7. Benthic Communities and Habitats Impact Assessment

7.1 EPA objective

To protect benthic communities and habitats (BCH) so that biological diversity and ecological integrity are maintained.

7.2 Legislation, policy, guidance

The legislative instruments, policies and guidelines considered relevant to the environmental impact assessment of BCH are provided in Table 7.1.

Table 7.1 Legislative instruments, policies and guidelines relevant to impact assessment of benthic communities and habitats

Legislative instrument
Environmental Protection Act 1986
EPA Policy or guidance
Statement of Environmental Principles, Factors and Objectives (EPA 2018b)
State Environmental (Cockburn Sound) Policy 2015 (EPA 2015)
Environmental Quality Criteria Reference Document for Cockburn Sound (EPA 2017)
Factor Guideline – Marine Environmental Quality (EPA 2016b)
Factor Guideline – Benthic Communities and Habitats (EPA 2016e)
Technical guidance – EIA of Marine Dredging proposals (EPA 2016c)
Technical Guidance – Benthic Communities and Habitats (EPA 2016f)
Other policy or guidance
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018)

7.3 Receiving environment

7.3.1 Environmental values

The project has the potential to impact the environmental value ‘ecosystem integrity’, and in particular, seagrasses near to the location of marine infrastructure and benthic macroinvertebrate communities more broadly across Cockburn Sound.

7.3.2 General description

Cockburn Sound is the most modified coastal system in WA, which has left a long-term legacy of impacts to benthic habitats on the Eastern Shelf (BMT 2018a). As a result, the shelf is now largely degraded relative to pre-European conditions.

Since the 1950s, a number of dredging and related capital works have been undertaken within Cockburn Sound for the purposes of navigation and shoreline management. Within Cockburn Sound, there are five designated shipping navigation channels: the Woodman and Jervoise channels are naturally deep waterways (Figure 7.1). The Stirling and Calista channels and their associated basins have been dredged to depths of ~11.7 m to enable access to the Alcoa and Kwinana Bulk Terminal jetties (FP & DoP 2012). The Medina Channel has been dredged to -10 m chart datum to enable access to the AMC. Dredging has also been undertaken in the Jervoise Bay Southern Harbour and at the Armaments Jetty on Garden Island (Figure 7.1). Occasional maintenance dredging of these channels will continue to be required to ensure safe navigation.

The material from the majority of these navigational dredging projects has been disposed to the seabed at locations within Cockburn Sound, while the dredged sediment from the Jervoise Bay Southern Harbour was used to fill the harbour reclamation area. Shoreline nourishment (the artificial delivery of sediment from an external source) has been used to manage shoreline erosion at a number of sites within Cockburn Sound. This process helps to mitigate erosion effects and can provide a recreational beach resource but does not change the underlying physical forces causing the erosion. Several of the southern beaches have been nourished regularly (including Palm Beach, Mangles Bay and Kwinana Beach; Figure 7.1), with volumes of sand from 500 to 30 000 m^3, using sand excavated from the shoreline to the west of the Point Peron boat ramp (DOT 2009).

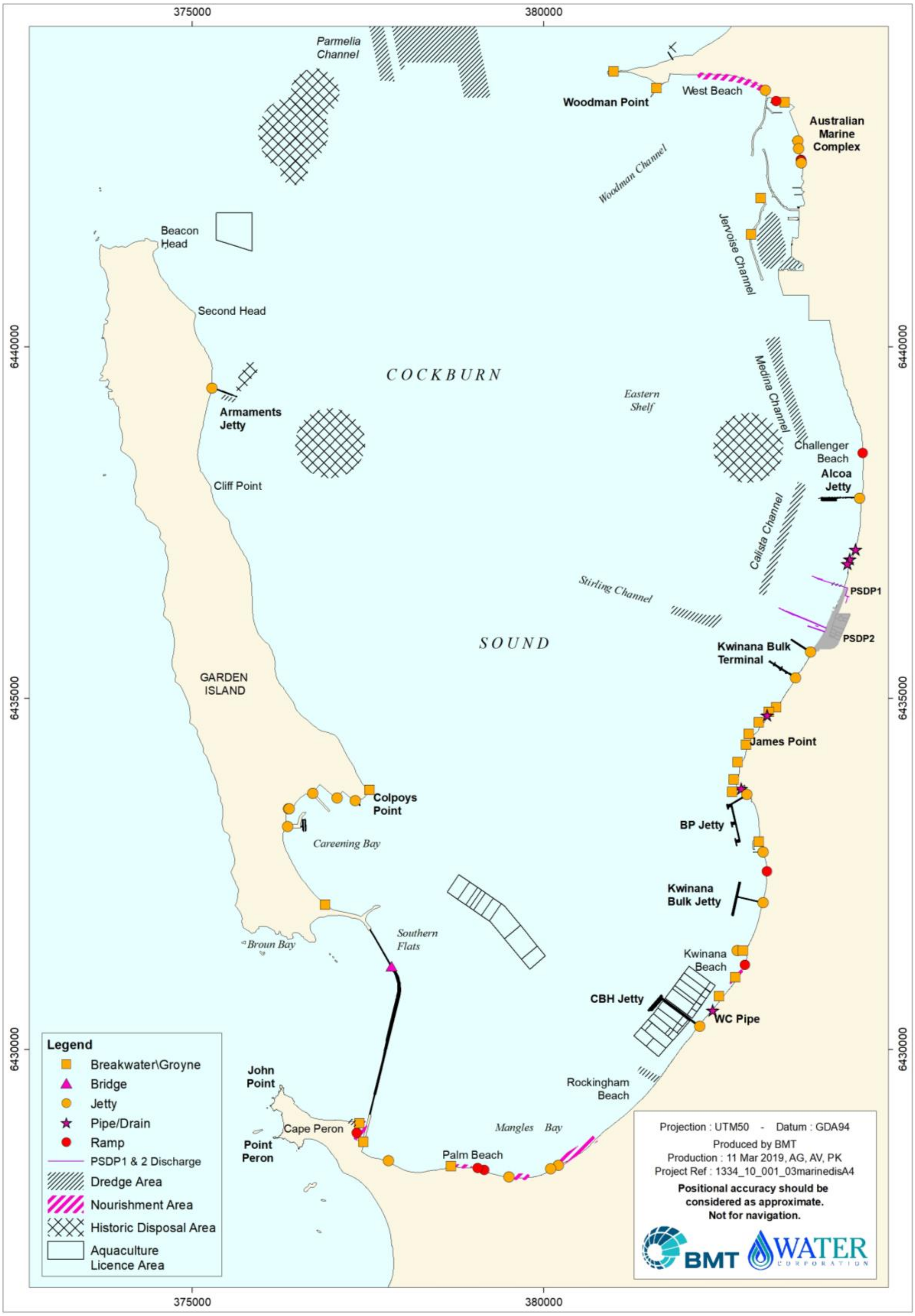


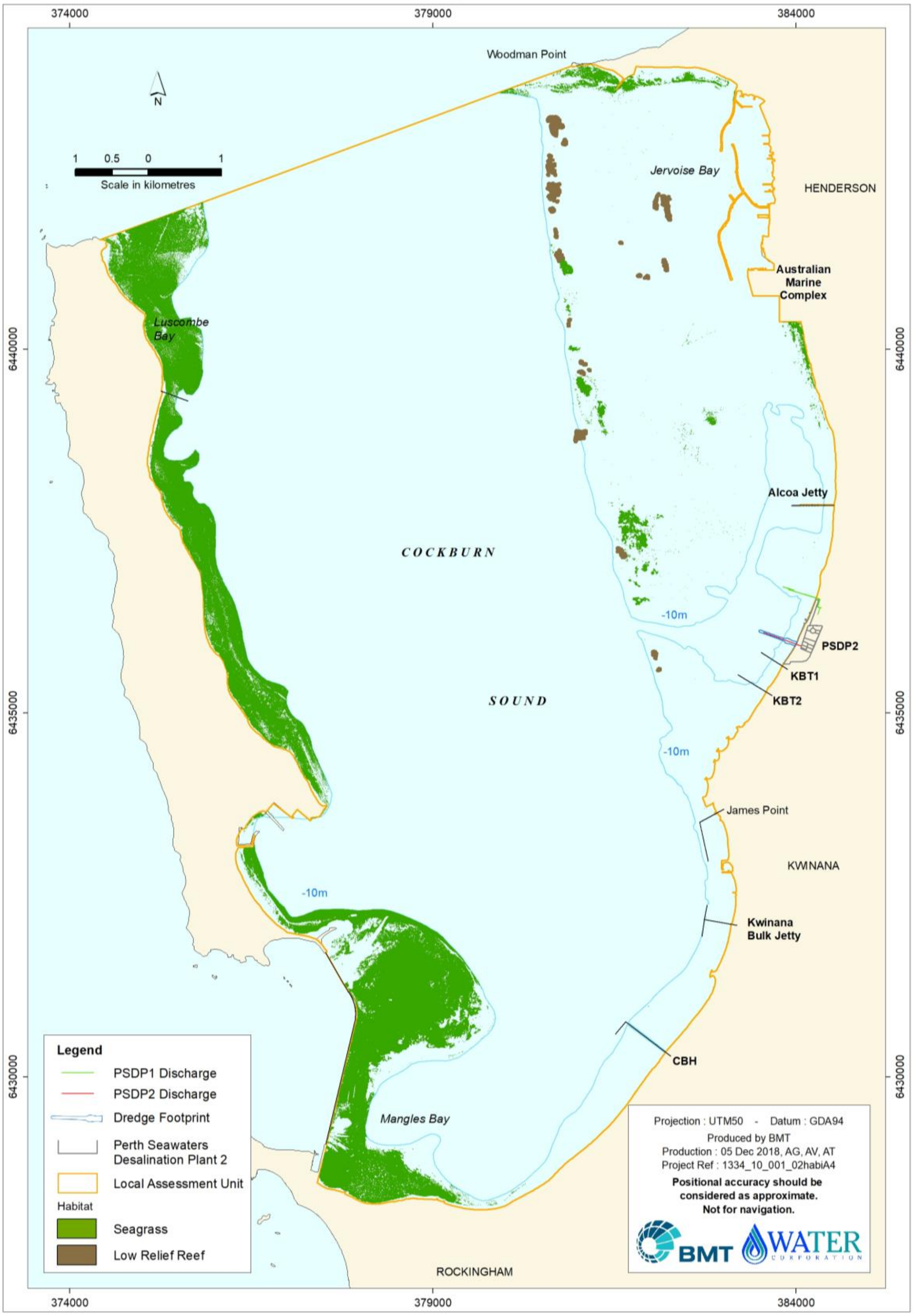
Figure 7.1 Coastal modifications in Cockburn Sound

Benthic primary producer habitat

Seagrasses are the dominant benthic primary producer (BPP) of Cockburn Sound in terms of productivity (>3050 t C/yr; BMT 2018a) and are mainly comprised of species from the genera *Posidonia* and *Amphibolis* (Hovey & Fraser 2018). Microphytobenthos is also thought to contribute significantly to benthic primary production in Cockburn Sound (~1104 t C/yr), although it remains poorly understood (Oceanica 2009). Algal epiphytes, which grow on the leaves and stems of seagrasses, contribute ~998 t C/yr, while macroalgae (e.g. *Ecklonia radiata*) and some corals of the Faviidae family are minor contributors to primary production in Cockburn Sound (~100 t C/yr; Oceanica 2009b).

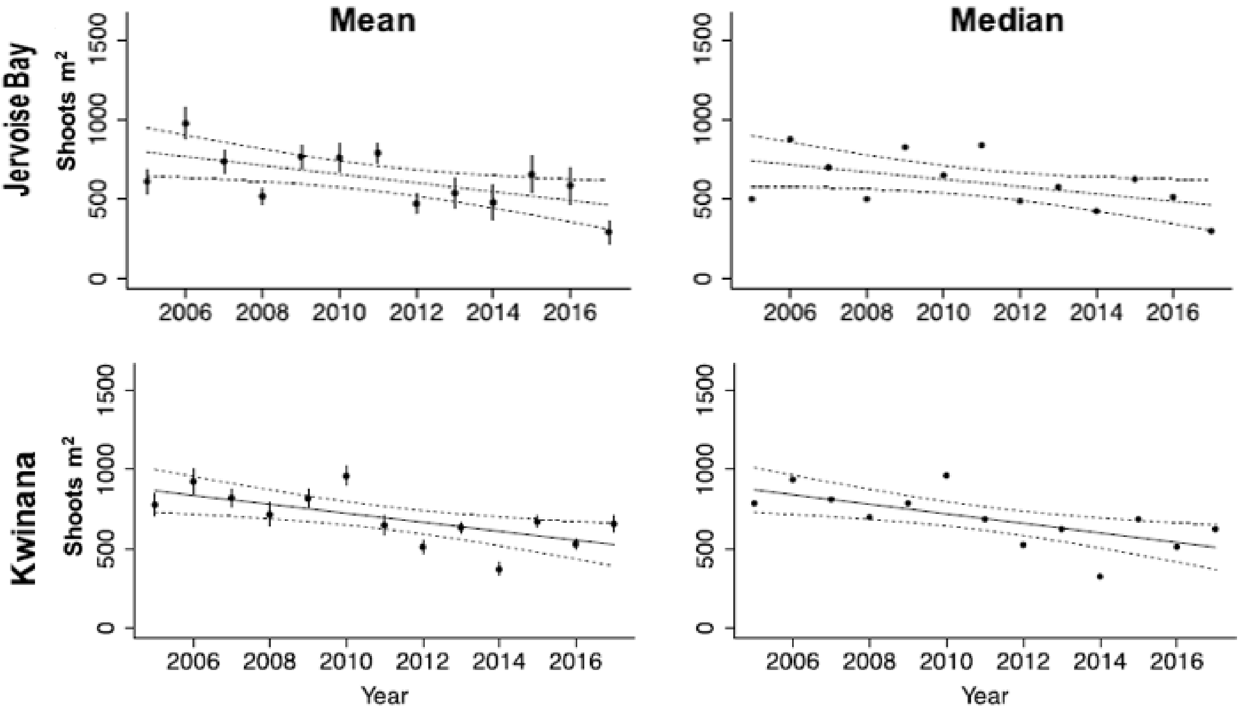
Because of their central ecological importance and dominant role in primary production, seagrasses have drawn the most attention of the BPP groups in Cockburn Sound. Historically (pre-1950s), Cockburn Sound supported large seagrass meadows that occupied ~4000 ha and covered most of the seabed to depths of 10 m (Kendrick et al. 2002). The extent of seagrass meadows in Cockburn Sound declined severely during the late 1960s and early 1970s due to poor water quality. By 1978, it was estimated that only 872 ha (~22%) of seagrass remained (Cambridge & McComb 1984, Kendrick et al. 2002). Corresponding with the large loss in seagrass extent, Oceanica (2009b) estimated that there was reduction in primary production of ~92%. However, since the 1980s, water quality conditions have improved and seagrass distribution has stabilised. The most recent estimate of seagrass extent in the assessment area is ~860 ha (Hovey & Fraser 2018), which is an appreciable improvement from 728 ha in 2008 (Figure 7.2).

Despite these positive signs, there remains a long-term decline in seagrass health in some areas within Cockburn Sound. On the Eastern Shelf, seagrass health has shown significant declines in mean shoot density since 2003 at both 'Jervoise Bay' and 'Kwinana' long-term monitoring locations (Figure 7.3). The reasons for declines in seagrass health remain speculative, although trends are not confined to the Eastern Shelf (Fraser et al. 2017). Mohring and Rule (2013) attempted to link ongoing trends in seagrass density with potential physical and biogeochemical variables in the water column and found the best explanatory factor was temperature. However, this relationship was found to be weak, and it is more likely to involve a combination of stressors acting in concert (BMT 2018a).



Source: seagrass benthic layer supplied by Department of Water and Environmental Regulation (UWA 2018)

Figure 7.2 Extent of benthic primary producer habitat in Cockburn Sound, 2017



Source: UWA (2017)

Note:

1. Solid lines show significant trends at α = 0.05; dotted lines show potential trends at α = 0.2; dashed lines show 95% confidence bands

Figure 7.3 Trends in mean shoot densities at Jervoise Bay (top) and Kwinana (bottom) monitoring sites, located on the Eastern Shelf of Cockburn Sound

Benthic communities

Benthic macrofauna are an important component of marine and coastal ecosystems of Cockburn Sound. In this report, 'benthic macrofauna' refers to infauna and epifauna (described in Table 7.2). They can influence both the physical and chemical properties of the sediment and the overlying water column and have a number of important functional roles, including the alteration of geochemical conditions at the sediment–water interface and the promotion of decomposition and nutrient cycling (Jernakoff et al. 1996). Benthic macrofauna also occupy an important intermediate trophic position, particularly in their capacity for converting primary production (e.g. phytoplankton) into secondary production (Jernakoff et al. 1996) that is then available to higher trophic levels including fish, crabs and birds (Klumpp et al. 1989, Gartner et al. 2015). Other groups consume detrital or planktonic food sources (e.g. through filtering the water column) and similarly become a food source for higher trophic levels (Jernakoff et al. 1996).

Oceanica (2009b) estimated that the total biomass of benthic macrofauna across the Sound is ~1339 t (ash-free dry weight). Infauna and epifauna in habitat of fine sediment (>10 m water depth) contribute the most (51%) to the overall secondary producer biomass, while infauna and epifauna in habitat of fine sediment (<10 m water depth) and within *Posidonia* spp. seagrass habitat contribute 30% and 13% of benthic secondary producer biomass, respectively (Oceanica 2009b).

The total water filtering capacity of benthic invertebrate fauna within Cockburn Sound is estimated at 25 billion L/d across the entire Sound, or 230 ML/km^2, most of which occurs in unvegetated sediment in >10 m water depth – i.e. the deep basin (Oceanica 2009b).

Three comprehensive investigations of benthic macrofauna in the deep basin of Cockburn Sound have been undertaken over the last 40 years. While earlier studies are not directly comparable with later studies (because of differences in the sites sampled, methods and taxonomic identifications), it is evident that there have been marked decadal changes in the benthic macrofauna communities between the 1970s and recent years (Oceanica 2013); benthic invertebrate data from the deep basin from 2013 are shown in Figure 7.3. Differences between times include shifts in species abundances and distribution, as well as community indices such as species diversity (Oceanica 2013). It is probable that modifications to the benthic marine environment, at least in part, explain these shifts (BMT 2018a).

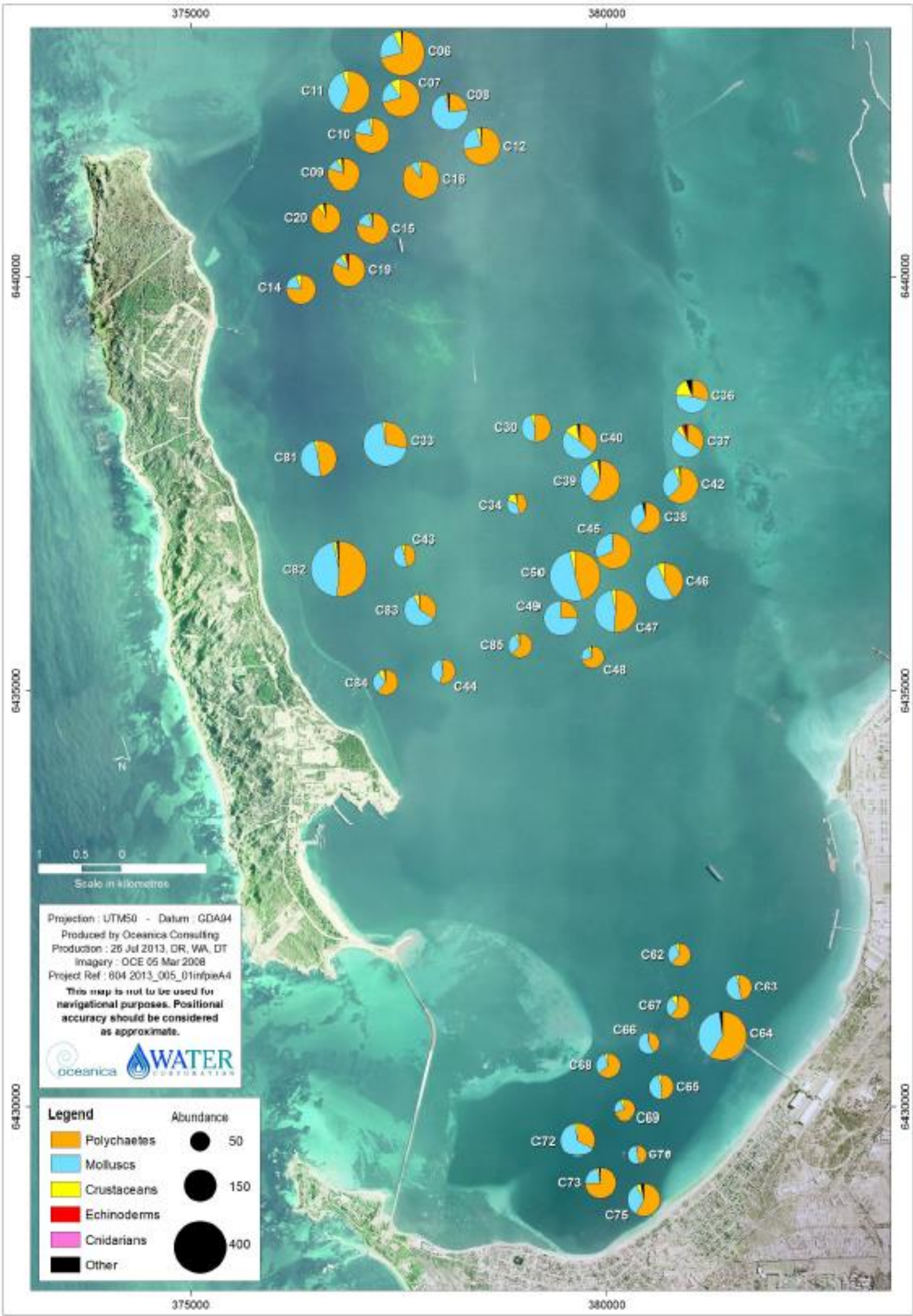
Table 7.2 Dominant benthic macrofauna within the habitats of Cockburn Sound

Habitat type	Infauna or epifauna	Taxa
Fine sediments	Infauna	Polychaetes, crustaceans, bivalves
	Epifauna	Echinoderms, anemones, ascidians, gastropods, decapods
Seagrass beds	Infauna	Polychaetes, crustaceans, bivalves
	Epifauna	Crustaceans, sponges, echinoderms, gastropods, decapods
Reef	Epifauna	Echinoderms (holothurians and ophiuroids), crustaceans (barnacles, crabs), sponges, ascidians

Source: Oceanica (2013)

Notes:

1. Infauna are those animals that live within the sediment
2. Epifauna are animals that live on top of the sediment, seagrass or reef surface



Source: Oceanica (2013)

Table 7.3 Composition and abundance of benthic infauna across Cockburn Sound in March 2013

7.3.1 Study effort

Water Corporation has used the results from the surveys outlined in Table 7.4 to support the assessment of potential impacts of the Proposal on BCH. Relevant reports are included as appendices.

Table 7.4 Marine studies used to inform the Proposal

Title	Description
Perth Metropolitan Desalination Plant Effects of Low Dissolved Oxygen Concentrations on Marine Organisms: A Review (Oceanica 2005)	The document collates the information presented in a selection of the available literature on the effects of low DO concentrations on various life history stages of marine fish and invertebrates.
Cockburn Sound Benthic Macrofauna: Low DO Event Sampling May 2006 Community and Sediment Habitat Monitoring (Oceanica 2006)	This report provides the outcome sampling undertaken to compare benthic invertebrate communities and sediment habitat in May 2006 (post low DO event) with those sampled in early/mid-March 2006 (pre-low DO event), to provide a snapshot assessment of the potential effects on the communities and habitat resulting from a low DO event (~12 hr period <2.0 mg L^{-1}).
Benthic Macroinvertebrate Fauna Assessment (Oceanica 2007, 2009c, 2013; Appendix J)	Following environmental approval of PSDP1, Water Corporation has undertaken considerable research effort in sampling benthic invertebrate communities in the deeper basin of Cockburn Sound to determine if links exist in long-term patterns in composition and abundance, with desalination discharges. Monitoring included one pre-commissioning baseline survey (March 2006) and two post-commissioning repeat surveys (March 2008, March 2013). In combination, the baseline, 2008 and 2013 surveys highlight the natural spatial and temporal variation in benthic macrofauna communities in Cockburn Sound and also assess the likelihood of desalination discharges from PSDP1 effecting those patterns.
Perth Seawater Desalination Plant 2 Construction Impact Assessment (BMT 2019b; Appendix A)	Described in Marine environmental quality section 6.3.3, (Table 6.2).
Perth Desalination Discharge Modelling: Effects on Stratification and Dissolved Oxygen (BMT 2019c; Appendix E)	Due to the risk of discharge of desalination return water promoting conditions which can lead to reductions in DO concentrations, Water Corporation commissioned BMT to develop a hydrodynamic and water quality numerical model of Cockburn Sound and its surrounds, to address regulatory concerns about the fate and mixing of desalination discharges. This report provides a summary of the work presented in BMT (2018b) and BMT (2018c), with a focus on patterns in stratification and DO
Other supporting data and documentation	
The 2017 survey of selected seagrass meadows in Cockburn Sound, Owen Anchorage and Warnbro Sound (Fraser et al. 2017)	Seagrass was surveyed in fixed quadrats at 27 sites across Cockburn Sound, Warnbro Sound, and Owen Anchorage – 16 ‘potential impact’ sites, five ‘reference’ sites, and six ‘depth transect’ sites. At each site, seagrass (primarily *Posidonia sinuosa*) shoot density and canopy heights were measured from up to 24 fixed quadrats.

Benthic Habitat Mapping of Cockburn Sound (UWA 2018)	This survey updates the distribution of seagrass in shallow (<10 m) areas of Cockburn Sound in 2017 and compares this to distributions from maps from 1999 and 2012. Seagrass data from this survey were supplied to BMT by Department of Water and Environment Regulation (DWER) and Cockburn Sound Management Council (CSMC) to enable mapping of seagrass extent within the project area (Section 7.4.1).
Cockburn Sound-Drivers-Pressures-State-Impacts-Responses Assessment 2017 Final Report (BMT 2018a)	This report was commissioned by DWER and CSMC. The intent of the report was to provide a comprehensive critical assessment of the current and emerging driving forces and pressures on the Cockburn Sound marine area, the Sound's current condition and trends, impacts and management responses.

Note:

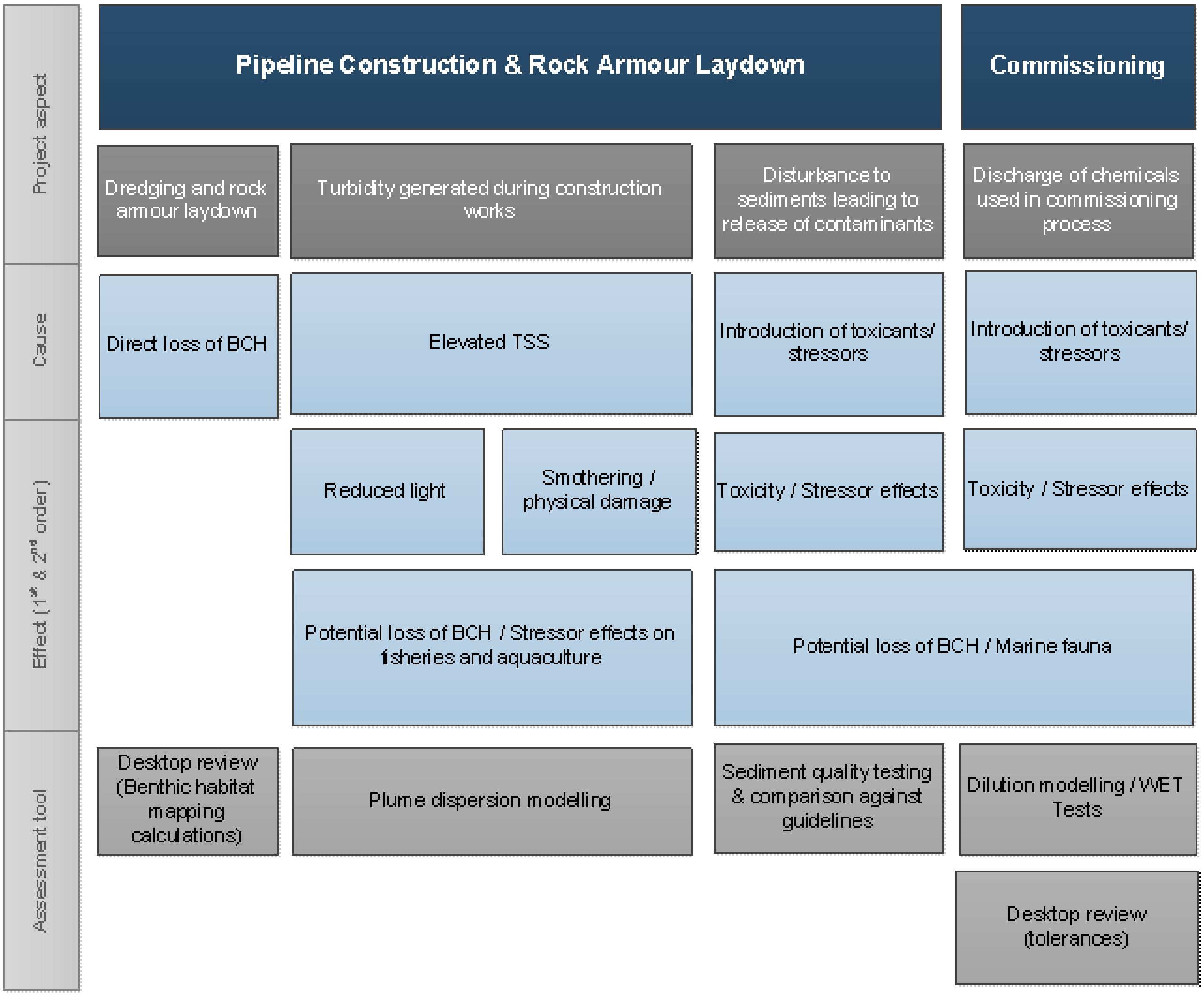
1. Marine water and sediment quality studies commissioned for the PSDP2 Proposal approvals that are referred to in this section are listed in Section 6.3.2, Table 6.2.

7.4 Potential impacts

7.4.1 Potential construction impacts to benthic communities and habitat

Potential cause-effect pathways of impacts of dredging and plant commissioning on BCH associated with the PSDP2 Proposal are shown in Figure 7.4 and include:

- direct loss of benthic habitat in the diffuser pipeline corridor due to dredging and rock armour laydown
- periods of elevated enhanced TSS, reduced light and sediment deposition during dredging activities, which in turn may lead to loss of BCH
- release of toxicants to the water column due to disturbance of sediments
- release of toxicants to water column during PSDP2 plant commissioning.



Note:

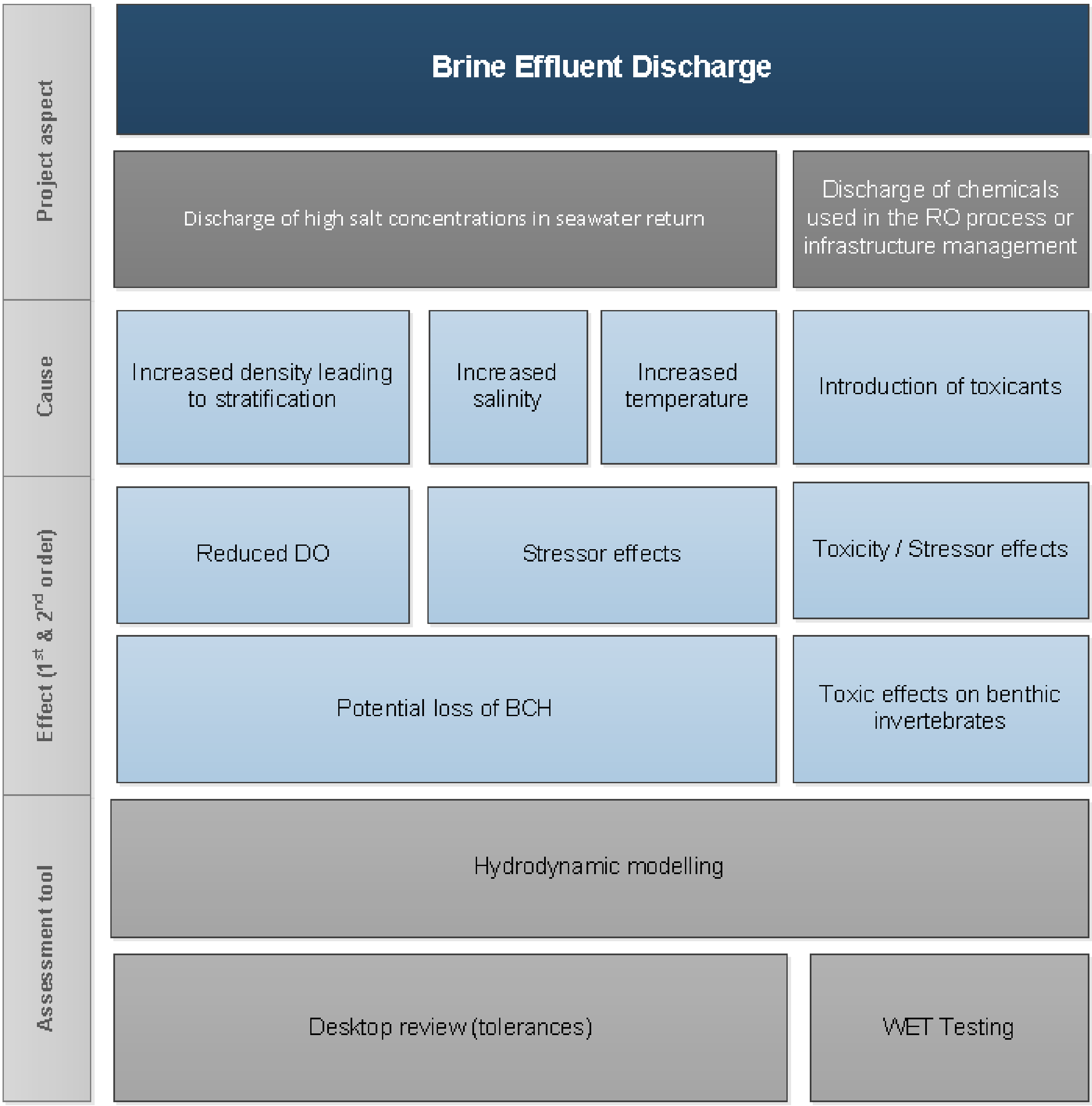
1. BCH = benthic communities and habitats; PSDP1 = Perth Seawater Desalination Plant 1; TSS = total suspended solids; WET = whole of effluent toxicity

Figure 7.4 Potential impacts to benthic communities and habitat and flow-on effects, associated with PSDP2 marine construction activities

7.4.2 Potential operational impacts to benthic communities and habitat

The discharge of desalination wastewater may contain constituents that can alter marine quality, which in turn can impact BCH. Potential operational impacts considered relevant to the PSDP2 Proposal are shown in Figure 7.5, and include:

- discharges of brine effluent can potentially enhance the strength of stratification and in turn, promote reduced DO leading to loss of BCH
- changes to marine salinity can induce osmotic stress
- elevated return water temperature can induce temperature stress
- release of toxicants in brine effluent used in the RO process can contaminate and impact marine organisms.



Note:

1. BCH = benthic communities and habitats; DO = dissolved oxygen; RO = reverse osmosis; WET = whole of effluent toxicity

Figure 7.5 Potential impacts to benthic communities and habitat, and flow-on effects, associated with PSDP2 marine operational activities

7.5 Assessment of impacts

7.5.1 Assessment framework

Construction impacts

EPA's *Technical Guidance - Protection of Benthic Communities and Habitats* (EPA 2016f), and *Environmental Impact Assessment of Marine Dredging Proposals* (EPA 2016c) have been applied here to determine the potential extent and significance of direct and indirect impacts to BCH as a consequence of the PSDP2 Proposal.

In accordance with the EPA (2016c), potential impacts on BCH have been defined as:

- Zone of influence (ZoI): is the area within which changes in environmental quality associated with plumes are predicted and anticipated during the construction, but where these changes would not result in a detectible impact on benthic biota (here defined as minor change in water quality/turbidity and potential minor and short-term reduction in shoot density, with predicted recovery to near initial density within 1 year).
- Zone of moderate impact (ZoMI): is the area within which predicted impacts on benthic organisms are recoverable within a period of five years following completion of construction activities (here defined as predicted recovery of shoot density to near initial density within 2 years).
- Zone of high impact (ZoHI): is the area where impacts on BCH are predicted to be irreversible (here defined as possible recovery of shoot density to near initial density in >2 years, but with potential for permanent loss).

The rationale and justification for the conservative establishment of these zones is provided below, and is based on: (i) predictive modelling of the plume extent and intensity, and sediment deposition rates (Section 6.5.2); and (ii) the tolerance of benthic biota to these stressors.

