8.5 Potential for and nature of any cumulative impacts

The Proposal has the potential to exacerbate the fragmentation of flora and vegetation of the Cape Peron portion of the RLRP and in turn Bush Forever Site 355. Implementation of the Proposal will not terminate connectivity between Bush Forever Site 358 (Lake Richmond) and the vegetation on Cape Peron; however, the importance of the connectivity provided by the vegetation adjacent to the south western shoreline (Shoalwater Bay) increases. Rehabilitation effort will be focused on improving the quality and linkage capabilities of these areas.

8.6 Management measures and performance standards

Clearing of vegetation will be minimised as far as practicable while still allowing construction and operation to be undertaken in a safe manner. Management strategies will include the use of a ground disturbance authorisation procedure, clear demarcation of areas approved for clearing, and environmental awareness training to ensure that employees are aware of the requirement to minimise ground disturbance.

The Proposal will clear 1.93 ha of TEC FCT 30a. It is proposed to retain and consolidate TEC FCT 30a into a more sustainable shape of a remnant of approximately 3.95 ha, where the boundary to area ratio is improved when compared to the current configuration of the remnant. This will comprise the retention of 1.12 ha of Very Good condition vegetation, rehabilitation of 1.61 ha that currently does not support FCT 30a and 1.22 ha of FCT 30a that has been identified as being in Good – Degraded condition.

In addition to reducing the footprint of the development during the design process, comprehensive mitigation measures are proposed for 56 ha of vegetation locally within the RLRP to offset the potential impacts of the proposed development, including impacts on vegetation and flora values. Proposed vegetation and flora mitigation measures also address the impact on the Bush Forever Site and include the protection and rehabilitation of the remnant vegetation of Cape Peron within the Bush Forever Site to enhance the conservation values and ecological linkage with Lake Richmond. The rehabilitation program would include:

- a strategic weed control program with the aim of a net decrease in weeds in the area
- planting and/or seeding disturbed areas with local provenance species where appropriate
- consolidating and formalising walking tracks in sensitive areas to reduce disturbance to vegetation
- fencing where required to protect vegetation
- stabilisation of disturbed dune areas
- establish a monitoring program to evaluate rehabilitation performance.

A community objective for the Proposal is to provide a sum of up to $5 000 000 to enhance the balance of Cape Peron outside the Proposal area. The funding will be for activities including rehabilitation activities and the acquisition of land with comparable or greater conservation value to secure the land for conservation. The funding will be part of an offsets package to offset the vegetation loss and area excised from the RLRP and Bush Forever Site 355. The offsets package will be developed in consultation with DEC, OEPA, DoP and the City of Rockingham.

Specific rehabilitation prescriptions for the final Proposal will be identified in consultation with DEC and detailed in a Rehabilitation Management Plan.

The final form and extent of the above offsets will be determined in accordance with EPA Position Statement No 9.

The potential for the introduction of weeds will be managed through vehicle hygiene procedures for earth-moving equipment during the pre-construction and construction phases. Ongoing weed management during the construction phase will be undertaken through regular weed spraying programs.

Dust will be managed through the use of water trucks or other suitable dust suppression methods.

8.7 Predicted environmental outcomes against environmental objectives, policies, guidelines, standards and procedures

Development will result in the clearing of up to 40 ha of remnant vegetation which has experienced varying degrees of disturbance, including extensive weed invasion. Notwithstanding these disturbances, some of the vegetation to be cleared is considered regionally significant on the basis of floristic communities, as defined by Gibson *et al*. (1994).

FCT 30a near the corner of Memorial Drive and Safety Bay Road is a 4.3 ha ha area that is an example of a TEC of variable condition. The Proposal will clear 1.93 ha of TEC FCT 30a. It is proposed to retain and consolidate TEC FCT 30a into a more sustainable shape of a remnant of approximately 3.95 ha, where the boundary to area ratio is improved when compared to the current configuration of the remnant. This will comprise the retention of 1.12 ha of Very Good condition vegetation, rehabilitation of 1.61 ha that currently does not support FCT 30a and 1.22 ha of FCT 30a that has been identified as being in Good – Degraded condition. By area the outcome will provide a limited loss of TEC, however, an improvement in condition and future management will be achieved.

The Proposal will not result in any vegetation complexes being cleared to less than 10% of the original extent. Approximately 48% of the pre-European extent Quindalup Vegetation Complex remains in the Metropolitan area. No DRF or Priority Flora will be affected by the Proposal as no specimens were located during the extensive flora and vegetation surveys of the Cape Peron.

Changes in groundwater quality and levels are not anticipated to impact vegetation in the area.

The Proponent will provide offsets in accordance with EPA Position Statement No 9. The Proponent is discussing opportunities with the DEC to achieve no net loss to the conservation estate, possibly through a contribution to a land acquisition with similar or greater conservation value. The proposed support for the management, protection and rehabilitation of vegetation in the Regional Park to enhance the biodiversity, including botanical values in the Regional Park and improving the ecological linkage between Lake Richmond and Cape Peron, will assist to offset any loss of conservation values within the Regional Park.

9. Terrestrial fauna impact assessment

9.1 Relevant environmental objectives, policies, guidelines, standards and procedures

9.1.1 EPA objectives

The EPA applies the following objectives in assessing proposals that may affect fauna:

To maintain the abundance, diversity geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement of knowledge

To maintain biological diversity that represents the different plants, animals and microorganisms, the genes they contain and the ecosystems they form, at the levels of genetic diversity, species diversity and ecosystem diversity.

9.1.2 EPA Position Statements, Guidance Statements and Guidelines

EPA Position Statement No. 3

EPA Position Statement No. 3 (EPA 2002) discusses the principles the EPA would apply when assessing proposals that may have an effect on biodiversity values in Western Australia. The outcomes sought by this Position Statement are intended to:

- promote and encourage all proponents and their consultants to focus their attention on the significance of biodiversity and, therefore, the need to develop and implement best practice in terrestrial biological surveys
- enable greater certainty for proponents in the environmental impact assessment process by defining the principles the EPA will use when assessing proposals that may have an effect on biodiversity values.

EPA Guidance Statement No. 56

EPA Guidance Statement No. 56 (EPA 2004c) provides guidance on standards and protocols for terrestrial fauna surveys, particularly those undertaken for the environmental impact assessment of proposals.

EPA Guidance Statement No. 20

EPA Guidance Statement No. 20 (EPA 2009a) provides guidance on standards and protocols for surveys for Short Range Endemics (SRE) fauna, particularly those undertaken for the environmental impact assessment of proposals.

9.1.3 Regulatory Framework

State Protection

The preservation and conservation of fauna is covered by the following Western Australian legislation:

- *Wildlife Conservation Act 1950 (WA)*
- *Conservation and Land Management Act 1984.*

In Western Australia, rare or endangered species are protected by the Wildlife Conservation (Specially Protected Fauna) Notice 2010(2), under the WC Act. Schedules 1 and 4 in this notice are relevant to this assessment, providing a listing of the species protected by this Notice.

Fauna are also listed by DEC as Priority species if they are potentially threatened but for which there is insufficient evidence to properly evaluate their conservation significance. They range from Priority 1 to Priority 5 species, and are as follows:

- Priority 1: Poorly Known Taxa. Taxa, which are known from one or a few (generally <5) populations, which are under threat
- Priority 2: Poorly Known Taxa. Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat
- Priority 3: Poorly Known Taxa. Taxa which are known from several populations, at least some of which are not believed to be under immediate threat
- Priority 4: Rare Taxa. Taxa which are considered to have been adequately surveyed and which whilst being rare, are not currently threatened by any identifiable factors
- Priority 5: .Taxa that are conservation dependent. If conversation programs were ceased, the taxa would become threatened within five years.

Note that the Priority status does not have statutory standing. The Priority fauna classifications are employed by the DEC to manage and classify their database of species considered potentially to be at risk, but these categories have no legislative status for protection in addition to the native vegetation clearing legislation.

Australian Government Protection

The Federal EPBC Act protects species listed under Schedule 1 of the Act. In 1974, Australia became a signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). As a result, an official list of endangered species was prepared and is regularly updated. This listing is administrated through the EPBC Act. The current list differs from the various State lists; however, some species are common to both.

Australia is party to the Japan-Australia (JAMBA), China-Australia (CAMBA) and Republic of Korea-Australia (ROKAMBA) Migratory Bird Agreements. Most of the birds listed in these agreements are associated with saline wetlands or coastal shorelines. A number of migratory birds not associated with freshwater wetlands are also listed on these international treaties. In addition, migratory birds are protected by the EPBC Act.

9.2 Findings of surveys and investigations

The Proposal area was subject to extensive terrestrial fauna, subterranean fauna, SRE invertebrate fauna and a targeted GSM survey (Bamford 2005; Subterranean Ecology 2010a, 2010b, 2010c, 2010d; ENV 2011a; ENV 2011b) (refer to Figure 53 for an outline of the Survey area). Objectives of these surveys were to identify the abundance and diversity of fauna likely to occur within the Proposal area and the significance of the potential impacts of the Proposal to those identified species, particularly those of conservation significance. Studies were completed in accordance with EPA Position Statement No.20 (EPA 2009a) and Guidance Statement No. 56 (EPA 2004c).

The following description of the fauna of the Proposal area is adapted from Bamford (2005), Subterranean Ecology (2010a, 2010b, 2010c, 2010d) and ENV (2011a and 2011b) unless otherwise stated. The methodology and full results of these surveys are included in Appendix 5.

9.2.1 Terrestrial fauna habitats

Four terrestrial fauna habitats were identified within the survey area:

- shoreline habitat
- coastal heath habitat
- woodland habitat
- wetland habitat (ENV 2011a).

Cleared and degraded areas were also present. Wetland habitat was not found within the area to be cleared for land development. All habitat types within the Survey area were present outside the land development area (Table 17 and Figure 54).

Table 17 Areas of fauna habitat within Proposal area

Habitat type	Total in survey area (ha)	Percentage of survey area (%)	Total in Proposal area (ha)	Total to be cleared for the Proposal (ha)	Percentage cleared of total surveyed habitat (%)
Shoreline	4.15	2.0	1.89	0,9	21
Coastal heath	113.37	54.5	37.52	35.2	31
Woodland	19.29	9.3	5.75	2.18	10.8
Wetland	16.93	8.1	0	0	0
Cleared/degraded	54.26	26.1	22.24	22.24	41
Total	208.01 (153.74 ha not cleared or degraded)	100%	67.41 (45.17 ha not cleared or degraded)	60.52 (38.28 ha not cleared or degraded)	23%

Source:
Aerial photography supplied by Landgate (2010)
Fauna mapping supplied by ENV (2010)
Coordinate System: MGA94 Zone 50
Date: 8/2/2012
NB: Potential errors may occur in some areas

STRATEGEN environmental consultants

Drawn:
CAD Resources

CAD Resources File No:
g1937_MB_PER_F043.dgn

Extent of ENV fauna surveys across Cape Peron

Figure No:
53

Source:
Cadastral data supplied by Landgate
Fauna Habitats supplied by ENV (2011)
Coordinate System: MGA94 Zone 50
Date: 8/2/2012

NB: Potential errors may occur in some areas

STRATEGEN
environmental consultants

Drawn:
CAD Resources

CAD Resources File No:
g1937_MB_PER_F007.dgn

Fauna habitat types surveyed (ENV 2011a)

Figure No:
54

Shoreline habitat

The Shoreline habitat type fringes the coastline within the Proposal area and consists of tidal reef platforms, limestone outcropping and sandy bays. The vegetation within this habitat type consists of an open heath of *Frankenia pauciflora* (sea heath) and scattered *Sarcocornia blackiana* on sandy or limestone soils (ENV 2011a). This habitat type has a minor representation within the survey area being 4.15 ha or 2% of the survey area (Figure 54).

This habitat provides shelter and foraging opportunities for a number of different species including migratory waders and marine birds on the sandy bays and headlands, and small ground-dwelling reptiles and mammals in the rocky limestone outcropping at Cape Peron (ENV 2011a). Pied cormorants and silver gulls were observed roosting on the rocky limestone outcropping (ENV 2011a). Pied Oystercatchers and common sandpipers are also known to forage within the exposed rocky limestone outcropping and reef platforms (ENV 2011a). The shoreline habitat type can provide foraging opportunities to waders, as well as nesting opportunities for sooty and bridled terns (ENV 2011a). The Shoreline habitat type is considered as having a moderate habitat value for fauna species within the survey area and was generally in an 'Excellent' condition (ENV 2011a).

Coastal heath habitat

The Coastal Heath habitat type formed the coastal and near-coastal areas of the survey area and was the dominant habitat type within the survey area (113.4 ha or 54.5% of the survey area) (Figure 54). The vegetation within this habitat type consists of a closed to open heath of *Acacia rostellifera* (summer-scented wattle) and *Olearia axillaris* (coastal daisy bush) over a closed mixed grassland of *Lomandra maritima* and introduced species over white to light brown sands (ENV 2011a). This habitat provides shelter and foraging opportunities for a number of different species including ground-dwelling reptiles and mammals in the near-coastal and coastal areas (ENV 2011a).

This habitat showed signs of disturbance through cleared and developed areas along with a strong influx of weed species (ENV 2011a). The Coastal Heath habitat type was deemed as having a moderate habitat value to fauna species within the Survey area (ENV 2011a). Based on the Keighery condition scale, the Coastal Heath habitat was found to be in 'Very Good' to 'Good' condition, with areas of disturbance, clearing and weed infestation (ENV 2011a).

Woodland habitat

The Woodland habitat type is found in small isolated pockets of dense vegetation within the survey area and forms a small proportion of the Proposal area (19.3 ha or 9.3% of the Survey area) (Figure 54). The vegetation within this habitat type consists of an open forest of *Eucalyptus gomphocephala* (tuart) and *Agonis flexuosa* over a closed shrubland of *A. rostellifera* and mixed grassland of introduced species over light brown sands (ENV 2011a).

This habitat provides shelter and foraging opportunities for a number of different species including arboreal reptiles and mammals and a number of different avian species (ENV 2011a). Burrowing frogs may be found in this habitat type as the dense vegetation provides comparatively moist conditions suitable for frogs (ENV 2011a).

There were signs of disturbance through cleared and developed areas along with a strong influx of weed species, with the habitat being in 'Good' condition based in the Keighery scale (ENV 2011a). The tuarts did not contain any breeding hollows suitable for nesting black cockatoo species and only provide a minor amount of roosting potential (ENV 2011a). The Woodland habitat type was deemed as having a moderate habitat value to fauna species within the Survey area (ENV 2011a).

Wetland habitat

The Wetland habitat type is outside the Proposal area and is primarily located around Lake Richmond. A total of 16.9 ha or 8.1% of the Survey area was found to be wetland habitat. However, extensive wetland areas occur outside the survey area, around Lake Richmond (Figure 54). The lake is bordered by flats devoid of permanent vegetation, and then sedges at the base of surrounding coastal dunes. The sedge land is several metres wide and is dominated by *Baumea juncea* (bare twigrush), *Schoenoplectus validus* (lake club rush) and clumps of the introduced bulrush **Typha orientalis*[9] (ENV 2011a).

This Wetland habitat provides shelter and foraging opportunities for a number of different species including wetland waders and ducks on the fringes of the lake to small ground dwelling reptiles and mammals in the associated fringing vegetation. Lake Richmond also provides a permanent freshwater system in which frogs can carry out their life cycle. The Wetland habitat type can provide foraging opportunities for waders and *Merops ornatus* (Rainbow Bee-eater).

The Wetland habitat type was deemed as having a high habitat value for fauna species within the Survey area. The condition of the Wetland habitat surveyed was found to be Excellent according to the Keighery scale (ENV 2011a).

Regional context of fauna assemblage

In terms of species composition and richness, Cape Peron has been identified as being typical of small woodland remnants on the Swan Coastal Plain (ENV 2011a).

To verify the similarity of Cape Peron with other localities in the Swan Coastal Plain, the fauna assemblage was compared with baseline surveys and fauna compositions of the following neighbouring sites (Table 18):

- Jandakot Airport
- East Rockingham
- Norman Road
- Talbot Road.

Table 18 Regional comparisons of fauna assemblage

Location	Amphibians	Reptiles	Birds	Mammals	Overall
Cape Peron	5	19	65	6	95
Jandakot Airport	3 (2)	21 (13)	46 (29)	14 (5)	84 (49)
East Rockingham	0 (0)	17 (12)	44 (30)	12 (4)	73 (46)
Norman Road	4 (2)	12 (9)	N/A	5 (2)	21 (13)
Talbot Road	7 (3)	13 (10)	N/A	4 (1)	24 (14)
Swan Coastal Plain	13	64	311	33	421

+Values in parentheses are the number of species in each fauna group, or overall, shared with the ENV 2010 Cape Peron field survey.

The two nearest comparison sites, Jandakot Airport and East Rockingham, have a high degree of similarity to Cape Peron; particularly in the case of songbirds (87.5% shared similarity). The reptile assemblage at these sites is also similar to Cape Peron (>50% of similarity), likely a result of the relatively close proximity of the sites. In addition Cape Peron demonstrates a high level of reptile assemblage similarity (75%) with the Norman Road and Talbot Road comparison sites, likely due to the similarity in size of these remnant woodlands.

[9] Asterisks (*) denote species that are not native.

Although there are strong similarities between the comparison site assemblages and that of Cape Peron, there are a number of species which were not recorded at all of the sites, particularly mammals and reptiles. This is likely a function of the fragmentation of habitats and urbanisation of these areas which has occurred since European settlement. Reductions in available habitat area are likely to limit the ability for fauna species to maintain a viable population, resulting in localised extinctions within the small woodland fragments found on the Southwest Coastal Plain.

Significance of fauna habitat

The bushland of the Proposal area and surrounds is part of Bush Forever Site 355, as discussed in Section 8.2.1. Although considered to be of regional significance through the Bush Forever classification, in terms of fauna habitat the area is not considered to be of critical regional significance due to the high level of commonality of the habitats within both the survey area and wider surrounds (ENV 2011a). Each of the four habitat types mapped within the Cape Peron study area extend beyond the Proposal area and has already been subject to a high level of fragmentation and disturbance.

The survey area is isolated from other woodland remnants due to existing urbanisation, thus the only regional connectivity with the site is for highly mobile species such as birds. Disjunct habitats, such as the pocket present at Cape Peron, are utilised by birds as stepping stones between different areas. In addition to being disjunct at a regional level, the habitat present in the vicinity of the Proposal area is fragmented due to the previous land use and disturbance in Cape Peron (Table 19).

Table 19 Condition of fauna habitat present in the vicinity of the Proposal area

Habitat condition	Coastal Heath (ha)	Shoreline (ha)	Wetland (ha)	Woodland (ha)	Total (ha)
Excellent	-	-	16.23	-	16.23
Very Good	16.12	-	-	1.26	18.08
Very Good to Good	-	-	-	-	-
Good	14.68	0.01	-	3.84	20.09
Good to Degraded	1.39	0.10	-	-	1.49
Degraded to Completely Degraded	2.31	-	-	-	2.41
Completely Degraded	1.49	-	-	0.20	1.69

9.2.2 Terrestrial vertebrate fauna recorded within the Proposal area

Desktop studies of potential fauna abundances conducted during previous investigations were undertaken by Bamford (2005), which identified 187 non-marine species that may either potentially occur or have previously been recorded in the surveyed area. This total included 121 species of birds, 17 species of native mammals, 42 species of reptiles and seven amphibians. Surveys within the Proposal area, Lake Richmond and Bush Forever Site 353 by ENV (2011a) recorded 17% of the native mammals, 52% of the birds, 45% of the reptiles and 71% of the amphibians potentially occurring (Table 20). This low percentage of findings is considered likely to be due to the degraded and fragmented nature of the habitat (ENV 2011a). The migratory nature of bird species in the area is likely to also have reduced the number of species observed (Bamford 2005).

Table 20 Species recorded in the Survey area (after Bamford 2005; ENV 2011a)

Fauna Group	Species potentially present (Bamford 2005)	Species recorded (ENV 2005; Bamford 2005; Harewood 2009)	Species recorded (ENV 2011a)
Birds	121	44	66 (includes3 introduced species)
Mammals	17	12	6 (includes 3 introduced species)
Reptiles	42	17	19
Amphibians	7	-	5
Conservation significant	53	-	7 (34 potentially occurring)
Total	187	73	96 (includes 6 introduced species)

Mammals

A total of six mammal species from five families were recorded during the survey. The most frequently represented family was Muridae with two species, the remaining four families were represented by only one species.

Thirty one mammal species have previously been recorded within the surrounds of Cape Peron. A mammal survey was undertaken within the area by ENV (2011a) to support the Proposal. The survey included Lake Richmond (Bush Forever site 358). ENV (2011a) recorded three native mammal species within the Survey area, being:

- *Chalinolobus gouldii* (Gould's wattled bat)
- *Austrononus australis* (white-striped freetail-bat), also known as *Tadarida australis*
- *Rattus fuscipes* (western bush rat).

The white-striped freetail-bat and western bush rat are both found within the southwest of the state and are commonly recorded in biological surveys (ENV 2011a). Gould's wattled bat is common in Southern Australia.

No Priority or EPBC listed mammals were found in the survey area. A full copy of the ENV survey can be found in Appendix 5.

Introduced species

ENV (2011a) recorded three native introduced mammal species within the survey area, being:

- **Mus musculus* (house mouse)
- **Oryctolagus cuniculus* (rabbit)
- **Vulpes vulpes* (red fox).

Birds

A total of 66 bird species from 29 different families were recorded during the ENV survey (ENV 2011a) (Appendix 5). The most frequently represented family was Anatidae (ducks) with six species and *Meliphagidae* (honeyeaters) with five species (ENV 2011a). Six species of migratory birds were found in the Survey area, but no other conservation listed species (ENV 2011a).

Introduced species

Three introduced bird species were recorded:

- **Columba livia* (domestic pigeon)
- **Streptopelia senegalensis* (laughing turtle-dove)
- **Dacelo novaeguineae* (laughing kookaburra).

These species are widespread across much of the southwest of Western Australia (Johnstone and Storr 1998).

Herpetofauna

Reptiles

Nineteen reptile species from seven separate families were recorded during the survey (ENV 2011a). The most frequently represented family was Scincidae (skinks) with nine species followed by Pygopodidae (legless lizards) with three species (ENV 2011a). The most commonly recorded species were *Acritoscincus trilineatum* (southwestern cool skink), *Hemiergis quadrilineata* (two-toed earless skink) and *Tiliqua rugosa* (bobtail) (ENV 2011a).

A total of 51 reptile species have previously been recorded within the surrounds of Cape Peron, with the current survey recording only one new species; the *Chelodina oblonga* (oblong turtle), which is commonly found within wetlands on the Swan Coastal Plain (ENV 2011a).

One species of conservation significance was recorded in the survey area; *Lerista lineata* (the lined skink). Listed as Priority 3 by the DEC, the lined skink was recorded 31 times at all six sites within the survey area (ENV 2011a).

Amphibians

The survey recorded five amphibian species from two families (ENV 2011a). The most commonly recorded species was *Litoria moorei* (Motorbike Frog) and *Heleioporus eyrei* (Moaning Frog) (ENV 2011a).

No conservation listed amphibians are recorded as occurring in the Proposal area (ENV 2011a).

Freshwater fish and crustacea

Aquatic vertebrates in Lake Richmond were surveyed by Rose (1998) and Rose *et al.* (2004). The 2004 survey found that the native *Pseudogobius olorum* (Swan River goby) was the most common species (Rose *et al.* 2004). One native *Mugil cephalus* (sea mullet) was also caught (Rose *et al.* 2004).

No conservation listed fish or crustaceans have been recorded in the Proposal area.

Introduced species

The following species of introduced freshwater fish and crustacean have also been recorded (Rose *et al.* 2004):

- *Gambusia holbrooki* (mosquito fish)
- *Carassius auratus* (goldfish)
- *Cherax destructor* (yabbie).

9.2.3 Species of conservation significant terrestrial vertebrate fauna

Conservation significant vertebrate fauna species indicated in searches of the DEC NatureMap Database or EPBC Act Protected Matters Database as potentially occurring in the Proposal area are summarised in Table 21.

Table 21 Potentially occurring conservation significant vertebrate fauna species

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Mammals						
Isoodon obesulus fusciventer (quenda)	Priority 5	-	Occurs within forest, heath or coastal scrub. Distributed along the coast of south western Western Australia from Moore River to Israelite Bay.		*	Likely. Suitable habitat is present.
(Chuditch, western quoll)	Schedule 1	Vulnerable	Occurred on the Swan Coastal Plain until 1930s, current distribution restricted to southwest of Western Australia. Main portion of remaining populations occur within Jarrah forest, and drier woodland and Mallee shrublands associated with the Wheatbelt.			Unlikely. Due to lack of suitable habitat.
(Red-tailed phascogale)	Schedule 1	Endangered	Wandoo, Sheoak woodland associations. Exhibits a preference for long unburnt habitat with continuous canopy, as well as tree hollows.			Unlikely. Due to lack of suitable habitat.
Setonix brachyurus (quokka)	Schedule 1	Vulnerable	Current distribution includes two offshore islands (Rottnest and Bald Islands) and a number of sites in the southwest of Western Australia. Prefers dense streamside vegetation, heaths and shrubs of mainland and offshore islands, to *Agonis linearifolia*-dominated swamps in Jarrah forest and re-growth within Karri forest.			Unlikely. Due to lack of suitable habitat.
Hydromys chrysogaster (water rat, rakali)	Priority 4	-	Freshwater habitats, from subalpine streams and other inland waterways to lakes, swamps, and farm dams			Unlikely, but may occur at Lake Richmond, which is outside the Proposal area.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Birds						
Calyptorhynchus banksii naso (forest red-tailed black cockatoo)	Schedule 1	Vulnerable	Inhabits dense Jarrah, Karri and Marri forests receiving more than 600 mm average rainfall annually (DSEWPaC 2011c). Also known to occur in woodlands which include Blackbutt, Wandoo and Tuart species.		*	The fauna survey undertaken by ENV in 2009 (2011a) did not record this species during the survey. Potential habitat for this species is present within and outside the Proposal area as individual Tuart species. The ENV fauna survey (ENV 2011a) however, did not record potential foraging or breeding habitat with little roosting potential for cockatoo species within the Proposal area. The potential habitat within the Proposal area is located within the 'area to remain uncleared' with Tuart species present within the TEC "Callitris preissii (or Melaleuca lanceolata) forest and woodlands'. Tuart species are also present PEC SCP30b 'Quindalup Eucalyptus gomphocephala and/or Agonis flexuosa woodlands'. The Proposal does not propose to clear any tuart species.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Calyptorhynchus latirostris (Carnaby's cockatoo, short-billed black-cockatoo)	Schedule 1	Endangered	Inhabits native eucalypt woodlands that contain Salmon Gum and Wandoo and in shrubland or kwongan heathland dominated by Hakea, Dryandra, Banksia and Grevillea species (DSEWPaC 2011c). Nests in hollows of smooth-barked eucalypts especially Salmon Gum (*Eucalyptus salmonophloia*) and Wandoo (*Eucalyptus wandoo),* nests have also been found in other eucalypts including York Gum (*Eucalyptus loxophleba*), Flooded Gum (*Eucalyptus rudis*), Tuart (*Eucalyptus gomphocephala*) and the rough-barked Marri (*Corymbia calophylla*). During the non-breeding season, the species roosts in tall native or introduced eucalypts, and occasionally in Marri and pines. Species known to be used for roosting include Flat-topped Yate (*E. occidentalis*), Salmon Gum, Wandoo, Karri (*E. diversicolor*), Blackbutt (*E. patens*), Tuart (*E. gomphocephala*), Blue Gum (*E. globulus*, introduced), *Pinus radiata* and *P. pinaster* (DSEWPaC 2011c).		*	Investigations undertaken by ENV (2011a) did not record evidence of these species in the Survey area and indicated a lack of potential habitat within the proposed action footprint. The species however, is known to occur within the Rockingham area with species recorded by Birds Australia and historical surveys within 10 km of the Proposal area (ENV 2011a). The potential habitat distribution, within and surrounding the Proposal area for this species is similar to the Forest Red-tailed Black Cockatoo described above.
Diomedea exulans gibsoni (Gibson's albatross)	Schedule 1	Vulnerable	Gibson's Albatross is marine, pelagic and aerial and breeds on Adams Island and Auckland New Zealand (DSEWPaC 2011d). On breeding islands, this species nests on coastal and inland ridges, slopes, plateaux and plains, often on marshy ground (DSEWPaC 2011d).			Unlikely to occur. Only occurs in Australia between Coffs Harbour and Wilson's Promontory (Environment Australia 2001). The ENV fauna survey (2011a) did not record this species during the survey and did not identify this species in either Birds Australia, DEC or NatureMap database searches and previous fauna survey records within 10 km of the Proposal area. It is unlikely that this species would be found within or surrounding the Proposal area as the area does not support ideal habitat for this species.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Macronectes giganteus (southern giant-petrel)	Schedule 1	Endangered	The Southern Giant Petrel occurs mainly in Antarctic waters and during summer, it possibly concentrates north of 50° S in winter, as it is rare in waters of the southern Indian Ocean, but common off South America, South Africa, Australia and New Zealand. It occurs in both pelagic and inshore waters and is also attracted to land at sewage outfalls and scavenges ashore.		*	Likely. The species was not recorded during the ENV 2010 survey however is listed as occurring in the Rockingham area and SIMP (NatureMap). The species may potentially occur within the Proposal area but is likely only an infrequent visitor.
Macronectes halli (northern giant-petrel)	-	Vulnerable	The Northern Giant-Petrel is marine and oceanic, occurring mainly in sub-Antarctic waters, but also regularly occurs in Antarctic waters of the south western Indian Ocean, the Drake Passage and west of the Antarctic Peninsula. Its range extends into subtropical waters mainly between winter and spring and it frequents both oceanic and inshore waters near breeding islands and in the non-breeding range. During its first year, it occurs mainly on continental shelves, slopes and cold eastern boundary currents off South America, South Africa, Australia and New Zealand. It may be more oceanic from its second year. It is attracted to land at sewage outfalls and scavenges at colonies of penguins and seals.		*	Likely. The Northern Giant Petrel was not recorded during the ENV 2010 survey however is recorded as occurring in the Rockingham area by NatureMap. Given the availability of suitable habitat, it is possible that this species occurs in the Proposal area during the winter months of May to October however it is likely to be an infrequent visitor.
Thalassarche cauta cauta (shy albatross, Tasmanian shy albatross)	Schedule 1	Vulnerable	The Shy Albatross is a marine species occurring in sub-Antarctic and subtropical waters. Its preference for sea surface temperatures is not well known and it has been observed over waters ranging from 6.4 to 13.5º C. During the non-breeding season, it occurs around continental shelves around continents. It occurs both offshore and inshore and is known to enter harbours and bays.		*	Likely. The Shy Albatross was not recorded by the ENV 2010 survey however is recorded by NatureMap as occurring in the coastal Metropolitan area. It is potentially only an infrequent visitor to the Proposal area.
Ardea sacra (eastern reef egret)	Schedule 3	Migratory	The Eastern Reef Egret occurs in coastal areas along the entire Western Australia coast, although it is more common in the warmer regions to the north. The species inhabits beaches, rocky shores, tidal rivers and inlets, mangroves, and exposed coral reefs. Although it is listed as migratory, the Eastern Reef Egret is largely sedentary in nature (Johnstone and Storr 1998).		*	Likely. The beaches and rocky shores of the Proposal area are typical habitat for this bird and it is likely to occur there.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Plegadis falcinellus (glossy ibis)	Schedule 3	Migratory	The Glossy Ibis is listed as Migratory under the EPBC Act and inhabits areas of freshwater wetlands, estuaries and creeks, with occasional foraging in dry grasslands. This species is generally uncommon, but has a widespread and erratic distribution.		*	Likely. The area dry grassland within the Proposal area contains suitable foraging habitat for the Glossy Ibis and it is likely to reside there from time to time.
Falco peregrinus (peregrine falcon)	Schedule 4	Migratory	The Peregrine Falcon occurs mainly along coastal cliffs, rivers and ranges as well as wooded watercourses and lakes (Johnstone and Storr 1998). The Peregrine Falcon nests primarily on cliffs, granite outcrops and quarries, and feeds mostly on birds (Johnstone and Storr 1998). The coastal cliffs provide some potential nesting habitat and there is plentiful supply of prey items in the area.		*	Likely. Peregrine Falcon is likely to only forage within the Survey area and only as part of a larger home range.
Limosa limosa (black-tailed godwit)	Schedule 3	Migratory	The Black-tailed Godwit is an uncommon summer non-breeding migratory shorebird that occurs along most of the coast of Western Australia (Geering *et al.* 2007). It inhabits fresh and brackish wetlands as well as intertidal mudflats (Geering *et al.* 2007).		*	Likely. Fresh water and intertidal regions of the Survey area provide an adequate habitat for this species and it is likely to occur during its migration.
Limosa lapponica (bar-tailed godwit)	Schedule 3	Migratory	The Bar-tailed Godwit is a relatively common summer non-breeding migratory shorebird that occurs along most of the coast of Western Australia, including Garden Island which is situated just north of the Survey area. It inhabits mudflats, sandy and sea-weedy beaches (Johnstone and Storr 1998).		*	Likely. The habitat around the Survey area is well suited for the Bar-tailed Godwit and it is likely to occur there during its migration.
Numenius phaeopus (whimbrel)	Schedule 3	Migratory	Whimbrel is a large non-breeding migratory shorebird, found commonly along the north coast of Western Australia and intermittently found on the south coast (Johnstone and Storr 1998). It inhabits mudflats of estuaries or lagoons, particularly those with Mangroves where it often roosts (Geering *et al.* 2007).		*	Likely. The Survey area contains habitat suitable for the Whimbrel and as such it is possible the Whimbrel may be found in this area on its migratory route.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Numenius madagascariensis (eastern curlew)	Schedule 3	Migratory	Occurs commonly along the north coast of Western Australia, but is known to migrate south to Bunbury along the South Coast (Johnstone and Storr 1998). It inhabits a range of coastal habitats, but primarily intertidal mudflats, particularly on exposed seagrass beds or mudflats with burrowing crabs or shrimps (Geering *et al.* 2007).		*	Likely. The Survey area does contain habitat suitable for the Eastern Curlew and it is possible the Eastern Curlew may be found in this area on its migratory route.
Tringa stagnatilis (marsh sandpiper)	Schedule 3	Migratory	A summer non-breeding migratory shorebird that occurs in Western Australia along the coast, coastal plains, and less frequently inland (Johnstone and Storr 1998). It inhabits freshwater or saltwater wetlands but avoids open beaches and mudflats unless well protected (Geering *et al.* 2007).		*	Likely. The marine and freshwater environments of the Survey area are possible habitats for the Marsh Sandpiper during its migratory routes.
Tringa nebularia (common greenshank)	Schedule 3	Migratory	A non-breeding migratory shorebird, common along most of the coast of Western Australia (Geering *et al.* 2007). It inhabits intertidal mudflats, as well as fresh and saltwater wetlands of the coast or inland (Geering *et al.* 2007).		*	Likely. The shorelines of the Survey area are a suitable habitat for the Common Greenshank. As such it is likely to inhabit this area on its migratory route. Also likely to occur on Lake Richmond, which is located outside the Proposal area.
Tringa glareola (wood sandpiper)	Schedule 3	Migratory	A summer non-breeding migratory shorebird that occurs along the coastal as well as inland regions of Western Australia (Geering *et al.* 2007). It primarily inhabits freshwater wetlands and rarely on intertidal mudflats (Geering *et al.* 2007).		*	Unlikely. The closest suitable habitat for the Wood Sandpiper is Lake Richmond, which is outside the Proposal area.
Xenus cinereus (terek sandpiper)	Schedule 3	Migratory	The Terek Sandpiper is a summer non-breeding migratory shorebird that occurs along the north coast of Western Australia, but intermittently found as far south as Bunbury and Albany (Johnstone and Storr 1998). It inhabits exposed seagrass beds in estuaries and bays or on intertidal mudflats fringed by mangroves (Geering *et al.* 2007).	*		Confirmed. Recorded by ENV (2011a) Occurs on sandy beaches around the Survey area.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Tringa brevipes (grey-tailed tattler)	Schedule 3	Migratory	A non-breeding migratory shorebird, common on the north and west coasts of Western Australia, rare on the south coast. It has been recorded on Garden Island which is situated just north of the Survey area (Johnstone and Storr 1998). It inhabits sheltered coasts with reef and rock platforms or with intertidal mudflats (DSEWPaC 2011d). It often roosts in mangroves or artificial structures such as piers and breakwaters (Geering *et al.* 2007).		*	May inhabit the small areas of rocky coast within the Proposal area that area suitable for the Grey-tailed Tattler on its migratory route.
Arenaria interpres (ruddy turnstone)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs on the coast of Western Australia and has been recorded on Penguin Island which is situated just south of the Survey area (Johnstone and Storr 1998). It occurs primarily on rocky coasts and rocky reefs, as well as tidal mudflats and beaches and pebbly shores of near-coastal salt lakes and salt-work ponds (Johnstone and Storr 1998).		*	The Survey area only has small areas of rocky coast with seaweed, suitable for the Ruddy Turnstone. As such it may inhabit this area on its migratory route.
Calidris canutus (red knot)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along most of the coast of Western Australia with records from Garden Island which is situated just north of the Survey area (Johnstone and Storr 1998). It inhabits larger intertidal mud and sand flats (Geering *et al.* 2007).		*	The tidal sands of the Survey area are a suitable habitat for the Red Knot. As such it is likely to inhabit this area on its migratory route.
Calidris tenuirostris (great knot)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along most of the coast of Western Australia with records from Garden Island which is situated just north of the Survey area (Johnstone and Storr 1998). It inhabits larger intertidal mud and sand flats (Geering *et al.* 2007).		*	The tidal sands of the Survey area are a suitable habitat for the Great Knot. As such it may inhabit this area on its migratory route.
Calidris alba (sanderling)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along most of the coast of Western Australia with records from Garden Island which is situated just north of the Survey area (Johnstone and Storr 1998). This species inhabits sandy beaches, inlets, estuaries and coastal salt lakes (Johnstone and Storr 1998).		*	The sandy coastal beaches of the Survey area are suitable habitats for the Sanderling. As such it may inhabit this area on its migratory route.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Calidris ruficollis (red-necked stint)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along most of the coast of Western Australia with records from Penguin Island which is situated just south of the Survey area (Johnstone and Storr 1998). It inhabits a wide range of fresh and saltwater habitats (Geering *et al.* 2007).		*	The coastal waters of the Survey area are suitable habitat for the Red-necked Stint. As such it may inhabit this area on its migratory route.
Calidris subminuta (long-toed stint)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along the mid West coast of Western Australia as far south as Busselton (Johnstone and Storr 1998). This species prefers coastal and inland swamps for habitat (Simpson and Day 2004).			Unlikely. Only Lake Richmond and other wetlands located outside the Proposal area are suitable habitat for the Long-toed Stint. No wetlands are located within the Proposal area.
Calidris acuminata (sharp-tailed sandpiper)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along most of the coast of Western Australia as far south as Busselton, and in well-watered parts of the interior and casually in the arid east south of Lake Gregory.			Unlikely. It inhabits both coastal and inland areas but prefers non-tidal fresh or brackish wetlands, which occur outside the Proposal area. No wetlands are located within the Proposal area.
Calidris ferruginea (curlew sandpiper)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along most of the coast of Western Australia (Geering *et al.* 2007). It inhabits exposed tidal mudflats, and less frequently on inland freshwater wetlands (Geering *et al.* 2007).			Unlikely. Only Lake Richmond and other wetlands located outside the Proposal area are suitable habitat for the Curlew Sandpiper. No wetlands are located within the Proposal area.
Philomachus pugnax (ruff)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along the south-west coast of Western Australia (Johnstone and Storr 1998). It inhabits tidal mudflats, sewerage farms and freshwater wetlands (Pizzey and Knight 2007).			Unlikely. Only Lake Richmond and other wetlands located outside the Proposal area are suitable habitat for the Ruff. No wetlands are located within the Proposal area.
Pluvialis fulva (Pacific golden plover)	Schedule 3	Migratory	A summer non-breeding migratory shorebird that occurs along the coast of Western Australia (Johnstone and Storr 1998). The Pacific Golden Plover inhabits marine waters such as beaches, mudflats and among rocky areas, sometimes inland (Simpson and Day 2004).		*	Likely. The beaches and rocky areas of the Survey area are suitable habitats for the Pacific Golden Plover. As such it may inhabit this area on its migratory route.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Pluvialis squatarola (grey plover)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along the coast of Western Australia with records from Penguin Island which is situated just south of the Survey area (Johnstone and Storr 1998). The Grey Plover inhabits coastal areas, preferring marine shores of estuaries or lagoons on broad open mudflats, sandy bars or beaches and rocky coasts as well as coastal salt lakes and swamps (Morcombe 2000). They occasionally are found in drying freshwater lakes (Johnstone and Storr 1998).		*	Likely. The beaches and rocky areas of the Survey area are suitable habitats for the Grey Plover. As such it may inhabit this area on its migratory route.
Charadrius mongolus (lesser sand plover)	Schedule 3	Migratory	summer non-breeding migratory shorebird that occurs on the north and west coast of Western Australia as far south as Albany Johnstone and Storr 1998). It inhabits exposed sand and mud flats and often intermingles with flocks of the Greater Sand Plover (Geering *et al.* 2007).		*	Likely. The exposed sand of the Survey area is suitable habitat for the Lesser Sand Plover. As such it may inhabit this area on its migratory route.
Charadrius leschenaultii (greater sand plover)	Schedule 3	Migratory	Summer non-breeding migratory shorebird that occurs along the coast of Western Australia (Johnstone and Storr 1998). It inhabits exposed sand and mud flats (Geering *et al.* 2007).	*		Confirmed. Recorded by ENV (2011a) The exposed sand of the Survey area is suitable habitat for the Greater Sand Plover. As such it may inhabit this area on its migratory route.
Haliaeetus leucogaster (white-bellied sea-eagle)	Schedule 3	Migratory	Distributed along the coast, islands and estuaries of Western Australia (Johnstone and Storr 1998). They feed on fish, sea snakes and nesting seabirds. Nests are usually placed on high ground such as rock pinnacles, rigid shrubs or in tall trees.	*		Confirmed. Recorded by ENV (2011a)
Ardea modesta (eastern great egret, white egret)	Schedule 3	Migratory (and marine)	Inhabits mostly shallow fresh lakes, pools in rivers, lagoons, lignum swamps, claypans and samphire flats, large dams and sewage ponds (Johnstone and Storr 1998). It also inhabits shallow saltwater habitat such mangrove creeks, tidal pools, samphire swamps and salt work ponds. It breeds colonially at wooded swamps and river pools, nesting in various riparian trees (Johnstone and Storr 1998).			Unlikely. The Eastern Great Egret was recorded during the survey a number of times forging at Lake Richmond, which is outside the Proposal area.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Ardea ibis (cattle egret)	Schedule 3	Migratory (and marine)	The Cattle Egret occurs in the wetter parts of Western Australia, in particular the Kimberley and the south-west. The species inhabits short grass, in particular damp pastures and wetlands, usually in the company of cattle and occasionally other livestock. In Western Australia it is an irregular visitor, occurring mostly in autumn, and is not thought to breed within the State (Johnstone and Storr 1998).			Unlikely. The only suitable habitat that exists in the Survey area was at Lake Richmond, which is located outside the Proposal area.
Apus pacificus (fork-tailed swift)	Schedule 3	Migratory (and marine)	Summer migrant (October-April) to Australia, that has not been recorded breeding in Australia (DSEWPaC 2011d). This species is an aerial species, which forages high above the tree canopy and rarely lower so it is independent of terrestrial habitats in Australia (Johnstone and Storr 1998). It usually occurs in flocks of up to 2000 and is often seen accompanying Tree Martins and Masked Woodswallows (Johnstone and Storr 1998		*	Likely. This species forages over the site from time to time, high in the airspace.
Acrocephalus australis (Australian reed-warbler)	-	Migratory	sedentary and migratory species that inhabits tall dense vegetation such as bulrushes, sedges, rushes, reeds and long grass at the edges of lakes, springs, streams, claypans and dams, as well as sewage ponds and other artificial freshwater wetlands (Johnstone and Storr 1998). The Australian Reed-warbler was recorded during this survey. The bulrushes (Typha sp.) and reeds along the edge of Lake Richmond are typical habitat for this species.			Unlikely. The only sighting of this species was outside the Proposal area, adjacent to Lake Richmond. No suitable habitat occurs within the Proposal area.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Merops ornatus (rainbow bee-eater)	Schedule 3	Migratory	Migrates to south-western Australia to breed in spring and summer (Johnstone and Storr 1998). The Rainbow Bee-eater is a common and widespread species in Western Australia (Johnstone and Storr 1998). It occurs in lightly wooded, often sandy country, preferring areas near water. The Rainbow Bee-eater feeds on airborne insects, and nests throughout its range in Western Australia in burrows excavated in sandy ground or banks, often at the margins of roads and tracks (Johnstone and Storr 1998). During the survey it was recorded near Lake Richmond, and this is where it is most likely to forage. Contrary to the EPBC listing, this species is not included as a migratory species on the JAMBA agreement between the Government of Australia and Japan.		*	Likely to occur. Although the only sighting of this Species was outside the Proposal area near Lake Richmond, suitable habitat occurs in the sandy ground within the Proposal area.
Pandion cristatus (eastern osprey)	-	Migratory (and marine)	Distributed along the coast, islands and lower river courses of Western Australia. They feed on fish and other marine animals (Johnstone and Storr 1998), nesting in trees, cliffs and sometimes structures such as radio towers, often close to the water. A single Eastern Osprey was recorded during the survey at different locations throughout the Survey area. A nest was also located on a small rocky island in Shoalwater Bay which is off the southern side of the Survey area.	*		Confirmed. One Osprey recorded by ENV (2011a), believed to be nesting in an offshore island.
Actitis hypoleucos (common sandpiper)	Schedule 3	Migratory (and marine)	Occurs along the coast of Western Australia, and in much of the interior. It inhabits sheltered salt and fresh waters such as estuaries, mangrove creeks, rocky coasts, salt lakes, river pools, lagoons, claypans, drying swamps, flood waters, dams and sewage ponds (Johnstone and Storr 1998). They occasionally occur inland in a variety of wetlands (Geering *et al.* 2007). They are a non-breeding migrant to Western Australia occurring at any time of year, but mostly September to March in the south-west (Johnstone and Storr 1998).	*		Confirmed. Recorded by ENV (2011a). Rocks and sandy beaches of the Survey area are the preferred habitat for the Common Sandpiper.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Sterna anaethetus (bridled tern)	Schedule	Migratory (and marine)	A migratory shore bird that breeds off the Western Australian coast from September to May. It inhabits blue water seas generally close to breeding sites, which are located on the many small rocks islands around Cape Peron (Johnstone and Storr 1998).			Unlikely. It was recorded as part of an opportunistic survey during the current survey outside the Proposal area on the very tip of Cape Peron. The coastal islands around the Survey area are suitable breeding habitat for the Bridled Tern during its migration.
Reptiles						
Lerista lineata (lined skink)	Priority 3	-	*Lerista lineata* occurs in sandy coastal heath and shrubland areas in disjunct and isolated populations in the south-west and mid-west coast of Western Australia (Wilson and Swan 2008). This burrowing species is found in loose soil or sand beneath logs and termite mounds, where it feeds on termites and other small insects (Cogger 2000).	*		Confirmed. The Lined Skink (Lerista lineata) was recorded thirty one times, at all six sites within the Survey area. The coastal heath and loose sand of the Survey area is ideal habitat for this skink (ENV 2011a).
Ctenotus gemmula (jewelled ctenotus)	Priority 3	-	The skink *Ctenotus gemmula* occurs in two disjunct populations, one in the southern section of the Swan Coastal Plain, the other along the south coast from Albany to Bremer Bay. It inhabits heathland located over pale sand-plains that are associated with Banksia or Mallee woodlands (Wilson and Swan 2008).		*	Likely. It is possible that the Jewelled Ctenotus resides within the Survey area as suitable habitat exists and the Proposal area is within this species' known distribution. None were recorded during the survey.
Morelia spilota imbricata (carpet python)	Schedule 4	-	The south-western population of the Carpet Python has a wide distribution in the south-west, but is generally uncommon, having been recorded from semiarid coastal and inland habitats, Banksia woodland, eucalypt woodlands, and grasslands. It commonly utilises hollow logs for shelter (Wilson and Swan 2008). Local populations in the south-west have suffered because of extensive clearing and removal of its habitat. Lack of habitat makes the species vulnerable to predation and severely limits the potential for radiation.		*	Likely. The Carpet Python has been recorded in coastal areas similar to that found within the Survey area and there is also a population on Garden Island. It is possible that the carpet python resides in the Survey area. However, none were recorded during the survey.

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011a)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Neelaps calonotos (black-striped snake)	Priority 3	-	The Black-striped Snake is typically found in sandplain habitat in association with Banksia species, having a very limited distribution exclusive to the Swan Coastal Plain. This taxon is particularly difficult to locate, and is infrequently collected during biological surveys on the Swan Coastal Plain.		*	Likely. The Survey area contains preferred habitat and lies within this species' known distribution, therefore this species may occur.

Mammals of conservation significance

As listed in Table 21, no conservation significant mammals have been recorded (ENV 2011a). One mammal of conservation significance Quenda (Priority 5; WA DEC) has been identified as potentially occurring within the Proposal area.

Birds of conservation significance

As listed in Table 21, of the 40 species of conservation significant bird species potentially occurring, five were recorded within the Proposal area, 26 species are likely to occur in the Proposal area, as suitable habitat was found to be present, nine species are unlikely to occur within the Proposal area.

The five recorded species of conservation significant bird species are:

- *Pandion cristatus* (eastern osprey) (Migratory)
- *Actitis hypoleucos* (common sandpiper) (Migratory)
- *Xenus cinereus* (terek sandpiper) (Migratory)
- *Charadrius leschenaultii* (greater sand plover) (Migratory)
- *Haliaeetus leucogaster* (white-bellied sea-eagle) (Migratory).

Reptiles of conservation significance

As listed in Table 21, one reptile of conservation significance Perth lined skink (Priority 3; WA DEC), was recorded as occurring within the Proposal area (ENV 2011a). Two other reptiles of conservation significance may occur within the Proposal area. These are jewelled ctenotus (Priority 3; WA DEC) and carpet python (Priority 4; WA DEC).

9.2.4 Occurrence of invertebrate fauna

A desktop study of potential invertebrate fauna abundance was undertaken by Bamford (2005) as a component of the terrestrial fauna assessment. No threatened invertebrates were identified within the search area investigated (Bamford 2005). Despite the absence of species, Bamford (2005) identified the following five species of conservation significant invertebrate fauna as having been recorded east of the study area:

1. *Synemon gratiosa* (graceful sun-moth) – Schedule 1 (WC Act); Endangered EPBC Act 1999 (C'wlth).
2. *Neopasiphae simplicio*r (native bee) – Schedule 1 (WC Act); .Critically Endangered EPBC Act 1999 C'wlth).
3. *Leioproctus douglasiellus* (native bee) – Schedule 1 (WC Act).
4. *Throscodectes xiphos* (cricket) – Priority 1 (WA DEC).
5. *Hylaeus globuliferus* (bee) – Priority 3 (WA DEC).

With the exception of the GSM, all species appear to be associated with understorey species of Banksia woodland that is not present within the study area (Bamford 2005). One species of butterfly (*Vanessa itea* – Yellow Admiral) (not listed as Threatened or Priority) was also identified as having the potential to utilise the Proposal area for mating (Bamford 2005).

The GSM is discussed further in Section 9.2.5.

Occurrence of short range endemic (SRE) terrestrial invertebrates

SREs are defined as terrestrial and freshwater invertebrate species, which have naturally small distributions of less than approximately10 000 km^2 (EPA 2009a). SREs are usually invertebrates, as these animals are more likely to have poor dispersal capabilities and possess a more defined or restrictive biology. Such species may be at greater risk of becoming threatened or endangered as a result of habitat loss or other threatening processes than species with larger ranges (EPA 2009a).

A desktop assessment was undertaken by Subterranean Ecology (2010d). Three groups of terrestrial invertebrates were identified that are known to include SRE species and that may possibly occur within the Proposal area:

1. Scorpion: a rare and undescribed species of *Lychas*, referred to as *Lychas 'majerourm'*.
2. Millipedes: two species of *Antichiropus, Antichiropus* 'G1' and *Antichiropus* 'UBS2'.
3. Land snails within the families of *Bulimulidae* and *Camaenidae*.

Sampling for scorpions, millipedes and snails, require different survey methods and are ideally undertaken in different seasons (EPA 2009a). For this reason a targeted survey for SREs was undertaken in two phases:

- Phase 1 Scorpions – 6 and 7 April 2010
- Phase 2 *Antichiropus* millipedes and land snails – 12 August 2010.

Survey methodologies followed guidelines outlined in EPA Guidance Statement No. 20 (EPA 2009a), and were also undertaken by Subterranean Ecology (2010d).

No conservation significant scorpions, millipedes or land snails were found during the surveys and it was considered that the area contained a paucity of SRE species due to previous disturbance and low diversity of habitats for invertebrates (Subterranean Ecology 2010d).

9.2.5 Occurrence of conservation significant terrestrial invertebrate fauna – Graceful Sun-Moth

Conservation significant invertebrate fauna species indicated from searches of the DEC NatureMap Database or DSEWPaC EPBC Act Protected Matters Database as potentially occurring in the Proposal area are summarised in Table 23.

Synemon gratiosa (GSM) is an endangered day-flying moth endemic to Western Australia, known to occur between Beekeepers National Park (10 km North of Leeman) and Preston Beach (Bishop *et al.* 2010).

Targeted GSM surveys were undertaken of the site in March 2010 and March 2011 by ENV (2011b). The targeted survey was conducted to determine the presence and abundance of the GSM in the Proposal area, and followed the desktop study of potential invertebrate fauna abundance undertaken by Bamford (2005), which identified the presence of the GSM habitat with the Proposal area.

The targeted GSM survey was carried out in accordance with the criteria set by the DEC in relation to GSM surveys (Bishop *et al.* 2010). During the GSM survey in March 2010 one GSM was found within the Proposal area and two outside of this area (approximately 125 m and 500 m from the Proposal area boundary), indicating that the species is represented locally outside the Proposal area (Figure 55) (ENV 2011b). No GSMs were observed or caught during the March 2011 survey (ENV 2011b).

Lomandra maritima densities were found to vary significantly across the Proposal area, with quadrats in close proximity to one another varying from 0%-50% density (ENV 2011b). Indicative *Lomandra* density across the Survey area is illustrated in Figure 56, with the areas of habitat mapped and to be cleared outlined in Table 22.

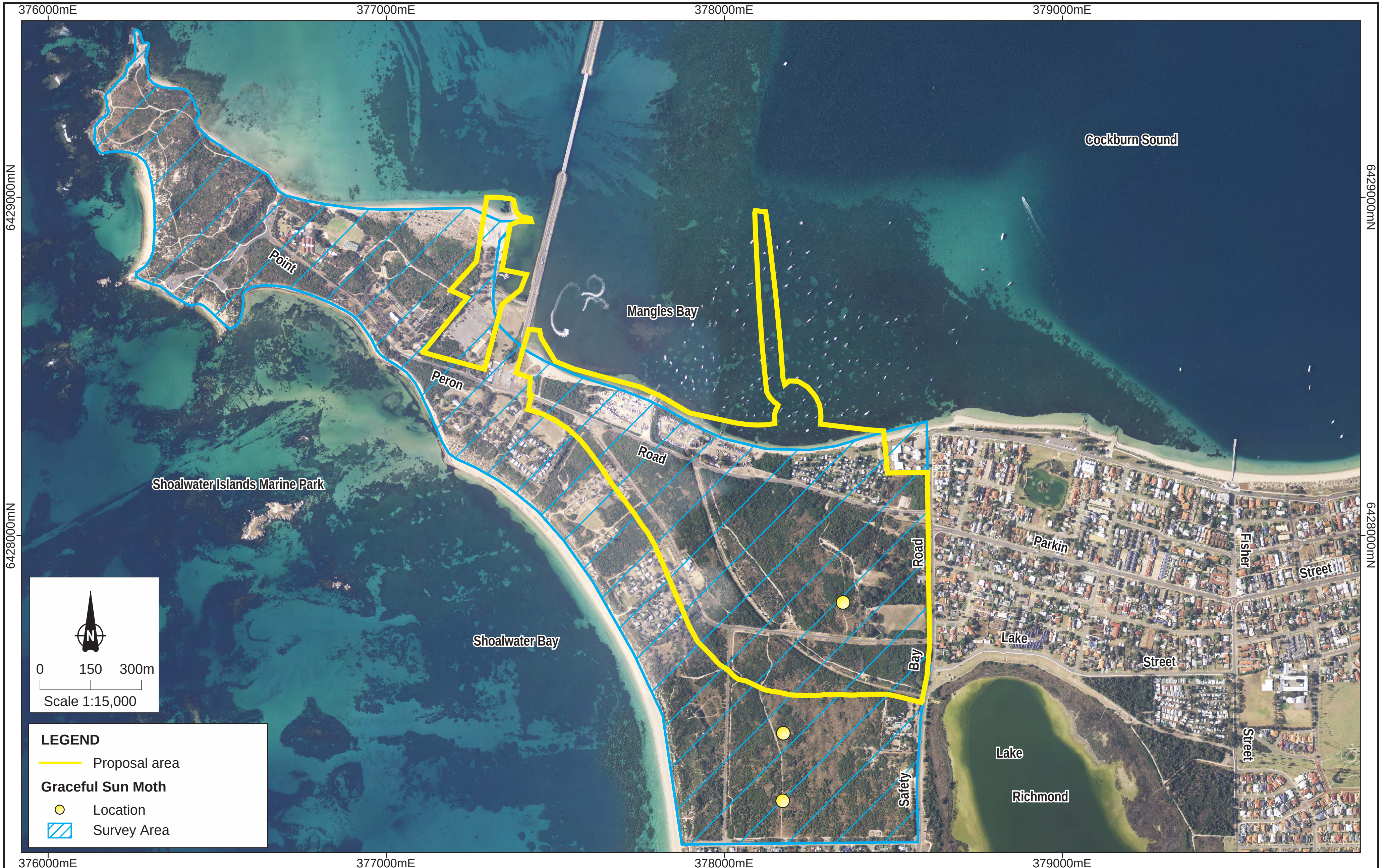
Table 22 Areas of Lomandra surveyed in the vicinity of the Proposal area

Density	Area surveyed (ha)	Area to be cleared (ha)	Percentage of mapped habitat to be removed (%)
High	11.18	6.54	58.5
Low	55.35	23.66	42.8
Medium	10.34	0.45	4.3
Total	76.88	30.65	39.9

The greatest threat to this species is through habitat loss, as this region is experiencing urban development. Other factors that make the species future uncertain are the ongoing threats of track maintenance, inappropriate fire regimes and damage to habitat from the recreational use of four wheel drive vehicles (DSEWPaC 2011d).

