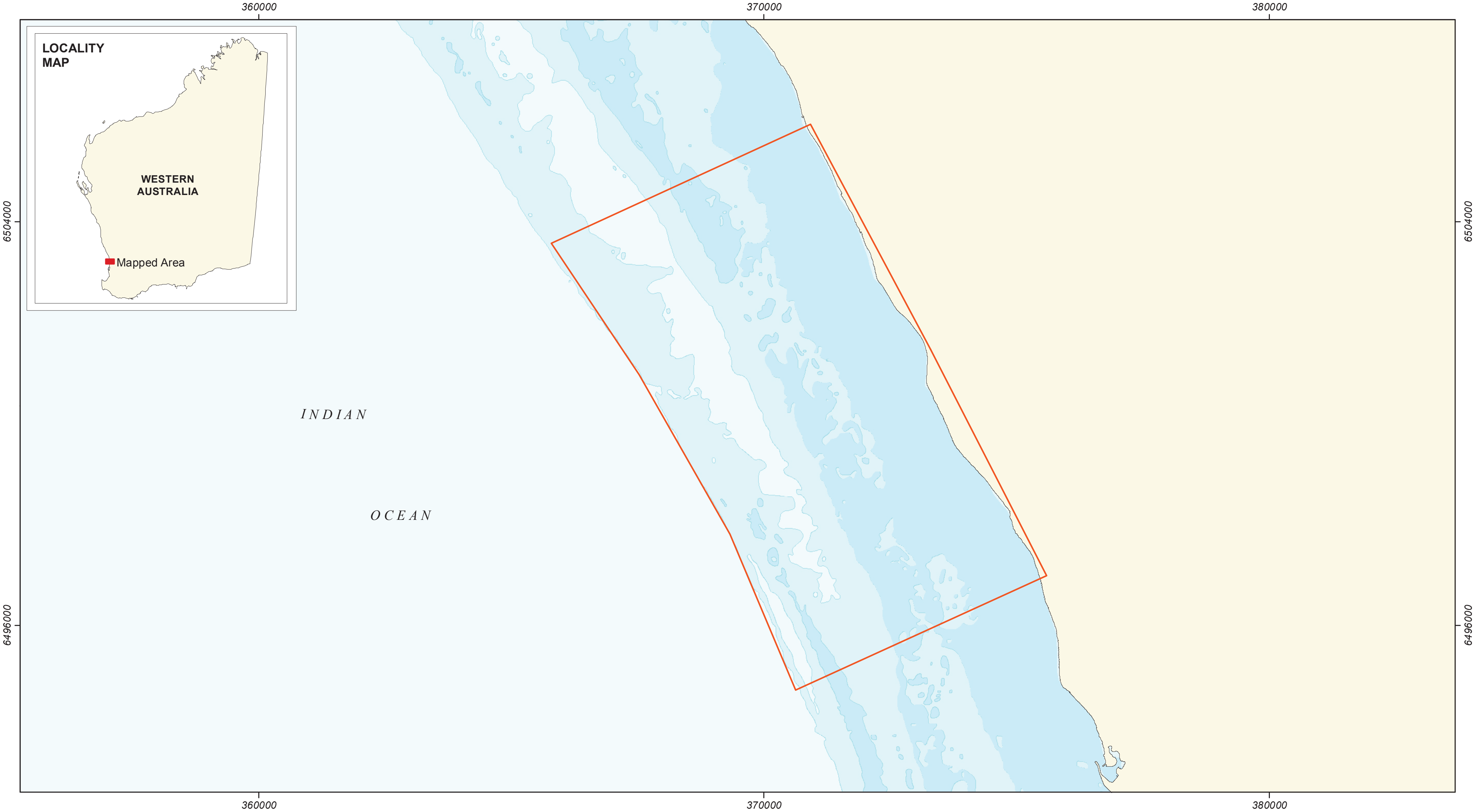

Figure 7-6: Spatial extent of the Alkimos LAU

N

Scale 1:45,346,102 at A4

0 1.5 3 km

Coordinate System: GDA 1994 MGA Zone 50

Date: 7/03/2019

Legend

Local Assessment Unit

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7.6.2 Construction impacts

Direct loss of benthic communities and habitats

The marine infrastructures, including the marine risers, the intakes structures and the outlet diffusers, will be installed at the end of subsea tunnels, drilled using a TBM.

Direct losses of BCH will therefore be limited to the four excavation sites, to an area of approximately 8 m radius (around each drilling point), a width roughly equivalent to the width of the intake and diffuser structures.

Direct losses of BCH will be limited to the four excavation sites, to an area of approximately 8 m radius (around each drilling point), a width roughly equivalent to the width of the intake and diffuser structures. However, to account for potential indirect effects, calculations were conservatively undertaken assuming the total loss of habitats within 100 m of the diffuser and intake arrays (following the results of conceptual modelling (Section 6.6.2). This equates to 8.38 ha each (Figure 7-7). This highly conservative approach was taken to account for the full range of potential impacts, including jack-up barge positioning and anchoring, drilling and the potential for losses due to smothering.

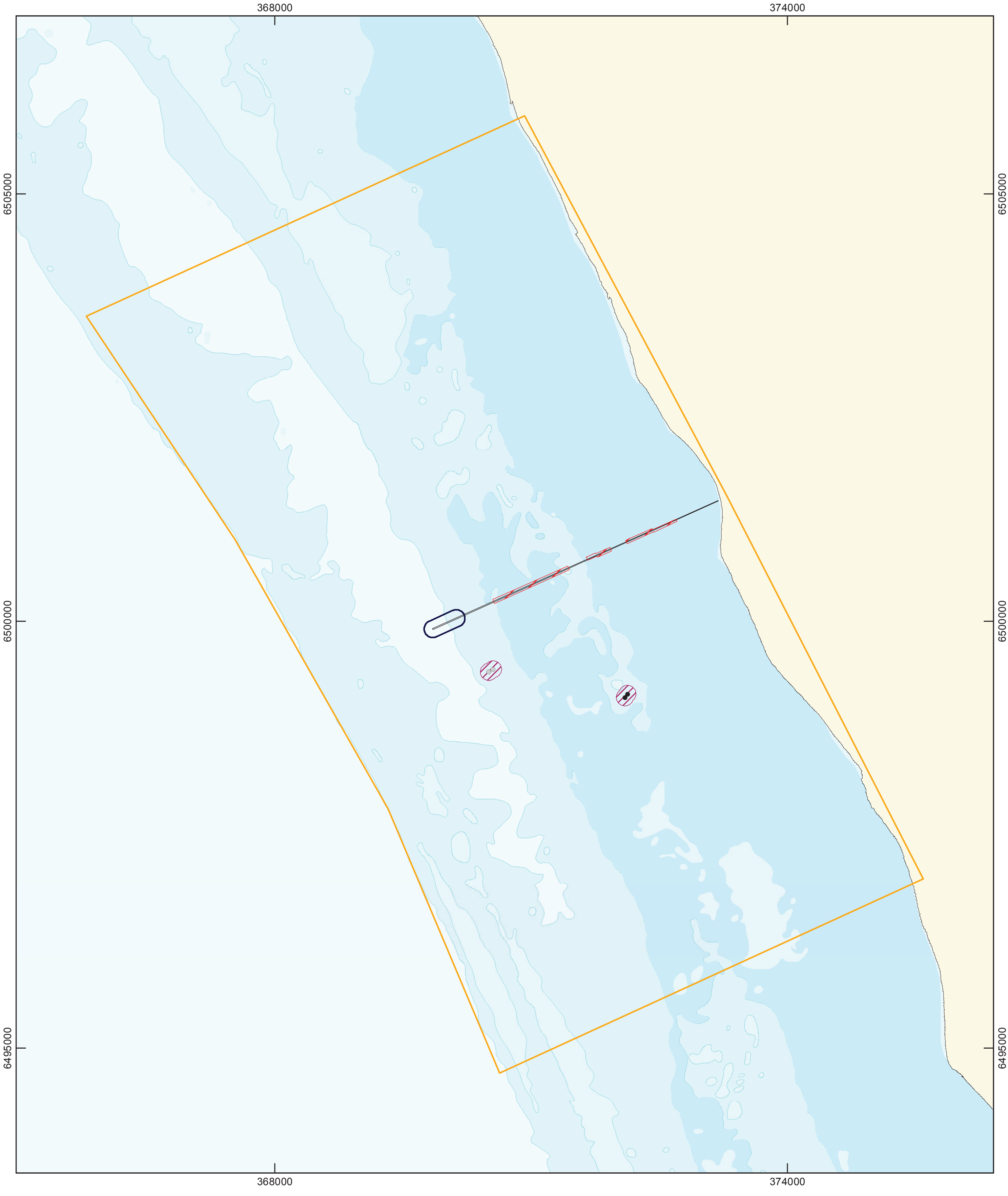

Figure 7-7: Zone of historical loss together with the zone of predicted loss

N

Scale 1:60,000 at A4

0 800 1,600 m

Coordinate System: GDA 1994 MGA Zone 50

Date: 7/03/2019

Legend

ASDP Outfall Diffuser

ASDP Intake Structure

WWTP 100m LEPA

WWTP Sidecast Disturbance Area

Desal Infrastructure Disturbance Area

Local Assessment Unit

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Loss of benthic habitats and communities via smothering / shading

Shading

The mechanisms leading to shading and its possible impacts are described in full in Section 6.6.2.

A conceptual hydrodynamic model was developed to the predict the likely rise and fall of particles, and the resulting spatial extent of sedimentation, due to the drilling process. While the results did not extend to prediction of TSS concentrations in the water column, it was reasonably concluded that the worst-case mobilisation of 32 m^3 of sediments over a three-week period (equating to ~1.5 m^3 per day per shaft), was unlikely to result in a significant sediment plume. The potential for impacts to BCH resulting from TSS and shading were therefore considered low.

Smothering

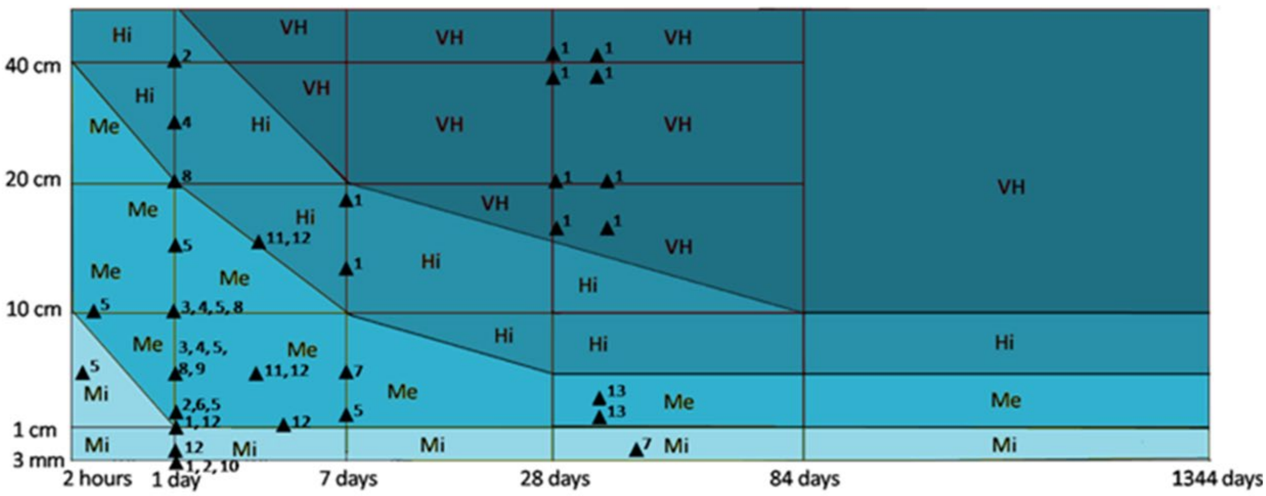
As described in Section 6.5.2, the extent that smothering may lead to impacts is related to the depth, or the 'thickness', of the sedimentation layer (Table 7-8). For the motile elements of the BCH (e.g. invertebrates), an organism's tolerance to sedimentation is based on its ability to escape burial (Table 7-8). Nichols et al (1978) (cited in Chou et al 2004) and Miller et al (2003), found that most invertebrates could avoid burial if deposition was restricted to a thickness of 5-10 cm; though other authors (Kranz 1974) cite much higher values of between 11 and 57 cm (Table 7-8).

Table 7-8: Escape potential for different bivalve groups for given rates of sediment burial

Bivalve group	EP10 (exotic sediment) (cm)	EP10 (native sediment) (cm)
Epifaunal species	–	–
Suspension feeders (on hard substrates)	0–4	–
Infaunal species	–	–
Labial palp deposit feeders	10	>45–>57
Mucus tube feeders	2-12	41 to >52
Non-siphonate suspension feeders	1–>10	5 to >15
Siphonate suspension feeders (deep burrowers)	>15	>11
Siphonate suspension feeders (shallow burrowers)	>6–>40	10–>45
Siphonate deposit feeders	>40	>36
Infaunal mud worm *Marenzellaria viridis*	-	>5
Epifaunal motile snail *Ilyanassa obsoleta*	-	10-30
Reef building polychaete *Sabellaria vulgaris*	-	<2
Infaunal tube building crustacean *Corophium volitator*	-	10 cm (per month)

1. EP10 means that 10% of the individuals can escape the given (maximum) depth of burial and re-establish themselves in normal feeding position at normal living depth.
2. Source: Kranz (1974 cited in Kjeilen-Eilertsen et al 2004), Miller et al (2003), Nichols et al (1978) and Birklund and Wijsman (2005).

In addition, Fehmarn (2013) provides a comprehensive review of infauna sedimentation thresholds, which includes an impact severity matrix with four categories: minor, medium, high and very high (Figure 7-8). The matrix is useful because unlike most thresholds (which use absolute values), the thresholds are based on two factors: magnitude and duration of effect.



1. The minimum duration is two hours, which is the minimum time step of the output data from the sediment spill modelling. The intensity duration envelopes for the four impact categories: minor (Mi), medium (Me), high (hi) and very high (VH) are provided as different shades of blue.
2. Source: Fehmarn (2013) and references contained within.

Figure 7-8: Infauna marine sedimentation thresholds

Based on the thresholds in the literature (Table 7-8, Figure 7-8), the predicted worst-case rates of sedimentation at Alkimos were within the non-lethal range (~1 cm per m^2 per day, based on a total deposition of 20 cm over 21 days), such that most invertebrates should be capable of escaping the effects of the predicted deposition. Given the one-off exposure at each site, together with the fact the highest sedimentation rates will be restricted to within 10 m of the excavation area, it is considered unlikely the drill cuttings will have a significant impact on BCH, which are naturally accustomed to frequent, natural turbidity and sedimentation events (e.g. on the back of winter storms) (see Section 6.6.2).

Secondary loss of benthic communities and habitats due to toxicity / exposure to residues

The commissioning phase requires flushing and disinfection of the pipelines and RO infrastructure. The essentially freshwater effluent from the pressure test and disinfection processes will be buoyant in seawater and will form a plume that will naturally rise to the water surface. Water Corporation has committed to no residual chlorine or TRO in the pressure test and disinfection waters discharged to the marine environment through the diffuser outlet following treatment.