Local Assessment Units

The EPA provides a risk-based spatial assessment framework for evaluating cumulative irreversible loss of and/or serious damage to BCH (EPA 2016f), which has been applied to determine impacts to seagrass habitat as a result of PSDP2 construction activities (see Section 7.4). The EPA has termed the areas within which to calculate cumulative losses 'local assessment units' (LAUs). For EPA to determine if potential losses to BCH are acceptable, the following calculations of the spatial extent of BCH are required (EPA 2016f):

- prior to all human-induced disturbance
- existing at the time of the Proposal
- remaining after implementation of the Proposal.

The EPA has designated an LAU of area 105.7 km^2 (10 570 ha) for Cockburn Sound (EPA 2015) 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 losses are totalled to determine a cumulative impact that is assessed by the EPA in light of the overall policy objective for Cockburn Sound, which is to ensure that water quality of the Sound is maintained and where possible improved so that there is no further net loss and preferably a net gain in seagrass areas.

Direct losses of benthic communities and habitat due to construction

Direct impacts occur predominantly within and immediately adjacent to infrastructure footprints where the seabed is excavated/disturbed. However, as the intake and outlet pipeline will be buried and covered with sediment from the site (i.e. constructed using 'cut and cover' techniques) only impacts within the excavated footprint will be considered; there are not anticipated to be any direct impacts due to the presence of infrastructure, and all remaining spoil that is not used for trench backfill, will be used for onshore site works or disposed of offsite at an appropriate facility in a manner that meets regulatory requirements.

All direct impacts will be assumed to involve irreversible loss of benthic habitats and communities within the dredge footprint. Direct impacts will be determined using contemporary mapping techniques.

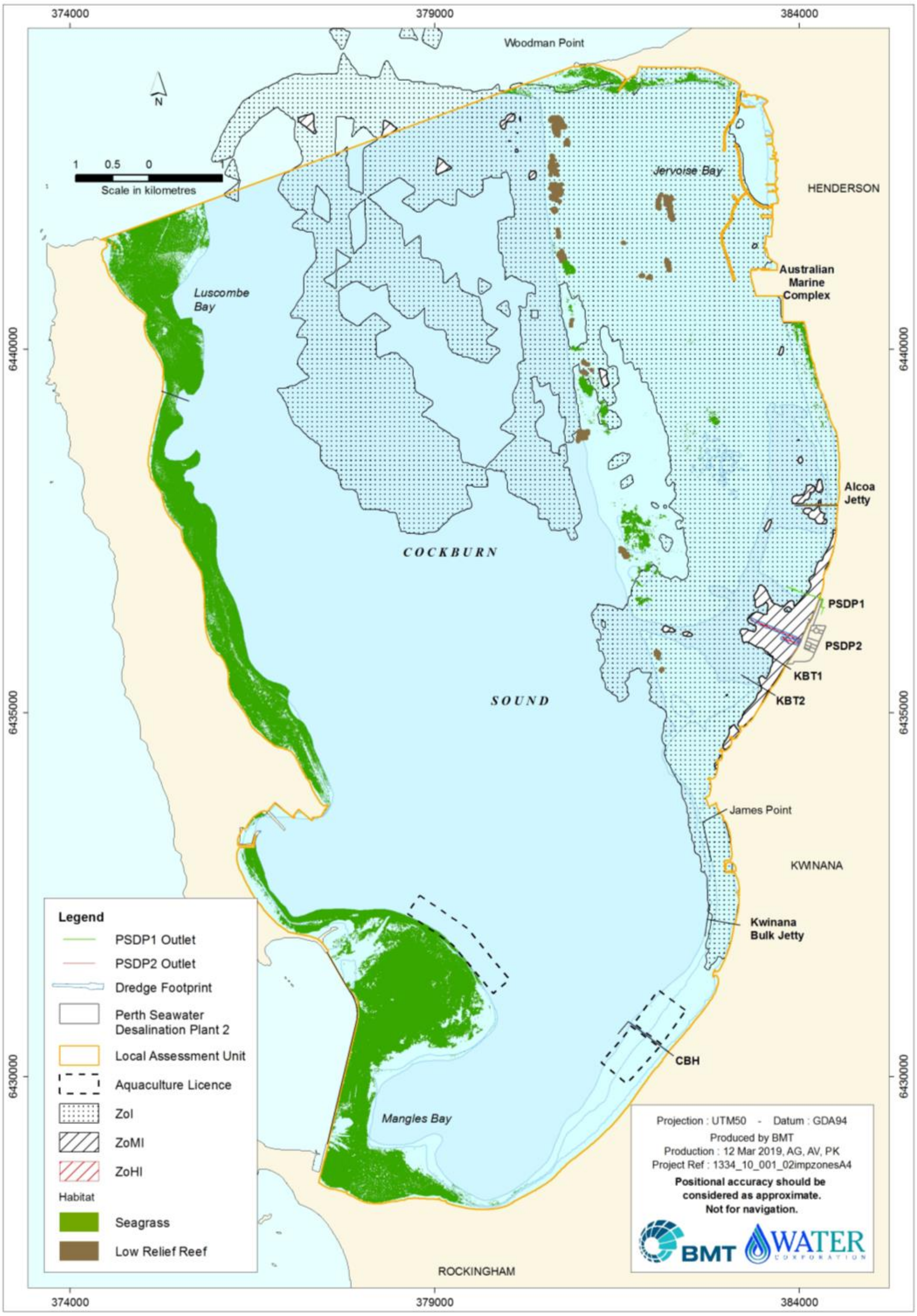
Indirect loss of benthic communities and habitats (shading and smothering)

EPA's Technical Guidance *Environmental Impact Assessment of Marine Dredging Proposals* (EPA 2016c) sets out guidance for predicting impacts to BCH due to significant construction activities, to ensure these are presented in a clear and consistent manner.

Likely impacts on seagrasses within 'zones of impact' have been estimated in accordance with EPA (2016c) and are shown in Figure 7.6. Zones were identified using stress threshold criteria to predict severity and extent of impact, according to the following general classifications and contextual interpretation for the assessment of the PSDP2 Proposal.

In accordance with EPA (2016c) zones were conservatively derived as follows:

- ZoI – the outer boundary of the ZoI was defined using the 100th percentile of the area where a TSS threshold of 2 mg/L above background was exceeded, 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 greatest extent that the plume may extend to during the construction program. That is, the region where a visible plume is expected will generally be restricted to within the vicinity of the excavation, although a plume may be visible up to several kilometres away at times.
- ZoMI – the outer boundary of the ZoMI was defined using the 99th percentile of the area where a TSS threshold of 10 mg/L above background was exceeded (see Section 6.5.2, Figure 6.7), indicating a low risk of sublethal effects on benthic organisms outside the ZoHI
- ZoHI – comprising direct losses due to the development footprint (pipeline installation area).



Notes:

1. Zone of influence (ZoI) = the 100th percentile of the area where a TSS threshold of 2 mg/L above background is predicted to be exceeded
2. Zone of moderate impact (ZoMI) = the 99th percentile of the area where a TSS threshold of 10 mg/L above background was exceeded
3. Zone of high impact (ZoHI) = comprising direct losses due to the development footprint

Figure 7.6 Calculated zones of influence, moderate impact and high impact for construction activity

Secondary & tertiary loss of benthic communities and habitats (toxicity)

The release of toxicants from sediments during construction and from discharges during plant commissioning may result in secondary impacts to BCH. Indirect impacts include a reduction in BCH health or quality. As demonstrated in Section 6, this risk was determined to be negligible and marine environmental quality is expected be maintained to an acceptable standard. As such, no indirect impacts to BCH are expected, and therefore, no further assessment of the issue is required.

Operational impacts

The secondary and tertiary effects of marine quality stressors (low DO, salinity, temperature and toxicants) on BCH associated with the discharge of brine effluent can result in changes in ambient DO, salinity and temperature. Such changes in marine quality have the potential to reduce BCH health or quality.

While it was demonstrated in Section 5 that marine environmental quality will be maintained to an acceptable environmental quality standard, potential effects of subtle changes to ambient DO and salinity that may occur on occasions as a result of the Proposal were further examined to determine their ecological consequences and risk. There are no specific environmental guidelines for determining ecological risk, so Water Corporation has undertaken a desk-top review of the available literature to determine the tolerances of benthic flora and fauna to anticipated changes in marine quality.

7.5.2 Construction impacts

Direct losses due to construction footprint related impacts

Potential damage to BCH can occur directly via removal during construction. However, while it is probable that solitary marine fauna (e.g. crabs, fish and other invertebrates) commonly pass through the site (Dr D Johnston 2018, pers. comm., 1 December 2018), the area is not recognised as significant BPP habitat (BMT 2018a) or known to support diverse benthic invertebrate communities (Oceanica 2013), so there will be no direct disturbance or removal of BPP habitat immediately within the dredge footprint.

In accordance with EPA (2016c), the pipeline installation footprint may nominally be described as the ZoHI (Figure 7.7). The ZoHI designates the area where impacts on BCH are predicted to be irreversible, where irreversible means ‘lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years'. Benthic habitat within the ZoHI consist of bare sand, with the likelihood of sparsely populated macroinvertebrate communities (such as polychaetes, crustaceans, bivalves, echinoderms, anemones, ascidians and gastropods), occupying an area of approximately 6.29 ha (Section 7.3.2).

The replacement of 6.29 ha of bare sand with a rubble reef and bare sand overlay is not considered to be ecologically significant and in time, any exposed reef will likely be a more productive system than the sand it replaced. Direct loss of 6.29 ha bare sand within a ~105.7 km^2 local assessment unit equates to a potential loss of <0.0006% of habitat. It is also expected that similar benthic macroinvertebrate communities and taxa will colonise areas of sand overlay following completion of construction and therefore there will not be a permanent loss of these communities. Further, it is not anticipated that any exposed reef will act as an impediment to solitary marine fauna that use the area in the future.

Monitoring and management of direct impacts to benthic habitat will focus on ensuring that construction does not occur outside of the approved project footprint (see Section 7.6.1).

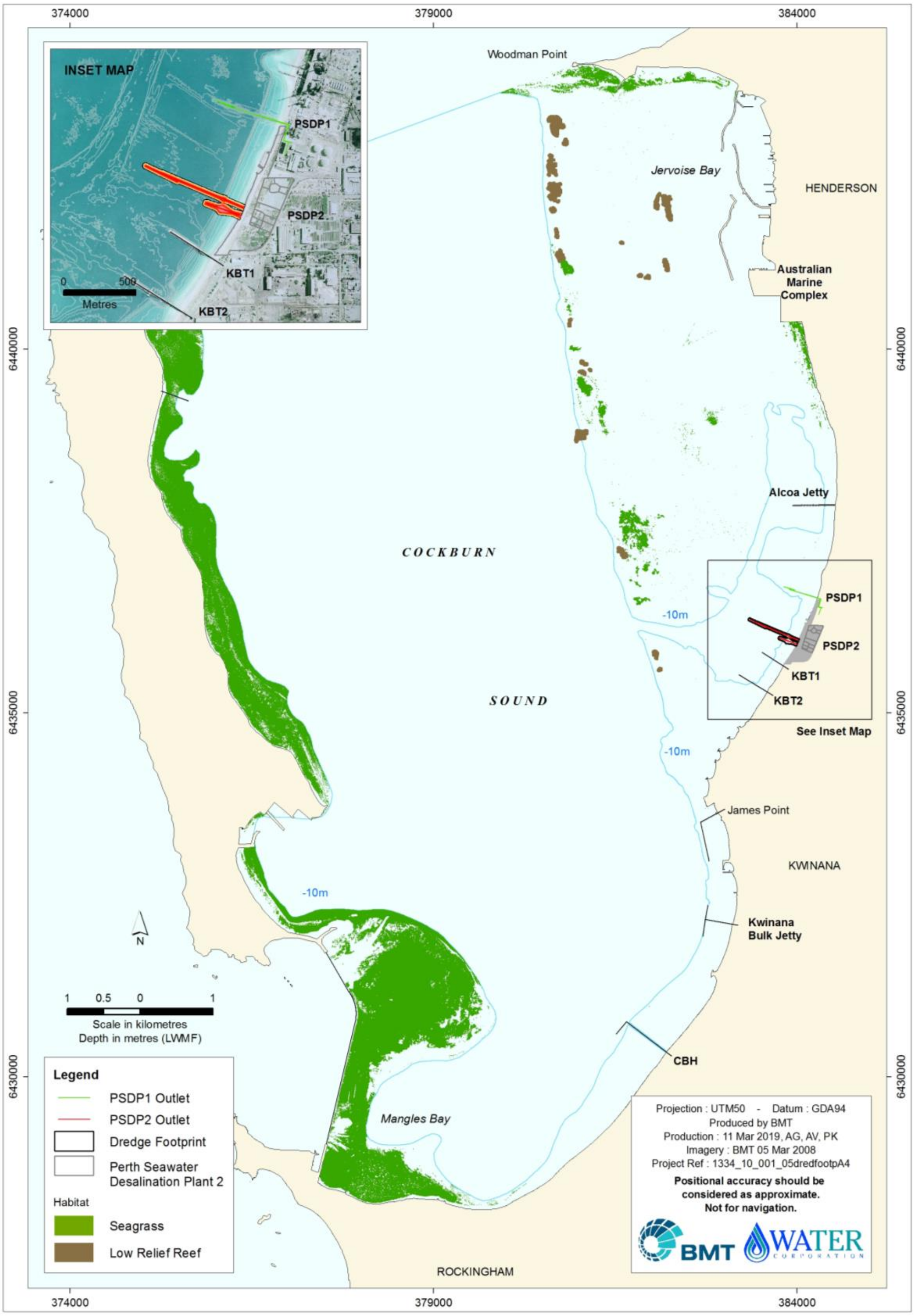


Figure 7.7 Marine construction footprint

Indirect impacts on seagrasses due to turbidity and sedimentation

Seagrasses have the potential to be impacted indirectly via shading from turbidity and sediment deposition created during dredging. While colonising seagrasses like *Halophila* spp. can recover quickly from a period of stress or disturbance (McMahon et al. 2017), impacts to perennials seagrasses – such as *Posidonia* spp. and *Amphibolis* spp. – from dredging activities can be greater, depending on the duration and intensity of the disturbance (Collier et al. 2009, Ralph et al. 2007).

The ZoMI (Figure 7.6) represents the area within which predicted impacts on benthic organisms are possible but are recoverable within a period of five years following completion of construction (EPA 2016c). In the project area, benthic habitat within the ZoMI is predominantly comprised of bare sand with small isolated patches of seagrass and sparsely populated macroinvertebrate communities (UWA 2018; Figure 7.6). Further, the Eastern Shelf of Cockburn Sound, where the project is planned, can be considered a highly modified environment that has a long-term history of disturbance (Fraser et al. 2017, UWA 2018, BMT 2018a).

Modelling indicates that the turbid plume generated by the Project is unlikely to shade any existing stands of seagrass and is generally restricted to nearshore areas that are used for shipping and other industrial activities (Section 6.5.2). While plume modelling indicates that TSS concentrations will be elevated above background by <20 mg/L for up to 13 days in isolated areas, these concentrations are restricted to immediately around the dredge footprint (Section 6.5.2, Table 6.6), and within a short distance from the dredge site (hundreds of metres), both duration and intensity of the turbidity plume diminish rapidly (i.e. hours-to-days; see Section 6.5.2, Table 6.6).

Sediment deposition rates, and total sediment deposition levels, were also predicted to be insignificant (Section 5.5.2; Figure 6.13 and Figure 6.14, respectively). As indicated by modelling (BMT 2019b), deposition will predominantly occur adjacent to the dredge area or immediately south of the dredge area and will only result in a thin veneer (~1 cm) of uncontaminated sediments overlaying existing unvegetated habitat.

In light of the above assessment outcomes, the impacts on benthic habitats within the ZoMI are unlikely to be significant as:

- the maximum light reduction anticipated in the ZoMI equates to ~0.177 LAC for a period of up to 13 days, however, most of the ZoMI will experience light reductions that equate to ~0.0987 LAC for a maximum period of 21 days, but typically less than 1–2 days (Section 6.5.2). According to Collier (2009), *P. sinuosa* is able to tolerate between three to six months of continuous and intense shading (<40% of ambient photosynthetic photon flux density) before lethal effects occur; although can survive for much longer periods (>1 year) under sub-optimal light conditions (e.g. >70% of ambient photosynthetic photon flux density). While these light reductions do not directly translate to TSS thresholds; it is contended that a TSS increase of 10–20 mg/L for less than 17 days over the entire 126 day dredging campaign is unlikely to reduce the light environment to lower levels than these thresholds require (and if they do, potential impacts to the perennial and ephemeral seagrasses will be recoverable within 5 years)
- it is also expected that exposure to TSS concentrations <20 mg/L above background for less than 17 days is likely tolerated by most benthic invertebrates and filter feeders in the zone (Pineda et al. 2017)

- most perennial seagrasses are reasonably expected to persist through a level of 2–3 cm of sedimentation (Erftemeijer & Lewis 2006, McMahon et al. 2017), noting the science supporting this threshold still does not allow species and location specific inferences (McMahon et al. 2017). Modelling of the degree of sedimentation at the end of the entire construction period showed highly localised effects within a very short distance (200-300 m) of the dredge area, with no significant degree of sediment deposition (>1 cm) outside the ZoMI, and no seagrasses occurring within the ZoMI.

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, ~80% of the seagrasses have been historically lost either due to water quality changes or direct physical impact, although in the past decade there has been evidence of some recovery in seagrass extent (UWA 2018). The EPA's (2016f) environmental objective in these areas is to ensure no net loss of BCH and, where possible, to generate a net gain in the area of BCH and/or their associated BPP communities.

An assessment was undertaken of the potential cumulative impacts for BCH in Cockburn Sound. Cumulative seagrass loss has been calculated based on the final PSDP2 dredging design, in-line with the EPA's methods for determining cumulative impact on BCH (EPA 2016f). The seven required steps to calculate losses are described below.

Step 1: What is the Local Assessment Unit?

The LAU has been defined by the EPA as Cockburn Sound, the total area of this LAU is 10 566 ha (~105.7 km^2).

Step 2: What is the current area of each BCH 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 (UWA 2018). The most recent work was completed in 2017 (UWA 2018) and provides a description of the extent of seagrass across Cockburn Sound. These data have been reproduced by BMT to enable assessment of the extent of the various benthic habitat types (UWA 2018); post processing of data was required to interpret some seagrass habitats[5] and to differentiate unvegetated areas by depth.

The dominant benthic habitat types were identified and subject to detailed characterisation, including photographic documentation and estimation of spatial coverage (UWA 2018):

1. fine sediment above 10 m depth
2. fine sediment below 10 m depth
3. seagrass (including the species *Posidonia sinuosa*; *P. australis* and *P. coriacea* either as mixed or monospecific meadows)

[5] *Estimates of seagrass extent (ha) vary between sources (e.g. Hovey & Fraser (2018) reported seagrass extent in 2018 as 965 ha) depending on the size of the assessment area considered in the investigation and complexity of the classification scheme used. BMT is aware that a few small areas of the habitat classified by Hovey and Fraser (2018) as seagrass on the Eastern Shelf consist of reef or unvegetated sediments, and have therefore modified the assumptions in this report accordingly.*

4. reef areas (typically low relief reef dominated by macroalgae and filter feeders, but also consisting of consolidated limestone dredge spoil).

Spatially, fine sediment above 10 m depth and fine sediment below 10 m depth were the most dominant habitats, comprising 64.5% and 27.2% of the LAU, respectively, followed by seagrass comprising 8.2% (863.5 ha) of the area. All other habitats spatially comprised less than 1% of the LAU area (Table 7.5).

Table 7.5 Current area of benthic habitats within Cockburn Sound

Habitat	Area (ha)	Area (%)
Fine sediment above 10 m depth	2871.6	27.2
Fine sediment below 10 m depth	6815.0	64.5
Seagrass	863.5	8.2
Reef areas	15.9	0.1
Total	**10 565.9**	**100**

Source: UWA (2018)
Note:
1. Reef areas include low relief reef and artificial structure

Step 3: Do any of the benthic communities have any particular tenure or conservation, ecological or social values that should be considered?

All BCH in Cockburn Sound is protected though the *State Environmental (Cockburn Sound) Policy 2015* (EPA 2015) under the environmental value of ecosystem integrity. The environmental quality management framework for Cockburn Sound (EPA 2017) was developed predominantly to ensure the long-term maintenance of seagrasses.

Step 4: What area of each BCH was originally within the LAU?

An estimate of the extent of each of the benthic habitat 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 7.8 and the habitat coverage areas are shown in Table 7.6. 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 7.6 Pre-impact benthic habitat coverage in Cockburn Sound

Habitat	Area (ha)	Percentage (%)
Fine sediment above 10 m depth	0	0
Fine sediment below 10m depth	6831	46.4
Seagrass	3760	25.6
Reef areas	15	0.1
Total	**10 605**	**100**

Source: BMT (2018a)

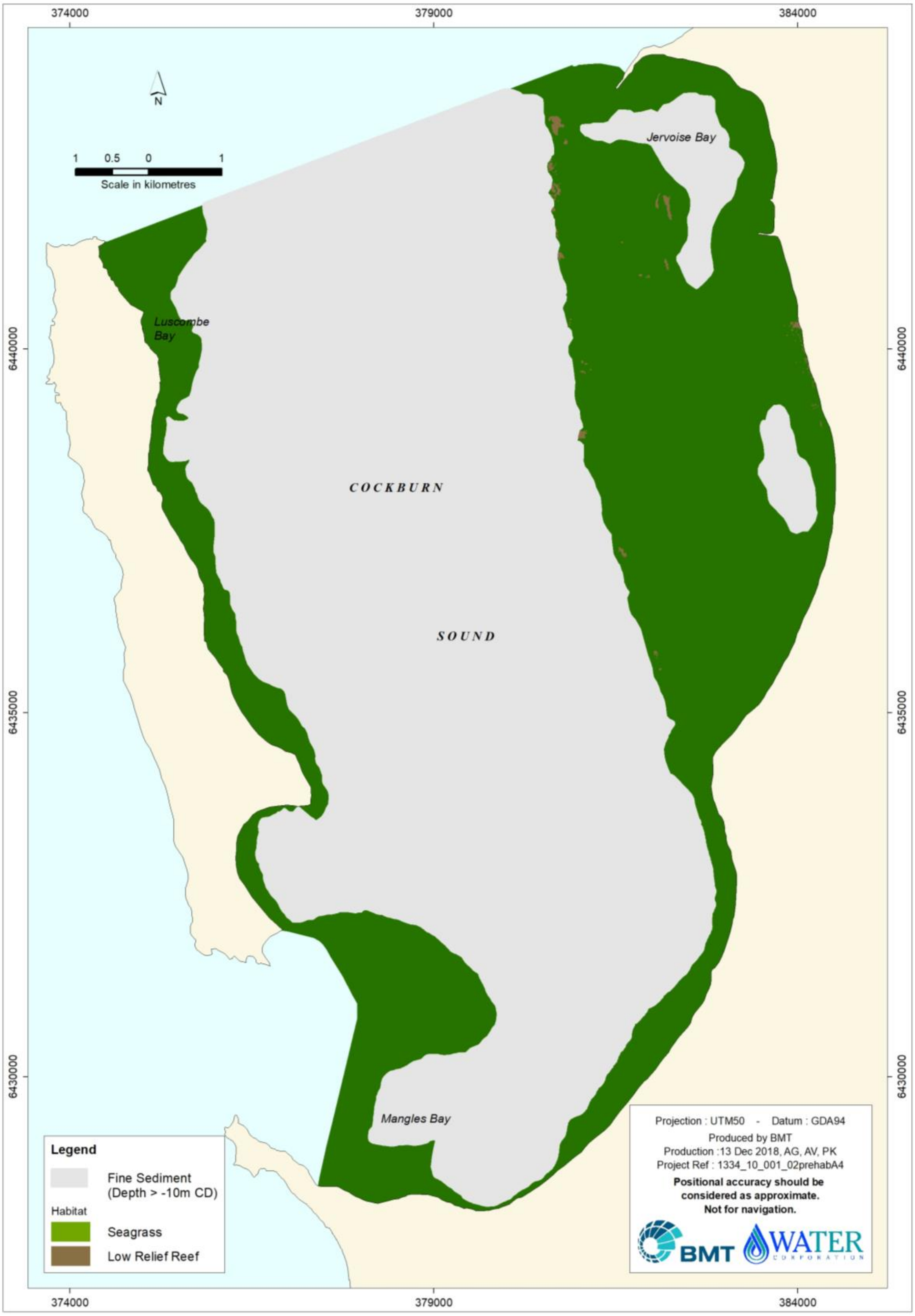


Figure 7.8 Estimated extent of seagrass in Cockburn Sound, pre-European settlement

Step 5: What percentage of the original area of each benthic community and its associated habitat 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 77% of the original (pre-European habitation) area of seagrass has been lost (Table 7.7). This is similar to the seagrass loss estimates (~80%) made by Hovey & Fraser (2018); slight variations are accounted for by differences in characterisation of some BCH.

Table 7.7 Estimated benthic habitat losses within Cockburn Sound since European habitation

Habitat	Cumulative losses of each habitat type	
	Change in area (ha)	Change in area (%)
Fine sediment above 10 m depth	+2872	N/A
Fine sediment below 10 m depth	-16	<0.001%
Seagrass	-2896	-77%
Reef areas	+0.9	+6%

Notes:
1. Loss indicated by a negative value, gain indicated by a positive value
2. Losses/gains of fine sediment (>10 m) shown for information only, although this is not a BPPH
3. Reef areas include: low relief reef and artificial structure

Step 6: How much more will be impacted and lost if this proposal was implemented?

Habitat losses (seagrass and bare sediment) due to the Proposal are shown in Table 7.8. A total loss of 6.29 ha of habitat is expected to be lost directly within the dredge footprint. The duration and intensity of the sediment plume associated with dredging was predicted to rapidly diminish with distance from the dredge footprint and there are not predicted be any losses of seagrass due to either direct or indirect impacts (Table 7.8).

Table 7.8 Benthic habitat losses (ha) due to the Proposal

Habitat type	Direct (ha)	Indirect (ha)	Total (ha)
Fine sediment above 10 m depth	6.29	0	6.29
Fine sediment below 10 m depth	0	0	0
Seagrass	0	0	0
Reef areas	0	0	0
Total	**6.29**	**0**	**6.29**

Step 7: How much would be lost in total if the proposal proceeds?

For impacts to be considered as a result of the Proposal, BCH losses have been calculated including all existing and EPA approved proposals that are still planned for completion by their proponents, as shown in Figure 7.9. It is noted that the Mangles Bay Marina proposal, which had environmental approval, did not receive planning permission and has been abandoned. The State Government's proposed further development projects in Cockburn Sound including a potential future port and associated shipping channels project has yet to complete prefeasibility studies or reached concept design stage and has not been referred to the EPA as a proposal.

The cumulative impacts considered as a result of these projects, in addition to losses since European habitation are shown in Table 7.10.

Table 7.9 Potential benthic habitat losses (ha) due to currently approved projects and the Proposal

Habitat	Port Rockingham Marina	Total loss
Fine sediment above 10 m depth	9.1	**9.1**
Fine sediment below 10 m depth	0	**0**
Seagrass	0	**0**
Total	**9.1**	**9.1**

Note:

1. Port Rockingham proposal received environmental approval on 18 February 2010: Ministerial Statement 826 (EPA 2010)

Table 7.10 Current cumulative losses of benthic habitats in Cockburn Sound

Habitat	Original area (ha)	Cumulative losses of each habitat type	
		Change in area (ha)	Change in area (%)
Fine sediment above 10 m depth	N/A (assumed all to be seagrass)	+2872	N/A
Fine sediment below 10 m depth	6831	-16	0.23%
Reef	15	0.9	N/A
Seagrass	3760	-2896.5	77%

Step 8: What will be the consequences for biological diversity and ecological integrity if the proposal proceeds?

The EPA's environmental objective is therefore to ensure no net loss of BCH and, where possible, to generate a net increase. In light of the information presented in addressing steps 1–7, it is concluded that the loss of an additional 15.39 ha (<0.001%) of unvegetated bare sediments in areas of Cockburn Sound that are historically disturbed, presents no ecological consequence for the biological diversity and ecological integrity of Cockburn Sound.

Release of toxicants from sediments during dredging

Concentrations of metals, organotins, and hydrocarbons sampled in sediments near the area to be dredged were generally below the laboratory limits of reporting; and in all cases were below the screening levels defined by the NAGD (Section 6.5.2). Based on these results, the risk of contamination to benthic invertebrate communities during dredging is considered negligible.

7.5.3 Operational impacts

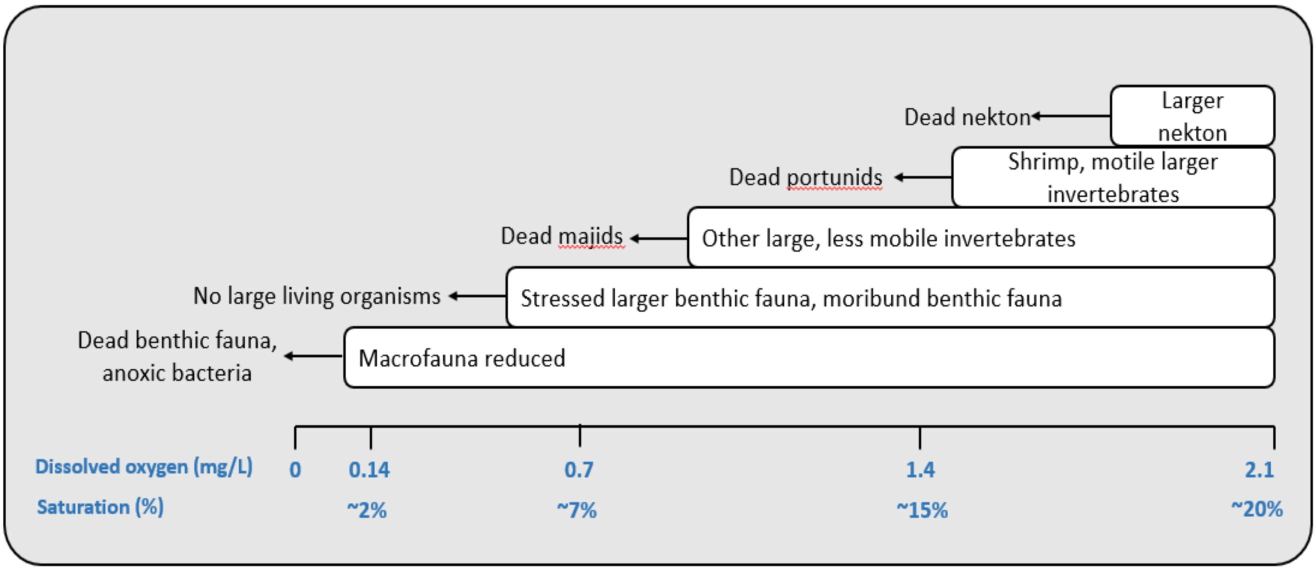
Stratification and low dissolved oxygen impacts

Most aquatic organisms require oxygen in specific concentration ranges for respiration and efficient metabolism, and concentration changes outside this range can have adverse physiological, behavioural and ecological effects (ANZG 2018). The effects of low DO concentrations on marine organisms are a function of:

- the temporal variation and timing, intensity and duration of periods of exposure to reduced oxygen concentrations—many species can survive short periods of reduced oxygen, but not longer periods, and
- the absolute concentration of DO.

Low DO conditions are known to induce behavioural responses and physical impacts to benthic organisms when tolerance thresholds are exceeded (Diaz & Rosenberg 1995). A comprehensive review of the sensitivity and response of marine fish and invertebrates to low DO concentrations are provided in Appendix E. Typically, DO levels of 5–6 mg L^{-1} are considered sufficient for maintaining health for most marine taxa, while levels of 3–5 mg L^{-1} are considered potentially stressful, especially if exposed to these conditions for prolonged periods (Diaz & Rosenberg 1995). However, levels of tolerance or resistance vary among species with some species able to tolerate very low DO concentrations for several days, surviving concentrations as low as 1 mg L^{-1} (Diaz & Rosenberg 1995; Appendix E). Few benthic organisms are able to survive persistently low periods of low DO of <1 mg L^{-1} (Appendix E; Figure 7.9).

The species most sensitive to low DO conditions are those inhabiting well oxygenated environments which are not normally exposed to low DO levels (Diaz & Rosenberg 1995; Appendix E). Many species possess behavioural and physiological mechanisms that enable survival of shorter-term aperiodic or periodic low DO concentration events, with low DO tolerance varying among phyla and orders and even between species within a single order. Long-term survival is limited in most cases by persistent anoxic conditions. Extended periods of low DO concentrations thus have more severe consequences than short episodes.



Source: Diaz & Rosenberg (1995)

Figure 7.9 Graded response of nekton, megafauna and infauna to declining oxygen concentrations

Once low DO concentrations have developed, the magnitude of effects on marine organisms is related to complex interactions between biological and physical parameters (e.g. the interaction between the duration of low DO concentrations and temperature). A review of field studies from the literature reveals a range of potential effects on benthic macrofauna communities associated with natural low DO events (BMT 2019c, Appendix E). These include:

- declines in the number of species and species richness, the number of individuals and biomass at sites influenced by low DO concentrations
- functional shifts away from “equilibrium type” communities towards early successional stage, disturbance adapted communities dominated by few short-lived opportunistic species at sites influenced by low DO concentrations
- shifts in species distributions within trophic groups, with communities at low DO sites having a lower proportion of surface deposit-feeders and a higher proportion of carnivorous species
- shifts in vertical distribution (burrowing depth) in sediment, with the vertical distribution of benthic infauna restricted to the upper few centimetres of sediment under conditions of low DO
- degradation of benthic community condition as estimated by multi-metric benthic indices of biotic integrity (representing measures of species diversity, community abundance and biomass, species composition, depth distribution within sediment, trophic composition) with exposure to low DO and/or increased frequency of low DO events
- degradation of benthic habitat (low benthic habitat quality indices).

Results of modelling

Due to the risk of desalination discharges promoting conditions that can lead to reductions in DO, and to meet regulatory requirements for assessing the fate and mixing of wastewater discharges into the marine environment, Water Corporation commissioned BMT to develop a hydrodynamic and water quality model of Cockburn Sound (Section 6.3.3). Results from modelling suggest that while effects appear subtle, it is apparent that under some circumstances (e.g. autumn conditions), desalination discharges can increase the duration of natural low DO events by up to 24 hours or more, thus elevating the risk to marine biota. Under such conditions the additional density associated with the salt is sufficient to prevent intermittent replenishment of DO, until after the stratification has been broken down. It appears that this effect is greatest in the north of the deep basin.

Hydrodynamic modelling, however, also demonstrated that while desalination discharges can also act to further reduce DO concentrations during low DO events, such changes are typically <2–3% and are unlikely to exceed 5% saturation (i.e. by less than <0.1–0.2 mg/L). For most species during 'worst case' episodic low DO events, similar to those that occurred in 2013 (DO with desalination = ~5.09 mg/L, DO without brine effluent = ~5.2 mg/L), such levels of decline would be unlikely to exceed tolerance thresholds, but may temporarily result in additional sublethal stress to more sensitive species (Appendix F). At a community level, the temporary nature of low DO events would be unlikely to induce changes in species patterns (composition, richness, trophic order, etc), especially given species that presently occur in Cockburn Sound would have evolved under a long-term regime of stochastic low DO events. These outcomes are supported by basin wide benthic invertebrate surveys, undertaken in 2006, 2008 and 2013, respectively (Oceanica 2013) and benthic invertebrate monitoring undertaken immediately post a low DO event (Oceanica 2006).

Field investigations

Because of the risk of low DO events to marine biota, Water Corporation has undertaken a considerable amount of monitoring and modelling to understand both effects of desalination discharges on DO levels in Cockburn Sound and patterns (composition and abundance) in benthic macroinvertebrates in response to naturally occurring low DO events. The outcomes of these investigations have shown that:

i. desalination discharges into Cockburn Sound are unlikely to further add to the strength of natural patterns in stratification in Cockburn Sound, or in turn, significantly enhance the intensity or duration of low DO events (BMT 2019a,c)
ii. benthic macrofauna communities have not undergone major shifts in either taxonomic composition or relative abundance of the dominant taxa following the low DO event[6] and minor differences between sampling times are most likely attributed to natural temporal patterns, but not desalination discharges (Oceanica 2006, BMT Oceanica 2013).

Further, basin-scale surveys completed prior to construction of PSDP1 and repeated in 2009 and 2013, have also been unable to identify any change in the distribution or abundance of benthic infauna over the period the plant has been operating (Oceanica 2007, 2009c and 2013) In response to this monitoring, the Office of the EPA (now DWER) concluded that the monitoring had adequately demonstrated that the risk of low-DO events was low and that the real-time monitoring required under condition 8-1 of Statement 832 was no longer required.

