# Port of Hay Point

## Marine Environmental Monitoring Plan

**9 August 2024**

**Version Control**

| Revision No. | Date | Revision details |
| --- | --- | --- |
| **0.1** | 26/03/2018 | Original |
| **0.2** | 14/04/2024 | Reviewed and amended for 2024 maintenance dredging program.<br>Amendments and summary of monitoring programs.<br>Updated to current NQBP document format.<br>Minor grammatical and spelling corrections. |
| **0.3** | 09/08/2024 | Amended for GBRMPA approval |

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## Abbreviations

| Abbreviation | Description |
|---|---|
| BoM | Bureau of Meteorology |
| IMP | Invasive marine pest |
| LMDMP | Long-term Maintenance Dredging Management Plan |
| MODIS | Moderate Resolution Imaging Spectroradiometer |
| NQBP | North Queensland Bulk Ports |
| the Port | the Port of Hay Point |

# 1 Introduction

## 1.1 Background to marine environmental monitoring plan

The Port of Hay Point was established in 1971. It is North Queensland Bulk Ports' (NQBP) southernmost port and home to two coal terminals – Dalrymple Bay Coal Terminal (DBCT) and Hay Point Coal Terminal (HPCT). The Port of Hay Point is a coastal Port with offshore trestle jetties extending approximately 4 km seaward. The Port has seven dedicated coal loading berths, with over 100 million tonnes of coal currently exported each year.

In addition to the coal terminals, the Port of Hay Point is home to the Half Tide Tug Harbour ), which includes tug berths, marine offloading facilities and a public boat ramp.

The environmental values surrounding the Port of Hay Point have been extensively studied over the past decades (Jacobs 2016). A great deal of this information has come from environmental impact assessment processes for different projects and many of these have resulted in monitoring being undertaken both during and after development. NQBP also undertakes non-project related ambient monitoring that provides an ongoing understanding of the long-term baseline environmental conditions. This plan currently focuses on managing suspended sediments, water quality, fringing coral, seagrass and invasive marine pests during maintenance dredging and placement at-sea.

## 1.2 Purpose

This document provides details on the marine monitoring commitments relating to maintenance dredging activities at the Port of Hay Point.

The marine monitoring outlined in this document is aimed at ensuring that best practice environmental management is applied to the design and execution of maintenance dredging at the Port of Hay Point.

Environmental Risk Assessment (ELA 2018) involving plume modelling, resuspension studies, and impact threshold analysis, indicates that impacts from maintenance dredging in volumes below 800,000m$^3$ are unlikely to result in residual impacts to sensitive environmental values.

With this in mind, **the specific aims of this monitoring plan are to**:

- monitor the long-term ambient environmental condition of the Port and nearby sensitive receptors
- detect any impacts from maintenance dredging, both immediately after dredging campaigns and over time
- Respond to real time environmental conditions during maintenance dredging to prevent unpredicted environmental impacts from maintenance dredging
- Collect data that will be used to drive continual improvement.

## 1.3 Relationship to other documents

This monitoring plan has key links to and should be read in conjunction with:

1. *Port of Hay Point Long-term Maintenance Dredging Management Plan 2018-2043* (LMDMP), dated May 2024. The LMDMP sets out the overall dredge management framework to inform long term planning and management of all dredging activities at the Port over a 25-year period.

2. *Port of Hay Point Maintenance Dredging Environmental Management Plan* (EMP), dated May 2024. The EMP outlines the management arrangements that will apply in relation to specific dredging operations.

The current approved versions of these plans will be maintained on the North Queensland Bulk Ports (NQBP) website – www.nqbp.com.au.

## 1.4 Continuous improvement

This monitoring plan provides the mechanism for driving continuous improvement using the data gained from each of the discrete monitoring programs. As such, the plan will be periodically reviewed to update (maintain, increase or decrease) monitoring effort and focus, based on the new and historical findings from the monitoring data.

## 1.5 Plan review

This monitoring plan will be reviewed and updated prior to each maintenance dredging campaign, or as required.

# 2 Environmental setting

The area from the south of the Port of Hay Point to north of the Port of Mackay has been highly modified. The area supports agricultural, urban, industrial, port and shipping, and commercial and recreational uses (Reef Catchments 2014).

The region also continues to support areas of international, national and state environmental significance. Historic land use practices have resulted in fragmented remnants of native vegetation throughout the landscape and along riparian corridors. These natural features provide important habitat corridors for a variety of native flora and fauna. The marine environment adjacent to the Port and coastline also contributes to the diversity of values in the region and forms part of the much larger Great Barrier Reef World Heritage Area.

The environmental values of the Port and surrounds are summarised in the LMDMP and are further described in detail in Jacobs (2016). Figure 1 provides a snap-shot overview of key environmental values of the marine environment, these include:

- Great Barrier Reef World Heritage Area and Great Barrier Reef Marine Park
- Deepwater and coastal seagrass meadows, which are seasonally variable
- Reefs dominated by sediment-tolerant hard coral species fringing Victor Island, Round Top Island, Flat Top Island, Taroba Rocks, Dudgeon Point, Keswick Island and St Bees Island
- Intertidal mangrove and saltmarsh areas that are important as feeding habitats and fish nursery areas
- Locally important populations of a number of threatened and migratory marine species, including marine turtles (green, flatback, leatherback and hawksbill), dugong, whales and dolphins
- Internationally important migratory shorebird roosting sites.

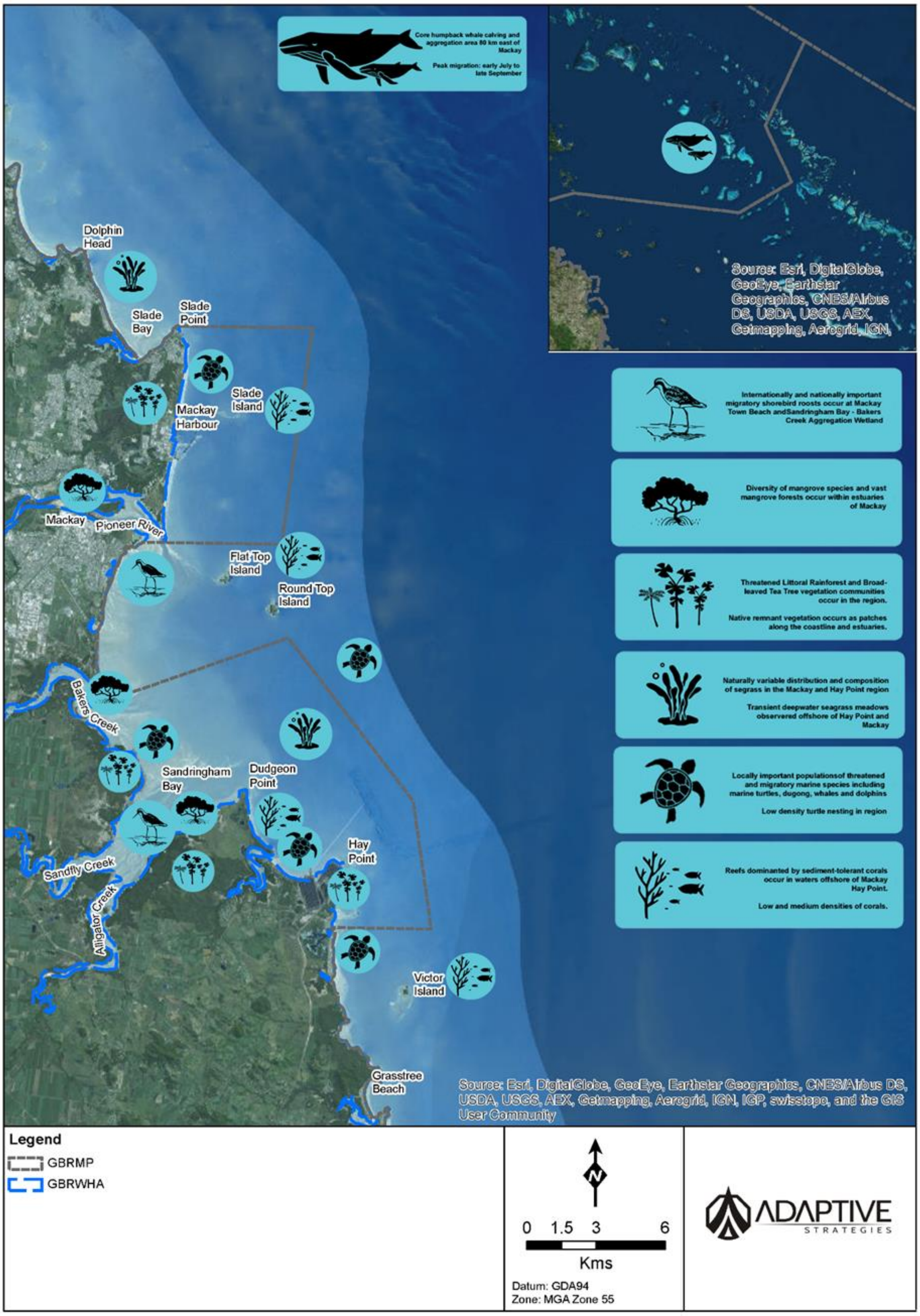



*Figure 1: Summary of environmental values at the Port of Hay Point and surrounds*

# 3 Previous monitoring

## 3.1 Sediment characteristics and quality

Sediment sampling has occurred across the Port of Hay Point for over two decades to support applications for capital and maintenance dredging under relevant environmental legislation. The sediment profile at the Port generally consists of a thin (<300 mm) veneer of silty sand, underlain by sands, clays and very stiff clays, interspersed with gravels, calcite nodules and decomposed bedrock (Jacobs 2016).

Earlier sampling for sediment quality in the 1990s indicated that tributyltin (TBT) was the only parameter to exceed the then-contemporary guideline levels. Large areas of the Port have subsequently been sampled from the mid-2000s onwards. Heavy metals, TBT and polycyclic aromatic hydrocarbons (PAHs) have been detected in some sediment samples, however on all occasions prior to 2024 results were below the relevant guidelines and sediments were considered suitable for unconfined ocean placement. In 2024, the sediments within HPCT Berth 1 and 2 and DBCT Berths 1 and 2 contained levels of TBT that were unsuitable for unconfined ocean placement, likely due to historic activities (Table 1).

The National Assessment Guidelines for Dredging (NAGD, DEWHA 2009), requires sediment sampling data to be current within 5 years. Sediment sampling data currency varies across the Port, with existing data remaining current from 2024 to 2029 (PaCE 2024).

*Table 1: Sediment testing results (2023/2024)*

| Port area | Dates | Estimated Volume | Suitable for ocean placement* |
|---|---|---|---|
| Departure path | July 2023 | 12,000 $m^3$ | ✓ |
| Aprons | July 2023 | 102,000 $m^3$ | ✓ |
| HTTH | July 2023 | 61,000 $m^3$ | ✓ |
| HPCT Berth 1 | January 2024 (Phase III) | 2,000 $m^3$ | ✗ |
| HPCT Berth 2 | January 2024 (Phase III) | 1,000 $m^3$ | ✗ |
| HPCT Berth 3 | July 2023 | 3,000 $m^3$ | ✓ |
| DBCT Berth 1 | January 2024 (Phase III) | 3,000 $m^3$ | ✗ |
| DBCT Berth 2 | January 2024 (Phase III) | 11,000 $m^3$ | ✗ |
| DBCT Berth 3 | July 2023 | 2,000 $m^3$ | ✓ |
| DBCT Berth 4 | July 2023 | 3,000 $m^3$ | ✓ |

*2024 sediment characterisation assessment subject to GBRMPA approval.

## 3.2 Water quality

Extensive water quality monitoring has previously been undertaken at the Port associated with individual dredging and capital works programs. In 2014, NQBP established an ambient marine water quality monitoring program in the coastal zone around the Ports of Hay Point and Mackay with the aim of developing a long term water quality dataset to characterise marine water quality conditions within the Mackay region, and to support future planned port activities.

The program has been refined over time and currently there are four monitoring sites located at Freshwater Point, Round Top Island, Slade Islet and Victor Island. Sites in the monitoring network have been chosen to spatially align with the location of key sensitive receptor habitats (e.g. corals and seagrass), along with key features in the study region (e.g. river flow points).

Overall, the results of the ambient monitoring program show that:

- The water column is generally well mixed, with dissolved oxygen and pH generally similar among the three depth horizons.
- There were periods of elevated turbidity, likely driven by resuspension of sediment during times of low rainfall. This is consistent with patterns along the Queensland coast.
- Ambient SSC and chlorophyll *a* are both found to be generally higher than relevant existing water quality guidelines, suggesting that the development of local water quality guidelines would be beneficial. Ongoing ambient data will help to inform locally relevant guideline values.

All of NQBP's ambient water quality monitoring reports are available on the website https://nqbp.com.au/.

## 3.3 Island fringing corals

In 2015, NQBP commenced an ambient coral monitoring program which is conducted twice yearly, before and after the wet season and builds on monitoring that had been conducted between 2006 and 2015. The aim of this program is to develop a long-term dataset to characterise the coral community during ambient conditions. Long term ambient conditions can then be used to plan and monitor port activities and developments. The program has been refined over time based on the data collected, and currently there are four monitoring sites at each of Slade Islet, Round Top Island and Victor Island. Keswick Island was removed from the program in 2020 as it is considered a more mid-shelf reef rather than an appropriate indicator of inshore coral communities.