Residues entrained in the initial flush (at beginning of the flushing phase) will be diluted in the pipe, and then again following discharge. Risks to BCH are therefore considered low, especially given the distance (~265 m) between the proposed outlet diffusers and the nearest seagrass and macroalgal communities.

7.6.3 Operational impacts

Tertiary impacts to BCH and macroinvertebrates (reduced DO, increased temperature)

As described in Section 6.6.3, the change in ambient DO is expected to be minimal. Therefore, the risk to BCH associated with DO stress is considered negligible. Similarly, the change in ambient temperature at the edge of the near-field mixing zone (~70 m) is expected to be minimal and well within the thermal tolerance limits of local BCH.

Tertiary impacts to BCH (increased salinity)

As described in Section 6.6.3, the RO desalination process will produce a liquid brine concentrate by-product that is roughly twice the salinity of seawater (69 to 71 psu).

Modelling confirmed that, even under worst case conditions, the proposed ASDP diffusers should achieve a 1 in 30 dilution within 70 m of the discharge point.

In this assessment, salinity was assessed as a 'stressor' using a threshold of +1.3 psu above background (Table 6-13). The 1 in 30 dilution projected by the model is expected to be sufficient to restrict near field salinity elevations to within +1.1 psu above background, well below the +1.3 psu criterion.

Median salinity elevations for the month of April (representing the period of lowest wind speeds, and therefore poorest dilution) are shown in Figure 7-9. When added to typical background salinities (Table 6-14), these translate to salinities that are well within the tolerance limits of marine species (Table 6-15) (Diaz and Rosenberg 1995).

Table 7-9: Published salinity tolerances seagrass and macroalgal communities

Common name	Scientific name	Tolerance (ppt)	Comments	Reference
Seagrass	*Posidonia australis*	33–55	Found in Perth coastal waters	Walker et al (1988)
Seagrass	*Posidonia coriacea*	30–50		

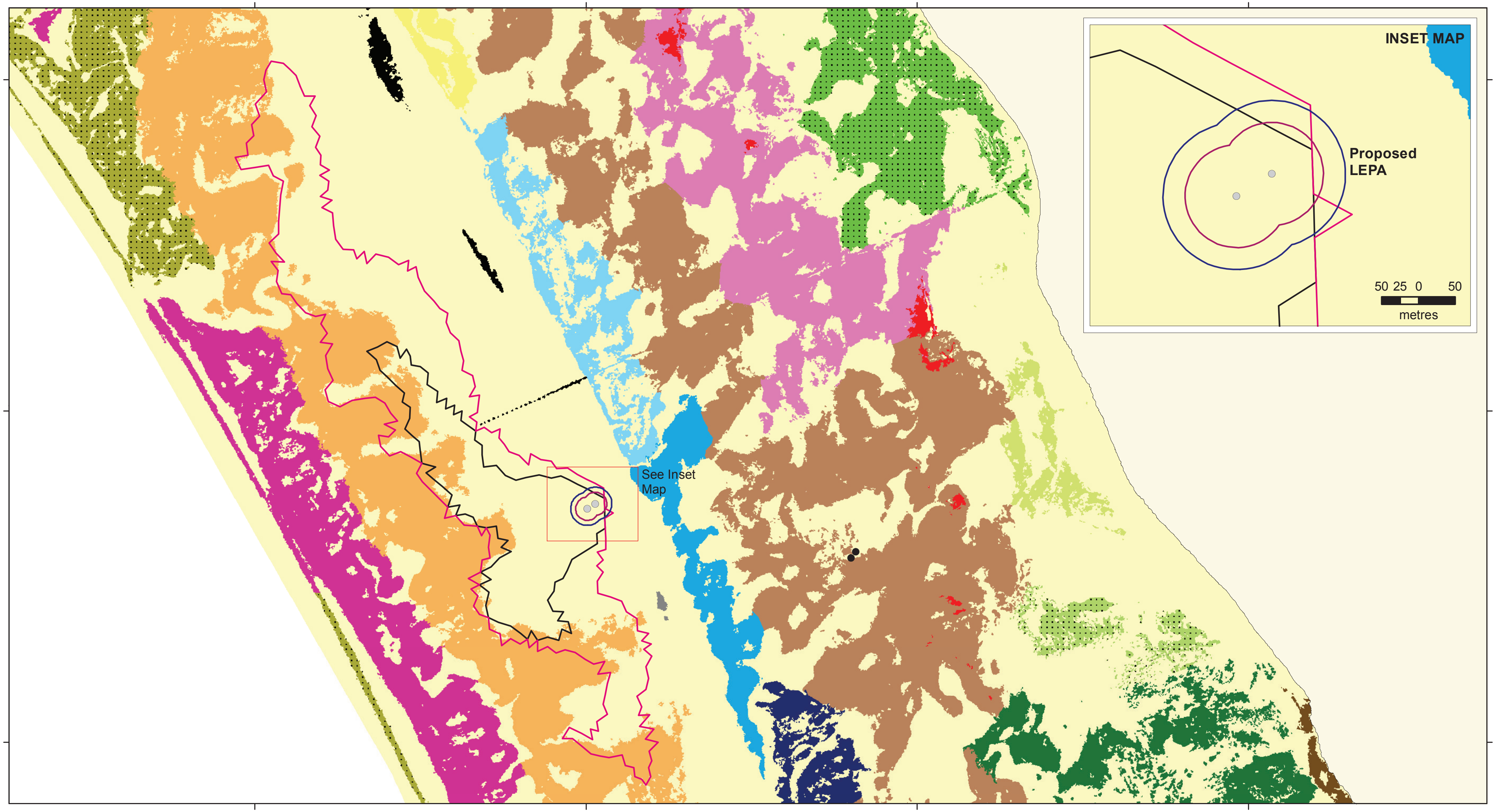


Figure 7-9: Predicted salinity elevations (50th percentile in April) above background overlain on marine habitats

N

Scale 1:7,070 at A4

0 400 800 m

Coordinate System: GDA 1994 MGA Zone 50

Date: 7/03/2019

Legend

ASDP Outfall Diffuser

ASDP Intake Structure

ppt Above Background

0.8 to 1.0

1.0 to 1.3

> 1.3

Benthic Habitat

Bare sand

Unknown

Macroalgae Reef (Mixed Assemblage)

Exposed Reef

Macroalgae Reef (Mixed Assemblage dominated by Ecklonia; <30% Caulerpa and Mixed Brown)

Macroalgae Reef (Mixed Assemblage; <30% Ecklonia, Caulerpa, Mixed Brown, Other Brown and Mixed Red); <30% Filter Feeders

Macroalgae Reef (Mixed Assemblage dominated by Ecklonia; <30% Caulerpa, Mixed Brown and Other Brown); <30% Filter Feeders

Macroalgae Reef (Mixed Assemblage dominated by Ecklonia; <30% Caulerpa, Mixed Brown, Sargassum, Mixed Red and Encrusting Red)

Macroalgae Reef (Mixed Assemblage; <30% Ecklonia and Sargassum); <30% Seagrass (Mixed Assemblage)

Macroalgae Reef (Mixed Assemblage; <30% Ecklonia, Mixed Brown); <30% Seagrass (Mixed Assemblage) and Filter Feeders

Macroalgae Reef (Mixed Assemblage dominated by Mixed Brown; <30% Mixed Red and Encrusting Red); <30% Seagrass (Mixed Assemblage)

Macroalgae Reef (Mixed Assemblage; <30% Ecklonia, Caulerpa, Mixed Brown, Mixed Red and Encrusting Red); <30% Seagrass (Mixed Assemblage)

Macroalgae Reef (Mixed Assemblage dominated by Ecklonia; <30% Caulerpa, Mixed Brown and Other Brown); <30% Seagrass (Mixed Assemblage) and Filter Feeders

Seagrass (Mixed Assemblage dominated by Amphibolis; <30% Posidonia and Zostera)

Seagrass (Amphibolis; <30% Posidonia, Zostera, Mixed Assemblage); <30% Macroalgae (Mixed Brown)

Seagrass (Mixed Assemblage; <30% Amphibolis and Halophila); <30% Macroalgae (Mixed assemblage; <30% Sargassum)

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Secondary and tertiary effects to BCH (toxicity)

WET testing completed on a sample of the SSDP reject stream complete with CIP chemicals suggested that the dilutions required to maintain a high level of ecological protection increase marginally from 1:22 to 1:29 (Table 6-16). The small difference in toxicity between the brine only and brine + CIP samples suggests that the toxic effect of the effluent is predominantly due to the osmotic imbalance caused by salinity and that CIP chemicals make a small contribution. The CIP chemicals will be used intermittently and in low volumes relative to the overall volume of the discharge. The risk posed by the discharge of RO maintenance chemicals is therefore considered negligible. The potential for adverse effects resulting from salinity are addressed fully in Section 6.6.3.

7.6.4 Cumulative impacts

The Alkimos WWTP represents the only source of BCH impact within the defined LAU, while the Two Rocks and Mindarie Marinas represent the closest anthropogenic developments to the north and south, respectively. Therefore, the BCH mapped for the Alkimos WWTP baseline studies (Oceanica 2005c) is considered the best representation of pre-European BCH cover in the LAU (Table 7-10).

Table 7-10: Alkimos Wastewater Treatment Plant baseline benthic communities and habitats extent (Water Corporation 2005)

Habitat Type	Area (ha)	Composition of total (%)
Posidonia sp.	0.20	0.06
Amphibolis sp.	2.78	0.83
Amphibolis sp. and reef	10.16	3.03
Halophi*la* sp.	0.02	0.01
Heterozostera sp.	0.00	0.00
Thalassodendron sp.	0.02	0.01
Mixed *Halophila* sp. and *Heterozostera* sp.	0.16	0.05
Wrack	3.58	1.07
Low relief reef	20.28	6.06
Reef	64.68	19.31
High relief reef	46.01	13.74
Exposed reef	1.29	0.39
Sand	185.70	55.45
Total	**334.88**	**100**

A total of 3.3 ha of BCH was lost during the construction of the Alkimos WWTP, and the operation of the WWTP has had no detectable impacts on BCH communities since that time (Water Corporation 2016). Historical and predicted losses therefore amount to a total of 11.68 ha (Table 7-11), representing less than 1% of the LAU (Table 7-11).

Table 7-11: Cumulative loss assessment of benthic communities and habitats mapped within the local assessment unit

Habitat Type	Mapped extent (2017)	Habitat loss			
		WWTP	ASDP	Total	Proportion
Amphibolis sp. & reef	371	0.19	0.00	0.19	<0.5%
High relief reef	645[4]	0.83	2.22	3.79	0.6%
Low relief reef		0.06			
Reef		0.68			
Bare sand	2 742	1.54	6.16	7.70	<0.5%
All other habitat types[1]	1 640	0	0	0	0

1. Represents habitat types mapped but not impacted by historical or proposed developments.

7.7 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 7-12.

Table 7-12: Summary of mitigation measures to ensure maintenance of ecological integrity

Impact	Avoid	Minimise	Management and monitoring
Direct loss of BCH	The marine pipeline will be installed via a sub-sea tunnel, using a TBM. Wherever possible, marine infrastructures (risers, intakes and outlets) will be installed on open sandy meadows, while avoiding seagrass and macroalgal communities.	Surface excavations will be limited to the installation of marine risers at four sites, each of approximately 12 m radii.	Described in the MCEMF (Water Corporation, in prep).
Indirect loss of BCH	Tunnelling effectively eliminates any serious issues associated with turbidity plumes, including increased TSS and reduced light. Excavation is limited to four sites of approximately 12 m radius. Drilling will proceed over several days and is not expected to significantly impact environmental quality.	Excavation requires drilling of approximately 32 m^3 of sediments per site. Risers will be installed by drilling into the seabed within a vertical casing. The intent of the casing is to minimise escape of cuttings and support the integrity of the shaft.	Described in the MCEMF (Water Corporation, in prep).
	The outlet diffusers have been designed to meet strict minimum performance criteria. This included a requirement to achieve a 1:30 dilution in the near field environment.	The diffuser configuration has been designed to achieve a 1:30 within 70 of the diffuser. The marine environment will be managed to achieve a high level of ecological protection with 100 m of the outlets.	Described in the MCEMF (Water Corporation, in prep).

7.7.1 Construction mitigation

A preliminary register of measurable and/or auditable environmental commitments to manage the environmental impacts associated with construction activities (Section 7.6.2) are provided in Table 7-13. The environmental management framework (EMF) will be outlined in further detail in a marine construction EMF (MCEMF) (Water Corporation, in prep).

Table 7-13: Relevant environmental objectives, performance indicators and proposed measurement criteria for benthic communities and habitats

Environmental objective	Performance criteria	Standards	Performance indicators
To protect benthic communities and habitat so that biological diversity and ecological integrity are maintained.	Ensure that benthic communities and habitat outside of the excavation footprints are managed so that any impacts are recoverable within 5 years.	Implement management procedures for turbidity and smothering, e.g.: • conduct all drilling activities within vertical casings • maintain a visual record of the extent of any resulting sediment plumes.	Records (e.g. notes and/or photographs etc) of surveillance during discharge events e.g.: • compile baseline photographic records of nearby benthic communities • demonstrate no change in benthic communities post construction.

7.7.2 Operations mitigation

A preliminary register of measurable and/or auditable environmental commitments to manage the potential environmental impacts to BCH from the SDP operation (Section 7.6.3) are provided in Table 7-14. Environmental monitoring and management will be outlined in further detail in the MOEMP, which will be finalised prior to commencement of plant operations. It is anticipated that the MOEMP will include:

- detailed monitoring and management requirements (in-line with Table 7-14)
- 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

Environmental objective	Performance criteria[1]	Standards[2]	Performance indicators[3]
To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained.	No persistent impacts to benthic communities and habitats resulting from inputs of brine.	Detailed procedures for: • implementation of an MOEMP to ensure compliance with the EPA (2017) high ecological protection criteria. Detailed management procedures for return seawater discharges, including: • on-going water quality monitoring • control of brine discharges at the SDP plant.	• evidence of normal plant operation and performance • regular third-party audits of MOEMP outcomes • evidence of compliance with MOEMP objectives and procedures • regular reporting of performance against the EQC.

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 to assess the company's environmental performance.

7.7.3 Predicted outcomes

A key component of this assessment was to identify the stressors related to the construction and operation of the SDP. These include (a) the disturbance of the benthic environment due to placement of marine infrastructure and (b) the discharge of return seawater (brine) to the marine environment.

Potential impacts will be mitigated through: (a) installing pipelines in sub-marine tunnels (as excavated using a TBM); and (b) optimising the design of the outlet diffusers, to achieve dilutions compliant with high ecological protection criteria.

The outcomes of these mitigation strategies are described in detail in Section 6.8 in the context of Marine Environmental Quality. By protecting the environmental values associated with Marine Environmental Quality, much of the risk to BCH is considered manageable.

Despite the adoption of the tunnelling technology, small areas of benthic communities and habitats (BCH) were considered at risk due to localised drilling activities, and the flow on effects to light attenuation and dispersal of drill cuttings (sedimentation). However, the assessment concluded that the mobilisation of 32 m^3 of sediments over a three-week period (equating to ~1.5 m^3 per day per shaft), was unlikely to affect local light conditions, and that the worst rates of sedimentation are within the non-lethal range for most invertebrates.

