Species name	IUCN Red List	EPBC Act	NC Act	Preferred habitat in the Weipa/ Cape York region	Likelihood of Occurrence within the Project Area and Areas of Proposed Disturbance within the Project Area
Leatherback Turtle (*Dermochelys coriacea*)	Critically endangered	Endangered Migratory species	Endangered	Pelagic environment. The Albatross Bay area is identified as a potential foraging area for the species.	**Project Area** ***Likely:*** The species is likely to occur in the Project Area, using it for foraging. However, Leatherback turtles are rarely found in Queensland so any presence would be sporadic. No Leatherback Turtle nesting has been recorded in eastern Australia since 1996. **Proposed Port Site** ***Likely:*** The species is likely to occur sporadically in the vicinity of the proposed port site, using it for foraging. **Proposed Spoil Ground** ***Likely:*** The species is likely to occur sporadically in the vicinity of the proposed spoil ground, using it for foraging. **Albatross Bay Spoil Ground** ***Likely:*** The species is likely to occur sporadically in the vicinity of the Albatross Bay spoil ground, using it for foraging. **<u>Ferry/Barge Terminals – Hey and Embley Rivers</u>** ***Unlikely:*** This species prefers oceanic environments to estuarine environments, so it is unlikely to utilise the estuaries that contain the proposed footprints of the ferry/barge terminals as habitat.
Loggerhead Turtle (*Caretta caretta*)	Endangered	Endangered Migratory species	Endangered	Coastal waters including subtidal and intertidal coral and rocky reefs and seagrass meadows as well as soft-bottomed habitats.	**Project Area** ***Likely:*** The species is likely to be transient in the Project area and use it for foraging or resting. No rookeries are present in the Project Area. **Proposed Port Site** ***Likely:*** The species is likely to be transient in the vicinity of the proposed port and use it for foraging or resting. **Proposed Spoil Ground** ***Likely:*** This species is likely to occur within the proposed spoil ground for the same reasons that it is likely to occur in the vicinity of the proposed port. **Albatross Bay Spoil Ground** ***Likely:*** This species is likely to occur within the Albatross Bay spoil ground for the same reasons that it is likely to occur in the vicinity of the proposed port. **<u>Ferry/Barge Terminals – Hey and Embley Rivers</u>** ***Likely:*** This species is likely to occur in the vicinity of the ferry/barge terminals for the same reasons that it is likely to occur within the proposed port footprint.

EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
NC Act = Queensland *Nature Conservation Act 1992* (Queensland)
IUCN = International Union for the Conservation of Nature
— = Species not listed

6.6.2 Whales and Dolphins (Cetaceans)

A number of dolphin species are known to occur in the Gulf of Carpentaria. These include the Indo-Pacific Humpback Dolphin (*Sousa chinensis*), inshore (*Tursiops aduncus*) and offshore (*Tursiops truncatus*) forms of the Bottlenose Dolphin, and the Australian Snubfin Dolphin (*Orcaella heinsohni*). One whale species, Bryde's Whale (*Balaenoptera edeni*) inhabits inshore tropical waters, so it may occur sporadically in the Project area.

There are no specific studies of the distribution and abundance of cetaceans in the Project area. Incidental observations while undertaking the habitat mapping at the proposed port site described in **Section 6.3.2** confirmed the presence of the Indo-Pacific Humpback Dolphin, at least one species of the Bottlenose Dolphin (most probably the inshore form) and the Australian Snubfin Dolphin.

Potential impacts on cetacean populations in the vicinity of the Project area, including potential impacts on these populations associated with the construction of the port, barge and ferry terminals (including dredging and spoil dumping operations) is discussed in **Section 6.9.2.4**.

Dolphins

The Indo-Pacific Humpback Dolphin and Australian Snubfin Dolphin are listed migratory species under the EPBC Act. They usually inhabit shallow coastal waters less than 20m deep and are often associated with tidal riverine and estuarine systems, enclosed bays and coastal lagoons (Corkeron *et al.* 1997; Hale *et al.* 1998; Jefferson 2000; Parra 2006). On the east coast of Australia, the inshore bottlenose dolphin inhabits estuaries and shallow offshore waters (<30m) (Hale *et al.* 1998, 2000).

The SPRAT database suggests that the regional population levels (e.g. Queensland) of the Indo-Pacific Humpback Dolphin are likely to be in the order of thousands rather than tens of thousands (Parra *et al.* 2002). Aerial survey in the western Gulf of Carpentaria (which includes the Project area) estimated a population of about 1000 Australian Snubfin Dolphins (Freeland & Bayliss 1989). However, the estimate has been questioned due to the known difficulty of identifying dolphin species in turbid waters from the air (Parra *et al.* 2002). Based on the low numbers of Australian Snubfin Dolphins sighted during aerial and boat based surveys of the east coast of Queensland (Parra *et al.* 2002; Parra 2006) the population at a regional level (Queensland) is likely to be in the thousands rather than tens of thousands (Parra 2006). It is therefore difficult to quantify exactly an actual population size of this species within the vicinity of the Project area, however based on the above information; the Indo-Pacific Dolphin population within the vicinity of the Project area is likely to be negligible.

Bottlenose dolphins are listed cetacean species under the EPBC Act but are not threatened or a migratory species (It is noted that the Arafura/Timor Sea sub-population of *Tursiops aduncus* is migratory, but their distribution does not include the Project area or Gulf of Carpentaria). The SPRAT database notes that the Bottlenose Dolphin total population size is not known, but it is likely to be common in offshore waters of south-eastern and southern Australia (V. Peddemors & R. Harcourt 2006, pers. comm.). The total population size of inshore Bottlenose Dolphin (*Tursiops aduncus*) is also not known. However, it is likely that this species is common in inshore and nearshore waters of eastern, western and northern Australia (Ross 2006). Local population estimates suggest that 102 individuals occur in Jervis Bay, 140 in Port Stephens (Möller *et al.* 2002), about 350 in Moreton Bay (Corkeron 1990), 900 in coastal waters off North Stradbroke Island (Chilvers & Corkeron 2003), and about 1800–2400 in Shark Bay, Western Australia (Preen *et al.* 1997). Although incidental sightings were recorded of this species during field studies, its distribution does not normally include the vicinity of the Project area, therefore any population within the vicinity of the Project area is likely to be transient and of a small size.

The DSEWPaC (2010) Species Profile and Threats Database (SPRAT Database) identifies the main threats to the Indo-Pacific Humpback Dolphin and Australian Snubfin Dolphin as habitat destruction and degradation, bycatch in gillnets and shark nets, overfishing of prey species, pollution and poisoning, and interaction with vessels. The main threats likely to affect Australian Bottlenose Dolphin populations include bycatch in gillnets, entanglements in debris, and overfishing. Elsewhere in Australia, the three dolphin species co-exist with coastal development including extensive port facilities such as the Port of Brisbane and Cleveland Bay (Townsville) (Hale *et al.* 1998; Parra 2006).

Bryde's Whale

There are two forms of Bryde's Whales: coastal and offshore. The coastal form of Bryde's whale appears to be limited to the 200m depth contour, moving along the coast in response to availability of suitable prey (Best *et al.* 1984). The SPRAT database states that it is likely that Australian inshore stocks of Bryde's Whales will be small, possibly of similar size to those off South Africa (estimated at 582 ±184 animals: Best *et al.* 1984), and therefore it is unlikely that significant numbers would occur in the vicinity of the Project area. There is no evidence of large-scale migrations of the inshore form of Bryde's Whales. The offshore form is found in deeper water (500 to 1000m). Bryde's Whale is considered to be a fairly opportunistic feeder, readily consuming whatever shoaling prey is available (Kato 2002; Martin 1990). The DSEWPaC (2010) SPRAT Database identifies the main threats to Bryde's Whales as ingestion of discarded plastic, pollution, disturbance (possibly from seismic and/or defence operations), collisions with large vessels, and entanglement in fishing gear. In addition, competition with commercial fisheries may also affect these animals. The following listed threatened and migratory species were recorded on the EPBC Act protected matters search as possibly occurring within the Project area; however, they are unlikely to be present due to a lack of suitable habitat: Humpback Whale, Killer Whale and Blue Whale.

Review of the Queensland Marine Wildlife Stranding and Mortality Database annual reports from 2002-2007 (most recent) indicates that no cetacean deaths were recorded in the Western Cape York region associated with boat strikes.

6.6.3 Dugong

In the Gulf of Carpentaria, most dugongs are found in the shallow waters around the Wellesley Islands in Queensland (485km from the project area) and from the Sir Edward Pellew Islands to Blue Mud Bay in the Northern Territory (Saalfeld and Marsh 2004). Aerial surveys of the Queensland coast of the Gulf in 1997 and the Northern Territory coast of the Gulf in 1985 and 1994 indicate that the total number of Dugongs in the Gulf of Carpentaria is in the range 20,000 to 30,000 (Seagrass Watch, 2005). In 1997, Saalfeld and Marsh (2004) estimated that the population of Dugong on the Queensland Gulf of Carpentaria Coast to be 4,266 +/-657, which represents approximately 14-21% of the estimated Gulf of Carpentaria population. Based on an estimated Australian population of 80,000 (Saalfeld and Marsh 2004), the Queensland Gulf of Carpentaria dugong population represents approximately 5% of the Australian population.

In a 1997 survey (Saalfeld and Marsh 2004), the following number of Dugongs were sighted within the vicinity of the Project area.

- two Dugongs within Albatross Bay;
- three Dugongs at sea adjacent to Albatross Bay;
- one Dugong near Aurukun; and
- one Dugong to the north of Jantz Point.

This represents a total of seven Dugongs sighted within the vicinity of the Project area, which represents approximately 0.2% of the Queensland Gulf of Carpentaria Coast population, between 0.023% and 0.035% of the Gulf of Carpentaria population and 0.009% of the Australian population.

Dugongs prefer to feed on seagrasses that are early or "pioneer" species, particularly species of the genera *Halophila* and *Halodule* (DEWHA 2010a). Field studies verify that seagrass beds do not occur at the proposed port site or the proposed new dredge disposal area. While no foraging areas for Dugong occur in the area of the port development, it is likely Dugong traverse it as they travel between seagrass resources. However, Dugongs were not observed at the proposed port location during the marine ecology surveys undertaken for the purposes of this EIS. The seagrass beds in the Embley and Hey Rivers potentially constitute feeding habitat for Dugong; however, no Dugong were observed associating with these seagrass beds during field studies. The long, strap-like seagrass *Enhalus acoroides*, which dominates the seagrass beds of the Embley and Hey Rivers, is not a preferred species in the Dugong diet.

Dugong mortality in the Gulf of Carpentaria may currently be caused by traditional hunting, incidental capture in commercial mesh nets, targeted capture by illegal foreign fishing vessels in Australian waters, and boat strikes from fast moving vessels. Populations would be vulnerable to a reduction in the area and quality of seagrass beds.

Potential impacts on any Dugong population in the vicinity of the Project area, including potential impacts on any dugong population associated with the construction of the port, barge and ferry terminals (including dredging and spoil dumping operations) is discussed in **Section 6.9.2.3**.

6.6.4 Sharks and Rays

The shark and ray fauna of Albatross Bay is diverse and abundant (Blaber *et al.* 1990): 23 shark species are recorded, 18 of these being whaler sharks (Family Carcharhinidae). The numerically dominant shark species in Albatross Bay is the spot-tail shark (*Carcharhinus sorrah*) and the blacktip shark (*Carcharhinus tilstoni*), comprising 83% of the shark and ray assemblage (Salini *et al.* 1992). Three species of sawfish are also recorded:

- Green Sawfish, *Prisitis zijsron*;
- Narrow Sawfish, *Anoxypristis cuspidata*; and
- Dwarf Sawfish, *Pristis clavata.*

While only the Green Sawfish and Dwarf Sawfish are listed threatened species (Vulnerable) under the EPBC Act, all are listed as critically endangered by the IUCN. The populations of sawfishes in the Gulf of Carpentaria are of global significance. The major threat to sawfish populations is incidental capture in fishing nets (refer also to **Section 8.10**).

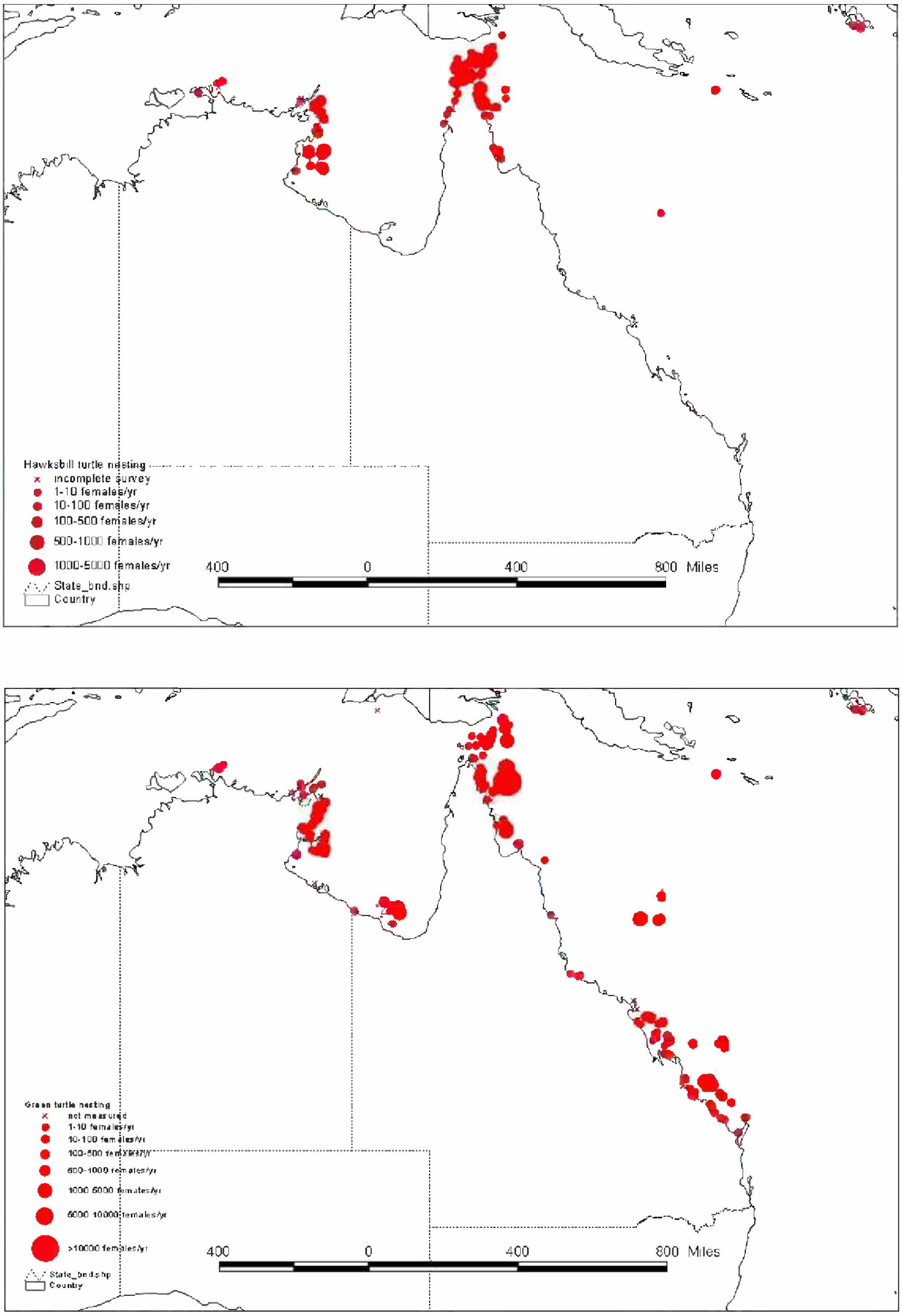
The preferred habitat of sawfishes is shallow inshore sedimentary habitats (less than 10m), although they have been recorded in the Gulf of Carpentaria from waters deeper than 20m. Sawfishes in the Gulf of Carpentaria breed through the wet season until the beginning of the dry period in May (Peverell 2005). A further 16 species of stingrays and shovelnose rays are also recorded from Albatross Bay, all with a wide geographic distribution.