Overall the results of the monitoring program show that (Chartrand et al 2022):

- Four cyclonic events occurred between 2010 and 2015, resulting in decreased hard coral cover at Slade Islet (from 42% to 30%) and Round Top Island (from 44% to 25%) while Victor Islet remained unaffected (33%).
- Sponge and soft coral cover both remained consistent over the same time period at all location, however macroalgae cover increased significantly from <1% to approx. 30% at all locations.
- Extensive physical damage from Cyclone Debbie in March 2017 caused hard coral cover to drop from 27% to 22% on Round Top Island, from 35% to 25% on Victor Islet and from 31% to 22% on Slade Islet. Minimal recovery in hard coral cover has been observed since Cyclone Debbie.
- A marine heat wave occurred in the region in early 2020, resulting in a mass bleaching event. This significantly reduced hard coral cover at Slade Islet in particular and depressed hard coral trends at the other two locations, and soft coral at Round Top Island.
- Given the major impacts on hard cover coral resulting from physical damage during cyclonic events, recovery time to baseline levels of cover is estimated to be at least 10 years, assuming best-case recovery scenarios and no further climatic impacts, which is considered unlikely.

All of NQBP's coral monitoring reports are available on the website https://nqbp.com.au/.

## 3.4 Seagrass

A long-term seagrass monitoring program and strategy was developed for the Mackay-Hay Point region following a broad-scale baseline survey of the region in 2014. The program builds on seagrass monitoring that had been conducted at offshore areas around the Port of Hay Point since 2005, as well as coastal surveys conducted in 2010 and 2011. The annual monitoring assesses five offshore monitoring areas between Mackay and Hay Point, an inshore region between Dudgeon Point and Hay Point, and two inshore subtidal meadows at the Keswick Island group.

Overall, the results of the monitoring show that (York et al 2022):

- Seagrass habitats in the Mackay-Hay Point region are highly variable and assemblages are generally dominated by species that are adapted to surviving in low light and dynamic benthic conditions.
- These species show lower resistance to light deprivation when conditions for seagrass are unfavourable, but are known to recover quickly following disturbance.
- From 2018 to 2022, the region experienced no major flood or cyclonic events, allowing seagrass meadows to build resilience.

All of NQBP's seagrass monitoring reports are available on the website https://nqbp.com.au/.

## 3.5 Invasive marine pests

NQBP have maintained an invasive marine pest (IMP) monitoring program since 2002, with the objective to provide early detection of incursions of IMP's. IMP presence is monitored quarterly using settlement plates; these are currently located at HTTH, loading trestles at the Port of Hay Point and various locations within the Port of Mackay.

The Port of Hay Point is considered low risk for IMPs and no IMPs have been detected to date. A suspected incursion of Colonial sea squirt (*Didemnum perlucidum*) was reported in 2020; however, visual inspection confirmed the growth was most likely a native species and detailed taxonomic identification was not required.

# 4 Monitoring framework

## 4.1 Framework

The monitoring detailed in this plan is an important component of the overarching Dredge Management Strategy as described in the LMDMP. NQBP will oversee the implementation of the monitoring plan, with each component being undertaken by appropriately qualified marine scientists contracted for their support.

Overall, the monitoring plan is made up of a combination of regular ambient monitoring (long-term monitoring) and individual dredging event related monitoring (short-term and adaptive monitoring). The three-tiered approach to monitoring is outlined in Figure 2. A summary of the key monitoring parameters for each tier is provided in Table 3.

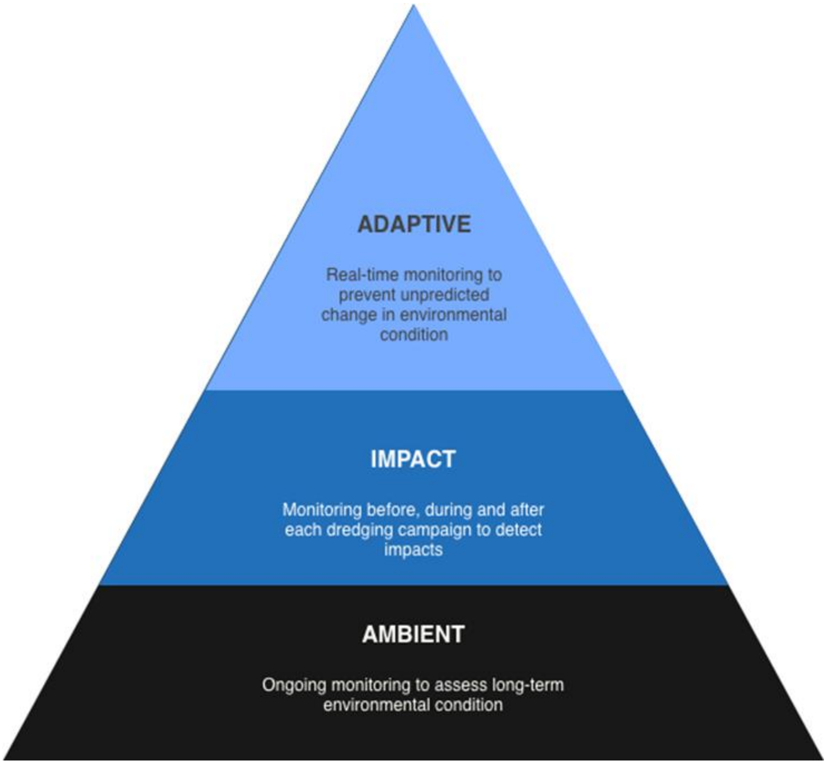



*Figure 2: Tiered approach to monitoring*

Further details of each tier of the program is provided in Sections 5 – 7 below.

## 4.2 Parameters

The parameters listed below in Table 2 will be monitored as part of this monitoring plan. A rationale for each is provided below.

*Table 2: Key parameters to be monitored*

| Parameter | Ambient | Impact | Adaptive |
|---|---|---|---|
| Marine water quality | ✓ | ✓ | ✓ |
| Island fringing corals | ✓ | ✓ | |
| Seagrass and benthic habitat | ✓ | | |
| Invasive marine pests | ✓ | | |
| Sediment quality | ✓ | ✓ | |
| Marine megafauna | | | ✓ |

### 4.2.1 Water quality

Water quality parameters will be monitored during all tiers of the monitoring plan. Good water quality underpins the ecological success of key sensitive environmental receptors in the Hay Point region, including seagrass and corals.

Water quality monitoring will be undertaken during all phases of this plan. Monitoring across both ambient and impact programs allows for an understanding of long-term trends, which may be analysed in conjunction with trends in ecological data. Key water quality parameters (NTU, SSC) can also be effectively monitored in real time during dredging campaigns. With the application of appropriate trigger levels, real time adaptive management actions can be undertaken. This ensures predicted water quality targets are being tracked and met, and that water quality does not deteriorate to levels that may cause unacceptable environmental harm.

Water quality monitoring data may also be used as part of the program of continual improvement, including to provide validation of hydrodynamic modelling.

### 4.2.2 Island fringing corals

Island fringing corals are one of the key sensitive environmental receptors in the Hay Point region. These communities are at risk from poor water quality, both due to decreased light levels and physical smothering. Effects post-dredging may take some time to become evident, particularly if stresses are sub-lethal. There is also broader concern about the overall health of coral communities inhabiting inshore areas of the GBR.

Monitoring of island fringing corals will be undertaken across ambient and impact programs. This will allow for an understanding of annual trends, which can be reviewed in the broader context of GBR inshore reef health. Impact monitoring will specifically test for effects from maintenance dredging.

### 4.2.3 Seagrass and benthic habitats

Seagrasses are a sensitive environmental receptor within the Hay Point region that can be impacted from poor water quality, however their presence is both temporally ephemeral and spatially patchy.

Monitoring of seagrass will be undertaken during the ambient program only. This will allow for an understanding of annual trends, which can be review in the broader context of conditions and events in the region, including dredging and placement. Impact monitoring of seagrasses is not proposed. The ephemeral and spatially patchy nature of the seagrass in the area is unlikely to allow meaningful data to be collected, particularly if dredging occurs during January – June when seagrasses are not present. If declines are detected during the ambient program in years post-dredging, further investigations will be scoped in collaboration with relevant marine scientists.

### 4.2.4 Invasive marine pests

Invasive marine pests (IMP) have the capacity to enter ports in ballast water, internal seawater systems and on the hulls of vessels (ships and yachts). The operation of the dredge vessel is a small contributing factor to the overall risk of IMPs. Monitoring will be undertaken as part of the ambient program.

### 4.2.5 Sediment quality

Monitoring of sediment characteristics at the Port will be undertaken to ensure dredge material is suitable for ocean placement as per the requirements of the NAGD. This guideline requires 5-year data currency and will therefore be undertaken as necessary to ensure currency of data.

### 4.2.6 Marine megafauna

Marine megafauna will only be monitored during the adaptive monitoring, whilst the dredge is operating. The primary aim of this is to prevent interactions between the vessel and any marine fauna.

# 5 Ambient monitoring

The following section describes the ambient monitoring that will continue be undertaken at the Port of Hay Point. The aim of this monitoring is to provide a long-term baseline environmental condition assessment of the Port and nearby sensitive receptors.

The ambient monitoring focuses on sediment quality, water quality, coral, seagrass and invasive marine pests.

## 5.1 Sediment testing

In order to be placed at sea, dredged sediments must be considered suitable for unconfined ocean placement as per criteria established under the *Environment Protection (Sea Dumping) Act 1981*. At the time of writing this Plan, the criteria are set out in the National Assessment Guidelines for Dredging (NAGD, DEWHA 2009).

Monitoring of sediment characteristics at the Port will be undertaken to ensure dredge material is suitable for ocean placement as per the requirements of the NAGD.

### 5.1.1 Parameters

The specific parameters to be tested will be determined in accordance with the NAGD and may differ depending on the area of the Port under consideration and its history of testing and sediment contamination. However, as a general rule, the following sediment characteristics will be tested:

- Basic sediment characteristics
    - Moisture content
    - Total organic carbon
    - Particle size and settling rate
    - Bulk density
- Organic compounds
    - Hydrocarbons (incl. PAHs)
    - Organochlorines
    - PCBs
    - Benzene, toluene, ethylbenzene, xylene
    - Pesticides
    - Organotin compounds
- Inorganic compounds
    - Metals and metalloids
    - Cyanide
    - Nutrients
    - Ammonia

### 5.1.2 Protocol

Sampling will be undertaken in accordance with the requirements of the NAGD and as per an approved Sampling and Analysis Plan (SAP). Sediment sampling results will be compared against criteria in the NAGD to determine suitability for ocean placement.

If required, elutriate and bioavailability testing and toxicity and bioaccumulation testing will be carried out.

### 5.1.3 Timing and frequency

Sediment sampling will be undertaken at relevant navigational areas within the Port to ensure that data is current to within 5 years.

### 5.1.4 Sites

The areas of the Port listed below will be a focus for sediment testing. The location of specific sampling sites will be determined prior to each sampling occasion in accordance with the NAGD and an approved SAP.

- DBCT Berth pockets (no. 1, 2, 3 and 4)
- HPCT Berth pockets (no. 1, 2 and 3)
- Apron
- Departure channel
- Half Tide Tug Harbour
- Dredged Material Placement Area

## 5.2 Ambient water quality

Water quality data is temporally variable and continued monitoring provides the ability to fully characterise the ambient conditions in the Hay Point region.

### 5.2.1 Parameters

The following water quality parameters will be measured:

- Water physio-chemistry (including turbidity)
- Nutrients and chlorophyll a
- Ultra-trace dissolved metals
- Pesticides and herbicides
- Sediment deposition
- Photosynthetically active radiation (PAR)
- Water current speed and direction

### 5.2.2 Protocol

A full protocol for collection of water quality samples is provided in Appendix A.

#### *5.2.2.1 Physio-chemical analysis*

The following ambient physio-chemical water quality parameters will be measured in situ using a calibrated multi-probe, secchi disk and LiCor meter:

- Water temperature
- Electrical conductivity (salinity)
- pH
- Dissolved oxygen (%)
- Turbidity
- Secchi disk depth (measure of optical clarity)
- PAR Light attenuation

These parameters will be sampled at three depths: surface (0.25 m), mid-depth and bottom.