The extent of potential habitat loss due to placement of infrastructure and the effects of sedimentation was conservatively estimated based on a cumulative impact zone of 16.7 ha. Within this impact zone, losses of reef, seagrass and macroalgal habitats were conservatively estimated at 8.3 ha, which when combined with the estimated historical losses, accounted for less than 1% of BCH in the LAU.

Based on this, the proposed drilling and infrastructure laydown activities are not expected to contribute tangible losses of BCHs.

8. Marine Fauna

8.1 EPA objective

The EPA's environmental objective for marine fauna is:

"To protect marine fauna so that biological diversity and ecological integrity are maintained" (EPA 2018b).

8.2 Policy and guidance

The relevant EPA policy and guidelines, and the scope of each of these as relevant to the Proposal, are presented in Table 8-1.

Table 8-1: Policies and guidelines

Policy or guidance	Consideration
Statement of Environmental Principles, Factors and Objectives (EPA 2018b)	This document was written according to EPA's (2018b) Principles, Factors and Objectives.
Environmental Factor Guideline – Marine Fauna (EPA 2016d)	Provides guidance on the frameworks for protecting Marine Fauna in Western Australia.
Technical Guidance – Protecting the quality of Western Australia's marine environment (EPA 2016g)	Provides guidance on the environmental quality management frameworks for protecting Western Australia's Marine Environment. It defines the Environmental Values and Objectives for Ecosystem Health, Fishing and Aquaculture, Recreation and Aesthetics, Industrial Water Supply and Cultural and Spiritual Values, as well as the approach to setting Levels of Ecological Protection. The studies executed in support of the ERD, including hydrodynamic and water quality modelling, were designed and executed in the context of EPA (2016g).
Other policy or guidance	**Consideration**
Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy No. 4 (ANZECC & ARMCANZ 2000)	This document and the assessments of impacts contained herein are based on guidance in the relevant EPA documents (cited above), which are in turn based on the high-level guidance provided in ANZECC & ARMCANZ (2000) and ANZG (2018).
Australian Water Quality Guidelines for Fresh and Marine Waters (ANZG 2018)	As above.

8.3 Overview of studies

The occurrence, frequency and distribution of marine fauna within a 10 km radius of the proposed SDP was examined via a review of the EPBC Act Protected Matters Report (Appendix E) and the literature. The EPBC Act Protected Matters Report (PMR) identified protected avifauna, marine reptiles, marine mammals and finfish species, which were subsequently considered by this review. The Department of Primary Industries and Regional Development (DPIRD), Fisheries Division, was also consulted regarding the distribution, frequency, biology and value of relevant commercial fisheries in the region (finfish, octopuses, abalone and western rock lobster).

8.4 Receiving environment

8.4.1 Marine fauna

Avifauna

The EPBC Act PMR listed 53 bird species – many of which are migratory – as potentially occurring within 20 km of the SDP (Table 8-2). The great egret (*Ardea alba*), silver gull (*Larus novaehollandiae*) and bridled turn (*Onychoprion anaethetus*) are the only bird species known to breed in the area (Table 8-2). While all the listed bird species may fly over or utilise habitats within or near the area of the SDP, the area is not known to encompass waters or habitats that are critical for the survival of any of these species.

Table 8-2: Avifauna listed in the EPBC Act Protected Matters Report that may occur within 10 km of the Seawater Desalination Plant

Common name	Scientific name	Presence type in SDP area[4]						
		A	B	C	D	E	F	G
Common Sandpiper[3]	*Actitis hypoleucos*	X						
Common Noddy[2,3]	*Anous stolidus*		X					
Australian Lesser Noddy[1,3]	*Anous tenuirostris melanops*			X				
Fork-tailed Swift[2,3]	*Apus pacificus*		X					
Great Egret[3]	*Ardea alba*							X
Cattle Egret[3]	*Ardea ibis*			X				
Flesh-footed Shearwater[2]	*Ardenna carneipes*					X		
Australasian Bittern[1]	*Botaurus poiciloptilus*		X					
Sharp-tailed Sandpiper[3]	*Calidris acuminata*	X						
Red Knot[1,3]	*Calidris canutus*	X						
Curlew Sandpiper[1,3]	*Calidris ferruginea*	X						
Pectoral Sandpiper[3]	*Calidris melanotos*			X				
Red-necked Stint[3]	*Calidris ruficollis*	X						
Forest Red-tailed Black-Cockatoo[1]	*Calyptorhynchus banksii naso*		X					
Carnaby's Cockatoo[1]	*Calyptorhynchus latirostris*	X						
Great Skua[3]	*Catharacta skua*			X				
Amsterdam Albatross[1,2,3]	*Diomedea amsterdamensis*			X				
Southern Royal Albatross[1,2,3]	*Diomedea epomophora*					X		
Wandering Albatross[1,2,3]	*Diomedea exulans*					X		
Northern Royal Albatross[1,2,3]	*Diomedea sanfordi*					X		
White-bellied Sea-Eagle[3]	*Haliaeetus leucogaster*				X			
Blue Petrel[1,3]	*Halobaena caerulea*			X				

Common name	Scientific name	Presence type in SDP area[4]						
		A	B	C	D	E	F	G
Pied Stilt[3]	*Himantopus himantopus*	X						
Caspian Tern[2]	*Hydroprogne caspia*				X			
Silver Gull[3]	*Larus novaehollandiae*							X
Pacific Gull[3]	*Larus pacificus*						X	
Malleefowl[1]	*Leipoa ocellata*		X					
Bar-tailed Godwit (baueri)[1,3,5]	*Limosa lapponica baueri*			X				
Northern Siberian Bar-tailed Godwit[1]	*Limosa lapponica menzbieri*			X				
Southern Giant-Petrel[1,2,3]	*Macronectes giganteus*			X				
Northern Giant Petrel[1,2,3]	*Macronectes halli*			X				
Rainbow Bee-eater[3]	*Merops ornatus*			X				
Grey Wagtail[3]	*Motacilla cinerea*			X				
Eastern Curlew[1,3]	*Numenius madagascariensis*			X				
Bridled Tern[2,6]	*Onychoprion anaethetus*							X
Fairy Prion (southern)[1,3,7]	*Pachyptila turtur subantarctica*	X						
Osprey[2,3]	*Pandion haliaetus*	X						
Sooty Albatross[1,2,3]	*Phoebetria fusca*			X				
Soft-plumaged Petrel[1,3]	*Pterodroma mollis*			X				
Little Shearwater[3]	*Puffinus assimilis*				X			
Flesh-footed Shearwater[2,3]	*Puffinus carneipes*					X		
Red-necked Avocet[3]	*Recurvirostra novaehollandiae*	X						
Australian Painted-snipe[1,2,8]	*Rostratula australis*			X				
Caspian Tern[3]	*Sterna caspia*				X			
Roseate Tern[2,3]	*Sterna dougallii*					X		
Australian Fairy Tern[1]	*Sternula nereis*				X			
Indian Yellow-nosed Albatross[1,2,3]	*Thalassarche carteri*						X	
Shy Albatross[1,2,3,9]	*Thalassarche cauta*			X				
White-capped Albatross[1,2,10]	*Thalassarche cauta steadi*					X		
Campbell Albatross[1,2,3]	*Thalassarche impavida*			X				
Black-browed Albatross[1,2,3]	*Thalassarche melanophris*			X				
Hooded Plover[3]	*Thinornis rubricollis*			X				
Common Greenshank[3]	*Tringa nebularia*	X						

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 known to occur within area, E = foraging, feeding or related behaviour likely to occur within area, F = foraging, feeding or related behaviour may occur within area, G = breeding known to occur within area.
5. Species is listed under a different name (*Limosa lapponica*) in the in the EPBC Act - migratory species list.
6. Species is listed under a different name (*Sterna anaethetus*) in the Other Matters Protected by the EPBC Act list.
7. Species is listed under a different name (*Pachyptila turtur*) in the Other Matters Protected by the EPBC Act list.
8. Species is listed under a different name (*Rostratula benghalensis* [sensu lato]) in the Other Matters Protected by the EPBC Act list.
9. Species is listed under a different name (*Thalassarche cauta*) in the EPBC Act - migratory species list.
10. Species is listed under a different name (*Thalassarche steadi*) in the EPBC Act - migratory species list.

Marine mammals

The EPBC Act PMR listed 14 marine mammal species that may occur within 20 km of the SDP (Table 8-3). While 14 marine mammal species were listed in the PMR, only five species were considered as 'known' or 'likely' to occur within 20 km of the SDP (Table 8-3). Of these, all are mobile species and therefore capable of avoiding the area during construction activities.

Table 8-3: Marine mammals listed in the EPBC Act Protected Matters Report that may occur within 10 km of the Seawater Desalination Plant

Common name	Scientific name	Presence type in SDP area[4]						
		A	B	C	D	E	F	G
Cetaceans								
Minke Whale[3]	*Balaenoptera acutorostrata*			X				
Bryde's Whale[2,3]	*Balaenoptera edeni*			X				
Blue Whale[1,2,3]	*Balaenoptera musculus*		X					
Pygmy Right Whale[2,3]	*Caperea marginata*			X				
Southern Right Whale[1,2,3,5]	*Eubalaena australis*							X
Humpback Whale[1,2,3]	*Megaptera novaeangliae*	X						
Killer Whale[2,3]	*Orcinus orca*			X				
Common Dophin[3]	*Delphinus delphis*			X				
Risso's Dolphin[3]	*Grampus griseus*			X				
Spotted Dolphin[3]	*Stenella attenuata*			X				
Indian Ocean Bottlenose Dolphin[3]	*Tursiops aduncus*		X					
Bottlenose Dolphin[3]	*Tursiops truncatus s. str.*			X				
Pinnipeds								
Arctocephalus forsteri[3]	*Long-nosed Fur-seal*			X				
Australian Sea-lion[1]	*Neophoca cinerea*	X						

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 known to occur within area, E = foraging, feeding or related behaviour likely to occur within area, F = foraging, feeding or related behaviour may occur within area, G = breeding known to occur within area.
5. Species is listed under a different name (*Balaena glacialis australis*) in the EPBC Act - migratory species list.

Marine reptiles

The EPBC Act PMR listed four turtles that may occur within 10 km of the SDP (Table 8-4), including: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*) and flatback turtles (*Natator depressus*). In addition, Alkimos was listed as an important foraging area for three species of seasnakes including the Shark Bay seasnake (*Aipysurus pooleorum*), spectacled seasnake (*Disteira kingii*) and yellow-bellied seasnake (*Pelamis platurus*) (Table 8-4).

Table 8-4: Marine reptiles listed in the EPBC Act Protected Matters Report that may occur within 10 km of the Seawater Desalination Plant

Common name	Scientific name	Presence type in SDP area[4]						
		A	B	C	D	E	F	G
Turtles								
Loggerhead Turtle[1,2,3]	*Caretta caretta*				X			
Green Turtle[1,2,3]	*Chelonia mydas*				X			
Leatherback Turtle[1,2,3]	*Dermochelys coriacea*				X			
Flatback Turtle[1,2,3]	*Natator depressus*				X			
Seasnakes								
Shark Bay Sea snake[3]	*Aipysurus pooleorum*			X				
Spectacled Sea snake[3]	*Disteira kingii*			X				
Yellow-bellied Sea snake[3]	*Pelamis platurus*			X				

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 known to occur within area, E = foraging, feeding or related behaviour likely to occur within area, F = foraging, feeding or related behaviour may occur within area, G = breeding known to occur within area.

Finfish

The EPBC Act PMR listed 20 species of bony fishes that may occur within 20 km of the SDP, all of which are listed as ‘Other Matters Protected by the EPBC Act’ (Table 8-5).

The marine habitats of Alkimos provide suitable habitat for syngnathid fish (Foster & Vincent 2004, Kendrick & Hyndes 2003). While most syngnathids demonstrate a high fidelity for seagrass habitats (Kendrick & Hyndes 2003 and references cited therein) seadragons are more prevalent in kelp-dominated reefs to 50 m depth (Australian Museum 2015, 2016).

Alkimos is not listed as an important habitat for grey nurse sharks and great white sharks (DSEWPaC 2013a, 2013b). Porbeagle sharks primarily inhabit oceanic waters and the edge of the continental shelf, and movement into coastal waters is rare (DoEE 2018). Although whale sharks have a wide range and broad distribution in tropical and temperate waters, they are not frequent visitors to the south-west marine region (DSEWPaC 2012a).

As identified in the PMR, reef manta rays (*Manta alfredi*) and giant manta rays (*Manta birostris*), or their habitat, may occur within 20 km of the SDP (Table 8-5). Perth is the southern distribution limit of reef manta rays (Bray 2017a), and giant manta rays are relatively uncommon in Australian waters. Giant manta rays instead prefer tropical offshore oceanic waters (Bray 2017b).

There is no evidence to suggest the Alkimos marine environment supports significant nursery and/or spawning grounds for commercial finfish.

Table 8-5: Finfish listed in the EPBC Act Protected Matters Report that may occur within 10 km of the Seawater Desalination Plant area

Common name	Scientific name	Presence type in SDP area[4]						
		A	B	C	D	E	F	G
Bony fishes								
Southern Pygmy Pipehorse[3]	*Acentronura australe*			X				
Gale's Pipefish[3]	*Campichthys galei*			X				
Pig-snouted Pipefish[3]	*Choeroichthys suillus*			X				
Brock's Pipefish[3]	*Halicampus brocki*			X				
Western Spiny Seahorse[3]	*Hippocampus angustus*			X				
Short-head Seahorse[3]	*Hippocampus breviceps*			X				
West Australian Seahorse[3]	*Hippocampus subelongatus*			X				
Prophet's Pipefish[3]	*Lissocampus fatiloquus*			X				
Sawtooth Pipefish[3]	*Maroubra perserrata*			X				
Western Crested Pipefish[3]	*Mitotichthys meraculus*			X				
Bonyhead Pipefish[3]	*Nannocampus subosseus*			X				
Leafy Seadragon[3]	*Phycodurus eques*			X				
Common Seadragon[3]	*Phyllopteryx taeniolatus*			X				
Pugnose Pipefish[3]	*Pugnaso curtirostris*			X				
Gunther's Pipehorse[3]	*Solegnathus lettiensis*			X				
Spotted Pipefish[3]	*Stigmatopora argus*			X				
Widebody Pipefish[3]	*Stigmatopora nigra*			X				
Double-end Pipehorse[3]	*Syngnathoides biaculeatus*			X				
Hairy Pipefish[3]	*Urocampus carinirostris*			X				
Mother-of-pearl Pipefish[3]	*Vanacampus margaritifer*			X				
Sharks								
Grey Nurse Shark (west coast population)[1]	*Carcharias taurus*	X						
White Shark[1,2]	*Carcharodon carcharias*	X						
Porbeagle, Mackerel Shark[2]	*Lamna nasus*			X				
Whale Shark[1,2]	*Rhincodon typus*			X				

Common name	Scientific name	Presence type in SDP area[4]						
		A	B	C	D	E	F	G
Rays								
Reef Manta Ray[2]	*Manta alfredi*			X				
Giant Manta Ray[2]	*Manta birostris*			X				

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 known to occur within area, E = foraging, feeding or related behaviour likely to occur within area, F = foraging, feeding or related behaviour may occur within area, G = breeding known to occur within area.