The Whale Shark was recorded on the EPBC Act protected matters search as possibly occurring within the Project area; however, this species is unlikely to be present due to a lack of suitable habitat.

6.6.5 Marine Turtles

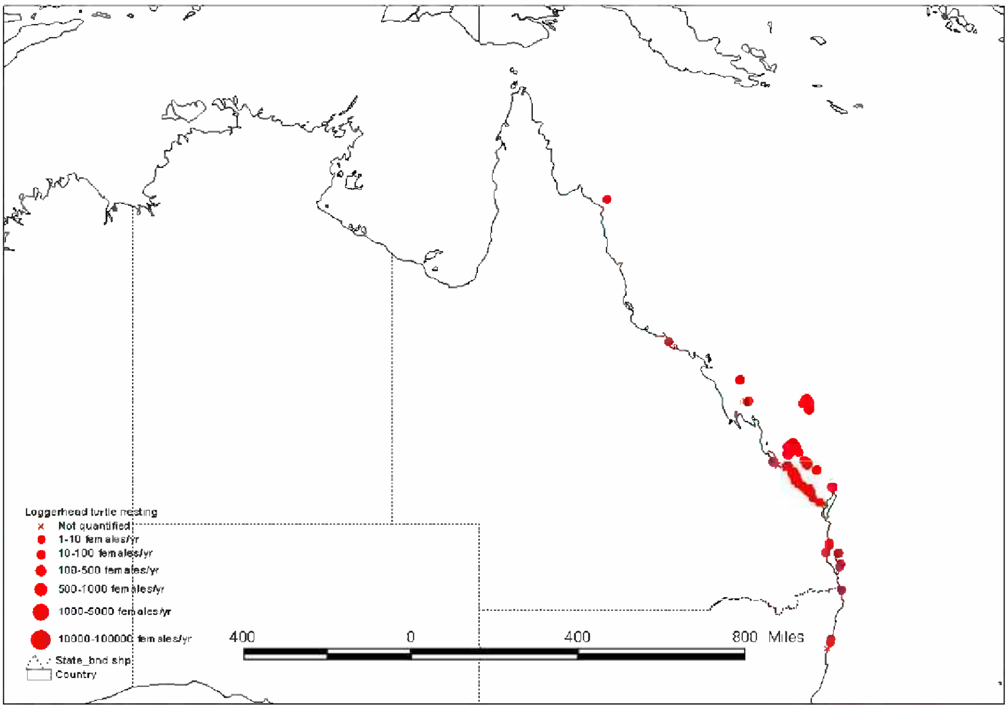
Three species of marine turtles – the Flatback Turtle (*Natator depressus*), the Olive Ridley Turtle (*Lepidochelys olivacea*), and the Hawksbill Turtle (*Eretmochelys imbricata*) – are known to nest on the beaches in the vicinity of the Project area and feed in the surrounding waters. The Flatback Turtles nest all year round, peaking in May through to September. Uncertainty exists over the peak timing of nesting of the other species in the Project area.

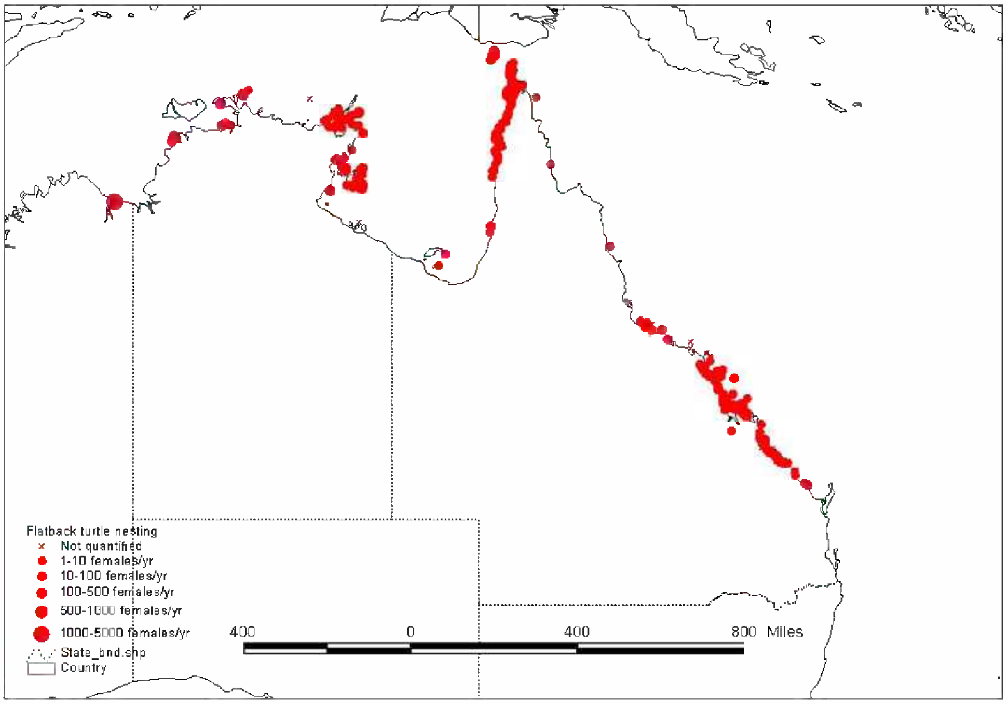
A further three marine turtle species – the Loggerhead Turtle (*Caretta caretta*), the Leatherback Turtle (*Dermochelys coariacea*) and the Green Turtle (*Chelonia mydas*) – also feed in the waters surrounding the proposed port but do not nest on the beaches. The Leatherback Turtle is generally recognised as principally utilising offshore pelagic areas for foraging. Coastal waters such as the proposed port site are not key habitat. The known nesting locations of these marine turtle species in northern and eastern Australia are shown in **Figure 6-50** to **Figure 6-52**. All are listed as threatened species under the EPBC Act. The foraging characteristics of all six turtle species are summarised in **Table 6-35**.



Source: Limpus and Miller 2008

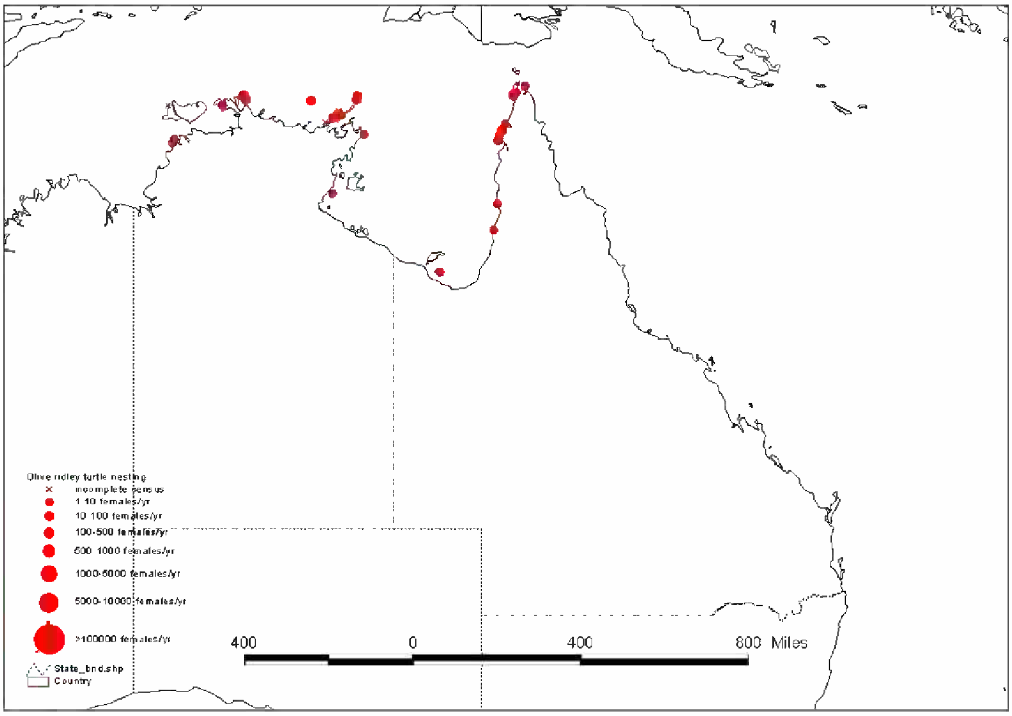
Figure 6-50 Nesting Locations for Hawksbill Turtles (top) and Green Turtles (bottom)

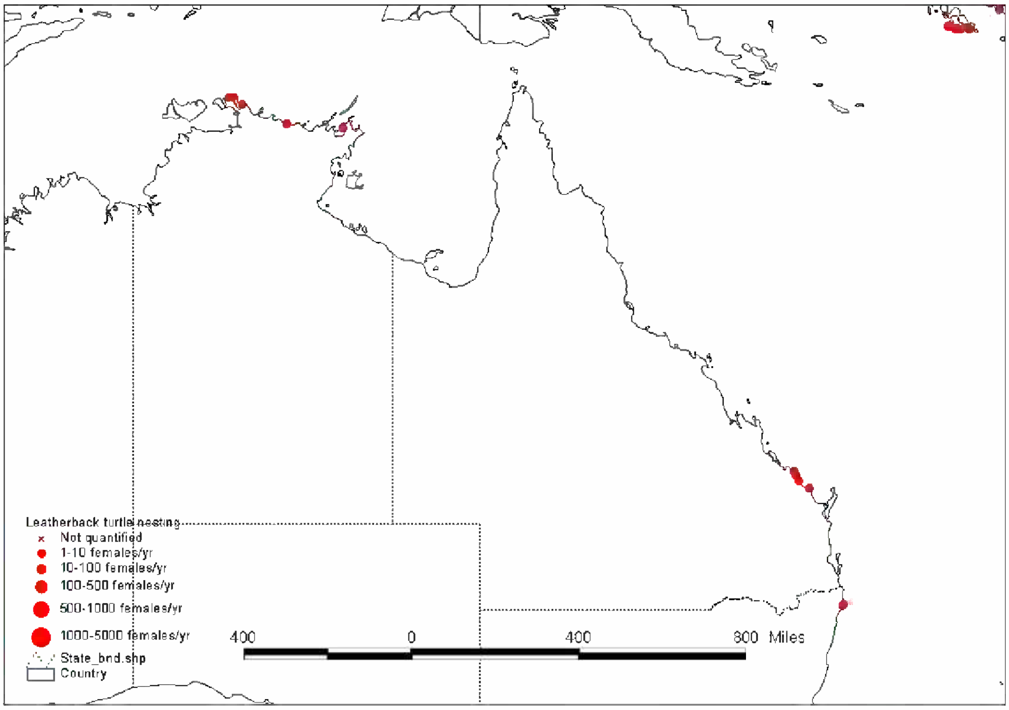




Source: Limpus and Miller 2008

Figure 6-51 Nesting Locations for Loggerhead Turtles (top) and Flatback Turtles (bottom)





Source: Limpus and Miller 2008

Figure 6-52 Nesting Locations for Olive Ridley Turtles (top) and Leatherback Turtles (bottom)

Table 6-36 Sea Turtle Foraging Characteristics

Turtle Species	Foraging Habitats	Preferred Food Items	Reference
Green Turtle (*Chelonia mydas*)	Shallow coastal area, in particular seagrass beds	Seagrass and seaweeds, although juveniles are also carnivorous	Brand-Gardner et al. (1999)
Hawksbill Turtle (*Eretmochelys imbricata*)	Rocky reef and coral reef habitats	Algae, seagrass and sponges	Limpus (2009a)
Flatback Turtle (*Natator depressus*)	Shallow coastal environments including rocky reef and sedimentary habitats	A wide variety of soft-bodied animals including soft corals, sea pens, sea cucumbers, jellyfish and other large plankton	Limpus (2007)
Loggerhead Turtle (*Caretta caretta*)	A wide range of intertidal and subtidal habitats including coral and rocky reefs, seagrass meadows, and unvegetated sand or mud areas	Although their diet is diverse, typical items include bivalve and gastropod molluscs and crabs	Limpus (2008a)
Olive Ridley Turtle (*Lepidochelys olivacea*)	Principally shallow unvegetated coastal environments	Principally feeds on gastropod molluscs and crabs	Limpus (2008b)
Leatherback Turtle (*Dermochelys coriacea*)	Oceanic environments from the sea surface to the seabed	Principally feeds on colonial ascidians such as *Pyrosoma* spp., jellyfish such as *Catostylus* spp. and other soft-bodied invertebrates	Limpus (2009b)

The methodology for the turtle nesting activity survey was developed based on advice from Dr. Colin Limpus (Chief Scientist, Freshwater and Marine Sciences, Queensland Department of Environment and Resource Management). Daylight field surveys were undertaken on foot from 22 to 24 April 2008 to identify marine turtle tracks and nests between Norman Creek to approximately 5km north of Boyd Point, encompassing 27km of beach, including the proposed port site. Consent to conduct the survey was provided by Traditional Owners. The survey was led by Dr Daryl McPhee (Worley Parsons) assisted by Mr Les Player (RTA) and two Traditional Owners – Mr Henry Kelinda and Mr Norman Kerindun.

April was chosen as a survey month to complement previous studies and to focus on a period when Olive Ridley Turtles may be more likely to nest in the area. Previous studies of nesting activity in the area were undertaken in May to July (GHD 2007b) and August to September (Bell 2003). Surveys were undertaken between 7.00am and 12.00pm to maximise the visibility of nests from the previous night's nesting activity (Schroeder and Murphy 1999).

Previously, field investigations by Bell (2004) recorded 41 Flatback Turtle nests and two Olive Ridley/Hawksbill Turtle nests over a 4 day survey in August 2003 along 38km of beach from Boyd Point south to False Pera Head. During 2007 field investigations, GHD (2007b) recorded 15 nesting events during three separate daily survey periods between May and July 2007 along a 10km stretch of foreshore between Boyd Point and Pera Head, with most nesting activity occurring at Boyd Point. Again, the majority of nesting activity represented that of Flatback Turtles, with Olive Ridley or Hawksbill Turtles next identified. Methodologies for the 2003 and 2007 surveys are provided in the survey reports. In the 2003 survey nesting beaches were accessed by water or land and observations of nesting tracks were documented and an assessment of the impact of pig predation on individual nests was recorded. In the 2007 survey standard beach surveying methodology was used.

For the current study and the 2007 survey, nesting activity is described in **Table 6-37** and an example of a Flatback Turtle nesting track is shown in **Plate 6-9**. **Figure 6-53** identifies the marine turtle nesting locations recorded by GHD (2007b) and in the present study. Specific locations and details from the 2003 study have not bee provided as the report only summarises the total nesting activity for each species.

The proposed location of the port is not considered a high density turtle nesting beach. The nearest major rookery on Cape York is Crab Island (Limpus 2007). On Crab Island, Leis (2008) found an average of 30 nesting tracks per kilometre per day of beach surveyed during May 2008. This compares with Bell (2004) who found 0.3 turtle tracks per kilometre per day from False Pera Head to Boyd Bay and GHD (2007b) who found 0.6 tracks per kilometre per day in a similar area. The April 2008 survey of the proposed port area found 0.1 tracks per kilometre per day. The proposed port area can be considered to have a low to medium density nesting population. .

