (eds) On the use of Coral Spawning Predictions for Management: Workshop Proceedings. Published by MScience Pty Ltd, Perth, Western Australia.

> Smith A, Brunner B, Costen A, Rasheed MA. 2005. Science informing management to ensure sustainable ports in Queensland. In: Goggin L, Harvey T. (eds). Rainforest meets Reef: Joint Conference of CRC Reef and Rainforest CRC. CRC Reef Technical Report No. 64. 22 - 24 November 2005. CRC Reef & Rainforest CRC, Townsville, Australia. CRC Reef & Rainforest CRC, Townsville.

> Costen, A. Smith, A. Hassel, J. Monkivitch, J. and Koloi, P.GBRMPA (2004), Dredge and Dredge Material Management Policy for the Great Barrier Reef Marine Park. www.gbrmpa.gov.au

> Smith, A. Costen, A. Hassel, J. Monkivitch, J. and Koloi, P.GBRMPA (2004) Environmental Impact Management Policy for the Great Barrier Reef Marine Park. www.gbrmpa.gov.au

> Larcombe, P., Costen, A., and Woolfe, K (2001), The hydrodynamic and sedimentary setting of nearshore coral reefs, central Great Barrier Reef shelf, Australia: Paluma Shoals, a case study. Sedimentology 48: 811-835.

> Costen, A (1996). The sedimentary, hydrodynamic and turbidity regimes at inner-shelf coral reefs, Halifax Bay, Great Barrier Reef, Australia. Honours Thesis, Department of Earth Sciences, James Cook University of North Queensland, 132 pp.)

Appendix D – Method Statement - GIS Database

A database of the files received by Cardno from the Great Barrier Reef Marine Park Authority was created. The aim of the database was to help in the understanding and use of the files collected and created as a part of the grounding of the Shen Neng 1 at Douglas Shoal.

The process undertaken to create the database is outlined in Figure 1-1.

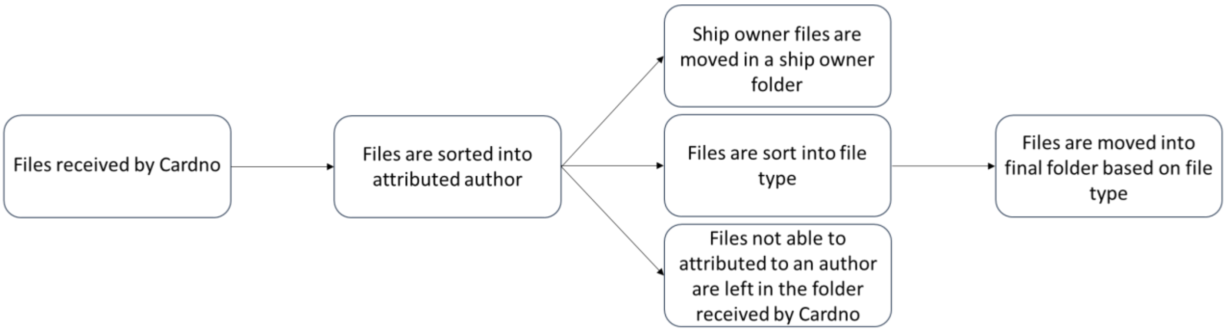


Figure 1-1 Process undertaken to create database.

1.2 Files received by Cardno

The files were received by Cardno in 49 separate zipped folder, shown in Figure 1-2.

- 20100413 Shen Neng grounding at Douglas Shoal by PaulMarshall and TyroneRidgway.zip
- CM-affidavit-files.zip
- IMAGES_20100404 Aerials Shen Neng grounding by Russell Reichelt.zip
- IMAGES_20131015 Shen Neng grounding Douglas Shoal by Adam Smith.zip
- Photos-20100412-Marshall-Ridgway.zip
- SDC160606-Animations.zip
- SDC160606-Animations-Data-AUSREP2010.zip
- SDC160606-Anim-Data-Bathy1.zip
- SDC160606-Anim-Data-Bathy2.zip
- SDC160606-Anim-Data-Charts.zip
- SDC160606-Anim-Data-Excel.zip
- SDC160606-Anim-Data-GDB.zip
- SDC160606-Anim-Data-KMLsKMZs.zip
- SDC160606-Anim-Data-KMLsKMZs-Revised.zip
- SDC160606-Anim-Data-Shapefiles.zip
- SDC-TUMRAs-2016.zip
- SDC-Unsorted-4.3.zip
- SDC-unsorted-6.3.-Photos2.zip
- SDC-unsorted-6.3-2011-DataVideos.zip
- SDC-unsorted-6.3-2012-2014.zip
- SDC-unsorted-6.3-20110523-am-Photos.zip
- SDC-unsorted-6.3-20110523-pm-Photos.zip
- SDC-unsorted-6.3-20111025-Photos.zip
- SDC-unsorted-6.3-20111026-Photos.zip
- SDC-unsorted-6.3-20111027-Photos.zip
- SDC-unsorted-6.3-Data1.zip
- SDC-unsorted-6.3-Data2.zip
- SDC-unsorted-6.3-Photos1.zip
- SDC-unsorted-6.3-Photos3.zip
- SDC-unsorted-6.3-Photos4.zip
- SDC-unsorted-6.3-Photos5.zip
- SDC-unsorted-6.3-Photos6.zip
- SDC-unsorted-6.3-Photos7.zip
- SDC-unsorted-6.3-Photos8.zip
- SDC-unsorted-6.3-Photos9.zip
- SDC-unsorted-6.3-Photos10.zip
- SDC-unsorted-6.3-Photos11.zip
- SDC-unsorted-6.3-Videos1.zip
- SDC-unsorted-6.3-Videos2a.zip
- SDC-unsorted-6.3-Videos2b.zip
- SDC-unsorted-6.3-Videos3.zip
- TG-Exhibit_TDG-2.zip
- TG-GeoImage-18546-16Dec2016.zip
- TG-GeoImage-others.zip
- TG-KMZs.zip
- TG-MetOcean.zip
- TG-Old KMZs.zip
- TG-Shen Neng Animations.zip
- Video-20100412-Marshall-Ridgway.zip

Figure 1-2 First level zipped folders received by Cardno

1.3 Files are sorted into attributed author

The files were sorted into the attributed author. The attributed authors are outlined in Figure 1-3. All files attributed to the ship owner were moved into to a separate folder, in a separate location to ensure that these files were not used. As not all files could be associated with an author these files were left in the folder received by Cardno.

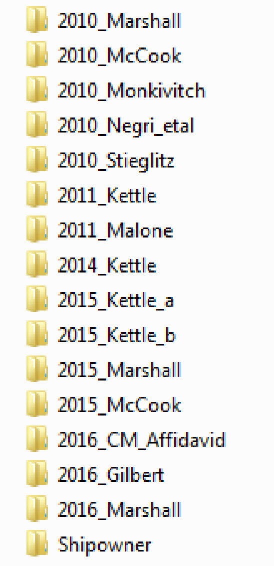


Figure 1-3 Attributed Authors

1.4 Files are moved into final folder based on file type

Files that were associated with an author who were not the ship owner, were finally moved into a folder based on the file type as outlined in Figure 1-4. Under each of these headings the files are located in folders based on attributed author. Files which could not be associated with an author have been left in the folder ZZ_Files_Still_To_Be_Sorted, under the folder received by Cardno (Note: that these files my contain ship owner data as the author is unknown)

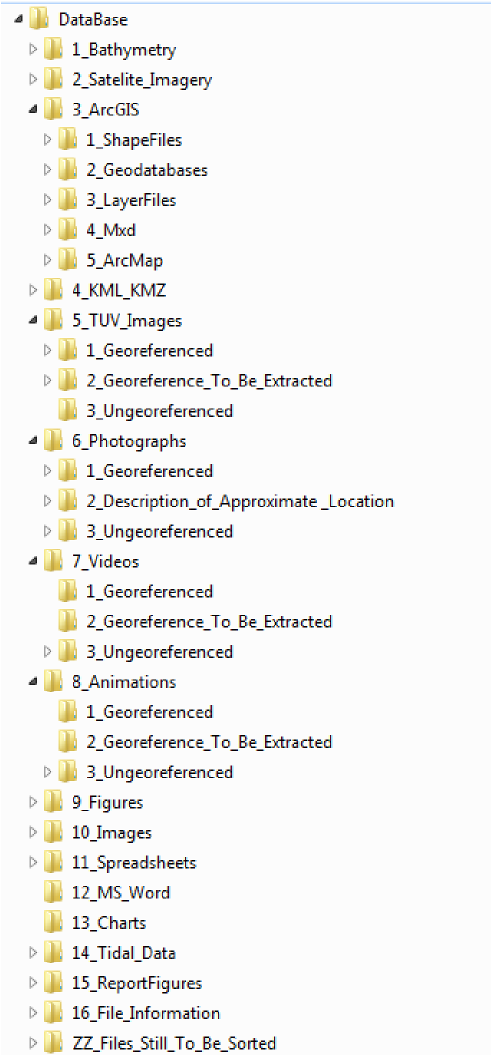


Figure 1-4 Adopted database structure for the grounding incident at Douglas Shoal.

Appendix E – Build Reports for Maps and Figures

Sorting of files received by Cardno from GBRMPA

- The files received by Cardno from GBRMPA, were sorted into by attributed author and then moved to the relevant folder based on data type. As each file was moved, the folder from which it was moved, attributed author and new location was recorded in the excel file: DataBase\File_Locations.xlsx.

- Files that haven't been able to attributed to an author have remained in the folder that they were received from GBRMPA: DataBase\ZZ_Files_Still_To_Be_Sorted.

- Files that have been have been redacted, have been removed from the provided data set and moved into their own folder, to ensure that these files were not accidently used here: DataBase\ZZ_Files_Still_To_Be_Sorted\ZZ_Authors\Shipowner.

Bathymetry

- The raw bathymetry of Douglas Shoal (Negri et al) (xyz format) was brought into MapInfo and a tin (ascii) was created. The process of creating this tin, infilled areas where bathymetry was not collected based on triangulation of neighbouring cells. This tin was then exported as a very high resolution .jpg image. This final was then brought into ArcGIS and georeferenced to the xyz final which was brought into ArcGIS. This was done as MapInfo has superior asci visualisation tools compared to ArcGIS.

- The Regional Bathymetry was obtained from eAtlas (http://eatlas.org.au/). Then using the same process as outline for the bathymetry of Douglas Shoal a .tif file was created in MapInfo and then georeferenced in ArcGIS.

Cross Sections of Douglas Shoal

- The cross sections were created in MapInfo using the Draw Profile tool. The ascii file Bathymetry.asc was used where coverage was available, with the regional bathymetry (from eAtlas) used where local bathymetry (Negri et al. 2010) was not available. The cross sections were then exported in in .csv format and called A-B.csv, C_D.csv, E_F.csv obtained from Nergi at al. and A_B_eAtlas.csv and C_D_eAtlas.csv were obtained from eAtlas bathymetry.

- The file CrossSectionGraphs.xlsx was used to create cross section graphs (used in figures 2-3 and 2-4).

Shape Files

- Airport_Marina.shp was used to indicate towns/islands which have either an airport/airfield, marina, harbour or anchorage. This layer is only used to shows towns/islands where these features are present and not the actual location of each facility. The column titled *type* identifies where it is an airfield, airport, anchorage or marina.

- AreaOutsideGBRManagmentArea.shp was created by merging the shape file MGMT_Areas_arc.shp and the shape file AustraliaOutline.shp into polygons. The areas between these two layers was the extracted and called AreaOutsideGBRManagmentArea.shp. The column titled *type* have been left bank as the polygon identifies the areas.

- AustraliaOutline.shp was retrieve from a Cardno maintained database which maintains datasets including geographical divisions of Australia. The attribute table has not been modified after the data was obtained, was the dataset was obtained for the outline of Australia and Queensland.

- BathymetryCrossSections.shp shows the location where the bathymetry cross sections were obtained. The column *CrossSecti* identifies which cross section the line is a part of, with the column *Source* identifying whether Negri et al or eAtlas bathymetry has been used.

- CorrectedVideoTowData.shp was the replotting of VideoTowData.shp to the correct coordinates. VideoTowData.shp was identified to have been incorrectly plotted. This file was re-plotted to the attributes TOWLAT and TOWLON (within attribute table). This replotted file then aligned within the georeferenced tow photographs, the Meta data within the table (substatek) and Figure 12 in Negri 2010. The attribute table has not been modified from the attribute table in VideoTowData.shp

- CrossSectionDepscription.shp was created by defining each section of Douglas Shoal as either High Relief Terrace, Low Relief Terrace, Reefal Shoal Floor or Reefal Shoal Slope. The column *Description* identifies defines what each section of Douglas Shoal was classified as.

- DouglasShoal.shp was created as a point located at Douglas Shoal. The column *Name* identifies the point of Douglas Shoal.

- eAtlasBathymetry_1m_Contours.shp is contours at 1 meter intervals obtained from the eAtlas regional bathymetry. The contours were created in MapInfo using the tool "Contour". The column *Level* identifies the elevation of the contour in meters.

- GreatBarrierReefMarinePark.shp is MGMT_AREAS_arc.shp but the polygons changed to polylines. This was undertaken using the ArcGIS add on ET GeoWizards and the polygon to polyline tool. The attribute table has been modified for the column *Loc_Name_L* to specify the outline has been changed to a polyline.