Assessment outcome

[6] *Between 24 March and 28 March 2006 a low dissolved oxygen event was recorded at site in the north-western central basin of Cockburn Sound. Over the periods between the late evening of 24 March to the early morning of 25 March and the evening of 25 March to the late morning of 28 March, recorded dissolved oxygen levels were consistently lower than 3 mg L^{-1}, declining to less than 2 mg L^{-1} on three separate occasions for periods of tens of minutes to hours on each occasion.*

Model outcomes show that the behaviour of additional desalination discharges associated with the Proposal are highly unlikely to result in a different outcome on DO compared to existing conditions associated with operation of the PSDP1, either under 'normal' or 'worst-case' conditions. While subtle changes in DO as a result of desalination discharges may cause minor additional sublethal stress in some benthic fauna, on some occasions, it is considered highly unlikely that this would lead to mortality or community-scale effects. This outcome has been verified by multiple field surveys. In light of the information presented here, it therefore appears highly unlikely that impacts to benthic macroinvertebrate communities in Cockburn Sound will occur in response to changes in ambient DO resulting from the discharged seawater concentrate.

Exposure to elevated salinity and inability for osmotic regulation

Seagrasses

High salinity can result in osmotic stress and ion toxicity in seagrasses, which can affect plant–water relations, ion concentrations in cytoplasm and the vacuole, and reduce growth and photosynthesis. Physiological and morphological responses of seagrasses to salinity stress can include:

- modification of osmotic potential (ion sugar and amino acid concentrations; Cambridge et al. (2016))
- decreased concentrations of non-structural carbohydrate (soluble and reserve) in rhizomes (Ruiz et al. 2009)
- inhibition of photosynthesis and respiration (Ruiz et al. 2009)
- reduced leaf length and leaf area (Koch et al. 2007)
- increased frequency of necrosis in the leaves (Sánchez-Lizaso et al. 2008).

However, the impact that salinity (above background ambient levels) has on seagrasses is complex to determine as effects can vary between species, location, concentrations, duration and the pattern of exposure (Koch et al. 2007). Further, disentangling effects of the total brine constituents (i.e. inclusive of CIP chemicals) from osmotic effects alone adds another layer of ambiguity (Cambridge et al. 2019).

The pattern of exposure to higher salinity can also have an important role in determining the magnitude of effect of salinity on seagrasses (Koch et al. 2007). Koch et al. (2007) reported critical tolerance threshold limits can drop by up to 20 PSU when salinity is pulsed without slow osmotic adjustment as cellular morphological changes are required in addition to biochemical adaptations; however, Koch et al. (2007) also suggested that a slow rate of salt increase would allow plants time to acclimate. Seagrasses growing within their optimal salinity range can achieve equilibrium fairly rapidly; however, plants exposed to waters outside their typical salinity distribution, but within their tolerance range, may require additional time (days to weeks) to acclimate (Touchette 2007).

The known range of tolerances for *Posidonia* spp. to salinity is ~27–60 PSU (Table 7.11). While at least two *Posidonia* spp. found in Cockburn Sound - *P. australis* and *P. coriacea* - can occur across this broad range of salinities, other *Posidonia* spp., such as *P. oceanica* (most commonly found in the Mediterranean) occupy a much narrower band (~36.5–38.5 PSU), with critical tolerance thresholds often only slightly above ambient salinity (Ruiz et al. 2009). No published results are available on tolerance thresholds for *P. sinuosa*, which alongside *P. australis*, dominates most seagrass meadows in Cockburn Sound (Kendrick et al. 2002).

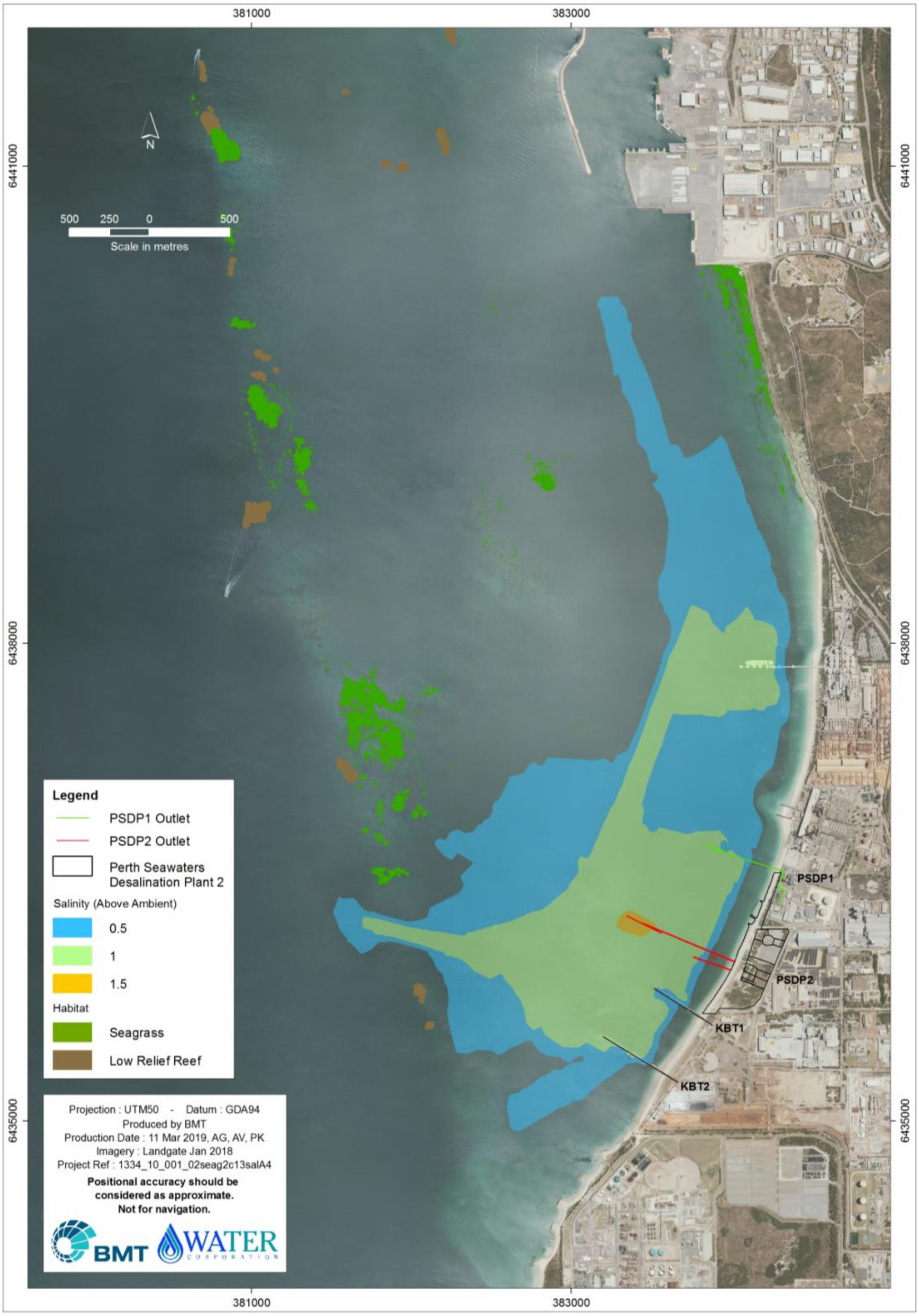
The results of modelling (BMT 2019a) indicate that median elevation in salinity on the seafloor (0-0.5 m) at the nearest seagrass meadow to the PSDP2 diffusers will be less than +1 PSU above ambient salinity during typical autumn months and during 'worst case' conditions experienced in 2013 (Figure 7.10); the April 2013 period was assessed as it was determined to have lowest mixing and therefore highest risk of inducing osmotic stress (BMT 2019a; see Section 6.5.3). This difference from background salinity is well below all reported critical tolerance thresholds for *Posidonia* spp. seagrasses to elevated salinity (Table 7.11) and no lethal effects on seagrass are expected to arise because of the Proposal. Predicted changes in salinity are also far below those which Cambridge et al. (2017) reported physiological changes in seagrass performance and productivity for *P. australis* (46–54 PSU). With PSDP1 already in existing operation, it is also expected that patterns in exposure to the diluted desalination brine are already well established, and therefore pulsed contact with elevated salinity is considered unlikely.

In light of the of predicted changes in salinity due to PSDP2 desalination discharges, it is not expected that the Proposal will induce either physiological or morphological changes in the nearby seagrasses. This outcome is consistent with Cambridge et al. (2019) who determined that desalination brine concentrations below 25% (or equivalent salinity of 42 PSU) are unlikely to yield any detectable physiological or morphological response in *P. australis*. While tolerance thresholds to elevated salinity remain unknown for *P. sinuosa*, it is not expected that the very minor variations from ambient salinity associated with the Proposal pose a risk to this species from osmotic stress.

Table 7.11 Summary of known upper tolerances of *Posidonia* species to salinity

Scientific name	Known upper tolerance range	Critical tolerance threshold (lethal exposure)	Reference
P. angustifolia	-	-	-
P. australis	27–60 PSU	50–65 PSU	Tyerman et al., (1984) Walker et al. (1988) Walker and McComb (1990) Cambridge et al (2019)
P. coriacea	30–50 PSU	-	-
P. oceanica	36.5-38 PSU	39.3 PSU	Ruiz et al. (2009)
P. ostenfeldii	-	-	-
P. sinuosa	-	-	-

Note:
1. PSU = Practical Salinity Unit



Notes:

1. Salinity are shown as predicted elevation above ambient salinity (PSU)
2. Data are based on depth-average of salinity from 0 to 0.5 m above the seabed
3. Salinity plume characterisation is provided in greater detail in Section 6.5.3

Figure 7.10 Predicted salinity plume extent in bottom waters in worst case conditions (April 2013)

Macroinvertebrates

All marine invertebrates possess a capability of ionic regulation and are typically little affected by slight increases of <5 PSU in seawater salinity, both at adult and larval stages of their life cycles (Diaz & Rosenberg 1995, Koch et al. 2007, Touchette 2007). A summary of tolerances of similar taxa to those commonly found in Cockburn Sound is provided in Table 7.12.

While the list of available studies examining the tolerances of marine biota to enhanced salinity remains limited in terms of representation of Cockburn Sound BCH, it can be inferred from the tolerance thresholds of similar species cohorts (Table 7.12) that most BCH are unlikely to be affected by the expected increases in salinity in Cockburn Sound introduced by the PSDP2 brine effluent which will rarely exceed +1.3 PSU from background, except in the Stirling and Calista shipping channels (Section 6.5.3) which are degraded and routinely disturbed habitats.

Table 7.12 Salinity tolerances of similar marine organisms to those occurring in Cockburn Sound

Common name	Scientific name	Salinity tolerance (PSU)	Comments	Reference
Scallop	*Pecten fumatus*	25–40	Australian species	Niel and Gibbs (1986)
Pipi (clam)	*Plebidonax deltoides*	20–45		
Flay oyster	*Ostrea angasi*	20–45		
Blue mussel	*Mytilus edulis*	15–45		
Sydney cockle	*Anadara trapezia*	15–45		
Crab larva	*Pagurus criniticornis*	15–55	Salinity influenced temperature tolerance with thermal limits being greater at 25 and 35, than at 45.	Blaszkowski and Moreira (1986)
Spotted Seatrout larva	*Cynoscion nebulosus*	6.4–42.5	This is a minimum tolerance range for marine spawned larvae	Banks and Holt (1991)
Lesser Blue Crab (juveniles)	*Callinectes similis*	5–45	21 day LC50[1] values were 2.6 and 60.8 at low and high salinities, respectively	Guerin and Stickle (1997)
Penaeid Shrimp (juvenile)	*Metapenaeus stebbingi*	10–50	Salinities of 5, 55 and 60 were lethal (100% mortality within 24 hours of exposure).	Ahmed and Ayub (1999)

Note:
1. LC50 = the lethal concentration required to kill 50% of the population

Assessment outcome

In light of the information presented here, it appears highly unlikely that impacts will occur to either seagrasses or benthic macroinvertebrate communities in Cockburn Sound in response to changes in ambient salinity resulting from the discharge of brine effluent.

Exposure to elevated temperature on marine biota

As determined in Section 6.5.3, effects of desalination discharge on ambient seawater temperature are extremely localised to around the diffuser and even there, will only result in marginal elevations in the order of 0.3–0.4°C for PSDP1 and 0.4–0.5°C for PSDP2, which is lower than the 80th and 95th percentiles of the natural temperature range from Cockburn Sound). Accordingly, the risk to BCH associated with temperature stress is considered negligible.

Contamination from release of discharge effluent

Brine discharges from marine desalination plants can contain a range of chemicals - including antiscale additives, biocides, surface active agents from back flushing and sanitising agents – which are used to maintain plant infrastructure and ensure process flow (described in greater detail in Section 6.5.3).

Recent studies by Cambridge et al. (2019) have demonstrated that the chemical component of brine discharges can increase the speed and symptoms of stress in seagrasses. In particular, Cambridge et al. (2019) found that desalination brine can have a greater effect on adult plants of the seagrass *P. australis* than elevated salinity alone, and that negative impacts to adult plants can arise within two weeks (of exposure) in undiluted brine, but seedlings can be more resilient to longer exposure to brine. Reported plant responses included inhibited photosynthesis, unbalanced water relations, reduced leaf growth and increased concentrations of sugars and some amino acids in leaves that can indicate the rapid onset of physiological stress in adult plants (Cambridge et al. 2019).

While this cause-effect pathway is a relevant consideration, it is also important to highlight that plant responses to brine discharges were not detected until they were exposed to highly concentrated solutions (50% dilution mixed with seawater), and therefore, concentrations that were determined to be toxic by Cambridge et al. (2019) are not representative of the level of dilution that seagrasses around the PSDP2 would experience. For example, even under worst case mixing scenarios (e.g. autumn 2013), it is likely that dilutions around the seagrasses meadows directly west of the outlet would experience a dilution factor of greater than 1:200 as seagrasses in the area occur upslope (shallow waters) compared to the diffuser, while brine typically follows the path of depth contours into deeper water due to gravity, and therefore would not interact with the seagrass. It is also relevant to note that Cambridge et al. (2019) reported that seagrass responses to concentrations of brine that were <25% did not differ from controls, and therefore experimentation around these treatments was abandoned.

Given the comparatively low volumes of treatment chemicals within the seawater outflow, it was determined that the brine discharge will be efficiently diluted in the waste stream and further diluted after discharge. In light of the low volumes of chemicals and high levels of dilution, the risk posed by the maintenance process chemicals to seagrasses is considered negligible, and therefore, no further investigation on this matter is considered necessary.

7.5.4 Cumulative impacts

Potential cumulative impacts (cumulative loss of benthic primary producers) associated with direct and indirect impacts to seagrasses as a result of construction activities have been addressed in Section 7.5.2.

The potential for flow-on effects to benthic invertebrate communities due to the additive effect of desalination discharges from PSDP2 to PSDP1, and to other industrial discharges to Cockburn Sound, has been addressed in Sections 6.5.3 and 7.5.3, and justified in Section 6.5.4, respectively.

In light of the above, Water Corporation has determined that all relevant cumulative impacts have been sufficiently incorporated into the impact assessment and that there is no requirement for further assessment of cumulative impacts on BCH within Cockburn Sound due to this Proposal.

7.6 Mitigation

Water Corporation has applied the mitigation hierarchy to the Proposal to protect BCH so that biological diversity and ecological integrity are maintained. Mitigation measures are summarised in Table 7.13.

Table 7.13 Summary of mitigation measures to ensure maintenance of marine quality

Impact	Avoid	Minimise	Management and monitoring
Direct removal of habitat	Site selection includes the already disturbed Eastern Shelf of Cockburn Sound. In terms of BCH, this means that ~6.2 ha of the Proposal footprint has already been disturbed by historical losses due to poor water quality, reducing the predicted residual loss of BCH as a result of the Proposal. The location of the diffuser was designed to improve mixing and in turn reduce potential for stratification impacts to BCH.	Not applicable. The length of the pipeline and selection of diffuser have been designed to maximise desalination discharge mixing, and therefore, the Proposal footprint could not be reduced without compromising this objective.	Described in CEMP
Reduction in marine environmental quality during construction	The avoidance of impacts to marine environmental quality is not possible, however, construction effects will be temporary and will naturally ameliorate once construction ceases. The marine construction footprint is sufficiently separated in distance from significant BCH to avoid indirect effects of turbidity and sedimentation generated during dredging.	Construction management to minimise turbidity and sedimentation will include: • use of a backhoe dredge, to reduce generation of TSS • containment of turbidity from the rest of construction use of silt curtain(s).	Described in CEMP
Reduction in marine environmental quality during operation	The avoidance of impacts to marine environmental quality is not possible.	Operational management to minimise impacts associated with stressor effects: • diffuser configuration has been designed to achieve acceptable dilution of the brine effluent with the receiving waters and this has been tested with hydrodynamic modelling	Described in MEMP

		• establishment of a LEPA to ensure marine quality is maintained to acceptable levels outside of this boundary.	

7.6.1 Construction

A preliminary register of measurable and/or auditable environmental commitments to manage the environmental impacts associated with construction activities (Section 7.5.2) is provided in Table 7.14. Environmental monitoring and management will be outlined in further detail in a CEMP to be finalised prior to commencement of dredging. The CEMP will include:

- detailed monitoring and management requirements (in-line with Table 6.18)
- timing/frequency of monitoring and management commitments
- responsibilities for monitoring and management commitments
- contingency planning/measures in the event of an environmental or safety issue
- stakeholder consultation
- reporting requirements to government and environmental regulators.

Table 7.14 Relevant environmental objectives, performance indicators and proposed measurement criteria to protect benthic communities and habitat

Environmental objective	Performance criteria[1]	Standards[2]	Performance indicators[3]
To protect benthic communities and habitat so that biological diversity and ecological integrity are maintained	Ensure that benthic communities and habitat outside of the Project footprint are not impacted as a result of the Proposal	Detailed management procedures of turbidity, including: • remain within approved construction areas • standard dredging management controls, including use of silt curtains, will be employed to limit plume dispersion • monitoring and control of turbidity/production at the construction site • plume sketches • site photographs • remote imagery; and/or aerial imagery.	• System in place to review plume sketches and photography to determine plume extent is within modelled expectations • Tracking device on key construction plant to confirm positioning • Post-construction bathymetric survey • Third-party audit of CEMP outcomes.

Notes:

1. Performance criteria = the performance criteria are the proposal-specific desired state for an environmental factor/s that an organisation sets out to achieve from the implementation of outcome-based provisions
2. Standards = can include company standards, regulatory requirements, and recognised Australian and International Standards
3. Performance indicators = measurable/auditable outcomes that ensure that the company's environmental performance

7.6.2 Operations

Mitigation measures that are to be put in place to protect BCH from operational impacts associated with desalination discharges are described in detail Section 6.6.2. Environmental monitoring and management will be outlined in further detail in a PSDP2 MEMP, which will be finalised prior to commencement of plant operations.

7.7 Predicted outcomes

The construction of the Proposal is unlikely to result in the net loss of any BCH. There is no known seagrass that occurs in the construction footprint, and indirect effects of turbidity on seagrasses are not expected to result in either sublethal or lethal impacts. Further, standard dredging management controls, including use of silt curtains, will be employed to limit plume dispersion.

While it was determined that the operation of the Proposal may have a minor negative effect on DO concentrations and salinity at times, differences from background concentrations were predicted to be minor and within the known physiological tolerances of known BCH in the project area. There are also not anticipated to be any impacts associated osmotic stress or contamination from release of toxicants in brine water.

After the application of mitigation measures as described in Section 7.6, the EPA objective for BCH (i.e. to protect BCH so that biological diversity and ecological integrity are maintained) is expected to be met.

There is no significant residual impact to BCH predicted to occur from the construction and operation of the Proposal; and therefore, no subsequent consideration of offsets for this environmental factor are required.

8. Marine Fauna Impact Assessment

8.1 EPA objective

To protect marine fauna so that biological diversity and ecological integrity are maintained.

8.2 Legislation, policy, guidance

The legislative instruments, policies and guidelines considered relevant to the environmental impact assessment of marine environmental quality are provided in Table 8.1.

Table 8.1 Legislative instruments, policies and guidelines relevant to marine fauna impact assessment

Legislative instrument
Environmental Protection Act 1986
Environment Protection and Biodiversity Conservation Act 1999
Biodiversity Conservation Act 2016
EPA policy or guidance
Statement of Environmental Principles, Factors and Objectives (EPA 2018b)
State Environmental (Cockburn Sound) Policy 2015 (EPA 2015)
Environmental Quality Criteria Reference Document for Cockburn Sound (EPA 2017)
Environmental Factor Guideline – Marine Fauna (EPA 2016g)
Environmental Factor Guideline – Marine Environmental Quality (EPA 2016b)
Technical guidance – Environmental Impact Assessment of Marine Dredging Proposals (EPA 2016c)

8.3 Receiving environment

8.3.1 Environmental values

The marine fauna of Cockburn Sound are highly valued for their ecological significance, and in some cases, also for their commercial and recreational value. Of the significant values identified by EPA (2015), the following are considered relevant to the Proposal:

- benthic communities and habitats
- conservation of significant fauna and critical habitat
- active or passive recreation.

The marine fauna values identified above are consistent with the relevant values identified in the Cockburn Sound SEP, including ecosystem health, and fishing and aquaculture, and cultural and spiritual values (see Section 6.3 for complete list of environmental values for Cockburn Sound).

8.3.2 General description

Cockburn Sound supports a wide range of fauna and has significant fauna values because of its utilisation by dolphins, a large range of seabirds, protected migratory birds and little penguins. The whole of Cockburn Sound is considered significant as a fish nursery/habitat. About 130 species of fish and 14 large crustacean and mollusc species are estimated to exist in Cockburn Sound (BMT 2018a).

The *EPBC Act Protected Matters Report* (Appendix K) listed 92 Listed Marine Species, 49 Threatened and 58 Migratory species that are listed under the EPBC Act and which may occur nearby the proposed project area Most of the listed species are expected to possibly pass through/over the Project the area on occasions, for example during migration, as the area does typically not encompass waters or habitats that are critical to their survival (Bamford 2011, TSSC 2015, 2016, DoEE 2018). A description of the key faunal groups represented in Cockburn Sound is presented below.

Coastal and seabirds

The *EPBC Act Protected Matters Report* listed 62 bird species – many of which are migratory – as potentially occurring within 20 km of the Project area (Appendix K). While all listed bird species may fly over or utilise habitats within or near the Project area, the Project area is not known to encompass waters or habitats that are critical for the survival of any of these species; a summary of those species that are either known to, or are most likely to occur in the area, is provided in Table 8.2.

Despite the potential, GHD found limited evidence of conservation significant species of coastal seabirds recorded within the PSDP2 development envelop, during their terrestrial site survey in November 2016 (GHD 2017; Appendix B). It was suggested that due to the lack of suitable beach habitat, lack of known breeding records and relative disturbance on the beach by horses and beach goers, there was a low likelihood of conservation significant marine or wading species inhabiting the shoreline or dune areas (GHD 2017).

Table 8.2 Summarised Protected Matters Search Tool results – coastal and seabirds

Common name	Scientific name	Presence type in Proposal area[4]						
		A	B	C	D	E	F	G
Little Penguin	*Eudyptula minor*	x					x	x
Fork-tailed Swift[2]	*Apus pacificus*		x					
Flesh-footed Shearwater[2]	*Ardenna carneipes*		x					
Red Knot[1]	*Calidris canutus*	x						
Curlew Sandpiper[1]	*Calidris ferruginea*		x					
Forest Red-tailed Black-Cockatoo[1]	*Calyptorhynchus banksii naso*		x					
Carnaby's Cockatoo[1]	*Calyptorhynchus latirostris*		x					
Amsterdam Albatross[1,2]	*Diomedea amsterdamensis*			x				
Tristan Albatross[1,2]	*Diomedea dabbenena*			x				
Blue Petrel[1,2]	*Halobaena caerulea*			x				
Malleefowl[1]	*Leipoa ocellata*			x				
Bar-tailed Godwit (baueri)[1]	*Limosa lapponica baueri*		x					
Bar-tailed Godwit (menzbieri)[1]	*Limosa lapponica menzbieri*			x				
Southern Giant Petrel[1,2]	*Macronectes giganteus*			x				

Common name	Scientific name	Presence type in Proposal area[4]						
		A	B	C	D	E	F	G
Northern Giant Petrel[1,2]	*Macronectes halli*			x				
Eastern Curlew[1]	*Numenius madagascariensis*		x					
Fairy Prion[1]	*Pachyptila turtur subantarctica*		x					
Soft-plumaged Petrel[1,2]	*Pterodroma mollis*			x				
Australian Painted Snipe[1]	*Rostratula australis*			x				
Australian Fairy Tern[1]	*Sternula nereis nereis*						x	

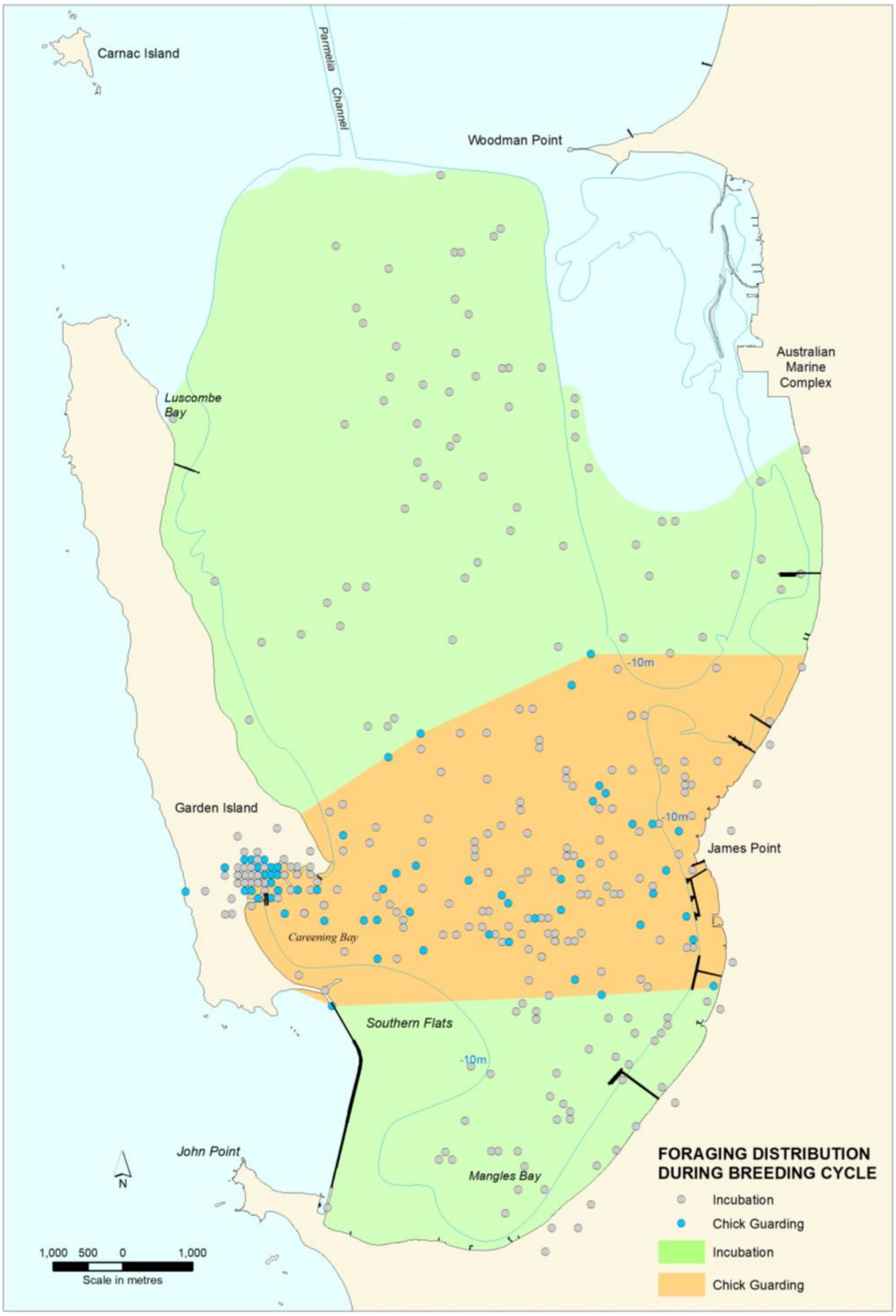
Notes:

1. Matters of National Environmental Significance listed as vulnerable, threatened, endangered, or critically endangered species
2. Matters of National Environmental Significance listed migratory species
3. Other Matters Protected by the EPBC Act listed marine species
4. A - Species or species habitat known to occur within area, B - Species or species habitat likely to occur within area, C - Species or species habitat may occur within area, D – Foraging, feeding or related behaviour may occur within area, E - Foraging, feeding or related behaviour likely to occur within area, F - Foraging, feeding or related behaviour known to occur within area, G – Breeding known to occur within area

Outside of the immediate development envelope, the little penguin is perhaps the most iconic to Cockburn Sound. Within the Perth metropolitan region, there are little penguin (*Eudyptula minor*) colonies on Penguin, Garden and Carnac Islands; the largest is on Penguin Island (Cannell 2011). Little penguins in the south-west marine region are recognised as having a high conservation value and for being under threat (DSEWPaC 2012a, Cannell 2016, Cannell et al. 2016). 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 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 are known to occur across most areas of the Sound, although their distribution is more restricted during chick guarding periods (Figure 8.1); 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 (Cannell 2011), and in between dives they rest on the surface. Penguins usually return to the colony after sunset or can remain at sea overnight (Cannell 2011).

Cockburn Sound is one of several core foraging areas in the region (Cannell 2016, Cannell et al. 2016). Penguins from the Garden Island colony appear to forage almost exclusively within the southern half of Cockburn Sound (Cannell 2011). The prey of little penguins includes pilchards (*Sardinops neopilchardus*), garfish (*Hyporhamphus melanochir*), anchovy blue sprat (*Spratelloides robustus*) and whitebait/sandy sprat (*Hyperlophus vittatus*) (Cannell 2017), all of which occur in Cockburn Sound (Fletcher et al. 2017).



Source: Cannell (2009)

Figure 8.1 Reported foraging distribution of little penguins within Cockburn Sound

Reptiles

According to the *EPBC Act Protected Matters Report*, four marine turtles, including loggerhead (*Caretta caretta*), green (Chelonia mydas), leatherback (*Dermochelys coriacea*) and flatback turtles (*Natator depressus*) are thought to possibly occur in Cockburn Sound for the purpose of foraging, feeding or related behaviour (Table 8.3). Although adults and sub-adults are sometimes found in the Perth region between Rottnest Island and Geographe Bay, the Perth metropolitan area is not identified as an important foraging area for turtles and sightings of these reptiles are extremely rare in Cockburn Sound (DEC 2010; cited in DSEWPaC 2012b).

Table 8.3 Protected Matters Search Tool results – reptiles

Common name	Scientific name	Presence type in Proposal area[1]						
		A	B	C	D	E	F	G
Loggerhead Turtle[1,2]	*Caretta caretta*						x	
Green Turtle[1,2,]	*Chelonia mydas*						x	
Leatherback Turtle[1,2]	*Dermochelys coriacea*						x	
Flatback Turtle[1,2]	*Natator depressus*						x	

Notes:

1. Matters of National Environmental Significance listed threatened species
2. Matters of National Environmental Significance listed migratory species
3. Other Matters Protected by the EPBC Act listed marine species
4. A - Species or species habitat known to occur within area, B - Species or species habitat likely to occur within area, C - Species or species habitat may occur within area, D – Foraging, feeding or related behaviour may occur within area, E - Foraging, feeding or related behaviour likely to occur within area, F - Foraging, feeding or related behaviour known to occur within area, G – Breeding known to occur within area

Cetaceans

The *EPBC Act Protected Matters Report* listed 12 marine mammal species as potentially occurring within 20 km of the Project area (Appendix K), however, only nine species were considered as ‘known’ or ‘likely’ to occur within 20 km of the Project area (Table 8.4). Marine mammal species deemed as ‘known’ or ‘likely’ to occur are mobile species, and considered at low risk of impact from the PSDP2 Proposal.

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 WA, pygmy blue whales aggregate in deep water 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.

Principally found around the southern coastline off southern WA and far west South Australia, the southern right whale commonly occurs between Sydney and Perth, including off Tasmania and eastern South Australia (Bannister 1979–2005). The southern right whale calving grounds are found at mid to lower latitudes and are occupied during the austral winter and early-mid spring. Mating occurs within these breeding grounds as evidenced by many observations of intromission and mating behaviours (Burnell et al. 1990). In Australia, peak periods for mating are from mid-July through August as documented in population biology studies at Head of Bight, South Australia (Burnell 1999).

The migration pathway for the western Australian humpback whale population is generally within 200 km from shore (Double et al. 2010) and there are anecdotal reports of individuals occasionally straying into Cockburn Sound. There are number of known important resting areas that have been identified during the southern migration (including Augusta, Geographe Bay, Shark Bay, Exmouth and the Kimberley), although Cockburn Sound is not among these.

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

A residential sub-population of bottlenose dolphins is known to occur in Cockburn Sound (*Tursiops* sp.) including both the *T. truncatus* and *T. aduncus* haplotypes (Finn 2005). Studies undertaken in 1993-7 and 2008 have identified more than 150 individual bottlenose dolphins within Cockburn Sound and Owen Anchorage (Finn and Davies, 2008). More recent analyses of association patterns of photo-identified bottlenose dolphins by Chabanne et al. (2017a) revealed that dolphins occurring in Cockburn Sound form a distinct social community from other dolphin communities in Perth waters, and demonstrate high site fidelity and residency patterns (Figure 8.2). There are three broad habitat areas for dolphins within Cockburn Sound (Figure 8.3):

- 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).

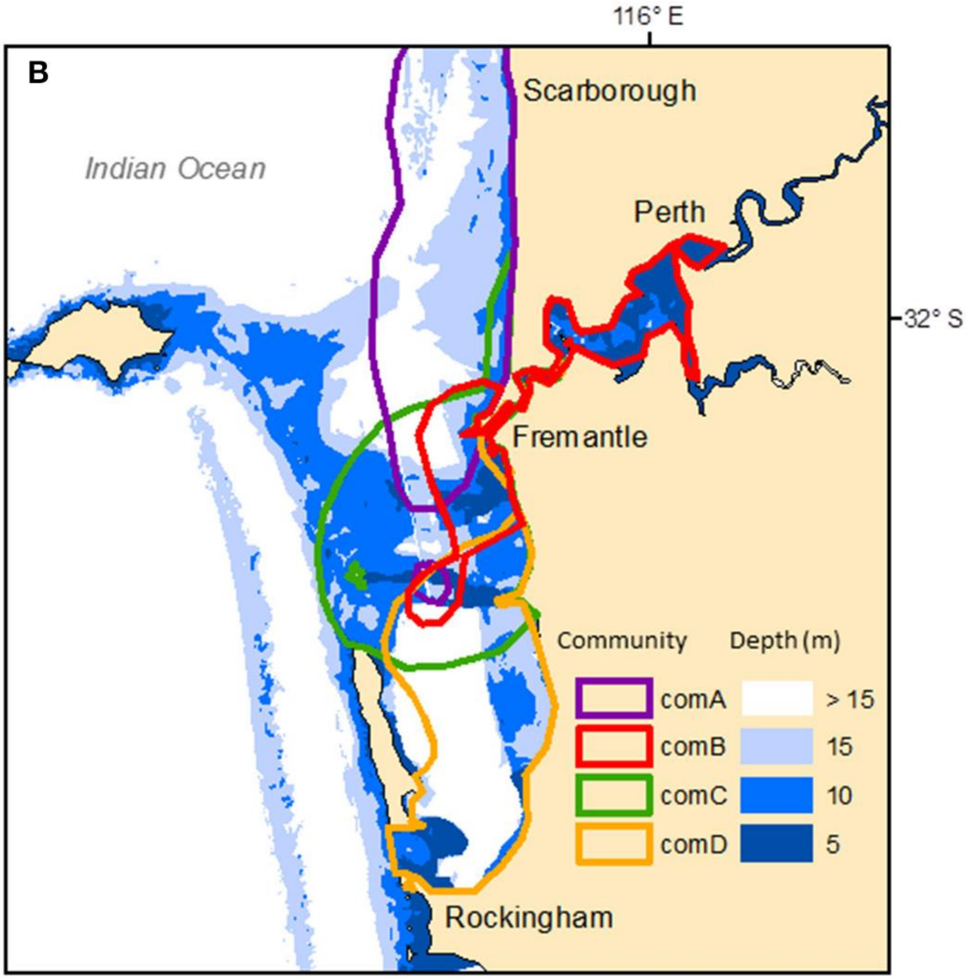
The distribution and habitat-use patterns of dolphins vary seasonally, and these patterns are likely to reflect changes in the abundance and distribution of fish in the locations. Finn and Calver (2008) suggest that most dolphin foraging interactions occur on the southern half of Kwinana Shelf, along the eastern margin between the Alcoa Jetty and James Point (Figure 8.3). Aggregations of dolphins on the Kwinana Shelf are more prevalent during autumn–spring period, when cooler water enters the Sound and the abundance of foraging fish is higher (Finn & Calver 2008). The food requirements of dolphins are considerable; making them sensitive to factors that make it difficult for them to capture prey.