Abalone

In WA, the most common abalone is Roe's abalone (*Haliotis roei*), followed by greenlip abalone (*Haliotis laevigata*) and brownlip abalone (*Haliotis conicopora*). Of these, only Roe's abalone is relevant in the context of Alkimos, since the distribution of greenlip and brownlip abalone only extend as far north as Cape Naturaliste and Fremantle, respectively (DoEH 2004). Nearshore limestone reefs, which are common at Alkimos, are known to support Roe's abalone. While there are no reliable numbers for the Alkimos region, nearby Burns Beach reef ~15 km south of Alkimos, supports Roe's abalone densities of between 6–113 individuals per m^2 (BMT Oceanica 2016c).

Western rock lobster

The western rock lobster is endemic to WA, inhabiting clear, well-oxygenated waters from the North West Cape (21°45'S) south to Cape Leeuwin (34°22'S; Chittleborough 1975). The species is most abundant between Geraldton and Perth (DoF 2011). The life cycle of the western rock lobster is well known and includes a planktonic pelagic stage (living in the open ocean) of ~9–11 months before they actively swim to shallow coastal (<20 m) regions to begin the benthic stage (living on the seafloor) of their life (DoF 2011). Full development from larvae to sexual maturity takes between 4.5 and 6 years (Gray 1992).

Inshore and outer reefs, such as those at Alkimos, serve as an important habitat for post-puerulus and juvenile western rock lobster, which typically inhabit small holes in the face of coastal limestone reefs (Chittleborough 1975, Fitzpatrick et al 1989; cited in MacAurthur et al 2007, Jernakoff 1990). Juveniles usually reside at these reefs for 3–4 years.

The western rock lobster is common at Alkimos, where they have anecdotally been observed inhabiting crevices upon the inshore reef line in waters of 10–12 m depth. Alkimos is also one of four DPIRD monitoring locations along the West Coast Bioregion (DPIRD 2018a).

Octopus

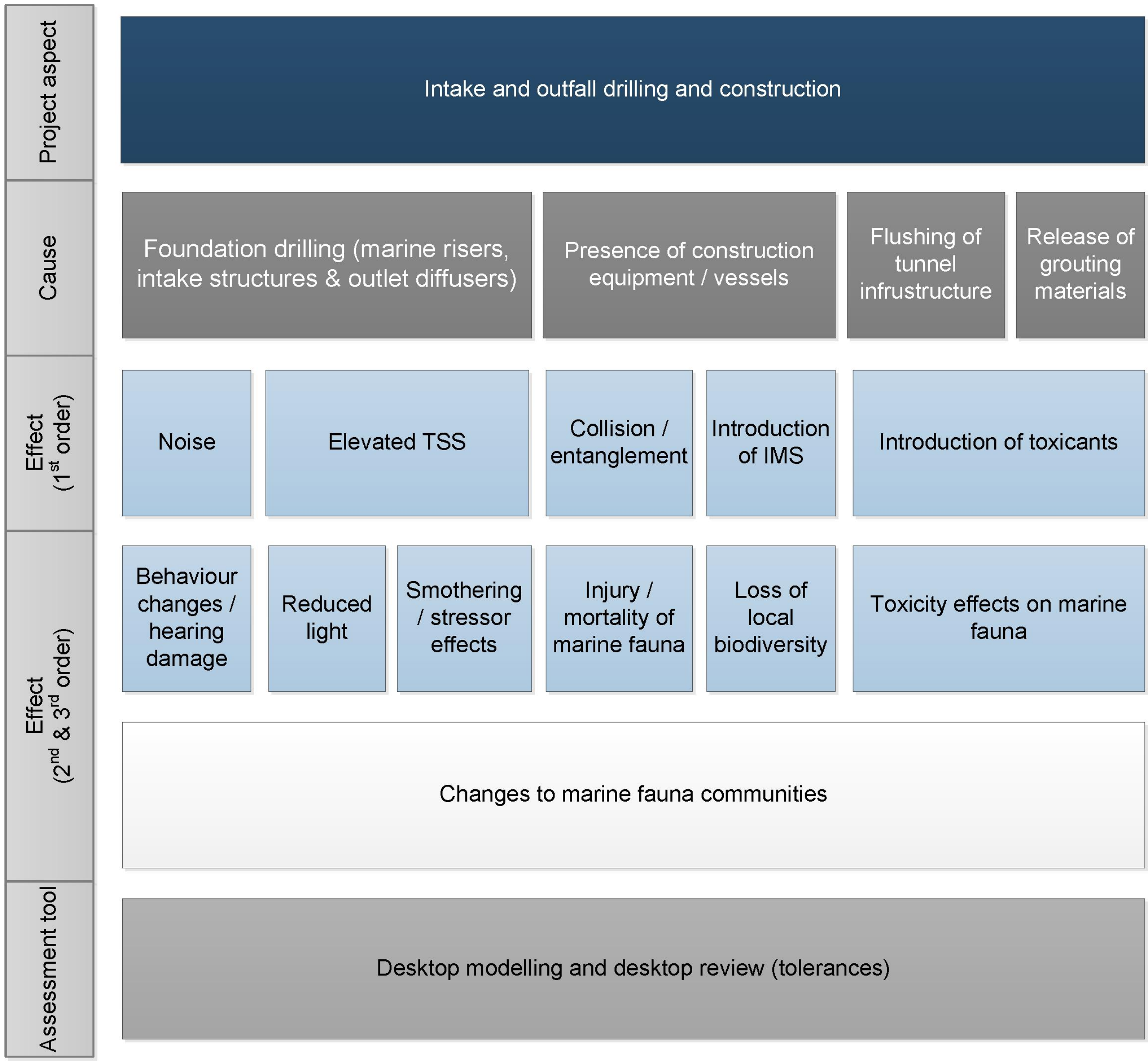
Commercial octopus catch is harvested from three fisheries within the West and South Coast Bioregions which extend from near Shark Bay (26°30'S) to the South Australia border (129°E). (DPIRD 2018b). The target species in WA is *Octopus cf. tetricus* which is endemic to the south-west temperate waters of Australia (DPIRD 2018b). While the majority of the commercial catch is from the Octopus Interim Managed Fishery (OIMF), small but significant quantities are also captured in the Cockburn Sound Line and Pot Managed Fishery (CSLPMF) and the West Coast Rock Lobster Managed Fishery (WCRLMF) (DPIRD 2018b; Gaughan & Santoro 2018).

O. cf. tetricus stock is highly productive, as well as abundant and widely distributed along the west and south coast of WA (Hart et al 2016). *O. cf. tetricus* inhabit a variety of habitat types including rocky reefs, seagrass meadows, and sandy substrates (Hart et al 2016). The estimated area of fished habitat (~460 km^2 in 2016) represents only ~2% of the total estimated area inhabited by *O. cf. tetricus* (>30000 km^2) and t the current annual catch (252 tonnes in 2016) is considerably lower than the estimate of sustainable harvest (800–2200 tonnes) (Hart et al 2016).

8.5 Potential Impacts

8.5.1 Potential construction impacts

Figure 8-1 and Table 8-6 list the relevant cause-effect pathways and the impacts that may arise during proposed construction activities. Risks associated with construction activities were assessed via a desktop review and conceptual modelling. Modelling investigated the theoretical dispersal of excavated material during the installation of the marine risers, intake structures and outlet diffusers, under a worst-case scenario. Section 6 of this document addressed the effects of the construction phase on water and sediment quality. Section 8.6.2 addresses the potential flow on effects to Marine Fauna.



1. 'Causes' are represented in the dark grey boxes and 'effects' are shown in light blue and white boxes.

Figure 8-1: Potential impacts to marine fauna associated with ASDP marine construction and commissioning activities

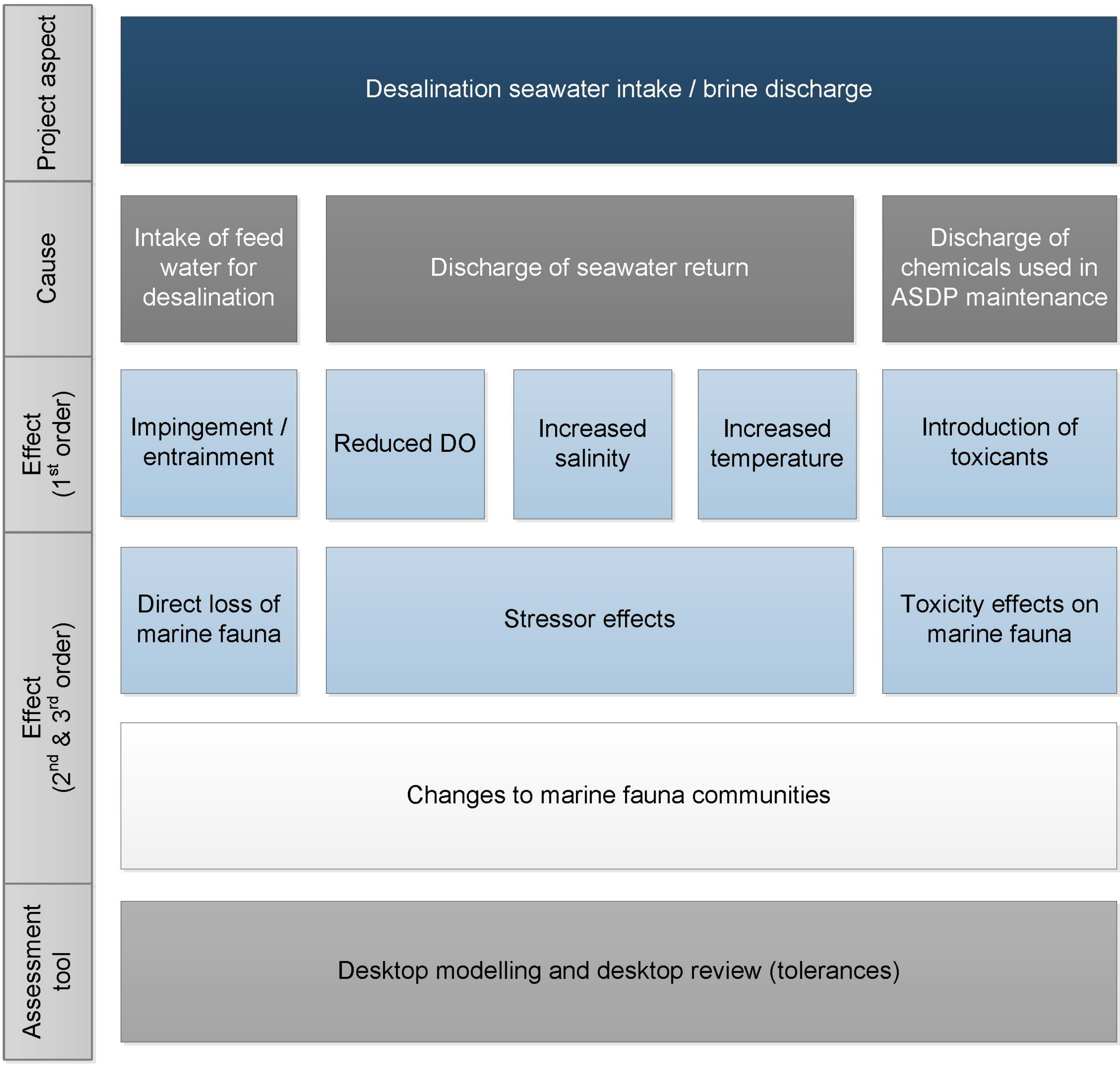
Table 8-6: Potential construction impacts to marine fauna

Potential impacts	Context
Changes in marine fauna behaviour/hearing damage (noise)	Underwater noise from construction activities may interfere with communication systems of marine fauna, masking biological cues or causing behavioural disturbance. Depending on the duration and intensity of the noise, an animal may avoid the source of the disturbance.
Reduced light and smothering/stressor effects (elevated TSS)	There is potential for periodic and/or short-term elevations in turbidity generated through excavation of foundations, which may lead to a range of direct and indirect impacts to marine fauna.
Injury/mortality of marine fauna (collision/entanglement)	The presence of vessels and machinery during construction activities may interact with marine fauna and potentially result in marine fauna collision. Construction also has the potential to contribute waste and building materials in the construction zone thereby increasing the possibility of marine fauna entanglement.
Loss of local biodiversity (introduction of IMS)	Construction has the potential to allow the settlement of Introduced Marine Species (IMS) via construction vessels, machinery and equipment.
Toxicity effects on marine fauna (introduction of toxicants)	The potential release of toxicants (grouting materials, chemicals) during construction / commissioning has the potential to adversely impact marine fauna.

8.5.2 Potential operational impacts

Figure 8-2 and Table 8-7 list the relevant cause-effect pathways and the impacts that may arise during proposed operations. Risks to marine fauna were assessed using a three-dimensional numerical model (DHI 2019) to determine the dilution of toxicants and map the trajectory of the brine and its possible interaction with marine fauna.

Section 6 of this document addressed the effects of the operational phase on water and sediment quality. Section 8.6.2 addresses the potential flow on effects to Marine Fauna.



1. 'Causes' are represented in the dark grey boxes and 'effects' are shown in light blue and white boxes.
2. DO = dissolved oxygen.

Figure 8-2: Potential impacts to marine fauna associated with ASDP marine operational activities

Table 8-7: Potential operational phase impacts to marine fauna

Potential impacts	Context
Direct loss of marine fauna (impingement/entrainment)	The intake of seawater through the intake structures has the potential to impinge and entrain marine fauna.
Stressor effects on marine fauna (reduced DO)	Disposal of brine may lead to stratification (a persistent layer of high salinity water at the bottom of the water column). Reduced mixing due to stratification may lead to oxygen drawdown.
Stressor effects on marine fauna (increased salinity)	The discharge of brine to the receiving environment may lead to persistent increases in salinity near the diffuser and in low low-lying habitats. Elevated salinity may result in osmotic stress and ion toxicity which affect plant water relations, ion concentrations in cytoplasm and the vacuole and growth and photosynthesis (Cambridge 2019).
Stressor effects on marine fauna (increased temperature)	The discharge of brine at temperatures higher than ambient may lead to artificial warming of the receiving environment. Persistent elevations in temperature may exceed the tolerance limits of some marine fauna species.
Toxicity effects on marine fauna (introduction of toxicants)	Chemicals used in plant maintenance may lead to localised toxicity in the mixing zone. The introduction of toxicants may adversely impact marine fauna near the diffuser.

8.6 Assessment of impacts

EPA's *Environmental Factor Guideline - Marine Fauna* (EPA 2016d) has been applied to determine the significance of direct and indirect impacts to marine fauna due to SDP construction and operation. The potential for impacts were examined particularly in the context of noise, construction and the discharge of brine.

8.6.1 Construction impacts

Changes in marine fauna behaviour/hearing damage (noise)

Construction activities in the marine environment can contribute significantly to marine noise (Green Jr. and Moore 1995, cited in Koper & Plon 2012). Noise will primarily occur during tunnelling and the drilling of the riser shafts (Jacobs 2018).

Marine fauna can exhibit increased stress, behavioural changes (including avoidance of important habitat and modification of vocal behaviour) and chronic responses (including sensitisation and habituation as well as cumulative and synergistic effects) in response to changes or increases in underwater noises (Koper & Plon 2012).