- Grid.shp and Grid_NoBackScatter.shp were created in MapInfo using the tool GridMaker at a 10m grid size. This tool allows for a grid of any size to be created over a defined area, with each cell automatically labelled with both a row and column ID. Additional columns were added to these files and called:
    - Damage – where 2 indicates identified damage within the grid cell, 1 indicates not damaged within the grid cell, and 0 indicates no data was avail be for that particular cell. If a cell was to be classified as both damaged and undamaged from available data the cell was classified as damaged. The identification of physical damage came from the following files:
        - Team1GreenAllPhotosWithObs_Damage.shp - Dam_Ranking (Damage)
        - Team2OrangeAllPhotosWithObs_Damage.shp - Dam_Ranking (Damage)
        - Team3BlueAllPhotosWithObs_Damage.shp - Dam_Ranking (Damage)
        - CorrectedVideoTowData.shp – SUBSTRATEK (Grounding & Rubble)
        - Team1_Green_AllPhotosWithObs.shp – Broken_Cor (Yes)
        - Team3_Blue_AllPhotosWithObs.shp – Broken_Cor (Yes)

        - Team1_Green_AllPhotosWithObs.shp - Damaged_be (>50)
        - Team2_Orange_AllPhotosWithObs.shp - Damaged_be (>50)
        - Team3_Blue_AllPhotosWithObs.shp - Damaged_be (>50)
        - MantaTow1.shp – Damage_cod (Red & Orange)
        - MantaTow2.shp – Damage_cod (Red & Orange)
        - PrelimAssess_GPS#15042010#Unclassified – Comment (Any comment retaliating to damage)
        - _2010_McCook_Photos - Damage
        - _2010_Marshall_Photos - Damage
        - ShenNengImpactSitesFromSonar.shp- all shapes – confidence_Grid.shp only
        - Insets_VisableScars.shp – all shapes - ConfidenceGrid_NoBackScatter.shp only
    - Contamination – was given a ranking of between 0-8 based on a combination of both TBT sampling and the number of paint flakes within the cell.
        - TBT – the maximum severity of the TBT detected within the cell was assigned a ranking, not detected was given a ranking of 1, < 9 µg Sn/kg a ranking of 2, 9 – 69.9 µg Sn/kg a ranking of 3, and > 70 µg Sn/kg a ranking of 4, with a value of 0 assigned to cells where no sampling for TBT occurred.
        - The maximum severity of the paint samples tested within the cell were also given a ranking, the rankings are as follows: > 20 samples = 4, 5-20 samples = 3, 1-4 samples = 2, 0 samples = 1, where no paint samples were found a cell value of 0 was assigned.
        - If a cell was contaminated with both TBT and paint then the maximum score from both TBT and number of paint flakes within each cell were added together to give a final contamination score up to a maximum value of 8.
        - The tables used are for contamination are:
            - SampleResults.shp – TBT_Colour
            - SiteAssess3_FinalSampleResults.shp – TBT_Conc
            - Sampling_Kettle_2015b_AppD
        - The tables not used are for contamination are:
            - Team2Dive2APPROXlocs.shp – was not used as the results could not be classified to the new ranges and intern the ranking system outlined above
            - Team3Dive2APPROXlocs.shp – was not used as the results could not be classified to the new ranges and intern the ranking system outlined above

- Insets_VisableScars.shp indicates the location of the insets included on the figures F1-F4, which show the location of the visible scars. The column *inset* identifies each inset.

- MantaTow1_Projected.shp & MantaTow2_Projected.shp, are the projected versions of unprojected MantaTow1_Projected.shp & MantaTow2_Projected.shp. The attribute table has not been modified from MantaTow1.shp & MantaTow2.shp.

- PriorityAreas.shp is the classification of each areas identified in VesselLocation_1hr_Segments.shp (and the addition of G), but grouped together to from 7 polygons. The column *Site* identifies which site the polygon refers too. The second column *OutsideShi* identifies whether the area is outside of the vessel path.

- RegionalCentres.shp is modified MAJOR_TOWNs.shp to also include a point at Gladstone, 1778, Agnes water and Yeppon. The column *Name* identifies the local of the corresponding point.

- Team1GreenAllPhotosWithObs_Damage.shp, Team2OrangeAllPhotosWithObs_Damage.shp, Team3BlueAllPhotosWithObs_Damage.shp, are the resultant shape files from cross reference of Team1_Green_AllPhotosWithObs.shp, Team2_Orange_AllPhotosWithObs.shp & Team3_Blue_AllPhotosWithObs.shp and DiveObs_Photo_Combined220710.xlsx. Each image in the spreadsheet DiveObs_Photo_Combined220710.xlsx was classified as either; Damaged, No Damaged, Chemical and Other. In column F any comment with relation to damage, impact, broken, scarring, were classified as Damaged. Any comment relation to 'undamaged' was classified as undamaged. Any comment in relation to antifoul or 'loose paint' was classified as chemical. With any other comment was classified as unsure. This spreadsheet was then joined to the three shape files mentioned above, with the new column being called Dam_Rankin which is explained above.

- VesselLocation_1hr_Segments.shp was created by merging the file Ship_swept_area_EST into hour segments based on the column Timestamp. Each merge started at the first time stamp after the hour and finished at the last timestamp before the start of the next hour. The resultant column *Time_UTC* states the hour (in UTC) that the ship was in that position, with *Date_UTC* being the date in UTC, and *Site* being the possible remediation site A, B, C, D, E & F.

- VesselPathOutline.shp was created by merging all objects in the file Ship_swept_area_EST to create the outline of the vessel impact area. No attribute have been included as the shape is the important feature in this dataset.

- Visable_scars.shp was created using both the files Bathymetry.jpg and ShenNengImpactSitesFromSonar.shp. Visable_scars.shp shows any damage clearly by the Shen Neng 1 in the bathymetry, with the file ShenNengImpactSitesFromSonar.shp used for guidance. The attribute table contains no data.

GeoDatabase

- The photographs that were sorted into attributed author, were sorted via using the GeoTagged Photos To Point tool in ArcGIS. This tool looks at the meta data in each photo and then extract coordinates and plots then in point format. This tool was run for all photographs associated with 2011_Marshall, 2010_McCook and 2011_Negri_etal. This tool was run with the option which allows the photo to be to be linked to the associated database. The raw photos that did have an associated georeference were moved into the georeferenced folder. And the photos that the GeoTagged Photos To Point tool identified as being not georeferenced were move into the un georeferenced folder. Each photo was then classified as to whether it contained visible damage, no visable damged was present, when a photo ould not be classified either as damaged of not damaged it was classified as 'unknown'.

- The Towed Underwater Video stills were sorted via the GeoTagged Photos To Point tool in ArcGIS. This tool looks at the data in each photo and then extract coordinates and plots then in point format. These stills were then sorted into the relevant georeferenced and ungeoreferenced folder. These georeferenced photos when compared against the supplied data set VideoTowData.shp helped to identify the plotting of the wrong coordinates in VideoTowData.shp.

Build Reports

Figure 2–1 – Douglas Shoal Location

Airport_Marina.shp:

- Airfield (aircraft) – shows islands with airfields.
- Airport (airplane) – shows towns with airports.
- Designated anchorages (black anchor) – shows islands with anchorages as designated by the GBRMPA layer Designated_Anchorages.shp.
- Anchorage Other (red Anchor) – shows the islands with an anchorage (other).
- Marina/Port/Harbour (ship) – shows towns with either a Marina, Port or Harbour and Yeppoon and Gladstone.

RegionalCentres.shp:

- Town (red dot) - Shows the location of the major towns.

DouglasShoal.shp

- Location of Douglas Shola (blue dot) – location of Douglas Shoal compared to Australia.

State_controlled_roads.shp

- Bruce Highway (grey line) – location of the Bruce Highway.

GreatBarrierReefMarinePark.shp

- Great Barrier Reef Marine Park Boundary (red line) – western boundary of the Great Barrier Reef Marine Park.

VesselPathOutline.shp

- Grounding Footprint (black polygon) – outline of the grounding footprint of the Shen Neng 1.

AreaOutsideGBRManagmentArea.shp

- Great Barrier Reef Marine Park Exclusion Area (grey hatching) – areas between the western boundary of the GBRMP and the Australian Coastline.

Designated_Shipping_Areas_of_the_GBRMP.shp

- Shipping Exlcusion Area (pink hatching) – areas as defined by the GBRMPA as being excluded to shipping.

AustraliaOutline.shp

- Land (orange polygon) – Australian mainland and islands.
- Outline or Australia – not in legend (grey polygon) outline of States and Territories of Australia.

RegionalBathymetry.tif

- Bathymetry (eAtlas) – bathymetry obtained from eAtlas.

Figure 2–2 – Quick Bird image and bathymetry data

eAtlasBathymetry_1mContours.shp

- 5m Contour (black line) – contour at 5m intervals (0, -5, -10 etc).
- 1m Contour (grey line) - contour at 1m intervals (-1, -2, -3 etc).
- 30m Contour - not in legend (black Line) – location map.
- Contours have been labelled at 10m intervals.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

DouglasShoal_WV2_50cm_13Sept2016_NC_x1.tif

- World View 2 Aerial Imagery (Date Taken 13/09/2016)

Figure 2-3 - Bathymetry of Capricorn-Bunker Group and the location of cross section (A-B) Douglas, Haberfield and Innamincka shoals

DouglasShoal.shp

- Location of Douglas Shoal (blue dot) – location of Douglas Shoal.

BathymetryCrossSections.shp

- Cross section (pink line) – location of cross section A – B.

AustraliaOutline.shp

- Outline or Australia – not in legend (grey polygon) outline of States and Territories of Australia.

RegionalBathymetry.tif

- Bathymetry (eAtlas) – bathymetry obtained from eAtlas.

CrossSectionGraphs.xlsx

- Cross section of A – B exported as a picture from excel, and annotated to show key features.

Figure 2-4 - Geomorphic features and zones of the south western section of Douglas Shoal

BathymetryCrossSections.shp

- Cross section (pink line) – location of cross section A – B (truncated to Negri at al. 2010 bathymetry), C – D and E - F.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

CrossSectionGraphs.xlsx

- Cross sections of A – B (truncated to Negri at al. 2010 bathymetry), C – D and E - F exported as a picture from excel, and annotated to show key features.

Figure 3-1 - Location, path and speed during grounding incident

AllAMSA_AISwithHeading.shp

- Stern of Shen Neng 1 (pink dot) – GPS location of Shen Neng 1 stern.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

AllAMSA_AISwithHeadingBuffer.shp

- Vessel heading and bearing (grey polygon) – corresponding vessel outline for each GPS location as identified in AllAMSA_AISwithHeading.shp

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

DouglasShoal_WV2_50cm_13Sept2016_NC_x1.tif

- World view 2 satellite Imagery (Date Taken 219/09/2016)

Figure 3-2 – Grounding footprint

AllAMSA_AISwithHeading.shp

- Stern of Shen Neng 1 (pink dot) – GPS location of Shen Neng 1 stern.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

Figure 4-1 – Composite map of physical damage

VesselLocation_1hr_segments.shp

- Grounding Footprint – 1 hour segments (pink polygon) – outline of the grounding footprint of the Shen Neng 1 broken into 1 hour intervals.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map

Grid_NoBackScatter.shp

- No data (grey polygon) - areas where no data on physical damage was available
- No physical damage (green polygon) - areas identified as not damaged
- Physical damage - less backscatter (yellow polygon) - areas identified as damaged not including backscatter.

Grid.shp - inset

- No data – not in legend - (grey polygon) - areas where no data on physical damage was available
- No physical damage – not in legend - (green polygon) - areas identified as not damaged
- Physical damage – not in legend - (yellow polygon) - areas identified as damaged including backscatter.

Figure 4-3 – Composite map of contamination

VesselLocation_1hr_segments.shp

- Grounding Footprint – 1 hour segments (pink polygon) – outline of the grounding footprint of the Shen Neng 1 broken into 1 hour intervals.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map

Grid_NoBackScatter.shp

- No data (grey polygon) - areas where no data on contamination was available.
- No contamination (green polygon) - areas identified as not contaminated.
- Contamination - (orange polygon) - areas identified as contaminated.

Figure 4-5 – Composite map of physical damage and contamination

VesselLocation_1hr_segments.shp

- Grounding Footprint – 1 hour segments (pink polygon) – outline of the grounding footprint of the Shen Neng 1 broken into 1 hour intervals.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map

Grid_NoBackScatter.shp

- No data (grey polygon) - areas where no data on contamination or physical damage was available.
- No contamination and or/physical damage (green polygon) - areas identified as not contaminated or physically damaged.
- Physical damage - less backscatter – not in legend - (yellow polygon) - areas identified as damaged including backscatter.
- Contamination (orange polygon) - areas identified as contaminated.
- Contamination and physical damage (red polygon) - areas identified as both damaged and contaminated.

Grid.shp - inset

- No data (grey polygon) - areas where no data on contamination or physical damage was available.
- No contamination and or/physical damage (green polygon) - areas identified as not contaminated or physically damaged.
- Physical damage – not in legend - (yellow polygon) - areas identified as damaged including backscatter.
- Contamination (orange polygon) - areas identified as contaminated.
- Contamination and physical damage (red polygon) - areas identified as both damaged and contaminated.

Figure 4-6 - 2016 World View 2 satellite imagery

VesselPathOutline.shp

- Grounding Footprint – (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

DouglasShoal_WV2_50cm_13Sept2016_NC_x1.tif

- World view 2 satellite Imagery (Date Taken 219/09/2016)

Figure 5-1 – Possible priority areas for remediation

SiteAreas.shp

- A (purple polygon) – area identified as area A.
- B (cyan polygon) – area identified as area B.
- C (lime green polygon) – area identified as area C.
- D (grey polygon) - area identified as area D.
- E (brown polygon) – area identified as area E.
- F (black polygon) – area identified as area F.
- G (yellow polygon) – area identified as area F.