Table 8.4 Protected Matters Search Tool results – mammals

Common name	Scientific name	Presence type in Proposal area[1]						
		A	B	C	D	E	F	G
Blue Whale[1,2]	*Balaenoptera musculus*		x					
Southern Right Whale[1,2]	*Eubalaena australis*							x
Pygmy Right Whale[2]	*Caperea marginata*			x				
Humpback Whale[1,2]	*Megaptera novaeangliae*	x						
Brydes Whale[2]	*Balaenoptera edeni*			x				
Australian Sea Lion[1]	*Neophoca cinerea*	x						
Killer Whale[2]	*Orcinus orca*						x	
Indian Ocean Bottlenose Dolphin[3]	*Tursiops aduncus*	x						
Bottlenose Dolphin[3]	*Tursiops truncatus s. str.*	x						

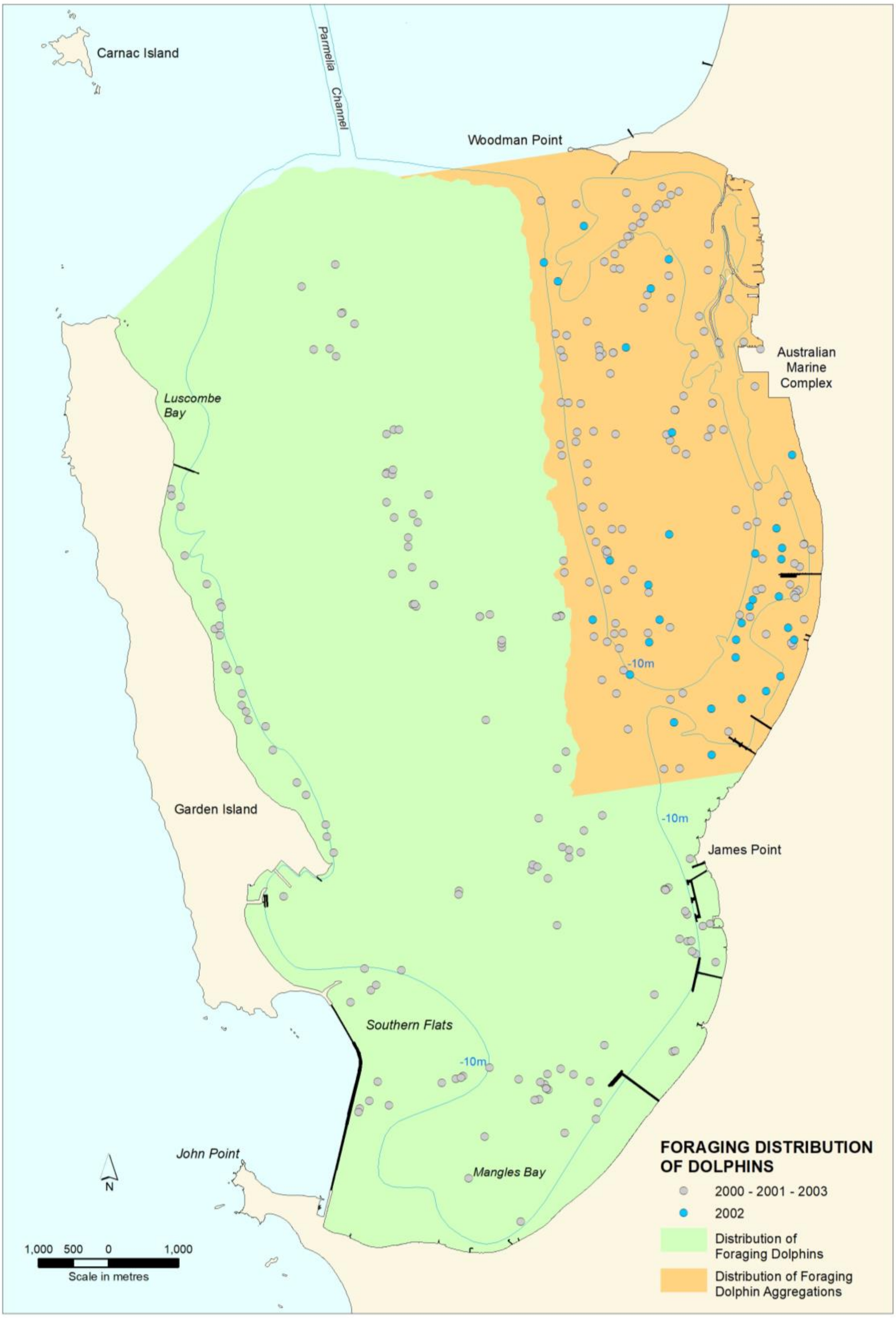
Notes:

1. Matters of National Environmental Significance listed threatened species
2. Matters of National Environmental Significance listed migratory species
3. Other Matters Protected by the EPBC Act listed marine species
4. A - Species or species habitat known to occur within area, B - Species or species habitat likely to occur within area, C - Species or species habitat may occur within area, D – Foraging, feeding or related behaviour may occur within area, E - Foraging, feeding or related behaviour likely to occur within area, F - Foraging, feeding or related behaviour known to occur within area, G – Breeding known to occur within area



Source: Chabanne et al. (2017b)

Figure 8.2 Core areas utilised by Perth's four coastal dolphin community groups



Source: Finn (2005)

Figure 8.3 Observations of foraging dolphins in Cockburn Sound

Bony fishes

Conservation significant fish

Twenty-three bony fish were identified in the *Protected Matters Report* (Appendix K) as listed species under other protected matters of the EPBC Act (note that *Stigmatopora olivacea = S. argus*; DoEE 2018). All 23 species of pipefish, pipehorses, seahorses or seadragons belong to the family Syngnathidae. None of the species are listed threatened species under the EPBC Act but all are included on the *IUCN Red List of Threatened Species* (IUCN 2017); 15 are listed under the Least Concern category, six as Data Deficient and two as Near Threatened. The two species considered Near Threatened (IUCN 2017) are seadragons (*Phyllopteryx taeniolatus* and *Phycodurus eques*), the latter of which is also listed as a Priority 2 (P2) species under the *WA Priority Flora and Priority Fauna List.*

A study targeting the syngnathid fish among seagrass, bare sand and deep habitats in the inshore waters immediately adjacent to the northern entrance to Cockburn Sound recorded 14 species and one unidentified taxa (Kendrick & Hyndes 2003). Twelve of these species are among the 23 species listed in the Protected Matters Report.

The marine habitats of Cockburn Sound include small patches of limestone reef, extensive soft sediment areas and seagrass meadows, all of which provide suitable habitat for syngnathid fish (Kendrick & Hyndes 2003) although a marked preference for seagrass habitats is evident among this group of fishes (Kendrick & Hyndes 2003 and references cited therein) with the exception of seadragons, which prefer kelp-dominated reefs to 50 m depth (Pogonokski et al. 2002).

Other significant fishes and invertebrates

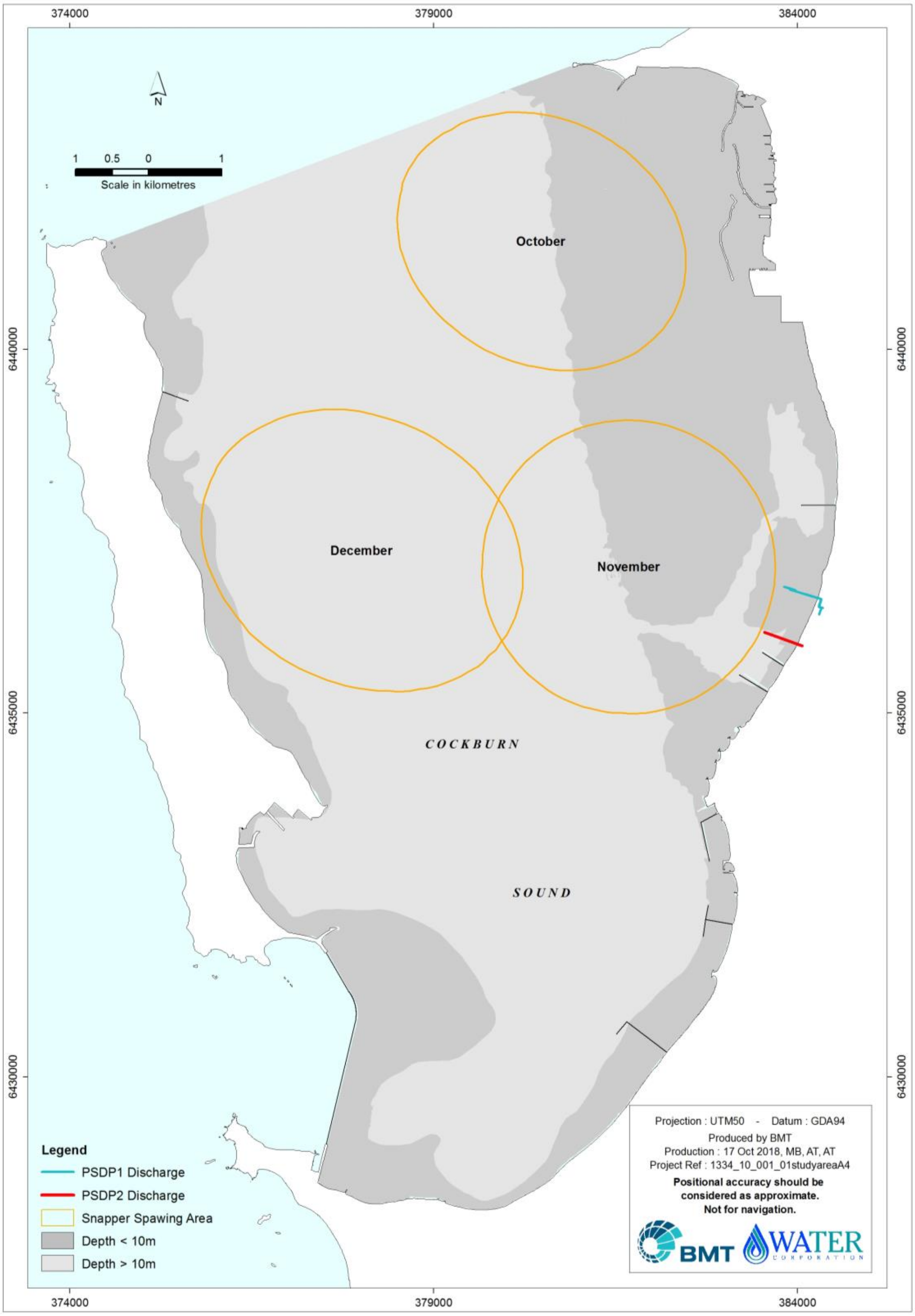
Potential ecological impacts to some commercially significant marine fauna (pink snapper and blue swimmer crabs) have are addressed in this section as they represent good indicator species for other groups of marine fauna (and therefore relevant background information is provided below), while potential impacts to the commercial fisheries are addressed in Section 10, under *Social factors* (Table 10.1).

Pink snapper

Cockburn Sound is one the most important locations in WA for pink snapper (*Pagrus auratus*) spawning and is an important nursery/spawning ground for other marine fauna (Wakefield & Johnston 2009). Pink snapper are highly valued by commercial and recreational anglers throughout its distribution, which in WA includes marine waters from Exmouth Gulf southwards along the entire west and south coasts.

Pink snapper have a predictable reproductive strategy of forming large spawning aggregations in protected nearshore areas at the same time and location each year, thereby making them highly vulnerable to overexploitation. The hydrodynamics of most of the protected nearshore areas used by spawning aggregations of snapper, including Cockburn Sound, result in the retention of progeny as eggs and pre-settled larvae. As a consequence, these areas are important nursery or recruitment locations for snapper. The large-scale retention of snapper eggs and larvae in Cockburn Sound make the area an important nursery.

Although snapper are widespread, relatively few spawning and nursery or recruitment areas have been identified in WA. Studies suggest that the marine embayment of Cockburn Sound represents an important area for snapper spawning and recruitment for a significant portion of the west coast managed bioregion. The preservation of snapper reproduction in such areas is deemed imperative to the continued replenishment of stocks.



Source: derived from Wakefield et al. (2009)

Note:

1. Elipses capture areas where Wakefield estimated >400 eggs/100 m^3 in field surveys.

Figure 8.4 Generalised pattern of spawning pink snapper

Blue swimmer crabs

The inshore sandy, muddy and seagrass habitats of Cockburn Sound provide breeding and foraging grounds for the recreationally and commercially important blue swimmer crab (*Portunus armatus*[7]), with anecdotal evidence to suggest that these crabs also occur in the Calista and Stirling shipping channels (Dr D Johnston 2018, pers. comm., 1 December 2018). Blue swimmer stocks and stock recruitment capacity has been below sustainable yields for several years. Potential reasons for the stock decline include combined effects of reduced levels of primary productivity within Cockburn Sound, regional changes in water temperature, increased predation and the negative effects of density-dependent growth which appears to have had an effect on the proportion of berried females (Johnston et al. 2011).

8.3.3 Study effort

Water Corporation has used the results from the surveys outlined in Table 8.5 to support the assessment of potential impacts of the Proposal on marine fauna; relevant reports are presented as appendices.

Table 8.5 Marine fauna studies used to inform the Proposal

Investigation	Scope
Perth Desalination Plant Expansion Flora and Fauna Survey (GHD 2017; Appendix B)	Water Corporation commissioned GHD to undertake a biological assessment (terrestrial) of the Proposal area, adjacent to the PSDP1 at Kwinana, in order to define biological environmental values, including their location, conservation significance and management considerations. The information has been used to inform environmental planning around the site's environmental constraints and opportunities.
EPBC Act Protected Matters Report 2018 (DEE 2018; Appendix K)	This report, created on 30th November 2018, provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act. The search is inclusive of a 10 km buffer of the Proposal area.
Perth Desalination Plant Discharge Modelling: Modelled Scenarios (BMT 2019a; Appendix D)	A particle tracking module was embedded in a three dimensional hydrodynamic model (refer to Table 6.2) so that the potential interaction of fish larvae and desalination plant intakes could be understood. The intake assessment comprised an evaluation of *Pagrus auratus* (pink snapper) eggs and larvae entrainment on the PSDP1 and PSDP2 intakes and its effects on viable larvae (i.e. those that survive and become fish at the end of the larvae life-cycle period). This assessment was undertaken with the combination of TUFLOW FV's particle-tracking module to simulate larvae movement and a stochastic approach to quantify larvae that entrain into the intakes. The simulation period was from September 2008 to January 2009 to mirror the spawning season in Cockburn Sound.
Perth Seawater Desalination Plant 2 Construction Impact Assessment (BMT 2019b; Appendix B)	The objective of this study was to assess potential impacts from TSS on fish (including filter feeders) associated with the intake and outfall dredging works with the purpose of informing decisions on construction method and the EIA process. A numerical model of Cockburn Sound was used to simulate the advection and dispersion of sediment plumes generated by the proposed construction works (refer to Table 6.2).

[7] *Previously named Portunus pelagicus*

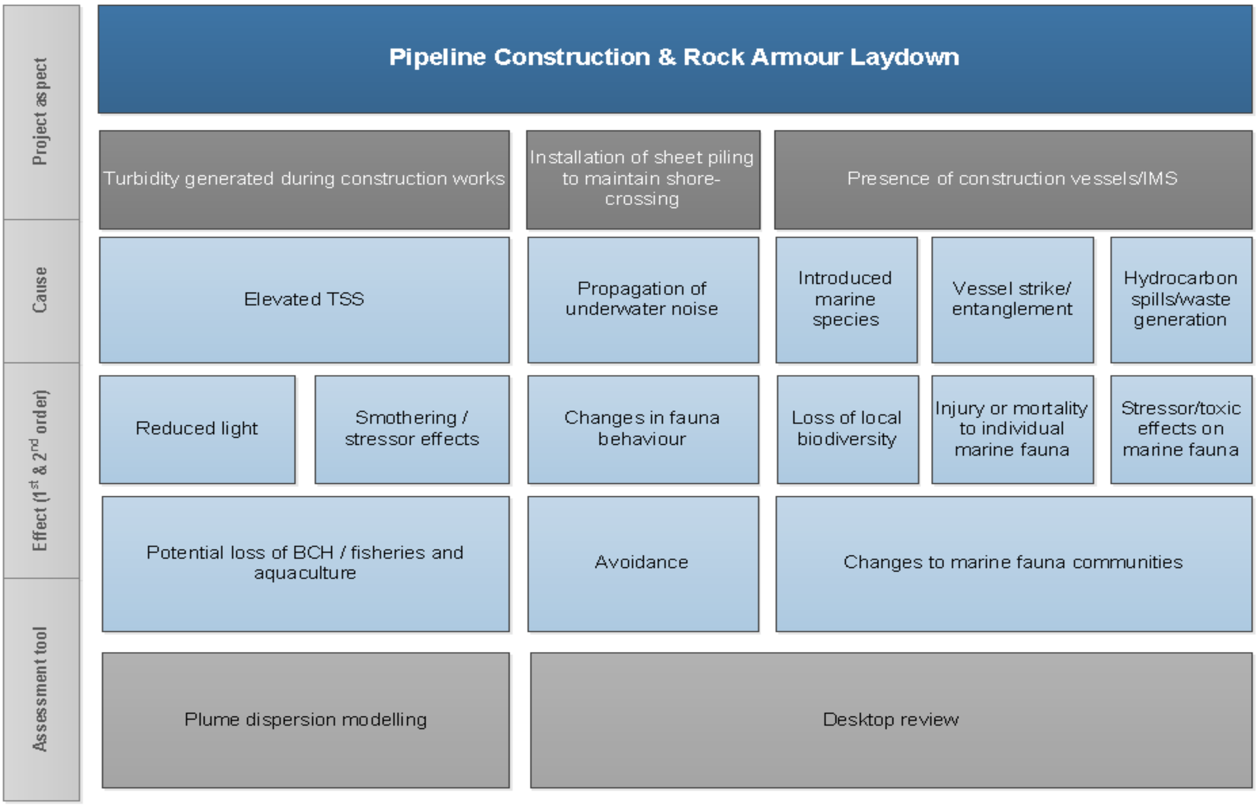
8.4 Potential impacts

Activities undertaken during the construction and operational phases of PSDP2 have the potential to directly and indirectly impact fauna within the Project area.

8.4.1 Potential construction impacts to marine fauna

Cause-effect pathways of potential impacts on marine fauna associated with construction of PSDP2 are shown in Figure 8.5 and include:

- dredging of the seabed and rock armour laydown may lead to periods of increased turbidity, elevated TSS, and reduced light during dredging activities, which in turn may lead to:
  - impacts to benthic fisheries and aquaculture
  - loss of benthic communities and associated marine fauna habitat
- presence of construction vessels and activities generating underwater noise which may lead to:
  - disruption to marine fauna migratory or foraging activities
  - changes in marine fauna behaviour
- vessel strikes that may cause marine fauna injuries or displacement
- dredging plant and construction vessels impacting local biodiversity through introduction of non-indigenous marine species (introduced marine species; IMS) to the area.



Note:

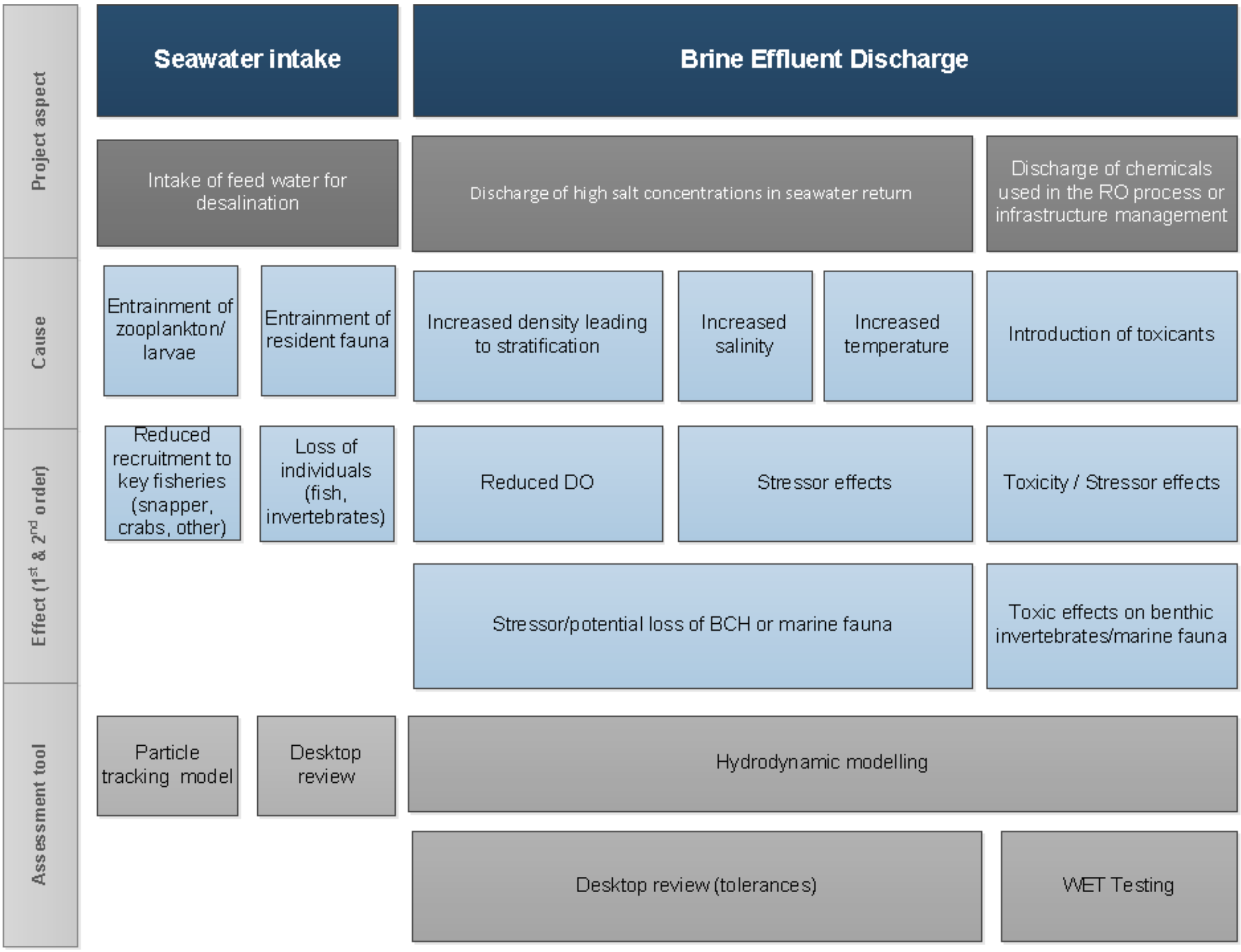
1. BCH = benthic communities and habitats

Figure 8.5 Potential impacts to marine fauna, and flow-on effects, associated with PSDP2 marine construction activities

8.4.2 Potential operational impacts to marine fauna

Potential cause-effect pathways of operational impacts on marine fauna associated with PSDP2 are shown in Figure 8.6 and include:

- intake of feed water for desalination, which may lead to:
  - entrainment of zooplankton/larvae
  - entrainment of resident fauna
- release of brine effluent into Cockburn Sound, which may lead to:
  - decreasing water quality through stratification, salinity, temperature or chemicals (and flow on effects)
  - loss of benthic communities and associated marine fauna habitat.



Note:

1. DO = dissolved oxygen; RO = reverse osmosis; WET = whole of effluent toxicity

Figure 8.6 Potential impacts to marine fauna, and flow-on effects, associated with PSDP2 marine operations

8.5 Assessment of impacts

8.5.1 Assessment framework

Assessment of potential impacts to marine fauna has been undertaken in accordance with EPA (2016g) and the following considerations for EIA have been addressed:

- the marine fauna species affected by the Proposal (Section 8.3)
- the spatial and temporal scale of the residual impacts to marine fauna and the flow-on implications for ecological integrity and/or biodiversity (Section 8.5)
- the current state of knowledge of the affected species of marine fauna and the level of confidence underpinning the predicted residual impacts (Section 8.5)
- application of the mitigation hierarchy, to avoid and minimise impacts to marine fauna, wherever possible (Section 8.6)
- the management measures and approaches proposed and whether they are technically and practically feasible (Section 8.6)
- the risk posed to marine fauna should those predictions be incorrect (Section 8.7).

8.5.2 Construction

Turbidity generated during construction

Turbidity generated by dredging and disposal of material can lead to a range of direct and indirect impacts to marine fauna. Direct effects of suspended solids on fishes and filter feeding organisms can result as a consequence of abrasion and the clogging of filtration mechanisms, thereby interfering with ingestion and respiration, with potentially adverse effects on growth, reproduction and/or mortality (Buermann et al. 1997). indirect effects stem primarily from increased turbidity leading to altered light regimes and resultant changes in feeding efficiency and behaviour (e.g. avoidance; Kerr 1995). Turbidity generated during dredging activities may also indirectly impact marine fauna through loss of benthic communities and associated marine fauna habitat (Section 7), and reduction in water quality (Section 6).

Modelling was used to understand the fate of sediment plumes generated by construction activities (quantified as TSS; see also Section 6.5.2) and how these sediment plumes may interact with key marine fauna in Cockburn Sound. This involved simulating the resuspension, dispersion and settling of sediment generated during construction using the TUFLOW FV ST module coupled with the wave and hydrodynamic models (BMT 2019b; Appendix C). Given their intrinsic ecological, social and commercial importance within Cockburn Sound, as well as known sensitivities to TSS during early life stages (Partridge & Michael 2009), pink snapper (eggs and larvae) were selected as the key indicator for impacts on fauna.

Pink snapper have a predictable reproductive strategy of forming large spawning aggregations in Cockburn Sound at the same time (October through to December) and location each year, making the local stock particularly vulnerable to nearshore perturbations during this period (Wakefield 2010). To assess potential impacts associated with dredging, should timing of dredging coincide with snapper spawning, TSS exposure thresholds, based on concentration and duration of exposure, can be applied to determine the proportion of snapper eggs and larvae that are anticipated to survive (Table 8.6), for those individuals that are predicted to interact with the dredge plume. The thresholds derived by Partridge and Michael (2009), were used as these were developed for local snapper with sediment sourced from Cockburn Sound.

Table 8.6 Assessment criteria for potential impacts of elevated total suspended solids on pink snapper larvae (applicable October–December)

Level of impact	TSS threshold (mg/L)[1]	Duration (hours)
No impact	≤14	≤12
Potential sublethal impact	14<TSS≤70	>12[2]
Lethal impact	TSS>70	>12[2]

Notes:
1. Average conditions 50th percentile daily TSS
2. Threshold met for period of greater than 12 hours within a 24-hour period

The potential impact of TSS on pink snapper spawn was assessed using a risk-based screening approach whereby:

1. The 50th percentile daily TSS dredge plume modelling results were used to delineate zones of no impact (TSS <14 mg/L), potential sublethal impact (14–70 mg/L for >12 hours within a 24 hour period) and lethal impact (>70 mg/L for >12 hours within a 24 hour period) (Figure 8.7).
2. Particle tracking modelling (Section 8.5.3) of pink snapper egg/larvae dispersion after the 80th percentile release event (November full moon) was used to determine particle location in relation to the zone of no impact, zone of potential sublethal impact, and zone of lethal impact (each particle represents an individual egg/larvae).
3. Twelve random temporal snapshots of particle position following the November full moon release were created.
4. The number of particles within the zone of no impact, zone of potential sublethal impact, and zone of lethal impact were quantified.

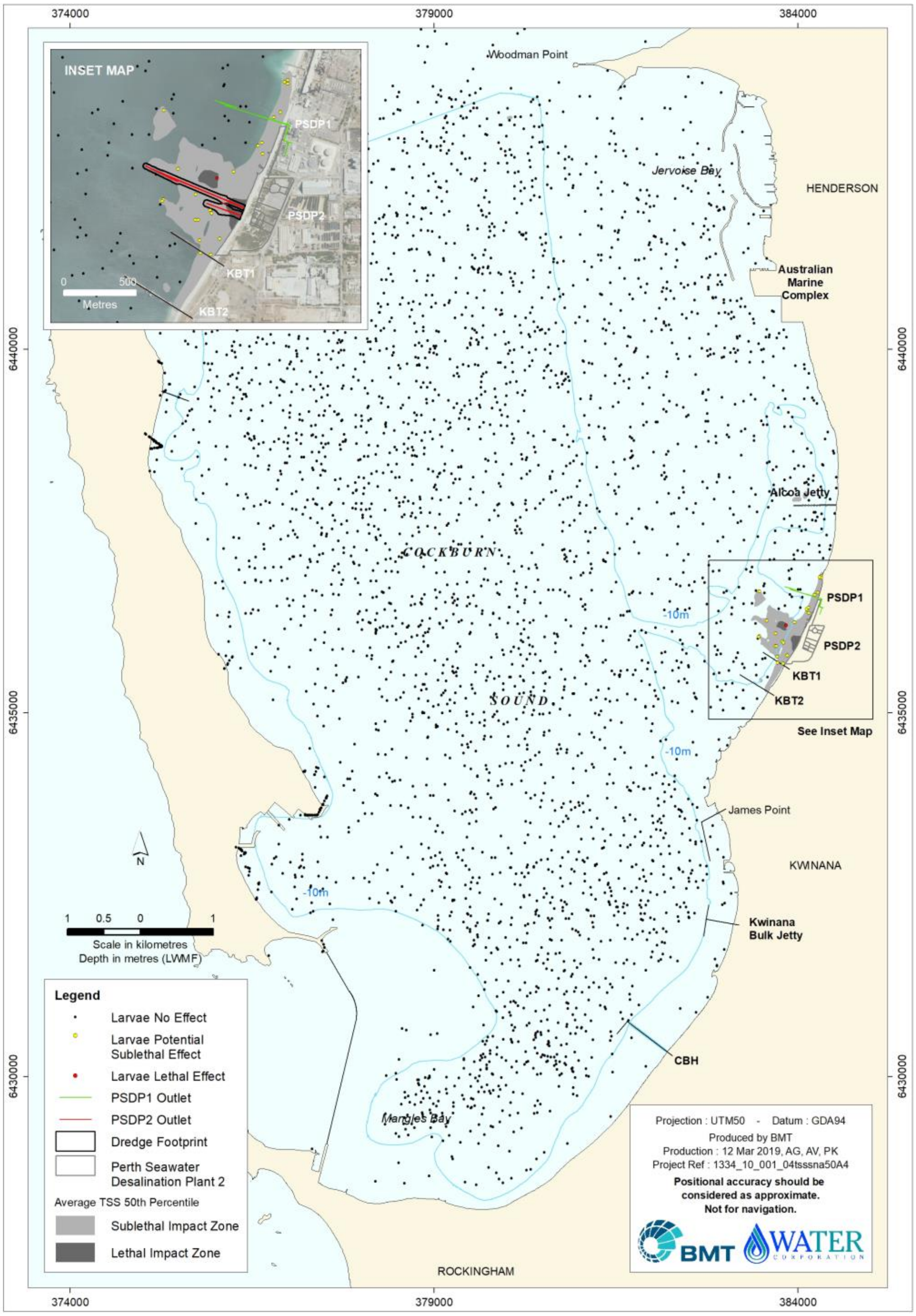
Potential impact zones are illustrated in Figure 8.7. Results of particle tracking modelling are shown in Table 8.7, and suggest that the total number of particles (number of snapper eggs/larvae = number of particles x 1000) potentially available to be impacted by the dredge plume at any one time is anticipated to be extremely low; ranging from 6 to 23 in the potential sublethal impact zone and 0 to 2 in the lethal impact zone from an initial pool of ~5,767 particles (Table 8.7). On average these results suggests that 0.13% of eggs/larvae may incur a potential sublethal impact and 0.06% eggs/larvae are likely to be lost due to contact with TSS, at any one time.

It is important to note that zones do not represent the area within which a plume will be permanently present for the entirety of the dredge program, but rather, only those areas which at times are predicted to exceed TSS thresholds for periods greater than 12 hours. As discussed in Section 6.5.2, plume modelling indicates that TSS concentrations will be elevated above background by <20 mg/L for up to 17 days, and these concentrations are restricted to immediately around the dredge footprint, and both duration and intensity of turbidity diminish rapidly with distance from the dredge site. Accordingly, the impact assessment approach here is considered very conservative.

Table 8.7 Number of modelled particles (snapper eggs/larvae) potentially interacting with elevated TSS concentrations generated during PSDP2 dredging activities

Snapshot scenario[1]	Total viable particles[2]	Particles in no effect zone[3]	Particles in potential sublethal impact zone[4]	Particles in lethal impact zone[5]
1	5,767	5,760	12	0
2	5,767	5,765	6	0
3	5,767	5,758	13	1
4	5,767	5,762	8	0
5	5,767	5,760	12	0
6	5,767	5,763	6	1
7	5,767	5,760	14	1
8	5,767	5,765	9	0
9	5,767	5,751	20	1
10	5,767	5,758	15	0
11	5,767	5,754	20	2
12	5,767	5,754	23	1

Notes:
1. Twelve snapshot scenarios taken during November full moon release event
2. Surviving particles after accounting for natural mortality
3. Particles in zone TSS <14 mg/L
4. Particles in zone TSS 14–70 mg/L for >12 hours within 24-hour period
5. Particles in zone TSS >70 mg/L for >12 hours within 24-hour period
6. Number of snapper eggs/larvae = number of particles x 1000



Notes:

1. Snapper larvae position shows maximum of November full moon snapshots (Table 8.7)
2. No larvae effect = particles in zone with TSS modelled <14 mg/L
3. Larvae potential sublethal effect = particles in sublethal impact zone with TSS modelled 14–70 mg/L for >12 hours within 24-hour period
4. Lethal effect = particles in lethal impact zone with TSS modelled >70 mg/L for >12 hours within 24-hour period

Figure 8.7 Potential extent of the dredging plume, based on hourly depth-averaged 50th percentile daily TSS values (mg/L)

To help understand potential for dredging impacts to other key fisheries in Cockburn Sound, examples of TSS tolerance thresholds reported to cause either acute or chronic mortality for adult and juvenile decapod crustaceans and benthic molluscan eggs/larvae, are provided in Table 8.8. It is clear that the TSS concentrations caused by dredging (typically <20 mg/L outside of the immediate dredge area; Section 6.5.2) would not cause impacts to these fauna at any life stage. The available literature describing tolerance thresholds to TSS exposure for other key commercial and recreational fisheries in Cockburn Sound is extremely limited (e.g. for whitebait or Australian herring), however, there is no evidence to suggest that the dredge program would lead to adverse impacts to these taxa.

Table 8.8 Lowest total suspended solid (TSS) concentrations reported to cause mortality in various life stages of decapod crustaceans and other taxa

Taxa/life stage	Lowest TSS concentration causing mortality (mg/L)	Effect	Reference
Crabs	3500	10% mortality over 28 days	Lunz (1987)
Other adult decapod crustaceans	230	40% mortality over 28 days	Wilber and Clarke (2001)
Juvenile crabs	1800	5% mortality over 28 days	Peddicord and McFarland (1976)
Other juvenile decapod crustaceans	180	10% mortality over 21 days	Wilber and Clarke (2001)
Eggs/larvae of benthic molluscan taxa	188	Negative impacts to oyster egg development	Wilber and Clarke (2001)

Outcome

Out of the total number of viable pink snapper eggs/larvae released in Cockburn Sound during the November full moon spawning event, the average number of particles in the sublethal impact zone was 0.13% and average number of particles in the lethal impact zone 0.06%. This limited proportion of potentially impacted particles suggests that construction-related activities pose a very low risk to snapper eggs and larvae, and in turn, there are not expected to be any impacts to snapper stocks in Cockburn Sound as a result of dredging, even if dredge timing were to coincide with peak spawning periods

The tolerance threshold to TSS for larval crabs is reported to be considerably higher than that for larval snapper, and therefore, the probability of impacts are much lower. As such, the potential impact of elevated TSS on a small proportion of crab larvae over a limited area during the spawning season in Cockburn Sound is considered to be negligible to the long-term survival of the blue swimmer crab population.

Underwater noise generated during installation of sheet piling to maintain shore-crossing

Construction activities along shorelines, as well as on the seabed itself, can potentially contribute to underwater noise levels (Green Jr. & Moore 1995, cited in Koper & Plon 2012). For the PSDP2 Proposal, noise may be generated during sheet piling activities (Section 3.2.2). Pile driving produces transient sounds over a broad frequency band from 0 to 200 kHz, with source levels up to 235 dB (Koper & Pon 2012). The difficulty with pile driving arises from the multiple pile strikes that might have a cumulative sound effect on marine animals (Popper & Hastings 2009), however, the vibratory or percussive hammers are to be used in PSDP2 construction activities as they generate less harmful noise impacts than striking methods. Other sources of noise include the use of heavy machinery, construction equipment and vessels.

Significant, long term impacts from underwater noise include physical responses (auditory and non-auditory). Marine fauna can also exhibit increased stress, behavioural changes (including avoidance of important habitat and modification of vocal behaviour), and chronic responses (including sensitization and habituation as well as cumulative and synergistic effects) in response to changes or increases in underwater noises (Koper & Plon 2012).

Given vibratory piling techniques are to be used to install sheets, it is anticipated that the only physical impacts that may arise from piling activities will be to cause avoidance of marine fauna in the immediate vicinity of construction activities (<20 m) and will be minor. Noise management and fauna monitoring will be completed during construction activities, as detailed in Section 8.6.1.