Table 23 Likelihood of occurrence of conservation significant invertebrate fauna species

Species	Conservation Status WA	EPBC Act Conservation Status	Preferred habitat (After ENV 2011b)	Recorded / sighted / evidence of presence within the Proposal area	Not recorded but suitable habitat present	Likelihood of occurrence within Proposal area
Insects						
Synemon gratiosa (GSM)	Schedule 1	Endangered	GSM is associated with coastal heath on Quindalup dunes and Banksia woodland on Spearwood and Bassendean dunes; in both cases it is associated with its preferred host plants, *Lomandra maritima* or *Lomandra hermaphrodita* (Bishop *et al.* 2010). The adults lay their eggs on the base of the plants and when the larvae hatch they burrow into the leaf bases, growing tip and rhizomes where they pupate for the next eleven months. It is thought that males are sedentary and females disperse less than 1 km from their birth location and are unlikely to cross unsuitable habitat (CALM 2005).	*		Confirmed. A total of three individual GSM were recorded during the 2010 survey (ENV 2011b). One GSM was found within the Proposal area and two outside of this area (approximately 125 m and 500 m from the Proposal area boundary), indicating that the species is represented locally outside the Proposal area. However the regional population is unlikely to be impacted.



Source:
Imagery supplied by Landgate
Graceful Sun Moth Data supplied by ENV (2010)
Coordinate System: MGA94 Zone 50
Date: 8/2/2012

NB: Potential errors may occur in some areas

STRATEGEN environmental consultants

Drawn: CAD Resources

CAD Resources File No: g1937_MB_PER_F012.dgn

Recorded Graceful Sun Moth individuals

Figure No: 55

Source:
Cadastral Data supplied by Landgate
Lomandra Data supplied by ENV (2010)
Coordinate System: MGA94 Zone 50
Date: 8/2/2012
NB: Potential errors may occur in some areas

STRATEGEN environmental consultants

Drawn: CAD Resources

CAD Resources File No: g1937_MB_PER_F008.dgn

***Lomandra maritima* density and locations recorded within Proposal area and surrounds**

Figure No: 56

9.3 Evaluation of options or alternatives to avoid or minimise impact

There are limited options to avoid clearing of vegetation from this Proposal.

The Proposal has been designed to minimise impact to / avoid the TEC located near the corner of Memorial Drive and Safety Bay Road, which forms part of the woodland habitat classification. Most of the vegetation within the Proposal area will be cleared, however rehabilitation has been planned for the surrounding areas, reducing the net habitat loss.

The Proposal has been designed to reduce the potential for ingress of saline groundwater into Lake Richmond and reduce the impact of saline groundwater on the woodland habitat. As described in Section 3.3, the Proposal has been amended to shorten the length of the canal that originally came close to the TEC *Callitris preissii*. Two different construction options for the Proposal have been considered in order to reduce groundwater drawdown and hence limit the potential impact on habitat. Groundwater modelling has identified that wet construction will have the smallest impact on groundwater levels (Section 6.3). This will limit the potential for short-term vegetation stress resulting from groundwater drawdown.

9.4 Assessment of likely direct and indirect impacts

The following aspects of the Proposal may affect terrestrial fauna values:

- clearing of vegetation for the Proposal will directly disturb fauna habitat, create fragmentation of fauna linkages and may result in the loss of individual terrestrial fauna
- vehicle movements and construction activities in the Proposal area may result in the loss or disturbance of individual terrestrial fauna
- predation on terrestrial fauna species from domestic pets from the land development
- indirect impacts from an increase in population degrading habitat quality over time thereby reducing habitat quality for terrestrial fauna
- indirect impacts from increase in saltwater interface as a result of the land based marina impacting groundwater-dependent vegetation.

Approximately 40 ha of fauna habitat will be cleared as a result of the Proposal.

9.4.1 Clearing of vegetation

Up to 40 ha of fauna habitat will be cleared for the development, as outlined in Figure 51. Of the total surveyed extent, 30.2% of the Coastal Heath habitat, 0.2% of the Shoreline habitat and 6.1% of the Woodland habitat will be cleared (Table 24). Wetland habitat will not be cleared as a result of the Proposal.

Table 24 Habitat areas within survey area and to be cleared

Habitat Type	Total in Survey area (ha)	Total to be cleared for the Proposal (ha)	Percentage of total habitat to be cleared (%)
Shoreline	4.15	0,9	21
Coastal Heath	113.37	35.2	31
Woodland	19.29	2.18	10.8
Wetland	16.93	0	0
Cleared/degraded	54.26	22.24	41
Total	208.01	60.52 (38.28 ha not cleared or degraded)	23%

The three habitat types identified as occurring within the Proposal area also occur beyond the Proposal area in both the Cape Peron area and broader Swan Coastal Plain region. The relatively small area of clearing required for the Proposal is not likely to present an impact to the regional significance of these habitat types and the fauna assemblage they support. The removal of 0.01 ha of Shoreline, 34.2 ha of Coastal Heath and 1.18 ha of Woodland is likely to have localised impacts on the less mobile species present, however this can be effectively mitigated through staged clearing and translocation (Section 9.6).

In addition to the direct removal of potential habitat, clearing may result in fragmentation of habitats and disruption of the linkages between areas of habitat, as well as increasing predation events as individuals move across cleared areas. The fauna habitats in the vicinity of the Proposal area are already in a fragmented state due to previous developments and recreational use of the area (Table 19).

The fragmentation of habitat caused by clearing within the Proposal area and the upgrade of Memorial Drive has the potential to create a barrier for some species that typically move between the Cape Peron and Lake Richmond areas to access the food, water and habitat resources of the lake. However the linkage to Lake Richmond is already fragmented by Safety Bay Rd, Memorial Drive, the Water Corp Reserve and other previously disturbed areas (Figure 49). Rehabilitation activities in the vicinity of the Proposal area will be targeted to effect an improvement of connectivity of viable fauna habitat in the area, and may reduce the fragmentation that is already present in these areas.

Clearing may also result in direct impacts due to fauna deaths. These are more likely to occur if the clearing happens during winter, when reptiles may be hibernating, and unable to move away from the impact, or in spring when birds may be nesting in the vegetation.

As discussed in Section 9.6, management actions will be implemented during the construction phase of the Proposal to mitigate the direct and indirect impacts of clearing on fauna and habitat within the Proposal area.

9.4.2 Impacts upon fauna of conservation significance

Predicted impacts of vegetation clearing and associated habitat disturbance to species of conservation significance identified in Table 21 and Table 23, as likely to occur within the Proposal area), are outlined in Table 25 below.

Impacts on Matters of NES are discussed in Section 14.

Table 25 Potential impact on terrestrial fauna of conservation significance likely to occur within the Proposal area

Species	Potential Impact
Mammals	
Isoodon obesulus fusciventer (quenda)	Quenda favour dense, low vegetation and is likely to cross roads in the area, making it vulnerable to vehicle strike (Bamford 2005). Because of the preference for dense vegetation, it may benefit from revegetation programs. The species is likely to occur within the Proposal area. The Proposal will result in a small reduction in Quenda habitat due to clearing of 34.2 ha of Coastal Heath habitat. Up to 47 ha of the Coastal Heath habitat is proposed to be rehabilitated in the vicinity of the Proposal area, which will provide viable habitat for this fauna. The proximity of this rehabilitation area to Lake Richmond and improvement of linkages to the water body is likely to benefit this species which favours the wetland habitat surrounding the lake.
Birds	
Calyptorhynchus banksii naso (forest red-tailed black cockatoo)	Two black cockatoo species, the Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*) and Carnaby's Cockatoo (*Calyptorhynchus latirostris*) have been identified as to potentially occur within the Proposal area. The Proposal will not result in the direct clearing of tuart species identified by ENV (2011b). Investigations undertaken by ENV (2010b) did not record evidence of

Species	Potential Impact
Calyptorhynchus latirostris (Carnaby's cockatoo, short-billed black-cockatoo)	these species in the Proposal area and indicated a lack of potential habitat within the proposed action footprint. The Proposal area does not contain foraging species such as Banksia, Marri or Jarrah trees and no suitable hollows were identified within trees within the area. Due to the lack of habitat available for these species, potential impacts from the Proposal from direct clearing will not result in a significant impact to the potential black cockatoo habitat or the population of black cockatoo species that may potential occur. Indirect impacts however, may occur to the tuart species as a result of the hydrological changes incurred as a result of the inland marina. These potential impacts are addressed in Section 14.
Macronectes giganteus (southern giant-petrel)	Southern Giant-Petrels cover a broad range of habitats and locations in Antarctic to subtropical waters. Their wintering areas include waters off South America, South Africa, Australia and New Zealand (Environment Australia 2001). There is no evidence that south western Australia is an important area for this bird, but it is considered likely to occur in the marine and coastal parts of the Proposal area as an infrequent visitor. The Proposal area and surrounding areas, including Lake Richmond, is not considered to be critical habitat for this species (Environment Australia 2001) as the species mainly occurs in Antarctic waters and during summer and concentrating north of 50° S in winter. While this species may occur as an infrequent visitor to the area, the potential habitat within and surrounding the Proposal is highly unlikely to be critical to its survival. The Proposal is considered highly unlikely to result in the introduction of invasive species or bird diseases within the marine or coastal zones or increase in trawler fishing that may impact upon this species. As this species is a non-breeding visitor to Australia, breeding only on the Antarctic continent, Peninsula and islands and on sub-Antarctic islands and South America, the Proposal will not disrupt the breeding cycle of this species.
Macronectes halli (northern giant-petrel)	This species may occur in the Proposal are as an infrequent visitor. The Proposal is highly unlikely to result in the decrease in size of the population of these species due to their broad range of existence. The Proposal will not significantly impact on the Northern Giant Petrel's range. The species occurs mainly in sub-Antarctic waters, but also regularly occurs in Antarctic waters of the south western Indian Ocean, the Drake Passage and west of the Antarctic Peninsula. The Northern Giant Petrel range extends into subtropical waters mainly between winter and spring. The home ranges of these species are very large, being estimated at 82 600 000 km^2 for the Northern Giant Petrel. The Proposal does not support critical breeding or feeding habitat for this species and is unlikely to reduce the size of the population of this species and unlikely to fragment the important population of this species, causing the species to decline. The Northern Giant Petrel mainly occurs in sub-Antarctic and Antarctic waters which are outside of the Proposal area. The species breeds on sub-Antarctic islands and South Georgia between 46º and 54º S, which are outside of the Proposal area. This Proposal will not disrupt the breeding cycle of this species. The key threats to the Northern Giant-Petrel is longline fishing which causes the direct loss of seabirds as bycatch and predation by black rats, feral cats and habitat degradation by rabbits. Disease is not a known threat to this species and the Proposal is unlikely to introduce disease to the Proposal area. The Proposal will not interfere with the recovery of the species. The species is likely to be an infrequent visitor to the area as its preferred breeding and feeding habitat occurs outside of the Proposal area. The Proposal is also unlikely to increase any of the key threatening process to this species.
Thalassarche cauta cauta (shy albatross, Tasmanian shy albatross)	The Proposal is unlikely to result in the decrease in size of the population, significantly impact on the range of the Shy Albatross or fragment the population due to their broad range of existence. The species occurs across all Australian coastal covers below 25º S and is most commonly found in south eastern Australia and Tasmania. The home range of this species is also very large, being estimated at 23 900 000 km^2 (BirdLife International 2011). This species occurs across all Australian coastal waters below 25º S, with breeding of the species known to occur on Albatross Island, Bass Strait, Mewstone and Pedra Branca off southern Tasmania. As the breeding site outside of the Proposal area, the Proposal will not disrupt the breeding cycle of this species and is unlikely to impact habitat to the extent that the species is likely to decline. This Proposal will not interfere with the recovery of this species as it preferred habitat is located outside of the Proposal area. In addition, the Proposal will not introduce any new or exacerbate any key threatening processes to this species.

Species	Potential Impact
Haliaeetus leucogaster (white-bellied sea-eagle)	The Proposal is unlikely to result in a significant impact to the White Bellied Sea Eagle as a result of clearing and edge effects associated with the Proposal. This species is known to inhabit coastal areas, with nests placed on high ground rock pinnacles and within wetland habitat of Lake Richmond (ENV 2011a). The Proposal however, will not impact rocky coastal habitat, as only a small section of the Mangles Bay shore line will be cleared with rocky areas associated with Cape Peron and the SIMP not impacted by the Proposal. The Proposal will not clear potential foraging habitat at Lake Richmond, as clearing will be confined to the Proposal area itself, 200 m northwest of Lake Richmond. Significant impact to this species will not occur as the potential habitat surrounding the Proposal area of the White bellied Sea Eagle will not be significantly impacted therefore not resulting in decline of the species or fragmentation of its potential habitat.
Apus pacificus (fork-tailed swift)	The Proposal is unlikely to result in a significant impact to the Fork-tailed Swift as the bird rarely lands and its' occurrence is likely to be spasmodic within the Proposal area.
Actitis hypoleucos (common sandpiper)	The Proposal is unlikely to result in a significant impact to the 19 species of migratory bird as a result of clearing and edge effects associated with the Proposal. Important habitat for migratory shorebirds is defined in the *Draft EPBC Act Policy Statement 3.21 Significant Impact Guidelines for 36 Migratory Shorebird Species* (2009), as: • an internationally important habitat for migratory bird species or • supports at least 0.1% of the flyaway population of a single species or • supports at least 2000 migratory shorebirds or • supports at least 15 shorebird species. The Proposal will therefore not result in a significant impact to this species as the Proposal area does not support important habitat for these migratory species. Whilst more than 15 shorebird species have been identified as occurring within the Proposal area (ENV 2011a) the Proposal will not result in a significant impact as: • there is widespread shoreline habitat outside the Proposal area • the small section of shoreline within the Proposal area is highly impacted by access (4WD and boating) • important habitat (Lake Richmond) in close proximity to the Proposal area will not be impacted.
Limosa limosa (black-tailed godwit)	
Limosa lapponica (bar-tailed godwit)	
Numenius phaeopus (whimbrel)	
Numenius madagascariensis (eastern curlew)	
Tringa stagnatilis (marsh sandpiper)	
Tringa nebularia (common greenshank)	
Tringa glareola (wood sandpiper)	
Xenus cinereus (terek sandpiper)	
Tringa brevipes (grey-tailed tattler)	
Arenaria interpres (ruddy turnstone)	
Calidris canutus (red knot)	
Calidris tenuirostris (great knot)	
Calidris alba (sanderling)	
Calidris ruficollis (red-necked stint)	
Pluvialis fulva (Pacific golden plover)	
Pluvialis squatarola (grey plover)	
Charadrius mongolus (lesser sand plover	

Species	Potential Impact
Charadrius leschenaultii (greater sand plover)	
Ardea sacra (eastern reef egret)	The Proposal is unlikely to result in a significant impact to the species, as the Eastern Reef Egret is likely to only forage within the shoreline within the Proposal area and there is widespread habitat outside the Proposal area.
Plegadis falcinellus (glossy ibis)	The Proposal is unlikely to result in a significant impact to the species, as the Glossy Ibis is likely to only forage within the dry grassland areas within the Proposal area, and there is widespread habitat occurring outside the Proposal area.
Merops ornatus (rainbow bee-eater)	The Proposal is unlikely to cause a significant impact to the Rainbow Bee-eater. The species was recorded at Lake Richmond, adjacent to the Proposal area. Lake Richmond provides the suitable wetland habitat for this species providing woodland and shrubland foraging habitat for this species. The Rainbow bee-eater is more likely to visit and forage at Lake Richmond, rather than the Proposal area. The Proposal will not clear potential foraging habitat at Lake Richmond, as clearing will be confined to the Proposal area itself, 200 m northwest of Lake Richmond. Therefore no impact to the foraging habitat of this species is to occur and therefore no significant impact to this species from clearing is to occur as the Proposal will not result in species decline or fragment habitat. The Proposal may disrupt the lifecycle of some Rainbow Bee-eaters surrounding the Proposal area if clearing and earthmoving occurs during the September-October breeding season. These potential impacts however are restricted to the Proposal area itself with potential edge effects from construction managed through a CEMP.
Pandion cristatus (eastern osprey)	The Proposal is unlikely to result in a significant impact to the Eastern Osprey. A species nest was recorded within the rocky areas of the Shoalwater Bay, where the small islands and bays of the area provide suitable habitat for this species. The Proposal will not be impacting Shoalwater Bay (approximately 250 m south west of the Proposal area) as clearing will be restricted to the Proposal area. Significant impact to this species will not occur as the potential habitat surrounding the Proposal area of the Eastern Osprey will not be impacted therefore not resulting in decline of the species or fragmentation of its potential habitat.
Falco peregrinus (peregrine falcon)	The Proposal is unlikely to result in a significant impact to the species, as the Peregrine Falcon is likely to only forage within the shoreline within the Proposal area and there is widespread habitat outside the Proposal area.
Reptiles	
Lerista lineata (lined skink)	The Lined Skink persists even in small remnants of native vegetation and may exist in gardens where soils are sandy (Bamford 2005). The Skink is also found in the Port Kennedy Scientific Park (DEC 2010a). The Proposal will remove 34.2 ha of the Skink's preferred Coastal Heath Habitat. However, extensive areas of this habitat will remain adjacent, within the RLRP and at Port Kennedy Scientific Park, approximately 5 km to the south of the site. It is therefore considered that the Proposal will have a minor impact on the Skink. Up to 47 ha of the Coastal Heath habitat is proposed to be rehabilitated in the vicinity of the Proposal area, which will increase the potential habitat for this fauna.
Ctenotus gemmula (jewelled ctenotus)	The species has not been recorded but may possibly reside within the Survey area as suitable habitat exists and is within this species' known distribution (ENV 2011a). The clearing of this area may potentially have a small impact on Jewelled Ctenotus numbers due to the reduction in habitat. The Proposal will involve the removal of up to 1.18 ha of Woodland habitat, however approximately 3 ha of this habitat type will be rehabilitated in areas adjacent to the Proposal area, reducing the net loss of potential habitat for this fauna.
Morelia spilota imbricata (carpet python)	The species occurs in undisturbed remnant bushland near Perth and the Darling Ranges, Yanchep National Park and Garden Island (DEC undated publication). It is considered unlikely that Carpet Pythons from Garden Island would travel to the mainland, unless transported in a vehicle or boat. The clearing of the area may potentially have a small impact on Carpet Python numbers due to the reduction in potential habitat. Up to 54 ha of native vegetation is proposed to be rehabilitated in the vicinity of the Proposal area.
Neelaps calonotos (black-striped snake)	The species has not been recorded but may possibly reside within the Survey area as suitable habitat exists and is within this species' known distribution (ENV 2011a). The clearing of this area may potentially have a small impact on Black-striped snake numbers due to the reduction in habitat. The Proposal will involve the removal of up to 1.18 ha of Woodland habitat, however approximately 3 ha of this habitat type will be rehabilitated in areas adjacent to the Proposal area, reducing the net loss of potential habitat for this fauna.

Species	Potential Impact
Insects	
Synemon gratiosa (GSM)	In response to the DEC recommendations within the latest report findings (Bishop *et al.* 2010) the DSEWPaC significant impact guidelines developed for the Golden Sun moth (*Synemon plana*) will be applied together with the latest DEC conservation advice (DEC 2011b) in determining the significance of impact of vegetation clearing on the GSM. The Proposal will result in GSM habitat loss through direct clearing of up to 30.7 ha of the 76.9 ha of the mapped habitat (Table 22). The total clearing of habitat includes clearing of approximately 6.5 ha of high density habitat (58.5 %), 0.45 ha of medium density (4.3%) and 23.66 ha of low density (42.8%) of GSM habitat. The Proposal includes clearing of an area greater than 0.5 ha within a contiguous GSM habitat of greater than 10 ha. This is considered to represent a significant impact to the GSM (Bishop *et al.* 2010). The potential habitat within the Proposal area is highly fragmented and cut off by unsuitable habitat which includes degraded and/or cleared areas, development and other anthropogenic influences. The Proposal area does not provide a linkage between GSM populations and as such, the habitat and recorded population within the Proposal area is considered to be isolated. The GSM has limited dispersal ability and sites greater than 200 m apart may be considered to be disjunct populations (Bishop *et al.* 2010). The Proposal area and adjacent bushland represents small, isolated and degraded patches of habitat. The bushland within the Mangles Bay area is at least 3 km from the nearest large area of vegetation and is such us not likely to contribute to the overall ecological health of the species. The Proposal may introduce barriers to dispersal however is unlikely to significantly impact upon GSM population due to the existing habitat fragmentation. Regionally, habitat exists within the Port Kennedy Scientific Park (Strategen 2011).

9.4.3 Impacts on short range endemic species

No conservation significant scorpions, millipedes or land snails were found during the surveys, and due to the paucity of SRE species in the area (Subterranean Ecology 2010d), it is considered unlikely that the Proposal will significantly impact SRE populations.

9.4.4 Impacts of vehicle movements and construction activities

Operational and construction phases of the Proposal are predicted to result in increased traffic flow on local roads, particularly with the upgrade of Memorial Drive (Section 19). Vehicle movements have the potential to directly injure or kill fauna through collisions, or disturb fauna through noise and pollution generation. Some loss of fauna on the surrounding roads may occur, however this will be mitigated through use of appropriate signage (speed and occurrence) and landscaping practices (Section 9.6). Movements of construction vehicles and earthmoving machinery within the Proposal area will be managed according to the CEMP (Appendix 1).

Construction activities for the Proposal will require the excavation of trenches onsite for the laying of services such as water, gas and electricity. Trenches may act as a linear barrier to the movement of terrestrial fauna and may entrap individual animals, potentially resulting in injury or death. Construction of trenches will be conducted in accordance to the CEMP (Appendix 1) and will include management as outlined in Section 9.6.

9.4.5 Impacts of predation on terrestrial fauna species

Domestic as well as feral animals (cats, dogs and foxes) may prey on native fauna and be responsible for fauna deaths. There is a risk that increased numbers of domestic animals in the area associated with urban development may result in increased predation of native species.

The Proposal is within part of the RLRP. Domestic animals are generally not permitted in the RLRP, but dogs are allowed to be exercised within defined Dog Exercise Areas at Cape Peron (DEC 2010a). Dog walking is a common activity in the RLRP through cleared areas and the numerous tracks in the areas (DEC 2010a).

Domestic cats can prey on native animals, if not kept inside. The City of Rockingham requires that outside rural areas and specialist premises (e.g. pet shops), no more than two cats over the age of three months may be kept on any property (CoR 2009). It is recommended by the City of Rockingham that all cats are sterilised and kept indoors from dusk until dawn (CoR 2009).

The development will result in an increased number of residents around the RLRP, and hence a likely increase in the number of pets, particularly cats. This increase in the number of residential dwellings may also result in an increase in the fox population due to a greater number of rubbish bins from which to scavenge from (foxes were recorded within the Proposal area by ENV 2011a). Therefore a risk of increased pet predation of native mammals, birds, frogs and reptiles is likely in the area. This risk will be managed where possible through additional signage, access control in rehabilitation areas and raising awareness with purchasers.

In addition to the increase in domestic animals present in the area, the clearing of native vegetation within the Proposal area will reduce the available cover, and thus may increase the risk of predation on native fauna.

9.4.6 Increase in human population

RLRP is currently impacted by human activities, including (DEC 2010a):

- uncontrolled vehicular access
- vandalism and anti-social behaviour (graffiti; burn-outs; damaged pagodas etc.)
- unauthorised rubbish dumping
- uncontrolled pedestrian and dog access.

These activities can result in habitat degradation, through removal or damage of native vegetation, introduction of weeds and creating situations in which weed species can thrive. Uncontrolled vehicular access and anti-social behaviour may also result in animal deaths. Much of the existing habitat is considered to be ‘degraded’ because of such activities (ENV 2010).

Development will result in an increased human population in the area by 1500 to 2000 residents, which is likely to result in increased pedestrian and bicycle movements in the RLRP. The Proposal will result in passive surveillance of parkland areas, in line with the *Liveable Neighbourhoods* Policy (WAPC and DPI 2009). *Liveable Neighbourhoods* requires that parks are overlooked by neighbouring houses to limit anti-social activities (WAPC and DPI 2009). Passive surveillance of bushland may reduce the potential for activities such as uncontrolled vehicle access and rubbish dumping, which are likely to be noticed by adjacent residents.

Rehabilitation areas will be monitored on a regular basis and fenced where required to restrict access.

9.4.7 Impacts from groundwater quality and quantity

The change in groundwater saltwater interface and groundwater levels is minimal and is considered unlikely to impact upon terrestrial fauna as:

- the salinity of Lake Richmond will not be impacted
- vegetation outside the area to be cleared is not expected to be impacted (Section 8.4).

The impact of the Proposal on surface water levels and quality is also expected to be minimal (Section 7.4) and therefore fauna utilising Lake Richmond and the Lake Richmond Outlet Drain are not expected to be impacted by the Proposal.

9.5 Potential for and nature of any cumulative impacts

Clearing of fauna habitat within the Proposal area, will further increase the fragmentation of fauna habitat within the Proposal area. Disruption of fauna linkages may result in an isolation and subsequent decline of the fauna population at Cape Peron (particularly less mobile species). Cumulative impact of this fragmentation will be substantially offset by the proposed rehabilitation of remnant vegetation in the vicinity of the Proposal area (Section 9.6).

The region surrounding the Proposal has been heavily urbanised, with only small patches of remnant vegetation scatted throughout areas of development. Although the removal of vegetation from the Proposal area will further reduce regional remnant vegetation, only a relatively small proportion of each habitat type will be cleared.

Clearing associated with this Proposal is not considered likely to have a significant cumulative impact on the regional habitat, especially when proposed rehabilitation activities are taken into account.

9.6 Management measures and performance standards

The following management measures will be implemented to minimise the impact of both the construction and operation phases of the Proposal on fauna:

- clearing within authorised areas only
- relocating mammals, reptiles and amphibians prior to clearing where practicable
- conducting clearing in stages to allow for the movement of any remaining fauna
- limiting noise and vibration that may disturb fauna during construction
- restricting the time and length excavated trenches are opened/exposed
- preventing vehicle access outside authorised areas during construction, and limiting vehicle speeds inside the construction area
- providing suitable areas as conservation offsets
- rehabilitating habitat areas in the vicinity of the Proposal area
- landscaping median strips of Memorial Drive and verges of Safety Bay Road.

A Fauna Management Plan will be developed as part of the CEMP (Appendix 1), to implement the required management measures associated with the construction and operational activities of the Proposal.

9.7 Predicted environmental outcomes against environmental objectives, policies, guidelines, standards and procedures

After application of mitigation measures described in Section 9.6, the Proposal is expected to result in the following impacts on terrestrial fauna:

1. Loss of 38.28 ha of habitat, of which 35.2 ha is coastal heathland, 0.9 ha is shoreline and 2.18 ha is woodland.
2. A reduction in potential Quenda habitat within the Proposal area due to clearing of coastal heathland.
3. Improvement in habitat condition through rehabilitation of existing coastal heath and woodland and coastal heath habitat outside the Proposal area.
4. A small reduction in numbers of Perth Lined Skink, Jewelled Ctenotus and Carpet Python.
5. Unlikely to have any impact on SRE terrestrial invertebrate fauna.
6. Reduction in area of available GSM habitat through clearing of up to 3.06 ha of habitat.
7. The Proposal area and adjacent bushland represents small, isolated and degraded patches of habitat. The bushland within the Mangles Bay area is at least 3 km from the nearest large area of vegetation and is such us not likely to contribute to the overall ecological health of the species. The Proposal may introduce barriers to dispersal, but is unlikely to significantly impact upon GSM population due to the existing habitat fragmentation.
8. The Proposal is not expected to result in a significant impact to migratory species as the Proposal area does not support important habitat for migratory species.
9. The Proposal will not result in a significant impact to the potential black cockatoo (Carnaby's and Forest Red-Tailed) habitat or the population of black cockatoo species that may potentially occur. This is due to the lack of habitat currently available for these species and potential impacts from the Proposal from direct clearing.

Overall, there are likely to be some local reductions in fauna populations within the Proposal boundary; but the Proposal is unlikely to significantly affect the regional diversity or abundance as the habitats are well distributed locally and regionally.

Potential impacts will be managed through implementation of the Fauna Management Plan within the CEMP (Appendix 1). The Proposal will not conflict with the WC Act, as no species will cease to exist as a result of the Proposal.

10. Marine water and sediment quality impact assessment

10.1 Relevant environmental objectives, policies, guidelines, standards and procedures

10.1.1 EPA objectives

The EPA environmental objectives for marine water quality and sediment quality are:

To maintain the integrity, ecological functions and environmental values of the seabed and coast.

To ensure that emissions do not adversely affect environmental values or the health, welfare and amenity of people and land use by meeting statutory requirements and acceptable standards.

10.1.2 Legislation, policy and guidance

State environmental policy (Cockburn Sound)

The *State Environmental (Cockburn Sound) Policy 2005* (Cockburn Sound SEP) establishes the framework within which Cockburn Sound and the adjacent land (the Cockburn Sound catchment) are managed to protect environmental quality in Cockburn Sound. The Cockburn Sound SEP establishes a risk-based approach to environmental management, which is underpinned by Environmental Values (EVs) and spatially defined Environmental Quality Objectives (EQOs) (Government of Western Australia 2005b), shown in Table 26. The CSMC has the responsibility for managing the environmental quality of Cockburn Sound.

Table 26 Environmental quality values and environmental quality objectives for Cockburn Sound

Environmental values	Environmental quality objectives
Ecosystem health	Maintenance of ecosystem integrity in terms of structure (such as biodiversity, biomass and abundance of biota) and function (such as food chains and nutrient cycles).
Seafood safe for eating	Maintenance of aquatic life for human consumption, such that seafood is safe for human consumption when collected or grown.
Aquaculture	Maintenance of aquaculture, such that water is of a suitable quality for aquaculture purposes.
Recreation and aesthetics	Maintenance of primary contact recreation values, such that primary contact recreation (e.g. swimming) is safe. Maintenance of secondary contact recreation values, such that secondary contact recreation (e.g. boating) is safe. Maintenance of aesthetic values, such that the aesthetic values are protected.
Industrial water supply	Maintenance of industrial water supply values, such that water is of suitable quality for industrial water supply purposes.

Environmental Quality Criteria (EQC) have been specifically developed for Cockburn Sound to provide the quantitative benchmarks for measuring success in achieving the EQOs set in the SEP (Government of Western Australia 2005b). EQCs are defined below:

1. Environmental Quality Guidelines (EQGs): threshold numerical values that, if met, indicate a high degree of certainty that the associated EQO has been achieved. If the EQG is exceeded it triggers a more detailed assessment process against an environmental quality standard to provide more certainty about whether the EQO is likely to be met or not.
2. Environmental Quality Standards (EQSs): threshold numerical values that, if met, indicate the EQO is likely to be achieved. If the EQS is exceeded, it indicates a significant risk that the associated EQO has not been achieved, and a management response is triggered.

The ecological EV of ecosystem health has different EQC for zones of high, moderate and low ecological protection. The area of Mangles Bay adjacent to the Proposal area lies within the area zoned for high ecological protection. The social EVs (Seafood Safe for Eating, Aquaculture, Recreation and Aesthetics, and Industrial Water Supply) have the same EQC applied throughout Cockburn Sound. The SEP has EQC for both water quality and sediment quality for the EV of Ecosystem Health and water quality EQC for the social EVs.

The operational effects of the Proposal on the marine waters of Cockburn Sound will need be assessed in terms of EQC for key water quality and sediment quality indicators for the EVs of Cockburn Sound, particularly Ecosystem Health (such as nutrient-related water quality, contaminants), and Recreation and Aesthetics (such as water clarity, faecal bacteria). Some temporary effects associated with construction (turbidity, contaminant release during dredging and disposal) will need be managed and monitored differently (although still using the same indicators), as they are likely to take place outside the summer monitoring season targeted by the Cockburn Sound SEP (outlined in Section 10.2.2).

The waters within the marina are an artificial inland waterway, and therefore not expected to be zoned for ecological protection under the SEP (the area is presently land and has no marine ecological value). It is, however, anticipated that the marine waters offshore of the existing shoreline that will be bounded by the proposal breakwaters (an area about 50 m by 180 m; refer Figure 7) will be zoned for moderate ecological protection under the SEP, and relevant EVs and EQOs will apply. The objective for marina waters entering the high ecological protection area of Mangles Bay will be to ensure that the relevant EVs and EQOs are not compromised. Water quality within the marina comes under WA Planning Commission (WAPC) Policy Number DC1.8 which provides Guidelines for approval of canal estates and other artificial waterway developments.

WAPC Policy Number DC1.8

WAPC Policy Number DC1.8 provides general guidelines that apply to artificial waterways and to their adjacent natural waters and/or source water. If the source water does not meet these requirements, a canal estate proposal for that location is considered inappropriate. General guidelines for water quality are:

1. Stormwater runoff or drainage to artificial waterways, particularly from vegetated or vehicle use areas, is a potential source of nutrient or contaminant input to artificial waterways and adjacent source waters. Developments must include appropriate design features and management strategies to minimise any inputs to an artificial waterway which may adversely affect water quality.
2. Water quality within artificial waterways must be such that the following beneficial uses should not be adversely affected:
    - occasional human immersion and wading
    - boating
    - adjacent development
    - passive recreation (which can be affected by odour, insects, rubbish).
3. A canal estate should not be permitted where the source water has a beneficial use or water quality that is a lower standard than the beneficial uses identified above.
4. The presence of one or several canal estates should not be permitted to measurably reduce the quality of the natural water body.
5. An artificial waterway should not have an unacceptable impact on the passage of fauna in the natural water body.
6. No industrial or residential waste or effluent of any nature (including air conditioner bleed off) should be discharged directly or indirectly into artificial waterways.
7. Parameters regarded as being significant for assessing water quality are: suspended solids, chemical constituents, pH, DO, bacteriological counts, nutrients and contaminants (particularly hydrocarbons). Other factors, such as salinity or biota may be significant in some instances.

8. It is apparent that boat toilets which can discharge into the waters are not compatible with artificial waterway uses. Action to prohibit this form of discharge will be necessary. Pump out or toilet facilities at service sites may therefore be required in each artificial waterway project.
9. The maintenance of artificial waterway water quality should be largely dependent on natural processes.

WAPC Policy Number. DC1.8 also provides general aesthetic guidelines that are desirable for waters within and adjacent to an artificial waterway development. These require that waters should be:

- free from substances which will settle to form putrescent or otherwise objectionable sludge deposits
- free from floating debris, oil, grease, scum, foam and other floating materials in amounts sufficient to be unsightly or otherwise objectionable
- free from materials which will produce colour, odour, turbidity, or other conditions to such a degree as to be unsightly or otherwise objectionable.

National Health and Medical Research Council Guidelines

The aim of the NHMRC Guidelines for Managing Risks in Recreational Water (NHMRC 2008) is to protect the health of the public from threats posed by the recreational use of coastal, estuarine and fresh waters. The guidelines cover risks due to physical hazards (rips, sandbars, breaking waves); sun, heat and cold; microbial water quality (faecal contamination); cyanobacteria and algae; dangerous aquatic organisms (such as stingers and sharks); chemical hazards (such as industrial outfalls and fuel spills); and aesthetics (such as transparency, surface scums, litter, odour and noise).

The guidelines are not mandatory, but are a tool to be used by State and Territory Governments to assist in developing legislation, policy and standards appropriate for local conditions. These guidelines therefore support the Cockburn Sound SEP and WAPC Policy NumberDC1.8, with a focus on microbial water quality (faecal contamination); cyanobacteria and algae; chemical hazards; and aesthetics.

Contaminated Sites Act 2003

The Proposal will involve the dredging of sediments in Mangles Bay to create the marina access channel. These sediments may contain contaminants from past or present boating activities. Marine sediment contamination in state waters (as well as contamination in terrestrial soils) is addressed under the *Contaminated Sites Act 2003* (CS Act). Relevant guidance on contaminated sites investigations is provided in the DEC Contaminated Sites Management Series (CSMS) (DEC 2010b), but sampling requirements for marine sediments are also typically guided by the National Assessment Guidelines for Dredging (NAGD).

The CSMS was developed to provide guidance for risk assessments prior to activities governed under the CS Act. Land disposal of dredged material is not dealt with specifically in the guidelines but falls under the CS Act for 'created land', and potential human and environmental impacts must be subject to a risk assessment.

Ecological Investigation Levels (EILs) and Health Investigation Levels (HILs) for soil, defined in the CSMS 'Assessment Levels for Soil, Sediment and Water' (DEC 2010b), are used as an initial screening assessment to determine whether there is potential risk to the environment. Contaminated soils disposed to land can pose a risk to human health through direct exposure (such as ingestion and inhalation) or indirect exposure (such as through groundwater contamination). HILs classified as 'D' (residential with minimal opportunities for soil access: includes dwellings with fully or permanently paved yard space such as high-rise apartments and flats), 'E' (parks, recreational open space and playing fields, includes secondary schools) and 'F' (commercial/industrial, includes premises such as shops and offices as well as factories and industrial sites) are typically deemed the most appropriate to use when spoil material is used in a development.

National Assessment Guidelines for Dredging (NAGD)

Although sea dumping of dredged material is not planned as part of the Proposal, the NAGD (Commonwealth of Australia 2009) provide a reference for the assessment and management of dredging operations, i.e. the potential impacts on the receiving marine environment from the disturbance of the sediment and the sediment metals, nutrients and hydrocarbons. The NAGD criteria for sediment quality are based on the national environmental quality criteria for sediments (ANZECC/ARMCANZ 2000).

Shoalwater Islands Marine Park Management Plan

SIMP borders Mangles Bay at the Garden Island Causeway (Figure 57). The SIMP covers an area of approximately 6545 hectares and contains the waters of Shoalwater Bay, Warnbro Sound and a part of Cockburn Sound off Cape Peron. The SIMP is vested to the MPRA, and managed by the DEC, apart from recreational fishing which is managed by the DoF in close cooperation with DEC. The Shoalwater Islands (i.e. the terrestrial portion) are managed under the 1992 Shoalwater Islands Management Plan.

The SIMP Management Plan 2007–2017 (the management plan) was formally approved by the Minister for the Environment in August 2007 (DEC 2007). The management plan sets out a zoning scheme and a ‘best practice’ model for managing the identified ecological and social values of the SIMP. Under the zoning scheme the areas to the north of Cape Peron (to the west of the Causeway) are within a ‘General Use Zone’. Shoalwater Bay (on the southern side of Cape Peron) is a recommended ‘Special Purpose Zone’ for wildlife conservation, and further south are two sanctuary zones (at Second Rock and Becher Point), and a ‘Special Purpose Zone’ for scientific reference at Murray Reef.

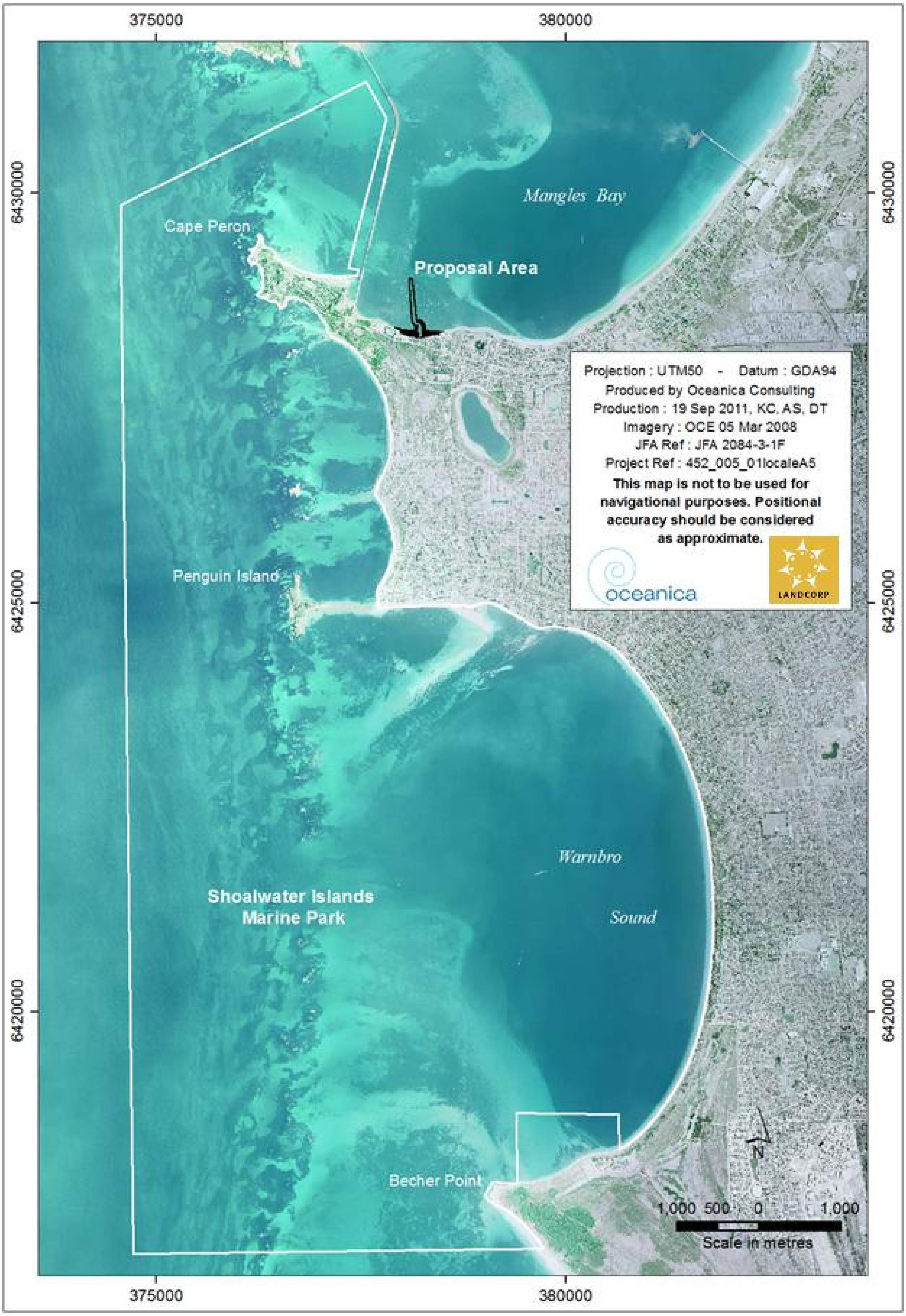
Each ecological and social value for the SIMP has identified management objectives, strategies, performance measures and targets to achieve. The management objective for marine water and sediment quality is:

To ensure the water and sediment quality of the marine park is not significantly impacted by future human activities.

The management plan places a high priority on maintaining a high level of water and sediment quality, and performance measures for marine water quality (DEC 2007) include:

- nutrients (chlorophyll a and inorganic nitrogen concentration in seawater)
- toxicant concentrations in seawater
- pathogens (faecal coliform concentrations in seawater)
- litter (mass [kg] of litter at selected monitoring sites).

Short-term targets will be developed as required, while long-term targets include maintaining water quality at the present level, except for designated areas where a different level of acceptable change is approved by the appropriate Government regulatory authority (DEC 2007). The SIMP is presently characterised by high water quality, with sites monitored in Warnbro Sound providing the reference data used to generate nutrient related water quality criteria for Cockburn Sound.



STRATEGEN

Mangles Bay Marina Based Tourist Precinct

Shoalwater Islands Marine Park

Figure 57

strategen
Oct-2011

10.2 Findings of surveys and investigations

10.2.1 Historical water quality in Cockburn Sound

Cockburn Sound

Water quality is one of the two primary marine environmental issues relevant to the Proposal identified in the EPA's Bulletin 1237 in its strategic advice to the Minister for the Environment, under section 16(e) of the EP Act (EPA 2006b). The water quality of Cockburn Sound is due, in part, to its enclosed nature (by Parmelia Bank to the north, Garden Island to the west, and the Garden Island Causeway to the south), which reduces exchange (flushing) with the water of Owen Anchorage to the north and the open ocean to the west and south. Flushing times affect the dilution of nutrient and contaminant inputs, and in turn affect a variety of ecological processes (such as plant growth rates and toxicity responses) that depend on the concentrations of these substances.

The first comprehensive environmental study of Cockburn Sound between 1976 and 1979 (the Cockburn Sound Environmental Study, DCE 1979) identified a large variety of contaminants in industrial discharges entering Cockburn Sound (CSMC 2006). The study recorded deterioration of water quality and widespread loss of seagrass on the eastern margin of Cockburn Sound, largely attributed to shading caused by nutrient-stimulated growth of epiphytes and phytoplankton. Industry in the area responded by reducing contaminant and nutrient discharges (particularly nitrogen). As a result, the water quality in Cockburn Sound improved by the early 1980s (CSMC 2006).

Nutrient-related water quality depends mainly on two factors:

- nitrogen inputs to the area (nitrogen is the main nutrient determining marine plant growth in Perth's coastal waters)
- how well the area is flushed with marine water.

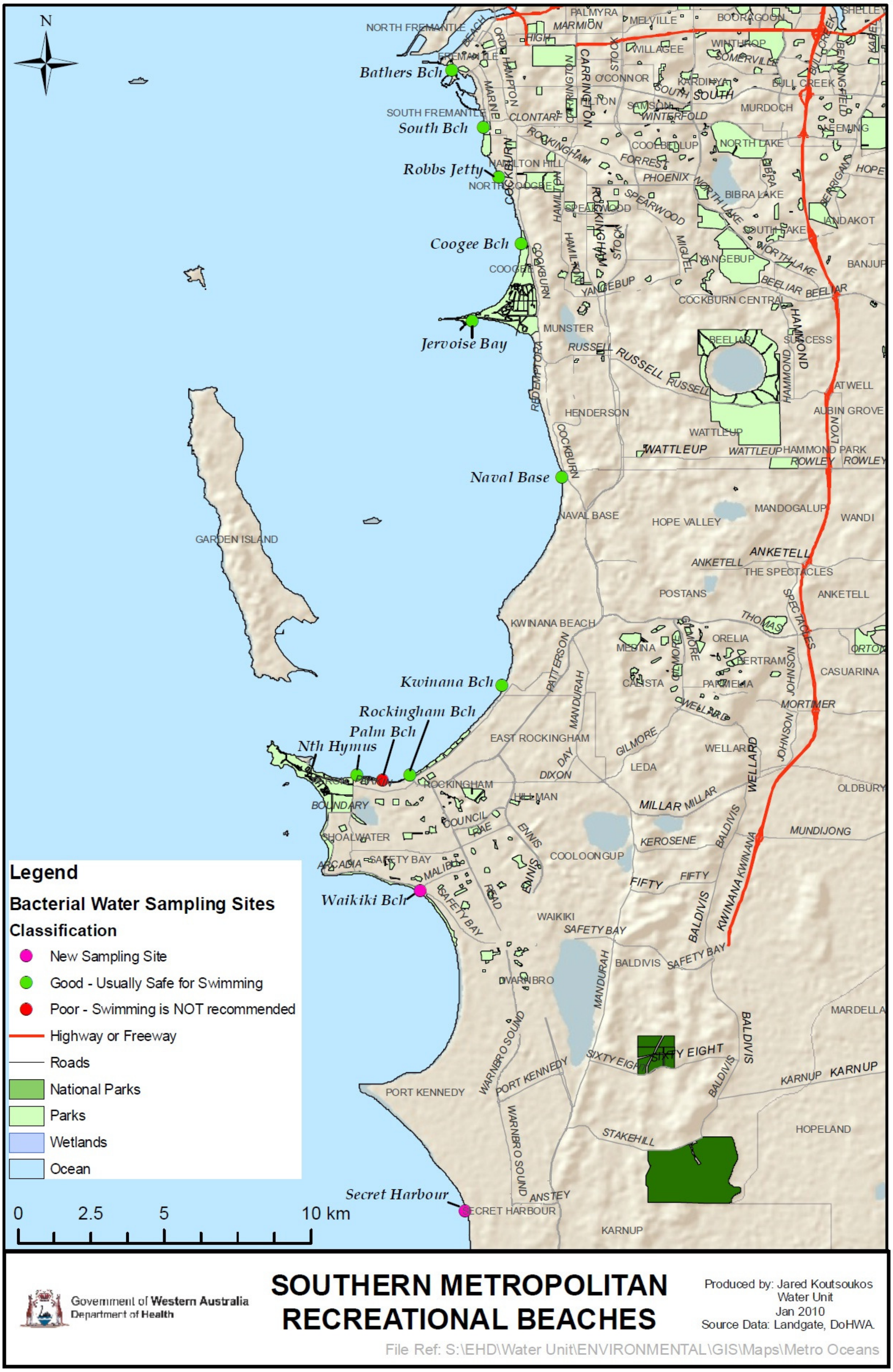
By the late 1980s, nutrient related water quality had declined again, which triggered the second comprehensive study from 1991 – 1994 (the Southern Metropolitan Coastal Waters Study, DEP 1996). This study found that nutrient-related water quality was only slightly better than in the late 1970s, with nutrient-rich groundwater from industrial sites (mainly Kwinana and Jervoise Bay) replacing direct industrial pipeline discharge as the main nutrient input to Cockburn Sound. The EPA subsequently provided Strategic Environmental Advice on the Marine Environment of Cockburn Sound in Bulletin 907 (EPA 1998), which included:

- the environmental issues that needed to be addressed through coordinated management action, including the reduction in sources of wastes from point sources and groundwater
- the need for a statutory management structure to coordinate management in Perth's coastal waters, especially Cockburn Sound and its catchment (which led to the formation of the CSMC)
- the EPA's statement of advice on long-term harbour scenarios (including the Mangles Bay marina), infrastructure issues (e.g. the Causeway, and shipping channels) and seagrass.

Subsequent management reduced groundwater nutrient inputs, and it was estimated that nutrient inputs from human activities had declined from an estimated 2000 tonnes/year in 1978 to about 300 tonnes/year in 2000, with 70% from groundwater (CSMC 2005).

Nutrient related water quality has been monitored in Cockburn Sound since 1977 by means of summer surveys (CSMC 2005). Nutrient concentrations in Cockburn Sound have reduced significantly since the late 1970s, as have chlorophyll-'a concentrations – a measure of the amount of phytoplankton growth that is fuelled by the available nutrient supply. Recent data indicate further significant decreases in chlorophyll-a concentrations for the years 2005 to 2010, compared with the 1990s and early 2000s (Wienczugow *et al.* 2010). Water quality monitoring remains the focus of management attention today due to the large number of multiple uses in Cockburn Sound. The CSMC coordinates water quality monitoring of Cockburn Sound, with a focus on nutrient related effects, especially chlorophyll-a levels. Water clarity (measured as light attenuation) is also measured, as it is affected by phytoplankton levels. The CSMCs water quality surveys involve weekly measurements from December to March inclusive, as required under the Cockburn Sound SEP, which targets the period unaffected by river flow and the most likely to show effects due to nutrient enrichment (EPA 2005a).

The Department of Health and the City of Rockingham also undertake fortnightly surveys of indicators of faecal contamination (measured as enterococci levels, in colony forming units per 100 ml) at popular beaches in the main bathing season (October to April) to ensure that waters are safe for recreation. The levels in Cockburn Sound are generally safe for recreational use (Figure 58), but exceedances of recreational guidelines (NHMRC 2008, also used as EQG under the Cockburn Sound SEP) occur in some areas of the Rockingham foreshore, especially after rainfall stormwater discharge into Cockburn Sound (Strategen 2006).



STRATEGEN

Mangles Bay Marina Based Tourist Precinct

Department of Health recreational beach classification: bacterial water

Figure 58

strategen Oct-2011

Flushing of waters in Cockburn Sound

Current speeds and circulation patterns (determined by wind and horizontal pressure gradients) determine the flushing of Cockburn Sound. Horizontal pressure gradients are the result of differences in water pressure between two areas, and may be grouped into those driven by:

- wind, tides, waves, seiches and atmospheric pressure (which cause differences in water level between areas)
- horizontal differences in water density (cold, salty water is denser than warm, freshwater).

Waves and currents in Cockburn Sound are primarily wind-generated. Wind is also the main driving mechanism of circulation within the Sound when the wind speed is above 5 metres/second. During calm periods (wind speed <5 m/s), circulation becomes complex and is driven by a combination of wind and horizontal pressure gradients.

Three distinct hydrodynamic regimes have been identified in Cockburn Sound based on the relative importance of wind and pressure gradients in determining circulation patterns and flushing: 'summer', 'autumn' and 'winter-spring' (DEP 1996). The key characteristics of the three seasons are as follows:

- summer: during summer, winds are the most important factor controlling hydrodynamics. Circulation is wind-driven and the waters within both the Sound and adjacent waters are vertically well mixed (and therefore well oxygenated)
- autumn: during autumn the wind subsides and pressure gradients determine the circulation. The waters in Cockburn Sound are of greater density (cooler and more salty) compared to adjacent water due to evaporation that has occurred during the summer and rapid cooling during autumn. The gradient between the denser waters of Cockburn Sound and the lighter adjacent water controls the flushing of Cockburn Sound to the greatest extent. Stratification (distinct vertical layering of water) also occurs due to movement of lighter water into Cockburn Sound. Flushing of the bottom waters of Cockburn Sound during autumn depends on wind events that vertically mix the whole water column (generally requiring wind speeds >5 m/s for 2-3 days or more), followed by re-establishment of density gradients. Such wind events are rare in autumn, and so the deep basin waters of Cockburn Sound are poorly flushed in autumn
- winter-spring: circulation is primarily driven by pressure gradients, punctuated by periods of wind-driven circulation due to storm activity. The waters within the Cockburn Sound become progressively lighter than waters further offshore due to the relative lowering of salinity by freshwater inflow, particularly from rivers. The relatively rapid response of the shallow waters of Cockburn Sound (compared to offshore waters) to heating as spring progresses also contributes to the relative decrease in density. Denser water moves into the lower depths of Cockburn Sound during calm periods (wind speeds typically < 5 m/s), and stratification persists until broken down by the passage of winter low pressure systems about every 7-10 days (D'Adamo & Mills 1995).

There are many ways to measure the time over which Cockburn Sound is flushed. To be consistent with previous modelling of Cockburn Sound (DEP 1996) the e-folding time is used here, which estimates the time taken for 63% of Cockburn Sound to be flushed. The e-folding time for Cockburn Sound is roughly one month: 37 days in autumn, 22 days in winter and 44 days in summer (highest in summer because the prevailing winds set up circulation gyres that tend to confine water within Cockburn Sound). These are flushing times for Cockburn Sound as a whole: flushing times for localised areas within Cockburn Sound are much less (about a day along the eastern margins of Cockburn Sound).

Nutrient inputs to Cockburn Sound

Approximately 300 tonnes/year of nitrogen enter Cockburn Sound from industrial outfalls, groundwater discharge, surface drainage (stormwater runoff) and the atmosphere. Of these, groundwater discharge is the largest contributor (about 75%) (DAL & PPK 2001).

The cycling of nutrients between sediments and the water column also plays an important role in determining water quality, particularly under conditions of low oxygen. The waters of the Sound are generally well oxygenated, although if calm weather persists for more than a week (which occurs most often in autumn), the deep waters at the southern end of Cockburn Sound may become low in oxygen. This is due to stratification and bacteria in the organic-rich sediments that use up oxygen faster than that supplied by diffusion down the water column. Oxygen levels in the bottom waters sometimes become so low that the release of nutrients from sediments to the water column increases.

Water movement plays a major role in determining sediment characteristics (including nutrient cycling) within Cockburn Sound. In calmer and/or deeper areas the sediments tend to be finer and siltier, while shallower/more exposed areas experience more wave and current action and so have sandier sediments (the finer particles are easily suspended and swept away). Calmer/deeper areas accumulate fine organic particles (such as dead plankton and faecal material), and so are more organically enriched than shallower/more exposed areas. Contaminants discharged to marine environments (and any increased production of organic matter due to a nutrient enrichment) typically accumulate in the sediments, especially in sheltered, relatively deep areas.

Mangles Bay

Mangles Bay is sheltered by the Garden Island Causeway and Cape Peron, and is therefore relatively calm and poorly flushed by marine waters under most circumstances, but is exposed to storms from the north (Strategen 2006). Chlorophyll-a levels in Mangles Bay are generally higher than most other sites in Cockburn Sound: this is believed to be largely due to the reduction in flushing of the area by the construction of the Garden Island Causeway in 1971–73, although the area would have been naturally calm and sheltered before this time.

Nutrient inputs

Nutrient inputs to Mangles Bay are from groundwater discharge (occurring all year round but largely in late winter, in response to rainfall recharge; refer Section 6.2.4) and stormwater drainage (occurring mainly in winter and early spring; refer Section 7.2.2). Appleyard (1994) has estimated groundwater discharge to the Mangles Bay area to be 53 Megalitres/year/km, and to contribute between 0.048 to 0.573 tonnes nitrogen/year/km along the 4 km of coast east of the Garden Island Causeway. The nitrogen is largely in dissolved inorganic forms readily available for aquatic plant growth (ammonia and nitrate). The variation in estimated loads is due to the variation in groundwater flows and nitrogen concentrations in groundwater bores in the region. More recent estimates by ERM (2011) indicate annual dissolved inorganic nitrogen (DIN) loads of 0.11 tonnes for a shoreline length of about 700 m, based on APASA's (Asia Pacific Applied Science Associates) model boundary. This value equates to 0.16 tonnes DIN/year/km entering the shoreline adjacent to the Proposal area. Little groundwater discharge is expected west of the Causeway, as the groundwater flow path to Mangles Bay or Shoalwater Bay is much shorter (Strategen 2006).

There are seven stormwater drains entering Mangles Bay (DoW 2007). The largest stormwater flow is from the Lake Richmond drain (R. Mort, City of Rockingham, pers. comm.), comprising overflow from Lake Richmond, which in turn receives surface water inputs from large urban catchments to the east, south and west of the lake (e.g. refer Figure 109 and Figure 110). There is little data for volumes of stormwater outflow from the drains, but outflow from Lake Richmond drain was measured between 1978 and 1986 and found to be highly variable, averaging 2,270 ML/year (DMH 1992). Based on water quality data for stormwater, DMH (1992) estimated the Lake Richmond drain contributed 0.25–8.3 tonnes/year TN, 32 kg/year copper, 98 kg/year lead and 104 kg/year zinc. More recent estimates indicate a lesser load of 0.122 tonnes nitrogen/year in the three months of winter 2002 (Water and Rivers Commission, cited Natural Resource Management Office, Naragebup Rockingham Regional Environment Centre [Inc.] 2003a), likely due to rainfall in recent years being below the historical long-term average. The Department of Water (DoW 2007) has also estimated nutrient loads from a minor Rockingham drain over approximately seven weeks in winter 2006 (0.416 ML of discharge) as 0.0018 tonnes TN, 0.003 tonnes TP, 0.029 kg copper and 0.108 kg zinc (lead concentrations were too low to estimate). These data indicate that even allowing for disparity in monitoring periods - the contribution from minor drains entering Mangles Bay is likely to be one to two orders of magnitude lower than from the Lake Richmond drain.