#### *5.2.2.2 Laboratory Analysis*

Additional ambient water quality parameters will be measured via surface water sampling and laboratory analysis, including:

- Ultra-trace dissolved metals including arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn)
- Nutrients (nitrogen and phosphorus)
- Chlorophyll a
- Pesticides and herbicides (Low LOR suite [EP234(A-I)])

#### *5.2.2.3 In situ data recording*
The following parameters will be recorded via in situ multi-parameter data loggers and Marotte current meter:

- Turbidity
- Sediment deposition
- Pressure (to provide data on water depth)
- Water temperature
- Photosynthetically Active Radiation (PAR)
- Current speed and direction

### 5.2.3 Timing and frequency
Ambient water quality monitoring will be undertaken according to the program in Table 3.

*Table 3: Water quality monitoring timing and frequency*

| Parameter | Frequency | Timing |
|---|---|---|
| Ambient physio-chemical (in situ) | 6 weekly | All year |
| Nutrients, chlorophyll a (via water samples) and TSS | 6 weekly | All year |
| Metals& pesticides/herbicides (via water samples) | 2 x per year | Wet season (~ November)<br>Dry season (~ March) |
| Parameters recorded via *in situ* data logger and current meter | Continuous (10 min intervals) | All year |

### 5.2.4 Sites
Sampling will be undertaken at the sites indicated in Table 4 and Figure 3.

*Table 4: Water quality monitoring sites*

| Location | Site ID | Latitude | Longitude | Parameters | | |
|---|---|---|---|---|---|---|
| | | | | Physio chemical and water samples | Loggers | |
| Freshwater Point | 1 | -21.42 | 149.34 | ✓ | ✓ | |
| Round Top Island | 3B | -21.17 | 149.26 | ✓ | ✓ | |
| Slade Island | 5 | -21.09 | 149.24 | ✓ | ✓ | |
| Victor Island | 10 | -21.32 | 149.32 | ✓ | ✓ | |
| Mackay Harbour | 11 | -21.11 | 149.22 | ✓ | | ✓ |

Site numbers have been carried over from previous monitoring work. Some original sites have been decommissioned.

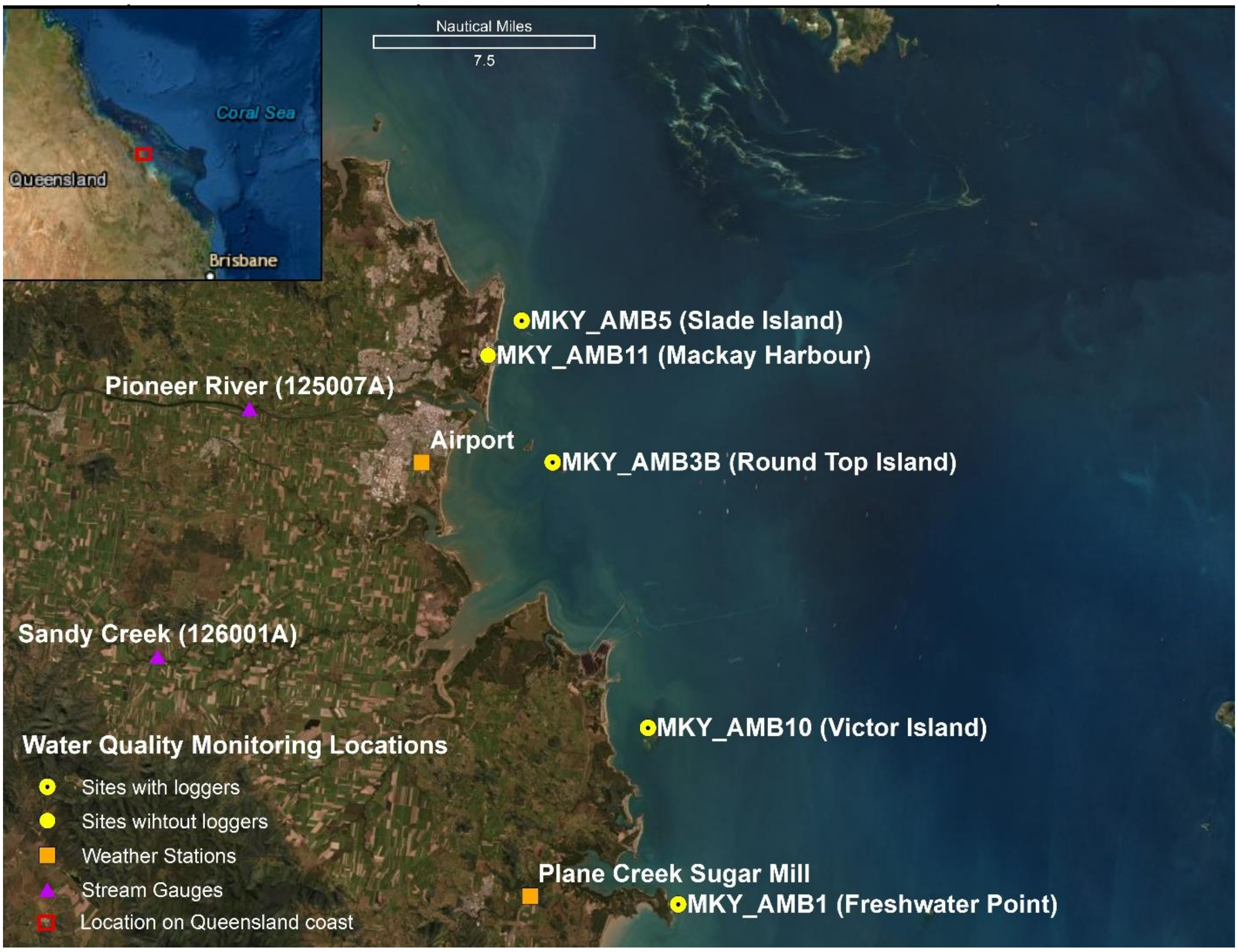



*Figure 3: Location of water quality monitoring sites*

## 5.3 Ambient island fringing corals

Inshore island fringing coral communities are sensitive receptors in the regional marine environment around the Port of Hay Point. Continued ambient monitoring will provide an ongoing understanding of the condition of these communities both at a given point in time and in the longer term.

### 5.3.1 Parameters

The following parameters relating to coral communities will be measured:

- Diversity and abundance of benthic communities
- Percentage coral bleaching
- Percentage coral mortality
- Sediment deposition
- Coral recruitment

### 5.3.2 Protocol

A full protocol for collection of coral community data is provided in Appendix B.

The data listed below will be recorded along permanent benthic line transects. At each site, four assessments along 20 m transects will be undertaken. The transects are located between 0.5 and 7 m water depth.

- Percentage cover of benthic organisms using a line intercept technique and as per the following categories: algae, sponges, hard corals (genus or growth form), soft corals
- Bleaching status of all corals as not bleached, partially bleached, totally bleached

The depth of sediment deposition will be measured on 20 hard corals located within 1 m of each transect.

The data listed below will be recorded within a 40 $m^2$ area centred on each of the permanent transects (i.e. 1 m either side of the 20 m transect):

- Total count of coral colonies
- Count of bleached or partially bleached coral colonies
- Count of sediment damaged colonies
- Count of diseased coral colonies

Coral recruitment (demography) will be recorded by identifying all juvenile corals within 30 cm of the shoreward side of each permanent transect. Corals will be identified to genus and place in a size category: 0 – 2 cm; 2 – 5 cm; 5 – 10 cm.

### 5.3.3 Timing and frequency

Coral community monitoring will be undertaken twice yearly around March – April (post wet season) and November (pre-wet season).

Surveys should be undertaken during periods where the long term weather forecast suggests an extended period of light winds (i.e. at least several consecutive days), as this will result in good underwater visibility and allow for more rapid and reliable surveys.

### 5.3.4 Sites

*Sampling will be undertaken at all 24 monitoring sites indicated in Table 5 and*


Figure 4.

*Table 5: Coral monitoring sites*

| Location | Ambient monitoring site ID | Historical site ID | Latitude | Longitude |
|---|---|---|---|---|
| Slade Island | S1 | S1 | -21.0989 | 149.2440 |
| | S2 | S2 | -21.0988 | 149.2450 |
| | S4 | S4 | -21.0961 | 149.2431 |
| | S5 | S5 | -21.0966 | 149.2450 |
| Round Top Island | S1 | S1 | -21.1699 | 149.2656 |
| | S3 | S3 | -21.1702 | 149.2668 |
| | S4 | S4 | -21.1719 | 149.2675 |
| | S6 | S6 | -21.1769 | 149.2665 |
| Victor Island | S2 | S2 | -21.3223 | 149.3267 |
| | S3 | S3 | -21.3232 | 149.3276 |
| | S5 | S5 | -21.3197 | 149.3215 |

| | | | | |
|---|---|---|---|---|
| | S6 | S6 | -21.3223 | 149.3191 |


*Figure 4: Map showing Port of Hay Point and the coral monitoring sites*

## 5.4 Ambient seagrass and benthic habitat

Seagrass communities are considered sensitive receptors in the regional marine environment around the Port of Hay Point. The communities have been historically highly ephemeral when compared year-on-year (McKenna et al. 2016). Seagrasses are also highly seasonal, with peak abundance and distribution in winter through spring. Summer die-off in seagrass communities can be extreme, with previous records of complete absence of plants between December and June at Hay Point between 2004 and 2009 (Chartrand et al. 2017). Continued ambient monitoring will provide an understanding of the condition of seagrass communities both at a given point in time and in the longer term.

### 5.4.1 Parameters

Seagrass habitat observations will be undertaken at sites in the Hay Point region. Post survey, site data will be analysed to produce meadow mapping, classification and condition assessment.

### 5.4.2 Protocol

A full protocol for collection seagrass data is provided in Appendix C.

At each survey site the following parameters will be recorded:

- Seagrass species composition
- Above-ground biomass
- Percent algal cover
- Depth below mean sea level
- Sediment type
- Percent cover of other major benthos

Survey method will depend on water depth and location and will include:

- Free diving – subtidal areas <8 m depth
- Boat based underwater digital camera mounted on a drop frame – subtidal inshore areas <8 m depth
- Boat based digital camera sled tows – offshore subtidal areas >8 m depth

Post-survey, data analysis will characterise:

- Habitat characterisation of the survey sites
- Seagrass meadow biomass and community type
- Seagrass landscape category
- Meadow mapping, classification and condition

### 5.4.3 Timing and frequency

Surveys will be conducted annually between September and December. This is when seagrasses are at the seasonal peak in distribution and abundance and when previous surveys have been undertaken (to facilitate historical comparisons).

### 5.4.4 Sites

Over 100 sites are surveyed during the annual monitoring survey, as indicated on

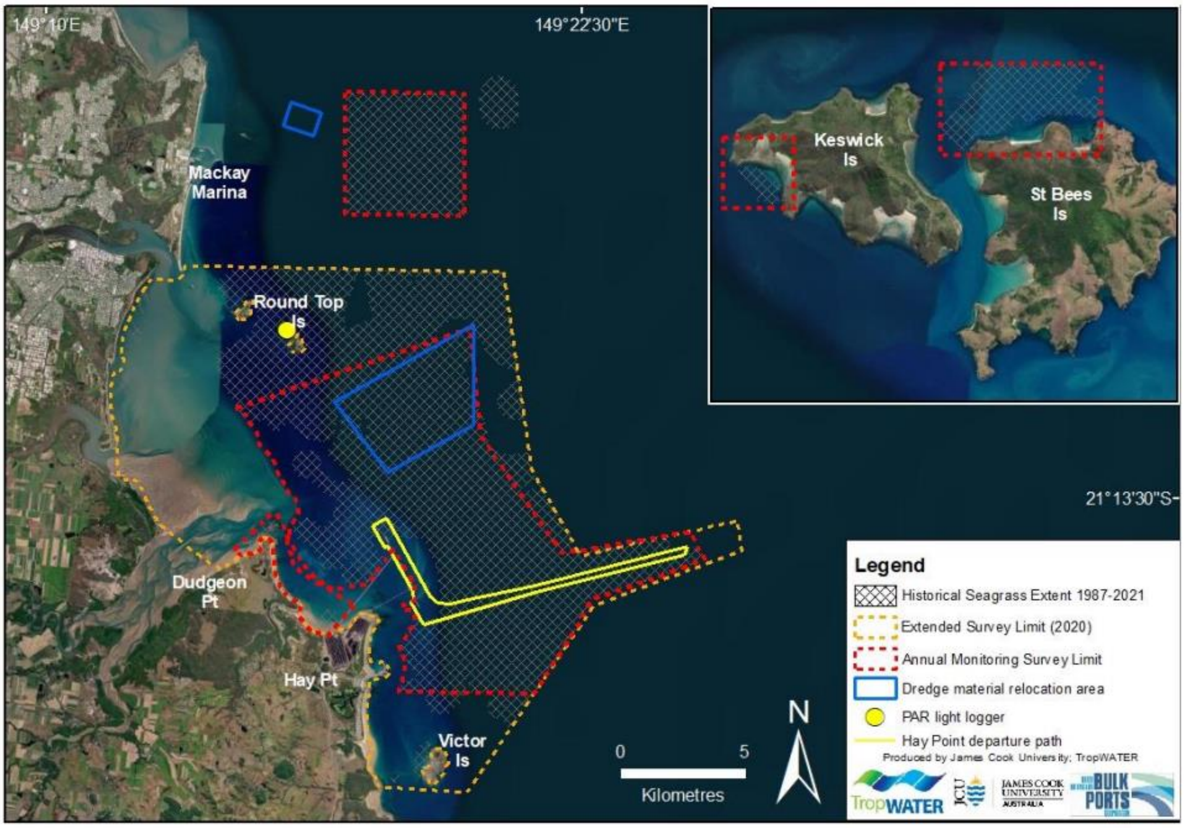



Figure 5 below. The exact number and location of sites will be determined prior to each annual survey taking account of previous years' results. From the results of the 2014 survey and further investigations in 2015, two inshore meadows at Keswick/St Bees Islands, one inshore region from Dudgeon Point to Hay Point, offshore areas around Hay Point, and one offshore area offshore from the Mackay Marina were identified as suitable for long term seagrass monitoring. Monitoring areas selected were representative of the range of seagrass communities in the Mackay-Hay Point region and were also located in areas considered ideal sensitive receptor sites for assessing seagrass condition in relation to port activity and development.