Grid_NoBackScatter.shp

- No data (grey polygon) - areas where no data on contamination or physical damage was available.
- No contamination and or/physical damage (green polygon) - areas identified as not contaminated or physically damaged.
- Physical damage - less backscatter – not in legend - (yellow polygon) - areas identified as damaged including backscatter.
- Contamination (orange polygon) - areas identified as contaminated.
- Contamination and physical damage (red polygon) - areas identified as both damaged and contaminated.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

Figure 5-2 – Possible priority area - A

SiteAreas.shp

- A (purple polygon) – area identified as site A within grounding footprint.
- Dashed purple polygon – area identified as site A outside grounding footprint.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Grid_NoBackScatter.shp

- No data (grey polygon) - areas where no data on contamination or physical damage was available.
- No contamination and or/physical damage (green polygon) - areas identified as not contaminated or physically damaged.
- Physical damage - less backscatter – not in legend - (yellow polygon) - areas identified as damaged including backscatter.
- Contamination (orange polygon) - areas identified as contaminated.
- Contamination and physical damage (red polygon) - areas identified as both damaged and contaminated.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

Figure 5-3 – Possible priority areas - C

SiteAreas.shp

- C (lime green polygon) – area identified as site C within grounding footprint.
- Dashed lime green polygon – area identified as site C outside grounding footprint.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Grid_NoBackScatter.shp

- No data (grey polygon) - areas where no data on contamination or physical damage was available.
- No contamination and or/physical damage (green polygon) - areas identified as not contaminated or physically damaged.
- Physical damage - less backscatter – not in legend - (yellow polygon) - areas identified as damaged including backscatter.
- Contamination (orange polygon) - areas identified as contaminated.
- Contamination and physical damage (red polygon) - areas identified as both damaged and contaminated.
-

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

Figure 5-4 – Possible priority area - E

SiteAreas.shp

- E (brown polygon) – area identified as site E within grounding footprint.
- Dashed brown polygon – area identified as site E outside grounding footprint

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Grid_NoBackScatter.shp

- No data (grey polygon) - areas where no data on contamination or physical damage was available.
- No contamination and or/physical damage (green polygon) - areas identified as not contaminated or physically damaged.
- Physical damage - less backscatter – not in legend - (yellow polygon) - areas identified as damaged including backscatter.
- Contamination (orange polygon) - areas identified as contaminated.
- Contamination and physical damage (red polygon) - areas identified as both damaged and contaminated.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

Figure 5-5 – Possible priority area – F

SiteAreas.shp

- F (dark grey polygon) – area identified as site F within grounding footprint.
- Dashed dark grey polygon – area identified as site F outside grounding footprint

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Grid_NoBackScatter.shp

- No data (grey polygon) - areas where no data on contamination or physical damage was available.
- No contamination and or/physical damage (green polygon) - areas identified as not contaminated or physically damaged.
- Physical damage - less backscatter – not in legend - (yellow polygon) - areas identified as damaged including backscatter.
- Contamination (orange polygon) - areas identified as contaminated.
- Contamination and physical damage (red polygon) - areas identified as both damaged and contaminated.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

Figure F-4 – Possible priority areas for remediation

_2011_Negri_TUV_Stills

- Substrate Images (pink dot) – location of each image shown in report, with label of name.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

Figure F-5 – Antifouling paint sampling locations

SampleResults.shp

- Sampling Location (pink dot) – location of site assessment 1.

SiteAssess3_FinalSampleResults.shp

- Sampling Location (pink dot) – location of site assessment 3.

Sampling_Kettle_2015b_AppD.shp

- Sampling Location (pink dot) – location of Kettle appendix D sampling.

Team2Dive2APPROXlocs.shp

- Sampling Location (pink line) – location of team 2 dive 2 sampling.

Team3Dive2APPROXlocs.shp

- Sampling Location (pink line) – location of team 3 dive 2 sampling.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

Figure F-6 – Antifouling paint sampling results – TBT concentrations

SampleResults.shp

- > 70 µg Sn/kg (red circle) – locations of samples with concentrations of TBT greater than 70 µg Sn/kg.
- 9 - 70 µg Sn/kg (yellow circle) – locations of samples with concentrations of TBT between 9 - 70 µg Sn/kg.
- < 9 µg Sn/kg (green circle) – locations of samples with concentrations of TBT less than < 9 µg Sn/kg.
- Not detected (black circle) – locations where samples had no detectable levels of TBT.

SiteAssess3_FinalSampleResults.shp

- > 70 µg Sn/kg (red circle) – locations of samples with concentrations of TBT greater than 70 µg Sn/kg.
- 9 - 70 µg Sn/kg (yellow circle) – locations of samples with concentrations of TBT between 9 - 70 µg Sn/kg.

- < 9 µg Sn/kg (green circle) – locations of samples with concentrations of TBT less than < 9 µg Sn/kg.
- Not detected (black circle) – locations where samples had no detectable levels of TBT.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

Figure F-7 – Antifouling paint sampling results – copper concentrations

Team2Dive2APPROXlocs.shp

- > 270 µg cu/kg (red line) – locations of samples with concentrations of copper greater than 270 µg cu/kg.
- 1 - 65 µg cu/kg (green line) – locations of samples with concentrations of copper between 1 -65 µg Sn/kg.
- Not detected (black line) – locations where samples had no detectable levels of copper.

Team3Dive2APPROXlocs.shp

- > 270 µg cu/kg (red line) – locations of samples with concentrations of copper greater than 270 µg cu/kg.
- 1 - 65 µg cu/kg (green line) – locations of samples with concentrations of copper between 1 -65 µg Sn/kg.
- Not detected (black line) – locations where samples had no detectable levels of copper.

SampleResults.shp

- > 270 µg cu/kg (red circle) – locations of samples with concentrations of copper greater than 270 µg cu/kg.
- 65 - 269 µg cu/kg (yellow circle) – locations of samples with concentrations of copper between 65 - 269 µg Sn/kg.
- 1 - 65 µg cu/kg (green circle) – locations of samples with concentrations of copper between 1 -65 µg Sn/kg.
- Not detected (black circle) – locations where samples had no detectable levels of copper.

SiteAssess3_FinalSampleResults.shp

- > 270 µg cu/kg (red circle) – locations of samples with concentrations of copper greater than 270 µg cu/kg.
- 65 - 269 µg cu/kg (yellow circle) – locations of samples with concentrations of copper between 65 - 269 µg Sn/kg.
- 1 - 65 µg cu/kg (green circle) – locations of samples with concentrations of copper between 1 -65 µg Sn/kg.
- Not detected (black circle) – locations where samples had no detectable levels of copper.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

Figure F-8 – Antifouling paint sampling results – zinc concentrations

Team2Dive2APPROXlocs.shp

- > 410 µg zn/kg (red line) – locations of samples with concentrations of zinc greater than 410 µg zn/kg.
- 200 - 410 µg zn/kg (green line) – locations of samples with concentrations of zinc between 200 - 410 µg zn/kg.
- Not detected (black line) – locations where samples had no detectable levels of zinc.

Team3Dive2APPROXlocs.shp

- > 410 µg zn/kg (red line) – locations of samples with concentrations of zinc greater than 410 µg zn/kg.
- 200 - 410 µg zn/kg (green line) – locations of samples with concentrations of zinc between 200 - 410 µg zn/kg.
- Not detected (black line) – locations where samples had no detectable levels of zinc.

SampleResults.shp

- > 410 µg zn/kg (red circle) – locations of samples with concentrations of zinc greater than 410 µg z/kg.
- 200 - 410 µg zn/kg (yellow circle) – locations of samples with concentrations of zinc between 200 - 410 µg Sn/kg.
- 1 - 200 µg zn/kg (green circle) – locations of samples with concentrations of zinc between 1 -200 µg zn/kg.
- Not detected (black circle) – locations where samples had no detectable levels of zinc.

SiteAssess3_FinalSampleResults.shp

- > 410 µg zn/kg (red circle) – locations of samples with concentrations of zinc greater than 410 µg z/kg.
- 200 - 410 µg zn/kg (yellow circle) – locations of samples with concentrations of zinc between 200 - 410 µg Sn/kg.
- 1 - 200 µg zn/kg (green circle) – locations of samples with concentrations of zinc between 1 -200 µg zn/kg.
- Not detected (black circle) – locations where samples had no detectable levels of zinc.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

Figure 4-9 – Antifouling paint sampling results – paint detritus counts

Sampling_Kettle_2015b_AppD.shp

- Number of paint flakes per sample >20 (red circle) - location where paint detritus counts of greater than 20 flakes per sample detected.
- Number of paint flakes per sample 5-20 (yellow circle) - location where paint detritus counts of between 5-20 flakes per sample detected.
- Number of paint flakes per sample 1-4 (green circle) - location where paint detritus counts of between 1-4 flakes per sample detected.
- Number of paint flakes per sample 0 (black circle) - location where paint detritus counts of 0 per sample detected.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

eAtlasBathymetry_1mContours.shp

- 30m Contour - not in legend (black Line) – location map.

Figure F-9 – Possible priority area - A

SiteAreas.shp

- A (purple polygon) – area identified as site A within grounding footprint.
- Dashed purple polygon – area identified as site A outside grounding footprint.

VesselLocation_1hr_segments.shp

- Grounding footprint - 1 hour segments (orange polygon) – outline of the grounding footprint of the Shen Neng 1 broken into 1 hour intervals.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

Figure F-10 – Possible priority areas - C

SiteAreas.shp

- C (lime green polygon) – area identified as site C within grounding footprint.
- Dashed lime green polygon – area identified as site C outside grounding footprint.

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

Figure F-11 – Possible priority area - E

SiteAreas.shp

- E (brown polygon) – area identified as site E within grounding footprint.
- Dashed brown polygon – area identified as site E outside grounding footprint

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

Figure F-12 – Possible priority area – F

SiteAreas.shp

- F (dark grey polygon) – area identified as site F within grounding footprint.
- Dashed dark grey polygon – area identified as site F outside grounding footprint

VesselPathOutline.shp

- Grounding Footprint (orange polygon) – outline of the grounding footprint of the Shen Neng 1.

Bathymetry.jpg

- Bathymetry (Negri at al 2010) – bathymetry of Douglas Shoal.

Appendix F – Additional Figures

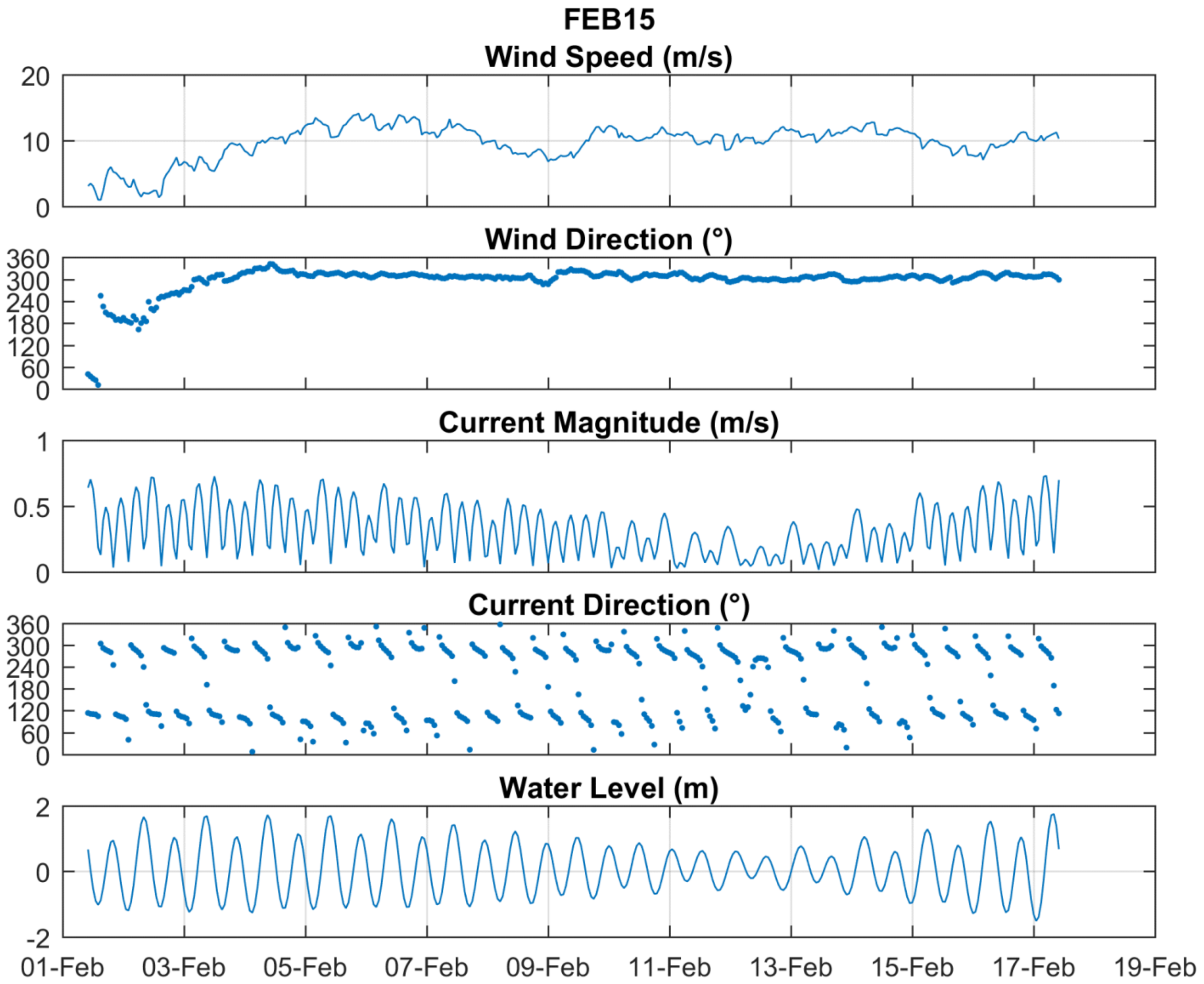


Figure F-1. Summary of February 2015 wind speed and direction, current strength and direction and tidal range data