Water quality data for Lake Richmond drain and the minor drains (Table 27) also suggest that in years of low to average rainfall the major input of nitrogen to Mangles Bay is from groundwater. The importance of groundwater inputs is also due to the fact that discharge occurs all year round (albeit at reduced levels in summer and autumn compared to winter and spring), and nitrogen is largely in the dissolved inorganic forms readily available for aquatic plant uptake. Stormwater flows mainly in the winter months, with the majority of nitrogen present as organic nitrogen, and not as readily available for plant uptake. The stormwater quality data in Table 27 are consistent with more recent data (September 2010) for water quality in the Lake Richmond stormwater outlet (refer MWH 2011d), which found total nitrogen concentrations 0.75 mg/L, total phosphorus concentrations of 0.03 mg/L and low levels of dissolved inorganic nutrients, and metals.

Table 27 Concentrations of contaminants in stormwater draining into Mangles Bay

Statement of Planning Policy 2.8 requirement	Lake Richmond Drain 2002, 2003*	Lake Richmond Drain 2004, 2005***	Minor drains, 2005**	Minor drains, 2005***
Total nitrogen	0.65–1.00 mg/L	0.506 mg/L	0.400–0.780 mg/L	0.150–0.586 mg/L
Kjeldahl nitrogen (organic nitrogen)	> 90% of total nitrogen	0.44 mg/L	53–85% of total nitrogen	0.124–0.390 mg/L
Nitrate-plus-nitrite	0.012–0.043 mg/L	0.064 mg/L	0.100–0.380 mg/L	0.028–0.200 mg/L
Ammonium	No data	0.068 mg/L	0.093–0.110 mg/L	0.038–0.102 mg/L
Total phosphorus	0.012–0.200 mg/L	0.016 mg/L	0.051–0.800	0.038–0.110 mg/L
Orthophosphate	0.005–0.028 mg/L	0.01 mg/L	0.036–0.047	0.021–0.057 mg/L
Total suspended solids	No data	~30 mg/L	3–8 mg/L	~30 mg/L
Copper	0.001 mg/L	<0.005 mg/L	0.006 mg/L	0.006–0.012 mg/L
Lead	0.001 mg/L	<0.010 mg/L	0.010 mg/L	<0.010 mg/L
Zinc	0.016– 0.062 mg/L	0.007 mg/L	0.021 mg/L	0.029–0.042 mg/L

* Natural Resource Management Office, Naragebup Rockingham Regional Environment Centre (Inc.) (2003a, b) for routine monitoring in winter 2002 and winter2003.
** Snapshot survey data provided courtesy of D. Mort, City of Rockingham, for Bell Park and Hymus St drains for winter 2005.
***DoW 2007 for monitoring of stormwater quality entering Perth beaches in winter 2004 and winter 2005 (site RMD = Lake Richmond Drain, and site ROC12, ROC14 and ROC16 = minor drains)

Contaminant inputs

Studies for the Proposal have found low concentrations of metals in groundwater (MWH 2011a), suggesting that in relative terms (i.e. compared to groundwater) stormwater contributes more of these contaminants to Mangles Bay than previously thought. There are no data for hydrocarbons in groundwater, and although these types of contaminants are more common in road runoff, the Department of Water's study of stormwater quality discharging at Perth beaches (DoW 2007) found hydrocarbon levels below laboratory detection limits in stormwater discharging at Rockingham beaches, so it is also unlikely that stormwater is a significant source. Nor do there appear to be significant amounts of herbicides or pesticides entering Mangles Bay from stormwater (Natural Resource Management Office, Naragebup Rockingham Regional Environment Centre [Inc.] 2003a, 2003b). However stormwater drains often discharge high loads of faecal bacteria (from animal and bird faeces), and the DoW (2007) found faecal bacterial concentrations (enterococci) that exceeded secondary contact recreation guidelines in stormwater and the adjacent swash zone of several drains to the west of Hymus Street, although guidelines were met in the stormwater and swash zone of the Lake Richmond Drain. The Cape Peron area west of Hymus St is on septic system, so there is also the possibility that groundwater is carrying faecal bacteria into Mangles Bay from the various leasehold sites.

In addition to groundwater and stormwater inputs of nutrients and contaminants to Mangles Bay, anecdotal evidence of inputs from boats moored in Mangles Bay was provided during the community consultation for this Proposal. These included fuel spills during informal refuelling, illegal sullage disposal and rubbish disposal. There would also be an assumed degree of contaminant input from moored boats and boat clubs.

Whilst places where boats are permanently moored, or there is heavy boating traffic, are generally not major diffuse sources of contamination to water bodies when compared to groundwater and stormwater runoff from industrial, commercial, urban, or agricultural areas, they can be locally significant sources of:

- fuel and oil (spills during refuelling; bilge discharge; stormwater runoff from areas where launching, maintenance and repair of boats takes place)
- copper and tin in antifoulants; aluminium, iron and chromium in the boats themselves; arsenic in pesticides, paint pigments and wood preservatives; zinc in boat anodes, oil and tyres; and mercury in float switches for bilge pumps and, shower water storage tank pumps and air-conditioning/heating thermostats; nickel in brake linings and pavements; cadmium in brake linings and batteries. There is some leaching while the boats are moored, but most metal is dislodged during boat cleaning either directly during 'in-water' cleaning, or indirectly if washing/maintenance occurs onshore and wash water is not directed to appropriate stormwater treatment areas
- solvents such as tetrachloroethane, trichloroethene and trichloroethylene (in degreasing agents, varnishes, paint removers and lacquers) in stormwater runoff from areas where launching, maintenance and repair of boats takes place
- acid from batteries (often also contains containing high levels of lead too) or cleaning compounds
- surfactants (detergents), either directly from 'in-water' cleaning, or indirectly if cleaning occurs onshore and wash water is not directed to appropriate stormwater treatment areas
- sewerage (due to illegal disposal of sullage) and other waste discharges (including fish cleaning waste, debris and litter).

10.2.2 Current nutrient-related water quality

Cockburn Sound 2009/2010, 2010/2011

The most recently available CSMC report on the water quality of Cockburn and Warnbro Sound (December 2009 to March 2010) provides monitoring data for 20 sites (outlined in Figure 59, 18 within Cockburn Sound and 2 within Warnbro Sound) (Wienczugow *et al.* 2010). This report included monitoring at a new site in the shallows of Mangles Bay (site MB) undertaken specifically for the Proposal, to see if water quality in the shallows was similar to that of the CSMC's routine monitoring site in the deep basin of Mangles Bay (site 11). Site MB has subsequently been included in the CSMC's routine monitoring program.

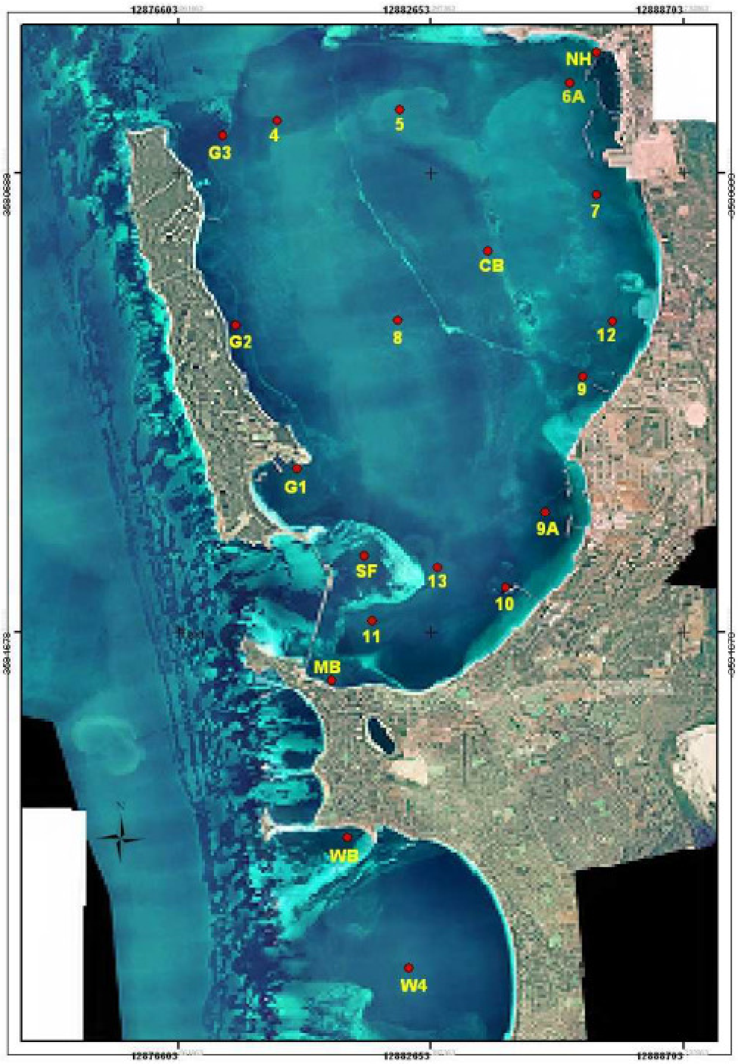


Figure 59 CSMC water quality monitoring sites for 2009/2010.

As noted earlier, Cockburn Sound water quality results for the years 2005 to 2010 showed a significant improvement in chlorophyll-a concentrations compared with the 1990s and early 2000s (Wienczugow *et al.* 2010). Light attenuation also showed some improvement over the last few years, while inorganic nutrient concentrations were similar to those of reference sites in Warnbro Sound (Wienczugow *et al.* 2010). However data for December 2010 to March 2011 (provided courtesy of the CSMC) showed a marked regional increase in chlorophyll-a, potentially related to the 'marine heat wave' recorded in February and March 2011, which saw water temperatures off the majority of the coast of Western Australia rising to unprecedented levels (2–4°C above average) (Pearce et al. 2011).

The data of Wienczugow *et al.* (2010) also illustrate the spatial differences in nutrient and phytoplankton distribution across Cockburn Sound. Higher concentrations of ammonia, nitrate+nitrite and orthophosphate (also known as filterable reactive phosphate) were recorded at sites along the eastern shore than in the centre of Cockburn Sound and Warnbro sound reference sites (although all concentrations were low, close to laboratory detection limits). Phytoplankton biomass (measured as chlorophyll-a concentration) was generally higher at the southern sites (especially along the eastern shore) than in the centre of Cockburn Sound and Warnbro Sound. , evident in the data for 2009/2010 (Wienczugow *et al.* 2010) and 2010/2011 (provided courtesy of the CSMC) in Table 28.

Table 28 Chlorophyll-a concentrations at monitoring sites

Monitoring site	Median chlorophyll-a concentration, 2009/2010	Median chlorophyll-a concentration, 2010/2011
Central Cockburn Sound		
4	0.60 µg/L	0.90 µg/L
5	0.60 µg/L	0.80 µg/L
8	0.65 µg/L	0.90 µg/L
Eastern shore		
MB10	1.65 µg/L	2.60 µg/L
9A	1.45 µg/L	1.50 µg/L
9	1.40 µg/L	1.50 µg/L
12	1.20 µg/L	1.20 µg/L
7	0.85 µg/L	1.10 µg/L
6	0.90 µg/L	0.70 µg/L
Southern Cockburn Sound		
11	1.15 µg/L	1.30 µg/L
13	1.40 µg/L	1.50 µg/L

Notes: * Source: 2009/2010 data from Wienczugow et al. (2010), and 2010/2011 data provided courtesy of the CSMC

Median chlorophyll-a concentrations in the centre of Cockburn Sound (sites 4, 5 and 8) met the high ecological protection zone EQG (0.8 µg/L) in 2009/2010, but only site 5 met the EQG in 2010/2011. In 2009/2010 all the eastern shore sites and southern sites exceeded the high ecological protection zone EQG (0.8 µg/L) and four sites exceeded the moderate protection zone EQG (1.3 µg/L). In 20010/2011 all eastern shore sites and southern sites exceeded the high ecological protection zone EQG (0.8 µg/L) and five sites exceeded the moderate protection zone EQG (1.2 µg/L). This comparison with the nutrient-enrichment EQG for chlorophyll-a is for information only, as the EQG are meant to be applied to the median of the combined data for all monitoring sites in each ecological protection zone, not the median of individual sites.

The focus of routine water quality monitoring in summer means there are few data for other times of the year. Recent data collected at seven sites in the region of the proposed Port Rockingham marina site are provided in RPS (2009), and are reproduced in Table 29 along with summer data collected at the same site, and relevant (summer) EQG and EQS. Winter and summer had similar levels of dissolved inorganic nutrient but chlorophyll-a concentrations in winter were about half of those in summer. The lower growth of phytoplankton in winter (reflected in lower chlorophyll-a levels) was attributed to the lower temperatures and lower available light. Summer water quality at the proposed Port Rockingham marina site also exceeded the high ecological protection zone EQG.

Table 29 Nutrient-related water quality data (median values) adjacent to the proposed Port Rockingham marina in summer and winter-spring

Date	Ammonia (µg/L)	Nitrate + nitrite (µg/L)	Ortho-phosphate (µg/L)	Chlorophyll 'a' (µg/L)	Light attenuation (/m)
Summer* (12 weeks, Jan - March 2007)	3	2	4	1.1	0.105
Winter-spring* (5 weeks, Sept – Oct 2007)	3	2	4	0.6	0.093
EQG for nutrient-related water quality (**summer**)	N/A	N/A	N/A	0.8 (high protection) 1.3 (moderate protection)	0.09 (high protection) 0.10 (moderate protection)
EQS for phytoplankton biomass (**summer**)	N/A	N/A	N/A	1.7 (high protection) 2.4 (moderate protection)	NA

Notes: * Source: RPS (2009)

Mangles Bay 2009/2010 and 2010/2011

As part of the environmental work for the Proposal, water quality measurements were undertaken in the shallows of Mangles Bay to establish baseline water quality prior to development, and to see if water quality was similar to that of the CSMC's routine monitoring site in the deep basin of Mangles Bay (site 11). A baseline survey of nutrient-related water quality was undertaken adjacent to the Proposal area during summer 2009/10 in accordance with protocols used by the CSMC Standard Operating Procedures (EPA 2005b). These data were made available to the CSMC, and are included as the 'MB' site (refer Figure 59) in the CSMC 2009/10 report (Wienczugow *et al.* 2010; Oceanica 2012).

CSMC's routine water quality monitoring is undertaken by Murdoch University's Marine and Freshwater Research Laboratory (MAFRL). As MAFRL was initially uncertain whether the MB site could be included in their routine program (due to logistic constraints), shore-based sampling was initially undertaken (December 2009 and January 2010) at the MB site by Oceanica Consulting Pty Ltd (Oceanica). Samples were collected each Monday morning (the same day as the MAFRL's monitoring program), and delivered to MAFRL for analysis the same morning. Collection methods later changed to boat-based sampling by MAFRL in February and March 2010. Results of the 2009/2010 sampling are shown in Table 30. Site MB has subsequently been included in the CSMC's routine summer water quality monitoring program, and so 2010/2011 data for chlorophyll-a (provided courtesy of the CSMC) are included in Table 30 (a final report incorporating nutrient data for 2010/2011 are not yet available).

Inorganic nutrient data are compared to the default national (ANZECC/ARMCANZ 2000) trigger values for nearshore marine waters in southwest Australia and chlorophyll data to Cockburn Sound EQGs and EQSs. For chlorophyll-a data there are both nutrient-related EQG and phytoplankton biomass EQG and EQS. The nutrient-related EQG are shown for information only, as they are intended for comparison to the median of all monitoring sites in each ecological protection zone, not the median of individual sites. The phytoplankton biomass EQG/EQS can be applied on a site basis according to the percentage of occasions in a summer monitoring period that the EQG/EQS value is exceeded. In the high ecological protection zone, if the phytoplankton biomass EQG/EQS value is exceeded on more than 25% of occasions in any year then the EQG is exceeded, and if this occurs in two consecutive years the EQS is exceeded. For the moderate protection zone, , if the phytoplankton biomass EQG/EQS value is exceeded on more than 50% of occasions in any year then the EQG is exceeded, and if this occurs in two consecutive years the EQS is exceeded. . It is noted that the waters of Mangles Bay are zoned for high ecological protection and therefore only high protection EQC are presently applicable, but moderate protection EQC are included in

Table 30 due to the moderate protection zoning anticipated for marine waters bounded by the Proposal breakwaters (refer Section 10.1.2).

The median chlorophyll-a concentration for site MB (1.65 µg/L) exceeded the nutrient enrichment EQG for high protection and for moderate protection in both 2009/2010 and 2010/2011 (Table 30), as did several other of the CSMC's routine monitoring sites (refer Table 28). Chlorophyll-a concentrations for site MB also exceeded the phytoplankton biomass EQG/EQS value for high protection for more than 25% of the time in both 2009/2010 and 2010/2011 (Table 30), exceeding both the EQG and EQS. The phytoplankton biomass EQG/EQS value for moderate protection was not exceeded in 2009/2010 but was in 2010/2011 (Table 30), exceeding the EQG in 2010/2011 but not the EQS.

Table 30 Water quality data for Mangles Bay shallows, December 2009 to March 2010 and December 2010 to March 2011

Date	Ammonia (µg/L)	Nitrate+nitrite (µg/L)	Ortho-phosphate (µg/L)	Chlorophyll-a (µg/L)	Total suspended solids (TSS) (mg/L)
Reporting Limit	**<3**	**<2**	**<2**	**<0.1**	**<0.5**
National trigger value[1]	**5**	**5**	**5**	**1.0**	**N/A**
EQG, nutrient-related water quality **- High protection** **- Moderate protection**	N/A	N/A	N/A	**0.8** (2009/10) **0.8** (2010/11) **1.3** (2009/10) **1.2** (2010/11)	N/A
EQG/EQS, phytoplankton biomass **- High protection** **- Moderate protection**	N/A	N/A	N/A	**1.7** (2009/10) **1.8** (2010/11) **2.4** (2009/10) **2.4** (2010/11)	N/A
Site MB Median[2], 2009/10 Site MB Median[3] 2010/11	4 Not available	2 Not available	5 Not available	1.65 2.40	2.2 Not available
% occasions site MB exceeded EQC[2], 2009/10 - High protection - Moderate protection % occasions site MB exceeded EQC [3], 2010/11 - High protection - Moderate protection	N/A	N/A	N/A	50% 12% 94% 69%	N/A

Notes: [1] Default trigger values for inshore marine waters in southwest Australia (ANZECC/ARMCANZ 2000).[2] For values reported as <LoR, the LoR was used to calculate the median. Data from Wienczugow et al. (2010)

[3] Chlorophyll-a data provided courtesy of CSMC. Data for nutrients and TSS not yet available.

The median chlorophyll-a concentrations at site MB in 2009/2010 and 2010/2011 were higher than at CSMC routine monitoring site 11 (refer Table 28), and site 11 did not exceed the phytoplankton biomass EQS for high protection (19% of occasions in 2009/2010 and 38% in 2010/2011),, indicating that:

- water quality data from CSMC routine monitoring site 11 (deep basin of Mangles Bay) cannot be used to predict water quality in the shallow flats adjacent to the proposed marina
- site-specific monitoring of water quality adjacent to the Proposal will be needed before and after development, to ascertain the degree to which outflow of water from the marina affects water quality in the Mangles Bay region.

10.2.3 Modelling approach used to assess impacts of the Proposal on marine water quality

Modelling approach for turbidity generated during construction

Modelling of the turbidity due to dredging and disposal of sediments was undertaken using an advanced sediment fate model; SSFATE (Suspended Sediment FATE), operating within the ASA DREDGEMAP system (Appendix 5). To represent the wave-induced effects on settlement and re-suspension of dredged sediment released during dredging of the approach channel, a wave model was established using the Simulating Waves Nearshore (SWAN) model. The wave model was run for the conditions required for the sediment fate analysis (winter of 2003): model output was stored hourly for input to the sediment fate model, DREDGEMAP.

SSFATE is a computer model developed by the US Army Corps of Engineers' Engineer Research and Development Centre and Applied Science Associates (ASA) which has been applied and validated against observations of sedimentation and suspended sediments at multiple locations in Western Australia, including Cockburn Sound for Fremantle Ports and Mermaid Sound for the Pluto dredging project (Appendix 5). The model predicts dispersion and settlement of suspended sediments, and also allows for potential re-suspension of newly settled sediments (which have higher water content and are more easily resuspended by lower shear stresses).

Modelling of turbidity was undertaken based on the following assumptions:

- dredging will start in early June and run through to early August (nine weeks), with the dredge operating six days a week during daylight hours (nominally 6.00 AM to 6.00 PM)
- dredging will commence from the offshore end of the access channel and progress shorewards towards the site of the proposed marina development (with the dredge remaining longer in the shallower areas)
- the particle size distribution data for dredged sediments were those supplied by the sediment sampling program undertaken for the Proposal (Section 10.2.4), and as no rock was encountered during this sampling program it was assumed that no cutting will be required during the dredging program.

The extent of the visible plume in these relatively clear waters is expected to be where the combined TSS of the dredge-generated plume and background TSS is above approximately 4 mg/l. Previous studies (DEP 1996) have identified background TSS values for Perth Coastal Waters of the order of 2–3 mg/L, as did studies of water quality in Mangles Bay undertaken for the Proposal (refer Section 10.2.2); hence a dredge-generated TSS threshold of 2 mg/L was plotted as the extent of the visible plume.

Modelling approach for marina water quality

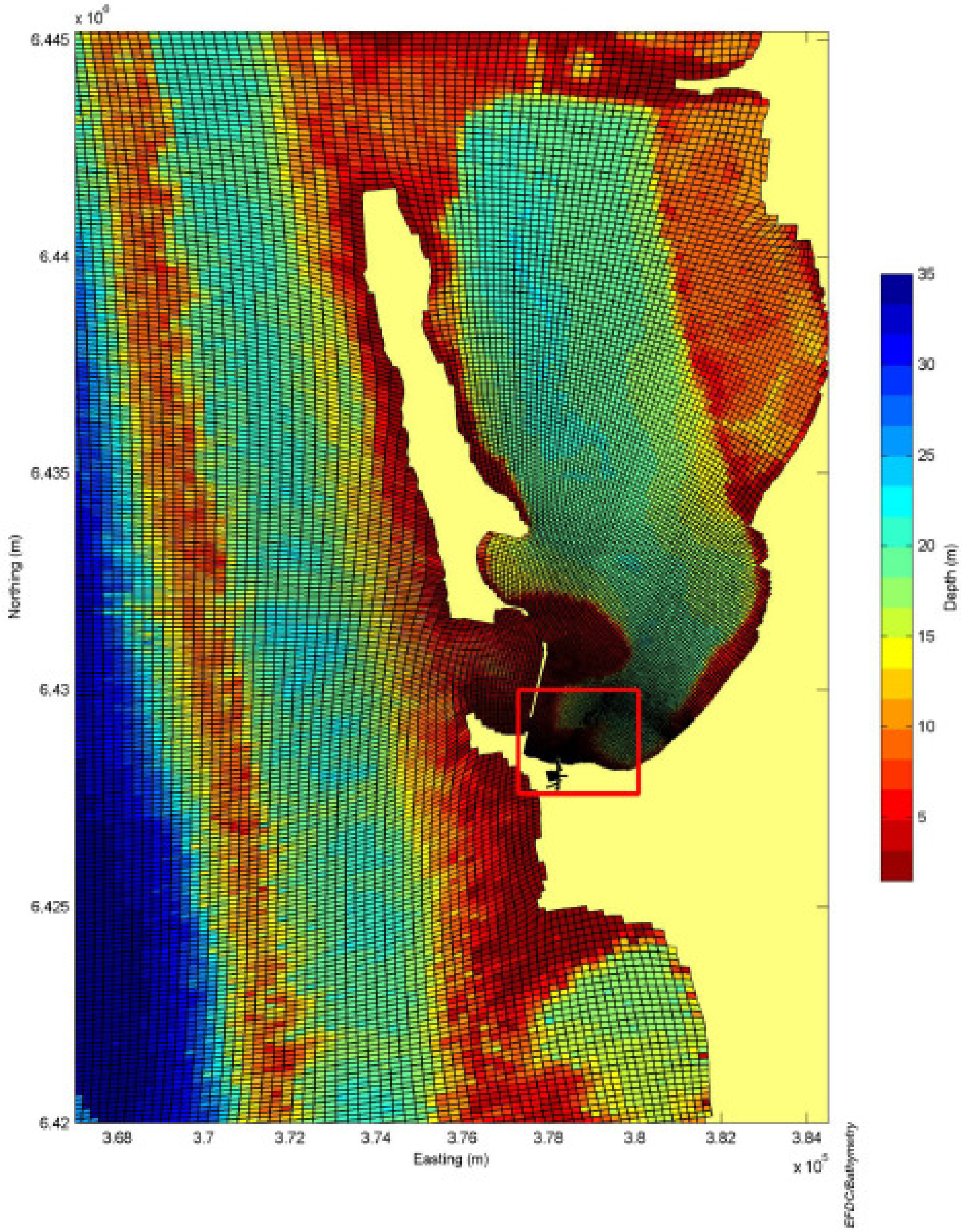
There were three models used in the Proposal assessment:

1. Environmental Fluid Dynamics Code (EFDC) model which simulates water movement (current velocity and direction) in relation to:
   - flushing (dye used as a conservative tracer)
   - nutrient concentration, with DIN used as a conservative tracer.
2. Simulating Waves Nearshore (SWAN) model: simulates settlement and suspension for sediments during dredging. The SWAN model was developed to simulate spatially-varying wave conditions over a wide domain, including the Cockburn Sound and Mangles Bay regions.
3. Equilibrium (box) model: used to predict the chlorophyll-a concentrations (and hence predict water quality) in the Proposal area based on flushing results from the EFDC flushing model component.

Modelling configuration and validation

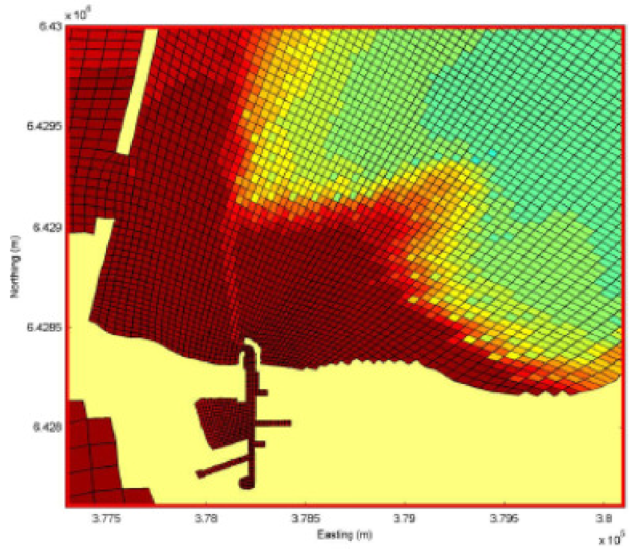
Due to the necessity to accurately simulate baroclinic (density-driven) current flows, wind, tide and groundwater inputs, modelling was undertaken using the EFDC model, applied within ASA's WQMAP framework. EFDC has been applied in numerous studies in Australia, including Cockburn Sound, Perth Coastal Waters, the Peel Inlet, Mermaid Sound, Port Hedland Harbour, Darwin Harbour, Hawkes Bay in New Zealand, and Caution Bay in Papua New Guinea (Appendix 5). Most of these studies involved rigorous validation of the hydrodynamic model performance, hence the model algorithms were considered robust and fit for the purposes of this study.

The model domain and computational grid developed for this study are shown in Figure 60 and . Horizontal model resolution was from 8-10 m within the marina and to 450 m at the outer edges of the domain. The model had six vertical layers, with middle layers specified as 20% of the local water depth, and the top and bottom layers as 10% of the local water depth to provide better resolution near the seabed and the water surface.



Note: Red area shown in more detail in Figure 61

Figure 60 Model domain, computational grid and bathymetry

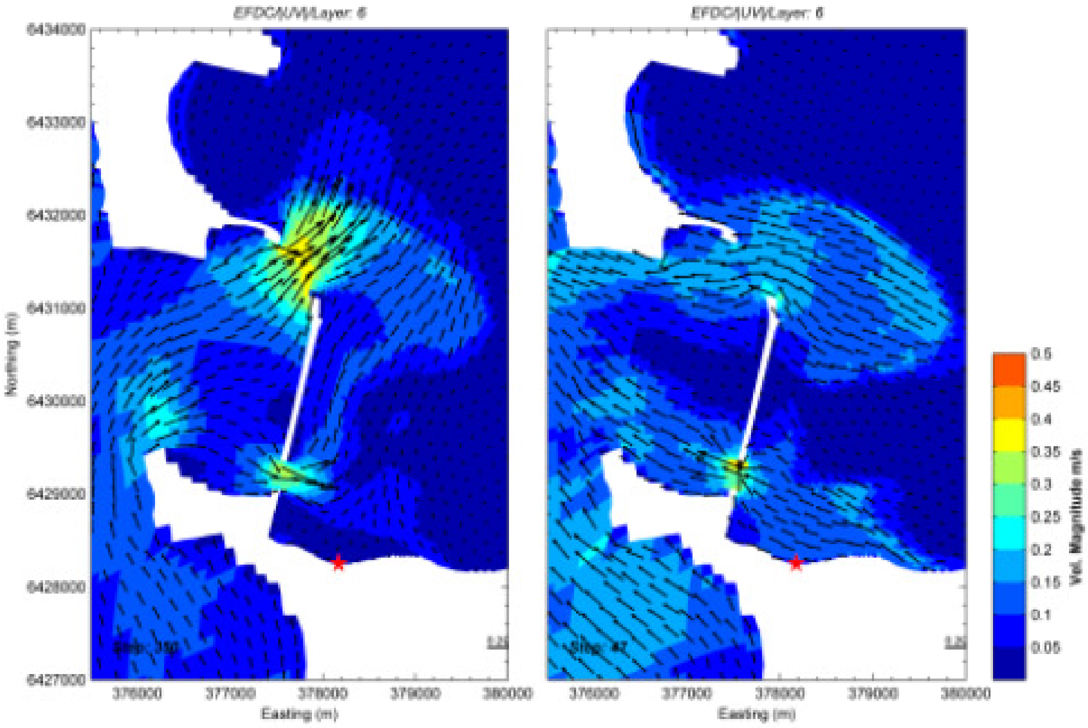


Source: APASA 2011

Figure 61 Model domain, computational grid bathymetry in region of proposed development

Model performance was validated using data collected from Acoustic Doppler Current Profilers (ADCPs) deployed in Mangles Bay from 10 February to 7 April 2011, and from 14 drogue deployments over the same period. Wind data were also collected at Mangles Bay (on Royal Australian Navy premises at the southern end of the Garden Island Causeway) to determine if wind measurements at the BoM site on the northern end of the Causeway were suitable for inclusion in the model. Wind speeds at Garden Island were consistently higher for winds from the southwest and east quadrant. In general, wind speeds at Mangles Bay were about 65% of those at Garden Island for south- easterlies, and 75% for easterlies. Wind directions for the two locations were generally similar, as were recorded wind speeds other than south-westerlies and easterlies (Appendix 5). This comparison suggested that winds in Mangles Bay will be slightly weaker from sheltered sectors than indicated in the long run records at the more exposed Garden Island location, and this was considered in the application of the wind data in the modelling.

Overall, model validation confirmed that the model provided a suitable basis for use in the assessment of the flushing performance of the proposed marina. Typical circulation patterns predicted by the model are shown in Figure 62. There is a region of strong currents to the east of the Garden Island Causeway, but this is highly localised and confined to the Garden Island Causeway openings and the relatively shallow area immediately adjacent. Current speeds are shown to reach around 0.35 m/s through both openings, consistent with the historical measurements of Pattiaratchi (2002). Calculated current speeds are significantly weaker adjacent to the proposed marina entrance and more variable in direction, as also indicated by field measurements (Appendix 5).

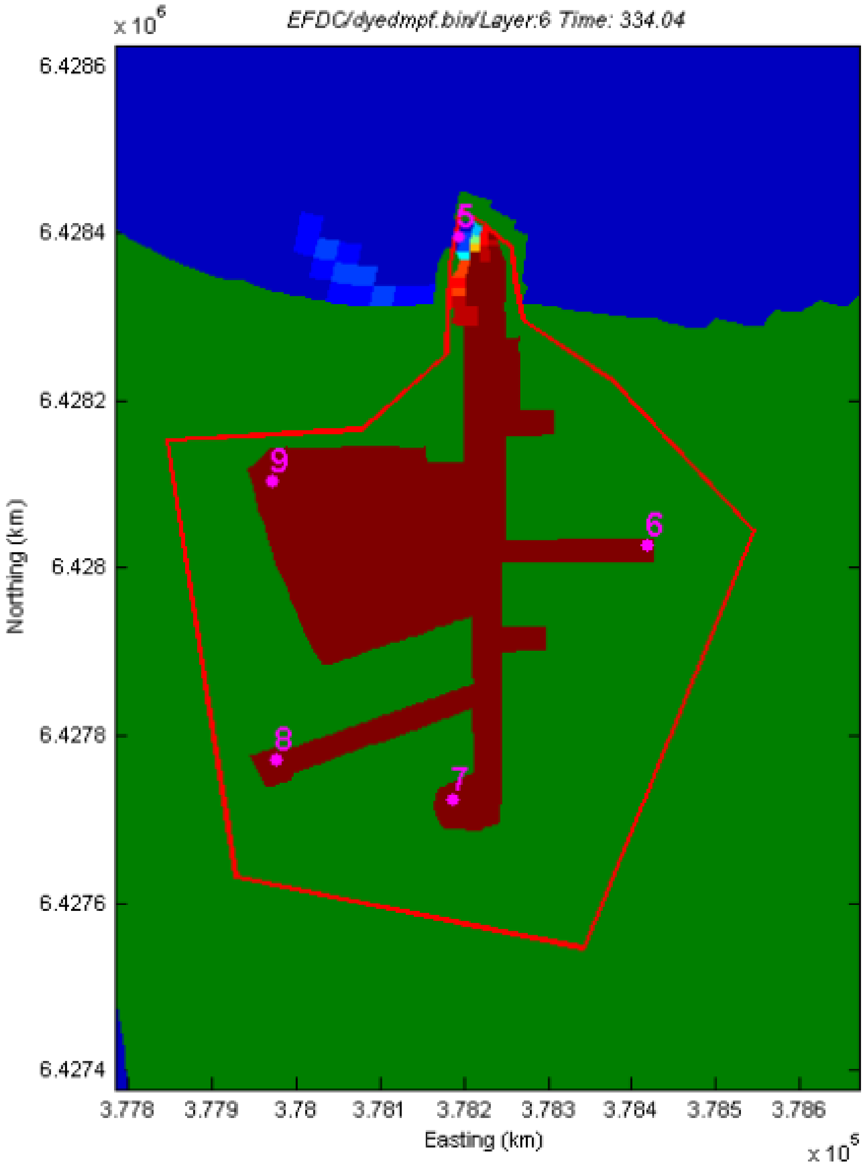


Note: From APASA (2011). The location of the proposed marina entrance is indicated by the red star. The colour scale reflects the relative current speed as per the scale, while the vector arrows point to where the current flow is going.

Figure 62 Typical current patterns in south western Mangles Bay during inflow (left) and outflow (right) conditions

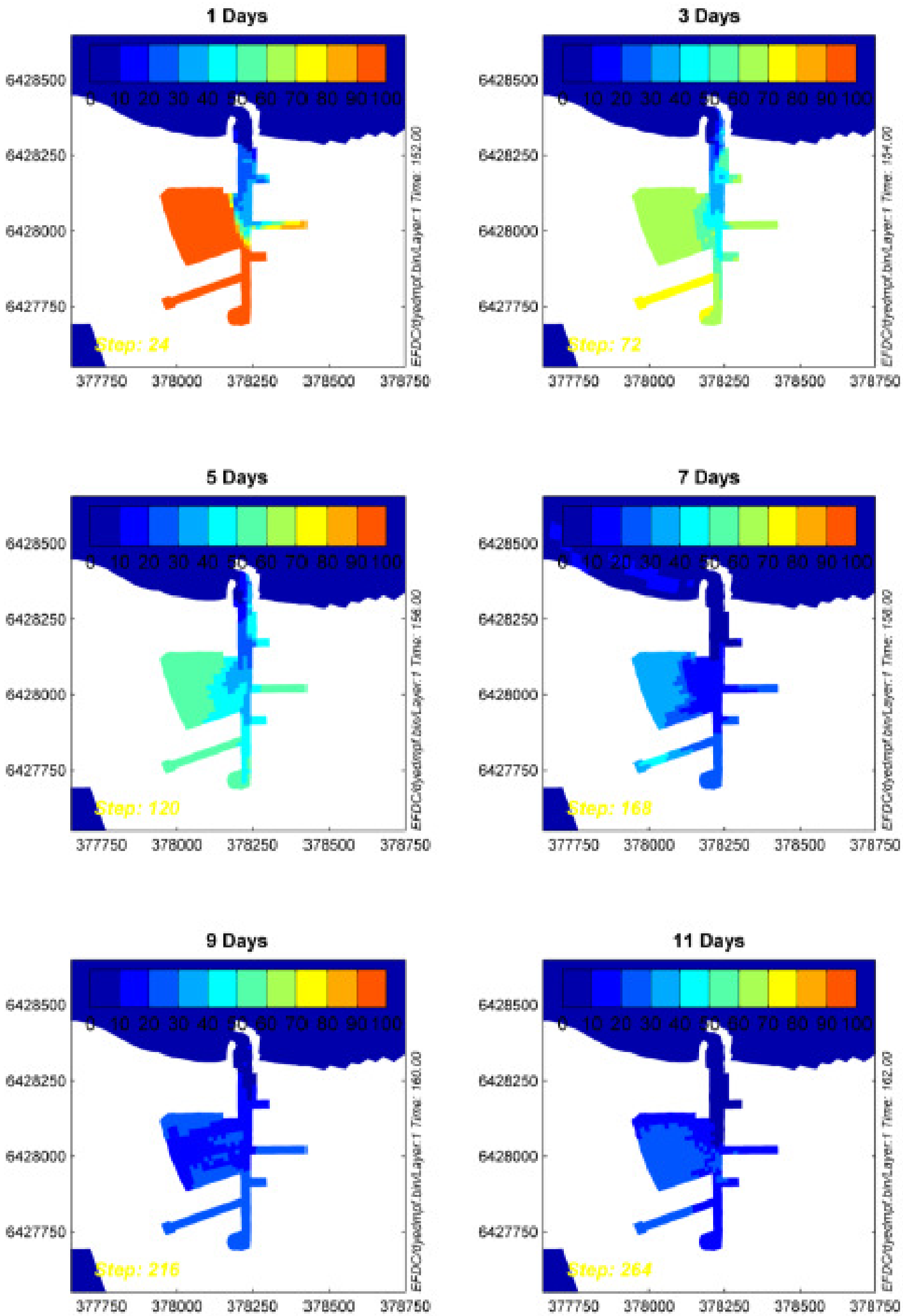
Flushing scenarios simulated

The flushing performance of the marina under different conditions of tides and winds was determined by seeding the marina waters with a conservative dye in the model (to ensure concentration only changes by dilution and dispersion) (Figure 63). The initial dye concentration was set to 100, representing 100% of an arbitrary contaminant. The flushing time was assessed as the time it takes for the concentration at a series of locations within the development to reduce to 1/e, or approximately 37% of the original concentration, also known as the e-folding time, consistent with the approach of DEP (1996). An example of model output is shown in Figure 64.



Note: The red boundary shows the marina precinct defined in the model.

Figure 63 Initial tracer dye within the marina and locations of the five assessment points used in water quality modelling



Source: APASA 2011

Figure 64 Illustrative snapshots of the surface layer dye concentration for winter scenario 1 at 1, 3, 5, 7, 9 and 11 days after the initialisation of the initial tracer distribution

Simulations were conducted to represent the three identified hydrodynamic regimes in Cockburn Sound/Mangles Bay: summer, autumn and winter/spring. The selection of representative conditions for each regime was based on an analysis of more than 10 years of wind data measured at Garden Island by the BoM. Simulations of each season were completed for the Proposal over a period of 60 days. As the flushing time depends on the prevailing conditions during each of the seasons, a range of model flushing tests was completed over differing tidal and wind conditions. Seven scenarios were modelled for each season (Table 31), ensuring a wide range of typical environmental conditions was covered. A further set of simulations for summer was completed to assess the sensitivity of results to the potential wind sheltering that may occur in Mangles Bay, with wind speeds from the southwest and the east factored, as discussed above.

Table 31 Flushing scenarios undertaken for water quality modelling (APASA 2011)

Season	Scenario	Conditions
Summer	**1**	**Tides** Moderate tides rising to spring range of 0.8 m then dropping to 0.2 m on neaps after 7 days. **Winds** Strong sea breeze cycle, SW dominated with weak easterlies. **Mean wind speed** 6.6 m/s.
	2	**Tides** Moderate tides rising to spring range of 0.6 m then dropping to 0.2 m on neaps after 7 days. **Winds** SW dominated with sea breeze pattern and stronger winds at end of period. **Mean wind speed** 6.9 m/s.
	3	**Tides** Spring tides with a range 0.9 m falling to neaps after 5 days. **Winds** Strong sea breezes to start followed by weaker and variable direction winds. **Mean wind speed** 7 m/s.
	4	**Tides** Moderate tides with range of 0.6 m progressing to neaps with a generally falling mean water level. **Winds** Weak winds at beginning before strong consistent sea breeze pattern. **Mean wind speed** 7.7 m/s.
	5	**Tides** Neap tides at the start rising to 0.8 m range after 7 days. **Winds** Persistent SW winds through most of the period with some sea breeze events. **Mean wind speed** 6.1 m/s.
	6	**Tides** Neap tides at the start rising to 1.0 m range after 8 days. **Winds** Early SW dominance then very strong winds after 9 days before a variable strength sea breeze cycle. **Mean wind speed** 7.4 m/s.
	7	**Tides** Neap tides at the start quickly rising to 0.6 m range for next 10 days. **Winds** Consistent sea breeze before sustained easterlies and weaker winds. **Mean wind speed** 7.1 m/s.
Autumn	**1**	**Tides** 0.5 m range at start, falling to neaps after 7 days. **Winds** Moderate to strong sea breeze cycle then weakening winds. **Mean wind speed** 7.1 m/s.
	2	**Tides** 0.5 to 0.6 m range throughout most of the period. **Winds** Moderate sea breeze to variable and strong SW winds later in the period. **Mean wind speed** 6.6 m/s.
	3	**Tides** 0.4 m range at the start rising to 0.6 m. **Winds** Generally weaker winds for most of the period with some light sea breezes. **Mean wind speed** 5.1 m/s.
	4	**Tides** 0.4 m range at the start rising to 0.6 m. **Winds** Weak sea breezes then sustained NW for a period followed by persistent easterlies. **Mean wind speed** 5 m/s.
	5	**Tides** Neap tides at the start progressing to 0.6 m after 7 days. **Winds** Clear sea breeze pattern throughout with some scattered easterly events. **Mean wind speed** 5.5 m/s.
	6	**Tides** 0.4 m range at the start increasing to 0.6 m after 7 days. **Winds** Strong wind events with a periodicity of around 5 days, mostly from the SW with some N winds. **Mean wind speed** 7.1 m/s.
	7	**Tides** 0.6 m at the start reducing to 0.2 m after 10 days. **Winds** Weak and variable winds from NW to SW mainly. **Mean wind speed** 4.6 m/s.
Winter/ Spring	**1**	**Tides** Spring tides with range of 0.6 m at start, reducing to neaps with range of 0.2 m with generally falling mean water level. **Winds** Episodic strong winds from variable directions. **Mean wind speed** 5.2 m/s.
	2	**Tides** Moderate range of 0.7 m at start on a rising mean water level. **Winds** Weak and persistent easterlies for first 8 days, then shifting to W to NW during storms. **Mean wind speed** 6.8 m/s.

Season	Scenario	Conditions
	3	**Tides** Moderate range of 0.7 m at start with neaps after 6 days. **Winds** Episodic W to NW storms. **Mean wind speed** 7 m/s.
	4	**Tides** Generally low 0.2 to 0.3 m range for first 10 days, rising to springs thereafter. **Winds** Weak easterlies to start then strong storm from SW after 7 days. **Mean wind speed** 5.7 m/s.
	5	**Tides** Neap tides with rang of 0.2 m to start rising to 0.8 m springs after 7 days. **Winds** Variable then prolonged period of weak easterly winds. **Mean wind speed** 4.4 m/s.
	6	**Tides** Neap tides to start with a generally falling mean water level, reaching 0.6 m range after 7 days. **Winds** Relatively strong W to NW dominated winds for the most part. **Mean wind speed** 8 m/s.
	7	**Tides** 0.3 m neap tides at the start increasing to 0.9 m range after 6 days over a generally falling mean water level. **Winds** Strong NW winds over the first 3 days then variable including weak easterlies after 8 days. **Mean wind speed** 6.5 m/s.

Source: APASA 2011

Nutrient tracer modelling

Modelling of the potential long-term build-up of contaminants and nutrients provides a more realistic indication of the likely effects. By assessing the variation from background values, the likely nature and impact of any change in water quality can be inferred. A series of model tests was conducted to demonstrate the potential effect of the marina on DIN within the Proposal area and in the adjacent waters. A constant background concentration value of 6 µg/L was assumed (refer Section 10.2.2), and the flux of DIN from the local groundwater system was applied along the marina edges using data provided by ERM (2011) for groundwater modelling undertaken for the Proposal. Groundwater inputs of DIN to the marina that were used were:

- summer – DIN load of 0.1 kg/day, based on a groundwater flow of 270 m^3/day and a DIN concentration of 0.37 mg/L
- autumn - DIN load of 0.2 kg/day, based on a groundwater flow of 620 m^3/day and a DIN concentration of 0.33 mg/L
- winter - DIN load of 0.7 kg/day, based on a groundwater flow of 940 m^3/day and a DIN concentration of 0.78 mg/L.

Groundwater flux was not applied to the adjacent coastline to allow the potential build up within the marina to be clearly modelled. Although release by sediments and decaying organic matter is ignored in this approach, the uptake by biological processes is also excluded, and the results are generally suitable for initial water quality assessments and for providing context to the likely effect of hydrodynamic flushing on water quality (Appendix 5).

Prediction of increased chlorophyll-a concentrations in marina waters

An indication of water quality (in terms of phytoplankton growth potential as measured by chlorophyll-a concentrations) in the Proposal area was obtained with an equilibrium (box) model using DIN as the modelled constituent. Studies in Perth's coastal waters have conclusively shown that phytoplankton growth is limited by nitrogen (DEP 1996), and so incorporation of DIN into phytoplankton biomass provides a conservative estimate of potential phytoplankton growth.

The ratio of chlorophyll-a to carbon, and carbon to nitrogen in phytoplankton is relatively uniform (50C:1Chl a, and 41C:1N; by mass) and if it is conservatively assumed that all available DIN is utilised by phytoplankton, the chlorophyll-a concentration will be approximately 0.117 times the predicted DIN concentration. The accuracy of this approach is at best moderate, as the efficiency with which DIN is converted to chlorophyll depends on a range of other parameters such as availability of other nutrients, light, temperature, phytoplankton species, mixing and phytoplankton numbers. For the simulations described below, it was conservatively assumed that all DIN was utilised by phytoplankton (DIN: chlorophyll conversion efficiency of 1.0) in summer and autumn (all DIN was converted to chlorophyll-a in the marina), but only half the DIN was utilised in winter, based on the results described in Section 10.2.2. This technique provides a guide to potential water quality (in terms of chlorophyll-a levels) in relative rather than absolute terms, and is best used to approximate chlorophyll levels in regions where they are likely to be moderate.

The input parameters for the equilibrium model are tabulated below. The model assumes that all input parameters remain constant in time. The flushing times chosen (six days and eight days) approximated typical values for the majority of marina waters in the three seasons (Table 32). Sediment nutrient inputs were based on Livery *et al.* (1993) for the Perth Coastal Waters study (and comparable to published rates for sandy, carbonate sediments). A zero sediment flux was also simulated as the work of Forehead (2006) in Cockburn Sound found that small rates of net uptake from sediments can occur as well as a small amount of net efflux.

Table 32 Input parameters used for equilibrium (box) modelling of water quality in the Proposal area (APASA 2011)

Parameter	Summer	Autumn	Winter
Volume of marina waters	Approx. 420 000 m^3	Approx. 420 000 m^3	Approx. 420 000 m^3
DIN load from groundwater	0.1 kg/day	0.2 kg/day	0.7 kg/day
DIN load from sediments (over 12 ha area of marina waters)	0 0.29 kg/day[1]	0 0.29 kg/day[1]	0 0.29 kg/day[1]
E-folding times	6 days 8 days	6 days 8 days	6 days 8 days
Conversion efficiency of DIN to chlorophyll	1	1	0.5
DIN concentration in source waters (Mangles Bay)	6 µg/L	6 µg/L	6 µg/L
Chlorophyll-a concentrations in source water (Mangles Bay)	1.3 µg/L(20th percentile) 1.7 µg/L (median) 2.1 µg/L (80th percentile)	1.3 µg/L(20th percentile) 1.7 µg/L (median) 2.1 µg/L (80th percentile)	0.6 µg/L(20th percentile) 0.8 µg/L (median) 1.0 µg/L (80th percentile)

Note: [1] Based on rate of 2.4 mg/m^2/day Livery *et al.* (1993).

10.2.4 Sediment quality

Sediment investigations and methods

The Proposal requires excavation of approximately 50 000 m^3 of marine sediments to create a marina access channel that is suitable for large (up to 25 m) power and sail craft. The excavation will result in some suspension of sediment, and any associated contaminants, into the water column. There is also potential for dissolved and particulate contaminants in the sediment to enter Mangles Bay through drainage from the settlement and infiltration ponds used for disposal of the dredged material. Accordingly, investigations were undertaken to assess the potential risk posed to the marine environment by any contaminants in the sediment in the area to be excavated.

Sediment sampling was undertaken on 28 February and 1 March 2011 as per NAGD (Commonwealth of Australia 2009), which requires sampling at 12 sites for the characterisation of 50 000 m^3 of dredged material (Figure 65). For sites sampled within the vicinity of the proposed channel footprint[10], sediment cores were taken to the full depth of dredging[11] and split into layers of 0.5 m for analysis.

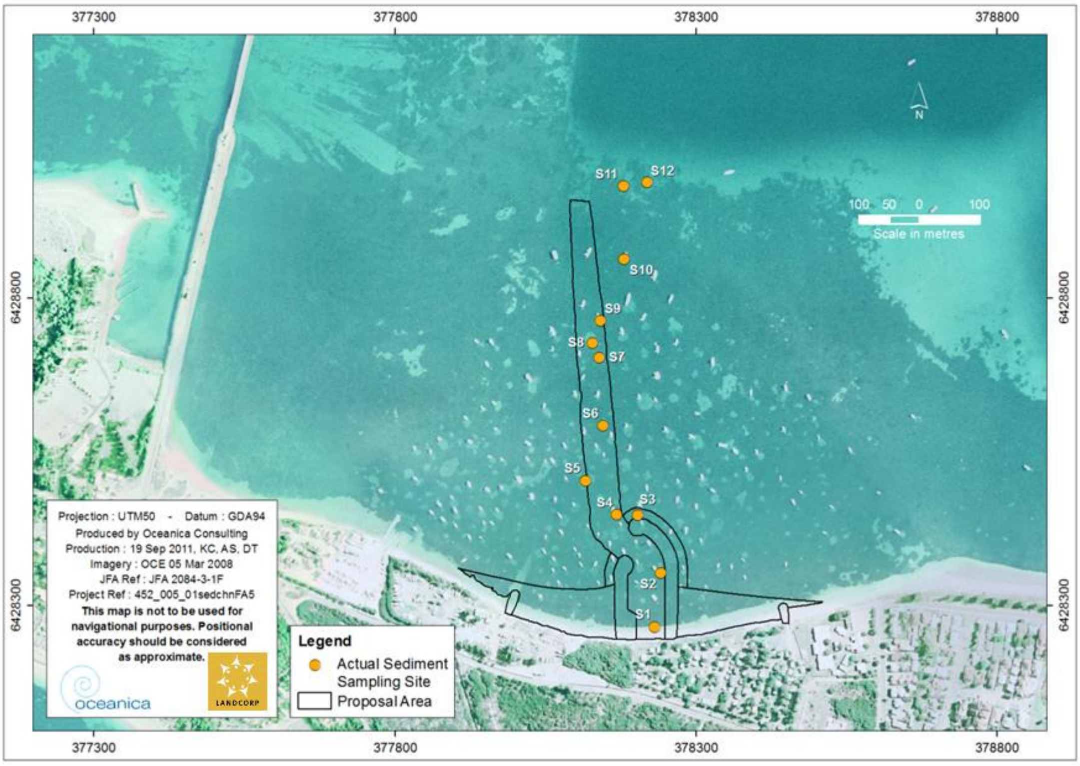


Figure 65 Sediment sampling sites within the vicinity of the proposed channel footprint

Sampling sites were located randomly within the area to be dredged; however, sites located closer to shore were slightly relocated to the closest mooring scar (the bare sand areas within seagrass meadows surrounding boat moorings). Site relocation within the mooring scars was undertaken for several reasons:

- it allowed for more straightforward sediment core extraction
- it provided a conservative approach to sediment assessment, as sediments in mooring scars (directly under moored boats) were more likely to be contaminated than sites under seagrass meadows
- it minimised damage to existing seagrass meadows.

In addition, four sites were sampled according to the methods specified in the Cockburn Sound SEP (EPA 2005b), in areas adjacent to the proposed access channel (Figure 66). This sampling was undertaken to provide baseline data on sediment contamination in the surface sediments of the region, to detect any future contamination should the Proposal proceed.

[10] The proposed channel design altered slightly after sediment sampling had been undertaken, resulting in several sampling locations being located outside of the proposed dredge channel. The sites sampled are still considered sufficiently representative of the region.

[11] The NAGD indicates that *"For capital dredging, samples are needed from the full depth of contaminated as well as potentially contaminated sediment. Full depth is taken to mean at least the top 1 metre of sediment, and more if contamination could be found deeper..."* consequently cores did not exceed a depth of 150 cm.

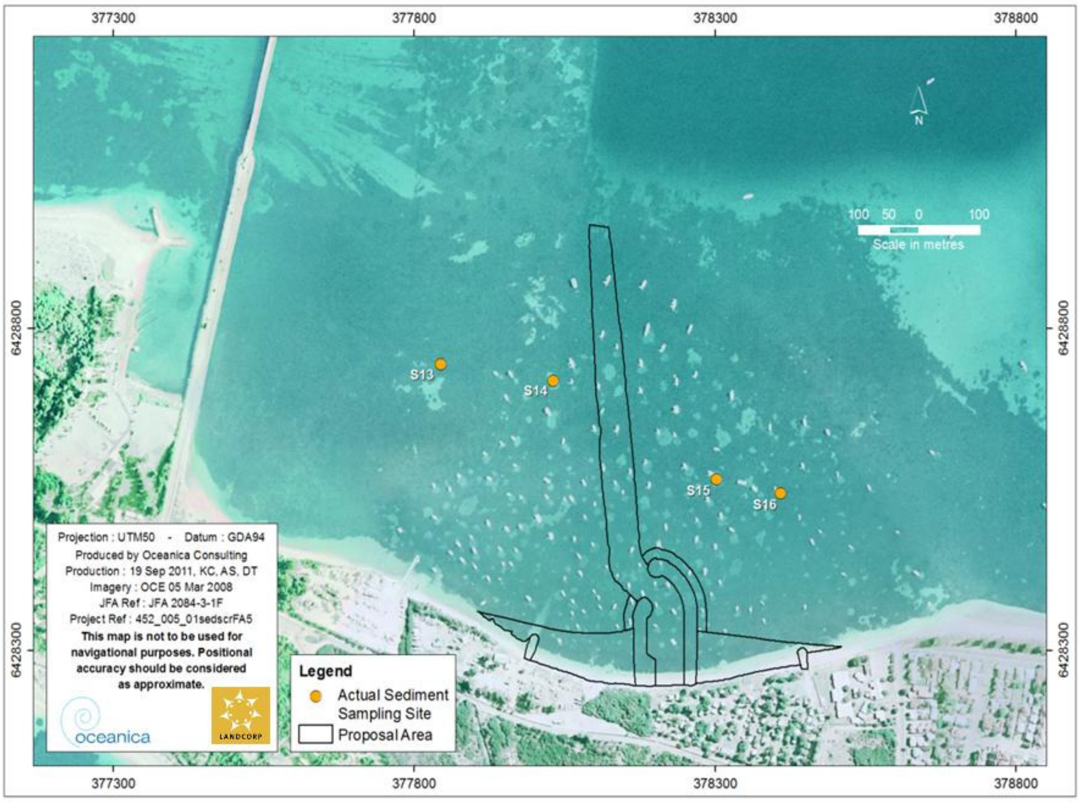


Figure 66 Baseline sediment sampling sites in adjacent mooring scars

Sampling methods and data are described in full in Appendix 5.

Particle size analysis

The sediments in the area to be excavated primarily comprised fine to median grained sands, with small percentages of silts and clays (Appendix 5). Representative data for the surface, middle and bottom layers of four sites are shown in (Figure 67). The particle size distributions in the 0-0.5 m layer (T), the 0.5-1 m layer (M) and the 1-1.5 m layer (B) of each site were generally similar with the exception of site S11, which had more silt and clay in the surface and middle sediment layers than in the bottom layer.

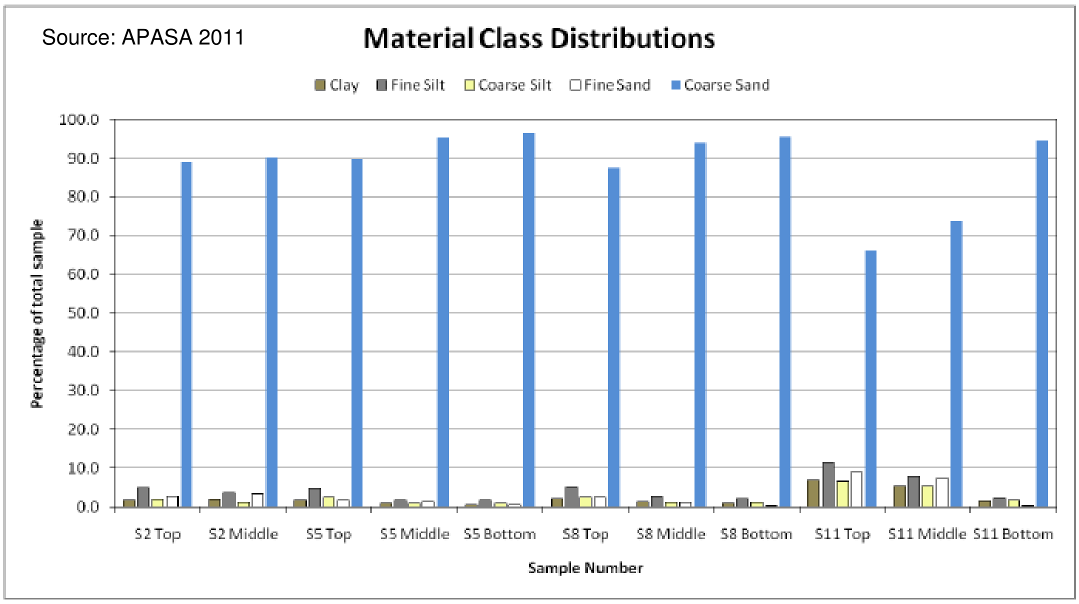


Figure 67 Particle size distribution data for sediments in area to be dredged

Metals

NAGD protocols require the 95% Upper Confidence Limit (UCL) of the mean (95% UCL) concentration of contaminants in dredged sediments to be compared to NAGD screening levels (Commonwealth of Australia 2009). A similar approach is typically used for comparison against EILs and HILs (DEC 2010b). Cockburn Sound SEP protocols require the median of sediment concentrations in a defined sampling are to be below the EQG value, and no single site to exceed the EQG re-sampling trigger (EPA 2005a).