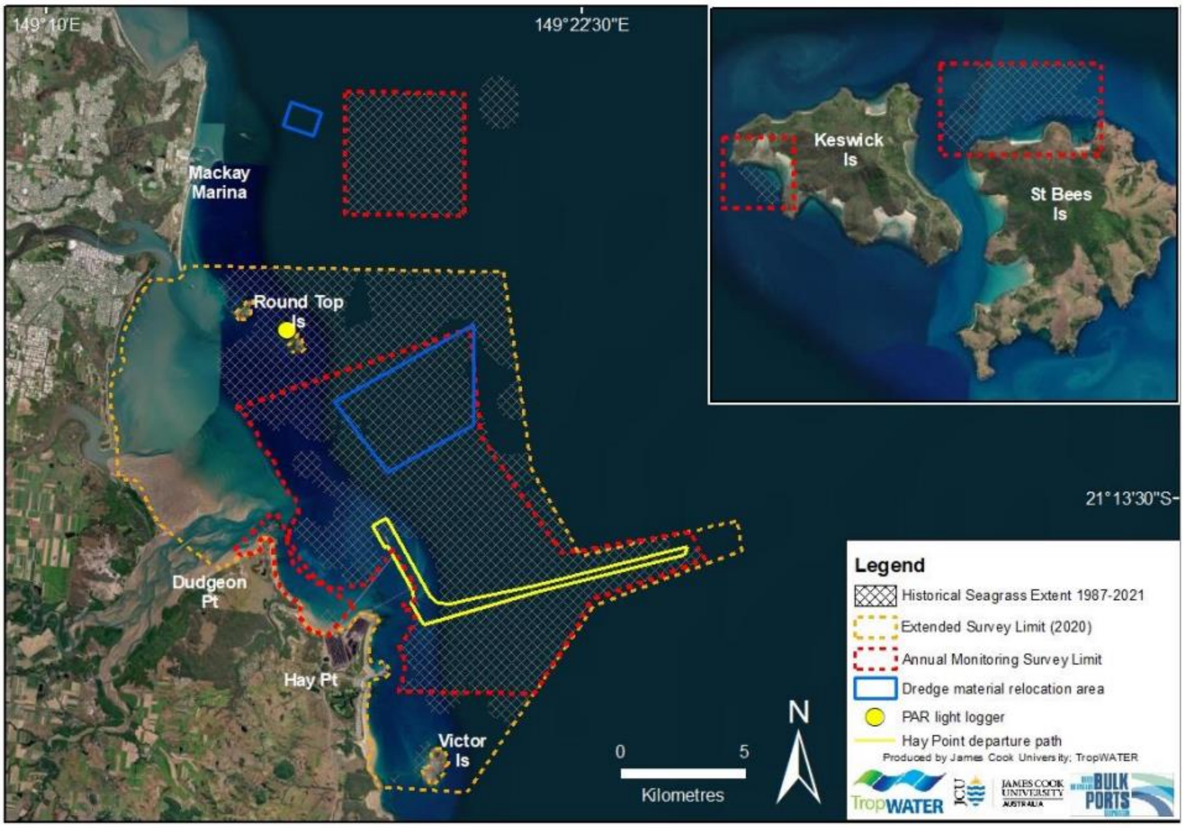



*Figure 5: Seagrass survey areas*

## 5.5 Ambient invasive marine pests

Invasive marine pests (IMP) have the capacity to enter into ports in ballast water, internal seawater systems and on the hulls of vessels (ships and yachts).

### 5.5.1 Parameters and protocol

IMP's will be monitored via the deployment of settlement plates. The two species of most concern are the Asian Green Mussel and Asian Bag Mussel. Monitoring will be undertaken in accordance with NQBP's Environmental Control Procedure *ECP120p: IMP Monitoring Network Guideline*.

### 5.5.2 Timing and frequency

Settlement plates will be checked quarterly.

### 5.5.3 Sites

Settlement plate locations are selected on a risk-based approach, with deployment at sites of the highest risk i.e. (locations likely to experience primary infestation). Existing monitoring sites are shown in Figure 6.

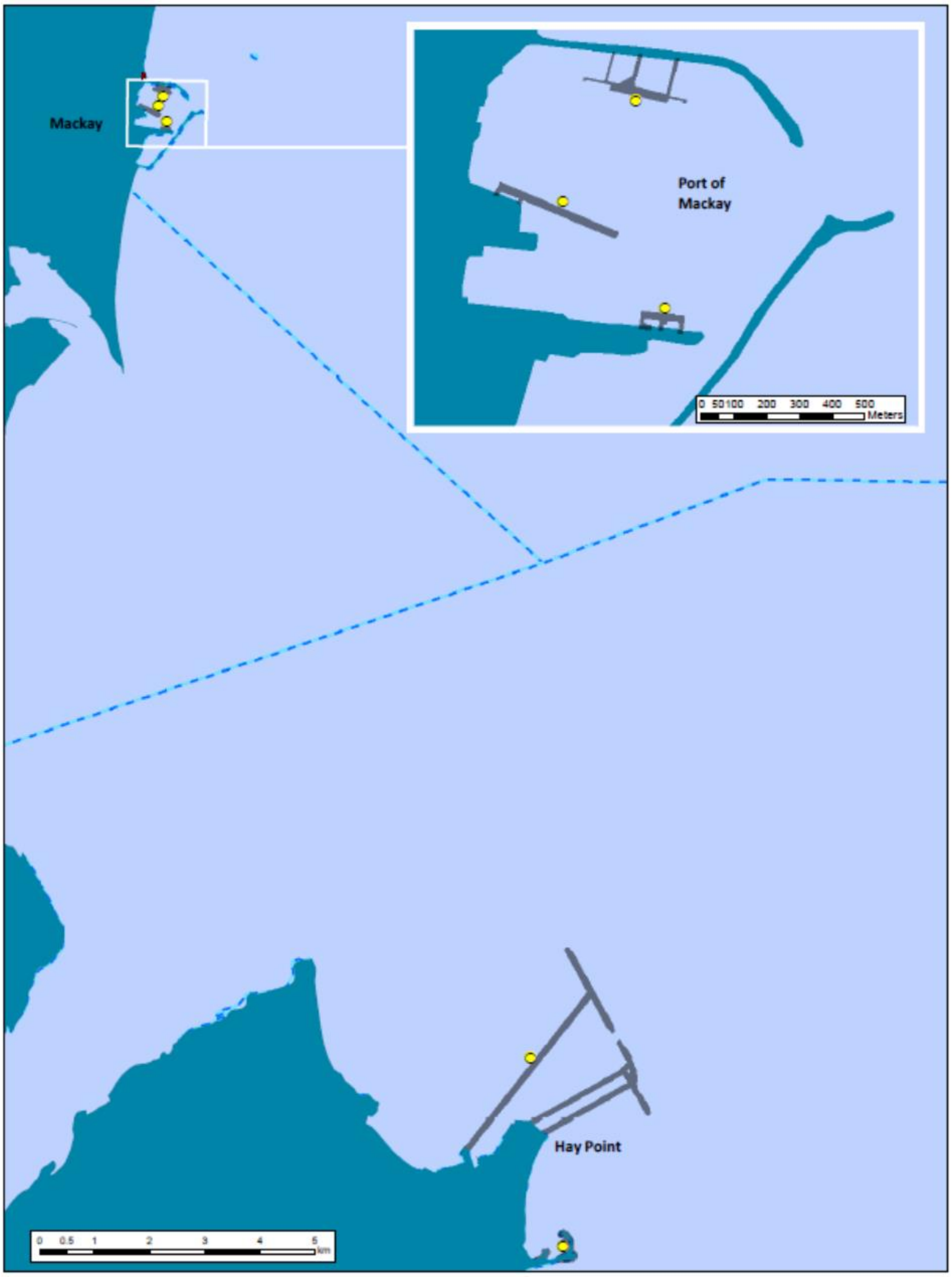



*Figure 6: IMP monitoring locations (Port of Hay Point and Port of Mackay)*

# 6 Impact monitoring

The following section describes the impact monitoring that will be undertaken at the Port of Hay Point. This monitoring will be implemented for each maintenance dredging campaign, with the aim of detecting any unpredicted changes in environmental condition and avoid impacts from maintenance dredging. If the results of the impact monitoring detect changes in the condition of sensitive receptors, this data can be used in conjunction with data from ambient and adaptive monitoring to understand likely cause of impact (i.e. was it dredging). The impact monitoring data can also be used to validate predictive modelling used as part of the maintenance dredging impact assessment. Appropriate management responses and adaptive frameworks to respond to impacts are provided in the LTMDMP.

The impact monitoring focuses on water quality and coral, as the two receptors most likely to be adversely impacted by dredging. The ephemeral nature of seagrass means that as a sensitive receptor it is less suited to short term impact assessment monitoring and detection of dredging related changes. A long-term seagrass data set is being established which may enable future analysis and correlation of seagrass health with other factors.

## 6.1 Impact water quality

Water quality is likely to be directly affected by dredging and will be monitored in detail for each campaign.

### 6.1.1 Parameters and protocol

Water quality impact monitoring will be undertaken for the same parameters and according to the same protocol as indicated in Section 5.1.2 for ambient water quality.

### 6.1.2 Timing and frequency

Water quality impact monitoring will be undertaken according to the program in Table 6.

*Table 6: Water quality monitoring timing and frequency*

| Parameter | Timing and frequency |
|---|---|
| Ambient physio-chemical (*in situ*) & nutrients | 4 weeks prior to commencement of dredging<br>Weekly during dredging<br>4 week post completion of dredging |
| Metals, chlorophyll a & pesticides/herbicides | 4 weeks prior to commencement of dredging<br>4 week post completion of dredging |
| Parameters recorded via data logger and current meter | Continuous (10 min intervals) commencing 4 weeks prior to dredging and finishing 4 weeks post dredging |

### 6.1.3 Sites

Sampling will be undertaken at the ambient monitoring sites indicated in Table 4 and Figure 3 (see Section 5.2.4)

## 6.2 Coral

To quantify if coral communities in the Hay Point region have been affected by maintenance dredging specific impact monitoring will be undertaken for each maintenance dredging campaign to evaluate condition.

Impact monitoring of coral communities will be undertaken according to the methodology and at the sites provided in Section 5.3, for ambient coral monitoring.

Monitoring will be undertaken four weeks prior to the commencement of dredging and four weeks following the completion of dredging.

# 7 Adaptive monitoring and management

The following section describes the adaptive monitoring and management that will be undertaken for each maintenance dredging campaign at the Port of Hay Point. Monitoring is focused on the real time observations, collection and analysis of data to detect changes in environmental condition and to assess whether such changes are natural or related to dredging and placement activities. The development of threshold triggers, which allow for corrective actions to be adopted before any potential impairment to the local ecosystem, is a key step in impact avoidance and management.

Monitoring of marine water quality, weather conditions and megafauna will be undertaken, as detailed in the monitoring protocol tables below. Responses to monitoring results will be required if trigger values are exceeded or when events occur. The nature of the proposed management response escalates according to the extent to which defined triggers are exceeded.

## 7.1 Consultation

### 7.1.1 Management Reference Group

As part of the adaptive management program, NQBP will establish a Management Reference Group (MRG) prior to the commencement of dredging. The MRG will be an advisory group to be consulted in the event of any parameter reaching the 'respond' management zone. The MRG will be comprised of NQBP staff, coal terminal staff, regulatory agency representatives, scientific experts and the dredge contractor. The role of the MRG will be to review the information obtained from the adaptive monitoring program and where there are unusual or unexpected results advise NQBP on the best course of management.

In addition to the MRG, NQBP will provide updates to the established Technical Advisory and Consultative Committee (TACC) during dredging operations.

## 7.2 Water quality

### 7.2.1 Establishing the thresholds

To assess the potential affect that maintenance dredging activities may have on marine ecological values, it is necessary to understand the natural water quality conditions in the region. A good understanding of natural change and variability allows the development and application of water quality thresholds, that can then be applied to manage changes to water quality condition that arise from maintenance dredging.

An ecological water quality thresholds assessment for the Port Hay Point was undertaken (Royal HaskoningDHV 2018). The intent of this assessment was to:

- Summarise knowledge on relevant ecological thresholds from published literature to inform management of maintenance dredging activities at the Port of Hay Point
- Undertake statistical analysis to contextualise published environmental thresholds with respect to actual water quality conditions at Hay Point (using a long term ambient water quality data set)
- Recommend appropriate water quality thresholds that can be considered for use in adaptive monitoring and management.