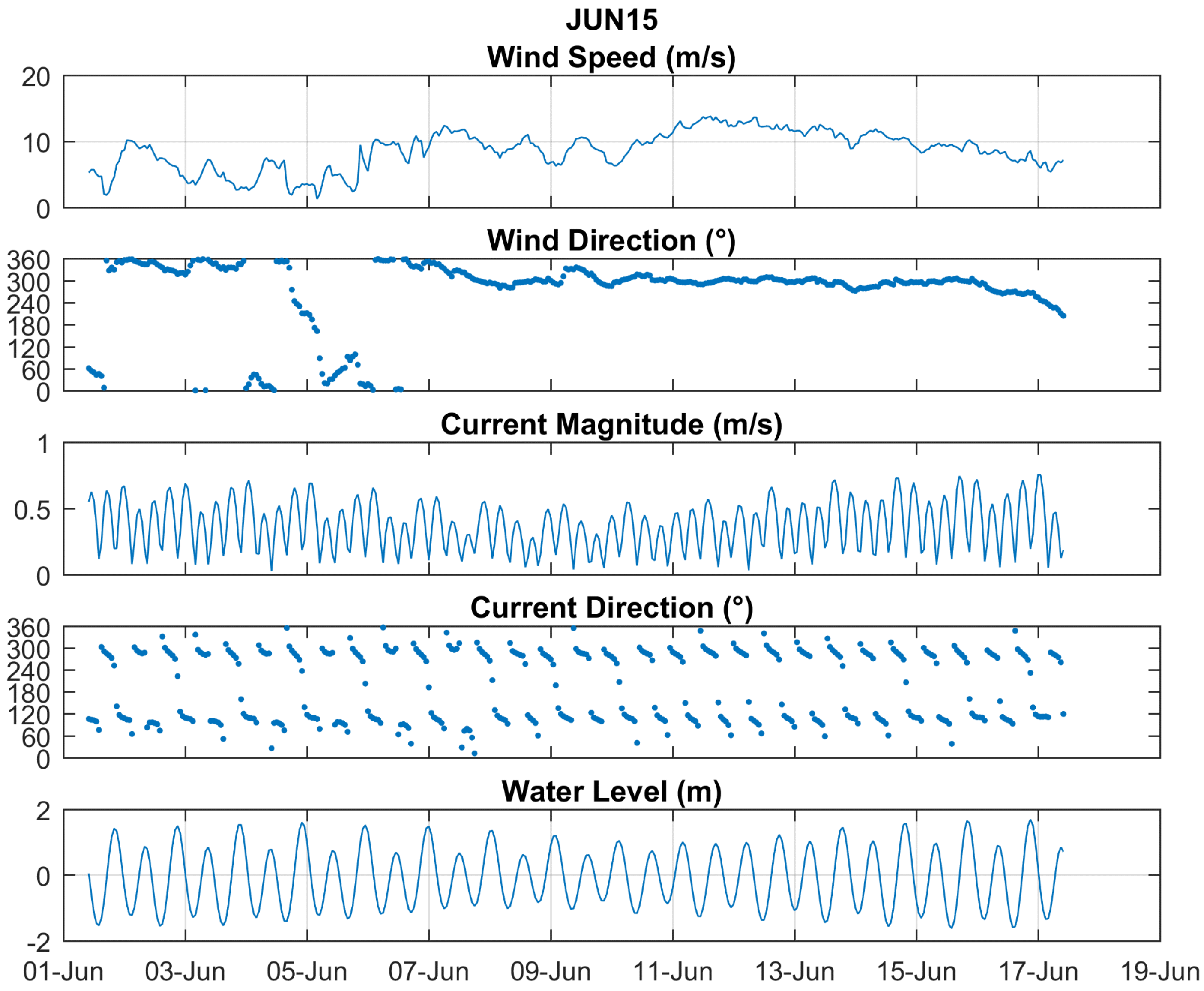


Figure F-2. Summary of June 2015 wind speed and direction, current strength and direction and tidal range data

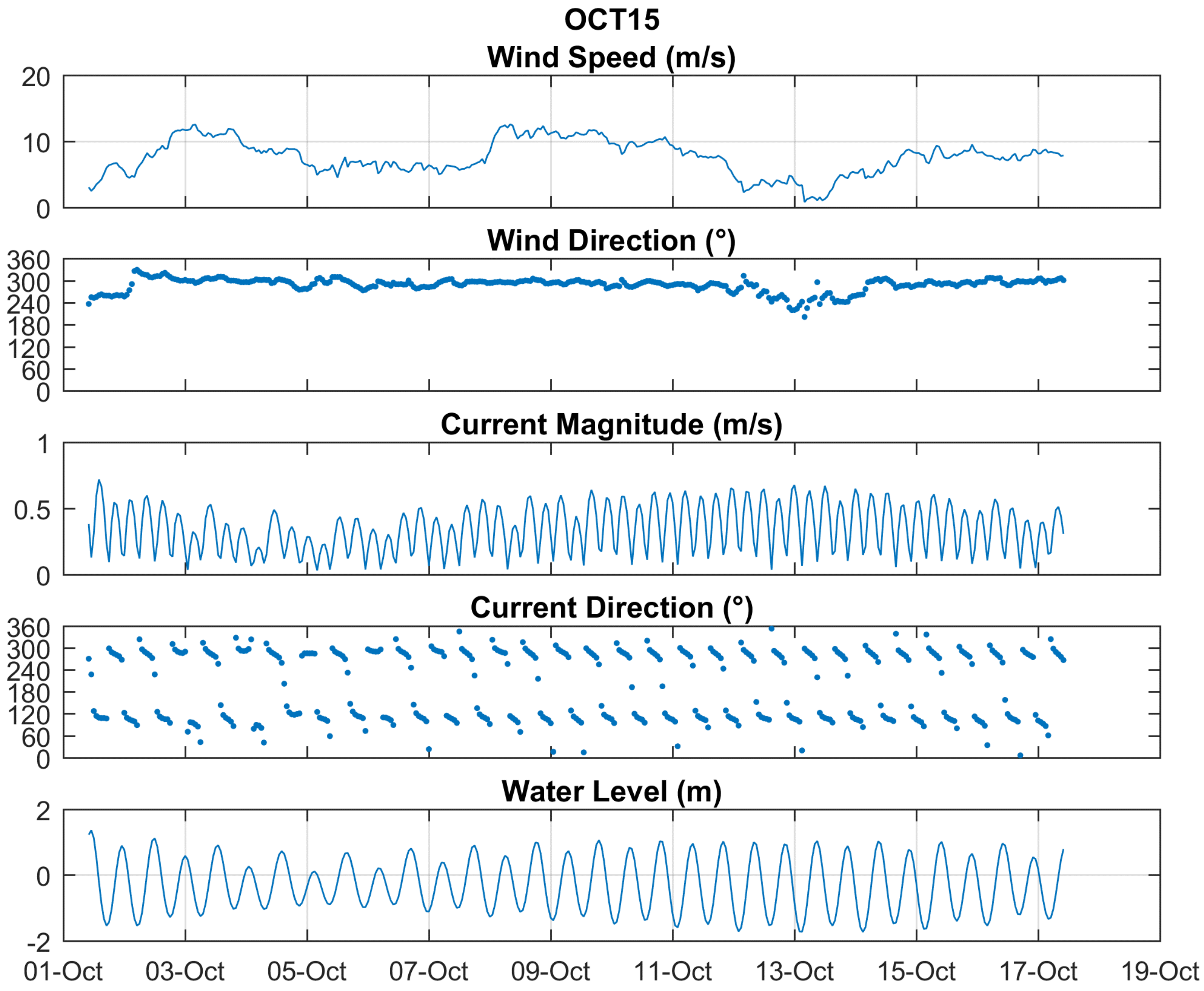
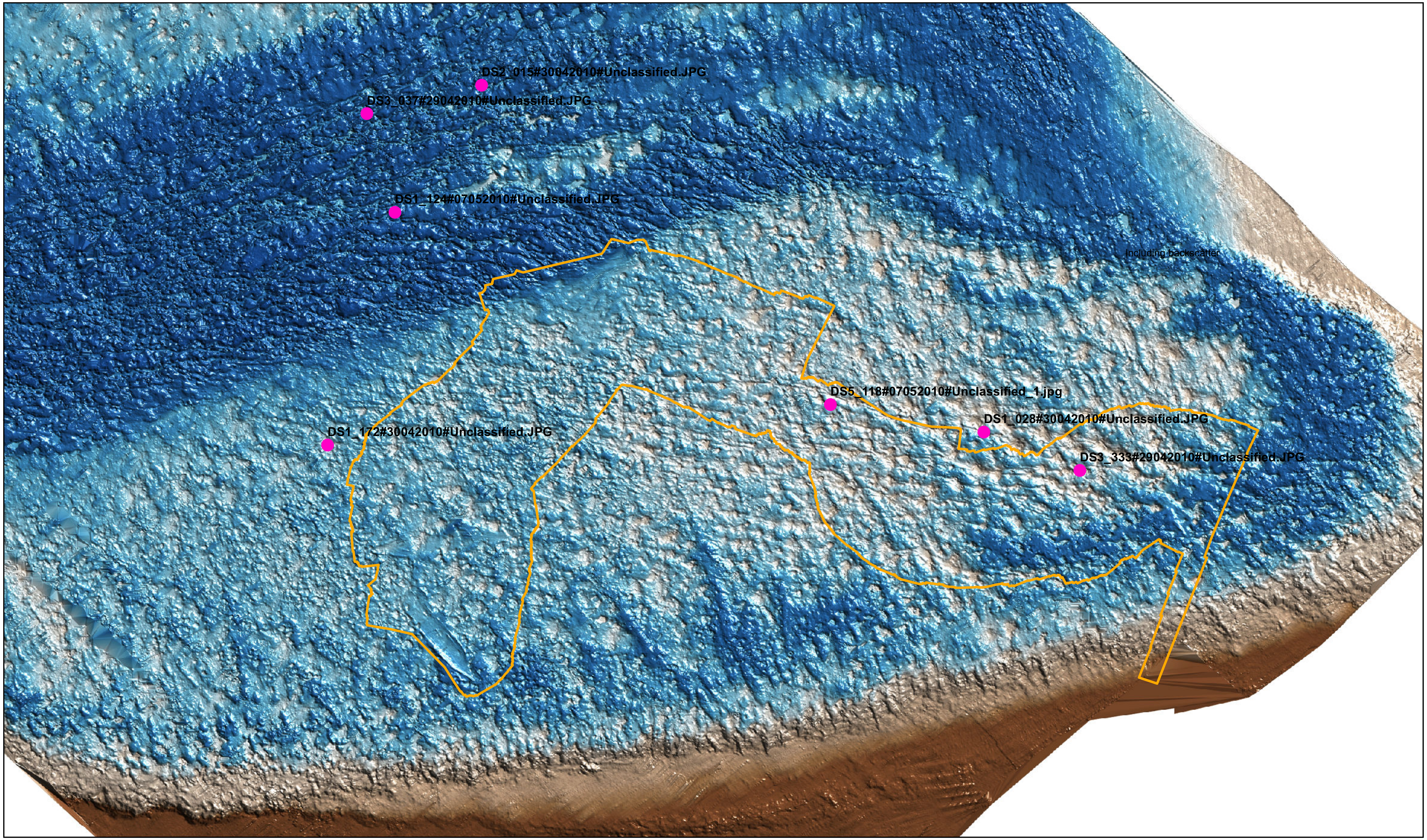
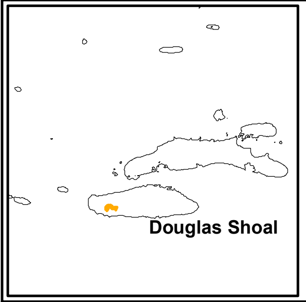


Figure F-3. Summary of October 2015 wind speed and direction, current strength and direction and tidal range data





Legend

- Substrate Images
- Grounding footprint

Bathymetry (Negri et al. 2010)

-5 m -30 m

Image Locations

Appendix F
Figure F - 4

N

1:6,000 Scale at A3

Meters

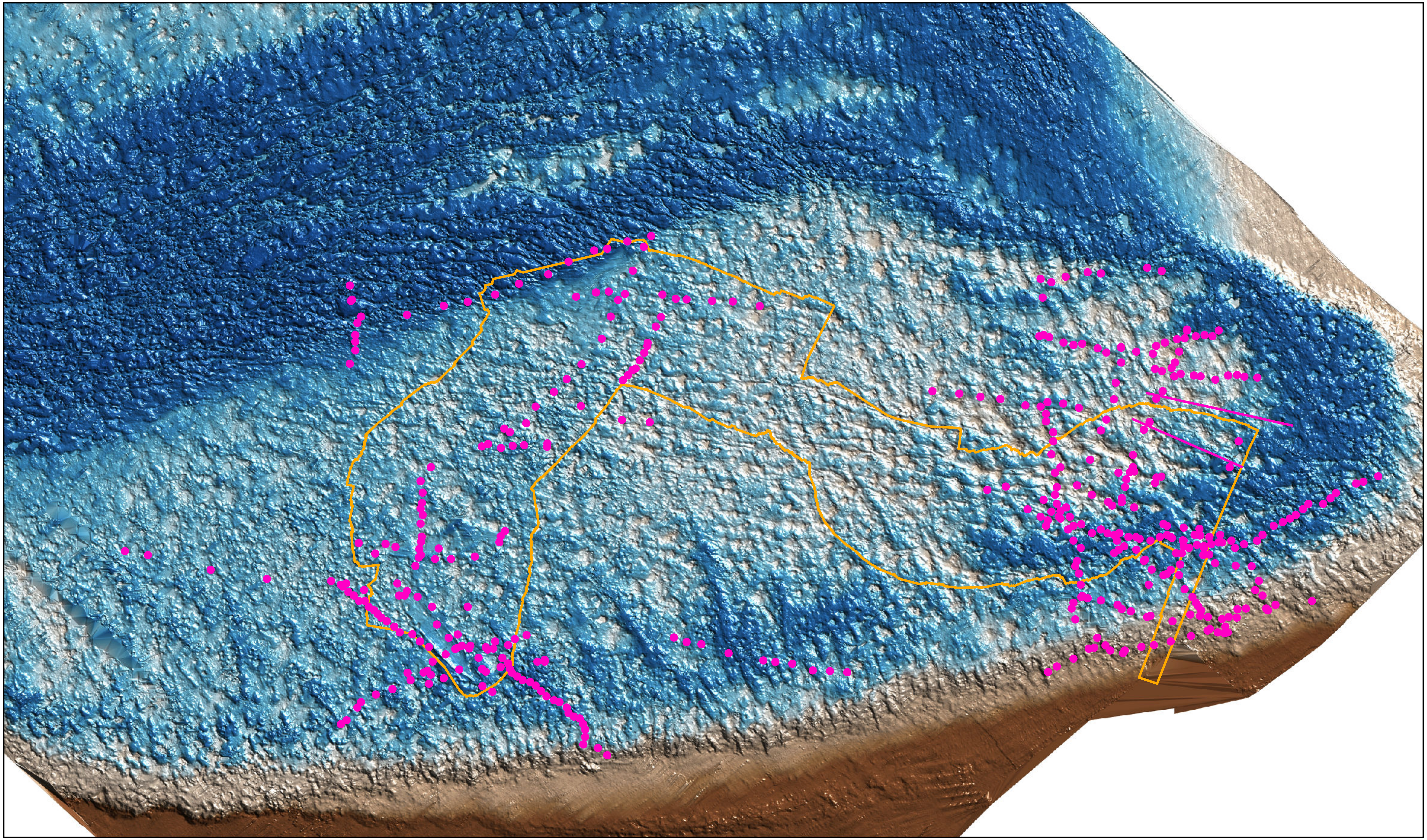
0 200

Map Produced by: NSW Water & Environment
Date: 2017-09-22
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_4_LocationImagesReport.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_4_LocationImagesReport.mxd