Table 6-37 Sea Turtle Tracks and Associated Nests in the Survey Area, 2007 and April 2008

Survey Date	Coordinates (WGS 84)	Species	Nest and Track Descriptions
May 2007	S12°54'787" E141°37'978"	Green Turtle (*Chelonia mydas*)	Large body pit, single egg shell found at surface, evidence of predation of eggs.
May 2007	S12°54'693" E141°38'107"	Flatback Turtle (*Natator depressus*)	Body pit with several egg shell fragments found on sand surface, evidence of predation of eggs.
May 2007	S12°54'675" E141°38'124"	Unidentified	Large body pit, no evidence of egg predation.
May 2007	S12°54'632" E141°38'124"	Unidentified (body pit only, no tracks)	Body pit with several egg shell fragments found on sand surface, evidence of predation of eggs.
May 2007	S12°54'721" E141°38'135"	Unidentified (old track)	False crawl, no associated body pit or nest.
May 2007	S12°54'613" E141°38'110"	Unidentified (old track)	False crawl, no associated body pit or nest.
June 2007	S12°54'060" E141°40'000"	Unidentified (body pit only, no tracks)	Small body pit, shell fragments evidence of pig predation.
June 2007	S12°54'619" E141°38'128"	Unidentified (body pit only, no tracks)	Small body pit, shell fragments evidence of pig predation.
June 2007	S12°54'693" E141°38'107"	Unidentified (body pit only, no tracks)	Large body pit, several egg shell fragments found at surface, evidence of predation of eggs.
June 2007	S12°54'859" E141°37'910"	Unidentified (body pit only, no tracks)	Small body pit, shell fragments evidence of pig predation.
June 2007	S12°54'875" E141°37'852"	Flatback Turtle (*Natator depressus*)	Body pit/nest. No signs of feral pig predation.
July 2007	S12°54'598" E141°38'106"	Unidentified (body pit only, no tracks)	Small body pit, shell fragments evidence of pig predation.
July 2007	S12°54'662" E141°38'090"	Unidentified (body pit only, no tracks)	Small body pit, shell fragments evidence of pig predation.
July 2007	S12°54'836" E141°37'921"	Flatback Turtle (*Natator depressus*)	No evidence of egg predation.
July 2007	S12°54'875" E141°37'857"	Unidentified (body pit only, no tracks)	Small body pit, shell fragments evidence of pig predation.
July 2007	S12°55'095" E141°37'672"	Olive Ridley Turtle (*Lepidochelys olivacea*) or Hawksbill Turtle (*Eretmochelys imbricata*)	Small body pit and narrow alternating tracks. No signs of predation. Multiple nesting attempts.
July 2007	S12°55'209" E141°37'618"	Flatback Turtle (*Natator depressus*)	No signs of predation. Multiple nesting attempts.
April 2008	S12°55'777" E141°37'299"	Flatback Turtle (*Natator depressus*)	Very fresh tracks and nest (probably only a few hours old). No sign of disturbance or predation. Nest shallow. Track and nest shown in **Plate 6-9**.
April 2008	S12°56'513" E141°36'795"	Flatback Turtle (*Natator depressus*)	Paired gait of flippers. Nest adjacent to cliff edge. Evidence of predation by feral pigs.
April 2008	S12°55'897" E141°36'514"	Flatback Turtle (*Natator depressus*)	Reasonably old track. Paired gait of flippers. Nesting against fallen timber. Predation of nest by pigs/dogs. Quad bike tracks leading to and from nest.
April 2008	S12°56'913" E141°36'500"	Flatback Turtle (*Natator depressus*)	Old track. Straight drag pattern down the centre of the track. Paired gait of flippers. Nesting against cliff and under fallen timber. Predation of nest by pigs/dogs.
April 2008	S12°56'957" E141°36'461"	Flatback Turtle (*Natator depressus*)	Old track but with sufficient morphology to identify it as a flatback. Predation of nest by pigs.

Survey Date	Coordinates (WGS 84)	Species	Nest and Track Descriptions
April 2008	S12°56'990" E141°36'455"	Unidentified	Old track without clear morphology. Predation of nest.
April 2008	S12°59'230" E141°35'320"	Flatback Turtle (*Natator depressus*)	Paired gait of flippers with a wide plastron imprint. Nest adjacent to cliff edge. No tail drag lines down the centre of the track. No evidence of predation.
April 2008	S12°59'608" E141°35'111"	Hawksbill Turtle (*Eretmochelys imbricata*)	Fresh track most probably from previous night. Tracks are in very coarse sand, meandering and in part over rock. Several attempts made to nest on the side of a vegetated dune. No evidence of predation, but feral pig tracks abundant in the general area (Thud Point).
April 2008	S12°54'704" E141°38'047"	Flatback Turtle (*Natator depressus*)	False crawl with no associated nest.
April 2008	S12°54'635" E141°38'133"	Unidentified	Old nest with no signs of tracks but fragments of egg shell present.

2007 Survey Data from GHD, 2007b


Plate 6-9 Flatback Turtle Nest (left) and Turtle Tracks between Boyd Point and Pera Head

Available information identifies that scattered nesting of Flatback Turtles occurs along most beaches of western Cape York, including the proposed Project site. There are no concentrated high density rookeries such as those that occur on islands of the Torres Strait such as Crab Island and Deliverance Island; however, the beaches of western Cape York represents an area of low to medium density nesting activity for this species. Nesting of the Olive Ridley and Hawksbill Turtles in the vicinity of the Project site and throughout the western Cape York beaches is identified as low density. There are uncertainties regarding whether nesting of Olive Ridley Turtles is still occurring in the western Cape York region.

Incidental observations while undertaking boat-based marine ecology field work identified that, within the area surveyed, marine turtles (predominantly Flatback Turtles) were frequently observed surfacing. The qualitative observations did not reveal any apparent preference for one part of the study area over the other. No quantitative assessment of the relative importance of the area as sub-tidal feeding habitat for marine turtles was undertaken.

Marine turtles are long-lived and late maturing with maturity reached at between 30 and 50 years of age (Miller 1996). Female marine turtles emerge from the water, generally at night, and move up the shoreline to select a nesting location. Most females do not nest in consecutive years (Miller 1996). However, a female marine turtle may lay several clutches of eggs per year (Limpus *et al.* 1984). Nesting marine turtles generally demonstrate fidelity to a nesting beach and return to nest on their natal beach with a high degree of precision (Limpus *et al.* 1984). The process by which turtles select nesting sites along a beach has not been clarified (Miller 1996); however, the light regime is considered to have a significant impact on the emergence of female marine turtles from the ocean. Marine turtles may also emerge from the water and return without attempting to excavate a nest or lay eggs – a phenomenon known as a "false crawl". Nesting generally occurs between the high water mark and the foredune; however, nests may also be laid below the high tide mark (Whiting *et al*. 2007). If inundation of nests is significant, the nest becomes unviable.

The sex ratio of turtle hatchlings is dependent on the temperature of incubation, which is a function of sand colour. Nests in darker sand incubate at higher temperatures and produce more females (Hays *et al*. 2001). For Flatback Turtles, the most numerically important nesting location, Crab Island, produces mostly male offspring while the scattered nesting in darker coloured beaches on western Cape York, such as those in the area of the proposed development, produce predominantly female offspring (Dr Colin Limpus, pers. comm.).

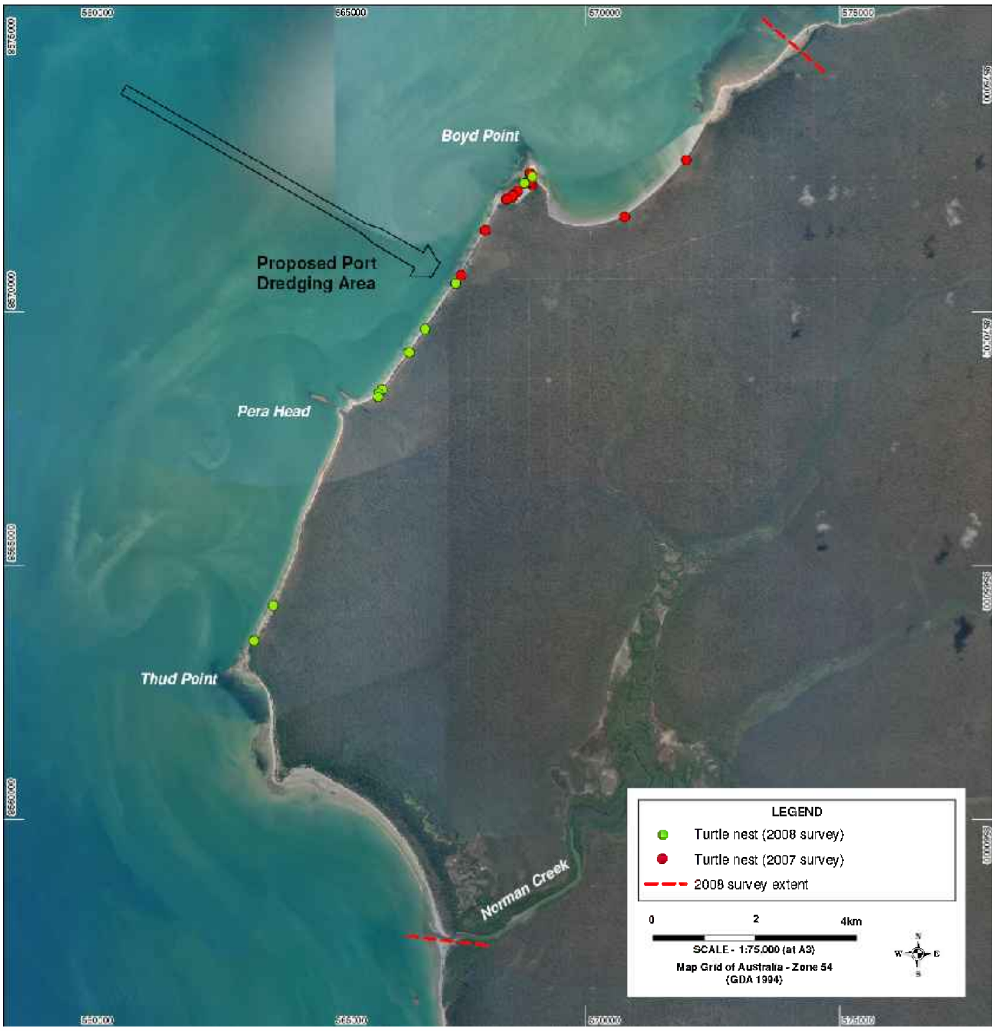


Figure 6-53 Location of Turtle Nesting Activity May – July 2007 and April 2008

Once hatched, lighting cues are identified as critical for hatchlings to move from the beach to the ocean – a behaviour known as sea-finding. In simple terms, where there are no anthropogenic light sources, hatchlings move away from the dark silhouetted shoreline towards the brighter ocean horizon. Brightness in this context, however, is a term that encompasses wavelength and intensity (Witherington and Martin 1996). The uniformity of the light regime can also act as a cue, whereby hatchlings may orientate away from a horizon that has patterns of light and shadow representing shoreline vegetation or structures. In practical terms, the turtles would see these patterns and orientate away from the shore and head towards the more uniform light environment of the ocean horizon (Godfrey and Barreto 1995; Witherington and Martin 1996).

Altered above-water, night-time light regime can have an effect on hatchlings' attempts to find water. Lights at a nesting beach can result in turtle hatchlings heading inland rather than into the ocean, with subsequent mortality. Lights adjacent to nesting beaches can result in hatchlings entering the ocean safely, only to re-emerge closer to the light source. At Hummock Hill Island (central Queensland), lighting from the Boyne Island smelter, which is approximately 18km north of the nesting beach, was observed to disorientate nesting turtles (Hodge *et al*. 2006). This lighting source is extremely bright and lacks any measures to mitigate impacts on marine turtles. A modified lighting regime may elicit an impact, with illumination of salt spray adjacent to a nesting beach being sufficient to alter sea-finding behaviour (Dr Colin Limpus pers. comm.). Offshore lighting may result in hatchlings aggregating under the light, effectively becoming a focus for predatory fish. Flashing lights (e.g. navigation beacons) are not recorded as inducing alteration to sea-finding behaviour.

Currently, there are two major anthropogenic threats to nesting marine turtles along the beaches of western Cape York – predation by feral pigs and entanglement in discarded fishing nets (ghost nets). The former is currently considered the most significant. Feral pigs are a well-acknowledged environmental problem in Australia. They are identified as a key threatening process under the EPBC Act and a Threat Abatement Plan (TAP) is currently in place to protect marine turtles in Australia. The impact from feral pigs on turtle nesting is a significant reason for listing feral pigs as a key threat.

Field surveys identified significant destruction of turtle nests by feral pigs, at and adjacent to the area of the proposed port development. Feral pig activity within the field survey area was particularly prevalent in areas with direct access to the beach from adjacent bushland. Where cliffs extended to the water edge, feral pig activity was considerably less, or absent. The two areas where feral pig activity was most prevalent were Boyd Point and Thud Point. Extensive feral pig activity, including turtle nest excavation, was observed just above the high tide mark at Boyd Point. Although exact estimates were not possible, approximately 50 to 60 nests appeared to be disturbed on approximately 500m of beach north of Boyd Point (refer **Plate 6-10**). This count includes nests with visible track marks, and those without track marks (time of nesting is unknown).

Ghost nets are discarded or lost nets that float in the ocean until they wash up on beaches (refer **Plate 6-11**). These nests can entangle and kill marine turtles in the open ocean and/or in inshore areas. According to the Carpentaria Ghost Nets Program, which is an Indigenous community and Commonwealth Government partnership in northern Australia, most ghost nets in the Gulf of Carpentaria originate from south-east Asian countries, in particular, Taiwan, Indonesia and Korea.

Plate 6-10 Example of Feral Pig Digging North of Boyd Point (background)

Plate 6-11 Juvenile Olive Ridley Turtle Carcass in a Ghost Net near Pera Head

6.6.6 Sea Snakes

The Gulf of Carpentaria contains a diverse and abundant sea snake assemblage of at least 17 species. In the Weipa area, the numerically dominant sea snake species is *Lapemis hardwicki,* which comprises approximately 90% of the sea snake population (Redfield *et al*. 1978).

Other species recorded in the Weipa area include: *Acalyptophis peronii*; *Aipysurus duboisii*; *Aipysurus laevis*; *Astrotia stokesii*; *Enhydrina schistose*; *Hydrophis elegans*; and *Hydrophis ornatus*.

All these species have been recorded from multiple locations elsewhere in the Gulf of Carpentaria (Redfield *et al*. 1978). There are no specific studies that have examined the sea snake fauna specifically at the sites of the proposed development. The main impact on sea snake populations in the Gulf of Carpentaria is incidental capture in the Northern Prawn Fishery.

6.6.7 Bony Fish and Nektobenthic Marine Invertebrates

Albatross Bay is recognised as extending in a straight line from Jantz Point southwards to Pera Head. Information from Albatross Bay is also relevant to areas directly adjacent. The fish assemblages of Albatross Bay have been well studied and much of this work has focussed in or directly adjacent to the Embley River estuary (e.g. Blaber *et al.* 1989, 1990a). 344 fish species have been recorded in Albatross Bay (Baker and Sheppard 2006).

No fish species listed under the EPBC Act or the NC Act have been recorded in Albatross Bay. Different fish assemblages occur in the various habitats sampled. The fish biomass estimates obtained by Blaber *et al.* (1989) for open water channels, sandy beach habitats and mangroves creeks were found to be similar to previously-published estimates from tropical estuarine areas. In contrast, the fish biomass of seagrass habitat was lower than that estimated for other tropical estuaries. The fish assemblages of Albatross Bay estuarine and shallow coastal waters are summarised in **Appendix 6-A**.

Along the foreshore, just south of the Embley River estuary, the dominant species caught by gill netting were Queenfish, Milkfish and Blue Salmon (Blaber *et al.* 1995). Overall, Blaber *et al.* (1995) found that fish catch rates along the Weipa foreshore were less than in the adjacent estuary and offshore waters. Nonetheless, Blaber *et al.* (1995) identified the area as a transition zone between estuarine and offshore waters for some species. In offshore waters, the dominant families of fish were those that occurred at similar depths and distance from the coastline throughout the eastern and south-eastern region of the Gulf of Carpentaria (e.g. Family Leiognathidae, Ponyfishes).

Although not well studied, the reef habitats in Albatross Bay support a diverse assemblage of demersal and pelagic species. Demersal species include members of the Families Serranidae (e.g. Coral Trout, *Plectropomus leopardus*), Lutjanidae (e.g. Fingermark, *Lutjanus johnii* and Red Emperor, *Lutjanus sebae*) and Labridae (e.g. tuskfish, *Choerodon* spp.). Pelagic species include mackerel (e.g. Spanish Mackerel, *Scomberomorus commersoni*) and various tunas.