Additionally, guidance on developing environmental thresholds, relevant to maintenance dredging and placement, was provided in 'Improved Dredge Material Management for the Great Barrier Reef

Region', prepared as part of the Great Barrier Reef Marine Park Strategic Assessment (SKM 2013). The report proposed that when developing suitable water quality thresholds, a reliable set of site-specific baseline data is necessary and analysis should consider the variability of natural conditions with regard to intensity, duration and frequency (IDF) of elevated turbidity.

In 2024, an updated water quality thresholds assessment was completed (PCS 2024) using additional ambient water quality data since the initial assessment completed in 2018 (Royal HaskoningDHV 2018).

A nine-year data set from the NQBP ambient Marine Water Quality Monitoring Program (provided by James Cook University (JCU), TropWater) was used to re-calculate the IDF of naturally elevated turbidity (SSC/NTU). The calculations were carried out to determine natural change over time that would be relevant to expected maintenance dredging periods, being:

- 400,000m$^3$ – 40 Days; and
- 200,000m$^3$ – 20 Days (ongoing estimated maintenance dredging requirement every 5 years).

The results of the analysis were assessed against previously published thresholds to contextualise their relevance and provide for more site-specific definition of thresholds for the dredging activities proposed at the Port of Hay Point.

The relevant published literature indicates that the types of coral which occur in the Hay Point region are tolerant or partially tolerant to elevated suspended solid concentrations (SSC) (Erftemeijer et al, 2012). The tolerances of these types of corals to continuous expose to SSC are understood to be:

- less than 20 mg/l - no impacts
- 20-40 mg/l - possible minor sublethal effects
- 40-100 mg/l - possible lethal and major /minor sublethal impacts
- more than 100 mg/l - lethal (partial mortality) and major lethal (mass mortality)

This aligns with the GBRMPA water quality guidelines, that propose an annual mean greater than 15 mg/l may cause stress for coral communities in the enclosed coastal areas of the Central Coast Region of the Great Barrier Reef Marine Park.

### 7.2.2 Suitable monitoring sites

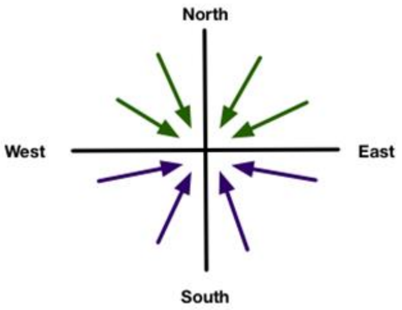
From the initial IDF analysis (Royal HaskoningDHV 2018), three key sites were assessed as being most practical for applying duration thresholds for adaptive management in relation to SSC/NTU:

- Round Top Island (Trigger Site) – prevailing southerly conditions
- Victor Island (Trigger Site) – prevailing northerly conditions
- Freshwater Point (Control Site) – prevailing southerly conditions.

In consultation with the TACC, an additional control site was chosen:

- Slade Island (Control Site) – prevailing northerly conditions.

Respective trigger sites and control sites have been determined based on IDF analysis and also prevailing wind direction, as outlined in Figure 7. The updated water quality thresholds assessment (PCS 2024) did not identify the need for additional or change in trigger and control sites.




| Wind direction | Trigger Site | Control Site |
|---|---|---|
| Northerly | Victor Island | Slade Island |
| Southerly | Round Top Island | Freshwater Point |

*Figure 7: Wind directions and respective trigger and control sites*

### 7.2.3 Local intensity thresholds

The analysis of the in situ long-term ambient marine water quality data from the region demonstrated that an intensity threshold of 15mg/l would be appropriate at Round Top Island, which is the nearest important coral value to the dredging and placement area. Round Top Island has considerably lower SSC/NTU than other inshore areas. The analysis showed that an intensity threshold of 15mg/l would be too low for other inshore sites, as the natural conditions are much more turbid.

Therefore, based on the site-specific data and relevant values from the literature, an intensity threshold of 15 mg/l is considered to be appropriate for Round Top Island (i.e. this intensity is known to naturally occur in this location, but does not on average occur for more than 10% of the time).

Applying a 15mg/l intensity threshold at Round Top Island would represent the 90$^{th}$ (wet season) and 97$^{th}$ (dry season) percentile SSC/NTUe.

Consistently applying these percentile values (90$^{th}$ percentile in wet season; 97$^{th}$ percentile in dry season) across other monitoring sites will allow for comparable interpretation of whether raised SSC/NTU levels are naturally occurring or are dredge related.

Applying the 90$^{th}$ percentile (Wet Season) and 97$^{th}$ percentile (Dry Season), to each of these other adaptive monitoring sites provides their respective equivalent intensity threshold values (Table 7).

*Table 7: Wet and dry season intensity thresholds*

| Site | Intensity (mg/l) | Intensity (NTUe) |
|---|---|---|
| **Wet season (90$^{th}$ percentile data)** | | |
| Round Top Island | 15 | 11 |
| Freshwater Point | 61 | 56 |
| Victor Island | 52 | 33 |
| Slade Islet | 53 | 40 |
| **Dry season (97$^{th}$ percentile data)** | | |
| Round Top Island | 16 | 12 |
| Freshwater Point | 47 | 43 |
| Victor Island | 39 | 25 |

| | | |
|---|---|---|
| Slade Islet | 42 | 31 |

### 7.2.4 Duration thresholds

The outputs of the IDF analysis at the trigger sites is considered the key measures on which to develop duration thresholds. Duration thresholds have been developed to reflect either a 40 day or 20 day dredge duration.

Duration thresholds are developed from the full nine-year dataset (excluding cyclones) and are represented as:

- **Average** – the average recorded cumulative time the intensity threshold is naturally exceeded over the given period
- **90$^{th}$ Percentile** – the cumulative time the intensity threshold is naturally exceeded
- **Maximum** – the highest recorded cumulative time the intensity threshold is naturally exceeded over the given time period.

Duration threshold values for the Trigger Sites are shown in Table 8. It is worth noting that adaptive monitoring will use turbidity monitors and, as such, using NTUe is more useful than SSC for management purposes.

*Table 8: Intensity and duration thresholds - 20 day period (wet and dry seasons)*

| Trigger Sites | Intensity (mg/l) | Intensity (NTUe) | Average Duration (hrs) | 90$^{th}$ Percentile Duration (hrs) | Maximum Duration (hrs) |
|---|---|---|---|---|---|
| **Wet Season (90$^{th}$ percentile)** | | | | | |
| Round Top Island (southerly) | 15 | 11 | 48 | 125 | 303 |
| Victor Island (northerly) | 52 | 33 | 48 | 111 | 369 |
| **Dry Season (97$^{th}$ percentile)** | | | | | |
| Round Top Island (southerly) | 16 | 12 | 14 | 55 | 114 |
| Victor Island (northerly) | 39 | 25 | 14 | 45 | 128 |

### 7.2.5 Application of triggers

At trigger sites the real time data is used to establish the cumulative duration (using real time 1 hour averages) above the threshold value. If and when the cumulative duration increases and reaches either the: average duration; 90th percentile duration; or max duration, a series of management zones are triggered. The respective NTUe values and duration points for the trigger sites are shown in Table 9 and Table 10.

*Table 9: Threshold values at trigger sites (wet season)*

| | | Duration (hours) | | |
|---|---|---|---|---|
| **Site** | NTUe | Average | $90^{th}$ | Max |
| **Round Top Island** | 11 | 48 | 125 | 303 |
| **Victor Island** | 33 | 48 | 111 | 369 |

*Table 10: Threshold values at trigger sites (dry season)*

| | | Duration (hours) | | |
|---|---|---|---|---|
| **Site** | NTUe | Average | $90^{th}$ | Max |
| **Round Top Island** | 12 | 14 | 55 | 114 |
| **Victor Island** | 25 | 14 | 45 | 128 |

If the 1-hour average is above the NTUe threshold then the duration of time above the intensity threshold is recorded on the relevant trigger site graph (see Figure 8 for an example). This will produce an ongoing cumulative count of time above the respective threshold (if the value is below the threshold, no increase in duration is recorded and the graph line will run horizontal). Once the cumulative duration exceeds the average, $90^{th}$ or max durations then escalating management responses are required.

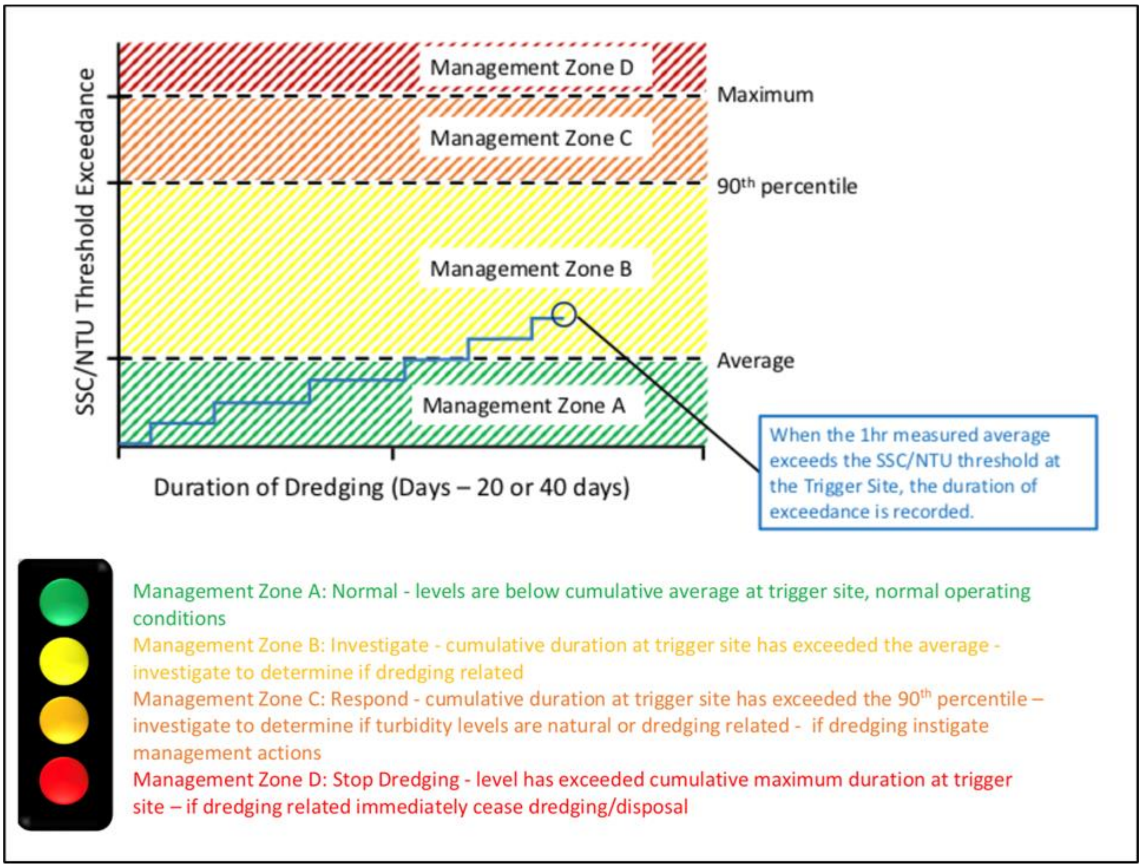



*Figure 8: Hypothetical example plot showing duration trigger limits and management zones*

While the cumulative hourly plot remains under the average duration, that is within Management Zone A, no response is required and dredging can operate as normal.

If the cumulative hourly plot increases and exceeds the other management zone thresholds then the instantaneous logger readings from the respective control site is reviewed to determine if the threshold exceedance is being caused by dredging or natural conditions, as follows:

1. If the control site reading is also above that site's intensity threshold (90/97th% NTUe) then the raised turbidity level will be assumed to be primarily being driven by natural conditions making management actions unnecessary and ineffective.
2. If the control site readings are below that site's intensity threshold (90/97th% NTUe) it should be assumed that dredging is resulting in the raised turbidity level at the trigger site, corresponding management response should be implemented.

Where there is doubt or where readings are only marginally different or cannot be explained, the MRG should review the data, climate conditions and other factors, such as where and when the dredge was operating. Based on available information the MRG should provide advice on appropriate management response.

The following tables indicate the combinations of trigger site and control site conditions and when management responses are or are not required.