Concentrations of metals within the sediments to be dredged did not exceed, EILs, HILs or EQGs (Table 33 and Table 34), indicating that there was a low risk of adverse ecological effects due to dredging or disposal, and that the material was suitable for use on land.

Table 33 Metal concentrations in Mangles Bay sediments S1-S12 (mg/kg)

Analyte	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
NAGD screening levels / EQG value	**1**	**20**	**1.5**	**80**	**65**	**0.15**	**21**	**50**	**200**
EQG re-sampling trigger	**3.7**	**70**	**10**	**370**	**270**	**1**	**52**	**220**	**410**
EIL	**n/a**	**20**	**3**	**400**	**100**	**1**	**60**	**600**	**200**
HIL 'D'	**n/a**	**400**	**80**	**480 000**	**4000**	**60**	**2400**	**1200**	**28 000**
HIL 'E'	**n/a**	**200**	**40**	**240 000**	**2000**	**30**	**600**	**600**	**14 000**
HIL 'F'	**n/a**	**400**	**100**	**600 000**	**5000**	**75**	**3000**	**1500**	**35 000**
Sites sampled for dredged sediment characterisation									
S1 S	0.68	3.6	0.21	13	2.8	<0.01	0.93	2.5	5.6
S1 M	0.74	5.8	0.20	13	0.8	<0.01	0.97	1.0	1.5
S1 B	0.75	6.6	0.17	13	0.57	<0.01	0.88	0.61	0.96
S2 S	0.68	3.5	0.19	13	2.1	<0.01	0.96	2.4	5.4
S2 B	0.73	10	0.21	14	0.52	<0.01	1.1	0.74	0.85
S3 S	0.70	7.7	0.20	14	32	0.03	0.89	8.2	5.6
S3 M	0.72	12	0.22	14	3.6	<0.01	0.96	1.3	1.0
S3 B	0.70	12	0.20	14	2	0.01	0.89	1.5	0.91
S4 S1	0.67	6.7	0.25	13	2.8	<0.01	1.3	1.6	6
S4 M1	0.70	10	0.19	13	0.42	<0.01	0.81	0.57	1.2
S4 B1#	0.68	12	0.20	14	0.39	<0.01	0.87	0.60	0.61
S5 S	0.68	5.8	0.19	13	2.1	<0.01	0.88	0.93	3.5
S5 M	0.69	8.2	0.22	14	0.48	<0.01	1.0	0.63	0.69
S5 B	0.67	12	0.25	14	0.36	<0.01	1.4	0.61	0.58
S6 S	0.69	4.4	0.16	13	2.4	<0.01	0.79	0.96	2.3
S6 M	0.81	7.8	0.2	14	0.44	<0.01	0.87	0.62	0.61
S6 B	0.65	9.2	0.25	14	0.42	<0.01	0.91	0.51	0.65
S7 S	0.67	5.5	0.17	14	0.69	<0.01	0.72	0.97	1.3
S7 M	0.66	7.5	0.17	13	0.36	<0.01	0.88	0.58	0.51
S7 B	0.64	9.4	0.21	14	0.31	<0.01	0.96	0.54	0.57
S8 S1#	0.70	5.5	0.17	14	0.79	<0.01	0.83	0.80	1.5
S8 M1	0.69	7.4	0.17	13	0.42	<0.01	0.74	0.60	0.59
S8 B1	0.64	11	0.19	13	0.39	<0.01	1.0	0.52	0.53
S9 S	0.66	6.7	0.20	14	1.5	<0.01	1.1	1.1	3.6
S9 M#	0.78	8.6	0.21	13	0.52	<0.01	1.2	0.66	0.78
S9 B	0.77	8.7	0.22	12	0.47	<0.01	1.2	0.61	0.59
S10 S	0.72	4.0	0.21	13	6.7	<0.01	1.3	1.6	8.0
S10 M	0.74	7.1	0.19	13	0.42	<0.01	1.0	0.53	0.61
S10 B	0.72	11	0.25	14	0.39	<0.01	1.0	0.56	0.64
S11 S	0.75	4.7	0.17	13	0.96	<0.01	1.2	0.92	1.8
S11 M	0.73	6.0	0.18	13	0.52	<0.01	1.1	0.55	0.52
S11 B	0.72	5.4	0.17	14	0.40	<0.01	0.88	0.61	0.64
S12 S	0.74	5.0	0.17	12	0.99	<0.01	1.1	1.0	2.9
S12 M	0.74	5.4	0.17	13	0.6	<0.01	1.0	0.66	0.67
S12 B	0.72	7.3	0.18	13	0.4	<0.01	0.94	0.51	0.59
Mean	*0.71*	*7.5*	*0.20*	*13.4*	*2.0*	*<0.01*	*0.98*	*1.1*	*1.8*
Standard deviation	*0.04*	*2.5*	*0.02*	*0.6*	*5.4*	*n/a*	*0.15*	*1.3*	*1.9*
95% UCL of mean	*0.72*	*8.3*	*0.20*	*13.6*	*3.8*	*<0.01*	*1.03*	*1.5*	*2.4*

Notes: [1] Average of data for three field replicates
[#] Average of data for two laboratory duplicates
EIL = Environmental Investigation Level
HIL = Health Investigation Level. HIL 'D' (residential with minimal opportunities for soil access: includes dwellings with fully or permanently paved yard space such as high-rise apartments and flats), 'E' (parks, recreational open space and playing fields, includes secondary schools) and 'F' (commercial/industrial, includes premises such as shops and offices as well as factories and industrial sites)

Table 34 Metal concentrations in Mangles Bay surface sediments S13-S16 (mg/kg)

Analyte	Silver (Ag)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
NAGD screening levels / EQG value	**1**	**20**	**1.5**	**80**	**65**	**0.15**	**21**	**50**	**200**
EQG re-sampling trigger	**3.7**	**70**	**10**	**370**	**270**	**1**	**52**	**220**	**410**
EIL	**n/a**	**20**	**3**	**400**	**100**	**1**	**60**	**600**	**200**
HIL 'D' **HIL 'E'** **HIL 'F'**	**n/a** **n/a** **n/a**	**400** **200** **400**	**80** **40** **100**	**480 000** **240 000** **600 000**	**4000** **2000** **5000**	**60** **30** **75**	**2400** **600** **3000**	**1200** **600** **1500**	**28 000** **14 000** **35 000**
Sites sampled for baseline sediment quality (surface sediments only)									
S13	0.72	4.2	0.15	13	1.1	<0.01	0.76	0.99	2.3
S14	0.79	4.3	0.16	13	1.7	<0.01	0.84	1.3	5.6
S15	0.76	4.2	0.15	15	19	<0.01	1.8	1.1	5.1
S16	0.78	3.4	0.15	13	1.3	<0.01	0.78	1	2.3
Median	*0.77*	*4.2*	*0.15*	*13*	*1.5*	*<0.01*	*0.81*	*1.1*	*3.7*

Notes: EIL = Environmental Investigation Level
HIL = Health Investigation Level. HIL 'D' (residential with minimal opportunities for soil access: includes dwellings with fully or permanently paved yard space such as high-rise apartments and flats), 'E' (parks, recreational open space and playing fields, includes secondary schools) and 'F' (commercial/industrial, includes premises such as shops and offices as well as factories and industrial sites)

Nutrients

Concentrations of TKN and TP in sediments were 56440 mg/kg and 370–420 mg/kg, respectively (Appendix 5). No trigger values exist for nutrients in sediments, however these values were within the ranges range previously reported for sediments of Cockburn Sound and Warnbro Sound: 80–2150 mg/kg for TKN and 350–500 mg/kg for TP, with the higher values associated with siltier sediments in the deep basins (DEP 1996).

Both NAGD protocols and Cockburn Sound SEP protocols require the 95th percentile of toxicant concentrations in water to be compared to relevant guidelines. Concentrations of ammonia in elutriates of Mangles Bay sediments did not exceed the toxicity guideline of the NAGD (Commonwealth of Australia 2009) or Cockburn Sound EQG for high ecological protection (EPA 2005a) (Table 35), indicating a low risk to marine biota from ammonia release during dredging.

Potential nutrient-enrichment effects (such as enhanced phytoplankton growth) may also occur due to release of ammonia, nitrate+nitrite and orthophosphate during dredging, but the mean concentrations of DIN (DIN = ammonia plus nitrate+nitrite) in Table 8 indicated a low risk as they represented minor loads (less than 0.04 kg/day potentially released during dredging, based on average DIN concentrations and 25% moisture content in sediments),compared to the estimated 0.7 kg DIN/day in groundwater presently discharged to the nearshore area during winter [Section 10.4.2]).

Table 35 Nutrient concentrations in elutriates of Mangles Bay sediments

Analyte	Ammonia	Nitrate+nitrite	Orthophosphate
Units	**µg.N/L**	**µg.N/L**	**µg.P/L**
NAGD screening level / EQG	**910**	**N/A**	**N/A**
S1 S S1 M S1 B	740 94 100	15 9 11	37 24 24
S2 S S2 M	200 120	10 9	73 38
S3 S S3 M S3 B	390 76 80	12 6 7	67 36 35
S4 S[1] S4 M[1] S4 B[1]	700 85 99	10 8 8	108 27 36
S5 S S5 M S5 B	670 81 55	6 5 6	42 41 38
S6 S S6 M S6 B	580 84 63	15 9 7	86 40 53
S7 S S7 M S7 B	490 34 12	10 6 7	62 30 23
S8 S[1] S8 M[1] S8 B[1]	270 63 51	12 7 6	85 39 31
S9 S S9 M S9 B	720 71 62	9 5 5	70 34 31
S10 S S10 M S10 B	1500 57 63	5 6 5	34 41 43
S11 S S11 M S11 B	340 77 53	7 4 7	96 41 30
S12 S S12 M S12 B	710 100 52	6 4 6	86 48 32
Mean	*255*	*8*	*47*
Standard deviation	*324*	*3*	*22*
95th percentile	*724*	*N/A*	*N/A*

Notes: [1] Average of data for three field replicates

Tributyltin (TBT) and total organic carbon (TOC)

Total Organic Carbon (TOC) values (0.1–0.5%) were within the range previously reported for sediments of Cockburn Sound and Warnbro Sound (DEP 1996) (Table 36).

EPA (2005a) and Commonwealth of Australia (2009) protocols require Tributyltin (TBT) data to be normalised to a 1% TOC content before comparison to guidelines. It should also be noted that the guideline for TBT differs slightly between EPA (2005a) and Commonwealth of Australia (2009), and there are no EILs or HILs for TBT. Concentrations of TBT were below laboratory reporting limits at nearly all sites and depths, and the 95% UCL concentration of TBT met the NAGD screening level (Commonwealth of Australia 2009), indicating a low risk of adverse ecological effects due to dredging or disposal. The median TBT concentration at baseline sediment sampling sites also met the EQG, indicating a low risk of adverse ecological effects.

Although the NAGD screening level for dredged sediments was met, as a precautionary measure further testing was undertaken on the two individual samples that exceeded the NAGD Screening Level. Samples for the bottom layer of site S3 and the surface layer of site S6 were re-analysed for sediment TBT concentrations and elutriate TBT concentrations. Re-analysis of the bottom layer of site S3 found sediment TBT concentration and elutriate TBT concentrations below laboratory reporting limits (and NAGD screening levels). Re-analysis of the surface layer of site S6 confirmed the same sediment concentration of TBT, and an elutriate concentrations exceeded the EQG for high ecological protection (Commonwealth of Australia 2009, EPA 2005a). Although the dredged material will be placed in land-based infiltration ponds at the Proposal area (removed from the marine environment) and meets the TBT screening level, the results for site S6 surface sediment indicate it would be prudent for the CEMP to include monitoring of water in the infiltration ponds to confirm predictions that overall TBT concentrations will meet marine guidelines.

Table 36 TOC and TBT concentrations in Mangles Bay sediments S1-S12

Analyte	Sediment				Sediment elutriate TBT
	TBT - original analysis[1]	**TBT – re-analysis**	**TOC**	**TBT original analysis[1], normalised to 1% TOC[2]**	**TBT**
Units	**µgSn/kg**	**µgSn/kg**	**%**	**µgSn/kg**	**µgSn/L**
Laboratory limit of reporting	**0.5**	**0.5**	**0.01**	**N/A**	**0.005**
EQG	**N/A**	**N/A**	**N/A**	**5.0 (value) 72 (re-sampling trigger)**	**0.006**
NAGD screening level	**N/A**	**N/A**	**N/A**	**9.0**	**0.006**
Sites sampled for dredged sediment characterisation					
S1 S	<0.5	-	0.3	0.8	-
S1 M	<0.5	-	0.3	1.0	-
S2 B	<0.5	-	0.3	1.9	-
S2 S	<0.5	-	0.3	0.9	-
S2 M	<0.5	-	0.2	1.1	-
S3 S	0.8	-	0.3	2.5	-
S3 M	0.6	-	0.2	2.7	-
S3 B	1.1	<0.50	0.2	***6.9***	<0.005
S4 S[1]	<0.5	-	0.5	0.5	-
S4 M[1]	<0.5	-	0.2	1.3	-
S4 B[1#]	<0.5	-	0.2	1.3	-
S5 S	<0.5	-	0.2	1.0	-
S5 M	<0.5	-	0.2	1.3	-
S5 B	<0.5	-	0.1	1.3	-
S6 S	11	11	0.3	***34.4***	***0.74***
S6 M	<0.5	<0.5	0.2	1.3	**-**
S6 B	<0.5	<0.5	0.2	1.3	**-**
S7 S	<0.5	-	0.3	0.9	-
S7 M	<0.5	-	0.2	1.3	-
S7 B	<0.5	-	0.2	1.3	-
S8 S[1#]	<0.5	-	0.3	0.8	-
S8 M[1]	<0.5	-	0.2	1.3	-
S8 B[1]	<0.5	-	0.2	1.3	-
S9 S	<0.5	-	0.5	0.5	-
S9 M[#]	<0.5	-	0.2	1.3	-
S9 B	<0.5	-	0.2	1.3	-
S10 S	<0.5	-	0.5	0.5	-
S10 M	<0.5	-	0.2	1.3	-
S10 B	<0.5	-	0.2	1.3	-
S11 S	<0.5	-	0.5	0.5	-
S11 M	<0.5	-	0.3	0.7	-
S11 B	<0.5	-	0.2	1.3	-
S12 S	<0.5	-	0.4	0.6	
S12 M	<0.5	-	0.4	0.7	-
S12 B	<0.5	-	0.2	1.3	-
Mean	*NA*	*NA*	*NA*	*2.3*	*NA*
Standard deviation	*NA*	*NA*	*NA*	*5.7*	*NA*
95% UCL of mean	*NA*	*NA*	*NA*	*4.2*	*NA*

Notes: [1] Average of data for three field replicates
[#] Average of data for two laboratory duplicates
[2] If TOC was <0.2%, TBT data were multiplied by five, as per Commonwealth of Australia (2009)
Exceedance of guidelines by individual samples highlighted in italicised bold text

Table 37 TOC and TBT concentrations in Mangles Bay sediments S13-S16

Analyte	Sediment				Sediment elutriate TBT
	TBT - original analysis[1]	**TBT – re-analysis**	**TOC**	**TBT original analysis[1], normalised to 1% TOC[2]**	**TBT**
Units	**µgSn/kg**	**µgSn/kg**	**%**	**µgSn/kg**	**µgSn/L**
Laboratory limit of reporting	**0.5**	**0.5**	**0.01**	**n/a**	**0.005**
EQG	**NA**	**NA**	**NA**	**5.0 (value) 72 (re-sampling trigger)**	**0.006**
NAGD screening level	**NA**	**NA**	**NA**	**9.0**	**0.006**
Sites sampled for baseline sediment quality (surface sediments only)					
S13	<0.5	-	0.4	0.6	-
S14	<0.5	-	0.4	0.7	-
S15	1.1	-	0.3	3.5	-
S16	<0.5	-	0.3	0.9	-
Median	*NA*	*NA*	*NA*	*0.8*	*NA*

Notes: [1] Average of data for three field replicates
[2] If TOC was <0.2%, TBT data were multiplied by five, as per Commonwealth of Australia (2009)
Exceedance of guidelines by individual samples highlighted in italicised bold text

Organics

Concentrations of total polycyclic aromatic hydrocarbons (PAHs) and each constituent PAH within sediments were all below the limits of reporting at all sites and depths (LOR 5 µg/kg and 100 µg/kg for individual PAH and total PAHs, respectively). Results are provided in Appendix 5.

Acid sulfate soils

The dredged sediments are to be disposed of on land, so testing for acid sulfate soil (ASS) potential was also undertaken (Table 38) (note: ASS is not a concern when sediments are disposed at sea).

At all sites and across all depths, values for sediment pHKCl (pH of potassium chloride suspension) were greater than 9, indicating none of the samples were acidic. This conclusion was supported by the Titratable Actual Acidity, which was zero at every site and depth. Just under half of the sediment layers analysed (16 of 35) had chromium reducible sulfur (%S_{CR}) values in excess of the Action Criteria value for soils (0.03%), and were therefore considered to be potential acid sulfate soils (PASS). However the net acidity data indicated that the potential acidity within the PASS samples would be buffered by alkaline components within the samples, as they had sufficient neutralising capacity to result in negative net acidity. Results therefore indicated that any acid produced following land disposal of sediments excavated to create the marina access channel would be effectively neutralised by the *in situ* buffering capacity of the sediments.

Table 38 ASS and acid base accounting (ABA) data for Mangles Bay sediments

Site	pHKCl	Potential Sulfidic Acidity			Acid Neutralising Capacity			Net Acidity
		%S (S_{CR})	**Equivalent Acidity (mol H+/tonne)**	**Existing Acidity**	**ANCBT (%CaCO3)**	**ANC (mol H+/tonne)**	**Fitness Factor**	**Net Acidity (mol H+/tonne)**
S1 S#	9.8	0.01	8.11	None	n/m	n/m	2	n/m
S1 M	9.8	0.03	17.46	None	n/m	n/m	2	n/m
S1 B	9.8	0.03	15.59	None	n/m	n/m	2	n/m
S2 S	9.8	**0.05**	28.69	None	86	17182.8	2	-8562.71
S2 M	9.8	**0.05**	31.81	None	84	16783.2	2	-8359.79
S3 S	9.8	**0.05**	28.07	None	85	16983	2	-8463.43
S3 M	9.8	**0.05**	32.43	None	86	17182.8	2	-8558.97
S3 B#	9.8	**0.05**	31.18	None	86	17282.7	2	-8610.16
S4 S	9.7	**0.04**	22.45	None	83	16583.4	2	-8269.25
S4 M	9.8	**0.04**	22.45	None	82	16383.6	2	-8169.35
S4 B	9.8	**0.05**	33.68	None	84	16783.2	2	-8357.92
S5 S	9.8	**0.04**	21.83	None	85	16983	2	-8469.67
S5 M	9.9	**0.04**	24.95	None	87	17382.6	2	-8666.35
S5 B	9.8	**0.04**	27.44	None	88	17582.4	2	-8763.76
S6 S	9.8	0.02	13.72	None	n/m	n/m	2	n/m
S6 M	9.9	0.02	11.85	None	n/m	n/m	2	n/m
S6 B	9.8	0.03	21.21	None	n/m	n/m	2	n/m
S7S#	9.8	0.02	10.30	None	n/m	n/m	2	n/m
S7 M	9.9	**0.04**	23.08	None	85	16983	2	-8468.42
S7 B	9.8	**0.05**	28.69	None	85	16983	2	-8462.81
S8 S	9.8	0.02	14.97	None	n/m	n/m	2	n/m
S8 M	9.9	0.03	18.71	None	n/m	n/m	2	n/m
S8 B	9.8	**0.05**	28.69	None	76	15184.8	2	-7563.71
S9 S	9.7	0.03	20.58	None	n/m	n/m	2	n/m
S9 M	9.8	0.03	20.58	None	n/m	n/m	2	n/m
S9 B	9.9	**0.05**	28.07	None	70	13986	2	-6964.93
S10 S	9.7	0.02	14.97	None	n/m	n/m	2	n/m
S10 M#	9.8	0.02	15.90	None	n/m	n/m	2	n/m
S10 B	9.8	0.04	27.44	None	69	13786.2	2	-6865.66
S11 S	9.8	0.02	12.47	None	n/m	n/m	2	n/m
S11 M	9.8	0.03	17.46	None	n/m	n/m	2	n/m
S11 B	9.9	0.02	11.23	None	n/m	n/m	2	n/m
S12 S	9.7	0.03	16.84	None	n/m	n/m	2	n/m
S12 M	9.8	0.03	16.22	None	n/m	n/m	2	n/m
S12 B	9.9	**0.04**	23.08	None	81	16183.8	2	-8068.82

Notes: # Average of data for two laboratory duplicates
%S_{CR} values in bold font exceed the Action Criteria value for soils (0.03%)
n/m = not measured

10.3 Evaluation of options or alternatives to avoid or minimise impact

10.3.1 Marina design and construction management

The Proposal has been designed to maximise the natural flushing of inner marina waters by wind and tide. Marina bathymetry does not have holes or sills, water depth increases towards the entrance. The marina configuration is simple, and the arms are largely oriented to take advantage of prevailing wind directions. This will reduce the extent of nutrient enrichment and anoxia within the marina, and the likelihood of poor quality waters entering Mangles Bay. Contaminant inputs to marina waters will be minimised using best practice measures for facility design and management (such as minimising stormwater contaminant inputs, implementing relevant water sensitive urban design, and state planning requirements), and strict regulations regarding general boating related activities. The proposed development will be internally draining with all stormwater being infiltrated onsite and high flood flows being designed to flow into the marina. The Proposal will be sewered (so there is no faecal contamination of groundwater beneath residences), and will also have sullage disposal facilities so vessels using the marina do not cause faecal contamination of marina waters.

The Lake Richmond stormwater drain (the major contributor of stormwater nutrients and contaminants to Mangles Bay) presently traverses the Proposal area, and is planned to be relocated as part of the development, to better flushed waters further east along the shoreline (Section 7).

A CEMP will be prepared to specify the proposed breakwater and other construction methods and proposed management measures. The CEMP will include monitoring of turbidity in the water of Mangles Bay and contaminant levels in the waters of the settling basins.

10.3.2 Dredging program

The proposed dredging program for the marina has been designed to avoid or minimise impact on water quality as follows:

- the short duration of the dredging program (three months) will reduce the period of elevated turbidity levels. Turbidity associated with dredging is also predicted to be minimal (Section 10.4.1) due to the low proportion of fine particles in the material to be dredged, and the relatively clean dredging method (a small cutter suction dredge)
- silt curtains will be used (weather and sea conditions permitting) during the dredging process, to further control turbidity release and dispersion, minimising potential impacts on water quality
- dredged sediment will be pumped to onshore infiltration basins via a floating pipeline, and water from the settling basins will be managed via infiltration, with some overflow discharged into Mangles Bay. The water quality and velocity levels at the overflow will be managed such that they do not impact on the marine environment (see Appendix 1)
- maintenance dredging is proposed to take place should trigger values indicate it is required. Appendix 1 further details maintenance dredging requirements.

10.4 Assessment of likely direct and indirect impacts

The Proposal will result in temporary impacts on marine water quality during construction, and ongoing impacts on marine water quality due to outflow of water from the marina. The following aspects of the Proposal may affect marine water quality and sediment quality values:

1. Construction of the marina will cause localised, temporary increases in turbidity:
    - dredging of the seabed during construction of the access channel into the Proposal area may temporarily affect water quality due to increased turbidity, nutrients and contaminants in dredged sediments (including the potential for ASS when the dredged material is temporarily stored in the Proposal area)

- seepage or discharge of return water from bunded areas used for temporary storage of dredged sediments, which may temporarily impact water quality through increased turbidity, nutrients and contaminants in dredged sediments
- placement of limestone for breakwaters, as well as leaching of fines from the limestone may cause temporary increases in turbidity both during and after the limestone is placed.

2. Operational impacts of the marina include:
    - outflow of lower quality water from within the Proposal area could result in reduced water quality and sediment quality in Mangles Bay and adjacent waters. Marinas are, by necessity, calm, sheltered environments therefore the waters of the proposed development will be less well flushed than the adjacent waters of Mangles Bay, thus may be of lower quality. There will also be effects on water quality in the Proposal area due to the concentration of boats in the area, plus any stormwater runoff from the development (both potential sources of a source of nutrients, contaminants and bacteria)
    - accidental spills of fuel or sullage within the Proposal area from sullage disposal facilities or refuelling facilities could cause temporary effects on water quality within the Proposal area, Mangles Bay, and adjacent waters of Cockburn Sound and the SIMP
    - increased boat numbers will increase the potential for diffuse pollution in the area, such as the slow leaching of antifoulants from boat hulls, and low level hydrocarbon emissions from boat engines.

It is not anticipated that the construction of the marina will cause any significant changes in water quality through changes in the overall water circulation patterns of Cockburn Sound, due to the small size of the marina breakwaters and their location in very shallow flats at the south eastern extreme of Cockburn Sound.

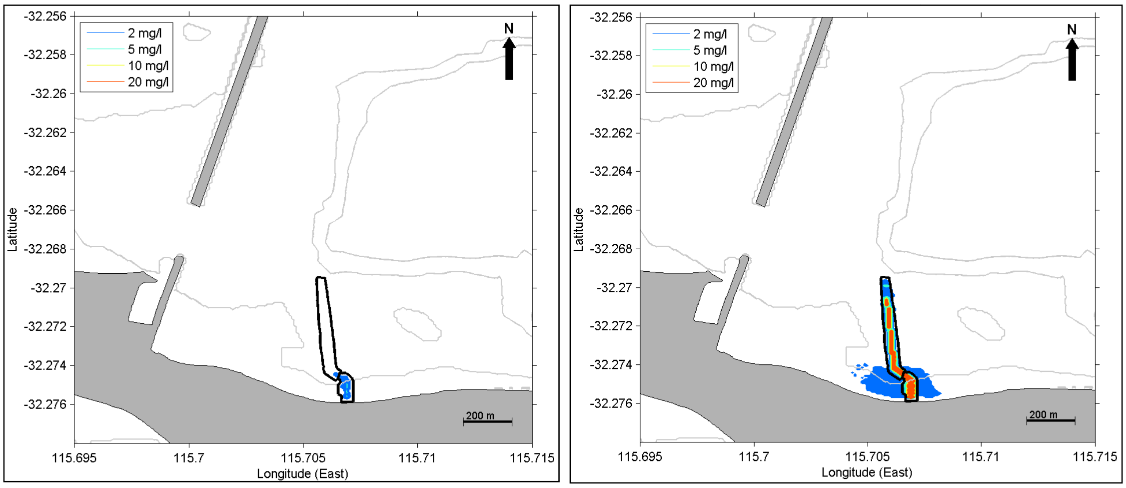
10.4.1 Impacts of turbidity and other contaminants

Turbidity

The results of turbidity modelling were interpreted using spatially-defined zones in accordance with Environmental Assessment Guideline No. 7 *Environmental Assessment Guideline for Marine Dredging Proposals* (EAG 7; EPA 2011):

- Zone of High Impact (ZoHI) - the area where impacts on seagrass meadows and associated benthic organisms were predicted to be irreversible (defined as lacking a capacity to return or recover to a pre-dredging state within a timeframe of five years or less)
- Zone of Moderate Impact (ZoMI) - the area where predicted impacts on seagrass and benthic organisms were expected to be sub-lethal, and/or the impacts were recoverable within a period of five years following completion of the dredging activities
- Zone of Influence (ZoI) - the area where changes in environmental quality associated with dredge plumes were predicted, but these changes were not expected to result in a detectible impact on benthic biota. The ZoI represents the predicted maximum extent of the dredge plumes, and beyond it there should be no dredge-generated plumes discernible from background conditions at any stage during the dredging campaign. EAG 7 (EPA 2011) notes that the ZoI can be large, but at any point in time the dredge plumes are likely to be restricted to a relatively small portion of the ZoI.

Predicted dredge-generated elevations in TSS were initially examined using values of 2, 5, 10 and 20 mg/L (Appendix 5), with 10 mg/L (the EQG for aquaculture under the Cockburn Sound SEP) conservatively representing a value protective of sensitive marine fauna, and 2 mg/L representing the approximate visible plume threshold. The 95th and 99th percentile contours for these values are shown Figure 68: TSS for the nominated values would be exceeded outside of 99th percentile contour for 1% of the time (a total of about six hours over the entire dredging program), and outside the 95th percentile for a total of up to three days over the entire dredging program. As seen in Figure 68 , the 5 and 10 mg/L threshold would be exceeded over an extremely restricted region within the access channel footprint. This is attributed to the relatively coarse nature of the sediment to be dredged, the very small-scale of the dredging (less than 50 000 m^3) and the relatively clean dredging method used (cutter suction dredge) (Appendix 5).



Note: From APASA (2011). The TSS plume will not cover the entire area shown at any one moment in time, but represents the total ‘footprint’ for the entire dredging program. TSS concentrations represent values above background TSS concentrations. The black line denotes the access channel footprint.

Figure 68 Potential extent of the dredging plume, based on the 95th percentile (left image) and 99th percentile (right image) of total suspended solids (TSS) concentrations

Zones according to EAG 7 (EPA 2011) are shown in Figure 69, and were conservatively derived as follows:

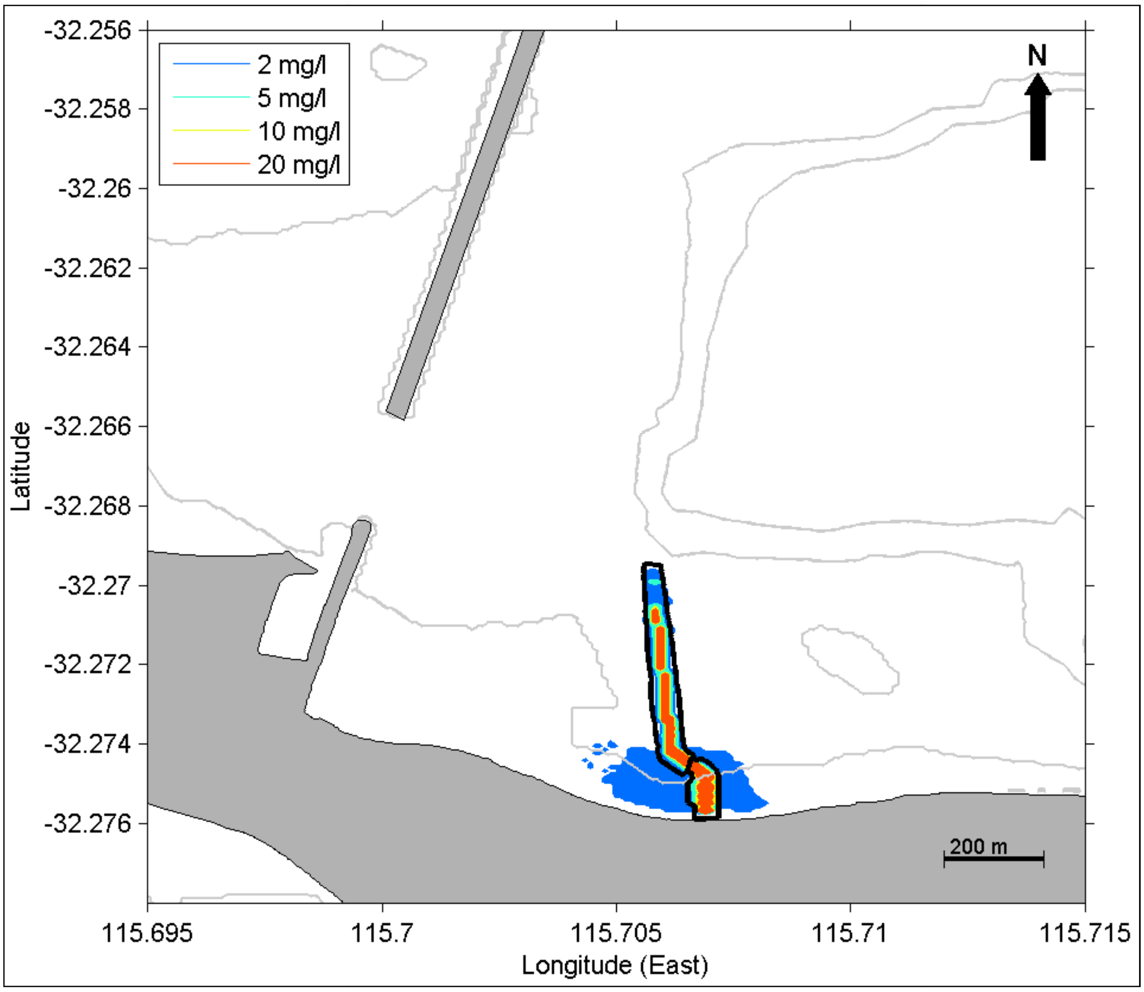
- Zone of High Impact (ZoHI) - comprising the development footprint (direct losses due to the access channel and batters, breakwaters and beach breakwaters, reclamation areas, and indirect loss due to a 15 m halo effect around the breakwaters
- Zone of Moderate Impact (ZoMI) – modelling results indicated the 99th percentile contour for a TSS concentration of 5 mg/L would be within the access channel footprint (Figure 69), indicating little risk of sublethal affects on benthic organisms outside the ZoHI, and implying an outer boundary of the ZoMI that coincides with the outer boundary of the ZoHI. Rather than having a boundary marking a change from ‘irreversible loss of benthic biota’ to ‘no detectable impacts on benthic biota’, an outer boundary for the ZoMI was notionally defined as extending 10 m beyond the ZoHI
- Zone of Influence (ZoI) - the outer boundary of the ZoI was defined using the 100th percentile of the area where a TSS threshold of 2 mg/L was exceeded at, representing the maximum extent of the visible plume. It should be noted that the zone does not represent the area within which a visible plume may be seen at any one moment in time, rather it represents the summation of conditions over the entire dredging program. The region where a visible plume is expected will generally be restricted to within the vicinity of the dredging channel, although a weakly concentrated plume may be visible up to 100-200 m away at times (refer Figure 69 and Appendix 5).

Note: The TSS plume will not cover the entire area shown at any one moment in time, but represents the total 'footprint' for the entire dredging program. The visible plume within the Zone of Influence at any one time will be much smaller.

Figure 69 Predicted zones of turbidity-related effects on the marine environment during dredging

Modelling results for turbidity

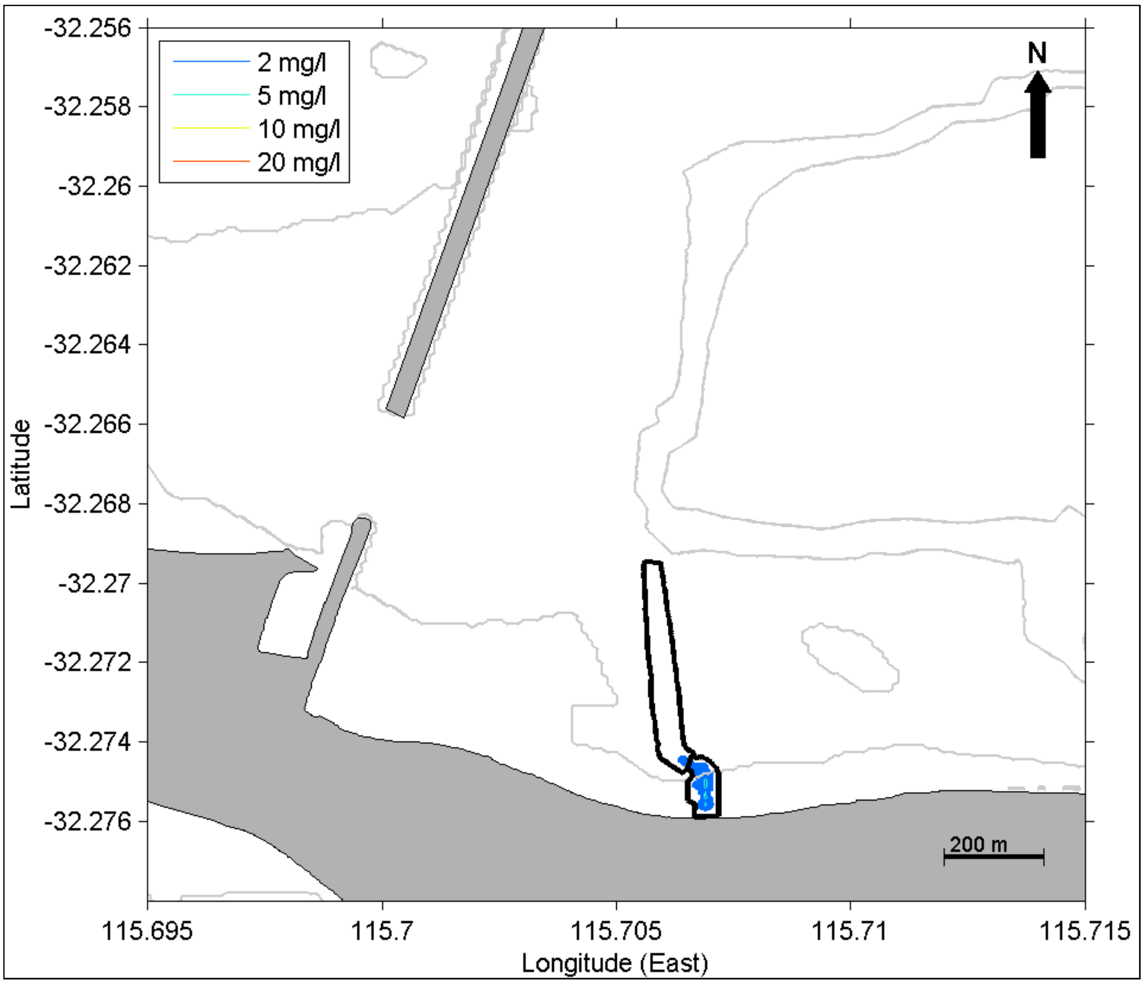
The predicted extent of the visible plume over the entire dredging period is presented by the 99th percentile TSS in Figure 70. The 99th percentile has been used to indicate the potential extent of the visible plume based on the EPA's Draft Environmental Assessment Guidelines for Marine Dredging Proposals (EPA 2010a). The 99th percentile shows the turbidity footprint where the dredge-generated TSS threshold of 2 mg/L is exceeded up to 99% of the time. Predicted TSS concentrations outside the footprint would only exceed the visible threshold for a total of about six hours over the entire dredging campaign. It should be noted that the 99th percentile plot does not show where the visible plume may be seen at one moment in time, rather it represents the summation of conditions over the entire dredging program. The region where a visible plume is expected to occur will generally be restricted to within the vicinity of the dredging channel, although a weakly concentrated plume may be visible up to 100-200 m away at times Appendix 5).



Note: From APASA (2011). The TSS plume will not cover the entire area shown at any one moment in time, but represents the total 'footprint' for the entire dredging program. TSS concentrations represent values above background TSS concentrations.

Figure 70 Potential extent of the visible plume, based on the 99th percentile of total suspended solids (TSS) concentrations

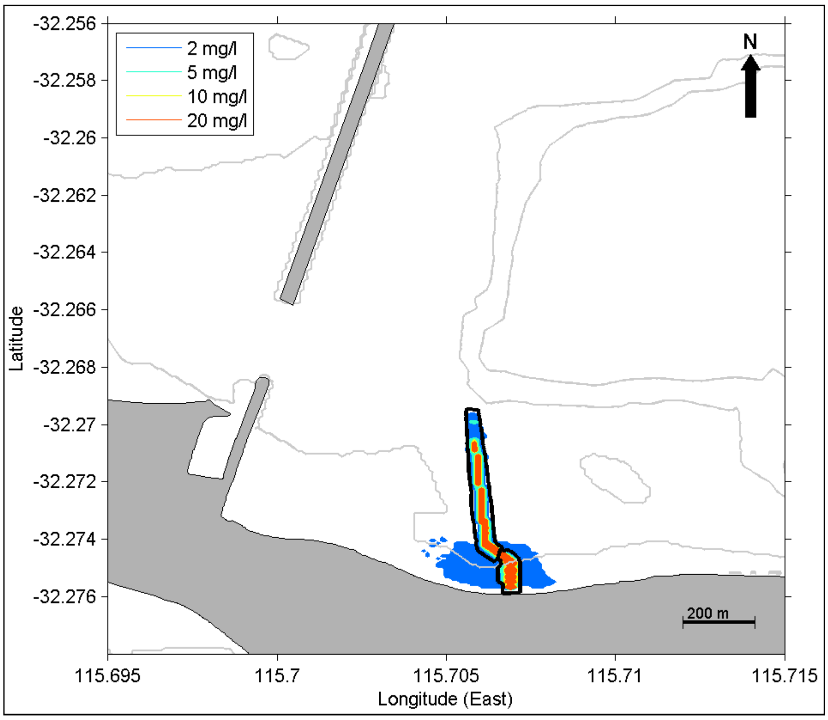
The predicted dredge-generated elevations in TSS were assessed against nominal threshold values of 5, 10 and 20 mg/L for the 50th , 80th and 95th percentiles throughout the dredging operation (Appendix 5), with 10 mg/L (the EQG for aquaculture under the Cockburn Sound SEP) conservatively representing a value protective of sensitive marine fauna. The 2 mg/L contour was included in the threshold analysis, as representing the approximate visible plume threshold. The 95th percentile plot is shown in Figure 68 and Figure 71. TSS for the nominated thresholds would be exceeded outside of the relevant footprints for 5% of the time (a total of up to three days over the entire dredging duration). As seen in Figure 71, the 5 and 10 mg/L threshold would be exceeded over an extremely restricted region. This is attributed to the relatively coarse nature of the sediment to be dredged, the very small-scale of the dredging (less than 50 000 m^3) and the relatively clean dredging method used (cutter suction dredge) (Appendix 5).

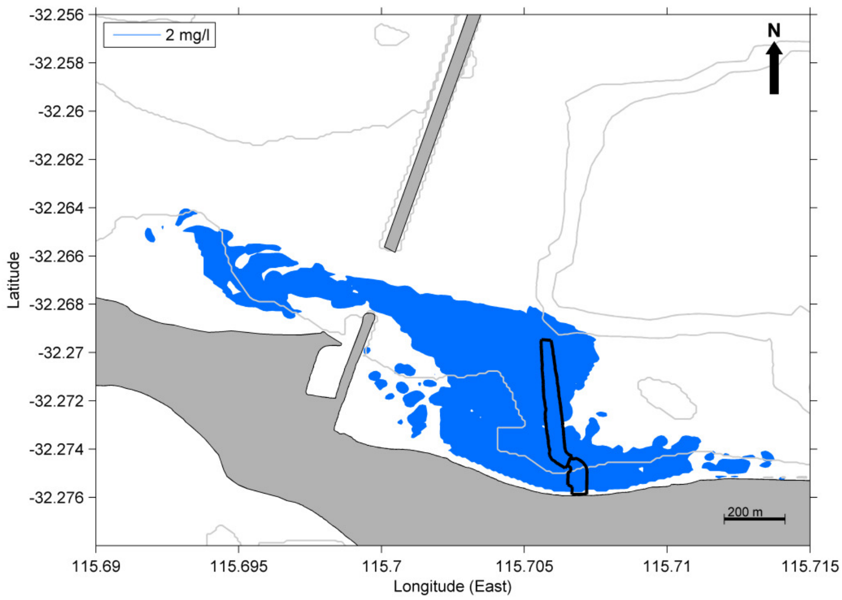


Note: Source: APASA (2011). The TSS plume will not cover the entire area shown at any one moment in time, but represents the total 'footprint' for the entire dredging program. TSS concentrations represent values above background TSS concentrations.

Figure 71 Potential extent of the visible plume, based on the 95th percentile of TSS

Figure 72 shows a comparison between the 99th and 100th percentile TSS thresholds. Relevant to note is that the 100th percentile image has been included to show the worst case extent of TSS during dredging. It is important to note that the 100th percentile scenario would occur for a maximum of 6 hours throughout the entire construction dredging program.





Note: Source: APASA (2011). The TSS plume will not cover the entire area shown at any one moment in time, but represents the total ‘footprint’ for the entire dredging program. TSS concentrations represent values above background TSS concentrations.

Figure 72 Potential extent of the visible plume, a comparison between the 99th and 100th percentile of TSS

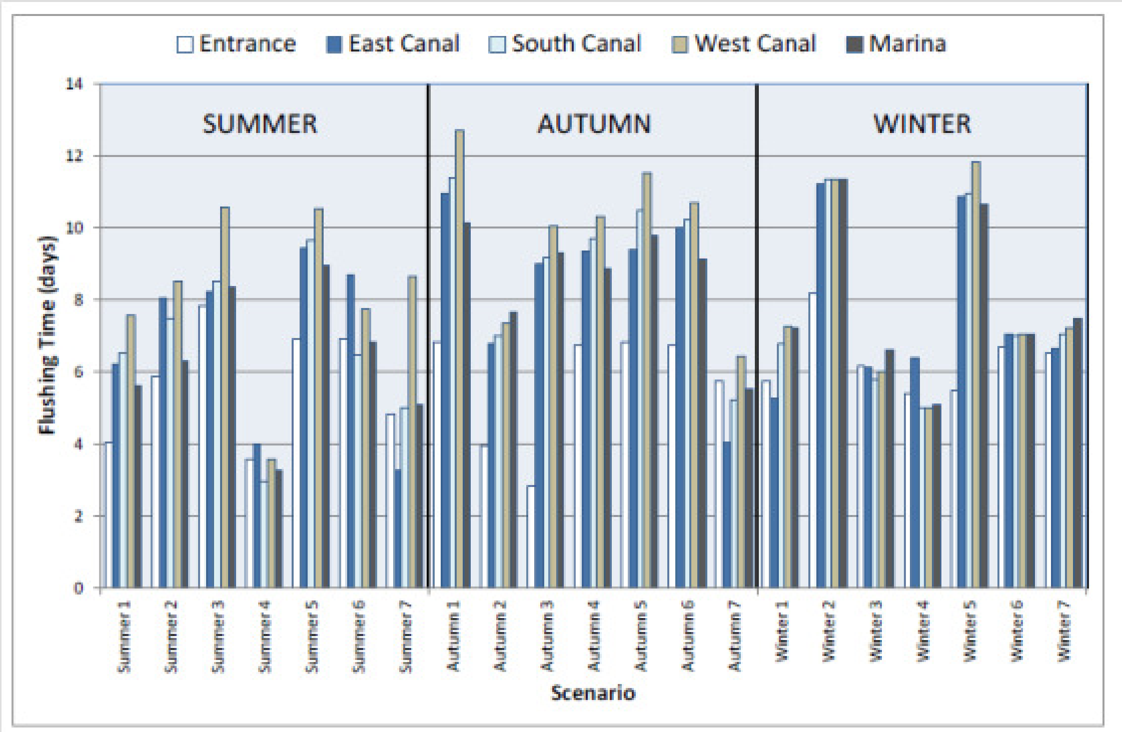
Contaminant release

The potential for contaminant release during dredging and disposal is considered very low, as contaminant concentrations in the sediments met NAGD screening levels (Commonwealth of Australia 2009), EILs and relevant HILs (refer Section 10.2.3).

10.4.2 Flushing related impacts

Flushing times

Flushing times for all the simulations and all of the sites are shown in Figure 73. The median flushing time for all sites and all simulations was predicted to be 6.8 days, with a maximum for the modelled scenarios of 12.7 days. 83% of the flushing time predictions were 10 days or less, and 55% were 7 days or less. Flushing typically proceeded from near the entrance towards the areas furthest away from the entrance, with the longest flushing times predicted to occur at the West Canal (Site 8, refer Figure 63), which is the most remote location from the marina entrance (furthest point of this canal is approximately 820 m from the entrance). Simulations for the autumn period also produced a higher proportion of flushing times exceeding 10 days. The concentration of the bottom waters generally also reached the e-folding level slightly before the surface waters were considered flushed (Appendix 5).



Note: Source: APASA (2011)

Figure 73 Summary of predicted flushing times (e-folding times) at the five analysis sites across all scenarios modelled.

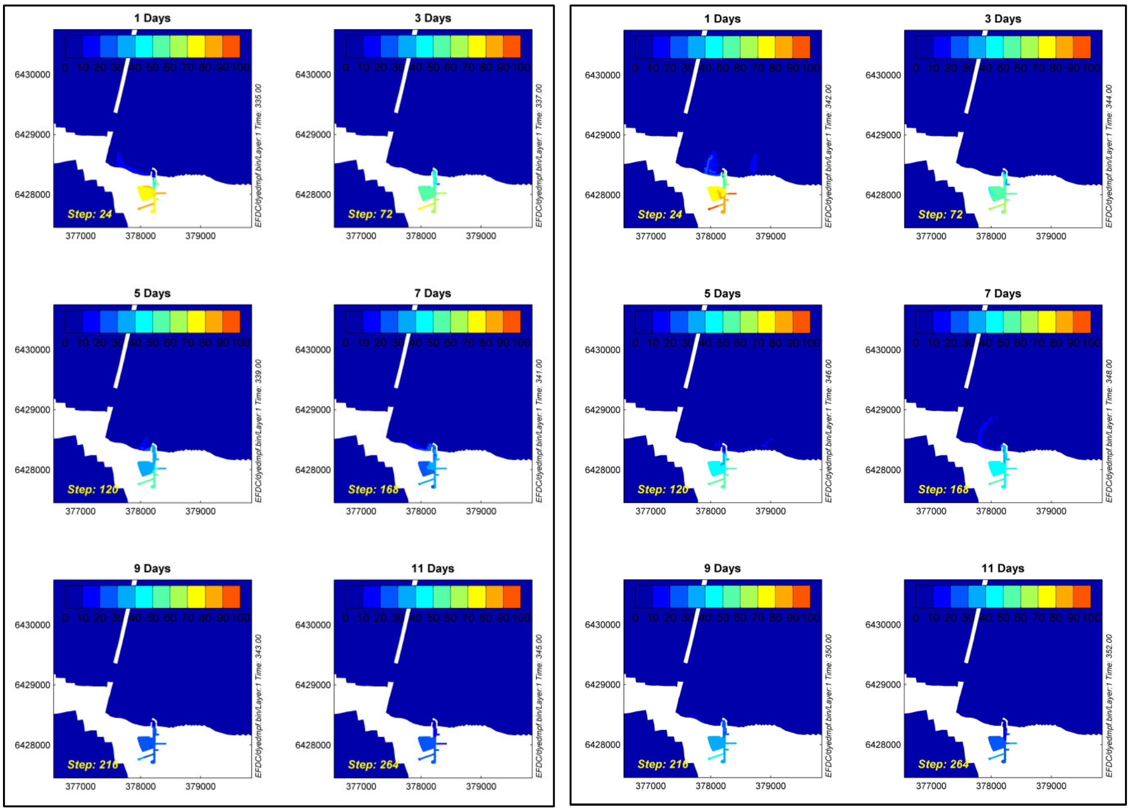
The predictions of flushing rates were carried out for a large number of combinations of winds, tides and atmospheric conditions. Calm conditions were not always associated with poor flushing, as wind is only one of the important mechanisms for exchange of water, with the others being the tides/water levels and density gradient driven flows. A weak wind event can therefore yield different results depending on whether it coincides with spring or neap tides, a previously well mixed or stratified water body, or stable versus highly fluctuating air temperatures. Weak wind speeds may also lead to better flushing than strong winds if the wind direction retards two layer flows.

In terms of the wind speed, the worst case for flushing in the modelled scenarios was when the 12 day average wind speed was 4.16 m/s (from early to mid-June, 2003). Reviewing the available Garden Island data set from November 2001 through to March of 2011, this event represented the 1.28th percentile of the record. This means that only 1.28% of recorded 12 day periods had average wind speeds weaker than this modelled scenario. The weakest (0th percentile) from this record was a 12 day average of 3.68 m/s, occurring during late April and early May of 2003. Wind speeds for around 99% of the time are therefore expected to be greater than the modelled scenario that yielded the longest flushing time, and so the model results (Figure 73) are considered representative of all but rare events.

It should be further noted that the marina varies in depth from 2.7 to 4.0 m AHD, but three of the five points used in estimating residence times and nutrient tracer modelling were in shallow waters at the end of canals. As a result, 60% of the modelled flushing times (Figure 73) are based on the most poorly flushed parts of the marina that represent less than 25% of the volume of marina waters. The assessment of water quality is therefore considered conservative.

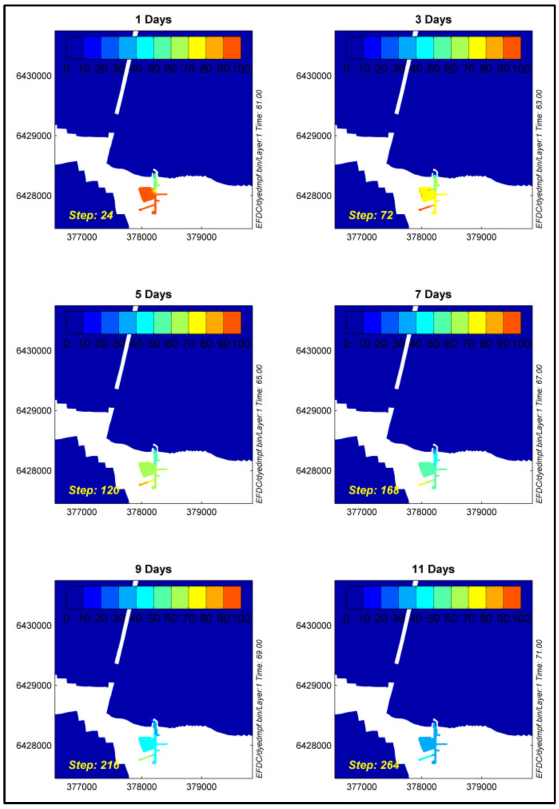
Effects on water quality in Mangles Bay

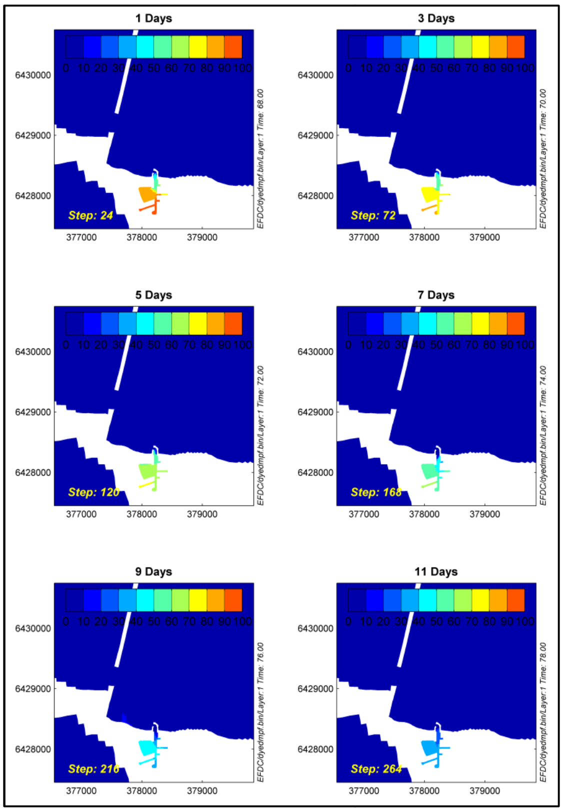
Effects on water quality in Mangles Bay were minor, and - when discernible - were largely confined to shallow nearshore waters west of the access channel (Figure 74 to Figure 76, see also nutrient tracer modelling results below).