Auditory responses primarily result in temporary (TTS) or permanent (PTS) threshold shifts (the minimum level an organism can hear the sound) (Hildebrand 2005). A TTS involves successful recovery to normal hearing thresholds while during a PTS the sensory hair cells in the inner ear are permanently lost making recovery impossible (Weilgart 2007). The auditory response of a living organism to a given sound is dependent on the species; each species has its own range of frequencies over which it can hear and its own hearing sensitivity.

Non-auditory responses occur from severe damage to body tissues or embolism (gas bubbles in the blood stream) (Koper & Plon 2012) as sound oscillations pass through an animal. Marine mammals are particularly susceptible, owing to their increased levels of fatty tissues and respiratory systems (Koper & Plon 2012). Mortality generally occurs if fauna is exposed to sound levels greater than 200 dB (Table 8-8).

Underwater noise may also interfere with the communication systems of fauna, masking important biological cues necessary for normal biological and/or ecological functioning (Richardson et al 1995, NRC 2005, Southall et al 2007, Popper & Hastings 2009). These impacts may affect critical behaviours and functions, such as feeding, migration, breeding and response to predators, all of which may ultimately affect an individual animal's survival (NRC 2005). Depending on the duration and intensity of underwater noise, an animal may avoid the source of the disturbance, causing temporary or long-term avoidance of an area that may be important for feeding, reproduction or sheltering.

In general, the degree to which an individual animal is exposed to underwater noise is dependent upon the source sound pressure level and frequency, as well as species, and size and condition of the animal (e.g. small fish are more prone to injury by intense sound waves than larger fish of the same species; Popper & Hastings 2009). Behavioural responses (avoidance) typically occur when fauna is exposed to levels of 120–180 dB (Table 8-8).

Example thresholds for marine fauna potentially impacted by the ASDP are given in Table 8-8. For comparison, the predicted noise levels during construction activities at Alkimos are listed in the subsections below.

Table 8-8: Potential noise level impacts and noise thresholds for marine fauna associated with the Proposal (McCauley et al 2010)

Species	Behavioural response	Temporary Threshold Shift (TTS)	Permanent Threshold Shift (PTS)	Mortality
Whales	140–160 or 120 dB (SEL) when migrating	180 dB (SEL)	178–198 dB (SEL)	>200 dB (RMS)
Dolphins	120–180 dB (SEL)	183 dB (SEL)	178–198 dB (SEL)	>200 dB (RMS)
Sea lions	120–150 dB (SEL)	183 dB (SEL)	178–198 dB (SEL)	>200 dB (RMS)
Fish (including sharks)	120–150 dB (RMS)	180–190 dB (RMS)	190 dB (RMS)	>200 dB (RMS)

1. SEL = sound exposure level, RMS = root mean square.

Tunnelling

Estimated underwater sound pressure levels due to TBM tunnelling are estimated at between 155 dB (on the seabed directly above the tunnel) and 135 dB (at a projected distance 200 m from the tunnel) (Jacobs 2018). Constant noise at these levels is not sufficient to cause TTS or injury to marine fauna (Table 8-8) but may cause behavioural responses in the form of avoidance. This may result in a zone of avoidance of approximately 300 m radius that travels with the TBM cutting face as it advances at 0–15 m per day towards the intake and outlet locations.

Given the slow nature of tunnelling, it is likely that soft-start procedures will be sufficient to ensure there are no susceptible fauna within the 300 m avoidance zone during maximum noise generation.

Drilling for risers

Drilling will be required to install the intake and outlet risers to the tunnels. Drilling is estimated to result in a source noise level of 145–190 dB (UNEP 2012) RMS @1 m, over a period of approximately three weeks per site (of which there are four in total). The estimated noise source strength will not result in injury/mortality or TTS but does have the potential to result in behavioural changes (avoidance). As above, soft-start procedures are expected to be sufficient to manage susceptible fauna during the drilling process.

***Reduced light and smothering/stressor effects (elevated TSS*)**

Increases in TSS within the water column may lead to a range of direct and indirect impacts to marine fauna. Direct effects may result due to abrasion or the clogging of filtration mechanisms, thereby interfering with ingestion and respiration. Indirect effects may stem from increased turbidity leading to altered light regimes and resultant changes in feeding efficiency and behaviour (e.g. avoidance). Turbidity generated from drilling activities may also indirectly impact marine fauna through loss of benthic communities and associated marine fauna habitat (Section 7).

As described in Section 6.5.2, the volume of material released due to drilling activities is very low in comparison to capital dredging or trenching programs and is therefore expected to dilute rapidly in the open ocean environment (Neff 2005). The rapid dilution of materials together with the ability of most marine fauna to avoid the construction area, is expected to mitigate against the potential for impacts to marine fauna or benthic communities. This is supported in the work of Neff (2005), who concluded that marine fauna or flora are unlikely to be impacted by drill cuttings or associated discharges (Neff 2005).

Injury/mortality of marine fauna (collision/entanglement)

The presence of jack up barges during marine construction activities may disrupt marine fauna via collision, or by eliciting avoidance behaviour. The results of collision and/or entanglement may include death, injury, adverse behavioural and physiological changes, and reduced body condition and/or immune function to individual fauna.

Given that construction vessels will be slow moving or stationary during construction and equipment or infrastructure will be lowered to the seabed slowly, the risk of collision with fauna is considered low. There are also no known aggregation areas of marine megafauna within the Alkimos marine area, thereby further reducing the likelihood of a collision.

Standard mitigation measures will be implemented during construction to minimise the risk of collision and entanglement. These measures are described further in Section 8.7.

Loss of local biodiversity (introduced marine species)

Introduced marine species (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 of vessel hulls and equipment entering the marine area 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).

Introduction of IMS has been identified as a potential risk. The increased number of vessel movements and deployment of equipment associated with ASDP construction may increase exposure to IMS. Further, IMS could potentially lead to detrimental impacts to the composition and function of the natural ecosystem through changes in competition, predation, or habitat modification. Accordingly, to minimise the risk of IMS, standard mitigation measures will be implemented during marine construction activities, as described in Section 8.7.

Toxic effects on marine fauna (introduction of toxicants and flushing residues)

The commissioning phase requires flushing and disinfection of the pipelines and RO infrastructure. The essentially freshwater effluent from the pressure test and disinfection processes will be buoyant in seawater and will form a plume that will naturally rise to the water surface. Water Corporation has committed to no residual chlorine or TRO in the pressure test and disinfection waters discharged to the marine environment through the diffuser outlet following treatment.

The impacts of pH will be controlled by neutralisation with sulphuric acid (H2SO4) if the pH of the discharge does not meet the criteria stated in the ANZEG (2018) guidelines. This requires the Water Corporation to ensure the discharge is not outside the 8.0–8.4 pH range required to be in compliance with discharge to south west inshore marine areas.

To ensure compliance, the pH of the pressure test water and disinfection water will be field tested using a water quality meter at the discharge point prior to discharge. Testing will take place to ensure that there is no residual chlorine in the wastewater discharged into the marine environment.

Considering the potential risks from the chemical additives and the respective management measures to be implemented, no significant adverse environmental impacts are expected to result from the discharge of the treated disinfection and pressure test waters beyond the boundary of the LEPA.

8.6.2 Operational impacts

Direct loss of marine fauna (impingement/entrainment)

Direct loss of marine fauna thorough processes of impingement (fauna trapped against plant intake screens by force of the flowing water) and/or entrainment (fauna actively drawn into plant intake) are expected to be minimised via the engineering of the plant intake, as described in Section 8.7, and summarised below:

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 0.15 m/s to allow small fish to escape
- an intake screen bar will be in place to prevent large fish from entering
- the intake is located ~5 m above the seabed to reduce potential for demersal species to enter.

Entrainment is the process whereby marine fauna are actively drawn into a plant intake pipe. 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. While the modelling applied to this assessment did not extend to the potential entrainment of larvae, it was assessed under the PSDP2 Proposal (Water Corporation 2018).

A validated hydrodynamic model (BMT 2018c) was used to determine the dispersal of larvae and eggs (e.g. Doak 2004), to estimate the percentage of eggs and larvae that may be entrained during the spawning season. 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. Over the entire October–December spawning period, 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. Over a two-decade period, the predicted impact of entrainment on pink snapper stocks was minimal relative to natural mortality and fishing pressures.

Given the results of the PSDP assessment, together with the fact there are no known significant nursery and/or spawning grounds for marine fauna in the Alkimos marine region, the impact of direct loss of marine fauna through the processes of impingement and/or entrainment, at a population or community level, was considered negligible.

Stressor effects on marine fauna (reduced DO and increased temperature and salinity)

As described in Section 6.6.3, the desalination process will produce a liquid brine concentrate by-product that is roughly twice the salinity of seawater (69 to 71 psu).

Modelling confirmed that, even under worst case conditions, the proposed ASDP diffusers should achieve a 1 in 30 dilution within 70 m of the discharge point.

In this assessment, salinity was assessed as a 'stressor' using a threshold of +1.3 psu above background (Table 6-13). The 1 in 30 dilution projected by the model is expected to be sufficient to restrict near field salinity elevations to within +1.1 psu above background, well below the +1.3 psu criterion.

Published salinity thresholds for commercially important species relevant to Alkimos are presented in Table 8-9. Median salinity elevations for the month of April (representing the period of lowest wind speeds, and therefore poorest dilution) are shown in Figure 7-9. When added to typical background salinities (Table 6-14), these translate to salinities that are well within the tolerance limits of the commercial species in Table 8-9, and marine species generally (Table 6-15) (Diaz and Rosenberg 1995).

Table 8-9: Available published salinity tolerances of key commercial fishery species in Alkimos

Common name	Scientific name	Salinity tolerance (ppt)	Comments	Reference
Western rock lobster	*Panulirus cygnus*	25–45	Nil	Dall (1974)
Greenlip abalone	*Haliotis laevigata*	23–40	2 ppt outside of this range is likely to induce mortality	Burke et al (2001) Freeman (2001)
Blacklip abalone[1]	*Haliotis rubra*			

1. Conspecific species to brownlip abalone known to occur in the Alkimos region.

Toxicity effects on marine fauna (introduction of toxicants)

WET testing completed on a sample of the SSDP reject stream complete with CIP chemicals suggested that the dilutions required to maintain a high level of ecological protection increase marginally from 1:22 to 1:29 (Table 6-16). The small difference in toxicity between the brine only and brine + CIP samples suggests that the toxic effect of the effluent is predominantly due to the osmotic imbalance caused by salinity and that CIP chemicals make a small contribution. CIP chemicals will be used intermittently and in low volumes relative to the overall volume of the discharge. The risk posed by the discharge of RO maintenance chemicals is therefore considered negligible. The potential for adverse effects resulting from salinity are addressed fully in Section 6.6.3.

8.6.3 Cumulative impacts

Cumulative impacts refer to the impacts associated with new proposals combined with those of historical proposals. Section 6.5.4 addresses the potential impacts of ASDP proposal, along with the historical and potential future impacts of the Alkimos WWTP. Modelling examined the potential for interaction between the plumes and the ramifications for dilution performance (due to the mixing of TWW with brine).

With exception of the area immediately above the Alkimos WWTP outlet, modelling indicated little scope for interaction between the respective plumes. Any interaction, if it were to occur at all, would occur in the middle of the water column, between two already very diluted plumes. For this reason, it was concluded that any interaction is unlikely to materially affect the dilution, dispersion and/or trajectory of the plumes in the near, or far-field environments (DHI, pers comm).

8.7 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 8-10.

Table 8-10: Summary of mitigation measures to ensure maintenance of marine fauna

Impact	Avoid	Minimise	Monitoring and management
Stressor effects on marine fauna during construction.	The avoidance of stressor effects (i.e. elevated TSS) on marine fauna during marine construction activities is not possible, however, stressor effects will naturally ameliorate once construction ceases.	The assessment includes a model to predict drill cutting dispersion to assess the fate of TSS particles.	Described in MCEMF (Water Corporation, in prep).
Generation of underwater noise during construction.	Underwater construction will generate some noise.	The MCEMF (Water Corporation, in prep) describes clear management actions to minimise potential impacts from noise on marine fauna during marine construction activities.	Described in MCEMF (Water Corporation, in prep).
Collision/entanglement of marine fauna during construction.	The presence of construction vessels (jack up barges), machinery and equipment during marine construction activities that may interact with marine fauna via collision/entanglement will not be avoidable.	A MCEMF describes clear management actions to minimise risk of collision/entanglement of marine fauna incidences during marine construction activities.	Described in MCEMF (Water Corporation, in prep).
Introduction of IMS from construction activities.	Vessels (jack up barges), machinery and equipment during marine construction activities that may introduce IMS to the Alkimos marine region.	A MCEMF has been developed that describes clear management actions for the Contractor to follow to minimise risk of introducing IMS to the Alkimos marine region during marine construction activities.	Described in MCEMF (Water Corporation, in prep).
Impingement and entrainment of marine fauna during operation.	Impingement and entrainment of marine fauna, including zooplankton and larvae, during operation is possible.	The seawater intake will be engineered so that: • the screen approach velocity is minimised to allow 33% occlusion by marine growth	Not applicable.

Impact	Avoid	Minimise	Monitoring and management
		and ultimate velocity of 0.15 m/s to allow small fish to escape • an intake screen bar will be in place to prevent large fish from entering • the intake is located ~2 m above the seabed to reduce potential of demersal species to enter.	
Stressor/toxicity effects on marine fauna during operation.	Routine maintenance will contribute stressor/toxicants to the marine environment.	Water Corporation has developed a hydrodynamic model to predict changes in marine environmental quality associated with discharge of RO return water during operation. Seawater outlet diffusers will be orientated to optimise mixing and therefore minimise risk of stratification. The desalination outlet diffuser ports have been designed to optimise mixing within the near-field and therefore minimise potential temperature/salinity stress. Establishment of a LEPA to ensure marine environmental quality is maintained to acceptable levels outside of this boundary during operation of the desalination plant.	Described in MOEMP (Water Corporation, in prep).

8.7.1 Construction mitigation strategies

A preliminary register of measurable and/or auditable environmental commitments to manage the environmental impacts associated with construction activities are provided in Table 8-11. Environmental monitoring and management will be outlined in further detail in a MCEMF to be finalised prior to commencement of dredging. The MCEMF 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 8-11: Relevant environmental objectives, performance indicators and proposed measurement criteria

Environmental objective	Performance criteria	Standards	Performance indicators
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 Proposal (i.e. noise, collision/entanglement, impingement/entrainment, IMS) is acceptably low.	Detailed procedures for the management of construction works, including: • Water Corporation will implement EPBC Regulations 2000 – Part 8 Division 8.1: Interacting with cetaceans during drilling activities • presence of a dedicated Marine Fauna Observer (MFO) during drilling activities • pre-start (15 minute) visual survey to ensure no marine fauna are present at the time of machine start-up • definition and maintenance of marine fauna exclusion zone and/or stand down for vessels underway • notification of introduced marine pest species and document any disturbance or impacts to marine mammals; including date, number of individuals, corrective actions undertaken • contractor to complete the vessel risk assessment for the machinery and support vessels in consultation with the DPIRD, where non-local vessels or machinery are required • machinery in good working order to reduce any unnecessary noise • where possible leave engines, thrusters or other noise generating equipment on standby or switched off if not in use.	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 MCEMF outcomes. Retain vessel check paperwork for audit purposes.