*Table 11: Wet season with northerly wind 90th% trigger and control site scenarios*

| WET SEASON | NORTHERLY WIND | | | | |
|---|---|---|---|---|---|
| **Cumulative duration level** | **Trigger site** | **Control Site** | | | |
| | VICTOR | SLADE | | | |
| Zone A | 🟢 | <40 | 🟢 | >40 | 🟢 |
| Zone B | 🟡 | <40 | 🟡 | >40 | 🟢 |
| Zone C | 🟠 | <40 | 🟠 | >40 | 🟢 |
| Zone D | 🔴 | <40 | 🔴 | >40 | 🟢 |

*Table 12: Dry season with northerly wind 97th% trigger and control site scenarios*

| DRY SEASON | NORTHERLY WIND | | | | |
|---|---|---|---|---|---|
| **Cumulative duration level** | **Trigger site** | **Control Site** | | | |
| | VICTOR | SLADE | | | |
| Zone A | 🟢 | <31 | 🟢 | >31 | 🟢 |
| Zone B | 🟡 | <31 | 🟡 | >31 | 🟢 |
| Zone C | 🟠 | <31 | 🟠 | >31 | 🟢 |
| Zone D | 🔴 | <31 | 🔴 | >31 | 🟢 |

*Table 13: Wet season with southerly wind 90$^{th}$% trigger and control site scenarios*

| WET SEASON | SOUTHERLY WIND | | | | |
|---|---|---|---|---|---|
| Cumulative duration level | Trigger site | Control Site | | | |
| | ROUND TOP | FRESHWATER | | | |
| Zone A | 🟢 | <56 | 🟢 | >56 | 🟢 |
| Zone B | 🟡 | <56 | 🟡 | >56 | 🟢 |
| Zone C | 🟠 | <56 | 🟠 | >56 | 🟢 |
| Zone D | 🔴 | <56 | 🔴 | >56 | 🟢 |

*Table 14: Dry season with southerly wind 97$^{th}$% trigger and control site scenarios*

| DRY SEASON | SOUTHERLY WIND | | | | |
|---|---|---|---|---|---|
| Cumulative duration level | Trigger site | Control Site | | | |
| | ROUND TOP | FRESHWATER | | | |
| Zone A | 🟢 | <43 | 🟢 | >43 | 🟢 |
| Zone B | 🟡 | <43 | 🟡 | >43 | 🟢 |
| Zone C | 🟠 | <43 | 🟠 | >43 | 🟢 |
| Zone D | 🔴 | <43 | 🔴 | >43 | 🟢 |

*Table 15: Management responses based on trigger and control site combinations*

| TRIGGER | CONTROL | MANAGEMENT RESPONSE |
|---|---|---|
| 🟢 | 🟢 | = NO ACTION (CONTINUE DREDGING OPERATIONS AS NORMAL |
| 🟡 | 🟡 | = INVESTIGATE |
| 🟡 | 🟢 | = NO ACTION |
| 🟠 | 🟠 | = RESPOND – TURBIDITY REDUCTION MEASURES |
| 🟠 | 🟢 | = NO ACTION |
| 🔴 | 🔴 | = STOP DREDGING (until instantaneous NTUe falls below 90$^{th}$/97$^{th}$% @trigger site) |
| 🔴 | 🟢 | = NO ACTION |

### 7.2.6 Management actions

Based on the Management Zones the following response actions will apply (Table 16). These actions are included in the *Maintenance Dredging Environmental Management Plan*.

*Table 16: Management response actions*

| Status | Action |
|---|---|
| NO ACTION | No response actions required<br>Apply standard measures to ongoing dredging program |
| INVESTIGATE | This zone indicates that the cumulative duration has increased beyond the average. The environmental manager should investigate to determine if the exceedance is potentially dredging related. Examine:<br>1. the monitoring equipment for any faults/defects that may have influenced data collection at both monitoring and control sites.<br>2. the dredge and placement activity and locations in the 24 hours preceding exceedance.<br>3. the results against:<br>• turbidity levels at control site<br>• recent meteorological and current/wave/tide conditions (particularly due to any events or wind direction that may not also be affecting control site)<br>• sediment transport patterns using MODIS or other aerials/satellite imagery.<br>4. where possible, examine the monitoring site to ensure no natural processes or other human activity (e.g. vessel movements, fishing activity) are contributing to the elevated turbidity level.<br>5. whether any significant rainfall events resulting in increased surface runoff or river sedimentation outfall from Pioneer River or Bakers Creek are affecting the trigger site.<br>If it is determined that dredging activities have contributed to the exceedance, the dredging operations should be placed on a warning status. |
| RESPOND | If the trigger site cumulative duration and instantaneous control site reading indicate that dredging is causing an exceedance above the 90$^{th}$ percentile duration the following management measures should be progressively applied.<br>1. Change the placement location and vessel route within spoil grounds<br>2. Slow vessel speed during disposal<br>3. Alteration of overflow regime<br>4. Change the dredging location (e.g. move to Half Tide Tug Harbour)<br>5. Modification of placement phase with respect to the tide (e.g. placement activities on ebb tide only)<br>6. Reduce the dredge load<br><br>The measures should be applied sequentially. One measure should be applied to each sequential placement run and NTUe monitored at the trigger site to determine if levels stabilise or fall. If they continue to increase or remain above the threshold then the next measure should be applied and so forth. Normal operations can resume once NTUe falls below threshold or matches equivalent percentile reading at control site. Additionally, climate conditions should be used to inform expected turbidity responses. |
| STOP DREDGING | Instigate stop dredging and placement measures until either:<br>• NTUe falls below threshold or trigger site matches equivalent percentile reading at control site<br>• Weather conditions have stabilised to a point where continued raised NTUe is unlikely |

### 7.2.7 Monitoring protocol

Adaptive monitoring of water quality during dredging campaigns will be undertaken according to the protocol provided in Table 17, at the locations in Figure 9.

*Table 17: Adaptive water quality monitoring protocol*

| Protocol | Details |
|---|---|
| ***In situ* water quality parameter sampling (refer to** Appendix A **for detailed protocol)** | |
| Parameters | • Turbidity (NTU)<br>• Total Suspended Solids (derived from NTU results)<br>• Pressure (to provide data on water depth)<br>• Water temperature<br>• Photosynthetically Active Radiation (PAR)<br>• Current speed and direction |
| Method | • Data recorded on *in situ* multi-parameter data loggers and Marotte current meter<br>• Loggers to be telemetered to provide real time data feeds |
| Timing and frequency | • Continuous data collection and analysis during dredging (10 min frequency)<br>• Deploy 4 weeks prior to dredging commencing<br>• Retrieve 4 weeks post conclusion of dredging |
| Sites (see information on site selection below) | • Trigger sites at Round Top Island and Victor Island<br>• Control sites at Freshwater Point and Slade Point |
| Data analysis | • Data telemetered and delivered as recorded (every 10 minutes)<br>• Data QA/QC undertaken to review and remove (if appropriate) unexplained spikes (e.g. algae covering sensor)<br>• Calculation of average hourly value<br>• At trigger sites, if above hourly IDF 90th/97th % threshold, add 1 hour to cumulative duration total - refer to trigger responses above |
| **Satellite imagery analysis** | |
| MODIS image analysis | • Daily visual analysis of images to compare actual plume location (from MODIS) and with predicted plume location (from hydrodynamic model) |

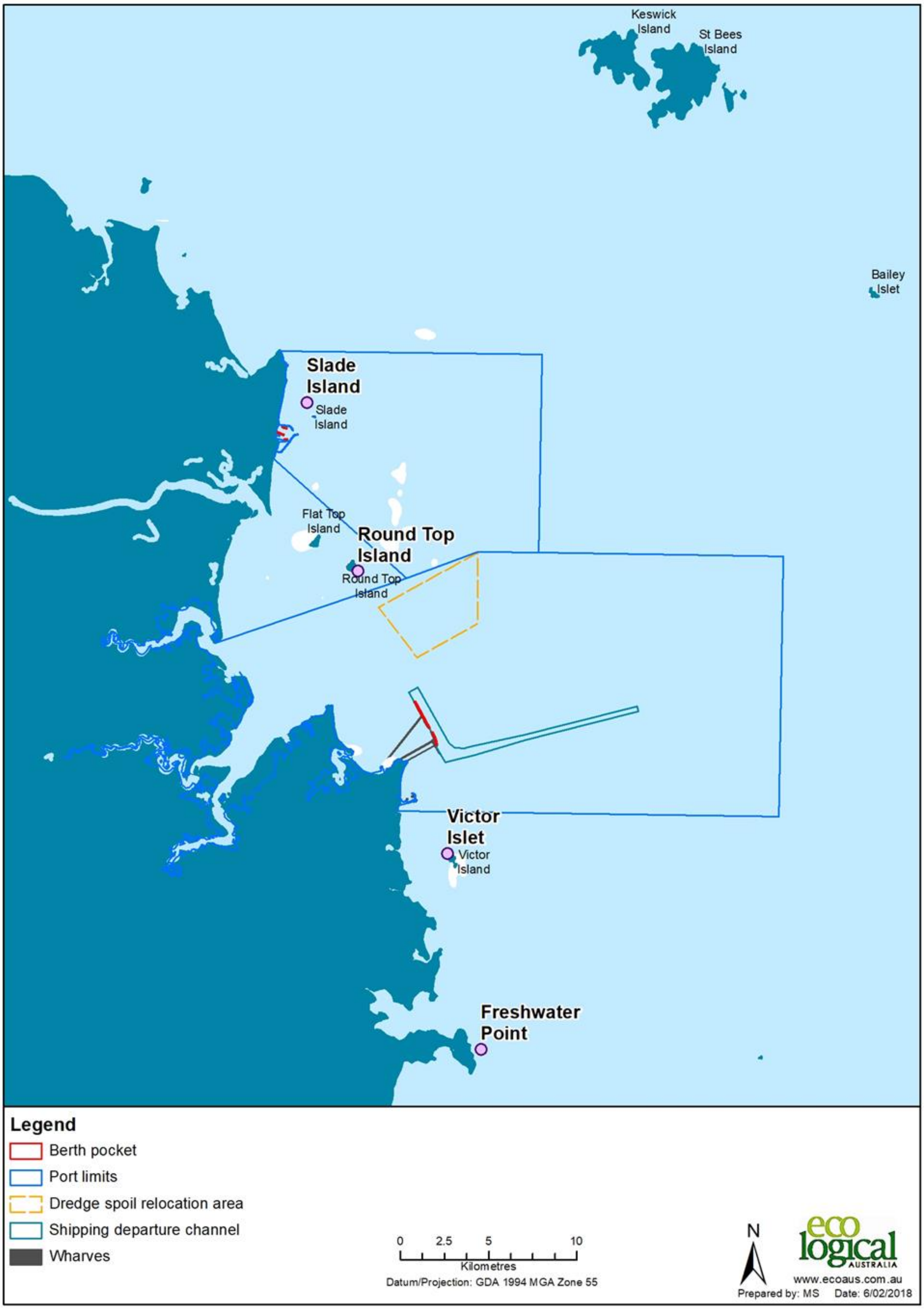



*Figure 9: Adaptive water quality monitoring sites*

## 7.3 Weather monitoring

Monitoring of weather conditions during dredging campaigns will be undertaken according to the protocol provided in Table 18.

*Table 18: Adaptive weather conditions monitoring protocol*

| Protocol | Details |
|---|---|
| Parameters | • Tides<br>• Wind strength and direction<br>• Weather warnings |
| Method | Forecast reports from Bureau of Meteorology (BoM) |
| Timing and frequency | • 12-hourly weather checks<br>• If warnings have been issued, review as each new update issued by BoM |
| Sites | Port of Hay Point |
| Data analysis | Data to be reviewed by Master *TSHD Brisbane* and NQBP Principal Advisor - Environment to inform dredge operations |

## 7.4 Megafauna monitoring

Adaptive monitoring of marine megafauna during dredging campaigns will be undertaken according to the protocol provided in Table 19.

*Table 19: Adaptive marine megafauna monitoring protocol*

| Protocol | Details |
|---|---|
| Parameters | Presence of marine megafauna in monitoring zone:<br>• Megafauna includes whales, dolphin, dugong, turtles<br>• Monitoring zone is within 300 m of dredging activity |
| Method | • Observations using binoculars from bridge of dredger by crew trained in PBPL's marine megafauna observation process and under the supervision of the experienced Vessel Master.<br>• Guidance for species identification is available on the bridge to assist observers in identifying species observed.<br>• If marine megafauna are sighted, works cannot commence until 20 minutes after last sighting/marine megafauna is observed to leave the monitoring zone OR the vessel is to move to another area to maintain a minimum distance of 300m from the marine megafauna. |
| Timing and frequency | • Throughout dredging campaign<br>• Observations to commence prior to any activities commencing and will continue until all activities cease |
| Sites | Wherever dredge is operating |
| Data analysis | Record observations in Masters' log and reported daily to the environment manager |

Management responses are provided in the *Maintenance Dredging Environmental Management Plan*.

# 8 Data analysis and reporting

## 8.1 Ambient monitoring

Data analysis and reporting will be undertaken annually for water quality, coral and seagrass surveys. Data analysis will focus on reporting on each parameter investigated and will include analysis of the most recent year's data (i.e. new data) and the long-term dataset (historical trends). Individual reports will be prepared for water quality, coral and seagrass results.

Summary reports of ambient monitoring will be placed on NQBPs website.

## 8.2 Impact monitoring

Data analysis and reporting will be completed within 6 months of the completion of each dredge campaign. Data analysis will focus on comparing the before, during and after results to determine any potential impacts from dredging. Data from ambient monitoring will be used to provide regional and long-term context. Individual reports will be prepared for water quality and coral results.

## 8.3 Adaptive monitoring

Data analysis for the adaptive water quality monitoring will occur in real time for the entirety of the dredge campaign. Daily reports on weather conditions and marine megafauna monitoring will be provided by the dredge contractor. The TACC and MRG will be provided weekly updates on dredge progress, incidents and an overview of the adaptive monitoring from the previous week.

Any incidents that occur, including any involving marine mammals or turtles, will be reported to the relevant regulatory authorities in accordance with NQBP's regulatory approvals, the LMDMP and program-specific dredge management plans.