Three species of sygnathids (pipefish and seahorses) that are listed marine species under the EPBC Act (section 248) – *Hippichthys heptagonus* (Big Belly Seahorse), *Hippocampus kuda* (Spotted Seahorse) and *Hippocampus whitei* (White's Seahorse) – are confirmed to occur in Albatross Bay (Blaber *et al.* 1990). As the distribution and abundance of sygnathids are poorly known, it is highly likely that other species of sygnathids also occur in Albatross Bay.

Albatross Bay is known to be an important nursery area for the juvenile tiger and banana prawns that are the principal target species in the Northern Prawn Fishery area. Banana prawns migrate from estuarine areas into the Gulf of Carpentaria for spawning from September to November and March to May. At low tide, juvenile and sub-adult prawns are most abundant in small tidal creeks and gutters that drain from mangrove forests (Vance *et al.* 1998; Kenyon *et al.* 2004).

The Brown Tiger Prawn (*Penaeus esculentus*) and the Grooved Tiger Prawn (*Penaeus semisulcatus*) are abundant in the Gulf of Carpentaria. Brown Tiger Prawns spawn throughout the year, with peak spawning occurring from August to September (Kenyon *et al.* 2004). Grooved Tiger Prawns' spawning peaks between August and October, with a minor peak in the months of January and February. Juvenile tiger prawns are generally associated with vegetated habitats (particularly large seagrass beds) in the vicinity of estuaries (Haywood *et al.* 1995; Rothilsberg *et al.* 1996). Other prawn species that occur in abundance in Albatross Bay are Endeavour Prawns (*Metapenaeus endeavouri* and *Metapenaeus ensis*) and Eastern King Prawns (*Penaeus plebejus*).

The cephalopod (squid and cuttlefish) assemblage in the Gulf of Carpentaria is diverse and abundant, with at least 21 species. The numerically dominant species of squid and cuttlefish recorded are *Photololigo chinensis* and *Photololigo edulis*, and *Sepia elliptica* and *Sepia pharaonis* respectively (Dunning *et al.* 1994). There are no specific studies that have examined the squid and cuttlefish assemblage at the sites of the proposed marine infrastructure.

Mud crabs are common in the creeks and rivers of Albatross Bay.

6.6.8 Macrobenthic Infauna

Long and Poiner (1994) examined the macrobenthic infaunal assemblage in sub-tidal areas of the Gulf of Carpentaria. Species assemblages consisted primarily of overlapping species distributions rather than highly-structured, discrete communities with well-defined groups that are characteristic of the community. Polychaete worms were identified as the numerically dominant group of animals, followed by crustaceans and bivalve molluscs. The benthic infauna assemblage has been impacted for many years by prawn trawl operations.

The structure of macrobenthic assemblages was surveyed at six locations within three sites: the proposed new disposal ground, the proposed port area and the existing disposal ground in Albatross Bay using a benthic grab to collect four replicate samples and sieving them using a 1mm mesh sieve. Remaining infauna material was preserved and identified to lowest practical taxonomic level (typically Family morphospecies level, whereby each apparently different taxonomic "species" of a family is a different "morphospecies"). The taxa richness and abundance of the assemblage, and the five numerically dominant taxa at each of the survey sites, was assessed (**Table 6-38** and **Table 6-39** respectively).

Of the three sites, it is noteworthy that the existing spoil ground in Albatross Bay had an exceptionally high abundance of the small bivalve *Gouldia* sp., which comprised approximately 90% of the total abundance (refer **Table 6-39**). The high abundance of *Gouldia* sp. at the existing disposal site is most likely a direct response of the species rapidly colonising the area after dredge spoil deposition. Although available information is limited, a similar response by populations of this genus was recorded in the United States in response to dredge disturbance and spoil deposition (Iversen and Beardsley 1974).

The majority of taxa surveyed at the three sites were previously recorded by Long and Poiner (1994).

Table 6-38 Taxa Richness and Abundance of Macrobenthic Infauna at the Three Survey Sites

Site	Taxa Richness	Abundance
New Disposal Ground (6 locations)	148	851
Port Area (6 locations)	111	504
Disposal Ground in Albatross Bay (6 locations)	97	4562

Table 6-39 Five Dominant Macrobenthic Infaunal Taxa at the Three Survey Sites

Rank of abundance	New Disposal Ground	Port Area	Disposal Ground in Albatross Bay
1	Polychaete worm – *Eunice vittata sp?*	Polychaete worm – F. Chaetopteridae	Bivalve mollusc – *Gouldia* sp.
2	Polychaete worm – F. Maldanidae	Peanut worm – *Aspidosiphon* sp.	Bivalve mollusc – *Nuculana* sp.
3	Polychaete worm – F. Capitellidae	Polychaete worm – *Eunice vittata sp?*	Bivalve mollusc – *Yoldia* sp.
4	Anemone – F. Zooanthidae	Polychaete worm – F. Maldanidae	Polychaete worm – F. Maldanidae
5	Tusk shell – F. Laevidentaliidae	Amphipod crustacean – *Apseudes* sp.	Bivalve mollusc – *Yoldia narthecia sp?*

6.6.9 Introduced Marine Species

In Australia, there are existing protocols in place to minimise the risk of marine pest incursions and to ensure the early detection of an incursion if one occurs. Pests may be introduced by ships' ballast water or hull fouling. There is a National System for the Prevention and Management of Marine Pest Incursions, which includes three major components: prevention, emergency response, and ongoing control and management of existing pests. Since 2001, requirements have been in place for the management of internationally-sourced ballast water that apply to all ships arriving from overseas. The Australian Ballast Water Management Requirements (DAFF 2008) details the controls to minimise the risk of introducing harmful aquatic organisms into the environment. These requirements are implemented through the *Quarantine Act 1908* and are administered by the Seaports Program within the Australian Quarantine Inspection Service (AQIS). No ballast water may be discharged from internationally trading vessels in Australian waters without express written permission from AQIS as discussed in further detail in **Section 13.3.8**.

All vessels owned and contracted by RTA would manage ballast water through a Ballast Water Management Plan which would comply with Australian mandatory requirements and the International Convention for the Control and Management of Ships Ballast Water and Sediments (IMO 2004). There would be no hull cleaning at the proposed port; however, pests may still be present on ships hulls. Monitoring would be undertaken to provide a means of early detection of introduced pests (refer **Section 6.9.4.6** and **Section 13.3.8**).

Extensive surveying for marine pest species has been undertaken at the Port of Weipa and no invasive marine pest incursions have been recorded (Hoedt *et al.* 2001; PCQ 2007; PCQ 2009). While no invasive species have been found, at least two introduced species were identified in the 1999 baseline survey (Hoedt *et al.* 2001). The detailed baseline survey of the Port of Weipa has been supplemented since 2006 by inspection every three months of larval monitoring devices installed in the port and targeted surveys by DEEDI of high-risk areas in the port. This monitoring was instigated following the discovery of the high-risk species Asian green mussel (*Perna viridis*) on a non-trading vessel that had been in the Port of Weipa. No Asian green mussels or other non-indigenous species have been detected since the monitoring began in 2006 (PCQ 2009).

6.7 Marine Fisheries Resources

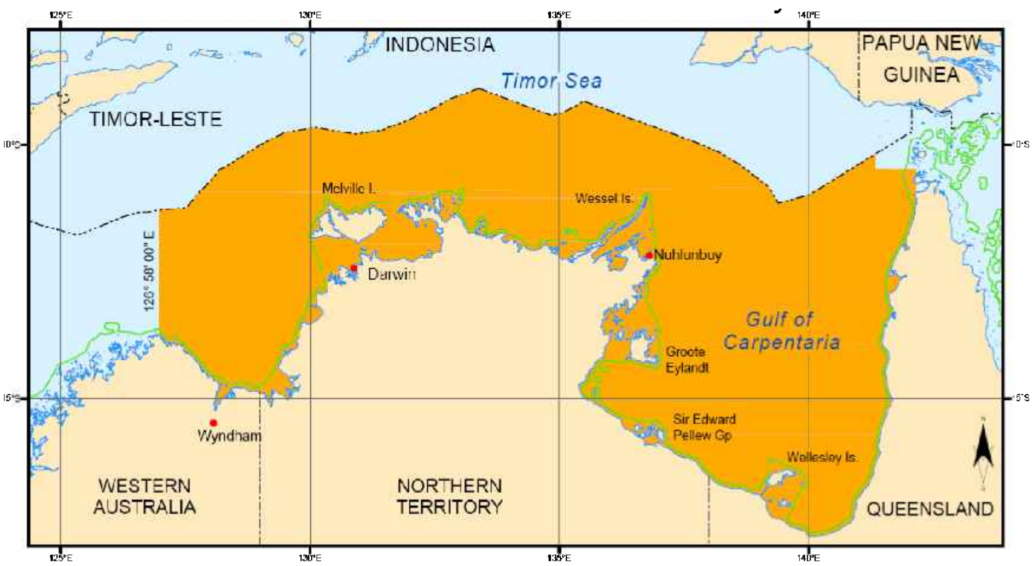
The Gulf of Carpentaria hosts commercial fisheries that are managed by the Queensland Government, Commonwealth Government, and jointly through the Queensland Fisheries Joint Authority (QFJA). The Queensland Government manages the commercial mesh net fisheries and crab fisheries through DEEDI. The Commonwealth Government manages the Northern Prawn Fishery (NPF) through the Australian Fisheries Management Authority. The line fishery is managed through the QFJA. There is also a Developmental Finfish Trawl Fishery managed through the QFJA. The recreational and charter fisheries are managed by DEEDI.

Catch information for the fisheries managed by the State and the QFJA is recorded by operators in compulsory logbooks that are submitted to DEEDI. The catch data for the fishery is recorded at a very broad spatial scale of "30 minute grids". The area of the proposed development is within reporting grid "AB8". For monitoring and assessment purposes, the NPF is divided into 15 large statistical areas, with the Weipa statistical area being relevant for the proposed development.

Recreational fishing catches are monitored through a biennial phone survey and diary program. These surveys collect information at the spatial level of the ABS statistical division (based on where an angler resides), and can only provide very broadscale information. Weipa falls within the Far Northern Statistical Division, which stretches from the Herbert River just north of Townsville, through the Torres Strait, to the Edward River on the mid-western coast of Cape York. As such, this information cannot be relied upon to provide relevant information at the appropriate spatial scale.

6.7.1 Northern Prawn Fishery

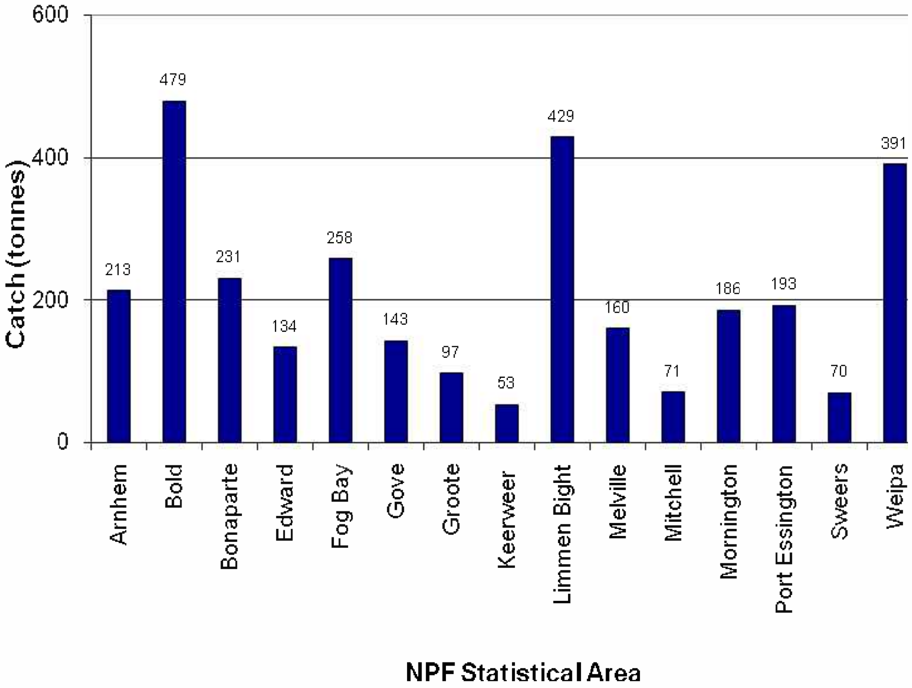
The NPF is Australia's most valuable commercial fishery, with an annual value of production averaging $95 million (1999–2007). In 2007 there were 52 operators accessing the fishery. The prawn fishing area extends across the northern part of Australia from Cape Londonderry (Western Australia) east to Cape York (refer **Figure 6-54**). In practice, fishing is focussed on a number of "hotspots", although the relative importance of these hotspots varies between years in response to climatic factors, in particular rainfall.



Source: Raudzens 2007

Figure 6-54 Permitted Fishing Area of the Northern Prawn Fishery

The main species caught in the NPF are tiger prawns and banana prawns, targeted at different times and generally in different locations. For catch and effort reporting purposes the NPF is divided into 15 statistical areas. The proposed port development area is within the Weipa statistical area, which extends from approximately Port Musgrave southwards to Thud Point. Tiger prawn fishing takes place in the western Gulf of Carpentaria from August to November, with little catch recorded in the Weipa statistical area or in the eastern Gulf of Carpentaria in general. The banana prawn season extends from April to June, with the Weipa statistical area being a significant area of production (refer **Figure 6-55**). Banana prawns are targeted in waters less than 20m deep. Areas adjacent to the proposed port site between Pera Head and Boyd Point and the potential spoil ground location are important areas within the Weipa statistical area for catching banana prawns (refer **Figure 6-56**). These species spawn offshore and give rise to larvae that migrate into 'nursery' grounds, usually seagrass beds or mangrove areas, in shallow coastal areas where they feed and grow. After three months in these nursery grounds, juveniles migrate offshore into the fishing grounds where they feed and grow for at least another three months before attaining commercial size. Peak times of migration of larvae onshore and juveniles offshore are from August to April. The potential impacts on prawn nursery grounds within the Project area are discussed in **Section 6.9.6.1**.