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.

8.7.2 Operation mitigation strategies

Mitigation measures required to protect marine fauna from operational impacts associated with desalination discharges are described in detail (Section 8.7). Environmental monitoring and management will be outlined in further detail in an MOEMP, which will be finalised prior to commencement of plant operations.

8.8 Predicted outcome

A key component of this assessment was to identify the potential impacts to Marine Fauna related to the construction and operation of the SDP.

The potential impacts to marine fauna will be mitigated by: (a) installing pipelines in sub-marine tunnels (as excavated using a TBM); and (b) optimising the design of the outlet diffusers, to achieve dilutions compliant with high ecological protection criteria.

The outcomes of these strategies are described in detail in Section 6.7, in the context of Marine Environmental Quality. By protecting the values associated with Marine Environmental Quality, it is reasonably expected that the factor, Marine Fauna, will be protected by default.

The risk posed by entrapment of larger fauna on the intake screens, and/or the entrainment of larvae and plankton was considered in the engineering of the intakes, which will adopt best practice technology to: (a) minimise the intake velocity (0.15 m/s) to allow small fish to escape (b) prevent the entry of larger fishes and (c) limit the intrusion of drift algae and seagrass wrack.

Remaining impacts that are not considered manageable via the key mitigation strategies, were limited to the effects of noise. The effects of noise due to tunnelling and drilling were estimated based on the literature. For both, sound pressures of between 145 and 190 dB were predicted in the immediate vicinity of the activities.

The assessment concluded that constant noise at these levels is not sufficient to cause TTS or injury to marine fauna but may cause behavioural responses in the form of avoidance. This may result in a zone of avoidance of approximately 300 m radius that travels with the TBM cutting face as it advances at 0–15 m per day towards the intake and outlet locations. Given the slow nature of tunnelling, the proposed soft-start procedures are expected to ensure there are no susceptible fauna within the 300 m avoidance zone, during maximum noise generation.

9. Flora and Vegetation

9.1 EPA objective

The EPA's environmental objective for flora and vegetation is:

"To protect flora and vegetation so that biological diversity and ecological integrity are maintained" (EPA 2106h).

9.2 Policy and guidance

The relevant EPA policy and guidelines, and the scope of each of these as relevant to the Proposal, are presented in Table 9-1.

Table 9-1: Policies and guidelines

Policy or guidance	Consideration
Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA 2016i)	The baseline flora surveys undertaken by Ecoscape (2018), AECOM (2017) and Strategen (2017) were conducted in accordance with the requirements for environmental surveying and reporting for flora and vegetation in Western Australia as outlined in the technical guidance. Several spring surveys have been completed within the DAF by experienced botanists.
Guidance Statement No. 6 – Rehabilitation of Terrestrial Ecosystems (EPA 2006b)	Guidance statement No. 6 has been consulted in the development of the Proposal and in the consideration and management of impacts. A rehabilitation strategy has been developed following construction of the ASDP site.
Environmental Factor Guideline, Flora and Vegetation (EPA 2016h)	The EPA's position in relation to clearing of native vegetation has been considered in the selection of the ASDP site and pipeline route. Alternative development scenarios were identified and assessed as part of the design process. The preferred option for the Proposal was chosen based on minimising impacts to native vegetation and biological diversity to the extent possible.
Environmental Protection Bulletin No. 20 – Protection of Naturally Vegetated Areas through Planning and Development (EPA 2013)	Given its location in an urban area, Environmental Protection Bulletin 20 was consulted in the development of the Proposal. The EPA's objectives for flora and vegetation have been considered in the design of the Proposal and in avoiding, minimising and mitigating potential impacts.

9.3 Overview of studies

The terrestrial component of the DAF has been subject to a number of detailed flora and vegetation surveys as described in Table 9-2.

Table 9-2: Flora and vegetation studies

Investigation	Scope
Northern Services Corridor: Phase 1 route selection report (AECOM 2012)	AECOM was commissioned in April 2012 to assist with the planning for the future Northern Corridor of the Perth Metropolitan Bulk Water Transfer System. AECOM conducted a desktop review of all publicly available spatial datasets and undertake a risk-benefit analysis of environmental constraints for construction of a pipeline within the study area. The northern corridor alignment considered several options which intersect with the current DAF; and vegetation type, condition and communities were described within each corridor alignment.
Perth Northern Pipeline Corridor Public Environmental Review (AECOM 2015) - withdrawn	AECOM conducted a targeted Level 2 flora and fauna survey in Spring 2014 along portions of the DAF, as part of the Northern Pipeline Corridor Public Environmental Review. Vegetation type, condition and communities were described.
Eglinton Groundwater Investigations Flora, Fauna, Vegetation and Dieback survey: Site 2 (Ecoscape 2018; Appendix I)	Ecoscape was commissioned to conduct a detailed flora and vegetation survey of several pipeline options and sites for a Groundwater Treatment Plant and pipeline alignment in November 2017.
Alkimos SDP Investigations – Integration, Alkimos to Wanneroo Reservoir (AECOM 2017; Appendix F)	AECOM conducted a detailed flora and vegetation assessment to define and map the environmental values for a linear infrastructure corridor between Yanchep and the Wanneroo reservoir. A flora and vegetation assessment was undertaken in November 2017 and January 2018.
Alkimos Flora and Vegetation Survey - Spring 2016 (Strategen 2017; Appendix H)	Strategen was commissioned to undertake a detailed flora and vegetation assessment of land surrounding the current Alkimos Waste Water Treatment Plant (ASDP site) to identify the flora and vegetation values present. The surveys were undertaken in November 2016 and September 2017.
Ecological Assessment – Alkimos SDP Pipeline Integration (AECOM 2018; Appendix G)	Further biological investigations were undertaken by AECOM to define and map environmental values for a linear infrastructure corridor in Alkimos. The detailed flora and vegetation survey was conducted from 16 to 18 July 2017.
Strategen gap survey November 2018	Gaps identified in the vegetation mapping for the pipeline DAF were surveyed and mapped in November 2018 by Strategen. The results of this survey were used directly in this assessment.

The results from the above surveys have been used to describe the flora and vegetation values within the DAF in the following sections.

9.4 Receiving environment

The terrestrial component of the DAF covers a total area of 139 ha, of which 62 ha is native vegetation. The ASDP site is 29 ha of which 24 ha is native vegetation. The pipeline DAF covers an area of 110 ha of which 38 ha is native vegetation.

9.4.1 Vegetation complexes

The Proposal lies within the Swan Coastal Plain 2 IBRA region. Native vegetation in the DAF has been mapped as comprising four vegetation complexes (Government of Western Australia 2018a; Heddle et al 1990) as described in Table 9-3.

Table 9-3: Vegetation complexes

Vegetation class	Description	Extent remaining (ha)	% remaining	Area within DAF (ha)	% in DAF
Quindalup complex	Coastal dune complex consisting mainly of two alliances - the strand and fore-dune alliance and the mobile and stable dune alliance. Local variations include the low closed forest of *Melaleuca lanceolata* - *Callitris preissii*, the closed scrub of *Acacia rostellifera* and the low closed *Agonis flexuosa* forest of Geographe Bay.	32 982.87	60.44	38.4	0.11
Cottesloe complex – central and south	Supports heaths on the limestone outcrops which resemble those in the north. The deeper sands support a mosaic of *Eucalyptus gomphocephala* and an open forest of *Eucalyptus gomphocephala-Eucalyptus marginata-Corymbia calophylla*.	14 571.43	32.17	35.9	0.22
Pinjar complex	Vegetation ranges from woodland of *Eucalyptus marginata-Banksia* species on the upper dune slopes to a woodland of *Eucalyptus rudis-Melaleuca preissiana* and sedgelands. The swamp vegetation associated with semi-permanent and permanent lakes include *Regelia ciliata, Hakea varia, leptospermum ellipticum, Hypocalymma angustifolium* and species of *Baumea, Juncus, Scirpus* and *Leptocarpus.*	1452.45	29.69	28.3	1.9

Vegetation class	Description	Extent remaining (ha)	% remaining	Area within DAF (ha)	% in DAF
Herdsman complex	Dominated by sedgelands and woodland of *Eucalyptus rudis* and *Melaleuca* species. This vegetation complex is associated with the series of small lakes and swamps that occur on the Swan Coastal Plain. Common plants include *Typha, Baumea, Juncus, Leptocarpus* and *Scirpus* species. Elevated areas of the Herdsman complex support vegetation mainly associated with that of the adjacent Cottesloe and Karrakatta complexes.	3081.05	31.88	2.7	0.09
Karrakatta complex – central and south	Predominantly open forest of *Eucalyptus gomphocephala-Eucalyptus marginata-Eucalyptus calophylla* where *Eucalyptus gomphocephala* is replaced with *Eucalyptus marginata* and *Corymbia calophylla* on the eastern fringes. Common species include *Banksia attenuata, Banksia menziesii, Banksia grandis, Allocasuarina fraseriana* and to a lesser extent *Agonis flexuosa*. Shrubs include *Jacksonia sternbergiana, Jacksonia furcellata, Acacia cyclops, Acacia saligna, Hibbertia* species, *Allocasuarina humilis, Calothamnus quadrifidus* and *Grevillea thelemanniana*.	12 465.24	23.48	33.2	0.3

The Quindalup, Cottesloe, Pinjar and Karrakatta complexes are equally represented within the DAF, at between 28 and 38 ha, whereas the Herdsman complex comprises a small proportion (2.7 ha).

There is more than 30% of the pre-European extent of the Quindalup, Cottesloe and Herdsman complexes remaining within the Swan Coastal Plain 2 IBRA region and the Pinjar complex has just under 30% remaining (29.7%). The Karrakatta complex has less than 30% of its pre-European extent remaining. For major urban areas, the EPA target for retention is at least 10% of vegetation present prior to European settlement.

9.5 Vegetation associations

Four vegetation associations have been mapped over the DAF, based on Shepherd et al (2002). Regional Pre-European vegetation associations identified in the DAF are presented in Table 9-3.

The majority of the DAF composes vegetation association 1007 (mosaic of shrublands, heaths and thickets), followed by association 6 (woodlands of Tuart and Jarrah) and smaller proportions of Banksia woodlands (949) and Tuart woodlands (998).

Three associations (949, 998 and 1007) have more than 30% of their pre-European extent remaining at both a State and local level and are therefore, considered to be of least concern. The remaining vegetation association (6) has less than 30% of its pre-European extent remaining at 23%. All are well above the 10% threshold for urban areas.

Table 9-4: Vegetation associations (Government of Western Australia 2018b)

Vegetation system association no. (pre-European)	Description	Current extent (ha)	Percentage remaining (%)	Area within DAF (ha)	% in DAF
998	Medium woodland; Tuart	18,411	36.20	1.6	0.009
1007	Mosaic: Shrublands; *Acacia lasiocarpa* & *Melaleuca acerosa* heath / Shrublands; *Acacia rostellifera* & *Acacia cyclops* thicket.	20,688	68.71	36.8	0.18
949	Low woodland; Banksia	120,150	57.22	8.5	0.007
6	Medium woodland; Tuart and Jarrah	13,304	23.61	15.3	0.12

9.6 Vegetation types

A total of 23 native vegetation types (VT) have been recorded within the DAF (AECOM 2017, AECOM 2018, Ecoscape 2018, Strategen 2017). These are described in Table 9-5 and shown in Figure 9-1.

The dominant native vegetation type within the ASDP site is VT1, comprising an area of 16 ha (55%), which can broadly be described as open heath to scrub of *Acacia saligna*, *Banksia sessilis* and *Xanthorrhoea preissii*.

Within the pipeline DAF, the dominant native vegetation is BsMs, comprising an area of about 9 ha (8%), which can be broadly described as Banksia and Xanthorrhoea open shrubland over Jacksonia and Hibbertia low shrubland. The remaining vegetation types recorded are represented by small areas within the pipeline DAF ranging from 0.3 to 4.7 ha.

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Table 9-5: Vegetation types

Vegetation code	Vegetation description	Survey	Extent (ha) in DAF	Vegetation complex	% Remaining in SCP Bioregion	% Change in extent	Vegetation Association	% Remaining in SCP Bioregion	% Change in extent
ASDP site									
VT1	Open heath to open scrub of *Acacia saligna* or *Banksia sessilis* and *Xanthorrhoea preissii* over low shrubland of *Melaleuca systena*, *Calothamnus quadrifidus* and *Hibbertia hypericoides* over herbland of *Lomandra maritima* and mixed exotic grasses on sand.	Strategen (2017)	16.0	Quindalup Complex	60.44	-0.0485	1007	68.71	-0.0532
VT2	Shrubland of *Spyridium globulosum*, *Melaleuca systena* and *Adriana quadripartita* over *Lepidosperma ?calcicola, *Euphorbia terracina* and **Poaceae* sp.	Strategen (2017)	5.8	Quindalup Complex	60.44	-0.0176	1007	68.71	-0.0192
VT3	*Eucalyptus gomphocephala* open woodland over *Myoporum ?caprarioides* and *Spyridium globulosum* open low shrubland over mixed exotic grasses including **Ehrharta calycina* and **Avena barbata* on sand.	Strategen (2017)	1.6	Cottesloe Complex-Central and South	32.17	-0.0034	998	36.20	-0.0030
VT4	Revegetated areas of *Melaleuca systena*, *Olearia axillaris*, *Acacia lasiocarpa, Scaevola crassifolia* and *Acacia saligna*, with emergent *Eucalyptus sp.* and *Melaleuca huegelii*.	Strategen (2017)	0.9	Quindalup Complex	60.44	-0.0027	1007	68.71	-0.0029
Planted	Planted *Eucalyptus* sp.	Strategen (2017)	1.7	N/A					
Cleared		Strategen (2017)	3.0	N/A					
Sub-total			*28.9*						
Pipeline DAF									
VT1	Open heath to open scrub of *Acacia saligna* or *Banksia sessilis* and *Xanthorrhoea preissii* over low shrubland of *Melaleuca systena*, *Calothamnus quadrifidus* and *Hibbertia hypericoides* over herbland of *Lomandra maritima* and mixed exotic grasses on sand.	Strategen (2017)	0.8	Cottesloe Complex-Central and South	32.17	-0.0018	1007	68.71	-0.0027
Planted	Planted *Eucalypt sp. Pinus sp.* and exotic species.	Strategen (2017) AECOM (2018)	3.2	N/A			N/A		
AfHhMp	*Allocasuarina fraseriana*, *Banksia attenuata*, *Eucalyptus marginata subsp. marginata* and *Banksia menziesii* mid woodland over *Hibbertia hypericoides, Xanthorrhoea preissii, Stirlingia latifolia, Daviesia triflora* and *Hypocalymma robustum* mid shrubland with *Mesomelaena pseudostygia, Lepidosperma pubisquameum* and *Schoenus grandiflorus* low open sedgeland over *Tricoryne elatior*, *Podolepis gracilis*, *Ursinia anthemoides, *Dampiera linearis* and **Gladiolus caryophyllaceus* low sparse forbland with *Alexgeorgea nitens, Desmocladus flexuosus*, and *Lyginia imberbis* low sparse rushland.	AECOM (2018)	2.4	Karrakatta Complex-Central and South	23.48	-0.0045	949	57.22	-0.0011