Note: Source: APASA

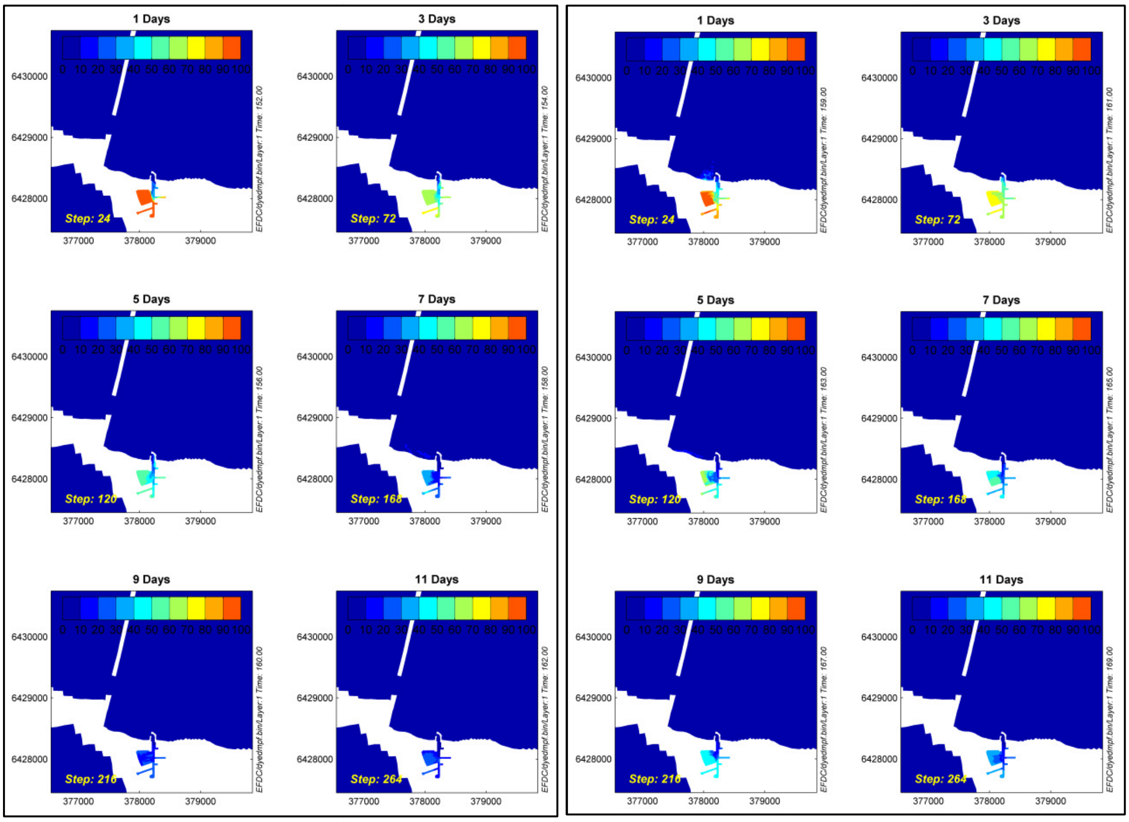
Figure 74 Illustrative snapshots of dye concentrations entering Mangles Bay for modelling scenario 1 (left) and scenario 5 (right) in summer





Note: Source: APASA

Figure 75 Illustrative snapshots of dye concentrations entering Mangles Bay for modelling scenario 1 (left) and scenario 5 (right) in autumn



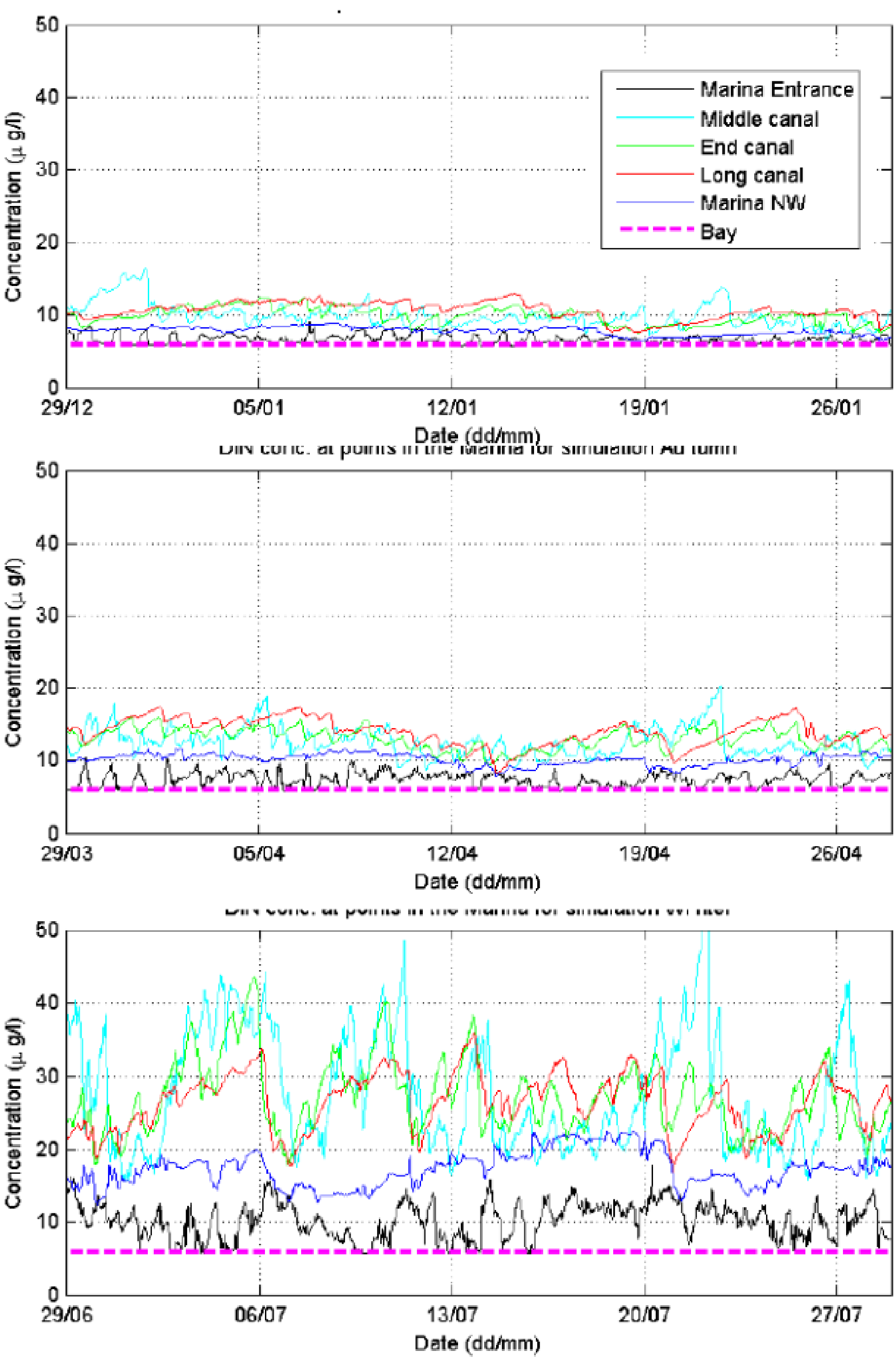
Note: Source: APASA

Figure 76 Illustrative snapshots of dye concentrations entering Mangles Bay for modelling scenario 1 (left) and scenario 5 (right) in winter

Nutrient tracer modelling

Time-series of DIN concentrations at the five output points of the marina (points 5 to 9 on Figure 63) are shown for each of the modelled scenarios over the 30-day analysis period in . There is an overall seasonal variation in the predicted DIN concentrations within the marina, with smaller variations occurring within each season due to the variable flushing rate. As expected, there was a general increase in the predicted DIN concentration at points further away from the entrance, and little discernible effect on water quality at the marine entrance. Importantly, the results also indicated that the flushing should be sufficiently effective to prevent the gradual build-up of the concentrations of nutrients or other contaminants over time. This suggests that the risk of adverse escalations (of nutrients or contaminants) in the marina is relatively low, based on the assumptions made and the input data provided for the modelling. The modelled results do not include inputs due to stormwater discharge, but as discussed in Section 10.5.4, due to stormwater management measures no stormwater runoff is expected under 99% of rainfall events. During large rainfall events it is proposed to discharge stormwater into Mangles Bay through the marina (when it is likely to rapidly exit the marina as a surface freshwater flow), and/or into the realigned Lake Richmond Drain.

During autumn and summer, predicted DIN concentrations in the marina were generally less than twice the background concentration in Mangles Bay. DIN concentrations within the marina were highest in winter (when groundwater DIN loading is highest), with concentrations generally up to four times background concentrations. However the high winter concentrations also coincide with low growth rates for phytoplankton (due to lower temperatures and light availability: Section 10.2.2).



Note: Source: APASA (2011). The background concentration (6 µg/L) is shown by the pink dotted line.

Figure 77 Predicted DIN concentrations at sites within the marina (30 day analysis period) for each season (summer, autumn and winter, arranged vertically from the top)

Increased chlorophyll-a concentrations in marina waters

Predicted increases in chlorophyll-a concentrations from equilibrium (box) modelling are shown in along with a summary of effects on water quality predicted by modelling. Chlorophyll-a concentrations in the marina are predicted to be about twice those of the adjacent waters of Mangles Bay. Data are presented in full in Appendix 5. The relatively modest increase in chlorophyll-a concentrations (e.g. compared to those in water bodies such as the Jervoise Bay Northern Harbour) is attributed to a combination of marina design, the relatively small size and simple configuration of the marina (compared with other marinas in WA), and the small scale of groundwater nutrient inputs.

Table 39 Summary of modelling results for impacts on water quality

Factor	Summer	Autumn	Winter
Average flushing time of marina.	6–8 days	6–8 days	6–8 days
Background chlorophyll-a concentrations Mangles Bay	1.3–2.1 µg/L	1.3–2.1 µg/L	0.6–1.0 µg/L
Estimated average chlorophyll-a concentrations in marina, based on equilibrium (box) modelling.	2.1–3.5 µg/L	2.3–3.7 µg/L	1.5–2.4 µg/L
Contaminant build-up in marina waters.	Not expected. Flushing sufficient to prevent any gradual build-up of the concentrations of dissolved nutrients or other dissolved contaminants over time, and stormwater management measures (refer Section 10.5.4) should ensure little or no inputs of nutrients and contaminants in particulate form.		
Effects on water quality in Mangles Bay.	Marina outflow confined to Mangles Bay. Impacts on water quality due to outflow from marina entrance are occasional, slight (e.g. increases in chlorophyll-a concentrations of 0.1–0.3 µg/L**) and highly localized, extending several 100 metres along shallow nearshore waters towards the Causeway (refer Figure 74 to Figure 76). No significant impact on overall water quality in Mangles Bay.		
Regional effects on water quality in Cockburn Sound.	No significant adverse effect.		
Regional effects on water quality in SIMP.	No significant adverse effect.		

Note: *Using a DIN to chlorophyll conversion ratio of 0.117 in summer and autumn, and 0.0585 in winter.
**Estimated using the predicted chlorophyll-a concentrations in the marina, and the relative impacts on water quality in Mangles Bay shown in Figure 74 to Figure 76.

Consideration of other factors

In addition to flushing times, other important factors determining marina/canal water quality in Western Australia have been found to include:

- trapping of seagrass wrack (e.g. Jurien Boat Harbour and Port Geographe Marina)
- trapping of wind-blown algae and debris (e.g. South Yunderup Canals)
- capture of contaminated groundwater discharge (e.g. Jervoise Bay Northern Harbour, and Hillarys Marina)
- acid sulphate soils (e.g. canals in Mandurah region)
- siltation of entrances
- poor ambient water quality in the environment they were built (e.g. canals on Murray River)
- long-term build up of organic matter (most inland canals).

The Proposal does not involve any of these issues, so the above modelling predictions that are based on flushing times are considered a fair representation of likely water quality.

10.4.3 Impacts due to increased numbers of boats

The Proposal will result in an increased number of boats traversing Mangles Bay and adjacent waters; however this is inevitable with or without the Proposal due to population growth and increased levels of boat ownership in the region (refer Section 16). Water quality impacts due to sediment re-suspension by boating activity will be minimised by provision of well signed access channels with appropriately sign-posted speed limits. The Proposal will also mitigate increased boat traffic impacts as it will help manage the presently uncontrolled movement of boats in Mangles Bay.

The release of hydrocarbons and heavy metals from engine emissions will increase in proportion to boating traffic, but this is expected to be mitigated by management of the presently uncontrolled refuelling activities and sullage disposal in Mangles Bay (via provision of refuelling facilities and sullage pump-out facilities in the marina).

10.5 Potential for and nature of any cumulative impacts

10.5.1 Impacts of turbidity

There will be no cumulative impacts on the marine environment as a result of dredging, as all sediment will be treated and disposed offsite or used onsite for construction where appropriate. Turbidity during breakwater construction and dredging is expected to cause minor, highly localised, and short-term impacts on water quality (and therefore seagrasses) in Mangles Bay. Turbidity generated during construction is not expected to cause any long-term impacts on seagrasses (see also Section 12)

10.5.2 Flushing related impacts

The modelling undertaken for the Proposal indicates chlorophyll levels in the marina will be about twice that of Mangles Bay, but there will be little effect on water quality in Mangles Bay and adjacent waters in Cockburn Sound and the SIMP due to the effects of dilution once the marina waters disperse into Mangles Bay. Modelling further predicts that flushing should be sufficient to prevent any gradual build-up of the concentrations of nutrients or other contaminants over time. Also, with the Proposal, a proportion of groundwater nutrients that presently fuel epiphyte growth on the extensive seagrass meadows of Mangles Bay will instead be taken up by phytoplankton growth in marina waters. Therefore, any slight, localised changes in water quality in Mangles Bay due to outflow of marina waters may be offset by reduced epiphyte growth on seagrass. The seagrasses most likely to be affected by any slight, localised changes in water quality in Mangles Bay are also in extremely shallow waters close to the shore, and therefore much less vulnerable to changes in water quality than seagrass at their depth limit.

The main mechanism for poorer-than-expected water quality will be due to sediment nutrient fluxes being higher than expected. In this case, removal of surficial sediments would be the main management measure, and would comprise part of the operational management plan (Section 10.6.2).

10.5.3 Impacts due to increased numbers of boats

The Proposal is not expected to cause significant cumulative impacts on contaminant-related water quality in Mangles Bay and adjacent waters. Although boat numbers in the area will increase these will be located in the marina, and any contaminants will tend to accumulate in marina sediments rather than Mangles Bay or adjacent waters. The potential for contamination of marina sediments can be gauged by the Swan River Trust's sediment quality data for nine yacht clubs/marinas in the Swan River (Oceanica 2007b; see also *http://www.swanrivertrust.wa.gov.au/science/river/Documents/Sediment%20Mussel%20Report.pdf*), which are arguably more sheltered and less well flushed with marine waters than the proposed Mangles Bay marina. These data indicate that although some elevation of copper and zinc concentrations can be expected in sediments within the marina, concentrations of metals (arsenic, arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc) should meet relevant EQGs. Swan River data for tributyltin (Oceanica 2007b) do, however, indicate consistent exceedance of the EQG, but it was not clear whether this was due to historic or recent contamination. As the proposed Mangles Bay marina will start with uncontaminated sediments (i.e. no legacy of historical contamination) and boats moored there should not be using tributyltin as an antifoulant, the potential for contamination is considered low: this is supported by the Mangles Bay sediment data in Table 36 and Table 37. The potential for contamination of sediments with polycyclic aromatic hydrocarbons is also considered low as EQGs are rarely exceeded in local coastal and estuarine waters, even in sheltered estuarine waters adjacent to major urban drains (DoW 2009).

The Proposal also provides opportunities for water quality benefits via the relocation of boats presently moored in Mangles Bay, the conversion to sewerage of properties presently still on septic tanks, and improved capabilities (such as appropriate management of stormwater runoff) to manage boat hardstand activities.

10.5.4 Impacts due to stormwater discharge

Available information indicates stormwater discharging into Mangles Bay contains appreciable quantities of nutrients (mostly in particulate rather than dissolved forms), some metals and (excluding the Lake Richmond Drain) faecal bacteria, but little hydrocarbons, pesticides or herbicides (Section 10.2.1). The Lake Richmond Drain is the largest contributor of stormwater to Mangles Bay due to its large urban catchment, estimated to outweigh the contribution of the minor urban drains by one to two orders of magnitude (Section 10.2.1).

The Proposal involves the urban development of approximately 50 ha of land, and urbanisation will potentially result in an increase in the quantity and decrease in the quality of stormwater runoff from this area. This will be mitigated by the use of Best Management Practices for stormwater in the Proposal area, and the relocation of the Lake Richmond stormwater drain to better flushed waters further east (at Hymus Street, which will reduce stormwater inputs of nutrients and contaminants to Mangles Bay.

In small rainfall events (i.e. less than the 1 in 1 year event), stormwater from roads within the Proposal area will be infiltrated through the use of Best Management Practices such as soakwells, swales and/or underground infiltration cells (refer Section 7.4.3). Rainfall on future residential lots will be managed through the use of soakwells and/or rainwater tanks in smaller rainfall events with the potential for overflow to the road drainage system in larger events (refer Section 7.4.3). Vegetated detention areas and gross pollutant traps will be used to treat stormwater to reduce nutrient and contaminant concentrations, prior to infiltration or discharge. The small rainfall events (less than the 1 in 1 year events) constitute 99% of the volume of rainfall (DoW 2004-2007). Options for stormwater management in larger events may include discharge into Mangles Bay through the marina (as currently occurs at Port Bouvard and Mandurah Ocean Marina), discharge into the realigned Lake Richmond Outlet Drain, or a combination of these options. The design will be outlined in the Low Water Management Strategy that will accompany the Local Structure Plan, as required by *Better Urban Water Management* (WAPC and DPI 2008) (refer Section 7.4.3).

Estimates of contaminant loads to Mangles Bay from stormwater from the Proposal area during large rainfall events (representing 1% of annual rainfall) are compared to other estimates of stormwater contaminant loads to Mangles Bay in Table 40. The added contaminant loads due to the Proposal are minor compared to existing loads, and will be mitigated by the relocation of discharge from Lake Richmond Drain to Hymus Street, where waters are less sheltered and greater dilution of contaminants should occur.

Table 40 Approximate loads of contaminants in stormwater entering Mangles Bay

Contaminant	Lake Richmond Drain*	Minor drains**	Total load without marina	Additional load due to marina***
Total nitrogen	122–8,300 kg	12–830 kg	134-9,130 kg	1.25 kg
Total phosphorus	n/a	n/a	n/a	0.21 kg
Copper	32 kg	3.2 kg	35.2 kg	0.042 kg
Lead	98 kg	9.8 kg	107.8 kg	0.004 kg
Zinc	104 kg	10.4 kg	114.4 kg	0.146 kg

* Refer to Section 10.2.1. Lower end of range for TN is for 2002 and is more representative of lower rainfall years. Metal loads are probably overestimates as they are for higher rainfall years.
** Estimated as an order of magnitude lower than loads from the Lake Richmond Drain, refer to Section 10.2.1
***Based on DoW (2007) data for minor drains in

Table 27, Representative contaminant concentrations used were 0.3 mg/L TN, 0.05 mg/L TP, 0.010 mg/L copper, 0.001 mg/L lead and 0.035 mg/L zinc. Calculations were based on runoff from a land area of 49 ha, for large rainfall events representing 1% of an annual rainfall of 850 mm.

10.6 Management measures and performance standards

10.6.1 Construction

Breakwater construction and dredging of the Proposal area access channel are expected to be the main causes of turbidity during construction, and have the potential to cause localised, minor, short-term impacts on water quality (and therefore seagrasses) in Mangles Bay. Construction activities are not expected to cause any long-term impacts on seagrasses, as the predicted turbidity is minimal. The seagrasses on the shallows of Mangles Bay have also survived much longer construction activities (i.e. construction of the Garden Island Causeway) during periods of far worse water quality (1971–1973). However, all construction activities will be managed under a comprehensive CEMP that includes:

- baseline monitoring of water quality and seagrass health at sites agreed to by the Proponent, DEC and CSMC
- ongoing monitoring of water quality and seagrass health at sites agreed to by the Proponent, DEC and CSMC
- agreed reporting requirements, management triggers for water quality and seagrass health, and required actions if management triggers are exceeded (such as the deployment of silt curtain, temporary cessation of construction activities)
- post-construction monitoring of seagrass health.

It is also proposed to include monitoring of water and sediments in the infiltration ponds used for temporary storage of dredged material, to confirm predictions that overall concentrations of contaminants (especially TBT) meet relevant EQG.

The protocols used to derive the EQGs and EQSs of the Cockburn Sound SEP (Mangles Bay is within the high protection zone) will provide the basis to assess construction impacts on water quality in Cockburn Sound. There are no formal criteria or targets presently defined for the SIMP, but if Cockburn Sound EQC are met in Mangles Bay during construction, marine park values should also be protected.

10.6.2 Operational impacts

With respect to the Cockburn Sound SEP's EQO of Maintenance of Ecosystem Integrity, the shallow waters of Mangles Bay presently:

- 'exceed' the nutrient-related water quality EQG for high ecological protection and moderate ecological protection, as do many other sites in southern end of Cockburn Sound (refer Section 10.2.2, noting that comparison with these EQG is for information only, as they are not meant to apply to individual sites)
- exceed the site-based phytoplankton biomass EQG and EQS for high ecological protection and the EQG for moderate protection, but not the EQS for moderate protection (refer Section 10.2.2).
- meet nutrient-related EQS for seagrass health for high ecological protection at most sites, but not all, and moderate ecological protection at all sites monitored adjacent to the Proposal Section 12)
- meet EQGs for contaminants in sediments at sites adjacent to the Proposal (Section 10.2.4).

With respect to the EQO of Maintenance of Primary Contact Recreation Values (such that primary contact recreation [such as swimming] is safe), the waters of Mangles Bay adjacent to the Proposal area also meet relevant EQG for faecal bacteria (refer Figure 58).

It is proposed that the ongoing (operational) effects of the Proposal on the marine waters of Cockburn Sound be assessed in terms of the above EQC, with the objective of ensuring that the existing level of compliance is maintained. It is anticipated that the marine waters between the breakwaters (an area about 50 m by 180 m; refer Figure 7) will be zoned for moderate ecological protection, and relevant EVs and EQOs will apply: spatial patterns of water quality in the marina indicate water quality in this area should be little different to Mangles Bay (e.g.) and therefore that it should meet the site-based EQG and EQS for phytoplankton biomass, excluding atypical years such as 2010/2011 (when water quality in Mangles Bay did not meet the EQG). In addition, relevant EQC for the EQO of Maintenance of Aesthetic Values should be met in Mangles Bay.

The majority of marina waters (i.e. excluding the small area between the breakwaters) should comply with WAPC Policy No. DC1.8 general aesthetic guidelines, which require artificial waterways to be:

- free from substances which will settle to form putrescent or otherwise objectionable sludge deposits
- free from floating debris, oil, grease, scum, foam and other floating materials in amounts sufficient to be unsightly or otherwise objectionable
- free from materials which will produce colour, odour, turbidity, or other conditions to such a degree as to be unsightly or otherwise objectionable.

Marina activities will need to be managed under an Operational Management Plan that includes:

- a fuel spill management plan
- maintenance and management plan for marina facilities (including maintenance dredging and – if required - removal of subtidal wrack, or nutrient-rich surficial sediments))
- codes of conduct for, and surveillance of, users of the marina (including sullage management)
- ongoing monitoring of water quality and sediment quality within the marina, and water quality, sediment quality and seagrass health at agreed sites in Mangles Bay.

As with construction-related impacts, if relevant EQC are met in Mangles Bay, the values of the adjacent waters of SIMP should also be protected.

10.7 Predicted environmental outcomes against environmental objectives, policies, guidelines, standards and procedures

Construction of the Proposal will generate some turbidity, mainly during dredging of the marina access channel; however modelling predictions indicate it will cause only minor, highly localised, and short-term impacts on water quality in Mangles Bay. This is attributed to the short duration of the dredging program, the low proportion of fine particles in the material to be dredged, and the relatively clean dredging method (a small cutter suction dredge). Dredging will also be timed to minimise potential impacts on marine biota (refer Section 12 and 13). No adverse effects expected due to contaminant release during dredging and disposal, as contaminant levels in the sediments to be dredged meet all relevant ecological and human health guidelines.

Marinas are, by necessity, calm, sheltered environments, and therefore are less well flushed than adjacent waters. Any marina will have lesser water quality than its adjacent waters: Perth's existing ocean marinas typically have chlorophyll levels 1.5 to 4 times higher than adjacent waters (Bowman Bishaw Gorham 2001). The Proposal's marina has been designed to maximise the natural flushing of inner marina waters by wind and tide, and modelling indicates chlorophyll levels in the marina will be about twice that of Mangles Bay, with little effect on water quality in Mangles Bay and adjacent waters (Cockburn Sound and the SIMP). This relatively modest increase in chlorophyll-a concentrations is attributed to a combination of marina design, the relatively small size and simple configuration of the marina (compared with other marinas in WA), and the small scale of groundwater nutrient inputs. Nor does the Proposal have any of the associated problems of some other marinas in WA, such as extensive areas of seagrass wrack (such as at Jurien Boat Harbour and Port Geographe Marina), trapping of wind-blown algae and debris (such as at South Yunderup Canals) or acid sulphate soils (such as in canals in the Mandurah region). Modelling further predicts that flushing should be sufficient to prevent any gradual build-up of the concentrations of nutrients or other contaminants over time.

The Proposal may also result in impacts on marine water quality with increased recreational boat activity resulting in sediment re-suspension, inputs of metals and hydrocarbons from engine emissions, antifoulants, fuel spills and sullage disposal. The increase in boat activity will be minor in comparison to increases that will occur anyway due to increases in population and the level of boat ownership in the region (refer Section 16), but can be managed by:

- provision of better management and facilities (recreational boating activity is largely unregulated at present)
- use of 'best practice' measures and strict regulations for the Proposal, to ensure minimal inputs of contaminants to the marine environment
- provision of well marked access channels with appropriately sign-posted speed limits, to reduce sediment re-suspension by boating activity. The Proposal will also mitigate impacts due to increased boat traffic as it will help manage the presently uncontrolled movement of boats in Mangles Bay
- management of the presently uncontrolled refuelling activities and sullage disposal in Mangles Bay via provision of refuelling facilities and sullage pump out facilities in the marina
- opportunities for water quality benefits via the relocation of some boats presently moored in Mangles Bay, the conversion to sewerage of properties presently still on septic tanks, improved capabilities (such as appropriate management of stormwater runoff) to manage boat hardstand activities, and better management of stormwater drains entering Mangles Bay, including the Proposal's relocation of the Lake Richmond stormwater drain further east.

With the above mitigation measures, it is considered that the Proposal meets EPA objectives and SIMP objectives for marine water quality and sediment quality. It is acknowledged the shallow waters of Mangles Bay presently do not meet phytoplankton biomass EQG and EQS for high ecological protection, and only met the moderate protection EQG in 2009/10 but not in 2010/11: the latter exceedance is, however, considered to be due to an atypically hot summer. EQC for seagrass health for high ecological protection were met at three of the four sites monitored in the shallow waters of Mangles Bay, and sediment quality EQC were met at all sites monitored. The Department of Health's data also indicate recreational EQC (faecal bacteria) are met. It is considered that the Proposal will not result in any significant lessening of water quality in Mangles Bay, and that EQC for those environmental indicators that are presently met will continue to be met. The marine waters between the Proposal's breakwaters are expected to be zoned for moderate ecological protection, and should meet the EQG and EQS for phytoplankton biomass, excluding atypical years such as 2010/2011 (when water quality in Mangles Bay did not meet the EQG). The majority of marina waters (i.e. excluding the small area between the breakwaters) should also meet WAPC Policy No. DC1.8 guidelines for artificial waterways.

11. Coastal processes impact assessment

11.1 Relevant environmental objectives, policies, guidelines, standards and procedures

11.1.1 EPA objectives

The EPA objective for the marine environment is:

To maintain the integrity, ecological functions and environmental values of the seabed and coast.

11.1.2 Legislation, policy and guidance

Planning and Development Act 2005

The *Planning and Development Act 2005* (PD Act) provides for a system of land use planning and development in the State and for related purposes.

The purposes of the PD Act are:

- consolidate the provisions of the Acts repealed by the *Planning and Development (Consequential and Transitional Provisions) Act 2005* (the *Metropolitan Region Town Planning Scheme Act* (1959) , the *Town Planning and Development Act* (1928) and the *Western Australian Planning Commission Act* (1985) in a rewritten form
- provide for an efficient and effective land use planning system in the State
- promote the sustainable use and development of land in the State.

Under section 5AA of the repealed *Town Planning and Development Act (1928*), the Commission is authorised to prepare State Planning Policies with the approval or direction of the Minister. Section 25 of the PD Act provides that any statement of planning policy in force under the *Town Planning and Development Act (1928)* continues in force as a State Planning Policy under the new act (PD Act). The preparation of State Planning Policies is to have regard for the following:

- demographic, social and economic factors and influences
- conservation of natural or cultural resources for social, economic, environmental, ecological and scientific purposes
- characteristics of land
- characteristics and disposition of land use
- amenity, design and environment
- communications
- developmental requirements of public authorities.

Government and industry guidelines

Western Australian Planning Commission (WAPC) guidelines require development of coastal facilities to take into account coastal processes including erosion, accretion, storm surge, tides, wave conditions, sea level change and biophysical criteria to ensure sustainable use of coastal areas for maritime industry, commercial and other activities. The two overarching WAPC policies are outlined below.

Statement of Planning Policy No. 2.6 State Coastal Planning Policy

Statement of Planning Policy No. 2.6: State Coastal Planning Policy (SPP2.6) was developed under section 5AA of the *Town Planning and Development Act* (1928) (WAPC 2006). The policy applies to the coast throughout Western Australia with the objectives to:

- protect, conserve and enhance coastal values, particularly in areas of landscape, nature conservation, indigenous and cultural significance
- provide for public foreshore areas and access to these on the coast
- ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities
- ensure that the location of coastal facilities and development takes into account coastal processes including erosion, accretion, storm surge, tides, wave conditions, sea level change and biophysical criteria.

SPP2.6 outlines the requirements in terms of the application of coastal foreshore reserves and development setbacks for physical processes. Coastal setbacks refer to the distance required between development and specific coast features to provide for the protection of both physical and ecological factors.

The setback requirements for developments that benefit from the protection of existing formal coastal protection systems will be determined on a case by case basis, with any coastal processes setback distance taking into account the nature of the structure(s) in question.

Coastal development in Mangles Bay may take existing setbacks and adaptive management strategies into account when determining an acceptable coastal protection strategy for the proposed area. The coastal environment in the Proposal area is already cleared and modified with seawalls and jetty structures.

The consideration of SPP2.6 in the Proposal is discussed further in Section 11.5.2.

Sea Level Change in Western Australia – Application to Coastal Planning

In recognition of nationally accepted and adopted increases in sea level rise projections, the WAPC considered it necessary to amend the sea level rise value in SPP2.6. These amendments are discussed in the DoT publication *Sea Level Change in Western Australia – Application to Coastal Planning* (DoT 2010), for which the key outcomes are:

- a vertical sea level rise of 0.9 m is adopted when considering the setback distance to allow for the impact of coastal processes over a 100 year planning timeframe (2010 to 2110)
- for planning timeframes beyond 100 years, a vertical sea level rise of 0.01 m/year is added to 0.9 for every year beyond 2110.Findings of surveys and investigations

In order to identify the existing coastal processes surrounding Mangles Bay and the potential for impacts to these processes by the Proposal, the Proponent commissioned a coastal processes assessment. The coastal processes assessment was conducted by JFA (2011) and incorporated the following approach:

- preliminary desktop review of the regional geomorphology, metocean and synoptic setting and historical shoreline movement
- wave modelling to define the annual nearshore wave conditions
- investigation of sediment transport processes utilising annual wave modelling results
- analysis of historical shoreline movements
- determination of post construction equilibrium beach shapes and identification of areas of erosion and accretion utilising modelled nearshore wave conditions.

The coastal processes assessment recommended strategies to appropriately manage the beaches within the Proposal area in order to minimise impacts and maintain stability. Unless otherwise specified, the following description of the coastal processes of the Proposal area has been adapted from the Mangles Bay Marina Based Tourism Precinct Project Coastal Processes Assessment (JFA 2011) (provided in Appendix 5).

11.1.3 Regional coastal setting

Cockburn Sound comprises a large basin area confined by shallow banks to the north and south (Figure 78). The broad and relatively deep central basin, which gently slopes to a maximum depth of 22 m, is flanked by the relatively steep slopes of the surrounding banks, shoals and shoreline to the north, south and Garden Island to the West, and a lower gradient bank to the East (Geoscience Australia 2005a). The shallow sheltered waters of Cockburn Sound (and Mangles Bay) support extensive seagrass meadows and a wide range of marine fauna (Strategen 2010).

Stratigraphic studies have identified that Cockburn Sound consists primarily of marine carbonate muddy sediment over the clay soil deposited prior to the Holocene sea level rise (Geoscience Australia 2005a). Sampling conducted in 2004 identified that the sediments of Cockburn Sound are primarily biogenic carbonates (Table 41).

Table 41 Summary of Cockburn Sound sediment (adapted from Geoscience Australia 2005a)

Area within Sound	Approximate depth	Sediment description
Central basin	15 – 20 m	Sandy mud and mud
Marginal banks	2 – 10 m	Carbonate sand
Eastern nearshore zone	-	Mixed carbonate and quartz sand

Cockburn Sound is bound to the west by Garden Island and to the north by Parmelia Bank (Figure 78). These formations result in the sound being relatively sheltered from swell energy. Limited swell does penetrate through from the northern entrance to the Sound. The local seas are dependent on wind conditions and basin dimensions. In the southern portion of Cockburn Sound, the locally generated seas have been found to come from the south or south west in summer, and from the west to northwest in winter.

The coast, where the Proposal is located, experiences diurnal microtidal conditions, with a maximum spring tidal range of 0.6 m. At Fremantle, approximately 25 km north of the Proposal area, the average high and low water levels recorded are 0.97 m and 0.5 m respectively (JFA 2011). Studies of extreme water levels at Fremantle have estimated the 1 in100 year peak tide level at 2 m, and a 1 in 10 year high water level of approximately 1.8 m (JFA 2011). Due to the proximity to the Proposal area, these values have been used to develop the models for the coastal processes assessment.

Source: Imagery supplied by Landgate (2010)
Coordinate System: MGA94 Zone 50
Date: 8/2/2012
NB: Potential errors may occur in some areas

STRATEGEN environmental consultants

Drawn: CAD Resources

CAD Resources File No: g1937_MB_PER_F026.dgn

Cockburn Sound

Figure No: 78

11.1.4 Geomorphology of the Proposal area

Mangles Bay, located in the southern end of Cockburn Sound, contains a series of narrow beaches dropping to large subtidal platforms populated by seagrass. The Mangles Bay foreshore currently comprises of sandy beach backed by low dunes and is presently backed by storage facilities for the local yacht club. It is reported that the beaches in this sector are not popular swimming beaches and are mainly used for transiting along by walking and for the launching of boats (Strategen 2011).

The beaches at Mangles Bay have been identified as low energy beaches. The defining characteristics of low energy beaches which can be seen at Mangles Bay include:

- minimal non-storm significant wave heights
- low significant wave heights during strong onshore winds
- narrow beachface widths in microtidal environments
- morphological features defined by higher energy events.

A classification system has been developed for low energy beaches at Cockburn Sound, which are classified in four different categories; Exponential, Segmented, Concave-Curvilinear and Convex-Curvilinear (Travers 2007). The beaches at Mangles Bay display characteristics of the exponential classification, including:

- concave upper beach
- long, flat, sub tidal terrace
- fine grained sediment.

Low energy and exponential beaches occur at sites sheltered from the effects of ocean waves. At Mangles Bay the beaches are sheltered primarily by the man-made Garden Island Causeway.

In the case of low energy beach environments, morphological change (changes to the physical characteristics of the beach profile) are primarily driven by high energy, low frequency storm events. At Mangles Bay sediment transport is restricted to movement between the upper and lower foreshore. This is caused by changes in the energy of locally generated waves due to variations in wind speeds. Sediment transport in the Proposal area is discussed further in Section 11.1.6.

11.1.5 Wave climate of Proposal area

The wave characteristics of low energy environments are typically a mixture of local and non local wave regimes. Locally generated waves are usually found within areas where the wave energy is limited by the size of the wave generation area (fetch limited), such as enclosed basins. Non-locally generated waves are characteristic of sheltered environments in the lee of islands, behind submerged barriers or near entrances to larger external basins. Wave modelling at Mangles Bay and Cockburn Sound indicates that a mix of both regimes exist within the Proposal area.

Offshore waves

In order to develop an understanding of the offshore wave climate surrounding the Proposal area, wave modelling was conducted utilising data from Department of Transport (DoT) monitoring buoys at Rottnest, Owen Anchorage and Cottesloe.

The modelling identified three predominant swell wave conditions with incident wave directions of 225 degrees (south southwest), 255 degrees (south west) and 285 degrees (west northwest); swell from the south south-west and south west directions; and storm event waves from the northwest. The entrance to Cockburn Sound between Garden Island and Cape Peron is constricted by the Garden Island Causeway resulting in two smaller openings, north and south of the Causeway. Swell waves are able to penetrate into Cockburn Sound through both entrances. The approaches of the predominant offshore waves is summarised in Table 42.

Table 42 Predominant wave patterns at the Proposal area

Source – direction	Predominance	Entrance to Cockburn Sound	Wave approach to Proposal area
Offshore swell – South southwest (225 degrees)	5%	Southern causeway	Southerly
		Northern causeway	Southerly
Offshore swell – Southwest (255 degrees)	75%	Southern causeway	Northerly and north easterly
		Northern causeway	Northerly and north easterly
Storm event – West northwest (285 degrees	20%	Southern causeway	Southerly
		Northern causeway	Southerly

Incident south south westerly waves

South south westerly incident swell waves (225 degrees) make up approximately 5% of the swell waves approaching Cockburn Sound. As these swell waves reach Cape Peron a proportion of the waves diffract over the headland (south of the Causeway), gradually changing direction and decreasing in wave height until they approach the Proposal area in a southerly direction (Figure 79). A second set of waves diffract over the northern tip of the Garden Island Causeway consequently resulting in southerly waves with lower wave heights approaching the site.

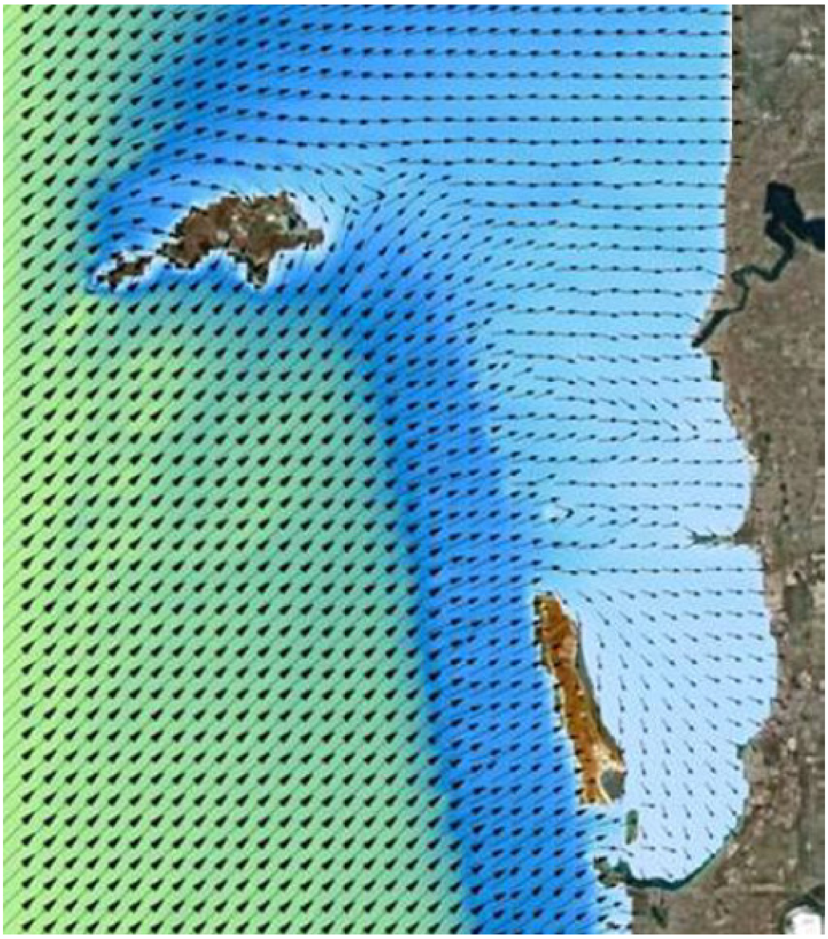


Figure 79 Incident south southwest swell waves

Incident south westerly waves

Modelling has identified that the dominant offshore swell wave condition surrounding Cockburn Sound has an incident wave direction of 255 degrees (south westerly). As these offshore swell waves approach Cockburn Sound and refract along the shallow regions of the Rottnest Shelf and surrounding reefs, they gradually change to a westerly direction as they approach Cockburn Sound (Figure 80).

The presence of the Garden Island Causeway greatly restricts swell wave penetration into Cockburn Sound. However, swell waves are able to penetrate into Cockburn Sound from two entrances referred to previously (the southern and northern ends of the Causeway). Through the southern entrance, waves diffract around the Cape Peron headland resulting in lower wave heights and north to north easterly wave directions. Through the north entrance, waves diffract around the northern tip of the Causeway, again resulting in northerly to north easterly waves.

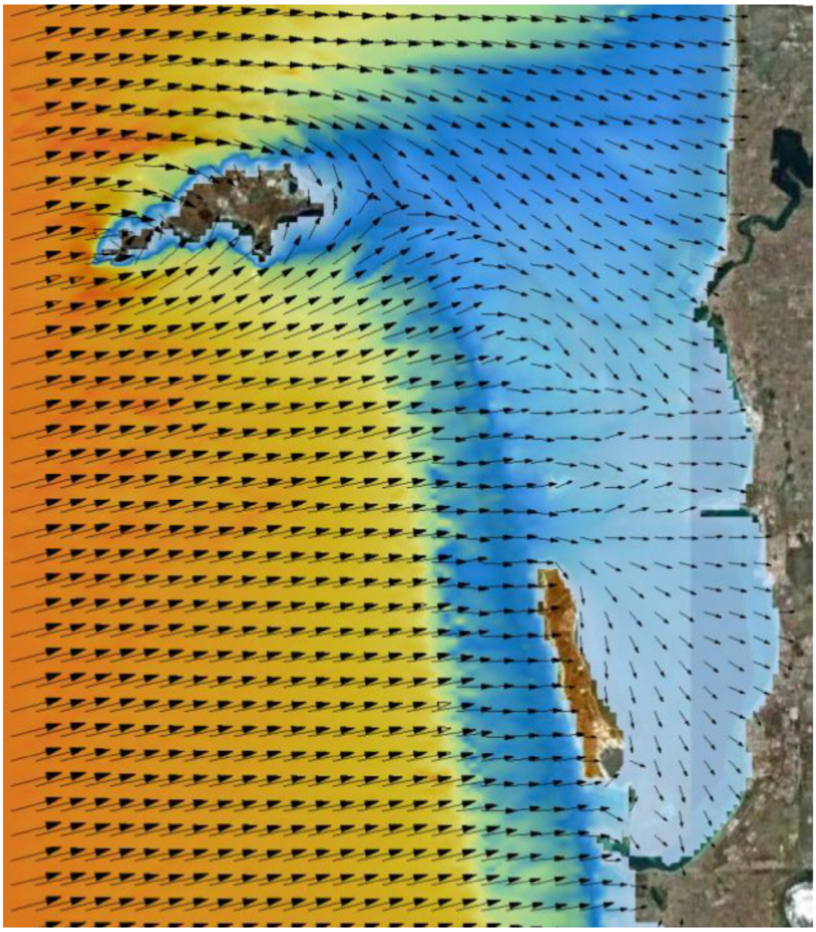


Figure 80 Incident SW swell waves

Incident west north westerly waves (Storm event waves)

As storm generated incident waves approach Cockburn Sound from a west north westerly direction they decrease in wave height as they travel nearshore, diffract around the Garden Island Causeway and travel south into Cockburn Sound (Figure 81). Waves which have refracted into the Garden Island entrance diffract around Cape Peron, and continue to refract until they are almost perpendicular to the shoreline at Mangles Bay.

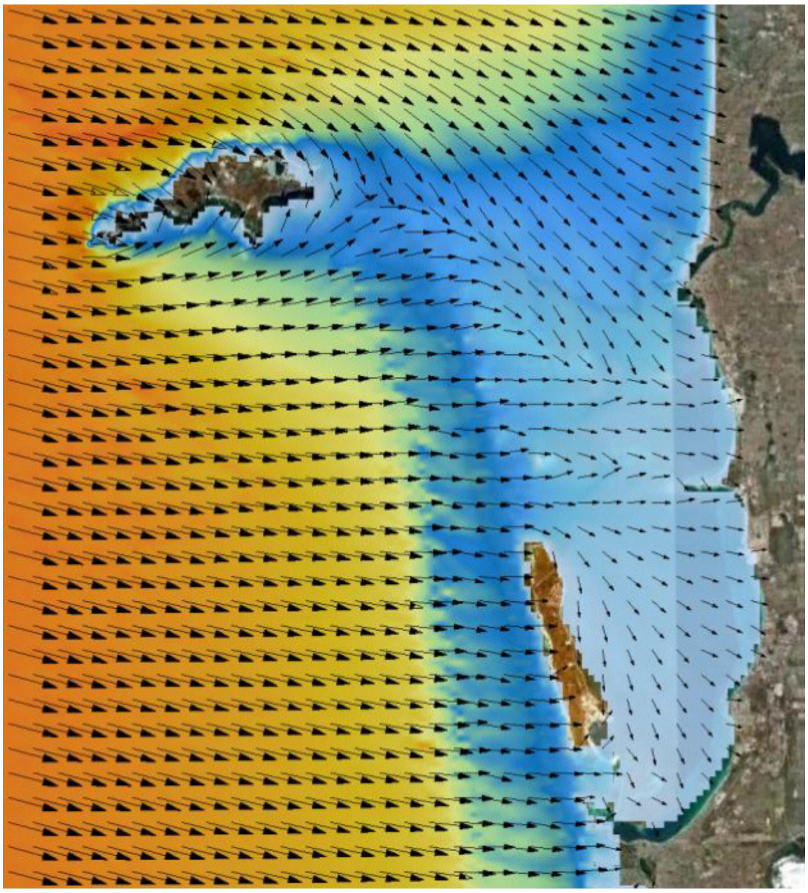


Figure 81 Incident west northwest swell waves

Locally generated waves

In addition to offshore swell and storm waves, the seas at Mangles Bay also have a locally generated component. Located in the southern end of Cockburn Sound, the locally generated waves come from the long fetches to the north northeast and are driven by strong northerly winds.

11.1.6 Sediment transport and morphological change

Sediment in Cockburn Sound is transported southwards along the eastern edge, driven by oblique waves arriving at the shoreline (DoT 2009). Mangles Bay is located in the 'Rockingham sedimentary sub-cell' of Cockburn Sound, bounded by Cape Peron to the southwest and Woodman Point to the north.

Coastal structures

A number of shoreline structures have been constructed in the vicinity of the Proposal area since 1971, the most significant of which is the Garden Island Causeway. Prior to the construction of the Garden Island Causeway, sediment was transported east into Mangles Bay. Since the causeway was constructed (1971 – 1973) sediment has built up on the west side of the groyne and in the Cape Peron Boat Harbour sand trap. Since the construction of the causeway a number of coastal protection measures have been installed along Mangles Bay including:

- original sand trap groyne west of Causeway (1973)
- 90° extension to sand trap groyne (1986)
- spur added to sand trap groyne (1990)
- DEC sea wall (late 1980)
- Hymus St Groyne (post causeway)
- Fishing Club seawall and ramp (post causeway)
- Palm Beach groynes (post causeway).

The construction of the causeway interrupted sand supply from the west, resulting in the beaches of Mangles Bay becoming primarily erosive (losing sediment). However analysis of historical movement patterns indicates that most of the beaches had relatively stabilised by 1988.

Sediment transport trends

To assess the sediment transport at Mangles Bay, the beaches can be divided into four distinct segments, called compartments, based on differences in beach orientation (Figure 82). The variation in orientation between these segments is a function of swell wave patterns and the influence of the physical structures listed above. The historical trends in morphology of the four Mangles Bay compartments were indentified through a comparison between the 1988 and 2010 vegetation lines (Figure 83 to Figure 85).

Figure 82 Mangles Bay beach compartments

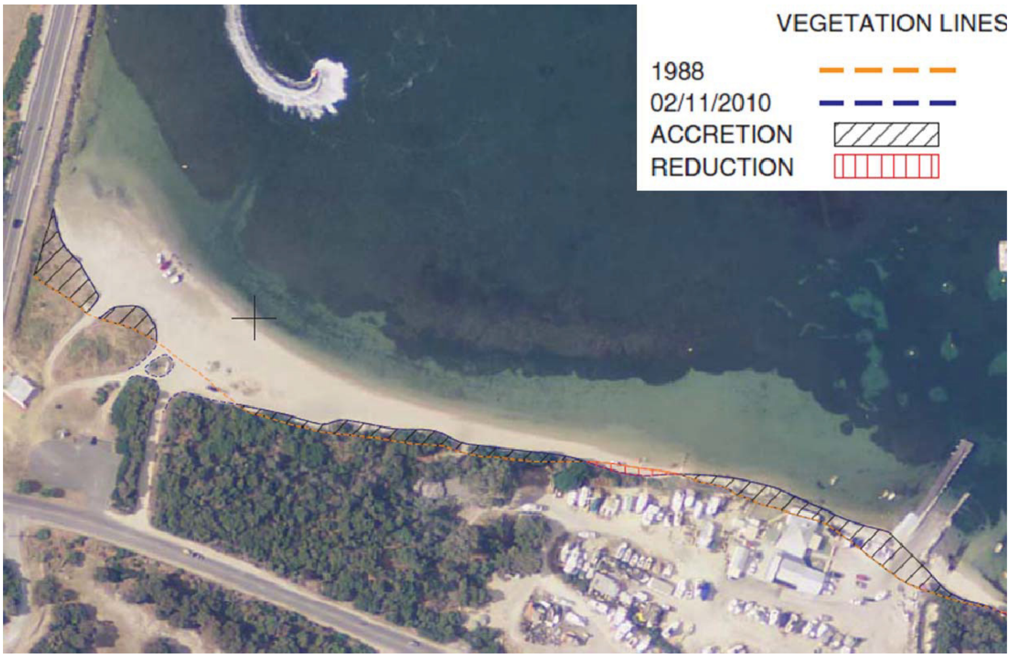


Figure 83 Vegetation line changes at Compartment 1

Figure 84 Vegetation line changes at Compartments 2 and 3

Figure 85 Vegetation line changes at Compartment 4

In addition to an assessment of historical trends, sediment transport calculations were conducted on each beach compartment, based on the height and period of the incident wave, the beach grain size, the angle of wave propagation and the slope of the seabed. The results of these calculations indicated that the annual swell wave energy is the primary determining factor of sediment transport within Mangles Bay.

Historical shoreline movement and present day morphology differs between each segment as sediment transport is influenced by the structures (Table 43).

Table 43 Sediment transport and beach morphology at Mangles Bay (adapted from JFA 2011)

Beach Section	Historical trend (1988 – 2010)	Sediment transport trend
Compartment 1	Considerable accretion immediately adjacent to the causeway and existing boat ramp.	Potential sediment transport is towards the east. Beach orientation is stable.
Compartment 2	Consistent accretion at a relatively small accretion rate. Erosion west of Hymus St groyne due to diffraction of dominant swells around the headland. Ongoing sand renourishment is being implemented.	Potential sediment transport is towards the east. Beach orientation is stable. Expected accretion between each end.
Compartment 3		Potential sediment transport is towards the west from the groyne at Hymus Street. Transitional orientation.
Compartment 4	Orientations were rotated following installation of groynes, aligning with the dominant swell direction. Substantial accretion.	Potential sediment transport is towards the west. Beach orientation is stable.

The existing beach orientations at Compartments 1, 2 and 4 are considered to be relatively stable (JFA 2011). The existing orientation of the beach in Compartment 3 has been stabilised with the seawall at the end of the Hymus Street and the nearby groyne which acts as a headland. This beach is in transition between the alignments at Compartment 2 and 4, influenced by sand renourishment activities and the presence of the Hymus Street Groyne (JFA 2011).

In summary, the existing beaches at Mangles Bay have been characterised as low energy beaches with little sediment supply. Sediment exchange is limited to the region between the upper swash and subtidal terrace (as indicated by the edge of the seagrass). There is very little or no longshore sediment transport within the Proposal area region and beach alignments have been identified as stable. Additionally, the coastline spanning the Proposal area is currently divided into distinct sub compartments by existing coastal structures.

11.1.7 Climate change

Global sea level rise

Studies have established that the global sea level has risen over the past two centuries, with an increasing rate of rise seen in recent times (DoT 2010). Sea level rise is in part comprised of short-term fluctuations caused by seasonal variations, astronomical tides, storm surges and El Nino-Southern Oscillation (ENSO) events. Table 44 outlines the influence these processes have on sea level variability along the WA coastline.

Table 44 Major processes influencing sea level variability along the southwest WA coastline (Pattaratchi & Eliot 2005)

Time scale	Dominant Processes	Maximum range
12-24 hours	Astronomical tide	0.8 m
1-10 days	Storm surge	0.8 m
Seasonal	Leeuwin Current	0.3 m
Inter-annual	ENSO	0.3 m

The other contribution to sea level rise is driven by climate change, the alteration to global climate patterns attributed to the increase in greenhouse gas emissions into the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) provides projections for sea level change based on future emission scenarios. Their projections for sea level rise are made up of thermal expansion and melt waters from glaciers, ice caps, the Greenland Ice Sheet and the Antarctic Ice Sheet (DoT 2010). The long-term estimates for global average sea level rise are between 1.5 – 3.5 m by 2200, and between 2.5 – 5.1 m by 2300 (DoT 2010).

Regional sea level rise

As sea level change is not likely to be uniform across the globe, CSIRO (2007) used the results of the IPCC modelling for Australia to investigate regional diversions to global projections. This investigation identified that the average sea level rise estimated for Australia is close to the global averages. Based on a review of these studies, DoT (2010) made recommendations which were subsequently incorporated into *State Planning Policy 2.6 State Coastal Planning Policy Schedule 1 Sea Level Rise* (refer to Section 11.1.2) (WAPC 2006).

A rise in sea levels has implications for coastal development and considerations must be made with regards to setback distances and the implementation of coastal defence structures. These steps are discussed further in Sections 11.5.1 and 11.5.2.

11.2 Evaluation of options or alternatives to avoid or minimise impact

There are a number of coastal defence options available, with both hard and soft engineering measures to provide a range in protection and beach amenity. The five options considered for beach management for the Proposal include:

1. Groynes.
2. Seawalls.
3. Sills.
4. Detached Breakwaters.
5. Beach Nourishment.

Of these options outlined above, the use of groynes, seawalls and beach nourishment measures have been selected as appropriate management measures for the Proposal.

11.3 Assessment of likely direct and indirect impacts

The following aspects of the Proposal may potentially impact on coastal processes:

- construction of the marina entrance breakwater and channel which may interrupt longshore sediment transport
- construction of the breakwaters may result in the accumulation of seagrass wrack against the structure.

In addition to consideration of the potential impacts of the Proposal on coastal processes, the effects of sea level rise and processes on coastal infrastructure need to be considered in the design of coastal structures.

11.3.1 Longshore sediment transport

The proposed development lies in between compartments 2 and 3 of the Mangles Bay beaches (Figure 82). Construction of structures along the shoreline has the potential to change incident wave height, directions and sediment transport regimes. Changes to incident wave characteristics will result in a reorientation of the beach face until it reaches a new equilibrium. JFA (2011) modelled the potential changes to beach orientation at Mangles Bay as a result of the installation of the Proposal's breakwaters.

The construction of the marina entrance breakwaters will change the incident ambient wave pattern west of the proposed development. Waves arriving from the dominant northerly wave direction will diffract around the western breakwater head, creating a gradient in wave height and consequently wave setup along the coast. This will generate a gradual transfer of sediment from the exposed area towards the area sheltered by the structure.

This sediment transfer will result in a reorientation of the beach to the west of the proposed breakwater, with an accumulation of sediment along the western side of the structure. Sediment transport within compartment 3 (to the east of the proposed marina entrance structure) is in a westerly direction from the existing groyne at Hymus Street. Following the construction of the proposed breakwater, this sediment trend will result in build up against the eastern edge of the breakwater.

Deposition and beach realignments along both sides of the marina entrance would continue until a new equilibrium is reached, with significant losses to the subtidal area and seagrass meadows. The reorientation of the beaches either side of the proposed marina breakwater entrance will be mitigated through the incorporation of beach defence structures (discussed further in Section 11.5.1)

The potential beach realignment as a result of the Proposal is shown in Figure 86.

Figure 86 Long-term shoreline orientations driven by the Proposal

11.3.2 Accumulation of seagrass wrack

Beach stability and reclamation impacts

The proposed area development concept as shown in Figure 5 requires the development of beaches fronting the development limited in area as defined in the ESD. Coastal processes studies have indicated that beaches developed in the Proposal area will be stable, oriented to the diffracted background energy and have morphological responses similar to the existing beaches. The beach alignments shown will only develop in the presence of available sediment.

Impacts on seagrass will be limited to the same active profile widths as evident on the existing beaches and as indicated by the shoreward edge of the seagrass meadow.

Impact on wrack accumulation

The dynamics of seagrass wrack accumulation on the beaches of Port Geographe, South West Australia, located approximately 150 km south of Mangles Bay were studies by Oldham *et al.* (2010) and provides useful information for the assessment of the potential for seagrass accumulation at Mangles Bay.

The key findings related to factors influencing seagrass wrack accumulation on the beaches of Port Geographe are outlined in the following paragraphs. The corresponding effects of these factors on seagrass wrack accumulation at Mangles Bay is also outlined.

Wrack Production

In the study of seagrass wrack dynamics at Port Geographe, Oldham *et al*., (2010) found that seagrass wrack is mostly produced in offshore seagrass meadows in the Summer – Spring season due to the shedding of mature leaves. Additionally, in the Autumn – Winter season, some leaves and whole clumps of meadow can be ripped out of the sediment during storm events.

Geographe Bay has nearly 8725 ha of seagrass, mostly *Posidonia sinuosa* (~80%) but some *Amphibolis*. About 32 500 tonnes of wrack is produced each year, and ~7500 tonnes (about 25%) ends up on the beach. Each hectare of *Posidonia* meadows in Geographe Bay produce about 2-3 tonnes of wrack each year.

By comparison, Mangles Bay has 100 ha of seagrass, mostly Posidonia sinuosa. There are no other seagrass meadows that might contribute wrack to Mangles Bay and half of the meadows in Mangles Bay are to the west of the breakwaters, and so northwest storms would push any wrack from this area away from the breakwaters.

Nearshore wrack transport from offshore meadows

Oldham found that the first major storms of the autumn – winter period transport a proportion of the offshore wrack into the surf zone and onto the beaches of Geographe Bay. The Oldham *et al.* study was conducted over the 2008 – 2009 period whereby, at the end of May more than 98% of the wrack that had been produced since the previous winter was located in the offshore habitats however, only 1.3% was on the beaches of Port Geographe (Oldham *et al*. 2002).

Geographe Bay is also a more dynamic environment to Mangles Bay. Wave energy potentially impacting Mangles Bay during storms is significantly limited by the Bay's orientation, Garden Island and the causeway. In comparison, Geographe Bay is sheltered but is not protected by high energy events which both produce seagrass wrack and transport it into nearshore environments.

Given these factors and that the extent of the seagrass meadows influencing wrack accumulation at the proposal site is significantly less than at Port Geographe, seagrass wrack accumulation on the beaches of Mangles Bay is expected to be small in volume as is indicated by current observations.

Factors reducing onshore wrack accumulation

In addition to the small quantities of seagrass wrack accumulations on the beaches of the proposal area, other factors affecting any accumulation of wrack in any one location are outlined below.

Offshore wrack transport

Due to the low energy environment and the narrow mean energy direction range, beaches developed in accordance with the proposed layout are considered to be highly stable in orientation and governed largely by low frequency cross shore sediment processes.

Wrack is deposited onto beaches largely during storm events, when water levels are high. If it remains on the beach long enough, it gradually becomes compacted, incorporating sand, making it denser and more difficult to be washed off the beach. At the same time, however, the wrack particles dry and become more buoyant. At the next high water event that covers the wrack, or during the next winter storm(s), wrack accumulations are eroded and wrack particles are returned to the water and many remain buoyant enabling them to be transported away from the beach.

In this way, beach cast wrack can subsequently be transported back offshore, into the surf zone, where longshore transport can move it until it is obstructed by coastal structures where it accumulates, for example the Port Geographe breakwater. Mangles Bay, has relatively little net longshore transport, in the order of less than 1000 to 2000m^3/y, resulting in a potential for only very small amounts of wrack to accumulate against the coastal structures.

