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## Hazard assessment of water quality threats to Torres Strait marine waters and ecosystems



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Australian Government  
Department of the Environment



Centre for Tropical Water and Aquatic Ecosystem Research



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## Executive Summary

The Torres Strait region is a group of over 100 islands located between north east mainland Australia and PNG (PNG). Only 17 of the islands are inhabited and thus the Torres Strait retains a high degree of natural and wilderness value. In addition to the numerous continental islands, the region has large areas of seagrass meadows, coral reefs, and mangroves. The massive freshwater and sediment input from nearby coastal rivers in PNG further influence this unique marine ecosystem.

Given the large range of cultural, biological and economic values of the region, an understanding of the status of water quality in Torres Strait and its influence on marine foods, human health, marine ecosystems and ecological processes in the Straits is important. Potential water quality threats include a range of regional and local issues. Regional issues include discharge of metal pollution (and other pollutants in the future) associated with mining from the Fly River in PNG, future projects involving oil palm plantation development, the port at Daru, other mines in PNG or West Papua and other land clearing and shipping issues (potential oil spills and ship groundings). Local issues include waste and wastewater management and small scale vessel loading and maintenance facilities.

This study, *Project 4.4 Hazard Assessment for water quality threats to Torres Strait marine waters, ecosystems and public health* was funded as part of the National Environment Research Program (NERP) Tropical Ecosystems Hub. It provides an assessment of current and potential water quality issues in the Torres Strait region for the first time. The study included an assessment of potential and current pollutant sources in the region to inform a desktop hazard assessment, drawing on new knowledge of circulation patterns in the Torres Strait from hydrodynamic modeling and remote sensing imagery. The study included several components, summarised below.

### Review of current water quality information in Torres Strait

The Torres Strait has been the subject of a number of biological and physico-chemical investigations over the last 15 years although there has been limited work more recently (reviewed in Section 2). Many of these studies have been undertaken to investigate the estuarine and marine impacts of large-scale mining activities that have been carried out in the Papuan highlands over the last 30 years. The most comprehensive study to date is the Torres Strait Baseline Study conducted during 1992 and 1993. The study determined that high concentrations of several trace metals including cadmium were present in a number of seafoods commonly eaten in Torres Strait including prawn, crayfish, turtle and dugong. However, the high concentrations of trace metals were considered unlikely to be related to anthropogenic factors. Comparable patterns were found for the analysis of trace metals in sediment samples in 1998. In 2000, a study of pesticides in sediment samples extending north to the Torres Strait (Thursday Island) showed that no herbicides or insecticides were detected in subtidal sediments at sites north of the Daintree River (10 locations). In the Torres Strait sites, no herbicides or insecticides were detected in subtidal sediment, intertidal sediment or seagrass samples.

There is limited direct evidence on the potential impacts of degraded water quality on ecosystems in the Torres Strait including coral reefs and seagrass. The Torres Strait has some of the most extensive seagrass meadows in northern Australia, with 11 species of tropical seagrasses in sub-tidal waters. These meadows provide important habitat for dugong and turtle populations. A number of assessments have been undertaken to map seagrasses in the Torres Strait in the past. The region also has many coral reefs that support marine species which have cultural as well as commercial significance to Torres Strait communities. While there is currently limited information on the condition of coral reefs in the region and changes in coral cover



through time, a NERP Tropical Ecosystems Hub project is currently investigating the condition of coral reefs in the Torres Strait.

### **Pollutant sources in the Torres Strait**

Information on the status of current and potential pollutant sources in the Torres Strait was collated as part of the study to inform the hazard assessment of water quality issues in the region (Section 3). The main pollutant sources that were documented were: a) Island waste management including sewage management and waste disposal; b) shipping, commercial vessels and marine infrastructure; and c) large scale developments in adjacent areas. For each of these sources the potential environmental issues and information on current status were summarised. We completed site inspections at 8 islands in the Torres Strait in August 2012 in collaboration with Torres Strait Regional Authority, the Torres Strait Island Regional Council and the Torres Shire Council. These were Horn Island, Thursday Island, Erub Island, Masig Island, Badu Island, Warraber Island, Iama Island and Saibai Island. The information from these visits was used to inform the hazard assessment of water quality issues in the Torres Strait referred to below.

### **The Torres Strait hydrodynamic model**

Understanding the hydrodynamics of the Torres Strait region is required for confident predictions of pollutant transport. Through this study the extensive existing data set on the oceanography of Torres Strait (separating Australia and PNG) was reviewed and used to show that water circulation in Torres Strait is driven by the wind, the tides and the circulation in the Coral Sea, the northern Great Barrier Reef continental shelf, the Gulf of Papua, and the Gulf of Carpentaria. These data were used to set the open boundary conditions for a high resolution, finite element, depth-integrated (2D) model of Torres Strait.

The model shows that the water circulation in Torres Strait is characterised by events lasting a few days to three weeks and that this explains the observations of a very small net circulation in Torres Strait. The model predicts that net east-west flow through Torres Strait is small in agreement with field data, and reveals that areas of shallow waters and areas densely populated with reefs and islands are poorly flushed. Only reef passages and reef-free open waters are relatively well flushed.

Further improvements to the model require additional meteorological and oceanographic field data to be collected to quantify the spatial gradients of the wind field as well as the sea levels and the waves in the northwest Coral Sea. Ultimately a 3D model would be useful to provide additional information, particularly near river mouths, but at present this may be cost-prohibitive because the model cannot sacrifice horizontal resolution in order to gain vertical resolution because the strong friction-driven interaction between tidal and net currents requires that any model of Torres Strait has to incorporate the complex bathymetry of reef passages.

### **Remote sensing of river plumes**

Surface turbidity distribution in the Torres Strait results from the combined action of tides, wind, waves, currents, resuspension and turbid river discharge. Complemented with in-situ water quality data and hydrodynamic models, MODIS satellite images are useful tools to map the distribution of turbid river plumes in the Torres Strait region because of their synoptic coverage and spatial resolution. These images are freely distributed and are available from 2002. This study successfully tested the application of MODIS true colour imagery in combination with land surface reflectance products to observe turbid (sediment-dominated) river plumes from PNG and surface turbidity distribution in the Torres Strait region. These first analyses and



comparisons with true colour composites show that MODIS land surface reflectance product can help to map the plumes and turbidity levels in the Torres Strait region.

Our preliminary dataset of MODIS satellite images suggests that high turbidity levels along the PNG coast are constrained to the coast, and that intrusions of the Fly River plumes in the Torres Strait region and protected area are limited. High turbidity levels recorded along the south-western PNG coast suggest a combined influence of turbid outflows from the several rivers draining the southern New Guinea margin, enhanced by bottom resuspension in the shallow coastal zone.

It is evident that cloud levels in the Torres Strait study region are important consideration for future applications, as the area is regularly masked by dense and developed clouds. This can limit the number of images available, particularly during the Northwest monsoon season (November to April) when most of the annual rainfall occurs in the region. The limited number of images processed for this study gave only snapshots of surface turbidity dynamic in the Torres Strait. More images should be acquired for a more comprehensive study of the dynamic of surface turbidity in Torres Strait and of PNG turbid river plumes.

### **Assessing the potential hazards to the Torres Strait from water quality issues**

A qualitative assessment of the key threats to the Torres Strait region from water quality issues concludes that the hazards from water quality to the environmental values of the region are currently relatively minor. However, a number of important potential hazards have been identified. The largest threats in the future are most likely to be associated with the potential hazards from the transit of large ships through the region. Because of the limited water exchange in and out of Torres Strait, there are concerns that if Torres Strait water became polluted it would probably remain in the Strait for some time. This may pose a hazard of adverse and prolonged impacts on ecological communities, indigenous and commercial fisheries and the life style of Torres Strait Islander people. The primary hazards to the Torres Strait from water quality issues are summarised below.

1. **Increased shipping traffic:** Shipping and associated hazards (oil spills, groundings, ghost nets) appear to pose significant potential threats to the Torres Strait. The shipping route through Torres Strait is already an obvious bottleneck for Australian east coast shipping traffic. With the expansion of ports, especially coal loading ports, on the Australian east coast in response to proposed large increases in coal export (GBRMPA, 2012) large increases in shipping traffic up the Queensland coast are predicted. Additional increased shipping through the Torres Strait will also result from the construction of the major port at Daru. Under these scenarios a large increase in shipping traffic through the Torres Strait is predicted over the next decade. These increases will result in greatly increased risk of accidents in the Torres Strait. Currently there is very limited capacity to respond in any meaningful way to a large oil spill in the Torres Strait. The area is remote in Australia with strong winds and currents and a matrix of reefs and islands on which oil could impinge. Any large oil spill would have devastating consequences for the populated islands on which it landed as well as severe environmental consequences. While new management strategies may mitigate the increase in risk we consider this increase in shipping traffic to be a major water quality and environmental threat to Torres Strait environment and people.
2. **Large scale development in PNG:** Large scale development in PNG including gas platforms, oil palm expansion and Daru port development may also be significant. Preliminary analysis of proposed developments in western PNG suggest that although large scale development is likely to occur adverse effects in the Australian part of the Torres Strait are likely to be restricted to the northern islands – Boigu, Saibai, Erub and

Ugar. This is because both the hydrodynamic modeling (Section 4) and remote sensing analysis (Section 5) show that excursions of water from the Fly River drainage basin predominantly move to the east into the northern Coral Sea and along the PNG coast towards Port Moresby and are uncommon to the west of the river mouth. In addition the currents in this western region are generally from east to west both in the central Torres Strait and along the PNG coast.

3. **Localised waste management issues:** Potentially localised issues with wastewater management (all marine outfalls) exist and general waste management. Prioritisation of remedial actions will be developed more fully after this draft report has been reviewed. Saltwater inundation also important in some locations.

Recommendations and options for the development of an ongoing program to monitor water quality issues in the Torres Strait region has been developed using this information. The recommended design is presented in Section 6.

This study has provided the first hazard assessment of water quality issues in the Torres Strait region and provides guidance for environmental managers to make decisions regarding the relative importance of pollutant sources. A recommended monitoring program design will provide a sound basis for a more detailed analysis of water quality risks in the Torres Strait, and enable changes in these pressures to be assessed over time.

# 1. Introduction

## 1.1. Background

Torres Strait is a relatively shallow (typically <20m) area that separates the Australian mainland from PNG (PNG) (Figure 1) and the Indian Ocean (Arafura Sea) from the Pacific Ocean (Coral Sea). The tidal influences of two ocean systems result in frequent anomalous tidal regimes and have a great effect on the area's biodiversity. There are over 100 islands located in Torres Strait though only 17 islands are inhabited. The Torres Strait thus retains a high degree of natural and wilderness value. The massive freshwater and sediment input from nearby coastal rivers further influence this unique marine ecosystem. Benthic communities, fish assemblages, seagrass coverage and coral communities are relatively well documented. The Torres Strait provides critical habitat for many vulnerable or endangered species, including dugongs, green and flatback turtles, as well as supporting commercial fisheries for tiger and endeavour prawns, Spanish mackerel, tropical rock lobster, reef fish, pearl oysters, trochus and beche-de-mer. Coral reefs and clear waters support a rich fauna of reef fish, molluscs, echinoderms and crustaceans. In addition to the numerous continental islands, the region is characterised by seagrass meadows and coral reefs, and coral cays with mangroves are found on some of the larger reefs (Long and Poiner, 1997).

The climate is dominated by alternating periods of wet and dry weather. The dry season, from May to October, is characterised by the south-east trade winds which blow persistently with speeds of over 20 knots for approximately two-thirds of the time (Wolanski et al. 2013). A period of relative calm follows with winds slowly veering and backing to northerly between November and December. This period is accompanied by increasing humidity and occasional thunderstorms. Late December to April is characterised by the north-west monsoon season, bringing frequent but isolated squalls and storms. Winds often gust to 60-70 knots for a few hours and are accompanied by torrential rain. Passing tropical cyclones in the Gulf of Carpentaria and Coral Sea influence the Strait at this time but cyclones per se are infrequent in Torres Strait itself. The narrow channels connect two entirely different oceanic tidal regimes. The tidal regime is extremely complex and tidal heights frequently deviate significantly from those predicted. Very strong tidal streams occur throughout Torres Strait and rates of up to 8 knots may be experienced (Wolanski et al. 2013).

Torres Strait is a culturally unique area within Australia with 6,500 of Australia's indigenous Melanesian people – the Torres Strait Islanders. They live in small coastal communities on Cape York, on the islands off the southern coast of PNG and on the larger islands of the Torres Strait itself. The islanders have a strong seafaring and trading tradition and hence a close relationship with the seas, coast and reefs of the area. The consumption of seafood by Torres Strait Islanders is amongst the highest in the world on a per capita basis (Johannes and MacFarlane, 1991). Indigenous people of the Torres Strait traditionally hunt dugong, turtle, fish and a variety of marine species for food. Much of the fishing is done from small craft operating either singly or in small groups. The success of fishing is based more on local knowledge accumulated over years rather than on use of scientific know how and research (IMO MEPC, 2005).

The area also supports locally important commercial and traditional fisheries based on pearl oyster, trochus shell, beche-de-mer, crayfish, prawns, barramundi and pelagic species such as Spanish mackerel and a wide variety of other shell fish and invertebrates are gleaned from reefs for subsistence consumption. A commercial fishery estimated at 2,000 tonnes contributed approximately A\$35 million to the Australian economy in 1999/2000 (IMP MPEC, 2003). Pearl farms operate on a number of islands. The Torres Strait has a small but expanding tourism industry.



**Figure 1.** Map showing the Torres Strait region and the Torres Strait Protected Zone.

## 1.2. Context of this Study

Given the large range of cultural, biological and economic values of the region, an understanding of the status of water quality in Torres Strait and its influence on marine foods, human health, marine ecosystems and ecological processes in the Straits is important. Potential water quality threats include a range of regional and local issues. Regional issues include discharge of metal pollution (and other pollutants in the future) associated with mining from the Fly River in PNG, future projects involving oil palm plantation development, the port at Daru, other mines in PNG or West Papua and other land clearing and shipping issues (potential oil spills and ship groundings). Local issues include waste and wastewater management and small scale vessel loading and maintenance facilities.

To date no detailed water quality issues hazard assessment has been done for the region. This project, *Project 4.4 Hazard assessment for water quality threats to Torres Strait marine waters, ecosystems and public health* within the National Environment Research Program (NERP) Tropical Ecosystems Hub, provides an assessment of current and potential water quality issues in the Torres Strait region.

The study includes an assessment of potential and current pollutant sources in the Torres Strait region. This includes a review of available water quality information for the region, documentation of the status of island sewage treatment and other discharges such as desalination waste on the islands, documentation of the status and scope large scale developments in the broader region incorporating PNG, and review of current and projected shipping activity in the region. This information will be used as part of the desktop hazard assessment, to be undertaken using circulation patterns from hydrodynamic modelling and knowledge of pollutant sources.

### **1.3. Approach**

To identify water quality issues of concern for the Torres Strait region, we completed two primary tasks:

1. Review of existing water quality information in the Torres Strait from past studies.
2. Collation of information on the current status of pollutant sources in the Torres Strait including:
  - a. Sewage treatment plants
  - b. Waste disposal
  - c. Shipping, ports and commercial vessels
  - d. Major developments in adjacent areas

The primary sources of information were:

- The findings of the Torres Strait Baseline Study early 1990s (Dight, Gladstone, Brodie, Evans-Illidge and others).
- Further studies on metal pollution by Haynes and Kwan (mid 1990s).
- Studies on the Fly River plume (Wolanski and others, 1980-1990s).
- Basic studies on ecosystem health, including the Continental Shelf Research special issue 2008) with limited recent work.
- Review of the island Sustainable Land Use Plans.
- Discussion with current stakeholders in the region including staff from the Torres Strait Regional Authority (TSRA), Torres Strait Regional Council, Torres Strait Shire Council, Australian Maritime Safety Association (AMSA), Ports North and Maritime Safety Queensland.
- Visits to eight islands in the Torres Strait in August 2012 involving inspection of specific pollutant sources and meetings with the above organisations.
- Documentation prepared by the International Maritime Organisation Marine Environment Committee and Australian Maritime Safety Authority (AMSA) for shipping activities in the Torres Strait.

We have also completed two supporting studies to assist with further assessment of water quality influences in the Torres Strait:

1. A hydrodynamic model to estimate water circulation in the Torres Strait, and therefore, the potential dispersal and transport of pollutants in the Torres Strait region (Wolanski et al., 2013).
2. Testing the application of high resolution and high frequency remote sensing data for assessing turbidity and in particular, the potential influence of PNG river plumes in the Torres Strait region (Petus, 2013).

Finally, we have used the above information to establish a set of conclusions and recommendations for addressing potential water quality issues in the Torres Strait, and proposed a suitable water quality monitoring program to identify and assess status.

## **2. Review of water quality information in the Torres Strait**

### ***2.1. Past water quality studies***

The Torres Strait has been the subject of a number of biological and physico-chemical investigations over the last 15 years (Haynes and Kwan, 2002). Many of these studies have been undertaken to investigate the estuarine and marine impacts of large-scale mining activities that have been carried out in the Papuan highlands over the last 30 years. In particular, gold and copper mining on the Ok Tedi River (a tributary of the Fly River) is estimated to contribute 750,000 tonnes per day of copper-rich mine tailings and 90,000 tonnes of sediment per day to the river (Apte and Day, 1998).

#### ***2.1.1. Torres Strait Baseline Study***

The Torres Strait Baseline Study (TSBS) was initiated in 1990 in response to concerns particularly from Torres Strait Islanders, about the potential effects on the Torres Strait environment from mining operations in the Fly River catchment of southern PNG (Dight and Gladstone, 1993; Gladstone, 1996). The study comprised four component programmes: Commercial Fisheries (Evans-Illidge, 1997), Community Fisheries, Marine Sediments and Indicator Organisms (Dight and Gladstone, 1993; Dight, 1996).

A pilot study assessed concentrations of trace metals in selected marine organisms, sediments and seagrass in 1991-1992 (Dight and Gladstone, 1993), and was followed by a more comprehensive baseline study in 1992-1993 (Gladstone, 1996). The 1992-1993 baseline study indicated that the influence of the Fly River on trace metal concentrations in sediments and selected indicator organisms of Torres Strait was largely limited to north-eastern Torres Strait. In contrast, trace metal concentrations in marine sediment from the north-central region of Torres Strait were determined to be primarily influenced by smaller coastal rivers flowing from PNG.

Other studies have also concluded that the impact of the Fly River discharge on local trace metal levels is generally restricted to the northern Torres Strait (Alongi et al., 1991; Baker et al., 1990; Baker and Harris, 1991).

The 1992-1993 baseline study determined that high concentrations of several trace metals including cadmium were present in a number of seafoods commonly eaten in Torres Strait including prawn, crayfish, turtle and dugong. However, the high concentrations of trace metals were considered unlikely to be related to anthropogenic factors.

The baseline study report recommended commencement of longer-term monitoring of trace metal concentrations in sediments and selected indicator organisms in Torres Strait (Gladstone, 1996). A number of further studies of Torres Strait trace metals concentrations have been conducted since the early 1990s including assessment of heavy metals in commercial prawn and crayfish species (Evans-Illidge, 1997), and metal concentrations in sediment (Haynes and Kwan, 2002).

#### **Metal concentrations in commercial prawn and crayfish species**

Three species of prawns were studied which comprise the majority of the catch landed in the Torres Strait. Generally, metal levels were reported as either significantly less than those reported previously from reported environments, or additionally, in agreement with or less than those from representative unpolluted areas, including previous studies in the Torres Strait. This was not the case for cadmium which was recorded in concentrations comparable to those

reported from elsewhere in Australia and a polluted coastal site in the Arabian Sea and higher than those reported from some unpolluted sites. While this indicates a high cadmium bioavailability in the Torres Strait, it is not due to pollution. Cadmium is not a metal associated with the Fly River runoff but a naturally occurring element in marine carbonate sediments, which are prevalent in the Torres Strait (Evans-Illidge, 1997).

In the same study, the main commercial crayfish species were analysed for metal concentrations and the levels of most metals generally agreed with the levels found in comparable tissues in Torres Strait prawns, with some exceptions. For example, arsenic and copper occurred in higher concentrations in crayfish, and cadmium levels in crayfish were much lower than in prawns. Crayfish tails from a site within Fly River influence did not contain elevated levels of metals, compared with other sites. Further monitoring in 2001 (Haynes and Kwan, 2001) supported these results and showed that detectable concentrations of all metals analysed were present in samples of hepatopancreas and head tissue (as opposed to tail tissue). Avoidance of consumption of these tissues was recommended as a result of these studies.

### **2.1.2. Sediment sampling**

In 1998, further monitoring of heavy metals in the marine environment was supported by the Australian Government in response to requests from the Torres Strait Regional Authority (TSRA). A modest study was undertaken to more precisely determine the concentrations of heavy metal pollutants in traditional seafood, and assess the viability of undertaking long term monitoring of temporal changes in heavy metal concentrations in the Torres Strait (Haynes and Kwan, 2002).

Sediment samples were collected from 28 sites across the Torres Strait region and Gulf of Papua in February 2000 (Figure 2). Detectable concentrations of all metals analysed were present in the Torres Strait sediment samples. All metals except strontium and cadmium were negatively correlated with calcium carbonate concentrations and positively correlated with aluminium, iron and silica concentrations, which is indicative of their terrestrial origin. In contrast, both strontium and cadmium were primarily associated with carbonates of marine origin and the lowest concentrations were present in the Gulf of Papua and northern Torres Strait.

Average concentrations of sediment metals were similar to those detected in past surveys of Torres Strait, although concentrations of arsenic, chromium and nickel were high enough to exceed sediment quality guidelines (ANZECC, 2000) at a number of sites. Nickel sediment concentrations were elevated (i.e.  $>21 \text{ mg kg}^{-1}$  dry weight) at all Gulf of Papua sampling sites and all but one of the northern Torres Strait sampling sites. Similarly, sediment concentrations of chromium were elevated (i.e.  $>80 \text{ mg kg}^{-1}$  dry weight) at all Gulf sites and at a majority of northern Torres Strait sampling sites. Concentrations of arsenic were elevated (i.e.  $>20 \text{ mg kg}^{-1}$  dry weight) at approximately half of the Gulf of Papua and northern Torres Strait sampling sites. Average sediment metal and calcium carbonate concentrations were significantly different from north to south. Calcium carbonate concentrations increased with increasing distance from the Gulf of Papua. Lowest concentrations of strontium and cadmium were also present in the Gulf of Papua and northern Torres Strait. In contrast, concentrations of all other metals were significantly higher in sediments collected from the Gulf of Papua and/or northern Torres Strait than in sediments collected from more southern sites in central and southern Torres Strait.

As a result of the circulation patterns in the region, most of the freshwater delivered to the Gulf by large Papuan rivers travels eastwards, while only a small proportion flows towards Torres Strait (Woolfe et al., 1997). This pattern of water circulation and sediment movement within the region is substantiated by the distribution of metals in sediments across the Gulf of Papua and Torres Strait determined by the study.