Build Sheet: Appendix E



Legend

- Sampling location
- Sampling location
- Grounding footprint

Bathymetry (Negri et al. 2010)

-5 m — -30 m

Antifouling paint sampling locations

Appendix F
Figure F - 5

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N

1:6,000 Scale at A3

Metres

0 200

Map Produced by: NSW Water & Environment
Date: 2017-09-22
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_5_AFPSamplingLocations.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_5_AFPSamplingLocations.mxd

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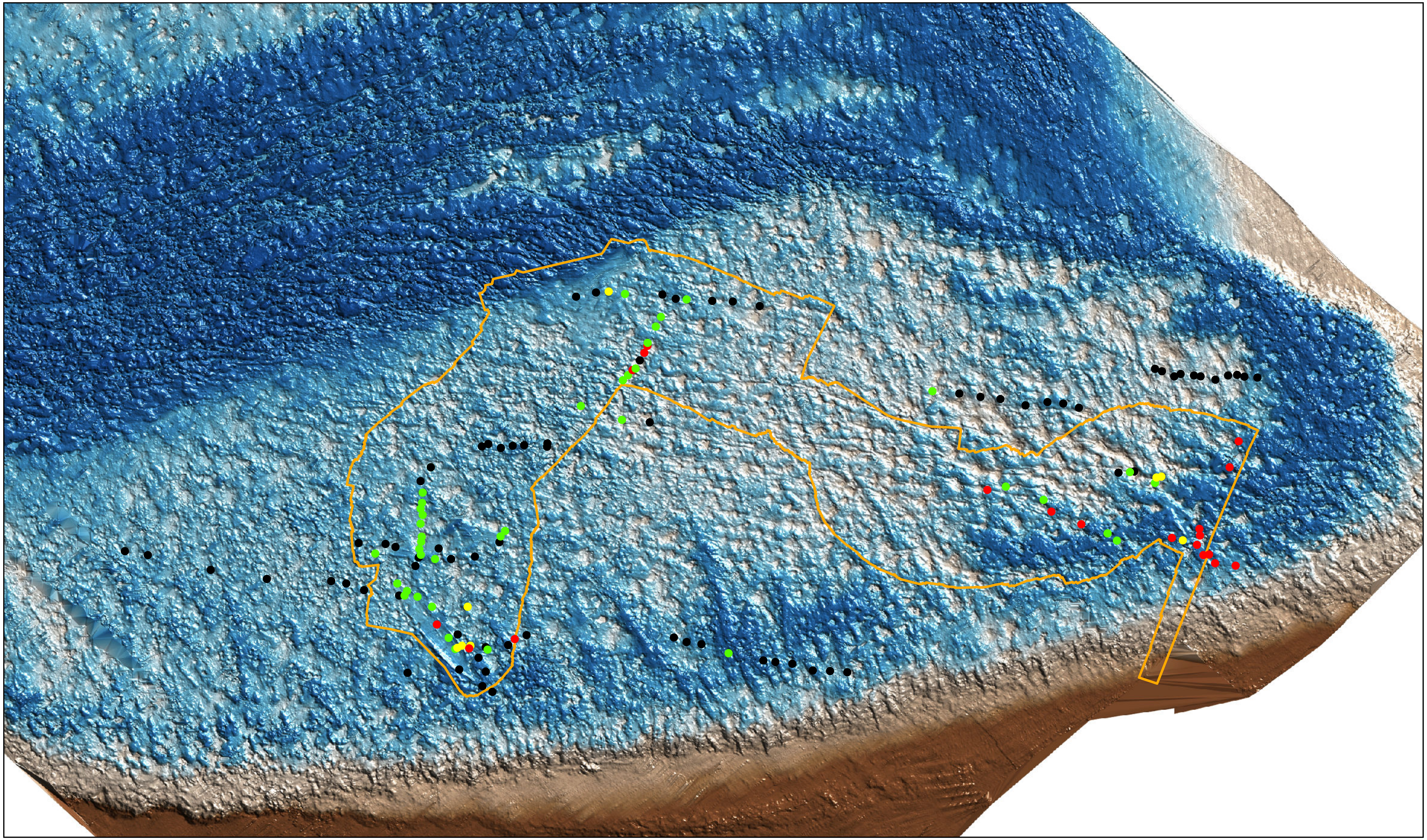

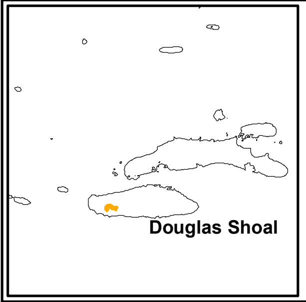

Legend

Concentration of TBT

- > 70 µg sn/kg
- 9 - 70 µg sn/kg
- < 9 µg sn/kg
- Not detected

Grounding footprint

Bathymetry (Negri et al. 2010)

-5 m — -30 m

Antifouling paint sampling results – TBT concentrations (raw)

Appendix F
Figure F - 6

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N

1:6,000 **Scale at A3**

Metres

0 200

Map Produced by: NSW Water & Environment
Date: 2017-09-22
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_6_AFPSamplingTBTConc.mxd 01

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_6_AFPSamplingTBTConc.mxd

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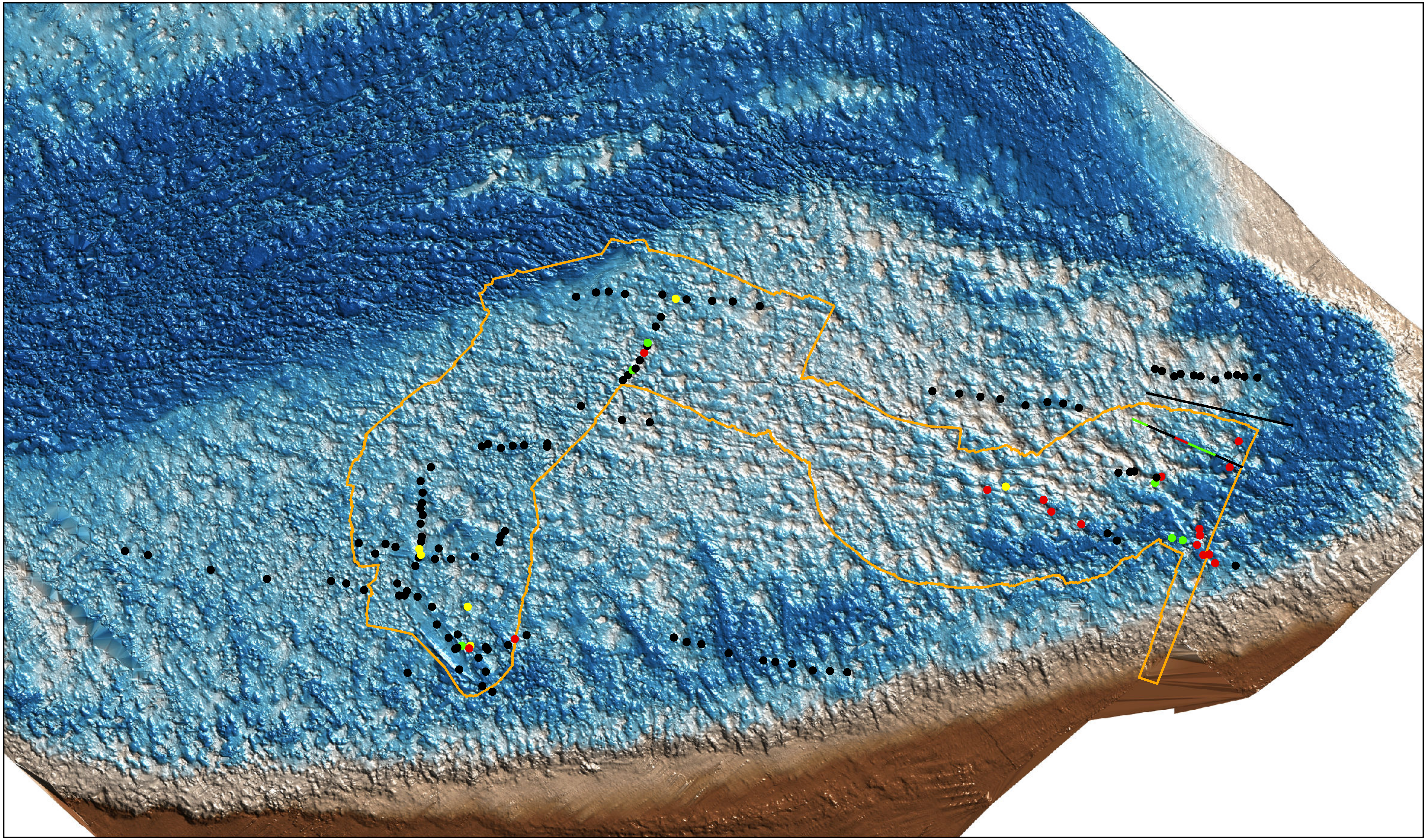
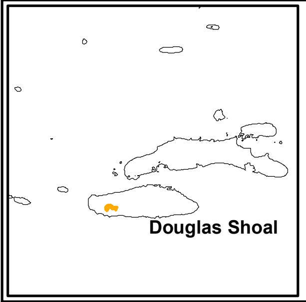




Legend

Concentration of copper
- > 270 µg cu/kg
- 1 - 65 µg cu/kg
- Not Detected

- > 270 mg cu/kg
- 65 - 269 mg cu/kg
- 1 - 65 mg cu/kg
- Not Detected

Grounding footprint

Bathymetry (Negri et al. 2010)

-5 m   -30 m

Antifouling paint sampling results – copper concentrations

Appendix F
Figure F - 7

N

1:6,000 **Scale at A3**

Metres

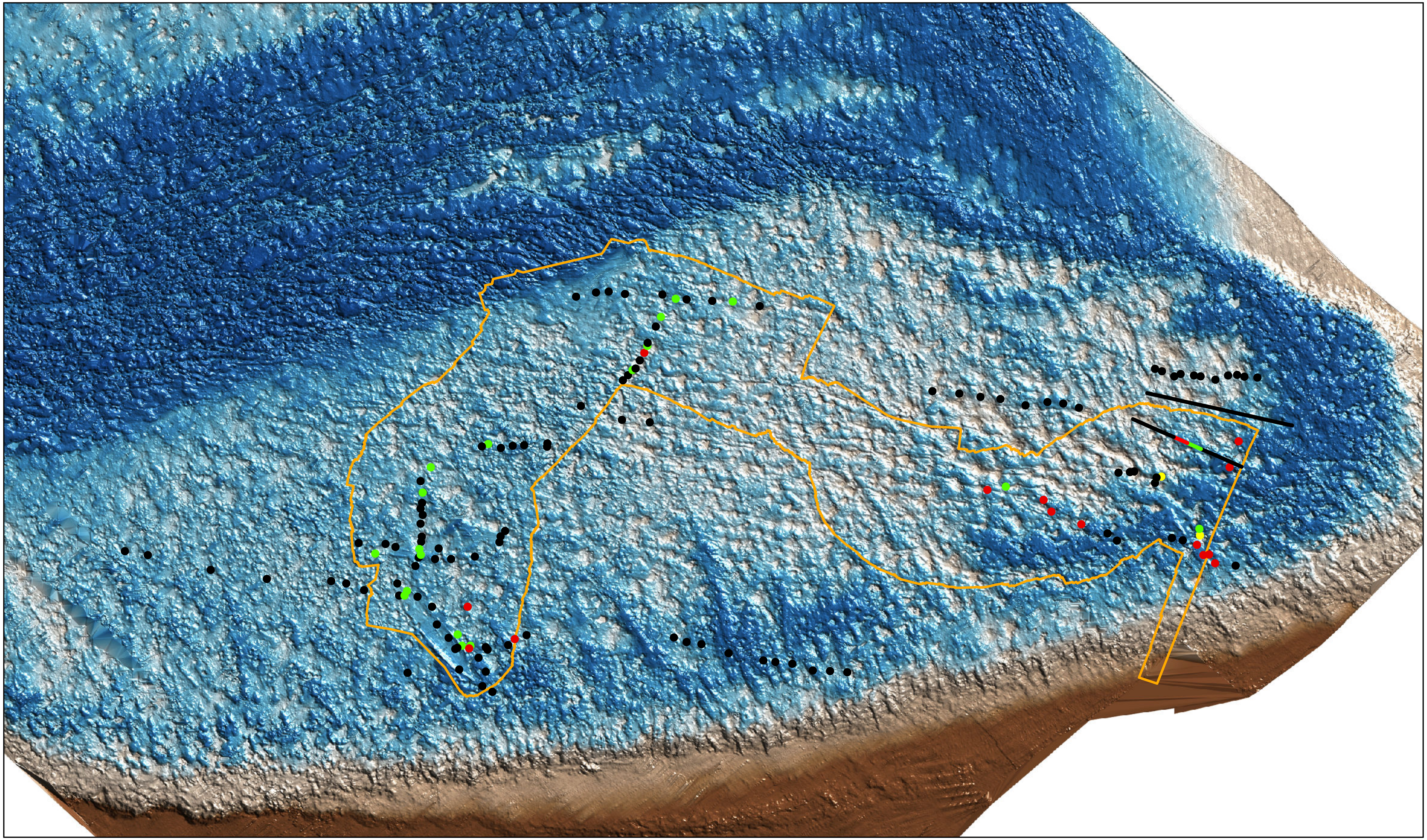
0 200

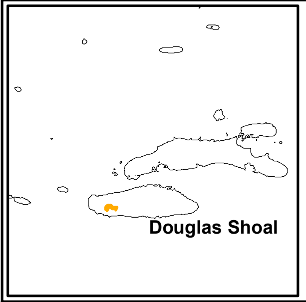
Map Produced by: NSW Water & Environment
Date: 2017-09-22
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_7_AFPSamplingCopperConc.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_7_AFPSamplingCopperConc.mxd