Source: Raudzens 2007

Figure 6-55 Total Catch of Banana Prawns for Each Area of the Northern Prawn Fishery, 2006

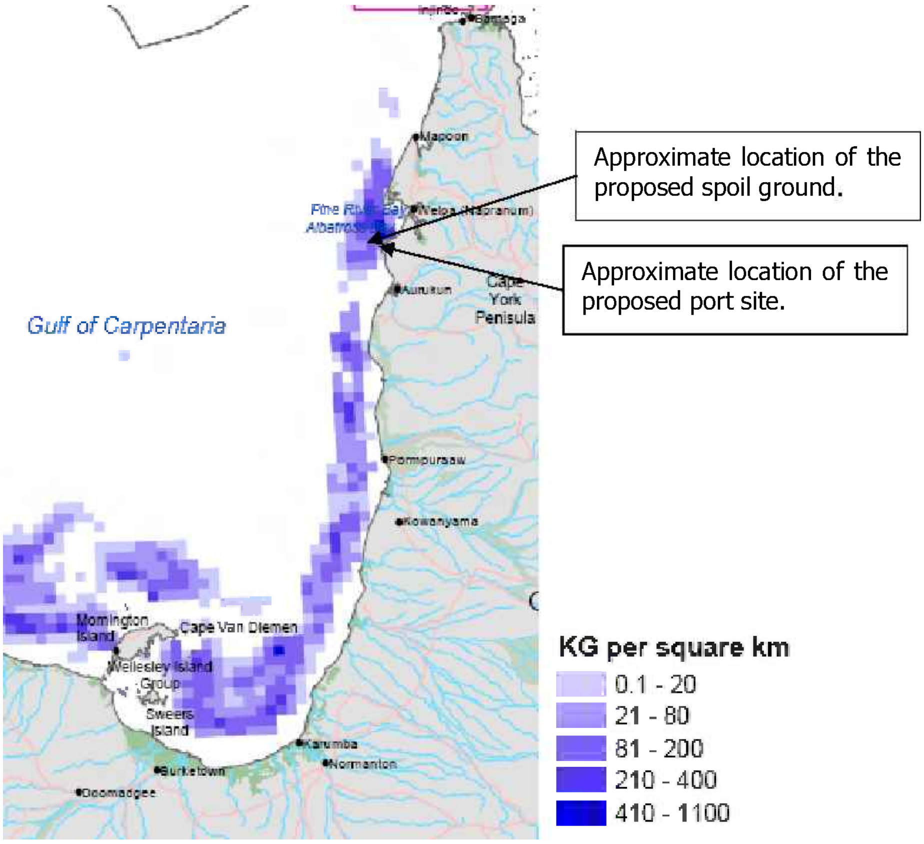


Figure 6-56 Prawn Catch – Eastern Gulf of Carpentaria Region of the Northern Prawn Fishery

6.7.2 Gulf of Carpentaria Commercial Fisheries

The Gulf of Carpentaria Inshore Finfish Fishery is a commercial mesh net fishery managed by the Queensland Government that extends from the Queensland – Northern Territory border to Slade Point on the north-west coast of Cape York Peninsula. It has an inshore component (0–7 nautical miles), targeting species such as barramundi and threadfins (*Polynemus* spp.), and an offshore component (7–25 nautical miles), targeting various shark species and grey mackerel (*Scomberomorus semifasciatus*). In 2006, 87 licensed fishers harvested 1,782 tonnes of fish with a landed gross value of production of $12.8 million. The rivers flowing into Albatross Bay are closed to the fishery, although the foreshores and sub-tidal areas can be accessed. Norman Creek can be accessed by the fishery, but the coarse spatial scale of the catch and effort data does not allow for determining the relative importance of this area for the fishery.

Production of the key target species in the inshore and offshore fishery components is reliant on intact and functioning inshore habitats such as mangroves and seagrass and the connectivity between habitats. There is a closed season between November and February to protect the spawning stock of key target species. On average, reporting grid AB8 contributes approximately 3% of the total annual catch of the Gulf of Carpentaria Inshore Finfish Fishery.

The Gulf of Carpentaria Commercial Line Fishery is managed by the Queensland Government and extends from the Queensland – Northern Territory border to Slade Point on the north-west coast of Cape York Peninsula. In 2006, 27 licensed fishers harvested 237 tonnes of fish with a landed gross value of production of $1.6 million. The main target species is Spanish mackerel, which constitutes 90% of the total catch. On average, reporting grid AB8 contributes approximately 12% of the total annual catch of the Gulf of Carpentaria Commercial Line Fishery. Commercial line fishermen recognise the reef areas in the vicinity of Pera Head, Boyd Point and Thud Point as key locations for Spanish mackerel (*Scomberomorus Commerson*) in the Weipa region. The peak season for Spanish mackerel in the Weipa region extends from August to November.

Unlike the commercial net and line fisheries discussed in the previous two sections, there is no specific fishery restricted to Gulf of Carpentaria waters for the taking of mud crab. Any licensed mud crab operator in Queensland can operate in Gulf of Carpentaria waters. At the regional level, there is a strong positive correlation between areas of mangrove forest and mud crab production. The creeks and rivers that drain into Albatross Bay are the most important mud crab harvesting areas in the Gulf of Carpentaria (Williams 2002). Mud crabbing generally focuses on areas directly adjacent to large mangrove stands, including small creeks draining such stands. The proposed port development and spoil ground is remote from these areas and therefore would not impact on mud crab populations or access to the mud crab fishery areas. Mud crabbing occurs in the Embley and Hey Rivers but the proposed barge and ferry terminal locations are not considered prime habitat for mud crabs.

Developmental fisheries are those that use new methods and/or target new and underutilised species. In the Gulf of Carpentaria there is a Developmental Finfish Trawl Fishery, extending north of 15 degrees south latitude to a distance of 25 nautical miles from the coastline. This fishery intersects the proposed Project area. The principal target species are crimson snapper (*Lutjanus erythropterus*), saddletailed snapper (*Lutjanus malabaricus*) and mangrove jack (*Lutjanus argentimaculatus*). In 2005, there were two vessels that captured 479 tonnes of fish with a landed gross value of production of $1.5 million.

6.7.3 Recreational Fishery

Recreational fishing is a popular pastime in the Project area and a range of species including barramundi, mangrove jack, fingermark, threadfins and mackerel are caught (Baker and Sheppard 2006). Common recreational fish species are identified in **Appendix 6A**. It is estimated that 9% of tourists who visit Weipa do so primarily to fish (GHD 2005). There is no information on the recreational catch and the distribution of fishing effort in the Project area.

Guided fishing supports recreational fishing tourism and attracts international tourists to Weipa. It is estimated there are eight guided fishing businesses in Weipa with a combined income of $396,000 (Fenton and Marshall 2001). Anecdotal information suggests the current income of the charter vessel fishery based in Weipa has increased substantially since 2001. The charter fishing businesses based at Weipa principally fish at the reefs in Albatross Bay, including nearby

Pera Head and Thud Point, the rivers and creeks that drain into it, and the sandflats that extend from the Embley River south to Norman Creek. Popular recreational reef fishing spots in relation to the Project marine facilities are shown in **Figure 6-57**.

6.8 Environmental Values

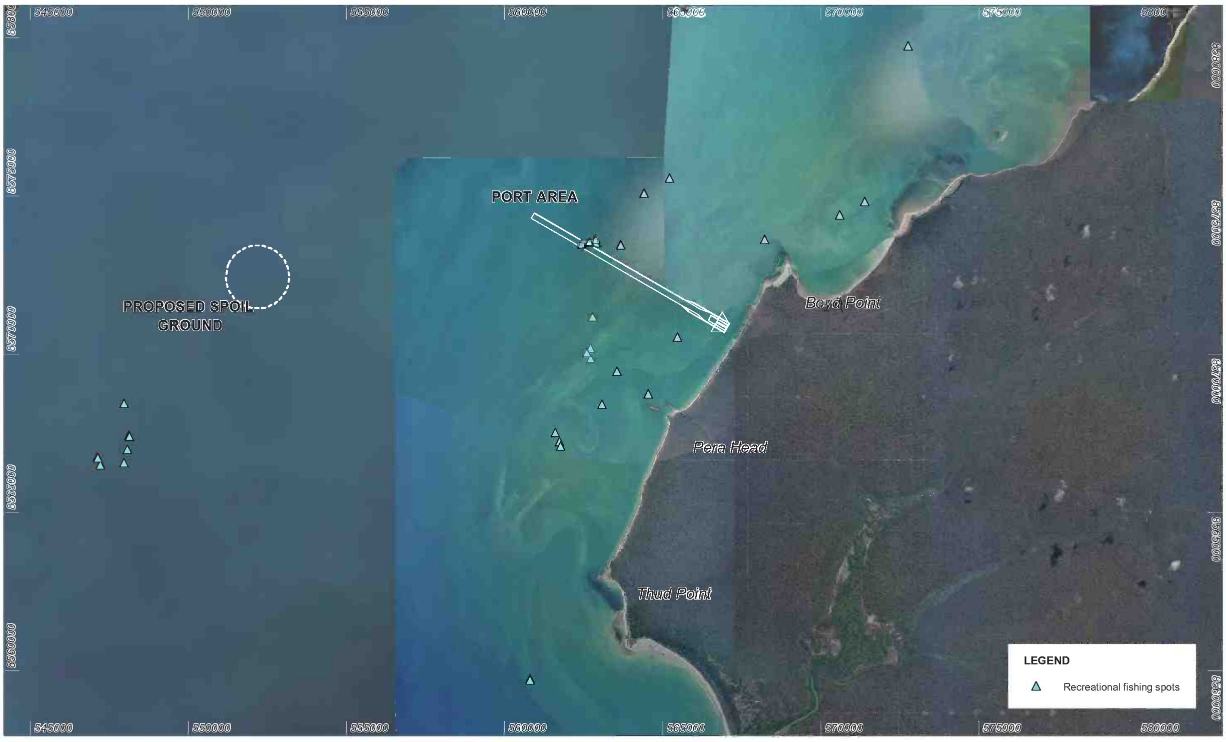
As identified in **Section 6.4.1**, no specific EVs or WQOs have been determined for the Western Cape York area. The marine ecosystem in the Project area is effectively unmodified and is considered of high ecological value under the EPP (Water). The EV to be protected is the biological integrity of the aquatic ecosystem. The Project area includes diverse habitat that supports species of conservation significance, and commercial and recreational fishing in water quality relatively unaffected by human impacts.

The EVs in the vicinity of the proposed port area are the diversity of habitats that support the local marine assemblages, and the use of the foreshore by nesting marine turtles. The area includes a diverse reef assemblage comprising soft and hard corals, algae, sponges and soft corals centred around Boyd Point, Pera Head, and reefs south to Thud Point. These reef assemblages occur adjacent to, but not at, the proposed port site. The importance of these reef systems (Boyd Point to Thud Point) in a regional context is considered to be high, as they support resources that are of conservation, cultural, commercial and recreational importance. Large soft sediment habitats provide habitat for macrobenthic infauna and fish species, including sawfishes, which are of conservation significance. Various fish species that support recreational, guided and commercial mesh net and line fishing occur in the reef areas and along the foreshore flats. Seagrasses are present in Boyd Bay to the north of the proposed port development and have historically been recorded in sparse isolated patches south of Thud Point.

The EVs of the proposed spoil ground include habitat for benthic infauna, fish and mobile invertebrate species that prefer sub-tidal soft sediment habitats. This type of habitat is widespread throughout the Gulf of Carpentaria. Banana prawns seasonally occur in the area and are targeted by the Northern Prawn Fishery.

The EVs of the barge/ferry terminal locations in the Embley and Hey Rivers include seagrass beds directly adjacent to the Hornibrook Terminal dredge area and isolated seagrass patches within and adjacent to the Humbug Terminal dredge area. Seagrass beds provide food and shelter for fish and invertebrates including those that support various commercial and recreational fisheries. The soft sediment estuarine area within the Embley and Hey Rivers also support macrobenthic infauna that contributes to fisheries production.

The Traditional Owners value the coastal environment for the protection of flora and fauna, for fishing and for recreation (refer **Section 16.2.2**).



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Map Grid of Australia - Zone 54
Geocentric Datum of Australia 1994

Aerial photography and vector data supplied by client.

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SOUTH OF THE EMBLEY PROJECT

FIGURE 6-57

Recreational fishing spots near port area and proposed spoil ground

Project No: 301001-01069 | Figure: 01069-00-GM-EN-0020 | Rev: A

Compiled by BRISBANE GEOMATICS SECTION

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6.9 Potential Impacts and Mitigation Measures – Marine

Potential impacts that may occur during the construction and operational phases of the Project are listed in **Table 6-40**.

Potential impacts and proposed management measures are discussed below in terms of: alterations to coastal processes, dredging, water quality, habitat, species, fisheries and pest species. A summary of mitigation strategies is presented in **Section 6.9.8**.

Table 6-40 Potential Impacts During Construction and Operation

Potential Impact	Port Area	New Disposal Ground	Embley River – Hornibrook & Humbug Terminals	Albatross Bay Spoil Ground	Hey River Terminal
Creation of a turbidity plume, and subsequent deposition and re-suspension of fine sediments	Construction and operation	Construction and operation	Construction and operation	Construction and operation	Construction and operation
Physical destruction to benthic habitats, including hard and soft coral communities, and fauna from dredging and construction of infrastructure	Construction and operation	Construction and operation	Construction and operation	Construction and operation	Construction and operation
Changes to coastal processes (erosion and deposition)	Construction and operation	—	—	—	—
Introduction of pollutants to marine waters and sediments	Construction and operation	Construction and operation	Construction and operation	—	Construction and operation
Underwater acoustic impacts from piling driving and vessel movement	Construction and operation	—	Construction and operation	—	Construction and operation
Disturbance from boating and shipping activities including exclusion from habitat	Construction and operation	—	Construction and operation	—	Construction and operation
Introduction of hard artificial substrata (e.g. piles) into the marine environment and shading effects from wharf structures	Operation	—	Operation	—	Operation
Altered light regime	Construction and operation	—	—	—	—
Boat strike	Construction and operation	—	Construction and operation	-	Construction and operation
Introduction of pest species	Operation	—	—	—	—

— = Limited potential for impacts

6.9.1 Altered Coastal Processes

The proposed open-piled wharf jetty and berth pockets have a low potential to impact the alongshore transport of sediment. There is a greater potential for impact to the longshore beach profile and cliffs due to the increased depth of the proposed berth and departure area allowing higher wave energy to reach shore during a storm. Any impacts would be limited to a reasonably short distance both sides of the wharf trestle structure. Potential impacts would be monitored and mitigation undertaken if cliff erosion is exacerbated.

Cross-shore transport of sediment occurs during storm events and alters the nearshore morphology by forming storm sand-bars. This is a natural beach response. Modelling indicates migration of the coarser sands as bed forms would not extend far enough offshore to pose infill issues with the proposed dredged berths. However, there may be a low potential for the finer beach sands to infill the proposed dredged berth area, although the effects of this process are limited due to the small volume of this fraction of sediment in the upper beach material. Furthermore, there is a reduction in transport potential of suspended cross-shore sediment with increasing water depth towards the berth pocket.

The influence of the proposed dredging inshore on the local tidal current pattern is determined by the following:

- berth and channel dimensions (length, width and side wall slope);
- angle between the main axis and direction of approaching current;
- strength of local current; and
- local bathymetry.

The existing peak spring tide current at the location of the proposed berth pockets, averaged over depth, is 0.33m/s. After dredging, this peak current speed would reduce to an average of 0.15m/s. Current speed would decrease over the extent of the berth but would increase again when the depth reverts to the normal profile.

The primary risk that reduced currents over the proposed dredged berth would increase silt within the proposed dredge area is addressed in discussion regarding maintenance dredging in **Section 6.9.2.11**.

6.9.2 Marine Water Quality Impacts

The potential marine impacts associated with dredging and operational activities are discussed below in terms of water quality. A review of the proposed development has identified the following key sources of possible marine water quality impacts:

- port area capital dredging and disposal plume generation at proposed new spoil ground;
- dredge spoil re-suspension at the proposed spoil ground;
- inshore sediment deposition;
- capital dredging at barge and ferry terminals;
- Albatross Bay spoil ground disposal plume generation;
- introduction of contaminants during operational ship loading; and
- maintenance dredging requirements and turbid plume generation.

The key potential impacts of dredging and spoil disposal on water quality are:

- possible mobilisation of contaminants into the water column;
- generation and migration of turbid plumes;
- reduction in benthic light regimes; and
- increased local sediment deposition.

Water quality at the proposed port, new spoil ground, and proposed ferry and barge facilities all exhibit significant natural fluctuations in suspended sediment and turbidity (refer **Section 6.4.4**). The extent of this natural variation buffers water quality impacts associated with dredging, disposal, construction and operation to some extent. Generally, these habitats may be described as being more resilient to short-term water quality changes.

Periodic alterations in chemical water quality are currently experienced during event-based elevations in ambient turbidity. As fine sediments are mobilised throughout the water column, nutrient and metal concentrations naturally increase. Seasonal alterations in chemical water quality are also experienced during the monsoon and cyclone periods.

Analysis of the sediments to be dredged from the proposed port area and the barge/ferry terminals have not identified any constituents present at levels of environmental concern that would persist in the water column during dredging or sea disposal at respective spoil grounds (refer **Section 6.5.4.3** and **Section 6.5.6**).