Vegetation code	Vegetation description	Survey	Extent (ha) in DAF	Vegetation complex	% Remaining in SCP Bioregion	% Change in extent	Vegetation Association	% Remaining in SCP Bioregion	% Change in extent
BaEpDf	*Banksia attenuata, Eucalyptus todtiana, Nuytsia floribunda and Banksia menziesii* mid open woodland over *Eremaea pauciflora var. pauciflora, Leucopogon polymorphus, Hibbertia hypericoides, Xanthorrhoea preissii* and *Conostephium pendulum* mid shrubland over *Desmocladus flexuosus, Alexgeorgea nitens* and *Lyginia barbata* low sparse rushland with *Mesomelaena pseudostygia* and *Schoenus sp*. low sparse sedgeland over **Hypochaeris glabra, *Gladiolus caryophyllaceus, Patersonia occidentalis, Drosera erythrorhiza and Conostylis setigera* low sparse herbland.	AECOM (2018)	2.5	Karrakatta Complex-Central and South	23.48	-0.0047	949	57.22	-0.0012
BaSlAn	*Banksia attenuata, Banksia menziesii, Corymbia calophylla, Eucalyptus marginata subsp. marginata* and *Allocasuarina fraseriana* mid woodland over *Stirlingia latifolia, Jacksonia furcellata, Hibbertia hypericoides, Xanthorrhoea preissii*, and *Scaevola repens* low open shrubland over *Alexgeorgea nitens, Hypolaena exsulca* and *Lyginia barbata* low open rushland with **Briza maxima, Amphipogon turbinatus* and *Tetrarrhena laevis* low open grassland.	AECOM (2018)	2.7	Karrakatta Complex-Central and South	23.48	-0.0051	949	23.61	-0.0048
BaXpAc	*Banksia attenuata, Eucalyptus todtiana, Banksia menziesii* and *Allocasuarina fraseriana* low open woodland over *Xanthorrhoea preissii, Hibbertia hypericoides, Jacksonia calcicola, Acacia pulchella var. glaberrima* and *Calothamnus sanguineus* low shrubland with *Mesomelaena pseudostygia, Schoenus clandestinus* and *Tetraria octandra* with *Austrostipa elegantissima* and **Avena barbata* low open grassland over *Podolepis gracilis, *Ursinia anthemoides, Ptilotus manglesii, Acanthocarpus preissii* and **Gladiolus caryophyllaceus* low open herbland.	AECOM (2018)	0.4	Karrakatta Complex-Central and South	23.48	-0.0008	949	57.22	-0.0002
EgBaXp	*Eucalyptus gomphocephala* tall forest over *Banksia attenuata, Allocasuarina fraseriana* and *Banksia menziesii* low open woodland over *Xanthorrhoea preissii, Hibbertia hypericoides, Jacksonia furcellata, Macrozamia riedlei* and *Hardenbergia comptoniana* mid open shrubland over **Euphorbia terracina, Lomandra maritima, *Romulea rosea*, and *Acanthocarpus preissii* low open herbland with **Briza maxima, *Eragrostis curvula* and **Avena barbata* mid grassland.	AECOM (2018)	0.4	Karrakatta Complex-Central and South	23.48	-0.0008	6	23.61	-0.0007

Vegetation code	Vegetation description	Survey	Extent (ha) in DAF	Vegetation complex	% Remaining in SCP Bioregion	% Change in extent	Vegetation Association	% Remaining in SCP Bioregion	% Change in extent
EgHgAb	*Eucalyptus gomphocephala, Eucalyptus marginata* and isolated *Banksia attenuata* and *Banksia grandis* mid woodland over *Hibbertia hypericoides, Xanthorrhoea preissii, Bossiaea eriocarpa, Macrozamia riedlei* and *Hardenbergia comptoniana* mid open shrubland with **Avena barbata* and **Briza maxima* low open grassland over *Tricoryne elatior, Conostylis aurea, Conostylis candicans subsp. candicans, *Gladiolus caryophyllaceus* and **Sonchus asper* low open herbland with *Mesomelaena pseudostygia* and *Tetraria octandra* low open sedgeland.	AECOM (2018)	0.3	Karrakatta Complex-Central and South	23.48	-0.0006	6	23.61	-0.0005
EmGtPo	*Eucalyptus marginata subsp. marginata* and isolated *Corymbia calophylla* mid woodland over *Gompholobium tomentosum, Bossiaea eriocarpa, Xanthorrhoea preissii, Hibbertia hypericoides* and *Daviesia triflora* low shrubland over *Patersonia occidentalis, *Ursinia anthemoides, Podotheca angustifolia, Haemodorum laxum* and *Opercularia vaginata* low open herbland with *Alexgeorgea nitens, Lyginia barbata* and *Desmocladus flexuosus* low sparse rushland.	AECOM (2018)	3.8	Karrakatta Complex-Central and South	23.48	-0.0072	6	23.61	-0.0067
EmXpDb	*Eucalyptus marginata subsp. marginata, Allocasuarina fraseriana, Banksia menziesii* and *Banksia attenuata* mid woodland over *Xanthorrhoea preissii, Hibbertia hypericoides, Adenanthos cygnorum subsp. cygnorum, Bossiaea eriocarpa* and *Stirlingia latifolia* mid shrubland over *Dasypogon bromeliifolius, Patersonia occidentalis, Conostylis juncea, Dampiera linearis* and *Phlebocarya ciliata* low open herbland with *Alexgeorgea nitens, Lyginia imberbis, Desmocladus fasciculatus, Desmocladus flexuosus* and *Hypolaena exsulca* low sparse rushland.	AECOM (2018)	0.1	Karrakatta Complex-Central and South	23.48	-0.0002	6	23.61	-0.0002
MpHaEc	*Melaleuca preissiana, Banksia ilicifolia, Eucalyptus rudis subsp. rudis* and *Eucalyptus gomphocephala* mid woodland over *Adenanthos cygnorum subsp. cygnorum, Jacksonia furcellata* and *Kunzea glabrescens* tall sparse shrubland over *Hypocalymma angustifolium, Jacksonia furcellata, Gompholobium tomentosum* and *Xanthorrhoea preissii* mid sparse shrubland over **Ehrharta calycina, *Briza maxima, *Pentameris airoides* and **Vulpia myuros* tall to low tussock grassland over **Carpobrotus edulis, Patersonia occidentalis, Gonocarpus cordiger* and *Corynotheca micrantha* low open herbland.	AECOM (2018)	1.7	Pinjar Complex	29.69	-0.0347	6	23.61	-0.0030

Vegetation code	Vegetation description	Survey	Extent (ha) in DAF	Vegetation complex	% Remaining in SCP Bioregion	% Change in extent	Vegetation Association	% Remaining in SCP Bioregion	% Change in extent
EmHlMp	*Eucalyptus marginata subsp. marginata, Allocasuarina fraseriana, Banksia attenuata* and *Banksia grandis* mid to tall open woodland over *Hakea lissocarpha, Hibbertia hypericoides, Xanthorrhoea preissii, Acacia pulchella var. glaberrima* and *Gompholobium tomentosum* mid to low shrubland with *Mesomelaena pseudostygia, Lepidosperma leptostachyum, Tetraria octandra* and *Schoenus clandestinus* low sparse sedgeland with **Carpobrotus edulis*, **Hypochaeris glabra, Drosera erythrorhiza, Lomandra nigricans* and *Gonocarpus pithyoides* low sparse herbland.	AECOM (2018)	0.5	Karrakatta Complex-Central and South	23.48	-0.0009	6	23.61	-0.0009
ErAcEc	*Eucalyptus rudis subsp. rudis* and occasional *Banksia ilicifolia* mid open woodland over *Adenanthos cygnorum subsp. cygnorum, Acacia rostellifera, Acacia saligna* and *Jacksonia furcellata* tall open shrubland over **Eragrostis curvula, *Lagurus ovatus, *Cynodon dactylon* and **Avena barbata* mid grassland over **Oxalis pes-caprae, *Pelargonium capitatum, *Euphorbia terracina* and **Carpobrotus edulis* low herbland.	AECOM (2018)	4.7	Pinjar Complex	29.69	-0.0961	6	23.61	-0.0083
ArMOS	*Acacia rostellifera, Spyridium globulosum* and *Melaleuca systena* mid open shrubland over *Lomandra maritima, Desmocladus asper* and **Euphorbia terracina* low forbland/rushland.	Ecoscape (2018)	4.0	Cottesloe Complex-Central and South	32.17	-0.0088	1007	68.71	-0.0133
BaLW	Banksia attenuata, Allocasuarina fraseriana and Banksia menziesii low woodland over Xanthorrhoea preissii, Macrozamia riedlei and Jacksonia sternbergiana mid open shrubland over Hibbertia hypericoides, Leucopogon polymorphus and Mesomelaena pseudostygia low shrubland/sedgeland.	Ecoscape (2018)	0.5	Karrakatta Complex-Central and South	23.48	-0.0009	949	57.22	-0.0002
BsMS	*Banksia sessilis var. cygnorum* and *Xanthorrhoea preissii* mid open shrubland over *Jacksonia calcicola* and *Hibbertia hypericoides* low shrubland.	Ecoscape (2018)	8.7	Cottesloe Complex-Central and South	32.17	-0.0192	1007	68.71	-0.0289
BsMOS	Banksia sessilis var. cygnorum and Xanthorrhoea preissii mid open shrubland over Jacksonia calcicola and Hibbertia hypericoides low shrubland.	Ecoscape (2018)	0.6	Cottesloe Complex-Central and South	32.17	-0.0013	1007	68.71	-0.0020
CcMOF	*Corymbia calophylla* and *Eucalyptus marginata* mid open forest over *Xanthorrhoea preissii* and *Jacksonia furcellata* mid open shrubland over *Hibbertia hypericoides, Dichopogon capillipes* and *Desmocladus flexuosus* low shrubland/forbland/rushland.	Ecoscape (2018)	0.7	Cottesloe Complex-Central and South	32.17	-0.0015	6	23.61	-0.0012
EgMOF	*Eucalyptus gomphocephala* mid open forest over *Spyridium globulosum, Banksia sessilis var. cygnorum* and *Melaleuca systena* tall shrubland over *Hibbertia hypericoides, Calothamnus quadrifidus subsp. quadrifidus* and *Jacksonia calcicola* mid shrubland.	Ecoscape (2018)	3.1	Cottesloe Complex-Central and South	32.17	-0.0068	6	23.61	-0.0055

Vegetation code	Vegetation description	Survey	Extent (ha) in DAF	Vegetation complex	% Remaining in SCP Bioregion	% Change in extent	Vegetation Association	% Remaining in SCP Bioregion	% Change in extent
EtLW	*Eucalyptus todtiana* and *Banksia attenuata* low woodland over *Allocasuarina humilis*, *Xanthorrhoea preissii* and *Banksia sessilis var. cygnorum* mid open shrubland over *Hibbertia hypericoides, Desmocladus flexuosus* and *Mesomelaena pseudostygia* low shrubland/rushland.	Ecoscape (2018)	0.02	Karrakatta Complex-Central and South	23.48	<0.0001	949	57.22	<0.0001
Paddock			13.40						
Cleared			54.8						
Sub-total			*109.7*						
TOTAL AREA			**138.6**						

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9.6.1 Vegetation condition

Native vegetation remaining within the ASDP site (24 ha) is relatively undisturbed and described as 'Good to Very Good' and 'Good' condition. The remainder of the ASDP site (5 ha) is in a 'Completely Degraded' condition comprising cleared and planted areas.

Along the pipeline DAF, native vegetation present (38 ha) varies from 'Excellent' to 'Completely Degraded' condition. Most of the pipeline DAF is in 'Completely Degraded' condition (72 ha; 66%), with 55 ha comprising cleared land, 13 ha of paddock and 3 ha of planted areas.

Vegetation condition within the ASDP site and pipeline DAF is presented in Figure 9-2 and Table 9-6.

Table 9-6: Vegetation condition

Vegetation condition	Area within the DAF (ha)	Percentage of the DAF (%)
ASDP Site		
Good - Very Good	21.8	75.4
Good	2.4	8.4
Completely Degraded	4.7	16.2
Sub-total	*28.9*	*100*
Pipeline DAF		
Excellent	6.8	6.2
Very Good	6.0	5.5
Very Good – Good	0.02	0.02
Good – Very Good	3.3	3.0
Good	9.1	8.3
Good - Degraded	0.6	0.5
Degraded	11.9	10.8
Completely Degraded	71.9	65.5
Burnt	0.01	0.01
Sub-total	*109.7*	*100*
TOTAL	**138.6**	