Vessel strikes from construction and dredging vessels

Cockburn Sound experiences ~1200 commercial vessel movements per year. It is anticipated that three vessels will be required to complete construction activities, representing a <0.01% increase in vessel traffic. Construction vessels will be either slow moving or stationary while working on the Project. Given that most marine fauna at risk of vessel strike (dolphins, pinnipeds, little penguins and other seabirds) are fast moving, it is extremely unlikely that vessel strikes will occur. Further, subsea infrastructure will be lowered to the seabed slowly. Therefore, collision with fauna from construction machinery and materials is unlikely. Slow moving mega-fauna (whales) are unlikely to be found in the Sound at the construction site (due to shallow water and limited access), therefore risk of vessel strike is unlikely.

Construction also has the potential to result in an increase in waste and building materials in the vicinity of the PSDSP2 thereby increasing the possibility of fauna entanglement. Construction will increase the number of people, the amount of building materials and potential litter within the vicinity of the Proposal. Buildings materials and litter have the potential to affect marine fauna such as dolphins and sea-lions by ingestion or entanglement in discarded litter such as plastic bags or rope.

While the likelihood of either vessel strikes and entanglement occurring are considered highly improbable, the results of vessel strike and/or entanglement 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. Accordingly, to limit the risk of vessel strike and/or entanglements, standard management and mitigation measures to minimise the potential for entanglements will be implemented (Section 8.6.1).

Risk of introduced marine species from construction and dredging vessels

The introduction of marine species into areas outside their native range is a serious risk to Australia's native marine life and can greatly impact on commercial fisheries and aquaculture industries. IMS are marine plants or animals that are not native to a region but have been introduced by human activities such as shipping (DAWR 2018). The primary mechanisms by which IMS may be introduced to the Proposal area are through biofouling and vessel ballast water transferred from vessels, such as dredges and barges, entering from international or interstate waters. IMS have the potential to impact native species and the local environment by:

- displacing native species through competition for food and/or habitat
- changing community structure and food webs
- altering ecosystem processes (e.g. via nutrient cycling or sedimentation)
- degrading habitat
- damaging marine industries through diminishing fisheries, fouling ship's hulls and clogging intake pipes (Molnar et al. 2008).

Fremantle Ports and the Department of Defence conduct a voluntary marine pest surveillance program in cooperation with Department of Primary Industries and Regional Development (DPIRD) which covers much of Cockburn Sound. Monitoring involves early warning surveillance (e.g. passive arrays, crab traps and shoreline surveys) which typically occur seasonally, and more targeted monitoring for introduced marine pest (e.g. beam trawls, phytoplankton and zooplankton trawls and infrastructure surveys) which occur once annually (CSMC 2016a). From this monitoring, over 60 species have been recorded as being introduced into WA waters (Enzer 2008, Wells et al. 2009) including 46 that are known non-indigenous species in the Cockburn Sound and Fremantle Harbour area (McDonald & Wells 2009). Of the 46 introduced marine species in Cockburn Sound, four are now considered to be pests according to the National Introduced Marine Pest Information System (CA 2017):

- Asian date mussel/bag (*Arcuatula senhousia*)
- European fanworm (*Sabella spallanzanii*)
- colonial ascidian (*Didemnum pellucidum*)
- toxic dinoflagellate (*Alexandrium catenella*).

Introduction of marine pests due to the Proposal has been identified as a potential risk to marine fauna. The increased number of vessel movements associated with dredging and construction could represent an increased threat of exposure to IMS. Further, the introduction of IMS could potentially lead to irreversible detrimental impacts to the composition and function of the natural ecosystem through changes in competition, predation, or habitat modification. Water Corporation will manage risks associated with IMS through a Marine CEMP (Section 7.6.1).

The use of machinery and vessels during construction may potentially introduce non-native marine species and impact local biodiversity. Marine pests may potentially be transported via ballast water and on vessel hulls (i.e. biofouling). Mitigation strategies to minimise the possibility of introduced marine species are outlined in Section 8.6.1.

Incidental hydrocarbon spills from construction and dredging vessels

Various hydrocarbons will be used during the construction works, including fuel, oil and lubricants for the operation of machinery and engines. There is a risk of hydrocarbon spills to both the marine and terrestrial environment. Rubbish and hazardous waste may also be generated, which can pollute the environment if not contained and removed from site. Therefore, hydrocarbon use, and waste generation will require management. Mitigation strategies to minimise the possibility of stressor effects with toxicants are outlined in Section 8.6.1.

8.5.3 Operations

Entrainment of marine fauna

Entrainment is the process whereby marine fauna are actively drawn into a plant intake pipe. The PSDP2 seawater intake has the potential to entrain marine fauna larvae, zooplankton and resident fauna. Resident fauna can typically avoid entrainment, as intake screens stop larger fauna becoming entrained and the fauna can actively swim against the passive water intake to protect against impingement and entrainment. Entrainment of resident fauna as a proportion of those in Cockburn Sound is likely very low and limited to species such as Western Smooth Boxfish (*Anoplocapros amygdaloides*) and Western King Wrasse (*Coris auricularis*); species common and widely distributed throughout Cockburn Sound and not targeted recreational or commercial species. Due to this, resident marine fauna were not directly addressed as part of this assessment.

Marine larvae are at particular risk of entrainment as they are passive particles in the water column and typically of a size that can pass through intake screens. As Cockburn Sound is one the most important locations in WA for pink snapper spawning, the potential entrainment of pink snapper larvae was assessed using particle tracking modelling. It is known that other fish species use Cockburn Sound to spawn at similar times to pink snapper (Breheny et al. 2012); the *Portunus auratus* larvae model results also provide an assessment of the risk of entrainment on stocks of other species using the Sound for spawning (e.g. *S. robustus*, *H. vittatus* and *A. georgianus*). Given the broad distribution of *Portunus armatus* throughout the Sound and their habitat being the seabed, it is highly unlikely that localised entrainment of seawater ~3–5 m above the seabed will result in an impact on crab stocks.

Pink snapper particle tracking modelling

As the spawning dynamics of pink snapper in Cockburn Sound and potential impacts of construction are well documented (Wakefield & Johnston 2009, Wakefield 2010) and it is possible to model the dispersal of larvae and eggs (e.g. Doak 2004), the validated hydrodynamic model of Cockburn Sound was used to estimate the percentage of eggs and larvae that may be entrained during the spawning season (BMT 2019a; Appendix D). The particle transport model approach considered the following known spawning dynamics of pink snapper in Cockburn Sound:

- distribution of spawning in Cockburn Sound
- timing of spawning in Cockburn Sound
- relative number of eggs per spawning event
- physical characteristics of eggs and larvae
- persistence of eggs and larvae in the water column
- natural mortality.

Modelling techniques were preferred over empirical sampling (i.e. at the PSDP1 intake) as it offers a much more powerful mechanism to determine relative impacts on the stock over its entire life expectancy, compared to intake testing from which results offer little to infer or benchmark impacts against.

Distribution of spawning in Cockburn Sound

Spawning aggregations of pink snapper move clockwise around Cockburn Sound with October spawning occurring near Woodman Point, November spawning occurring north-west of James

Point and December spawning occurring in the centre of Cockburn Sound and towards Garden Island (Wakefield 2010). As the exact location of pink snapper spawning aggregations varies year to year, but the pattern remains the same, a generalised movement pattern was used for release of spawning particles in the model (Figure 8.4).

Timing of spawning in Cockburn Sound

Pink snapper spawning occurs between September and January each year, when water temperatures range 15.8–23.1°C (Wakefield 2010). The spawning fraction of females is monthly bimodal and peaks at night during the 3 hours following the high tide during new and the full moons at 96–100% and ~75%, respectively (Wakefield 2010). For the purpose of entrainment modelling, particles (larvae) were released over a three-hour tidal period following new and full moons within each of the months of September/October, November and December 2008 (Table 8.9).

Table 8.9 Pink snapper larvae particle transport model release parameters

Date	Time	Moon phase	High tide	Model simulation phase
29/09/2008	16:12	New moon	29/09/2008 22:00	October New
15/10/2008	04:02	Full moon	15/10/2008 21:30	October Full
29/10/2008	07:14	New moon	29/10/2008 20:30	November New
13/11/2008	13:17	Full moon	19/11/2008 21:00	November Full
28/11/2008	00:54	New moon	29/11/2008 21:00	December New
13/12/2008	00:37	Full moon	13/12/2008 22:00	December Full

Relative number of eggs per spawning event

The proportional number of particles to be released in the model relative to the maximum average release in November was estimated based on the approximation of annual spawning cycle in Wakefield 2010 (Table 8.10). The maximum number of eggs in Cockburn Sound in any event has been estimated at around 2250 million in December, although the November average is highest at 1625 million (Wakefield). The relative number of eggs released in September and January is typically so low as to be considered negligible, therefore was set to zero for modelling purposes.

Table 8.10 Generalised abundance of pink snapper eggs on consecutive moons

Moon phase	September	October	November	December	January
New	0%	34%	100%	58%	0%
Full	0%	25%	75%	44%	0%

Source: Wakefield (2010)

Physical characteristics of eggs and larvae

Pink snapper spawn 3–5 m below the surface of the water and eggs are positively buoyant immediately post-fertilisation (Kitajima et al. 1993). The eggs have been shown to become more neutrally buoyant during development (Jackson 2007). In deeper waters larvae may become concentrated at different heights of the water column (Le Port et al. 2014), but as Cockburn Sound is relatively shallow and well mixed, and as per Doak (2004) and Nahas et al. (2003), the eggs and larvae were treated as neutrally buoyant and mixed through the top 5 m of the water column.

Persistence of eggs and larvae in the water column

Pink snapper eggs hatch after ~20–30 hours (Le Port et al. 2014, Norriss & Jackson 2002) and endure a pelagic larval phase of ~20–25 days prior to metamorphosis, settlement and commencement of the demersal juvenile phase (Tapp 2003). Each spawning event in the model was attributed a 'lifespan' of 25 days as larvae become motile after a worst-case scenario of 25 days. The particles in the modelling were switched off after 25 days as they are no longer being moved by ambient currents.

Natural mortality

Pink snapper are a long-lived species (maximum ~40 years) with low rates of natural mortality (Wise et al. 2007, Norris & Crisafulli 2010). For the particle transport model, natural mortality of larvae was estimated at 21.3% per day for the first 25 days (Partridge et al .2017). There are no existing data for estimates of annual natural mortality (*M*) of pink snapper in Cockburn Sound, therefore an average value of 0.10 was used based on available reference material (Table 8.11).

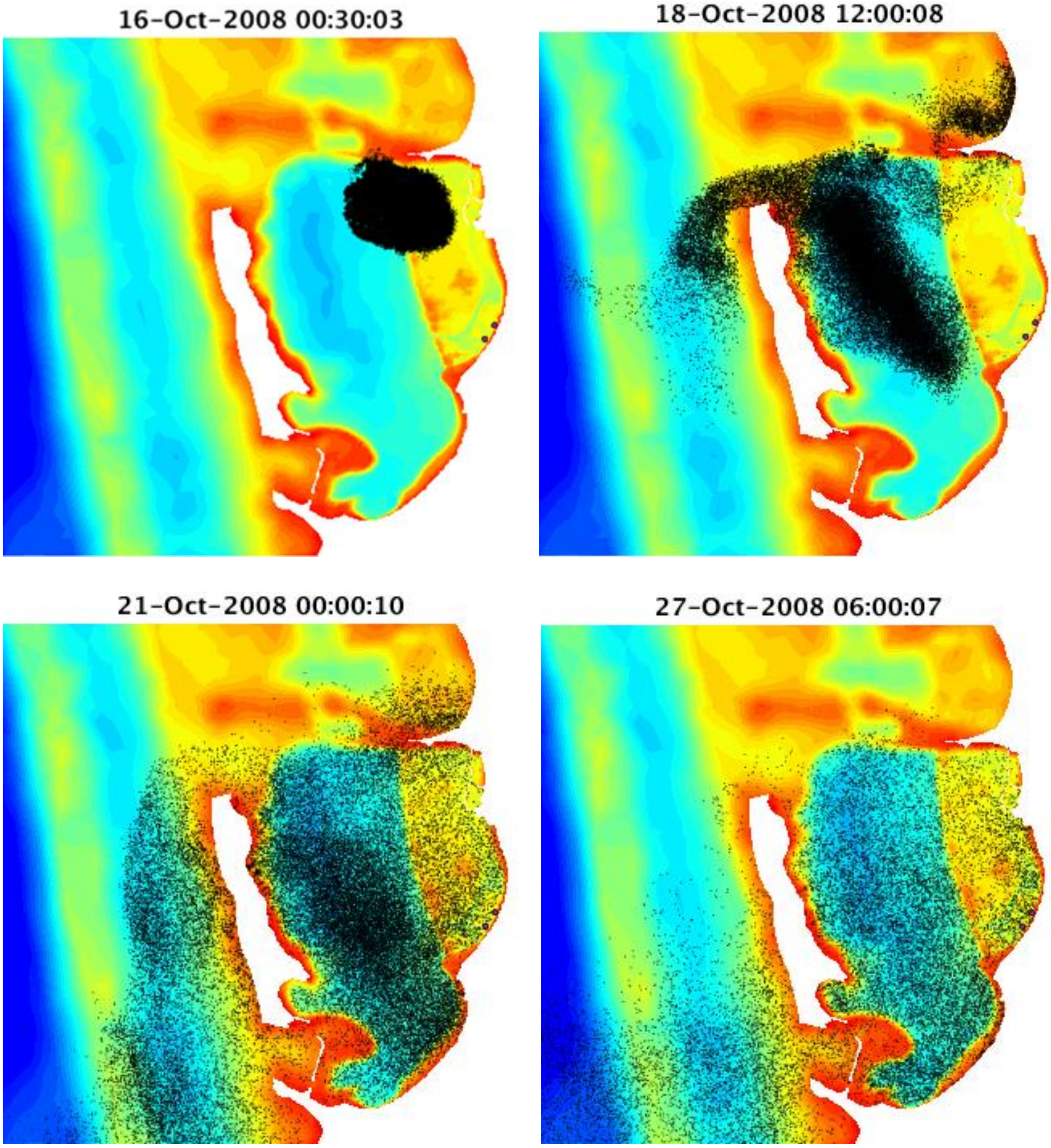
Table 8.11 Estimates of pink snapper natural mortality

Mortality rate	Reference	Context
0.05	Fowler et al. (2016)	Instantaneous mortality constant for pink snapper in South Australia
0.075	Gilbert et al. (2006), Gilbert et al. (2010)	Natural mortality used for stock assessments in New Zealand, where individuals of the species live up to 60 years of age (Francis R.I.C.C. et al. 1992) compared with ~40 years in Western Australia
0.05–0.10	Norriss & Crisafulli (2010)	Pink snapper natural mortality range estimate based on one individual pink snapper (age 40 years and 10 months) calculated using Hoenig (1983), Hewitt & Hoenig (2005) and Hewitt et al. (2007) methods
0.12	Wise et al. (2007)	Pink snapper natural mortality estimated using the maximum age method
0.22	Jackson (2007)	Shark Bay natural mortality rate was estimated at 0.22 year-1 (Jackson 2007). Natural mortality may be higher in Shark Bay due to higher densities of predators (e.g. sharks and dolphins).
0.10	**Annual mortality rate used as part of this assessment**	

Assessment outcome

The model assessed entrainment as a probability function of radial distance from the intake locations; larvae that pass directly over the intake structure will have a high likelihood of being entrained, larvae passing the intake at a distance have a lower likelihood, and beyond a certain distance there is no entrainment (Largier et al. 2007). Modelling scenarios of entrainment only at PSDP1, only at PSDP2, and at both intakes were run independently to isolate the entrainment of a single intake and the combination of both.

For ease of presentation, snapshots from the October 2008 full moon event have been selected to illustrate the general movement of particles, as predicted by the TUFLOW FV PTM model Figure 8.8).



Note:
1. Particles are the black dots, whilst the colours represent the model bathymetry

Figure 8.8 Snapshots of a subset of the released particles (approximately 50,000) following the spawning event during full moon of October 2008

The proportion of pink snapper larvae entrained by PSDP1 for each discrete spawning event was low, ranging from 0.10% during the October full moon scenario, to 0.61% for the December full moon scenario (Table 8.10). For each scenario, a larger proportion of entrainment was observed for PSDP1 compared to PSDP2. The cumulative entrainment impact of the PSDP1 and PSDP2 intakes was also low, with the highest proportion of entrained larvae occurring during the December full moon scenario (1.32%). Over the entire October–December spawning period, the particle tracking modelling estimated that a total of 158,000 larvae were entrained by PSDP1, and 268 000 by PSDP1 and PSDP2; 0.60% and 1.03% of viable larvae respectively (Table 8.10).

Table 8.12 PSDP1 and PSDP2 snapper larvae modelling entrainment estimates

Spawning event	October		November		December		Total
Moon phase	Full	New	Full	New	Full	New	
Number of larvae released (000's)	**406,280**	**552,745**	**1,218,100**	**1,625,560**	**715,150**	**942,585**	5,460,420
Number of surviving larvae without entrainment (000's)	1,942	2,647	5,826	7,773	3,418	4,510	26,116
Number of surviving larvae with PSDP1 entrainment (000's)	1,935–1,940	2.632–2,638	5,785–5,797	7,731–7,743	3,394–3,400	4,481–4,487	25,958[2]
Proportion of larvae entrained by PSDP1 (%)	0.10–0.36	0.34–0.57	0.50–0.70	0.39–0.54	0.53–0.70	0.51–0.58	0.61[2]
Number of surviving larvae with PSDP1 and PSDP2 entrainment (000's)	1,931–1,936	2,623–2,632	5,758–5,774	7,703–7,717	3,373–3,389	4,460–4,472	25,848[2]
Proportion of larvae entrained by PSDP1 and PSDP2 (%)	0.31–0.57	0.57–0.91	0.89–1.17	0.72–0.90	0.85–1.32	0.84–1.11	1.03[2]

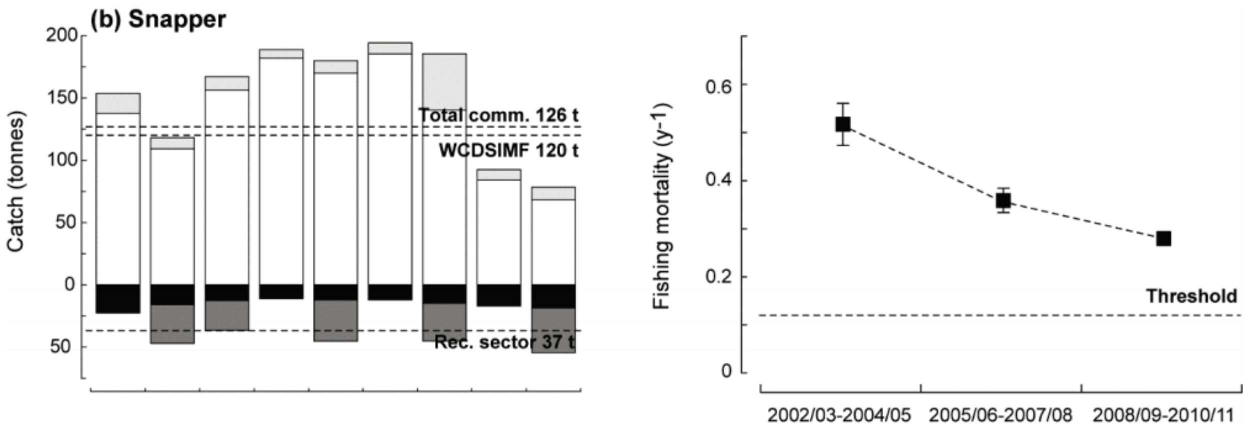
Notes:

1. Modelling scenarios based on 2008 weather conditions
2. Total numbers and proportions of surviving larvae with entrainment were calculated based on the worst-case scenario for each modelling event (lower range value)

To assess the relative impact of entrainment on the Cockburn Sound pink snapper population over time, the total number of surviving individuals from spawning to 20 years, were compared for four scenarios:

1. natural mortality only
2. natural mortality and potential PSDP1 entrainment
3. natural mortality and cumulative PSDP1 and PSDP2 entrainment
4. natural mortality and fishing pressure.

For the purpose of temporal assessment of pink snapper stocks, fishing mortality for pink snapper was estimated at ~0.30/year (Gaughan & Santoro 2018) and applicable to pink snapper individuals in the years after they reach the 500 mm minimum recreational and commercial size limit (~5 years; Smallwood et al. 2013).



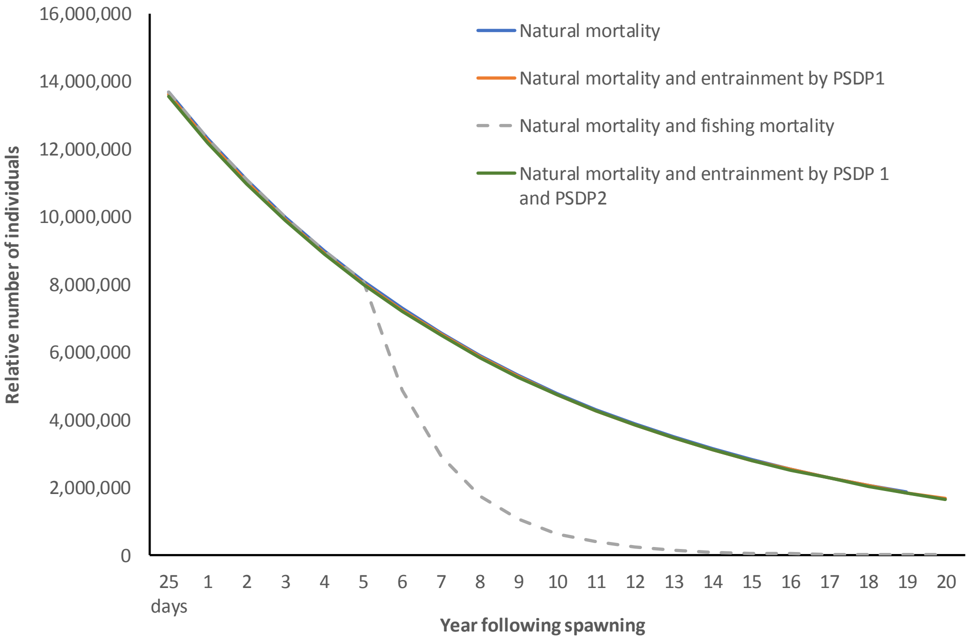
Source: Gaughan & Santoro (2018)

Table 8.13 Pink snapper fishing mortality estimate

As entrainment potentially impacts larvae in the 25 days post-spawning only, this portion was removed from the total population in year one, and entrainment did not continually remove pink snapper from the population. Natural mortality and fishing pressure are ongoing sources of population decline, therefore impact pink snapper from day zero (natural mortality) and ~year 5 (fishing pressure). Over a two decade period, the predicted impact of entrainment on pink snapper stocks was minimal relative to natural mortality and fishing pressures Figure 8.9).

Many temperate Australian fish species spawn at the same time as pink snapper (Breheny et al. 2012); therefore, the proportion of pink snapper larvae entrainment can be used as a proxy for entrainment of larvae of other marine fauna. It therefore assumed that the overall potential of marine larvae entrainment is negligible.

It is important to highlight that the intent of this assessment is to illustrate the potential for changes in relative abundances of fish (due to losses of some larvae) above natural cycles in life expectancy and those associated with fishing; however, it is not a stock assessment, which are carried out annually by DPIRD.



Note:

1. Time series plotted starting at 25 days post-spawning, the number of individuals at time zero (not shown) was the same for each scenario (5,460,420,000 individual pink snapper eggs/larvae)

Figure 8.9 Comparative effects of natural mortality, PSDP2 caused entrainment mortality and fishing mortality on the abundance of the Cockburn Sound pink snapper cohort from age 25 days to age 20 years

Change in environmental quality due to discharge of brine effluent (stressor effects)

As determined in Section 5.5.3, seawater temperature and salinity are expected to meet EPA guideline requirements in all but a very small area of Cockburn Sound (i.e. <0.005% by surface area) immediately adjacent to the PSDP2 diffuser, which is proposed to be designated as LEPA (Section 6.5.1). Outside of the LEPA, as a result of dilution and mixing, the PSDP2 Proposal is anticipated to enhance salinity and water temperatures only marginally above present ambient conditions (salinity by less than 1.4 PSU in areas designated as MEPA and 1.3 PSU in areas designated as HEPA while temperature differences outside of the LEPA will typically be less than 0.5°C). Such changes are determined to be acceptable (EPA 2017), and therefore no impacts to marine fauna are predicted that could be attributed to these stressors.

Potential indirect impacts from the Proposal associated with stratification and low DO events on marine fauna, are considered possible, but as discussed in Section 7.5.3, unlikely. The critical DO concentration for fish is generally considered to be higher than that of most benthic invertebrates, and between 2–3 mg L^{-1} (e.g. Howell and Simpson 1994) and 3–5 mg L^{-1} (e.g. Stiff et al. 1992, Breitburg 2002). For most species during normal, or even 'worst case' conditions similar to those that occurred in 2013, the predicted DO is not anticipated to decline below 5.09 mg/L with brine effluent (and ~5.29 mg/L without brine effluent), and therefore unlikely to exceed individual tolerance thresholds, but may temporarily result in additional sublethal stress to more sensitive species. While it is important to highlight this risk, in a broader context, it also needs to be considered that differences in patterns in DO between PSDP1 and PSDP2 scenarios were determined to be negligible (Section 6.5.3), therefore the PSDP2 Proposal should not change the existing risk profile of Cockburn Sound.

Related to this matter, between 19 and 23 November 2015, Cockburn Sound experienced a fish kill event. Based on synoptic-scale meteorological data, oceanographic satellite data, and numerical modelling data, Pattiaratchi (2016) hypothesised that meteorological and oceanographical conditions could have led to persistent upwelling of anoxic waters contributing to the observed fish kill. The Cockburn hydrodynamic model (BMT 2018b) was also used to investigate whether the fish kill event in November 2015 may have been likely caused by anoxia. However, noting that the model does not take into consideration algal dynamics, its predictions did not support the hypothesis that hydrodynamic conditions generated low DO at depth, or that such waters were brought to the surface of the Sound. The model therefore suggested that the fish kills were more likely associated with other processes that occurred during that event, as also concluded by the Department of Fisheries, WA (DOF 2015).

In light of the above, and outcomes of the risk posed by the discharge of brine effluent stressor effects on marine fauna is considered very low.

Release of toxicants in brine effluent

Toxicants discharged in brine effluent during the operational phase of the PSDP2 will be monitored and managed at a LEPA boundary to meet guidelines designed to protect 99% of species (ANZG 2018). Adverse impacts on marine fauna associated with the potential release of toxicants in brine effluent will therefore be restricted to those that reside near the discharge outfall.

8.5.4 Cumulative impacts

There are no long-term potential cumulative impacts identified from the construction of the PSDP2 on marine fauna and associated environmental values.

The potential for flow-on effects to fish and other marine fauna communities due to the additive effect of desalination discharges from PSDP2 to PSDP1, and to other industrial discharges to Cockburn Sound, has been addressed in Sections 6.5.3 and 8.5.3, and justified in Section 6.5.4 , respectively. Modelling was also used to determine the potential effect of loss of some larvae to PSDP1 and PSDP2 desalination intakes, relative to losses associated with natural cycles in life expectancy and those associated with fishing pressures and was determined to be negligible.

Water Corporation has determined that all relevant cumulative impacts have been sufficiently incorporated into the impact assessment and that there is no requirement for further assessment of cumulative impacts on marine fauna within Cockburn Sound due to this Proposal.

8.6 Mitigation

Water Corporation has applied the mitigation hierarchy to the Proposal to protect marine fauna so that biological diversity and ecological integrity are maintained. Mitigation measures are summarised in Table 8.14.

Table 8.14 Summary of mitigation measures to ensure maintenance of marine fauna

Impact	Avoid	Minimise	Management and monitoring
Reduction in marine environmental quality during construction	The avoidance of impacts to marine environmental quality is not possible, however, construction effects will be temporary and will naturally ameliorate once construction ceases. The marine construction footprint is sufficiently separated in distance from aquaculture activities to avoid indirect effects of turbidity generated during dredging Where possible, the timing of construction activities will be planned to avoid the peak spawning period for snapper (October to December)	Construction management to minimise turbidity and sedimentation will include: • the short duration and the design of the dredging will minimise impact on marine fauna communities • use of a backhoe dredge, to reduce generation of TSS during dredging and backfill activities • containment of turbidity from the rest of construction through use of silt curtain(s) • induction of all construction workers about correct waste management procedures • implementing strict environmental management standards for the Proposal during construction, including handling procedures for hazardous substances (including hydrocarbons)	Described in CEMP
Underwater noise generated during construction	The generation of some underwater noise will be unavoidable.	Sheet piling used to temporarily maintain onshore trench integrity during construction will be installed using vibratory hammers, which minimise underwater noise generation considerably.	Described in CEMP
Introduced marine species	To detect presence of introduced marine species, the dredge contractor will ensure all vessels and dredge related equipment (i.e. pipeline) have been risk assessed using the DPIRD risk assessment tool (https://vesselcheck.fish.wa.gov.au/) and completed the actions to manage vessels and equipment to a low risk rating.	The dredge contractor will ensure that: • ensure that any equipment or vessels are either new, or have been thoroughly cleaned, dried for >24 hours, and inspected prior to being deployed. • report the presence of any suspected marine pests to FishWatch (1800 815 507).	Described in CEMP

Impact	Avoid	Minimise	Management and monitoring
Entrainment of marine fauna	The avoidance of entrainment of some snapper larvae and other marine fauna is not possible.	Water Corporation has developed a hydrodynamic model to better understand the risk of entrainment to snapper larvae The seawater intake will be engineered so that: • the screen approach velocity is minimised to allow 33% occlusion by marine growth and ultimate velocity of 0.15m/s to allow small fish to escape • and intake screen bar will be in place to prevent large fish from entering. • location of intake ~5 m above the seabed to reduce potential of demersal species to enter.	Not applicable.
Reduction in marine environmental quality during operation	The planned location of the desalination discharge outlet is sufficiently separated from marine fauna so that mixing occurs prior to interaction with the desalination plume	Water corporation has developed a hydrodynamic model to predict changes in marine quality (salinity) associated with discharge of RO return water during operations. Seawater outlet diffusers will be oriented to optimise mixing and therefore prevent exposure to elevated salinities Intake pipeline radius and roughness allowance for marine growth annulus in preference to chlorination dosing	Described in MEMP

8.6.1 Construction

A preliminary register of measurable and/or auditable environmental commitments to manage the environmental impacts associated with construction activities (Section 8.5.2) are provided in Table 8.15. Environmental monitoring and management will be outlined in detail in a CEMP to be finalised prior to commencement of dredging. The CEMP will include:

- detailed monitoring and management requirements
- timing/frequency of monitoring and management commitments
- responsibilities for monitoring and management commitments

- contingency planning/measures in the event of an environmental or safety issue
- stakeholder consultation
- reporting requirements to government and environmental regulators.

Table 8.15 Relevant environmental objectives, performance indicators and proposed measurement criteria to protect marine fauna

Environmental objective	Performance criteria[1]	Standards[2]	Performance indicators[3]
To protect marine fauna so that biological diversity and ecological integrity are maintained	Ensure the risk of harm to susceptible marine fauna from all aspects of the Project (including noise, TSS, collision, entrainment, introduced marine species) is acceptably low	Detailed procedures for the management of works, including: • Water Corporation will implement EPBC Regulations 2000 – Part 8 Division 8.1: Interacting with cetaceans, throughout the all phases of the Project • Pre-start (15 minute) visual survey to ensure no marine fauna are present at the time of dredge start-up • Definition and maintenance of marine fauna exclusion zone and/or stand down for vessels underway • Notification of introduced marine species and document any disturbance or impacts to marine mammals; including date, number of individuals, corrective actions undertaken • Subcontractors complete the vessel risk assessment for the dredge and support vessels in consultation with the Department of Primary Industries and Regional Development • Machinery in good working order to reduce any unnecessary noise • Where possible leave engines, thrusters or other noise generating equipment in standby or switched off if not in use • Turn suction pumps off when not in close proximity to the sea floor.	• Systems in place to record presence and location of protected marine fauna • Reporting process for detection of dead or injured marine fauna • Third-party audit of CEMP outcomes • Retain vessel check paperwork for audit purposes.

Notes:

1. Performance criteria = the performance criteria are the proposal-specific desired state for an environmental factor/s that an organisation sets out to achieve from the implementation of outcome-based provisions
2. Standards = can include company standards, regulatory requirements, and recognised Australian and International Standards
3. Performance indicators = measurable/auditable outcomes that ensure that the company's environmental performance
4. Construction = monitoring and management during the Project
5. Operation = monitoring and management implemented during standard Port operations, following the Project

8.6.2 Operations

Mitigation measures that are to be put in place to protect marine fauna from operational impacts associated with desalination discharges are described in detail Section 6.6.2. Environmental monitoring and management will be outlined in further detail in a PSDP2 MEMP, which will be finalised prior to commencement of plant operations.

8.7 Predicted outcome

During construction of the Proposal there will be temporary elevated TSS and noise associated with construction. Effects of enhanced TSS on marine fauna are expected to be minimal and will be managed under an appropriate CEMP. Further, standard dredging management controls, including use of silt curtains, will be employed to limit plume dispersion.

While it was determined that the operation of the Proposal may have a minor effect on marine quality (DO concentrations and salinity), differences from background concentrations were predicted to be minor and within the known physiological tolerances of fish in the project area.

The proportion of pink snapper larvae entrainment was determined to be negligible relative to the total number of eggs that are released each year, and no effect on snapper stocks is predicted. Snapper larvae can be used as a proxy for entrainment of larvae of other marine fauna and the modelling study is concluded that the potential for impacts due to entrainment of marine larvae is negligible.

After the application of mitigation measures as described in Section 8.6, the EPA objective for marine fauna (i.e. to protect marine fauna so that biological diversity and ecological integrity are maintained) is expected to be met.

There is no significant residual impact to marine fauna predicted to occur from the construction and operation of the Proposal; and therefore, no subsequent consideration of offsets for this environmental factor are required.

9. Coastal Processes Impact Assessment

9.1 EPA objective

To maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected.

9.2 Legislation, policy, guidance

The legislative instruments, policies and guidelines considered relevant to the environmental impact assessment of coastal processes are provided in Table 9.1.

Table 9.1 Legislative instruments, policies and guidelines relevant to coastal processes impact assessment

Legislation
Environmental Protection Act 1986
Biodiversity of Conservation Act 2016 / Wildlife Conservation Act 1950
Environmental Protection and Biodiversity Conservation Act 1999
EPA policy or guidance
Statement of Environmental Principles, Factors and Objectives (EPA 2018b)
State Environmental (Cockburn Sound) Policy 2015 (EPA 2015)
Environmental Factor Guideline – Coastal Processes (EPA 2016h)
Other policy or guidance
WA Coastal Zone Strategy (DPLH 2017)
State Planning Policy No. 2.6: State Coastal Planning Policy (WAPC 2013a)
State Coastal Planning Policy Guidelines (WAPC 2013b)
Coastal Hazard Risk Management and Adaptation Planning Guidelines (WAPC 2014)
Sea Level Change in Western Australia - Application of Coastal Planning (DOT 2010)

9.3 Receiving environment

9.3.1 Environmental values

The coastal zone is highly valued for its aesthetic, cultural, social and recreational values; as well as being important for commercial infrastructure and facilities (EPA 2016h).

The EPA environmental factor guideline for coastal processes identifies seven significant coastal values (Table 9.2). From these, one (active or passive recreation) is included within this assessment on coastal processes; and for those values considered as not applicable, no further description or assessment has been included.

In addition, while the Cockburn Sound SEP is primarily focused on the marine environment, the policy also applies to the catchment area and therefore covers the eastern coastal zone of Cockburn Sound (EPA 2015). he coastal environmental values identified above are consistent with the relevant values identified in the Cockburn Sound SEP, including recreation and aesthetics, and cultural and spiritual values (refer to Section 6.5.1 for full list of environmental values for Cockburn Sound).

Table 9.2 Environmental values in the coastal zone

Environmental value	Relevance to coastal processes EIA at Proposal site	Description
Benthic communities and habitats	Not applicable	No change in benthic communities and habitats are predicted to occur as a result of the Proposal. Therefore, no subsequent change in coastal morphology from any change in moderating effects on coastal processes would be expected to occur.
Conservation significant marine fauna and critical habitat	Not applicable	No conservation significant marine or wading species are considered likely to occur (GHD 2017). No critical coastal habitat[1,2] is known to occur within the vicinity of the Proposal.
Conservation significant low-lying areas	Not applicable	There are no conservation significant low-lying coastal features (e.g. tidal creeks, deltas, river mouths etc.) within the vicinity of the Proposal
Conservation significant flora and vegetation, and terrestrial fauna species	Applicable, however this has been assessed within Section 10.	No conservation significant flora or vegetation are considered likely to occur within the vicinity of the Proposal (GHD 2017). Refer also to assessment of 'Flora and Vegetation' in Section 10. Due to the lack of connectivity with suitable habitat, the likelihood of conservation significant fauna relying on the site is very low; the fauna survey did not identify any sign of these species occurring on the site.
Unique landforms	Not applicable	The Cockburn Sound coast is part of the Tamala Limestone formation (which extends from Cape Range to Albany) (Smith et al. 2012) and is typically overlain by foredune plains and carbonate sediments (Stul 2005; Skene et al. 2005, CZM 2013). There are no unique coastal landforms only occurring within the vicinity of the Proposal. Refer also to assessment of 'Landforms' in Section 9.
Significant cultural and aesthetic values	Not applicable	The Proposal is within the Kwinana Strategic Industrial Area and is therefore not subject to Native Title. No registered Aboriginal heritage sites occur within the vicinity of the Proposal. Refer also to assessment of 'Social Surroundings' in Section 10.
Active or passive recreation	Applicable	Barter Road Beach is a publicly accessible section of coast in Cockburn Sound, known for horse exercising and other recreational uses.