A summary report will be completed within 6 months of the completion of each dredge campaign detailing both impact and adaptive monitoring results, permit condition compliance and dredging execution parameters (volumes, post dredge bathymetry, operational timing and shut downs). This report will be provided to regulators and TACC members.

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# Appendix A
## Water quality monitoring protocol

Water quality data is temporally variable and continued monitoring provides the ability to fully characterise the ambient conditions in the Hay Point region. To accurately log these variables, a number of water quality parameters are to be monitored across the Hay Point region. Frequency and timing of monitoring of parameters will vary as per the protocol below.

### Ambient physio-chemical (*in situ*) monitoring

*Timing:*

- Every six weeks

*Location:*

- Five pre-determined water sampling sites (see Table 4 and Figure 3)

*Parameters to measure:*

- Water temperature
- Electrical conductivity (salinity)
- pH
- Dissolved oxygen (%)
- Turbidity
- Secchi disk depth (measure of optical clarity)
- Light attenuation

*Protocol:*

*Multi-purpose probe*

- Calibrate the multi-purpose probe
- Measure and record water temperature, electrical conductivity (salinity), pH, dissolved oxygen (%) and turbidity at three depth horizons; surface (0.25m), mid-depth and bottom.

*Secchi Disk Depth*

- Slowly lower the Secchi disk into the water on the shady side of the boat until it is no longer visible. Record this depth.
- Slowly raise the disk until it just becomes visible once again. Record this depth.
- Average the depths from steps 1 and 2 to get the Secchi depth.
- This may be repeated for a measurement of precision.

*LiCor Meter*

- Calibrate the LiCor meter
- Measure and record light attenuation at each site

### Laboratory Analysis

*Timing:*

- To be carried twice per year; once during the wet season (~ November) and again during the dry season (~ March).

*Location:*

- Five pre-determined water sampling sites (see **Error! Reference source not found.** and Figure 3)

*Parameters to measure:*

- Ultra-trace dissolved metals including arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn)
- Nutrients (nitrogen and phosphorus)
- Chlorophyll a
- Pesticides and herbicides (Low LOR suite [EP234(A-I)])

*Protocol:*

*Ultra-trace dissolved metals*

- Collect water by placing water sampler 1-2 m under water
- Using a 60 mL sterile syringe, pass water through a 0.45 µm disposable membrane filter (Sartorius)
- Place filtered water for trace metal analysis into 60 mL bottles, store on ice in eskies immediately after sampling aboard the vessel.
- Upon return, refrigerate until laboratory processing.

*Nutrients*

- Collect water by placing water sampler 1-2 m under water
- Using a 60 mL sterile syringe, pass water through a 0.45 µm disposable membrane filter (Sartorius)
- Place filtered water in 10 mL bottles, store on ice in eskies immediately after sampling aboard the vessel.
- Upon return, freeze samples until laboratory processing
- Unfiltered water for total nitrogen and total phosphorus analysis are to be placed into 60 mL tubes and frozen until laboratory processing.

Nutrient processing is by a National Association of Testing Authorities (NATA) accredited laboratory.

**Laboratory testing standards**

| Element Testing | Standard |
|---|---|
| Total Nitrogen and Total Phosphorus | • Standard Methods for the Examination of Water and Wastewater, 4500-NO3- F. Automated Cadmium Reduction Method<br>• Standard Methods for the Examination of Water and Wastewater, 4500-P F. Automated Ascorbic Acid Reduction Method |
| Nitrate and Ammonia | • Standard Methods for the Examination of Water and Wastewater, 4500-NO3- F. Automated Cadmium Reduction Method<br>• Standard Methods for the Examination of Water and Wastewater, 4500-NO2- B. Colorimetric Method<br>• Standard Methods for the Examination of Water and Wastewater, 4500-NH3 G. Automated Phenate Method'. |
| Filterable Reactive Phosphorous | • Standard Methods for the Examination of Water and Wastewater, 4500-P F. Automated Ascorbic Acid Reduction Method |

*Chlorophyll-a*

- Collect water by placing water sampler 1-2 m under water
- Place water into a 1 L dark plastic bottle
- Within 12 hours of collection, filter water through a Whatman 0.45 µm GF/F glass-fibre filter with the addition of approximately 0.2 mL of magnesium carbonate.
- Wrap filters in aluminium foil and freeze.
- Chlorophyll a to be extracted in acetone and measured with spectrophotometry as per the method described in 'Standard Methods for the Examination of Water and Wastewater, 10200 H. Chlorophyll.

**In situ data recording**

*Timing:*

- Continuous (15 minute intervals)

*Location:*

- Five pre-determined water sampling sites

*Parameters to measure:*

The following parameters will be recorded via in situ multi-parameter data loggers manufactured at the Marine Geophysics Laboratory, School of Engineering and Physical Sciences, James Cook University. These instruments are based on a Campbell's Scientific 1000 data logger that has been programmed to measure and store these marine physical parameters using specifically designed sensors.

- Turbidity
- Sediment deposition
- Pressure (to provide data on water depth)
- Water temperature
- Photosynthetically Active Radiation (PAR)
- Current speed and direction

*Data logger measurements*

*Turbidity*

- The turbidity sensor provides data in Nephelometric Turbidity Unit's equivalent (NTUe) and can be calibrated to Suspended Sediment Concentration (SSC) in mg/L (Larcombe et al., 1995).
- The sensor is located on the side of the logger, pointing parallel light-emitting diodes (LED) and transmitted through a fibre optic bundle.
- The backscatter probe takes 250 samples in an eight second period to attain an accurate turbidity value.
- The logger is programmed to take these measurements at 15 minute intervals. The sensor interface is cleaned by a mechanical wiper at a two hour interval allowing for long deployment periods where bio-fouling would otherwise seriously affect readings.

It must be noted the international turbidity standard ISO7027 defines NTU only for 90 degree scatter, however, the Marine Geophysics Laboratory instruments obtain an NTUe value using 180 degree backscatter as it allows for much more effective cleaning. Because particle size influences the angular scattering functions of incident light (Ludwig and Hanes 1990; Conner and De Visser 1992; Wolanski et al., 1994; Bunt et al., 1999), instruments using different scattering angles can give different measurements of turbidity (in NTU). This has to be acknowledged if later comparison between instruments collecting NTUe and NTU are to be made. To enhance the data, all sites are to be calibrated to provide a measure of SSC (mg/L) and enable for the accurate comparison between 90 degree backscatter and 180 degree.

*Sediment Deposition*

- Deposition is recorded in Accumulated Suspended Sediment Deposition (ASSD) (mg/cm2).
- The sensor is wiped clean of deposited sediment at a 2 hour interval to reduce bio-fouling and enable sensor sensitivity to remain high.
- The deposition sensor is positioned inside a small cup shape (16 mm diameter x 18 mm deep) located on the flat plate surface of the instrument facing towards the water surface.
- Deposited sediment produces a backscatter of light that is detected by the sensor. Deposited sediment is calculated by subtracting, from the measured data point, the value taken after the sensor was last wiped clean. This removes influence of turbidity from the value and re-zeros the deposition sensor every 2 hours.
- Deposition data is provided as a measurement of deposited sediment in mg/cm2 and as a deposition rate in mg/cm2/day.
- The deposition rate is calculated over the 2 hour interval between sensor wipes and averaged over the day for a daily deposition rate.
- The deposition rate is useful in deposition analysis as it describes more accurately the net deposition of sediment by smoothing spikes resulting from gross deposition events.

If a major deposition event is in progress, the sensor reading will increase rapidly and will be considerably above the turbidity sensor response. Gross deposition will appear as irregular spikes in the data where the sediment is not removed by the wiper but by re-suspension due to wave or current stress. When a major net deposition event is in progress the deposited sediment will be removed by the wiper and the deposition sensor reading should fall back to a value similar to the turbidity sensor. The data will have a characteristic zigzag response as it rises, perhaps quite gently, and falls dramatically after the wipe (see Ridd et al., 2001).

*Pressure*

- A pressure sensor is located on the horizontal surface of the water quality logging instrument.
- The pressure sensor is used to determine changes in water depth due to tide and produce a proxy for wave action.
- Each time a pressure measurement is made the pressure sensor takes 10 measurements over a period of 10 seconds. From these 10 measurements, average water depth (m) and Root Mean Square (RMS) water height are calculated.

The average water depth and RMS water depth can be used to analyse the influence that tide and water depth may have on turbidity, deposition and light levels at an instrument location. The RMS water height is a measure of short term variation in pressure at the sensor. Changes in pressure over a 10 second time period at the sensor are caused by wave energy. RMS water height can be used to analyse the link between wave re-suspension and SSC. It is important to clearly establish that RMS water height is not a measurement of wave height at the sea surface. What it does provide is a relative indication of wave shear stress at the sea floor that is directly comparable between sites of different depths. For example, two sites both have the same surface wave height, site one is 10m deep and has a measurement of 0.01 RMS water height and site two is 1m deep and has a measurement of 0.08 RMS water height. Even though the surface wave height is the same at both sites, the RMS water height is greater at the shallower site and we would expect more re-suspension due to wave shear stress at this site.

*Water Temperature*

- Water temperature values are obtained with a thermistor that records every 10 minutes.

- The sensor is installed in a bolt that protrudes from the instrument and gives sensitive temperature measurements.

*Photosynthetically Active Radiation (PAR)*

- A PAR sensor, positioned on the horizontal surface of the water quality logging instrument, takes a PAR measurement at ten (10) minute intervals for a one second period.
- To determine total daily PAR (mol photons m2/day) the values recorded are multiplied by 600 to provide of PAR for a 10 minute period and then summed for each day.

*Current speed and direction*

- The Marotte HS (High Sampling Rate) is a drag-tilt current meter invented at the Marine Geophysics Laboratory.
- The instrument records current speed and direction with an inbuilt accelerometer and magnetometer.
- The current speed and direction data are smoothed over a 10-minute period. The instruments are deployed attached the nephelometer frames and data is download when the instruments are retrieved.

# Appendix B
## Coral monitoring protocol

**Coral Survey Set-up**

*Timing*

- Coral community monitoring is to be undertaken twice yearly around March – April (post wet season) and November (pre-wet season).
- Surveys should be undertaken during periods where the long term weather forecast suggests an extended period of light winds (i.e. at least several consecutive days), as this will result in good underwater visibility and allow for more rapid and reliable surveys.

*Location & monitoring sites:*

Coral monitoring is to be undertaken at three fringing coral reefs surrounding the Port of Hay Point, including:

- Round Top Island
- Victor Island
- Slade Island

Four pre-established sites are to be monitored at each location (see Table 5 and Figure 4).

*Parameters:*

Coral monitoring surveys are to consider the following through a several data collection techniques, including:

- Diversity and abundance of benthic communities
- Percentage of coral bleaching
- Percentage of coral mortality
- Rates of sediment disposition on corals
- Rates of coral recruitment

**Benthic Line Intercept (20 m transect)**

Protocol to measure the diversity and abundance of benthic communities and percentage of coral bleaching is as follows:

- At each site, establish four 20 m transects along the reef between a depth range of 0.5 m and 0.7 m below Lowest Astronomical Tide.
- Permanently mark transects with 12 mm reinforcing stakes driven into seabed at 5 m intervals.
- Stretch survey tape tightly between the stakes close to the substratum.
- Record the total length of benthic cover intersecting the transect, categorised as either:
    - Algae
    - Sponges
    - Hard corals (genus or growth form); or
    - Soft corals.
- Convert total cover (m) into percentage cover (%).
- Record the bleaching status of all coral intercepts at each transect, categorised as either:
    - Not bleached

- Partially bleached; or
- Totally bleached

**Coral Sedimentation Plots (20 m x 1 m)**

Protocol to measure the sedimentation rates on coral colonies is as follows:

- Within 1 m of each 20 m transect, select 20 hard coral colonies at random
- If sediment present on colony surface, measure the sediment depth (mm) with a plastic ruler at the point of maximum sediment
- One measurement to be recorded for each colony (i.e. maximum of 20 measurements per transect)

**Damaged Coral Plots (20 m x 2 m)**

Protocol to measure the abundance of damaged, diseased or bleached coral colonies is as follows:

- Within 2 m of each 20 m transect record the following:
    - Total number of coral colonies in each major coral group
    - Total number of bleached or partially bleached colonies in each major coral group
    - Total number of all sediment damaged colonies for major hard coral groups. Do not include colonies as sediment damaged if there is actively growing edge into an old sediment-smothered dead patch
    - Total number of all diseased, partially dead or recently dead colonies for each of the major hard coral groups. Do not record as diseased if there is an actively growing edge reclaiming a diseased-caused dead patch.

**Coral Recruitment**

Protocol to measure rates of coral recruitment is as follows:

- Corals growing within 30 cm of the shoreward side of each transect are to be measured and recorded in the following categories:
    - 0 – 2 cm diameter
    - 2 – 5 cm diameter
    - 5 – 10 cm diameter
- Record the genus of each young coral
- Sum the total number recorded at all four transects.