Build Sheet: Appendix E





Legend

Concentration of zinc
- > 410 µg zn/kg
- 1 - 200 µg zn/kg
- Not Detected

- > 410 mg zn/kg
- 200 - 410 mg zn/kg
- 1 - 200 mg zn/kg
- Not detected

Grounding footprint

Bathymetry (Negri et al. 2010)
-5 m — -30 m

Antifouling paint sampling results – zinc concentrations

Appendix F
Figure F - 8

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N

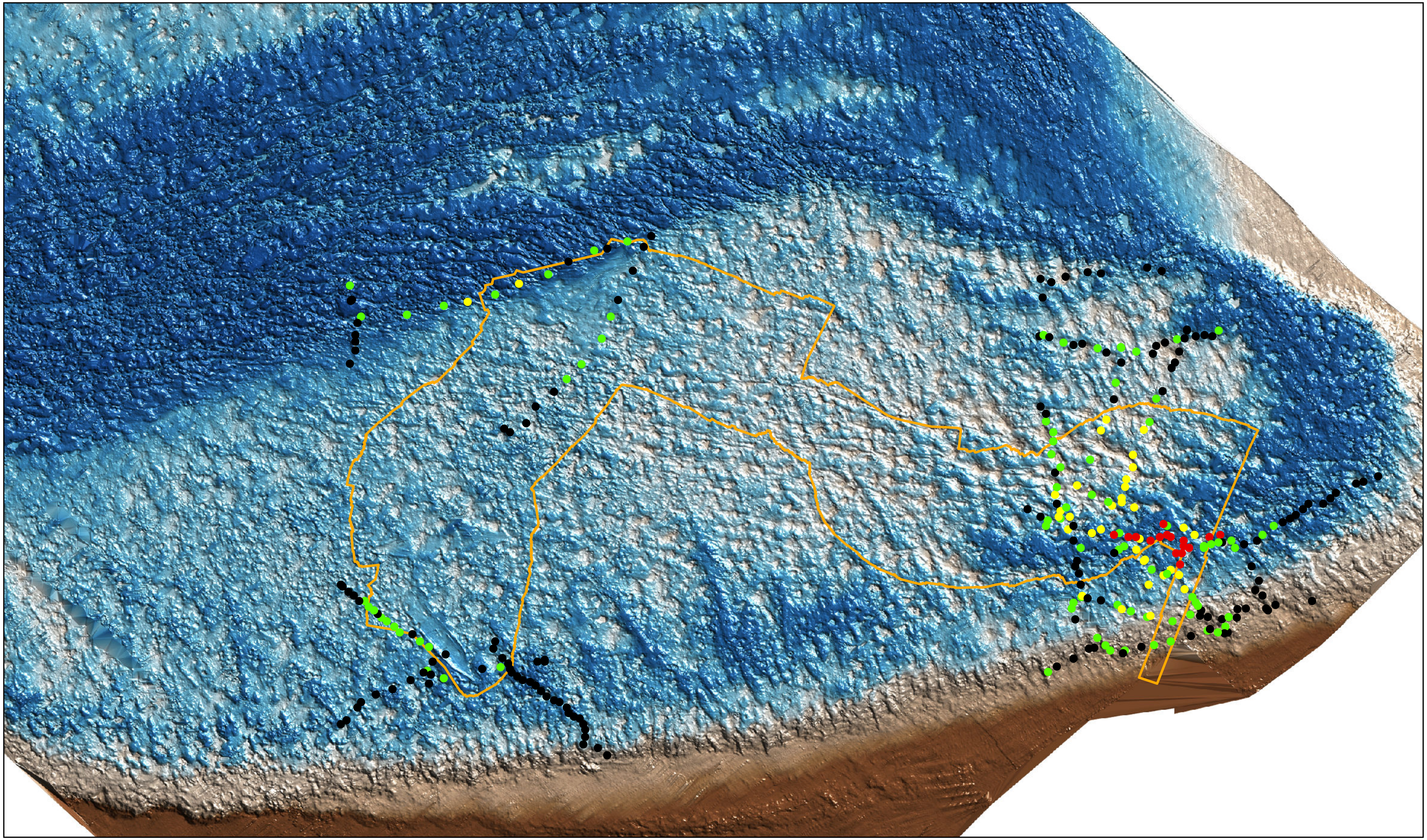
1:6,000 **Scale at A3**
Metres
0 — 200

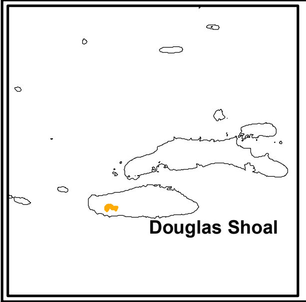
Map Produced by: NSW Water & Environment
Date: 2017-09-22
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_8_AFPSamplingZincConc.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_8_AFPSamplingZincConc.mxd

Build Sheet: Appendix E





Legend

Number of paint flakes per sample

- \>20
- 5 - 20
- 1 - 4
- 0

Grounding footprint

Bathymetry (Negri et al. 2010)

-5 m   -30 m

Antifouling paint sampling results – paint detritus counts

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N

1:6,000   Scale at A3

Metres

0   200

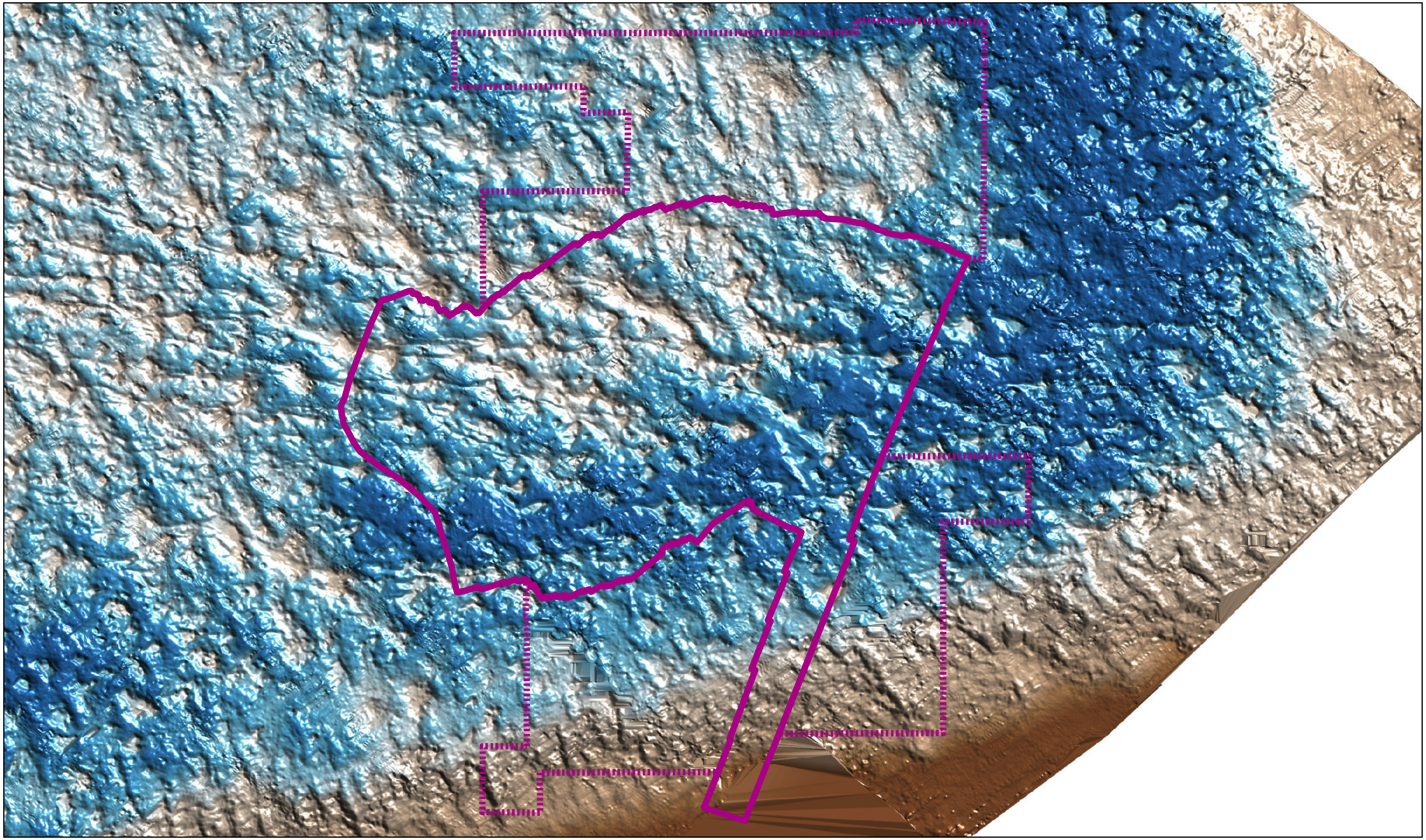
Map Produced by: NSW Water & Environment
Date: 2017-09-22
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_9_AFPSamplingPaintDetritus.mxd 01

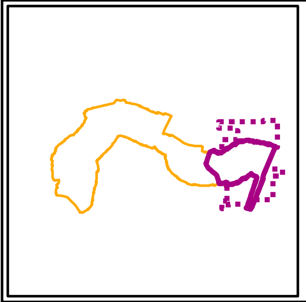
Appendix F
Figure F - 9

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_9_AFPSamplingPaintDetritus.mxd

Build Sheet: Appendix E





Legend

Area

A

Bathymetry (Negri et al. 2010)

-5 m — -30 m

Possible priority area - A

Appendix F
Figure F - 10

N

1:2,700 **Scale at A3**

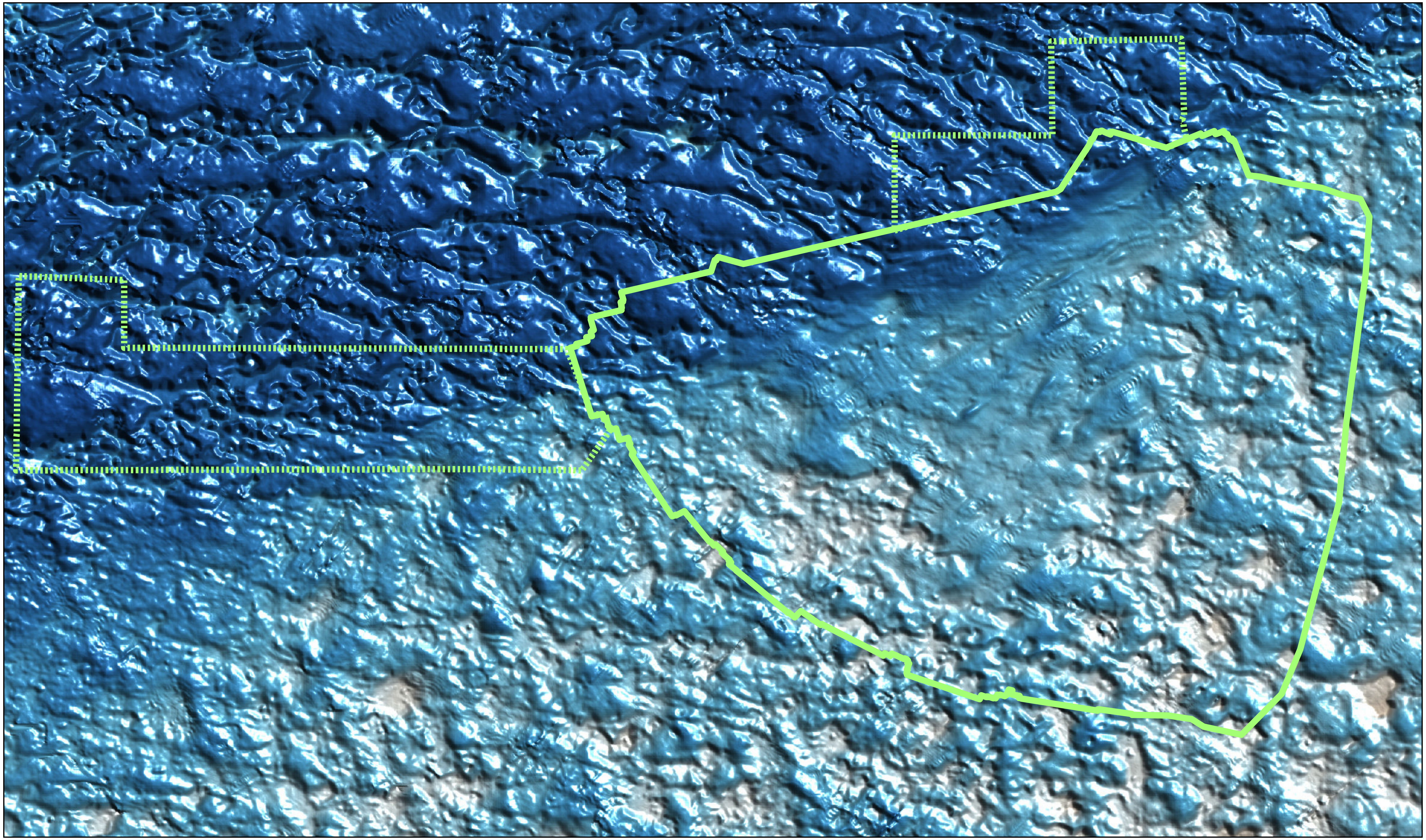
Metres

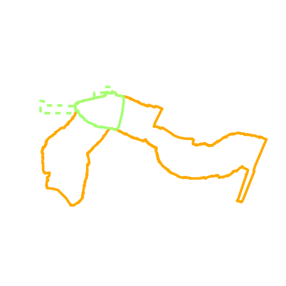
0 100

Map Produced by: NSW Water & Environment
Date: 2017-09-28
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_10_PossibleRemediationAreaA.mxd 01

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_10_PossibleRemediationAreaA.mxd