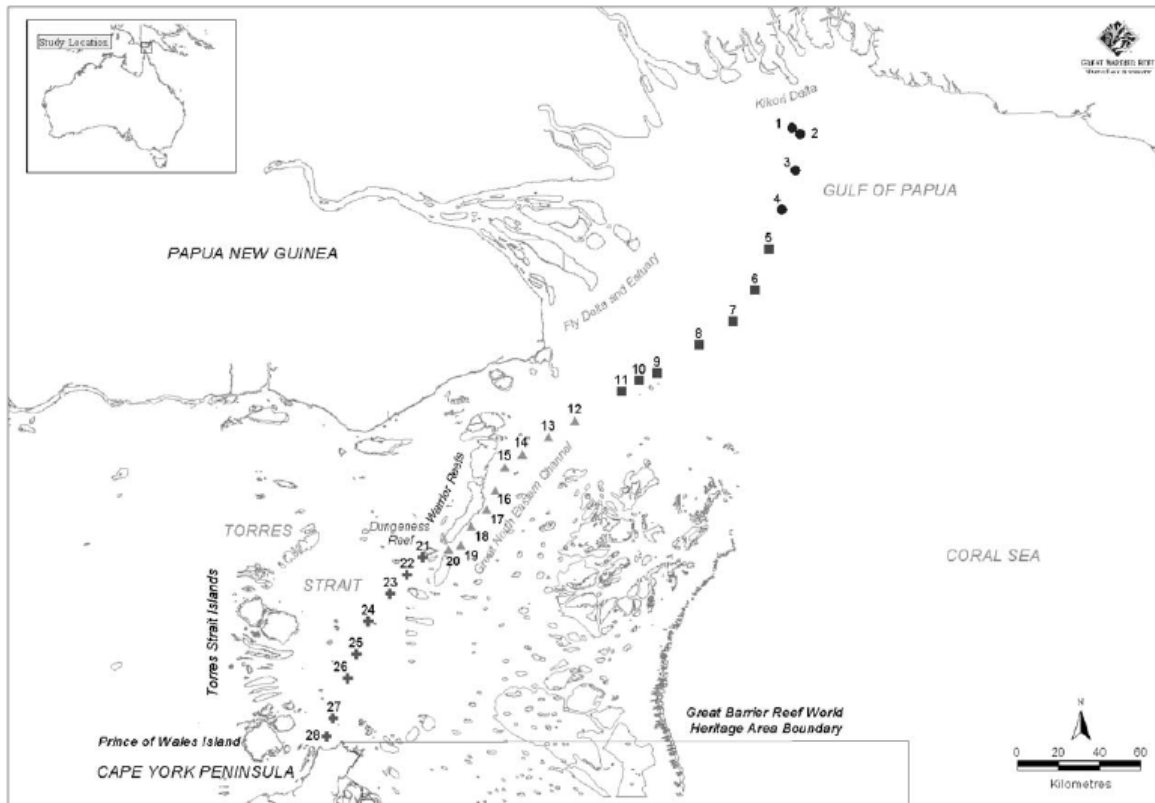


Figure 2. Torres Strait and Gulf of Papua sediment sampling sites. Source: Haynes and Kwan (2002).

### 2.1.3. Mangrove cockle monitoring

Accumulation of metals from the water column by bivalve shellfish has been shown to occur rapidly and to reflect ambient exposure concentrations for many metals. The suitability of mangrove cockle as a suitable indicator organism for metal accumulation in the Torres Strait was tested by Haynes and Kwan (2001). Mangrove cockle were collected from intertidal mangrove habitat in northern, central and southern Torres Strait and on northern Cape York by local community members between June 1998 and June 2000. Collected animals were analysed by arsenic, cadmium, chromium, copper, mercury, nickel, lead, selenium and zinc.

Nickel was the only metal which exhibited significant variation in mangrove cockle tissue between sampling years, with nickel concentrations in bivalves collected in 1998 being significantly higher than in samples collected in 1999. A majority of metals exhibited significant variation between sampling regions. Metal concentrations present in mangrove cockle represent the proportion of metals that are biologically available. Differences in the distribution of metals were more easily distinguished in mangrove cockles than in sediments. In particular, the monitoring indicated that concentrations of copper are higher in both northern and central Torres Strait compared with concentrations present in southern Torres Strait waters. This is predictable based on water circulation models, but was not detectable in sediment samples. However, cockles tended to be difficult to locate at many sampling sites, which often resulted in significantly reduced sampling of animals, making the species unsuitable for routine monitoring in the region.

A study of pesticides in sediment samples in the Great Barrier Reef extending north to the Torres Strait (Thursday Island) showed that no herbicides or insecticides were detected in subtidal sediments at sites north of the Daintree River (10 locations), whereas many samples collected further south (11 locations) had quantifiable levels of one or more contaminants

(Haynes et al., 2000a). Similarly, concentrations in intertidal sediments and seagrass were not detectable in the Torres Strait sites.

## **2.2. Water quality drivers**

Mean annual rainfall in Torres Strait is 1746mm, most of which falls during the monsoon season (Australian Bureau of Meteorology weather statistics at Thursday Island). With rainfall in the PNG highlands of 10–13 metres annually, the terrestrial runoff into the marine environment is around  $15,000\text{m}^3\text{ s}^{-1}$  and shows little evidence of seasonal fluctuations (Wolanski et al., 1995). The Fly River emptying into the Gulf of Papua accounts for about half the PNG discharge ( $7500\text{m}^3\text{ s}^{-1}$ ) and is characterised by water temperatures around  $26^\circ\text{C}$  and salinities around 12 PSU (Alongi et al., 1992).

It is estimated that rivers on the south coast of New Guinea annually deliver 4800 million tonnes of terrigenous sediment to the surrounding shallow shelf including the northern Australian margin (Milliman, 1995; Milliman et al., 1999; Walsh et al., 2004), a majority of which is sourced from the Fly River (4120 million tonnes; Harris et al., 1993). The rate at which the sediment is delivered to the south coast of New Guinea is relatively invariant throughout the year (Walsh et al., 2004; Wolanski et al., 1995). Sand is principally trapped at the coast and the mud fraction is deposited in coastal deltas and on the shelf (cf., Harris et al., 1993; Brunskill et al., 2004; Walsh et al., 2004).

Regional hydrodynamic modelling studies (Hemer et al., 2004; Keen et al., 2006) indicate that up to 11% of the total annual mud load from the Fly River may be transported into Torres Strait during the trade wind season. Terrigenous sediment inputs from the northern margin of Australia are negligible by comparison due to the absence of large river systems and prevalence of small, low relief catchments. River-borne terrigenous sediments eroded from New Guinea catchments are dominated by aluminosilicate clays (montmorillonite, kaolinite, chlorite and illite) and quartz, biotite, and feldspar silts and sands, with negligible carbonate minerals (Irion and Petr, 1983; Harris and Baker, 1991). Elemental analyses indicate that terrigenous sediments can be characterised by direct correlation between their terrestrial elements (e.g., aluminium, iron and titanium) and silicon (e.g., Brunskill et al., 1995; Haynes and Kwan, 2002). Terrigenous sediments are enriched with heavy metals, including copper and arsenic from mining activities in the local catchments (Brunskill et al., 2004), and elevated concentrations of these metals have been reported in local seafood (Gladstone, 1996).

The turbidity level in Torres Strait is expected to vary seasonally, but be out-of-phase with the seasonal circulation pattern, as a result of the seasonal transport of water and sediment through the strait. In particular, the turbidity level in Torres Strait is expected to peak at the end of the monsoon due to the presence of fine sediments and high turbidity water coming from the Gulf of Carpentaria, while turbidity level in Torres Strait is likely to be at a low at the end of the trade season due to an enhanced flushing of the strait with clearer water from the Coral Sea. This provides the driving mechanisms behind the persistent if not semi-permanent high turbidity feature reported by Harris and Baker (1991) in the central Torres Strait.

The highly turbid coastal waters of PNG are not expected to play a major role in central Torres Strait turbidity, because the transport pathways in the north of the strait (along PNG coast) show little connectivity with those at lower latitudes. Despite the seasonal expansion of the turbidity front during the monsoons, due to a southward meridional flow, the flow remains strongly streamlined through-strait with limited mixing across-strait below latitude  $9.5^\circ$  South. This is confirmed by the presence of a sediment transition zone, between Turnagain and Saibai Island, which separates terrigenous-dominated sediments to the north and carbonate-dominated sediments to the south (Daniell et al., 2006).

The seasonal turbidity cycle results in frequent and extended periods of low bottom light. Eventually, due to the inherent inter-annual variability of the circulation and sediment transport in Torres Strait, seasonal low bottom light may be further reduced. In particular, the combination of a weak trade and strong monsoon season is likely to increase the risk of a prolonged period of critically low bottom light and in turn enhance the risk of seagrass dieback in Torres Strait.

## **2.3. Ecosystem status**

### **2.3.1. Seagrass meadows**

The Torres Strait has some of the most extensive seagrass meadows in northern Australia, with 11 species of tropical seagrasses in sub-tidal waters (Rasheed et al., 2008). The seagrass meadows provide habitat for juvenile penaeid prawn and support populations of threatened species such as green turtle and dugong (Marsh et al., 2004). There are large spatial discontinuities in the meadows with almost no seagrass east of the Warrior Reef complex (Sheppard et al., 2008). An assessment of the value of different seagrass species as a food source for green turtle and dugong showed that *Halophila ovalis* is an important source of energy to marine herbivores that forage sub-tidally in the Torres Strait (Sheppard et al., 2008). These sub-tidal meadows are prevalent in the north-central and south-western regions. Consequently the central Torres Strait region is particularly important for the traditional dugong fishery and has been described a “powerhouse” for dugong in the Torres Strait (Marsh et al., 2004).

Despite the significance of the resource, information on seagrass resources, other than mapping distributions, has been quite limited in Torres Strait (Mellors et al., 2008). Recognition of the health and extent of seagrass within natural variability is of vital importance to sustain turtle, dugong, and important commercial fisheries in the Torres Strait (Torres Strait NRM Reference Group, 2005). Seagrass Watch has been operating in the area since 2004<sup>1</sup> and engages the local community (through the Tagai College Secondary Campus) in monitoring seagrass abundance and habitat characteristics (Mellors et al., 2008). The data collected through this program were the first to document natural variability of seagrass meadows in the Torres Strait, showing seasonal and inter annual variability associated with climatic variables. The studies also revealed localised issues, for example, at front beach of Thursday Island near the harbour facilities. Here, persistent low seagrass cover is likely to be a result of the influence of a storm water drain and observation of large amounts of sediment delivered to the site and burying the seagrass. Also, its proximity to the main harbor results in frequent physical damage from vessel careening, scarring, and anchoring (Mellors et al., 2008).

Seagrass meadows can be highly dynamic, changing as a result of natural and anthropogenic influences. Water and sediment quality and light are major factors controlling seagrass growth (Livingston et al., 1998) and the effects of light deprivation on the seagrasses can be devastating during pulsed turbidity (Longstaff and Dennison, 1999). Environmental factors controlling seagrass variability on the shelf are not well understood. Strong currents and waves maintain an extremely high-energy environment in the Torres Strait and cause frequent resuspension of sediments with net horizontal displacement of the sediment masses. Pulsed turbidity events during spring tides and storms, along with seasonally varying patterns of suspended and bottom sediments, may have significant impacts on seagrass physiology and morphology (Livingston et al, 1998; Longstaff and Dennison, 1999; Saint-Cast and Condie, 2006).

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<sup>1</sup> [http://www.seagrasswatch.org/Torres\\_strait\\_archived\\_data.html](http://www.seagrasswatch.org/Torres_strait_archived_data.html)

Torres Strait seagrass communities are subjected to episodic diebacks (Marsh and Kwan, 2008), which are likely to be caused largely by light deprivation resulting from sediment resuspension. Several widespread seagrass dieback events have been recorded in central Torres Strait (Long and Poiner, 1997; Long et al., 1997) including a major event of widespread and prolonged sea grass dieback in both intertidal and deepwater areas of Torres Strait during the early 1970s (Johannes and MacFarlane, 1991). The causes and precise dates of this dieback are uncertain. Some Islanders linked the event to pollution resulting from the grounding of the oil tanker, *Oceanic Grandeur*, in 1970; the limited scientific information about the spill does not support this explanation but it cannot be ruled out (Johannes and MacFarlane, 1991). Nietchsmann (1977 unpublished cited by Johannes and MacFarlane, 1991) attributes this dieback to overgrazing by an unusually large numbers of dugongs and green turtles. Both deep and shallow water sea grasses were reportedly affected by the dieback and to have recovered by the early to mid 1980s (Johannes and MacFarlane, 1991).

Subsequent diebacks appear to have been more localised and to have occurred largely in north-western Torres Strait. For example, Poiner and Peterken (1996) report the loss of several hundred square kilometres of seagrass meadows in north-western Torres Strait in 1991–1992, which they tentatively attribute to high turbidities from flooding of the Mai River in PNG. Marsh et al. (2004) provide anecdotal evidence of another dieback event in the Orman Reef area north-east of Mabuiag Island (9.95°S, 142.15°E) in 1999–2000.

There are a number of anecdotal hypotheses that have been proposed to explain the causes of the seagrass dieback. For example, that increased terrigenous sediment produced from mining activities in the New Guinea catchments is accumulating on the seabed and smothering the seagrasses, or causing elevated turbidity throughout Torres Strait and reducing light at the bed to levels unsuitable for seagrass survival. Changes in regional circulation are also proposed to have caused widespread bedform migration that has smothered the seagrasses (Heap and Sbaffi, 2008).

These episodic events have major implications for dugong populations, and their response strategies are believed to include moving away from the affected area, and/or postpone breeding (Marsh and Kwan, 2008). The impact of sea grass dieback events can be exacerbated by poor land-use activities (Preen and Marsh, 1995; Preen et al., 1995). Herbicides including diuron (associated with agricultural land use, primarily sugarcane production) found in nearshore sediments along the eastern coast of north Queensland (Haynes et al., 2000a) have the potential to impact local seagrass communities (see Haynes et al., 2000b) and human health. Co-operation between Australia and PNG will be essential to ensure that future land use in the region does not compromise water quality in Torres Strait. This matter and the associated potential impacts on human health are of long standing concern to Islanders, (e.g. Dight and Gladstone, 1993).

The possible role of sediments as a factor in widespread seagrass dieback in central and northern has recently been investigated (Heap and Sbaffi, 2008). Assessment of the composition and distribution, and sedimentological and geochemical properties, of seabed and suspended sediments in north and central Torres Strait showed that terrigenous sediments from New Guinea could not be uniquely traced to Turnagain Island in central Torres Strait. If sediments are a factor in the widespread seagrass dieback in central Torres Strait, then the data suggest these are marine-derived sediments sourced from resuspension and advection from the immediate shelf areas and not terrigenous sediments dispersed from New Guinea rivers. This finding is consistent with outputs from recently developed regional hydrodynamic and sediment transport models (Wolanski et al. 2013; Saint-Cast, 2008) that show that the predominant water and sediment movements in Torres Strait are oriented east–west and disperse sediments parallel to the coast. These currents would form an effective hydraulic barrier to sediment

transport southwards from New Guinea to central and southern Torres Strait, and account for the patterns identified above. Saint-Cast (2008) suggests that resuspension is driven by two major depocentres on either side of the Strait. Prolonged periods of monsoon winds and / extreme weather events enhance sediment resuspension.

### **2.3.2. Coral Reefs**

The coral reefs of Torres Strait support many marine species that have cultural as well as commercial significance to Torres Strait communities. While there have been many studies that map and document the characteristics of coral reef ecosystems in the region (eg. Haywood et al., 2007; Taranto et al., 1997), there is limited current information on their condition and for example, changes in coral cover through time have not been assessed for any Torres Strait reef. NERP Project 2.3 aims to initiate a program to monitor the status of coral reefs in the Torres Strait, and have recently conducted a review of existing information on coral reef communities in the Torres Strait (Sweatman, 2012). The information below has mostly been extracted from this review.

The review indicates that the great majority of biological datasets from the Torres Strait show a major divide along a line running from ESE to WNW across the region (drawn from Haywood et al., 2007). This reflects the relative dominance of coral habitats in the clearer water on the eastern shelf edge compared with the relative dominance of seagrass habitats in the more turbid and sediment-laden conditions in the west, closer to the Gulf of Papua. This is true for hard corals; hard coral cover is greatest on the edges of reefs in the East, and the composition of the coral communities also changes across the Torres Strait region. Overall, eleven categories of hard corals were distinguished in the surveys, though the categories used varied among the different surveys. Most coral was found on reef edges (median cover of 10% versus 5% on reef tops). Coral cover was generally higher in the eastern Torres Strait, reaching 47% on some sites on the edges of the eastern Ribbon reefs.

The presence of crown of thorns starfish (*Acanthaster planci*) has been associated with poor water quality in the Great Barrier Reef (eg. Fabricius et al., 2010; Brodie et al., 2005) and observed to influence the condition of reefs on a large scale in the adjacent ecosystems of the GBR. CMAR surveys in 1995-96 found densities up to 56 starfish ha<sup>-1</sup> in reefs in the eastern central region of Torres Strait (Taranto et al., 1997). Skewes et al. (2006) recorded a drop in living coral (tabulate and branching *Acropora*) in the presence of large numbers of *A. planci* on one reef (Popo Reef) near Mer between 2002 and 2005. There were very high numbers of *Acanthaster* at Ugar, Erub, Masig, and Poruma in 2007 (Duckworth et al., 2007). The impression is that there are persistent populations of *A. planci* in the eastern central region of Torres Strait.

In a global analysis of the decline of coral reef ecosystems (Pandolfi et al., 2003), the Torres Strait reefs rated relatively well compared to other global systems, with an estimate of 40% degradation on a scale of pristine to ecologically extinct (based on the ecological state of all seven guild inhabitants at the 14 reef regions).

## **3. Pollutant sources in the Torres Strait**

Information on the status of current and potential pollutant sources in the Torres Strait has been collated, and incorporated into a spatial database. The main pollutant sources that documented are:

- a. Island waste management including sewage management and waste disposal
- b. Shipping, commercial vessels and marine infrastructure

## c. Large scale developments in adjacent areas

For each of these sources a summary of the potential issues, the information gathered for this project, and the contact person for key data is summarised in Table 1.

As part of this study we completed site inspections at 8 islands in the Torres Strait in August 2012 in collaboration with TSRA, the Torres Strait Island Regional Council and the Torres Shire Council:

- Horn Island
- Thursday Island
- Erub Island
- Masig Island
- Badu Island
- Warraber Island
- Iama Island
- Saibai Island

A detailed report of these inspections is provided in Attachment 1 which is available for internal use by the of the Department of Sustainability, Environment, Water, Population and Communities, the Torres Strait Regional Authority and local council staff.

Table 1. Summary of pollutant sources in the Torres Strait.

Pollutant issue	Issues	Information required	Contact	Location
a) Island waste management				
Sewage treatment plants	Marine outfalls Saltwater inundation Secondary / primary treatment	Location Capacity Type Standard of treatment Discharge method Discharge location Discharge volume Receiving environment License requirements Proposed changes / improvements	Mat Brodbeck, Torres Strait Island Regional Council  Nicky Sabatino, Torres Shire Council	Moa (St Pauls and Kubin) Badu Mabuiag Boigu Saibai Iama Warraber Masig Mer Erub Thursday Horn  Septics: Ugar Dauan Poruma
Rubbish tips	Lack of space on smaller islands & alternatives, inundation, leachate, marine litter, light industrial waste / trade waste, port operations	Location Status	Mat Brodbeck, Torres Strait Island Regional Council Nicky Sabatino, Torres Shire Council	Horn Moa (St Pauls and Kubin) Badu Mabuiag Boigu Saibai Iama Warraber Masig Mer Erub Ugar

Pollutant issue	Issues	Information required	Contact	Location
				Dauan Poruma
Urban development	Acid sulphate soils, drainage management, construction and sediment control		Sustainable Land Use Plans	Badu Boigu Dauan Erub Hammond Iama Kubin Mabuyag Masig Mer Poruma Saibai St Pauls Ugar Warraber
b) Shipping, commercial vessels and marine infrastructure				
Vessel sewage Note: Commercial fleets include Prawn, Lobster, Fish	Localised discharge	Size of commercial fleets Dominant mooring locations Current requirements	Frank Thomson, MSQ Annabel Jones, AMSA	
Slipways	Antifoulant paints, waste disposal	Location Status Operations	Adrian Davidson, AMSA Nicky Sabatino, TS Council Qld Transport	Thursday Horn
Boat ramps, vessel loading facilities	Waste disposal	Location Status Operations	Local staff from TS Council and Torres Strait Island Regional Council	Badu Saibai Iama Warraber Masig Erub
Local Ports	Dredging maintenance, port construction and operations, traffic	Location Status Traffic Operations	Adrian Davidson, AMSA Frank Thomson, MSQ Ports Corporation, Greg Kirk	Horn Thursday
Transit Shipping	Ballast disposal, bilge disposal, antifoulant paints, oil spills, grounding, loss of cargo, ghost nets (navigation hazards)	Current and Projected: Route Numbers (current and projected) Cargo Depth of major routes Environmental values	Adrian Davidson, AMSA Jamie Storrie, AMSA	East Coast Queensland
Oil spill response capacity	Limited capacity at outer islands especially	Local plans Environmental values Preliminary modelling to show high risk areas	Adrian Davidson, AMSA Jamie Storrie, AMSA	



Pollutant issue	Issues	Information required	Contact	Location
			Frank Thompson, MSQ	
c) Large scale developments in the broader region				
Palm oil	Erosion from clearing in first stages Ongoing application fertiliser and pesticides Mills – high DO waste Increased runoff volumes Refineries	Location Status Scale and duration Associated infrastructure		See Section 3.3, Table 4 and 5
Mining and gas development	Waste disposal / tailings– copper and sediment in Fly River Habitat destruction Associated infrastructure eg. port development	Location Status Product Scale and duration Associated infrastructure Waste management		See Section 3.3, Table 4 and 5

A summary of the status of the three main groups of pollutant sources in the Torres Strait region is presented below.

### ***3.1. Island waste management including sewage management and waste disposal***

#### ***3.1.1. Sewage management***

There are 17 inhabited islands in the Torres Strait. The populations range from 85 (Ugar Island) to around 3,800 people (Thursday Island). A majority of the islands have populations between 200 and 300 people (Figure 3), and some islands have more than one community.

There are 18 communities among the 17 inhabited islands in the Torres Strait. Thirteen communities are serviced by a sewage treatment plant (STP), and the remaining 5 communities are small and are serviced by septic tanks. Of the 13 STPs in the Torres Strait region, 10 of the plants are designed to secondary treatment standard; 4 of these are lagoons in series, 6 are packaged intermittent aeration treatment plants. Three of the systems are activated sludge plants incorporating alum dosing and can be considered to be tertiary standard. The remaining systems are primary standard septic tank systems.

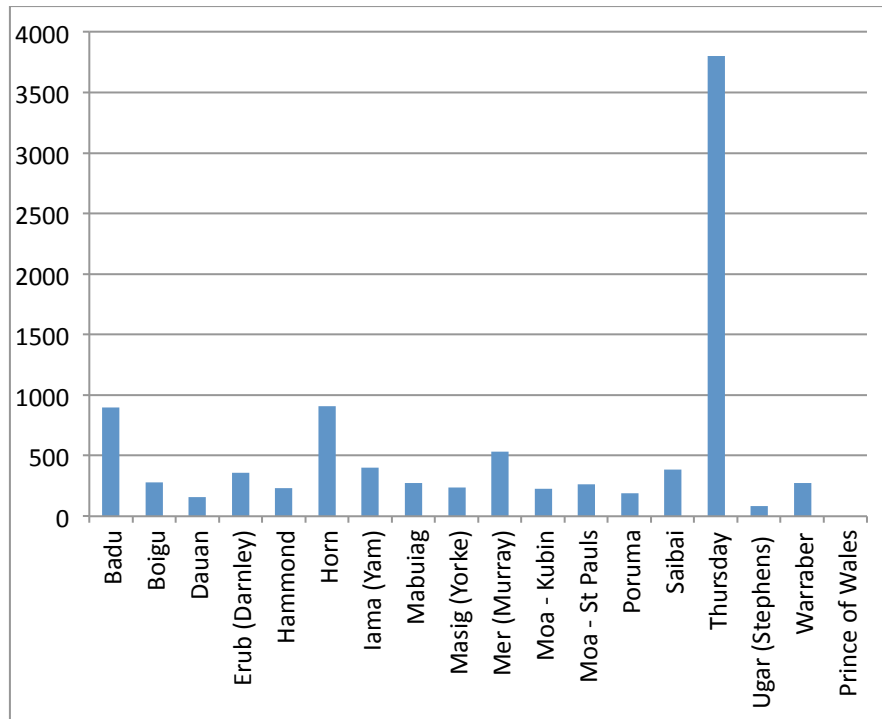


Figure 3. Torres Strait island population estimates. Source: Torres Strait Island Regional Council and Torres Shire Council.