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Vegetation type	Vegetation description
AfHhMp	Allocasuarina fraseriana, Banksia attenuata, Eucalyptus marginata subsp. marginata and Banksia menziesii mid woodland over Hibbertia hypericoides, Xanthorrhoea preissii, Stirlingia latifolia, Daviesia triflora and Hypocalymma robustum mid shrubland with Mesomelaena pseudostygia, Lepidosperma pubisquameum and Schoenus grandiflorus low open sedgeland over Tricoryne elatior, Podolepis gracilis, *Ursinia anthemoides, Dampiera linearis and *Gladiolus caryophyllaceus low sparse forbland with Alexgeorgea nitens, Desmocladus flexuosus, and Lyginia imberbis low sparse rushland.
ArMOS	Acacia rostellifera, Spyridium globulosum and Melaleuca systena mid open shrubland over Lomandra maritima, Desmocladus asper and *Euphorbia terracina low forbland/rushland.
BaEpDf	Banksia attenuata, Eucalyptus todtiana, Nuytsia floribunda and Banksia menziesii mid open woodland over Eremaea pauciflora var. pauciflora, Leucopogon polymorphus, Hibbertia hypericoides, Xanthorrhoea preissii and Conostephium pendulum mid shrubland over Desmocladus flexuosus, Alexgeorgea nitens and Lyginia barbata low sparse rushland with Mesomelaena pseudostygia and Schoenus sp. low sparse sedgeland over *Hypochaeris glabra, *Gladiolus caryophyllaceus, Patersonia occidentalis, Drosera erythrorhiza and Conostylis setigera low sparse herbland.
BaLW	Banksia attenuata, Allocasuarina fraseriana and Banksia menziesii low woodland over Xanthorrhoea preissii, Macrozamia riedlei and Jacksonia sternbergiana mid open shrubland over Hibbertia hypericoides, Leucopogon polymorphus and Mesomelaena pseudostygia low shrubland/sedgeland.
BaSlAn	Banksia attenuata, Banksia menziesii, Corymbia calophylla, Eucalyptus marginata subsp. marginata and Allocasuarina fraseriana mid woodland over Stirlingia latifolia, Jacksonia furcellata, Hibbertia hypericoides, Xanthorrhoea preissii, and Scaevola repens low open shrubland over Alexgeorgea nitens, Hypolaena exsulca and Lyginia barbata low open rushland with *Briza maxima, Amphipogon turbinatus and Tetrarrhena laevis low open grassland.
BaXpAc	Banksia attenuata, Eucalyptus todtiana, Banksia menziesii and Allocasuarina fraseriana low open woodland over Xanthorrhoea preissii, Hibbertia hypericoides, Jacksonia calcicola, Acacia pulchella var. glaberrima and Calothamnus sanguineus low shrubland with Mesomelaena pseudostygia, Schoenus clandestinus and Tetraria octandra with Austrostipa elegantissima and *Avena barbata low open grassland over Podolepis gracilis, *Ursinia anthemoides, Ptilotus manglesii, Acanthocarpus preissii and *Gladiolus caryophyllaceus low open herbland.
BsMOS	Banksia sessilis var. cygnorum and Xanthorrhoea preissii mid open shrubland over Jacksonia calcicola and Hibbertia hypericoides low shrubland.
BsMS	Banksia sessilis var. cygnorum and Xanthorrhoea preissii mid open shrubland over Jacksonia calcicola and Hibbertia hypericoides low shrubland.
CcMOF	Corymbia calophylla and Eucalyptus marginata mid open forest over Xanthorrhoea preissii and Jacksonia furcellata mid open shrubland over Hibbertia hypericoides, Dichopogon capillipes and Desmocladus flexuosus low shrubland/forbland/rushland.
EgBaXp	Eucalyptus gomphocephala tall forest over Banksia attenuata, Allocasuarina fraseriana and Banksia menziesii low open woodland over Xanthorrhoea preissii, Hibbertia hypericoides, Jacksonia furcellata, Macrozamia riedlei and Hardenbergia comptoniana mid open shrubland over *Euphorbia terracina, Lomandra maritima, *Romulea rosea, and Acanthocarpus preissii low open herbland with *Briza maxima, *Eragrostis curvula and *Avena barbata mid grassland.
EgHgAb	Eucalyptus gomphocephala, Eucalyptus marginata and isolated Banksia attenuata and Banksia grandis mid woodland over Hibbertia hypericoides, Xanthorrhoea preissii, Bossiaea eriocarpa, Macrozamia riedlei and Hardenbergia comptoniana mid open shrubland with *Avena barbata and *Briza maxima low open grassland over Tricoryne elatior, Conostylis aurea, Conostylis candicans subsp. candicans, *Gladiolus caryophyllaceus and *Sonchus asper low open herbland with Mesomelaena pseudostygia and Tetraria octandra low open sedgeland.
EgMOF	Eucalyptus gomphocephala mid open forest over Spyridium globulosum, Banksia sessilis var. cygnorum and Melaleuca systena tall shrubland over Hibbertia hypericoides, Calothamnus quadrifidus subsp. quadrifidus and Jacksonia calcicola mid shrubland.
EmGtPo	Eucalyptus marginata subsp. marginata and isolated Corymbia calophylla mid woodland over Gompholobium tomentosum, Bossiaea eriocarpa, Xanthorrhoea preissii, Hibbertia hypericoides and Daviesia triflora low shrubland over Patersonia occidentalis, *Ursinia anthemoides, Podotheca angustifolia, Haemodorum laxum and Opercularia vaginata low open herbland with Alexgeorgea nitens, Lyginia barbata and Desmocladus flexuosus low sparse rushland.
EmHlMp	Eucalyptus marginata subsp. marginata, Allocasuarina fraseriana, Banksia attenuata and Banksia grandis mid to tall open woodland over Hakea lissocarpha, Hibbertia hypericoides, Xanthorrhoea preissii, Acacia pulchella var. glaberrima and Gompholobium tomentosum mid to low shrubland with Mesomelaena pseudostygia, Lepidosperma leptostachyum, Tetraria octandra and Schoenus clandestinus low sparse sedgeland with *Carpobrotus edulis, *Hypochaeris glabra, Drosera erythrorhiza, Lomandra nigricans and Gonocarpus pithyoides low sparse herbland.
EmXpDb	Eucalyptus marginata subsp. marginata, Allocasuarina fraseriana, Banksia menziesii and Banksia attenuata mid woodland over Xanthorrhoea preissii, Hibbertia hypericoides, Adenanthos cygnorum subsp. cygnorum, Bossiaea eriocarpa and Stirlingia latifolia mid shrubland over Dasypogon bromeliifolius, Patersonia occidentalis, Conostylis juncea, Dampiera linearis and Phlebocarya ciliata low open herbland with Alexgeorgea nitens, Lyginia imberbis, Desmocladus fasciculatus, Desmocladus flexuosus and Hypolaena exsulca low sparse rushland.
ErAcEc	Eucalyptus rudis subsp. rudis and occasional Banksia ilicifolia mid open woodland over Adenanthos cygnorum subsp. cygnorum, Acacia rostellifera, Acacia saligna and Jacksonia furcellata tall open shrubland over *Eragrostis curvula, *Lagurus ovatus, *Cynodon dactylon and *Avena barbata mid grassland over *Oxalis pes-caprae, *Pelargonium capitatum, *Euphorbia terracina and *Carpobrotus edulis low herbland.
EtLW	Eucalyptus todtiana and Banksia attenuata low woodland over Allocasuarina humilis, Xanthorrhoea preissii and Banksia sessilis var. cygnorum mid open shrubland over Hibbertia hypericoides, Desmocladus flexuosus and Mesomelaena pseudostygia low shrubland/rushland.
MpHaEc	Melaleuca preissiana, Banksia ilicifolia, Eucalyptus rudis subsp. rudis and Eucalyptus gomphocephala mid woodland over Adenanthos cygnorum subsp. cygnorum, Jacksonia furcellata and Kunzea glabrescens tall sparse shrubland over Hypocalymma angustifolium, Jacksonia furcellata, Gompholobium tomentosum and Xanthorrhoea preissii mid sparse shrubland over *Ehrharta calycina, *Briza maxima, *Pentameris airoides and *Vulpia myuros tall to low tussock grassland over *Carpobrotus edulis, Patersonia occidentalis, Gonocarpus cordiger and Corynotheca micrantha low open herbland.
Planted - Process Plant	Planted Eucalypt sp.
Planted - Route Section	Planted Eucalypt sp. Pinus sp. and exotic species.
VT1	Open heath to open scrub of Acacia saligna or Banksia sessilis and Xanthorrhoea preissii over low shrubland of Melaleuca systena, Calothamnus quadrifidus and Hibbertia hypericoides over herbland of Lomandra maritima and mixed exotic grasses on sand.
VT2	Shrubland of Spyridium globulosum, Melaleuca systena and Adriana quadripartita over Lepidosperma ?calcicola, *Euphorbia terracina and *Poaceae sp.
VT3	Eucalyptus gomphocephala open woodland over Myoporum ?caprarioides and Spyridium globulosum open low shrubland over mixed exotic grasses including *Ehrharta calycina and *Avena barbata on sand.
VT4	Revegetated areas of Melaleuca systena, Olearia axillaris, Acacia lasiocarpa, Scaevola crassifolia and Acacia saligna, with emergent Eucalyptus sp. and Melaleuca huegelii.

Figure 9-1: Vegetation Types

Date: 18/03/2019

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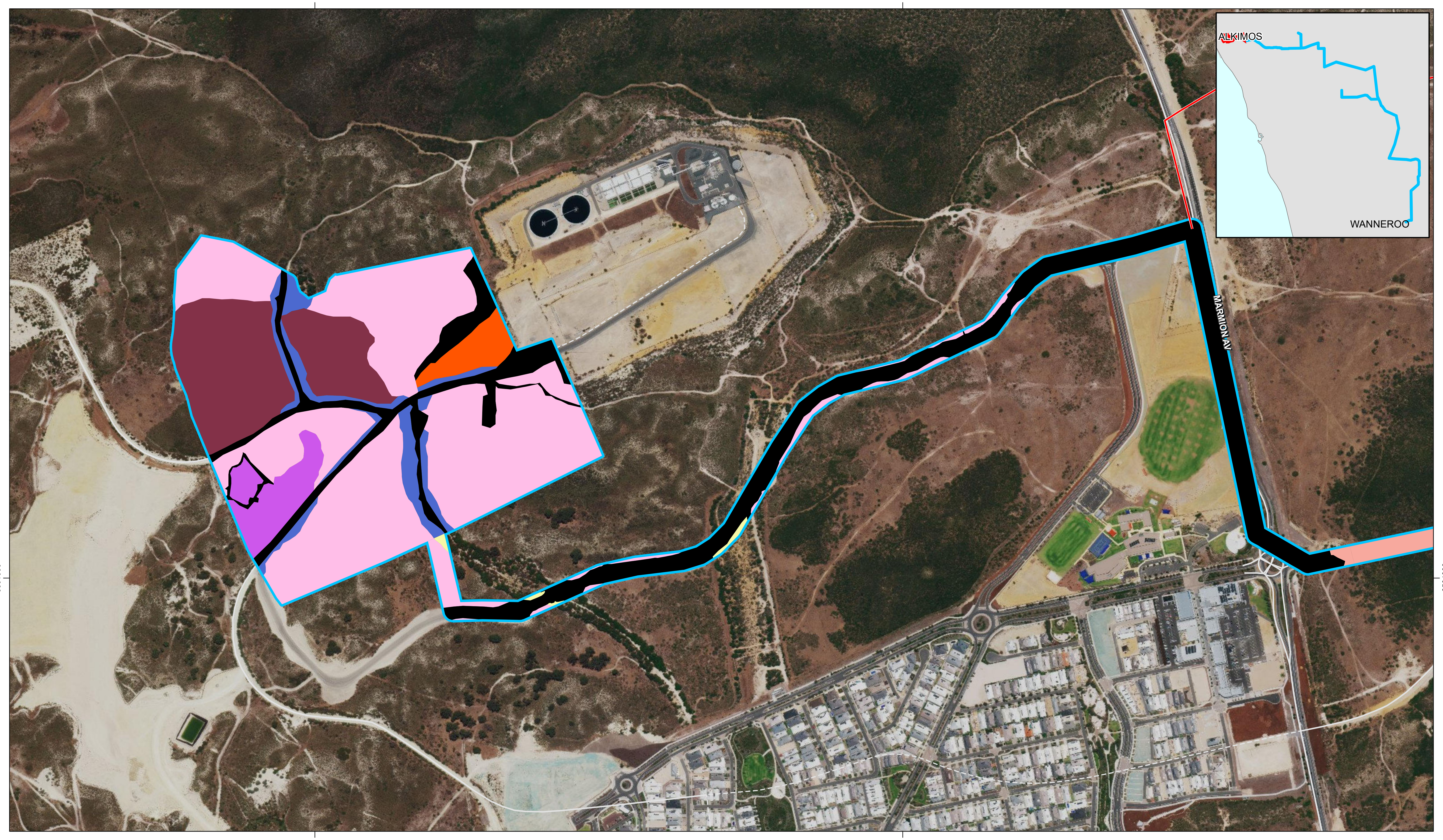

Figure 9-1: Vegetation Types

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Scale 1:6,000 at A3

0 100 m

Coordinate System: GDA 1994 MGA Zone 50

Date: 18/03/2019

Legend

- Development Area Footprint
- Northern Route Option
- Minor Road
- Track

Vegetation Type

- 1
- 2
- 3
- 4
- ArMOS
- Cleared
- Paddock
- Planted

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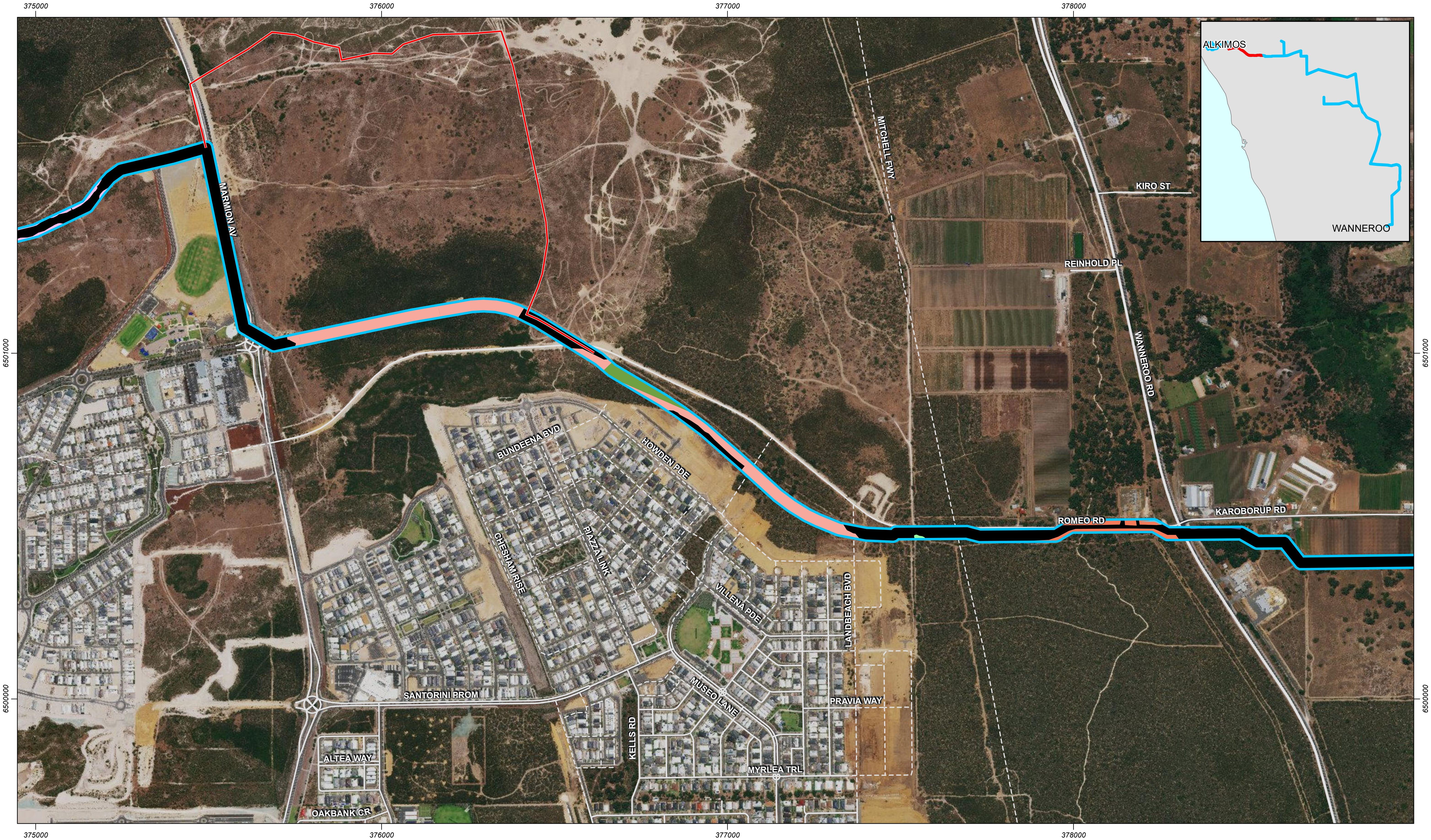

Figure 9-1: Vegetation Types

Legend

- Development Area Footprint
- Northern Route Option
- Major Road
- Minor Road
- Track

Vegetation Type

- 1
- ArMOS
- BaLW
- CcMOF
- Cleared
- EgBaXp
- EgMOF
- EtLW

N

Scale 1:10,000 at A3

0 100 m

Coordinate System: GDA 1994 MGA Zone 50

Date: 18/03/2019

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