Build Sheet: Appendix E





Legend

Area

C

Bathymetry (Negri et al. 2010)

-5 m -30 m

Possible priority area - C

Appendix F
Figure F - 11

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N

1:1,500 **Scale at A3**

Metres

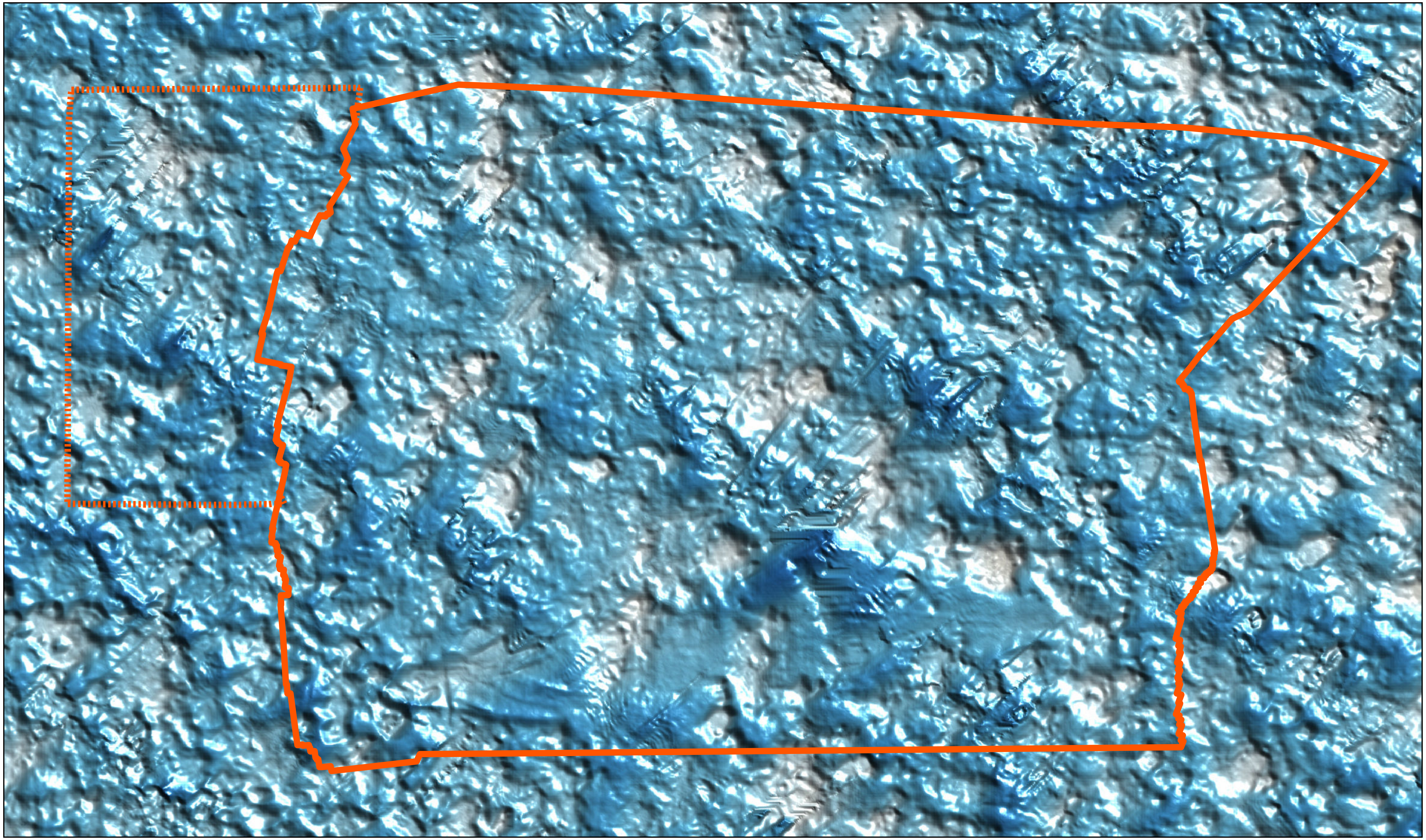
0 50

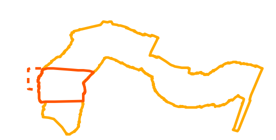
Map Produced by: NSW Water & Environment
Date: 2017-09-28
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_11_PossibleRemediationAreaC.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_11_PossibleRemediationAreaC.mxd

Build Sheet: Appendix E





Legend

Area

E

Bathymetry (Negri et al. 2010)

-5 m -30 m

Possible priority area - E

Appendix F
Figure F - 12

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N

1:1,200 **Scale at A3**

Metres

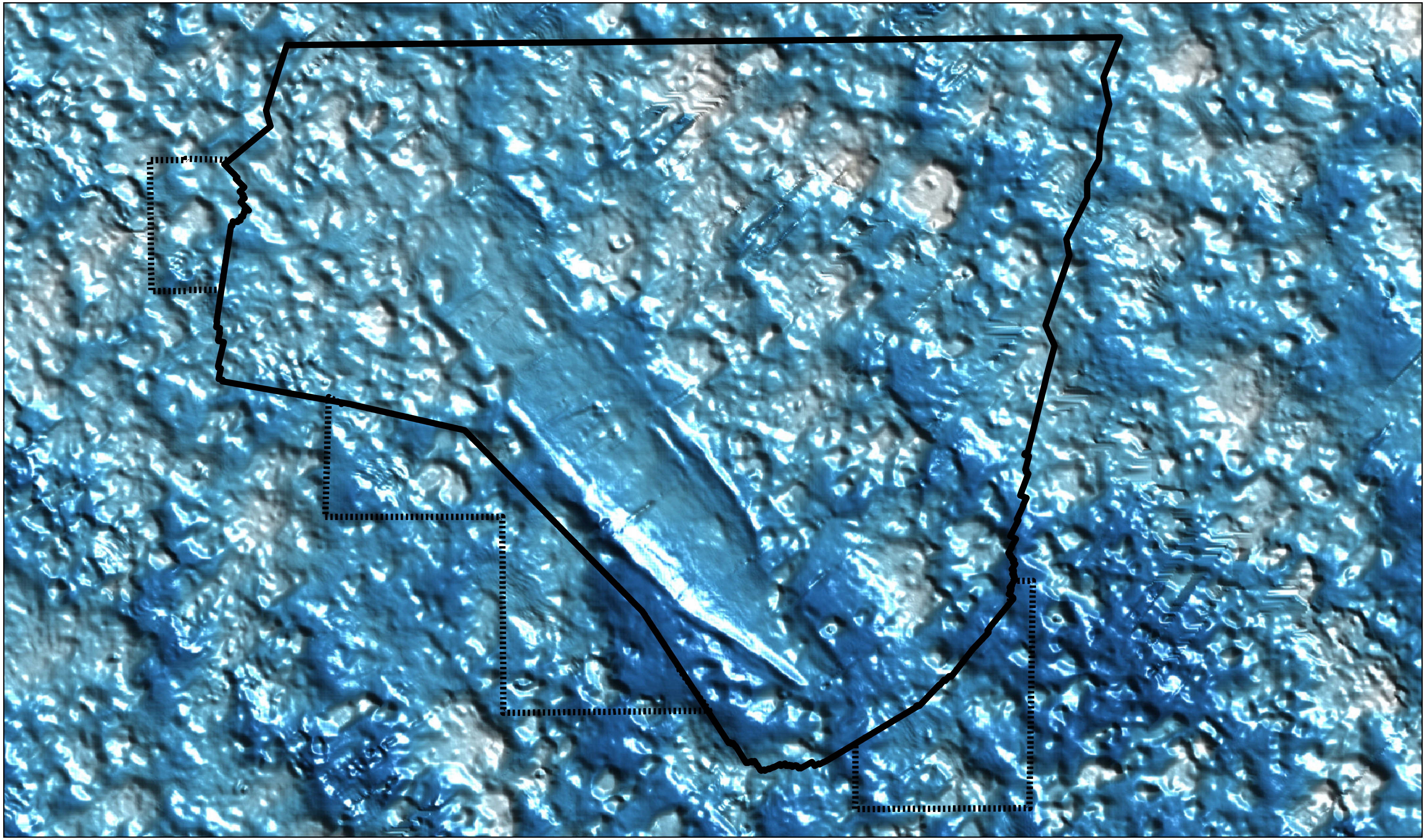
0 50

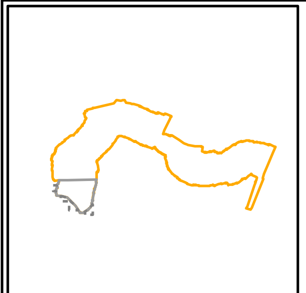
Map Produced by: NSW Water & Environment
Date: 2017-09-28
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_12_PossibleRemediationAreaE.mxd 01

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_12_PossibleRemediationAreaE.mxd

Build Sheet: Appendix E





Legend

Area

☐ F

Bathymetry (Negri et al. 2010)

-5 m — -30 m

Possible priority area - F

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N

1:1,100 **Scale at A3**

Metres

0 — 50

Map Produced by: NSW Water & Environment
Date: 2017-09-28
Coordinate System: GCS GDA 1994
Project: 59918002_001
Map: F_13_PossibleRemediationAreaF.mxd 01

Appendix F
Figure F - 13

Cardno

File Path: P:\Jobs\002_GBR_Dougls_Shoal_PrlimAss\DataBase\3_ArcGIS\4_Mxd\2017_Cardno\F_13_PossibleRemediationAreaF.mxd

Build Sheet: Appendix E

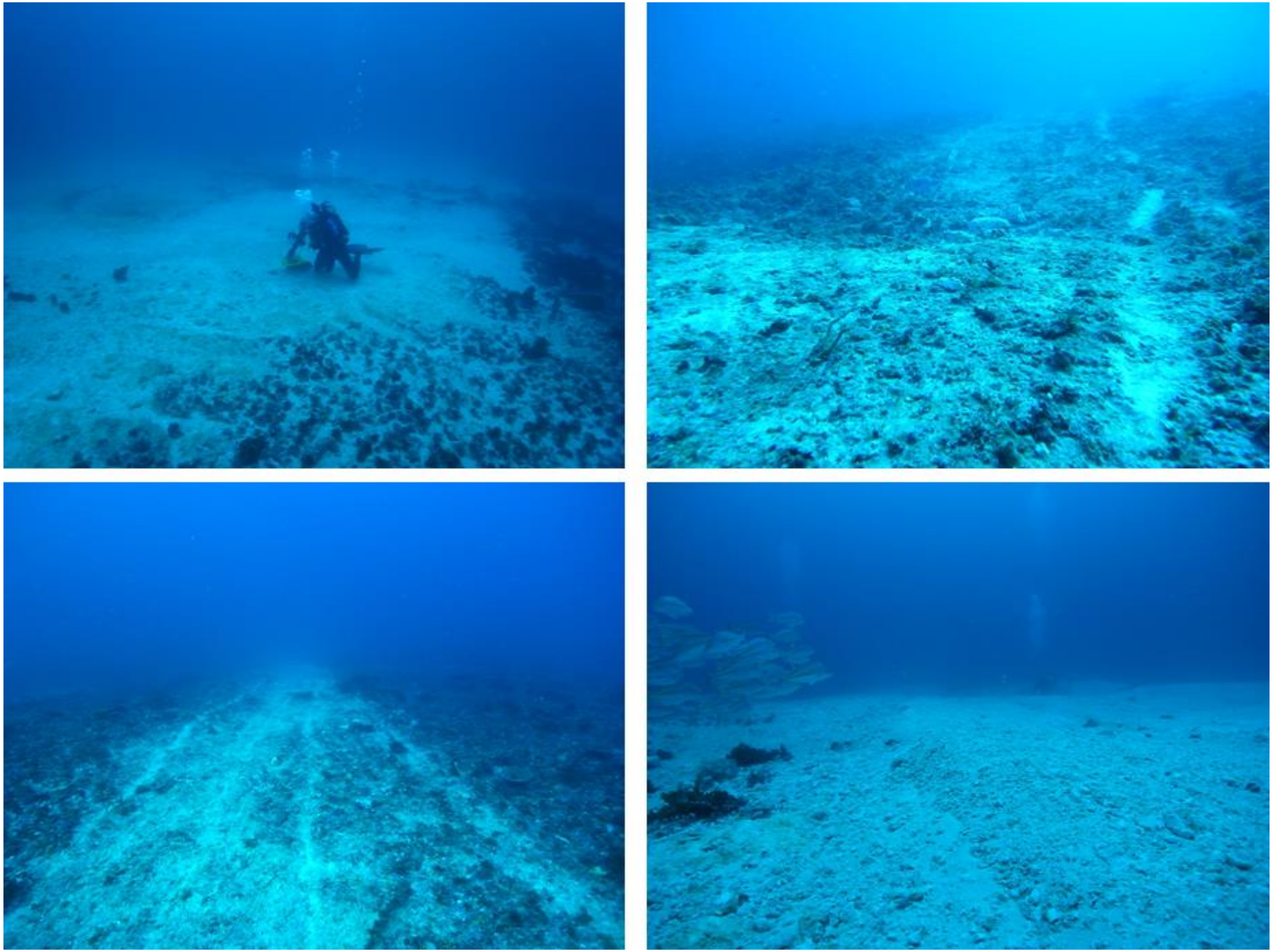


Figure F – 13 Photos taken from within the grounding footprint, April 2010 (Marshall 2010)