Notes:

1. Biologically important areas (BIAs) for foraging have been established in Cockburn Sound for some bird species (e.g. terns, shearwaters, gulls and little penguin) and the Australian sea lion. However, all the above identified species are oceanic foragers, i.e. their foraging is not focused on the coastal zone.
2. No breeding or haul-out activity is known to occur within the vicinity of the Proposal.

9.3.2 General description

Barter Road Beach extends for approximately 2.5 km between the most northern of the shore-parallel breakwaters at James Point to the southern Verge Energy pipeline (Short 2006). The beach is classified as a low-energy, wave-dominated, reflective system (Short 2006). This beach receives slightly higher swell wave energy than James Point (i.e. the beach to the south), and typically maintains a narrow, attached bar (Short 2006). The beach is backed by a dune system of varied width.

Coastal processes

The key geophysical processes (i.e. wind, waves and currents) that drive coastal processes are described in Section 3.3.2.

Cockburn Sound is a relatively enclosed, low-energy system with limited sediment sources and sinks available for the littoral transport system. Onshore sediment sources include sediment feed from Parmelia Bank and through the gaps in the Garden Island causeway. Empirical estimates of the rate of onshore feed are low, in the order of 1 m^3/m/yr (Van Rijn 1989; MRA 1999). The main sediment sinks within Cockburn Sound are the loss of wind-blown sand to the dune systems, and sedimentation into the deep central basin. Losses to both sediment sinks are expected to be minor, with estimates of wind-blown sand in the order of several hundred cubic metres per year (MRA 1999). In Cockburn Sound, the net longshore sediment transport is typically small, and northward in the south and southward in the north, due to the partial obstruction of south-west wave penetration caused by Garden Island and the causeway (DOT 2009). The numerous existing coastal structures also influence the longshore sediment transport patterns within Cockburn Sound. Note, under low-energy conditions, coastal change can tend to be more episodic in nature (CZM 2013).

Sediment cells are spatially discrete areas of the coast within which marine and terrestrial landforms are likely to be connected through processes of sediment exchange, often with little or no sediment movement across cell boundaries. Cockburn Sound operates as a single primary sediment cell, with three smaller secondary cells within it (Stul et al. 2015). Barter Road Beach occurs within a secondary sediment cell that extends between James Point and the Australian Maritime Complex (Stul et al. 2015).

Within the James Point to Australian Maritime Complex sediment cell, net sediment transport is to the south and is supply controlled (CZM 2013; Figure 3.17). It has been estimated from previous sediment transport modelling that the net alongshore sediment transport in the vicinity of Barter Road Beach is approximately 2500 m^3/year (MRA 2009).

Shoreline position in the vicinity of the Barter Road Beach has varied, with the periods of both erosion and accretion observable in mapped vegetation lines (Figure 9.1). The period between 1942 and 1976 appears to show a beach rotation, with the area at the southern end of the Proposal site accreting, but the area at the northern end of the site retreating. This movement was likely a response to the construction of the BP facilities at James Point and the subsequent accumulation of material to the north of this infrastructure, rather than being a result of storms or a change in the key geophysical processes. More recent periods (e.g. 2008 to 2016) show a relatively stable or slight accretion (Figure 9.1).

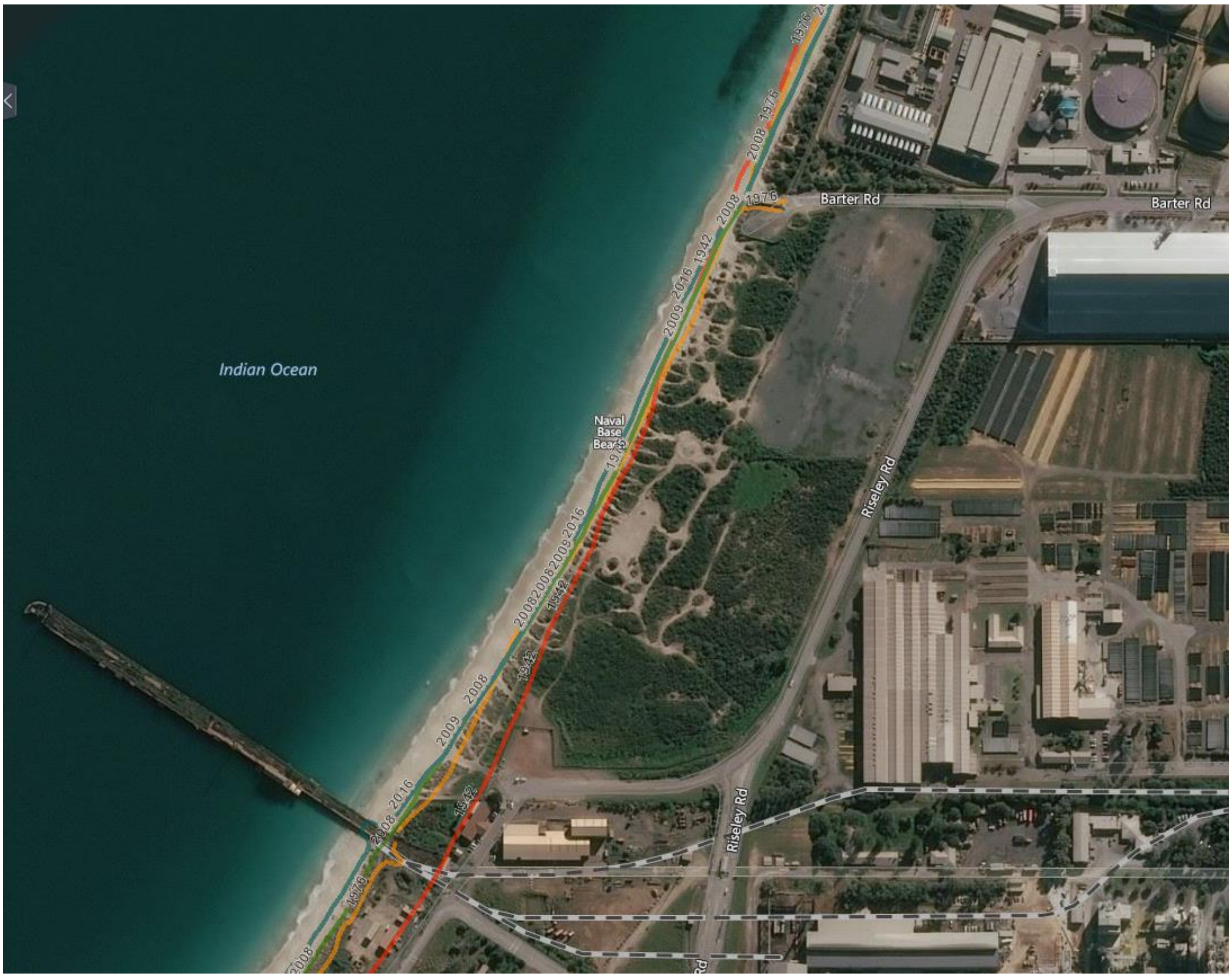


Figure 9.1 Mapped vegetation lines (1942, 1976, 2009, 2016) for Barter Road Beach

Coastal flora and fauna

A desktop review and field survey of the flora and fauna within the PSDP2 site, including the beach and dune areas, has been completed (GHD 2017). The vegetation present within the survey area is consistent with vegetation on dunes along the Perth coastline (GHD 2017). The dunes are comprised of a low vegetation complex of *Spinifex longifolia*, *Rhagodia baccata* and *Olearia axillaris*. During the field survey, the condition of the vegetation complex within the foredunes was noted as being highly variable in condition, ranging from good to degraded (GHD 2017). Evidence of ongoing disturbance through the dunes and foredunes was also noted due to beach access, wind erosion and weed invasion (GHD 2017).

Active or passive recreation

Barter Road Beach is known to be used for horse exercising, fishing and other recreational activities (EPA 2002) but is not highly utilised (DEP 1996; EPA 2002). Rockingham Beach is considered the major regional beach within Cockburn Sound, with high levels of use recorded (Eliot et al. 2005); and Challenger Beach and Kwinana Beach (i.e. either side of Barter Road Beach) have both been identified as important local beaches (EPA 2002). Recorded use of Challenger Beach is an order of magnitude lower than Rockingham Beach (Eliot et al. 2005;

BMT 2018a). It would therefore be expected that use of Barter Road Beach is further below this level.

Public accessibility to the coast within Cockburn Sound has decreased over time with the increasing industrial development of the area. Areas currently accessible for recreational use include West Beach, Challenger Beach, Barter Road Beach, Kwinana Beach, Rockingham Beach and Palm Beach (BMT 2018a).

There is no foreshore reserve along Barter Road Beach, with the land to the low water mark being owned by Water Corporation[8] for industrial development; this beach is within the Kwinana Strategic Industrial Area. This effectively makes the beach private property, however, there has been no formalisation of no-go zones by the Kwinana Town Council and this beach is informally used by public (DAL 2001). It is noted within policy statements of the *Town of Kwinana Town Planning Scheme No. 2* that where shore-crossing of industrial facilities is required within the Cockburn Sound foreshore (including Barter Road Beach), that, where practicable, provision shall be made for the continuity of public access.

Barter Road Beach can be publicly accessed via Riseley Road (access via the end of Barter Road is currently closed-off). Public use of the beach extends north from the Riseley Road access to the Verge Energy canals; use of the southern end of the beach[9] is restricted, with no public access extending south from the Kwinana Bulk Berths.

9.3.3 Study effort

Water Corporation has used the results from the studies outlined in Table 9.3 to support the assessment of potential impacts of the Proposal on coastal processes.

Table 9.3 Coastal processes related studies used to inform the Proposal

Study	Description
PSDP Stage 2 Expansion – Preliminary Coastal Protection Advice (GHD 2018a)	This report presents (i) a high-level literature review relating to coastal processes and risks relevant to the proposed PSDP2 site in Cockburn Sound; and (ii) conceptual protection options for the functional life of the PSDP2 plant.
Marine Pipeline Construction Methodology (GHD 2018b)	Technical memorandum providing information on construction methods and sequence for the offshore pipeline and shore crossing.
Perth Desalination Plant Expansion Flora and Fauna Survey (GHD 2017; Appendix B)	Spring flora and fauna survey of the proposed PSPD2 site (including beach area), to define biological environmental values, including their location, conservation significance and management recommendations.
Other supporting data and documentation	
Recreational Beach Users in the Perth Metropolitan Area (Eliot et al. 2005)	A study on recreational beach use between Singleton and Two Rocks, focused on identifying the adequacy of existing facilities and open space, and an estimate of future demands.

[8] *The area of beach in front of the Kwinana Power Station is owned by Verge Energy.*

[9] *Based on Short's (2006) definition of beach boundaries, the Barter Road Beach extends from northernmost of the shore-parallel breakwaters at James Point to the southern Verge Energy pipeline (see Section 9.3.2).*

Study	Description
The Geomorphology and Sediments of Cockburn Sound (Skene et al. 2005)	This report examines the geomorphology and sediments of Cockburn Sound through the analysis of a suite of sediment grab samples and vibracores as well as existing data in published reports and scientific papers.
Coastal Sediment Cells for the Vlamingh Coast (Stul et al. 2015)	The aim of this report is to identify a hierarchy of sediment cells to assist planning, management, engineering, science and governance of the Vlamingh coast (i.e. between Cape Naturalist and Moore River, Western Australia).
Cockburn Sound-Drivers-Pressures-State-Impacts-Responses, Assessment 2017 (BMT 2018a)	The intent of the report is to provide a comprehensive critical assessment of the current and emerging driving forces and pressures on the Cockburn Sound marine area, the Sound's current condition and trends, impacts and management responses.
Cockburn Sound Coastal Alliance Vulnerability Study: Erosion and inundation hazard assessment report (CZM 2013)	This report is the first stage of the Cockburn Sound Coastal Vulnerability and Flexible Adaptation Pathways Project. This report summarises the outcomes of a coastal vulnerability assessment undertaken for Cockburn Sound, Owen Anchorage and the east coast of Garden Island.
Cockburn Sound Coastal Vulnerability Values and Risk Assessment Study (BMT Oceanica 2014b)	This report is the second stage of the Cockburn Sound Coastal Vulnerability and Flexible Adaptation Pathways Project. This report applies the outcomes of the Stage 1 assessment to identify the cost of risk to the coastal assets and presents a first-pass adaptation approach to managing these coastal risks.

9.4 Potential impacts

9.4.1 Potential construction impacts to coastal processes

Potential cause-effect pathways of impacts of PSDP2 marine and coastal construction works associated on coastal processes are shown in Figure 9.2 and include:

- dredging and shore-crossing activities may result in a disruption to local coastal processes, which may subsequently result in changes to erosion/accretion patterns, and/or an interruption to longshore sediment transport
- construction of shore-crossing involves the removal of dune vegetation, which may result in enhanced erosion
- restricting public use of the beach during construction works, which may result in a reduced public amenity of the area.

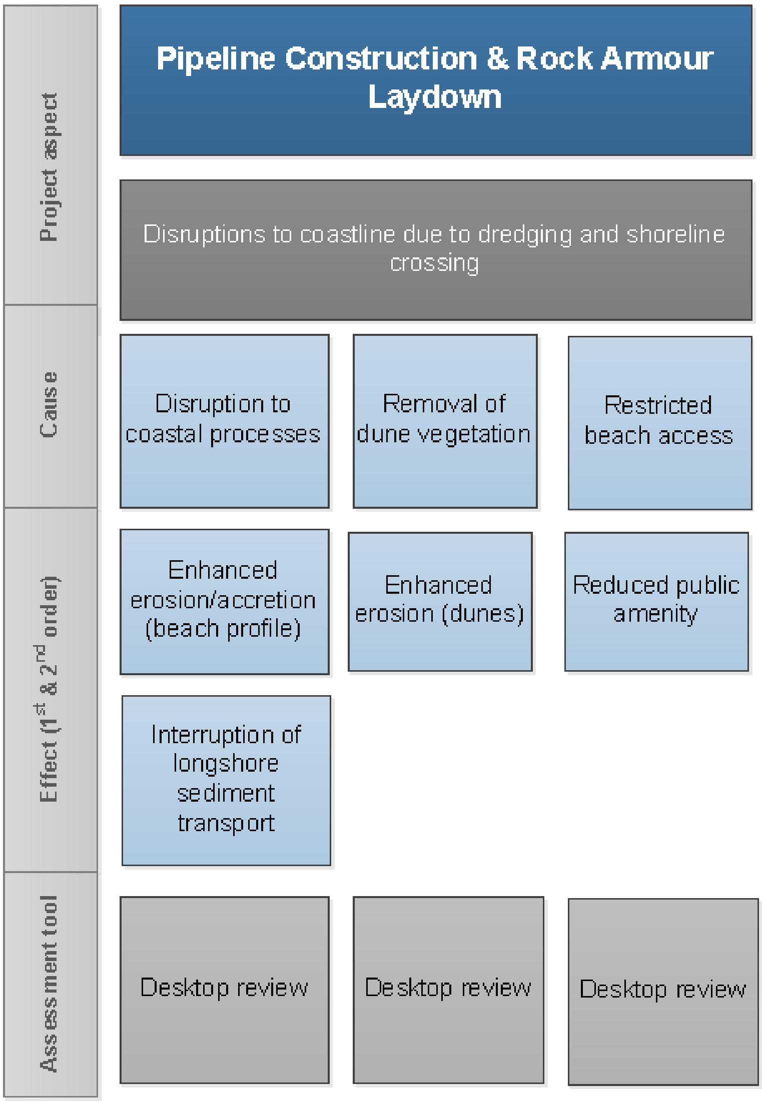


Figure 9.2 Potential impacts to coastal processes, and flow-on effects, associated with PSDP2 marine and coastal construction activities

9.4.2 Potential operational impacts to coastal processes

There are no potential impacts identified from the operation of the PSDP2 on coastal processes and associated environmental values.

9.5 Assessment of impacts

9.5.1 Western Australia Coastal Zone Strategy

To facilitate an assessment of the significant of impacts of the PSDP2 on coastal processes and the associated environmental values, the goals and objectives of the *WA Coastal Zone Strategy* (DPLH 2017) have been used (Table 9.4).

Table 9.4 Goals and objectives of the Western Australia Coastal Zone Strategy

Component (selected)[1]	Goal	Objectives (selected)[2]
Environment	Conserve the State's natural coastal values and assets through sustainable use	• Protect, conserve, enhance and maintain natural coastal values. • Protect and restore foreshores along the coast, estuaries, and their wetlands. • Maintain, restore and manage natural coastal processes where necessary such as sediment transport patterns, erosion/accretion cycles, environmental flows and hydrological cycles. • Integrate coastal zone management with catchment, estuarine and offshore planning and management programs.
Community	Ensure safe public access to the coast and involve the community in coastal planning and management activities	• Facilitate and promote public usage and enjoyment of the coast. • Protect, conserve, enhance and maintain registered heritage sites and places of cultural significance in the coastal zone. • Recognise the native title rights of Aboriginal people in the coastal zone. • Retain the widest possible range of management options for future users of the coast. • Ensure coastal planning and management activities conserve or enhance coastal values and assets (natural and built) to benefit the community and minimise interference with natural coastal processes.
Infrastructure	Ensure the location of facilities and infrastructure in the coastal zone is sustainable and suitable	• Concentrate urban development in and around existing settlements with established infrastructure and services. • Locate and design coastal development, infrastructure and facilities taking into account coastal processes, landform stability, water quality, environmental flows, hydrological cycles, coastal hazards and climate change. • Ensure coastal hazard risk management and adaptation planning for brownfield development (including infill). Locate any development at risk from coastal hazards within a 100-year timeframe on the least vulnerable portion of the site. • Undertake protection works only as a last resort when justified in the public interest to protect high value property and infrastructure – and ensure funding arrangements are based on cost-benefit and user pays principles.

Notes:
1. For economic and governance components and associated objectives, refer to DPLH (2017).
2. For the full suite of objectives, refer to DPLH (2017).

9.5.2 Construction impacts

Disruption to coastal processes

Disruption to coastal processes (short-term)

The construction works associated with the shore-crossing include dredging in the nearshore, excavation and installation of sheet piles through the beach and primary dune, placement of rock armour and backfilling; these works are expected to occur over an 18 month period (Table 3.6). While there are no changes to the key geophysical processes (i.e. wind, waves and currents) predicted to occur as a result of the construction of the PSDP2, the marine construction activities themselves have the potential to directly interrupt longshore sediment transport and/or alter local erosion and accretion patterns.

The temporary installation of the sheet piles through the nearshore and active beach face provides a physical barrier to longshore sediment transport. While longshore sediment transport rates within the vicinity of the Proposal are relatively low, any extended period of construction may result in a sediment accumulation occurring on the updrift side. However, once construction works are completed the beach face and primary dune will be reinstated to pre-construction form, including the smoothing of any accumulated sediment. Given the above, the impact of construction on longshore sediment transport is considered low.

The construction of the offshore trench for the pipeline installation may create a local sediment sink (i.e. act in a similar way to the deep central basin of Cockburn Sound). However, given its temporary nature, and the low rates of sediment movement on the eastern shoal, impact of dredging on sediment transport and erosion/accretion patterns is considered low.

Storage of sediment material during the construction period will occur within the main development footprint, and as such will not influence local coastal processes.

Once installation of the pipelines is complete, the offshore trench will be backfilled to seabed height, and the beach face and primary dune will be reinstated to pre-construction form. Therefore, there will be no long-term or cumulative impact to sediment transport patterns due to the construction of PSDP2.

Disruption to coastal processes (long-term)

The functional life of the PSDP2 is approximately 100-years (GHD 2018a), and therefore falls within the 100-year planning timeframe applicable under the *State Coastal Planning Policy* (WAPC 2013). Coastal vulnerability, hazard assessments and initial adaptation planning have independently been undertaken as part of the Cockburn Sound Coastal Vulnerability and Flexible Adaptation Pathways Project managed by the Cockburn Sound Coastal Alliance (e.g. CZM et al. 2013, BMT Oceanica et al. 2014b, GHD 2016).

The PSPD2 site is within an area identified as being at risk of erosion and inundation over the 100-year planning timeframe. The area is predicted to be more susceptible to erosion compared to inundation due to the height of the primary dune; however, as these processes can occur over different time-scales we note that this susceptibility can change. Initial adaptation planning has identified coastal protection options (e.g. dune stabilisation or installation of revetments) that could be implemented for this section of coast (GHD 2016, 2018a).

The dredging and installation of buried intake and outfall pipes for the PSDP2 is not expected to have any long-term impacts on coastal processes; and therefore, is not expected to alter the long-term local erosion and inundation risk. Similarly, flattening of the secondary dune is not expected to significantly alter this risk as the primary dune is the predominant protection to the identified inundation risk.

Based on available data, and assuming present state (i.e. presence of only existing coastal infrastructure, and assuming no management intervention), it is estimated that the PSDP2 footprint may become at risk by approximately 2040–2050 (GHD 2018a). It is expected that any future coastal zone management within the vicinity of the PSDP2 will be aligned with planning outcomes of the *Cockburn Sound Coastal Vulnerability and Flexible Adaptation Pathways Project*.

Outcome

The temporary impact to local coastal processes by interrupting longshore sediment transport, and changing local erosion and accretion patterns, from the construction works is low given the naturally low rates of sediment movement within the area and the relatively short period of disturbance.

As there is no permanent change to the existing sediment transport mechanisms resulting from the construction of the PSDP2, impacts to the environmental values associated with the coastal processes factor are not considered significant.

The long-term continuity of coastal processes is aligned with objectives of the environment and infrastructure components of the *WA Coastal Zone Strategy* (DPLH 2017; Table 8.3).

Removal of dune vegetation

The construction works associated with shore crossing will involve the temporary removal of both primary dune vegetation and the underlying dune material during the construction period. It is noted that the main development footprint for the Proposal extends into the secondary dune system, and that this area will be permanently cleared.

The removal of primary dune vegetation can be associated with increased aeolian sediment transport. However, since the construction of the shore-crossing also involves the removal of the dune sediment material, this risk of increased sediment transport is effectively removed. The estimates of aeolian transport within Cockburn Sound are also relatively low (MRA 1999), and so any loss that did occur would be considered minor. Given the above, the impact of construction on increased erosion due to dune vegetation removal is considered low.

Once dune rehabilitation works have been completed, it would be expected that aeolian transport would return to its previous rate. Therefore, no long-term or cumulative impact to sediment transport from the removal of dune vegetation is expected from the construction of the PSPD2.

The temporary impact to sediment transport from the removal of primary dune vegetation during the construction works is low, given the immediate dune material will also be removed and areas outside of the shore-crossing footprint will not be disturbed.

As there is no permanent change to the coverage of primary dune vegetation resulting from the construction of the PSDP2, impacts to the environmental values associated with the coastal processes factor are not considered significant.

The long-term continuity of dune vegetation is aligned with objectives of the environment component of the *WA Coastal Zone Strategy* (DPLH 2017; Table 8.3).

Refer also to the assessment 'Flora and Vegetation' in Section 10.

Restricted beach access

Public access to Barter Road Beach will be restricted for approximately 18 months during dredging and shore-crossing construction and/or rehabilitation works for the PSPD2. Restrictions to public access for the full duration of works will be in place to protect public safety and to ensure the safety of construction activities.

Barter Road Beach is not a highly utilised beach for recreational activities but is one of the few beaches within the region that is used for horse exercising. There is another beach, between the Kwinana Grain Jetty and the Kwinana wreck, further south in Cockburn Sound that can also be used for horse exercising; however, this beach has time restrictions on this use (early mornings only). Water Corporation acknowledge that Barter Road Beach is one of the limited locations allowing horse access and has actively engaged with users as part of the stakeholder engagement process (Section 3); where concerns were raised, these have been addressed.

Given the short period of disturbance, and that an alternative location for horse use is available within 10 minutes from the PSDP2 construction site, and the low use of the area for other recreational activities, the impact of construction on public amenity is considered low.

Once construction and rehabilitation works have been completed, access to this area of coast will revert to its current state of informal public access (refer to Section 8.3.3). Therefore, no long-term or cumulative impact to beach access and public amenity is expected from the construction of the PSPD2.

The temporary impact to public amenity from reduced access during the construction works is low, given access to adjacent local beaches is maintained.

As there is no permanent change to the existing state of public access or usage of Barter Road Beach resulting from the construction of the PSDP2, impacts to the environmental values associated with the coastal processes factor are not considered significant.

The long-term continuity of public access is aligned with objectives of the community component of the *WA Coastal Zone Strategy* (DPLH 2017; Table 9.4) and the intent of the *Town of Kwinana Town Planning Scheme No. 2*.

9.5.3 Operational impacts

There are no potential impacts identified from the operation of the PSDP2 on coastal processes and associated environmental values; as such no assessment is required.

9.5.4 Cumulative impacts

There are no long-term potential impacts identified from the construction or operation of the PSDP2 on coastal processes and associated environmental values. As such, there is no requirement for an assessment of cumulative impacts on coastal processes within Cockburn Sound as a result of this Proposal.

9.6 Mitigation

Water Corporation has applied the mitigation hierarchy to the Proposal to ensure coastal processes are maintained so that environmental values are protected in Cockburn Sound. Mitigation measures are summarised in Table 9.5.

Table 9.5 Application of the mitigation hierarchy to potential construction impacts on coastal processes

Impact	Avoid	Minimise	Management and monitoring
Dredging and shore-crossing activities may result in a disruption to local coastal processes, which may subsequently result in changes to erosion/accretion patterns, and/or an interruption to longshore sediment transport	Alternative methods for installation of inlet and outlet pipes were not considered technically feasible (horizontal directional drilling) or economically viable (pipe-jacking).	The use of buried infrastructure minimises any change in sediment transport and erosion/accretion zones. Intake and outfall pipeline sharing a single trench minimises disturbance time and area during construction. Proposed use of a backhoe dredge to minimise turbidity during construction.	Implementation of a Marine Construction EMP.
Construction of shore-crossing involves the removal of dune vegetation, which may result in enhanced erosion	Alternative methods for installation of inlet and outlet pipes were not considered technically feasible (horizontal directional drilling) or economically viable (pipe-jacking).	Design is based on only a temporary disturbance to the primary dune system. Primary dune will be back-filled and revegetated once construction works completed.	Implementation of a Terrestrial Construction EMP.
Restricting public use of the beach during construction works, which may result in a reduced public amenity of the area	The temporary restrictions to public access to Barter Road Beach are unavoidable to maintain public safety and safety of construction activities.	The use of buried infrastructure through the coastal zone minimises the need for any long-term restriction to public access or change in beach usage.	Implementation of a Marine Construction EMP. Stakeholder consultation (including ongoing communications during construction)

9.6.1 Marine Construction Environmental Management Plan

A preliminary register of measurable and/or auditable environmental commitments to manage the environmental impacts associated with marine construction activities are provided in Table 9.6. Environmental monitoring and management will be outlined in further detail in a Marine CEMP to be finalised prior to the commencement of construction works.

Table 9.6 Relevant environmental objectives, performance indicators and proposed measurement criteria to maintain coastal processes (marine)

Environmental objective	Performance criteria[1]	Standards[2]	Performance indicators[3]
To maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected	No persistent change in local sediment transport	Prepare and implement a coastal processes SAP, including visual surveillance of beach morphology	Visual (ground and/or aerial) surveillance of beach morphology and sediment accumulation pre-, during, and post-construction
	No persistent change in public accessibility of coast	Remove temporary closure of beach	Inspection/audit that beach is re-opened following completion of construction works.

Notes:
1. Performance criteria = the performance criteria are the proposal-specific desired state for an environmental factor/s that an organisation sets out to achieve from the implementation of outcome-based provisions
2. Standards = can include company standards, regulatory requirements, and recognised Australian and International Standards
3. Performance indicators = measurable/auditable outcomes that ensure that the company's environmental performance
4. Construction = monitoring and management during the Project

9.6.2 Terrestrial Construction Environmental Management Plan

A preliminary register of measurable and/or auditable environmental commitments to manage the environmental impacts associated with construction activities are provided in Table 9.7. Environmental monitoring and management will be outlined in further detail in a Terrestrial CEMP to be finalised prior to the commencement of construction works.

Table 9.7 Relevant environmental objectives, performance indicators and proposed measurement criteria to maintain coastal processes (terrestrial)

Environmental objective	Performance criteria[1]	Standards[2]	Performance indicators[3]
To maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected	No persistent change in shape of the beach and primary dune profile	Procedures for stripping and stockpiling of dune and beach material, and subsequent implementation of dune and beach profile grading	Pre- and post-construction beach profile surveys
	No persistent change in type and coverage of dune vegetation	Procedures for removal, stockpiling and reinstatement of dune vegetation. Procedures for dune stabilisation during revegetation.	Pre- and post-construction flora and vegetation surveys

Notes:
1. Performance criteria = the performance criteria are the proposal-specific desired state for an environmental factor/s that an organisation sets out to achieve from the implementation of outcome-based provisions

2. Standards = can include company standards, regulatory requirements, and recognised Australian and International Standards
3. Performance indicators = measurable/auditable outcomes that ensure that the company's environmental performance
4. Construction = monitoring and management during the Project

9.7 Predicted outcome

The Proposal is likely to result in temporary disturbances to local nearshore sediment transport, coverage of dune vegetation and public beach access; however, no long-term change to any of these elements is expected to occur.

After the application of mitigation measures as described in Section 9.6, the EPA objective for coastal processes (i.e. to maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected) is expected to be met.

There is no significant residual impact to coastal processes predicted to occur from the construction and operation of the Proposal; and therefore, no subsequent consideration of offsets for this environmental factor are required.

10. Other Environmental Factors or Matters

The Water Corporation has identified the following other environmental factors or matters relevant to the Proposal:

- flora and vegetation
- inland waters
- landforms
- air quality
- social surroundings
- human health.

Due to the low level of impact, application of industry standard controls and other regulatory mechanisms (Table 10.1), these factors are not expected to be required to be assessed in detail by the EPA.

Table 10.1 Other values surrounding the Proposal

Element	Description
Flora and Vegetation	
EPA objective	To protect flora and vegetation so that biological diversity and ecological integrity are maintained.
Policy and guidance	EPA Environmental Factor Guideline – Flora and Vegetation (EPA 2016i).
Potential impacts	Construction of the Proposal will result in the loss and fragmentation of native vegetation through clearing. Movement and stockpiling of soil may lead to the spread of declared pests and weed species.
Mitigation	Avoid:
	The native vegetation in the DAF has been subject to high levels of disturbance and the condition of the vegetation has been significantly altered with much of the understorey dominated by introduced species.
	Minimise:
	The loss of 7.8 ha of native vegetation represents a small proportion (less than 0.1 %) of the broad vegetation types mapped in the Swan Coastal Plain and Perth bioregions. A high proportion of the vegetation that will be permanently lost (i.e. areas that will not be revegetated) is highly disturbed and in a degraded or completely degraded condition. Areas of the primary dune system that will be cleared for marine infrastructure will be revegetated to pre-construction conditions through the implementation of the TCEMF. Declared pest species such as Bitou bush will also be managed through the implementing of the TCEMF.
Outcomes	Residual impact:
	Based on the scale and nature of impacts, the location away from sensitive areas, and the mitigation to be implemented, the Proposal is not expected to result in a significant impact on flora and vegetation, and biological diversity and ecological integrity will be maintained. Accordingly, it is expected that the EPA's objective for flora and vegetation will be met.
Inland Waters	
EPA objective	To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Policy and guidance	EPA Factor Guideline – Inland Waters (EPA 2018d)
Potential impacts	No wetlands occur within the Quindalup Dune system. Therefore, the PSDP site does not intersect or occur near identified wetlands. The closest surface water feature to the Proposal is the Conservation Category Wetland - Long Swamp, which is approximately 2.7 km to the north east. The deep excavation of the Wet Well for the seawater pump station will require dewatering. Groundwater levels are up to +0.6 mAHD, with the pump station base at a depth of approximately -6.0 mAHD. Therefore, part of the Wet Well will be up to 7 m below ground water level. Any dewatering would require a draw down at the pump station of up to 8 m resulting in a radius of draw down up to a kilometre, extending into the ocean and potentially impacting vegetation. Acid Sulfate Soils (ASS) also have the potential to affect soil quality as dewatering for the Wet Well is carried out.
Mitigation	Avoid:
	The Proposal will avoid any impacts on wetlands or surface water features. Risk mapping identifies the site has no known risk of ASS within 3 m of the surface. Generally, potential ASS material forms in organic rich waterlogged environments low in oxygen. Typically, organic material is largely removed from nearshore environments due to wave action and is not often found in high energy environments.
	Minimise:
	Ground water flow into the Wet Well and radius of influence will be minimised by using diaphragm wall methods to build the outer walls and to cut off the ground water flow around the perimeter of the excavation against the underlying Osborne rock formation. Dewatering works will require treatment and management. A Dewatering Management Plan will be developed which will form part of the TCEMF. Extracted water will be discharged on site via infiltration within cleared areas. Infiltration of water will be within a defined area (may require earth bunding) and will be managed through the Dewatering Management Plan. Effects of potential ASS will be investigated and managed as part of the Dewatering Management Plan and if required monitoring of surrounding vegetation health will be conducted.
Outcomes	Residual impact:
	Significant impacts to inland waters from construction of the Proposal are considered unlikely to occur. Accordingly, it is expected that the EPA's objective for inland waters will be met.

Element	Description
Landforms	
EPA objective	To maintain the variety and integrity of significant physical landforms so that environmental values are protected
Policy and guidance	EPA Factor Guideline – Landforms (EPA 2018c).
Potential impacts	Construction of the marine pipeline will result in part of the primary dune system adjacent to the site being temporarily removed. The dune formation provides coastal protection from erosion and storm surge events.
Mitigation	Avoid:
	Most of the primary dune system will be retained, with the PSDP2 constructed in the secondary dune system.
	Minimise:
	Existing features of the primary dune system that will be disturbed for marine infrastructure will be reinstated and rehabilitated to pre-construction conditions through the implementation of the TCEMF. Dune stabilisation, protection and revegetation of the primary dune system will occur during construction and operation of the Proposal. Any excess cut volume of dune sand will be retained on site to build and enhance the natural beach and dune system in front of the plant (if required). This will increase the natural protective buffer in front of the plant which will increase the natural buffer to erosion.
Outcomes	Residual impact:
	Dune landforms are unlikely to be significantly impacted by construction activities. Accordingly, it is expected that the EPA's objective for landforms will be met.
Social Surroundings - Terrestrial	
EPA objective	To protect social surroundings from significant harm.
Policy and guidance	EPA Factor Guideline – Social Surroundings (EPA 2016j)
Potential impacts	Construction of PSDP2 may impact surrounding recreational/beach areas through noise and dust and impacts to visual amenity. Operation of the PSDP2 may have noise and odour impacts. Construction of PSDP2 may impact Aboriginal heritage values. No non-Aboriginal heritage values are known to occur within the PSDP2 site.
Mitigation	Avoid:
	A search of the Aboriginal Sites and Places Register revealed there are no previously recorded registered Aboriginal sites located in the Proposal area. No new ethnographic sites of significance were identified through consultation with the relevant Native Title Claim group.
	Minimise:
	The proposal is in the established Kwinana Industrial Area (KIA) which is home to many highly visible heavy industrial facilities and is subject to elevated noise levels. Noise levels are regulated under the Environmental Protection (Noise) Regulations 1997, which contains specific provisions for the KIA. Construction noise and dust will be managed through the TCEMF and any impacts to beach users will be temporary and transient. Significant noise generating equipment associated with the operation of the plant will be located within noise attenuating buildings/enclosures. Potentially odour generating putrescible waste removed from the seawater intake screen will be thickened, dewatered and transferred via enclosed conveyor to enclosed bins to minimise odour. Bins will be removed from site at an appropriate frequency to prevent significant odour generation. Residential areas are over 3.5 km from the site with sufficient separation distance to mitigate impacts. Temporary residences at Challenger Beach are 2 km to the north, but are adjacent to an existing heavy industrial area. During construction, any previously unidentified Aboriginal artefacts or scatters uncovered during excavation and earthworks activities will be recorded and managed through the TCEMF.
Outcomes	Residual impact:
	Based on the location of PSDP2 in the KIA, the separation distance to residential areas, and the implementation of the TCEMF it is expected that the EPA's objective for social surroundings will be met.