**Data analysis**

The design of the coral monitoring allows for a repeated measures Analysis of Variance (ANOVA) to be completed after subsequent surveys. The ANOVA is designed to test the significance of changes of three factors that may influence benthic abundance, being:

- **Location**: Significance of the four locations on benthic abundance
- **Survey sites**: Significance of the six survey sites at each location on benthic abundance. Each site is nested within the location factor as site 1 at one location is no necessarily subject to the same influences as site 1 at other locations.
- **Time**: Determine whether there are any significant changes in benthic abundance between successive surveys at the same sites.

Interactions between the three factors can also be determined in the ANOVA. Specifically, the interaction between time and location is important. A significance interaction may indicate changes at only one site over time as a result of local disturbances, as opposed to no changes over time at all sites (and no significant interaction).

Changes in sediment depth on coral colonies are tested at each location with a two factor ANOVA. Sediment depth is measured on a different random selection of corals during each survey, repeated measures analysis is no appropriate.

Two factor repeated measure ANOVA is used to assess the significance of changes in the density of damaged and diseased coral colonies in each location. Damaged and diseased colonies are assessed within the same transect area during each survey enabling the use of repeated measures ANOVA.

# Appendix C
## Seagrass monitoring protocol

*Timing*

Surveys will be conducted annually between September and December. This is when seagrasses are at the seasonal peak in distribution and abundance and when previous surveys have been undertaken (to facilitate historical comparisons).

*Location*

*Up to 100 sites will be surveyed within the annual monitoring areas indicated on*

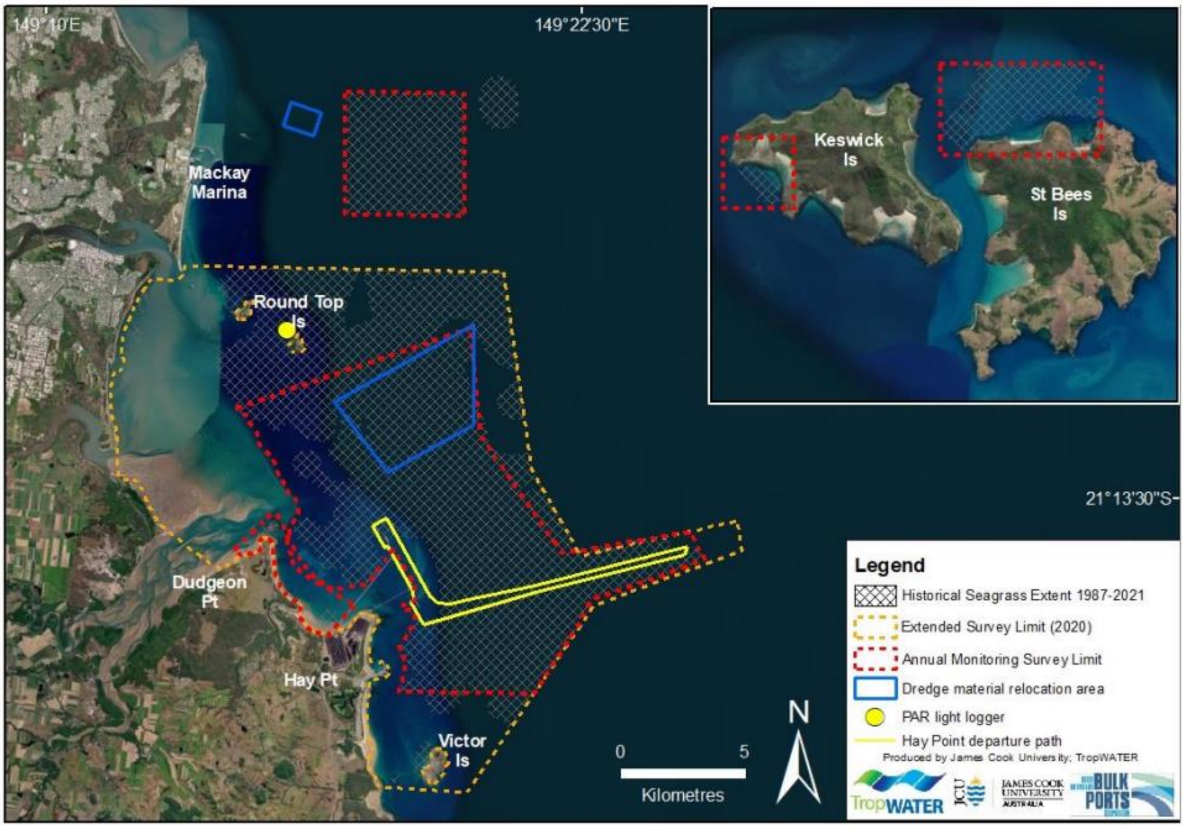


Figure 5. The exact number and location of sites will be determined prior to each annual survey taking account of previous years' results. In general, the annual survey area will include sites that are located:

- Within the port limits
- Around Victor Island
- Around Round Top and Flat Top Islands
- Around Keswick and St Bees Islands

*Parameters*

Seagrass habitat observations will be undertaken at sites in the Hay Point region. Post survey, site data will be analysed to produce meadow mapping, classification and condition assessment.

At each survey site the following parameters will be recorded:

- Seagrass species composition
- Above-ground biomass

- Percent algal cover
- Depth below mean sea level
- Sediment type
- Percent cover of other major benthos

Post-survey, data analysis will characterise:

- Habitat characterisation of the survey sites
- Seagrass meadow biomass and community type
- Seagrass landscape category
- Meadow mapping, classification and condition

### *Sampling Techniques*

Three sampling techniques are to be are to be used and will vary depending on the physical characteristics of the site (i.e. depth), visibility, logistics and safety considerations:

- Free diving – subtidal areas <8 m depth
- Boat based underwater digital camera mounted on a drop frame – subtidal inshore areas >8 m depth
- Boat based digital camera sled tows – offshore subtidal areas >8 m depth

### *Above Ground Biomass Protocol*

At each site, above ground biomass is estimated using a 'visual estimates of biomass' technique (Kirkman 1978, Mellors 1991) as follows:

- At free driving and camera drop sites, three 0.25 $m^2$ quadrats are placed at random at each site
- At digital camera sled tow sites, the video is paused at 10 random time frames and advanced to the nearest point on the recording where the bottom is visible and the sled is stable. A 0.25 $m^2$ quadrat, scaled to the video camera lens used in the field is to be superimposed on the screen to standardise biomass estimates.
- An observer ranks biomass at all sites in reference to a series of quadrat photographs of similar seagrass habitats for which above ground biomass has previously been measured.
- Relative proportion of above ground biomass (percentage) for each seagrass species is also recorded
- Field biomass ranks are converted into above-ground biomass estimated in grams dry weight per square meter (g DW $m^2$)
- At the completion of sampling, observers are to identify a series of calibration quadrats that represent the range of seagrass biomass in the survey. Seagrass in these quadrats are harvested and the actual biomass (separated by species) determined in the laboratory.
- A separate regression of ranks and biomass from calibrated quadrats are to be generated for each observer and applied to the field survey data to standardise the above-ground biomass estimates.

### *GIS Database Presentation Protocol*

Enter all survey data into Geographic Information System (GIS) database for presentation of seagrass species distribution and density. Three GIS layers are to be created to describe seagrass habitat in the survey areas:

- Habitat characterisation survey sites:
    - Above ground biomass (total and for each species)

- Depth below mean sea level
- Sediment type (visual estimates)
- Latitude & longitude
- Sampling methods & comments

- Seagrass meadow biomass and community types:
  - Area data for seagrass meadows with summary information on meadow characteristics
  - Seagrass community types are to be determined according to overall species composition from nomenclature developed for seagrass meadows of Queensland. This is to be based on the percent contribution of each species within the meadow.
  - This assessment also includes a measure of the meadow density determined by the mean above ground biomass of the dominant species within the community.
- Seagrass landscape category:
  - Area data for seagrass meadows showing the seagrass landscape category.
- Precision of seagrass area boundaries:
  - Mapping of meadow sizes are to be expressed with an error (±ha) around the total meadow area (ha). Precision of which is to be determined using an estimate of mapping reliability, based on the distance between sites.

*Nomenclature for seagrass community types in Queensland*

| Community Type | Species Composition |
|---|---|
| Species A | Species A is 90 – 100% of composition |
| Species A with Species B | Species A is 60 – 90 % of composition |
| Species A with Species B/Species C | Species A is 50% of composition |
| Species A/Species B | Species A is 40 – 60% of composition |

*Density categories and mean above ground biomass ranges for each species in determining seagrass community density in Queensland*

| Density | Mean above-ground biomass (g DW m2) | | | | |
|---|---|---|---|---|---|
| | *H. uninervis* (narrow) | *H. ovalis* *H. decipiens* | *H uninervis* (wide) | *H. spinulosa* *H. tricostata* | *Z. mulleri* |
| Light | <1 | <1 | <5 | <15 | <20 |
| Moderate | 1 – 4 | 1 – 5 | 1 – 25 | 15 – 35 | 20 – 60 |
| Dense | >4 | >5 | <25 | >35 | >60 |

*Seagrass landscape category descriptions*

| Category | Description |
|---|---|
| Isolated seagrass patches | The majority of area within the meadows consists of un-vegetated sediment interspersed with isolated patches of seagrass |
| Aggregated seagrass patches | Meadows are comprised of numerous seagrass patches but still feature substantial gaps of un-vegetated sediment with in the meadow boundaries |
| Continuous seagrass cover | The majority of area within the meadows comprised of continuous seagrass cover interspersed with a few gaps of un-vegetated sediment |

*Mapping precision and methodology for boundary mapping*

| Mapping precision | Mapping methodology |
|---|---|
| 5 m | • Subtidal meadow boundaries determined from free diving surveys<br>• Relatively high density of survey sites<br>• Recent aerial photography aided mapping |
| 50 m | • Subtidal meadow boundaries determined from free diving and underwater camera drops<br>• Moderate to high density of survey sites<br>• Recent aerial photography aided in mapping |

### *Seagrass meadow condition index protocol*

The condition index is only to be applied to offshore monitoring sites at Hay Point. There is insufficient data at the inshore sites to apply the method however, this may be reviewed as monitoring progresses.

Meadow condition is calculated by comparing the condition of current meadows against baseline conditions, and divided into one of five categories as listed below:

1. A (very good)
2. B (Good)
3. C (Satisfactory)
4. D (Poor)
5. E (Very poor)

Biomass, area and species composition grade are to be determined for each seagrass meadow (note: offshore areas are only measured every three years), as previously described.

Meadows are also classified as either stable or variable. This is done by calculating the coefficient of variation (CV) for each meadow for biomass, area and species composition. CV is calculated by dividing the standard deviation by the mean for each condition indicator.

*Seagrass meadow classification table*

| **Indicator** | **Class** | | | |
|---|---|---|---|---|
| | Highly Stable | Stable | Variable | Highly Variable |
| Biomass | - | CV < 40% | CV ≥ 40% | - |
| Area | <10% | CV ≥ 10, < 40% | CV ≥ 40, < 80% | CV ≥ 80% |
| Species composition | - | CV < 40% | CV ≥ 40% | - |

Seagrass condition is then assigned one of the five grades by assessing the threshold level for each grade, relative to the baseline data, based upon the meadow class (i.e. stable or variable).

*Seagrass condition grading table*

| Seagrass Condition Indicators / Meadow Class | | Seagrass Grade | | | | |
|---|---|---|---|---|---|---|
| | | A<br>Very Good | B<br>Good | C<br>Satisfactory | D<br>Poor | E<br>Very Poor |
| Biomass | Stable | More than 20% above the baseline | Within 20% of the baseline (above or below) | Between 20% and 50 % below the baseline | Between 50% and 80% below the baseline | More than 80% of below the baseline |
| | Variable | More than 40% above the baseline | Within 40% of the baseline (above or below) | Between 40% and 70% below the baseline | Between 70% and below 90% below the baseline | More than 90% below the baseline |
| Area | Highly Stable | More than 5% above the baseline | Within 5% above and 10% below the baseline | Between 10% and 20% below the baseline | Between 20% and 40% below the baseline | More than 40% below the baseline |
| | Stable | More than 10 above the baseline | Within 10% of the baseline above or below) | Between 10% and 30% below the baseline | Between 30% and 50% below the baseline | More than 50% below the baseline |
| | Variable | More than 20% above the baseline | Within 20% of the baseline (above or below) | Between 20% and 50% below the baseline | Between 50% and 80% below the baseline | More than 80% below the baseline |
| | Highly variable | More than 40% above the baseline | Within 40% of the baseline (above or below) | Between 40% and 70% below the baseline | Between 70% and 90% below the baseline | More than 90% below the baseline |
| Species Composition | Stable; Single species dominated | More than 0% above the baseline | <20% below the baseline | Between 20% and 50% below the baseline | Between 50% and 80% below the baseline | More than 80% below the baseline |
| | Stable; mixed species dominated | More than 20% above the baseline | <40% below the baseline | Between 40% and 70% below the baseline | Between 70% and 90% below the baseline | More than 90% below the baseline |
| | Variable; Single species dominated | More than 0% above the baseline | <20% below the baseline | Between 20% and 50% below the baseline | Between 50% and 80% below the baseline | More than 80% below the baseline |
| | Variable; Mixed species dominated | More than 20% above the baseline | <40% below the baseline | Between 40% and 70% below the baseline | Between 70% and 90% below the baseline | More than 90% below the baseline |