Seagrass may potentially move into the dredge channel and harbour, but as seagrass wrack production volumes are considered to be relatively small, this is not considered to be a significant problem for the development.

Mitigation in Design

Segmentation of the beaches into a number of compartments by training structures and control groynes to protect the development waterfront limits accumulation of wrack at any one location by reducing the catchment. This largely eliminates management problems of odour due to wrack breakdown in large masses and facilitates natural removal of wrack.

The breakwaters themselves are also aligned so that any wrack coming from ‘eastern’ Mangles Bay meadows is unlikely to enter the marina.

11.4 Potential for and nature of any cumulative impacts

As outlined in Section 11.1.6, a number of structures have been installed along the coast of Cape Peron and the beaches of Mangles Bay, including the beach management groynes and the Garden Island Causeway. The presence of these structures has already played a role in establishing the current beach profiles and sediment transport conditions. The Proposal is likely to have some cumulative effect on the overall sediment transport of Mangles Bay and the morphology of its beaches, resulting in an altered profile which is not only different from the current stable state, but also modified from the original natural beach profile.

Future infrastructure developments along this coast will also add to this history of a changing shoreline and alteration in longshore sediment transport. The proposed Port Rockingham Marina will be located adjacent to the intersection of Wanliss St and Rockingham Beach Road, to the northeast of the Proposal Area. This development will further interrupt longshore sediment transport along the southern end of Cockburn Sound.

On the basis of the relatively limited longshore transport within Mangles Bay, it is assessed that the structures associated with the Proposal will impact on the current dynamics, however, the changes will not be significant or dramatic and the system will achieve a new equilibrium.

11.5 Management measures and performance standards

In order to meet the environmental objectives for coastal processes, measures will be implemented to protect the shore from erosion while ensuring that existing and planned recreation areas are not compromised. This will require the maintenance of beaches fronting the development to improve and protect social amenity and public access to mitigate the loss of a small amount of beach.

This level of maintenance requires that sufficient buffers are provided to allow for natural variability or that the structures are built to maintain access as the beach level changes in response to varying conditions. Natural variability in the Proposal area has diminished due to additional protection afforded by the Garden Island Causeway and existing beach defence structures. However, storm erosion has been considered, including the maintenance for any losses from the beach compartments as part of the management measures required for the Proposal.

The Proposal includes development which would bisect the already compartmentalised coastal sector with a marina entrance channel, protected by coastal structures against the penetration of infrequent high energy storm events (Section 3.4). In addition to the management and beach protection infrastructure required for the coastal infrastructure, coastal protection will also be required for the land-based aspects of the Proposal such as the Yacht club and accommodation.

The utilisation of coastal defence structures and application of appropriate setbacks is discussed below.

11.5.1 Coastal defence

Groynes

Groynes are shore structures designed to reduce longshore sediment transport and to retain beach material. The shoreline between the groyne and adjacent structure (potentially another groyne) realigns towards the dominant wave direction and as a consequence, longshore sediment transport is reduced. Groynes slow longshore drift rates, causing accumulation in groyne bays, with the enhanced beach profile providing greater protection to the shoreline.

The installation of two groynes has been incorporated into the Proposal, as an important management measure, located on either side of the proposed marina breakwater entrance. A short groyne is proposed to the west of the marina entrance at the location of the existing boat ramp. The second groyne will be located to the east of the marina entrance approximately 250 m from the existing Hymus Street Groyne. The primary function of these structures is to compartmentalise the beach and interrupt the potential beach realignment and sediment accumulation against the edge of the breakwater entrance (as outlined in Section 11.3.1).

In addition, segmentation of the beaches into a number of compartments limits accumulation of seagrass wrack at any one location by reducing the catchment of potential transport. This minimises problems of odour due to wrack breakdown in large masses and facilitates natural removal of wrack.

The resulting beach orientation as driven by these groyne placements is illustrated in Figure 86.

Buried Sea walls

Seawalls are generally built along the coastline to advance a coastal frontage into the sea, to protect the land from erosion and flooding or to provide an amenity function. A buried seawall will be installed adjacent to development along the beaches within the Proposal area. Although the location of the buried seawall has not been finalised, the following characteristics will be incorporated into the design:

- sea walls will only be exposed to waves during extreme weather events
- consideration of appropriate crest height of storm waves
- consideration of the variability of the natural system as well as any additional clearances (e.g. to road reserves, property etc).

The sea wall will act as a demarcation between the coastal zone and the adjacent development reserves, as is required by SPP 2.6 (WAPC 2003). The structure will act to mitigate the erosive effects of a severe storm on infrastructure and developed land.

Internationally, the recommended best practice has been developed with the aim to raise coastal systems with rising sea levels i.e. as sea level rise increases. The buried seawall will also serve as a foundation element to allow the height of the coastal system to be raised while affording protection against shoreline retreat.

Beach nourishment

As outlined in Section 3.4, the construction of breakwaters and other shoreline structures can interrupt longshore transport and cause realignment of the beach fronts.

Developed beaches fronting the Proposal area may require maintenance to improve and protect social amenity and public access to offset the loss of a small amount of beach. Given the low energy environment, infrequent storm events and compartmentalisation of the beaches of the Mangles Bay area, maintenance requirements are expected to be very small. The reoriented beaches designed with a buffer for short and medium-term variability should require no more maintenance than the current shoreline segment already managed by the City of Rockingham.

The City of Rockingham currently excavates approximately 10,000 m^3 of sand yearly from the sand trap west of the Garden Island Causeway (JFA 2011). A portion of this sediment may potentially be deposited along the beaches at Mangles Bay as part of an integrated adaptive management strategy for this coastal segment.

Beach nourishment, if undertaken regularly and coupled with regular monitoring of sand levels, will afford protection against long-term shoreline erosion, ensuring that the beaches retain their width over time. Episodic maintenance can be expected to be small in quantity and in excess of 10 year intervals and generally only in response to adaptation to projected rising sea levels over the next 100 years.

11.5.2 Coastal Setback Management

Existing coastal setback requirements for Mangles Bay

The existing coastal setback requirements for the beaches at Mangles Bay were defined in the Southern Perth Metropolitan Coast Coastal Setback Study (MRA 2005). Four components have been considered in identifying the setback requirements at Mangles Bay as summarised in Table 45. These four components were addressed to calculate setback requirements for the Proposal (JFA 2011).

Table 45 Summary of previous setback requirements for Mangles Bay

Setback component	Setback calculations (MRA 2005)
(S1) Distance for absorbing Acute Erosion.	Storm erosion potential in the vicinity of the Proposal area at 7 m.
(S2) Distance to allow for Historic Trend.	Historic erosion trend of 65 m.
(S3) Distance to allow for Sea Level Change.	Allowance for sea level in the vicinity of the site with a 100 year planning horizon of 38m using the Bruun Rule. Under the revision of the sea level rise allowance to 0.9m in recent coastal planning guidance for sea level rise and its application to coastal planning (DoT 2010) this would be calculated to give an S3 allowance of 90m.
Regional Setback allowances – 100y.	MRA (2005) calculated a total setback in the vicinity of the site with a 100 year planning horizon of 110m. Under current guidance for S3 to allow for sea level rise, this would be 162m. A setback of this proportion does not currently exist within this coastal sector.

Setback calculations for the Proposal

The recommended coastal setback allowance calculation, as outlined in SPP 2.6 (WAPC 2003) is comprised of three distinct components, each of which have been addressed for the Proposal (JFA 2011). The calculated setback requirement for the Proposal also considered the management structures and beach nourishment activities which have been incorporated into the Proposal design. Table 46 summarises the setback requirements of the Proposal as per SPP 2.6 requirements.

Table 46 Setback requirements of the Proposal

Setback component	Calculated setback distance	Distance considering management measures
(S1) Distance for absorbing Acute Erosion	<10 m	0 m
(S2) Distance to allow for Historic Trend	20 m	20 m
(S3) Distance to allow for sea level change	90 m	0 m
Final setback distance	20 m	

(S1) Distance for absorbing Acute Erosion

The (S1) component of SPP 2.6 (WAPC 2003), was calculated as <10 m, which is in agreement with MRA (2005) calculations. However, the implementation of coastal defence structures (buried seawall), coupled with active beach management (beach nourishment) is considered to mitigate the effects of infrequent storm erosion thus eliminating the requirement for the (S1) setback buffer as this will be incorporated into the minimum allowance of (S2) below. It is also noted that nourishment sources within the Proposal area are available for future management.

(S2) Distance to allow for Historic Trend

Shoreline movement trends were estimated from shoreline movement plans produced by DPI (DoT 2009). In all compartments, the rate of shoreline movement was assessed as having either 0 m net erosion trend since 1988 or to be accretionary unless disturbed by anthropogenic factors. This is generally attributed to the stabilising influence of coastal structures within the Proposal area coastal segment. Therefore, the shoreline along the Proposal area has been identified as stable and a 0 m net historic trend assumed.

In addition, the construction of a buried seawall will protect against long-term beach erosion. In this regard, to allow for natural variability and ease of management, the minimum (S2) component of the setback allowance at Mangles Bay of 20 m is considered appropriate.

(S3) Distance to allow for sea level change

As per SPP 2.6 (WAPC 2003) guidelines, the (S3) component of the setback allowance at Mangles Bay has been calculated as 90 m. However, active beach management in conjunction with coastal defence structures (buried seawall) will be used as an adaptation strategy to maintain the position of the shoreline, to mitigate against the effects of sea level rise. Changes to the beach height and crest levels to manage impacts can be implemented in the future, if required. In this regard, the requirement for the (S3) setback buffer is eliminated.

11.6 Predicted environmental outcomes against environmental objectives, policies, guidelines, standards and procedures

It is expected that the implementation of the coastal management activities (Section 11.5) will have the following outcomes relating to coastal processes:

- reorientation of beach profiles at Mangles Bay, with sediment deposition on either side of the marina breakwater
- minor seagrass accumulation in the dredge channel and harbour
- minimal impact to development and foreshore area by sea level rise and storm events.

12. Benthic primary producer habitat impact assessment

12.1 Relevant environmental objectives, policies, guidelines, standards and procedures

12.1.1 EPA Objective

The EPA environmental objective for Benthic Primary Producer Habitat (BPPH) is:

To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.

12.1.2 Legislation, policy and guidance

EPA Environmental Assessment Guidelines No. 3

EPA Environmental Assessment Guideline No. 3 '*Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment'* (EAG No. 3; EPA 2009b) recognises the fundamental ecological importance of BPPH and the potential consequences of their loss for marine ecological integrity. BPPHs are defined as seabed communities within which algae, seagrass, mangroves, corals or mixtures of these groups are prominent components; and also include areas of the seabed that can support these communities.

Environmental Protection Principles

EAG No. 3 expects the following hierarchy of principles to be addressed by all proponents when assessing proposals that could cause damage/loss of BPPH (EPA 2009b):

1. All proponents should demonstrate consideration of options to avoid damage/loss of BPPH (Section 12.3.1).
2. Where avoidance of BPPH is not possible, then design should aim to minimise damage/loss of BPPH and proponents will be required to justify the need for damage/loss of BPPH (Section 12.3.2).
3. Proponents will need to demonstrate 'best practice' design, construction methods and environmental management aimed at minimising further damage/loss of BPPH through indirect impacts. This item is addressed through the impact assessment and management options of this PER (Sections 12.4 and 12.6).

The Proponent has addressed each of these principles through the consideration of options or alternatives for the Proposal (Section 12.3). The management of construction methods in order to minimise effects on BPPH (including direct losses as well indirect losses such as shading effects) will be outlined in the CEMP. Potential impacts and management, including the offset of seagrass losses through rehabilitation within Cockburn Sound are described in Section 12.6. These principles are also outlined below in EPA Environmental Assessment Draft Guideline No. 7 '*Marine Dredging Proposals'* (EAG No. 7; EPA 2011).

Local Assessment Units

The EPA has provided a risk-based spatial assessment framework for evaluating cumulative irreversible loss of and/or serious damage to BPPHs (EPA 2009b). The EPA has termed the areas within which to calculate cumulative losses 'Local Assessment Units' (LAU). The proponent is required to determine the boundary of the LAU.

There are six categories of marine ecosystem protection (category A through to F) defined in EAG No. 3 and used to define the cumulative percentage loss threshold for BPPH within any defined LAU. In order to apply an appropriate protection category, the following calculations of the spatial extent of BPPH are required (EPA 2009b):

- prior to all human induced disturbance (i.e. prior to European habitation)
- estimate of existing losses at the time of the proposal
- the additional loss or damage as a result of the proposal (i.e. cumulative losses of BPPH).

Cockburn Sound is defined by the EPA as a LAU with an area of 105.7 km^2 (10 570 ha); and includes the region bounded by the east coast of Garden Island, a line drawn from the north end of Garden Island across to Woodman Point, along the eastern shore of Cockburn Sound and the causeway linking Rockingham to Garden Island. The proposed loss and previous habitat loss are totalled to determine a cumulative impact that is assessed by the EPA in light of the ecosystem's level of protection. The Guidelines classify Cockburn Sound as a Category F: areas where cumulative loss guidelines have been significantly exceeded (refer Section 12.2.1). Due to the application of this category, proposals in Cockburn Sound (including Mangles Bay) must therefore not cause any net damage/loss of seagrass.

EPA Environmental Assessment Guidelines No. 7

EPA Environmental Assessment Guideline No. 7 '*Environmental Assessment Guideline for Marine Dredging Proposals'* (EAG7, EPA 2011) sets out guidance for predicting impacts to benthic communities and habitats due to significant dredging activities, to ensure these are presented in a clear and consistent manner. In particular, it advocates a spatially-based zonation scheme for the predicted extent, severity and duration of impacts, as follows:

- Zone of High Impact (ZoHI) - the area where impacts on benthic communities are predicted to be irreversible (defined as lacking a capacity to return or recover to a pre-dredging state within a timeframe of five years or less)
- Zone of Moderate Impact (ZoMI) - the area where predicted impacts on benthic communities are expected to be sub-lethal, and/or the impacts recoverable within a period of five years following completion of the dredging activities
- Zone of Influence (ZoI) - the area where changes in environmental quality associated with dredge plumes are predicted, but these changes are not expected to result in a detectible impact on benthic communities.

Predicted impacts as per EAG7 (EPA 2011) requirements are provided in Section 10.4.

Western Australian Government's Environmental Offsets Policy

The Western Australian Government's Environmental Offsets Policy provides the overarching framework that underpins environmental offset assessment and decision-making in Western Australia. The use of environmental offsets is underpinned by six principles:

1. Environmental offsets will only be considered after avoidance and mitigation options have been pursued.
2. Environmental offsets are not appropriate for all projects.
3. Environmental offsets will be cost-effective, as well as relevant and proportionate to the significance of the environmental value being impacted.
4. Environmental offsets will be based on sound environmental information and knowledge.
5. Environmental offsets will be applied within a framework of adaptive management.
6. Environmental offsets will be focussed on longer term strategic outcomes.

The policy also specifies the need for detailed guidelines on the respective roles and responsibilities of relevant parties; legislative requirements; and assessment and decision making processes, auditing, monitoring and review to be prepared in consultation with key stakeholders. Further, it describes the Offsets Register intended to provide a public record of all offset agreements in WA in a centralised form, and that includes the following information:

- spatial location of the offset;
- type of offset and values being offset;
- compensatory values of the offset;
- timelines for implementation; and
- agency that is responsible for monitoring the environmental offset.

EPA Position Statement No. 9

EPA Position Statement No. 9 '*Environmental Offsets*' (EPA 2006c) sets out the EPA's overarching policy for the use of environmental offsets in the context of EIA in Western Australia. The EPA's policy position is that environmental offsets should be used with an aspirational goal of achieving a 'net environmental benefit'. The policy includes guiding principles and a decision framework for the use of environmental offsets. The guiding principles of the policy are as follows:

- Environmental offsets should only be considered after all other reasonable attempts to mitigate adverse impacts have been exhausted
- An environmental offset package should address both direct offsets and contributing offsets
- Environmental offsets should ideally be 'like for like or better'
- Positive environmental offset ratios should apply where risk of failure is apparent
- Environmental offsets must entail a robust and consistent assessment process
- Environmental offsets must meet all statutory requirements
- Environmental offsets must be clearly defined, transparent and enforceable
- Environmental offsets must ensure a long lasting benefit

These principles have been used in the development of the Proposal's seagrass transplantation offset (Section 12.7).

EPA Guidance Statement No. 19

EPA Guidance Statement No. 19 '*Environmental Offsets – Biodiversity*' (EPA 2008b) sets out the EPA's advice on when offsets are considered to be appropriate as part of the EIA process for a proposal, and how proponents should address and present environmental offsets in those instances. The advice complements EPA Position Statement No. 9, which provides the EPA's overarching policy and position on environmental offsets. EPA Guidance Statement No. 19 provides further clarification in relation to the policy's interpretation and implementation on the following aspects:

- the EPA's expectation for the appropriate use of environmental offsets;
- application of offset principles in relation to significant adverse impacts to biodiversity assets – in particular the 'like for like or better' principle;
- situations where the application of offset principles are extremely difficult or challenging to implement;
- timing of offset considerations during the EIA process; and
- transparency and auditing effectiveness of offsets packages.

With respect to the third bullet point above, at the time at the time Guidance Statement No. 19 was written the success of seagrass restoration techniques was still considered unproven, and so it states that "...*offsets (particularly direct offsets) in the marine environment pose significant technical and tenure-related difficulties"*. It therefore advises that "*Proponents should be mindful of the difficulties in developing and implementing marine-based offsets before proceeding with these*". As seagrass transplantation now has a proven track record in Cockburn Sound (Section 12.7), it has been used as an offset in the Proposal.

The *State Environmental (Cockburn Sound) Policy 2005* (Cockburn Sound SEP) establishes the framework within which Cockburn Sound and the adjacent land (the Cockburn Sound catchment) are to be managed so as to protect environmental quality in the Sound. The Cockburn Sound SEP establishes a risk-based approach to environmental management, which is underpinned by EVs and spatially defined EQOs (Government of Western Australia 2005b) to ensure the EVs are protected (Table 47).

Table 47 Environmental values and environmental quality objectives for Cockburn Sound

Environmental values (EVs)	Environmental Quality Objectives (EQOs)
Ecosystem health	Maintenance of ecosystem integrity in terms of structure (e.g. biodiversity, biomass and abundance of biota) and function (e.g. food chains and nutrient cycles).
Seafood safe for eating	Maintenance of aquatic life for human consumption, such that seafood is safe for human consumption when collected or grown.
Aquaculture	Maintenance of aquaculture, such that water is of a suitable quality for aquaculture purposes.
Recreation and aesthetics	Maintenance of primary contact recreation values, such that primary contact recreation (e.g. swimming) is safe. Maintenance of secondary contact recreation values, such that secondary contact recreation (e.g. boating) is safe. Maintenance of aesthetic values, such that the aesthetic values are protected.
Industrial water supply	Maintenance of industrial water supply values, such that water is of suitable quality for industrial water supply purposes.

EQC have been specifically developed for Cockburn Sound to provide the quantitative benchmarks for measuring success in achieving the EQOs set in the SEP (Government of Western Australia 2005b). There are two types of EQC:

1. Environmental Quality Guidelines (EQGs): threshold numerical values which, if met, indicate a high degree of certainty that the associated EQO has been achieved. If the guideline value is not met then a more detailed assessment process against an environmental quality standard is triggered.
2. Environmental Quality Standards (EQSs): threshold numerical values that indicate a level beyond which there is a significant risk that the associated EQO has not been achieved and a management response is triggered (Government of Western Australia 2005b).

The ecological EV of ecosystem health has different EQC for zones of high, moderate and low ecological protection, whereas the social EVs (safe seafood, aquaculture, recreation and aesthetics, and industrial water supply) have the same EQC applied throughout Cockburn Sound.

There are specific EQSs for seagrass health established under the Cockburn Sound SEP (EPA 2005a), based on annual measurements of seagrass shoot density in summer. As with phytoplankton biomass EQC (refer Section 10.2.2), comparisons are made to percentiles derived from reference site data that are updated each year. There is an EQS that must be met in each current year, and an EQS that must be for two concurrent years.

For the high ecological protection area the EQSs are:

1. Ambient values for seagrass shoot density during January and in two consecutive years (“2-year EQS”) are:
   - greater than the 20th percentile of seagrass shoot density at an appropriate reference site or
   - greater than the value for that indicator as specified in Table 48.
2. Ambient values for seagrass shoot density in any one year (“1-year EQS) are:
   - greater than the 5th percentile of seagrass shoot density at an appropriate reference site or
   - greater than the value for that indicator as specified in Table 48.
3. The upper and lower depth limit of seagrass meadows must not show a statistically significant retreat relative to baseline distribution.

Table 48 Numerical environmental quality criteria for seagrass in Cockburn Sound for 2011

Environmental Quality Indicators (seagrass)	EQS’s (High protection)
2-year EQS shoot density (shoots m-2)	
1.5 – 2.0 m depth	775
2.0 - 3.0 m depth	625
3.0-4.0 m depth	425
5.0 – 6.0 m depth	425
7.0 - 8.0 m depth	150
1-year EQS (shoots m-2)	
1.5 – 2.0 m depth	438
2.0 - 3.0 m depth	390
3.0-4.0 m depth	108
5.0 – 6.0 m depth	150
7.0 - 8.0 m depth	75

Source: Data provided courtesy of the CSMC

The ongoing (operational) effects of the Proposal on the marine waters of Cockburn Sound will be assessed in terms of these EQSs. A baseline seagrass health survey was conducted at four sites in Mangles Bay in March 2011 (refer Section 12.2.2) to ascertain the status of seagrass health prior to the proposed development. Temporary effects due to construction (e.g. turbidity and any nutrient-related effects during dredging) will be managed and monitored separately (although still based on measures of seagrass shoot density), as they are likely to take place outside the summer monitoring season targeted by the Cockburn Sound SEP (refer to the CEMP, Appendix 1).

12.1.3 Shoalwater Islands Marine Park Management Plan

The SIMP borders Mangles Bay at the Garden Island Causeway (Figure 87). The SIMP covers an area of approximately 6545 ha and contains the waters of Shoalwater Bay, Warnbro Sound and a part of Cockburn Sound off Cape Peron. The SIMP is vested to the MPRA, and managed by the DEC, apart from recreational fishing which is managed by the DoF in close cooperation with DEC. The Shoalwater Islands (i.e. the terrestrial portion) are managed under the 1992 Shoalwater Islands Management Plan.

The *Shoalwater Islands Marine Park Management Plan 2007–2017* (the management plan) was formally approved by the Minister for the Environment in August 2007 (DEC 2007). The management plan sets out, among other things, a zoning scheme and a ‘best practice’ model for managing the identified ecological and social values of the SIMP. The zoning scheme proposes that the areas to the north of

Cape Peron (to the west of the Causeway) be within a General Use Zone. Shoalwater Bay (on the southern side of Cape Peron) is a recommended Special Purpose Zone for wildlife conservation, and further south are two sanctuary zones (at Second Rock, and Becher Point), and a Special Purpose Zone for Special Purpose Zone for scientific reference at Murray Reef.

Each ecological and social value for the SIMP has identified management objectives, strategies, performance measures and targets to achieve. For example, the management objective for seagrass communities in the SIMP is summarised as:

> *Seagrass is an important primary producer and the extensive and diverse perennial seagrass meadows are important habitats for invertebrates and finfish.*

Performance measures for seagrass include diversity and biomass. Short-term targets are to be developed as required, while long-term targets include no net loss of seagrass species diversity as a result of human activity in the SIMP; and no loss of perennial seagrass biomass as a result of human activities in the SIMP (DEC 2007). The Proposal area lies outside the boundary of the SIMP, however these objectives, strategies, performance measures and targets have been considered in order to mitigate any potential for indirect or flow-on effects from the construction and operation phases of the Proposal.

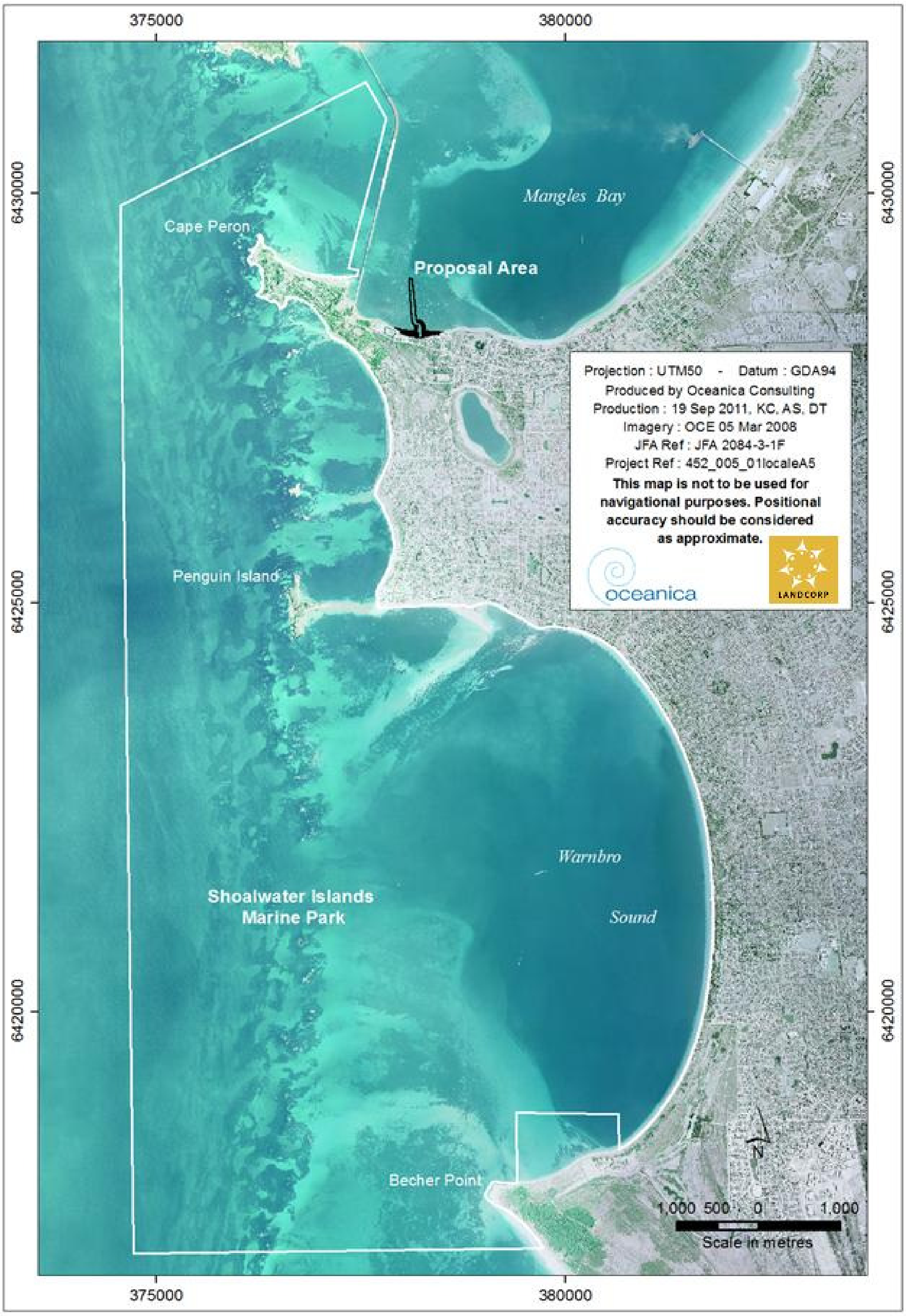


Figure 87 Shoalwater Islands Marine Park boundary

12.2 Findings of surveys and investigations

12.2.1 Historical seagrass loss

Cockburn Sound has a history of poor water quality and large-scale loss of seagrass meadows dating from the 1960s and 1970s. Although environmental conditions have improved markedly since the 1970s, a legacy of this past is that water quality and seagrass meadows remain key environmental concerns. In Cockburn Sound, seagrass meadows originally occupied approximately 4000 ha (predominantly *Posidonia* sp.) and covered much of the seabed where water depths were less than 8-10 m (DEP 1996). Between 1942 and 1957, seagrass cover and distribution remained relatively unchanged, however between 1957 and 1968 there was a gradual retreat of meadows from the deeper margin of the eastern bank and thinning along portions of the adjacent shoreline. By 1972, most of the seagrass meadows on the eastern margin had disappeared and by the late 1970s only about 900 ha remained, with an estimated 750 ha remaining in 1993 (DEP 1996). The need for the protection of the remaining seagrass meadows and potential seagrass habitat is identified in the EPA's Strategic Environmental Advice on the Marine Environment of Cockburn Sound (Bulletin 907, EPA 1998), and at the time the advice was written the success of seagrass restoration techniques was also unproven.

The shallow flats of Mangles Bay contain approximately 100 ha of seagrass, comprising the main area of seagrass meadow that remains on the eastern shore of Cockburn Sound between the Causeway and Woodman Point. Loss of seagrass is one of the two primary marine environmental issues relevant to the Proposal identified in the EPA's Bulletin 1237 in its strategic advice to the Minister for the Environment, under section 16(e) of the EP Act (EPA 2006b).

In Mangles Bay there has been an estimated 3 ha of seagrass loss due to mooring scars, as detailed in Section 12.2.3.

12.2.2 Seagrass health monitoring

Maintaining existing seagrass meadows within Cockburn Sound is one of the EPA's key environmental objectives, with seagrass shoot density also used as an indicator of seagrass health under the Cockburn Sound SEP (EPA 2005a). In assessing seagrass health, monitoring of sites in Cockburn Sound is compared against a reference site in Warnbro Sound, which is assumed to be unaffected by the same pollution pressures as Cockburn Sound (Auditor General 2010).

The Proponent undertook a baseline survey of seagrass health at two sites (one either side of the Garden Island Causeway) during January 2010 (Figure 88). In addition four long-term seagrass health monitoring sites were established in March 2010. These sites were located approximately 100 m and 200 m distance either side of the proposed marina channel in water depths of approximately 2 m, to allow future comparison with Cockburn Sound EQC (Figure 88). The results of these two studies are described below.

Preliminary assessment of seagrass health 2010

Seagrass monitoring was undertaken during January 2010 in *Posidonia sinuosa* meadows at one site west of the causeway (Site MBW, water depth 2.6 m) and one site to the east of the causeway in Mangles Bay (Site MBE, water depth 1.4 m) (refer Figure 88). Shoot density counts were documented based on standard operating procedures established for the Cockburn Sound SEP (EPA 2005b) (refer Appendix 5).

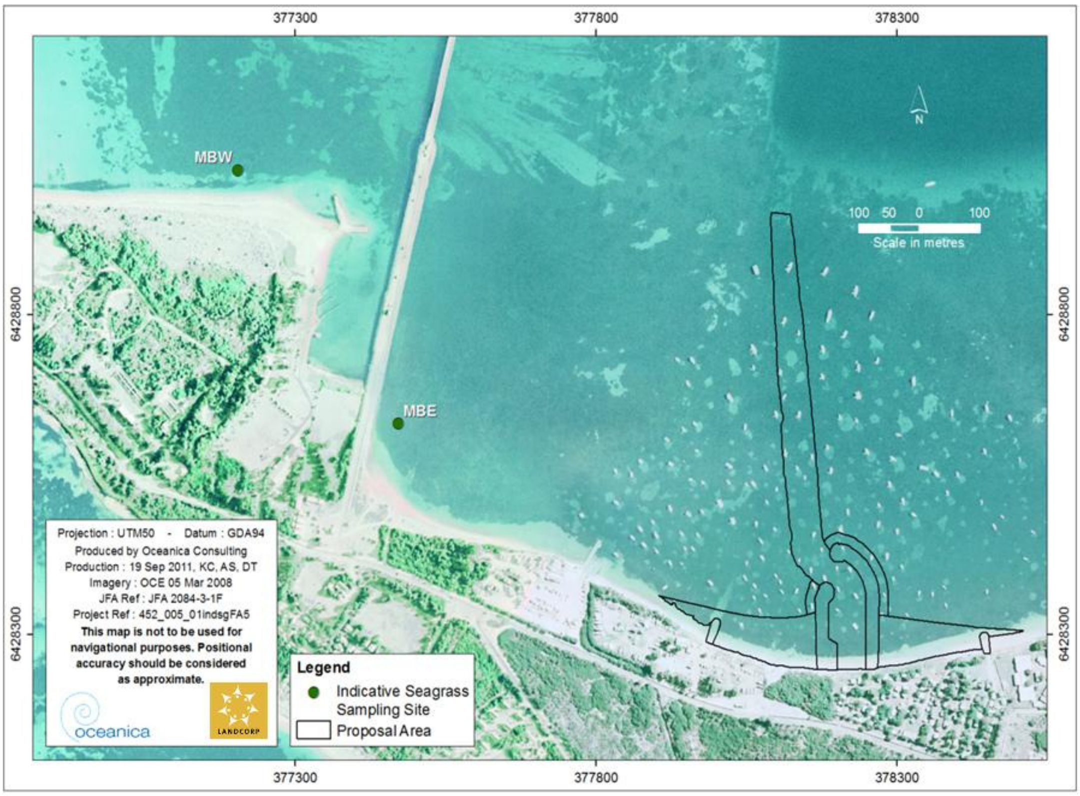


Figure 88 Seagrass health monitoring sites in Mangles Bay, summer 2010

The average shoot density for *Posidonia sinuosa* at the site west of the causeway (656 ± 76) was greater than the site east of the causeway in Mangles Bay (399 ± 40). The median shoot density count for *P. sinuosa* at site MBW was 544/m^2 and at MBE was 376/m^2 (Table 49). The median for the reference site (MBW) met the 1 year shoot density EQS for high ecological protection, but the potential impact site (MBE) did not (Table 49).

Table 49 Seagrass shoot density counts (1 m^2) at Mangles Bay, January 2010

	Site MBW (water depth 2.6 m) 2	Site MBE (water depth 1.4 m)3
Mean ± S.E.	656 ± 76	399 ± 40
Median	544	376
High protection area EQS for 1 year1	**375**	**458**

[1] Cockburn Sound Environmental Quality Standard (EQS) for a high ecological protection area derived from data obtained between 2003 and 2010 for Warnbro Sound.

[2] EQS based on Warnbro Sound data for 2.0 to 3.0 m water depth. Data supplied courtesy of the CSMC.

[3] EQS based on Warnbro Sound data for 1.5 to 2.0 m water depth. Data supplied courtesy of the CSMC.

Seagrass health 2011

Seagrass monitoring was undertaken in March 2011 using standard operating procedures established for the Cockburn Sound SEP (EPA 2005b). The seagrass shoot density counts were undertaken in *Posidonia sinuosa* meadows at four sites in water depths of 2.5–3.0 m, apart from one site at a depth of 1.5 m (Figure 89). The 2011 sites adjacent to the Proposal area were specifically located in deeper water than the 2010 survey (where shoot densities easily met the 1 year EQS for a high ecological protection area), as these were expected to be more sensitive to lesser water quality. Although attempts were made to locate all sites along the 2.5–3.0 m depth contour, the rapid shallowing of waters towards the Causeway meant that this was not possible for the westernmost site (refer Oceanica 2012, Appendix 5).

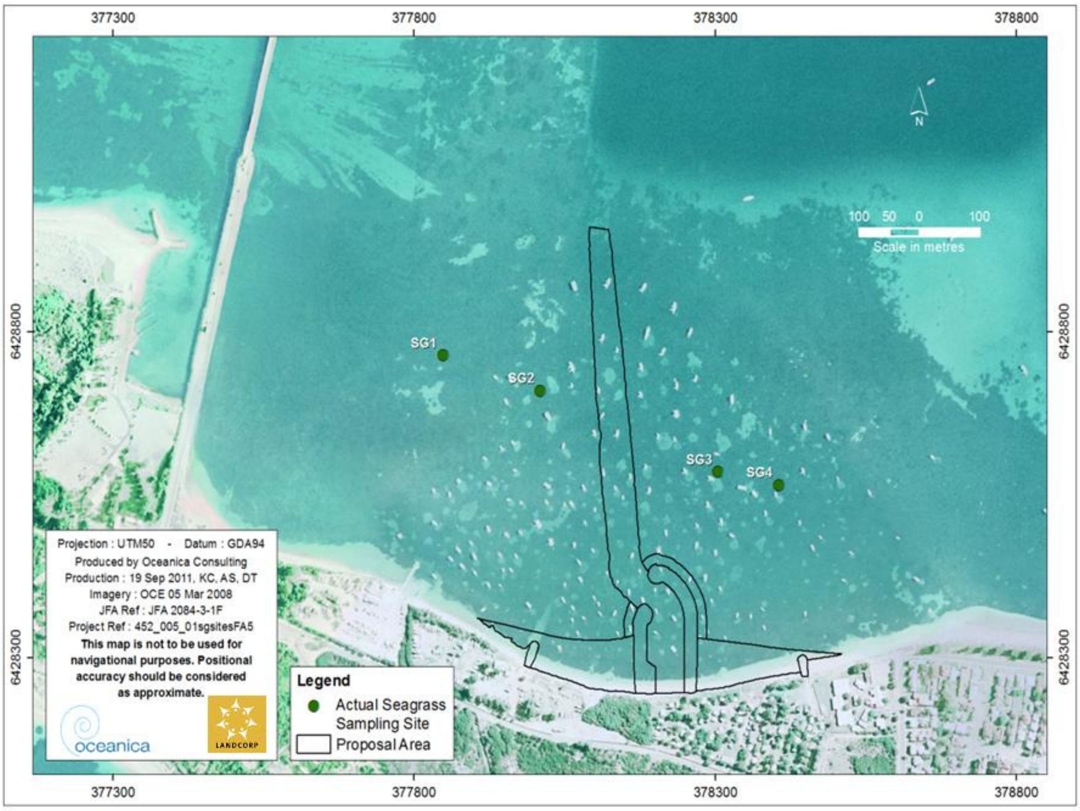


Figure 89 Seagrass health monitoring sites in Mangles Bay, March 2011

The average shoot density for *Posidonia sinuosa* was lowest at site SG4 (447 ± 57) and highest at site SG1 (707 ± 73) (Table 50). The median shoot density count for *P. sinuosa* at all sites met the 1 year shoot density EQS for moderate ecological protection area (Table 50). Sites SG1, SG2 and SG3 met the 1 year EQS for a high ecological protection area, while site SG4 was below the 1 year EQS for a high ecological protection area (Table 50).

Table 50 Seagrass shoot density counts (1 m^2) at Mangles Bay, March 2011

Site	SG1 (1.5 m)	SG2 (2.5 m)	SG3 (3.0 m)	SG4 (3.0 m)
Mean ± S.E.	707 ± 73	822 ± 100	531 ± 64	447 ± 57
Median	713	913	438	363
High protection area EQS for 1 year	**438**[1]	**390**[2]	**390**[2]	**390**[2]

[1] Cockburn Sound EQS derived from data obtained between 2003 and 2011 for Warnbro Sound (1.5 to 2.0 m water depth).

[2] Cockburn Sound EQS derived from data obtained between 2003 and 2011 for Warnbro Sound (2.0 to 3.0 m water depth).

CSMC Report Cards and WA Auditor General's Report

The CSMC has a routine seagrass monitoring site in Mangles Bay, located in a water depth of 3.2 m, that has occasionally failed to meet the high protection EQS in the past. A review of the Environmental Management of Cockburn Sound in the *Western Australian Auditor General's Report Environmental Management of Cockburn Sound* (Auditor General 2010) showed that seagrass shoot density at Mangles Bay met the EQS between 2005 and 2007, but did not meet the EQS between 2008 and 2010. Shoot density improved in 2011 (in contrast to water quality in 2011), and although the 1 year EQS was met the 2 year EQS was still exceeded (information supplied courtesy of the CSMC).

The Auditor General's report notes that Mangles Bay seagrass health has been a known problem for many years, but there is no clearly identifiable single source contributing to excessive nutrient loads. The report identified Lake Richmond stormwater drain as a significant contributing factor to the nutrient enrichment at Mangles Bay, but also highlighted poor water circulation.

The results of seagrass health monitoring at four sites in Mangles Bay in 2011 undertaken for the Proposal further indicate considerable spatial variability in the 'health' of the seagrass meadows in Mangles Bay (i.e. in addition to the variability with time noted by the Auditor General's Report), as assessed using shoot density counts. As noted earlier, three sites (SG1, SG2 and SG3) met the 1 year EQS for a high ecological protection area, but site SG4 did not.

12.2.3 Seagrass Transplantation in Mooring Scars

Historical analysis of seagrass loss due to mooring scars

As part of preliminary environmental work for the Mangles Bay marina, the extent to which the number of moorings and associated seagrass loss in Mangles Bay has increased over the years was documented. This information had the two-fold purpose of emphasising the need for better management of boating activities, and assessing the potential area of mooring scars available for seagrass transplantation. Historical aerial photography was used for this purpose, to produce a time series of mooring scar damage of seagrass in Mangles Bay (refer Appendix 5).

Of the available aerial imagery for the Mangles Bay region, six years were considered suitable for historical analysis:

- March 1967 (Figure 90)
- May 1972
- June 1981
- March 1999
- March 2002
- March 2008 (Figure 91).

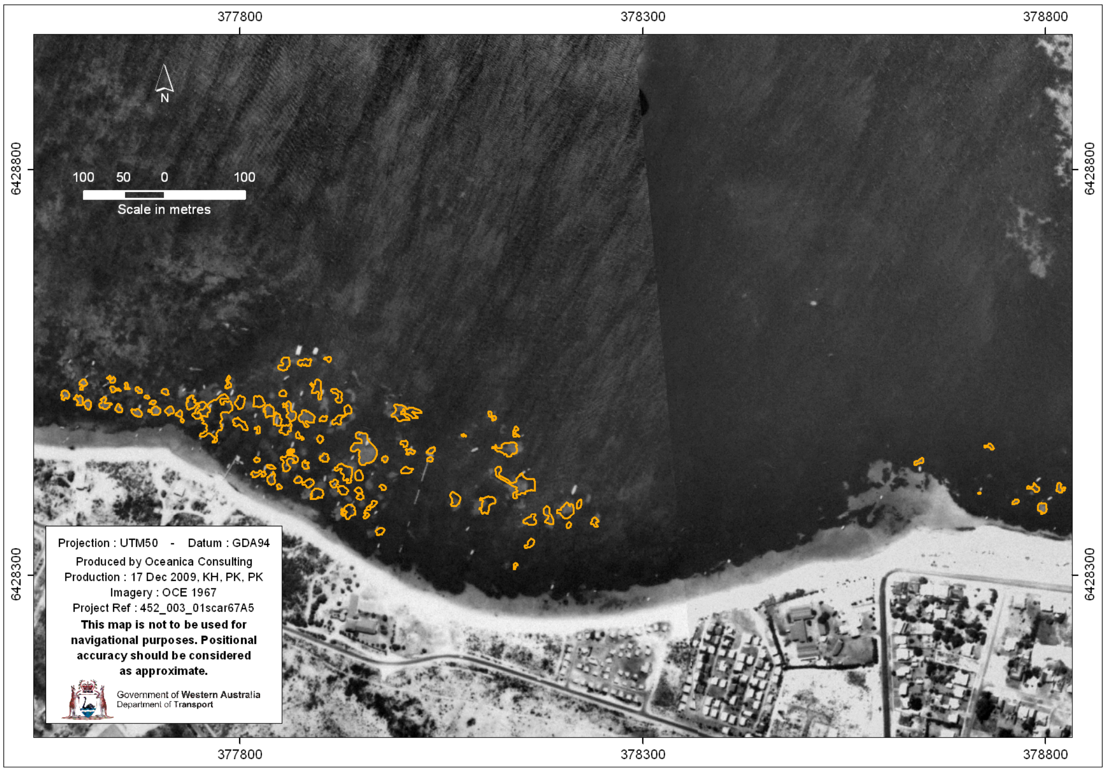


Figure 90 1967 aerial imagery with digitised mooring scars

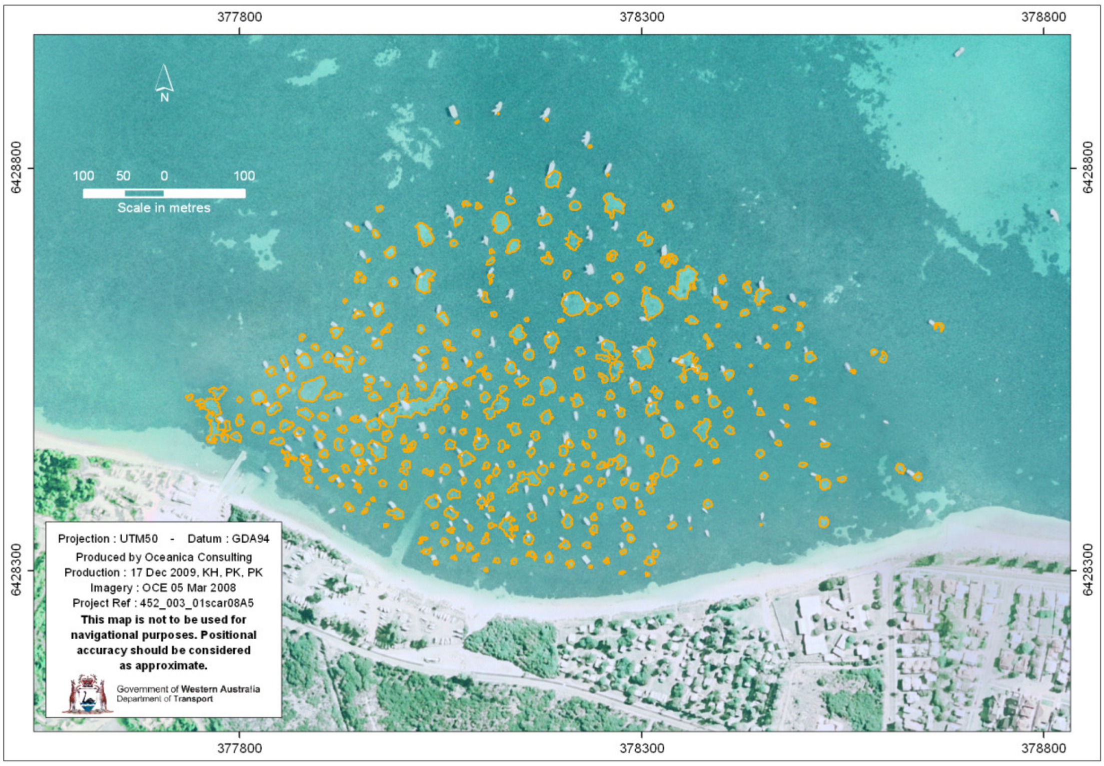


Figure 91 2008 aerial imagery with digitised mooring scars

The results of the analysis showed a considerable increase in the number of mooring scars and subsequent increase in the area of seagrass loss over the investigated period (Table 51). It should be noted that in some cases one mooring scar might cover two or more moorings, while some moorings in the Mangles Bay region are of environmentally friendly design and have no associated mooring scar, hence the disparity with the approximately 600 moorings presently registered with the Department of Transport for Mangles Bay.

Table 51 Historical changes in number of mooring scars and associated seagrass loss in Mangles Bay, Cockburn Sound

Characteristic	Year					
	1967	1972	1981	1999	2002	2008
No. of mooring scars	93	93	114	199	249	312
Area of seagrass loss (ha)	1.06	1.60	2.14	2.71	3.04	3.20

Transplantation trials in mooring scars

Seagrass transplant rehabilitation trials in Mangles Bay were initiated by LandCorp (prior to the appointment of Cedar Woods as the Proponent) in April 2010 to provide local data on the success rate of seagrass transplanting. Seagrass transplantation requires suitable bare substrate to transplant into. Potential transplantation areas identified for the Proposal included the numerous mooring scars in the seagrass meadows of Mangles Bay.

The heavy mooring chains of traditional-style moorings 'scythe' seagrass when a boat swings around on its mooring, and this leaves a characteristic circular bare patch within the seagrass meadow. If traditional-style moorings are replaced by more modern, environmentally-friendly moorings, then the 'scything' effect no longer occurs and the mooring scar is potentially suitable for seagrass to re-grow. Natural re-growth of seagrass meadows into mooring scars can also occur, but is not guaranteed and can be very slow even if it does occur.

Existing moorings were replaced with environmentally-friendly 'Ezyrider' moorings (Figure 92) at three mooring scars (8184, 8185 and 8304, Figure 93) in March 2010, and then transplanted with seagrass by MAFRL. The three mooring scars selected by MAFRL were all in similar water depth (2.7 m), had a similar size scar (~10 m diameter), and were all surrounded by meadows of the seagrass *Posidonia sinuosa* (Oceanica 2012).

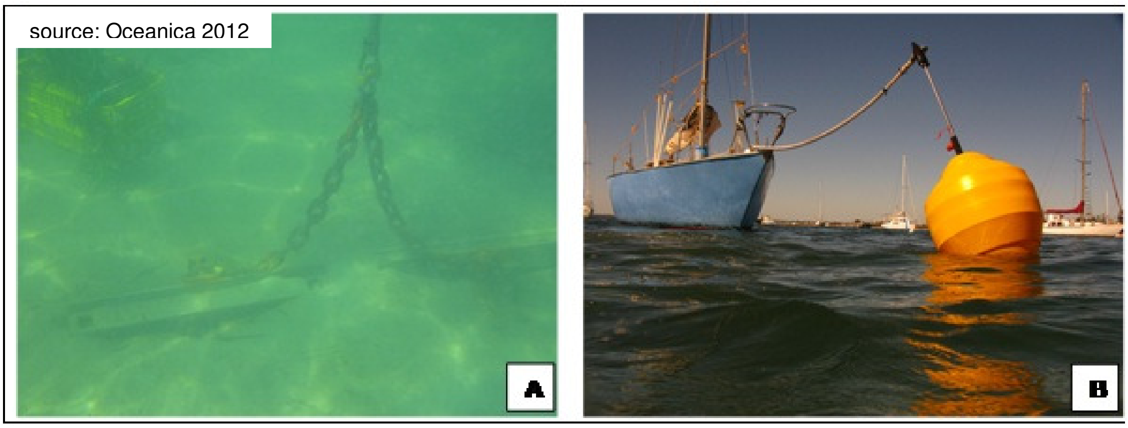


Figure 92 Ezyrider moorings bases (a) beneath and (b) above the water at Mangles Bay

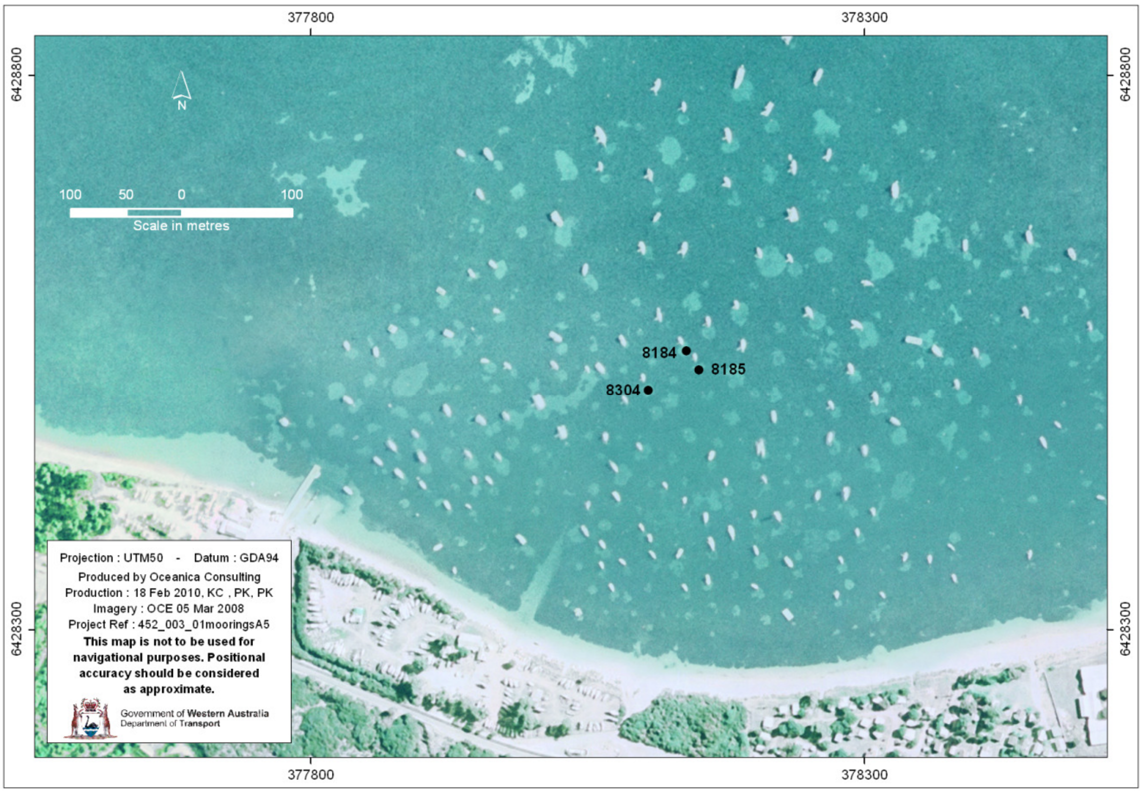


Figure 93 Aerial photograph showing the mooring scars in Mangles Bay for seagrass transplantation trials

The large-scale seagrass rehabilitation techniques developed by MAFRL have undergone considerable improvements in recent years, and based on these results the target species used for the transplanting exercise was *Posidonia australis*. This locally endemic species is found within Cockburn Sound, and is more robust for handling and anchoring than *P. sinuosa*, and therefore better survival and growth are achieved. Once the *P. australis* meadow is established, natural colonisation processes are likely to result in *P. sinuosa* ultimately invading and out-competing the transplanted *P. australis* in the longer-term (Oceanica 2012).

Donor material (*P. australis*) was harvested from an area that has been partially dredged on Parmelia Bank at a depth of 5-6 m (Figure 94a). MAFRL's seagrass rehabilitation research has also shown that donor meadows readily recover from harvesting within approximately two years, and the area used for donor material was located within an area approved for dredging by Cockburn Cement Limited.

Sprigs[12] were harvested from the donor material and then tied to a purpose-designed wire peg (30 cm in length) using two or three biodegradable cable-ties (Figure 94b). Sprigs were collated into groups of five before being secured with string to enable accurate quantification, transport, handling and planting at the planting site (Figure 94c and d). Details on the seagrass transplantation of the three mooring scars, including scar diameter, number of sprigs (*P. australis*) planted and spacing of sprigs is provided in Table 52. The size difference of the sprig and the differing planting densities resulted in a varying amount of sprigs planted in the individual mooring scars.

[12] 'Sprig' refers to 10-20 cm lengths of seagrass rhizome (underground stem) with roots and shoots attached.

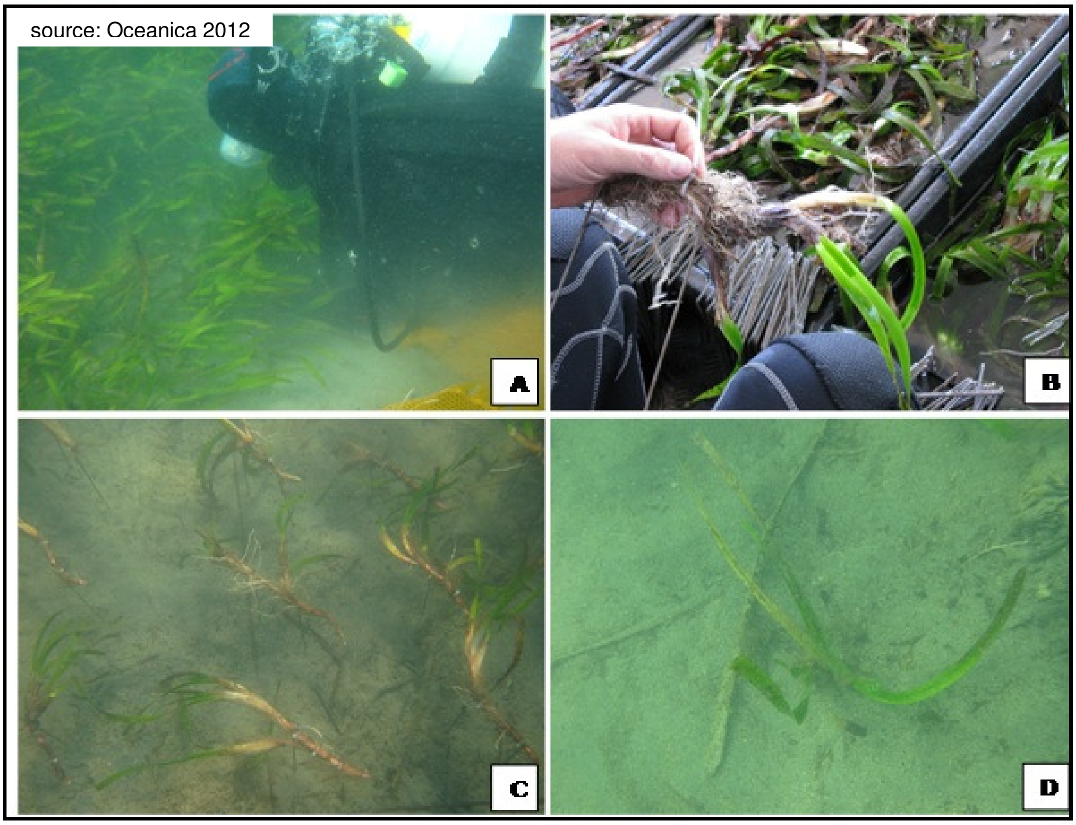


Figure 94 Seagrass rehabilitation techniques: (a) diver harvesting seagrass material from meadow edge, (b) tying sprig onto wire peg, (c) sprigs prior to burial and (d) transplanted seagrass sprig in mooring scar.

Table 52 Mooring scar seagrass transplantation details

Mooring scar	Scar diameter	Number sprigs transplanted	Spacing of transplanted sprigs[1]
8184	9 m	934	0.25 m
8185	8 m	600	Between 0.25 m and 0.5 m
8304	9.5 m	607	Between 0.25 m and 0.5 m

[1] Sprigs initially spaced at 0.5 m and were then filled in with remaining sprigs, resulting in a density between 0.25 m and 0.5 m.

Monitoring of seagrass transplants has been conducted by MAFRL at 3, 6 and 12 months after planting to confirm survival and growth of sprigs (Table 53). Results were as follows:

1. Three months after initial planting the overall survival was 70 %, and casual observations showed bioturbation, low hydrodynamic activity and low light availability as a potential threat of survival in this area.
2. Six months after the initial planting the overall survival was 55.3%, with a decline of nearly 15% since July 2010. Shoots that had survived had grown, with an increase from the initial 2.4 ± 0.1 shoots/sprig in March 2010 to 4.8 shoots/sprig ± 0.63 (mean ± SE [standard error]) in September 2010. Several shoots were observed to be flowering. Observations again showed evidence of bioturbation, low hydrodynamic activity and low light availability as a potential threat of survival of newly planted sprigs in this area, as well as large areas of algal growth.
3. One year after planting, overall survival was 48.2%, and surviving shoots had grown, with an increase from the original 2.4 ± 0.1 shoots/sprig in March 2010 to 7.5 ± 0.7 shoots/sprig (mean ± SE) in March 2011.