Element	Description
Social Surroundings - Marine	
EPA objective	To protect social surroundings from significant harm.
Policy and guidance	EPA Factor Guideline – Social Surroundings (EPA 2016j)
Potential impacts	Commercial and recreational fisheries Cockburn Sound supports substantial commercial fishing activities and an aquaculture industry (DOF 2008). Some of the commercially important species known to frequent different habitats within Cockburn Sound include: • open (deep) water: pink snapper, pilchards and bonito • shallow water with sandy seabed: whiting, juvenile king prawns, pilchards, blue sprat and • whitebait • seagrass meadows: octopus, leatherjackets, wrasse, crabs and herring • jetties and groynes: herring, yellowtail scad, trevally, samson fish and mussels. Three lease areas for mussel aquaculture (Mytilus edulis) exist within Cockburn Sound: • north Garden Island (currently not active) • Kwinana Grain Jetty • Southern Flats. The main mussel farming area is in southern Cockburn Sound (east of Southern Flats), where conditions are sheltered and the nutrient and planktonic food levels are sufficient to promote good growth rates. The industry in Cockburn Sound is limited by the availability of protected and productive waters, and increased use of the Sound by proposed developments may increase resource-sharing issues (Lawrence & How 2007). Marine safety Commercial shipping and recreational boating is very common in Cockburn Sound (BMT 2018a). The project area lies immediately adjacent to an operating shipping terminal, managed by Fremantle Ports. While recreational boating occurs across the whole of Cockburn Sound, most vessels typically concentrate in southern areas such as Mangles Bay, where many of the boat launching and mooring facilities are located.
Mitigation	Avoid:
	Based on hydrodynamic modelling (Section 6.5.2), it is anticipated that: • the discharge of brine effluent will result in minor changes in DO concentrations from background concentrations, only on occasions, and not in a range that is likely to cause lethal impacts • changes in ambient salinity will occur, but that are well below known tolerance thresholds for fishes and benthic macroinvertebrates • predicted temporary, ambient levels of TSS generated through dredging will not be sufficient to cause either sublethal or lethal impacts to any fishes that are presently commercially harvested in Cockburn Sound (Section 8.5.2) • further, as shown in in Section 7.5.1, the maximum extent of the dredging plume is highly unlikely to extend to the aquaculture zones in Cockburn Sound, and therefore, no impacts are expected. The potential maritime safety risks associated with increased vessel traffic during dredging and backfill works are negligible, particularly given the works will take place nearby Fremantle Ports managed water and any recreational vessels can easily avoid the area and/or the slow-moving vessels/plant. However, a temporary notice to mariners will be issued by the Fremantle Ports Harbour Master to inform the general public on the project activities and location.
	Minimise:
	The Marine CEMP will provide guidance on management to restrict the dispersion of sediment plumes.
Outcomes	Residual impact:
	It is expected that the EPA's objective for social surroundings will be met.
Air Quality (Greenhouse Gas Emissions)	
EPA objective	To maintain air quality and minimise emissions so that environmental values are protected.
Policy and guidance	EPA Factor Guideline – Air Quality (EPA 2016a)

Element	Description
Potential impacts	Due to the criticality of the infrastructure energy is required to be sought from a reliable source and will be supplied from the Western Power grid. The proposed desalination plant's emissions are categorised as indirect 'Scope 2' emissions 'GHG emissions released to the atmosphere from the indirect consumption of an energy commodity'. Estimated power consumption (kWh) includes: • 25 GL/a: 89,806,800 • 50GL/a: 173,422,800 Estimated indirect greenhouse gas emissions per year for each proposed stage include: • 25 GL/a: 62,865 • 50 GL/a: 121,396 Applying the relevant management framework for Scope 2 emissions, Water Corporation has incorporated both avoidance and continuous improvement in the Proposal design as follows.
Mitigation	Avoiding emissions through best practice design:
	The following outlines the key considerations incorporated into the PSDP2 concept design: • energy efficiency through Energy Recovery Devices: Reverse Osmosis uses high pressure pumps to generate high pressure to overcome the osmotic pressure when desalinating seawater. Energy Recovery Devices are included in the design to recover energy from the concentrate stream (brine) and apply this recovered energy to the feed stream to the RO process • energy efficiency through optimised plant recovery: plant design, particularly in the RO process configuration and membrane selection, will aim to optimise overall plant recovery and reduce the volume of seawater that is pumped and pre-treated at the plant, which saves energy • the design incorporates gravity intake and outfall tunnels which avoids the requirement for additional energy use in the provision of raw feed water and/or discharge of brine • energy efficiency through plant location: the location of PSDP2 immediately adjacent to the coast and the proposed site layout limits the distance and elevation that pumped seawater flows travel through the desalination process, which minimises energy requirements • energy efficiency through pipeline duplication: the duplication of sections of trunk pipeline downstream of PSDP2 and the existing plant reduces energy requirements for bulk water transfer from these sources into the IWSS network (i.e. connecting into Thomsons Reservoir).
	Continuous improvement to reduce emissions over project life:
	A key aspect of the operation and maintenance planning for Water Corporation's desalination assets is to optimise energy efficiency and thereby reduce power consumption and the associated indirect scope 2 greenhouse gas emissions, the following summarises the key considerations for PSDP2; • energy efficiency in plant operation: specific energy consumption for the total process will be monitored and Key Performance Indicators set for energy efficiency, which will trigger corrective actions (such as membrane replacement or pump overhauls) to ensure that the plant continues to operate at target energy consumption levels or better • energy efficiency through advances in membrane technology: higher efficiency seawater RO membranes are progressively being released to the market and will be considered for future membrane replacements to improve energy efficiency • energy efficiency through membrane process maintenance: as membranes are fouled and/or scaled during normal operation, the hydraulic efficiency and performance of the membrane can deteriorate which in turn impacts energy efficiency – a common operating intervention is a regular cycle of chemical cleaning and flushing to maintain membrane performance.
	Reporting of emissions:
	As a requirement of the *National Greenhouse and Energy Reporting Act 2007* (NGER Act) Water Corporation reports its annual greenhouse gas emissions, energy consumption and production to the Clean Energy Regulator. All GHG emissions are reported using the emission factors and methodologies as set out under the NGER Technical Guidelines.
Outcomes	Residual impact:
	Significant impacts to air quality (greenhouse gas emissions) from the operation of the Proposal are unlikely to occur.
Human Health	
EPA objective	To protect human health from significant harm.
Policy and guidance	EPA Environmental Factor - Human Health (EPA 2016k).
Potential impacts	Chemical spills during construction or operation may result in significant harm to the health of the operators of the Proposal or recreational users surrounding the Proposal.

Element	Description
Mitigation	Avoid:
	All bulk storage of liquid chemicals will be located on bunded hardstands with fully self-contained storage for spilt liquid in accordance with AS3780.
	Minimise:
	All chemicals will be stored in accordance with their MSDS in vessels designed to contain the material in them and minimise the effects of the corrosive coastal environment. The TCEMF will prescribe chemical spill procedures, including definition of roles and responsibilities and the location of spill kits.
Outcomes	Residual Impact:
	Chemical spills are likely to be contained on hardstand surfaces and the EMFs will contain procedures for clean-up and notification. Significant impacts are unlikely to occur because of chemical spills.

11. Holistic Impact Assessment

The EIA process needs to consider the connections and interactions between parts of the environment to inform a holistic view of impacts to the whole environment. This requires consideration of the impacts of the Proposal in a regional context as well as at the local scale.

Due to a combination of drying climate and increasing demand, Water Corporation needs to be prepared to enable the supply of sufficient water to meet Perth (and surrounds) long-term requirements. The PSDP2 Proposal, which forms part of Water Corporation's broader IWSS, will in part, help reduce the projected drinking water supply gap and increase the supply capacity of the IWSS

In a regional context, the Proposal is one of two desalination plants discharging brine effluent into Cockburn Sound, while a third major desalination plant (SSDP) exists a further 110 km south of Cockburn Sound, discharging into open ocean waters. The Cockburn Sound shoreline is the most modified coastal system in WA and now supports major recreational, commercial, defence and industrial areas. While the considerable development that has taken place has led to a history of nutrient pollution, which contributed to significant losses of seagrasses between the early 1960s and early 2000s, following concerted effort by industry, government and the community, water quality in the Sound has now dramatically improved to an extent that environmental guidelines are only rarely exceeded, and seagrass loss has stabilised.

The environmental studies commissioned for this Proposal have considered and assessed potential Proposal impacts at a local and regional scale, as well as cumulative impacts of the Proposal in combination with other industrial discharges into Cockburn Sound. The results of these studies have informed the Proposal impact assessment and development of mitigation measures.

Table 11.1 provides a discussion of the predicted outcomes in relation to the environmental principles of the EP Act.

Table 11.2 provides a summary of the impact assessment and predicted outcomes of the Proposal in relation to the EPA's objectives for each factor.

Water Corporation considers the potential impacts for the preliminary key environmental factors can be appropriately managed through the implementation of specific mitigation measures. Management plans applicable to the implementation of this Proposal will include:

- Marine Construction Environmental Management Plan
- Marine Operation Environmental Management Plan
- Terrestrial Construction Environmental Management Plan

Table 11.1 Environmental principles and Proposal predicted outcomes

Principle	Predicted outcomes
The precautionary principle *Where there are threats of serious irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.* *In the application of the precautionary principle, decisions should be guided by:* *careful evaluation to avoid, where practicable, serious or irreversible damage to the environment; and* *an assessment of the risk-weighted consequences of various options.* *The principle of intergenerational equity* *The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.* *The principle of the conservation of biological diversity and ecological integrity* *Conservation of biological diversity and ecological integration should be a fundamental consideration.*	The Proposal will require vegetation clearing of up to 7.8 ha within a development envelope of 12.8 ha. Terrestrial vegetation in the study area, and regionally, have been extensively surveyed and are well understood. No conservation significant flora are expected to be present, due to the composition and condition of the vegetation within the proposed PSDP2 site. The Proposal lies within the Drummond Botanical Subdistrict of the Southwest Botanical Province and contains two vegetation complexes within the development area (Cottesloe Complex and Quindalup Complex), both of which have greater than 30% of their pre-European extents remaining on the Swan Coastal Plain. Clearing of vegetation for the construction of PSDP2 is not expected to impact regional flora or vegetation values. The study area has been subject to ongoing marine quality monitoring for many years and is very well understood. While the marine quality in the study area has historically been poor, significant effort by government and industry in the past two decades has resulted in considerable improvements and it is now considered good. Three-dimensional hydrodynamic modelling was undertaken to determine effects on marine quality arising from the Proposal (brine effluent discharges). All key physico-chemical (DO, salinity, temperature) and chemical (RO cleaning agents) stressors were predicted to be maintained within environmental quality standards, and EPA objectives for marine quality are predicted to be met. The Proposal will result in the direct loss of 6.29 ha of unvegetated marine sediments to enable construction of a seawater intake and diffuser. The broader area in which dredging is to occur has a previous history of disturbance and has not supported significant marine flora or fauna communities for several decades. While the dredge plume is anticipated to extend to nearby seagrasses, impacts to marine quality (turbidity) are predicted to be temporary and below levels that are known to cause impacts to seagrasses. The potential direct (osmotic stress and toxicity) and indirect effects (declines in DO) of desalination discharges on benthic invertebrate communities were also examined and determined to be inconsequential. Most conservation significant marine fauna identified during project scoping are known to occasionally traverse the broader study area during migration and few are permanent residents or solely rely on habitat in the project area. Permanent residents in Cockburn Sound include little penguins, sea-lions, dolphins and marine fishes. An assessment of potential ecological consequences of exposure to desalination discharges was undertaken based on known tolerance thresholds to elevated salinities and low DO. The outcome of this assessment demonstrated that the changes to marine quality resulting from the Proposal are highly unlikely to case ambient marine quality to exceed known tolerance thresholds, and therefore, EPA's objective for marine fauna is expected to be met. The Proposal is likely to result in temporary disturbances to local nearshore sediment transport, coverage of dune vegetation and public beach access; however, no long-term change to any of these elements is expected to occur. There is no significant residual impact to coastal processes predicted to occur from the construction and operation of the Proposal and therefore EPA objects for coastal processes are expected to be maintained. The ERD demonstrates that construction and operation of the PSDP2 desalination plant will not have a significant impact at either a local or regional scale, through the implementation of appropriate mitigation measures.
Improved valuation, pricing and incentive mechanisms *Environmental factors should be included in the valuation of assets and services.* *The polluter pays principle – those who generate pollution and waste should bear the cost of containment, avoidance or abatement.* *The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste.* *Environmental goals, having been established, should be pursued in the most cost-effective way, by establishing incentive structures, including market mechanisms, which benefit and/or minimise costs to develop their own solutions and responses to environmental problems.*	The Proponent accepts that costs for environmental mitigation and management are part of the overall Proposal costs. This includes identified rehabilitation and/or residual impact management actions as addressed within the construction and operations environmental management plans. The Proponent considers that the Proposal meets the principle of improved valuation, pricing and incentive mechanisms.
The principle of waste minimisation *All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.*	The Proposal's approach to waste is consistent with the waste management (avoid, recover, disposal) principles. The key ongoing waste item for the Proposal is the discharge of brine effluent to Cockburn Sound. The mitigation hierarchy has been applied to this waste stream to reduce the impact of this discharge.

Principle	Predicted outcomes
	Waste management for the Proposal is addressed within the relevant construction and operations environmental management plans. This also includes consideration of reusing natural materials (e.g. excavated dune sediments) where practicable. The Proponent considers that the Proposal meets the principle of waste minimisation.

Table 11.2 Summary of environmental assessment for key environmental factors

Context	Potential impact(s)	Management and mitigation	Predicted outcomes
Marine quality	**EPA objective:** *to maintain the quality of water, sediment and biota so that environmental values are protected.*		
Cockburn Sound is a unique environment which undergoes natural changes in water quality associated with seasons, daily weather patterns, temporal currents, rainfall and biological events. Historically, nutrient discharges, contaminated land and groundwater inputs and coastal modifications have negatively influenced Cockburn Sound's marine environment leading to declines in marine quality. However, following concerted effort by government, industry and the community over the past two decades, marine water and sediment quality in Cockburn Sound is now considered acceptable when compared against relevant guidelines. The Cockburn Sound SEP establishes five environmental values for Cockburn Sound, all of which are relevant to the factor marine quality and this project: • ecosystem health • fishing and aquaculture • recreation and aesthetics • cultural and spiritual • industrial water supply.	*During construction:* • dredging of the seabed and laydown of rock armour • release of toxicants to the water column due to disturbance of sediments • short-term (3–4 months) flushing of the desalination outlets and intakes during commissioning to remove debris, including grouting materials. Some of the materials are potentially acidic resulting in a low pH discharge. *During operation:* • discharges of brine effluent can potentially enhance the strength of stratification and in turn, promote reduced DO • changes to marine salinity (osmotic stress) • elevated return water temperature (temperature stress) • release of toxicants in brine effluent used in the RO process.	Implementation of a CEMP during construction works Construction management to minimise turbidity and sedimentation will include: • use of a backhoe dredge, to reduce generation of TSS • containment of turbidity from the rest of construction use of silt curtain(s). Implementation of a Sediment Quality SAP in advance of dredging activities to update marine quality within the dredge footprint. Implementation of a MEMP to ensure compliance with EQC defined in EPA (2017) within HEPA and MEPA. Detailed management procedures for brine effluent discharges, including: • on-going real-time salinity monitoring with Cockburn Sound • control of brine effluent discharges at PSDP2 plant.	*Outcome(s):* During marine construction works, the Proposal is likely to result in temporary disturbances to water quality by elevating TSS, however, no long-term change is expected. There is not expected to be any impacts (contamination) to marine quality associated with disturbance of sediments through dredging, or during plant commissioning. During plant operations, the Proposal has the potential to slightly enhance the strength of natural patterns in stratification in northern areas of the deep basin, which in turn, may lead to slight reductions (2-3%) in DO relative to background concentrations, on occasions. Similar magnitude differences (relative to background concentrations) were predicted during low DO events, which are prompted by natural climatic events. Such events may lead to EQS being exceeded. An envelope drawn around each seasonal representation to compile a LEPA around both PSDP1 and PSDP2, consistent with the approach in EPA (2016d) has been proposed to manage the small area over which a moderate level of ecological protection cannot be maintained for salinity (within 100 m of each diffuser). There are not predicted to be any impacts on marine water temperatures because of the Proposal. The comparatively low volumes of chemicals relative to the discharge will be efficiently diluted in the waste stream and further diluted after discharge. *Assessment against EPA objective:* After the application of mitigation measures, the EPA objective for marine quality is expected to be met.
Benthic communities and habitats	**EPA objective:** *to protect benthic communities and habitats so that biological diversity and ecological integrity are maintained.*		
Seagrasses are the dominant benthic primary producer of Cockburn Sound in terms of production and are mainly comprised of species from the genera *Posidonia* and *Amphibolis*. Historically (pre-1950s), Cockburn Sound supported large seagrass meadows that occupied ~4000 ha and covered most of the seabed to depths of 10 m. The extent of seagrass meadows in Cockburn Sound declined severely during the late 1960s and early 1970s due to poor	*During construction:* • direct loss of benthic habitat in the diffuser pipeline corridor due to dredging and rock armour laydown • periods of elevated TSS and reduced light during dredging activities, which in turn may lead to loss of benthic primary producers • release of toxicants to the water column due to disturbance of sediments during dredging	Implementation of a CEMP, which include construction management to minimise turbidity and sedimentation (described above). Implementation of a MEMP which will include management to minimise impacts associated with stressor effects on benthic invertebrate communities.	*Outcome(s):* The construction of the Proposal is unlikely to result in the loss of any BCH. There is no known seagrass that occurs in the dredge footprint, and indirect effects of turbidity on seagrasses are not expected to result in either sublethal or lethal impacts. While it was determined that the operation of the Proposal may have a minor negative effect on DO

Context	Potential impact(s)	Management and mitigation	Predicted outcomes
water quality. However, since the 1980s, water quality conditions have improved considerably, and seagrass distribution has stabilised. The most recent estimate of seagrass extent in the assessment area is ~860 ha Benthic macrofauna are an important component of marine and coastal ecosystems of Cockburn Sound. Studies have shown that over the last 40 years, there have been marked decadal changes in the benthic macrofauna communities between the 1970s and recent years. Differences between times include shifts in species abundances and distribution, as well as community indices such as species diversity. It is probable that modifications to the benthic marine environment, at least in part, explain these shifts	• release of toxicants to water column during PSDP2 plant commissioning. *During operation:* • discharges of brine effluent can potentially enhance the strength of stratification and in turn, promote reduced DO leading loss of fauna and fauna • changes to marine salinity can induce osmotic stress • elevated return water temperature can induce temperature stress • release of toxicants in brine effluent used in the RO process can contaminate marine organisms.		concentrations and salinity at times, differences from background concentrations were predicted to be minor and within the known physiological tolerances of BCH in the project area. *Assessment against EPA objective:* After the application of mitigation measures, the EPA objective for BCH is expected to be met.
Marine fauna	**EPA objective:** *to protect marine fauna so that biological diversity and ecological integrity are maintained.*		
Cockburn Sound supports a wide range of fauna and has significant ecological value because of its utilisation by dolphins, a large range of seabirds, protected migratory birds, and little penguins. The whole of Cockburn Sound is considered significant as a fish nursery/habitat. About 130 species of fish and 14 large crustacean and mollusc species are estimated to exist in Cockburn Sound. While there are 92 Marine Species, 49 Threatened and 58 Migratory species that are listed under the EPBC Act and which may occur near-by the proposed project area, most listed species are not permanent residents and only pass through/over/near the Project the area on occasions, for example during migration, as the area does typically not encompass waters or habitats that are critical to their survival (Bamford 2011 TSSC 2015, 2016, DoEE 2018 x,x).	*During construction:* • dredging of the seabed and rock armour laydown may lead to periods of increased turbidity, elevated TSS, and reduced light during dredging activities, which in turn may lead to: ○ impacts to benthic fisheries and aquaculture ○ loss of benthic communities and associated marine fauna habitat ○ reduction in water quality • presence of construction vessels and activities generating underwater noise which may lead to: ○ disruption to marine fauna migratory or foraging activities ○ changes in marine fauna behaviour • vessel strikes that may cause marine fauna injuries or displacement • dredging plant and construction vessels impacting local biodiversity through introduction of non-indigenous marine species (introduced marine species; IMS) to the area. *During operation:* • intake of feed water for desalination, which may lead to: ○ entrainment of zooplankton/larvae ○ entrainment of resident fauna • release of brine into Cockburn Sound, which may lead to: ○ decreasing water quality through stratification, salinity, temperature or chemicals loss of benthic communities and associated marine fauna habitat.	Construction management to minimise turbidity and sedimentation will include: • the short duration and the design of the dredging will minimise impact on marine fauna communities • use of a backhoe dredge, to reduce generation of TSS during dredging and backfill activities • containment of turbidity from the rest of construction through use of silt curtain(s) • induction of all construction workers about correct waste management procedures • implementing strict environmental management standards for the Proposal during construction, including handling procedures for hazardous substances. Sheet piling used to temporarily maintain onshore trench integrity during construction will be installed using vibratory hammers, which minimise harmful underwater noise. The dredge contractor will ensure that: • any equipment or vessels are either new, or have been thoroughly cleaned, dried for >24 hours, and inspected prior to being deployed • report the presence of any suspected marine pests to FishWatch (1800 815 507).	*Outcome(s):* During construction of the Proposal there will be some temporary elevated TSS and noise associated with dredging. Effects on marine fauna, including fish larvae, are expected to be minimal and will be managed under an appropriate CEMP that includes fauna observation protocols for whales, dolphins, little penguins, sea lions and turtles during dredging. While it was determined that the operation of the Proposal may have a minor negative effect on marine quality (DO concentrations and salinity) at times, differences from background concentrations were predicted to be minor and well within the known physiological tolerances of fish, in the project area. The proportion of pink snapper larvae entrainment was determined to be negligible relative to the total number of eggs that are released each year, and no effects on snapper stocks are predicted. Snapper larvae can be used as a proxy for entrainment of larvae of other marine fauna; it therefore is assumed that the overall potential of adverse impacts due to entrainment of marine larvae, is negligible. *Assessment against EPA objective:* After the application of mitigation measures, the EPA objective for marine fauna is expected to be met.
Coastal processes	**EPA objective:** to maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected.		
The coastal zone in Cockburn Sound is highly valued for its aesthetic, cultural, social and recreational values; as well as being important for commercial infrastructure and facilities.	*During construction:* • dredging and shore-crossing activities may result in a disruption to local coastal processes, which may subsequently result in changes to erosion/accretion	Implementation of a Marine CEMP The use of buried infrastructure minimises any change in sediment transport and erosion/accretion zones.	*Outcome(s):* The Proposal is likely to result in temporary disturbances to local nearshore sediment transport, coverage of dune vegetation and public beach access; however, no long-

Context	Potential impact(s)	Management and mitigation	Predicted outcomes
The beach is in the immediate area of the PSDP2 Proposal is classified as a low-energy, wave-dominated, reflective system. This beach receives slightly higher swell wave energy than James Point (i.e. the beach to the south), and typically maintains a narrow, attached bar. The beach is backed by a dune system of varied width. There is no foreshore reserve along Barter Road Beach, with the land to the low water mark owned by Water Corporation; this beach is within the Kwinana Strategic Industrial Area. This effectively makes the beach private property, however, there has been no formalisation of no-go zones by the Kwinana Town Council and this beach is informally used by public.	patterns, and/or an interruption to longshore sediment transport • construction of shore-crossing involves the removal of dune vegetation, which may result in enhanced erosion • restricting public use of the beach during construction works, which may result in a reduced public amenity of the area.	Design is based on only a temporary disturbance to the primary dune system. Primary dune will be back-filled and revegetated once construction works completed. The use of buried infrastructure through the coastal zone minimises the need for any long-term restriction to public access or change in beach usage	term change to any of these elements is expected to occur. *Assessment against EPA objective:* After the application of mitigation, the EPA objective for coastal processes is expected to be met.

12. Conclusion

This document has provided information about the existing environment and potential impacts of implementation of the Proposal, in a local and regional context. This ERD explains Water Corporation's management approach to potential impacts for each of the EPA's preliminary key environmental factors identified for the Proposal.

Water Corporation has had due regard for the principles of ecological sustainable development of the EP Act and relevant EPA and other environmental guidelines.

Water Corporation has extensive data sets and proven current management practises on which the EIAs were based, resulting in a high level of confidence in impact predictions. Inherent impacts have been assessed and application of the mitigation hierarchy applied to reduce potential impacts to a level Water Corporation considers reasonable.

The EIA undertaken by Water Corporation for this Proposal has concluded that for all factors outlined in this ERD, the EPA objectives can be met and the residual impacts to the environment resulting from the Proposal are not significant. Water Corporation considers that the information and assessment presented in this ERD adequately identifies and addresses environmental impacts relevant to the Proposal and is suitable to enable the EPA to undertake its EIA of the Proposal.

13. References

ABC Rural (2017) WA mussel producer laments lack of nutrients as snapper eats his crop in Cockburn Sound. ABC News Rural, Western Australia. Available at <http://www.abc.net.au/news/rural/2017-01-27/hungry-snapper-eat-musselcrop/8207120> [Accessed June 2017]

Ahmed M, Ayub M (1999) Survival rates of the juveniles of the penaeid shrimp *Metapenaeus stebbingi* in different salinities. Pakistan Journal of Zoology 31:205–206

Antenucci JP, Mills R, Botelho DA (2009) Kwinana Quays: Hydrodynamic Modelling of Cockburn Sound. Prepared for Oceanica Consulting Pty Ltd (acting for Fremantle Ports) by University of Western Australia Centre for Water Research, Perth Western Australia, May 2009

ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at: <www.waterquality.gov.au/anz-guiedlines> [Accessed October 2018]

Bailey H, Senior B, Simmons D, Rusin J, Picken G, Thompson PM (2010) Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Marine Pollution Bulletin 60:888–897

Bamford M (2011) Mangles Bay Marina Project, Rockingham: Significance for Migratory Birds. Prepared by Bamford Consulting Ecologists for Strategen Environmental Consultants, Perth, Western Australia

Banks MA, Holt GJ (1991) Age-linked changes in salinity tolerance of larval spotted seatrout (*Cynoscion nebulosus*, Cuvier). Journal of Fish Biology 39:505–514

Bannister JL (1979-2005). Annual Reports on aerial surveys of Southern Right Whales on the southern Australian coastline. Western Australian Museum, Perth, Western Australia

Batchelor KL, Webber BL, Scott JK (2017) Invasion ecology of bitou bush (*Chrysanthemoides monilifera subsp. rotundata*) incursion in the Kwinana industrial area of Western Australia. Final report. CSIRO, Australia

Bath A, Shackleton B, Botica C (2004) Development of temperature criteria for marine discharge from a large industrial seawater supplies project in Western Australia. Water SA 30(5):100–106

Beadle LC (1931) Comparative Physiology: Osmotic and ionic regulation in aquatic animals. Annual Review of Physiology 19:329–358

Beard, JS (1979) Vegetation Survey of Western Australia: the Vegetation of the Perth Area Western Australia, map and explanatory memoir 1:250,000 series. Vegetation Series. University of Western Australia Press, Nedlands

Beard, JS (1990) Plant Life of Western Australia. Kangaroo Press, Kenthurst, New South Wales

Blaszkowski C, Moreira GS (1986) Combined effects of temperature and salinity on the survival and duration of larval stage of *Pagurus criniticornis* (Dana) (Crustacea, Paguridae). Journal of Experimental Biology and Ecology 103:77–86

BMT Oceanica (2014a) Fremantle Ports Marine Quality Monitoring Program – Annual Report 2014. Prepared for Fremantle Ports by BMT Oceanica Pty Ltd, Report No. 634_04_001/2_Rev1, Perth, Western Australia, October 2014

BMT Oceanica (2014b) Cockburn Sound Coastal Vulnerability Values and Risk Assessment. Prepared for Cockburn Sound Coastal Alliance by BMT Oceanica Pty Ltd and BMT WBM Pty Ltd, Coastal Zone Management Pty Ltd, SGS Economics and Planning Pty Ltd and Damara WA Pty Ltd, Report No. 1033_001/2_Rev1, Perth, Western Australia, November 2014

BMT Oceanica (2015) Fremantle Ports Marine Quality Monitoring Program Annual Report 2015. Prepared for Fremantle Ports by BMT Oceanica Pty Ltd, Report No. 634_05_001/2_Rev0, Perth, Western Australia, September 2015

BMT Oceanica (2016) Fremantle Ports Marine Quality Monitoring Program – Annual Report 2016. Prepared for Fremantle Ports by BMT Oceanica Pty Ltd, Report No. 634_07_001/2_Rev1, Perth, Western Australia, October 2016

BMT Oceanica (2017) Fremantle Ports Marine Quality Monitoring Program Annual Report 2017. Prepared for Fremantle Ports by BMT Oceanica Pty Ltd, Report No. 634_08_001/2_Rev0, Perth, Western Australia, February 2017

BMT (2018a) Cockburn Sound–Drivers–Pressures–State–Impacts–Responses Assessment 2017. Prepared for Department of Water and Environmental Regulation, The Kwinana Industries Council, The City of Rockingham, The City of Kwinana and Cockburn Sound Management Council by BMT Western Australia Pty Ltd, Perth, Western Australia, Report No. 1362_001/Rev1, July 2018

BMT (2018b) Perth Desalination Plant Discharge Modelling: Model Validation. Prepared for Water Corporation by BMT Eastern Australia Pty Ltd, Report No. R.B22253.002.04, August 2018

BMT (2018c) Fremantle Ports Marine Quality Monitoring Program Annual Report 2018. Prepared for Fremantle Ports by BMT Western Australia Pty Ltd, Report No. 634_09_001/2_Rev0, Perth, Western Australia, August 2018

BMT (2019a) Perth Desalination Plant Discharge Modelling: PSDP: Model Scenarios. Prepared for Water Corporation by BMT Eastern Australia Pty Ltd, Report No. R.B22253.005.00, December 2018

BMT (2019b) Perth Seawater Desalination Plant 2 Construction Impact Assessment. Prepared for Water Corporation by BMT Eastern Australia Pty Ltd, Report No. R.B22253.004, December 2018

BMT (2019c) Perth Desalination Plant Discharge Modelling: Effects of Desalination Discharges on Dissolved Oxygen. Prepared for Water Corporation by BMT Western Australia Pty Ltd, Report No. R-1334_10-1 Rev0, Perth, Western Australia, December 2018

Brandt MJ, Diederichs A, Betke K, Nehls G (2011) Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Marine Ecology Progress Series 421:205–216

Breheny NB, Beckley LE, Wakefield CB (2012) Ichthyoplankton assesmblages associated with pink snapper (*Pagrus auratus*) spawning aggregrations in coastal embayments of southwestern Australia. Journal of the Royal Society of Western Australia 95:103–114

Breitburg D (2002) Effects of hypoxia, and the balance between hypoxia and enrichment, on coastal fishes and fisheries. Estuaries 25:767–781

Buermann Y, Du Preez HH, Steyn GJ, Smit L (1997) Tolerance levels of redbreast tilapia, *Tilapia rendalli* (Boulenger, 1896) to natural suspended silt. Hydrobiologia 344(1-3):11–18

Burnell A, Burnell SR, Tagg M (1990) Observations on an apparent mating sequence in three Southern Right Whales, *Eubalaena australis* (Cetacea: Balaenidae). Australian Mammalogy 14:33–34

Burnell SR (1999) The population biology of southern right whales in southern Australian waters. Unpublished Ph.D. Thesis. Ph.D. Thesis. University of Sydney, Sydney, Australia

Burt JS, Masini RJ, Simpson CJ (1995) Light and *Posidonia sinuosa* seagrass meadows in the temperate coastal waters of Western Australia. I. Factors influencing water column light attenuation – A contribution to the Southern Metropolitan Coastal Waters Study (1991-1994). Technical Series 61. Department of Environmental Protection. Perth, Western Australia

CA (2009) National Assessment Guidelines for Dredging. Commonwealth of Australia, Canberra, ACT

CA (2017) The National System for the Prevention and Management of Marine Pest Incursions. Commonwealth of Australia, Canberra, Australian Capital Territory. Available at <http://www.marinepests.gov.au/Pages/marinepest-map.aspx> [Accessed on 6 June 2017]

Cambridge M, McComb A (1984) The loss of seagrasses in Cockburn Sound, Western Australia. I. The time course and magnitude of seagrass decline in relation to industrial development. Aquatic Botany 20:229–243

Cambridge ML, Zavala-Perez A, Cawthray GR, Mondon J, Kendrick GA (2016) Effects of high salinity from desalination brine on growth, photosynthesis, water relations and osmolyte concentrations of seagrass Posidonia australis. Marine Pollution Bulletin 115:252–260

Cambridge M, Zavala-Perez A, Cawthray G, Statton J, Mondon J, Kendrick G (2019) Effects of desalination brine and seawater with the same elevated salinity on growth, physiology and seedling development of the seagrass Posidonia australis. Marine Ecology Progress Bulletin 140:462–471

Cannell B (2004) Distributions of the major marine fauna found in the Perth metropolitan area (Yanchep to Mandurah). Technical Report: MMS/CWC, LNE/MMP, SEMP, SIMP-79/2004. Marine Conservation Branch, Department of Conservation and Land Management, Perth, Western Australia

Cannell B (2009) The ecology of Little Penguins from Garden Island, with particular reference to their use of Cockburn Sound and Threatening Processes. Prepared for Oceanica Consulting Pty Ltd and Fremantle Ports, Perth, Western Australia

Cannell B (2011) Potential Impacts of the Mangles Bay Marina Based Tourist Precinct on Little Penguins. Prepared for Oceanica Consulting Pty Ltd by Belinda Cannell, Perth, Western Australia

Cannell B (2016) How Resilient are the Little Penguins and the Coastal Marine Habitats they use? Report prepared for City of Rockingham and Fremantle Ports by Murdoch University, Perth, Western Australia

Cannell (2017) Understanding the toll of consecutive years of warm waters on Little Penguins and refining their capacity as bioindicators of the marine coastal ecosystem. Prepared for City of Rockingham, Fremantle Ports, Western Australia, April 2017

Cannell B, Campbell K, Fitzgerald L, Lewis JA, Baran IJ, Stephens NS (2016) Anthropogenic trauma is the most prevalent cause of mortality in Little Penguins, *Eudyptula minor*, in Perth, Western Australia. Emu 116(1):52–61

Chabanne DBH, Pollock KH, Finn H, Bejder L (2017a) Applying the multistate capture-recapture robust design to assess metapopulation structure of a marine mammal. Methods in Ecology and Evolution, DOI: 10.1111/2041-210X.12792

Chabanne DBH, Finn H, Bejder L (2017b) Identifying the relevant local population for environmental impact assessments of mobile marine fauna. Frontiers in Marine Science 4:148, DOI: 10.3389/fmars.2017.00148

Collier CJ, Lavery PS, Masini RJ, Ralph PJ (2009) Shade-induced response and recovery of the seagrass Posidonia sinuosa. Journal of Experimental Marine Biology and Ecology 370: 89–103

CSIRO (2006) Status of groundwater quality in the Cockburn Sound catchment. Prepared for Cockburn Sound Management Council by CSIRO, Perth, Western Australia

CSIRO, BOM (2015) Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia

CSMC (2013) State of Cockburn Sound Report – 2013. Cockburn Sound Management Council, Perth, Western Australia

CSMC (2016a) Cockburn Sound Annual Environmental Monitoring Report 2015–2016: Assessment Against the Environmental Quality Objectives and Criteria Set in the State Environmental (Cockburn Sound) Policy. Cockburn Sound Management Council, Perth, Western Australia, September 2016

CSMC (2016b) Cockburn Sound Report Card 2015–2016. Cockburn Sound Management Council, Perth, Western Australia

CWR (2007a) The nearfield characteristics of the Perth Seawater Desalination Plant discharge. Final Report. Prepared for Water Corporation. Centre for Water Research, Perth, Western Australia

CWR (2007b) Field investigations into the impact of the Perth Seawater Desalination Plant discharge on Cockburn Sound: Final Report. 102 pp. Prepared for the Water Corporation. Centre for Water Research, Perth, Western Australia

CWR (2008) Response to review of EPA Section 46 application by NIWA (Dr R. Spigel) and additional data analysis collected during shutdown events in early 2008. Memorandum addressed to the Water Corporation. Centre for Water Research, Perth, Western Australia, June 2008

CZM, Damara, UWA, Oceanica (2013) Cockburn Sound Coastal Alliance Vulnerability Study – Erosion and Inundation Hazard Assessment Report. Coastal Zone Management Pty Ltd, Damara WA Pty Ltd, University of Western Australia School of Environmental Systems Engineering and Oceanica Consulting Pty Ltd, Perth, Western Australia, March 2013

D'Adamo N (2002) Exchange and Mixing in Cockburn Sound, Western Australia: A Seasonally Stratified, Microtidal, Semi-Enclosed Coastal Embayment. PhD thesis, University of Canterbury, Christchurch, New Zealand