Overall, the STPs are generally operating well with a few exceptions where the issues were largely related to access to skilled labour for system repairs and extended breakdown of parts of the system. The primary issues raised were:

- Long periods between system failure and repair, leading to a number of flow-on problems due to the nature of the package treatment plants.
- Damage to the outfall pipe, resulting in discharge in areas that may not be well flushed.
- Breakdown of the UV disinfection treatment systems resulting in periods with inadequate disinfection and potentially high faecal coliform levels in the discharge areas. This is generally only a public health issue if the outfall structure is not located within deep waters.

The design standard of the STPs is relatively high in most cases, and with adequate preventative maintenance, a majority of them should continue to operate at a reasonable standard. In cases where the STPs are reaching 10 years old or more (eg. Erub Island), consideration should be given to a major overhaul as many of the electrical components of the system were failing.

From discussions with the Councils and the site inspections, the following issues were identified with the standard of the STPs and the marine outfall infrastructure (as at August 2012):

- **Boigu** – The STP needs major repair and the Council has identified a list of works to be completed, even though the system was upgraded and had major maintenance works undertaken in 2010. In the aeration tanks the blowers need replacing resulting in poor aeration, and poor treatment of the return activated sludge. The STP was not meeting the licence conditions.

- **Mer** - The STP needs major repair and the Council has identified a list of works to be completed, even though the system was upgraded and had major maintenance works undertaken in 2010. No onsite storage for water.
- **Horn** - One of the six effluent lagoons was recently cleaned out to remove seeding from the adjacent grassed areas and a number of large bubbles have formed under the plastic lining. There is also potential leakage from the pond from damage to the lining. This lagoon is not functioning which may lead to reduced residence times (and therefore inadequate treatment) of the effluent prior to discharge.
- **Badu** – We were not able to access the outfall but were advised that the effluent is currently discharged into the creek and mangrove area. In addition, the discharge has been controlled manually for some time. The presence of high algae in the final effluent pond would suggest that the standard of the effluent may need improving. It is recommended that the discharge environment is inspected for potential localized impacts.
- **Saibai** – Several parts of the STP have broken down and the outfall pipe is broken. The 2nd aeration chamber is not operating and had been out of order for at least 2 months, this results in inadequate effluent treatment. Seawater enters the STP man holes on king tides and the system fails due to the saltwater influx (disrupts the biological treatment process). The outfall pipe has been broken and currently extends ~50m onto mud flat, and would be exposed at low tide. We were advised that area is silting up at the break point. The original pipe extended beyond the edge of the mud flat into deeper water. The end of the pipe is marked by a buoy but there is no signage to alert people of sewage discharge. The effluent is discharged in an area which may be used for bait fishing by the locals. Discharge is automatically controlled by the level in clarifier so is not managed with tidal conditions in any way.

We did not visit any islands that did not have STPs but given the relatively small populations of these communities, we would not expect this to be a major problem in terms of local water quality.

### **3.1.2. Waste management**

All of the inhabited islands use landfill as their main method of waste disposal, and most of them also burn a portion of the domestic waste. In most cases, the landfill sites are located close to the coasts and therefore seepage from the landfill may influence the water quality of freshwater perched on beach rock or the adjacent marine environment; however the volume of landfill is relatively small in most cases.

A small number of islands have programs in place for separating out different kinds of waste including hazardous materials such as batteries, scrap metal and oil which are then supposed to be transported off the islands periodically; however there are issues with quarantine outside of the Torres Strait Protected Zone. Only one island we visited, Warraber, has a full recycling program in place for paper and cardboard, aluminium cans and plastic. Many of the locals that we met were interested in establishing similar programs if funding and support was provided.

A number of specific issues were raised which may warrant further investigation:

- On Saibai the landfill is spread out over three separate areas but is well organised with separate areas for different classes of rubbish, however, it is situated on land that is regularly influenced by high tide south of the township. While Saibai is a relatively large island, there is only a very small area of land that is above highest astronomical tide. This

is a low lying island and it is impossible to locate the landfill away from the marine environment. The landfill is probably inundated several times a year during spring tides and seepage from the landfill may influence marine water quality of the adjacent estuarine environment; however the volume of landfill is very small. There is no facility for recycling plastics or metals, however interest was expressed in having a recycling system as well as removing metal and whitegoods and batteries periodically from the island.

- A similar situation exists on Iama Island with the landfill located in an area that is influenced by king tides is probably partially inundated several times a year. It is likely that Boigu Island would also experience similar problems given the low lying nature of the island.
- There is a disused gold mine site on Horn Island that has the potential to cause localised water quality issues. The site has been rehabilitated and is generally well protected from erosion by grass and other native vegetation. However, the area still has disused tailings dams, borrow pits and a dam water supply, and experienced downstream leakage into the older dammed area several years ago. Seepage from the tailings dam may be impacting on downstream environments but it is unclear whether this poses any threat to marine water quality as long as the wall of the tailing dam is maintained. In the event of failure of the tailings dam wall, the local marine environment would be impacted. The borrow pits contain water of unknown quality, however they are unlikely to pose a threat to marine water quality. A range of new developments at the site including a new road around the dam and a new building were noted during the site inspection, however, no further information has been obtained on potential activity in the area as part of this project.

In terms of options for improving waste management in the Torres Strait, a number of trials have been established on Warraber Island which could be considered to demonstrate best practice for the region. There is a trial facility (operating approximately 2 years) for composting kitchen and garden waste utilizing a 'Bio bins' process (a concept of sealed bins with a heat supply). Food scraps are collected weekly from approximately 40 houses and processed in these facilities. The resulting material is then composted and used in the community gardens. There is also a pilot facility for recycling plastics and metals, established as a pilot program by the previous council. Recycling bins are collected from approximately 40 houses twice a week. Plastic bottles and cans are sorted, washed and compacted, then shipped in containers to Brisbane recycling facilities. The plant has been operating since 1995; initial cost \$1.5 million. At the time it was anticipated that the system would be adopted on Saibai, Boigu and Coconut Islands.

All islands expressed an interest in periodically removing scrap metal, whitegoods and batteries from the islands as part of the recycling process. The Torres Strait Island Regional Council has coordinated proposal to tender a barge service to undertake a removal circuit however the costs involved (potentially millions of dollars) has delayed the project.

### **3.1.3. Marine litter**

The issue of marine litter was raised by several locals in discussions. A number of people commented on an increase in marine litter in the Torres Strait in recent years, although this has not been monitored consistently, or in many locations. As part of the Tangaroa Blue Foundation Australian Marine Debris Database a number of cleanup sites in the Torres Strait have been

documented between 2009 and 2012 (Tangorua Blue Foundation, unpublished<sup>2</sup>). This is useful information for documenting the status of marine debris in the region. However, the sites have been visited at different times of the year not all sites are visited annually so it is difficult to compare between single data points between years as the amount of debris between the seasons is likely to be influenced by weather conditions, tidal currents and local storm events. For example in most cases, the lowest number of items were collected in the period February – March each year, and the highest numbers were recorded in October – November each year. These differences are likely to be associated with the seasonal patterns of wind direction.

The available data (28 sampling events supplied) includes a number of locations throughout the Torres Strait including several locations on Thursday Island, and individual sites on Erub, Horn, Iama, Warul Kowa and Bampfield Beach. The results show the greatest recording of the total number of items collected around Thursday, Erub, Sabai and Horn Island as shown in Table 2.

Table 2: Location, date and count of marine debris collected at several beaches in the Torres Strait as part of the Tangorua Blue Foundation Australian Marine Debris Database. Source: Tangorua Blue Foundation, unpublished.

Location	Date	Total number of items
Thursday Island Federal Beach	27/10/2009	696
Erub Island	27/10/2009	999
Saibai Island Sea Wall	29/10/2009	1,331
Horn Island	16/11/2009	1,483
Thursday Island Wharf to Boat Club	4/11/2009	2,105

The percentage of plastic in the collected items is recorded and ranges from 8% to 80%, with over half of the sites recording more than 50% plastic in the collection. At Horn Island, 76% of the debris collected in November 2011 was plastic and during this collection it was estimated that 74% of the debris was most likely to have arrived by sea. The highest proportions of plastic have been recorded at Federal Beach on Thursday Island and Bampfield Beach on Prince of Wales Island.

The data are also separated into a Land and Sea Source Index which estimates the percentage of debris most likely to have a land source at or near the cleanup site, or the percentage most likely to have a source away from the site with debris arriving by sea. Only 7 of the sampling events were estimated to have more than 50% of the material sourced from the sea.

### ***3.2. Shipping, commercial vessels and marine infrastructure***

The Torres Strait lies to the north and north east of Cape York and separates Australia and PNG. It is about 90 nautical miles wide and 150 nautical miles long although useable routes for larger commercial vessels are limited to the Prince of Wales Channel and the Great North East Channel. The area lies within the exclusive economic zones of Australia and PNG and includes some areas of the territorial sea and internal waters of both countries. A number of major

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<sup>2</sup> Tangorua Blue Foundation unpublished. Summary of marine debris data from the Tangorua Blue Foundation Australian Marine Debris Database. Supplied October 2012.

international shipping channels tranverse Torres Strait and this region of Australia forms a pivotal entry passage to the east coast shipping channels for international shipping servicing eastern Australian ports. The shipping risks in the Torres Strait naturally divide into: 1) an area of localised risk associated with the activities in Port Kennedy on Thursday Island and smaller marine infrastructure; and 2) the much greater risks associated with large ships transiting the Prince of Wales and Great North East Channel.

### **3.2.1. Marine infrastructure and local vessels**

#### **Port Kennedy, Thursday Island**

The Ports Corporation of Queensland (PCQ) administers Port Kennedy (Port of Thursday Island) (Figure 4 and 5) in the Torres Strait. Port Kennedy is a small port handling general cargo for the Torres Strait region. The majority of the port infrastructure is located on the southeastern side of Thursday Island (east Ellis Channel). Port facilities include the main cargo wharf that comprises a naval berth, customs berth and commercial berth; fuel wharf facility; a wharf to accommodate recreational vessel berths and local passenger vessels; public and commercial mooring pontoons; floating buoys and channel markers; and the Horn Island wharf (west Ellis Channel).

Supplies of diesel fuel and petrol fuels are landed at Thursday Island and nearby Horn Island for distribution in bulk, intermediate bulk containers or 200 litre drums to other islands within the Torres Strait Protected Zone (identified in Figure 1). Most islands within Torres Strait have barge ramps specially constructed for resupply of stores including fuel. While these light oil products do constitute a threat to the local marine environment they generally disperse and evaporate rapidly if spilled.

The southwestern side of Horn Island (southwest Ellis Channel) has anchorages for confiscated vessels, mostly apprehended illegal fishing vessels. Ellis Channel is subject to significant public vessel traffic originating from islands adjacent to Thursday Island and remote areas of Torres Strait, PNG and mainland Australia. Such traffic includes small and medium commercial passenger vessels and small-to-medium cargo vessels with regular cargo and passenger vessels from mainland Australia.

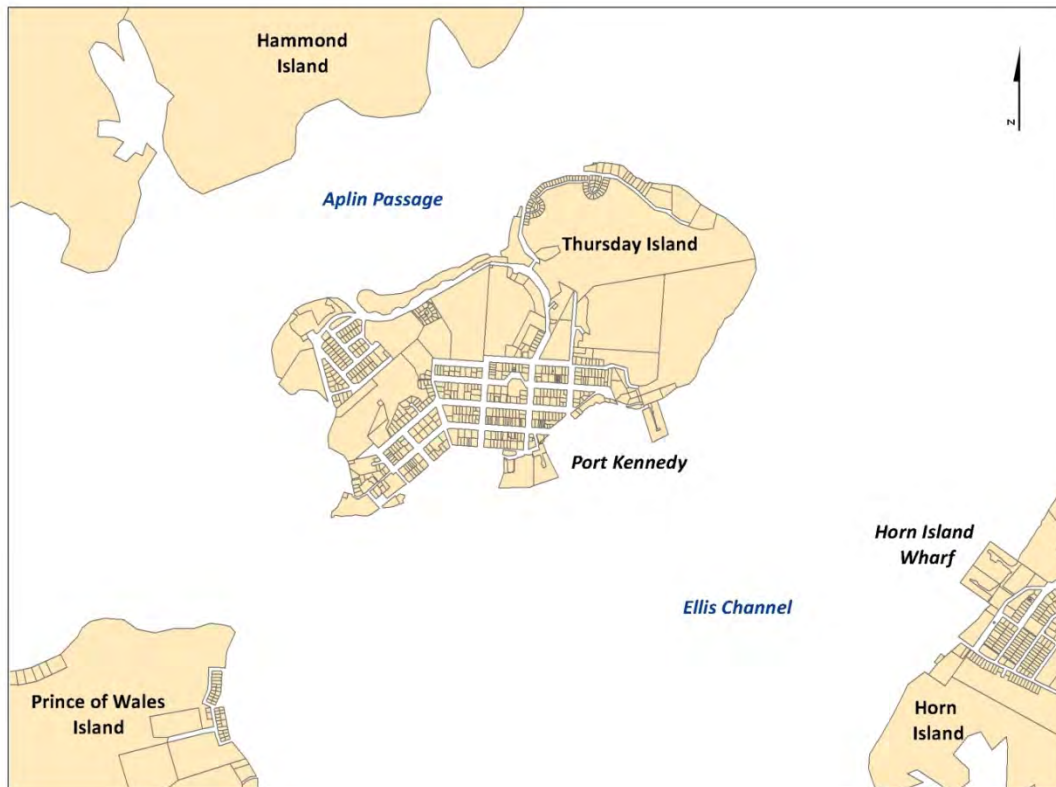


Figure 4. Map showing the location of Port Kennedy in southern Torres Strait.



Figure 5: Port Kennedy Port Limits. Source: MSQ, (2011).



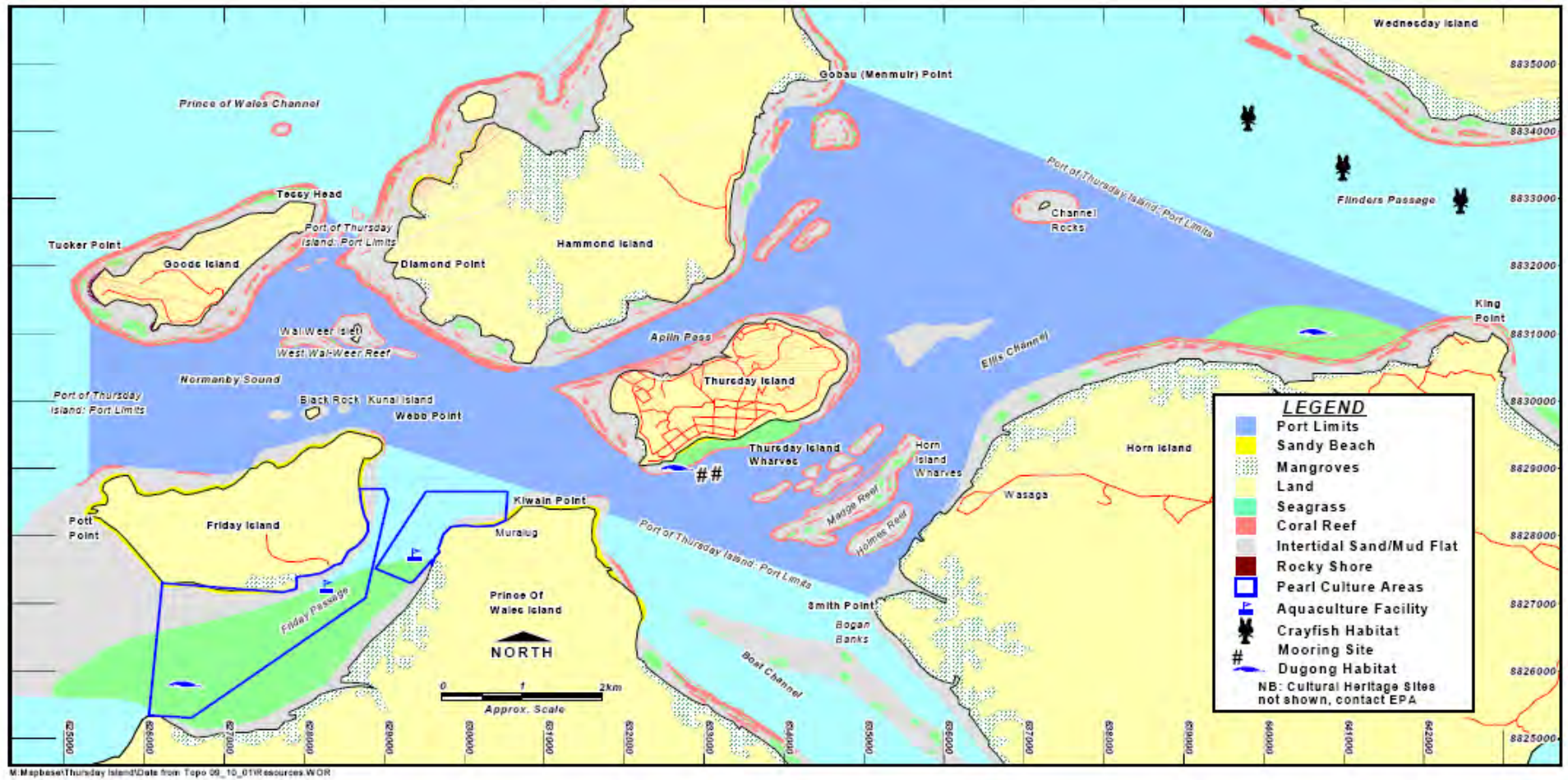


Figure 6: Marine resources of the Port Kennedy area, Thursday Island. Source: MSQ, 2011.

An Oil Spill Response Plan has been developed for Port Kennedy, last revised in April 2011. The plan includes a threat assessment (see marine resources in Figure 6) and identifies actions as a first strike response to oil spills from ships and other marine sources within the port of Thursday Island (Port Kennedy).

### **Introduction of pest species**

The Torres Strait region supports a number of critical fisheries habitats and ecosystem resources which sustain much of the local economy. Due to the high level of international and domestic vessel traffic through the region, Torres Strait marine communities and their economic and ecological values are at high risk from invasive marine species (IMS). Torres Strait has a sill depth of about 12 metres (Harris, 2001) and many large bulk carriers discharge ballast water in order to pass through the strait. Neil et al. (2008) studied the risks associated with pests introduced from ballast water and as hull fouling. They concluded that the Torres Strait region is at current risk of marine pest inoculation, particularly for species such as the blackstriped mussel (*Perna viridis*). However, the baseline survey conducted within the Port Kennedy area did not detect any marine pests of concern for Australian waters, despite the potential for either the blackstriped mussel or the Asian green mussel to have been introduced to the area. The findings from the survey were consistent with other surveys for marine pests conducted within northeastern Australia. The survey was, however, a snapshot in time and since that baseline was collected regular ongoing monitoring or surveying for marine pests in this region has not been conducted in a considered manner and the area remains at risk. Management strategies to minimise the risks of marine pest inoculations such as the establishment within Biosecurity Queensland of a specialist group and the development of the National System for the Prevention and Management of Marine Pest Incursions are being implemented.

### **Vessel sewage**

The Torres Strait supports a commercial fishing fleet which includes licensed vessels in the prawn fleet, rock lobster fishery, Spanish mackerel fishery and trochus fishery. There are also several hundred traditional inhabitant vessels authorised for the rock lobster fishery, net fishery, and beche de mer fishery. The potential water quality impact associated with these vessels is the discharge of sewage, and to a lesser extent, the release of antifoulant products from the hulls. The Queensland Government has a comprehensive policy for the discharge of sewage from vessels (depending on the number of people on board) in different waterbodies that is aimed at managing the potential risks of vessel discharge to environmental and human health (MSQ, 2010). This policy prevents discharge of untreated sewage in a marina or boat harbor, or in proximity to a person in the water, aquaculture fisheries resources or a reef and specifies distances depending on the level of treatment received. While many of the commercial vessels would often be anchored in concentrated areas, it is unlikely that the number of occupants on board would generate sewage at a volume to pose a risk to local water quality.

#### **3.2.2. Transit shipping**

The major shipping routes for large ships that transit the Torres Strait is the Prince of Wales Passage and the Great North East Passage (Figure 7). The Prince of Wales route is used primarily by large vessels trading between ports in southern Asia, Australia and New Zealand, South America, PNG and Pacific Island nations although the majority of tanker traffic bound for the Australian east coast refineries also uses it to link with the outer route of the Great Barrier Reef. Vessels entering or leaving the inner route of the Great Barrier Reef also use the Prince of Wales Channel at the western end of the Torres Strait.

The Great North East Channel also provides an important access point to the Torres Strait. The Alert Patches are the point of divergence for vessels continuing through the Torres Strait and

those using the Inner Route of the Great Barrier Reef. Vessels leaving Prince of Wales Channel for PNG, other South Pacific ports, New Zealand or the American west coast, direct their course to the northeast via the Great North East Channel. The critical part of this passage is Vigilant Channel, where depths of 12.8 metres are found with strong tidal streams. Pilots board and leave vessels at Dalrymple Island near Masig Island.

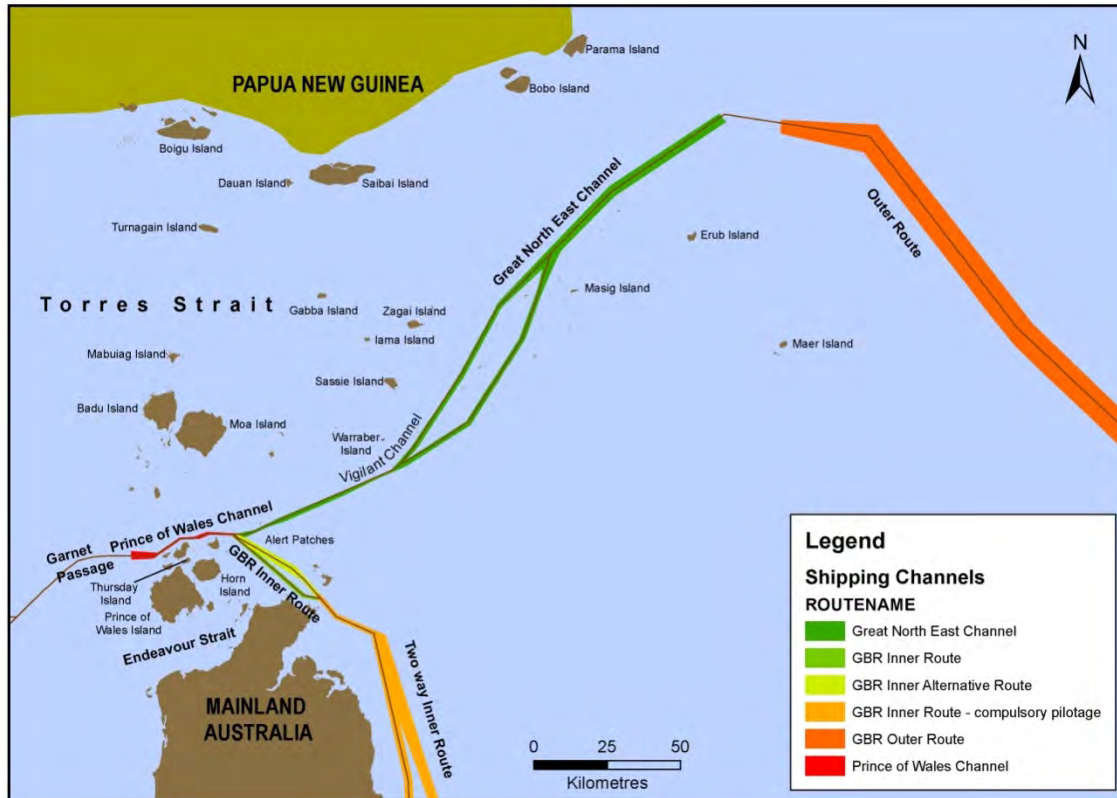


Figure 7: Torres Strait shipping routes.

There are approximately 3000 transits of Torres Strait per year by vessels of length overall greater than 50 metres. Traffic comprises bulk carriers 38%, general cargo 28%, containers 15%, loaded tankers 12% (MSQ, 2011).