Table 53 Survival of seagrass transplants (% survival)

Mooring Scar	July 2010 (3 months)	September 2010 (6 months)	March 2011 (12 months)
8184	74.5 %	56.4 %	46.7 %
8185	63.7 %	50.6 %	59.1 %
8304	70.2 %	58.8 %	38.8 %

Survival expressed as percentage of original number of sprigs initially planted in March 2010.

The survival rates are less than typically found by MAFRL for transplants on nearby Southern Flats in Cockburn Sound, but MAFRL research also indicates that if transplants survive for a year (i.e. they do not get uprooted or washed away by the storms of winter), transplantation is likely to be successful. Casual observations also showed natural re-growth into the mooring scars from the surrounding seagrass beds around the perimeter of the scars, with growth of 25-50 cm from the base markings (Figure 95). Based on the regrowth of existing mature plants into the scars alone, the “infilling” of the scars is estimated by MAFRL to take approximately seven years. The combination of growth of transplanted seagrass and natural regrowth into the scars is estimated by MAFRL to reduce the time it takes to fill in the scars to around four to five years.

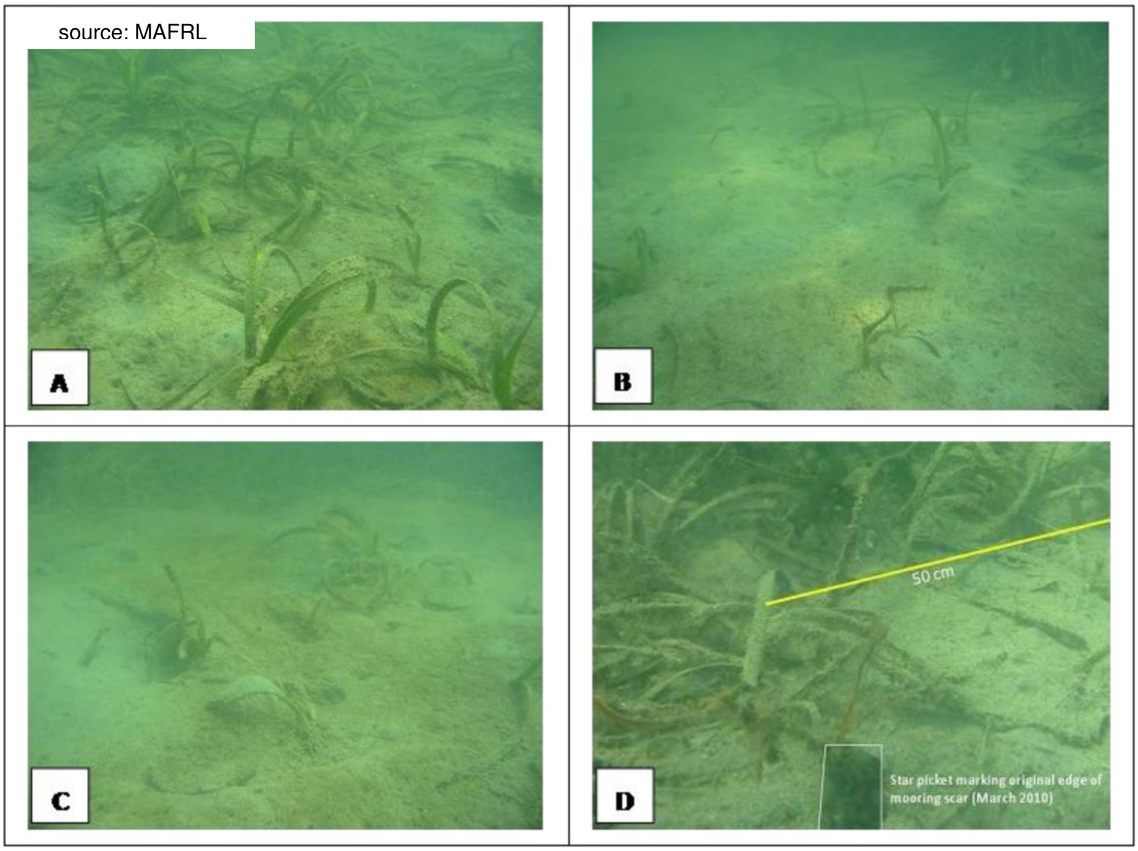


Figure 95 Transplanted shoots at mooring (a) 8184, (b) 8304, (c) 8185 and (d) extension of growth into scar 8184 from surrounding seagrass

12.3 Evaluation of options or alternatives to avoid or minimise impact

The Proposal has undergone a number of variations in order to minimise the environmental impact.

12.3.1 Site selection

Other sites were considered, however the current location was selected because it is an area currently used intensively for recreational boating. As discussed above, the presence of approximately 600 (illegal and legal) moorings within Mangles Bay has resulted in a significant amount of scarring in the seagrass meadows (Section 12.2.1). The location of the Proposal within this already disturbed area is preferable in contrast to other areas with more intact seagrass meadows.

12.3.2 Proposal layout design

The design of the Proposal was selected based on constraints between engineering, planning and the environment. Alternative design concepts have been considered in consultation with the community during the 2005 and 2006 process and the development of the current Proposal. All options involved an inland marina, however each differed with respect to layout and the extent of land footprint. In 1992 as offshore marina option in Mangles Bay was not considered acceptable by the EPA due to the substantial loss of seagrass, even with rehabilitation of seagrass.

A number of adjustments have been made to the Proposal throughout the course of the environmental impact assessment process. A key change has been the shortening the access channel and breakwaters, which serves to create a smaller offshore footprint area and thus a lessened impact in terms of area of seagrass disturbed.

12.3.3 Dredging program

The proposed dredging program for the marina has been designed to avoid or minimise impact on seagrass communities including:

1. Critical windows of environmental sensitivity (defined in EAG No. 7, EPA 2010a) for seagrasses have been considered. The time of year when dredging is proposed to take place is approximately between May and July 2011 when the seagrasses are not actively growing during the winter months.
2. The duration of the dredging program is predicted to be approximately two to three months duration, which is much less than the time taken for shoot loss to occur in *Posidonia sinuosa* even when heavily shaded .
3. Silt curtains will be used (weather and sea conditions permitting) during the dredging process, to control turbidity release and dispersion.

Maintenance dredging is proposed to take place should trigger values indicate it is required. Appendix 1 further details maintenance dredging requirements.

12.4 Assessment of likely direct and indirect impacts

The following aspects of the proposal that have the potential to affect BPPH values include:

- direct removal of seagrass to allow for the construction of the marina access channel and breakwaters
- indirect impacts to seagrass meadows as altered patterns of sediment movement and water flow due to the breakwaters result in the erosion or smothering of seagrass, creating a ‘halo’ effect around breakwaters
- indirect impacts to seagrass meadows due to the turbidity generated during dredging, and any return water from the settlement basins where dredged material is placed
- indirect impacts due to the relocated and redesigned Lake Richmond drain
- indirect impacts to seagrass meadows as a result of alteration in water quality within Mangles Bay as a result of the creation of the marina
- indirect impacts to seagrass meadows due to the turbidity generated during maintenance dredging
- direct impacts to seagrass meadows due to altered and increased boat movements (e.g. due to keel drag and anchor damage).

The Proposal has been estimated to involve up to 5.66 ha of total seagrass loss (refer Section 12.5), comprising direct seagrass removal of up to 5.36ha, and indirect loss (based on a 15 m halo effect around the breakwaters) of up to 0.3 ha. The target for the total area of seagrass rehabilitation will exceed the total losses (refer Section 12.6.1). There are no impacts to BPPH expected as a result of construction of the marina, due to turbidity plumes (as discussed in the marine water quality in Section 10) or the relocation and redesign of the Lake Richmond drain. Nor are ongoing additional impacts to BPPH expected due to altered and increased boat movements, turbidity generated during maintenance dredging, or outflow of lesser quality water from the marina. These potential effects are discussed further below.

As the Proposal lies outside the boundary and is within the sheltered southern end of Cockburn Sound, it is not expected that the construction and operation phases will have an impact on the SIMP.

12.4.1 Direct losses

Losses due to the development footprint (access channel and breakwaters)

The Proposal involves the direct removal of seagrass through dredging for the construction of the breakwaters, reclamation areas, channel and batters (Figure 7). The channel will be dredged using a "cutter suction dredge" in winter and the works are anticipated to take less than three months. Dredged material will be pumped to settlement and infiltration basins located within the Proposal area adjacent to the coast (Figure 9). As there will be no placement of dredge material directly either side of the dredge operation area, the area of seagrass directly impacted will be confined to the cut areas.

Losses due to altered and increased boat movements

Present boating activities in Mangles Bay have resulted in some seagrass loss, largely due to boat launching (and associated keel drag) across the beach adjacent to the premises of the local yacht club (The Cruising Yacht Club) and fishing club (Mangles Bay Fishing Club). Losses due to boat launching are particularly evident at the boat launching site 200 m east of the Mangles Bay Fishing Club jetty.

The Proposal involves the planned removal of the yacht club and fishing club's private boat ramps (and relocation to premises within the Proposal), and the cessation of most boat launching on the beach (it is proposed that the junior sailors can continue to launch their sailcraft from the beach). This should reduce scouring damage in the area and allow natural regeneration of seagrass.

Boating activity can also cause damage to seagrass due to keel drag and anchor drag. At present, recreational boating pressure within the shallow waters of Mangles Bay is largely due to the boats associated with the 650 registered moorings in the Bay (fishing occurs from moored boats, refer Section 16.2.2), boats launched from the private boat ramps of the yacht club and the fishing club in Mangles Bay, and boats launched at Cape Peron public boat ramp and Palm Beach public boat ramp (the two public boat ramps closest to Mangles Bay) (refer Figure 112).

The Proposal will not result in any further increases in trailerable boats other than those due to the regional population growth predicted by the Department of Transport, but will potentially result in an additional 128 non-trailerable boats in the medium-term (by 2018) (refer Section 16.4.3). The non-trailerable boats in the marina are expected to be stay within the access channel and not add to boat movements over seagrass meadows in Mangles Bay: mooring congestion to the east of the access channel will discourage movements into this area, and keel clearance will prohibit movement into the very shallow waters west of the access channel. The non-trailerable boats in the marina are expected to head out the marina access channel to Southern Flats, to the SIMP via the northern Causeway entrance, or to eastern side of Garden Island.

12.4.2 Indirect losses

Losses due to construction dredging

There are no indirect losses of seagrass expected due to turbidity generated during construction activities, as water quality modelling indicates this will be minimal (values of 5 mg/L or less only occurring outside the access channel footprint for 1% of the time for the duration of the dredging program), as well as being highly localised and short-lived (three months) (refer Section 10.4).

Additionally recent research undertaken on the effects of shading on *Posidonia sinuosa* in Cockburn Sound (Collier *et al* 2009) indicates that it can tolerate much greater periods of heavier shading than conditions anticipated during the proposed dredging for the Proposal. The time taken for shoot loss to occur in *P. sinuosa* is generally longer than for other seagrass species (3–6 months), with some shoots surviving over 12 months under conditions below minimum light requirements (Collier *et al*. 2009 and references contained therein). Results of the experiments showed that shoot density declined by 82%

within 105 days under the heavy shade treatment, though 6% of shoots remained after 198 days. Collier *et al.* (2009) estimate that complete shoot loss in high shade would have taken two years.

Dredged material will be placed in settlement basins within the Proposal area and the marine water allowed to infiltrate, but some water will be returned to the ocean via overflow channels. The water quality and velocity levels at the overflow will be managed such that they do not impact on the marine environment (refer to Section 10.4), therefore no losses of seagrass are anticipated due to turbidity associated with the return water.

Losses due to maintenance dredging

The Proposal is located in an area of minimal sediment movement (refer Section 11.1.6) and it is therefore anticipated that maintenance dredging will be required (see Appendix 1). Maintenance dredging will also be of less duration (i.e. involving less material) than construction dredging. As construction dredging is not predicted to cause indirect losses due to turbidity, no losses are expected due to maintenance dredging.

Losses due to a 'halo' effect around breakwaters

Habitat may be smothered due to altered patterns of longshore sediment transport adjacent to the breakwater, and/or eroded by bottom shear stresses due to wave shoaling and reflection in front of the breakwater. These effects typically result in a bare sand 'halo' around most breakwaters and groynes located in seagrass meadows.

Due to the low energy environment of Mangles Bay, the 'halo' effect is likely to be minimised. A conservative allowance of 15 m around the breakwaters has been allowed for the halo effect. Empirical evidence for Mangles Bay indicates that the halo effect is likely to be less than this: seagrass is present less than 10 m from the Causeway, and the Hymus Street groyne.

Losses due to the relocated and redesigned Lake Richmond drain

The Lake Richmond drain presently discharges near the Mangles Bay Fishing Club jetty, and is planned to be relocated to Hymus Street, to discharge to the east of the marina (Figure 28). The realigned drain may potentially impact on habitat due to changes in water quality and possible scouring in the vicinity of the discharge point, but the risk is considered minimal as seagrass loss in the vicinity of the present discharge point appears to be more associated with boat launching activities such as the above mentioned losses due to keel drag during boat launching across the beach. The new location of the drain can also be selected so that it is placed within an area where seagrass is already set further back from the shore, so that the potential for impacts is minimised.

Effects due to alteration of water quality within Mangles Bay

There are no indirect losses of seagrass expected due to the outflow of lesser quality water from the Proposal once it is constructed, since modelling indicates that any impact on water quality outside of the marina will be occasional, slight, and highly localized, extending several 100 metres along shallow nearshore waters towards the Causeway (refer Section 10.4). Seagrasses in this area are also in very shallow waters, and therefore less susceptible to adverse effects from lesser water quality.

Habitat may be smothered by longshore sediment transport adjacent to the breakwater, and/or eroded bottom shear stresses due to wave shoaling and reflection in front of the breakwater. Due to the low energy environment of Mangles Bay, the 'halo' effect is likely to be minimised.

As the Proposal lies outside the boundary and is within the sheltered southern end of Cockburn Sound, it is not expected that the construction and operation phases will have an impact on the SIMP.

12.5 The extent of seagrass loss (total direct and indirect losses) from the Proposal and potential for and nature of any cumulative impacts

In Cockburn Sound, approximately 80% of the seagrasses have been historically lost either due to water quality changes or direct physical impact (EPA 2006b). In view of this, any proposal that is predicted to result in further losses of seagrass will be considered in the context of a Category F area – areas where the cumulative loss threshold has been significantly exceeded (EPA 2009b). The EPA's environmental objective in these areas is to ensure no net loss of BPPH and where possible, to generate a net gain in the area of BPPH and/or their associated BPP communities. The Proponent proposes to address the EPA's environmental objective for Category F areas by including a program of seagrass rehabilitation of an equivalent area that will be lost as a result of the proposal (refer Section 12.6.3), which will form part of an environmental offsets package.

An assessment was undertaken of the potential cumulative impacts for BPPH in Cockburn Sound. Cumulative seagrass loss based on the final marina design has been calculated, based on the EPA's methods for determining cumulative impact on BPPH (EPA 2009b). The seven required steps to calculate losses are described below.

Step 1: What is the Local Assessment Unit?

The LAU has been defined as Cockburn Sound, the total area of this LAU is 10 541 ha (105 km^2).

Step 2: What is the current area of each BPPH within the LAU?

Benthic habitat mapping of Cockburn Sound has been undertaken in considerable detail using aerial photography, extensive spot dives and towed-video ground-truthing and side-scan sonar. The most recent work was conducted in 2008 and provides the most recent description of the dominant habitats across Cockburn Sound, reproduced courtesy of Fremantle Ports (refer Oceanica 2010).

The dominant habitat types were identified and subject to detailed characterisation, including photographic documentation and estimation of spatial coverage:

1. Fine sediment (depth >10 m).
2. Fine sediment (depth <10 m).
3. Seagrass *(Posidonia sinuosa*; *P. australis; P. coriacea;* mixed *P. australis* and *P. sinuosa; and* mixed *Amphibolis* sp. and *Posidonia* sp.
4. Turf algae.
5. Reef (dredge spoil reef and low relief reef).

Spatially, fine sediment (>10 m depth) and fine sediment (<10 m depth) were the most dominant habitats, comprising 64.7% and 27.7% of the management unit area, respectively, followed by seagrass comprising 7% (768 ha) of the area. All other habitats spatially comprised less than 1% of the LAU area (Table 54) and (Figure 96).

Table 54 Current area of habitats within Cockburn Sound (105 km^2)

Habitat	Area (ha)	Area (%)
Fine sediment (>10m)	6821	64.7
Fine sediment (<10m)	2917	27.7
Seagrass	768	7.3
Reef	33	0.3
Algae	2	0.0
Total	**10 541**	**100**

Source: Fremantle Ports

Step 3: What area of each BPPH was originally within the LAU?

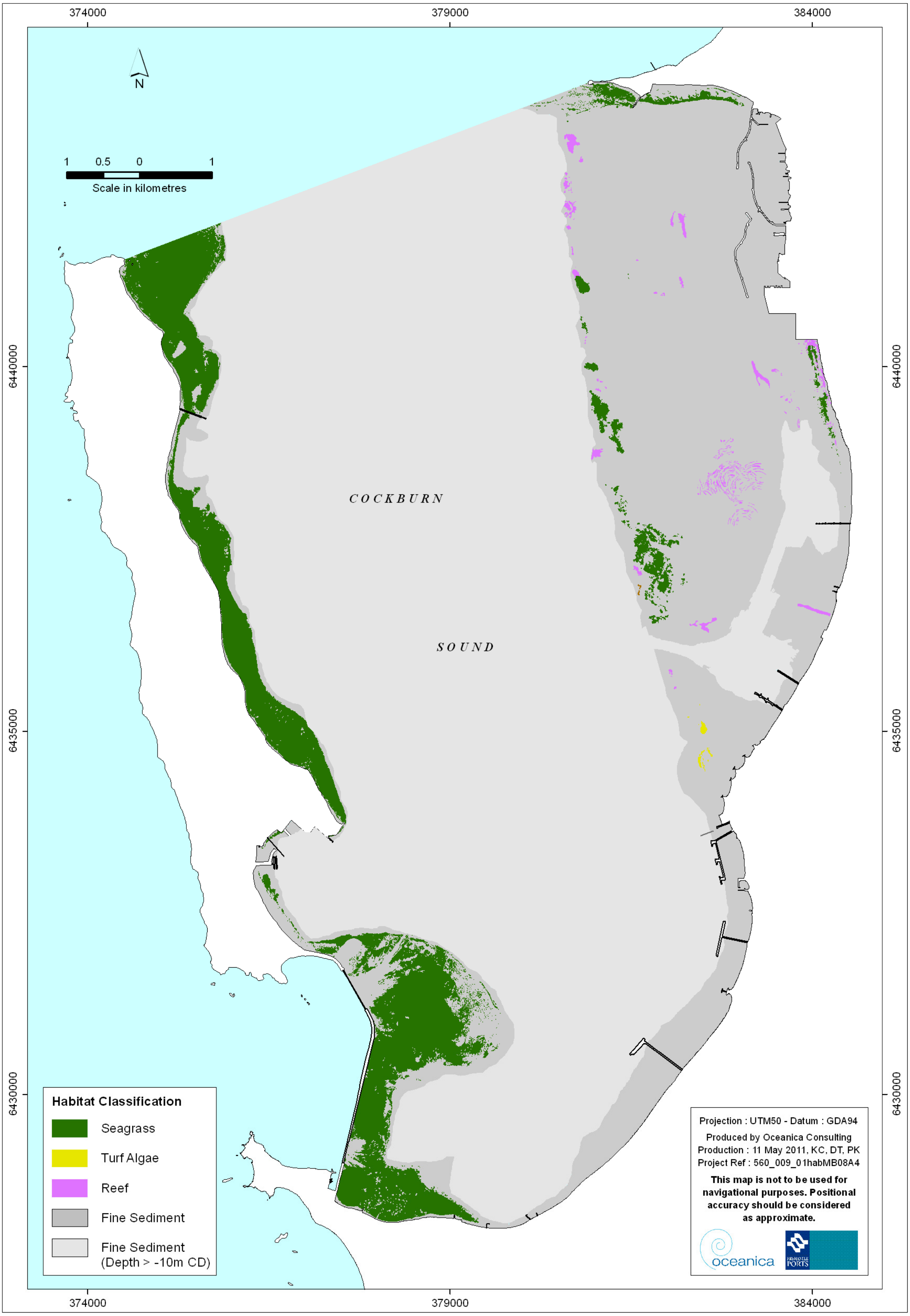
An estimate of the extent of each of the BPPH types present prior to European habitation has been derived for the LAU to establish the baseline for cumulative impact assessment. The pre-impact benthic habitat map is shown in Figure 97 and the habitat coverage areas are shown in Table 55. In estimating these losses, the following assumptions have been made:

1. Reef areas mapped in 2005 were also present before European habitation. Dredge spoil reef areas created by past dredge material disposal have not been included with natural reef features.
2. All sandy areas shallower than -10 m (Chart Datum) in 1944 were colonised by seagrasses. A similar assumption was used by the DEP (1996) in the Southern Metropolitan Coastal Waters Study (DEP 1996).

Table 55 Pre-impact habitat coverage in Cockburn Sound

Habitat type	Area (ha)	Percentage (%)
Deeper than 10 m	6831	46.4
Seagrass	3760	25.6
Reef	15	0.1
Total	**10 605**	**100**

Source: Fremantle Ports



Mangles Bay Marina Based Tourist Precinct

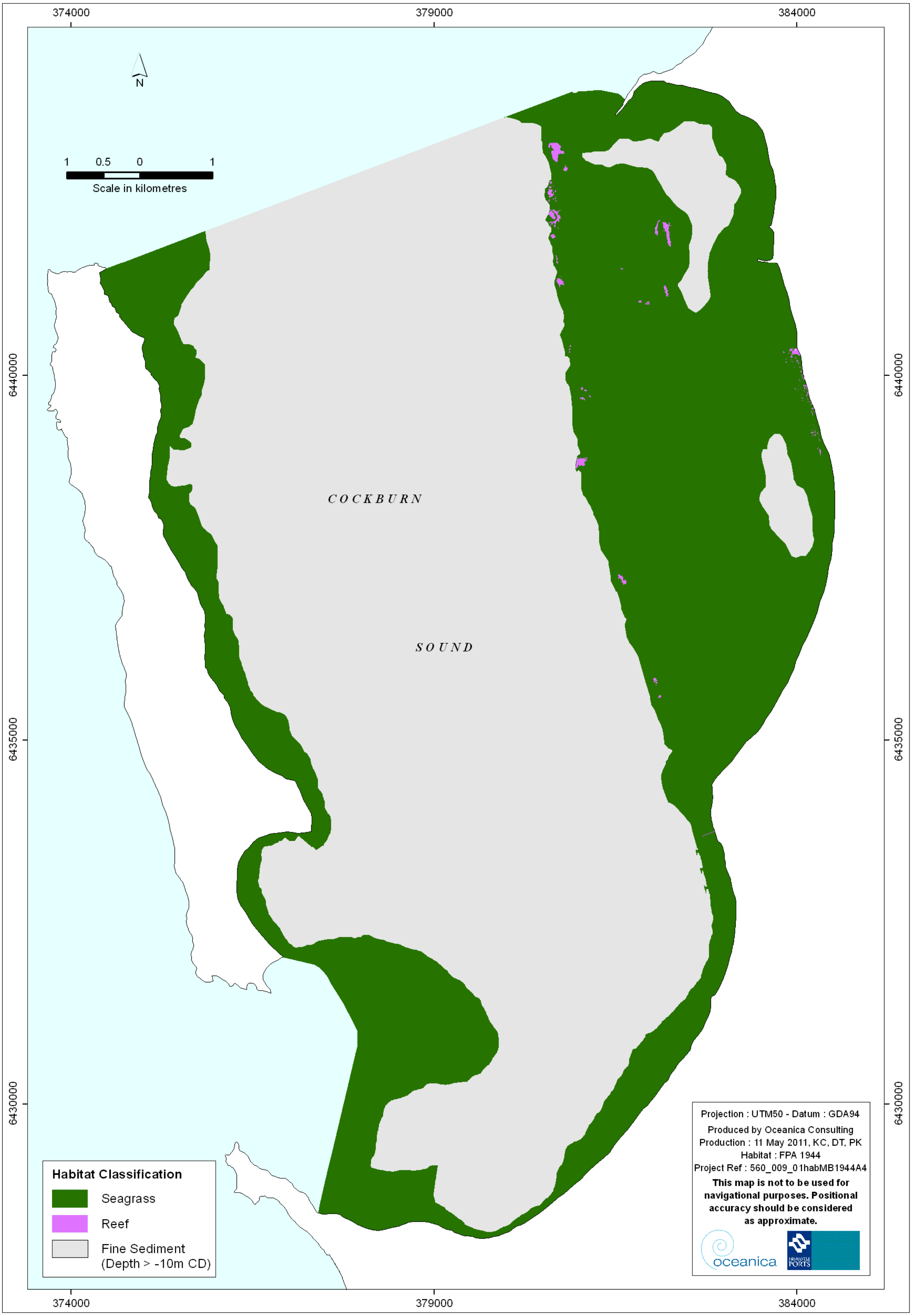
Habitat map of Cockburn Sound

Figure 96

STRATEGEN

strategen

Oct-2011



STRATEGEN

Mangles Bay Marina Based Tourist Precinct

Habitat map for Cockburn Sound prior to European habitation

Figure 97

strategen
Oct-2011

Step 4: What percentage of the original area of each BPPH is present now?

The major causes of past habitat loss in Cockburn Sound include dredging (Stirling and Calista Channels, Australian Marine Complex, Armaments Jetty), reclamation (Woodman Point, Careening Bay and Australian Marine Complex) and loss due to nutrient enrichment. Changes in shoreline position, both natural and following construction of breakwaters and groynes has also resulted in changes in the coverage of marine habitats.

The calculations show that approximately 80% of the original (pre-European habitation) area of seagrass has been lost (Table 56). This is equivalent to the seagrass loss estimates (80%) made by the EPA (EPA 2005b).

Table 56 Estimated BPP losses within Cockburn Sound since European habitation

Habitat	Cumulative losses of each habitat type	
	Change in Area (ha)	Change in area (%)
Fine sediment (<10m)	+2917	N/A
Fine sediment (>10m)	-10	0.2
Reef	+17	N/A
Seagrass	-2992	80

Source: Fremantle Ports

Loss indicated by a negative value, gain indicated by a positive value. Losses/gains of fine sediment (>10m shown for information only, although this is not a BPPH.

Step 5: How much more will be lost?

Habitat losses (seagrass and bare sediment) due to the Proposal are shown in Table 57. A total loss of 7.4 ha of habitat is expected, with ~7.0 ha direct loss and 0.4 ha indirect loss. Direct losses includes breakwaters, reclamation areas, channel and batters, and indirect loss includes a 15 m halo effect around the breakwaters.

Ground truth survey data from dives undertaken at selected locations within the study area enabled definition of two benthic habitat assemblages occurring within and adjacent to the Proposal area, which will be impacted:

1. Dense seagrass (primarily perennial[13] species *Posidonia sinuosa*, with smaller areas of *Posidonia australis* interspersed) (~5.7 ha).
2. Bare sediment (i.e. unvegetated habitat), primarily consisting of mooring scars (~1.7 ha).

Table 57 Habitat losses (ha) due to the Proposal

Habitat type	Direct	Indirect	Total
Seagrass	5.36	0.30	5.66
Fine sediment (<10 m)	1.63	0.06	1.69
Total	7.00	0.36	7.35

Direct loss includes breakwaters, reclamation, channel and batters. Indirect loss is a 15 m halo effect around the breakwaters.

[13] Perennial refers to plants that live from year to year.

Step 6: How much would be lost in total if project proceeds?

In order for impacts to be considered as a result of the Proposal, BPPH losses have been calculated including all existing and EPA approved proposals, as shown in Table 58; however proposals currently being assessed by the EPA were not included. The cumulative impacts considered as a result of these projects, in addition to losses since European habitation are shown in Table 59.

Table 58 Potential BPPH losses (ha) due to currently approved projects and the Proposal

Habitat	James Point Stage 1[1]	Port Rockingham[2]	The Proposal	Total loss
Fine sediment (<10 m)	27.9	9.1	1.69	**38.7**
Fine sediment (>10 m)	39.9	0	0	**39.9**
Seagrass	0	0	5.66	**5.66**
Total	**67.9**	**9.1**	**7.35**	**84.3**

[1] James Point Stage 1 proposal received environmental approval on 17th November 2004: Ministerial Statement 669 (EPA 2004e). Area calculations include reclamation and channel works.

[2] Port Rockingham proposal received environmental approval on 18th February 2010: Ministerial Statement 826 (EPA 2010b).

Table 59 Current cumulative losses of BPPH in Cockburn Sound

Habitat	Original area (ha)	Cumulative losses of each habitat type	
		Change in Area (ha)	Change in area (%)
Fine sediment (<10 m)	N/A (all assumed to be seagrass)	+2878	*N/A*
Fine sediment (>10 m)	6831	-50	0.7
Reef	15	+17	N/A
Seagrass	3 760	-2997	80

Step 7: Comparison with cumulative loss guideline.

Cockburn Sound is classified as a Category F as the cumulative loss guidelines have been significantly exceeded (Table 59) (EPA 2009b). The EPA's environmental objective is therefore to ensure no net loss of BPPH and, where possible, to generate a net increase. Accordingly, the loss of an additional 5.66 ha of seagrass associated with the Proposal must be offset by seagrass transplantation of at least this amount.

12.6 Management measures and performance standards

12.6.1 Construction management

Design and management measures will be applied to the construction, as outlined in the CEMP (Appendix 5). Seagrass health and water quality will be monitored during construction and if management criteria are exceeded, contingency measures will be implemented to avoid permanent impacts to seagrasses.

The construction of the breakwaters for the Proposal will involve the use of construction machinery, including excavators, loaders and trucks. Only trained operators will be employed to operate the machinery to ensure that materials are placed on the seabed in the correct location to ensure that loss of BPPH does not exceed the predicted footprint area. This will be the responsibility of the Proponent. A CEMP will be prepared to outline in detail the proposed breakwater and other construction methods and proposed management measures.

In addition to these management measures, the planned removal of the yacht club and fishing club's private boat ramps, and the cessation of boat launching on the beach, will also reduce scouring damage in these areas and allow natural regeneration of seagrass. It is proposed that the junior sailors can continue to launch their sailcraft from the beach.

Dredging Program

In accordance with EAG No. 7 (EPA 2010a), predictions of environmental impacts will be linked to environmental monitoring and adaptive management that will be executed during dredging operations and will be detailed in the CEMP.

12.6.2 Operational monitoring

Seagrass losses due to the halo effect

The extent of the 'halo' effect around the breakwaters will be determined after construction for a period of two years. Seagrass extent will be monitored through high resolution vertical digital imagery (captured from a plane).

Maintenance dredging

Predictions of environmental impacts during maintenance dredging will be linked to environmental monitoring and adaptive management, based on Department of Transport protocols for the maintenance dredging of its coastal facilities in Western Australia. A maintenance dredging management plan will be prepared, and monitoring will include seagrass health and water quality, as appropriate.

12.6.3 Seagrass transplantation and monitoring

In order to meet EPA guidelines, any loss of seagrass in Cockburn Sound will be offset by rehabilitation of at least an equal area of seagrass within Cockburn Sound. The total area proposed for seagrass replanting is 6 ha, which is greater than the 5.6 ha of seagrass area being removed. As work undertaken for the Proposal indicates there should be gradual natural reestablishment of seagrass within the mooring scars (Section 12.2.3) the Proponent will concentrate the replanting of 6ha in other areas agreed with OEPA and CSMC. A comprehensive seagrass rehabilitation plan will be developed (subject to environmental approval for the Proposal) describing the rehabilitation sites, seagrass species to be used, transplanting units and techniques, spacing of planting units and the proposed monitoring and management measures for the transplanted seagrass.

Target and performance indicators

It is proposed that completion criteria for any seagrass rehabilitation program be linked to a specific percentage survival of planting units for four years, to confirm that survival and growth are sufficient to attain 6 ha of seagrass of 75% average cover within 10 years following planting. Performance indicators will include percentage survival of transplanted seagrass sprigs and shoot density. These criteria are in accordance with projects already approved to undertake seagrass rehabilitation (e.g. Ministerial Statement 846 for Albany Port Expansion Project and Ministerial Statement 787 for the Albany Protected Harbour Development).

Rehabilitation techniques

Seagrass rehabilitation techniques will be in accordance with techniques previously established for seagrass rehabilitation in Cockburn Sound (refer Oceanica 2012) and previously described in Section 12.2.3 for transplantation of the mooring scars. These same techniques would be used for the rehabilitation of seagrass from the offshore footprint of the Proposal.

Selection of donor material

All donor material will be sourced from within the offshore footprint of the Proposal, from the seagrass beds that will be lost due to the development. This will be undertaken prior to construction affecting the seagrass. If infill (top up) planting is required in subsequent years as a contingency measure, then suitable donor material will need to be sourced from either Owen Anchorage or Cockburn Sound. If this is required, appropriate donor sites and donor bed monitoring requirements will be identified.

Site selection

Suitable sites for seagrass transplantation will be identified and surveyed to ensure suitable substrate, water quality and flow conditions. Potential sites for seagrass rehabilitation previously identified for the Proposal (Strategen 2006) included moorings, historical barge scars and existing mooring scars in Mangles Bay, as well as areas on nearby Southern Flats (Figure 98). There are over 500 moorings in Mangles Bay, which potentially create over 3 ha of mooring scars that could be used for seagrass rehabilitation if existing moorings were replaced by seagrass friendly moorings. However as work undertaken for the Proposal indicates there should be gradual natural reestablishment of seagrass within the mooring scars, the replanting of 6ha is likely to be in other areas agreed with OEPA and CSMC.

On Southern Flats, near the Garden Island causeway, an existing Seagrass Research and Rehabilitation Plan undertaken for Cockburn Cement Ltd and the State Government has also successfully transplanted 3 ha of seagrass, and suitable sites for seagrass rehabilitation for the Proposal lie immediately adjacent to this area (refer Oceanica 2012, Appendix 5).

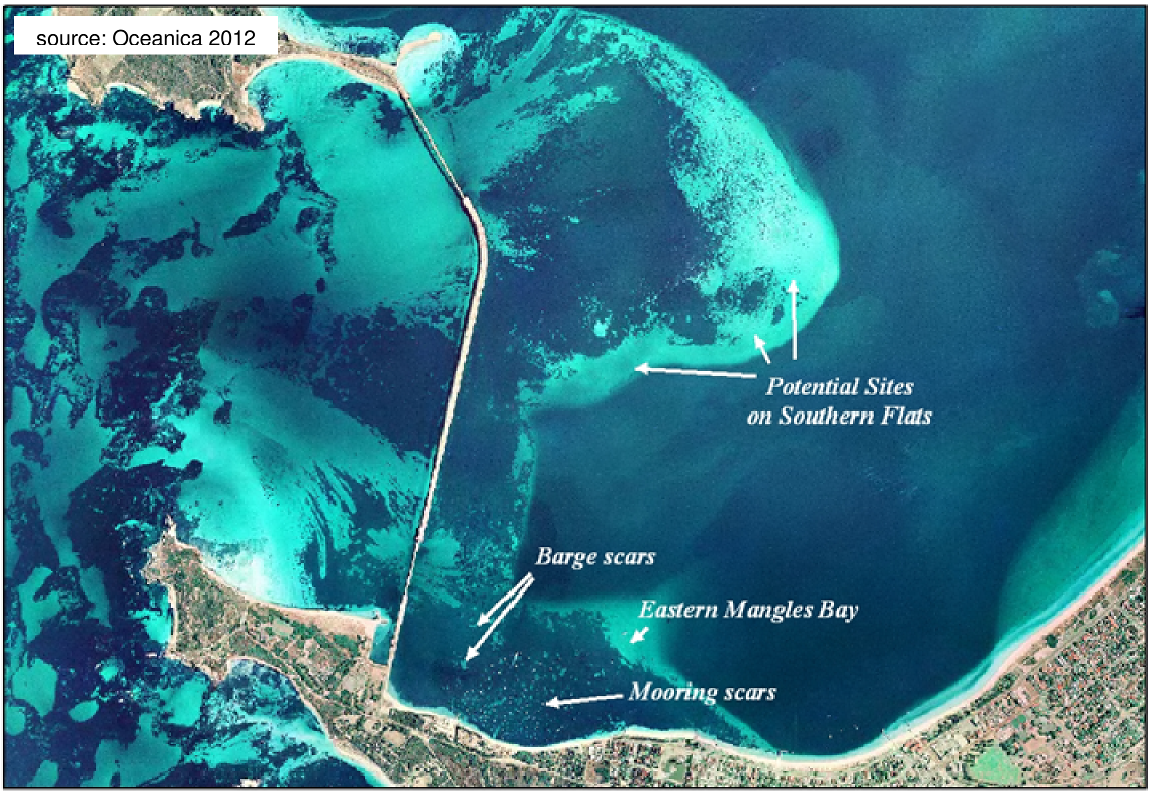


Figure 98 Aerial photograph showing potential sites for seagrass rehabilitation

Maintenance transplanting

Maintenance (or infill) planting may be required to ensure the performance targets are met. Seagrass material will be sourced from nearby seagrass meadows and transplanted using the same techniques.

Previous studies have indicated no detrimental changes in meadows at donor beds after the limited removal of donor material from the leading edge of the meadows. Donor bed recovery appears to be complete by approximately 2.5 years after harvesting (Oceanica 2012). Although no detrimental effects on donor beds are anticipated if maintenance planting is required, the donor beds will be monitored annually for two years to confirm this.

Monitoring

A monitoring program for the seagrass rehabilitation will be implemented on completion of construction activities and include monitoring of the survival and shoot density of rehabilitated seagrass annually for four years to confirm that survival and growth are sufficient to attain seagrass meadow of 75% average cover within 10 years following completion of planting.

The proposed monitoring program is outlined in Table 60 and includes:

- monitoring of the survival and growth of the rehabilitated areas planted to offset the seagrass losses
- monitoring of donor beds – only if maintenance planting is required.

Table 60 Proposed monitoring program for seagrass rehabilitation

Parameter	Frequency	Location	Purpose	Parameter
Area of seagrass loss due to development footprint	Monitored annually for the first two years	Dredge and marina area and immediately adjacent seagrass meadows	To quantify direct losses of seagrass due to the proposal footprint	Area of seagrass loss due to proposal footprint
% survival of rehabilitated seagrass planting units	Monitored annually in summer/autumn for four years after planting, then every two years until target shoot density (i.e. similar to natural meadows) is reached.	Rehabilitated seagrass sites in Cockburn Sound	To confirm that seagrass planting units will meet rehabilitation performance criteria % survival	% survival of rehabilitated seagrass planting units
Shoot density of rehabilitated seagrass planting units	Monitored annually in summer/autumn for four years then every two years until target shoot density (i.e. similar to natural meadows) is reached.	Rehabilitated seagrass sites in Cockburn Sound	To confirm that seagrass planting units are actively growing and expanding such that they will meet performance targets	Shoot density of rehabilitated seagrass planting units
Shoot density of donor beds*	Monitored annually in summer/autumn for following two years to ensure regrowth is occurring.	Donor seagrass sites in Owen Anchorage/Cockburn Sound	To confirm that recovery of shoot density in donor seagrass meadows is as expected	Shoot density of donor beds*

12.7 Predicted environmental outcomes against environmental objectives, policies, guidelines, standards and procedures

The construction of the Proposal will potentially result in approximately 5.66 ha of direct and indirect seagrass loss. Approximately 1.7 ha of bare, unvegetated habitat (primarily mooring scars) will also be removed. These losses will be offset by rehabilitation of 6 ha of seagrass in Cockburn Sound, resulting in no net loss of seagrass in Cockburn Sound in the medium to long-term. As the seagrass losses will be offset with seagrass rehabilitation, there is not expected to be any significant impact on marine flora, in accordance with the EPA objective for BPPH (refer Section 12.1.1). In addition, the *Shoalwater Islands Marine Park Management Plan 2007–2017* (DEC 2007) performance measures and long-term targets for seagrass will be met (refer Section 12.1.1).

13. Marine fauna impact assessment

13.1 Relevant environmental objectives, policies, guidelines, standards and procedures

13.1.1 EPA objectives

The EPA objective for marine fauna is:

To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.

The EPA does not have a specific environmental objective in relation to introduced marine species (IMS[14]), other than their broader objective for Land (Marine), which is:

To maintain the integrity, ecological functions and environmental values of the seabed and coast

To conserve WA's marine environment by managing and reducing the impacts of introduced marine species and by preventing further introductions and spread.

13.1.2 Legislation, policy and guidance

State Protection

The preservation and conservation of fauna is covered by the following Western Australian legislation:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984.*

The DoF is responsible for managing the State's finfish and crab stocks to ensure long-term sustainability and sustainable use of resources; this is done on the basis of sustainability assessments i.e. ensuring that fishing does not cause long-term decline of the resident population. The DoF is also responsible for coordinating WA's IMS control and management actions.

Commonwealth Protection

The Federal EPBC Act protects species listed under Schedule 1 of the Act. In 1974, Australia became a signatory to CITES. As a result, an official list of endangered species was prepared and is regularly updated. This listing is administrated through the EPBC Act. The current list differs from the various State lists; however, some species are common to both.

The EPBC Act also protects a range of shorebirds listed under the JAMBA and CAMBA Migratory Bird Agreements. Most of these are associated with saline wetlands or coastal shorelines. However, some migratory birds not associated with freshwater wetlands are also listed on these international treaties.

[14] Introduced Marine Species (IMS) are species that are not indigenous to Australia (or particular habitats within Australia) but have been transferred to local waters and have either established or have the potential to establish (DAFF, 2009). Introduced marine pests (IMP) are those foreign species that pose a significant risk to environmental values, biodiversity, ecosystem health, human health, fisheries, aquaculture, shipping, ports or tourism (DAFF, 2009).

Threatened marina fauna listed under State and/or Commonwealth

Marine fauna that are listed as threatened species under the Commonwealth (EPBC Act) and/or State WC Act, and that are considered likely to occur in Cockburn Sound and the SIMP, are:

- *Caretta caretta* (loggerhead turtle), listed as Endangered and Migratory under the EPBC Act, and is a Schedule 1 species under the WC Act
- *Dermochelys coriacea* (leatherback turtle), listed as Endangered and Migratory under the EPBC Act, and is a Schedule 1 species under the WC Act
- *Chelonia mydas* (green turtle), listed as Vulnerable and Migratory under the EPBC Act, and is a Schedule 1 species under the WC Act
- *Balaenoptera musculus* (blue whale), listed as Endangered and Migratory under the EPBC Act, and is a Schedule 1 species under the WC Act
- *Eubalaena australis* (southern right whale), listed as Endangered and Migratory under the EPBC Act, and is a Schedule 1 species under the WC Act
- *Megaptera novaeangliae* (humpback whale), listed as Vulnerable and Migratory under the EPBC Act, and is a Schedule 1 species under the WC Act
- *Carcharias taurus* (grey nurse shark), listed as Vulnerable and Migratory under the EPBC Act, and is a Schedule 1 species under the WC Act
- *Carcharodon carcharias* (great white shark), listed as Vulnerable and Migratory under the EPBC Act, and is a Schedule 1 species under the WC Act
- *Neophoca cinerea* (Australian sea lion), listed as Vulnerable under the EPBC Act, and listed as a Schedule 4 species under the WC Act (specially protected fauna).

The three species of marine turtles are seen occasionally in Cockburn Sound, being visitors brought southwards from tropical waters by storms and/or the southward flowing Leeuwin Current (refer also Section 13.2.1).

The Southern Right whale is often seen in Perth coastal waters during its annual southwards migration from late autumn to early spring: this species may occasionally enter Cockburn Sound (refer Figure 3 in Cannell 2004) but is highly unlikely in the southern end of Cockburn Sound due to the restriction posed by the Causeway. The Humpback whale is likely to occur offshore of Garden Island during its southward spring migration or northward autumn migration, but is unlikely to enter Cockburn Sound (refer Figure 2 in Cannell 2004). Two subspecies of the Blue Whale are thought to exist in the Southern Hemisphere, including the Southern Blue Whale and the Pygmy Blue Whale. Blue Whale sightings in Australia are widespread and they are believed to occur around the full extent of the continent. In Western Australia, Pygmy Blue Whales aggregate in deepwater habitat on the northern side of the Perth Canyon where the Leeuwin current causes eddies and downwelling and compensating upwelling as it passes over the canyon. The two species of sharks are likely to be occasional visitors to Cockburn Sound.

A male colony of Australian sea lions uses the waters of the SIMP waters to feed, and the islands as haul-out sites (refer Figure 8 in Cannell 2004), during the non-breeding season. Sea lions are also often seen in waters around Garden Island (including Cockburn Sound) (refer also to Section 13.2.1).

State Environmental (Cockburn Sound) Policy 2005

The State Environmental Policy for Cockburn Sound (SEP) protects the environmental quality within Cockburn Sound, using a framework of Environmental Values (EV) and EQO. Refer to Section 12.1.2 for further details on the SEP. Ecosystem health was identified as an EV, with the EQO for this being:

Maintenance of ecosystem integrity: "*The level of ecological protection to be maintained for ecosystem integrity is described in terms of structure (e.g. biodiversity, biomass and abundance of biota) and function (e.g. food chains and nutrient cycles)*".

The area of Cockburn Sound adjacent to the proposed site for the marina (i.e. Mangles Bay) has been assigned a high level of ecological protection, which allows small changes in the quality of water, sediments and biota.

The waters within the marina are classified as an artificial inland waterway, and therefore not zoned for ecological protection under the SEP. The objective for marina waters will therefore be to ensure that water quality exiting the marina does not compromise the relevant EV and EQO for Mangles Bay. Water quality within the marina comes under WA Planning Commission (WAPC) Policy No. DC1.8, which provides Guidelines for approval of canal estates and other artificial waterway development: this is discussed further in Section 10.

Shoalwater Islands Marine Park

The SIMP (refer Figure 57) borders Mangles Bay at the Garden Island causeway and therefore may potentially be impacted by the Proposal. *The Shoalwater Islands Marine Park Management Plan 2007–2017* (DEC 2007) lists management objectives, strategies, performance measures and targets to achieve, including the following management objectives in relation to marine fauna.

Finfishes

- to manage targeted finfish species for ecological sustainability in the SIMP
- to ensure non-targeted finfish species are not significantly impacted by recreational and commercial fishing in the SIMP.

Marine invertebrates

- to manage targeted invertebrate species for ecological sustainability in the SIMP
- to ensure non-targeted invertebrate species are not significantly impacted by recreational and commercial fishing in the SIMP.

Cetaceans (whales and dolphins)

- to ensure the abundance of cetaceans is not significantly impacted by future human activities in the SIMP.

Little penguins

- to ensure the abundance of the little penguin is not significantly impacted by a reduction in available prey species or from physical disturbance by boats or boat-strikes in the SIMP.

Australian sea lion

- to ensure Australian sea lions frequenting the SIMP waters are not injured, killed or significantly disturbed by human activities or interactions.

Introduced Marine Species (IMS)

The Management Plan’s objective for water and sediment quality ‘*To ensure that water and sediment quality is not significantly impacted by future human activities in the marine park*’ recognises that the presence of large ships in Cockburn Sound increases the potential for non-Indigenous marine species to be introduced to the SIMP via ballast water discharge and hull fouling, and hence may affect water and sediment quality in the SIMP.

Shoalwater Bay island nature reserves

The Shoalwater Bay islands are a chain of islands between Cape Peron and Becher Point, and include Penguin Island, Shag Rock, Seal Island, Gull Island, Bird Island, White Rock, The Sisters, Passage Rock, Third Rocks, First Rock and Second Rock. It covers an area of about 16ha. The Islands have significant conservation value. Penguin Island supports the largest breeding population of little penguins on the west coast of Australia, and the Australian sea lion uses Seal Island and occasionally other Islands as 'haul-out' or resting sites.

The islands consist of four nature reserves and vacant crown land that are managed under the *Shoalwater Islands Management Plan 1992–2002* (CALM 1992). Penguin Island is closed for the peak laying period of the Little Penguin (the winter months), and Seal Island is closed to the public to protect the Australian sea lions.

Carnac Island nature reserve

Australian sea lions use Carnac Island as a haul-out area during the non-breeding season. There is a small visitor exclusion zone on the beach at Carnac Island to allow sea-lions a sanctuary area where they can escape from people if they choose. The island also is an important nesting habitat for several species of seabirds, including little penguins.

Fisheries Resources Management Act 1994 (WA)

This Act provides for the declaration of certain aquatic species as "noxious fish," and makes it unlawful for an individual or body corporate to have, consign, keep or convey such species in Western Australia, or any designated part of Western Australia. Under Regulation 176 of the Fish Resources Management Regulations 1995, a person must not bring into the State a species of fish not endemic to the State without the written approval, or written authority, of the Chief Executive Officer of the DoF. The Act defines fish as "*an aquatic organism of any species (whether alive or dead) and includes:*

- the eggs, spat, spawn, seeds, spores, fry, larva or other source of reproduction of offspring of an aquatic organism; and
- a part only of an aquatic organism (including the shell or tail), but does not include aquatic mammals, aquatic reptiles, aquatic birds, amphibians or (except in relation to Part 3 and Division 1 of Part 11) pearl oysters[15]."

Amendments to the Act in 2006 broadened the definition to include "*live rock and live sand*".

13.2 Species of significance

13.2.1 Key species of marina fauna

Fish and invertebrates

The key potential impacts of the Proposal identified for fish and invertebrates (prior to the implementation of management measures), in order of importance were:

1. Increased human access and fishing pressure.
2. Loss of benthic habitat (seagrass).
3. Build up in chemical contaminants (bioaccumulation).

[15] It is proposed that "pearl oysters" specifically excluded in the existing definition should be only pearl oysters of the species *Pinctada maxima.*

Dolphins

The key potential impacts of the Proposal identified for dolphins (prior to the implementation of management measures), in order of importance were:

1. Loss or change in prey species.
2. Entanglement in ropes, nets and lines, and other marine debris.
3. Increased human-dolphin interactions and change in behaviour.

Little penguins

The key potential impacts of the Proposal identified for little penguins (prior to the implementation of management measures), in order of importance were:

1. Increased vessel movements, leading to displacement of penguins from feeding areas and/or to vessel strikes.
2. Loss or change in prey species.
3. Entanglement in ropes, nets and lines, and other marine debris.
4. Build up in chemical contaminants (bioaccumulation).

13.2.2 Other marine fauna

Marine turtles breed and are generally found from Shark Bay and northwards. They are only occasionally seen in the Perth Metropolitan area, with their presence thought to be largely due to a combination of storms and the southward flowing Leeuwin Current. The loggerhead has the most southerly nesting range of all species nesting in Western Australia (Shark Bay), and is also the most commonly observed marine turtle species in southwest region of Western Australia. The loggerhead turtle is considered a migratory visitor to the southwest region of Western Australia, with adult and large sub-adult turtles seen between Rottnest Island and Geographe Bay (DEWHA 2008). It is possible that the loggerhead turtles occasionally seen in the Perth Metropolitan area (usually in summer) are using these waters as seasonal foraging grounds (when the water temperature is warmer) and foraging further north in winter. However, marine turtles have not been identified as key species likely to be affected by the Proposal, as Mangles Bay is neither a nesting area nor a resident foraging area. This approach is consistent with other approved developments in Cockburn Sound, including James Point Port: Stage 1 (JPPL 2001) and the Port Rockingham Marina PER (RPS 2009), and with the SIMP Management Plan (DEC 2007; which notes that some species of marine turtles are occasional visitors to the park, but has no specific management objective for them).

The Australian sea lion is endemic to Australia. A colony of male sea lions uses the islands of the SIMP as haul-out sites. The haul-out sites are used during the non-breeding season, with Seal and Carnac islands being the primary sites in the Perth Metropolitan area (refer to Figure 8 in Cannell 2004). Australian sea lions are excellent divers and spend their time at sea foraging close to or on the seabed. They can feed in depths that can exceed 300 metres, but also use SIMP waters to feed (DEC 2007). Their feeding is opportunistic with fish, sharks, squid, octopus, cuttlefish, lobster and even occasionally birds and turtles making up their diet. Although Australian sea lions are often seen in waters around Garden Island (including Cockburn Sound), the area adjacent to the proposed Mangles Bay marina is very shallow and has high boat traffic, and therefore is not considered to be a key feeding area or habitat for Australian sea lions.

The current major pressure on Australian sea lions, as listed in the SIMP Management Plan (DEC 2007), is physical disturbance from human interaction (e.g. tourism and vessel activity, noise and boat strike). Boat strike is also a recognised risk to marine turtles. The marina will result in some increase in recreational boat traffic in Cockburn Sound and, to a lesser extent, the SIMP (see Section 16), so although marine turtles and the Australian sea lion are not considered key species at risk due to the Proposal, the potential impacts of recreational boating will still need consideration in the operational management of the marina. The construction management plan for the marina will also need to include fauna observation protocols for sea lions and turtles.

13.2.3 Introduced marine species

Introduction of marine pests due to the Proposal has been identified as a potential risk to marine fauna. The introduction of marine species into areas outside their native range is a serious risk to Australia's native marine life, and can also greatly impact on commercial fisheries and aquaculture industries (ABS 2001). The two primary mechanisms by which IMS can be introduced to a new location are through ballast water and biofouling[16].

13.3 Findings of surveys and investigations

The information contained in this section has primarily been prepared based on information from the following reports:

- fish and marine invertebrates (McLean 2012)
- dolphins (Finn 2011)
- little penguins (Cannell 2011).

13.3.1 Fish

The majority of the following information on fish (this section) and invertebrates (Section 13.3.2) has been summarised from a report by McLean (2011). In addition, a meeting was held with personnel from the Fisheries Research Division of the DoF, Oceanica Consulting and Mindabbie Marine on 13 March 2011 to discuss the proposed Mangles Bay marina and possible effects on fish. The key issues discussed at this meeting were increases in boat traffic, increased fishing pressure and loss of habitat (seagrass), which are discussed below and in Section 13.5.

Fish community of Mangles Bay

Over the past 30 years there have been a number of studies that have examined single fish species or assemblages of fish within Cockburn Sound (e.g. Dybdahl 1979; Hyndes *et al*. 1998; Vanderklift and Jacoby 2003; Valesini *et al*. 2004; Smith *et al*. 2008; Wakefield 2006; Breheny 2009; Wakefield *et al*. 2009). Few have provided information on fish specifically for the Mangles Bay area, but from these it is clear that the sheltered waters of Mangles Bay provide significant habitat for a wide range of fish species (Hyndes *et al*. 1998; Whitehead 2000; Valesini *et al*. 2004; Smith *et al*. 2008). Compared to the broader Cockburn Sound area, Mangles Bay is considered to have high fish diversity and abundance (Valesini *et al*. 2004; Smith *et al*. 2008). Mangles Bay is also an important nursery ground for a range of fish species, including those heavily targeted by fishers (Hyndes *et al*. 1998; Valesini *et al*. 2004; Smith *et al*. 2008), and is only one of a few known fish nursery ground locations within Cockburn Sound (Hyndes *et al*. 1998; Valesini *et al*. 2004).

The fish community in the shallow, predominantly seagrass habitat in Mangles Bay is characterised by: whiting (*Sillaginidae* spp.), trumpeters (*Teraponidae* spp.), tarwhine (*Sparidae*), mullet (*Mugilidae* spp.), hardy heads (*Atherinidae* spp.), gobies (*Gobiidae* spp.), flounder (*Bothidae*), toadfish (*Tetraodontidae* spp.), leatherjackets (*Monacanthidae* spp.) and cardinalfish (*Apogonidae* spp.) (Vanderklift and Jacoby 2003; Valesini *et al*. 2004). These fish species utilise the seagrass beds in Mangles Bay for shelter and/or a food source (mostly the large numbers of small invertebrates present, and decaying organic matter from

[16] Ballast water refers to water that a ship takes on board at a port before commencing a voyage in order to provide stability in unladen ships, with marine organisms taken on board as well. Biofouling refers to the attachment of biological material (microorganisms, plants, algae and animals) on submerged structures such as ships hulls and internal areas.

seagrass and algae, although a few species feed on seagrass and attached algae (Vanderklift and Jacoby 2003).

High numbers of juveniles from a wide range of species have been recorded in the seagrass meadows of Mangles Bay, including early juvenile King George whiting (*Sillaginoides punctulatus*) (Whitehead 2000). Late stage King George whiting larvae are considered to utilise the southern entrance of Cockburn Sound to enter into the sheltered waters of Mangles Bay to settle – a process that may be hindered by the Causeway which has almost closed off this entrance (Whitehead 2000). Fish larval assemblages in the seagrass meadows of Mangles Bay are considered to be quite different to those of the seagrass meadows of eastern Garden Island, possibly due to the presence of a clockwise gyre (wind driven circulation) causing localised upwelling in this area (Breheny 2009). The sheltered conditions of Mangles Bay may also simply provide favourable spawning sites for adults. The significance of Mangles Bay as a nursery habitat is also likely due to its high degree of shelter, as well as extensive seagrass meadows close to shore (providing protection from predators) and a high availability of food (invertebrate prey) (Hyndes *et al*. 1998; Valesini *et al*. 2004).

The DoF has undertaken annual surveys of juvenile fish abundance in Mangles Bay (among other areas) since 1999 (see Smith *et al*. 2008), and since mid-2005 has specifically focused on seven key fishery species: tailor (*Pomatomus saltatrix*), Australian herring (*Arripis georginaus*), Australian salmon (*Arripis truttaceus*), King George whiting (*Sillaginoides punctulatus)*, yellow-fin whiting (*Sillago schomburgkii)*, sea mullet (*Mugil cephalus)* and yellow-eye mullet (*Aldrichetta forsteri)*. Surveys are conducted monthly from September to April each year (Smith *et al*. 2008) and results confirm those of Valesini *et al*. (2004) in finding that Mangles Bay had the highest fish diversity and abundance of all sites surveyed on the southwest and south coast. Smith *et al*. (2008) suggest that many fish species might spawn exclusively at west coast sites such as Mangles Bay, which likely act as a source for south coast populations, and so any change to breeding stocks in Mangles Bay has the potential to affect the status of south coast inshore fish populations and fisheries.