Proposed works within the Embley River and Hey River are likely to generate turbidity concentrations that fall within the natural turbidity range. The rivers and estuaries of Cape York are subject to high ranges in turbidities over both the dry and wet seasons. The method of dredging in the Embley and Hey Rivers is likely to be by bucket or grab dredgers, which generate relatively low levels of turbidity. This is because there is no significant return of waters via overflow such as would occur through suction dredging methods. The turbidity generated would be substantially lower than that generated during routine maintenance dredging campaigns at the Port of Weipa using the TSHD Brisbane. These campaigns so far have not demonstrated a causal link with changes in seagrass density or meadow area in the estuary. As seagrass are the most sensitive receivers, this result is a good indicator of whether dredging activities are causing significant changes in turbidity levels. The short duration of dredging in each barge/ferry terminal area (1-2 weeks) would further limit potential for impacts. Potential impacts to water quality and coral health associated with dredging activities are discussed in detail in **Section 6.9.3.1.**

The migration and dispersion of turbid plumes during major capital dredging at the proposed port area and disposal at the proposed new spoil ground has been predicted through modelling due to the significant volume of material to be dredged.

6.9.2.1 Turbid Plume Generation Modelling

The Inner Gulf hydrodynamic Mike21 model coupled with the software's mud transport module (MT) has been used to predict the fate of dredge plumes and assist in determining the potential impacts for the port area capital dredging and disposal activity.

Plume modelling included the following methodology and assumptions:

- modelled concentrations are based on suspended sediments caused by dredging and represent expected increases above background;
- the entire nine-month period estimated for the dredging works is simulated;
- dredging commenced at the most seaward location for each cut, with the berth pockets dredged last;
- simulations are based on average tide and wind conditions;
- average wind conditions, derived from the long-term record at Weipa, are used for seasonal conditions (wet, dry and transitional seasons);
- dredging works are to commence in early May at the start of the dry season and continue until work is completed; and
- two dredge time series are used to represent the operations of the cutter suction dredge (CSD) and trailing suction hopper dredge (TSHD) (discussed further below).

The tidal conditions within the simulation cover the range of tidal states experienced under normal conditions in the Project area. Modelling of worst-case wind and tide scenarios (e.g. cyclonic events) was not undertaken as dredging would not be undertaken under such conditions due to safety risks.

To predict the behaviour of the plume resulting from dredging and spoil disposal activities, fine quadrangular elements were used to resolve the berth/departure area and departure channel. Detail of the mud transport module domain (Inner Gulf model) and hydrodynamic verification is provided in **Section 6.1.2**. Wind forcing is included and based on available records at the nearby Weipa Airport Gauge.

Based on recent PSD and settling tube test information, sediment particle size distribution and settling velocities have been established for the three sediment types representing the vertical sediment profile to be dredged and incorporated within the model (refer **Table 6-41**).

Table 6-41 Dredge Material Characteristics Used in Plume Modelling

Fraction	Material	Size (mm)	Particle Size Distribution (%)			Settling velocity (mm/s)
			Layer 1 (unconsolidated marine sediments and sandy clay)	Layer 2 (stiff sandy clay)	Layer 3/4 (siltstone)	
1	Clay	<0.002	44	11	13	0.03
2	Silt	0.06–0.002	35	50	10	1
3	Fine Sand	0.2 – 0.06	10	20	47	15

The spill rates from the dredging activities vary dependent on the sediment layer, as a result of the variable sediment composition and density of the layers (**Table 6-42**). Four layers have been identified for dredging. The adopted spill rate from the TSHD during overflow for the first dredge layer is 25kg/s and has been estimated by considering the results of loss estimation undertaken for recent dredging for the Port of Melbourne Channel Deepening Project, and the material structure/density variance in the sediment profile at the proposed SoE Project port. Dredging consultants for the Project identified that the losses found from the Port of Melbourne dredging are considered consistent with other findings in the dredging industry and applicable to the South of Embley Project port dredging study. The method of dredging and size of equipment is generally consistent with that which would be applied to the developing the proposed port. A reduced spill rate of 20kg/s adopted for the second dredge layer has been interpolated from these results, and again factors in the different physical properties of the material to be dredged. The spill rate adopted for the third and fourth dredge layers has been reduced to 10kg/s. Whilst this spill rate is not supported by actual measurements, it is based on the third and fourth dredge layers representing a hard siltstone, and being of differing physical properties to the clays above.

Table 6-42 Adopted Spill Rates (kg/s) for the Dredging Scenario

Activity	Dredge parameters		Spill Rates (kg/s)		
	Production Rate	Activity time per cycle	Layer 1 (unconsolidated marine sediments and sandy clay)	Layer 2 (stiff sandy clay)	Layer 3/4 (siltstone)
CSD redepositing via near bed diffuser	1,720 m^3/hr (berths and departure area) 1,420 m^3/hr (departure channel)	2hrs (over 3hr cycle) *	1	0.8	0.4
TSHD overflow	5,000 m^3/cycle	1hr40min (over 4hr10min cycle)	25	20	10
TSHD draghead and propeller disturbance	5,000 m^3/cycle	2hrs10min (over 4hr10min cycle)	4	3.2	1.6
TSHD disposal	n/a	15min (over 4hr10min cycle)	60	60	60

CSD = Cutter suction dredge; TSHD = Trailing suction hopper dredge (TSHD)
* Remaining time in cycle spent moving the dredge and repositioning the cutter

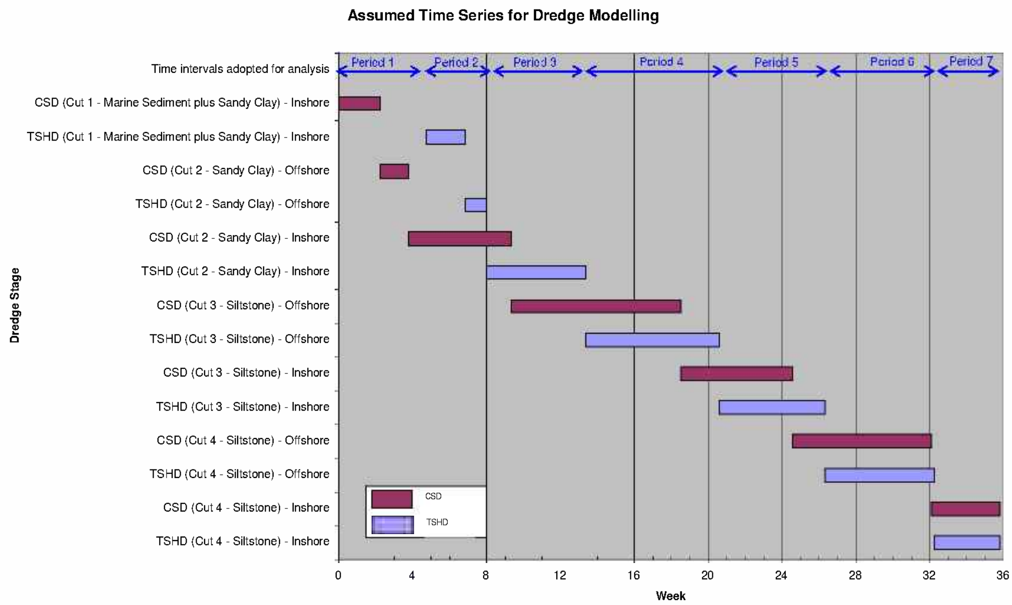
The adopted spill rates decrease with layer depth because material strength increases with depth resulting in more large clumps and less release of fine material during dredging. Given the physical differences in material within the vertical sediment profile, as documented by PSD and core inspections, these reductions in fine material release have been extended to apply to spill rates for the CSD, and TSHD drag head and propeller disturbance.

Resuspension is not included within the model predictions on the basis that there currently exists a layer of relatively fine unconsolidated material that covers a wide area of the nearshore area, and that is regularly suspended under natural conditions. Fines released from dredging will add to the unconsolidated material available for resuspension. However, the net change in material available for suspension is not considered significant.

The extent of geotechnical investigations are limited to the nearshore area surrounding the trestle and berth pockets. For areas to be dredged seaward of the extent of survey, the main assumption has been that the siltstone unit continues seaward at a similar level as identified by the nearshore boreholes (refer **Section 6.5.4.2**). This is a reasonable assumption based on the geology of the region (pers comm, Iain Turner, Coffey Geotechnics).

The dredge operation is simulated assuming the combined use of a CSD and TSHD. Approximately 6.5 million cubic metres of material is to be dredged within a 36-week period starting at the beginning of the dry season (early May) and continuing until work is completed (January). This 36-week dredging period does not allow for any delays such as for breakdowns or maintenance, which would extend the duration of dredging but also interrupt suspended sediment plume generation. Based on *Boyd Point Facility for Cape-Size Vessels Review of Options for Dredging and Disposal of Dredged Materials* (SKM 2010) and in consultation with Pro Dredging & Marine Consultants, the adopted time series of the two dredges is shown in **Figure 6-58**. The dredging schedule has been divided into seven distinct periods. The TSHD has been assumed to commence dredging 33 days after the CSD in order for the two dredgers to complete the operation at approximately the same time.

A turbid plume would eventuate as material is released to the water column during the operation of the CSD and TSHD dredgers. The plume would be reasonably uniform over the local water depth due to the well-mixed tidal hydrodynamics and the predominantly fine silt and clay bed material. Clay and silt with a lower settling velocity may remain in the water column for long periods (days) and a low concentration plume may disperse for several kilometres in the direction of the tide.



Legend: CSD = Cutter suction dredge; TSHD = Trailing suction hopper dredge

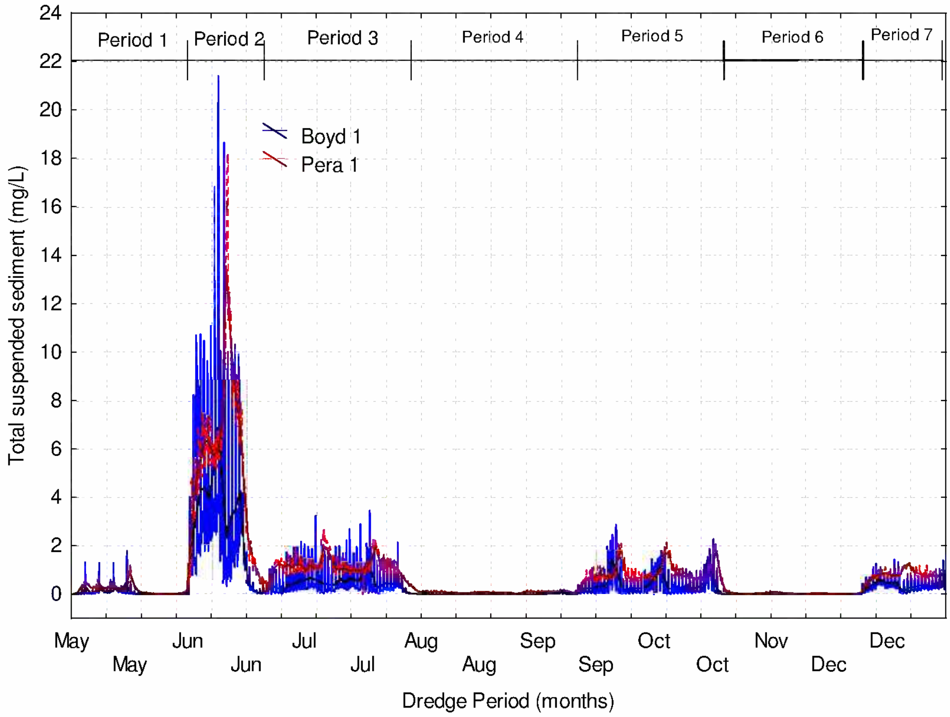
Figure 6-58 Dredge Time Series Adopted for Mud Transport Model Runs

Plumes are advected by current strength and direction; therefore the individual flood and ebb tide phases influence their shape and trajectory, as do spring and neap tide phases. Model results of the dredge plume during approximately 36 weeks of continuous dredging were examined.

6.9.2.2 Port Area Capital Dredging Turbid Plume Generation

Model outputs identify that during flood tides the turbid plume generated by port area capital dredging extends parallel, along the coast from the dredge location to beyond Pera Head. During the flood tide phase, Boyd Point experiences relief from the increased TSS concentration. During the ebb tide the dredge plume extends along the coast extending from Pera Head to Boyd Point. In contrast to Boyd Point, Pera Head does not experience total relief from the increased TSS concentration. This is due to the net south-west tidal current direction causing suspended material to accumulate between the proposed port and Pera Head.

Modelled TSS time series data from Pera 1 (Pera Head) and Boyd 1 (Boyd Point) have been divided into the seven distinct dredging periods (refer **Table 6-43**) and are shown in **Figure 6-59**). Refer to **Figure 6-61** for locations. Periods of high TSS concentration generally coincide with the TSHD operating in the inshore area (i.e. in the berths and departure area). Period 1 represents an initial phase of inshore and offshore dredging of layer 1 using just a CSD, and as a result TSS concentrations remain relatively low throughout this period. The remaining six periods all include both CSD and TSHD operation with the spill rates varying depending on which layer is being dredged and the location of the dredges. Following dredge cut 1, the CSD makes a relatively minor contribution to the overall TSS concentrations. Period 2 represents dredging of layer 1 in the inshore area by the TSHD, while Period 3 represents dredging of layer 2 in the inshore area by the TSHD. Periods 4 and 5 represent dredging of layer 3 by the TSHD in the offshore and inshore areas respectively, while Periods 6 and 7 represent dredging of layer 4 by the TSHD in the offshore and inshore areas respectively.



Note: Bold lines represent rolling daily averages

Figure 6-59 Above Background TSS Concentration Time Series Extract at Pera 1 and Boyd 1

Table 6-43 Dredge Event Duration and Median Plume TSS Concentration Above Background at Pera 1

Plume Period	Dredge Event Duration (days)	Median Plume TSS (mg/L) above background – Pera 1
1	33	0.2
2	25	5.3
3	36	1.1
4	54	0.1
5	39	0.8
6	40	0
7	25	0.8

The median and 80th percentile of the TSS concentrations from the dredge plume dispersion model have been plotted spatially for Periods 2, 3 and 4 (**Figure 6-60 a, b and c respectively**) as representing inshore and offshore dredging for sediment layers 1, 2 and 3, respectively. Periods 5-7 are not shown to avoid duplication as their TSS concentrations are suitably represented by periods 3 and 4 (refer **Figure 6-59**). Dredge plumes may not cover the entire dredge footprint as the different periods reflect different locations of dredging (inshore versus offshore) as described in **Section 6.9.2.1**. Summary statistics from key locations (refer **Figure 6-61**) for all seven periods are shown in **Table 6-44**. These locations include extract points from Pera Head, Boyd Point, Thud Point and the Boyd Bay beach area.

Modelling results indicate the Boyd Point reef area will experience greater respite from dredge plume migration than Pera Head and locations south (refer **Figure 6-59** and **Figure 6-60a-c**). Under ambient conditions, Boyd Point and Pera Head reef areas demonstrate a high variation in turbidity, driven primarily by local wind and associated wave events. Pera Head data loggers deployed during 2007–2008 recorded turbidity event periods of 9 and 24 days duration at median event concentrations of 248 and 127mg/L respectively (refer **Figure 6-33** in **Section 6.4.4**). Data captured from Boyd Point (GHD 2008) reported ambient events of 23 and 25 days duration, recording median event TSS concentrations of 163 and 184 mg/L respectively (refer **Figure 6-34** in **Section 6.4.4**). Respite between these events for both locations was approximately 13 days.

Median plume concentrations from all periods remain below event based ambient ranges reported from reef habitats (refer **Table 6-44**). Summary of plume duration and concentrations above background (ambient median TSS = 15mg/L) at Pera 1 is provided within **Table 6-43**. Modelling results indicate Thud Point locations south of Pera Head will experience similar patterns of TSS increases as predicted for Pera Head and Boyd Point during the seven periods but with a significant reduction in scale (refer **Figure 6-62**).