The shipping route through Torres Strait is confined in both width and depth. Parts of the Torres Strait are isolated, remote and very demanding on the navigator. Passage through these waters also involves navigation within confined waters for long periods, with limited water depths being a constant threat. The average depth of the Torres Strait is 30-50 metres in the east and 10-15 metres in the west. Careful calculations are required by Masters and pilots of deep draft vessels to establish the timing of "tidal windows" for their passage through the Torres Strait. Tidal streams can be strong and variable. Most of the region has a monsoon climate and visibility is frequently adversely affected by seasonal rain squalls. The area as a whole is subject to seasonal tropical storms and cyclones.

Two or three deep-draught vessels are often forced to manoeuvre in the same confined stretch of water as they make use of the available tidal height. There are narrow fairways and areas of converging traffic that, while not heavy by some standards, represent a wide range of ship types, carrying a variety of cargoes, including dangerous goods and potentially polluting materials. Ships navigating the area may encounter concentrations of fishing vessels, tourist vessels and recreational craft that, by their very numbers, increase the dangers of marine incidents. A major collision or grounding incident in these confined waters has the potential to

close the strait which would then force deep draught vessels to take long diversionary routes. The economic consequences of this have been assessed as significant (AMSA, 2012).

When considering potential hazards the types of substances carried on the ships transiting these areas is also important. In the absence of any limitations on the movement of particular types of cargo, the full range of materials listed in the International Maritime Dangerous Goods Code (IMDG Code, 2002) are carried through these waters, either as containerised deck cargo or in bulk. This includes hazardous wastes, chemical products and raw materials (including pesticides), bulk fertilisers, bulk cereals, crude oils, fuel oils and petroleum products, bulk coal, mineral concentrates, etc. Very few cargoes, if released in the event of a maritime incident, would not have an environmental impact. Even a completely inert cargo, such as fine silica sand, could smother seagrass beds with a significant impact on dugong feeding and prawn and lobster breeding (IMO MEC, 2003).

Based on the information above, it is concluded that the principal risk to the marine environment of Torres Strait is from larger trading ships that could sustain damage during a grounding or collision event. For example, a grounding event could result in the release of up to 700 tonnes of heavy fuel oil whilst a collision involving an oil tanker could result in a spill in excess of 20 000 tonnes of crude oil. The stranding of a fishing vessel on an isolated reef, possibly away from recognised shipping routes could also result in a spill of up to 5000 litres of diesel fuel and other oil products (AMSA, 2012).

In July 2005 the Great Barrier Reef Particularly Sensitive Sea Area (shown in Figure 8) was extended to include the Torres Strait, following submissions made to the International Maritime Organization (IMO) by the Australian and PNG governments. Particularly Sensitive Sea Areas (PSSAs) are areas of the marine environment that need special protection through action by IMO because of significance for recognized ecological, socio-economic, or scientific attributes where such attributes may be vulnerable to damage by international shipping activities.

Two associated protective measures were approved by IMO for application in the Torres Strait – a new two way shipping route and an extension of the system of pilotage that had applied in the Great Barrier Reef since 1990. These measures were selected to improve the safety of navigation in an area where freedom of movement of shipping is considerably inhibited by restricted sea-room, and where there are obstructions to navigation, limited depths and potentially unfavourable meteorological conditions.



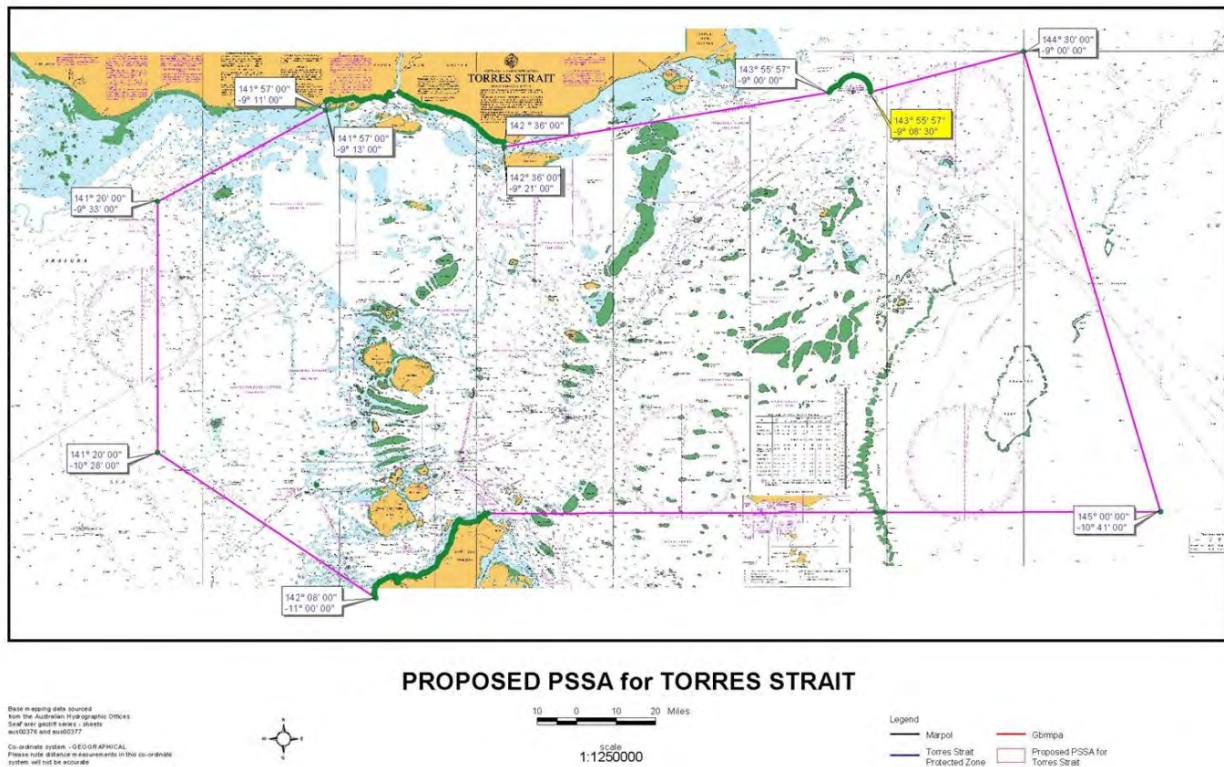


Figure 8: Map of the Torres Strait Particularly Sensitive Sea Area. Source: AMSA, 2012.

## Shipping routes

The Prince of Wales Channel (Figure 9) is the critical area of shipping risk in the Torres Strait Region. The channel has a charted 2 way route and in some cases a recommended track with navigational aids (Figure 10). The Prince of Wales Channel passes between the fringing coral reefs of Goods, Hammond and Wednesday Islands and is 1,500 metres wide at its narrowest point between Sunk and Mecca Reefs. At the eastern end of the Prince of Wales Channel the route is between Alert and Herald Patches, where the channel narrows to 800 metres. Both of these patches are sand waves. As described by Saint Cast (2008) this channel is subject to high rates of tidal stream and the tidal patterns are complex due to the confluence of two ocean systems in that area. The recommended maximum draft for ships passing through Gannet Passage in the western part of the Prince of Wales Channel is 12.2 metres which, for a large percentage of ships, provides an underkeel clearance of one metre at the higher stages of the tide cycle. Careful calculations are required by Masters and pilots of deep draft vessels to establish the timing of "tidal windows" for their passage through the Strait.

An extensive network of aids to aid in navigation including buoys, lights, sector lights, racons and day marks and a marine differential GPS exist, and where warranted, real-time transmitting tide gauges and a current meter provide information for under keel clearance management. The navigational aids are shown in Figure 10. In addition to the navigational aids, an automated position reporting system (REEFVTS) is available to enable the monitoring of shipping traffic with systems that can automatically identify ships that stray from 'typical' or 'usual' tracks. The hatched area in Figure 10 shows the scope of coverage of the system.



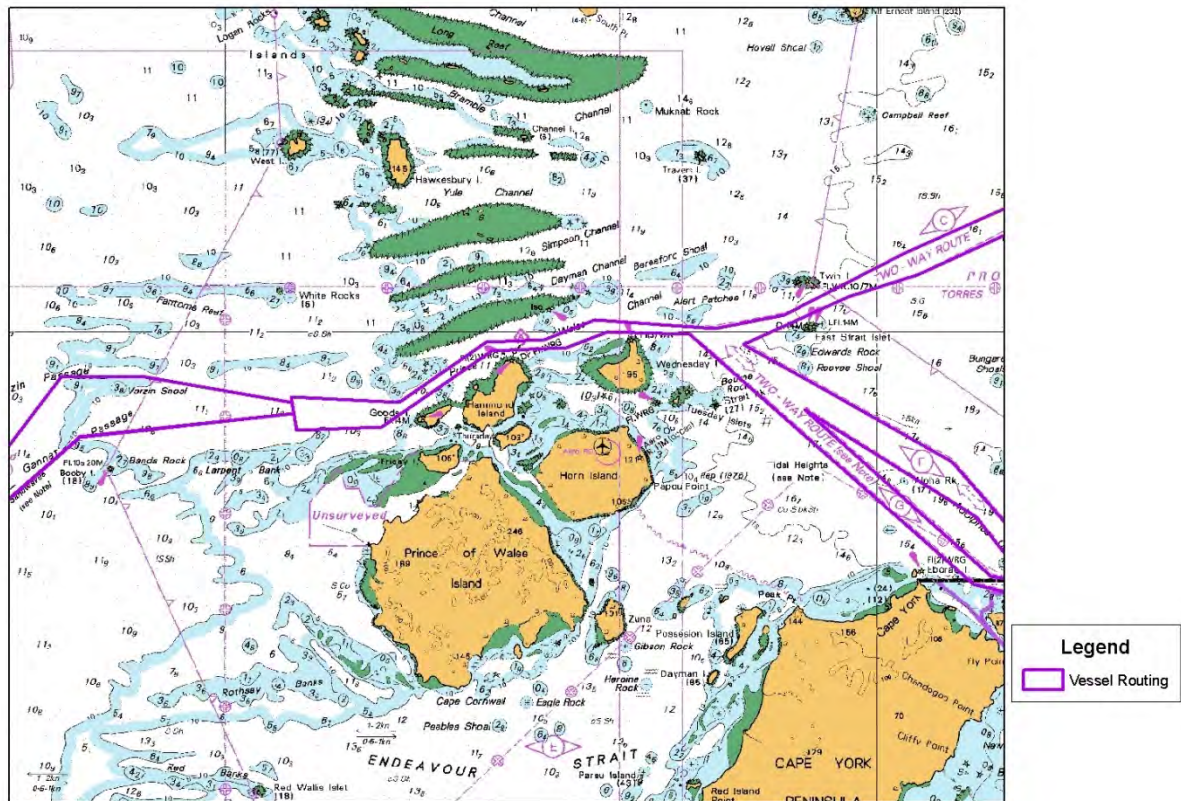


Figure 9: Prince of Wales Channel charted route. Source: AMSA, 2012.

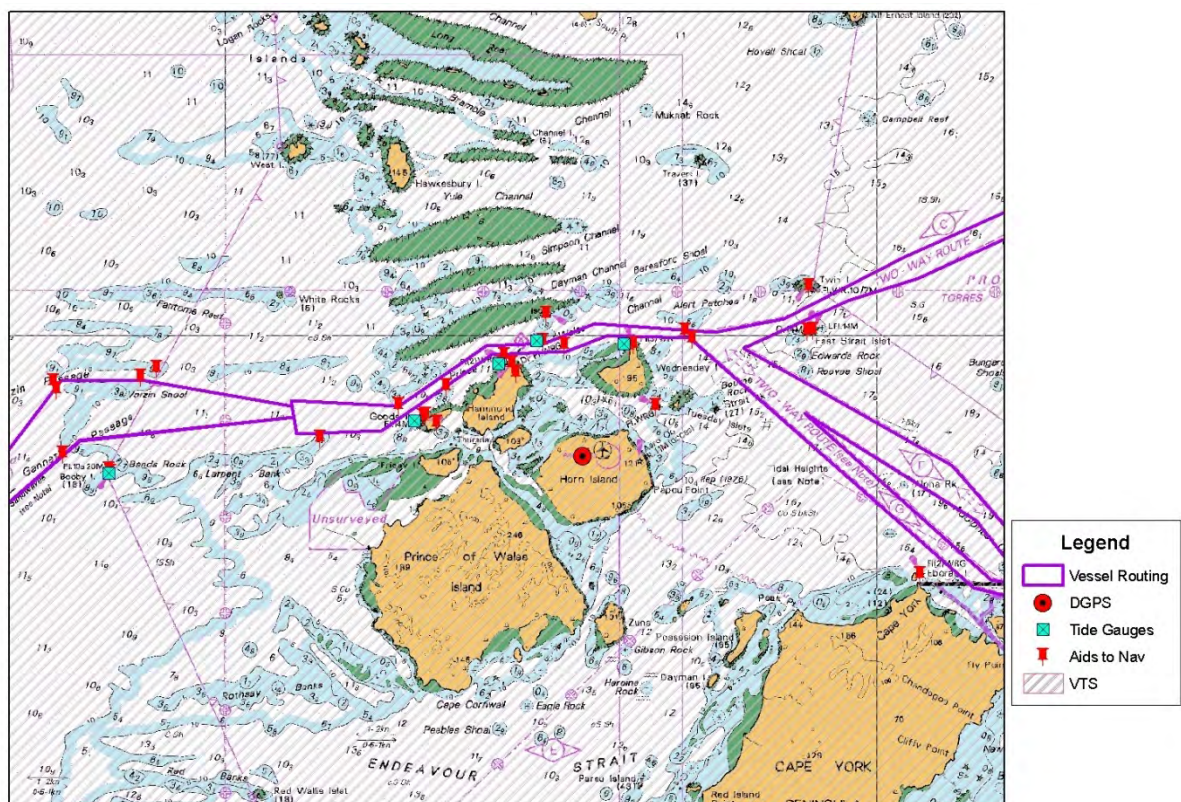


Figure 10: Navigation aids and scope of the REEFVTS in proximity to the Prince of Wales Channel (diagonal shaded areas). Source: AMSA, 2012.

The following information is extracted from Bateman (2010) explaining the pilotage system in the Torres Strait.

The Prince of Wales Channel also has a pilotage system. The IMO adopted a resolution in 1987 promoting voluntary pilotage in the Strait<sup>3</sup>. This was extended further with a 1991 resolution, superseding the earlier one, recommending that certain classes of vessel use a pilot when passing through the Torres Strait and Great North East Channel. While these recommendatory regimes were initially reasonably successful, non-compliance increased significantly. Data from 1995 and 2001 shows that while 70% of vessels on eastbound voyages were taking a pilot in 1995; this figure had fallen to 32% by 2001. Similar figures for westbound voyages were 55% and 38.5%. These figures equate to about 500 un-piloted transits each year. As a consequence, Australia and PNG agreed that the risks of a major shipping incident in the Strait leading to serious pollution of the area were unacceptably high, and jointly proposed an extension to the existing Great Barrier Reef PSSA to include the waters of the Torres Strait (see Figure 8). This was approved in July 2005 through a resolution regarding governments informing ships flying their flags to comply with the system of pilotage introduced by Australia.

This provides ship masters with expert local knowledge to assure the highest levels of navigation safety possible. In 2006 Australia introduced domestic legislation for a new compulsory pilotage area for the Torres Strait and Great North East Channel<sup>4</sup>. Australia has instituted measures to ensure that ships approaching the Torres Strait are notified well in advance of their approach of the need to take on a pilot when transiting the Torres Strait. Ships planning to enter Australia's EEZ are also required to report their intentions and are tracked using the Australian Maritime Information System (AMIS) managed by the Border Protection Command.

As a vessel approaches the Torres Strait, its Automatic Identification System (AIS) transmissions are detected by AIS shore stations and later used to enhance tracking along with shore-based radar. Within the vicinity of the Prince of Wales Channel, it will also be identified by a remotely operated video camera on Hammond Rock at the narrowest part of the channel. Should a vessel not take a pilot and fail to identify itself, it will be positively identified by surveillance aircraft and subject to legal proceedings when it next enters an Australian port. No attempt will be made to physically enforce the compulsory pilotage regime by denying passage.

The pilotage area is shown in Figure 11.

Figure 12 shows an example of shipping reporting data for the Australian coast. It highlights the density of traffic in a narrow section of the region.

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<sup>3</sup> Use of Pilotage Services in the Torres Strait and Great Barrier Reef Area, IMO Resolution A.619(15), adopted 16 November 1987.

<sup>4</sup> Australian Marine Notice 8/2006 and associated Marine Orders Part 54.



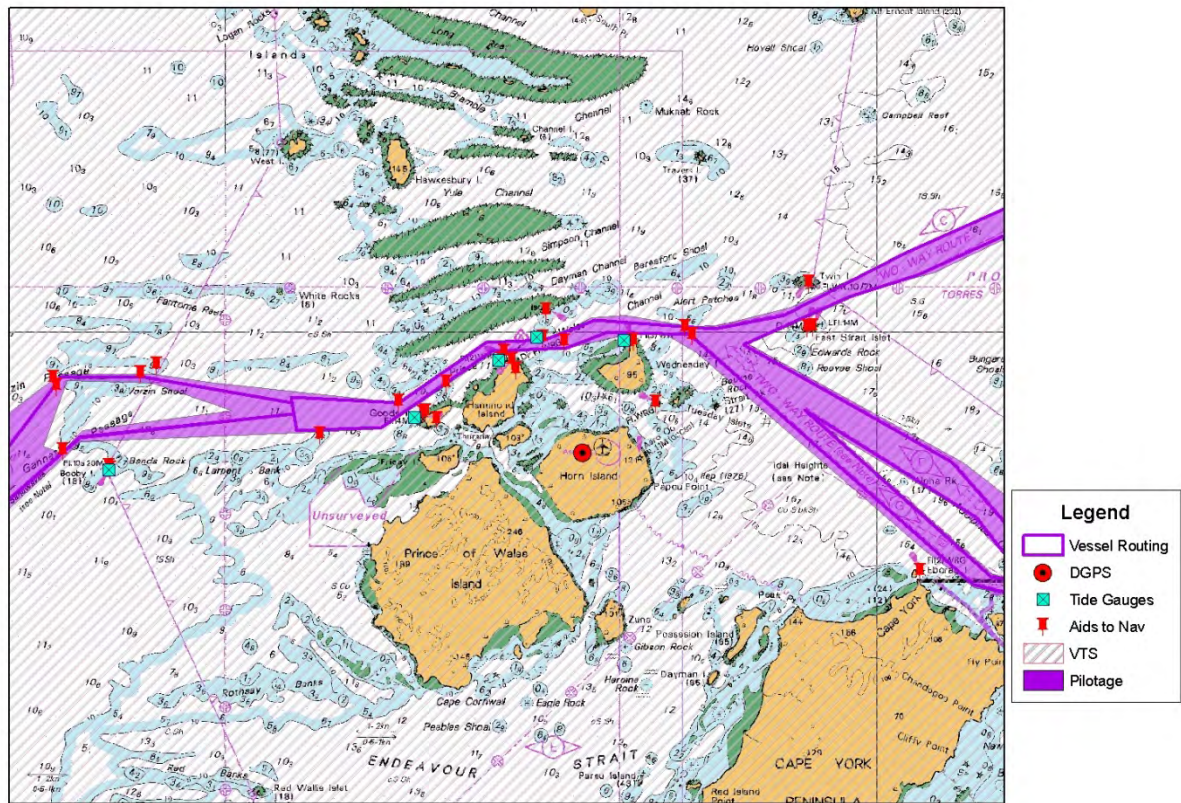


Figure 11: The defined pilotage area for the Prince of Wales Channel. Source: AMSA, 2012.

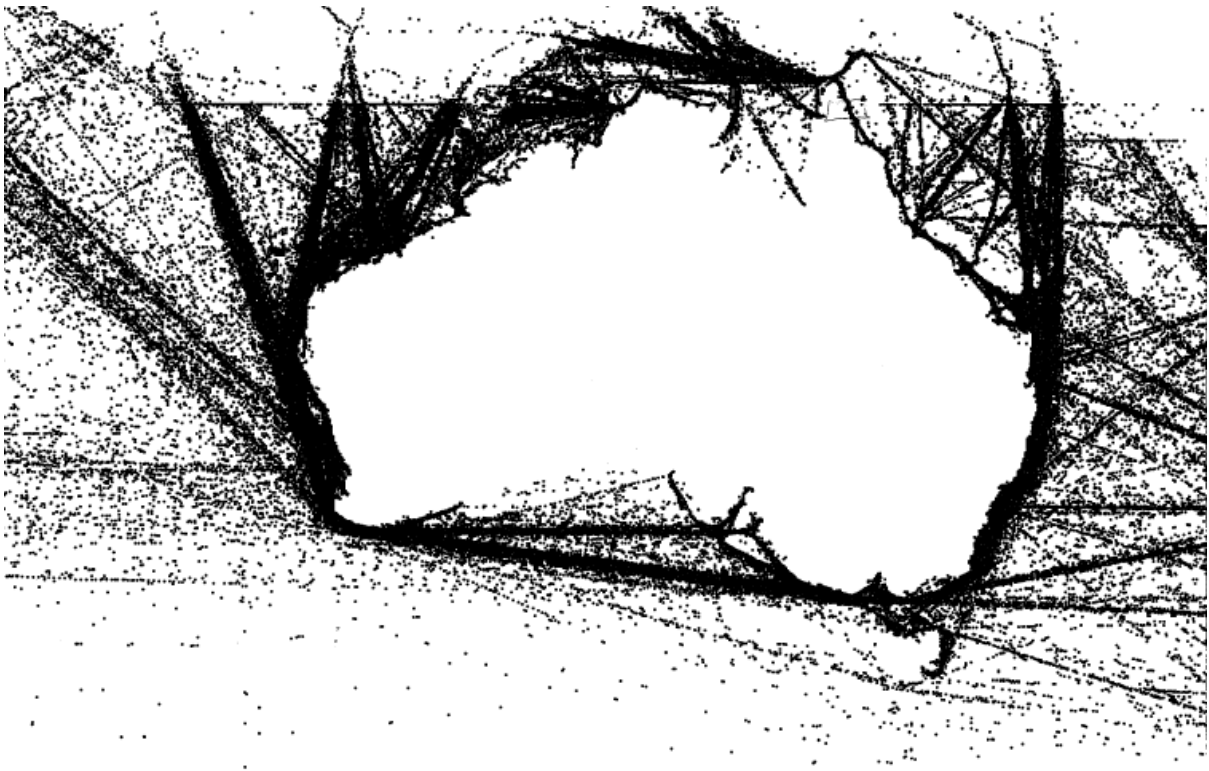


Figure 12: An example of AUSREP shipping reporting data, 2009. Source: DNV, 2011.



In the Great North East Channel the navigation of Vigilant Channel is also of considerable intricacy as it requires two major course changes exposing large ships to substantial windage problems and the consequence of the east-west tidal set on the beam (IMO MEC, 2003).

The Endeavour Strait lies between the Australian mainland and Prince of Wales Island in the south western sector of the Torres Strait region. Endeavour Strait can only be used at present by small ships as the western end is blocked by a sand bank with depths of between 6 and 7 metres. The remainder of Endeavour Strait appears to have depths of 10 to 15 metres (IMO MEC, 2003). However, many of these survey depths were originally measured by leadline and cannot be considered accurate enough to be recommended for safe use by larger vessels. Most of the ships using Endeavour Strait are in the 50-70 metre range and operate from Queensland ports along the inner route of the Great Barrier Reef, trading into ports in the Gulf of Carpentaria and Torres Strait islands and this contributes to potential traffic conflicts in the PSSA.

### **Shipping incidents**

Marine incidents that have occurred in the Torres Strait between 1970 and 2008 are listed in Table 3. The two areas of greatest concern, having regard to navigational risk are Prince of Wales Channel and Vigilant Channel.