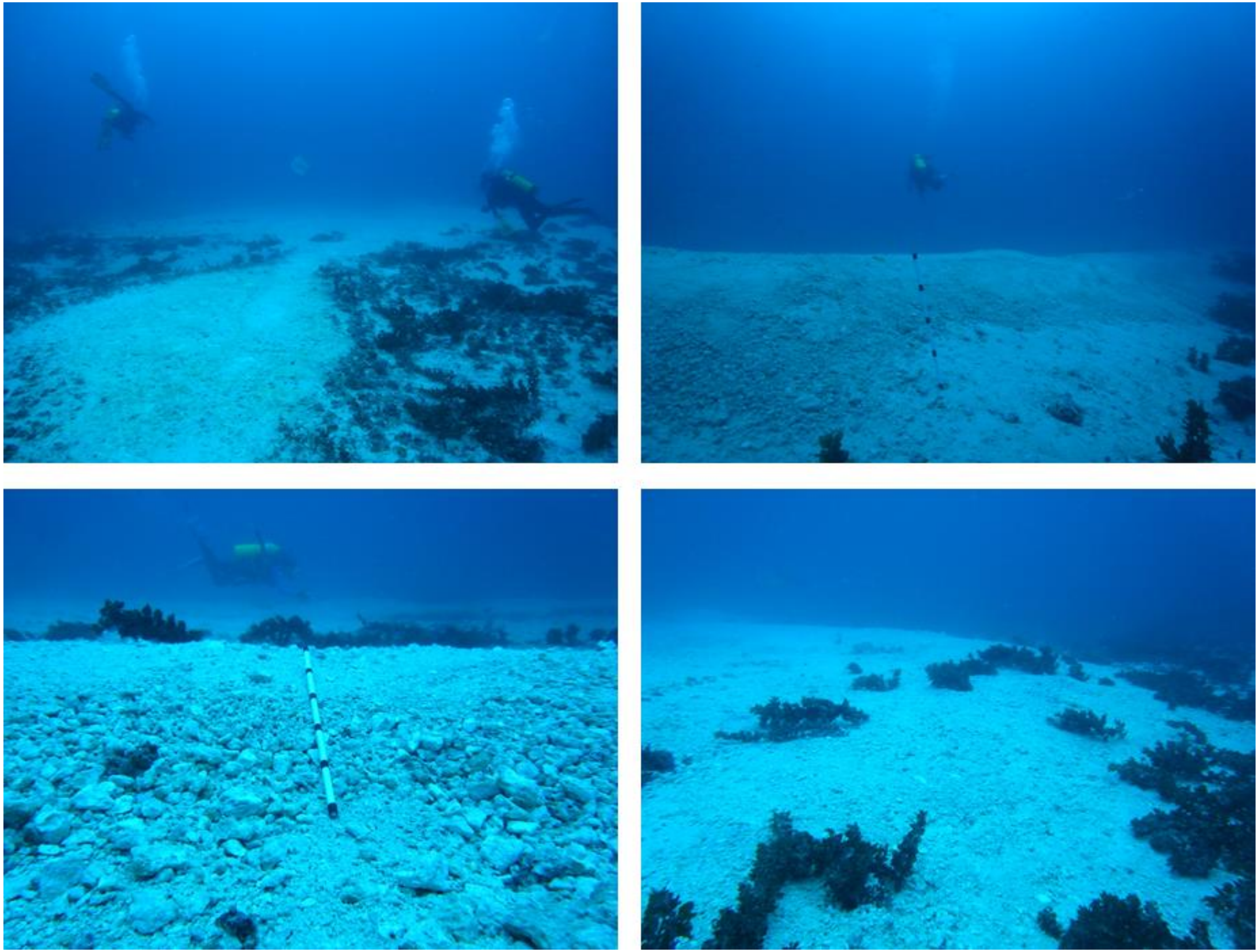


Figure F – 14 Photos taken from within the grounding footprint, April 2010 (Marshall 2010)

Figure F – 15 Photos taken from within the grounding footprint, April 2010 (Marshall 2010)

Figure F – 16 Photos taken from within the grounding footprint, April 2010 (Marshall 2010)

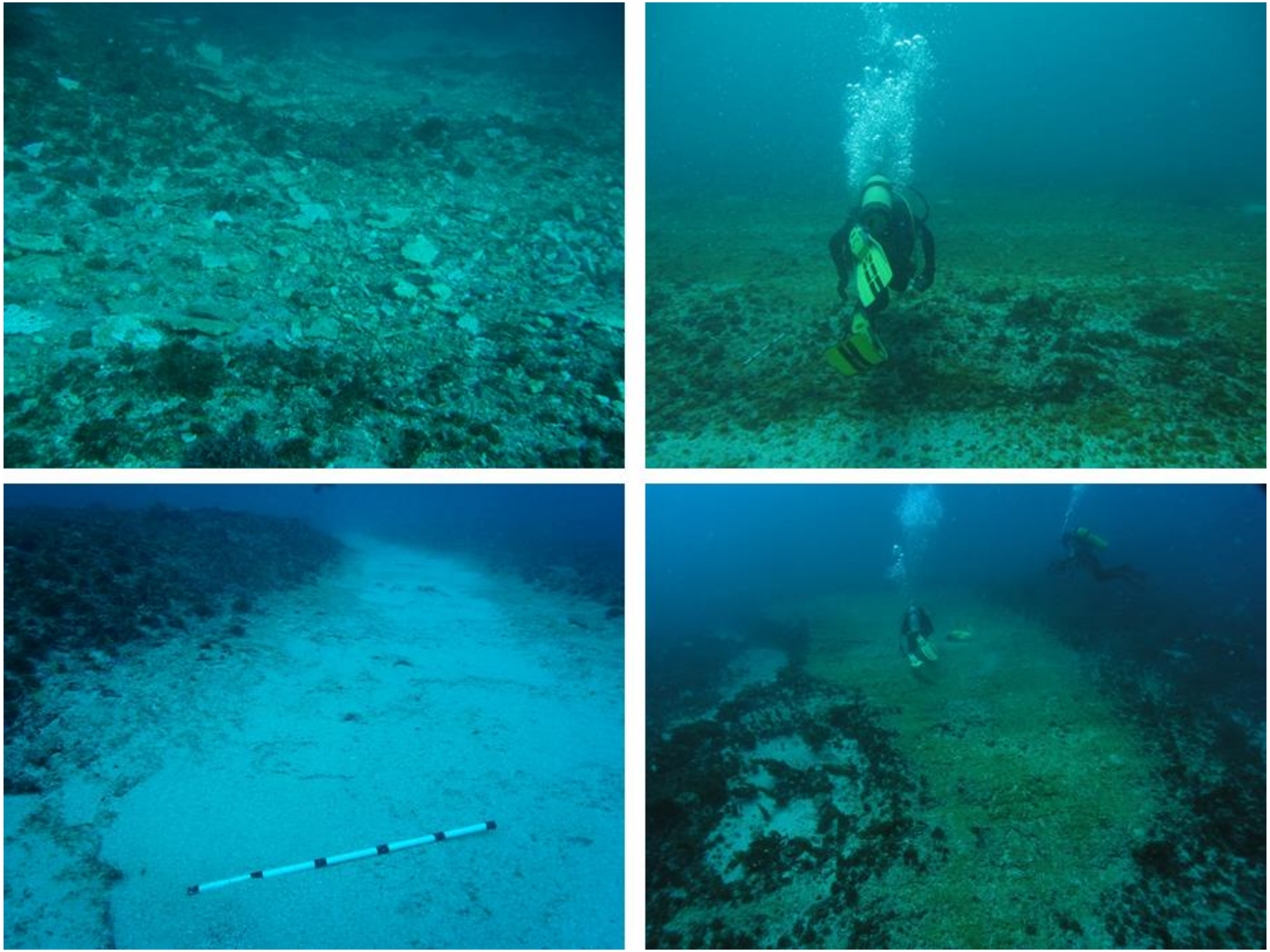


Figure F – 17 Photos taken from within the grounding footprint, April 2010 (Marshall 2010)

Appendix G – EPBC Act Protected Matters Report

Australian Government

Department of the Environment and Energy

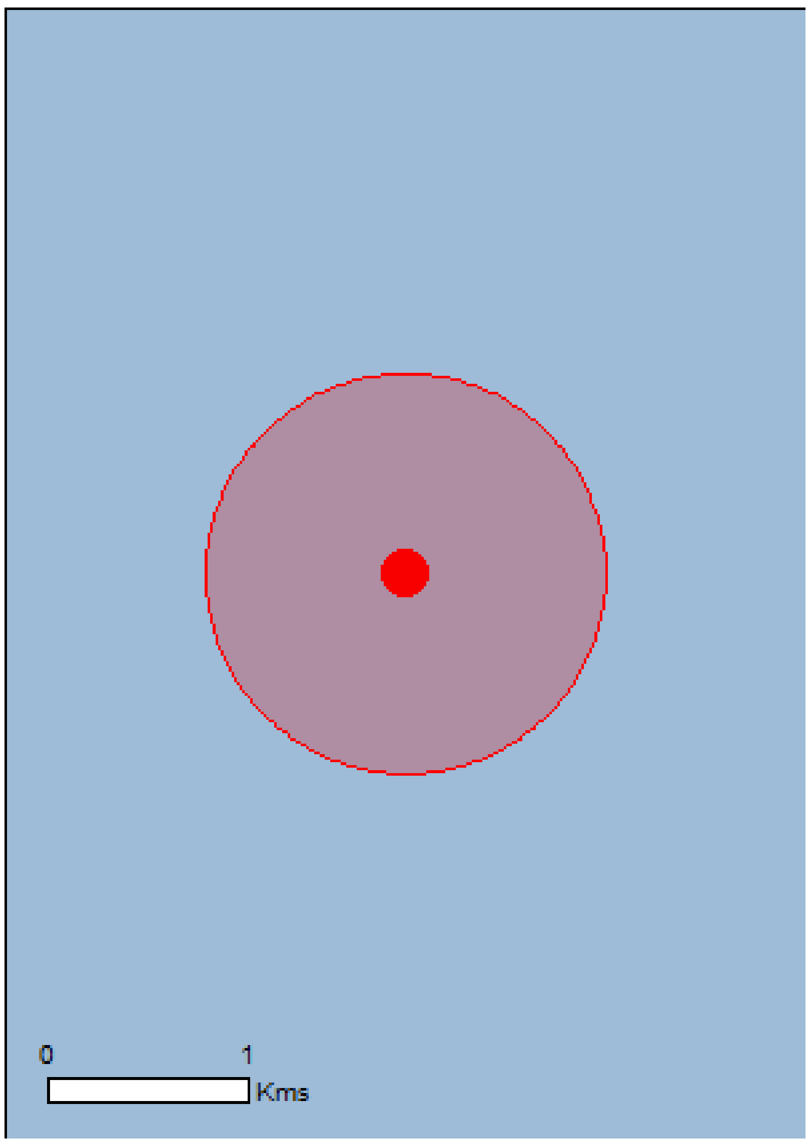
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 19/07/17 18:36:04



Coordinates

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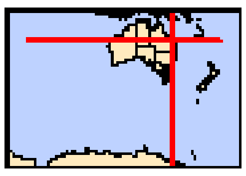

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	1
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	1
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	19
Listed Migratory Species:	31

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	67
Whales and Other Cetaceans:	11
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	None
Nationally Important Wetlands:	1
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Status
Great Barrier Reef	QLD	Declared property

National Heritage Properties [Resource Information]

Name	State	Status
Natural		
Great Barrier Reef	QLD	Listed place

Great Barrier Reef Marine Park [Resource Information]

Type	Zone	IUCN
Habitat Protection	HP-23-5350	VI

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside the Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area. Generally the Commonwealth Marine Area stretches from three nautical miles to two hundred nautical miles from the coast.

Name
EEZ and Territorial Sea

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Fregetta grallaria grallaria White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian) [64438]	Vulnerable	Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pterodroma neglecta neglecta Kermadec Petrel (western) [64450]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Mammals		
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species

Name	Status	Type of Presence
		habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sharks		
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Foraging, feeding or related behaviour known to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area

Migratory Wetlands Species

Name	Threatened	Type of Presence
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area
Anous stolidus Common Noddy [825]		Foraging, feeding or related behaviour known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat may occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat may occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Fish		
Acentronura tentaculata Shortpouch Pygmy Pipehorse [66187]		Species or species habitat may occur within area
Campichthys tryoni Tryon's Pipefish [66193]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Corythoichthys amplexus Fijian Banded Pipefish, Brown-banded Pipefish [66199]		Species or species habitat may occur within area
Corythoichthys flavofasciatus Reticulate Pipefish, Yellow-banded Pipefish, Network Pipefish [66200]		Species or species habitat may occur within area
Corythoichthys haematopterus Reef-top Pipefish [66201]		Species or species habitat may occur within area
Corythoichthys intestinalis Australian Messmate Pipefish, Banded Pipefish [66202]		Species or species habitat may occur within area
Corythoichthys ocellatus Orange-spotted Pipefish, Ocellated Pipefish [66203]		Species or species habitat may occur within area
Corythoichthys paxtoni Paxton's Pipefish [66204]		Species or species habitat may occur within area
Corythoichthys schultzi Schultz's Pipefish [66205]		Species or species habitat may occur within area
Doryrhamphus excisus Bluestripe Pipefish, Indian Blue-stripe Pipefish, Pacific Blue-stripe Pipefish [66211]		Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish [66214]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Halicampus dunckeri Red-hair Pipefish, Duncker's Pipefish [66220]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Hippichthys cyanospilos Blue-speckled Pipefish, Blue-spotted Pipefish [66228]		Species or species habitat may occur within area
Hippichthys heptagonus Madura Pipefish, Reticulated Freshwater Pipefish [66229]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus bargibanti Pygmy Seahorse [66721]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus zebra Zebra Seahorse [66241]		Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Micrognathus andersonii Anderson's Pipefish, Shortnose Pipefish [66253]		Species or species habitat may occur within area
Micrognathus brevirostris thorntail Pipefish, Thorn-tailed Pipefish [66254]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paegnius Rough-snout Ghost Pipefish [68425]		Species or species habitat may occur within area
Solenostomus paradoxus Ornate Ghostpipefish, Harlequin Ghost Pipefish, Ornate Ghost Pipefish [66184]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat may occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Crocodylus porosus Salt-water Crocodile, Estuarine Crocodile [1774]		Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Lapemis hardwickii Spine-bellied Seasnake [1113]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Laticauda colubrina a sea krait [1092]		Species or species habitat may occur within area
Laticauda laticaudata a sea krait [1093]		Species or species habitat may occur within area
Lepidochelys olivacea Olive Ridley Turtle, Pacific Ridley Turtle [1767]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat may occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat may occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

Nationally Important Wetlands	[Resource Information]
Name	State
Great Barrier Reef Marine Park	QLD

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-23.09828 151.67106

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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