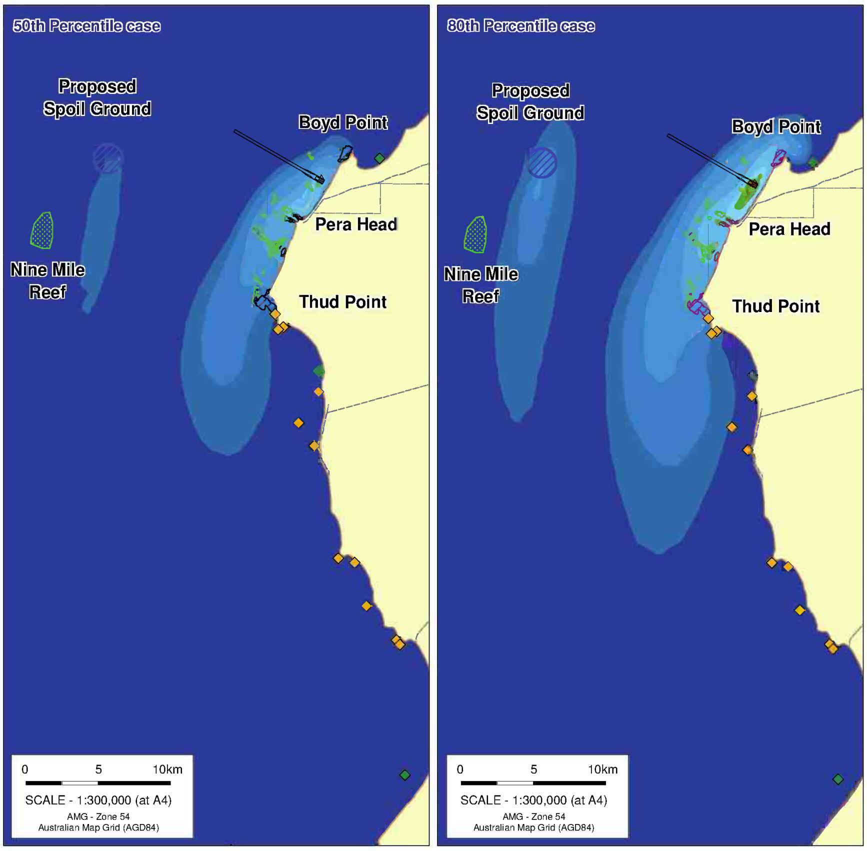
The durations of TSS plume concentrations at or above 5, 10 and 15mg/L above background (ambient median TSS = 15mg/L) have been extracted from the model for plume Periods 2 and 3 (refer **Figure 6-63a-c** respectively**)**. This is a duration-based plot based on percentage occurrence of concentrations for Periods 2 and 3. The 5mg/L case extends to 1-2km north of Thud Point during Period 2, while during Period 3 it remains local to the dredge. The 10mg/L case during Period 2 extends from Pera Head to Boyd Point, while during Period 3 it is restricted to within the immediate location of the area to be dredged. Results show that concentrations in excess of 15mg/L are not predicted to occur beyond Pera Head or Boyd Point for any of the periods for over 5% of the time. It is only during Period 2 that TSS concentrations in excess of 15mg/L occur for more than 5% of the time, and these concentrations do not occur for more than 20% of the time. Period 4 TSS concentrations do not exceed 5mg/L, so an exceedance figure is not presented.

Given a predicted peak plume period of approximately 25 days (approximately the same as natural event durations of 30 days), only areas identified within **Figure 6-63** as having a duration exceedance approaching 100% may be described as approaching the currently understood limits of natural conditions. Given this comparison, plume duration effects at the 15mg/L concentration beyond that encountered during ambient events are not experienced throughout any of the dredge periods.

6.9.2.3 Proposed Spoil Ground Turbid Plume Generation

Modelling of turbid plumes at the proposed new spoil ground identified a median TSS concentration of less than 1mg/L above background and a maximum of 13mg/L above background (refer **Table 6-45**) over the dredging and disposal period of 36 weeks. These concentrations at the proposed new spoil ground are relatively low due to an increased dilution within the water column (i.e. depth averaged concentration), low duration (disposal approximately every four hours) and prevailing southerly currents providing dispersion.

The disposal plumes tend to disperse along a south-south-east trajectory due to tidal currents and are not predicted to impact Nine Mile Reef, which is located approximately 6km south-south-west of the spoil ground (refer **Figure 6-60a-c**). Modelling has predicted that a median TSS of less than 0.2mg/L and maximum of 1.2mg/L above background would occur over Nine Mile Reef (refer **Table 6-45**). These increases are negligible given background TSS characteristics at offshore areas, as represented by existing conditions at the proposed spoil ground where recorded TSS concentrations had a median of 33mg/L, mean of 135mg/L and maximum of 1056mg/L during the Project's in-situ logger program (refer to **Section 6.4.4.1**).



LEGEND

- Towns
- Unconfirmed reef locations
- Seagrass locations - indicative
- Roads and tracks
- Dredge area
- Proposed new spoil ground

Indicative Reef Classes

- Hard coral
- Soft coral or sponge

Median TSS above ambient mg/L

- 0.25 to 0.5
- 0.5 to 1
- 1 to 2
- 2 to 3
- 3 to 4
- 4 to 5
- 5 to 6
- 6 to 7
- 7 to 8
- 8 to 9
- 9 to 10
- 10 to 11
- 11 to 12
- 12 to 13
- 13 to 14
- 14 to 15
- 15 to 16

Indicative Seagrass Locations
Queensland Seagrass Meadows 1984-1988 Department of Primary Industries and Fisheries 2002
Coastal Habitat Resources Information System http://chrisweb.dpi.qld.gov.au/CHRIS/
Pers. Comm. Michael Rasheed, 2010

Modeled dredge plume point data provided by WorleyParsons Newcastle office on 19/07/2010.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
C	02/11/2010	Re-issued for information	JMM	DH		
B	27/07/2010	Re-issued for information	KM	NA		
A	27/07/2010	Issued for information	MM	NA		

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Figure 6-60a - Dredge plume dispersion model (median and 80th percentile cases) for port area dredging and disposal at proposed new spoil ground (Period 2)

Project No: 301001-01069	Figure: 01069-00-GM-EN-0010	Rev: C

Compiled by BRISBANE GEOMATICS

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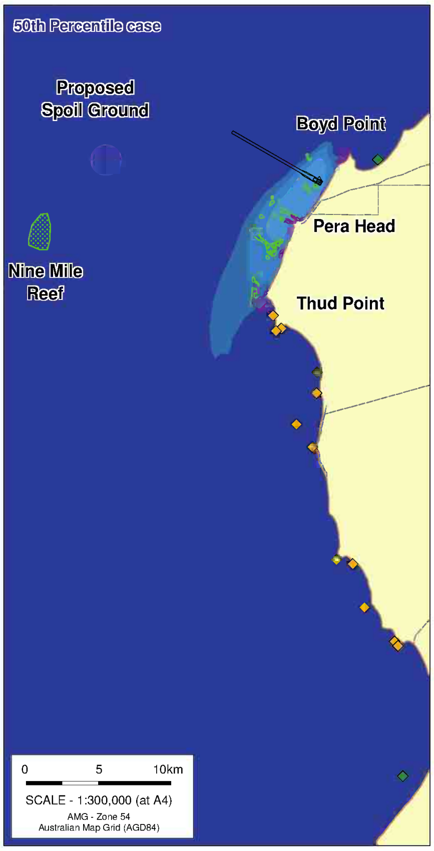

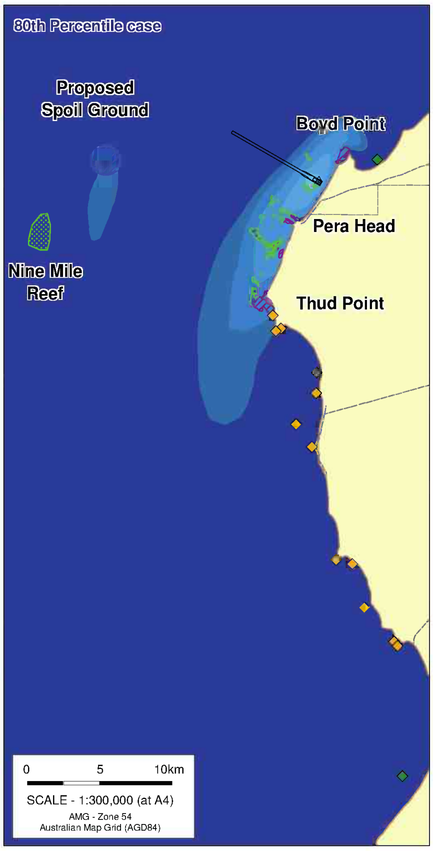

LEGEND

- Towns
- Unconfirmed reef locations
- Seagrass locations - indicative
- Roads and tracks
- Dredge area
- Proposed new spoil ground

Indicative Reef Classes

- Hard coral
- Soft coral or sponge

Median TSS above ambient mg/L

- 0.25 to 0.5
- 0.5 to 1
- 1 to 2
- 2 to 3
- 3 to 4
- 4 to 5
- 5 to 6
- 6 to 7
- 7 to 8
- 8 to 9
- 9 to 10
- 10 to 11
- 11 to 12
- 12 to 13
- 13 to 14
- 14 to 15
- 15 to 16

Indicative Seagrass Locations
Queensland Seagrass Meadows 1984-1988 Department of Primary Industries and Fisheries 2002
Coastal Habitat Resources Information System http://chrisweb.dpi.qld.gov.au/CHRIS/
Pers. Comm. Michael Rasheed, 2010

Modeled dredge plume point data provided by WorleyParsons Newcastle office on 19/07/2010.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
C	02/11/2010	Re-issued for information	JMM	DH		
B	28/07/2010	Re-issued for information	KM	NA		
A	27/07/2010	Issued for information	MM	NA		

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Figure 6-60b - Dredge plume dispersion model (median and 80th percentile cases) for port area dredging and disposal at the proposed new spoil ground (Period 3)

Project No: 301001-01069 | Figure: 01069-00-GM-EN-0011 | Rev: C

Compiled by BRISBANE GEOMATICS

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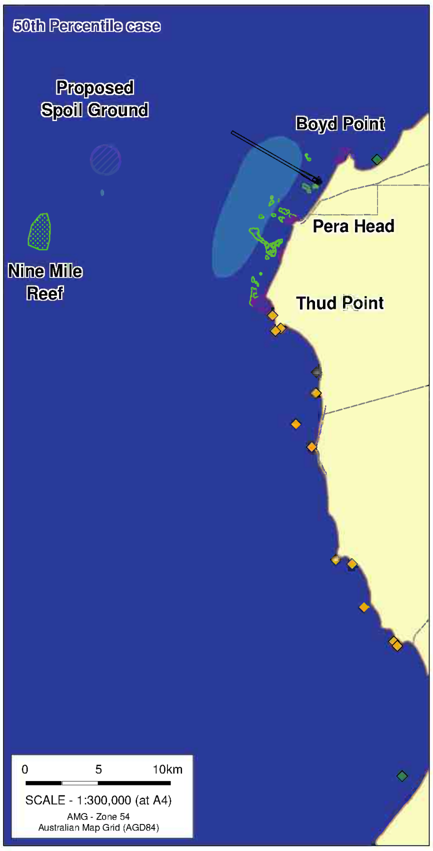

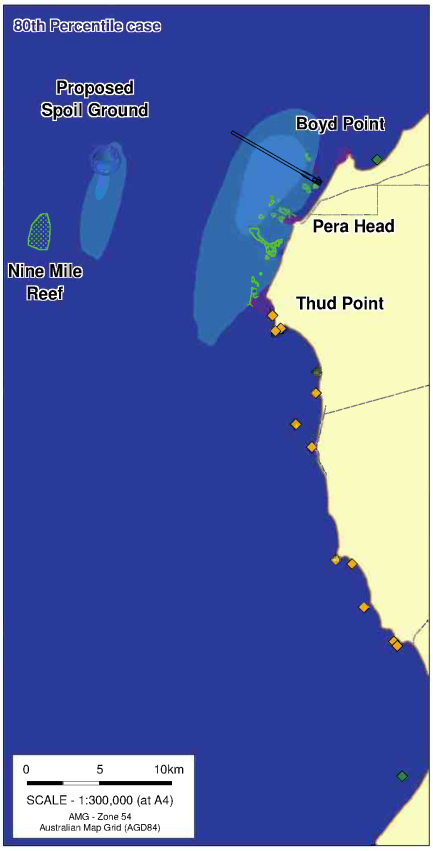

LEGEND

- Towns
- Unconfirmed reef locations
- Seagrass locations - indicative
- Roads and tracks
- Dredge area
- Proposed new spoil ground

Indicative Reef Classes

- Hard coral
- Soft coral or sponge

Median TSS above ambient mg/L

- 0.25 to 0.5
- 0.5 to 1
- 1 to 2
- 2 to 3
- 3 to 4
- 4 to 5
- 5 to 6
- 6 to 7
- 7 to 8
- 8 to 9
- 9 to 10
- 10 to 11
- 11 to 12
- 12 to 13
- 13 to 14
- 14 to 15
- 15 to 16

Indicative Seagrass Locations
Queensland Seagrass Meadows 1984-1988 Department of Primary Industries and Fisheries 2002
Coastal Habitat Resources Information System http://chrisweb.dpi.qld.gov.au/CHRIS/
Pers. Comm. Michael Rasheed, 2010

Modeled dredge plume point data provided by WorleyParsons Newcastle office on 19/07/2010.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
A	02/11/2010	Issued for information	JMM	DH		

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Figure 6-60c - Dredge plume dispersion model (median and 80th percentile cases) for port area dredging and disposal at the proposed new spoil ground (Period 4)

Project No: 301001-01069	Figure: 01069-00-GM-EN-0028	Rev: A

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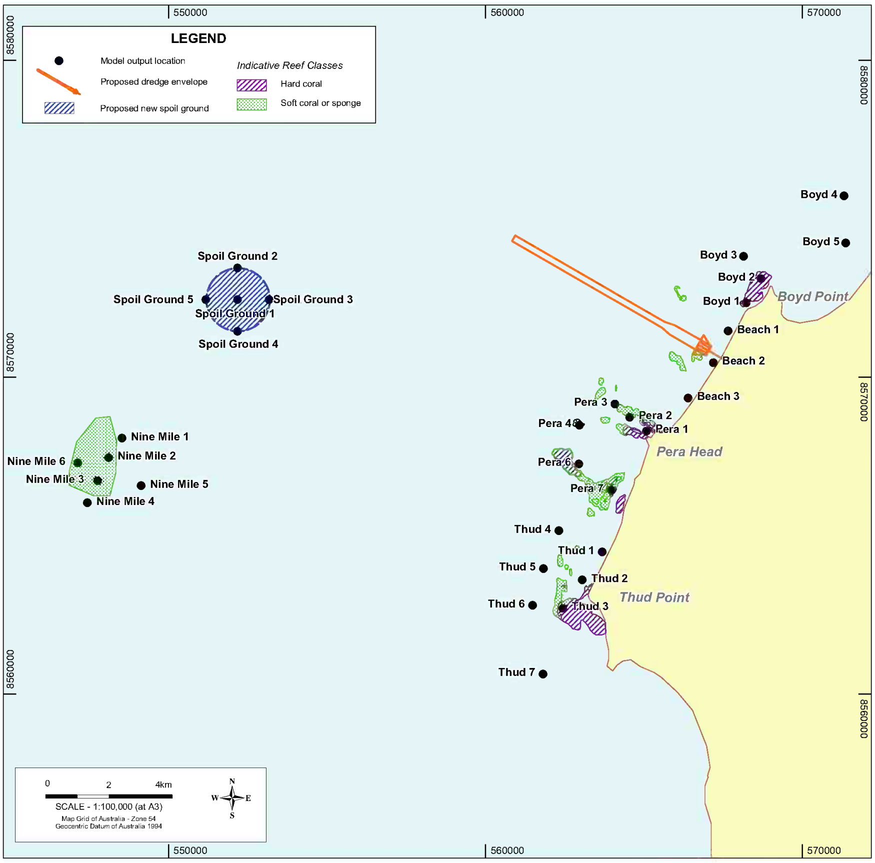

Note:
Model output locations are points selected from hydrodynamic model to provide data for characterisation of turbidity plumes for seven dredge periods. Statistics are provided in Table 6-44 and Table 6-45. Selected inshore locations also provide data to characterise sediment deposition rates in Table 6-46.