AMSA data provides the following summary of shipping incidents:

- A spill occurred in Prince of Wales Channel in 1970 (Oceanic Grandeur) and numerous other groundings and near misses have occurred due to the combination of shallow water, narrow channels, strong tidal streams and strong winds. The tanker Oceanic Grandeur grounded on an uncharted rock off Wednesday Island in the Torres Strait. Between 1,400 and 4,100 tonnes of oil was released sporadically over several weeks while a ship-to-ship transfer was undertaken to remove the cargo of 55,000 tons of crude oil. While the oil impacted mangroves on a number of islands, favourable weather conditions and use of dispersants minimised the extent of environmental damage. The impact on those mangroves affected by the spill is, however, still evident. A 1997 study found a recovery rate of 75% some 27 years after the oil spill (Duke et al. 1997).
- Another significant incident also occurred in September 2002 when the Philippines registered bulk carrier Aegean Falcon grounded on Herald Patches in the Torres Strait near the eastern end of Prince of Wales Channel. There was no pilot on board the vessel at the time of the grounding. While in this incident the vessel grounded on a sandy bottom and was refloated without any pollution damage, the vessel was well outside the normal shipping route, and there was potential for a major spill. Had the vessel not grounded on the sandy bottom, it is highly likely that the vessel would have grounded on a rock outcrop several nautical miles further along the vessel's intended track (IMO MEC, 2003).
- NOL Amber ran aground on Larpent Banks in November 1997 while waiting for sufficient depth of water to enter the western approaches to Prince of Wales Channel.
- Many minor groundings, where no assistance is required, may go unreported (IMO MEC, 2003).

The impacts of these events can be detrimental to large areas of the region. For example, high mortality of oysters in pearl farms and serious depletion of major juvenile pearl collecting beds in the western Torres Strait followed an oil spill and clean up operation when the Oceanic Grandeur grounded in Torres Strait in 1970. Pearl oyster stocks are also subject to variation from natural causes including seasonal cyclonic weather patterns (IMO MEC, 2003).

The toxicity and persistence of TBT anti-fouling paint in the environment makes any ship grounding a potentially significant environmental issue with a high risk of long-term impact on local biodiversity at the grounding site. The high tidal streams in Torres Strait can readily spread the impact of the abraded anti-fouling paint over a much wider area. TBTs are of such high toxicity that they can have a detrimental impact on marine ecosystems at the level of a single nanogram per litre, that is one gram in a thousand megalitres. Minor groundings can also introduce invasive marine organisms with potentially serious long-term consequences on biodiversity.

Table 3: Reported marine incidents in the Torres Strait between 1970 and 2008. Source: AMSA.

Name of Ship	Flag	Incident type	Date	Location	Ship type / cargo
Oceanic Grandeur	Liberia	Grounding	Mar-70	TS Uncharted Rock	Oil tanker/crude oil
Wongala	Australia	Grounding	July-81	TS Bett Reef	Auxiliary Schooner
Maritime Gardenia	Liberia	Grounding	Aug-85	TS Alert Patches	Bulk/Wheat
Mobil Endeavour	Liberia	Grounding	Jul-86	TS Alert Patches	Tanker/Oil
River Embley	Australia	Grounding	May-87	TS Alert Patches	Bulk/Bauxite
Leichhardt	Australia	Grounding	Dec-87	TS Endeavour Strait	Ro/Ro
Gulf Tide	Australia	Grounding	Jan-91	TS Endeavour Strait	Mother Ship/Oil
TNT Carpentaria	Australia	Grounding	Oct-91	TS Harrison Rock	Bulk/Alumina
Darya Kamal	Hong Kong	Grounding	Mar-93	TS Hammond Rock	Bulk/Coal
M Nuri Cerrahoglu	Turkey	Grounding	Nov-94	TS Larpent Bank	Bulk/Coal
Carola	Germany	Grounding	Mar-95	TS Sth Ledge Reef	Containers
Thebes	Egypt	Grounding	Jun-97	TS Larpent Bank	Light
Dakshineshwar	India	Grounding	Jul-97	TS Wednesday Island	Coal
No I Amber	Singapore	Grounding	Nov-97	TS Larpent Bank	Containers
Aegean Falcon	Philippines	Grounding	Sep-02	TS Herald Patches	Bulk carrier (loaded in Dalrymple Bay / Hay Point)
Not released	Korea	Close grounding – missed by 150m	Aug-05	TS Hammond Rock	General cargo
Not released	Panama	Grounding	Feb-08	TS Larpent Bank	General cargo

### **National Oil Spill Risk Assessment**

In 2011 an assessment was undertaken of the risk of pollution from marine oils spills in Australian ports and waters (DNV, 2011). The report contains comprehensive information on factors that determine potential risk to the environment, including those of the Torres Strait. For example, Figure 13 shows the overall frequencies of spills exceeding 1,100 and 10,000 for each sub region. The Torres Strait region is High in the west and Moderate in the east. An Environmental Sensivity Index was also developed as part of the assessment (not shown); the Index in the Torres Strait region is low in the west and very high in the east. An Environmental Risk Index (Figure 14) shows the Torres Strait region to be Moderate in the west and High in the east.



Figure 13: Frequencies of spills greater than 1 tonne. Source: DNV, 2011.

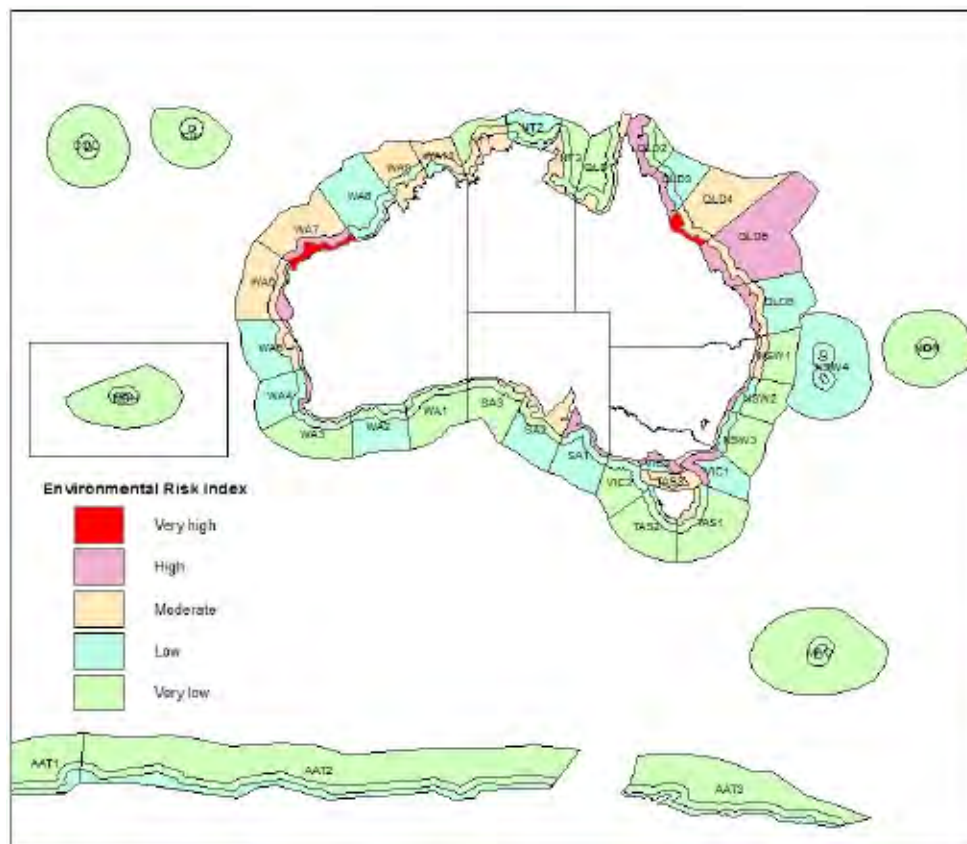


Figure 14: Environmental Risk Index developed as part of the National Oil Spill Risk Assessment. Source: DNV, 2011.

### **3.2.3. Oil Spill Response Capacity**

The oil spill response capacity for the Torres Strait is documented in '*TorresPlan – Marine Oil Spill Response Plan for Torres Strait – A supplement to the Queensland Coastal Contingency Action Plan*' (Queensland Transport Maritime Division, 2001). TorresPlan applies to spills of oil from ships that impact or are likely to impact:

- all waters and foreshores of Torres Strait encompassed by the Protected Zone;
- all waters and foreshores within the adjacent zone incorporated in REEFPLAN; and
- all waters and foreshores enclosed by a line extending from the south-west corner of the Protected Zone to Crab Island off western Cape York.

The plan is a supplement to and must be read in conjunction with parts 1-8 of Queensland Coastal Contingency Action Plan. Other related documents include:

- First-strike oil spill response plan for the port of Thursday Island (Port Kennedy) – see Appendix 28 of QCCAP.
- Ports Corporation of Queensland Emergency Response Plan for the port of Thursday Island.
- REEFPLAN, the marine pollution contingency plan for the Great Barrier Reef Marine Park. This is also a sub plan of the National Plan.
- AMOSPLAN – the Australian oil and associated industries oil spill contingency plan.
- The Chevron Niugini Pty Ltd Oil Spill Contingency Plan developed for the Kutubu Petroleum Development project.

The Plan includes an assessment of the environmental sensitivity of several locations to oiling. The grading is based on the relative socio-economic and biological importance of a site or an area, and has been developed to prioritise the most important sites in the proximity of the shipping channel. In this assessment six locations are assessed to be Extremely Sensitive to oiling, including:

- All home reefs in the Twin Island to Warraber Island
- Vigilant Channel - Warraber Island home reef
- Vigilant Channel - Bet Island Reef
- Sassie Island and surrounding reef (Vigilant Channel to Bramble Cay - Great North East Channel)
- Bramble Cay
- Crab Island

The National Plan holds a wide strategic range of response equipment at nine regional stockpiles (see map in Figure 15). Equipment provided by AMSA is generally targeted at larger spills (Tier 2 and 3). This is complemented by equipment held by port authorities for Tier 1 spills, individual oil and chemical companies and by the Australian Marine Oil Spill Centre (AMOSOC) stockpile in

Geelong. AMOSC operates Australia's major oil spill response equipment stockpile on 24 hour stand-by for rapid response anywhere around the Australian coast to the scene of a spill.

Types of equipment include oil spill control booms of varying types and sizes, self-propelled oil recovery vessels, static oil recovery devices and sorbents. A range of storage devices including free standing tanks, and towable storage bladders and bags, complement recovery devices. Examples are shown in Figure 16. Equipment used for chemical spills depends on the type of chemical. Chemical substances have properties that vary widely and can damage or cause failure to some types of equipment. Appropriate chemical response and clean up equipment is identified by the chemical industry and fire authorities. Suitable oil response equipment may be used in a chemical spill.

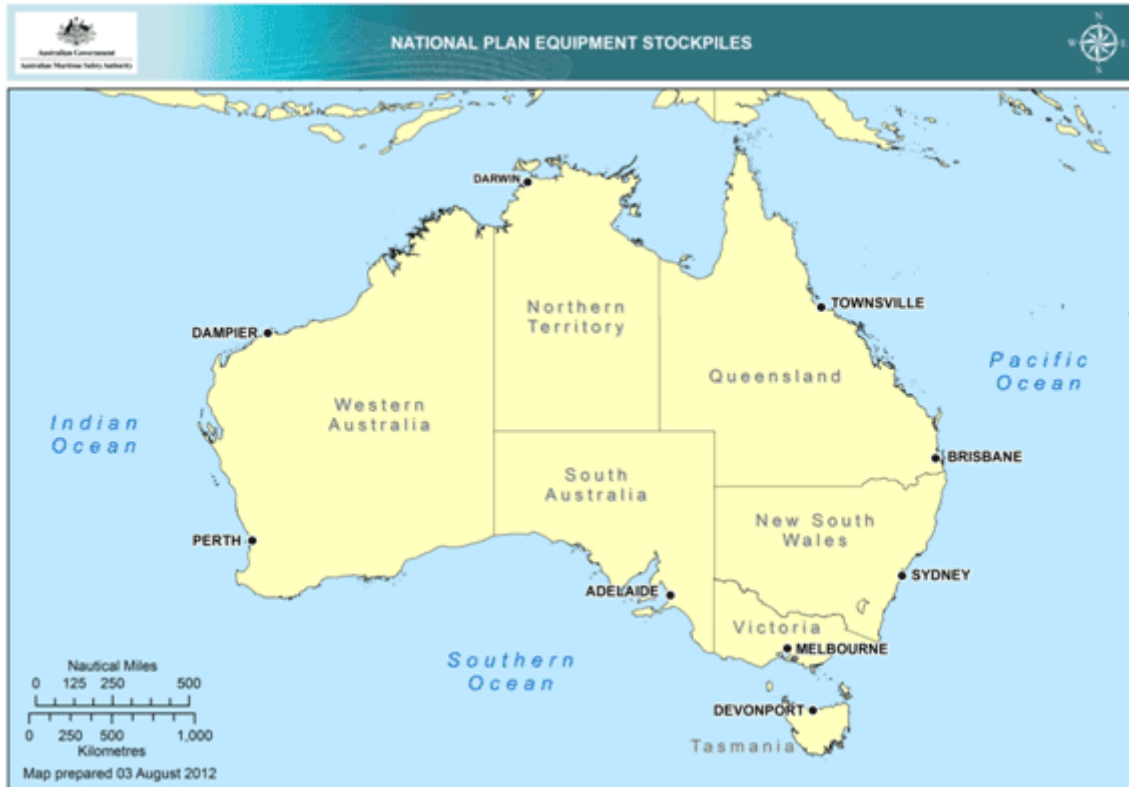


Figure 15: National Plan Equipment Stockpiles. Source: AMSA, 2012<sup>5</sup>.

<sup>5</sup> [http://www.minister.infrastructure.gov.au/aa/releases/2012/August/aa175\\_2012.aspx](http://www.minister.infrastructure.gov.au/aa/releases/2012/August/aa175_2012.aspx), accessed 1 December 2012.





Figure 16: Examples of oil spill response equipment.

#### ***3.2.4. Increased risk due to forecast increases in shipping traffic***

The shipping route through Torres Strait is already an obvious bottleneck for Australian east coast shipping traffic (Figure 17 – sourced from GBRMPA July 2012). With the expansion of ports, especially coal loading ports, on the Australian east coast in response to proposed large increases in coal export (GBRMPA 2011) large increases in shipping traffic along the Queensland coast are predicted as shown in Figure 18.

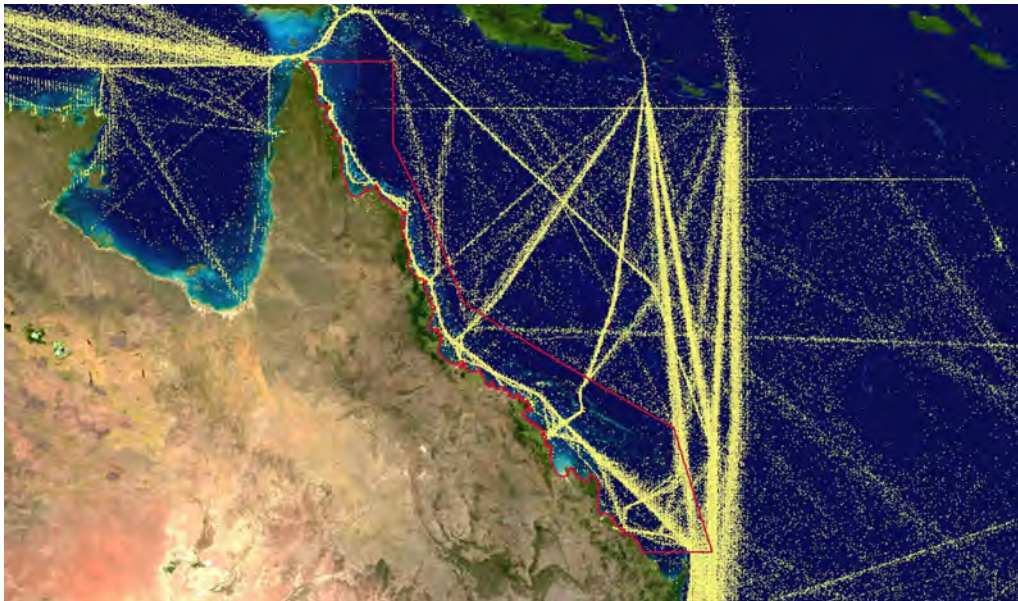
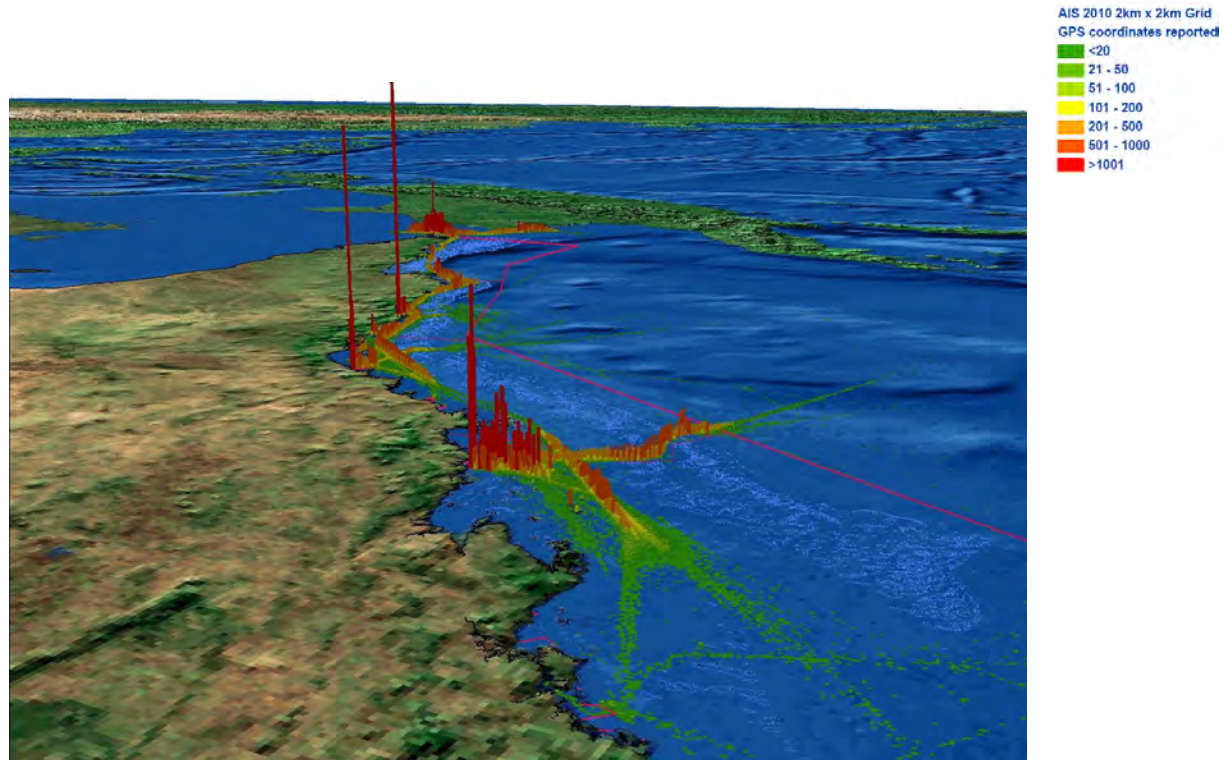
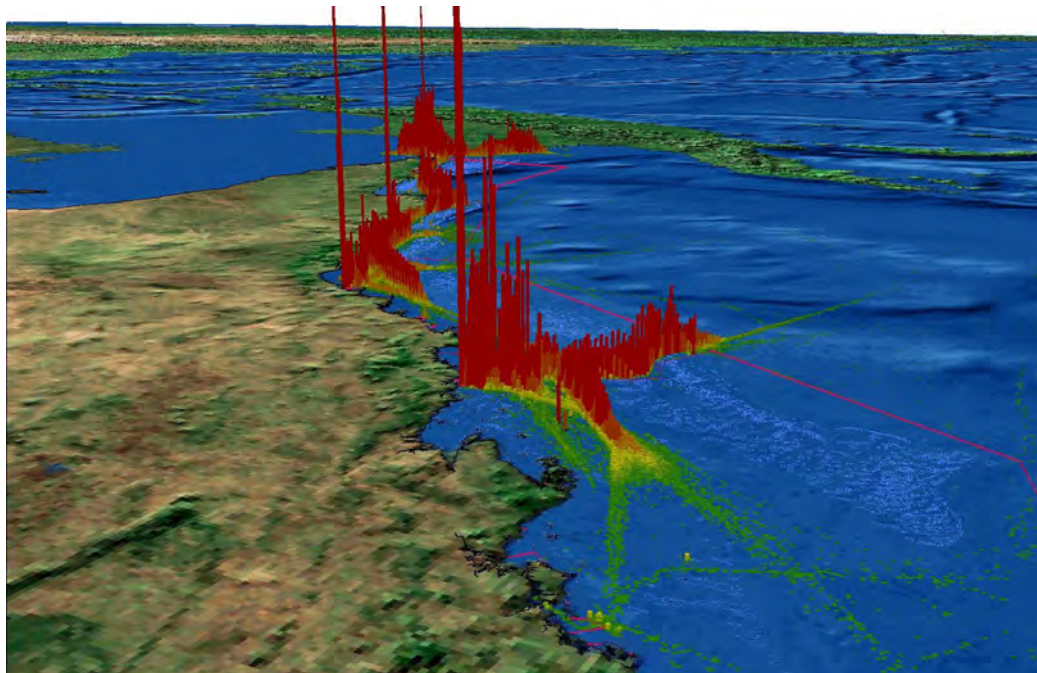


Figure 17. Shipping traffic in north east Australia. Source: GBRMPA, supplied July 2012.



a.



b.

Figure 18. Estimated shipping traffic with a modeled threefold increase in shipping from 2010. (a) AIS Reports 2010 in GBR on a 2 x 2 kilometre grid to (b) expected trend using a trebling of reports for future shipping volumes. Shipping traffic is represented by the height of the line and colour with red having highest frequencies and green showing lowest frequencies. Source: GBRMPA (2012).

Additional increased shipping through the Torres Strait is also likely to occur from the construction of a major port at Daru. Under these scenarios a large increase in shipping traffic through the Torres Strait is predicted over the next decade. These increases will result in greatly

increased risk of accidents in the Torres Strait. Currently there is very limited capacity to respond in any meaningful way to a large oil spill in the region. The area is remote in Australia with strong winds and currents and a matrix of reefs and islands on which oil could impinge. Any large oil spill would have devastating consequences for the populated islands on which it landed as well as severe environmental consequences. While new management strategies may mitigate the increase in risk we consider this increase in shipping traffic to be a major water quality and environmental threat to Torres Strait environment and people.

### ***3.3. Large scale developments in adjacent areas***

Information on large scale developments in the Torres Strait and surrounding areas has been collected as part of another NERP TE project (11.1) led by Dr James Butler from CSIRO<sup>6</sup>. A summary of present and proposed forestry concessions in PNG is provided in Table 4. These areas are mapped in Figure 19. The greatest threat to water quality from forestry activities is associated with increased erosion and sediment runoff, especially on steep land. The degree of influence depends on many factors including soil type, slope, rainfall and management practices. Oil palm development can lead to greatly increased sediment delivery to adjacent waterways especially in the forest clearing – first planting stage (Brodie and Turak, 2004). While erosion and sediment delivery abate with the maturation of the crop loss of fertiliser nutrients and pesticides is a potential ongoing issue. The development areas of greatest concern to the Torres Strait would most likely be constrained to the western parts of PNG in the area of the Fly River catchment. Discharge from the Mai River immediately to the north of Boigu may be more significant in delivering contaminants to Boigu as the catchment of the Mai is developed for crops such as oil palm.

Large areas of forestry concessions exist in western areas of PNG, including a large area on the northern part of the Fly River catchment called East Awin (186,000 ha) and Aimbak (area unknown). The Wipim Tipalia concession (244,000 ha) is located north of Daru in the southern reaches of the Fly River. Many concessions are recorded to be operating unlawfully. In addition, there is a very large (790,000 ha) concession that is proposed in western PNG that abuts one of the Fly River tributaries that is yet to receive formal approval. An inspection of Google Earth imagery shows that a large proportion of these areas appear to be bare ground on relatively steep slopes. However, further investigation would be required before any conclusive statements could be made regarding potential impacts on downstream areas.