DAL (2001) Cockburn Sound Management Council, The State of Cockburn Sound – A pressure-state-response report, Report prepared for Cockburn Sound Management Council by DA Lord & Associates Pty Ltd, Perth, Western Australia, June 2001

DEP (1996) Southern Metropolitan Coastal Waters Study (1991–1994). Department of Environmental Protection, Report No. 17, Perth, Western Australia, November 1996

DER (2014) A guide to the assessment of applications to clear native vegetation, under Part V Division 2 of the Environmental Protection Act 1986. Department of Environmental Regulation, Perth, Western Australia, December 2014

DER (2015) Identification and investigation of acid sulfate soils and acidic landscapes and Treatment and management of soils and water in acid sulfate soil landscapes, Department of Environment Regulation, Perth, Western Australia, June 2015

De Robertis A, Ryer CH, Veloza A, Brodeur RD (2003) Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. Canadian Journal of Fisheries and Aquatic Sciences 60(12):1517–1526

Diaz RJ, Rosenberg R (1995) Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanography and Marine Biology 33:245–303

DMIRS (2018) Geological Survey of Western Australia, Department of Mines, Industry Regulation and Safety, Perth, Western Australia

Doak C (2004) Hydrodynamic modeling of snapper (*Pagrus auratus*) eggs and larvae in Cockburn Sound. BSc (Hons) thesis, University of Western Australia, Perth, Western Australia

DoEE (2018f) *Calidris leschenaultii* in Species Profile and Threats Database. Department of the Environment and Energy, Canberra, ACT. Available at: <http://www.environment.gov.au/sprat>. Accessed February 2018> [Accessed August 2018]

DoEE (2018g) *Calidris mongolus* in Species Profile and Threats Database. Department of the Environment and Energy, Canberra, ACT. Available at: <http://www.environment.gov.au/sprat>. [Accessed February 2018]

DOF (2008) Commercial and Recreational Fishing in Cockburn Sound and Owen Anchorage (Draft). Prepared for Oceanica Consulting Pty Ltd by Department of Fisheries, Perth, Western Australia

DOF (2015) Fish kill incident: Cockburn Sound, Western Australia November–December 2015. Department of Fisheries, Perth, Western Australia

DOT (2000) Western Australian sea level variability due to tides, weather and extreme events. Prepared for the Government of Western Australia by Coastal Management Branch, Department of Transport, Perth, Western Australia

DOT (2009) Shoreline Movement Study, Point Peron Rockingham. Prepared for the Department of Environment and Conservation by Department of Transport, Perth, Western Australia, December 2009

Double MC, Gales N, Jenner KC, Jenner MN (2010). Satellite tracking of south-bound humpback whales in the Kimberley region of Western Australia. Report to the Western Australian Marine Science Institution, Perth, Western Australia

DOW (2006) Toxicants in Sediment Survey Report 2006, Cockburn Sound and Owen Anchorage. Prepared for Cockburn Sound Management Council by Department of Water, Perth, Western Australia, October 2006

DPLH (n.d.), Aboriginal Heritage Inquiry System, [Online]. Department of Planning, Lands and Heritage, Available from https://maps.daa.wa.gov.au/AHIS/

DSEWPaC (2012a) Species Group Report Card – Seabirds: Supporting the Marine Bioregional Plan for the South-west Marine Region. Department of Sustainability, Environment, Water, Population and Communities, Canberra, ACT. Available at: http://www.environment.gov.au/topics/marine/marine-bioregional-plans/south-west> [Accessed August 2018]

DSEWPaC (2012b) Species Group Report Card – Marine Reptiles: Supporting the Marine Bioregional Plan for the South-west Marine Region. Department of Sustainability, Environment, Water, Population and Communities, Canberra, ACT. Available at <http://www.environment.gov.au/topics/marine/marine-bioregional-plans/south-west> [Accessed 7 November 2018]

DWAR (2018) Marine pests. Department of Agriculture and Water Resources. Available at: <http://www.agriculture.gov.au/pests-diseases-weeds/marine-pests> [Accessed N8 ovember 2018]

DWER (2015), Perth Groundwater Map, Department of Water and Environmental Regulation, Available at: <https://maps.water.wa.gov.au/#/webmap/gwm> [Accessed 5 September 2018]

Eliot I, Tonts M, Eliot M, Walsh G, Collins J (2005) Recreational Beach Users in the Perth Metropolitan Area – March 2005 in Summer 2004–2005. Prepared by The Institute of Regional Development, Perth, Western Australia, August 2005

Enzer (2008) Introduced Marine Pests Report for the Kwinana Quay Development. Prepared for Oceanica Consulting Pty Ltd and Fremantle Ports, Perth, Western Australia

EPA (2002) James Point State One Port, Kwinana – Report and recommendations of the Environmental Protection Authority. EPA Bulletin 1076. Environmental Protection Authority, Perth, Western Australia

EPA (2005) Manual of Standard Operating Procedures – For Environmental Monitoring against the Cockburn Sound Environmental Quality Criteria (2003–2004) – A Supporting Document to the State Environmental (Cockburn Sound) Policy 2005, Perth, Western Australia. Environmental Protection Authority, Perth, Western Australia

EPA (2008) Southern Seawater Desalination Project, Water Corporation, Report and recommendations of the Environmental Protection Authority, Environmental Protection Authority Perth, Western Australia, Report 1302, October 2008

EPA (2010) Ministerial Statement No. 826: Port Rockingham Marina Cockburn Sound. Environmental Protection Authority, Perth, Western Australia, February 2010

EPA (2015) State Environmental (Cockburn Sound) Policy. Environmental Protection Authority, Perth, Western Australia, December 2015

EPA (2016a) Factor Guideline – Air Quality, Environmental Protection Authority, Perth, Western Australia

EPA (2016b) Factor Guideline – Marine Environmental Quality. Environmental Protection Authority, Perth, Western Australia, December 2016

EPA (2016c) Technical guidance – Environmental Impact Assessment of Marine Dredging proposals. Environmental Protection Authority, Perth, Western Australia, December 2016

EPA (2016d) Technical Guidance – Protecting the quality of Western Australia's marine environment. Environmental Protection Authority, Perth, Western Australia, December 2016

EPA (2016e) Factor Guideline – Benthic Communities and Habitats. Environmental Protection Authority, Perth, Western Australia, December 2016

EPA (2016f) Technical Guidance – Protection of Benthic Communities and Habitats. Environmental Protection Authority, Perth, Western Australia, December 2016

EPA (2016g) Factor Guideline – Marine Fauna. Environmental Protection Authority, Perth, Western Australia, December 2016

EPA (2016h) Factor Guideline – Coastal Processes. Environmental Protection Authority, Perth, Western Australia, December 2016

EPA (2017) Environmental Quality Criteria Reference Document for Cockburn Sound – A Supporting Document to the State Environmental (Cockburn Sound) Policy 2015. Environmental Protection Authority, Perth, Western Australia, April 2017

EPA (2018a) Instructions on how to prepare an Environmental Review Document. Environmental Protection Authority, Perth, Western Australia, April 2018

EPA (2018b) Statement of Environmental Principles, Factors and Objectives. Environmental Protection Authority, Perth, Western Australia, June 2018

Erbe C (2009) Underwater noise from pile driving in Moreton Bay, Qld. Acoustics Australia 37:3–87

Erftemeijer PL, Lewis RR (2006) Environmental impacts of dredging on seagrasses: A review. Marine Pollution Bulletin 52:1553–1572

Finn H (2005) Conservation biology of bottlenose dolphins (*Tursiops* sp.) in Perth metropolitan waters. PhD thesis, Murdoch University, Perth, Western Australia

Finn H, Calver MC (2008) Feeding aggregations of dolphins and seabirds in Cockburn Sound, Western Australia. The Western Australian Naturalist 26:157–172

Fisher Scientific (2008). Material Safety Data Sheet. Calcium carbonate. https:// fscimage.fishersci.com/ msds/ 03880.htm

Fletcher CR (1974) Volume regulation in *Nereis diversicolor* - I. The steady state. Comparative Biochemistry and Physiology 47:1199–1214

Fletcher WJ, Mumme MD, Webster FJ (eds) (2017) Status Reports of the Fisheries and Aquatic Resources of Western Australia 2015/16: The State of the Fisheries. Department of Fisheries, Perth, Western Australia

Fletcher WJ, Santoro K (eds) (2007) State of the Fisheries Report 2006/07. Department of Fisheries, Perth, Western Australia

Fowler AJ, McGarvey R, Carroll J, Feenstra JE, Jackson WB, Lloyd MT (2016) Snapper (*Chrysophrys auratus*) Fishery. SARDI Aquatic Sciences, Report No. F2007/000523-4

FP, DOP (2012) Kwinana Quay Project Offshore Island Port Facility, Draft Environmental Review and Management Program. Prepared by Fremantle Ports and Department of Planning, Perth, Western Australia, October 2012

Francis R, Paul LJ, Mulligan KP (1992) Ageing of adult snapper (*Pagrus auratus*) from otolith annual ring counts: validation by tagging and oxytetracycline injection. Australian Journal of Marine and Freshwater Research 43:1069–1089

Fraser MW, Short J, Kendrick GA, McLean D, Keesing J, Byrne M, Caley MJ, Clarke D, Davis AR, Erftemeijer PLA, Field S, Gustin-Craig S, Huisman J, Keough M, Lavery PS, Masini R, McMahon K, Mengersen K, Rasheed M, Statton J, Stoddart J, Wu P (2017) Effects of dredging-related pressures on critical ecological processes for organisms other than fish or coral. Report of Theme 9 – Project 9.1. Prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia, 47 pp

Fraser MW, Kendrick GA, Rule MJ (2017) The 2017 survey of selected seagrass meadows in Cockburn Sound, Owen Anchorage and Warnbro Sound. Report prepared for the Department of Environment Regulation on behalf of the Cockburn Sound Management Council, Perth, Western Australia, April 2017

Gartner A, Lavery PS, Lonzano-Montes H (2015) Trophic implications and faunal resilience following one-off and successive disturbances to an *Amphibolis griffithii* seagrass system. Marine Pollution Bulletin 94:131–143

Gaughan DJ, Santoro K (2018) Status Reports of the Fisheries and Aquatic Resources of Western Australia 2016/17: The State of the Fisheries. Department of Primary Industries and Regional Development, Perth, Western Australia

Gentilli J (1971) Climates of Australia and New Zealand. In: Landsberg H (ed) World Survey of Climatology. Elsevier, Amsterdam, p 108–114

GHD (2016) City of Kwinana: Coastal Adaptation Plan. Prepared for City of Kwinana and the Cockburn Sound Coastal Alliance by GHD, Perth, Western Australia

GHD (2017) Perth Desalination Plant Expansion Flora and Fauna Survey. Prepared for Water Corporation by GHD, Perth, Western Australia, September 2017

GHD (2018a) PSDP Stage 2 Expansion – Preliminary Coastal Protection Advice. Prepared for Water Corporation by GHD, Perth, Western Australia, June 2018

GHD (2018b) Memorandum – Marine Pipeline Construction Methodology. Prepared for Water Corporation by GHD, Perth, Western Australia, June 2018

GHD, Water Corporation (2018) Perth Seawater Desalination Plant Expansion Investigations – Concept Design Report. Water Corporation Project Number: CW03473. GHD Document Number: 61-36503-00000-PR-RPT-002. July 2018

Gilbert DJ, Davies NM, McKenzie JR (2006) Development of an age-length structured model of the Hauraki Gulf–Bay of Plenty snapper (*Pagrus auratus*) population. Marine and Freshwater Research 57:553–568

Gilbert DJ, McKenzie JR, Davies NM, Field KD (2000) Assessment of the SNA 1 stocks for the 1999–2000 fishing year. New Zealand Fisheries Assessment Report 2000/38. Ministry of Fisheries, Wellington

Giling D, Reina RD, Hogg Z (2008) Anthropogenic influence on an urban colony of little penguin *Eudyptula minor*. Marine and Freshwater Research 59:647–651

GoWA (2016) 2016 Statewide Vegetation Statistics incorporating the CAR Reserve Analysis (Full report). Government of Western Australia, Perth, Western Australia. Available at <https://data.wa.gov.au/> [Accessed January 2017]

GoWA (2017) 2016 South West Vegetation Complex Statistics. Government of Western Australia, Perth, Western Australia. Available at <https://data.wa.gov.au/> [Accessed January 2017]

Guerin JL, Stickle WB (1997) Effect of salinity on survival and bioenergetics of juvenile lesser blue crabs, *Callinectes similis*. Marine Biology 129:63–69

Harris JE, Antenucci JP (2009) Kwinana Quays: Offshore Development Scenario Modelling. Prepared for Oceanica Consulting Pty Ltd (acting for Fremantle Ports) by University of Western Australia Centre for Water Research, Perth, Western Australia, August 2009

Hart AM, Leporati SC, Marriott RJ, Murphy D (2016) Innovative development of the *Octopus* (cf.) *tetricus* fishery in Western Australia. FRDC Project No 2010/200. Department of Fisheries, Fisheries Research Report, No. 270, Perth, Western Australia

Heddle EM, Loneragan OW, Havel JJ (1980) Vegetation of the Darling System. IN: DCE 1980 Atlas of Natural Resources, Darling System, Western Australia. Department of Conservation and Environment, Perth, Western Australia

Hewitt DA, Hoenig JM (2005) Comparison of two approaches for estimating natural mortality based on longevity. Fishery Bulletin 103:433–437

Hewitt DA, Lambert DM, Hoenig JM, Lipcius RN, Bunnell DB, Miller TJ (2007) Direct and indirect estimates of natural mortality for Chesapeake Bay blue crab. Transactions of the American Fisheries Society 136:1030–1040

Hildebrand JA (2005) Impacts of anthropogenic sound. p. 101–124 in Reynolds JE, Perrin WF, Reeves RR, Montgomery S, Ragen TJ (Eds) Marine mammal research: conservation beyond crisis. The Johns Hopkins University Press, Baltimore, Maryland, United States of America

Hipsey MR, Bruce LC, Hamilton DP (2013) Aquatic Ecodynamics (AED) Model Library Science Manual. DRAFT v4

Hoenig J (1983) Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 82:898–903

Howell P, Simpson D (1994) Abundance of marine resources in relation to dissolved oxygen in Long Island Sound. *Estuaries* 17:394–402

IOCI (2012) Western Australia's Weather and Climate: A Synthesis of Indian Ocean Climate Initiative Stage 3 Research. Indian Ocean Climate Initiative, CSIRO and BOM, Australia

Jackson G (2007) Fisheries biology and management of pink snapper, *Pagrus auratus*, in the inner gulfs of Shark Bay, Western Australia. Thesis presented for the degree of Doctor of Philosophy at Murdoch University, Perth, Western Australia, December 2007

Jasny M, Reynolds J, Horowitz C, Wetzler A (2005) Sounding the depths II: The rising toll of sonar, shipping, and industrial noise on marine life. Report prepared by the Natural Resources Defense Council. California, United States of America. 76pp

Jernakoff P, Brearley A, Nielsen J (1996) Factors affecting grazer-epiphyte interactions in temperate seagrass meadows. Oceanography and Marine Biology: An Annual Review 34:109–162

Johnston D, Harris D, Caputi N, Thomson A (2011) Decline of a blue swimmer crab (*Portunus pelagicus*) fishery in Western Australia—History, contributing factors and future management strategy. Fisheries Research 109(1):119–130

Keesing JK, Greenwood J, Donn M, McFarlane D (2016) Spatial and Temporal Analysis of Water Quality Monitoring Data Collected from Cockburn Sound and Warnbro Sound between 1982/83 and 2013/14. Prepared for Cockburn Sound Management Council and the Western Australian Department of Water by CSIRO, Perth, Western Australia, February 2016

Kendrick AJ, Hyndes GA (2003) Patterns of abundance and size distribution of syngnathid fishes among habitats in a seagrass-dominated marine environment. Estuarine Coastal and Shelf Science 57(4):631-640

Kendrick GA, Aylward MJ, Hegge BJ, Cambridge ML, Hillman K, Wyllie A, Lord DA (2002) Changes in seagrass coverage in Cockburn Sound, Western Australia between 1967 and 1999. Aquatic Botany 73:75–87

Kerr SJ (1995) Silt, turbidity and suspended sediments in the aquatic environment: an annotated bibliography and literature review. Ontario Ministry of Natural Resources, Southern Region Science & Technology Transfer Unit Technical Report TR-008. 277 pp

Kitajima C, Yamane Y, Matsui S, Kihara Y, Furuichi M (1993) Ontogenetic change in buoyancy in the early stage of red sea bream. Nippon Suisan Gakkaishi 59:209–216

Klumpp DW, Howard RK, Pollard DA (1989) Trophodynamics and nutritional ecology of seagrass communities. In: Larkum AWD, McComb AJ, Shepherd SA (eds) Biology of seagrasses: a treatise on the biology of seagrasses with special references to the Australian region. Elsevier, Amsterdam, p 394–457

Koch MS, Schopmeyer SA, Kyhn-Hansen C, Madden CJ, Peters JS (2007) Tropical seagrass species tolerance to hypersalinity stress. Aquatic Botany 86:14–24

Koper RP, Plön S (2012) The potential impacts of anthropogenic noise on marine animals and recommendations for research in South Africa. EWT Research & Technical Paper No. 1. Endangered Wildlife Trust, South Africa

Lange R (1972) Some recent work on osmotic, ionic and volume regulation in marine animals. Oceanographic Marine Biology Annual Review 10:97–136

Largier JL, White JW, Clarke L, Nichols KJ (2007) Assessment of larval entrainment by cooling water intake systems: models of larval dispersal and recruitment incorporating coastal boundary layer flow. Report prepared for California Energy Commission

Lavery PS, McMahon K, Mulligan M, Tennyson A (2009) Interactive effects of timing, intensity and duration of experimental shading on *Amphibolis griffithii*. Marine Ecology Progress Series 394:21–33

Lawrence C, How S (2007) Mussel Farming Status Report – State of the Fisheries Report 2006/07. Department of Fisheries, Perth, Western Australia

Lemm AJ, Hegge BJ, Masselink G (1999) Offshore wave climate, Perth (Western Australia), 1994-96. Australian Journal of Marine and Freshwater Research 50:95–102

Lenanton R, Brown J (2007) Cockburn Sound Fisheries. Presentation to Fremantle Ports Outer Harbour Project Marine Assessment Scoping Workshop, 14 February 2007. Fremantle, Western Australia

Le Port A, Montgomery J, Croucher A (2014) Biophysical modelling of snapper *Pagrus auratus* larval dispersal from a temperate MPA. Marine Ecology Progress Series 515:203–215

Li Y, Cai W, Campbell EP (2005) Statistical modelling of extreme rainfall in southwest Western Australia. Journal of Climate 18:852–863

Longstaff BJ, Dennison WC (1999) Seagrass survival during pulsed turbidity events: The effects of light deprivation on the seagrasses *Halodule pinifolia* and *Halophila ovalis*. Aquatic Botany 65:105–121

Lourey MJ, Dunn JR, Waring J (2006) A mixed-layer nutrient climatology of Leeuwin Current and Western Australian shelf waters: Seasonal nutrient dynamics and biomass. Journal of Marine Systems 59:25–51

Lucke K, Lepper PA, Blanchet M-A, Siebert U (2011) The use of an air bubble curtain to reduce the received sound levels for harbor porpoises (*Phocoena phocoena*). Journal of the Acoustical Society of America 130(5):3406–3412

Lunz JD (1987) Environmental considerations during dredging operations. Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station. Sedimentation Control to Reduce Maintenance Dredging of Navigational Facilities in Estuaries, Report and Symposium Proceedings. Committee on Sedimentation Control to Reduce Maintenance Dredging in Estuaries, Marine Board Commission on Engineering and Technical Systems, National Research Council. National Academy Press. Washington, DC

MAFRL (2017) Water Quality of Cockburn and Warnbro Sounds (December 2016 to March 2017). Prepared by Marine and Freshwater Research Laboratory for the Department of Environment Regulation on behalf of the Cockburn Sound Management Council, Perth, Western Australia, May 2017

Masselink G, Pattiaratchi C (2001) Characteristics of the sea breeze system on Perth, Western Australia, and its effect on the nearshore wave climate. Journal of Coastal Research 17(1):173–187

McCauley RD, Salgado Kent CP (2008) Underwater acoustics impact study report: Appendix C, Report prepared for Gunns Ltd by Curtin University, Perth, Western Australia, June 2008

McDonald JI, Wells FE (2009) Results of a 2007 Survey of the Swan River Region for Four Introduced Marine Species. Department of Fisheries, Report No 189, Perth, Western Australia

McMahon K, Lavery P, McCallum R, Hernawan U (2017) Current State of Knowledge Regarding the Effects of Dredging-Related 'Pressure' on Seagrasses. Report of Theme 5 – Project 5.1.1, Perth, Western Australia

Mohring M, Rule M (2013) Long-term Trends in the Condition of Seagrass Meadows in Cockburn and Warnbro Sounds. Prepared for Cockburn Sound Management Council by Department of Parks and Wildlife, Perth, Western Australia, October 2013

Molnar JL, Gamboa RL, Revenga C and Spalding MD (2008) Assessing the global threat of invasive species to marine biodiversity. Frontiers in Ecology and the Environment 6(9):485–492

MRA (2009) Fremantle Ports Outer Harbour Wave and Sediment Modelling, Report No. R241 Rev2, Prepared for Fremantle Ports by MP Rogers & Associates, Perth, Western Australia

Nahas EL, Jackson G, Pattiaratchi CB, Gregory IN (2003) Hydrodynamic modelling of snapper *Pagrus auratus* egg and larval dispersal in Shark Bay, Western Australia: reproductive isolation at a fine spatial scale. Marine Ecology Progress Series 265:213–226

Nell JA, Gibbs PJ (1986). Salinity tolerance and absorption of L-methionine by some Australian bivalve molluscs. Australian Journal of Marine and Freshwater Research 37:721–728

Norriss JV, Jackson G (2002) Identifying the development stages of preserved eggs of snapper, *Pagrus auratus*, from Shark Bay, Western Australia. Fisheries Research Report No 142. Department of Fisheries of Western Australia, Perth, Western Australia

Norriss JV, Crisafulli B (2010) Longevity in Australian snapper *Pagrus auratus* (*Sparidae*). Journal of the Royal Society of Western Australia 93:129–132

NRC (2005) Marine Mammal Populations and Ocean Noise: Determining when Noise causes Biologically Significant Effects. National Research Council, Washington, DC, USA

NTF (2000) Western Australian sea level variability due to tides, weather and extreme events. Prepared for the Government of Western Australia by Coastal Management Branch, Department of Transport, Perth, Western Australia

Oceanica (2005) Perth Metropolitan Desalination Plant Effects of Low Dissolved Oxygen Concentrations on Marine Organisms: A Review. Report n. 492/1. Prepared for Water Corporation by Oceanica Consulting Pty Ltd. Perth, Western Australia, December 2005

Oceanica (2006) Perth Metropolitan Desalination Plant – Cockburn Sound Benthic Macrofauna Community and Sediment Habitat Monitoring – Low Dissolved Oxygen Event Sampling May 2006. Prepared for Water Corporation by Oceanica Consulting Pty Ltd, Report No 519/1, Perth, Western Australia, June 2006

Oceanica (2007) Perth Metropolitan Desalination Plant – Cockburn Sound Benthic Macrofauna Community and Sediment Habitat – Comprehensive Baseline Survey. Prepared for Water Corporation by Oceanica Consulting Pty Ltd. Report No. 500/1, Perth, Western Australia, March 2007

Oceanica (2009a) Fremantle Ports Kwinana Quay Project Sediment Sampling and Analysis Implementation Report. Prepared for Fremantle Ports by Oceanica Consulting Pty Ltd. Report No. 560_09/1, Perth Western Australia, March 2009

Oceanica (2009b) Fremantle Ports Kwinana Quay Project – Ecosystem Component Characterisation: Habitat Function Assessment. Prepared for Fremantle Ports by Oceanica Pty Ltd, Report No. 560_010/3, Perth Western Australia, September 2009

Oceanica (2009c) Perth Metropolitan Desalination Plant – Cockburn Sound Benthic Macrofauna Community and Sediment Habitat – Repeat Macrobenthic Survey. Prepared for Water Corporation by Oceanica Consulting Pty Ltd, Report No 604_001/1, Perth, Western Australia, June 2009 cross check required

Oceanica (2013) Perth Metropolitan Desalination Plant – Cockburn Sound Benthic Macrofauna Community and Sediment Habitat – Repeat Survey 2013. Prepared for Water Corporation by Oceanica Consulting Pty Ltd, Report No. 604_01_006/1_Rev0, Perth, Western Australia, September 2013

Okely P, Antenucci JP, Imberger J, Marti CL (2007a) Field Investigations into the impact of the Perth Seawater Desalination Plant Discharge on Cockburn Sound. University of Western Australia Centre for Water Research, Perth, Western Australia, June 2007

Okely P, Antenucci JP, Marti CL, Imberger J (2007b) The near–field characteristics of the Perth Seawater Desalination Plant discharge. Prepared for Water Corporation by Centre for Water Research UWA, Report No. WP2175PO, Perth, Western Australia, December 2007

Okely P, Antenucci JP, Yeates PS, Marti CL, Imberger J (2007c) Summary of Investigations into the impact of the Perth Seawater Desalination Plant Discharge on Cockburn Sound. Centre for Water Research University of Western Australia, Report No. WP 2160 PO, Perth, Western Australia, August 2007

Partridge GJ, Michael RJ (2009) The Effect of Simulated Cockburn Sound Dredge Material on Eggs and Larvae of Pink Snapper (*Pagrus auratus*). Prepared for Oceanica Consulting Pty Ltd, Fremantle Ports by TAFEWA Challenger, Perth, Western Australia

Partridge GJ, Ginbey BM, Woolley LD, Fairclough DV, Crisafulli B, Chaplin J, Prokop N, Dias J, Bertram A, Jenkins GI (2017) Development of techniques for the collection and culture of wild-caught fertilised snapper (*Chrysophrys auratus*) eggs for stock enhancement purposes. Fisheries Research 186:524–530

Pattiaratchi C (2016) Oceanographic conditions along the Perth Metropolitan region leading to the observed fish kill event in Cockburn Sound, November 2015. 13 pp

PB (2009) Study of the Contaminants in the Waters of Cockburn Sound 2008. Prepared for the Cockburn Sound Management Council by Parsons Brinckerhoff Australia, Perth, Western Australia, January 2009

Peddicord R, McFarland V (1976) Effects of suspended dredged material on the commercial crab Cancer magister. In: P.A. Krenkel, J. Harrison, and J.C. Burdick III, editors. 'Proceedings of the specialty conference on dredging and its environmental effects'. American society of Civil Engineers, Mobile, Albama, pg 633–644

Pineda M, Strehlow B, Duckworth A, Webster NS (2017) Effects of dredging-related stressors on sponges: laboratory experiments. Report of Theme 6 – Project 6.4. Prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia, 157 pp

Pogonoski JJ, Pollard DA, Paxton JR (2002) Conservation Overview and Action Plan for Australian Threatened and Potentially Threatened Marine and Estuarine Fishes. Canberra: Environment Australia. Pp. 199–201

Popper AN, Hastings MC (2009) The Effect of Human-Generated Sound on Fish. Integrative Zoology 4:43–52

Ralph PJ, Durako MJ, Enriquez S, Collier CJ, Doblin MA (2007) Impact of light limitation on seagrasses. Journal of Experimental Marine Biology and Ecology 350:176–193

Richardson WJ, Greene Jr CR, Malme CI, Thomson DH (1995) Marine Mammals and Noise. Academic Press, San Diego, California, USA

Robertson JD (1949) Ionic regulation in some marine invertebrates. Journal of Experimental Biology 26:182–200

Rose TH, Smale DA, Botting G (2012) The 2011 marine heat wave in Cockburn Sound, southwest Australia. Ocean Science 8:545–550

Ruiz-Montoya L, Lowe RJ (2014) Summer circulation dynamics within the Perth coastal waters of south-western Australia. Continental Shelf Research 77:81–95

Ruız J, Marın-Guirao L, Sandoval-Gil JM (2009) Responses of the Mediterranean seagrass Posidonia oceanica to in situ simulated salinity increase. Botanica Marina 52:459–470

Salgado-Kent CP, McCauley RD, Paiva E, Gavrilov A, Woods A (2011) Bottlenose Dolphin Behaviour in association with Pile Driving within Fremantle Inner Harbour. Prepared for Oceanica Pty Ltd by Centre for Marine Science and Technology Curtin University, Report No. R2011-36, Perth, Western Australia, June 2011

Sánchez-Lizaso J, Romero J, Ruiz J, Gacia E, Buceta J, Invers O, Torquemada Y, Mas J, Ruiz-Mateo A, Manzanera M (2008) Salinity tolerance of the Mediterranean seagrass Posidonia oceanica: recommendations to minimize the impact of brine discharges from desalination plants. Desalination 221:602–607

Shepherd DP, Beeston GR, Hopkins AJ (2002) Native Vegetation in Western Australia – Extent, Type and Status, Resource Management Technical Report 249, Department of Agriculture, Western Australia

Short A (2006) Beaches of the Western Australian Coast: Eucla to Roebuck Bay. University of Sydney, NSW

Skene D, Ryan D, Brooke B, Smith J, Radke L (2005) The Geomorphology and Sediments of Cockburn Sound. Report No. 2005/10. Geoscience Australia, Western Aastralia

Smallwood CB, Hesp AS, Beckley LE (2013) Biology, stock status and management summaries for selected fish species in south-western Australia. Fisheries research report No. 242. Department of Fisheries, Perth, Western Australia

Smith AJ, Massuel S, Pollock DW (2012) Geohydrology of the Tamala Limestone Formation in the Perth Region: Origin of secondary porosity. CSIRO Publishing, Perth, Western Australia

Southall BL, Bowles AE, Ellison WT, Finneran JJ, Gentry RL, Greene Jr CR, Kastak D, Ketten DR, Miller JH, Nachtigall PE, Richardson WJ, Thomas JA, Tyack PL (2007) Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33:411–520

SSWA (2015) Marine Environmental Monitoring Program. Southern Seawater Alliance. Report No. 00-EN-PRO-0001, September 2015

Stead T (2016) Coastal Management Hotspots in WA. Prepared by the Department of Transport for the Australian Climate Change Adaptation Research Network for Settlements and Infrastructure, November 2016. Available at <https://www.nccarf.edu.au/settlementsinfrastructure /sites/www.nccarf.edu.au.settlements-infrastructure/files/Tim_Stead.pdf> [Accessed 26 June 2017]

Steedman R, Craig P (1979) Numerical Model Study of Circulation and Other Oceanic Aspects of Cockburn Sound. Prepared for Cockburn Sound Study Group by Department of Conservation and Environment, Perth, Western Australia

Stiff MJ, Cartwright NG, Crane RI (1992) Environmental Quality Standards for Dissolved Oxygen. National Rivers Authority Research and Development Program Note 130, Bristol, United Kingdom

Strategen (2012) Mangles Bay Marina Based Tourist Precinct – Public Environmental Review. Strategen Environmental Consultants, Perth, Western Australia

Stul T, Eliot I, Pattiaratchi C (2007) Sediment Cells along the Perth Metropolitan Coast. Proceedings of the 18th Australasian Coastal and Ocean Engineering Conference and 11th Australasian Ports and Harbours Conference Melbourne, Victoria, 2007

Stul T, Gozzard JR, Eliot IG, Eliot MJ (2015) Coastal Sediment Cells for the Vlamingh Region between Cape Naturaliste and Moore River, Western Australia. Prepared by Seashore Engineering Pty Ltd and Geological Survey of Western Australia for the Western Australian Department of Transport, Fremantle, Western Australia

Sumner N, Lai E (2012) Boat-based Recreational Fishing Catch and Effort in Cockburn Sound and Owen Anchorage during 1996/97, 2001/02 and 2005/06. Department of Fisheries, Report No 23, Perth, Western Australia, April 2012

Tapp N (2003) Do size differences of juvenile snapper (*Pagrus auratus*) in two regions of Shark Bay, Western Australia, reflect different environmental conditions? MSc Thesis, Edith Cowan University, Perth, Western Australia

Touchette BW (2007) Seagrass-salinity interactions: Physiological mechanisms used by submersed marine angiosperms for a life at sea. Journal of Experimental Marine Biology and Ecology 350:194–215

Travers A (2007) Low-Energy Beach Morphology with Respect to Physical Setting: A Case Study from Cockburn Sound, South-western Australia. Journal of Coastal Research 23:429–444

TSSC (2015) Conservation Advice: *Numenius madagascariensis*. Threatened Species Scientific Committee, Department of the Environment and Energy, Canberra, ACT

TSSC (2016) Conservation Advice: *Limosa lapponica menzbieri*. Threatened Species Scientific Committee, Department of the Environment and Energy, Canberra, ACT

Tyerman SD, Hatcher A, West RJ, Larkum AWD (1984) Posidonia australis growing in altered salinities: leaf growth, regulation of turgor and the development of osmotic gradients. Functional Plant Biology 11:35–47

Unsworth RKF, Collier CJ, Waycott M, McKenzie LJ, Cullen-Unsworth LC (2015) A framework for the resilience of seagrass ecosystems. Marine Pollution Bulletin 100:34–46

UWA (2018) Benthic Habitat Mapping of Cockburn Sound. Prepared by University of Western Australia for Department of Water and Environmental Regulation and Fremantle Ports, Perth, Western Australia, January 2018

van Rijn LC (1989) Handbook – Sediment Transport by Currents and Waves, Report No. H461. Delft Hydraulics, Netherlands

van Senden D, Miller BM (2005) Stratification and Dissolved Oxygen Issues in Cockburn Sound Pertaining to Discharge of Brine from Desalination. Report No. 2005/03, Manly Vale, New South Wales

Wakefield CB (2010) Annual, lunar and diel reproductive periodicity of a spawning aggregation of snapper *Pagrus auratus* (Sparidae) in a marine embayment on the lower west coast of Australia. Journal of Fish Biology 77:1359–1378

Wakefield CB, Johnston D (2009) A preliminary investigation of the potential impacts of the proposed Kwinana Quays development on the commercially and recreationally important fish and crab species in Cockburn Sound. Fisheries Research Report No. 186. Department of Fisheries, Perth, Western Australia

Walker DI, Kendrick GA, McComb AJ (1988) The distribution of seagrass species in Shark Bay, Western Australia, with notes on their ecology. Aquatic Botany 30:305–317

Walker D, McComb A (1990) Salinity response of the seagrass Amphilobus Antarctica (Labill.)Sonder etAschers.:An experimental validation of field results. Aquatic Botany 36:359–366

WAPC (2013) State Planning Policy No 2.6 – State Coastal Planning Policy. Western Australian Planning Commission, Perth, Western Australia

Warne MSJ, Batley GE, Braga O, Chapman JC, Fox DR, Hickey CW, Stauber JL, Van Dam R (2013) Revisions to the derivation of the Australian and New Zealand guidelines for toxicants in fresh and marine waters. Environmental Science and Pollution Research 21:51–60

Water Corporation (2013) Perth Seawater Desalination Plant Marine Monitoring & Management Plan. Final Report, August 2013. Water Corporation, Perth, Western Australia

Water Corporation (2016) Water Source Development Program: IWSS (2016-2016). Report No. 14874531. Water Corporation, Perth, Western Australia, August 2016

Water Corporation (2018) Historical streamflow. Water Corporation, Perth, Western Australia. Available at: <https://www.watercorporation.com.au/water-supply/rainfall-and-dams/streamflow/streamflowhistorical> [Accessed August 2018]

Wells FE, McDonald JI, Huisman JM (2009) Introduced Marine Species in Western Australia. Department of Fisheries, Report No 57, Perth, Western Australia, March 2009

Weilgart LS (2007) The impacts of anthropogenic ocean noise on cetaceans and implications for management. Canadian Journal of Zoology 85:1091–1116

Wilber DH, Clarke DG (2001) Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21:855–875

Wise BS, St John J, Lenanton R C (eds) (2007) Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 1: Stock status of the key indicator species for the demersal scalefish fishery in the West Coast Bioregion. Final report to Fisheries Research and Development Corporation on Project No. 2003/052. Fisheries Research Report No. 163, Department of Fisheries, Perth, Western Australia

Yeates PS, Okely P, Antenucci JP, Imberger J (2006) Hydrodynamic Modelling of the impact of the Perth Seawater Desalination Plant discharge on Cockburn Sound. Centre for Water Research, University of Western Australia, Report No. WP 2127 PY, Perth, Western Australia, November 2006

Appendix A

Marine Construction Modelling and Assessment Report

Appendix B

2016 Site Flora and Fauna Survey Report

Appendix C

Aboriginal Heritage Survey

Appendix D

Hydrodynamic Modelling: Validation Report

Appendix E

Hydrodynamic Modelling: Scenario Outcomes

Appendix F

Hydrodynamic Modelling: Effects of Desalination Discharges on Dissolved Oxygen

Appendix G

Technical Dredging Input Advice and Sediment Quality Assessment

Appendix H

Hydrodynamic Modelling Peer Review Panel Assessment

Appendix I

Low Ecological Protection Area Coordinates

Appendix J

2013 Benthic Macroinvertebrate Survey

Appendix K

EPBC Act Protected Matters Search