The deeper waters off Mangles Bay also appear to be an important nursery area for a range of baitfish species, with eggs of whitebait (*Hyperlophus vittatus*), and the juveniles of whitebait, blue sprat (*Spratelloides robustus*) and Australian anchovy (*Engraulis australis*) found in this area (Valesini *et al*. 2004; Smith *et al*. 2008). From 2006–2008, the DoF undertook repeat trawls in 10-20 m deep water at seven sites in southern Metropolitan waters: Owen Anchorage, an area at the NE edge of the Central Basin, Garden Island North, Garden Island South, Jervoise Bay, James Point and Mangles Bay. Anchovy were found in trawls at the Mangles Bay site (approximately 1.5 km offshore), and were second in abundance only to the Garden Island South site, yet anchovy were not listed as a common and widespread species within the Sound (Johnston *et al*. 2008). Another study in 2007 and 2008 sampled many sites within Cockburn Sound to determine larval fish assemblages associated with pink snapper (*Pagrus auratus*) spawning associations. Areas with high abundance of anchovy larvae varied between years: for example, abundance was lower overall in 2008 compared to 2007, and the highest abundance was found in the central basin of Cockburn Sound in 2007 and at James Point in 2008 (Figure 99; Breheny 2009). Similar variability occurred for other larval fish (Figure 100; Breheny 2009). Anchovy larvae were, however, found in similar abundances in the Mangles Bay area in both years, indicating the deeper waters (depth 10-20 m) off Mangles Bay may serve as a more consistent site for anchovy (Figure 99).

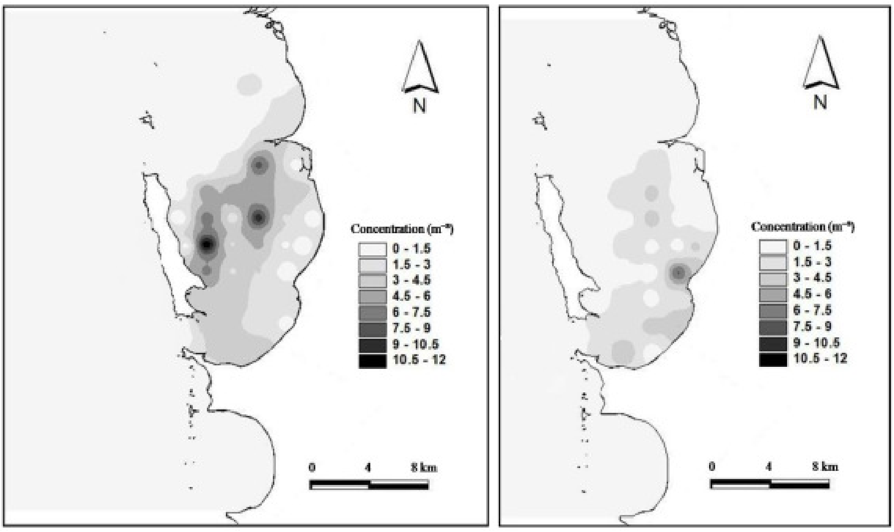


Figure 99 Spatial distribution of anchovy larvae, 10 – 12 November 2007 (left) and 27-28 November 2008 (right), source: Breheny 2009

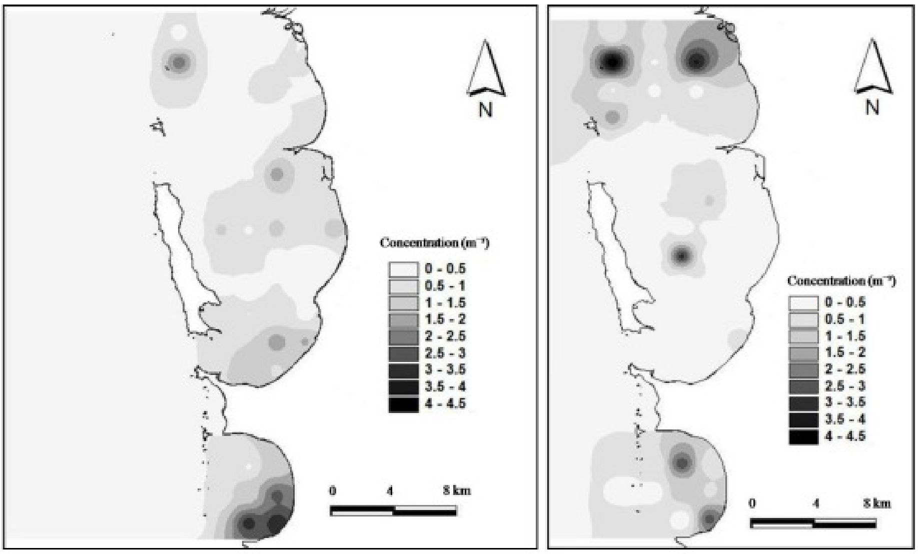


Figure 100 Spatial distribution of all larval fish species, excluding anchovy, 10-12 November 2007 (left) and 27-28 November 2008 (right)

Mangles Bay is not an important spawning or nursery habitat for pink snapper (*Pagrus auratus)*, which is perhaps the most important recreational and commercially targeted fish species in Cockburn Sound (Wise *et al*. 2007). The broader Cockburn Sound embayment is one of only a few known spawning grounds and nursery areas for the pink snapper in the West Coast Bioregion (Wakefield 2006; Lenanton *et al*. 2009; Wakefield *et al*. 2009).

Spawning times for important fish species in Mangles Bay are as follows:

- King George whiting spawn from winter to early spring (Hydnes *et al*. 1998)
- peak spawning for whitebait occurs from winter to spring, with egg concentrations also reportedly high at this time throughout Cockburn Sound
- spawning of Australian anchovy - and many other fish species (e.g. whiting species except King George whiting, leatherjackets, herring, wrasse, trevally, flounder) - is synchronous with the (temperature-dependent) spawning times for pink snapper, from October – December (Breheny 2009)
- Blue sprat spawn during the summer months (when they are most common in the diet of Penguin Island penguins; Cannell 2011).

Commercial fishing in Cockburn Sound

There are two managed commercial fisheries that operate wholly and target finfish within the broader region of Cockburn Sound:

1. Cockburn Sound Line and Pot fishery (13 licences).
2. Cockburn Sound Fish Net fishery (1 licence) (Smith and Brown 2010; D. Brown *pers comm*.).

The majority of the catch comprises garfish, herring and pink snapper.

Two additional fisheries also operate partly within Cockburn Sound:

1. West Coast Beach Bait Managed Fishery.
2. West Coast Purse Seine Managed Fishery (Smith and Brown 2010).

The first fishery targets whitebait, blue sprat, sea mullet, yellow-finned whiting, garfish and yellow-eye mullet (Smith and Brown 2010). The second fishery mainly captures pilchards (*Sardinops sagax*) and tropical sardine (*Sardinella lemuru*), with smaller catches of other species also reported (Molony and Lai 2010).

Commercial fishers do not operate within Mangles Bay itself, but the bay is an important nursery area for the whole of Cockburn Sound. As noted earlier, any changes that affect the suitability of this area as a nursery or that result in a decline in juvenile abundance have the potential to affect commercial fisheries in the broader Cockburn Sound area and even on the south coast.

Recreational fishing in Mangles Bay and surrounding areas

Recreational fishers in Mangles Bay and surrounding areas target a number of fish species, primarily Australian herring, King George whiting, skipjack trevally (*Pseudocaranx* spp.), pink snapper, tailor and garfish (*Hyporhamphus melanochir*). Recreational fishing is very popular in Mangles Bay (refer also Section 16) with fishing taking place from boats on moorings, boats at anchor, boats at drift and from the beach both during the week and on weekends (Dybdahl 1979; L. Dettagello [Mangles Bay Fishing Club] pers. comm.).

13.3.2 Marine invertebrates

Marine invertebrates include a very broad range of fauna such as molluscs (shellfish), crustaceans, anemones, sponges, sea urchins and worms. A number of benthic invertebrate surveys have been carried out in Cockburn Sound (Marsh 1978a; b; Devaney 1978; Wells and Threlfall 1980; Vanderklift and Jacoby 2003; Valesini *et al*. 2004; Johnston *et al*. 2008), however, findings have differed somewhat, largely as a result of the different sampling equipment used and habitats surveyed.

The trawl net study of Johnston *et al*. (2008) found Mangles Bay was dominated by few macroinvertebrate species, including: crabs (*Portunus pelagicus* and *P. rugosus),* orange sea pen (*Cavernularia* spp), prawns (*Metapenaeopsis fusca, M. lindae, Melicertus latisulcatus),* mantis shrimp (*Belosquilla laevis)* and seastars (*Astropecten preissi).* Present in lower abundances were: southern calamari squid (*Sepioteuthis* *australis),* cuttlefish (*Sepia novaehollandiae),* sponges (*Tethya* cf. *ingalli,* unidentified spp*)*; tube anemones (*Pachycerianthus sp.)*: and, sea pens (*Sarcoptilus grandis).*

Valesini *et al*. (2004) used a variety of techniques (sediment cores, plankton nets, sleds) to study invertebrate fauna within a range of nearshore habitats in Cockburn Sound, including shallow sheltered seagrass habitats such as Mangles Bay. Benthic macroinvertebrate assemblages in sheltered seagrass habitats were characterised by polychaetes (segmented worms), with high densities of other worms also present, particularly nematodes (small, thread-like unsegmented worms) and amphipods (small crustaceans). Polychaetes are sub-surface deposit feeders often abundant in sheltered environments that are high in sedimentary organic matter (such as Mangles Bay). Valesini *et al*. (2004) also reported juvenile decapods (e.g. crabs, prawns) and capitellid worms in sheltered seagrass habitats. Conversely, Valesini *et al*. (2004) found that zooplankton (a major food source for fish) were least abundant in sheltered seagrass habitats.

The most important recreational and commercially targeted invertebrate species in Cockburn Sound is the blue swimmer crab, *Portunus pelagicus.* This species lives from the intertidal zone to at least 50 m depth, in habitats ranging from sand and mud to seagrass (Edgar 1990; in Sumner and Malseed 2004). Blue swimmer crab are scavenging, opportunistic bottom-feeding carnivores (Kangas 2000). Mangles Bay and Jervois Bay are reported to have high abundances of blue swimmer crab in comparison to other locations within Cockburn Sound. These sites are also identified as important recruitment areas (Johnston *et al*. 2008).

Blue swimmer crabs spawn between October and January, with larvae settling up to 6 weeks later (Kangas 2000). Stocks of blue swimmer crab in Cockburn Sound have been shown to be genetically independent of other stocks in the state (Chaplin *et al*. 2001) and therefore overfishing or detrimental environmental changes could have severe consequence for these populations.

Commercial fishing of invertebrates in Cockburn Sound

Blue swimmer crabs are fished under the Cockburn Sound Crab Managed Fishery (12 licences; Johnston *et al*. 2011), using purpose-designed crab traps and are managed by input controls (Johnston and Harris 2010). This fishery was closed for two seasons 06/07 and 08/09 following a rapidly depleting catch. The decline was attributed to combined influences of irregular cool water temperatures and fishing practices (gear used, level and timing of fishing) (Johnston *et al*. 2011). A limited level of fishing was permitted during 2010 following sufficient recruitment and recovery of residual stock (Johnston and Harris 2010).

Other targeted invertebrates in Cockburn Sound include octopus (*Octopus tetricus*), southern calamari squid (*Sepioteuthis australis)* and mussels (*Mytilus edulis*). Commercial fishing for octopus occurs through the Cockburn Sound Line and Pot Fishery where there is currently no limit on the number of traps used. The Cockburn Sound Line and Pot Fishery also target squid using jigs, however fishing for squid mainly occurs in the recreational sector. Mussels are farmed in Cockburn Sound (near the CBH grain terminal, and also on Southern Flats) by collecting wild spat that is then attached to longlines for grow-out to market size (Lawrence 2005).

Recreational fishing in Mangles Bay

The main invertebrate targeted by recreational fishers in Mangles Bay is the blue swimmer crab (mainly from boats). Recreational fishers use drop-nets, or dive for crabs, with this fishery managed by size, catch and pot limits. Within Cockburn Sound, recreational crabbing effort is reported to be highest in the Mangles Bay area (Sumner and Malseed 2004, refer also Section 16). Jigging for squid (mainly from boats) is also popular. Recreational fishing restrictions for squid and octopus include a bag limit of 15 and a boat limit of 30.

13.3.3 Dolphins

Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) are generally found within in-shore and coastal areas throughout the Perth Metropolitan area and the southwest region, and common bottlenose dolphins (*T. truncatus*) are typically found in off-shore environments.

Studies in both 1993-7 and 2008 have identified more than 150 individual bottlenose dolphins within Cockburn Sound and Owen Anchorage, including a resident community in Cockburn Sound. Distinctive features of the ecology of bottlenose dolphins in Cockburn Sound include long-term site fidelity[17] and limited home ranges (e.g. less than 100 to 150 km^2). The dolphins forage throughout Cockburn Sound and use a broad range of habitats (refer Figure 101 and Figure 102). They use a variety of behaviours to capture prey (which allows them to adapt to seasonal changes in the prey availability), and feed on prey as small as 'baitfish' (e.g. anchovies) and as large as pink snapper. There are three broad habitat areas for dolphins within Cockburn Sound:

- the deep (18+ m) central basin extending from Mangles Bay northwards to Success Bank
- the Kwinana Shelf (Eastern Flats) in the northeast corner (James Point northwards to Woodman Point)
- seagrass meadows running along the western margin (Southern Flats and Garden Island).

The distribution and habitat-use patterns of dolphins vary seasonally, and these patterns are likely to reflect changes in the abundance and distribution of fish in the locations. For example, large feeding aggregations are common on the Kwinana Shelf from autumn to spring, probably targeting schools of baitfish that are seasonally present. The food requirements of dolphins are considerable; making them quite sensitive to factors that make it more difficult for them to find and capture prey.

[17] Site fidelity describes the tendency of an animal to use a defined area for a long period of time (often their entire life-time) and is a common characteristic of bottlenose dolphins inhabiting inshore and coastal ecosystems.

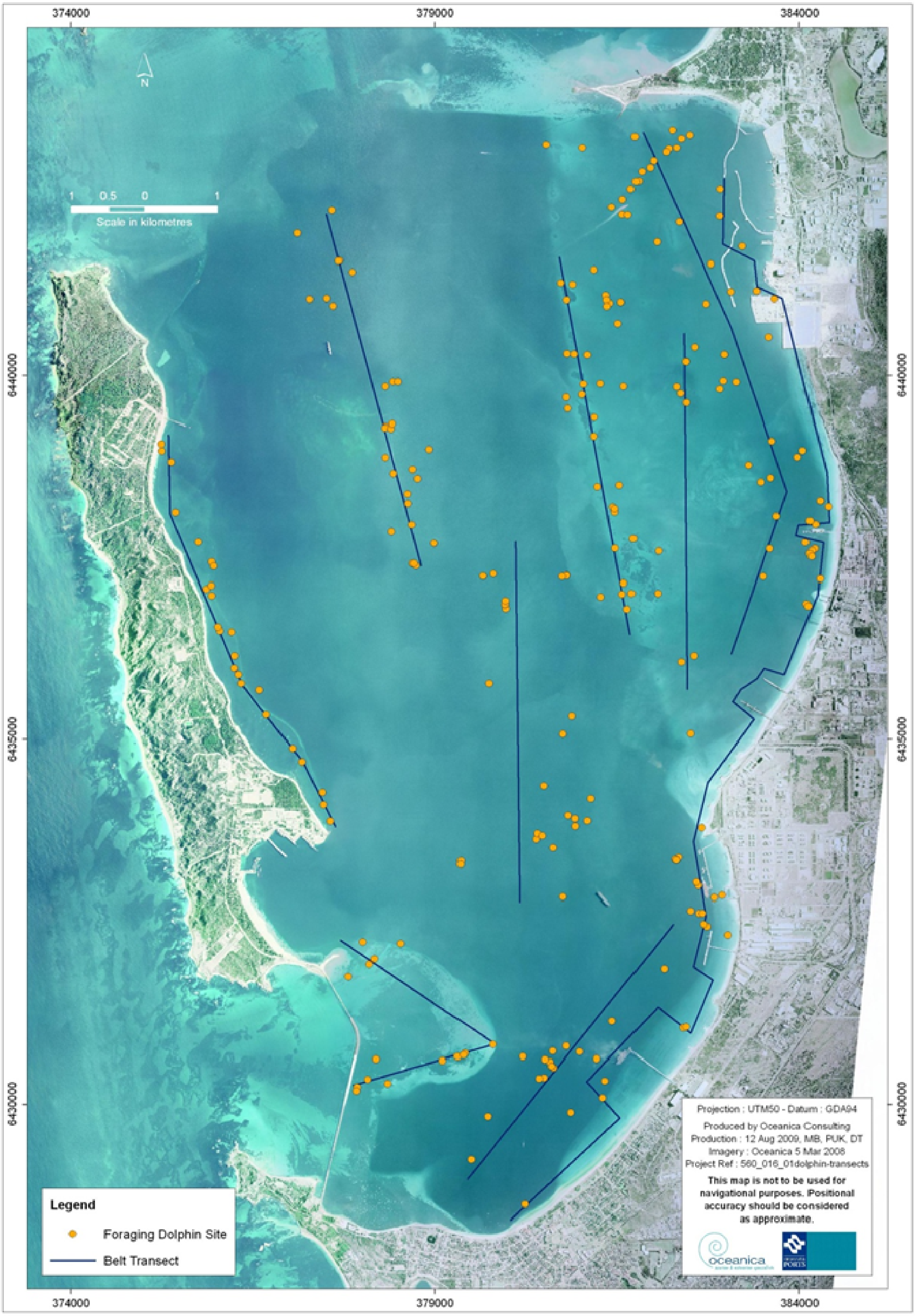


Figure 101 Indicative locations of dolphin sightings during a transect based study from June 2000 to April 2001 (source Finn 2011)

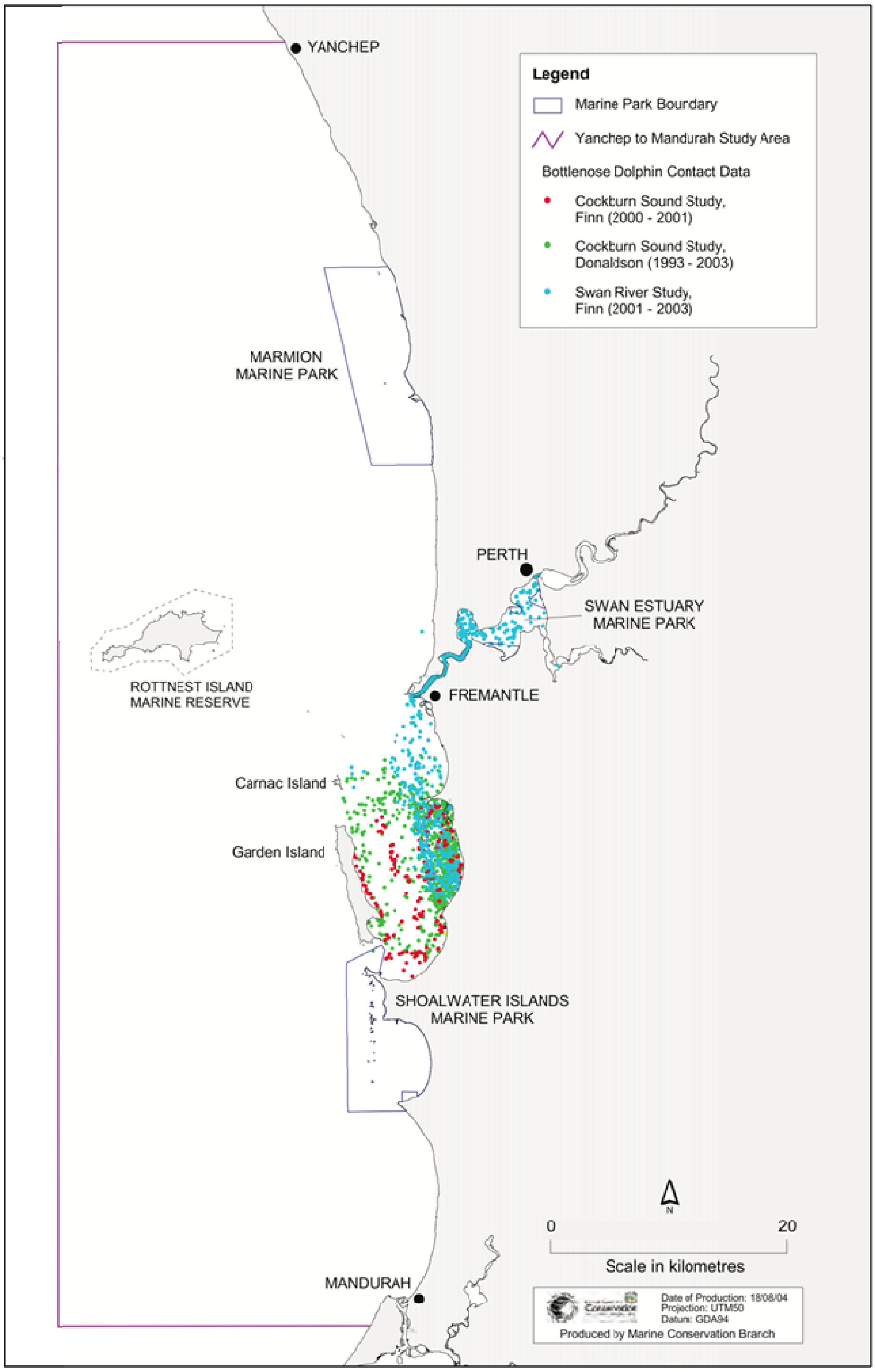
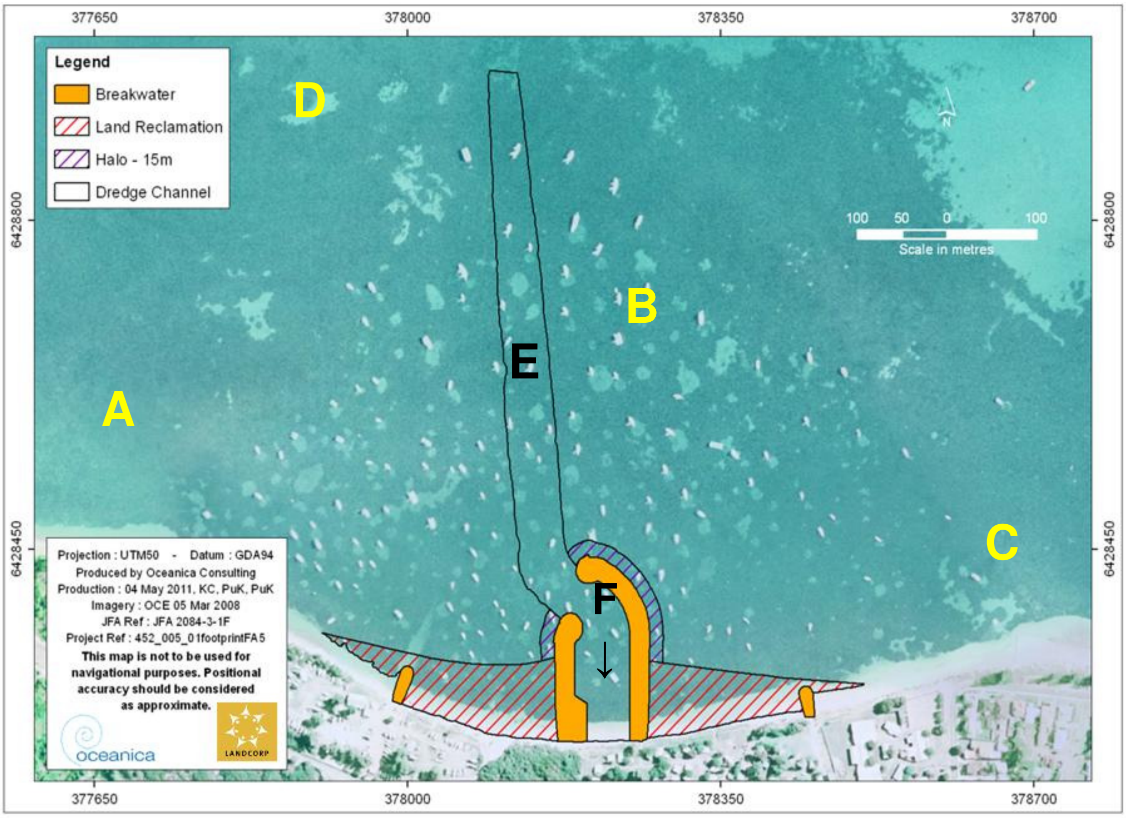


Figure 102 Locations for dolphins observed within the Swan Canning Riverpark and the southern Metropolitan coastal waters (source: Cannell 2004)

Previous research on dolphins has not focused on the shallow flats of Mangles Bay, but dolphins are known to utilise this part of Cockburn Sound. Observations of dolphins in the general Mangles Bay area have involved small groups of dolphins:

- moving through the area of moored parts ('B' in Figure 103)
- feeding in the border area between the seagrass areas and deeper basin areas of Mangles Bay
- travelling parallel with the shoreline.

These foraging behaviours and modes of movement are typical of dolphins in Cockburn Sound. Dolphins are also likely to use new habitats created by the Proposal, such as the dredged channel and the pens and jetties within the marina itself (Figure 103).



Note: Existing foraging habitats comprise shallow seagrass meadows (A), seagrass & sand with boats and moorings (B), sandy beach/shoreline (C) and patches of open sand (D). Potential foraging habitats comprise dredged channel (E) and boat pens within the marina (F).

Figure 103 Existing foraging habitats (in yellow font) for dolphins in the Proposal area, and potential foraging habitats (in black font) associated with the Proposal

The shallow flats of Mangles Bay adjacent to the Proposal do not appear to be a key feeding area for dolphins (refer Figure 99 and Figure 100), but is still of reasonable ecological significance to dolphins, mainly because seagrass areas in Cockburn Sound provide important breeding and nursery areas for fish and also sustain assemblages of dolphin prey species like herring, mullet, garfish, squid and whiting.

13.3.4 Little penguins

The largest colony of little penguins in Western Australia is found in the Perth Metropolitan region on Penguin Island, where population size has recently been estimated to be 1500 – 2500 penguins (Cannell et. al in prep.). Colonies are also found on Garden and Carnac islands. Currently, the total size of the colony on Garden Island could be 500 – 600 individuals or greater; these mainly inhabit Careening Bay, with a smaller nesting area at Colpoys Point (Figure 104).

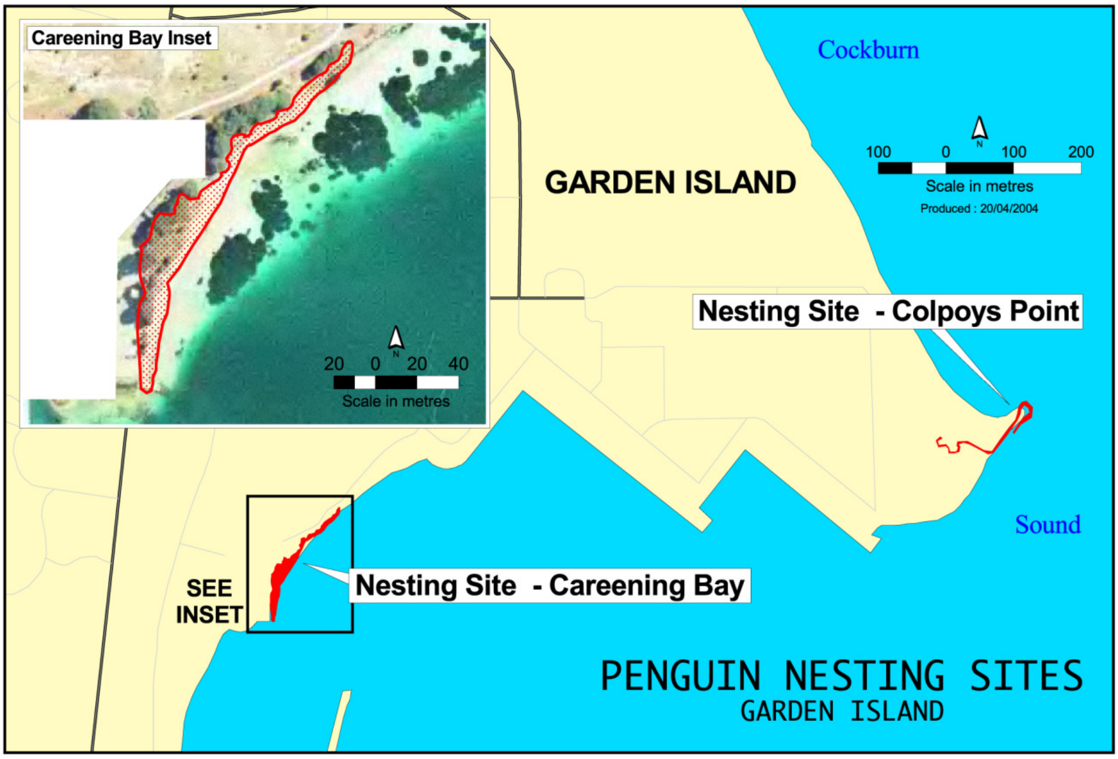


Figure 104 The major nesting site of little penguins at Careening Bay, and smaller site at Colpoys Point, Garden Island (Cannell 2011)

Cockburn Sound could potentially play an important role in the long-term maintenance of little penguins in the Perth region, as penguins on Garden Island generally have a higher breeding success than those on Penguin Island, and a higher proportion of the colony that breeds twice a year (Cannell 2011.). Little penguins on Garden Island can lay two clutches in a year, the first usually in June and the second usually in September. Generally two eggs are laid with incubation an average of 36 days. Chick guarding is shared by both parents (Chiaradia and Kerry 1999), while the other is at sea feeding. Chicks are guarded constantly for 2-3 weeks, and raised for an average of eight weeks (Stahel & Gales 1987).

After breeding, the adult penguins moult between November and February, replacing all their feathers. This is a critical process which the penguins must undergo every year. The moult takes 2 – 3 weeks, during which the penguins are confined to land. As they are unable to feed during the moult, the penguins must build up their fat reserves prior to moult, and can double their mass. Low body mass during moult can result in the penguins dying from starvation.

Penguins leave the colony before dawn and spend the day foraging at sea, where they can dive more than 100 times per hour searching for prey (Ropert-Coudert *et al*. 2003; Cannel 2011), and in between dives they rest on the surface. Penguins usually return to the colony after sunset (Cannell 2003), or can remain at sea overnight. Very limited dietary information is available for the Garden Island penguins, but results suggest anchovy predominate the diet, although scaly mackerel, pilchard, blue sprat and sandy sprat have also been found. Penguin Island penguins feed on a range of fish including pilchards, garfish, anchovy, blue sprat and sandy sprat.

The movements of Garden Island penguins have been tracked using satellite tags: adults guarding chicks in 2007 and 2008, and incubating adults in 2008 and 2009. Preliminary analysis of the data show that regardless of the time spent at sea, the penguins remained within Cockburn Sound, and the area used extended from the northern end of the Central Basin south to Mangles Bay. In both 2007 and 2008, the penguins guarding chicks almost exclusively used the southern half of Cockburn Sound. There were fewer locations on the Kwinana Shelf and in the northern Central Basin. Penguin Island penguins could also be foraging in Cockburn Sound, with those that nest on the northeast side of Penguin Island more likely to forage in Cockburn Sound than those penguins nesting in other areas on Penguin Island (Cannell 2011).

There are not sufficient data to fully determine the importance to penguins of the shallow flats of Mangles Bay compared to other areas in Cockburn Sound, although available data indicate that the deeper waters of southern Cockburn Sound are more important (e.g. Figure 105). However, as for dolphins, the shallow flats of Mangles Bay are ecologically important to penguins in providing important breeding and nursery areas for fish and also sustaining of assemblages of prey species. The shallow flats of Mangles Bay has been identified as an important nursery areas for blue sprat, sandy sprat and garfish, while deeper waters (depth 10–20 m) off Mangles Bay are areas where larval and older anchovy have been consistently found (refer Section 13.3.1).

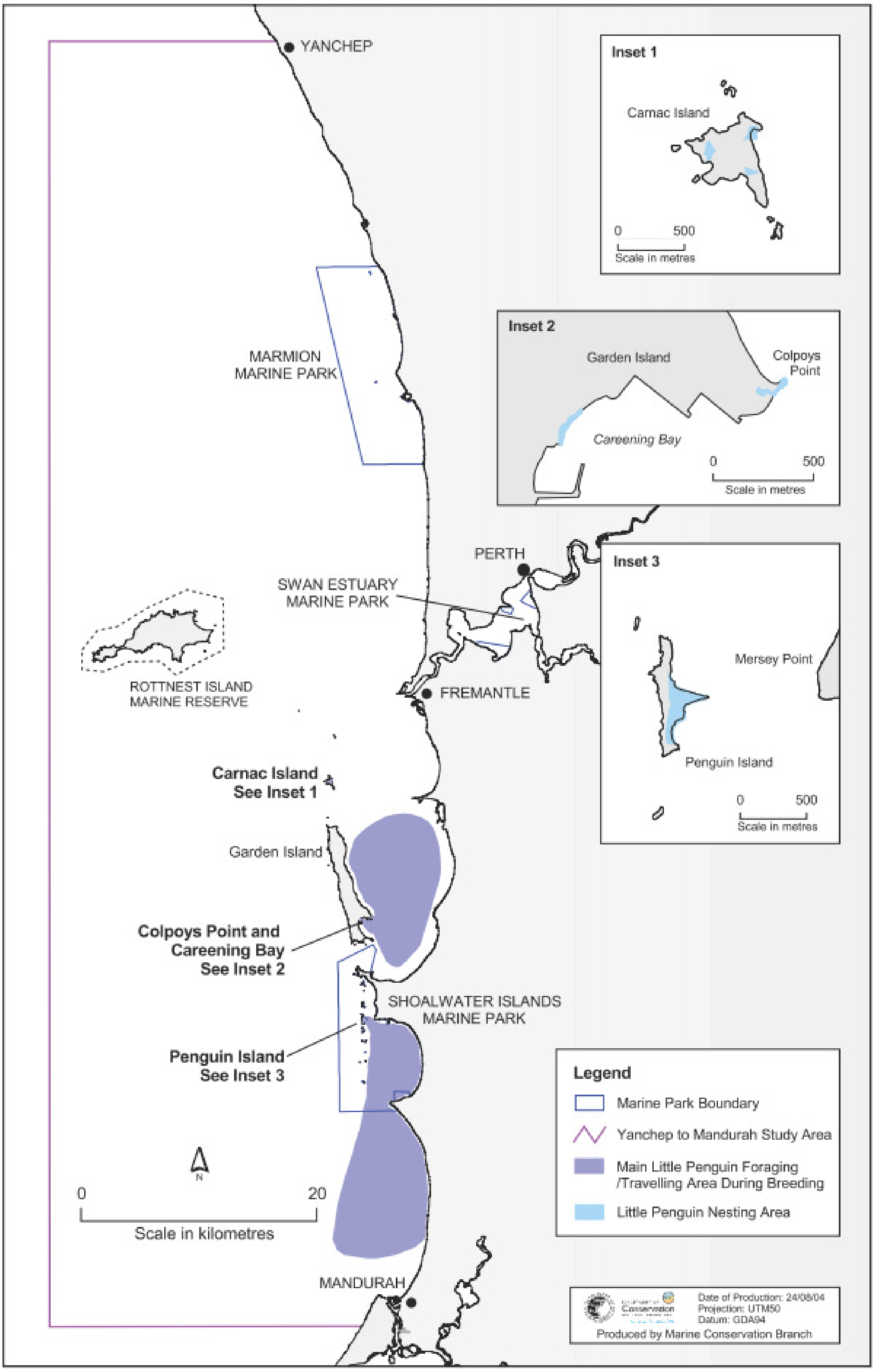


Figure 105 Locations of little penguin activity within southern Metropolitan coastal waters during breeding (Source: Cannell 2004)

13.3.5 Introduced marine pests

In 2000 Fremantle Ports undertook an IMS baseline study within port waters and adjacent coast (Hewitt *et al.* 2000). The survey found two pest species, the European fan worm *(Sabella spallanzanii)*, and the Asian date mussel (*Musculista senhousia)*, while the dinoflagellate species (*Alexandrium tamarense)* was also detected albeit in low concentrations.

Huisman *et al*. (2008) identified 60 IMS from Western Australia, 46 of which were found in the Fremantle (including Cockburn Sound and the lower Swan River) region, however only four are on the NIMPCG target list[18]:

1. The date mussel (*Musculista senhousia)*.
2. The European fan worm (*Sabella spallanzanii)*.
3. The toxic dinoflagellate (*Alexandrium minutum)*.
4. The European shore crab (*Carcinus maenas)*.

In 2007 Fremantle Ports partnered with the DoF to reassess the abundance and distribution of IMS (McDonald and Wells, 2009). Despite previous records of the European shore crab (*Carcinus maenas)* and the date mussel (*Musculista senhousia)* in this region, the investigation found no evidence of either species (McDonald and Wells, 2009). The European fan worm, (*Sabella spallanzanii)*, had actually increased its geographic spread up the Swan River, although the densities of this species in the more open waters of Cockburn Sound were much reduced from those reported in the early 1990's. Dinoflagellate pest species were not targeted due to difficulties with identification.

In April 2011, DoF undertook an IMS survey in Cockburn Sound, including Mangles Bay. Preliminary results are yet to be released; however preliminary data suggest that no additional IMP of concern were detected, other than those listed above (McDonald Principal Biosecurity Consultant pers. comm.,).

13.4 Evaluation of options or alternatives to avoid or minimise impact

13.4.1 Marina design and construction management

The marina access channel has been designed to minimise habitat loss. The marina has also been designed to maximise the flushing of inner marina waters. This will reduce the extent of nutrient enrichment and anoxia within the marina, and the likelihood of poor quality waters entering Mangles Bay and impacting on marine fauna. Contaminant inputs to marina waters will be minimised using 'best practice' measures for facility design and management, and strict regulations regarding general boating related activities. Water quality impacts are discussed in more detail in Section 10.

The construction of the breakwaters for the Mangles Bay marina will involve the use of construction machinery, including excavators, loaders and trucks. Only trained operators will be employed to operate the machinery to ensure that materials are placed on the seabed in the correct location to ensure that loss of habitat does not exceed the predicted footprint area and reduce available habitat for marine fauna. This will be the responsibility of the Proponent. There are no impacts to habitat expected as a result of turbidity plumes and associated smothering and light attenuation.

A CEMP will be prepared to specify the proposed breakwater and other construction methods and proposed management measures. The CEMP will include fauna observation protocols for dolphins, little penguins, sea lions and turtles during the dredging of the marina access channel.

[18] For the purposes of this document, IMP are defined as those species listed on the National Introduced Marine Pests Coordination Group's (NIMPCG) target list of 55 potential pest species (DAFF, 2009) and must be considered for a monitoring program for a given location in Australia.

13.4.2 Dredging program

The proposed dredging program for the marina has been designed to avoid or minimise impact on marine fauna communities including the following alternatives listed below:

1. The short duration of the dredging program over three months will reduce the time period of elevated turbidity levels, and noise – both of which may lead to avoidance of the area by marine fauna. Turbidity associated with dredging is predicted to be minimal (refer Section 10), and silt curtains will also be used (weather and sea conditions permitting) during the dredging process, to further control turbidity release and dispersion, thereby minimising potential impacts on fish stocks and foraging behaviour of marine fauna.
2. Impacts on fish eggs and larvae in the proposed development area will be minimised by timing dredging activities to avoid peak spawning and recruitment periods. The dredging has been proposed to occur between May and July, to reduce the impact on fish and invertebrate species. Spawning and recruitment generally occur for a number of important fish and invertebrate species (e.g. King George Whiting, pink snapper, blue swimmer crab) from late winter to late summer.
3. There is some conflict between preferred timing for fish and little penguins, since the peak penguin breeding time occurs in winter. This will be minimised by the planned dredging sequence (beginning from the outermost edge of the access channel, then moving shorewards) and could be further minimised by commencing the dredging in late autumn.

A dedicated Marine Fauna Observers (MFO) will be engaged during dredging and marine-related construction works who must:

- demonstrate a knowledge of marine wildlife species in the Perth metropolitan region, particularly species listed under the Wildlife Conservation Act 1950 and associated notice
- be on duty at all times during dredging and marine-related construction works
- maintain a log of observations of marine fauna, including injured or dead fauna (of any species) within 500 m of dredging and construction, which is to be submitted to DEC at the completion of dredging and construction.

No dredging will commence until the MFO has verified that no dolphins or sea lions have been observed within a radius of 500 m of dredge machinery or the construction site during the 30 minute period immediately prior to commencement of dredging or construction work. If the MFO observes a dolphin or sea lion entering within 500 m of dredging or construction work, the dredging or construction work is to be suspended.

Dredging and construction work that has been suspended as above, shall not recommence until the dolphin has moved on of its own accord beyond 500 m from the dredging or construction area, or has not been seen within 500 m for 30 minutes.

Dredging and construction will only occur during daylight hours to enable an adequate level of observation by the Marine Fauna Observer. Dredging and marine construction works will occur outside the months of September to March to avoid the peak dolphin calving period (refer above).

13.4.3 Introduced marine pest (IMP) inspections

Consideration of options or alternatives to avoid or minimise the impact of IMP establishment is restricted to the use of commercial vessels during the construction phase (i.e. dredging equipment and construction vessels) since there are currently no guidelines applicable to recreational vessels during the operation phase. Prior to any dredging plant or equipment entering State Waters, the Proponent shall arrange for an inspection by an appropriately qualified expert (on advice of DoF) to ensure that:

- there is no sediment on the dredging equipment
- ballast water (if applicable) has been managed according to the AQIS ballast water requirements
- any fouling organisms on the dredging equipment do not present a risk to the ecosystem integrity of the marine waters of Cockburn Sound.

13.5 Assessment of likely direct and indirect impacts

13.5.1 Potential sources of impact

The following aspects of the Proposal may potentially affect marine fauna:

- temporary changes in water quality during construction (turbidity, nutrient-related water quality, contaminants) due to dredging and the discharge of return water
- ongoing changes in water quality due to outflow of lesser water quality from the marina into Mangles Bay
- direct and indirect loss of habitat due to construction of the access channel and breakwaters of the marina
- increased risk of IMS due to increased numbers of large recreational vessels berthing in the marina
- increased human access causing littering
- increased vessel numbers causing increased fishing pressure and the potential for boat strike
- increased marine noise levels due to pile driving and rock dumping during construction.

In order to define key environmental risks and potential impacts to key faunal groups (fish, invertebrates, little penguins and dolphins) in Mangles Bay and identify appropriate measures to manage or mitigate those risks to acceptable levels, a risk assessment workshop was held on 18 April 2011. Participants at the workshop were from Oceanica Consulting, Strategen, Dr McLean (Mindabbie Marine), Dr Cannell (Murdoch University) and Dr Finn (Murdoch University). The key potential environmental issues associated with the overall Proposal were identified as:

- loss of BPPH – predominantly seagrass
- increased recreational fishing pressure on fish stocks and thus food availability for dolphins and penguins
- increased vessel movements and therefore increased vessel strikes on fauna
- entanglement in ropes, nets and lines, and other marine debris.

This assessment was based on the assumptions that potential impacts due to dredging (noise, turbidity and release of contaminants) will be minimal (refer to Section 10), and that the quality of water entering Mangles Bay from the marina will not be harmful to marine fauna (refer to Section 10).

This section discusses the potential risks posed to marine fauna in Mangles Bay through the development of the Proposal, specifically in relation to key species of marine fauna. The key species are considered to be fish and marine invertebrates (due to the importance of Mangles Bay as a fish and invertebrate habitat), and dolphins and little penguins (iconic species that maintain significant resident population in Cockburn Sound). This section also includes an assessment of the risk from IMS.

13.5.2 Loss of benthic habitat and associated prey species

The benthic habitat in the shallow flats of Mangles Bay is mainly dense seagrass, but it has a large number of mooring scars consisting of bare sand where boat swing moorings have scoured the seafloor. There are also bare areas adjacent to the boat launching areas of the yacht club and fishing club where boat hulls have scoured the seagrass (refer to Section 12).

The Proposal will result in the loss (direct and indirect) of 5.66 ha of seagrass meadow and 1.69 ha of unvegetated sediment (Section 12). The loss of habitat (seagrass) may potentially cause a reduction in fish stocks due to egg loss and/or larval mortality. In turn, loss of fish biomass or change in fish communities may lead to reduced reproductive success and survivorship of dolphins and little penguins in Cockburn Sound (due to lower availability of prey species). However not all impacts on dolphin feeding habitat will necessarily be adverse. Dolphins are likely to use new, modified, and unaffected habitats within the marina and access channel as a feeding habitat.

13.5.3 Increased recreational fishing pressure

Increased human access will place a variety of pressures on marine fauna, primarily through a higher usage of boats and increased people traffic. There is likely to be an increase in recreational boating in the area as a result of the provision of boat pens, a refuelling station and the residential canal development. This is likely to lead to higher levels of recreational fishing that will place pressure on already heavily targeted species and indirectly on non-targeted species, and potentially cause a change in fish assemblage composition.

Increased recreational fishing pressure due to increased population is predicted for the waters of Cockburn Sound and SIMP, irrespective of whether the Proposal goes ahead or not. The population of suburbs immediately adjacent to Cockburn Sound and the SIMP is expected to increase from 171,751 in 2010 to 221,759 in 2020 and to 249,145 in 2025 (DPI 2007). Shore-based recreational pressure will increase accordingly. Recreational boating numbers are predicted to increase by 18–45% in the medium-term (by 2018) to long-term (by 2025) (refer to Section 16). Department of Transport (DoT) predictions (refer to Section 16) for the suburbs immediately adjacent to Cockburn Sound and the SIMP – without the marina - are:

- the number of trailerable boats will increase by 1,506 – 3,901 over the medium-term (2018) to long-term (2025), and about three quarters of this increase will be in the Rockingham region
- the number of non-trailerable boats will increase by 112 – 258 vessels over the medium-term (2018) to long-term (2025) and about two-thirds of this increase will be in the Rockingham region.

Increased recreational fishing pressure due to the Proposal will constitute only a small proportion of that predicted due to population increase: this is discussed further below. Increased recreational fishing pressure in Cockburn Sound and the SIMP is a regional issue that comes under the jurisdiction of the DoF, in collaboration with the DEC (for the SIMP).

Recreational fishing pressure in Cockburn Sound and Shoalwater Islands Marine Park

The marina will not result in an increase in trailerable boats in the waters of Cockburn Sound and the SIMP above the anticipated numbers predicted by the DoT due to the regional population growth, but it will increase the number of large vessels. Of the up to 500 pens/berths within the marina, approximately half will be for the new marina club and the remainder for the public and marina residents. The marina is expected to add 128 more boats than DoT predictions based on regional population growth. DoT data also indicate that about 20% of registered boats are launched each day during peak times in summer (refer to Section 16). The marina will thus increase recreational boat traffic, over and above that due to the regional population growth in the medium-term, by approximately 26 boats/day during peak times in summer, all due to large vessels. This would represent 19% of traffic due to large (non-trailerable) vessels in Cockburn Sound and the SIMP in the medium-term, but about 1% of total recreational boat traffic (trailerable and non-trailerable boats). The marina will have no effect on regional levels of boat traffic in the long-term (2025).

Recreational fishing pressure in the shallow waters of Mangles Bay

Shore-based recreational fishing does not constitute the majority of fishing pressure in Mangles Bay. Although shore-based fishing takes a greater proportion of the total recreational catch of finfish (about three quarters) than boat-based fishing effort in Cockburn Sound, it is focussed around jetties and the northern half of the Sound, especially Woodman Point (Fletcher and Santoro 2007). Boat-based fishing effort for crabs far outweighs shore-based effort (Williamson 2005, cited Oceanica 2007). Predictions of changes in shore-based fishing effort with the marina are also difficult. Access to the shore adjacent to the proposed marina is presently limited due to the local yacht club, fishing club, and chalet accommodation. Shore-based fishing is probably mainly by persons using these facilities, with some use by persons accessing the area by walking along the beach. The Proposal will interrupt pedestrian access along the beach shoreline (due to the marina access channel and breakwaters), interfering with the continuous shoreline of Mangles Bay, but will allow improved access to the beach via the marina development itself. It is, however, likely that the Proposal will result in some increase in shore-based recreational fishing pressure.

At present, boat-based recreational fishing pressure within the shallow waters of Mangles Bay is largely due to the boats associated with the 600 swing moorings in the Bay (fishing from the moored boats is popular, refer to Section 16), boats launched from the private boat ramps of the yacht club and the fishing club in Mangles Bay, and boats launched at Cape Peron public boat ramp and Palm Beach public boat ramp (the two public boat ramps closest to Mangles Bay).

The marina is likely to cause a small increase in recreational boat pressure within the shallow waters of Mangles Bay due to the trailerable boats owned by marina residents (91 boats, assuming the 2,000 marina residents have the same level of ownership of trailerable boats as Rockingham residents; refer to Section 16). The non-trailerable boats in the marina are not expected to add to recreational fishing pressure in the shallow waters of Mangles Bay as their keel clearance will prohibit movement into the very shallow waters west of the marina access channel, while the existing mooring congestion will discourage movements to the east of the access channel. The non-trailerable boats in the marina are expected to head out the marina access channel to Southern Flats, to the SIMP via the northern Causeway entrance, or to eastern side of Garden Island. Non-trailerable boats will thus contribute to recreational fishing pressure within the broader region of Cockburn Sound and the SIMP (see above), rather than the shallow waters of Mangles Bay.

The above information is summarised in Table 61, and indicates that although the marina will cause a small increase in boat-based recreational fishing pressure within the shallow waters of Mangles Bay, it will not constitute the major source of recreational pressure.

Table 61 Potential sources of recreational boat pressure within the shallow waters of Mangles Bay at present, and in the medium-term (2018) to long-term (2025)

Source of recreational boating pressure	Potential boat numbers during peak times at present	Potential boat numbers at peak times in the marina in the medium-term to long-term
Swing moorings in Mangles Bay	600 moorings, a large proportion with boats.	600 moorings, a large proportion with boats. Level of usage continues.
Cruising Yacht Club ramp	unknown	Level of usage continues – club members use marina boat ramp
Mangles Bay Fishing Club ramp	unknown	Level of usage continues – club members use marina boat ramp
Cape Peron public boat ramp	100-175 boats launched at peak times. Proportion entering Mangles Bay unknown, but area popular for trailerable boats.	118-254 boats[1] launched at peak times. Proportion entering Mangles Bay unknown, but area popular for trailerable boats.
Palm Beach public boat ramp	100 boats launched at peak times. Proportion entering Mangles Bay unknown, but area popular for trailerable boats.	118–145 boats[1] launched at peak times. Proportion entering Mangles Bay unknown, but area popular for trailerable boats..
Mangles Bay marina – resident's trailerable boats	Not applicable	9 boats during peak times in summer[2], also assumes they all stay in Mangles Bay

1. Based on predicted increases in recreational boat ownership of 18–45% in the medium-term (2018) to long-term (2025)
2. Assumes 10% of boats are launched during peak times. This is higher than the 5% typically used by the DPI (2009), but has been used as a conservative estimate of the higher level of boat usage of marina residents.

13.5.4 Increased interactions between humans and marine fauna

Dolphins

The proposed development will result in a small increase (1%) in the number of vessels able to access Cockburn Sound and the SIMP in the next 10–15 years (within the context of predicted increases of boat ownership; see above) and as such, it will also increase the amount of human-dolphin interaction that occurs. Some interactions will be adverse (e.g. disturbance, harassment, illegal feeding) and some may cause injury or mortality (e.g. entanglement in discarded fishing line, vessel strikes). While the overall impact of this increase in human interactions may not exert a biologically significant effect on the dolphin population in Cockburn Sound (and the SIMP), it will add to the human-related stress that animals experience in this ecosystem. Increased human interactions may cause a change in feeding behaviour or the displacement of dolphins from feeding areas.

Other marine fauna

The small increase (1%) in the number of vessels able to access Cockburn Sound and the SIMP in the next 10–15 years will also lead to increased human interactions with other marine fauna within the waters of Cockburn Sound and the SIMP, and on the Shoalwater Bay and Carnac Island nature reserves, Point Peron and the northern end of Garden Island. As for dolphins, some interactions will be adverse (e.g. disturbance, harassment, illegal feeding) and some may cause injury or mortality (e.g. entanglement in discarded fishing line, vessel strikes).

The majority of boating activity in Cockburn Sound and the SIMP is associated with recreational fishers, and most boats focus on waters within Cockburn Sound and east of Garden Island compared to the SIMP (refer Section 16.2.2). The increased level of human interaction with other marine fauna in the SIMP and island nature reserves should therefore be minor (within the context of predicted regional increases of boat ownership), but will add to the human-related stress that animals experience in this region.

13.5.5 Entanglement and marine debris

An increase in the people utilising the foreshore area of the Proposal's tourist precinct and the broader area of Cockburn Sound and the SIMP may increase the litter in these areas (such as plastic bags, fishing line and other fishing gear). Litter can affect marine fauna such as dolphins, little penguins and sea lions by ingestion, and entanglement in discarded fishing line or plastic. The effects can include death, injury, adverse behavioural and physiological changes, and reduced body condition and/or immune function to individual fauna. These processes may also interact with the natural processes such as disease and predation.

13.5.6 Increased vessel strikes

The proposed development will result in a small increase (1%) in the number of vessels able to access Cockburn Sound and the SIMP in the next 10–15 years (within the context of predicted increases of boat ownership due to population increase; see above). An increased number of vessels using Cockburn Sound is likely to result in an increase in the number of marine fauna (particularly penguins) injured or killed from collisions with the vessels. Increased vessel movements could also cause an interruption of a penguin's resting period on the surface, or make it move away from feeding areas, potentially causing long-term impacts on the penguin's energetic costs and lowering the carrying capacity of penguins in Cockburn Sound. Little penguins are often very difficult to observe at sea because they are low in the water when at the surface and also swim much slower than most boats (Bethge *et al*. 1997), making it difficult for them to get out of the way of vessels. Injuries as a result of increased vessel strikes could result in the death of individuals, or affect a penguin's ability to catch prey, and thus its ability to successfully raise chicks or maintain itself.

Although the Proposal will result in a small increase in the number of vessels in Cockburn Sound and the SIMP, this increase will be due to larger vessels that are more likely (than smaller vessels) to traverse

Southern Flats and move northwards up the eastern side of Garden Island, or pass through the northern Causeway entrance to the SIMP. Boats moving up the eastern side of Garden Island will traverse waters that penguins regularly cross to feed in southern Cockburn Sound, when they are incubating eggs or feeding chicks. Boats travelling out through the northern Causeway entrance may also interact with Penguin Island penguins.

The penguin breeding season (June to November) is outside peak boat activity time (summer), and so boat numbers will be less (≤2% registered boats launched each day, outside of peak times in summer; refer to Section 16). As with increases in recreational fishing pressure, population-driven increases in recreational boating will cause an increased risk of vessel strikes, irrespective of whether the Proposal proceeds or not. Assuming 2% registered boats are launched each day during the penguin breeding season, in the medium-term the Proposal will result in about 14 large vessels/day versus 11 large vessels/day from population-driven increases alone and 14 vessels/day with or without the Proposal in the long-term. The expected number of small vessels in off-peak periods in the medium-term to long-term is 190-235/day (with or without the Proposal), but it is not known what proportion would travel up the eastern side of Garden Island. However the data of Sumner *et al.* (2008) for recreational fishing catches from boat ramp surveys in 2005-06 indicate that an appreciable number of trailerable boats do fish the waters west of Garden Island, particularly for dhufish, pink snapper, breaksea cod, herring and whiting.

13.5.7 Chemical contamination (bioaccumulation)

With increased boating traffic and berthing of vessels there is a risk of higher levels of organic and inorganic chemicals than presently exists in the area. Water quality within the marina, and in waters entering Mangles Bay from the marina, will potentially be influenced by factors within the marina itself such as the combustion of fuel in boat engines, stormwater run-off from impermeable surfaces, boat maintenance and sewage (Scott 2003). Boats are potentially a significant source of organic and inorganic chemicals (e.g. trace elements, TBT, polychlorinated biphenyls, and petroleum hydrocarbons). Many of these compounds can also accumulate in marina sediments where they have the capability to adversely affect benthic fauna (McGee *et al*. 1995), and fauna that feed on them.

13.5.8 Introduced marine pests

The major potential impacts of introduced marine pests are:

- reduction or loss of biodiversity
- reduction or loss of ecosystem function
- increase in the cost of maintaining infrastructure (for example cleaning biofouling from seawater intake pipes).

The increased number of vessel movements associated with dredging and construction could represent an increased threat of exposure to IMS. The introduction of IMS could lead to irreversible detrimental impacts to the composition and function of the natural ecosystem through changes in competition, predation, or habitat modification.

13.5.9 Marine Noise

The Proposal plans to utilise pile driving during jetty construction and rock dumping during breakwater construction. Curtin University Centre for Marine Science and Technology were approached regarding the impacts of this noise on the marine environment and were of the opinion that noise associated with these construction methods will not be of detriment to marine fauna in the area. It is thought that some noise during construction may cause temporary avoidance of the area by some marine fauna, but that the depth of water and sheltered nature of Mangles Bay will mean that no significant physiological impacts on marine fauna will occur. (*pers comm*. Dr Alec J Duncan, Curtin University August 2011). A full copy of the letter report by Curtin University is included in Appendix 5.

13.6 Potential for and nature of any cumulative impacts

In evaluating the impacts specific to the Proposal, consideration also needs to be given to the cumulative impact of other projects, and a general increase in boating and recreational activity in Cockburn Sound due to population increase. Cumulative impacts relate primarily to an increase in fishing pressure and habitat loss. The proposal will also have a cumulative impact in terms of vessel movements, with a predicted increase in the number and size of vessels. As noted above, the larger vessels berthed at the marina are likely to exit Cockburn Sound to the SIMP and/or deeper waters offshore, either through the Causeway or by travelling up the eastern side of Garden Island.

The cumulative impacts of benthic habitat loss are discussed in Section 12, and the cumulative impacts of boating and recreational pressures due to population increase have been incorporated in the sections above. The other potential source of recreational boating pressure that will contribute to cumulative impacts in the region is the approved (Ministerial Statement 826) Port Rockingham marina, adjacent to the Wanliss Street and Rockingham Beach Road intersection (Figure 106).

The Port Rockingham Marina will provide 500 pens for non-trailerable boats (RPS 2009). The Mangles Bay marina and Port Rockingham Marina will potentially result in about a two-fold increase in non-trailerable boats in the medium-term (by 2018) to long-term (by 2025) but minor increases in total boat numbers (trailerable boats comprise the large majority of boat numbers, so increases in total boat numbers are driven mainly by regional population increases). The large vessels in both marinas are more likely to move into the SIMP and/or deeper waters offshore via the northern Causeway entrance, or to travel up the eastern side of Garden Island. The cumulative increase in larger vessels could therefore potentially cause an increase in vessel strikes on marine fauna (especially penguins) that is proportionally higher than their contribution to boating traffic (refer Section 13.5.6).

Figure 106 Location of Port Rockingham Marina (Source: RPS 2009)