Rev	Date	Revision Description	DRN	CHK	ENG	APPD
B	01/04/2011	Re-issued for review	DH	MM		
A	20/07/2010	Issued for squad check	KM	MZ		

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Figure 6-61 Location of modelled time series extracts

Project No: 301001-01069 | Figure: 01069-00-GM-DAL-0004 | Rev: B

Compiled by BRISBANE GEOMATICS

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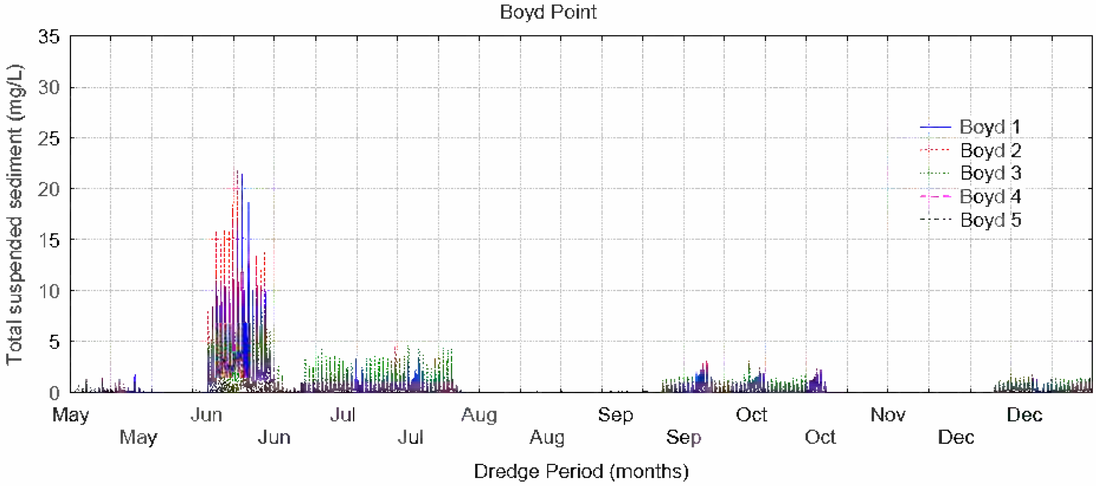
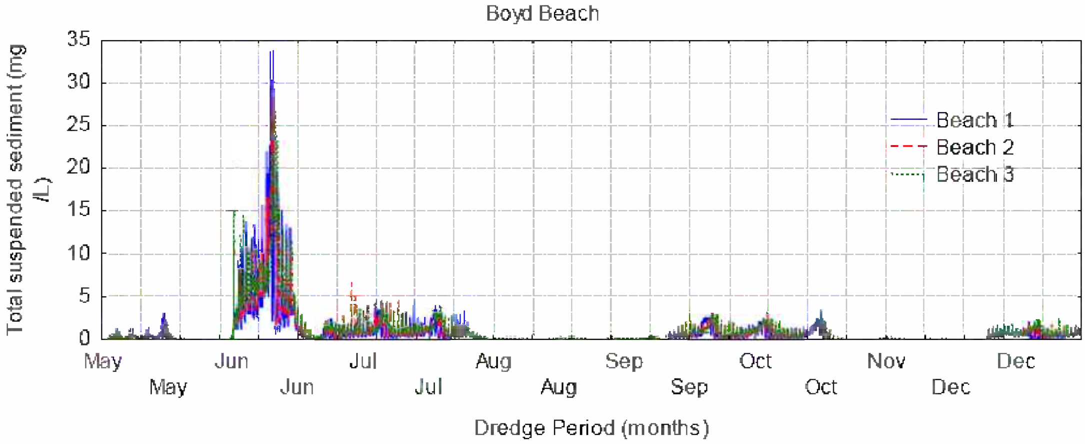
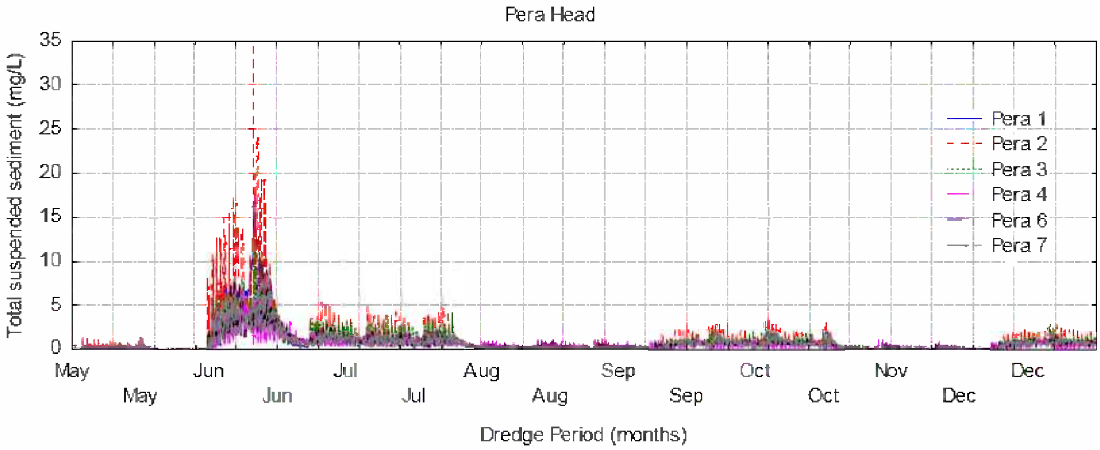
Table 6-44 Above Background TSS Summary Statistics for Plumes at Inshore Locations (refer Figure 6-61 for locations)

Location	Mean TSS (mg/L)							Median TSS (mg/L)							80th Percentile TSS (mg/L)							Maximum TSS (mg/L)						
Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Boyd Bay Beach																												
Beach 1	0.2	4.4	0.9	0.1	0.8	0	0.5	0	2.3	0.6	0	0.6	0	0.5	0.2	7.1	1.3	0.1	1.3	0	0.8	3	33.8	4.4	1.9	3.4	0.3	2.2
Beach 2	0.2	4.7	1.1	0.1	0.9	0	0.7	0	3.2	0.8	0	0.8	0	0.6	0.3	7.9	1.5	0.1	1.3	0	1	2.6	29.2	6.6	1.2	3.2	0.8	2.5
Beach 3	0.2	5.3	1.3	0.1	1	0	0.8	0.1	4.5	1.1	0	0.9	0	0.7	0.3	8.4	1.6	0.1	1.4	0	1.1	2.3	26.6	4.4	1.2	3.2	0.9	2.3
Boyd Point Reef																												
Boyd 1	0.1	2.6	0.5	0	0.5	0	0.4	0	1.5	0.3	0	0.2	0	0.3	0.1	3.9	0.9	0	0.8	0	0.6	1.8	21.4	3.5	2.1	2.9	0.1	1.4
Boyd 2	0	1.5	0.3	0	0.3	0	0.3	0	0.4	0.1	0	0	0	0.2	0	2.3	0.4	0	0.6	0	0.5	1.4	21.8	4.6	3.4	3.1	0.1	2
Boyd 3	0.1	1.4	0.7	0	0.4	0	0.3	0	0.3	0.1	0	0	0	0	0.1	3.3	1.5	0	0.8	0	0.8	0.9	9.5	4.7	4.3	2.9	0.1	1.6
Boyd 4	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	1.5	0.3	0.1	0.1	0	0.1
Boyd 5	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	2.2	0.2	0.1	0	0	0.3
Pera Head Reef																												
Pera 1	0.2	4.8	1.2	0.1	0.9	0.1	0.8	0.2	5.3	1.1	0.1	0.8	0	0.8	0.3	7.2	1.4	0.1	1.1	0.1	1	1.3	18.2	2.7	1.1	2.1	0.8	1.4
Pera 2	0.2	5.1	1.6	0.2	1.1	0.1	1	0.1	4.4	1.3	0.2	1	0.1	0.9	0.3	7.1	2.1	0.3	1.4	0.1	1.2	1.5	34.8	5.4	1.6	3.6	1.1	2.8
Pera 3	0.2	3.1	1.4	0.3	0.8	0.1	0.8	0.1	2.8	1.2	0.2	0.8	0.1	0.8	0.3	4.7	1.8	0.5	1	0.2	1	0.8	16.7	3.6	1.5	2.3	1	2.9
Pera 4	0.1	2	0.8	0.4	0.5	0.2	0.5	0.1	1.6	0.7	0.3	0.5	0.2	0.4	0.1	2.8	1	0.5	0.7	0.3	0.7	0.4	9.8	2.2	1.3	1.3	1.1	1.7
Pera 6	0.1	2.7	1	0.3	0.7	0.2	0.7	0.1	2.2	0.9	0.3	0.6	0.1	0.6	0.2	4.1	1.5	0.4	0.9	0.2	0.9	0.4	10.2	2.8	1.2	1.6	0.8	1.8
Pera 7	0.1	2.9	1	0.2	0.8	0.1	0.7	0.1	2.5	0.9	0.2	0.7	0.1	0.7	0.2	4.7	1.4	0.3	1.1	0.2	0.9	0.4	8.2	2.2	1.2	2.1	0.9	1.4
Reefs between Pera Head and Thud Point																												
Thud 1	0.1	2	0.7	0.2	0.5	0.1	0.5	0.1	1.7	0.6	0.2	0.4	0.1	0.5	0.2	3.4	1	0.3	0.7	0.1	0.7	0.3	6.8	1.6	0.9	1.4	0.8	1.2
Thud 2	0.1	1.6	0.6	0.2	0.4	0.1	0.4	0	1.1	0.5	0.1	0.3	0.1	0.4	0.1	2.7	0.9	0.3	0.7	0.1	0.6	0.3	6.6	1.6	0.9	1.2	0.8	1.1
Thud 3	0.1	1.2	0.4	0.2	0.3	0.1	0.3	0	0.7	0.3	0.1	0.2	0.1	0.3	0.1	2.2	0.8	0.2	0.6	0.1	0.6	0.3	5.6	1.4	0.9	1	0.8	1
Thud 4	0.1	1.8	0.7	0.3	0.5	0.2	0.5	0.1	1.5	0.6	0.2	0.5	0.1	0.4	0.1	2.7	1	0.4	0.7	0.2	0.7	0.4	7.2	2.1	0.9	1.5	0.8	1.4
Thud 5	0.1	1.3	0.5	0.2	0.4	0.1	0.4	0	1.1	0.5	0.2	0.3	0.1	0.4	0.1	2.1	0.7	0.4	0.5	0.2	0.5	0.3	5.7	1.5	0.9	0.9	0.7	1
Thud 6	0.1	1.1	0.4	0.2	0.3	0.1	0.3	0	0.9	0.4	0.1	0.3	0.1	0.3	0.1	1.8	0.6	0.3	0.5	0.2	0.4	0.3	4.9	1.1	0.8	0.8	0.6	0.8
Thud 7	0	0.8	0.3	0.1	0.2	0.1	0.2	0	0.6	0.2	0.1	0.1	0.1	0.2	0.1	1.3	0.5	0.2	0.4	0.1	0.4	0.2	3.4	0.9	0.7	0.8	0.6	0.7


Boyd Point
Total suspended sediment (mg/L)
35
30
25
20
15
10
5
0
Boyd 1
Boyd 2
Boyd 3
Boyd 4
Boyd 5
May
May
Jun
Jun
Jul
Jul
Aug
Aug
Sep
Sep
Oct
Oct
Nov
Dec
Dec
Dredge Period (months)


Boyd Beach
Total suspended sediment (mg /L)
35
30
25
20
15
10
5
0
Beach 1
Beach 2
Beach 3
May
May
Jun
Jun
Jul
Jul
Aug
Aug
Sep
Sep
Oct
Oct
Nov
Dec
Dec
Dredge Period (months)


Pera Head
Total suspended sediment (mg/L)
35
30
25
20
15
10
5
0
Pera 1
Pera 2
Pera 3
Pera 4
Pera 6
Pera 7
May
May
Jun
Jun
Jul
Jul
Aug
Aug
Sep
Sep
Oct
Oct
Nov
Dec
Dec
Dredge Period (months)

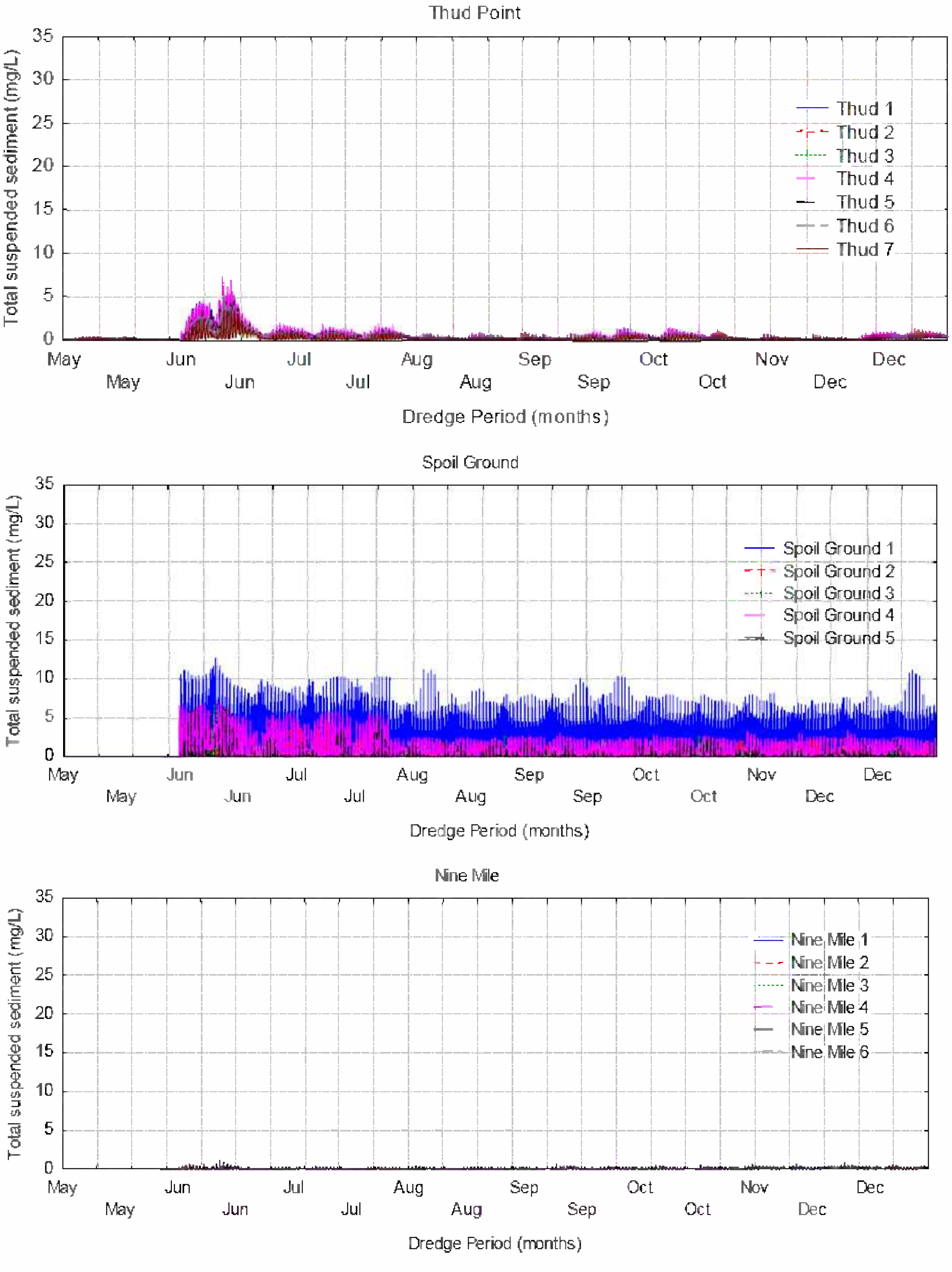


Figure 6-62 Time Series Extract from the Plume Model over the Nine-Month Dredge Period