A summary of present and proposed mining, oil and gas development in PNG is provided in Table 5. These areas are mapped in Figure 20. The largest existing developments in PNG are Ok Tedi copper and gold mine on the northern parts of the Fly River, Porgera gold mine in the highlands and Kutubu / Gobe Moran oil development with the associated Kumul terminal. There are many proposals for LNG, gold, silver and copper mines in PNG that may discharge into rivers that flow into the Torres Strait region. In addition, it is now almost certain the Ok Tedi mine will continue production for at least another 10 years instead of shutting down in 2014 as was suggested earlier. Given the possible role in introducing toxic metals into the northern Torres Strait via Fly River discharge this can only be viewed with concern given the absence of transparent monitoring programs as to the effects of the discharge in the lower Fly River and Torres Strait. While the TSBS showed little influence of Fly River discharge on metal levels in Torres Strait, the data is now 20 years old and it would be valuable to repeat the study (in a more limited way) to assess the changes since the early 1990s.

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<sup>6</sup> <http://www.nerptropical.edu.au/project/building-resilient-torres-strait-communities>

Using the information in Table 4 and 5 we conducted a preliminary analysis of proposed developments in western PNG. It is concluded that although large scale development is likely to occur, adverse effects in the Australian part of the Torres Strait are likely to be restricted to the northern islands – Boigu, Saibai, Erub and Ugar. This is because both the hydrodynamic modeling (Section 4) and remote sensing analysis (Section 5) show that excursions of water from the Fly River drainage basin predominantly move to the east into the northern Coral Sea and along the PNG coast towards Port Moresby and are uncommon to the west of the river mouth. In addition, the currents in this western region are generally from east to west both in the central Torres Strait and along the PNG coast. However construction and operation of a major port at Daru has the potential to lead to excursions of contaminated water along the PNG south west coast and this is likely to Saibai and Boigu.

Table 4. Summary of present and proposed forestry concessions in PNG. Source: Butler et al. (2012).

Province	Forest area	Concession size (ha)	Concession	Permit holder	Comments	References
Present concessions						
Western	Wipim Tapila	244,000	1996	Forest Management Services Ltd (PNG)	At present WWF is planned to assist in the establishment of a Forest Stewardship Council certified forestry project	WWF 2007 Forest Trend 2006
Western	Kiunga to Aimbak	Not known	No proper FMA*, the project was originally based on a Timber Authority for road construction – In 2003 the project was halted by courts	Concord Pacific (Samling)	Logging road with substantial log export. A review found that the project was in breach of both the National Forest Policy and the Forestry Act	Roger 2007 Forest Trend 2006
Western	Wawoi Guavi	448,300	Timber Permit in 1992 with extension in 2002	Rimbunan Haijau (Malaysia)	A review found faults in the engagement process of landowners, in the application of legal requirements for sustainability and in the application of a legal process	Roger 2007 Forest Trend 2006
Western	Makapa	301,500	Timber Permit in 1991 and extended in 2003	Innovision		Forest Trend 2006
Western	East Awin	184,000	Timber Permit in 2003	CS Bos Ltd (Malaysia)	Even though in 2004 the Permit was void by courts the activities have continued	Forest Trend 2006
Western	Semabo	54,000			At 2006 the logging project had not started yet	Forest Trend 2006
Gulf	Vailala blocks 2/3	268,000	Timber Permit in 1992 with extension in 2002	Rimbunan Haijau (Malaysia)	Timber Permits found to be unlawful but logging activities have continued	Forest Trend 2006
Gulf	Vailala block 1	113,400	Timber Permit in 1991 with extension in 2003	Rimbunan Haijau (Malaysia)		Forest Trend 2006



Province	Forest area	Concession size (ha)	Concession	Permit holder	Comments	References
Future concessions						
Western	Kamula Doso	790,000	1998, declared not valid in 2010 The area is still to be given in concession. There is a dispute in between an agroforestry and a conventional logging project. A former carbon trading scheme has been ruled out.	Rimbunan Haijau (Malaysia) - proposed		Filer 2012 Forest Trend 2006
Southern Highlands	East Pangia	98,750	In 2001 a Timber Permit was ready to be signed by landowners			Roger 2007
Western	Kinga to Nomad				Logging road which would become part of the Trans Papua Road – in assessment with DEC	Roger 2007
Southern Highlands	Hekiko	199,000	In 2001 a project agreement was toward completion To date concession passed from proposed to active			Roger 2007 Forest Trend 2006
Gulf	Hekiko	196,000	In 2001 a Project agreement concluded but did not progressed	Yeung Group Ltd - proposed		Roger 2007 Forest Trend 2006
Gulf	Vailala (Meporo)	79,000	In 2000 the project was at very early stages	Rimbunan Haijau (Malaysia)		Forest Trend 2006

\*Forestry Management Agreements (FMA) transfers timber harvesting rights from the landowners to the state in return for royalties and other benefits from a commercial logging operation, which the state alone can authorise (Filer 2012).

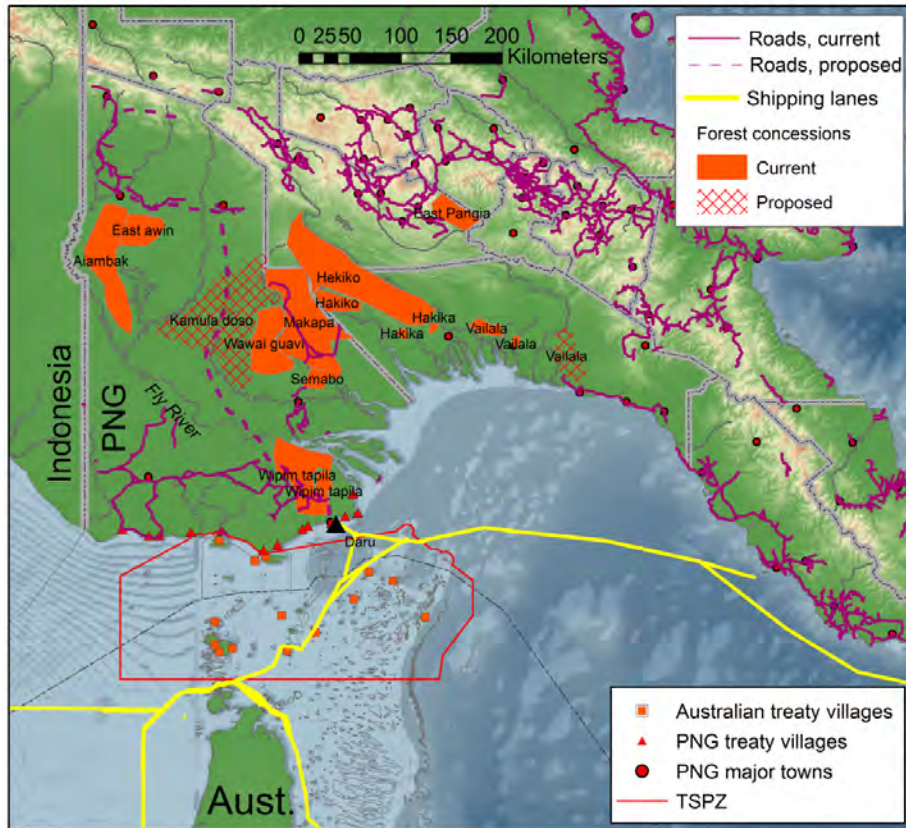


Figure 19. Mapped extent of current and proposed forestry concessions in PNG. Source: Butler et al. (2012).

Table 5. Summary of present and proposed mining and resource development in PNG. Source: Butler et al., (2012).

	Province	Development	Start	End	Shareholders	Infrastructures	Reference
Existing develop-ments							
Ok Tedi	Western	Copper, Gold	1984	2013 to 2022	Ok Tedi Mining Ltd (52%) PNG Government (15%) Inmet Ltd (18%)		Swales 2000 Smith 1990 Banks 2003
Porgera		Gold	1991	2015 to 2023	Barrick Gold (95%) Mineral Resources Enga (5%)		Gilberthorpe & Banks 2011
Kutubu/Gobe Moran		Oil	1992	-	Oil Search Ltd (53%) ExxonMobile Merlin PNG Govt BP Chevron (19%)	Kumul export terminal Underground pipelines to Kumul	Owen and Latimore 1998 Banks 2003
Planned develop-ments							
LNG PNG	Southern Highlands	LNG	2014	2042	ExxonMobile Oil Search Ltd	Gas conditioning plants	Dixon et al 2010



	Province	Development	Start	End	Shareholders	Infrastructures	Reference
	Western				PNG Government Santos Ltd Nippon Oil Exploration Petromin Mineral Resources Development Company	Underground pipelines to the coast LNG facility near Port Moresby	McGilraith 2011
Gulf LNG	Gulf	LNG	2014	-	InterOil Petromin	Underground pipelines to the coast Floating LNG facility LNG refinery near Port Moresby	Price 2012 InterOil Report 2011
LNG consortium	Western	LNG	2014	-	Horizon Oil Talisman Energy Eaglewood Energy	Underground pipelines to the coast Gas facility in Daru Deep water port in Daru Commercial centre in Oriomo Infrastructure corridor from Kiunga to Nomad and Balimo to the coast in Oriomo	Price 2012 PNG SDP Report 2009, 2010
Mt Kare	Enga	Gold, Silver	Feasibility study started 2011	-	Indochine mining Ltd	*Due to its position close to the Porgera mine it can replace it in the economic and ecological scenario of local populations once its operations will end	Indochine website
Frieda River	Sepik	Gold, Copper	Feasibility study started in 2010	-	Xstrata Highlands Pacific	*Shareholders envisage replacing the Ok Tedi mine once its operation will end by providing economic benefits, infrastructures, and services to highland communities	Xstrata Report 2010
Purari River	Gulf	Hydro-electricity	MoC signed recently	-	PNG Energy Development Ltd Origin Energy Limited	Undersea transmission cable to Daru and then to North Queensland, Australia. The project is	Origin website

	Province	Development	Start	End	Shareholders	Infrastructures	Reference
						planned to provide electricity to the area around Daru.	

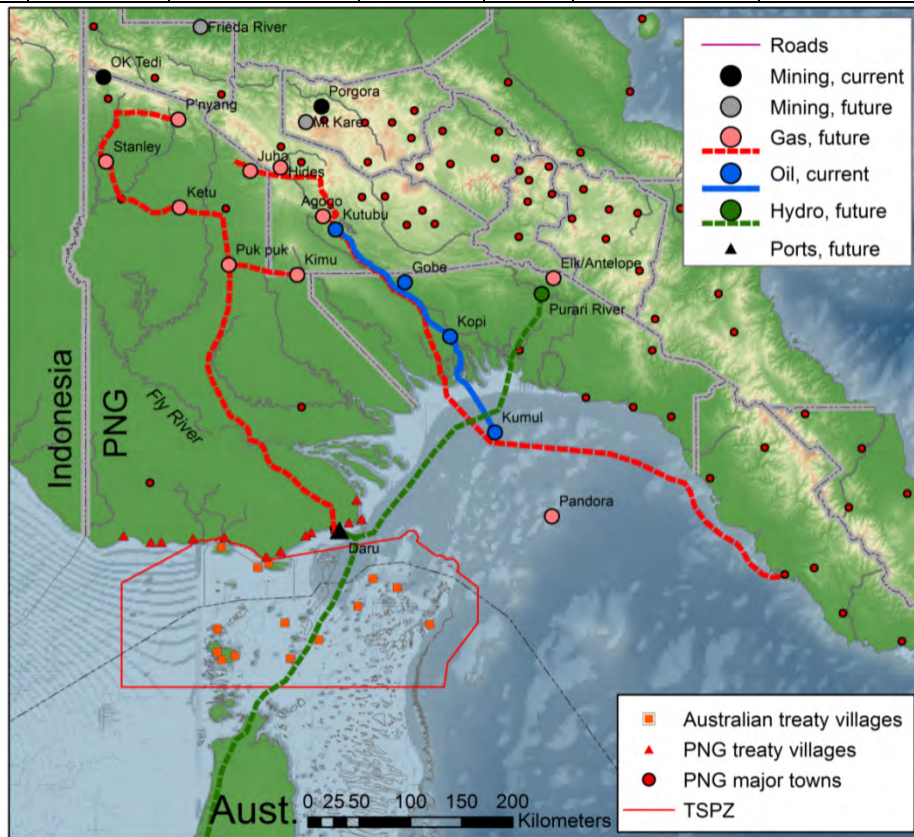


Figure 20. Location of present and proposed mining, oil and gas development in PNG. Source: Butler et al., (2012).

## 4. Hydrodynamics of the Torres Strait region

Many of the potential pollutant issues in the Torres Strait region are large scale and may be derived from areas outside of the region. An oceanographic model able to be used in the complex Torres Strait physical and ecological environment is required for confident predictions of pollutant transport from source to effect area. Overall, due to the shallow waters of Torres Strait, and the complex bathymetry that includes numerous reefs, islands, shoals and reef passages (Figure 21), a fine scale 2-dimensional model based on an extensive observational network is needed for the Torres Strait. Such a model must rely heavily on high quality oceanographic data because the water circulation in Torres Strait is very complex due to the complex bathymetry, the separate forcing by the Coral Sea and the Arafura Sea, as well as local forcing by the wind, waves and rivers including the Fly River (Figure 22). Even at present the sea levels are somewhat unpredictable and automatic real-time sea level observations are made and relayed by telemetry to passing ships.

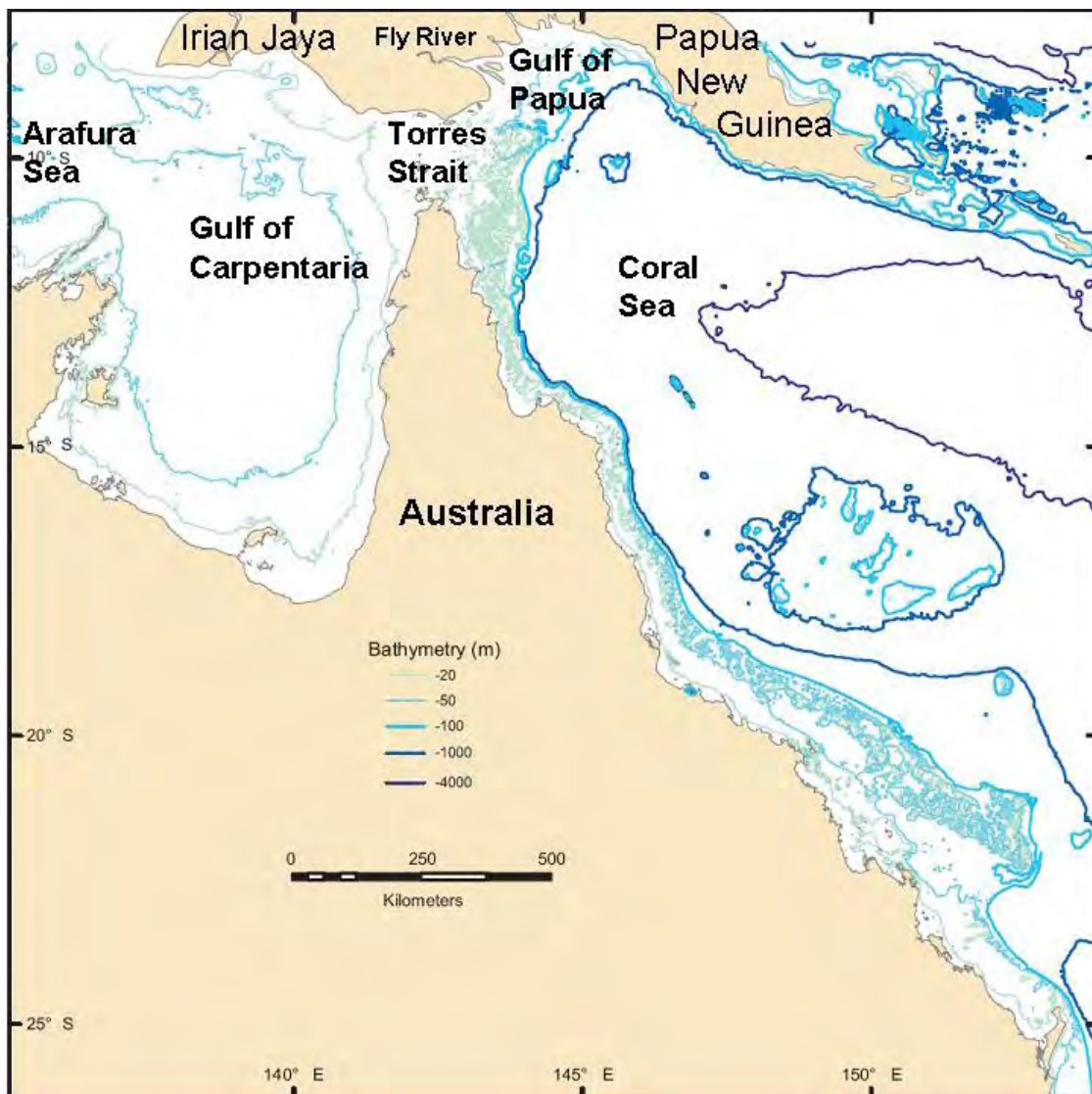


Figure 21. A general location map of the major water bodies in the Torres Strait with depth in metres.  
Source: Wolanski (2013).

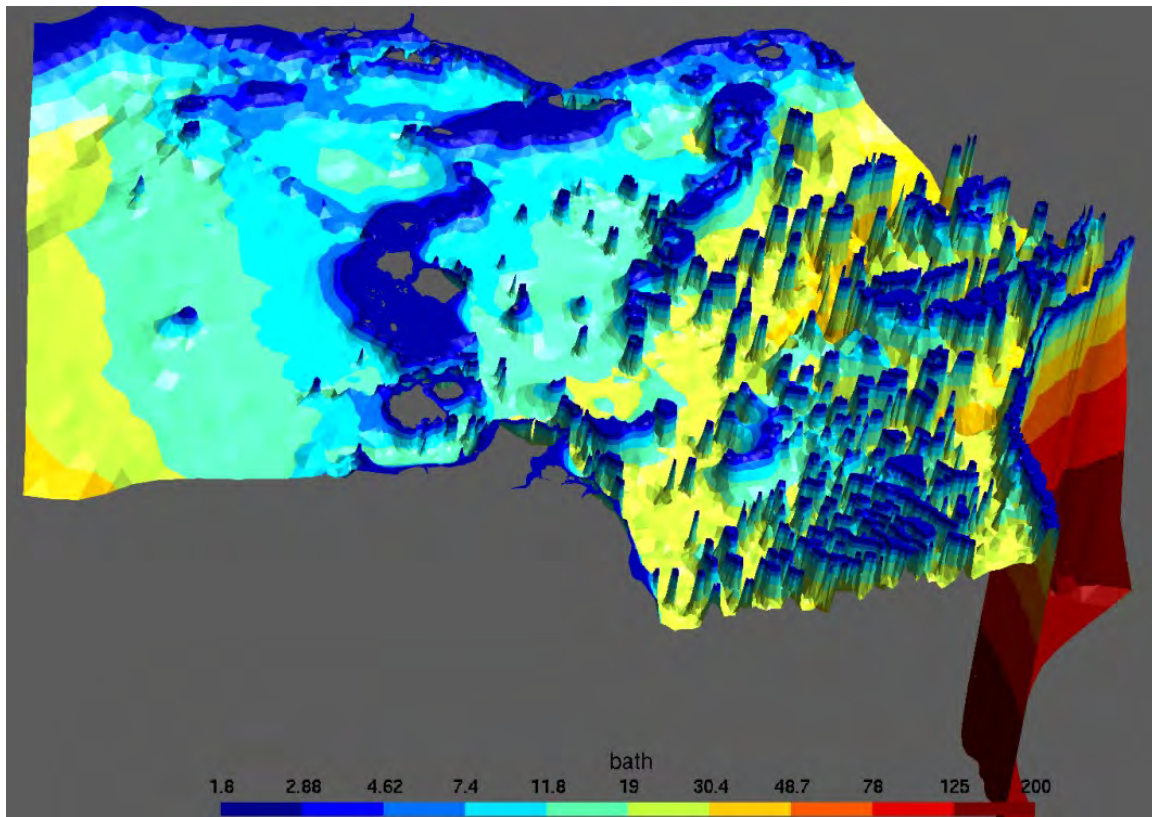


Figure 22. A 3-D visualization of the bathymetry in Torres Strait. Source: Wolanski (2013).

As part of this project, a detailed bathymetric map of Torres Strait was constructed by merging a number of data sets. The extensive data set on the oceanography of Torres Strait was reviewed and used to show the importance of the wind and the water circulation in the Coral Sea, the northern Great Barrier Reef continental shelf, the Gulf of Papua, and the Gulf of Carpentaria in driving the water circulation in Torres Strait. These data were used to set the open boundary conditions for a high resolution, unstructured grid, 2-D model of Torres Strait. Rather than provide further detail of the method to developing the model here, a detailed description of this work and the supporting information is provided in Wolanski (2013) and Wolanski et al., (2013).

The model revealed the large scale flow dynamics in Torres Strait (see Figure 23), highlighting that some areas are flushed relatively quickly while water tends to stagnate in other areas. The model also revealed the prevalence of highly energetic small scale flow dynamics near shoals, reefs, islands and reef passages.



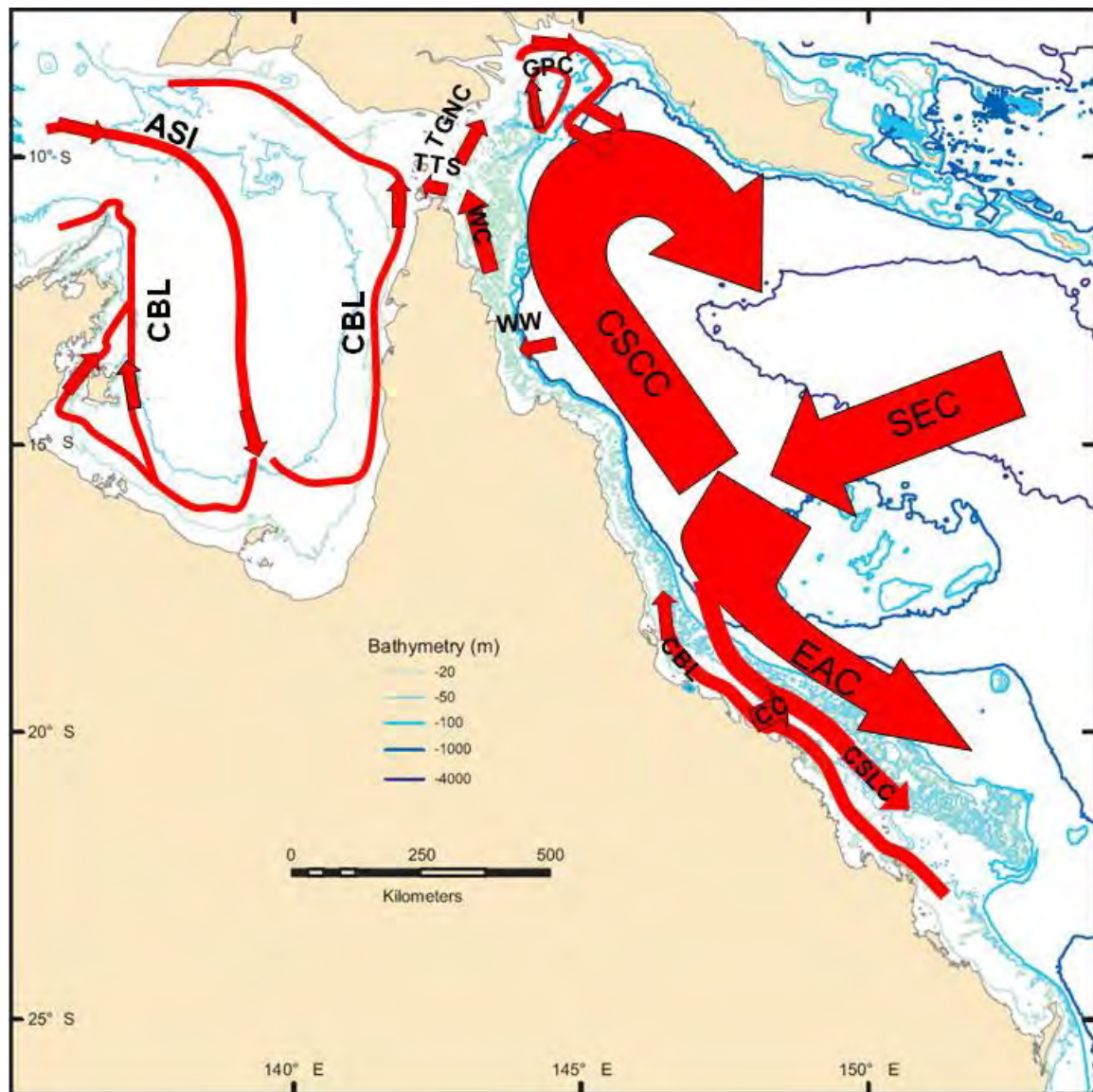


Figure 23. A sketch map of the general surface water circulation during south-easterly trade winds in the study area.

SEC= South Equatorial Current; EAC = East Australian Current. CSLC = Coral Sea Lagoonal Current; CC: Cross Shelf Current; CBL = (wind-driven) Coastal Boundary Layer current; CSCC: Coral Sea Coastal Current; WW = inflow from Wind and Wave breaking; WC = Wind-driven Current. TTS= Through Torres Strait current; TGN = Through Great North East Channel current; GPC = Gulf of Papua current; ASI = Arafura Sea inflow.

### Movement of the Fly River plume

The bulk of the Fly River plume in the Gulf of Papua is entrained in the Coral Sea by the NQCC, and at least during strong south-easterly trade winds this forms an eddy in the Gulf (Figure 24). A small fraction of Fly River plume is entrained in Torres Strait by the currents in the Great North East channel. The river plume is vertically stratified in the Gulf of Papua and generally vertically well-mixed in Torres Strait. When these currents are northeastward, there is only a small intrusion of river plume water in the Great North East Channel with salinity of only 34 at Bramble Cay (Figure 25). When these currents are southwestward and persist for at least 10 days, much more Fly River plume water enters Torres Strait and its presence can be detected all over the northern Torres Strait both east and west of the Warrior Reefs, with salinity as low as 24 psu at Bramble Cay and 26 psu at Pearce Cay (Figure 25; Wolanski et al., 1995 and 1999).

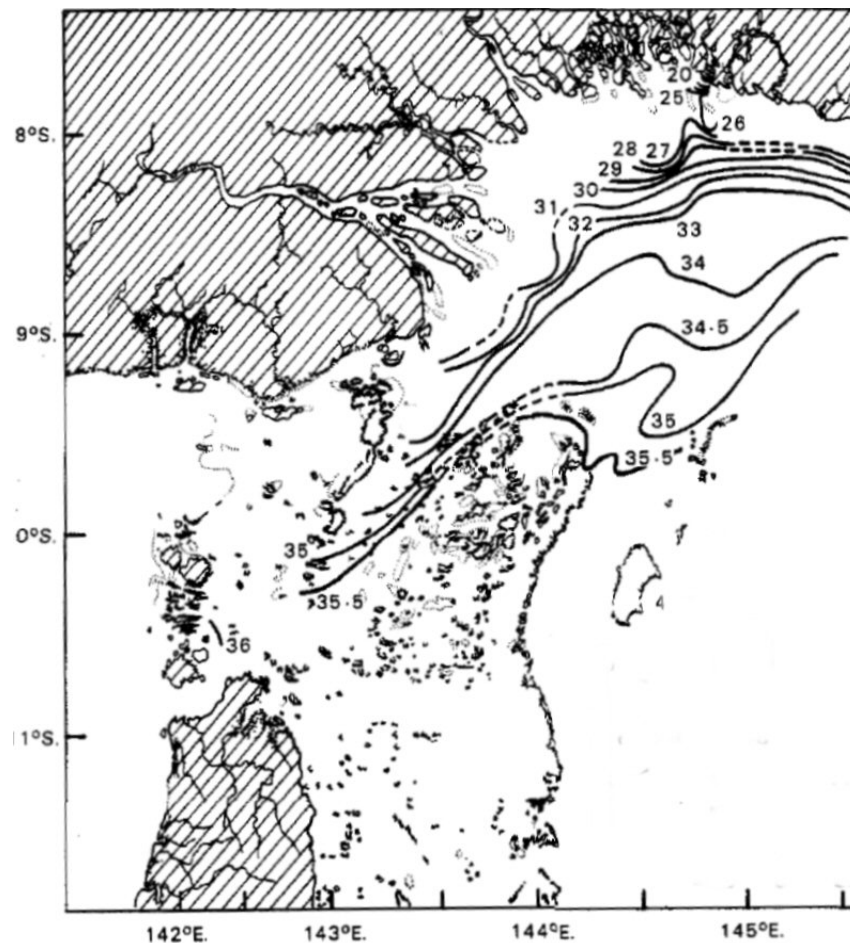


Figure 24. Surface salinity in the Gulf of Papua, November 1979. Reproduced from Wolanski and Ruddick (1981).

This map of the surface salinity (in psu) in the Gulf of Papua shows an intrusion of the Fly River plume in Torres Strait through the Great North East channel on 19-26 November 1979.



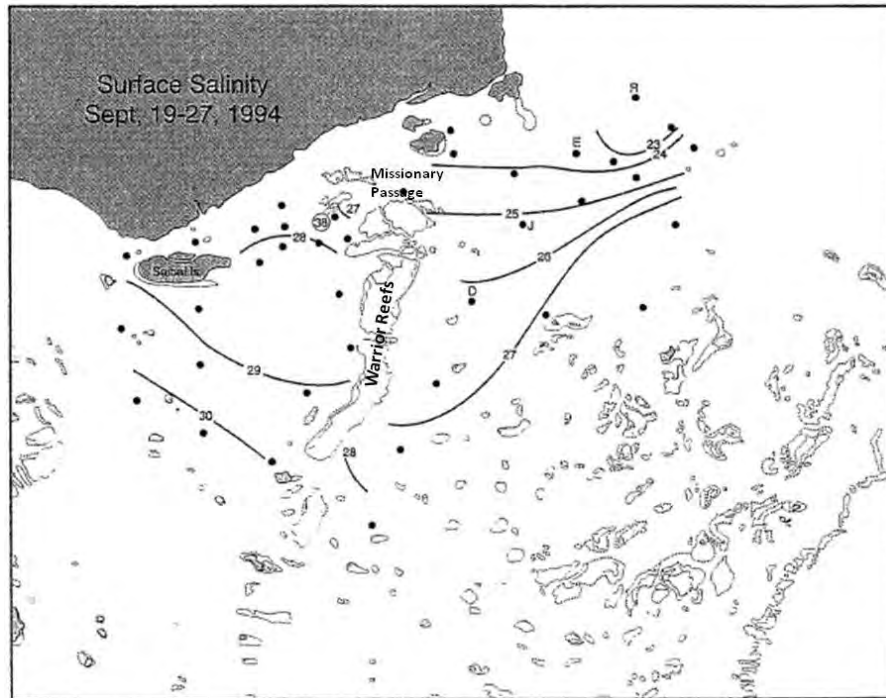


Figure 25. Surface salinity in the Gulf of Papua, September 1994. Reproduced from Wolanski and Ruddick (1981).

This map of the surface salinity (in psu) shows a major intrusion of the Fly River plume in northern Torres Strait both east and west of the Warrior Reefs on September 19-27, 1994. The waters were vertically well-mixed in salinity. Modified from Wolanski et al. (1995).

The low-frequency currents in Missionary Passage are generally small, typically smaller than  $0.1 \text{ m s}^{-1}$ , alternating between eastward (i.e. Torres Strait flowing into the Gulf of Papua) and westward (i.e. Gulf of Papua water entering Torres Strait) at periods of days to weeks, with negligible yearly-averaged currents. Thus the Fly River plume intrudes in Torres Strait west of the Warrior reefs in events lasting days to weeks. About 3% of the Fly River freshwater discharge could be carried west of the Warrior Reefs during such events (Wolanski et al., 1995).

Through much of the year low-salinity water is detected in Torres Strait along the PNG coast of Torres Strait (Mulhearn, 1989). Fly River plume waters could possibly reach Saibai Island but not further west. Thus brackish waters found along the PNG coast west of Saibai Island probably originates from rivers along the Irian Jaya - PNG coastline

### Prediction of dispersal from specific locations

To calculate the fate of water-born tracers, the advection-diffusion model of Andutta et al. (2012) was used because it was verified for the GBR. Tracers were released at the nine sites shown in Figure 26. These sites include the waters off Thursday Island harbour, Endeavour Strait, the edge of the Prince of Wales Channel, Missionary Passage, the southern Warrior Reefs, and sites near inhabited islands.

For tides alone the resulting dispersion plumes after 1, 3, 5 and 7 days are shown in Figure 26. It is apparent from this figure that the flushing of Torres Strait waters varies from place to place. Under calm weather conditions, the waters around Boigu Island are very poorly mixed and do not exit the area after 7 days. There is also very slow flushing, only marginally better, of the waters around Saibai Island. Of the 9 sites, Missionary Passage waters are flushed the fastest as

all its water is entrained in the Great North East Channel after 7 days. Next down the list of flushing rates are the waters around Thursday Island, Endeavour Strait, and the Prince of Wales Channel. Even further down the order of flushing rates are the waters around Masig Island and Iama Island.

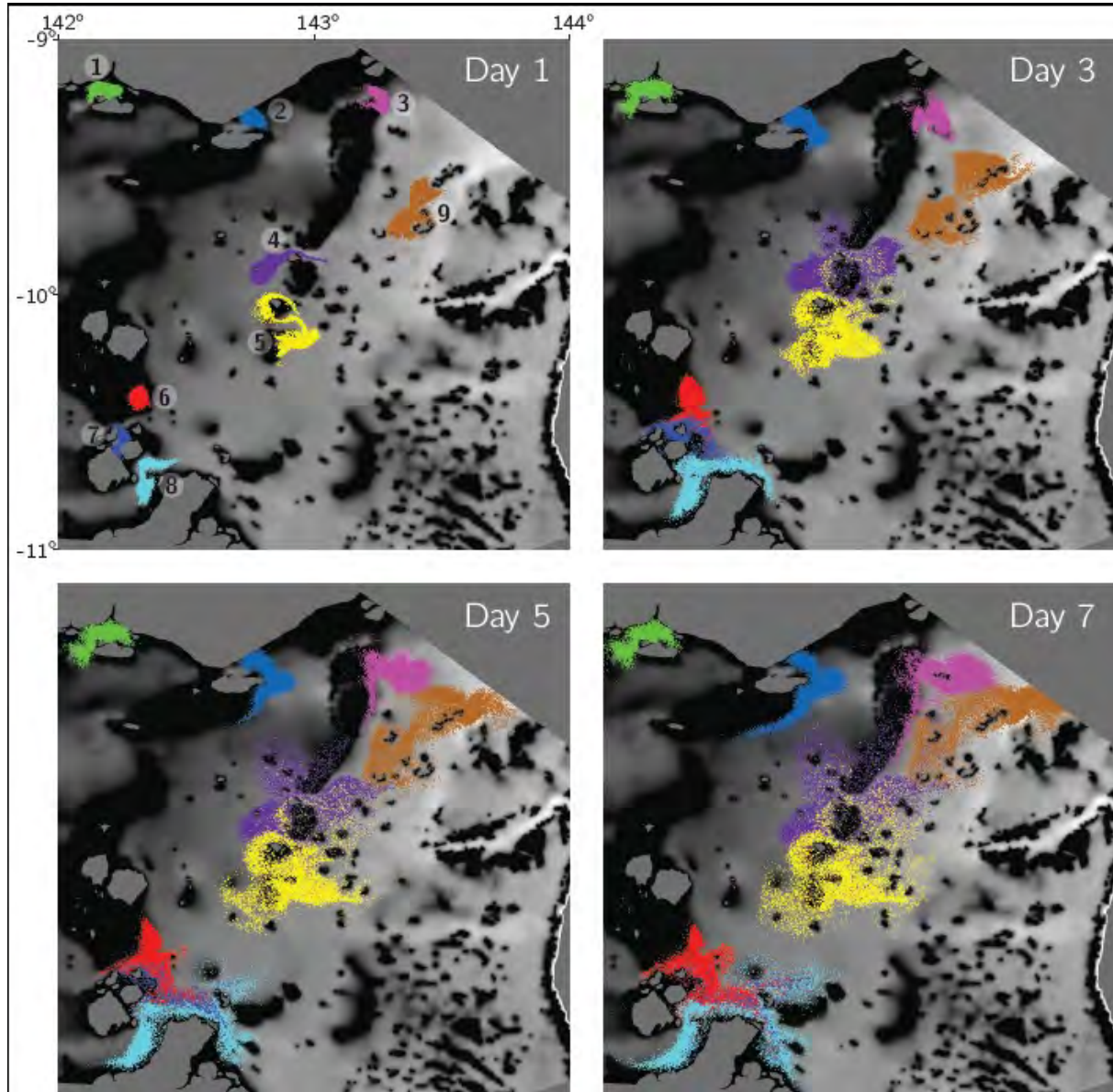


Figure 26. Predicted plumes for in the Torres Strait from the hydrodynamic model. Source: Wolanski (2013).

Predicted plumes include those from tides alone (no wind effect) after 1, 3, 5 and 7 days, for waterborne tracers released at time 0 at sites 1 (near Boigu Island), 2 (near Saibai Island), 3 (Missionary Passage), 4 (Warrior Reefs), 5 (near Iama Island), 6 (Prince of Wales Passage), 7 (near Thursday Island), 8 (Endeavour Strait), 9 (near Masig Island in the Great North East Channel).

The fastest flushing of Torres Strait waters occurs for a scenario during Southeast trade wind with a 2 metre swell in the Coral Sea. For that scenario the dispersion plumes (Figure 27a) show rapid flushing from all sites, except for Boigu Island and in Missionary Passage. This is explained

by the net currents which show that the northward net current in the GBR shelf splits into two components on reaching Cape York, namely a westward flowing current (which is largely restricted to three passages) exporting Torres Strait waters to the Gulf of Carpentaria, and a northeastward flowing current that is largely restricted to the Great North East channel exporting Torres Strait waters to the Gulf of Papua.

For a monsoonal wind event scenario, the model predicts (Figure 27b) that water enters both from the Gulf of Carpentaria and from the Gulf of Papua and this generates a net flow is towards the northern GBR shelf. Tracers released off Thursday Island are moving slower than those released in Endeavour Strait and the Prince of Wales channel due to trapping in the passages, until they reach open waters. Waters near Iama and Masig Islands are moving southward. Waters from Saibai Island are moving slowly towards Missionary Passage. Waters near Boigu Island are flushed very little.

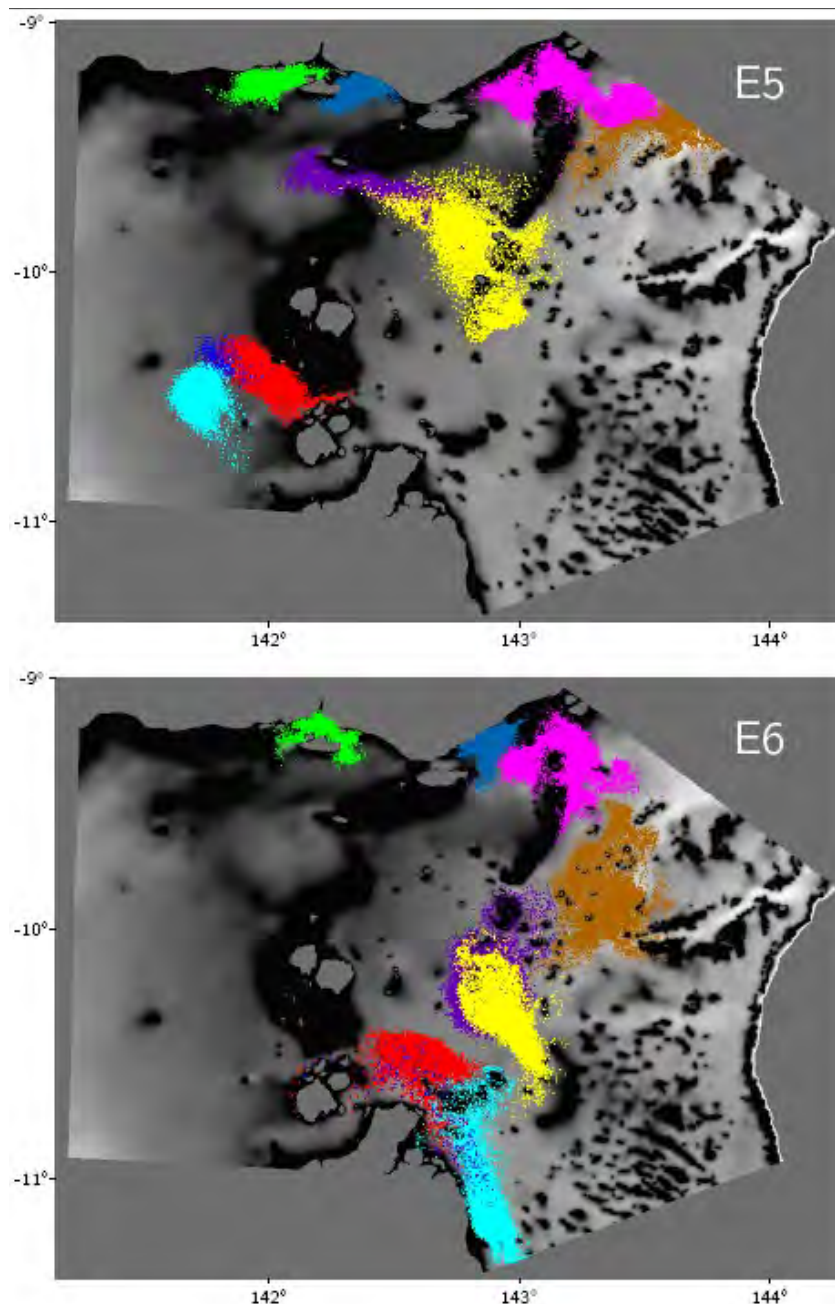


Figure 27. Predicted plumes after 7 days for (a) scenario during Southeast trade wind with a 2 metre swell in the Coral Sea and (b) scenario with a monsoonal wind event. The release points are shown in Figure 6.

A number of other scenarios were tested in the model to demonstrate the influence of different drivers on plume movement. These are described in more detail in Wolanski, (2013).

The new findings from the field data and from the ocean modeling enable us to propose a simple model of the net circulation in Torres Strait during Southeast trade winds (Figure 28a). The wind and the waves breaking on the outer reefs of the GBR generate a landward flow (WW) from the Coral Sea. The wind pushes this incoming Coral Sea water longshore northward on the GBR shelf, as a wind-driven current (WC). On reaching the latitude of Cape York, a fraction of WC waters turns westward to form the Through Torres Strait current (TTS) which flows into the Gulf of Carpentaria mainly through Endeavour Strait and the Prince of Wales Channel. The remaining WC waters keep flowing north to form the Through Great North East Channel Current (TGNC) which exits Torres Strait and enters the Gulf of Papua. West of the Warrior Reefs the net currents are negligible. This circulation is largely controlled by the difference in mean sea level between the Coral Sea and the Gulf of Carpentaria, and by the non-linear interaction between tidal and low-frequency currents in the shallow waters of Torres Strait. In terms of the influence of the Gulf of Carpentaria, the non-linear interaction of tidal and wind-driven currents in shallow coastal waters in the Gulf of Carpentaria results in the formation of a coastal boundary layer (CBL) on the Gulf of Carpentaria side of Torres Strait. This water is ultimately exported from the Gulf of Carpentaria and is replaced by an inflow of water from the Arafura Sea. In terms of the influence of the Gulf of Papua, the bulk of the Fly River plume in the Gulf of Papua is entrained in the Coral Sea by the Coral Sea Coastal Current (CSCC), and at least during strong Southeast trade winds this forms an eddy in the Gulf (Figure 28b; Wolanski et al. 1995 and 1999). A small fraction of Fly River plume is entrained in Torres Strait by the currents in the Great North East channel.

The Torres Strait was the last area of the GBR for which the oceanography was not sufficiently documented before this study. As it forms an integral part of the GBR, the water circulation through Torres Strait, discussed above, has a significant impact on the circulation in the whole northern GBR. The new understanding of the circulation in Torres Strait therefore enables us to propose a new net circulation model of the GBR in the Southeast tradewind season, showing how the circulation in Torres Strait fits into the wider picture of the circulation in the entire GBR. The proposed circulation scheme is summarised in Figure 28b.



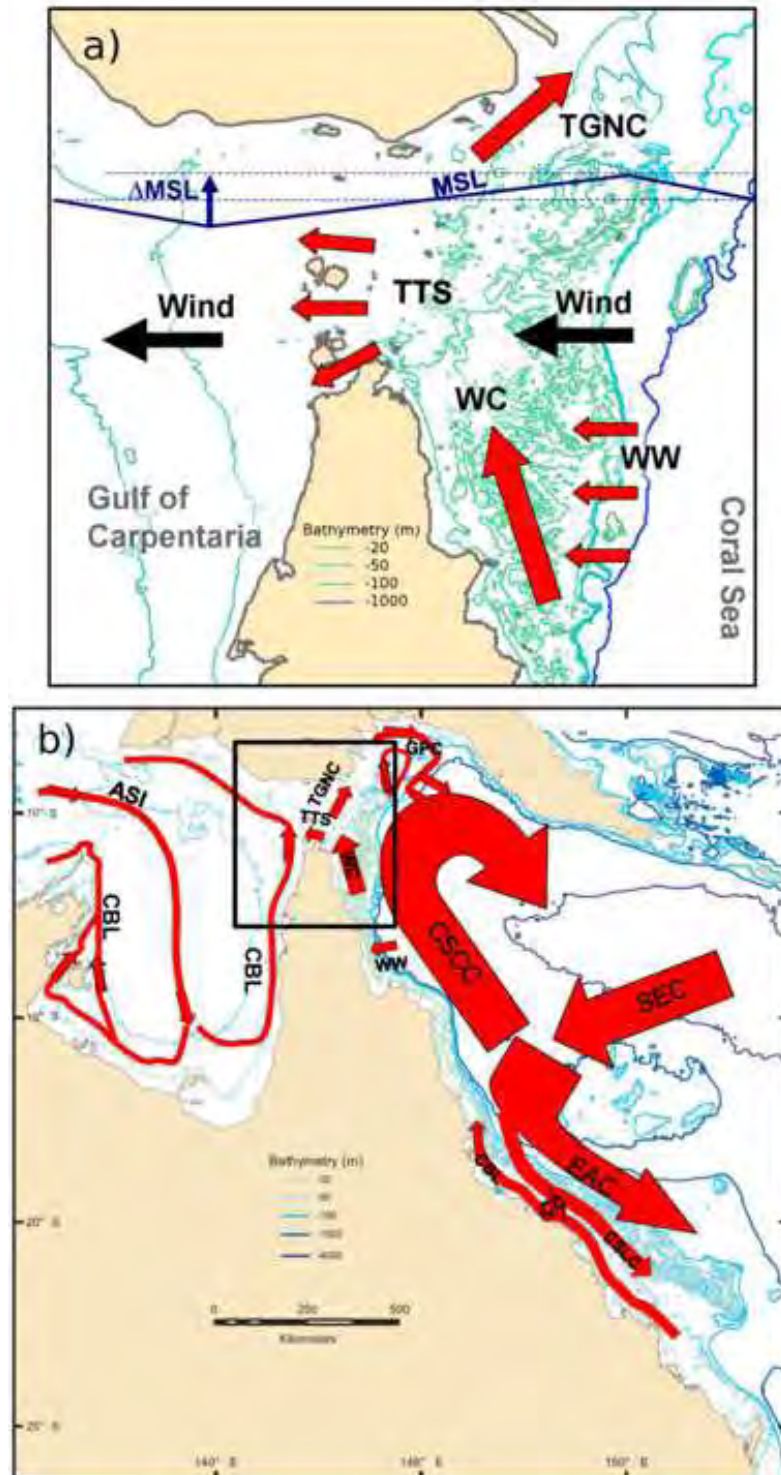


Figure 28. A sketch map of the general surface water circulation during Southeast trade winds in (a) Torres Strait and (b) the Great Barrier Reef.

The boxed area corresponds to the area shown in Figure 10a. MSL = mean sea level; MSL = sea level difference between the Coral Sea and the Gulf of Carpentaria on either side of Torres Strait. SEC = South Equatorial Current; EAC = East Australian Current. CSLC = Coral Sea Lagoonal Current; CC = Cross Shelf Current as discovered by Andutta et al. (in press); CBL = (wind-driven) Coastal Boundary Layer current; CSCC = Coral Sea Coastal Current; WW = inflow from the wind raising the sea level in the Coral Sea and wave breaking on the outer reefs; WC = Wind-driven Current. TTS= Through Torres Strait current; TGNC = Through Great North East Channel current; GPC = Gulf of Papua current; ASI = Arafura Sea inflow. The CSCC was the original name given to that current by oceanographers (Andrews and Clegg 1989) and it is also known as the Hiri current.

## 5. Application of remote sensing for monitoring turbid river plumes in the Torres Strait region

The influence of river plumes within the Torres Strait region from the adjoining areas of PNG is potentially important for water quality conditions in the Torres Strait, particularly as the pollutant loads in these river plumes may change with increasing catchment development in PNG. As part of this study we tested the potential of MODIS data to map river plumes from PNG in terms of extent and potential and develop a first data base of satellite images documenting the behaviour of plumes and their areal extents within the Torres Strait Protected Zone. This section summarises the outcomes of this part of the study, and a full description is provided in Petus, (2013) *Application of MODIS remote sensing imagery for monitoring turbid river plumes from PNG in the Torres Strait Region: a test study*.

Moderate Resolution Imaging Spectroradiometer (MODIS) imagery is a free satellite data with a medium spatial resolution (250 m for bands 1 and 2) and sufficient revisit times (at least once a day) available for monitoring turbid river plumes regularly and over multi-annual time periods (since 2000). MODIS images have been used for monitoring turbid river plume plumes worldwide (e.g. Miller and McKee 2004; Petus et al. 2010; Devlin et al., 2012). For this initial Torres Strait database, the MODIS-Aqua 'surface reflectance' land product (MYD09GQ) in combination with MODIS True Colour composites (TC) was used.

The Torres Strait Protected Zone is located at the cross-junction between 4 image tiles. This means that for each day of satellite acquisition, the 4 tiles must be downloaded in order to produce maps of our study area.

Following a request of our team, a subset for the Torres Strait area has been added by the NASA to the LANCE website (<http://lance-modis.eosdis.nasa.gov/>) where NASA displays true colour images for different areas around the world. True colour images of our area of interest are now freely available since May 2008 on a daily basis.

In order to run a first test, we downloaded daily MODIS 'surface reflectance' imagery between 1 October 2009 and 19 June 2010 (292 days \* 4 tiles = 1168 MODIS scenes downloaded). A selection of cloud free true colour images was also downloaded between 2008 and 2012. To process the MODIS data, a customized script was developed to mosaic the 4 MODIS tiles together and process the images to produce the maps of the study area. True colour images were also exported into Google Earth and the maps for our study area were produced.

Figure 29 presents a selection of MODIS True Colour images of the study area recorded between 2008 and 2012. Clouds (white areas on the true color images) regularly cover about 20 to 50% of the sky but turbid water masses in the region are clearly detectable in clear sky areas by their differences in colour (brownish to beige) from ambient marine waters (navy blue). Turbidity patterns observed in the selection of true colour images are in agreement with those described from hydrodynamic and sediment transport models and field observations in the region (e.g. Heap and Sbaffi, 2008; Margvelashvili et al., 2008; Saint-Cast, 2008, Wolanski et al., 2013):

- An area of turbid water is regularly located in central TS (Figure 29a);
- Figure 29b suggest turbid water movements parallel to the coast and orientated east-west in central and south TC;
- High turbidity levels along the PNG coast are mainly constrained to the coast, even during the monsoon season (Figure 29c).



Petus (2013) goes on to explain the results of more detailed analysis of the test study and demonstrates the successful application of remote sensing imagery to monitor turbid river plumes in the Torres Strait. The following conclusions can be made:

- The Torres Strait region is a very complex hydrodynamic system due to the complex bathymetry, the separate forcing by the Coral Sea and the Arafura Sea, as well as local forcing by the tide, wind, waves and rivers including the Fly River.
- Surface turbidity distribution in the Torres Strait result from the combined action of tides, wind, waves, currents, resuspension and turbid river discharge.
- First analyses and comparisons with true colour composites show that MODIS land surface reflectance product can help to map the plumes and turbidity levels in the Torres Strait region. The surface reflectance measured in the MODIS band 1 can be used as proxy for surface turbidity levels in our study area.
- Complemented with in-situ water quality data and hydrodynamic models, MODIS satellite images are useful tools to map these dynamic oceanographic structures because of their synoptic coverage and spatial resolution. These images are freely distributed and cover more than a decennial period (2000 – 2012).
- Our preliminary dataset of MODIS satellite images suggests that high turbidity levels along the PNG coast are constrained to the coast, and that intrusions of the Fly River plumes in the Torres Strait region and Torres Strait Protected Zone are limited.
- High turbidity levels recorded along the south-western PNG coast suggest a combined influence of turbid outflows from the several rivers draining the southern New Guinea margin, enhanced by bottom resuspension in the shallow coastal zone.
- Cloud levels in the study area are important and the Torres Strait region is regularly masked by dense and developed clouds. This can limit the number of images available, particularly during the Northwest monsoon season (November to April) when most of the annual rainfall occurs in the region. Further detail of techniques to overcome these issues are discussed in Petus (2013).
- The limited number of images processed for this study gave only snapshots of surface turbidity dynamic in the Torres Strait. More images should be acquired for a more comprehensive study of the dynamic of surface turbidity in Torres Strait and of PNG turbid river plumes.

A number of technical recommendations are also included in Petus (2013) for future application of the remote sensing imagery in the Torres Strait region.

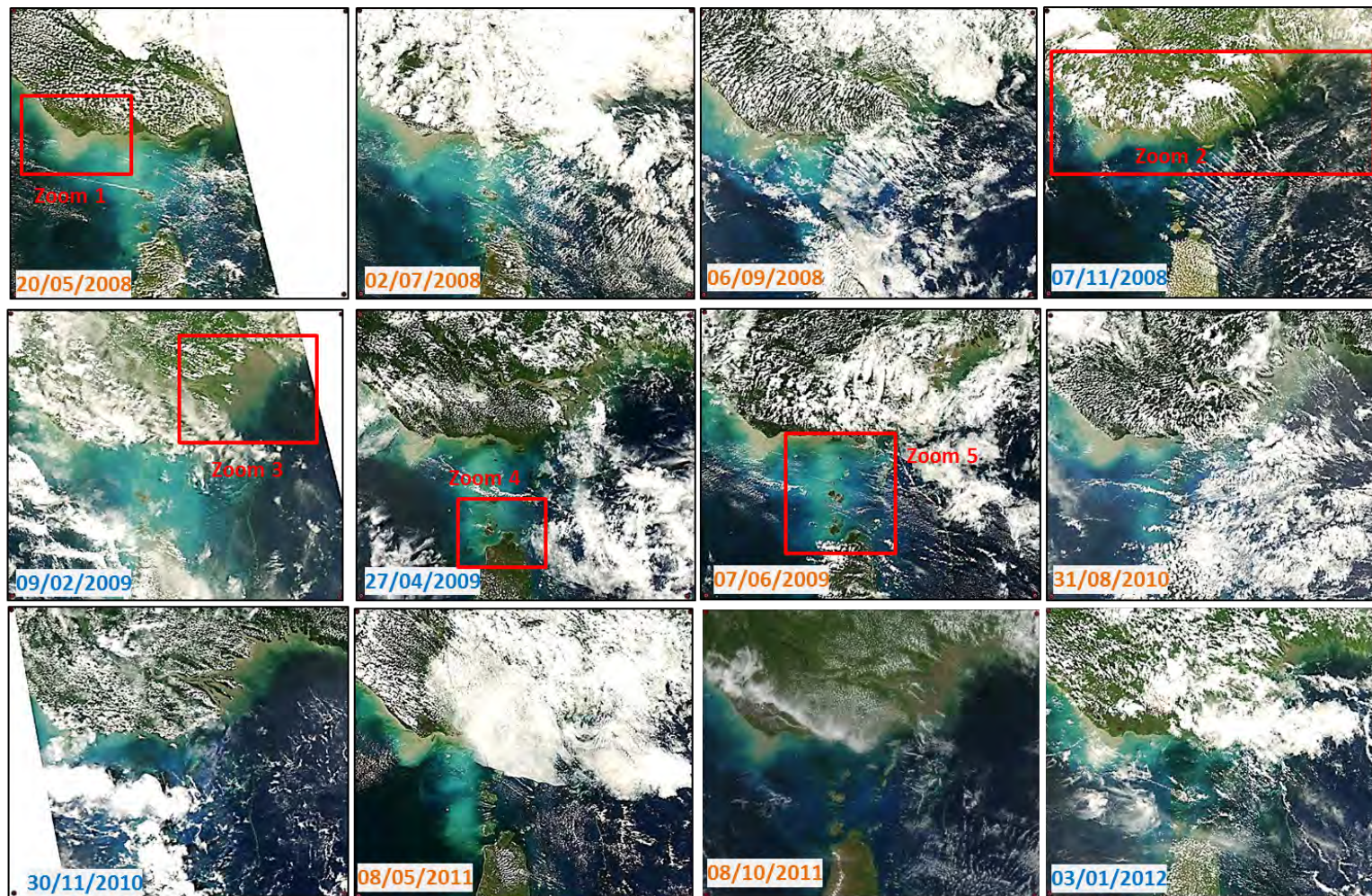


Figure 29: Selection of MODIS True Colour images of our study area recorded between 2008 and 2012 (NASA Lance website) during the Southeast trade-wind season (May to October, blue labels) and the Northwest monsoon season (November to April, orange labels).

This dataset of images illustrate the strong spatial, temporal and sedimentary variability of the PNG turbid plumes.

## 6. Hazard assessment of pollutant sources for the Torres Strait

### 6.1. *Conclusions and Recommendations*

Using the information gathered in this study on pollutant sources and our new understanding of water circulation and river plume movement in the Torres Strait region, we conducted a simple hazard assessment of pollutant sources for the Torres Strait. The assessment was undertaken through consideration of the collated information by the project team and judged on expert opinion. The resources allocated to this study precluded the option of adopting more of a mathematical approach to the hazard assessment; however, the results provide a useful indication of the likely outcomes of a more formal hazard or risk assessment approach.

While the study identified a number of relatively minor local pollutant sources that may pose a risk to the ecological values of the Torres Strait, the information we have gathered suggests that the largest threats are most likely to be associated with the potential risks from the transit of large ships through the region. Because of the limited water exchange in and out of Torres Strait, there are concerns that if Torres Strait water became polluted it would probably remain in the region for some time. This may pose a risk of adverse and prolonged impacts on ecological communities, indigenous and commercial fisheries and the life style of Torres Strait Islander people. The main conclusions and associated recommendations are provided below.

#### **The Torres Strait hydrodynamic model**

Understanding the hydrodynamics of the Torres Strait region is required for confident predictions of pollutant transport. Through this study the extensive existing data set on the oceanography of Torres Strait (separating Australia and PNG) was reviewed and used to show that water circulation in Torres Strait is driven by the wind, the tides and the circulation in the Coral Sea, the northern Great Barrier Reef continental shelf, the Gulf of Papua, and the Gulf of Carpentaria. These data were used to set the open boundary conditions for a high resolution, finite element, depth-integrated (2D) model of Torres Strait.

The model shows that the water circulation in Torres Strait is characterised by events lasting a few days to three weeks and that this explains the observations of a very small net circulation in Torres Strait. The model predicts that net east-west flow through Torres Strait is small in agreement with field data, and reveals that areas of shallow waters and areas densely populated with reefs and islands are poorly flushed. Only reef passages and reef-free open waters are relatively well flushed.

Further improvements to the model require additional meteorological and oceanographic field data to be collected to quantify the spatial gradients of the wind field as well as the sea levels and the waves in the northwest Coral Sea. Ultimately a 3D model would be useful to provide additional information, particularly near river mouths, but at present this may be cost-prohibitive because the model cannot sacrifice horizontal resolution in order to gain vertical resolution because the strong friction-driven interaction between tidal and net currents requires that any model of Torres Strait has to incorporate the complex bathymetry of reef passages.

#### **Remote sensing of river plumes**

The following conclusions can be made from our study which tested the application of MODIS imagery to observe river plumes from PNG in the Torres Strait region:

- MODIS satellite data can help to map turbidity levels and river plumes from PNG in the Torres Strait Protected Zone. Complemented with in-situ water quality data and hydrodynamic models, satellite images are useful tool to map these dynamic oceanographic structures because of their adapted spatial and temporal resolutions. These daily images are freely distributed and cover more than a decennial period (2000 – 2012).
- The Torres Strait Protected Zone is a complex area and movements of plumes is linked to combined influence of Coriolis force, local currents (coastal and tidal), intensity and orientation of winds, as well as the local bathymetry.
- First analyses and comparisons with True Colour composites show that MODIS surface reflectance product is adapted to map the plumes and turbidity levels in the Torres Strait Protected Zone. The surface reflectance measured in the MODIS band 1 can be used as proxy for the TSM concentration in our study area.
- The use of satellite images calibrated into water quality metrics/proxies (here the remote sensing reflectance values were used as proxy for total suspended solids levels) in combination with true colour images can be useful for further analyses of the extent of PNG river plumes in the region. Indeed the use of an adapted  $R_{rs}(645)$  threshold values can help to automatically delineate surface plume boundaries over long time periods.
- Finally, cloud levels in the area are important and the Torres Strait region is regularly masked by dense and developed clouds. This meteorological characteristic can limit the number of images available, particularly during the stormiest conditions.

## **Assessing the potential risks to the Torres Strait from water quality issues**

A qualitative assessment of the key threats to the Torres Strait region from water quality issues concludes that the risks from water quality to the environmental values of the region are currently relatively minor. However, a number of important potential risks have been identified. The primary risks to the Torres Strait from water quality issues are summarised below in order of priority.

### **1. Shipping**

Shipping and associated hazards (oil spills, groundings, ghost nets) appear to pose significant potential threats to the region. The shipping route through Torres Strait is already an obvious bottleneck for Australian east coast shipping traffic. With the expansion of ports, especially coal loading ports, on the Australian east coast in response to proposed large increases in coal export (GBRMPA 2012) large increases in shipping traffic up the Queensland coast are predicted. Additional increased shipping through the Torres Strait will also result from the construction of a major port at Daru. Under these scenarios a large increase in shipping traffic through the Torres Strait is predicted over the next decade. These increases will result in greatly increased risk of accidents in the Torres Strait. Currently there is very limited capacity to respond in any meaningful way to a large oil spill in the Torres Strait. The area is remote in Australia with strong winds and currents and a matrix of reefs and islands on which oil could impinge. Any large oil spill would have devastating consequences for the populated islands on which it landed as well as severe environmental consequences. While new management strategies may mitigate the increase in risk we consider this increase in shipping traffic to be a major water quality and environmental threat to Torres Strait environment and people.



Recommendations:

- That further investigation of the options for compulsory pilotage in the Prince of Wales Channel is undertaken to Torres Strait. While it appears that the Prince of Wales Channel has a form of compulsory pilotage, in effect this is still at the discretion of each vessel and when vessels do not choose to take a pilot Australia does not take action to refuse passage.
- A complete review of shipping risk response in the Torres Strait is needed given the likely increase in shipping.

**2. Large scale development in PNG**

Large scale development in PNG including gas platforms, oil palm expansion and Daru port development may also be significant. Preliminary analysis of proposed developments in western PNG suggest that although large scale development is likely to occur adverse effects in the Australian part of the Torres Strait are likely to be restricted to the northern islands – Boigu, Saibai, Erub and Stephens. This is because both the hydrodynamic modeling (Section 4) and remote sensing analysis (Section 5) show that excursions of water from the Fly River drainage basin predominantly move to the east into the northern Coral Sea and along the PNG coast towards Port Moresby and are uncommon to the west of the river mouth. In addition the currents in this western region are generally from east to west both in the central Torres Strait and along the PNG coast. However construction and operation of a major port at Daru has the potential to lead to excursions of contaminated water along the PNG south west coast and this is likely to Saibai and Boigu. Discharge from the Mai River immediately to the north of Boigu may be more significant in delivering contaminants to Boigu is the catchment of the Mai is developed for crops such as oil palm. Oil palm development can lead to greatly increased sediment delivery to adjacent waterways especially in the forest clearing – first planting stage (Brodie and Turak 2004). While erosion and sediment delivery abate with the maturation of the crop loss of fertiliser nutrients and pesticides is a potential ongoing issue.

It is now almost certain the Ok Tedi mine will continue production for at least another 10 years instead of shutting down in 2014 as was suggested earlier. Given the possible role in introducing toxic metals into the northern Torres Strait via Fly River discharge this can only be viewed with concern given the absence of transparent monitoring programs as to the effects of the discharge in the lower Fly River and Torres Strait. While the TSBS showed little influence of Fly River discharge on metal levels in Torres Strait the data is now 20 years old and it would be valuable to repeat the study in a more limited way to assess the changes since the early 1990s.

Recommendations:

- Implement a monitoring program to capture the above issues.
- Further investigation of the use of the newly developed hydrodynamic model in pollution tracking and forecasting is needed.

**3. Localised waste management issues**

Potentially localised issues with wastewater management (all marine outfalls) exist and general waste management. Prioritization of remedial actions will be developed more fully after this draft report has been reviewed. Saltwater inundation is also important in some locations.

#### Recommendations: Sewage management

- Sewage treatment plant operator training – Certificate II or III in Water Operations – across the 3 councils. Torres Strait Regional Island Council ~ 50 staff – currently not all fully trained.
- Workshop / meeting of sewage treatment plant operators across region – share knowledge and experiences; offer specific training.
- Outfall monitoring in conjunction with Rangers – annual. Looking for condition and integrity of structure, plus change in receiving environment.
- Desk top assessment of STP license discharge conditions to ensure addressing priority issues (eg. Follow up why no coliform condition for Thursday Island).
- System for providing results back to STP Operators. It is noted to be in place and results are provided to the Council – entered into spreadsheet and the Operator contacted if exceedance occurs. A review of this system is needed.
- Maintenance strategy to address minor technical issues – skills development (especially electrical).
- Options for irrigation of treated effluent in locations where water shortage and / or issues with outfall.
- Sea level rise issues for plant and pipes on Saibai (and most likely Boigu).

#### Recommendations - Waste management

- Litter monitoring on islands closer to the Shipping Route.
- Recycling waste at coral cay islands.
- Clarify status and longer term plan for management of the Horn Island disused mine site.

## **6.2. Recommended monitoring program design**

The project team has developed a proposal for a monitoring project which would allow reporting on the status of water quality in the Torres Strait with a particular focus on assessing the influence from large scale developments in adjacent areas of PNG. The monitoring program would provide an update of extensive studies undertaken almost 20 years ago as an updated baseline to assess the influence of expanding large scale development in PNG.

The proposed program addresses the following objectives:

1. Collate and report knowledge of the risk of shipping incidents in the Torres Strait region.
2. Assess incursion of northern river influences into the Torres Strait region, including:
  - a. Analysis of satellite imagery to determine incursion of sediment in the Torres Strait from PNG rivers.
  - b. Deployment of data loggers to measure turbidity, salinity and other water quality parameters.
3. Assess incursion of northern river influences into the Torres Strait in terms of prevalence of key pollutants:
  - a. Use of thin film technique to assess metals in water column.
  - b. Analysis of metals in sediment samples.



4. Identify the key sources of marine debris in the Torres Strait to inform the development of a marine litter management strategy for the Torres Strait.
5. Communicate the results of the monitoring back to stakeholders.
6. Assess any changes to local environments as a result of localised waste management.
7. Improve the knowledge base for marine incident response in the Torres Strait.
8. Assessment of potential implications of metal concentration in dugong and turtles.

Note that the objectives 1 to 5 address the highest priorities.

To achieve these objectives we propose a number of techniques described below.

1. *Collate and report knowledge of the risk of shipping incidents in the Torres Strait region.* The study identified that likely increases in shipping traffic pose the greatest pollutant risk to the Torres Strait. This activity should be conducted by the Torres Strait Regional Authority to collate current knowledge of the status of shipping incidents in the region to track any change in time in order to assess likely risks in collaboration with AMSA.
2. *Remote sensing of river discharge.* Our study demonstrated that MODIS satellite data can help to map turbidity levels and river plumes from PNG in the Torres Strait Protected Zone. Complemented with in-situ water quality data and hydrodynamic models, satellite images are a useful tool to map these dynamic oceanographic structures because of their adapted spatial and temporal resolutions. These daily images are freely distributed and cover more than a decennial period (2000 – 2012). The assessment would show where river discharge moves in the region. With further development, the analysis could also consider turbidity concentrations which are relevant for seagrass and coral reef communities in the region.
3. *In situ water quality monitoring.* Routine monitoring of water quality (temperature, salinity and total suspended solids) at specific locations will provide an indicator of current status and variability in water quality conditions of the Torres Strait. The data will also provide information to assist in the validation of remote sensing imagery (above). Water quality data loggers provide continuous data series of a range of variables, and are relatively easy to deploy. However, site selection, set up and training for deployment and data retrieval may initially be resource intensive but should not require extensive effort beyond the initial set up.
4. *Metals in the water column.* The remoteness of Torres Strait presents particular difficulties for regular environmental monitoring. Progress has recently been made on the use of 'artificial bivalves' to measure environmental concentrations of metals. These are known as diffusive gradients in thin films (DGT). DGT techniques are based on a simple device that accumulates solutes on a binding agent after passage through a hydrogel that acts as a well-defined diffusion layer. The use of this technique reduces some of the problems inherent in the analysis of water, sediment and biota samples for metals. These devices are now available in northern Queensland (Townsville) and are relatively cheap. DGTs are likely to be a more reliable to long-term technique to measure metals in Torres Strait than the use of the locally occurring bivalves given potential issues with adequate sample sizes of bivalves in some locations.
5. *Metals in sediment, turtle and dugong.* The 1992-1993 Torres Strait Baseline Study determined that high concentrations of several trace metals including cadmium were present in a number of seafoods commonly eaten in Torres Strait including prawn, crayfish, turtle and dugong. However, the high concentrations of trace metals were considered unlikely to be related to anthropogenic factors. The baseline study report recommended commencement of longer-term monitoring of trace metal concentrations

in sediments and selected indicator organisms in Torres Strait (Gladstone, 1996). A number of further studies of Torres Strait trace metals concentrations have been conducted since the early 1990s including assessment of heavy metals in commercial prawn and crayfish species (Evans-Illidge, 1997), metal concentrations in sediment (Haynes and Kwan, 2002). These studies would require considerable preparation and planning and have a different objective related to health issues in the region.

The primary outcomes of the suggested program would include:

- Provision of an assessment of the current status of water quality in the Torres Strait region associated with large scale developments in adjacent areas of PNG as a comparison to previous studies (late 1990s) to assess whether there have been any changes in the Torres Strait as a result of development in the last 10-15 years. The study would also provide a new baseline to assess the influence of expanding mining, gas and port development in the region.
- Contribution and synthesis of the results to a coordinated report of the 'state of the environment' in the Torres Strait region.
- Torres Strait Ranger capacity building in understanding of water quality issues at a range of scales, and monitoring techniques.

In conclusion, this study has provided the first hazard assessment of water quality issues in the Torres Strait region and provides guidance for environmental managers to make decisions regarding the relative importance of pollutant sources.

While an extensive research effort was conducted in the Torres Strait in the 1990s including the Torres Strait Baseline Study there has been limited recent effort to understand pollutant issues in the region since then. These issues are likely to become more pertinent as the adjacent areas of PNG are developed by mining and forestry investments, and associated service developments. The recommended monitoring program design will provide a sound basis for a more detailed analysis of water quality risks in the Torres Strait, and enable changes in these pressures to be assessed over time.

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